

MANAGEMENT PERSPECTIVES FOR AVIAN POPULATION CONSERVATION AND ENRICHMENT IN DEEPOUR BEEL RAMSAR SITE, NORTH-EAST INDIA

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Abstract

Deepor Beel is one of the largest and most important riverine wetland in the Brahmaputra Valley of lower Assam, India and is representative of the wetlands found within the Burma Monsoon Forest biogeographic region. Altogether 232 bird species belonging to 42 families were recorded during a sixty months survey in Deepor Beel. Of all the species recorded, 137 were resident and 97 were migratory. About 4.1 km² of the wetland was declared as a wildlife sanctuary in 1989 and larger area (40 km²) as a Ramsar wetland of international importance in November, 2002. Further it has been identified as an Important Bird Area (IBA) by BNHS and Birdlife International since 2003. There are fourteen villages (1200 families) around Deepor Beel wetland, most of which belong to low income groups living under the poverty line and depend directly or indirectly on the wetland's natural resources. Present field investigation has recognized that, at least above 500 families of poor scheduled cast people in an around Deepor beel Ramsar site have entirely depends their livelihood on fishing and other herbaceous plant resources collection at Deepor beel Ramsar site and sell them at nearby daily markets. Currently, the wetland and its biota are facing a numerous threats in the form of encroachments, civil construction, garbage dumping, rail road development, unregulated fishing practices and rice cultivation and most importantly the lack of a single authority with mandate to manage the wetland. Conservation of this wetland has been proposed keeping in view the needs for bird populations and local villagers. Involvement of local communities in the conservation measures is emphasized. The wetland with additional terrestrial forest land should be conserved as Deepor beel Environmental Park with adequate legislative and administrative provisions and certain usages right to the indigenous people.

INTRODUCTION

Deepor beel is a large natural wetland having great biological and environmental importance (Deka & Goswami, 1992). It is endowed with rich floral and faunal diversity. Besides huge congregation of residential water birds, the Deepor beel ecosystem harbours large numbers of migratory waterfowl each year. Hence, Deepor beel attracted large numbers of ornithologist, tourists and nature lovers. It was declared as an internationally important wetland and was included in the Directory of Asian Wetlands. The inflow of wastewater from Guwahati City to this beel has degraded its water quality making it hazardous for the aquatic flora and fauna (Report, Govt. of Assam, 1989; Deka & Goswami, 1993).

STUDY AREA

Geographic Setting and Hydrology

Deepor beel is one of the largest and most important riverine wetlands in the Brahmaputra Valley of lower Assam, India and is representative of the wetlands found within the Burma Monsoon Forest biogeographic region. It is located between Latitude: 26°05'26"N to 26°09'26"N and Longitude: 90°36'39"E to 91°41'25" E, and altitude of 165-186 feet above MSL (Saikia & Bhattacharjee, 1987; Saikia & Saikia, 2011). The wetland is situated on the southern bank of Brahmaputra River on the southwestern fringe of Guwahati City, covering an area of ~40 km² (Figure 1). The Morabharulu rivulet is the main inlet for water into the wetland (Chetry, 1999). It brings in the storm water from Guwahati city during the rainy season when the Brahmaputra flows above the water level of the

Bharalu channel. Bharalu drains city water into the Brahmaputra during the dry season. During the dry season, these streams do not carry much water and the wetland water is drained into the Brahmaputra (Coordinates: 26°09'49"N and 91°39'01" and height 42 m MSL) through the sluice gate at Khanajan channel located on the north side of the wetland.

Ecological Significance, Social Setting, and Land Use

Deepor beel has been serving since a long time as a storm water receptacle of the surrounding areas and the city of Guwahati (population ~1,500,000) (Deka & Goswami, 1992). It is a unique wetland habitat for wild flora and fauna. The Government of Assam has declared it as a wildlife sanctuary in 1989 (Government of Assam, 1989) and was included in the Directory of Asian wetlands (IUCN, 1987). A number of endemic, endangered and threatened animals and plants are found in Deepor Beel (Barman *et al.*, 1995; Bhattacharjee *et al.*, 1987; Saikia & Bhattacharjee, 1987; Saikia 2005; Saikia & Saikia, 2011). The wetland was included in the list of Ramsar sites in November, 2002 and Birdlife International lists the wetland an Important Bird Area since 2004 (Islam & Rahmani, 2004).

There are fourteen villages (1200 families) around Deepor beel wetland, most of which belong to low income groups living under the poverty line and depend directly or indirectly on the wetland's natural resources. Of which, above 500 poor families belongs to scheduled cast and scheduled tribes have entirely depend their livelihood on fishing at Deepor beel Ramsar site. All the native villagers around Deepor beel have mostly belongs to socio-economically backward scheduled castes and scheduled tribes. The socio-economic survey conducted on the fourteen villages in the Deepor beel fringe unveils that 22.63% of the people are dependent on the natural resources of the wetland for their livelihood, 17.3% of the people are partially dependent and 45-56% of the families depend on the wetland for fodder for their domestic animals (Aaranyak, 2003). Fish productivity in the wetland is very high and is a source of income for about 500 poor families of fisherman in five villages (Aaranyak, 2003; Saikia, 2005; Saikia & Saikia 2011). The dry weight fish biomass of the wetland is ~15-38 kg/ha and the live fish yield in the wetland is 245 kg/ha (Saikia, 2005, Saikia & Saikia 2011). The primary productivity of plant biomass (aquatic plants & phytoplankton) in Deepor beel is estimated to be ~ 300-500 kg/m². The people of the surrounding villages and Garigoan-Sadilapur areas use the fringe areas of Deepor beel for agricultural activities. About 600 ha of land in the fringe areas are under agriculture with an average rice productivity of more than 2.5 metric tons/ha (Government of Assam, 1990).

Habitat and Biological Diversity

Deepor beel is one of the richest biodiversity areas within the wetland ecosystem of Assam. Its deep and shallow waters and occasional highland support large numbers of plant and animal species. The hills and natural forests adjoining the wetland support large numbers of endangered and threatened vertebrate species. Traditionally the beel has been used as a recreational ground for hunting of deer, elephant, birds (Phukon, 19??) and boating, sight seeing, picnic etc. High diversity of Phytoplankton is one of the major components of the lowest level of the producers in the Deepor beel ecosystem (Chetry, 1999; Saikia & Bhattacharjee, 1987).

Climate

Deepor beel has a meso-thermal climate, characterized by high humidity and moderate temperature (Singh & Dutta, 1969; Barthakur, 1986). The average field temperature during this period remains at ~20°C and the relative humidity measures ~78%. This season also experiences occasional rainfall due to the west monsoon. January is the coldest month, with a lowest temperature of ~18°C (Saikia & Bhattacharjee, 1987).

The objective of this paper is to present an environmental management plan for Deepor beel Ramsar site with specific reference to birds and the local communities who depend on the wetland in various ways.

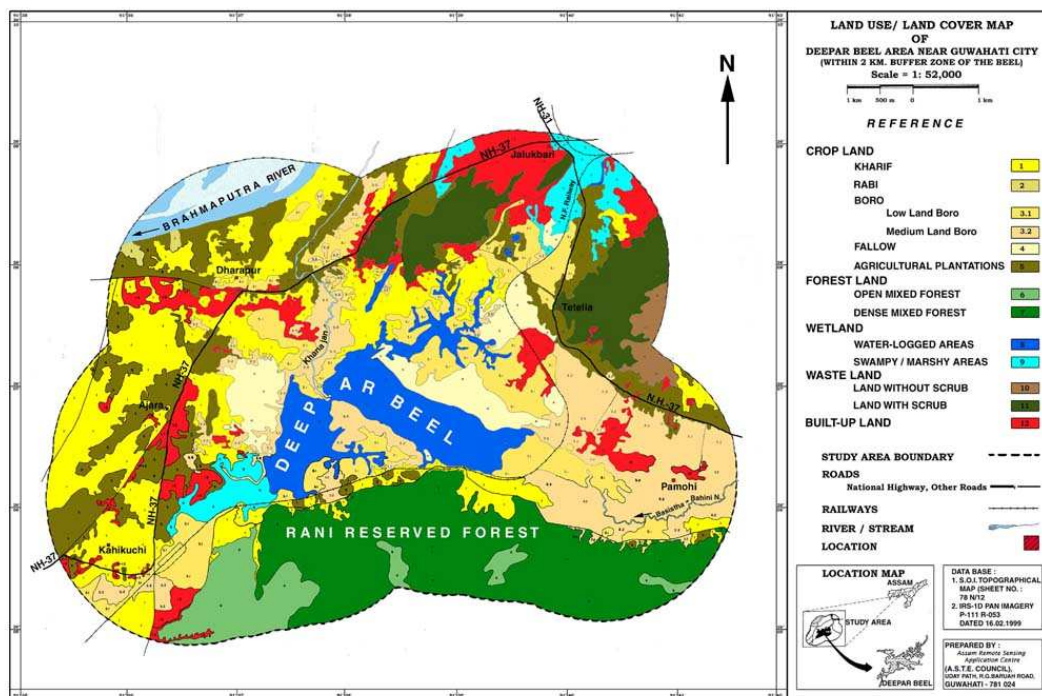


Figure 1 Location map of Deepor Beel wetland. The map shows the other Ramsar Sites in Northeast India.

METHODS

Study design

The study has been carried out from November, 2000 to October, 2006 to gathered the data. To convenient of study, the entire Deepor beel Ramsar site (wetland) including adjoining areas were categorized into six different study zones (Table 1) based on habitat stratification. Overall six permanent line transects have established in six different study zones of Deepor beel Ramsar site to collect the monthly data (Table 1). Additional methods, viz., point transect, flush count and total count methods were also applied on the previously selected study zones to aid the line transect data. Transect design was made as per standard methods of Bibby *et al.* (1999) and Gaston (1984). Bird identification was made as per the books of Ali & Ripley (1983, 1987) and Grimmett *et al.* (1999). Zenith binoculars 7×50, 10×50 and 8×35 and 10×50 telescopes were used in bird population survey and identification.

Bird Data Collection

Intensive regular survey of avian fauna has been made in previously selected six line transects in monthly wise basis as per the methods used by Bibby *et al.* (1999) and Gaston (1984). To collect the avian data, the survey was carried out in active period of birds from 05.00 hours to 11.00 hours in the morning and 1500 hours to 1700 hours in the after noon. For monthly data gathered of avian fauna, the entire month was again divided into three parts viz., first part of the month, middle part and end of the months and the birds data were collect in each part and the highest counts were used for analysis.

Data Analysis

The wetland birds were categorized from others based on the resource used types as per the methods of Vijayan (1986). To know the seasonal use of Deepor beel wetland by aquatic birds, the proportional abundance of avian faun in both dry and wet season was computed using SPSS software version 11.0.1. For this purposes, the entire 12 months period (annual cycles) was divided into two half, dryer and wetter half based on mean total amount of rainfall occurred in each half (six months period) of the year. The analysis revealed that, the amount of rainfall during the month from May-October (total six months) was significantly higher than the months from November-April (total six months; t-test using equal variance, $t = -27.21$, $P < 0.001$). To provide this information for every species, we

calculated the proportion of individuals recorded during the 'dryer half' of the year (November-April) and 'wetter half' of the year (May-October) and used this as an index of each species' dry and wet season preference (as used by Hamer *et al.*, 2005 for butterflies). All analysis of seasonality was restricted to species where $N \geq 12$ (i.e. one or more individuals sampled per month on average) (Davis *et al.*, 2001). Proportional abundance of individuals in each species of birds recorded at wet season (WET) were computed [formulae used, $(\text{wet})/(\text{wet} + \text{dry})$, where $\text{wet} + \text{dry} \geq 12$] to indicate wet season preference (value of '1' for species only in 'wet season', value of '0' for species only in 'dry season') and proportional abundance of individuals in each species of birds recorded at dry season (DRY) were computed [formulae used, $(\text{dry})/(\text{dry} + \text{wet})$, where $\text{dry} + \text{wet} \geq 12$] to indicate dry season preference (value of '1' for species only in 'dry' season, value of '0' for species only in 'wet' season) of the bird species (as used by Kakati, 2005 & Kakati *et al.* 2009).

The diversity of avian fauna was estimated in terms of species evenness (or Equitability), using Shannon Wiener Index and bootstrap method was also used to calculate 95% confidence intervals (Magurran, 1988; Hurlbert, 1971). Evenness or Equitability refers to the pattern of distribution of the individuals between the species. In order to test the differences in diversity between months and selected study zones, pair-wise randomization tests were carried out, based on 10,000 re-samples of species abundance data following Solow (1993). Species richness was estimated using rarefaction (Heck *et al.*, 1975). The Species Diversity and Richness Software version 3.0 (Pisces conservation Ltd., UK) was used to analyses all the diversity indices.

RESULTS AND DISCUSSION

Bird Diversity

Deepor Beel system supports a considerable number of bird species recorded in India. Examination of species richness of wetland bird species belonging to seventeen families and their comparison to mainland India indicate that Deepor Beel Ramsar site is a hotspot for these species when compared with the Indian scene (Figure 2). During the period of one year (November 2004 to October 2005), altogether 232 species (84,866 individuals) were sampled belonging to 42 families in 72 different sampling events within the six study zones in Deepor Beel wetland. Of the species recorded, 83 species are exclusively wetland birds and three species of birds of prey (family Accipitridae) frequently associated with wetlands. Further, 137 species were resident birds which breed in the region and 97 species were migratory birds. The highest wetland bird counts were made in December 2004, January and September 2005 respectively (Figure 3). The time period coincide with winter and arrival of migratory waterfowl and happens to be favored by tourists. However, examination of number of species (Figure 4) and the Shannon-Weiner Index for species diversity (Figure 5) indicate the year round richness of the wetland birds making it a potential site for eco-tourism round the year. Species richness of major wetland bird groups in Deepor Beel is depicted in Table 2 and species richness of non-wetland birds in the vicinity are shown in Table 3. Availability of 83 wetland bird species and 149 non-wetland species in Deepor Beel is indicative of its habitat diversity (Vijayan, 1986).

Threatened Birds

Altogether 17 IUCN listed globally threatened species and 15 endangered species of avian fauna under Indian Wildlife protection Act of 1972 (Anonymous, 1997) were recorded in Deepor Beel during the survey period (Table 4). The species *Dendrocygna bicolor* was the highest counted (e.g. 2837 individuals altogether) species amongst schedule-I species, indicating the assemblage of 88.88% of total south Asian population as per 1991 Mid-winter waterfowl census and 35.9% as per 2004 census (Perennou & Mundkur, 1991; Li & Mundkur, 2007). Among the globally threatened species, 3 species as listed as critically endangered (CR), 2 are endangered (EN) and 12 are listed as vulnerable (VU) or near threatened (NT) (Islam & Rahmani, 2004).

Residency and Activity Patterns

Study showed that out of 232 avian fauna recorded in Deepor Beel Ramsar site 135 were residential and 97 were migratory in status. During dry season (November-April), the abundance of both migratory and residential birds is significantly higher than wet season (May-October) in Deepor Beel (see text in methodology for dry and wet season). The migratory birds visit the wetland every year and utilized the Deepor Beel resources. The major activity patterns of the birds at the wetland were

observed to be breeding, foraging and shifting locally for water. The study showed that, of the total 232 avian species recorded at Deepor Beel Ramsar site, 92 species used the wetland habitat as their regular breeding ground, and 22 species used it as their regular site for local migration depending on water condition at neighboring habitats. Deepor Beel was the permanent foraging site for 122 bird species. The analysis of various groups of birds sampled in Deepor Beel showed that the proportional abundance of breeding birds was significantly higher during wet season than dry season. The proportional abundance of local migratory and foraging birds was significantly higher during dry season.

Feeding Guilds

Present study revealed that the birds recorded in Deepor Beel belonged to 10 feeding guild. Insectivores has the highest (80-81 species) presence in Deepor Beel while scavenger feeding guild has the lowest number of species (4) (Table 5). The study also showed that the species occurrences of insectivorous, picivorous, birds of prey and omnivorous were comparatively higher than the other feeding guild species during 12-month study period. Analysis of proportional abundance during dryer and wetter half of the year in each species of birds at Deepor beel ramsar site shows that, majority of birds prefers dry season than wet season (Total mean proportion in Dry season: 0.6989 ± 0.28928 , Wet season: $.3016 \pm 0.29015$, $N = 232$; see Appendix 2; Figure 6& 7). Of the total 42 bird families recorded in deepor beel, the preferences of dry season was higher in 32 families than the others 10 families that prefers mostly in wet season (see Appendix 2). During dry season, both wetland birds (including migratory waterfowl) and terrestrial birds are meeting together to utilize the available resources, whereas, during wet season rarely visit the terrestrial birds and migratory avian fauna.

Management action plan

Deepor Beel with its enormous potential is located in the environmentally sensitive North-east Indian state of Assam. It is a representative wetland type found within the Burma Monsoon Forest biogeographic region and supports large numbers of wetland biota including 232 birds, 24 mammals, 61 fish, 32 reptiles, and 11 amphibian species (Saikia, 2005; Saikia & Saikia, 2011). This rich biotic diversity has been observed despite the fact that there is no formal management plan and institutional support for the conservation of the wetlands. The wetland supports considerable numbers of IUCN critically endangered, endangered, vulnerable and near threatened species of birds underlining the urgent need for conservation of the wetland. The wetland supports three species of critically endangered vultures. Further, it supports two endangered wetland bird species viz., Greater Adjutant stork (*Leptoptilos dubius*) and Spoon-billed sandpiper (*Eurynorhynchus pygmeus*). The remarkable findings of this study are the sighting of high abundance of Fulvous whistling duck (*Dendrocygna bicolor*) in the wetland. An increased number of Asian open-bill stork (*Anastomus oscitans*) was sighted as compared to ten to twenty years earlier when only occasional sighting were recorded (Mid Winter water Fowl Census, Perennou *et al.*, 1990; Perennou & Mundkur, 1991). The numbers of other migratory birds is declining over the last ten years even though the overall diversity of avian species has not changed remarkably. Among migratory waterfowl, the wader populations have declined drastically during last ten years. This might have happened owing to extensive human interferences in the ecosystem in form earth cutting, cultivation, and similar human activities in the shallow part of the wetland and shoreline areas. About 5% (i.e., 560) species of total 10,000 birds species living on earth need freshwater habitat in order to satisfy at least one of their life history traits (Dehorter & Guillemain, 2008) and Deepor Beel provides this much needed habitat to about 83 wetland birds and 149 species of other bird species. In addition, the Ramsar site supports 18 globally threaten and 35 endangered vertebrate species under Indian Wildlife Protection Act, 1972 (Saikia, 2005). Asiatic Elephants (*Elephas maximus*) found in the adjoining Rani-Garbhangra reserve forest maintain an inseparable relationship with the wetland and its buffer zones (Saikia, 2005).

Primary Major Threats

During past two decades, the Deepor Beel area has undergone rapid changes due to various human activities within the wetland and in the fringe areas. These include industrialization, agricultural activities, deforestation in the adjoining reserved forests, human settlement, and other unregulated activities. This has resulted in an imbalance in the wetland eco-system. Moreover, the inflow of untreated stormwater from Guwahati city to this wetland is degrading its water quality making it hazardous for the aquatic flora and fauna. The threats to Deepor Beel are typical of wetlands in this

region and other developing countries. The three major anthropogenic threats to Deepor Beel that need immediate attention are: (1) municipal garbage and other solid waste dumping in the wetland, (2) illegal land use and settlement in and around the wetland, allotment of land within of the Ramsar site to private entities, governmental, and non-governmental organizations, and (3) lack of a comprehensive management policy with adequate institutional arrangements. There are other threats faced by the wetland and they need long-term management plans for effective mitigation.

Secondary Major Threats

(1) **Railroad within the Ramsar site:** The Indian railways have constructed Assam state's southern railroad along the southern boundary and through Deepor Beel in 1990. That has segregated the wetland to more than three subsystems. The most disastrous ramification of having the railroad on the southern side of the wetland is that it has fragmented the Deepor wetland-Rani and Garbhanga Forest ecosystem into two. The railroad is hampering in wetland-animal (specifically wild Asiatic elephants) interactions. The Assam-Meghalayas population of wild elephant has regularly visited the Deepor beel Ramsar site to forage on aquatic vegetation during winter pre-monsoon and monsoon season. But this frequency has been reduced alarmingly due to existing rail road. Moreover, the elephant and their cubs could not move easily and safely due to frequent running of passenger and goods train. Causality of two wild elephant was also occurred during 2006 due to train accident. The rail road is also expediting the land encroachment and wetland draining process as accessibility into the previously inaccessible areas has increased and the market value of land has gone up. Recently, new settlements of illegal immigrant population also seen along the stretches of vacant lands between rail road and wetland. (2) **Industrial development within and along the periphery of the wetland:** Establishment of industries within periphery of the wetland system is leading to water quality deterioration and soil pollution. Permitting temporary brick kilns and associated soil quarrying from within the wetland have led to massive destruction of top soil and other ecosystem components. There are long term negative environmental impacts of establishment of brick kilns on soil productivity and soil micro-flora and fauna. (3) **Unregulated fishing and illegal hunting:** Unplanned and unregulated intensive fishing practices have depleted a lot of fish species from the wetland. While the wetland still has very high fish productivity, there has been a gradual decline over the years. Fishing activities in Deepor Beel are controlled by the government, public cooperatives, and private entities. However, the fishing activities are not coordinated because of the complex property rights issues involved. While most of the land belongs to the government, there are pockets where private land holding within. Another major threat to the Deepor Beel ecosystem is the illegal hunting, trapping and killing of wild birds and animals in Deepor Beel and adjoining areas. Large numbers of water birds are netted illegally during the winter months for consumption and as well as for sale in the local markets. It is illegal to kill and/or sale wild fauna under Indian Wildlife Protection Act (Anonymous, 1997.). However, enforcement is very slack or little. (4) **Logging in Rani-Garbhangha Reserved Forests:** The adjoining Rani and Garbhanga Reserved Forests have been experiencing government permitted and illegal logging activities for many decades. There is no best management practice for logging nor there is any forestation effort following logging. Unplanned and rarely regulated logging leads to heavy soil erosion which in turn causes rapid siltation in the wetland. Loss of trees also leads to habitat loss. For example cutting of bamboo in Rani and Garbhanga forests have affected the Asiatic elephant population to a great extent in terms of food and habitat and also leads to man-animal conflicts. Studies also indicate that loss or degradation of forest cover impacts avian population that directly or indirectly depend on the forest ecosystem. (7) **Farming and agricultural practices:** Deep water paddy cultivation and winter farming have increased soil erosion in the wetland. Associated fertilizer application may contribute to eutrophication of the water body. Agricultural practices are known to impact waterfowl (Duncan, *et al.*, 1999) and appropriate management practices are called for.

Conservation History

Some individuals (including one of the author, Saikia P. K. & others Dr. Achynty Nayan Bezbaruah, Associate Professor, North Dakota State University, USA and Mr. M. Raj Associate Professor, Darrang College, Assam) and a number of non-governmental organization led by Institute for Scientific and Technological Research (INSTER) started a mass movement for the conservation of Deepor Beel in 1989 in the face of a proposal to construct of a railroad through the wetland. As a response to the public outcry, the Forest Department of the Government of Assam proposed (1989)

4.14 km² (out of total 40 km²) of Deepor Beel as a Wildlife Sanctuary under Wildlife Protection Act of 1972. While the preliminary notification was issued almost two decades ago (Government of Assam, 1989), the final notification on the sanctuary is never forthcoming due to conflicting interests among various government departments and the lack of a conflict resolution mechanism. Villagers are worried about losing their rights on the wetland. Local political leaders intervened in the issue and turned it into a political issue. The railroad was eventually constructed through parts of the wetland based on report submitted by a technical committee (Government of Assam, 1990). In 1997, the Deepor Beel Management Authority was formed by Assam State Government to oversee conservation and development of Deepor Beel. However, it remains effectively non-functional till date due to the existence of numerous other authorities with jurisdiction over Deepor Beel. The Deepor Beel was declared in 2002 as a Wetland of International Importance under the Ramsar Convention. In 2004 Birdlife International included Deepor Beel among the five select wetlands from Assam-Sylhet region as an Important Bird Area with an *outstanding* grade (Islam & Rahmani, 2004). Assam Science, Technology, and Environment Council started a massive desilting and digging project at Deepor Beel in 2005-2006 with an objective of increasing water storage and deterring further encroachment into the wetland. Various socio-economic programs have been successfully undertaken by various non-profit and governmental organizations in the fringe villages of Deepor Beel. These programs target in capacity building, drinking water supply, alternative fisheries, alternative livelihood, children's education, and public awareness for wetland conservation. In 2007, North Dakota State University worked with Colorado based Global Response and started a global letter writing campaign to protect Deepor Beel.

New Measures Proposed

The authors of this paper have done extensive study of the bird population of the wetland and interacted with a number of stakeholders. Based on their study results and expectations of the stakeholders the following steps are proposed for sustainable management of the unique Ramsar site.

Management authority

Lack of a single management authority with a clear mandate and jurisdiction is a major hindrance in the management of Deepor beel. State departments of fisheries and forest, and the district administration all claim their share of the pie. There are also a few cooperative societies who run their fishing and agricultural activities at Deepor Beel in addition to individual land holders. Because of the presence of multiple authorities and interests, conflicts are very common and there is no effective conflict resolution mechanism. The government of Assam constituted Deepor beel Management Authority in 1989 and it remains non-function till date. In addition, Assam Science, Technology, and Environment Council and Assam Fisheries Development Corporation (both semi-governmental entities) have also carried out management activities at Deepor beel. While intentions of most stakeholders are good, the lack of a laid policy is hampering effective management. The Ramsar site needs a single institution with clear lines of authority to initiate a comprehensive management plan. To achieve this, legislative measures must be initiated at the state and central government levels to declare the Ramsar site as environmentally important and hence establish an authority to manage the site. The legislation should incorporate Rani and Garbhanga Reserved Forests within the protected site. It should, however, incorporate provisions to provide certain rights to the indigenous fisherman and tribal communities. It is important not to prohibit agricultural practices and fishing immediately to avoid antagonizing the local population (Maclean, *et al.*, 2006). However, long term plans should be drawn to reduce impact of such practices on the wetland. Erwin (2002) suggests simultaneous management for water birds and commercial crops like fish and rice in sensitive wetlands where public sentiments may go against waterfowl conservation if that is projected as the sole objective of wetland management. Staggered management approach can also be used to allow for crop production during certain time of the year at specified areas. In a multiple-use management approach the different uses of the wetland need to be optimized and prioritized. Careful planning and implementation are required with broad participation of stakeholders.

Boundary demarcation

The exact boundaries of Deepor beel Ramsar site are not known because of lack of coordinated policy and action towards identifying it. There is a vast difference between 'Deepor beel Ramsar Site' and 'Deepor Beel Wildlife Sanctuary' in terms of total spread area (Deepor is a part of Deepor beel complex, the deepor is the deeper parts and name was given after the deeper parts of the wetland). As

per the government record Deepor beel is only about 4.14 km² and the government has notified that as 'Deepor beel Wildlife Sanctuary' under Indian Wildlife Protection Act of 1972 (Government of Assam, 1989). Government's flood control department recorded the total water spread area of the Deepor Beel basin as 54.01 km² and proposed flood storage in the basin (Government of Assam, 1990) while the Deepor Beel Ramsar site is stated to be 40 km². These discrepancies have cropped up because of wrong terminologies used by the land record department in identifying various parts of the wetland system. Deepor should be called Deepor beel wetland system (or Deepor beel wetland Complex) rather than Deepor beel wetland (it is a complex of Borhola, Kalhola and Deepor Complex). Borhola, Choruhola and Kalhola are smaller wetlands parts within the Deepor beel Ramsar site. To achieve sustainability in the long run, the boundaries of Deepor beel should be so defined that it encompasses not only the water spread areas but also the buffer zones and possible future annexations. The area included within Engineering College Road and National Highway 37 (North), Gorchuk-Rani Road (South), National Highway 37 (East), and National Highway 37 and Rani Road (West) should be declared as Deepor beel System. Rani-Garbhangha forests and new Deepor Beel system should be declared as environmentally important area (Deepor beel Environmental Park). However, many of the buffer zone area within the proposed boundaries have already been developed for industries, business, and residential buildings. While it will be irrational to give up on those, it is impractical to assume that the people and businesses can be evicted and rehabilitated easily. The most practical way that will make sense and can be implemented would be to come up with strict environmental regulations for those who already have legal establishment in the peripheral areas. The boundaries should also exclude the villages and townships which are there for decades while new and recent encroachment should be removed. Results from previous efforts in other wetlands indicate that inclusion of buffer zones has positive impacts on biodiversity and overall health of the wetlands (Duncan, *et al.*, 1999).

Rail road diversion

The existing rail road through the southern periphery of the Deepor beel separates the wetland into at least three subsystems and, thus, the continuity of the system is lost. Further, the rail road segregates the wetland-forest ecosystem and is a major threat to the ecosystem particularly in terms of encroachments, forest destruction, soil erosion and ecological disturbances. Fragmentation of a wetland is known to have negative impacts on many bird species (Fletcher & Koford, 2003; Guadagnin, *et al.*, 2005; Maclean, *et al.*, 2006). The best alternative for the health of the wetland and Rani-Garbhangha Reserved Forests is to rehabilitate railroad on the Northern part of the wetland or along National Highway 37. Till such a massive project can be undertaken, the following measures should be initiated: (1) halting of trains and blowing of horn should be avoided within the boundary of Deepor beel, (2) rail traffic during dusk to dawn should be avoided to make it easier for the land animals to cross over to the wetland for water and food, (3) to keep the noise level down, suitable plantations should be raised on either side of the rail road.

Land settlement

Any form of land transaction or sale and land transformation should not be allowed within the Deepor Beel even if it is a private owned land. The private owned land should be purchased by the government or Deepor beel Development Authority as soon as possible. All illegal civil construction within and around the wetland area should be demolished or taken over by the government. .

Rani-Garbhangha protection

Further destruction of adjoining forests should not be allowed and eco-restoration should be initiated immediately. Rani-Garbhangha Reserved Forests should be included as part of the Deepor Beel Environmental Park and protected under appropriate regulations.

Long-term monitoring

Long-term monitoring of Deepor beel will be essential to develop a sustainable management plan for the wetland. The Ramsar Convention mandates regular monitoring in order to detect changes in ecological character at a listed site. Based on research done on tropical wetlands, Bennun (2001) lists three specific difficulties in long-term monitoring: conceptual, logistical and political and suggest that monitoring schemes must be carefully planned and designed. Keeping the possible constraints in mind the monitoring scheme should be so designed that appropriate corrective action can be taken based on data collected. This will involve a more detailed baseline data collection and establishment of a time series. The proposed Deepor Beel management authority should have a wing for monitoring

and surveillance. The monitoring program should be robust yet inexpensive and should involve local people and volunteers (Bennun, 2001). Training of staff and volunteers should be emphasized for capacity building. Remote sensing and similar techniques should be extensively used to identify and monitor the wetland and forest habitats of the proposed Deepor Beel Environmental Park. Remote sensing and GIS has been successfully used by others to monitor and develop sustainable management models for wetland habitats (Fletcher & Koford, 2003; Fuller, *et al.*, 2007).

Other conservation measures

It is vital include incorporate buffer zones within the Deepor Beel Ramsar site. The inclusion of buffer zones will help to support the nesting and roosting habitats of most of the residential and migratory waterfowl as well as small and large mammals. The Plantation Program should be started in highland within the Ramsar site to create breeding ground of residential waterfowl. The fast growing plant and tree species viz., bamboos (*Bambusa tulda*, *B. balcooa*, *B. arundinacea*, maturation period 3 years) and tall trees (*Anthrocephalus kadamba*, *Bombax ceiba*, maturation period 8-10 years) should be included.

The effectiveness of the Deepor Beel system as a storm water detention basin for Guwahati city should be preserved and the increasing pressure of storm runoff from the city to the wetland should be reduced through creation of additional storage capacity in the naturally depressed areas within the greater metropolitan area of Guwahati. Considering the urgency for solution of the water logging problem of the city, the use of the Deepor beel system as a storm water reservoir should receive high priority and other uses of the wetland system should be planned to be compatible with this overriding objective. The city runoff, which includes sewage, should be treated before being discharged into the Deepor beel system. While treatment using conventional sewage treatment plants may not be a feasibility, natural systems such lagoons and constructed wetland should be proposed. Such natural systems have successfully used to treat storm water all over the world (Govement of Assam, 1990). Silt traps in the main watershed would ease the siltation problem in the wetland to great extent (Deka & Goswami, 1992).

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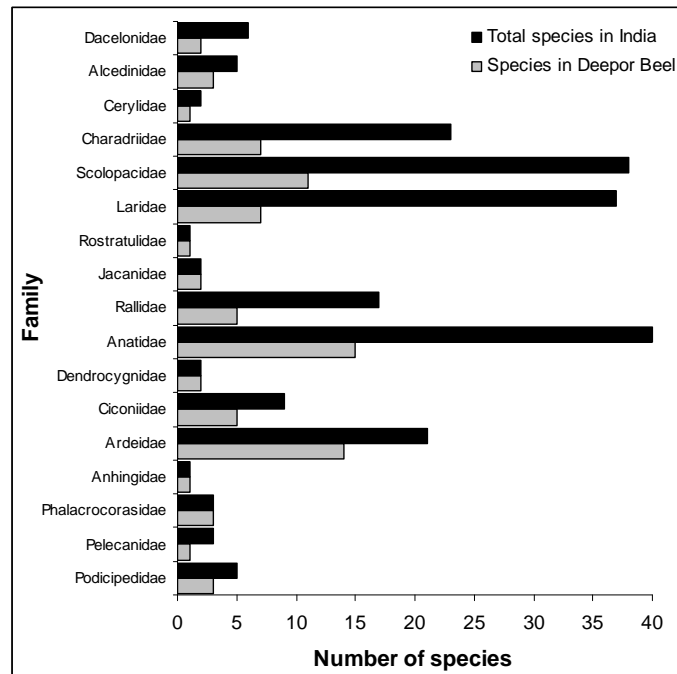


Figure 2 Comparison of species richness of wetland bird families recorded in Deepor Beel with total species richness of the families in India.

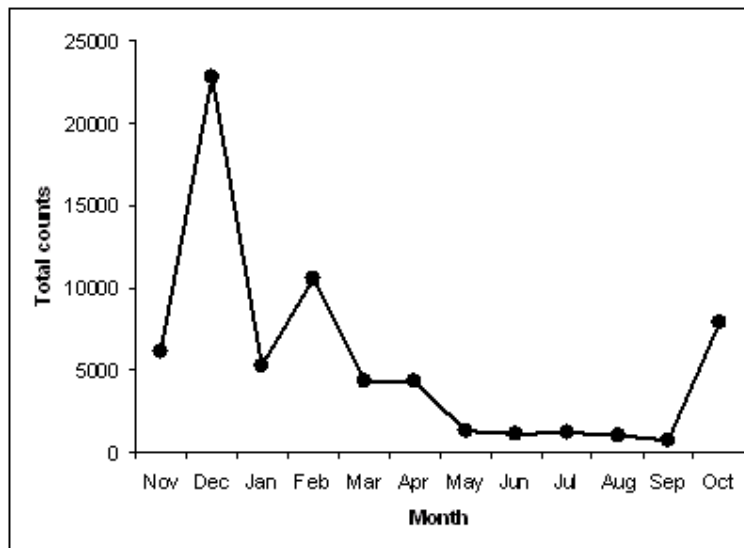


Figure 3 Temporal variations of the total counts of the wetland birds of Deepor beel

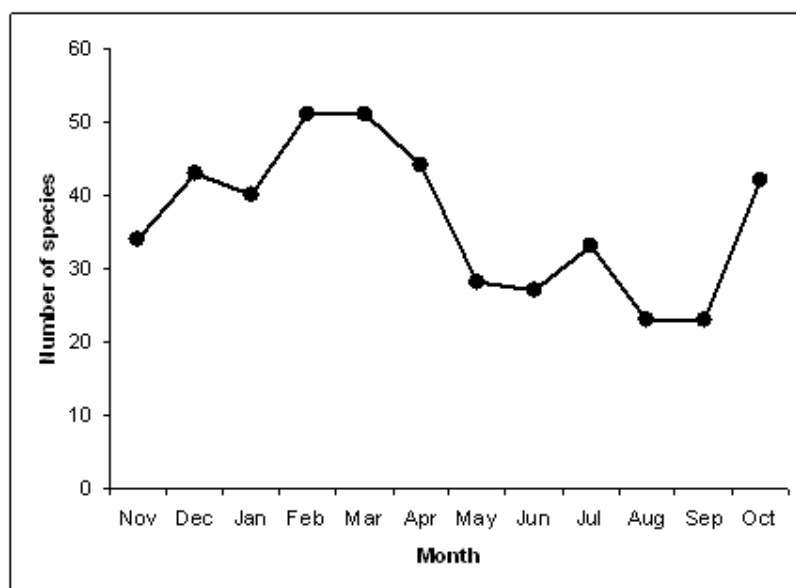


Figure 4 Temporal variations of the number of species of wetland birds of the wetland birds of Deepor Beel

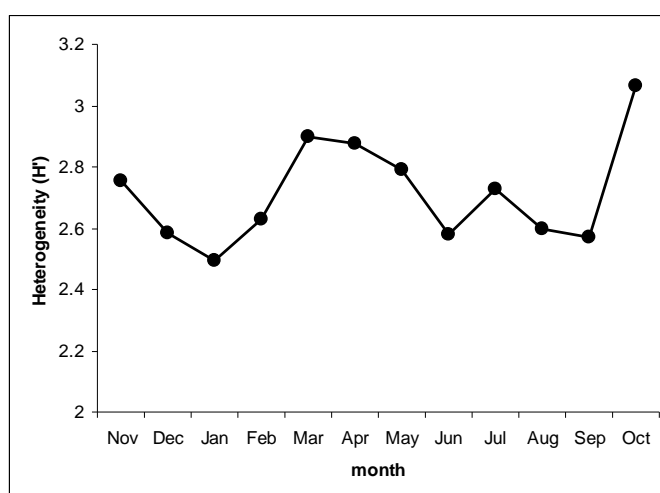


Figure 5: Temporal variations of the species diversity (Shannon-Weiner Index) of the wetland birds of Deepor Beel .

Table 1 Selected study zones in Deepor Beel wetland and its peripheral areas

Zone	Latitude	Longitude	Altitude m (msl)	Description
I	26°08' 5.2"- 26°07' 43.5"	91°39' 12"- 91°38' 46.6"	36-47	Northern bank of Deepor Beel near APRO and Assam Engineering College.
II	26°08' 02"- 26° 07' 24.3"	91°37' 40"- 91°38' 24.3"	47	North western bank of Deepor Beel starting from Khanajan outlet at NH 37 to Deepor Beel proper
III	26° 09' 5.2"- 26° 06' 47.7"	91° 40' 49.1"- 91° 40' 30.1"	38-48	North Eastern part of Deepor Beel starting from Tetalia railway crossing towards southern part of Deepor Beel on the rail line.
IV	26° 06' 58"- 26° 07' 13"	91° 37' 26"- 91° 38' 06"	44-45	Western part of Deepor Beel approaching From Azara Gadhuli Bazar/Battalion camp to Deepor Beel proper.
V	26° 06' 41.8"- 26° 05' 50"	91° 42' 40. 7"- 91° 37' 24"	48-56	Southern boundary of Deepor Beel adjoining to Garbhanga reserve forest from Garchuck to Matiapahar
VI	26° 06' 43.6"- 26° 06' 24"	91° 39' 47. 5"- 91° 37' 39"	42-51	This Zone covers the actual wetland (water area) starting from Bhanga than to Silar Tapu through proper wetland water area.

Table 2 Species richness of wetland birds in Deepor-Beel wetland.

Family	Group	Number of species
Podicipedidae	Grebes	3
Pelecanidae	Pelicans	1
Phalacrocoracidae	Cormorants	3
Anhingidae	Darters	1
Ardeidae	Heron, Egrets & Bitterns	14
Ciconiidae	Storks	5
Dendrocygnidae	Whistling ducks	2
Anatidae	Geese and ducks	15
Rallidae	Rails	5
Jacaniidae	Jacanas	2
Rostratulidae	Painted snipe	1
Laridae	Gulls & Terns	7
Scolopacidae	Sandpipers, Snipes & Stints	11
Charadriidae	Plovers & Lapwings	7
Cerylidae	Pied kingfisher	1
Alcedinidae	Kingfishers	3
Dacelonidae	Kingfishers	2
Total		83

Table 3: Species richness of non-wetland birds recorded in the vicinity of Deepor Beel wetland.

Family	Group	Number of species
Accipitridae	Eagles, Kites & Hawks*	22
Falconidae	Falcons	4
Passeridae	Weavers, Sparrows & Munias	5
Motacillidae	Wagtails & Pipits	8
Irididae	Leafbirds	2
Corvidae	Orioles, Crows, Drongos &	17
Megalaimidae	Barbets	6
Sturnidae	Starlings & Mynahs	7
Hirundinidae	Swallows & Martins	5
Pycnonotidae	Bulbuls	2
Meropidae	Bea-eaters	3
Nectarinidae	Sunbirds	5
Sylviidae	Babblers & Tailorbird	3
Muscicapidae	Flycatchers, Thrushes & allies	9
Cisticolidae	Prinias	1
Paridae	Tits	1
Lanidae	Shrike	1
Coraciidae	Rollers	2
Alaudidae	Larks	3
Apodidae	Swifts	5
Psittacidae	Parakeets	4
Culombidae	Doves	8
Picidae	Woodpeckers	3
Centropodidae	Coucals	2
Cuculidae	Cuckoos	12
Upopidae	Hoopoe	1
Strigidae	Owls	8
Total		149

* Three species frequently seen in wetland habitats.

Table 4 IUCN Red Data Book and Indian Wildlife Protection Act listed species of birds in Deepor Beel Ramsar site (recorded during study period).

Scientific Name	Common English Name	IUCN Red Data Book Status	Indian Wildlife Protection Act 1972 Status
<i>Gyps bengalensis</i>	White-rumped Vulture	CR	Schedule I
<i>Gyps indicus</i>	Long-billed Vulture	CR	Schedule I
<i>Sarcogyps calvus</i>	Red-headed Vulture	CR	-
<i>Eurynorhynchus pygmeus</i>	Spoon-billed Sandpiper	EN	-
<i>Leptoptilos dubius</i>	Greater Adjutant Stork	EN	Schedule I
<i>Aythya baeri</i>	Baer's Pochard	VU	Schedule I
<i>Dendrocygna bicolor</i>	Fulvous Whistling Duck	VU	Schedule I
<i>Haliaeetus leucoryphus</i>	Pallas's Sea Eagle	VU	Schedule I
<i>Leptoptilos javanicus</i>	Lesser Adjutant Stork	VU	Schedule I
<i>Pellorneum palustre</i>	Marsh Babbler	VU (endemic)	Schedule I
<i>Anhinga melanogaster</i>	Darter	NT	-
<i>Aythya nyroca</i>	Ferrugineous Duck	NT	-
<i>Circus macrourus</i>	Pallid Harrier	NT	-
<i>Ephippiorhynchus asiaticus</i>	Black-necked Stork	NT	-
<i>Ichthyophaga ichthyaetus</i>	Grey-headed Fish Eagle	NT	Schedule I
<i>Pelecanus philippensis</i>	Spot-billed Pelican	NT	Schedule I
<i>Sterna acuticauda</i>	Black-bellied Tern	NT	-
<i>Accipiter nisus</i>	Eurasian Sparrowhawk	LC	Schedule I
<i>Accipiter virgatus</i>	Besra	LC	Schedule I
<i>Falco chicquera</i>	Red-necked Falcon	LC	Schedule I
<i>Falco peregrinus</i>	Peregrine Falcon	LC	Schedule I
<i>Pandion haliaetus</i>	Osprey		Schedule I

CR: Critically endangered; **EN:** Endangered; **VU:** Vulnerable; **NT:** Near threatened; **LC:** Least concern

Schedule I: Highly protected species (under Indian Wildlife Protection Act, 1972) because of ecological significance and declining population.

Table 5 Abundance of different feeding guild species in Deepor Beel Ramsar site.

Feeding guild	Number of species	
	Dry season	Wet season
Insectivorous	80	81
Picivorous	38	38
Birds of Prey	30	30
Omnivorous	30	30
Granivorous	16	16
Herbivorous	12	12
Frugivorous	11	11
Carnivorous	5	5
Nectarivorous	5	5
Scavenger	4	4
Total	231	232

Appendix I Proportional abundance of avifaunal fauna surroundings of Deepor Beel Ramsar site (Recorded during study period).

Common English Name	Family	Scientific Name	Proportional Abundance	
			Dry Season	Wet Season
Little Grebe	<u>Podicepedae</u>	<i>Tachybaptus ruficollis</i>	0.86	0.14
Great Crested Grebe		<i>Podiceps cristatus</i>	0.95	0.05
Red-Necked Grebe		<i>P. grisegena</i>	1.00	0.00
Spot-billed Pelican	<u>Pelicanidae</u>	<i>Pelecanus philippensis</i>	1.00	0.00
Little Cormorant	<u>Phalacrocoracidae</u>	<i>Phalacrocorax niger</i>	0.94	0.06
Indian Cormorant		<i>Phalacrocorax fuscicollis</i>	0.75	0.25
Great Cormorant		<i>Phalacrocorax carbo</i>	0.70	0.30
Darter	<u>Anhingidae</u>	<i>Anhinga melanogaster</i>	0.81	0.19
Little Egret	<u>Ardeidae</u>	<i>Egretta garzetta</i>	0.60	0.40
Intermediate Egret		<i>Mesophoyx intermedia</i>	0.80	0.20
Cattle Egret		<i>Bubulcus ibis</i>	0.73	0.27
Great Egret		<i>Casmerodius albus</i>	0.52	0.48
Indian Pond Heron		<i>Ardeola grayii</i>	0.63	0.37
Black-Crowned Night Heron		<i>Nycticorax nycticorax</i>	0.35	0.65
Grey Heron		<i>Ardea cinerea</i>	0.54	0.46
Purple Heron		<i>Ardea purpurea</i>	0.58	0.42
Chinese Pond Heron		<i>Ardeola bacchus</i>	1.00	0.00
Goliath Heron		<i>Ardea goliath</i>	0.00	1.00
Yellow Bittern		<i>Ixobrychus sinensis</i>	0.50	0.50
Black Bittern		<i>Dupetor flavicollis</i>	0.00	1.00
Cinnamon Bittern		<i>Ixobrychus cinnamomeus</i>	0.43	0.57
Little Bittern		<i>Ixobrychus minutus</i>	0.14	0.86
Black Stork	<u>Ciconidae</u>	<i>Ciconia nigra</i>	1.00	0.00
Black-necked stork		<i>Ephippiorhynchus asiaticus</i>	1.00	0.00
Asian Openbill		<i>Anastomus oscitans</i>	0.76	0.24
Lesser Adjutant Stork		<i>Leptoptilos javanicus</i>	0.51	0.49
Greater Adjutant Stork		<i>Leptoptilos dubius</i>	0.16	0.84
Fulvous Whistling-Duck	<u>Dendrocygnidae</u>	<i>Dendrocygna bicolor</i>	0.90	0.10
Lesser Whistling-Duck		<i>Dendrocygna javanica</i>	0.77	0.23
Bar-Headed Goose	<u>Anatidae</u>	<i>Anser indicus</i>	0.13	0.87
Ruddy Shelduck		<i>Tadorna ferruginea</i>	0.78	0.22
Gadwall		<i>Anas strepera</i>	0.95	0.05
Mallard		<i>Anas platyrhynchos</i>	1.00	0.00
Spot-billed Duck		<i>Anas poecilorhyncha</i>	0.87	0.13
Common Teal		<i>Anas crecca</i>	0.99	0.01
Garganey		<i>Anas querquedula</i>	0.92	0.08
Northern Pintail		<i>Anas acuta</i>	0.95	0.05
Northern Shoveler		<i>Anas clypeata</i>	0.98	0.02
Red-crusted Pochard		<i>Rhodonessa rufina</i>	1.00	0.00
Common Pochard		<i>Aythya ferina</i>	0.98	0.02
Ferruginous Poached		<i>Aythya nyroca</i>	1.00	0.00
Baer's Pochard		<i>A. baeri</i>	0.98	0.02
Tufted Duck		<i>Aythya fuligula</i>	1.00	0.00
Cotton Pygmy-Goose		<i>Nettapus coromandelians</i>	0.14	0.86
White-breasted Waterhen	<u>Rallidae</u>	<i>Amaurornis phoenicurus</i>	0.33	0.67

Water Cock		<i>Gallicrex cinerea</i>	0.81	0.19
Common Moorhen		<i>Gallinula chloropus</i>	0.70	0.30
Water Rail		<i>Rallus aquaticus</i>	1.00	0.00
Common Coot		<i>Fulica atra</i>	0.88	0.12
Pheasant-tailed Jacana	<u>Jacanidae</u>	<i>Hydrophasianus chirurgus</i>	0.74	0.26
Bronze-winged Jacana		<i>Metopedius indicus</i>	0.58	0.42
Painted Snipe	<u>Rostratulidae</u>	<i>Rostratula bengalensis</i>	0.73	0.27
Common Snipe	<u>Scolopacidae</u>	<i>Gallinago gallinago</i>	0.60	0.40
Solitary Snipe		<i>Gallinago solitaria</i>	0.76	0.24
Eurasian Woodcock		<i>Scolopax rustica</i>	0.93	0.07
Wood Sandpiper		<i>Tringa glareola</i>	1.00	0.00
Common Redshank		<i>Tringa totanus</i>	1.00	0.00
Spotted Redshank		<i>Tringa erythropus</i>	1.00	0.00
Common Greenshank		<i>T. nebularia</i>	1.00	0.00
Nordman Greenshank		<i>T. guttifer</i>	1.00	0.00
Common Sandpiper		<i>Actitis hypoleucos</i>	0.63	0.37
Marsh Sandpiper		<i>T. stagnatalis</i>	1.00	0.00
Little Stint		<i>Calidris minuta</i>	0.50	0.50
Common Ringed Plover	<u>Charadriidae</u>	<i>Charadrius hiaticula</i>	1.00	0.00
Little Ringed Plover		<i>Charadrius dubius</i>	1.00	0.00
Pacific Golden Plover		<i>Pluvialis fulva</i>	1.00	0.00
Red-wattled Lapwing		<i>Vanellus indicus</i>	0.61	0.39
Grey-headed Lapwing		<i>Vanellus cinereus</i>	0.71	0.29
Northern Lapwing		<i>Vanellus vanellus</i>	1.00	0.00
River Tern	<u>Laridae</u>	<i>Sterna aurantia</i>	0.31	0.69
Black-bellied Tern		<i>Sterna acuticauda</i>	0.14	0.86
Whiskered Tern		<i>Chlidonias hybridus</i>	0.00	1.00
White-winged Tern		<i>C. leucopterus</i>	1.00	0.00
Brown-Headed Gull		<i>Larus brunnicephalus</i>	0.79	0.21
Black-headed Gull		<i>Larus ridibundus</i>	0.82	0.18
Mew Gull		<i>Larus canus</i>	1.00	0.00
Black-winged Stilt	<u>Himantopidae</u>	<i>Himantopus himantopus</i>	1.00	0.00
Osprey	<u>Accipitridae</u>	<i>Pandion haliaetus</i>	0.00	1.00
Black Kite		<i>Milvus migrans</i>	0.64	0.36
Brahmni Kite		<i>Haliastur indus</i>	0.74	0.26
Pallas's Fish Eagle		<i>Haliaeetus leucoryphus</i>	0.48	0.52
Grey-headed Fish Eagle		<i>Ichthyophaga ichthyaetus</i>	1.00	0.00

White-Rumped Vulture		<i>Gyps bengalensis</i>	1.00	0.00
Long-billed Vulture		<i>Gyps indicus</i>	1.00	0.00
Red-headed Vulture		<i>Sarcogyps calvus</i>	1.00	0.00
Crested Serpent Eagle		<i>Spilornis cheela</i>	1.00	0.00
Eurasian Marsh-Harrier		<i>Circus aeruginosus</i>	1.00	0.00
Pied Harrier		<i>Circus melanoleucos</i>	0.67	0.33
Hen Harrier		<i>C. cyaneus</i>	1.00	0.00
Pallied Harrier		<i>C. macrourus</i>	1.00	0.00
Montagu's Harrier		<i>C. pygargus</i>	1.00	0.00
Shikra		<i>Accipiter badius</i>	1.00	0.00
Besra		<i>Accipiter virgatus</i>	1.00	0.00
Eurasian Sparrowhawk		<i>A. nisus</i>	1.00	0.00
Common Buzzard		<i>Buteo buteo</i>	0.67	0.33
Oriental Honey-Buzzard		<i>Pernis ptilorhynchus</i>	1.00	0.00
Long-legged Buzzard		<i>Buteo rufinus</i>	1.00	0.00
Lesser Spotted Eagle		<i>Aquila pomarina</i>	1.00	0.00
Greater Spotted Eagle		<i>A. clanga</i>	1.00	0.00
Red-necked Falcon	<u>Falconidae</u>	<i>Falco chicquera</i>	1.00	0.00
Lesser Kestrel		<i>Falco naumanni</i>	1.00	0.00
Oriental Hobby		<i>Falco severus</i>	1.00	0.00
Peregrine Falcon		<i>Falco peregrinus</i>	1.00	0.00
Common Kingfisher	<u>Alcedinidae</u>	<i>Alcedo atthis</i>	0.00	1.00
Blyth's Kingfisher		<i>Alcedo hercules</i>	1.00	0.00
Blue-eared Kingfisher		<i>Alcedo meninting</i>	1.00	0.00
White-throated Kingfisher		<i>Halcyon smyrnensis</i>	0.43	0.57
Stork-billed Kingfisher	<u>Dacelonidae</u>	<i>Halcyon capensis</i>	0.30	0.70
Pied Kingfisher	<u>Cerylidae</u>	<i>Ceryle rudis</i>	0.47	0.53
Baya Weaver	<u>Passeridae</u>	<i>Ploceus philippinus</i>	0.04	0.96
House Sparrow		<i>Passer domestica</i>	0.61	0.39
Tree Sparrow		<i>Passer montanus</i>	0.65	0.35
Blackheaded Munia		<i>Lonchura malacca</i>	0.90	0.10
White-rumped Munia		<i>Lonchura striata</i>	0.00	1.00
White Wagtail		<i>Motacilla alba</i>	0.69	0.31
Yellow Wagtail		<i>Motacilla flava</i>	0.85	0.15
Grey Wagtail		<i>Motacilla cinerea</i>	0.66	0.34
Paddyfield Pipit		<i>Anthus rufulus</i>	0.85	0.15
Richard's Pipit		<i>Anthus richardi</i>	1.00	0.00
Citrine Wagtail		<i>Motacilla citriola</i>	0.87	0.13
Rosy Pipit		<i>Anthus roseatus</i>	1.00	0.00
Olive-backed Pipit		<i>A. hodgsoni</i>	1.00	0.00
Golden Fronted Leafbird	<u>Irinidae</u>	<i>Chloropsis aurifrons</i>	1.00	0.00
Orange Billed Leafbird		<i>Chloropsis hardwiskii</i>	0.50	0.50
Eurasian Golden Oriole	<u>Corvidae</u>	<i>Oriolus oriolus</i>	0.67	0.33
Black-hooded Oriole		<i>Oriolus xanthornus</i>	0.41	0.59
Rufous Treepie		<i>Dendrocitta vagabunda</i>	0.57	0.43
House Crow		<i>Corvus splendens</i>	0.54	0.46
Large-billed Crow		<i>Corvus macrorhynchos</i>	0.22	0.78
Black Drongo		<i>Dicrurus macrocercus</i>	0.67	0.33
Crow-billed Drongo		<i>Dicrurus annectans</i>	0.51	0.49
Bronzed Drongo		<i>Dicrurus aeneus</i>	0.13	0.87

Spangled Drongo		<i>Dicrurus hottentottus</i>	1.00	0.00
Ashy Drongo		<i>Dicrurus leucophaeus</i>	0.52	0.48
Lesser Racket-tailed Drongo		<i>Dicrurus ramifer</i>	0.39	0.61
Greater Racket-tailed Drongo		<i>Dicrurus paradiseus</i>	0.33	0.67
Common Iora		<i>Aegithina tiphia</i>	0.33	0.67
Black-naped Monarch		<i>Hypothymis azurea</i>	0.33	0.67
Scarlet Minivet		<i>Pericrocotus flammeus</i>	0.67	0.33
Large Cuckoo-shrike		<i>Coracina macci</i>	0.76	0.24
Ashy Wood Shallow		<i>Artamus fuscus</i>	0.96	0.04
Blue Throated Barbet	<u>Megalaimidae</u>	<i>Megalaima asiatica</i>	0.21	0.79
Coppersmith Barbet		<i>Megalaima haemocephala</i>	0.46	0.54
Lineated Barbet		<i>Megalaima lineata</i>	0.39	0.61
Golden-throated Barbet		<i>Megalaima franklinii</i>	0.26	0.74
Blue-eared Barbet		<i>Megalaima australis</i>	0.55	0.45
Great Barbet		<i>Megalaima viren</i>	0.50	0.50
Asian Pied Starling	<u>Sturnidae</u>	<i>Sturnus contra</i>	0.74	0.26
Common Maina		<i>Acridotheres tristis</i>	0.57	0.43
Bank Maina		<i>Acridotheres giginianus</i>	0.76	0.24
Jungle Myna		<i>Acridotheres fuscus</i>	0.24	0.76
White vented Myna		<i>A. grandis</i>	0.37	0.63
Greyheaded Myna		<i>Sturnus malabaricus</i>	0.76	0.24
Hill Myna		<i>Gracula religiosa</i>	0.78	0.22
Creg Martin	<u>Hirundinidae</u>	<i>Hirundo rupestris</i>	1.00	0.00
Barn Swallow		<i>Hirundo rustica</i>	0.88	0.12
Northern House Martin		<i>Delichon urbica</i>	0.88	0.12
Sand Martin		<i>Riparia riparia</i>	0.76	0.24
Nepal House Martin		<i>Delichon nipalensis</i>	1.00	0.00
Red-Whiskered Bulbul	<u>Pycnonotidae</u>	<i>Pycnonotus jocosus</i>	0.67	0.33
Red-Vented Bulbul		<i>Pycnonotus cafer</i>	0.68	0.32
Blue-tailed Bee-eater	<u>Meropidae</u>	<i>Merops philippinus</i>	0.10	0.90
Green Bee-eater		<i>Merops orientalis</i>	0.57	0.43
Chestnut-headed Bee-eater		<i>Merops leschenaulti</i>	0.76	0.24
Purple Sunbird	<u>Nectarinidae</u>	<i>Nectarinia asiatica</i>	0.00	1.00
Purple-throated Sunbird		<i>Nectarinia sepearata</i>	0.55	0.45
Mrs Gould's Sunbird		<i>Aethopyga gouldiae</i>	0.71	0.29
Crimson Sunbird		<i>Aethopyga siparaja</i>	0.50	0.50
Plain Flowerpacker		<i>Dicaeum concolor</i>	0.50	0.50
Common Tailor Bird	<u>Sylviidae</u>	<i>Orthotomus sutorius</i>	1.00	0.00
Jungle Babbler		<i>Turdoides striatus</i>	1.00	0.00
Marsh Babbler		<i>Pellorneum palustre</i>	0.40	0.60
Black Redstart	<u>Muscicapidae</u>	<i>Phoenicurus ochruros</i>	1.00	0.00

Oriental Magpie Robin		<i>Copsichus saularis</i>	1.00	0.00
Blue Whistling Thrush		<i>Myophonus horsfieldii</i>	0.26	0.74
Dark-sided Flycatcher		<i>Muscicapa sibirica</i>	1.00	0.00
Blackheaded Shrike- Babbler		<i>Pteruthius rufiventer</i>	1.00	0.00
Bluethroat		<i>Luscinia svecica</i>	1.00	0.00
Pied Buchchat		<i>Saxicola caparata</i>	1.00	0.00
Common Stonchat		<i>Saxicola torquata</i>	1.00	0.00
Verditer Flycatcher		<i>Eumyias thalassina</i>	1.00	0.00
Grey-breasted Prinia	<u>Cisticolidae</u>	<i>Prinia hodgsonii</i>	0.27	0.73
Great Tit	<u>Paridae</u>	<i>Parus major</i>	0.50	0.50
Graybacked Shrike	<u>Lanidae</u>	<i>Lanius tephronotus</i>	0.75	0.25
Indian Roller	<u>Coracidae</u>	<i>Coracias benghalensis</i>	0.38	0.62
Dollar Bird		<i>Eurystomus orientalis</i>	0.50	0.50
Oriental Skylark	<u>Alaudidae</u>	<i>Alauda gulgula</i>	0.84	0.16
Crested Lark		<i>Galirida cristata</i>	0.47	0.53
Rufous-winged Bushlark		<i>Mirafra assamica</i>	1.00	0.00
Common Swift	<u>Apodidae</u>	<i>Apus apus</i>	0.80	0.20
Alpine Swift		<i>Tachymarptis melba</i>	1.00	0.00
Fork-tailed Swift		<i>Apus pacificus</i>	0.80	0.20
House Swift		<i>Apus affinis</i>	1.00	0.00
Asian Palmswift		<i>Cypsturus balasiensis</i>	0.11	0.89
Rose-ringed Parakeet	<u>Psittacidae</u>	<i>Psittacula karmieri</i>	0.60	0.40
Alexandrine Parakeet		<i>Psittacula eupatria</i>	0.83	0.17
Blossom-headed Parakeet		<i>Psittacula roseata</i>	0.78	0.22
Vernal Hanging Parrot		<i>Loriculus vernalis</i>	0.75	0.25
Spotted Dove	<u>Culombidae</u>	<i>Streptopelia chinensis</i>	0.52	0.48
Red Collared Dove		<i>Streptopelia tranquebarica</i>	1.00	0.00
Eurasian Collared Dove		<i>Streptopelia decaocto</i>	1.00	0.00
Oriental Turtle Dove		<i>Streptopelia orientalis</i>	1.00	0.00
Emerald Dove		<i>Chalcophaps indica</i>	1.00	0.00
Yellow-footed Green		<i>Treron phoenicoptera</i>	0.48	0.52
Pigeon				
Wedge-tailed Green Pigeon		<i>Treron sphenura</i>	0.89	0.11
Orange-breasted Green		<i>Treron bicincta</i>	0.92	0.08
Pigeon				
Black-rumped Flameback	<u>Picidae</u>	<i>Dinopium bengalensis</i>	0.63	0.37
Yellow-crowned Wood pecker		<i>Dendrocopos mahrattensis</i>	0.71	0.29
Grey-capped Pygmy Woodpecker		<i>Dendrocopos canicapillus</i>	0.71	0.29
Greater Coucal	<u>Centropodidae</u>	<i>Centropus sinensis</i>	0.13	0.88
Lesser Coucal		<i>Centropus bengelensis</i>	0.50	0.50
Asian Koel	<u>Cuculidae</u>	<i>Eudynamys scolopacca</i>	0.50	0.50
Common Hawk Cuckoo		<i>Hierococcyx varius</i>	0.76	0.24
Hodgson's hawk Cuckoo		<i>Hierococcyx fugax</i>	0.42	0.58
Large Hawk Cuckoo		<i>Hierococcyx sparverioides</i>	0.67	0.33
Indian Cuckoo		<i>Cuculus micropterus</i>	0.67	0.33
Oriental Cuckoo		<i>Cuculus canorus</i>	0.80	0.20
Lesser Cuckoo		<i>Cuculus poliocephalus</i>	0.50	0.50

Chestnut-winged Cuckoo		<i>Clamator coromandus</i>	0.50	0.50
Pied Cuckoo		<i>Clamator jacobinus</i>	0.50	0.50
Plantative Cuckoo		<i>Cacomantis merulinus</i>	0.50	0.50
Drongo Cuckoo		<i>Surniculus lugubris</i>	0.50	0.50
Green-billed Malkoha		<i>Phaenicophaeus tristis</i>	0.50	0.50
Common Hoopoe	<u>Upopidae</u>	<i>Upupa epops</i>	0.33	0.67
Spotted Owlet	<u>Strigidae</u>	<i>Athene brama</i>	0.22	0.78
Collared Scops Owl		<i>Otus bakkamoena</i>	0.62	0.38
Asian Barred Owlet		<i>Glaucidium cuculoides</i>	0.62	0.38
Jungle Owlet		<i>Glaucidium radiatum</i>	0.69	0.31
Great Eared Nightjar		<i>Eurostopodus macrotis</i>	0.54	0.46
Brown Fish Owl		<i>Ketupa zeylonensis</i>	0.67	0.33
Tawny Fish Owl		<i>Ketupa flavipes</i>	0.53	0.47
Barn Owl		<i>Bubo bubo</i>	0.22	0.88

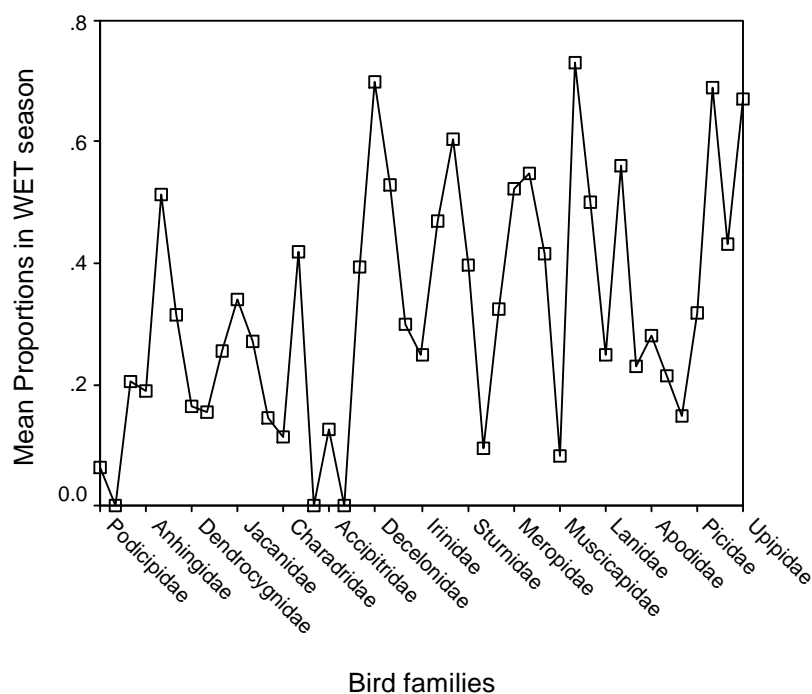


Figure 6 Mean proportional abundance of avian families in Deepor beel Ramsar Site during wetter half of the year indicating wet season preferences.

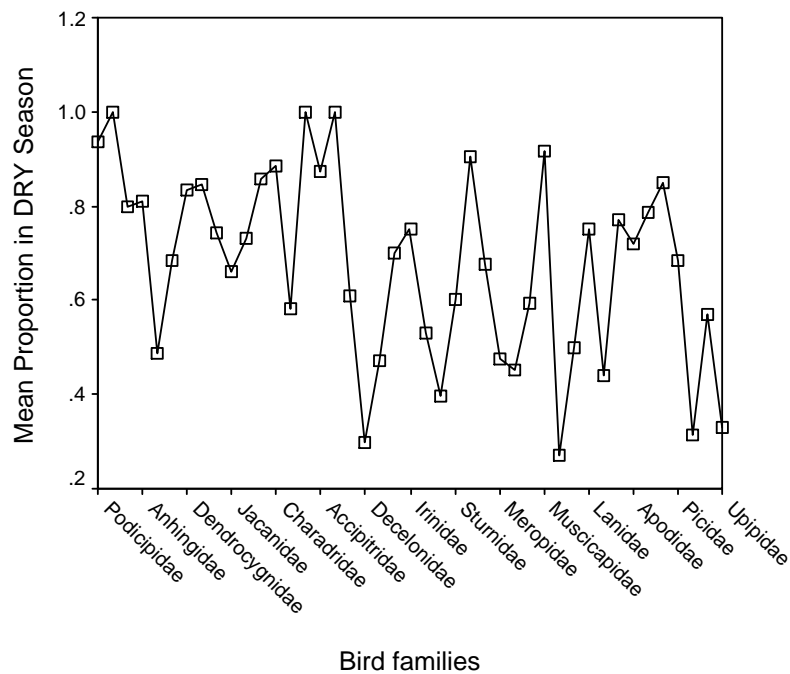


Figure 7 Mean proportional abundance of avian families in Deepor beel Ramsar Site during dryer half of the year indicating dry season preferences.

Appendix 2 Mean proportional abundance of avian families in dry and wet season indicating seasonal preferences of wetland habitat (Figures in Bold are significantly higher abundance in each season of the year).

Avian families	Proportional abundance in Dry Season	Proportional abundance in Wet Season	N
	Mean \pm SD	Mean \pm SD	
Podicipidae	0.9367 \pm .07095	0.0633 \pm .07095	3
Pelicanidae	1.0000 \pm 0	0.0000 \pm 0	1
Phalacrocoracidae	0.7967 \pm .12662	0.2033 \pm .12662	3
Anhingidae	0.8100 \pm 0	0.1900 \pm 0	1
Ardeidae	0.4871 \pm .28862	0.5129 \pm .28862	14
Ciconidae	0.6860 \pm .35718	0.3140 \pm .35718	5
Dendrocygnidae	0.8350 \pm .09192	0.1650 \pm .09192	2
Anatidae	0.8447 \pm .29430	0.1553 \pm .29430	15
Rallidae	0.7440 \pm .25579	0.2560 \pm .25579	5
Jacaniidae	.6600 \pm .11314	.3400 \pm .11314	2
Rostratulidae	.7300 \pm 0	.2700 \pm 0	1
Scolopacidae	.8564 \pm .19556	.1436 \pm .19556	11
Charadriidae	.8867 \pm .17840	.1133 \pm .17840	6
Laridae	.5800 \pm .41980	.4200 \pm .41980	7
Himantopidae	1.0000 \pm 0	.0000 \pm 0	1
Accipitridae	.8727 \pm .25157	.1273 \pm .25157	22
Falconidae	1.0000 \pm 0	.0000 \pm 0	4
Alcedinidae	.6075 \pm .48603	.3925 \pm .48603	4
Decoloniidae	.3000 \pm 0	.7000 \pm 0	1
Ceryliidae	.4700 \pm 0	.5300 \pm 0	1
Passeridae	.7015 \pm .33188	.2985 \pm .33188	13
Irididae	.7500 \pm .35355	.2500 \pm .35355	2
Corvidae	.5300 \pm .24107	.4700 \pm .24107	17
Megalaimidae	.3950 \pm .13546	.6050 \pm .13546	6
Sturnidae	.6029 \pm .21853	.3971 \pm .21853	7
Hirundinidae	.9040 \pm .10040	.0960 \pm .10040	5
Pycnonotidae	.6750 \pm .00707	.3250 \pm .00707	2
Meropidae	.4767 \pm .33975	.5233 \pm .33975	3
Nectarinidae	.4520 \pm .26696	.5480 \pm .26696	5
Sylviidae	.5918 \pm .25891	.4173 \pm .25891	11
Muscicapidae	.9178 \pm .24667	.0822 \pm .24667	9
Cisticollidae	.2700 \pm 0	.7300 \pm 0	1
Paridae	.5000 \pm 0	.5000 \pm 0	1
Lanidae	.7500 \pm 0	.2500 \pm 0	1
Coraciidae	.4400 \pm .08485	.5600 \pm .08485	2
Alaudidae	.7700 \pm .27185	.2300 \pm .27185	3
Apodidae	.7183 \pm .33349	.2817 \pm .33349	6
Pisittacidae	.7867 \pm .04041	.2133 \pm .04041	3
Columbidae	.8513 \pm .22113	.1488 \pm .22113	8
Picidae	.6833 \pm .04619	.3167 \pm .04619	3
Centropodidae	.3150 \pm .26163	.6900 \pm .26163	2
Cuculidae	.5683 \pm .12276	.4317 \pm .12276	12
Upipidae	.3300 \pm 0	.6700 \pm 0	1
Total	.6989 \pm .28928	.3016 \pm .29015	232

SD: Standard deviation; N= number of species in the family