EFFECT OF HABITAT CHARACTERISTICS ON WATERBIRD DIVERSITY ALONG RIVER GANGA IN ALLAHABAD, UTTAR PRADESH

Dissertation Submitted to

Saurashtra University, Rajkot

in partial fulfillment of Master's Degree in Wildlife Science

By

Kumar Ankit

Under the Supervision of

Dr. Gopi G. V.

Dr. S. A. Hussain

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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भारतीय वन्यजीव संस्थान
Wildlife Institute of India

CERTIFICATE

This is to certify that **Mr. Kumar Ankit** has carried out an original piece of research from Wildlife Institute of India, titled **"Effect of habitat characteristics on waterbird diversity along river Ganga in Allahabad, Uttar Pradesh"**, in partial fulfilment of a Masters Degree in Wildlife Science from Saurashtra University, Rajkot, India. The study was carried out under our supervision from December 2016 to June 2017. We hereby certify that this work has not been submitted for any other degree to any other University.

Dr. Gopi G.V.
Scientist E
Supervisor

Dr. S.A. Hussain
Scientist G
Co-supervisor

Date: 29.06.2017

Place: Dehradun

पत्रपेटी सं0 18, चन्द्रबनी, देहरादून – 248 001, भारत
Post Box No. 18, Chandrabani, Dehra Dun - 248001. INDIA
ई.पी.ए.बी.एक्स : + 91-135-2640111 से 2640115 फैक्स : 0135-2640117, तार : WILDLIFE
EPABX : + 91-135-2640111 to 2640115; Fax : 0135-2640117; GRAM : WILDLIFE
ई–मेल / E-mail : wii@wii.gov.in

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Summary

1. Riverine floodplains are a mosaic of different habitat available in the riverine area. It is extensively used by an array of flora and fauna. It supports a huge biodiversity by providing habitat as a resource to various taxa. Many waterbird species are directly and indirectly dependent on the riverine floodplains and use riverine habitat at a certain stage in their life cycle. The area also supports a high diversity of wintering waterbirds. Migratory bird takes refuge in the area during the severe winter in their native habitat. Habitat-specific species use different types of habitat present in the riverine floodplain. The riverine system also has an intricate relationship with the humans. Since a long time, these habitats are subjected to overexploitation that affects the natural ecological processes and the functioning of river. Degradations of floodplains of the major rivers of the world by alteration of water flow, encroachment in river islands and collection river bed materials, discharge of urban and industrial effluents, are threatening the biodiversity of rivers and their associated wetlands. The effect due to different levels of the disturbance is unknown on the diversity and abundance of waterbirds. On these lines, I conducted my study focused on identifying what are the habitat characteristics which is affecting the abundance and diversity of waterbirds and what are the anthropogenic factors affecting its diversity and abundance.

2. The study was carried out in Allahabad District of Uttar Pradesh. It is known for the confluence of two major rivers of India, river Ganga, and its tributary river Yamuna. It is one on the densely populated city of northern India which is famous for glorious past and present and religious-cultural heritage. It is also known as Prayag due to the congregation of peoples in confluence area in different time of year due to religious practices. The area supports the diversity of waterbirds and facilitates migratory waterbirds in peak winters as it provides the different mosaic of habitats. The intensive study was conducted in upstream and downstream of river Ganga and upstream of river Yamuna from the confluence point. Six mosaics of habitat were identified after the reconnaissance survey. Sixteen

transects were identified and sampling was done with the proportional effort in each habitat type. Number of transects were seven, six and three in upstream, downstream of river Ganga and upstream of river Yamuna respectively, from the confluence. Each transect was replicated thrice during the study and the habitat variable and anthropogenic factors were quantified in each transect.

3. The field work was carried out from Mid December 2016 to Mid April 2017. A systematic reconnaissance survey was conducted from Mid December 2016 and Mid January 2017. Whereas, the data for the abundance of waterbirds, habitat variable were collected from Mid January 2017 to Mid April 2017 from each transect on different dates to avoid biases.

4. 41 species of waterbirds of 12 families were observed in totality while sampling. In which 22 species are migratory. The transect data were analyzed in the software DISTANCE 6.2 categorizing all the 41 species in 6 different group. The group (Egrets, Herons, Storks and Ibis) were the group having the highest density i.e.1077 per river square kilometer area 1077, following Shorebirds 2, Shorebirds 1, Terns, gulls and Skimmer, Ducks and geese, and cormorants with density 455.71, 423.29,117.87,106.03 and 29.08 respectively. Rank abundance curve showing the result that River Lapwing *Vanellus duvaucelii,* Temminck's stint *Calidris temminckii* were the most abundant species in the study site, whereas, Whimbrel *Numenius phaeopus* and most of the species from the ducks and geese family Anatidae were the rarest in the study area except Ruddy Shelduck *Tadorna ferruginea* which was moderately abundant in the study area. The species rarefaction curve depicted that species richness was high where there is more heterogeneous habitat type. The presence of the river islands was also one of the important habitat characteristics which are defining the species richness and abundance of the waterbirds in the study area. The bi-plot of PCA ordination with the species abundance and associated site showing the result that the specialist species like Indian Skimmer *Rynchops albicollis* avoiding the areas which is having more anthropogenic pressure.

1. Introduction

Water is a multifaceted resource with the potential to develop habitat and support biodiversity in addition to providing public service (Ignatieva 2010, Hansson et al. 2005). Riverine systems are characterized by complex landscape structure owing to their dynamic nature. This, in turn, provides a diversity of habitats that sustain various successional stages of faunal assemblages. A dynamic riverine landscape sustains biodiversity by providing a variety of refugia and through ecological feedbacks from the organisms themselves (Robinson et al. 2002) "*Naturally functioning wetlands provide a range of benefits and services for people's livelihoods and well-being, including food, fiber, flood protection, water purification and support for cultural values, as well as water supply*"(Wetland International, 2012). Wetlands are areas where water is the crucial factor controlling environment, associated plant, animal life and support a rich biodiversity. Many animals depend on rivers, lakes, streams, and wetlands as habitat and they are important in supporting species diversity as well as having different values (Prasad et al. 2002). The Ramsar Convention uses a broad definition of wetlands. "It includes all lake, river, underground aquifers swamps and marshes, wet grasslands, peat lands, oasis, estuaries, deltas and tidal flat, mangrove and other coastal areas, coral reefs and all human-made sites such as fish pond, rice paddies, reservoir, and salt pan". Wetlands are internationally recognized as important habitat type for the conservation of waterbirds (Flaquer et al. 2009). Birds that are "ecologically dependent on wetlands" have been broadly defined as 'waterbirds' (Wetlands International, 2012; Kumar et al. 2005). Waterbirds offer a range of benefits, including ecosystem functioning and their association with wetland ecosystem makes them as wetland health indicators (Dynesius and Nilsson 1994). They have many features in their biology that includes colonial breeding, congregatory behavior and long distance migrations and (Burnette 2016).

The Ramsar wetland type M includes all the permanent river, streams, creek including waterfall (Islam and Rahmani, 2008). The river ecosystem encompasses river channels and its floodplains and forms a diverse mosaic of habitats with the riparian area at the transition zone between land and water. These linear ecosystems provide an important

sheltering, feeding and breeding area for wildlife and provide significant stopover sites and refugia habitats for waterbirds (Forneman et al. 2011). Also, large streams and river serve as important fly routes for many migrating waterbirds. The dynamic biophysical nature of rivers provides unique habitats to both aquatic flora and fauna (Osawas et al. 2010) which in turn attract several communities of waterbirds for feeding. They also host migratory waterbird species, during the severe winter in their breeding ranges (Dudgeon, 2000). Riverine floodplains are a mosaic of different habitats available in the riverine area which are extensively used by an array of flora and fauna (Robinson et al. 2002). Despite their ecological productivity, they are among the most endangered type of landforms worldwide. Habitats like river islands, mudflats, sandbar, pools, flowing water and vegetation play a major role in diversity and abundance of waterbirds (Islam and Rahmani 2008). It is well known that waterbirds have different adaptation to use a variety of wetlands for their survival and life history strategies which differ from species to species (Kantrud and Stewart 1977; Kaupinnen 1995). Different species of waterfowl like duck, geese, and coots use riverine habitat at a certain stage in their life cycles. The areas also support large numbers of wintering waterbirds (Page and Gill 1994). River islands are used as breeding ground by different species that nest on the ground (Rajguru 2017). More habitually waders and terns also use these areas as a roost. The main channel in the form of deep open water attracts several diving waterbirds like ducks and cormorants. Mudflats and shallow water are rich in food resources for waders. Larger waterbirds with long leg and bills such as egrets, pelicans, spoonbills, herons and curlew often use shallow water for foraging. Vegetation provides covers; also ducks and geese feed on the tubers, emergent vegetation, and grassy banks.

The riverine ecosystem has an intricate relationship with human since a long time. Many riverine habitats, particularly within urban centers in the developing countries are subjected to overexploitation that affects the natural ecological processes and the functioning of rivers. Riverine areas where the human activity can frequently disturb waterbird are less studied (Choi et al. 2015). Widespread decline of the riverine species is due to the combination of several anthropogenic factors throughout its range (Chowdhury et al. 2011). Some of the major factors are the land-use-change from water diversion has reduced and degraded habitat availability, to stop over and wintering sites of the

Waterbirds (Page and Gill 1994). Destruction of the breeding habitat as islands and sand-spits in the larger rivers are increasingly cultivated.

Several factors may have affected the numbers of waterbirds. Degradation of the riverine ecosystem has occurred due to the constructions of large dams and embankments as well as through agricultural encroachment on the mudflats. Sand and gravel extraction for development is also common in major rivers which are leading to disturbance for the waterbirds in many river systems of the world.

1.1. Rational of the study

Freshwater biodiversity is the main conservation priority during the International Decade for Action – 'Water for Life' – 2005 to 2015. Widespread degradation and various anthropogenic activities like agriculture, over-exploitation of resources, residential sprawl and modification to store or manage water resource are threatening the biodiversity of rivers and their associated wetland at global and regional scale (Burnette 2016; Kirby et al. 2008; Dudgeon 2000, Collen et al. 2010). Human impact on riverine biodiversity is more evident in Asia than any other part of the world. Flow regulation, construction of large dams, flood control, over-harvesting of fish, pollution, and conversion of riverine wetlands to agriculture are common threats to many Asian rivers and its biodiversity (Dudgeon 2000, 2002). There have been widespread reports in recent decades of alarming declines in wetland birds, which have been variously accredited to habitat loss (Morrison et al. 1994) global climate change, increasing salinity, disease, poaching and pollution (Sandilyan et al. 2010). The extent and impact of human disturbance on waterbird species are unclear (Custer and Osborn, 1977; Tremblay and Ellison, 1979; Safina and Burger, 1983). Despite being rich in avifauna, rivers are poorly documented, even in regards to basic ecological and conservation parameters such as species composition, relative abundance, diversity indices, density and feeding guilds (Kantrud and Stewart 1984).

The freshwater and inland waters of India support a huge biodiversity, especially the rivers provides a suitable habitat for different taxa. Ongoing degradation of riverine ecosystems, some taxa have been gravely affected especially riverine and waterbirds

(Dudgeon 2000). Also, rivers in India are a good refuge site for the migratory waterbirds (Islam and Rahmani 2008). It is highly important to investigate the species composition, abundance, diversity, and habitats of wetland-dependent birds in our river system to examine population trends and also to identify and highlight main causes of species decline due to growing pressure from anthropogenic activities.

Forty percent of India's human population inhabits the flood plain riverscape of the Indo-Gangetic Plain. The consequent high dependence on riverine ecosystem services has caused serious conflicts between conservation efforts for biodiversity and the demand for river resource (Dudgeon 2000). The stretch nearby confluence of river Ganga and Yamuna in Allahabad is one of the densely human populated areas in India. This stretch of Ganga near Allahabad is considered to be highly polluted (Venkatraman 2003). Coincidentally due to traditional belief and religious practice this area witnesses a high human congregation in and around the confluence at the time of the migration period of waterbirds. Despite the heavy anthropogenic pressure, area facilitates several winter migratory waterbirds. The study aims to determine forms and intensities of human-induced activities in the study area and establish how these relate to abundance and diversity of waterbirds. This assumes importance as the Government has done some major policy decision to clean the Ganga and revive the biodiversity (National Mission of Clean Ganga, 2015).

The river Ganga is the longest river in India with differential characteristics such as depth, flow, bank characteristics, river islands, throughout the river stretch. It supports a huge biodiversity and provides a heterogeneous habitat to the various taxa (Venkatraman 2003). The River and its associated wetlands facilitate huge diversity of waterbirds (Islam and Rahmani, 2008). It is used by several species of wintering waterbirds as a wintering ground. Studies suggest that the waterbird abundance and diversity are related to habitat characteristics of the wetland such as water level, aquatic vegetation and water area (Kaminski and Prince 1984; Edward and Otis 1999) and surrounding landscape characteristics. In most developing countries, waterbird habitats are among the most extensively exploited for various resources. The unregulated access by humans and livestock to such area affects the habitat for waterbirds and their community structure

(Burger et al., 2004). From the last few decades, the Ganga river ecosystem has been continuously altered by several ongoing anthropogenic processes, accommodating multi-dimensional pressure due to increase in human population density (Singh and Singh 2007). River Ganga and its associated wetlands support a large number of the waterbird diversity, especially during migratory period

1.2.Objective

1. To study the effect of habitat characteristics on abundance and diversity of waterbirds.

1.3.Research questions

1. What are the habitat characteristics affecting abundance and diversity of waterbirds in riverine landscape?

2. What are the anthropogenic factors affecting diversity and abundance of waterbirds?

2. Study Area

2.1 General Description

The study was carried out in Allahabad District 24°47′ N and 25°47′ N and 81°09′ E and 82°21′ E. Allahabad is a major city in the north Indian state of Uttar Pradesh. It is the seventh most populous city, a total population of 5,959,798 (2011 census) in Uttar Pradesh. The district is famous for its historically glorious past and present and rich religious-cultural heritage. The geographical area of Allahabad district is 5,137 square km. According to the biogeographical classification of India by Rogens and Panwar, 1988, it comes in Gangetic plain zone It is a part of Ganga-Jamuna Doab west of the Indo-Gangetic plain region. The district is drained by rivers Ganga, Yamuna, Tons and their tributaries. Allahabad is considered a very sacred place and also known as Prayag due to the confluence river Ganga, Yamuna and invisible Saraswati. The city is known for the Kumbh Mela which is organized at every interval of 12 years. Thousands of pilgrims come to the confluence area for prayer and take holy bath in the confluence of river Ganga and Yamuna.

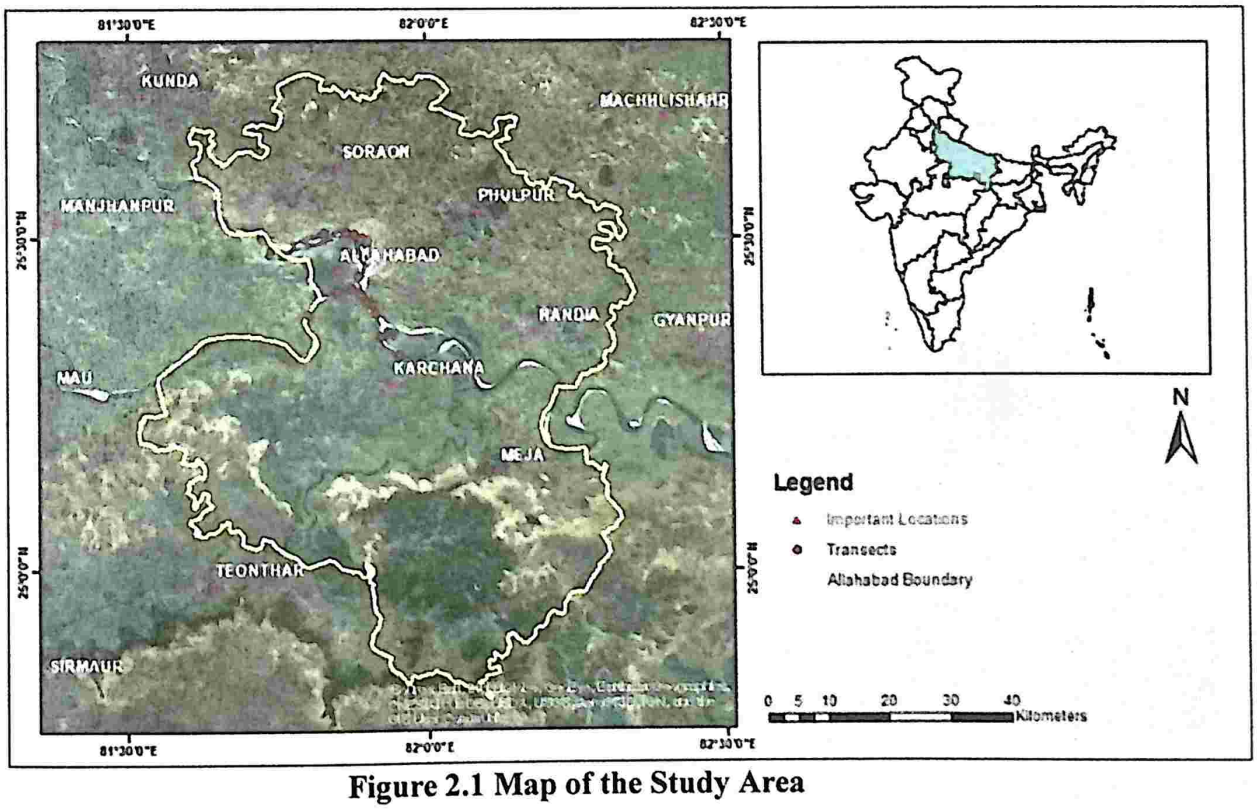

Figure 2.1 Map of the Study Area

2.2 Climate

The climate of Allahabad is humid subtropical, which is common to the cities in the plain of North India. The three main season of Allahabad is summer, monsoon, and winter. Summers are typically hot and dry which starts in March and last up to May. The maximum temperature reaches up to 48 °C. Allahabad experiences extremely humid monsoon the maximum temperature reaches up to 40°C, high humidity prevails till September. Monsoon arrives in June and lasts till September the average rainfall is 1027 mm. August receives the highest rainfall, approximately 296 mm. Winter starts in December and runs up to February. The temperature rarely drops to the freezing point. It also experiences dense fog during winters which are common in northern India.

2.3 Soil and Crops

Soils of the district are largely composed of the eroded materials brought by the rivers from the Himalayas and the Vindhyan upland. The most fertile alluvial soil has stretched both sides of river Ganga and Yamuna. Paddy, Wheat, Mustard, Sugarcane are the common crops cultivated in the fertile alluvial soil of the district. Vegetables of the family Cucurbitaceae, commonly cultivated on river islands and sand and banks of river Ganga and Yamuna.

2.4 Flora and Fauna

The city is having unique flora and fauna as it is situated on the western side of the Indo - Gangetic plain. Also, it is a part of Ganga- Jamuna Doab which is responsible for its unique species of biodiversity. Twenty-seven mammals have been reported from the district, Blue Bull or Nilgai *Boselaphus tragocamelus* and Black Buck *Antilope cervicapra* are found in isolated pockets of the district. Gangetic dolphin *Platanista gangetica* is reported from Ganga, Yamuna, and confluence of Ganga and Yamuna. Nineteen species of fishes, three hundred and nine species of birds, sixteen species of reptiles been reported from the district. Common birds are Peafowl *Pavo cristatus*, House sparrow *Passer domesticus,* and Cattle Egret *Bubulcus ibis.* Tree species are Babul *Acacia nilotica*, Arjun *Terminalia Arjuna,* Shisham *Dalbergia sissoo* is found in the the

district. Whereas planted species are Teak *Tectona Grandis*, Gulmohar *Delonix regia*, Eucalyptus. Different species of Bamboo is common in district.

There is a report of 309 bird species from different wetlands of Allahabad district (Bird Life International, 2011). Out of 309, 76 are waterbirds. The study aims to waterbirds in the riverine area.

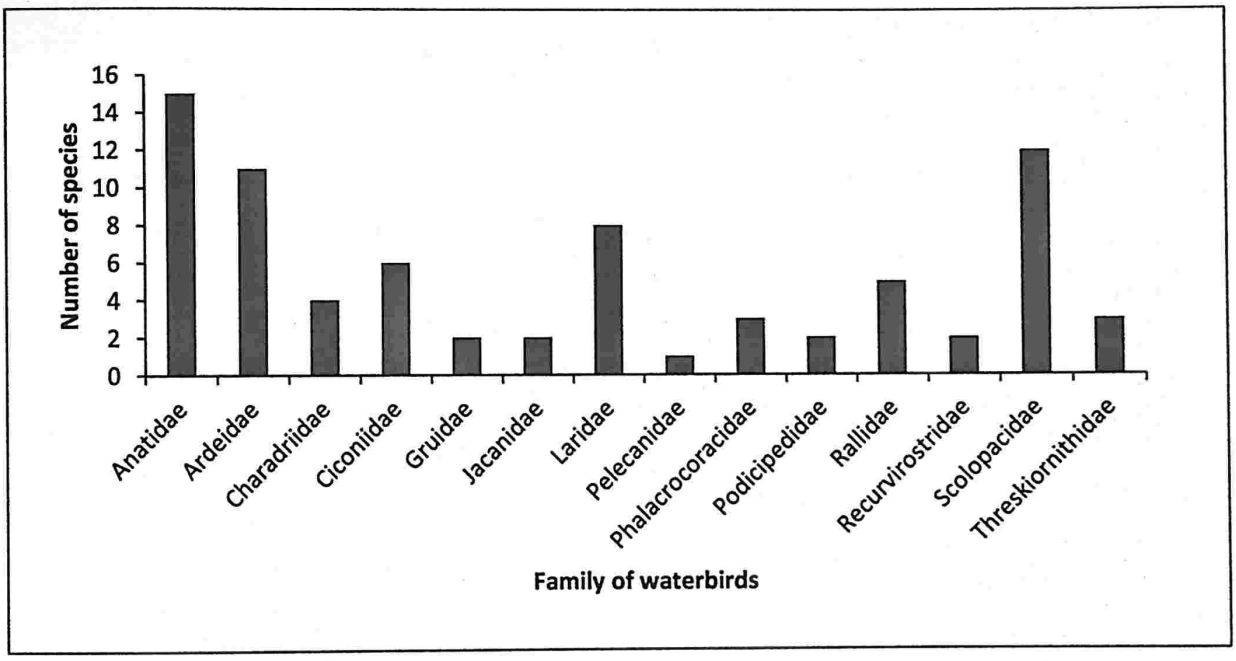

Figure 2.2 Family of waterbirds reported in Allahabad

2.5 Intensive Study area

The intensive study was carried out in the 25 km upstream of river Ganga, 25 upstream of the river Yamuna and 25 km downstream of the river Ganga from confluence of river Ganga and the Yamuna in Allahabad District. The river Ganga flows in the eastern edge of the city and Yamuna flows in the southern edge of the city.

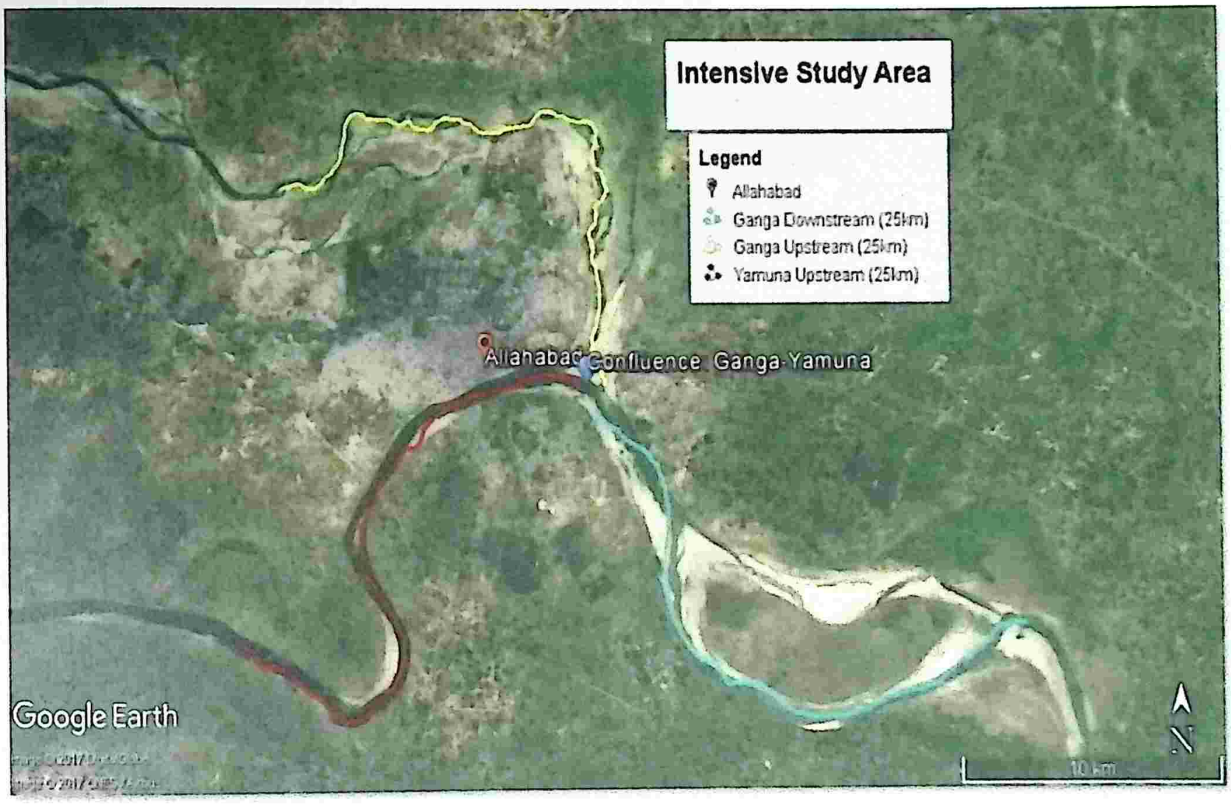

Figure 2.3 Map of Intensive Study Area

3. Study design

A reconnaissance survey was conducted in 25 Km upstream and downstream of river Ganga and upstream of river Yamuna in Allahabad District in the month of Mid December 2016 to Mid January 2017. It was observed that waterbirds were distributed all over the study area including the migratory waterbirds. Observation after the post-reconnaissance suggested that the distribution of waterbirds is overlapping with the several habitat characteristics and anthropogenic factors such as river islands, mudflats, and sandbar. Based on that, six combinations of different riverine habitats for the waterbirds were identified in the survey area. Three avifaunal surveys from mid-January 2017 to mid-April 2017 were carried out in the selected habitat type.

S.L no	Habitat	Code
1	Pool	P
2	River Islands, Mudflat, Sand Bar, Pool	RIMSP
3	River Island, Sandbar, Pool	RISP
4	Mudflat, Pool	MP
5	River Islands, Mudflat, Pool	RIMP
6	Mudflat, Sand Bar, Pool	MSP

Table 3.1 Summary of identified habitat characteristics of waterbirds in the study area after the reconnaissance survey

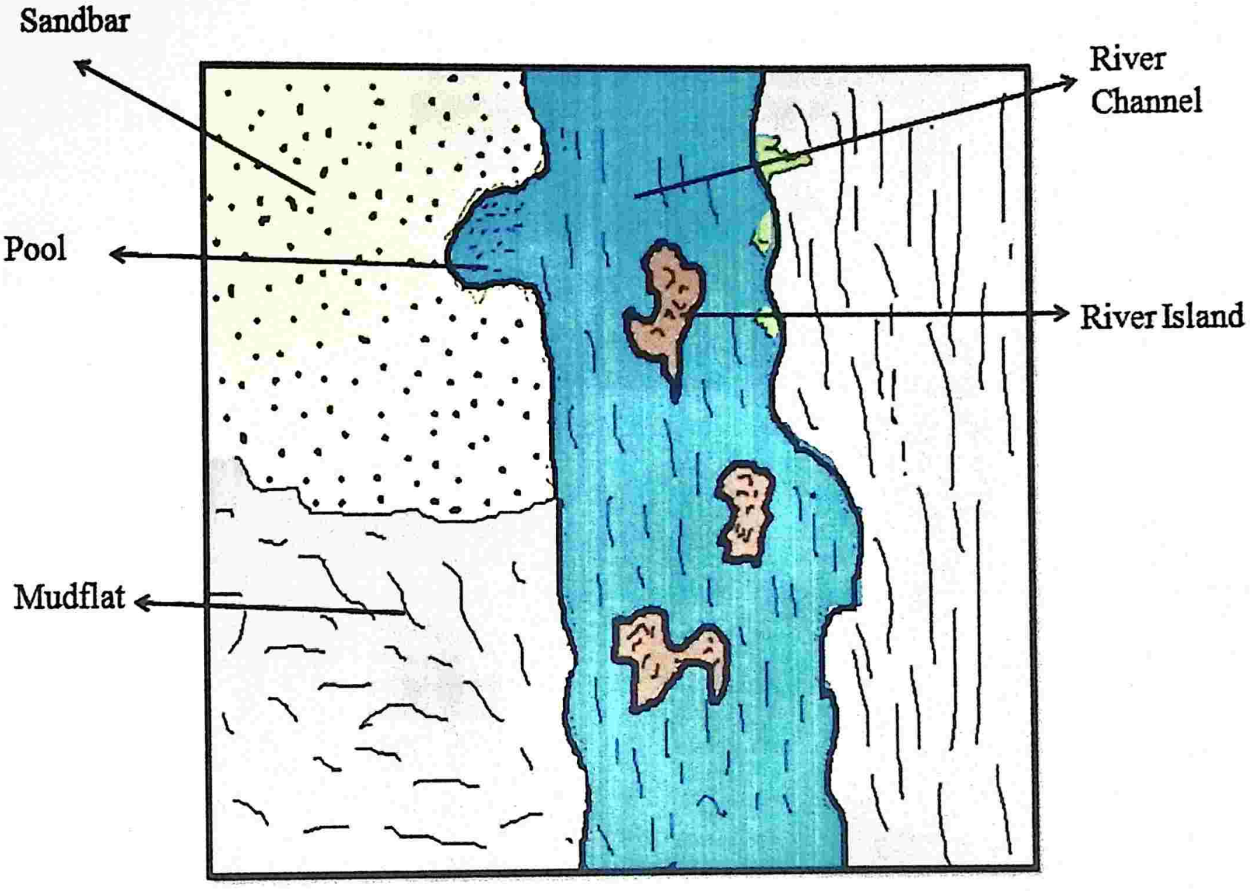

Figure 3.1 Pictorial depictions of habitats

3.1 Methodology

Waterbird Sampling

The waterbirds were surveyed in the different habitat by a single observer in the study period. Distance sampling method was used for the enumeration of waterbird densities in the study area. (Buckland et al. 2005) Sixteen line transects were identified covering above-mentioned habitat type with equal and proportional effort. Transects were replicated thrice during the study period January 2017 to April 2017 in different dates to avoid biases. Flying bird was not recorded during the study. Out of Sixteen transect number of transect were seven, six and three in upstream, downstream of river Ganga and upstream of river Yamuna respectively. The length of transects was in between 600 meters to 1200 meters

Figure 3.2 Map showing the transect placed in the study area

River Habitat characterization

After completing the waterbird survey, in each transects habitat characteristics like presence of vegetation, river islands, mudflats, and sandbar were recorded. Further, the vegetation was classified as emerged and submerged. River islands were also categorized as submerged, emerged and disturbed. Disturbed River Island was incorporated by anthropogenic disturbances in the form of cultivation of vegetables, liquor production, and livestock grazing.

Disturbance

Disturbances were quantified in each transect by noting the number of Human beings, number of stray dogs and number of livestock encountered in each transect. Other disturbances like river bed material collection, effluent discharge, fishing, was noted down. The scores for the river bed material were given as low, high and no river bed material collection. The low score was given where there was conventional river bed material collection; whereas high score was given where there was collection through mechanized machinery. The effluent discharge was also categorized in low, heavy and no effluent points. The low score was given where there was a rural waste coming from the village and high score was given to the industrial and urbanized effluent source. Fishing was also categorized as low medium and no fishing. The score was given low where there was fishing through angling, whereas the high score is given to the fishing activities with the cast net and guild net.

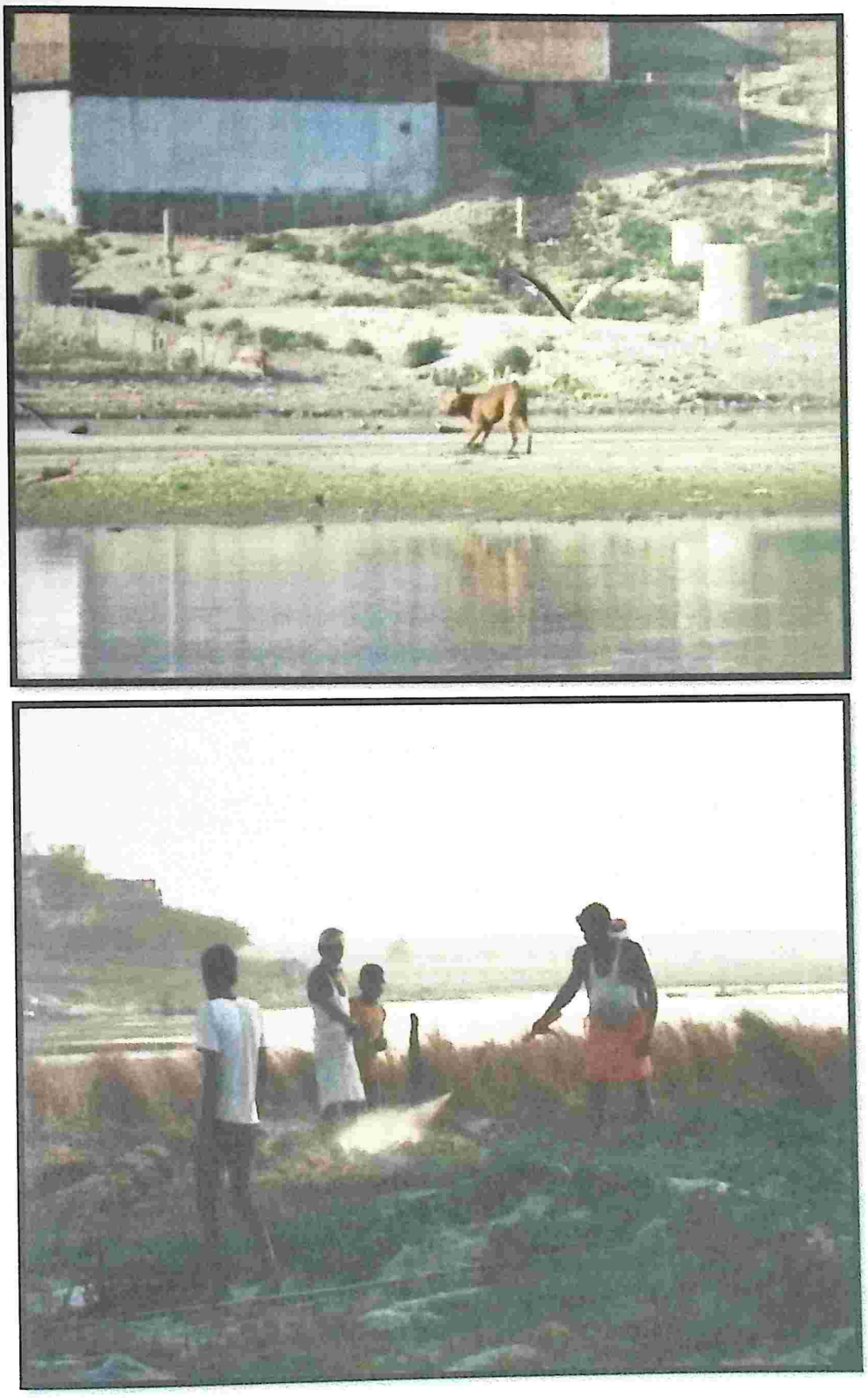

Plate 3.1 Disturbance by free-ranging dog and cultivation of vegetables on river islands

3.2 Analytical Methods

Density of waterbirds

Species were grouped together into six groups based on their habitat-specific guild and body size (Table 3.2). Distance 6.2 software was used to estimate the densities of the group in per river square kilometer area.

Species Group	Species
Cormorants	Great Cormorant, Little Cormorant
Ducks and geese	Ruddy Shelduck, Gadwall, Garganey, Northern Shoveler, Common Teal, Common Pochard, Northern Pintail, Bar-headed Goose Knob-billed Duck
Egrets, Herons Storks, Ibis	Painted Stork, Wooly-necked Stork, Asian Openbill, Red-naped Ibis, Eurasian Spoonbill, Grey Heron, Little Egret, Intermediate Egret, Great Egret, Indian Pond Heron
Terns, Gulls, Skimmers	Gulls, Indian Skimmer, Little Tern
Shorebirds 1	River Lapwing, Red-wattled Lapwing, Pied Kingfisher, Small Pratincole, White Wagtail White-throated Kingfisher, Kentish Plover Little Ringed Plover
Shorebirds 2	Common Sandpiper, Green Sandpiper, Temminck's Stint, Pied Avocet, Whimbrel, Eurasian Curlew, Black-Winged Stilt, Common Redshank, Spotted Redshank

Table 3.2 Species group based on habitat-specific guild and body size

Species rarefaction curve

Species accumulation curve of waterbirds in different habitats was calculated using rarefaction. It gives the estimate of what the species richness or the assemblage would be if at the particular level of sampling effort is made. It can be used to make comparison among assemblages differing in their sampling effort. The comparison can be directly made on the basis of the number of individuals in the smallest sample (Maguran, 2004). This is done by taking a mean of repeated re-sampling of all pooled individual or samples (Gotelli and Colwell, 2001). Thus the sample-based rarefaction curves can be used to account for natural levels of sampling heterogeneity in data. Therefore, the rarefaction curve of the waterbirds species found in different habitat was calculated using vegan package of R software 3.4.0

Rank abundance curve

Rank Abundance curve or Whittaker plot displays logarithmic species abundance against species rank order. It represents species abundance data. Species abundance is plotted in y-axis and rank abundance of species in the x-axis. The common species get plotted on the left side and rarest species on right. MS Excel 2007 was used to generate the rank abundance curve.

Relationship of the birds with habitat variable

Out of 41 observed species, 17 species were selected which was having encounter rate more than 30% in the study area (Table 3.3). For the relationship between habitat variable and disturbance regime, principle component analysis (PCA) was done taking the mean abundance of the birds in different sites. The interpretation was done by considering the habitat characteristics and disturbance regime (APPENDIX 3). PCA is a statistical technique used to examine the interrelations among a set of variables in order to identify the underlying structure of those variables. Bi-plot shows both the loadings and the scores for two selected components in parallel. The analysis was done in BiodiversityR of R software 3.4.0

S.No	Species	Encounter rate in percentage
1	River Lapwing	100
2	Little Egret	87
3	Intermediate Egret	81
4	Temminck's Stint	75
5	Green Sandpiper	75
6	Grey Heron	75
7	Common Sandpiper	68
8	Ruddy Shelduck	68
9	Little Cormorant	68
10	Black-Winged Stilt	56
11	Little Tern	56
12	Great Cormorant	56
13	Asian Openbill	43
14	Spotted Redshank	37
15	Pied Kingfisher	31
16	Indian Skimmer	31
17	Great Egret	31

Table 3.3 Encounter rate of species used for PCA

4. Results

41 species of waterbirds of 12 families were observed in totality while sampling the study site. 7,153 birds were detected during the study period.

Waterbird densities

Species Group	Model	Effective Strip Width	Density
Cormorants (n = 50)	Half-normal/Cosine	79.47 ±11.78	29.08 ±10.33
Ducks and geese (n = 101)	Half-normal/Cosine	121.0 ± 9.35	106.03 ±37.60
Terns, Gulls, Skimmers n = 44	Hazard/Hermite	53.94 ± 14.13	117.87 ±50.44
Shorebirds 1 (n = 302)	Hazard/Hermite	32.65 ±2.62	423.29 ±63.08
Shorebirds 2 (n = 174)	Half-normal/Cosine	38.22 ±3.41	455.71 ±101.32
Egrets, Herons Storks, Ibis (n = 912)	Half-normal/Cosine	121.0 ±9.35	1077.0 ±129.03

*n = Number of observation

Table 4.1 Density estimates of the group of species.

Rank Abundance

River Lapwing, Temminck's Stint, Gulls (Black-headed Gull and Brown-headed Gull), Pied Avocet, Spotted Redshank was the most abundant species in the sampled area, Though the species like Indian Pond Heron and White -throated Kingfisher showing the rareness in the rank abundance curve, ecologically they do not prefer, riverine areas often they are found in the wetlands were water is stagnant and not flowing. Whimbrel and most of the duck species like Knob-billed Duck, Gadwall, Garganey is also having the rareness except the Ruddy Shelduck, which was highly abundant in the study area.

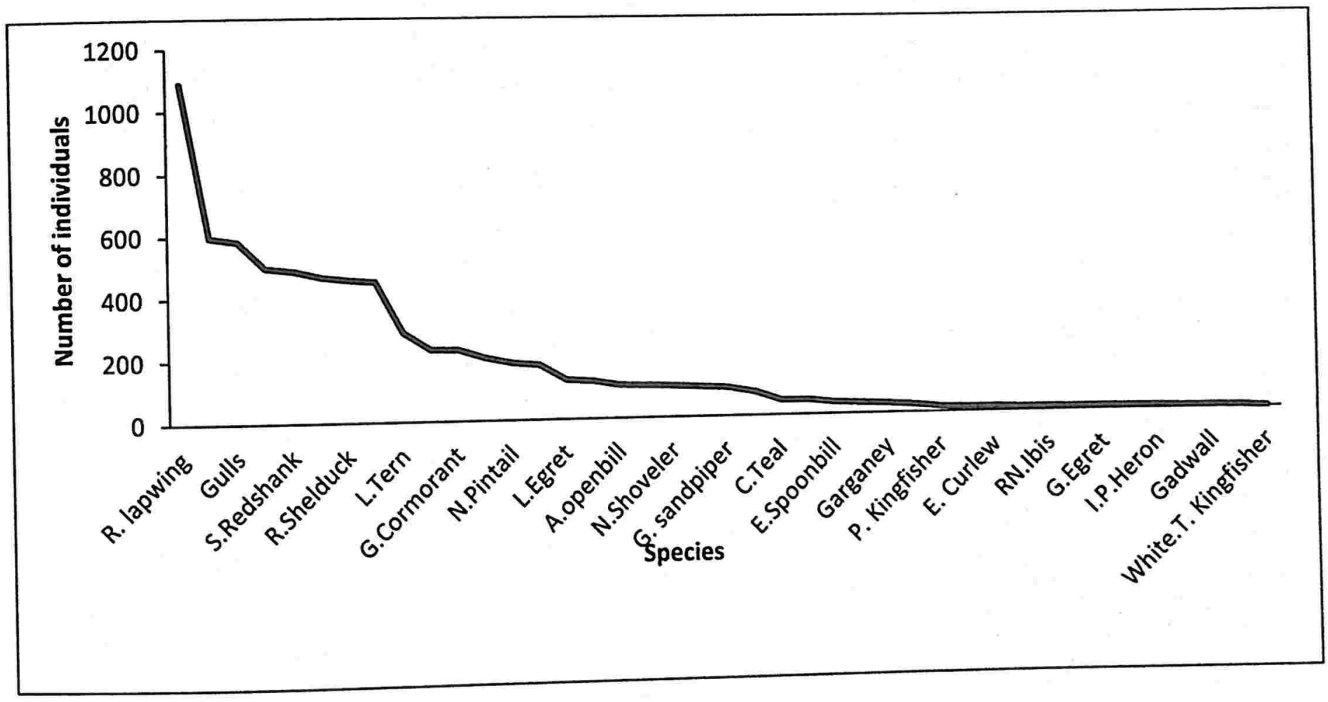

Figure 4.1 Rank Abundance Curve

Species Rarefaction curve

Species accumulation curve obtained shows that the species richness only in the habitat type RIMP (River Island, Mudflat, and Pool), depicts an asymptote where as habitat type RIMSP (River Island Mudflat, Sandbars, and Pool) is still showing the number of species within equal sampling area. In the other habitat types like P (Pools), M (Mudflats and Pool), MSP (Mudflat, Sandbar, and Pool), RISP (River Island, Sandbar and Pool), the available sampling area was not adequate, to compare the species rarefaction curve with above-mentioned habitat types.

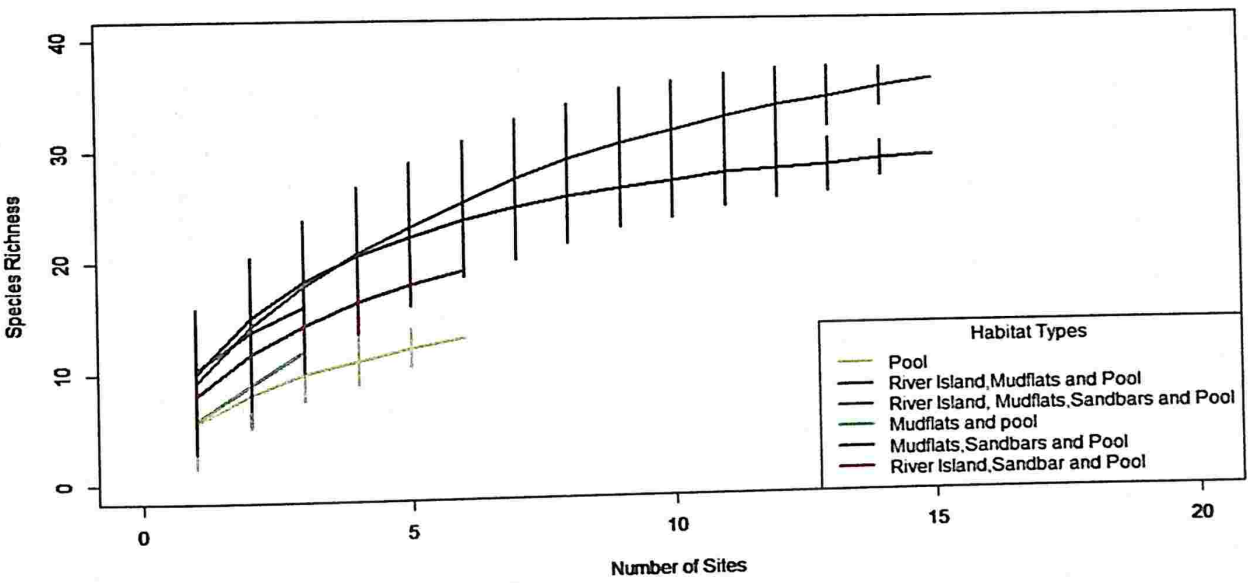

Figure 4.2 Species rarefaction curve

Relationship of the birds with habitat variable (PCA)

SL.no	Species	PC1	PC2	PC3	PC4	PC5
1	R.lapwing	-0.397592	0.172207	0.318277	0.088555	-0.055457
2	L.Egret	-0.245009	0.364386	0.208492	-0.103695	-0.055703
3	I.Egret	0.034514	-0.212514	0.310522	-0.329598	0.222223
4	T.Stint	0.012144	-0.181759	0.514189	0.26	-0.109387
5	G.sandpiper	-0.320384	-0.143829	-0.096704	-0.183922	0.459587
6	G.Heron	0.022025	-0.336136	0.410184	-0.107552	-0.122829
7	C.Sandpiper	0.255493	-0.317732	0.134855	-0.050514	-0.390867
8	R.Shelduck	-0.24444	-0.145688	-0.025147	0.573288	0.054718
9	L.Cormorant	-0.070503	0.346433	0.283343	-0.007951	-0.213755
10	BW.Stilt	-0.040048	-0.267327	-0.308677	-0.031039	-0.211539
11	L.Tern	-0.203134	-0.262185	0.14601	-0.247199	0.417817
12	G.Cormorant	0.115933	0.253697	0.142823	0.067122	0.213729
13	A.openbill	0.185676	-0.080545	-0.171419	-0.049352	-0.014875
14	S.Redshank	-0.360688	-0.20328	-0.108776	0.440681	0.017878
15	P.Kingfisher	0.171541	0.337958	-0.058663	0.071502	0.197374
16	I.Skimmer	-0.327547	0.114902	-0.107994	-0.315842	-0.362358
17	G.Egret	-0.435696	-0.060872	-0.156182	-0.245809	-0.262493

Table 4.2 Loadings of different component of PCA on waterbird species

Site	PC1	PC2	PC3	PC4	PC5
1	1.481014	0.546822	-1.43064	0.34466	-0.32776
2	0.776919	2.029124	2.188681	0.542831	0.65481
3	0.179797	-0.02008	1.610941	0.357363	-0.4558
4	1.126738	-0.10936	0.601446	0.483102	-0.45772
5	-0.02696	-0.31467	-0.70043	-0.58939	1.902565
6	2.229778	-0.65254	-1.24177	-0.82982	-0.47283
7	-0.55244	3.063888	2.00184	0.10079	-1.10721
8	1.093086	2.470246	-1.24493	0.116338	0.565204
9	1.864337	1.193165	-1.41416	0.683074	0.713372
10	-3.67505	1.408998	-0.82383	-2.15877	-2.04695
11	-2.83206	-1.14736	-0.44063	4.247218	-0.05813
12	-0.99058	-1.34727	-2.50228	-0.06384	-0.72104
13	-0.47468	-0.95191	-0.97186	-1.05466	0.623434
14	2.316782	-3.28442	1.579586	-0.08068	-2.11642
15	-1.33642	-1.93406	1.794768	-1.21737	1.163359
16	-1.18027	-0.95056	0.993252	-0.88084	2.141111

Table 4.3 Loadings of different component of PCA on different sites

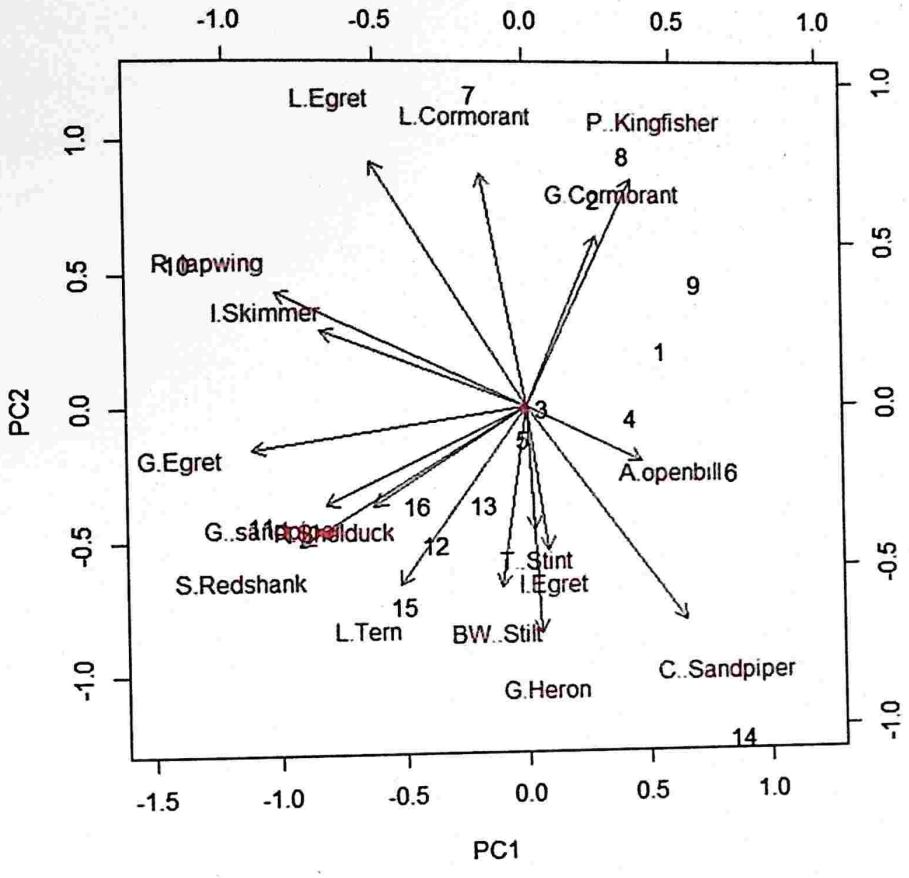

Figure 4.3 Bi-plot of the first and second axis of the PCA ordination showing the positions of 17 species of bird with associated sites

5. Discussion

The increase in habitat heterogeneity is associated with an increase in bird species richness and diversity by accommodating more niches in a given space (MacArthur et al., 1962). Studies have correlated the waterbird abundance and species richness with water level fluctuation, productivity, the cover of aquatic vegetation and habitat heterogeneity (Kaminski and Prince 1984; Edward and Otis 1999). The study area supports a good diversity of water birds due to the availability of different mosaics of habitat, which are used as foraging, roosting and breeding grounds. Rare species like Indian skimmer avoiding the area which is having a high anthropogenic pressure, whereas gulls species and most of the waders are common to the area where there is high anthropogenic pressure.

Waterbirds response to the habitat heterogeneity

Species rarefaction curve is showing a clear relation between the species richness and habitat heterogeneity. This shows that bird species are specifically responding to structural aspects of habitats in the riverine area. The encounter rate of the bird per site of the study area suggests that River Lapwing, Little Egret Temminck'Stint, Green Sandpiper were the most common to the different habitat type. River Lapwing is the Near Threatened species but it was highly abundant in the study in different habitat types. The presence of the river islands in different habitat type is also one of the major factors supporting the species richness. The disturbance is compared to be low on the river islands due to the inaccessibility of human beings, stray dog, and livestocks. River islands are used by waders and terns for roosting. Ducks and geese also prefer the river island for roosting and accessibility to the near water area for foraging. It is also used a breeding ground by different species that nest on the ground.

Waterbirds response to the disturbance

Anthropogenic factors are also one of the factors which affect the diversity of waterbirds. Many, waterbirds especially waders are found nearby the effluent area coming from the urban waste. Anthropogenic factors were not always negatively influence the diversity and abundance of waterbirds, some time it also facilitates them. Study suggests that

species like Brown-headed Gull positively influenced by anthropogenic factors. The Bi-Plot (Figure 4.3) shows a clear evident that abundance of Indian Skimmer *Rynchops albicollis* and River Lapwing *Vanellus duvaucelii* is more toward the site which is having the low disturbance regime and low pressure of livestock, dogs and peoples. Indian skimmer is avoiding the area which is having the high disturbance in the form of high boat traffic, high effluent discharge, and a high number of livestock, people, and dogs. Despite, highest encounter rate of River Lapwing, the abundance is getting affected due to the high disturbance regime in different forms. The species like Pied Kingfisher and Great Cormorant do not getting affected due to the high disturbance in the form of fishing, effluent discharge, people and dogs. Asian- open bill is inclined toward the site which is having comparatively low disturbance but the significantly high number of livestock shows there is no as such disturbance to relatively large body-sized due to the presence of the livestock in the area. Whereas the abundance of species like Ruddy Shelduck, Great Egret, Green Sandpiper, Spotted Redshank is aligned toward the sites which were having the moderate anthropogenic pressure.

Nesting Islands of India Skimmers

Two nesting islands of Indian Skimmer *Rynchops albicollis* were identified in end of March 2017 and Mid April. Nesting Island-1 (25.50589°N, 81.86179°E) was having 48 Nests of Indian Skimmers with 8 active nests and clutch size 4 to 1. Two active nests of River Lapwing *Vanellus duavacelii* was also present on the same Island. Nesting Island-2 (25.48021°N, 81.89689°E) was having 32 active nests of Indian Skimmer and 71 active nests of Little Tern *Sternula albifron.*

A B

Plate 5.1 (A) Indian Skimmer Incubating Eggs (B) nesting island of Indian Skimmer with anthropogenic pressure

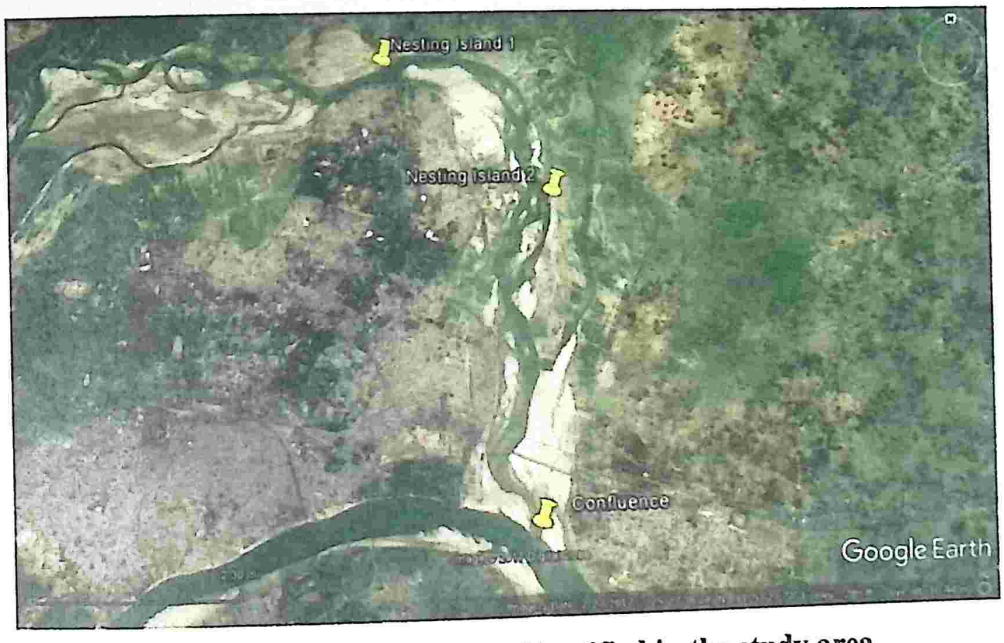

Figure 5.2 Nesting Islands identified in the study area

Nesting Island- 1 abandoned by the Indian Skimmer due to the severe anthropogenic pressure by the people visiting the island for fishing and other activities. Whereas, nesting island-2 was destroyed due to livestock trampling. Feral dogs and crows were also the main reason for the predation of eggs in the island.

Threats and Conservation efforts to be made

Encroachment in the riverine area in the form of agriculture practice in the river bed and river islands are the major threats to the riverine biodiversity and waterbirds. The use of

pesticides and fertilizer in the cultivated area can adversely impact the ecology of water birds, especially during their breeding time. Often, people visit the riverine bank and islands for cultivation lead to the disturbance in that particular riverine area. During my study, it was observed that the nest and fledgling of Small Pratincole and River Lapwing was trampled by the farmer working in the agricultural field in the bank of the river. The stray dog menace is also one of the emerging threat observed during the study time, not only they predate on waterbirds, but also their eggs and fledgling. Poaching, especially in the rural area is still a major problem for the conservation of migratory waterbirds and also the residential birds. The conservation efforts should be made through the community participation of the fisherman and people who practice farming in and around the river banks and river islands. Area should be identified by the forest department where there are breeding colonies of globally threatened birds and migratory birds and a proper protection is given during the breeding time.

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Online source

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- http://nmcg.nic.in accessed on 15 November 2016
- https://www.wetlands.org on 14 November 2016

APPENDIX 1

Checklist of bird during the study in Allahabad District

S.No.	Common Name	Scientific name	Family	IUCN status
1	Alexandrine Parakeet	*Psittacula eupatria*	Psittacidae	NT
2	Ashy Prinia	*Prinia socialis*	Cisticolidae	LC
3	Ashy-crowned Sparrow-Lark	*Eremopterix griseus*	Alaudidae	LC
4	Asian Koel	*Eudynamys scolopaceus*	Cuculidae	LC
5	Asian Openbill	*Anastomus oscitans*	Ciconiidae	LC
6	Asian Pied Starling	*Gracupica contra*	Sturnidae	LC
7	Bank Myna	*Acridotheres ginginianus*	Sturnidae	LC
8	Bar-headed Goose	*Anser indicus*	Anatidae	LC
9	Barn Owl	*Tyto alba*	Tytonidae	LC
10	Barn Swallow	*Hirundo rustica*	Hirundinidae	LC
11	Black Drongo	*Dicrurus macrocercus*	Dicruridae	LC
12	Black Kite	*Milvus migrans*	Accipitridae	LC
13	Black Redstart	*Phoenicurus ochruros*	Muscicapidae	LC
14	Black-crowned NightHeron	*Nycticorax nycticorax*	Ardeidae	LC
15	Black-headed Gull	*Larus ridibundus*	Laridae	LC
16	Black-headed Ibis	*Threskiornis melanocephalus*	Threskiornithidae	NT
17	Black-hooded Oriole	*Oriolus xanthornus*	Oriolidae	LC
18	Black-shouldered Kite	*Elanus axillaris*	Accipitridae	LC
19	Black-tailed Godwit	*Limosa limosa*	Scolopacidae	NT
20	Black-winged Stilt	*Himantopus himantopus*	Recurvirostridae	LC
21	Blue-tailed Bee-eater	*Merops philippinus*	Meropidae	LC
22	Blyth's Reed-Warbler	*Acrocephalus dumetorum*	Acrocephalidae	LC
23	Brahminy Starling	*Sturnia pagodarum*	Sturnidae	LC
24	Bronze-winged Jacana	*Metopidius indicus*	Jacanidae	LC
25	Brown-headed Barbet	*Psilopogon zeylanicus*	Megalaimidae	LC
26	Brown-headed Gull	*Larus brunnicephalus*	Laridae	LC
27	Cattle Egret	*Bubulcus ibis*	Ardeidae	LC
28	Cinereous Vulture	*Aegypius monachus*	Accipitridae	NT
29	Knob-Billed Duck	*Sarkidiornis melanotos*	Anatidae	LC
30	Common Babbler	*Argya caudata*	Leiotrichidae	LC
31	Common Buzzard	*Buteo buteo*	Accipitridae	LC
32	Common Crane	*Grus grus*	Gruidae	LC
33	Common Hawk-Cuckoo	*Hierococcyx varius*	Cuculidae	LC
34	Common Kingfisher	*Alcedo atthis*	Alcedinidae	LC

35	Common Myna	*Acridotheres tristis*	Sturnidae	LC
36	Common Pochard	*Aythya ferina*	Anatidae	VU
37	Common Redshank	*Tringa totanus*	Scolopacidae	LC
38	Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	LC
39	Common Tailorbird	*Orthotomus sutorius*	Cisticolidae	LC
40	Common Woodshrike	*Tephrodornis pondicerianus*	Tephrodornithidae	LC
41	Coppersmith Barbet	*Psilopogon haemacephalus*	Megalaimidae	LC
42	Crested Lark	*Galerida cristata*	Alaudidae	LC
43	Egyptian Vulture	*Neophron percnopterus*	Accipitridae	EN
44	Eurasian Collared-Dove	*Streptopelia decaocto*	Columbidae	LC
45	Eurasian Curlew	*Numenius arquata*	Scolopacidae	LC
46	Eurasian Hoopoe	*Upupa epops*	Upupidae	LC
47	Eurasian Moorhen	*Gallinula chloropus*	Rallidae	LC
48	Eurasian Spoonbill	*Platalea leucorodia*	Threskiornithidae	LC
49	Eurasian Wigeon	*Mareca penelope*	Anatidae	LC
50	Gadwall	*Mareca strepera*	Anatidae	LC
51	Garganey	*Spatula querquedula*	Anatidae	LC
52	Graceful Prinia	*Prinia gracilis*	Cisticolidae	LC
53	Grey Francolin	*Francolinus pondicerianus*	Phasianidae	LC
54	Grey Heron	*Ardea cinerea*	Ardeidae	LC
55	Grey Wagtail	*Motacilla cinerea*	Motacillidae	LC
56	Grey-breasted Prinia	Prinia hodgsonii	Cisticolidae	LC
57	Grey-throated Martin	*Riparia Chinensis*	Hirundinidae	LC
58	Grey lag Goose	*Anser anser*	Anatidae	LC
59	Great Cormorant	*Phalacrocorax carbo*	Phalacrocoracidae	LC
60	Great Egret	*Ardea alba*	Ardeidae	LC
61	Great White Pelican	*Pelecanus onocrotalus*	Pelecanidae	LC
62	Greater Coucal	*Centropus sinensis*	Cuculidae	LC
63	Green Bee-Eater	*Merops Orientalis*	Meropidae	LC
64	Green Sandpiper	*Tringa ochropus*	Scolopacidae	LC
65	House Crow	*Corvus splendens*	Corvidae	LC
66	House Sparrow	*Passer domesticus*	Passeridae	LC
67	Indian Bushlark	*Mirafra erythroptera*	Alaudidae	LC
68	Indian Cormorant	*Phalacrocorax fuscicollis*	Phalacrocoracidae	LC
69	Indian Golden Oriole	*Oriolus kundoo*	Oriolidae	LC
70	Indian Grey Hornbill	*Ocyceros birostris*	Bucerotidae	LC
71	Indian Nuthatch	*Sitta castanea*	Sittidae	LC
72	Indian Peafowl	*Pavo cristatus*	Phasianidae	LC
73	Indian Pond-Heron	*Ardeola grayii*	Ardeidae	LC
74	Indian Robin	*Saxicoloides fulicatus*	Muscicapidae	LC
75	Indian Roller	*Coracias benghalensis*	Coraciidae	LC
76	Indian Scops-Owl	*Otus bakkamoena*	Strigidae	LC
77	Indian Silverbill	*Euodice malabarica*	Estrildidae	LC
78	Indian Skimmer	*Rynchops albicollis*	Laridae	VU

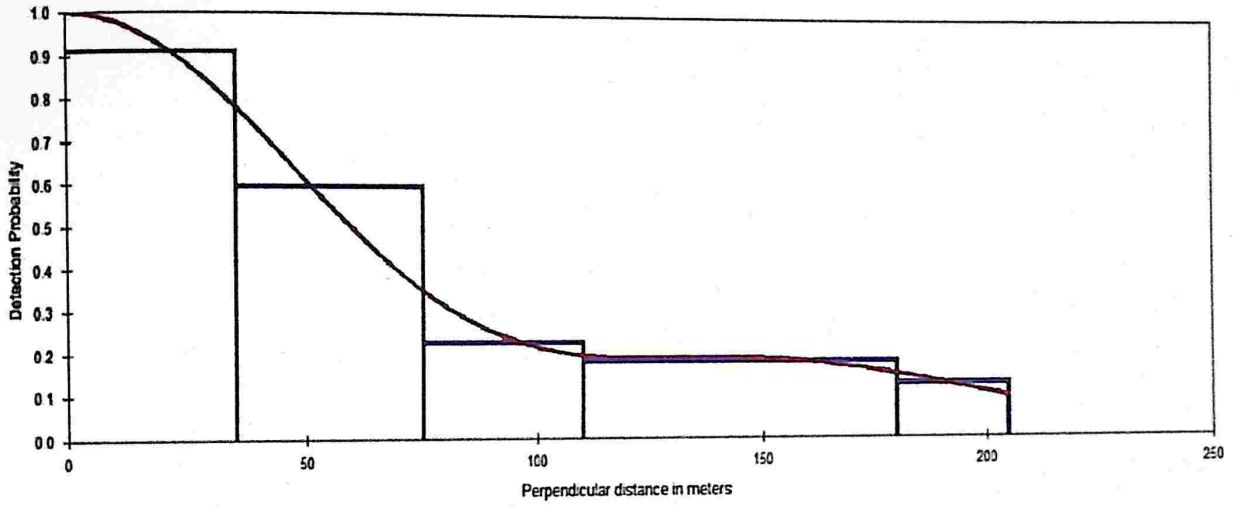
79	Indian Thick-knee	*Burhinus indicus*	Burhinidae	LC
80	Intermediate Egret	*Ardea intermedia*	Ardeidae	LC
81	Jungle Babbler	*Turdoides striata*	Leiotrichidae	LC
82	Jungle Myna	*Acridotheres fuscus*	Sturnidae	LC
83	Kentish Plover	*Charadrius alexandrinus*	Charadriidae	LC
84	Large-billed Crow	*Corvus macrorhynchos*	Corvidae	LC
85	Laughing Dove	*Spilopelia senegalensis*	Columbidae	LC
86	Lesser Whistling-Duck	*Dendrocygna javanica*	Anatidae	LC
87	Lesser Whitethroat	*Sylvia curruca*	Sylviidae	LC
88	Little Cormorant	*Microcarbo niger*	Phalacrocoracidae	LC
89	Little Egret	*Egretta garzetta*	Ardeidae	LC
90	Little Grebe	*Tachybaptus ruficollis*	Podicipedidae	LC
91	Little Ringed Plover	*Charadrius dubius*	Charadriidae	LC
92	Little Swift	*Apus affinis*	Apodidae	LC
93	Little Tern	*Sternula albifrons*	Laridae	LC
94	Long-tailed Shrike	*Lanius schach*	Laniidae	LC
95	Northern Pintail	*Anas acuta*	Anatidae	LC
96	Northern Shoveler	*Spatula clypeata*	Anatidae	LC
97	Oriental Darter	*Anhinga melanogaster*	Anhingidae	NT
98	Oriental Honey-buzzard	*Pernis ptilorhynchus*	Accipitridae	LC
99	Oriental Magpie-Robin	*Copsychus saularis*	Muscicapidae	LC
100	Oriental Skylark	*Alauda gulgula*	Alaudidae	LC
101	Oriental White-eye	*Zosterops palpebrosus*	Zosteropidae	LC
102	Osprey	*Pandion haliaetus*	Pandionidae	LC
103	Paddyfield Pipit	*Anthus rufulus*	Motacillidae	LC
104	Painted Stork	*Mycteria leucocephala*	Ciconiidae	NT
105	Pallas's Gull	*Larus ichthyaetus*	Laridae	LC
106	Peregrine Falcon	*Falco peregrinus*	Falconidae	LC
107	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	Jacanidae	LC
108	Pied Avocet	*Recurvirostra avosetta*	Recurvirostridae	LC
109	Pied Bushchat	*Saxicola caprata*	Muscicapidae	LC
110	Pied Kingfisher	*Ceryle rudis*	Alcedinidae	LC
111	Plain Prinia	*Prinia inornata*	Cisticolidae	LC
112	Purple Heron	*Ardea purpurea*	Ardeidae	LC
113	Purple Sunbird	*Cinnyris asiaticus*	Nectariniidae	LC
114	Red Collared-Dove	*Streptopelia tranquebarica*	Columbidae	LC
115	Red Spurfowl	*Galloperdix spadicea*	Phasianidae	LC
116	Red-crested Pochard	*Netta rufina*	Anatidae	LC
117	Red-naped Ibis	*Pseudibis papillosa*	Threskiornithidae	LC
118	Red-rumped Swallow	*Cecropis daurica*	Hirundinidae	LC
119	Red-vented Bulbul	*Pycnonotus cafer*	Pycnonotidae	LC
120	Red-wattled Lapwing	*Vanellus indicus*	Charadriidae	LC
121	Red-whiskered Bulbul	*Pycnonotus jocosus*	Pycnonotidae	LC
122	River Lapwing	*Vanellus duvaucelii*	Charadriidae	NT
123	River Tern	*Sterna aurantia*	Laridae	LC

124	Rock Bush-Quail	*Perdicula argoondah*	Phasianidae	LC
125	Rock Pigeon	*Columbia livia*	Columbidae	LC
126	Rose-ringed Parakeet	*Psittacula krameri*	Psittacidae	LC
127	Ruddy Shelduck	*Tadorna ferruginea*	Anatidae	LC
128	Rufous Treepie	*Dendrocitta vagabunda*	Corvidae	LC
129	Sand Lark	*Alaudala raytal*	Alaudidae	LC
130	Sarus Crane	*Antigone antigone*	Gruidae	VU
131	Scaly-breasted Munia	*Lonchura punctulata*	Estrildidae	LC
132	Shikra	*Accipiter badius*	Accipitridae	LC
133	Short-toed Snake-Eagle	*Circaetus gallicus*	Accipitridae	LC
134	Small Minivet	*Pericrocotus cinnamomeus*	Campephagidae	LC
135	Small Pratincole	*Glareola lactea*	Glareiolidae	LC
136	Spotted Dove	*Spilopelia chinensis*	Columbidae	LC
137	Spotted Owlet	*Athene brama*	Strigidae	LC
138	Spotted Redshank	*Tringa erythropus*	*Tringa erythropus*	LC
139	Stork-billed Kingfisher	*Pelargopsis capensis*	Alcedinidae	LC
140	Temminck's Stint	*Calidris temminckii*	Scolopacidae	LC
141	Thick-billed Flowerpecker	*Dicaeum agile*	Dicaeidae	LC
142	Verditer Flycatcher	*Eumyias thalassinus*	Muscicapidae	LC
143	Western Yellow Wagtail	*Motacilla flava*	Motacillidae	LC
144	Whimbrel	*Numenius phaeopus*	Scolopacidae	LC
145	White Wagtail	*Motacilla alba*	Motacillidae	LC
146	White-breasted Waterhen	*Amaurornis phoenicurus*	Rallidae	LC
147	White-browed Wagtail	*Motacilla maderaspatenis*	Motacillidae	LC
148	White-eyed Buzzard	*Bustastur teesa*	Accipitridae	LC
149	White-throated Kingfisher	*Halycon smyrnensis*	Alcedinidae	LC
150	Wire-tailed Swallow	*Hirundo smithii*	Hirundinidae	LC
151	Woolly-necked Stork	*Ciconia episcopus*	Ciconiidae	VU
152	Yellow-crowned Woodpecker	*Leiopicus mahrattensis*	Picidae	LC
153	Yellow-footed Pigeon	*Treron phoenicoptera*	Columbidae	LC
154	Yellow-wattled Lapwing	*Vanellus malabaricus*	Charadriidae	LC

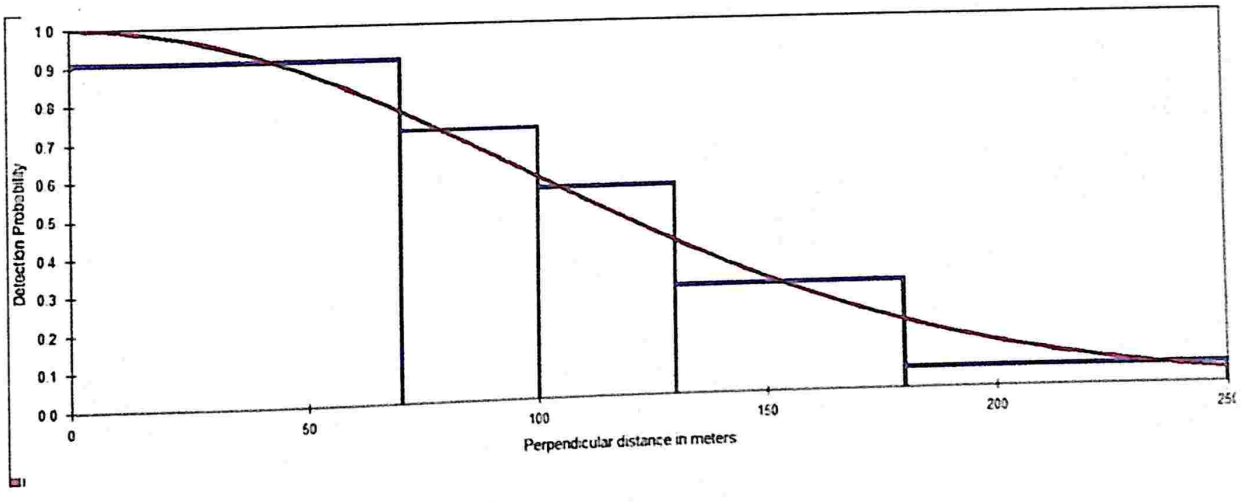
APPENDIX 2

The graph for calculating the waterbird densities

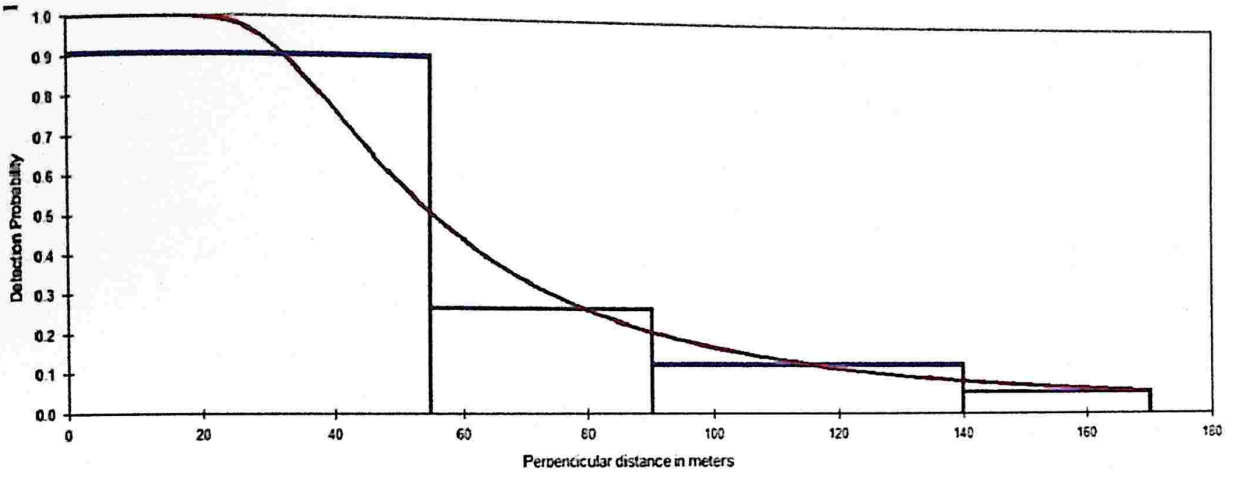
1. Detection of Cormorant



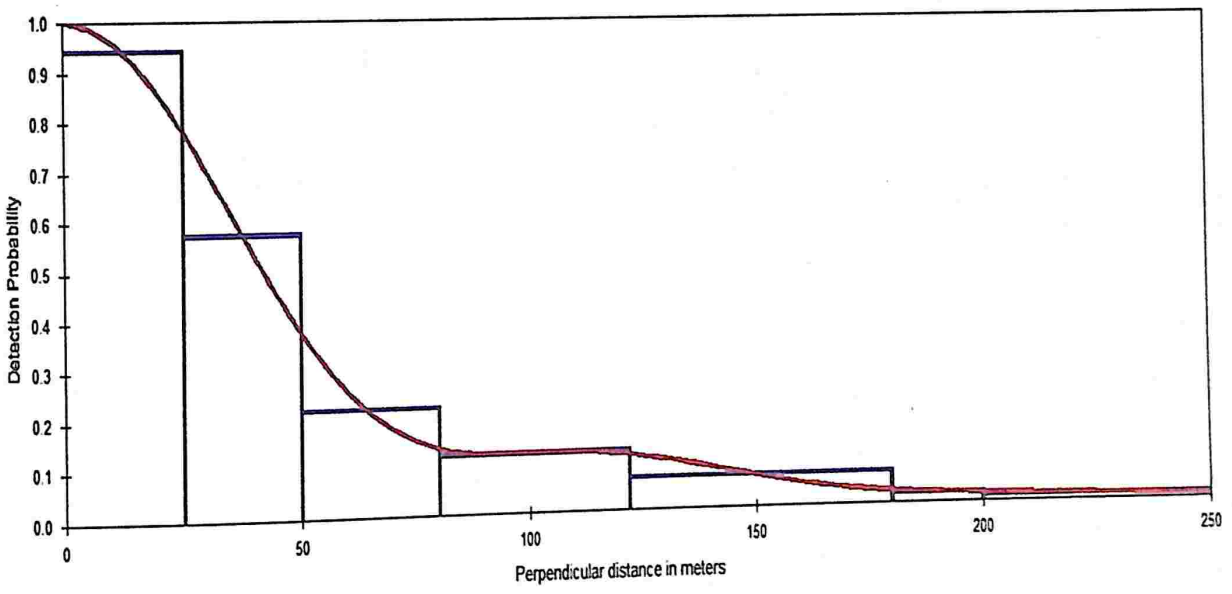
2. Detection of Ducks and Geese



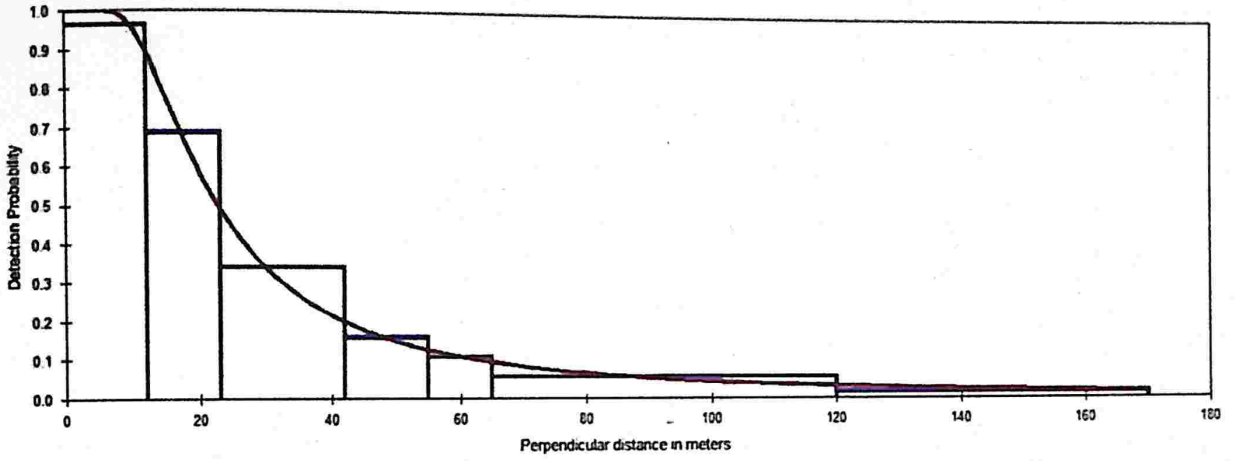
3. Detection of Gulls and Terns



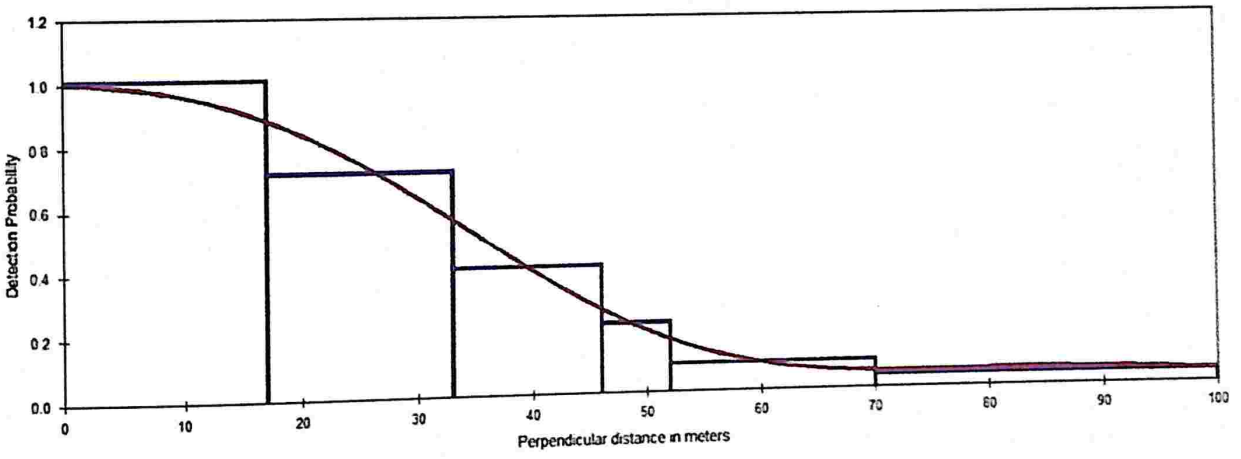
4. Detection of Egrets, Storks, Ibis and Herons



5. Detection of Shorebirds 1



6. Detection of Shorebirds 2



APPENDIX 3

Habitat Characteristics and Disturbance regime in different sites

Site	Site I.D	Habitat Characteristics	Disturbance Regime
1	GD 1	Emergent Vegetation	High boat traffic, Low river bed material collection, Low effluent, Low fishing. Average count of dogs = 3.66 Average count of people = 19 Average count of livestock = 5
2	GD 2	Island, Mudflat, Sandbar, Emergent, Vegetation	High boat traffic, No river bed material collection, No effluent discharge, High fishing. Average number of dogs = 3 Average number of people = 17.33 Average number of livestock = 2.66
3	GD 3	Island, Mudflat, Sandbar, Emergent, Vegetation	Low boat traffic, Low river bed material collection, No effluent discharge, High fishing Average count of dogs = 1.33 Average counts of people = 11 Average count of livestock = 4.33
4	GD 4	Island, Sandbar, Emergent Vegetation	Low boat traffic, High river bed material collection, Heavy effluent discharge, Low fishing Average count of dogs = 1.66 Average count of people = 1.33 Average count of livestock = 3.66

5	GD 5	Island, Sandbar	Low boat traffic, Low river bed material collection, No effluent discharge, Low fishing Average count of dogs = 2 Average count of people = 26.66 Average count of livestock = 2
6	GD 6	Mudflat, Emergent Vegetation	Low boat traffic, Low river bed material collection, No effluent discharge, Low fishing Average count of dogs = 3 Average count of people = 10.66 Average count of livestock = 19.66
7	Y 1	Island, Mudflat, Sandbar, Emergent Vegetation	High boat traffic, Low river bed material collection, No effluent discharge, Low fishing. Average count of dogs = 3.66 Average count of people = 8.66 Average count of livestock = 6.66
8	Y 2	Pool, Emergent Vegetation .	Low boat traffic, Low river bed material collection, Heavy Effluent discharge, High Fishing. Average number of dogs = 2.66 Average number of people = 12.66 Average number of livestock = 3.66
9	Y 3	Island, Mudflat	High boat traffic, Now effluent discharge, No river bed material collection, Low fishing. Average count of dogs = 1.33 Average count of people = 6.66 Average count of livestock = 0

10	GU 1	Island, Mudflat, Emergent Vegetation	Low boat traffic, No river bed material collection, No effluent discharge, Low fishing. Average count of dogs = 1.66 Average count of people = 10.66 Average count of livestock = 0
11	GU 2	Island, Mudflat, Emergent Vegetation	High boat traffic, Low river bed material collection, Low effluent discharge, High fishing. Average count of dogs = 2 Average count of people =26 Average count of livestock = 12.66
12	GU 3	Island, Mudflat, Emergent Vegetation	High boat traffic, Low river bed material collection, No effluent discharge, Low fishing. Average count of dogs = 1 Average count of people = 19.66 Average count of livestock= 0
13	GU 4	Mudflat, Sandbar, Emergent Vegetation	Low boat traffic, No river bed material collection, No effluent discharge, Low fishing. Average count of dogs = 1.33 Average count of people =15.33 Average count of livestock = 0

14	GU 5	Island, Mudflat, Sandbar, Emergent Vegetation	Low boat traffic, No river bed material collection, No effluent discharge, Low fishing. Average count of dogs = 2.33 Average count of people = 1.33 Average count of livestock = 1
15	GU 6	Island, Mudflat, Emergent Vegetation	Low boat traffic, No river bed material collection, No effluent discharge, Low fishing Average count of dogs = 1.66 Average count of people = 9.66 Average count of livestock = 0
16	GU 7	Island, Mudflat, Emergent Vegetation	Low boat traffic No river bed material collection, No effluent discharge, Low fishing Average count of dogs = 2 Average count of people = 21.33 Average count of livestock = 20.33

*GD = Ganga Downstream, GU = Ganga Upstream, Y = Yamuna