BIRD COMMUNITY DYNAMICS IN RELATION TO WATER LEVEL FLUCTUATION IN KOSHI TAPPU WILDLIFE RESERVE

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A thesis submitted in partial fulfilment of the requirements for the award of the degree of Masters of Science in Zoology with special paper Ecology & Environment

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DECLARATION

I hereby declare that the work presented in this thesis entitled **"BIRD COMMUNITY DYNAMICS IN RELATION TO WATER LEVEL FLUCTUATION IN KOSHI TAPPU WILDLIFE RESERVE"** has been done by myself, and has not been submitted anywhere for the award of any other degree. All sources of the information have been specifically acknowledged by references to the author(s) or institution(s).

Date: 2077/11/26

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RECOMMENDATION

This is to recommend that the thesis entitled **"BIRD COMMUNITY DYNAMICS IN RELATION TO WATER LEVEL FLUCTUATION IN KOSHI TAPPU WILDLIFE RESERVE"** has been carried out by Mr. **Aditya Pal** for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology. This is his original work and has been carried out under my supervision. To the best of our knowledge, this thesis work has not been submitted for any other degree in any institution. We recommend that the thesis be accepted for the Degree of Master of Science in Zoology with special paper Ecology.

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LETTER OF APPROVAL

On the recommendation of supervisor Dr. Tej Bahadur Thapa, this thesis submitted by Mr. Aditya Pal entitled **"BIRD COMMUNITY DYNAMICS IN RELATION TO WATER LEVEL FLUCTUATION IN KOSHI TAPPU WILDLIFE RESERVE"** is approved for the Examination in partial fulfillment of the requirements for the Degree of Masters in Science in Zoology with special paper Ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Aditya Pal entitled **"BIRD COMMUNITY DYNAMICS IN RELATION TO WATER LEVEL FLUCTUATION IN KOSHI TAPPU WILDLIFE RESERVE"** has been accepted as a partial fulfillment for the requirements of Master's Degree of science of zoology in special paper Ecology.

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Aditya Pal

ABSTRACT

Land cover was classified using satellite image in to four classes. Supervised method of classification was used to analyze change in microhabitat. Study area was classified into four groups according to availability of water level, i.e. Land, Shallow water, Wet-Muddy flat, Deep water. Wetland bird community was classified into four groups according to morphological adaptation i.e. Swimmers, Waders, Shorelines and others (which do not fall in above three categories). Wetland bird survey was conducted in four different seasons of 2018/2019. Bird survey was carried with continuous point transect method. A total of 1526 individuals of birds belonging to 53 species 17 families and 10 orders were recorded, among them 15 species of swimmers, 20 species of waders, 9 species of shoreliners and 7 species of others (river birds) were recorded. Pearson correlation test was used to establish the relation between bird community and landscape classes. Highest water level was observed in summer and lowest in autumn. Shannon diversity (H) was maximum of, 2.817 at intermediately disturbed site and lowest at the most disturbed site of, 0.636 both in winter season. Tukey HSD test, showed that bird community assemblage in summer and winter was significantly different. Regression analysis revealed that as water level decreases diversity and abundance of Waders increases. Canonical correlation analysis between bird and microhabitat showed that, Waders prefer open water and *Typha* spp. Wet-muddy flat habitat was favored by most of the species. Classification of microhabitat with remote sensing in each season showed that landscape composition has changed significantly from summer to winter. Swimmers showed significant positive correlation with Shallow water class (r=0.93). Shorelines also showed significant positive correlation with shallow water class (r=0.94) and slight positive correlation with wet muddy class (r=0.64) and with deep-water class (r=0.644) whereas significant negative correlation(r=-0.93) with land class. Waders showed significant negative correlation (r=-0.72) with deep-water class and shallow water class (r=-0.18) whereas positive correlation with wet-muddy and slight positive correlation(r=0.07), with land waders showed high correlation(r=0.06) with wet-muddy class. The study revealed that bird composition (NMDS F = 3.10; $p < 0.0001$, Stress value=0.14) was significantly different in four different seasons. This study suggests that water level fluctuations is one of the major factors, which influences the abundance, and composition of Wetland dependent birds.

Abbreviations

BOP - Bird Observation Point

CITES - Convection on International Trade in Endangered Species

ETM - Enhanced Thematic Mapper

GloVis - Global Visualization Viewer

GIS - Geographic Information System

GPS - Geographic Positioning System

IBA - Important Bird and Biodiversity Area

IDH- Intermediate Disturbance Hypothesis

IUCN - International Union for Conservation of Nature

KTWR - Koshi Tappu Wildlife Reserve

KML - Keyhole Markup Language

LULC - Land Use and Land Cover

NIR - Near Infrared

RS - Remote Sensing

SWIR - Short-wave Infrared

TM - Thematic Mapper

TIFF - Tagged Image File Format

WLF - Water level Fluctuation

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1. INTRODUCTION

1.1 Background

Birds are most significant component of wetland ecosystems, which is good indicator of the ecological conditions of the particular areas (Rajpar and Zakaria 2010). Among all factors driving wetland ecosystems, the local hydrology is of prominence (Kohfahl et al. 2008). Hydrology with specific mention of water level fluctuations, determines the structure i.e. its configuration and composition (Weller 1999) and complexity of wetland habitats (Mahmood et al. 2010). This is realized in the changes of nutrient cycles (Weller 1999) food webs (Jefferies 2000) as well as available and accessible suitable microhabitat for various bird species and guilds (Guadagnin et al. 2009). The change of water level in wetland ecosystem results in change of microhabitat variables, such as vegetation (Maviza 2010) and area of special water depth (Weller 1999). Water level fluctuation also essentially determines vegetation dynamics of wetland (Weller 1999, Naugle 2001). Furthermore, vegetation also provides nesting location, material and cover for water birds (Weller 1999, Murray 2000, Robert 2002). Considering the large amount of species, the selection of water depth for feeding is still a poorly studied (Weller 1999, Maviza 2010). The main reason being, not easy methods available for measurement of the water depth at a distance in field observation. Satellite remote sensing provided a way to solve this problem by monitoring the change in microhabitat responding to the variation of the water level. The main method using remote sensing in habitat research was to classify habitats according to spectral reflectance characteristics and ecological knowledge (Gottschalk et al. 2005).

1.1.1 Wetland bird community

Waterfowl serves an important component of the biotic community of wetland ecosystem (Weller 1999). In this regard, any change in the wetland ecosystem may result in both direct and indirect knock-on effects on the waterfowl population numbers and their diversity (Wang 2008, Wang 2013). As the composition and structure of the wetland landscapes influences bio-ecological processes related to the survival needs of the waterfowl e.g. food and space (Maviza 2010). Therefore, changes in the wetland landscapes will result in changes in species diversity and composition (Leibowitz 2003). Shifts in waterfowl community structure occur with certain species favored or disadvantaged depending on extent and magnitude of change in landscape and useful as bio-indicators of aquatic ecosystem quality, productivity and stability (Maviza 2010). Waterfowl population decline has been also related to human wetland encroachments (Weller 1999) and low species richness to pollution from intensive agriculture because these activities disturb the biophysical balance in the wetland ecosystem (Mahmood et al. 2010). Waterfowl species diversity has also been used as a surrogate to assess the impact of changing hydrological flow regimes on wetland configuration and quality (Wang et al. 2008). Changes in waterfowl community structure occur with certain species favored or disadvantaged depending on extent and magnitude of change of a specific landscape unit exploitable by a particular species (Weller 1999). This has been based on the fact that waterfowl will either respond differently or in a similar way to habitat changes caused by hydrological dynamics such that at any moment in time, the waterfowl community structure reflects not only the quality but also the capacity of the wetland system to meet the needs of that community (Mahmood et al. 2010).

1.1.2 Wetlands and wetland Birds of Nepal

A total of 886 species of birds has been recorded in Nepal (BCN and DNPWC 2018). Of these nearly 200 species of birds are heavily dependent on wetland habitats (Grimmett et al. 2016). Among the wetland species, almost all except seven species are found in the lowlands of Nepal (Bhandari 1998). Wetland birds in Nepal are also highly threatened because of habitat degradation. Many previous studies have evaluated overall wetland biodiversity (Sah 1997, Inskip et al. 2017) and few studies particularly on wetland birds (Maviza 2010, Baral 2004). So far, the studies of wetland birds seem to have concentrated into a specific area or region but no study of all the status, distribution and their habitat requirements in the country (Baral 2009).

The reduction of usable vegetative area reduces the food availability and the suitable breeding areas to birds (Weller 1999). Consequently, two species of resident wetland birds have become extinct from the country as early as late 1800. These are Pink-headed Duck (*Rhodonessa caryophyllacea*) and Imperial Heron (*Ardea imperialis*) (Inskipp and Inskipp 1991, Baral and Inskipp 2004). Nearly a dozen wetland species that are recorded in Nepal that has been listed as globally threatened, at a national level, as many as 44 wetland species have been considered threatened because of habitat loss, water pollution, fish poisoning, hunting and trapping, food shortages due to overfishing, and disturbance and destruction of nesting and feeding sites (Baral and Inskipp 2004). About two thirds of wetland birds at risk on national level are either critically threatened or endangered. These high threat categories are of big conservation concern for wetland birds (Inskipp et al. 2017).

1.1.3 Water level fluctuation

Fluctuations in water levels determine spatial extent and temporal periods of cycles of flooding which facilitate wetland nutrient balance and productivity through processes of aerobic and anaerobic decomposition (Toth et al. 1995). Therefore, the amount and type of food and total areal extent of specific microhabitats available for these processes determine different waterfowl species or guilds such as swimmers and waders will alter the waterfowl community structure at any given moment (Özesmi et al. 2002). Different waterfowl guilds or species affected differently by the hydrological dynamics through alteration of their specific microhabitats (Weller 1999, Maviza 2010). When a landscape is dominated by deep water, diving and swimming waterfowl such as ducks are expected to dominate the community (Maviza 2010). Similarly, in conditions of low water levels and wet- muddy flats, wader and shoreline species predominate the community structure (Hailey and Goutner 2002). It is therefore imperative that any comprehensive study of waterfowl entails a component focusing on the habitat spatio-temporal characteristics inherent to prevailing hydrological dynamics (Weller 1999). These type of relationships have been researched using diverse innovative approaches (Maviza 2010).

1.2 Objectives

1.2.1 General objectives

The general objective was to assess the effect of water level fluctuation on bird community structure.

1.2.2 Specific objectives

Specific objectives were:

1. To assess land cover dynamics of KTWR;
2. To explore water bird community structure;
3. To examine the effect of water level fluctuation on bird communities in the KTWR.

1.3 Rationale of study

Koshi Tappu Wildlife Reserve (KTWR) have a high total of 526 species of birds (Baral 2016). Among them more than 70 species are wetland dependent and most of these birds are regular and passage migrants and over eight species are globally threatened. However, in recent years there has been tremendous decrease in numbers of wetland birds (Baral 2009, Inskipp et al. 2017). This kind of study helps to understand dynamics of wetland ecosystem and broadens the understanding of wetland birds and their habitat use in relation to WLF.

1.4 Research questions

1. What is the relation between water level fluctuation and structure of vegetation, which affect the bird community structure?

2. How bird community assemblage changes in four seasons of a year according to WLF?

2. LITERATURE REVIEW

Literature review reveals most of the research conducted on wetland bird community in Nepal excluded the effect of water level fluctuation (WLF) until date, although WLF determines the food availability and vegetation, which provides shelter and reproductive success of the wetland bird. Most of the research conducted in Nepal, a found to be focused to document species richness and diversity.

2.1 Relationship between water level fluctuation, microhabitat and bird community structure.

The study of interactions between biotic and abiotic factors is essential to understand the community structure of an ecosystem and to find out the relationship between limnological characteristics of wetland (Jiahu et al. 2007, Schindler and Scheuerell 2002) and wetland bird population (Holomuzki et al. 2010). As animals depend directly or indirectly on plants and water chemistry, bird's distribution is expected to change with the change in water chemistry (Jefferies 2000). Change in water chemistry has been considered to influence the distribution of many aquatic plant species (Jefferies 2000, Bornette and Puijalon, 2011). No systematic work has been done in Nepal on the distribution of birds (biotic) in relation to water level fluctuations and physiochemical parameters (abiotic) of water until this study was conducted.

The change of water level would result in change of microhabitat variables, such as vegetation and area of special water depth (Weller 1999). Water depth is also an important habitat variable due to the bird's morphological characteristics (Wang 2013). Wading birds and shorebirds fed mainly in shallow water, because the shape and size of their body limit the water depth where they could reach (Yvonne 1993). Some species favors edge of the wetland, while diving birds prefer deeper water. Some even have a minimum requirement of water depth some waterfowl prefer water depths over 20 cm (Weller 1999, Yvonne 1993). Large diving birds, such as Cormorants, need water depth more than 1m (Robertson and Massenbauer 2005). Although some species like Waders could change their feeding behavior, location and even diet as a result of food availability each species seems to prefer a particular range of water (Kober and Bairlein 2009).

Factors like WLF, water chemistry and macrophytes impacts on the waterfowl numbers and diversity in either a negative or positive way depending on the waterfowl characteristics, sensitivity to changing water level have been studied from various dimensions (Weller 1999, Jefferies 2000 and Maviza 2010). Others have preferred to use guilds in similar studies arguing that it gives more comprehensive and representative results compared to using single-indicator species, which may not fully represent the diversities of behaviors and adaptations to exploit various resources by a large community of waterfowl (Mannan et al. 1984).

In ecological studies, hydrology is concerned as major driver governing wetland ecosystems, (Jiahu et al. 2007). Wetlands with specific mention to water level fluctuations, determines structure (Weller 1999), and complexity of wetland habitats (Schindler and Scheuerell 2002). Water level fluctuation also changes the nutrient cycles (Weller 1999), food webs as well as available and accessible suitable microhabitat for various bird species and guilds (Jefferies, 2000). Fluctuations in water levels determine spatial extent and temporal periods of cycles of inundation, which facilitate wetland nutrient balance and productivity through processes of aerobic and anaerobic decomposition (Schoenberg et al. 1988). Different waterfowl guilds or species will be affected differently by the hydrological dynamics through alteration of their specific microhabitats (Welller 1999, Maviza 2010).

2.2 Wetland and wetland birds in Nepal

Wetlands in Nepal are spatially distributed from lowlands to highlands and are of great value to local people for sustaining their livelihood (Lamsal et al. 2014). However, the degree of their dependency differs with their location. Though the dependency on wetland resources is high in Nepal, people still do not recognize all the ecosystem services of wetlands (Prusty et al. 2017).

Nepal is signatory of Ramsar conservation, 1987 and has 10 sites (Bhuju et al. 2007, Gauli et al. 2016). Ghodaghodi, Jagdishpur, Beeshazar, and Koshi Tappu are the four Ramsar sites located in the lowland. Koshi Tappu is first Ramsar site of Nepal designated in 1987 for conservation of the last remainig population of wild water buffalo (*Bubalus arnee*) but latter it proved to be best site for winter migratory birds (Sah 1997, Baral 2016).

About 526 bird species have been recorded from the Sapta Koshi flood plain (Baral 2016). Koshi is by far the most important wetland staging post for migrating waders and waterfowl in Nepal (Inskipp and Inskipp, 1991) and considered as one of the most important in Asia (Scott, 1989). Koshi Tappu had initially the largest heronry in Nepal (Baral 2009), where as many as 25,730 nests belonging to 12 species of medium to large waders were reported in 1996 (Inskipp and Inskipp, 1991, Baral 2004, Baral 2009). As many as 20 globally threatened bird species have been recorded in the Koshi Tappu and Koshi Barrage area and eleven of these occur regularly. This IBA is especially important for some wetland and grassland species, notably Swamp Francolin (*Francolinus gularis*), Baer's Pochard (*Aythya baeri*), Pallas's Fish Eagle (Haliaeetus *leucoryphus*), Greater Spotted Eagle (*Clanga clanga*), Imperial Eagle (*Aquila heliacal*), Lesser Adjutant (*Leptoptilos javanicus*), and Bristled Grassbird (*Chaetornis striata*). It holds the largest population of the globally threatened Swamp Francolin in Nepal (Inskipp and Inskipp, 1991, Baral 2009). Marked decline in wintering and passage migrant water bird has been recorded since 1990 and has been highlighted by the Annual Waterfowl Counts, in February 2003 a total of nearly 9,800 birds were counted at the site in one day, a very low number compared to twenty years ago when more than 50,000 birds were estimated (Sah 1997, Baral 2009). Bird richness and populations have declined in both Ghodaghodi Lake Complex and Bees Hazaari Tal in the recent years. Jagdishpur Reservoir considered to be in the best form and with great diversity of birds only a year ago (Baral 2008). At a national level, as many as 44 wetland species have been considered threatened because of habitat loss, water pollution, fish poisoning, hunting and trapping, food shortages due to overfishing, and disturbance and destruction of nesting and feeding sites (Baral and Inskipp 2004).

2.3 GIS and remote sensing in Wetland Mapping

The remote sensing images are available since 1970's, which enables ecologist to utilize it for ecological research. Integrated approaches such as GIS and RS have over the past years gained preference by many researchers (Miwei 2009) thus making them key in exploring the spatio-temporal domain of these studies and easily relate to research studies. Such data have been successfully used in classifying water birds habitat in wetland (Gautam et al. 2015).

The GIS and RS technology have been powerful analytical capabilities and its easy integration with other techniques in ecological research in large scale monitoring and mapping. The use of GIS and RS has tremendously increased in the mapping of the land cover and change detection analysis (Thakur et al. 2017). Determining the rate and status of wetland degradation such as wetlands are dynamic in nature and conventional method does not give feasibly to continuously mapping and monitoring and is time taking (Chen and Rao 2008). Monitoring on landscape level gives great advantage for conservation implications (Castaneda and Herrero 2009). Other quantitative studies in landscape ecology successfully covered wetland hydro-geologic processes related to climatic conditions (Maviza 2010, Maviza 2013).

In context of monitoring at landscape level integrating GIS, RS and other analysis, techniques have been used in the understanding of relationships between wetland landscape structure and waterfowl community dynamics at spatial and temporal scale (Brandt et al. 2013). Expert-knowledge based landscape models have been useful in studies exploring habitat evolution over time (McKinstry and Anderson 2002). This kind of research enables to simulate landscape gradients, calculate habitat diversity metrics of delineated ecoregions and correlate these to waterfowl communities. The implication of these studies has been in broader scale, which gives the ability to work on landscape structure quantification (Maviza 2010) and easy visualization through computer graphics programs enhances the understanding. Output from these researches has been used not only in conservation and management but also in landscape ecological planning processes (Xu et al. 2018) targeted at policy development to ensure balance in wetlands use as habitat and for other human activities. In context of Nepal, utility of remote sensing and Geographical Information Systems analysis has been in providing a spatiotemporal perspective for assessing management policies, which was studied in Chitwan National Park buffer zone, Nepal (Stapp et al. 2015). Spatial and temporal land use and cover change over the period of last 34 years (1976–2010) was analyzed in the KTWR, using remotely sensed data (Chettri et al. 2013).

Significant knowledge gaps exists that quantitative relationships for river birds and river flow regimes change. Koshi Basin harbors many species of bird that are listed as threatened however majority of the ecological research undertaken to date is related to birds in the Koshi Basin, where few studies report the water requirements of different species. Birds are incredibly important and diverse in the region (Doody et at. 2016). This study tried to establish the relationship between responses of wetland dependent bird with WLF.

3. MATERIALS AND METHODS

3.1 Study area

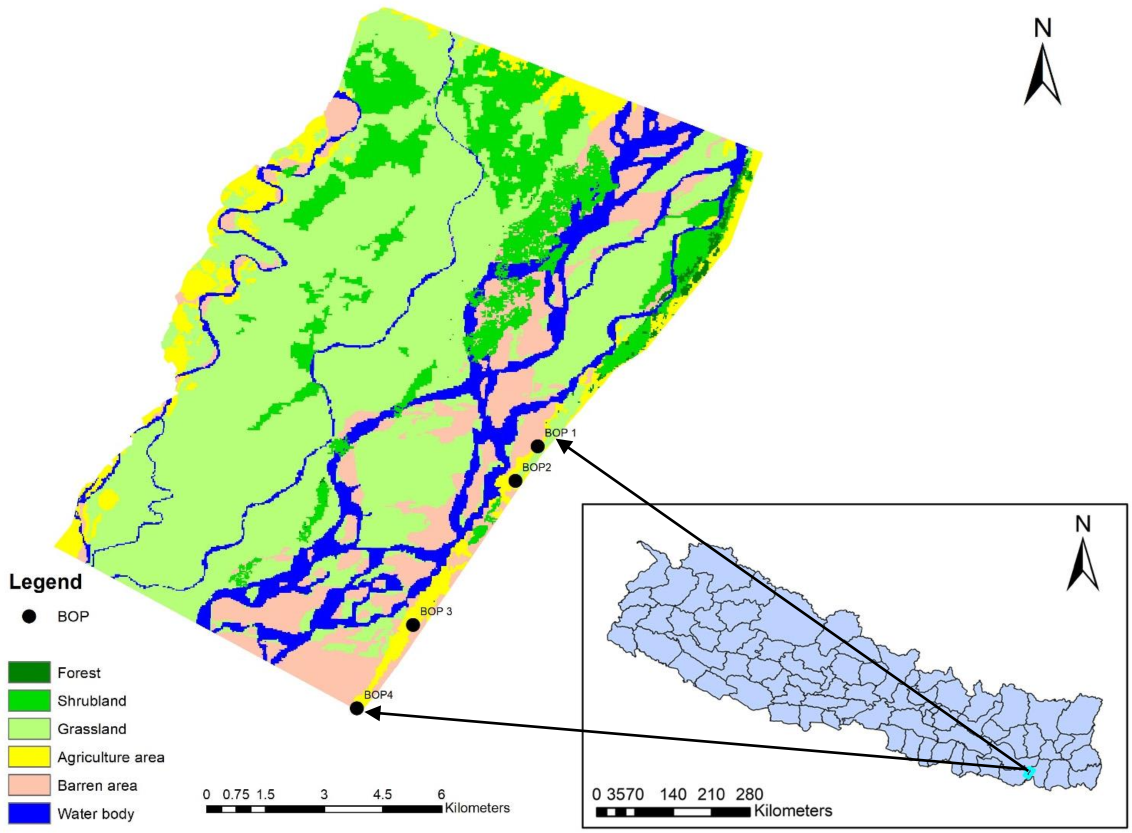

Figure 1: Map of Study Area (ICIMOD 2010)

The study area is located in the eastern Nepal between 26˚35 N to 26˚40 N and 86˚59 E to 87˚05 E and occupies 175 Km^2 area of the Sapta Koshi River floodplain and its altitude ranges from 75 to 100 m. Seventy percent of the reserve area is covered by grassland. The reserve is located between two flood control embankments and is subject to annual flooding. Approximately 70% of the reserve's land area is covered with grassland although during high flood years a large area of grassland is destroyed and replaced by new alluvial deposits (Sah 1997). Koshi Tappu Wildlife Reserve encompasses tropical climate, and average monthly rainfall ranged from 9.5 mm in December to 682 mm in July and more than 85% of precipitation occurs in the monsoon period between June and September (Devkota and Gyawali 2015).

3.1.1 Climate

The reserve has sub-tropical climate with temperature ranging from 8.3ºC in winter and 33.2ºC in summer and average annual rainfall is 2019 mm. There are primarily four seasons in the region. They are: the winter (December - February), the pre-monsoon period (March-May), the monsoon period (June-September) and the post-monsoon period (October-November) (Sah 1997). The rainfall is greatest during July but high humidity and temperatures are experienced throughout the season. Winter (October-January) is characterized by moderate temperature. About 80% of the total annual precipitation occurs during the months of June through September, however, this varies annually. It is observed that nearly 73% rainfall occurs from June to September near Chatara (Ueno et al. 2008).

3.1.2 Biodiversity

The vegetation is mainly tall grassland with few patches of Khair (*Acacia catechu*), Sisso (*Dalbergia sissoo),* scrub forest and deciduous mixed riverine forest. The reserve area have Simal tree (*Bombax cebia*), Sal tree (*Shorea robusta*), as major tree species. *Typha* and *Saccharum* are major grassland types found here, although patches of *Imperata* and *Phragmites* are often seen, medium size phantas interspersed with young Acacia trees are found in sandy islands. Riverine vegetation with *Acacia catechu/Dalbergia sissoo* forest dominates on the islands and edges of the reserve. Mostly young trees grow inside and on the edges of the reserve within embankments, the old mature trees being swept away by annual floods (Bhuju et al. 2007).

The reserve contains Nepal's last population of Wild water Buffalo (*Bubalus arnee*). The reserve provides important habitat for a variety of wildlife. Other mammals found in the park are Hog Deer (*Axis porcinus*), Wild Boar (*Sus scrofa*), Chital (*Axis axis*) and Blue Bull (*Boselaphus tragocamelus*). Koshi Tappu is home for 526 bird species including globally threatened birds like Swamp Francolin (*Francolinus gularis*), Baer's Pochard (*Aythya baeri*), Pallas's fish Eagle (*Haliaeetus leucoryphus*), Greater spotted Eagle (*Clanga clanga*), Eastern imperial Eagle (*Aquila heliaca*), *philippensis*), and Bristled Grassbird (*Chaetornis striata*) (Sah 1997, Baral 2016).

3.2 Materials used

- Binocular
- GPS (Garmin eTrex® 64s)
- Topographic map (1:25,000)
- Camera (Canon 7D mark II)
- Measuring tape
- Field Stationary

3.3 Preliminary field survey

Preliminary survey was done to identify the best possible site for studying the wetland dependent birds and its relation to water level fluctuation over the period of a year. Habitat heterogeneity was taken in consideration along with the persistence of water in the study area throughout the year.

3.4. Research design

The study was carried out along 11 km stretch of the eastern embankment. The embankment has villages to the east (outside the reserve) and narrow strip of land to the west that varies in width about 500m-800m.

Bird Observation Points (BOP) were established with a minimum distance of 500 m to maximum 2000m between the BOP's to avoid the counting of the same individual. In KTWR, most of the important wetland is located outside the reserve, between the wildlife reserve and Koshi barrage, and east of the eastern embankment (Sah 1997, Dahal et al. 2009), where study was focused. Bird survey was carried out in four seasons of a year (2018/2019). Summer (June-September), autumn (October-December), winter (January-February), spring (March-May).

Disturbances for bird was categorized into three types i.e. disturbed, intermediate disturbed and un-disturbed. Intensity of disturbance was measured by time and intensity people used the area (Table 1).

Table 1: Category of Disturbance

Category	Activity	
	People	Vehicle
Intermediate	Movement of more than 100 people per day	Private Vehicle only allowed in the area
Disturbed	Movement of less than 100 people per day	Public Vehicle and Private Vehicle both allowed in the area
Un-disturbed	Movement of less than 50 People per day	Private Vehicle only allowed in the area

3.4.1 BOP1

First sampling site was located at 26.63^0 N and 87.03^0 E and is northernmost part from where the eastern wetland starts. Small dam was created for storing water and to use for irrigation. The approx length was 1 Km and approx width was 500m. The wetland was approx 3 m deep during summer monsoon. Local people used it for fishing and bathing. Disturbance was Intermediate at this site as movement of people was only during dusk and dawn.

3.4.2 BOP2

The second sampling site was located at 26.61^0 N and 87.03^0 E in West Kusaha behind headquarter of KTWR. Where there were two ponds, having shallow depth of water attached to the park office. The approx length was 1.5 Km and approx width was 800m. Disturbance was of intermediate level, movement of people was during dusk and dawn.

3.4.3 BOP3

The third site was located at 26.57^0 N and 86.99^0 E at Titrigachhi. The site was used for fishing during winter but in other seasons, it was undisturbed area. The site was characterized by the bank fixation with gabion wall and continuous flow of water around the year. The approx length was 2 Km and approx width was 600m. It was categorizes as undisturbed area for birds as movement of people was for fishing only, otherwise not much movement.

3.4.4 BOP4

The last southernmost site was located at 26.60^0 N and 87.01^0 E near Haripur. Situated near the East- West highway and highly disturbed vehicle travel all day and night movement of people was from dusk to down. People use the area for bathing, cattle grazing. The habitat was characterized by fixed bank with gabion wall, shaded region and low flow of water. The water level in this site was highest among all four sites. The approx length was 2 Km and approx width was 400m. Disturbance was highest in this site, people used this site for various resources utilization, and it was one of the entry points of the reserve.

3.5 Land cover/Habitat assessment

Landsat satellite images were used in habitat characterization and dynamics of entire KTWR (Table 3). Multi-temporal landsat images were downloaded from GloVis (https://glovis.usgs.gov/). Landsat images were layers stacked and then subset was performed. Supervised maximum likelihood classification was used for analysis of remotely sensed image (Srivastava et al. 2012). True color composite and false coulure composite were made to identify different classes for classification of satellite image into four classes (Table 2).

Table 2: List of Band Combination used to LULC.

Color Composite	**Band combination**
Nature Color	4,3,2
False Color(Urban)	7,6,4
Vegetation	5,6,2
Land/Water	5,6,4

Supervised classification was used to classify the habitat types of eastern wetlands. The common supervised classification algorithm, maximum likelihood was used for habitat classification into four classes. Supervised classification is based on the idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. Training sites (also known as testing sets or input classes) are selected based on the knowledge of the user. The user also sets the bounds for how similar other pixels must be to group them together.

For wetland of eastern embankment, shape file of the study area was made with Google Earth Pro. Supervised classification approach was adopted for classification of the satellite image. Water depth was taken in consideration for supervised classification. Visual interpretation in each field survey and images taken during the survey was used to classify the study area in four group i.e. Land (0cm), Wet-muddy (0-3cm) Shallow water (3-20cm), Deep water (>20cm).

3.5.1 Data used for Land cover classification

Table 3: List of Landsat satellite images used in classification

Platform	Sensor	Date	Season	Resolution(m)
Landsat	OLI/TIRS C1 Level-1	2019-03-01	Spring	30
Landsat	OLI/TIRS C1 Level-1	2018-12-27	Winter	30
Landsat	OLI/TIRS C1 Level-1	2018-11-09	Autumn	30
Landsat	OLI/TIRS C1 Level-1	2018-10-24	Summer	30
Landsat	Landsat 5 TM C1 Level-1	2008-12-31	Winter	30
Landsat	Landsat 5 TM C1 Level-1	1998-12-04	Winter	30

3.6 Accuracy assessment

Among all the points taken in the field, 80% was used to make the map and 20% was used to test the accuracy and make error matrix in habitat characterization. All the points were grouped into deep water, shallow water, wet-mud and land. An error matrix in classification was developed and total accuracy was calculated. Accuracy percentage = (total true value/total sampled value) x100%.

3.7 Method of bird data collection

Point count method (Bibby et al. 2000) was used to record birds in the continuous line transect of 11 km. Four point were established and each point was surveyed for 20 minutes during 6:30 hrs to 12:30 hrs. Wetland birds seen and heard within the radius of 300 meters ware recorded along with its number and detail microhabitat (Land, Wet-muddy, Shallow water, Deep-water). Vegetation was recorded in the percentage cover at each site and disturbance was recorded on two factors, firstly movement of people and secondly number of vehicle.

3.8 Bird community structure

In this study, an integrated approach was adopted incorporating use of microhabitat preferences, foraging tactics, taxonomy and to some extent diet. Waterfowl were grouped into four guilds namely, swimmers, waders, shore liners and others (general species that do not fall in any of the three earlier guilds) based on these criteria. The criterion considered microhabitat preferences related to adaptations in physiology and behavior by the waterfowl i.e. Leg and bill length and foraging tactics (Weller 1999).

Swimmers **Waders** **Shoreliners** **Other (River birds)**

Figure 2: Wetland bird community

3.9 Water level measurement

Measuring rod was installed in the middle of the each wetland. Citizen scientist was recruited to take the photo of the measuring rod each week; data of water level was extracted from the field image using J software.

Amplitude of water level was calculated by the formula, water level amplitude (minimum minus maximum water level)

3.10 Data analysis

The data analysis was carried out in R Studio 1.3.1093 and graphs were prepared using Microsoft Excel.

i. Shannon-Wiener's Diversity Index [H̅]: - Σ $\left[\left(\frac{ni}{N}\right) * ln\left(\frac{ni}{N}\right)\right]$ Where,

ni = Total number of individual of each species

N = Total number of individuals of all the species

It was used to calculated bird diversity at BOP in four season of the study.

ii. ANOVA(between bird diversity at four BOP in four different seasons) test followed by post hoc Tukey HSD test and Kruskal- walis test followed post hoc Dunn test was carried out to determine the significant difference of environmental variables, water level and wetland birds among different seasons at four BOP.

iii. Pearson correlation was carried out to know the relationship between bird abundance and water level fluctuation.

iv. Polynomial regression was carried out to establish the relationship between bird abundance and water level fluctuation.

v. Canonical Correspondence Analysis (CCA) was done to establish relationship between Shannon(H) bird of diversity and environmental variables (deep water, shallow water, wet-muddy, land and macrophytes).

vi. Non-metric multidimensional scaling (NMDS) is an indirect gradient analysis approach, which produces an ordination based on a distance or dissimilarity matrix. Unlike methods, which attempt to maximize the variance or correspondence between objects in an ordination, NMDS attempts to represent, as closely as possible, the pairwise dissimilarity between objects in a low-dimensional space. It was performed to find how assemblage of waterfowl changes significantly in each season.

vii. Maps and LULC were prepared using ArcGIS 10.4

4. RESULTS

4.1 Land cover dynamics

Four general land cover patterns were identified river (water), sand, grassland and forest in KTWR. In 1998 river Koshi was flowing towards eastern side, in 2008 river course broke the eastern embankment with massive flooding, in 2018, the river course had shifted from eastern to middle of the reserve with the help of porcupine fencing by KTWR (Figure 3; Table 4).

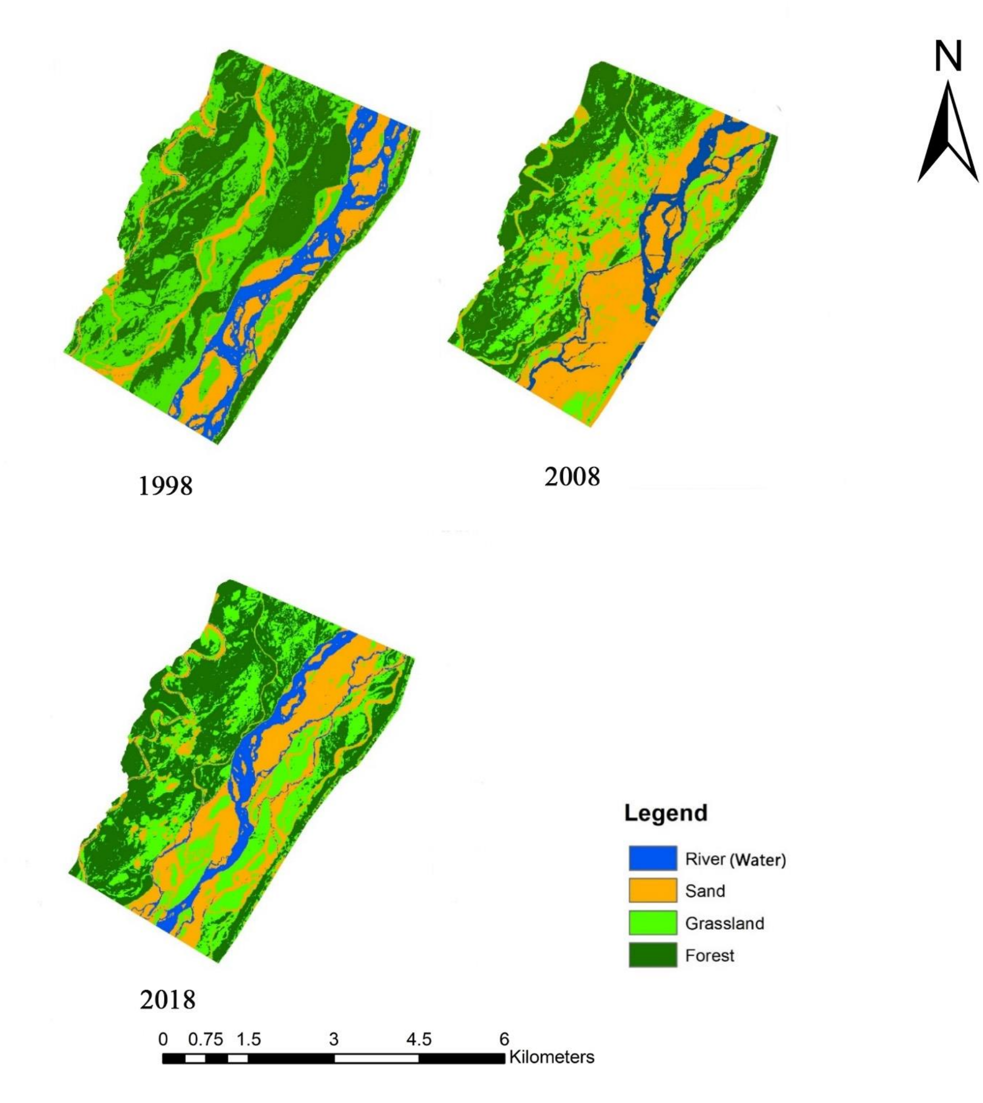

Figure 3: Land cover of KTWR in 1990, 2008 and 2018

From 1998 to 2008, areas of river (water cover), grassland and forest has decreased slightly but the river bed/sand has increased tremendously. From 2008- 2018, river (water), grassland cover and forest cover has increased slightly, but sand (river bed) cover has decreased tremendously (Figure 4).

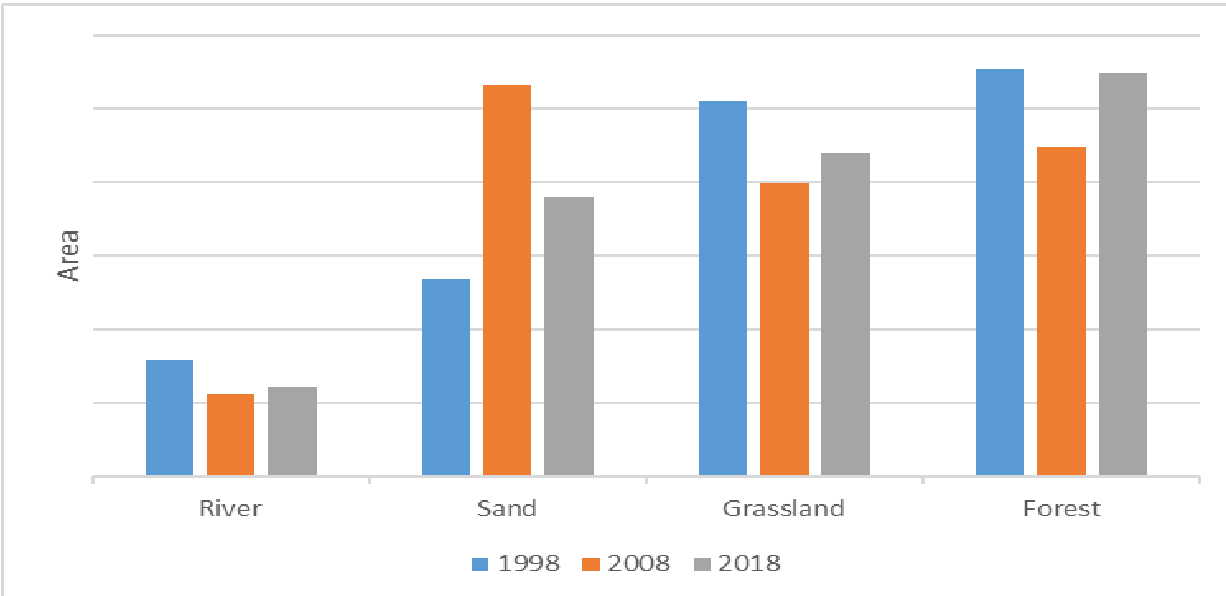

Figure 4: Changes in land cover type between 1998, 2008 and 2018 in KTWR.

Table 4: Land cover changes in Km^2 from 1998, 2008 and 2018 in KTWR.

Category	**1998**	**2008**	**2018**	**1998-2008(%)**	**2008- 2018(%)**	**1998-2018(%)**
River	15.8	11.31	12.11	-28.42	7.01	-23.40
Sand	26.81	53.34	38.1	98.98	-28.57	42.12
Grassland	51.09	39.81	44.12	-22.07	10.86	-13.63
Forest	55.54	44.77	54.91	-19.38	24.64	-1.34

4.1.1 Accuracy Assessment

Table 5: Error matrix for accuracy assessment of classification

Categories	**Water**	**Sand**	**Grassland**	**Forest**
Water	22	3	0	4
Sand	4	14	0	5
Grassland	0	5	58	3
Forest	1	0	22	13

A total of 138 samples were taken randomly for accuracy assessment. Total true value was found to be 107 and accuracy assessment was calculated. Based on Error matrix accuracy assessment of the classification was 77.53% (Table 5).

4.1.2 Habitat classification

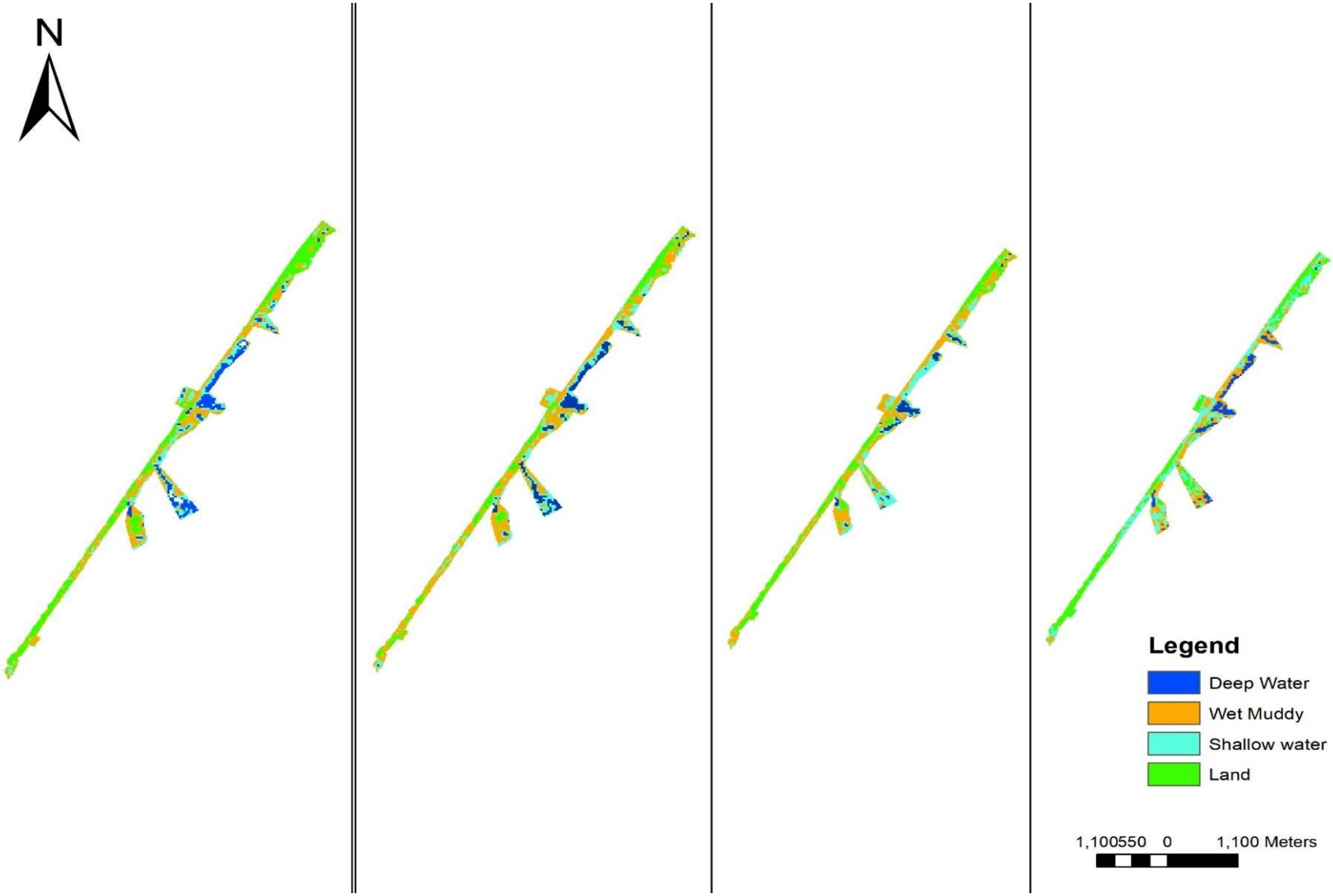

Figure 5: Microhabitat of each seasons (summer, autumn, winter and spring respectively) for eastern embankment.

Table 6: Microhabitat in km^2 for each seasons (Summer, autumn, winter and spring respectively) of eastern embankment.

	Summer	Autumn	Winter	Spring
Deep Water	0.94	1.03	0.95	0.80
Wet- Muddy	1.31	1.54	1.46	1.55
Shallow	2.06	2.50	2.50	2.26
Land	2.21	1.48	1.48	1.79

4.1.3 Microhabitat

In summer, Land class was dominant and Deep-water class covered least area. In autumn Shallow water, class was dominant and Deep-water class covered least area, similar was the case with winter and spring. Gradually from autumn to spring, Deep-water class has decreased (Figure 6).

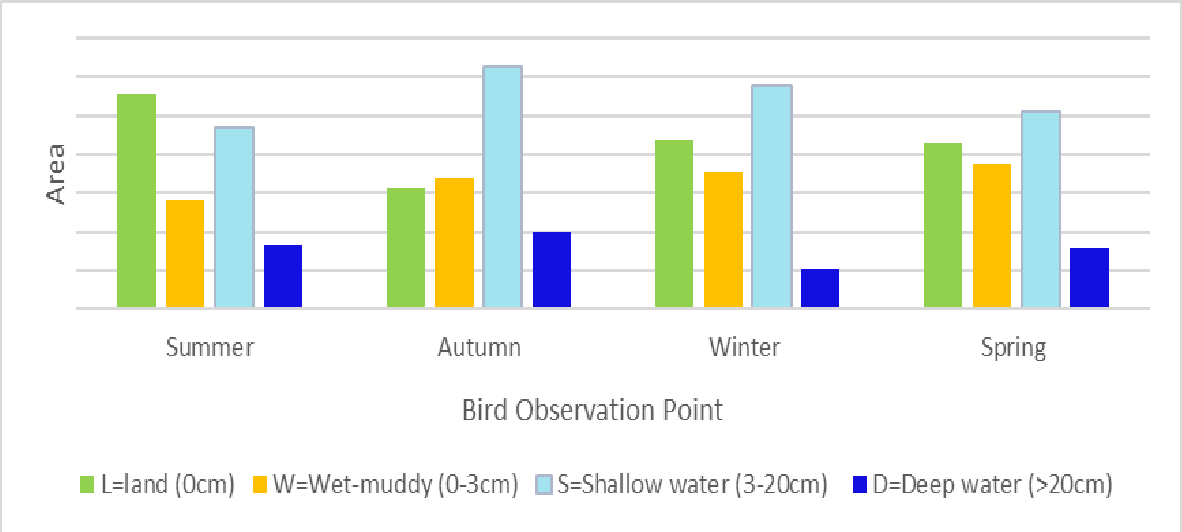

Figure 6: Microhabitat area of eastern wetland in four different seasons of a year.

4.2 Bird Community

A total of 1526 individuals of 53 species recorded belonging to 17 families and 10 orders (Appendix II). Highest number of species was recorded from the Ardeidae family and lowest was from Podicipedidae family (Figure 7).

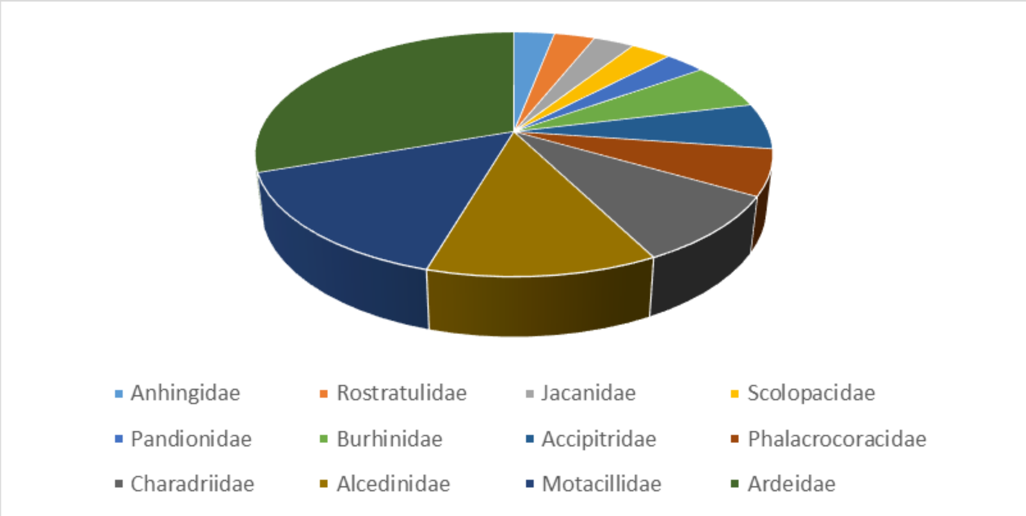

Figure 7: Family wise classification of bird recorded in study area in number.

4.2.1 Shannon diversity of bird

In summer, diversity was highest at BOP3 and lowest at BOP4. In autumn, diversity was highest at BOP1. In winter, diversity was highest and lowest was at BOP2. In spring, diversity was highest in BOP2 and lowest at BOP1 (Figure 8).

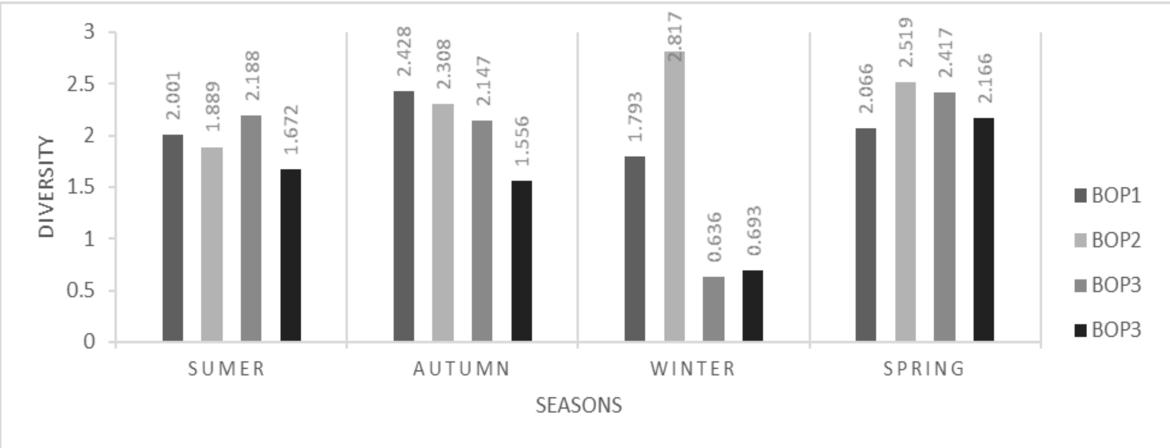

Figure 8: Shannon diversity of birds in four seasons at four observation points.

Tukey HSD test showed the diversity of bird species in autumn and spring was not significantly different, and diversity of winter was significantly different compared to autumn, winter and summer (Figure 9).

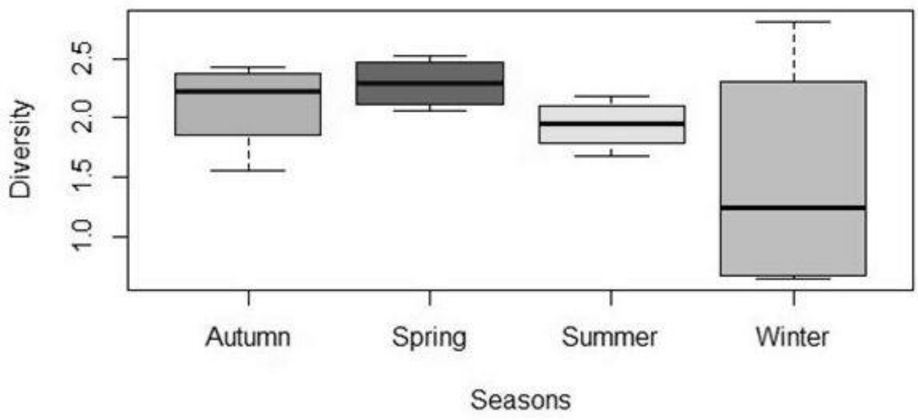

Figure 9: Box and whisker plot showing diversity Shannon index among different seasons

4.2.2 Abundance of birds

In summer, abundance was highest at BOP2, and lowest at BOP4, abundance ranged from 18-45. In autumn abundance was highest at BOP1, and lowest at BOP3, abundance ranged from 59-103. In winter, abundance was highest at BOP2, and lowest at BOP4, abundance ranged from 2-67. In spring, abundance was highest at BOP3, and lowest at BOP 4, abundance ranged from 49-111 (Figure 10).

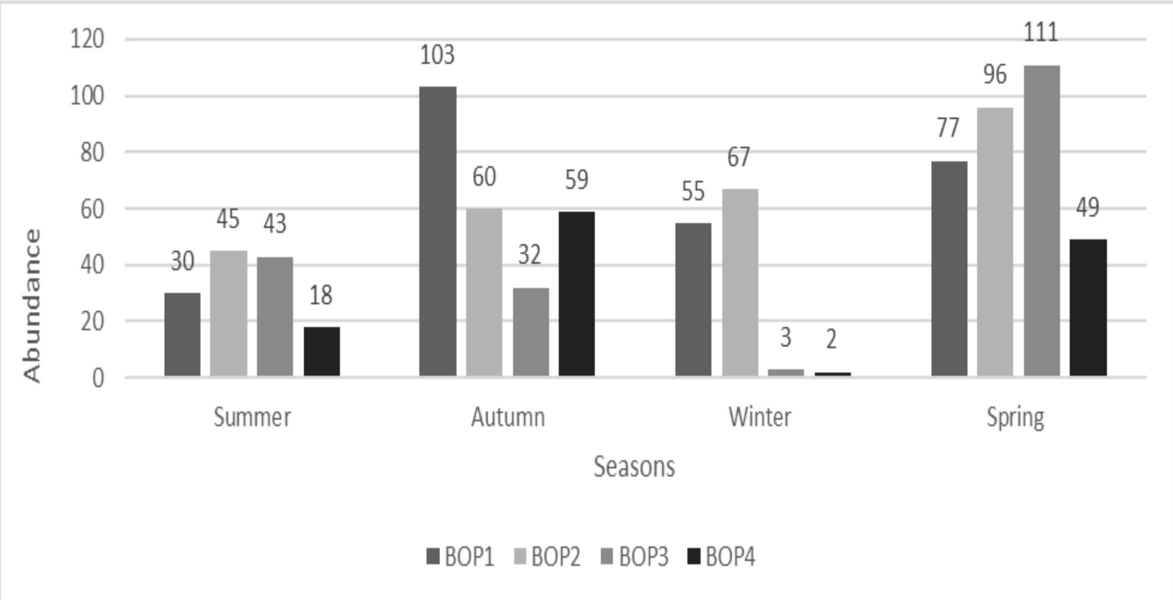

Figure 10: Abundance of birds in four seasons at four observation points.

4.2.3 Wetland birds community classes

Four types of birds were identified; Swimmers, Shoreliners, Waders and Others (Figure 11). Highest number (42%) waders were found among them Cinnamon Bittern (*Ixobrychus cinnamomeus*) was the only summer migratory bird in the study area. Grey Heron (*Ardea cinerea*) was only Wader, which was winter migratory. Remaining all including, Grey-headed swamp Hen (*Porphyrio poliocephalus*), Eurasian Coot (*Fulica atra*), and Great thick-knee (*Esacus recurvirostris*) were residential birds of the study area. Swimmers (28%) except Lesser whistling Duck (*Dendrocygna javanica*), Knob-billed Duck (*Sarkidiornis melanotos*) and Oriental Darter (*Anhinga melanogaster*) all were winter migratory species. Among shoreliners (17), Grey-headed Lapwing (*Vanellus cinereus*), Common Greenshank (*Tringa nebularia*) was winter migratory and remaining all were residential. Other birds (13%) (River birds) Osprey (*Pandion haliaetus*) was winter migratory remaining all was residential.

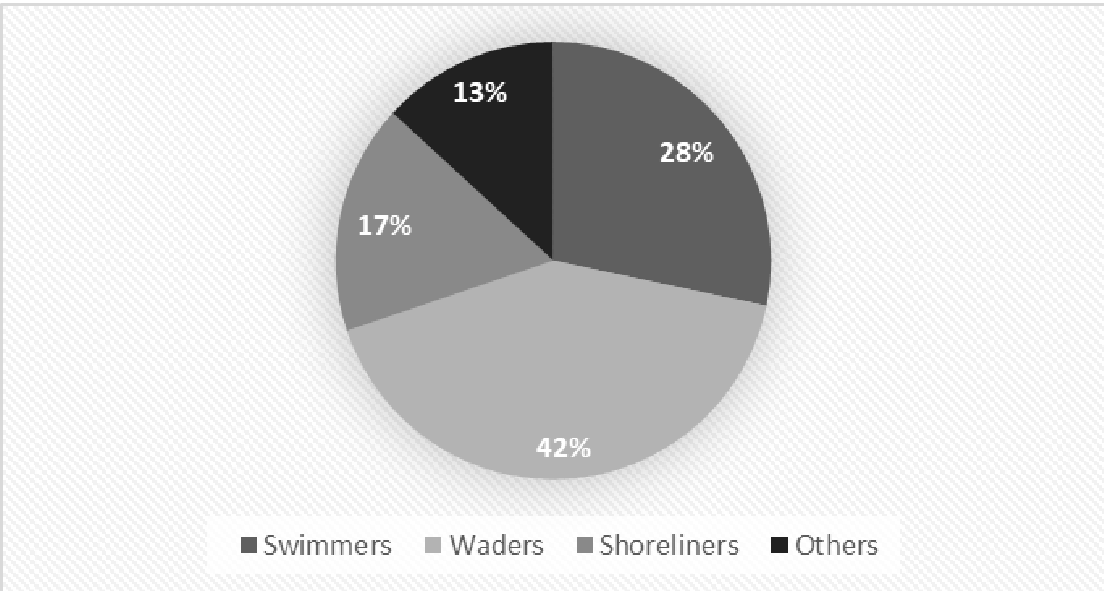

Figure 11: Abundance of different guild based on microhabitat preference

4.3 Water level

4.3.1 Annual water level fluctuation

The highest amplitude of water level fluctuations was in spring season followed by summer, winter and autumn season .The mean amplitude (maximum-minimum) of water level fluctuations in one year was found to be 91.67 cm (Table 12).

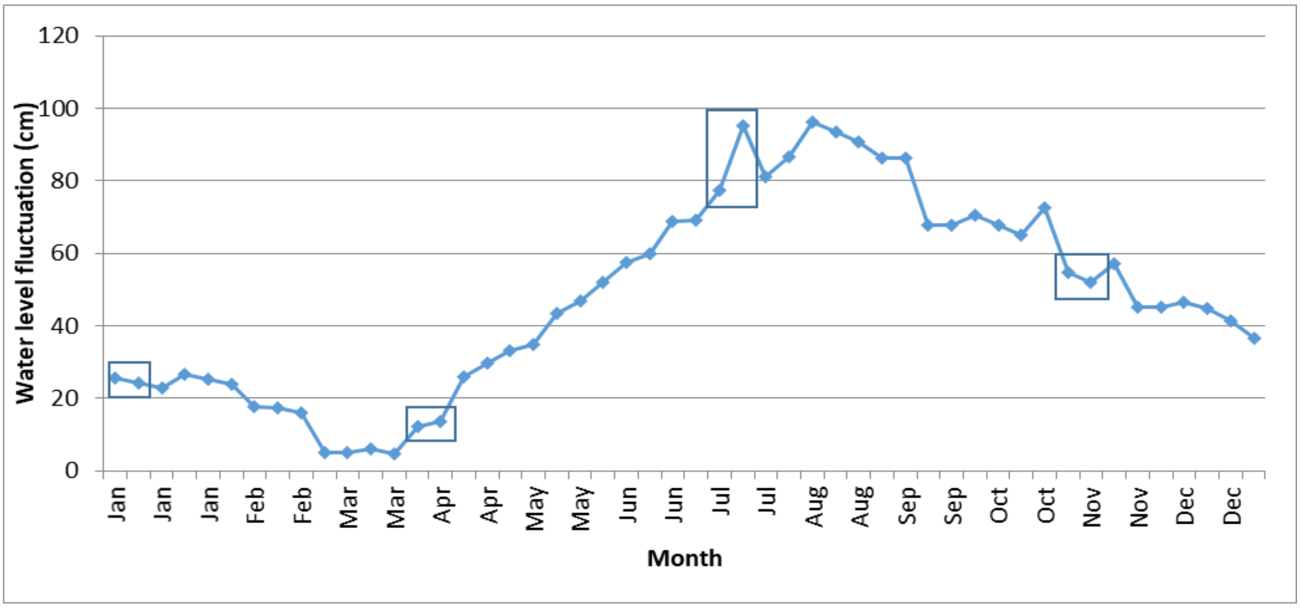

Figure 12 Line plot showing monthly WLFs throughout the year from 28th July 2018 - 11th July 2019. Small black frame shows water level during survey period.

Table 7: Amplitude of water level fluctuations of different seasons in KTWR wetlands

S.N	Seasons	Mean water level ± SD (cm)	Maximum (cm)	Minimum (cm)	Amplitude (cm)
1.	Summer	78.92 ± 12.98	96.17	57.43	38.74
2.	Autumn	58.88 ± 10.56	72.47	44.99	27.48
3.	Winter	28.31 ± 10.43	46.38	16.09	30.29
4.	Spring	23.94 ± 17.28	51.89	4.5	46.77
5.	In whole studied year	47.86 ± 27.15	96.17	4.5	91.67

4.4 Relation between bird community and the microhabitat

4.4.1 Waders

Waders were negatively correlated with deep-water class and shallow water class. Whereas positively correlated with wet-muddy land class and positively correlated with land class, and positively correlated with wet-muddy class (Table 8).

Table 8: Correlation table between landscape class and abundance of bird class

Landscape Class	Land	Wet Muddy	Shallow water	Deep Water
Waders	0.074	0.585	-0.182	-0.718
Swimmer	-0.907	0.496	0.929	0.497
Shoreliners	-0.931	0.648	0.942	0.644
Others	-0.703	0.996	0.618	-0.225

4.4.2 Swimmer

Swimmers positively correlated with Shallow water class whereas with land class it negatively correlated and positive correlation was found in-between Wet-muddy and Deep-water class (Table 8).

4.4.3 Shoreliners

Shoreliners negatively correlated with Shallow water and positively correlated with Wet-muddy and Deep water class whereas the land class shows significant negative correlation (Table 8).

4.4.4 Others (river birds)

Others (river birds) positively correlated with Wet-muddy class and positively correlated with Shallow water and negatively correlated with Land class and negatively correlated with Deep -water class (Table 8).

4.5 Seasonal assemblage of wetland birds

The non-metric multidimensional scaling between bird community assemblages and four seasons revealed that the abundance of bird was significantly different between different seasons, assemblage of birds (PERMANOVA -Bray-Curtis) index obtained with 9999 random permutations via the adonis function) showed bird communities among different seasons is significantly different ($F = 3.10$; $p < 0.0001$) with 0.14 stress value. The NMDS plot showed that bird community assemblages of summer and autumn are somehow similar and the bird community assemblage's winter and spring are dissimilar to each other due to distance clustering in multidirectional space (Figure 13).

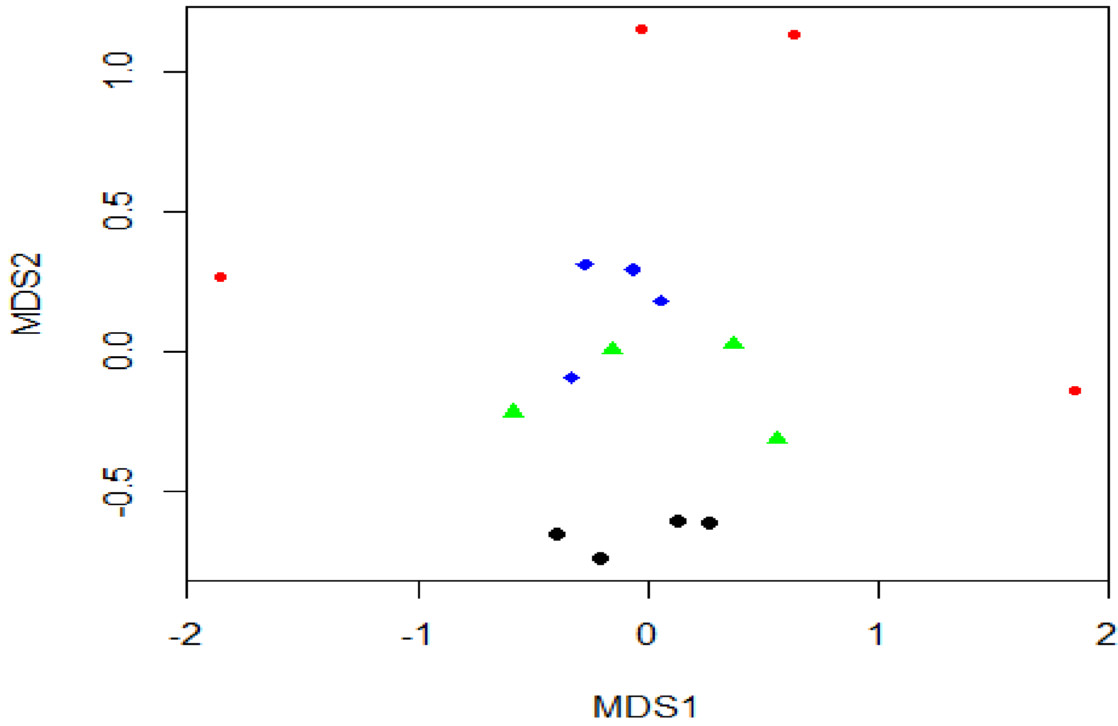

Figure 13: Non-metric multidimensional scaling representing multivariate distances among bird diversity of four different seasons, green=summer, blue=autumn, black=winter, red=spring)

4.6 Relationship between wetland bird and water level fluctuation

The first-degree polynomial regression was significant only for the diversity of Waders in relation to water level (Figure 14). The regression analysis revealed that, the diversity of waders' increases with decrees in water level.

Waders showed negative correlation (-0.460) with water level. As the water level, decrease diversity of waders decreases gradually. Regression analysis between water level and diversity of waders showed similar results. Swimmers showed negative correlation (-0.102) with water level. Regression analysis between water level and Swimmer was not significant as higher number of swimmers were present in the study area when water level was low; because study area is site where more number of migratory bird arrives in winter. Shoreliners showed slight negative correlation (-0.003) with water level. Others (river birds) showed slight positive correlation (0.287) with water level.

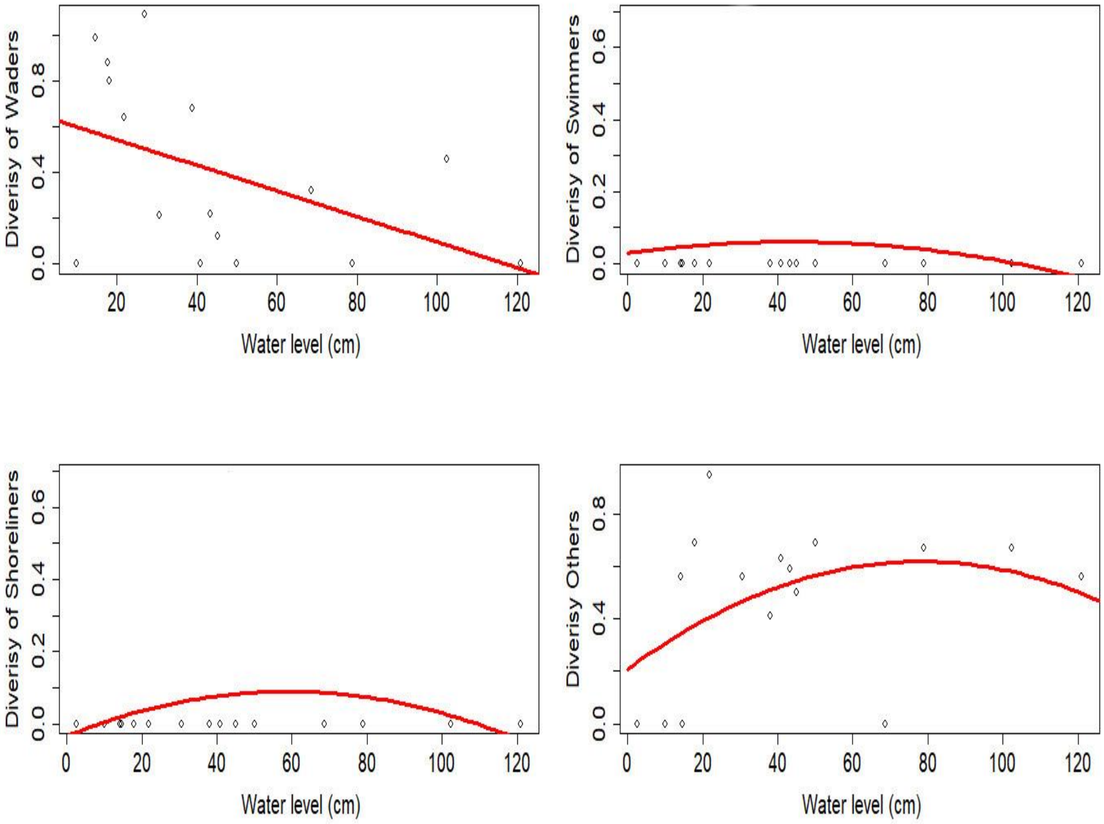

Figure 14: Regression line of water level fluctuations and diversity of four classes of birds (Waders, Swimmers, Shoreliners and Others)

4.7 Relationship between wetland bird abundance and microhabitat

Wading birds favored shallow water. CAA plot showed that, species like Common Moorhen (Gallinula *chloropus*) favored open water. White-breasted Waterhen (*Amaurornis phoenicurus*) and White-breasted Kingfisher (*Halcyon smyrnensis*) favored habitat with *Typha* spp. Purple Heron (*Ardea purpurea*), Asian Openbill (*Anastomus oscitans*), White-browed Wagtail (*Motacilla maderaspatensis*) and Common Greenshank (*Tringa nebularia*) favored shallow water micro-habitat .Wet muddy class was favored by species like Gadwall (*Mareca strepera*) and Cotton Pygmy-goose(*Nettapus coromandelianus*). Intermediate Egret (*Ardea intermedia*) and Great White Egret (*Ardea alba*) favored microhabitat class land (Figure 15).

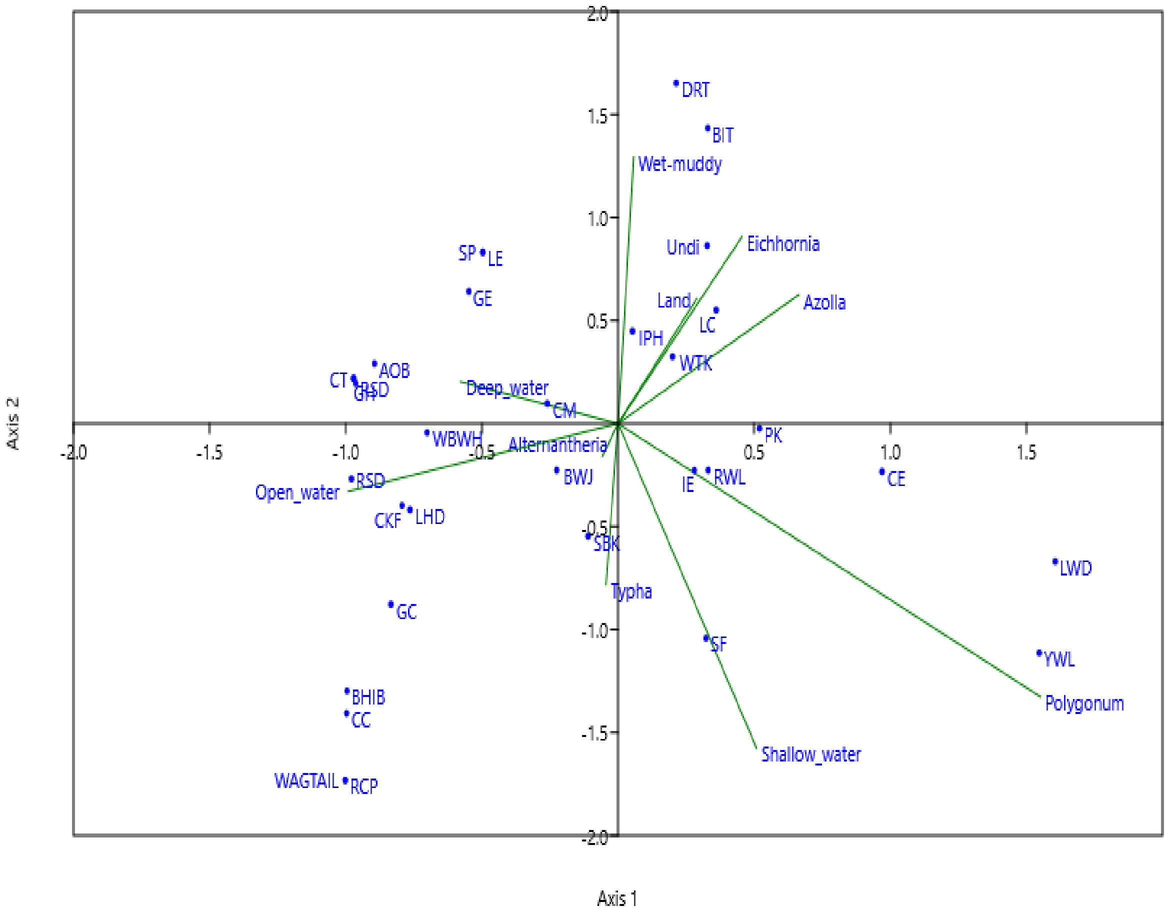

Figure 15: CCA between bird and microhabitat.

5. DISCUSSION

In this study wetland, bird community was divided into four categories Swimmers, Waders, Shorelines and Other (river bird). Swimmers are the birds specialized for swimming. Waders are birds commonly found along Shorelines and mudflats, they cannot swim. Others (river birds) have special characters like flight mechanism in kingfishers and raptors. Shorelines are the bird that prefers the area where the land and water meets i.e. shores. Effect of WLF was more obvious in Waders than Swimmers, Shorelines and others (river bird) in this study. Similar approach has been used such as the diet or forage based approach (Maviza 2010), inter species similarities based approach and the common habitat based approach (and other quantitative approaches which use statistics Weller 1999) for bird community analysis.

5.1 Land cover dynamics of KTWR

The result indicated that KTWR is the most dynamic landscape. During this study forest, grassland, and water (river) has considerably decreased and the sand has increased drastically due to massive flooding of 2008 and large amount of sand was deposited on eastern part of the reserve. One of the main reason for low value of water body might be due to high deposition of sand on the riverbank. Secondly, in KTWR the forest is mostly riverine and is subjected to annual flooding and the patches of riverine forest get highly affected by the monsoon flooding. The intent of this study was to analyze land cover change over period of 20 years from 1998, 2008 and 2018 and quantify wetland degradation, but scenario of 2008 massive flooding and its recovery was more dominant in the land cover changes. Current study revealed that from 1998, 2008 and 2018 forest cover has decreased considerably; similar was the finding of Sah (1997) where he also suggested landscape of KTWR is dynamic and changes periodically.

Previous studies in the KTWR have found similar land cover dynamics. Chettri et al. (2013) analyzed land cover dynamics for 34 years and reported, forest covers to be gradually decreasing in KTWR. Chaudhary et al. (2016) also reported that river Koshi change its course periodically from east to west and vice versa which alters the composition of land cover class periodically, which is in favor of the current study.

In similar study done by Castañeda et al. (2005) in lakes of Spain. It was found that floodplain and their hydrological regime and the land covers was found to be dynamic in nature. Change detection studies have taken advantage of the repeat coverage and archival data available with satellite remote sensing (Ozesmi and Bauer 2002). Detailed wetland maps can be updated using satellite imagery.

5.2 Water bird community structure of KTWR

A total of 53 species of wetland birds were recorded in this study during 2018/2019. Many studies were done after the massive flooding of 2008 to find the overall biodiversity of KTWR. After massive flooding of 2008, most of the eastern habitat of KTWR was destroyed with huge deposition of sand; a total of 66 species were recorded in 2008 and in the year 2009 a total of 72 species of water dependent birds were recorded Baral (2012). In current study which was performed only in 11km stretch of eastern embankment which might have limited the number of species. Many species preferring shallow wetlands were totally absent e.g., Cotton Pygmy Goose (*Nettapus coromandelianus)* and Pheasant-tailed Jacana (*Hydrophasianus chirurgus*) in study of Baral (2012) and few species of birds e.g., Great Cormorant, Goosander, gulls and tern species as well as Great Egret and Grey Heron were benefited due to flooding of 2008. Interestingly in this study conducted in 2018/2019, Cotton Pygmy Goose was recorded from the site, which was not recorded in 2008 and 2009. In current study similar was the case with Great Cormorant, Great Egret and Grey Heron, they were found in large number but gulls and tern were not recorded from the study area. This shows that diversity of the eastern part has recovered a lot from massive flooding of 2008 not only in terms of land cover but also in biodiversity.

The finding from the study also conforms presence of migratory bird especially in winter, NMDS plot showed that bird community assemblages of summer and autumn were somehow similar and the bird community assemblage of winter and spring are dissimilar to due to distance clustering in multidirectional space. Which suggest presence of winter as well as summer migratory bird in study area. The main objective of the study was to find the relation between WLF and wetland birds, so the study was designed in such a way where the availability of water can be ensured throughout the year. Therefore, core or middle area of the reserve was not taken as study site due to feasibility and logistics reason.

Thapa and Saund (2012) recorded 77 bird species belonging to 8 orders, and 31 families at Jagdishpur Reservoir, which lies in lowland of Nepal. Kafle (2005) recorded 60 species from Ghodaghodi Lake; earlier report suggested study 41 species of birds in same lake. Lamsal et al. (2014) recorded birds belonging to 20 families from Ghodaghodi Lake. Wetland of lowlands is wintering ground for wetland birds, compared to this study only conducted in eastern part of KTWR and only wetland birds were taken in consideration, which resulted in low number of species compared to Jagdishpur Reservoir and Ghodaghodi Lake. Nepal harbors 886 species of bird (BCN and DNPWC 2018) among 200 species are wetland dependent birds Grimmett et al. (2016) interestingly study by Bhandari (1998) states of these almost all except seven species are found in the lowlands of Nepal and are migratory in nature. KTWR has 526 birds (Baral 2016) but in our study, 53 species of birds were only recorded, as our study was confined only in eastern embankment. Wetland of eastern embankment was not so deep and disturbance was high compared to Koshi River, so there were not much migratory bird species.

5.3 Effect of water level fluctuation on bird communities in the KTWR

In the current study microhabitat having "*Typha*" as macrophyte was favored by small birds like Bronze-winged jacana, most of the wetland bird favors wet-muddy, shallow water and open water. Relationship between water level fluctuation and microhabitat was significant in few bird groups like Wading birds, Waders are birds having long legs and which lack the ability to swim, like Egret and Asian openbill they mostly favor's wet-muddy, shallow water and open water.

Dimalexis and Pyrovetsi (1997) at Lake Kerkini, a Ramsar site in Macedonia, Greece, found that, Log-linear analysis assessed the changes in the patterns of foraging habitat use by Great Egrets, Little Egrets and Grey Herons in response to the interactions of foraging habitat type and lake stage. Where water level fluctuations exceeded 5 m annually, similar result was seen in the Study conducted by Naugle et al. (2001) in South Dakota, found that, Logistic analyses indicate that habitat suitability for some species is related to local vegetation conditions within wetlands, while suitability is related to landscape structure at larger scales, similar was the result in current study. In current study, the most visible result was seen in Order Ciconiiformes (Storks and Waders) as the water level decreased from summer to spring diversity and abundance of Waders were increased. In study of Kushlan (1986), it was found that Wading birds (Ciconiiformes) might use diverse strategies to cope with the seasonal fluctuations of water levels characteristic of large tropical wetlands. Current finding showed the similar result, Storks and Waders seems to be most benefited from seasonal landscape change, which is favored by their morphological adaptation having long legs and bill for foraging in shallow water and muddy habitat.

Diversity was highest in spring as, it was the breeding season when birds are more active and it was the season where macrophytes like "*Typha*" was removed which added to the visibility in the survey. Among Swimmers, Waders, Shorelines and others, Waders were present in higher number in spring as they adopt themselves according to changing habitat. Diversity and abundance of class Swimmers were more in summer, when water level was high. As they need more availability of water for swimming and foraging. Shoreliners were more in medium water level (autumn) and waders (spring) in low water level. Regression analysis between bird diversity and WLF revealed that as the water level decreases the number of waders, increases. Regression with swimmer was not significant as number of swimmer were high in winter only when water level was low compared to summer. Overall diversity was highest in winter due to presence of migratory birds.

Area having open water and diverse habitat was favored by most of the birds as they favor's different bird activities like foraging, nesting and mating. Very low species favor's *Eichhornia* spp., as it restricts the other bird activities. Shallow water was dominant class in Autumn, Winter and Spring. Deep-water class was constantly low in each season; TukeyHSD test showed that there was no significance difference in microhabitat in four different seasons. Among four categorization of microhabitat, shallow water was most diverse in the study; the result in favor of study by Wang (2008) and Maviza, (2010). Similar result was obtained in study of Baral (2012), which was done after massive flooding of 2008 where Shallow water was found to be most diverse habitat and intermediate habitat type so it supported more bird species. Swimmer, dabbling ducks (Lesser whistling duck) favored the shallow water. Waders like Asian openbill and Lesser adjutant likes foraging in shallow water.

Paruelo et al. (1996) in his study found that species richness of floating-leaved and emergent macrophytes was reduced at both small and large water-level fluctuations, whereas species richness of submerged macrophytes was reduced at small water-level fluctuations only. In addition, species richness of submerged macrophytes was higher in lakes that experienced drawdown, whereas no similar pattern was detected for floating-leaved and emergent macrophytes. In this current study it was found that, *Typha* spp. favoured water, and as the water level decreased gardually from summer to spring , vegetation of *Typha* became thinner and thinner similar was the case with Water hyacinth. As water level beacme lower the vegetation cover and macrophytes gradually decreases. Geest et al., (2005) suggest that water-level regime is regarded to be an important factor for Lake ecosystem functioning and affects conservation values. Biota, in particular those living in vegetated areas, respond differentially to changes in hydroperiod dynamics. In current study at KTWR the WLF was upto 1 meter in one annual cycle. In similar study by Thapa and Saund (2012) in Jagdishpur Reservoir where water depth varied form 1-4 m. I this research study area was the wetland formed from seepage of Koshi River and wetland had very narrow depth compared to lake so the fluctuation of water level was only one meter, locals in the area also used the water from the wetland for irrigation purpose.

5.3.1 Bird guild and microhabitat

In current study it was found that, Waders were positively correlated (r= 0.585) with wet muddy class as they do not have ability to swim and was negatively correlated with shallow water and with deep water. Waders do not have swimming ability and cannot enter in deep-water, so it positively correlated with wet-muddy class and negatively correlated with deep-water class. Swimmers negatively correlated with land class and positively correlated with wet-muddy and deep-water class positively correlated with shallow water due to presence of majority of dabbling ducks. Swimmers use deep-water for various birding activities like foraging, nesting and even for hiding in case of emergency. Shoreliners negatively correlated with Land class, positively correlated with shallow water, and positively correlated with wet-muddy and deep-water class. Shoreliners are the bird that use shores of wetland for various bird activity and wet-muddy class and deep-water favors different bird activities. Others birds (river birds) positively correlated with wet-muddy class and shallow water and showed significant negatively correlated with land class and with deep water; the result was in favor of study done by Weller(1999),Wang (2008), Maviza, (2010), Wang (2013). Microhabitat selection by birds was based on the availability of water level, Swimmers significantly preferred deep water, while Waders negatively correlated with the shallow water class (Weller 1999). Shorelines showed unexpected results by having a relatively highest positive correlation with shallow water compared to wet- landscape class. They were also found to be significantly positively related to spatiotemporal changes in total perimeter of the wet-muddy class. The finding from this study suggest WLF is one of the major component determining the bird community composition.

Desgranges et al. (2006) found that in Lake Ontario and St. Lawrence River (LOSL) wetland bird abundance and diversity was greatly influenced by lake and river hydrology. Analyses also revealed strong associations between estimated breeding pair densities. Wantzen et al. (2008) suggested that, WLF affect the ecological processes and patterns of lakes in several ways. Aquatic habitats and feeding or breeding grounds are gained or lost, as light, climate and wave impacts change to mention only a few phenomena. However, in this study no breeding and nesting data were taken in consideration due to ethical and permission issue.

The change in water level results in change of microhabitat variables in the wetland for wetland dependent birds, such as vegetation and area of specific water depths. Which resulted in heterogeneous habitat i.e. Land, Shallow water, Wet Muddy flat and Deep-water similar was the finding of Wang (2008), Maviza (2010).

5.4 Disturbance and threat

This study showed that, intermediately disturbed sites favored more and diverse species of birds (i.e. BOP1 and BOP2) supported high bird diversity, but more of the common species like Indian pond heron *(Ardeola grayii)*, Bronze-winged jacana *(Metopidius indicus)*, Cattle egret *(Bubulcus ibis)* and White-throated kingfisher (*Halcyon smyrnensis*) favored these sites. BOP3 was un-disturbed site, with dense vegetation, and was difficult to spot the bird, species like Western swamphen (*Porphyrio porphyrio*) which is illusive in nature were found at that site. BOP4 was site where disturbance was high and very common species like Cattle egret, Indian pond heron were found. At intermediately disturbed sites, birds may find the food more easily compared to undisturbed site and lesser vegetation might have increased the visibility of birds at intermediately disturbed sites compared to undisturbed sites. Disturbed sites might not ensure places for hiding and nesting for birds so, the sites have low diversity. The finding is similar with Intermediate disturbance hypothesis, which says that, biodiversity peaks at intermediate levels of disturbance, is often extended to predict that productivity follows the same response pattern Baral (2009) reported that the water hyacinth (*Eichhornia* spp.) covers in wetland habitat makes difficulty for birding in foraging and nesting. That might be reason for low diversity and abundance in such area at BOP3 in all seasons except spring, there was around 80% cover of *Eichhornia* spp, which might have resulted in low diversity of birds.

It was difficult to estimate and quantify the disturbance for wetland bird in KTWR; similar was the finding of Hill, (1997) quantifying disturbance for birds of UK. Tubelis and Tubelis et al. (2000) found that, alert distance (the distance between an animal and an approaching human at which point the animal begins to exhibit alert behaviors to the human) has been proposed as an indicator of tolerance mainly for water birds; however, little is known about its utility for other bird species, similar was the case with current study, number of birds in spring at BOP3 increased dramatically in harvesting seasons of "*Typha*" (macrophytes, used by local) added to the visibility better for shorelines birds. BOP4 had constantly low abundance as this site experienced high disturbance.

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6. CONCLUSION AND RECOMMENDATION

The study was conducted from September 2018 to September 2019 over one year, covering all four major seasons Nepal experience. LULC from 1998, 2008 and 2018 was also analyzed to map and quantify the wetland change but scenario of 2008 flooding and its recovery was more obvious. After massive flooding of 2008 and breaking of eastern embankment, the authorities have tried to change the river course towards west and eastern wetlands are getting drier now especially in dry seasons. Wetland bird community was composed of summer as well as winter migratory bird. Shannon diversity was highest in winter due to presence of migratory duck species. Waders were the class of bird most benefited from the seasonal WLF as it adopt diverse foraging methods.

Following are some recommendations arisen from the study, which will help to better manage Wetland birds

1. Small patch of wetland should not let dry completely maintaining certain level (more than a meter) of water level, as complete dry environment does not support any macrophytes and wetland dependent birds.

2. Habitat heterogeneity should be maintained in wetland's (like deep water, shallow water and exposed shores) which favors diverse floral as well as faunal diversity and supports bird activities (like foraging, nesting and mating.).

3. Long-term study is required for proper quantification of relation between WLF and wetland birds.

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8. APPENDICES

Appendix I:

Table 9: Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

	Bands	Wavelength (micrometers)	Resolution (meters)
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

Source: - USGLOVIS

Landsat 8 has been online for a couple of months now, and the images look incredible. While all of the bands from previous Landsat missions are still incorporated, there are a couple of new ones, such as the coastal blue band water penetration/aerosol detection and the cirrus cloud band for cloud masking and other applications. Here's a rundown of some common band combinations applied to Landsat 8, displayed as a red, green, blue (RGB):

Natural Color	4 3 2
False Color (urban)	7 6 4
Color Infrared (vegetation)	5 4 3
Agriculture	6 5 2
Atmospheric Penetration	7 6 5
Healthy Vegetation	5 6 2
Land/Water	5 6 4
Natural With Atmospheric Removal	7 5 3
Shortwave Infrared	7 5 4
Vegetation Analysis	6 5 4

Source: - eris.com

Appendix II: **Order**	**Family**	**Common Name**	**Scientific Name**
Anseriformes	Anatidae	Lesser Whistling-Duck	*Dendrocygna javanica*
		Ruddy Shelduck	Tadorna ferruginea
		Cotton Pygmy-goose	Nettapus coromandelianus
		Northern Shoveller	*Anas clypeata*
		Gadwall	*Anas strepera*
		Northern Pintail	*Rhodonessa rufina*
		Red-Crested Pochard	*Rhodonessa rufina*
		Mallard	*Anas platyrhynchos*
		Common Teal	*Anas crecca*
		Knob-billed duck	*Sarkidiornis melanotos*
Podicipediformes	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*
Gruiformes	Rallidae	White-breasted Waterhen	*Amaurornis phoenicurus*
		Watercock	*Gallicrex cinerea*
		Purple Swamphen	*Porphyrio porphyrio*
		Common Coot	*Fulica atra*
		Common Moorhen	*Gallinula chloropus*
Ciconiiformes	Ciconiidae	Lesser Adjutant	*Leptoptilos javanicus*
		Asian Openbill	*Anastomus oscitans*
	Threskiornithidae	Black-headed Ibis	Threskiornis melanocephalus
		Red-naped Ibis	Pseudibis papillosa
Pelecaniformes	Ardeidae	Cinnamon Bittern	*Ixobrychus cinnamomeus*
		Black Bittern	*Ixobrychus flavicollis*
		Black-crowned Night-heron	*Nycticorax nycticorax*
		Indian Pond-heron	*Ardeola grayii*
		Grey Heron	*Ardea cinerea*
		Purple Heron	*Ardea purpurea*
		Cattle Egret	*Bubulcus ibis*
		Great White Egret	*Ardea alba*
		Intermediate Egret	*Ardea intermedia*
		Little Egret	*Egretta garzetta*
Suliformes	Phalacrocoracidae	Little Cormorant	*Microcarbo niger*

		Great Cormorant	*Phalacrocorax carbo*
	Anhingidae	Oriental Darter	*Anhinga melanogaster*
Charadriiformes	Burhinidae	Great Thick-knee	*Esacus recurvirostris*
		Indian Thick-knee	*Burhinus indicus*
	Charadriidae	Little Ringed Plover	*Charadrius dubius*
		River Lapwing	*Vanellus duvaucelii*
		Grey-headed Lapwing	*Vanellus cinereus*
	Rostratulidae	Greater Painted-snipe	*Rostratula benghalensis*
	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*
	Scolopacidae	Common Greenshank	*Tringa nebularia*
Accipitriformes	Pandionidae	Osprey	*Pandion haliaetus*
Coraciiformes	Alcedinidae	Common Kingfisher	*Alcedo atthis*
		White-breasted Kingfisher	*Halcyon smyrnensis*
		Stork-billed Kingfisher	*Pelargopsis capensis*
		Pied Kingfisher	*Ceryle rudis*
Passeriformes	Motacillidae	Paddyfield Pipit	*Anthus rufulus*
		Rosy Pipit	*Anthus roseatus*
		Olive-backed Pipit	*Anthus hodgsoni*
		Grey Wagtail	*Motacilla cinerea*
		White-browed Wagtail	*Motacilla maderaspatensis*

Appendix III: List of bird according to bird community

	Guilds
SWIMMER	1. Lesser Whistling-Duck 2. Ruddy Shelduck 3. Cotton Pygmy-goose 4. Northern Shoveller 5. Gadwall 6. Northern Pintail 7. Red-Crested Pochard 8. Mallard 9. Common Teal 10. Knob-billed duck 11. Little Grebe 12. Little Cormorant

	13. Great Cormorant 14. Oriental Darter
WADERS	1. Cinnamon Bittern 2. Black Bittern 3. Black-crowned Night-heron 4. Indian Pond-heron 5. Grey Heron 6. Purple Heron 7. Cattle Egret 8. Great White Egret 9. Intermediate Egret 10. Little Egret 11. Lesser Adjutant 12. Asian Openbill 13. Black-headed Ibis 14. Red-naped Ibis 15. White-breasted Waterhen 16. Watercock 17. Purple Swamphen 18. Common Coot 19. Common Moorhen 20. Great Thick-knee 21. Greater Painted-snipe 22. Bronze-winged Jacana 23. Black stork 24. Asian woolly neck
SHORELINES	9. Little Ringed Plover 10. River Lapwing 11. Grey-headed Lapwing 12. Common Greenshank

OTHERS	1. Common Kingfisher 2. White-breasted Kingfisher 3. Stork-billed Kingfisher 4. Pied Kingfisher 5. Osprey

9. PHOTOGRAPHS

Figure 16: Bird Survey

Figure 17: Purple heron (*Ardea purpurea*) foraging in wetland

Figure 18: Great thick-knee (*Esacus recurvirostris*)

Figure 19: Black-headed ibis (*Threskiornis melanocephalus*)

Figure 20: Fisherman fishing, where Asian openbill storks (*Anastomus oscitans*) are foraging

Figure 21: Children entering in KTWR for plucking "Neura" young shoot of fern used as vegetable

Figure 22: People entering in KTWR for resource utilization