

**IMPACTS OF WIND FARM ON AVIFAUNA OF
SAMAKHIALI REGION, KUTCH, GUJARAT**

Thesis submitted to the

BHARATHIAR UNIVERSITY, COIMBATORE

for the award of

DEGREE OF DOCTOR OF PHILOSOPHY

in

ZOOLOGY

by

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May 2017

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This is to certify that the thesis entitled “**Impacts of Wind Farm on Avifauna of Samakhiali Region, Kutch, Gujarat**” submitted to the Bharathiar University, in partial fulfillment of the requirements for the award of the **Degree of Doctor of Philosophy in Zoology** is a record of original research work done by **Mr. RAMESH KUMAR S** during the period September 2012 - May 2017 of his study in Division of Environment Impact Assessment, Sálim Ali Centre for Ornithology and Natural History under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title to any candidate of any University.

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Summary

Wind energy is one of the most preferred renewable energy across the globe. Although wind energy is widely accepted as a green energy, the impacts of wind farms, especially on wildlife have been reported from different countries over the past two decades. Compared to other taxa, birds and bats get affected mainly due to direct collision with the wind turbines, along with habitat loss & degradation. The collision of birds with turbines is considered as one of the major direct impact, which first came to notice in the late 1980s from USA. The annual bird mortality rate reported by studies across the world varies from 0 to 64 birds per turbine. Studies indicate that many birds tend to avoid areas close to the turbines and some species do not occupy the area even after five years of turbine installation. India is the fourth largest wind energy producer in the world with an installed capacity 27,151 MW as on December 2015 (MNRE, 2016). Moreover, wind energy is the fastest growing renewable energy sector in India with a target of 60 GW by 2022. Available studies on the impact of wind turbines on wildlife are scarce from India and most of the published studies are from Europe and North America. With this background, the present study was conducted in Gujarat, India with the following three major objectives 1) study the avifaunal composition of the area, 2) study the changes in the assemblage of land birds due to wind turbines, and 3) assess the bird mortality risk caused by wind turbines.

This study was conducted in Samakhiali region in the Kutch district of Gujarat, India. Kutch district has four 'Important Bird Area's (IBAs) and it is also a stopover point for many birds along the Central Asian Flyway. The region is generally dry, and arid dotted with many wetlands and receives rain mainly between July and September. The study area is about 200 sq. km, with 200 wind turbines installed since 2003. Most of the turbines were of 1.8 MW capacities with the hub at 95m height and a rotor diameter of 100 m.

In order to fulfil the first objective i.e. to study the avifaunal composition of the area, various survey methods including point counts (within 50 m radius for 10 min for land birds except raptors), long duration point counts or vantage point survey (for raptors); total counts (for water birds) were used. Apart from these surveys, birds sighted opportunistically were also recorded. A total of 175 bird species belonging to 47 families and 17 orders were observed, of which 56 % of species were land birds and 44 % were

water birds. Among the 17 orders, Passeriformes dominated the list with 58 species followed by Charadriiformes with 34 species and Falconiformes with 18 species. Among different families, Scolopacidae and Accipitridae (16 species) had maximum number of species. Of all bird species, 99 species were residents; 75 species were migrants. The recorded avifauna includes one Endangered species (Steppe Eagle *Aquila nipalensis*) and four Vulnerable species (Dalmatian Pelican *Pelecanus crispus*, Greater Spotted Eagle *Clanga clanga*, Common Pochard *Aythya farina* and Sarus Crane *Antigone antigone*). The list also includes 11 Near-threatened species (IUCN 2016).

The assemblage of birds is known to change after installation of wind turbines in that area. These changes may persist for years as a result of visual intrusion and also disturbances caused by noise and vibration which lead to habitat loss. There is a complete lack of study on this aspect from Asia. In order to know whether the land birds are get displaced or attracted in the present study condition, surveys were conducted between October 2012 and June 2014. Point counts were used to monitor the land birds except for raptors. A total of 79 sampling points were fixed: 48 points in wind farm site and 31 points in control site (area without turbines adjacent to the wind farms). All control site points were located away from the nearest turbine by at least by not less than 1 km away from the closest turbine. Each count lasted for 10 minutes covering the area within 50m radius from the base of the turbine. The difference in bird population between control and wind turbine site was assessed by comparing the species richness, abundance, and composition of avifauna. The role of variables such as Normalised Differential Vegetation Index (NDVI), turbine density, distance to the nearest turbine, distance to human habitation, distance to road, distance to salt marsh and distance to the nearest fresh water body were assessed using Generalized Linear Models (GLMs). A total of 54 species of land birds belonging to 24 families were recorded during this point count sampling. Among the 54 species 40 were resident, 12 were winter migrants and two species were passage migrants. There was a marked reduction in the species richness, diversity and composition of the birds between wind farm and the control sites. Majority of the species showed lower abundance in the wind farm area; however, a couple of species showed higher abundance in turbine sites. The GLM analysis revealed that, the lower species richness in wind farm area could be the effect of wind turbines along with NDVI and precipitation.

In order to study the displacement among raptors, diurnal raptors were counted using vantage point surveys. Totally, 17 species of raptors belonging to two families (Accipitridae: 15 species, Falconidae: 2 Species) were recorded. Unlike other land birds, raptor composition was similar among two sites, except for the difference in the abundance of Steppe Eagle *Aquila nipalensis*.

Bird collisions with the wind turbines are one of the major and direct impacts of the wind turbine. Surveys were conducted to address the following issues 1) magnitude of bird mortalities occurring in the Samakhiali wind farm and 2) species getting involved in collision. Bird carcasses were searched at 59 turbine locations from October 2011 to May 2014. The area under turbine was searched within 100m radial zone from the base of each turbine while slowly walking along a spiral path outwards from the centre. The time spent at one turbine site was approximately 30-40 minutes. Totally 23 cycles of searches were made at irregular intervals with an average gap of 42 days. These surveys revealed that bird collisions do occur in Samakhiali wind farms. Totally 47 dead birds belonging to 11 species (8 resident and 3 migrant) including globally threatened Dalmatian Pelican (Vulnerable) and Near-threatened Painted Stork *Mycteria leucocephala* were recorded. Eurasian Collared-dove *Streptopelia decaocto* contributed maximum number of mortalities (10) followed by Rock Dove *Columba livia* (6). Among the 47 mortalities, 43 were recorded in winter and 4 were recorded in summer. Out of the 60 turbines searched, 37 turbine sites had bird carcasses. The estimated annual mortality rate was 0.47 birds per turbine.

Species specific collision risk of birds at Samakhiali wind farm was studied by recording the flight activities of all species of birds in the wind farm area, from August to December 2013. Totally 92 hours of observation was done. The flying height of birds was classified into three height bands keeping wind turbine height as a reference i.e., 'Height band 1' (Below turbine blades), 'Height band 2' (the turbine blade sweeping area) and 'Height band 3' (above the turbine blades). In the present study, the information on the collision risk of 71 species including many migratory species in the Kutch region are discussed. About 70 % of the total observed species were recorded flying at heights coming within the Rotor Swept Zone (RSZ). Water bird species and raptors were at greater risk of collision with the wind turbines in the area.

The potential factors influencing the wind turbine bird mortalities such as bird morphology, flight behaviour, and vertical distribution of bird and location of turbines are also analysed using GLMs. It was found that, among bird morphological characteristics, wing length significantly influenced the mortality. The gliding birds were more prone to collision than non-gliders. The turbines located close to villages had higher bird mortalities than others.

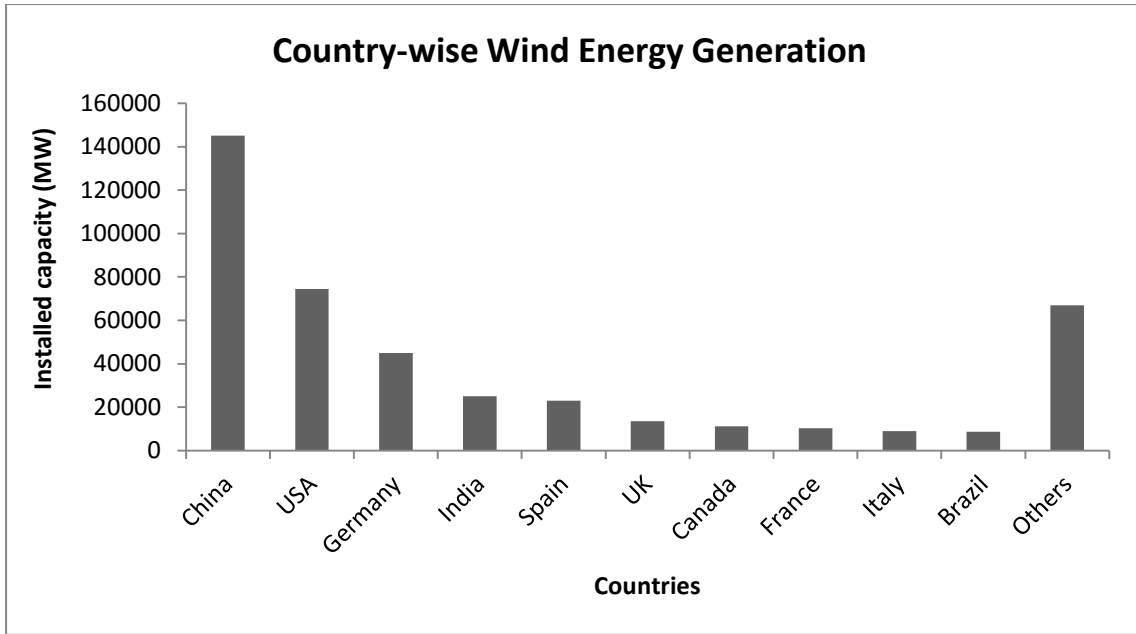
From the present study it is evident that wind farms cause negative impacts on birds at Samakhiali wind farm. This study presses the need to monitor sites before and after the installation of the wind turbines in India to understand and manage the impact of wind turbines on avifauna better.

1 GENERAL INTRODUCTION

Wind is produced as a result of the uneven heating of atmosphere by the sun and rotation of the earth. Wind as a resource was in use since time immemorial by human beings and most other living forms on earth. In past few decades wind is being extensively used for energy generation using wind turbines. Wind turbines are structures that convert the kinetic energy of wind into electricity by using rotating blades around a rotor. Wind turbines are generally of two types, horizontal axis turbines and vertical axis turbines. The horizontal axis wind turbine is the most commonly used wind turbines across the world. This turbine has a main rotor shaft, electrical generator attached to the top of the tower and rotor blades which rotates the generator. Turbines with vertical axis blades are less (~5%) in use.

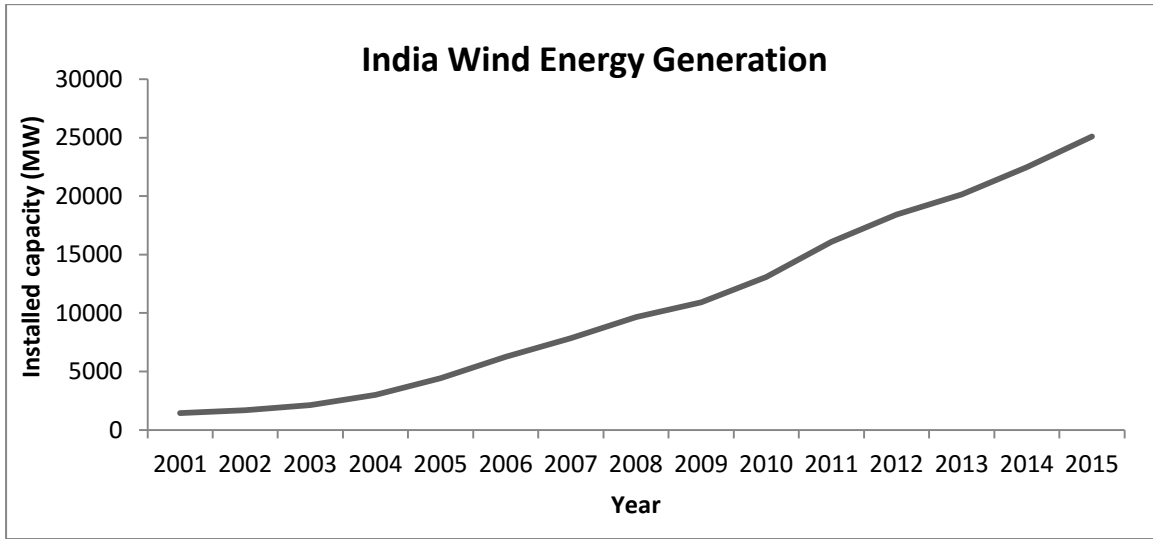
Wind energy is a renewable source of energy and it does not generate any greenhouse gases. Compared to other conventional mode of power generation such as thermal power and large hydro-electricity projects, wind energy is considered a "green energy". Wind energy is promoted worldwide, as it helps in lowering the greenhouse gas emissions and reduces the dependency on non-renewable sources of energy.

China is the leading wind energy producer in world with an installed capacity of 1,45,104 Mega Watt (MW) and it shares 33.6 % of the total wind energy production of the world followed by USA and Germany (Figure 1-1). India is in fourth position in wind energy production with an installed capacity 27,151 MW as on December 2015 (MNRE, 2016). Wind energy contributes to about 8 % of the total energy production in India and it is one of the fastest growing energy sectors (Figure 1-2). Among the states, Tamil Nadu has maximum installed capacity (30%), followed by Maharashtra (18.4 %), Gujarat (14.4%) and Rajasthan (14.4 %). Gujarat has a maximum potential capacity of 35,071 MW wind power at 80 m from the ground level (Figure 1-3). Ministry of New and Renewable Energy has set up a target of 60000 MW installed capacity by 2022 (MNRE, 2016). This fast lane increase of wind energy is not only in India, but a global scenario (the installed capacity of wind energy world over in the year 2015 alone was 63,467 MW).



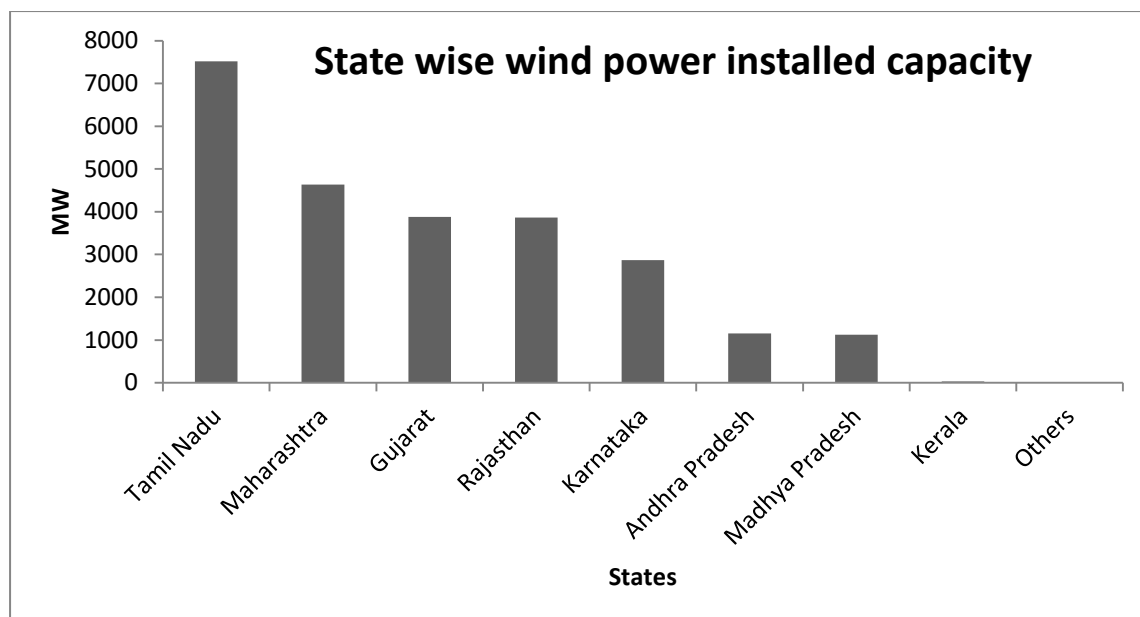
Source: (GWEC, 2015)

Figure 1-1. Major contributing countries in wind energy generation as on December 2015.



Source: (GWEC, 2015)

Figure 1-2. The growth of wind energy in India since 2001 in terms of installed capacity.



(Source: MNRE, 2016)

Figure 1-3. State wise installed capacity of wind energy in India as on December 2015.

1.1 GENERAL LITERATURE REVIEW

1.1.1 Impact on birds

Although wind energy is considered as green energy, there are growing concerns on its impacts on wildlife especially, birds and bats. Wind farms are known to affect terrestrial mammals and reptiles by habitat alteration and noise pollution (Kikuchi, 2008; Helldin *et al.*, 2012; Rafa & Mróz, 2016). Also flying fauna such as birds and bats are vulnerable to collision with the wind turbines (Hötcker, 2006). The major impacts of turbines on avifauna includes, 1) direct collision of birds with the rotating wind turbine blades, 2) displacement of birds from the turbine area due to the disturbance caused by the installation and operation wind of turbines 3) barrier effect i.e. wind turbines act as barriers to the movement of birds (Drewitt & Langston, 2006).

There are many reports of bird collisions from wind turbines over the last few decades mainly from Europe and USA (Hötcker, 2006). Birds during its flight tend to collide with the rotating blades of the wind turbine and gets killed or injured. These injuries of birds can also be caused from collision with towers, nacelles and associated structures. This issue came into light when many raptors got killed in Altamont pass of USA in early 1990s (Orloff & Flannery, 1992). While, the species which gets killed varies in different wind farms, raptors in general are found to be killed in more numbers (Orloff & Flannery,

1992). Similarly, the number of birds getting killed also varied widely from 0 to 64 birds/turbine annually (Hötker, 2006).

The displacement of birds from the wind turbine area has also been reported by many studies (Pearce-Higgins *et al.*, 2012; Villegas-Patracca *et al.*, 2012; Shaffer & Buhl, 2016). These studies indicate that many birds tend to avoid areas close to the turbines (100-300 m) and this effect can be often long-term (Shaffer & Buhl, 2016; Villegas-Patracca *et al.*, 2012). There are also few other studies which reported that the turbine presence does not negatively affect abundance of passerines and its breeding (Hatchett *et al.*, 2013; Bennett *et al.*, 2014; Hale *et al.*, 2014). It is also considered that the displacement behaviour of birds is species specific and may vary geographically (Stevens *et al.*, 2013; de Lucas, 2005).

Other impacts on avifauna include, barrier effect, noise pollution etc. (Drewitt & Langston, 2006; Whittingham *et al.*, 2014). Among these, barrier effect has been studied in detail. At times birds take alternative long migratory and local flight routes in order to avoid a wind farm. This will lead to the increased use of energy and the disruption of connection between distant feeding, roosting and breeding areas, and is called the barrier effect (Drewitt & Langston, 2006). Studies show that, the distance between turbines sometimes allows the birds to fly between turbine rows. For instance, Common Eider *Somateria mollissima* at Nysted, reportedly passes through turbines which are 480 m apart (Drewitt & Langston, 2006). Although the barrier effect may not cause direct impact on populations, there are situations where it might lead indirectly to population level impacts (Masden *et al.*, 2010). This effect may vary among species, type of bird movement, flight height, and wind speed and wind direction.

Habitat loss due to the development of wind farm can vary depending on the land use of the area. If large wind farms are developed in a sensitive habitat, direct habitat loss may be additive to the displacement. Wind farm associated construction activities like development of access roads, substations, turbine bases, etc., will involve alteration of the habitat. This could considerably affect forests and grasslands where birds could suffer fragmentation (Langston & Pullan, 2003). Generally at wind farms, the actual habitat loss amounts to 2–5% of the total development area, though effects could be more where developments obstruct the hydrological patterns or flows on wetland sites (Drewitt & Langston, 2006). Development of wind farms in the habitat of threatened species is of

serious concern e.g. Lesser Prairie-chicken *Tympanuchus pallidicinctus* at Oklahoma, US (Pruett *et al.*, 2009).

There is a mixed result regarding the magnitude of impacts of wind turbines on bird population level. Some studies suggest that the impacts on bird population during wind farms construction are high however after construction the impact is minimal (Pearce-Higgins *et al.*, 2012; Garcia *et al.*, 2016). However, some studies reported the effect of wind turbines on the bird population (Carrete *et al.*, 2009; Schaub, 2012). The number of bird mortalities caused by wind turbines are less in general when compared to mortalities caused by other anthropogenic structures like building, power line, automobile etc. and also few other forms of energy generation (Sovacool, 2009 ;Loss *et al.*, 2015). However, type of species getting affected should be considered and cumulative impact of these activities on bird population also needs to be taken into consideration.

Studies on the impacts of wind farm on wildlife in Asia are scarce. Sugimoto and Matsuda (2011) and Tajiri *et al.* (2013) explored the collision risk models for White-fronted Geese with wind turbines in Japan. There are only very few studies exist in India, which includes (Pande *et al.*, 2013 and Arun *et al.*, 2014). Pande *et al.*, (2013) reported mortality of five species of birds (Black Kite *Milvus migrans*, Bonelli's Eagle *Hieraaetus fasciatus*, Changeable Hawk-eagle *Nisaetus cirrhatus*, Red-rumped Swallow *Hirundo daurica* and Dusky Crag-martin *Ptyonoprogne concolor*) at 'Bhambarwadi Wind Farm Plateau' in northern Western Ghats of Maharashtra from 2008 to 2010. The maximum individual killed was Black kite *Milvus migrans* and Red-rumped Swallow *Hirundo daurica* with three mortalities each. They also found reduction in overall bird activities during the construction phase which persisted even after the completion of construction works. The other study conducted by Arun *et al.*, (2014) at Hara wind farm, Karnataka reported seven mortalities belonging to at least four species in one year period. There are no other studies reported so far on this issue in India. Other literature specific to each chapters are reviewed under respective chapters.

1.1.2 Impact on bats

The bat fatalities at wind farms are mostly reported from Europe and USA (Arnett *et al.*, 2008; Rydell *et al.*, 2010). The first report on mortality of bat species was from Australia, where Hall & Richards (1972) reported 22 White-striped Mastiff Bat *Tadarida australis*

mortalities over a four-year study period. Development in the wind energy sector over the years has increased its impact on bats and it is reported from different parts of the world. (Georgiakakis *et al.*, 2012; Hull & Cawthen, 2013). The causes for wind turbine related bat mortality are due to three major reasons: collision with the tower, collision with rotating turbine and Barotrauma (Cryan & Barclay, 2009). Bat mortality in collision with towers seems very rare, as it has not been reported from non-operational turbines or meteorological towers (Arnett *et al.*, 2008). Collision with the rotating blades is the major reason for bat fatalities (Johnson *et al.*, 2003). Apart from the direct collision with the blades, vortex caused due to the rotation of blades causes drop in atmospheric pressure which leads damage of blood vessels (Barotrauma) in the lungs leading to death (Cryan & Barclay, 2009).

There are several hypotheses that have been put forward to explain how insectivorous bats are prone to collision with wind turbines (Kunz *et al.*, 2007, (Cryan & Barclay, 2009). Three major hypotheses were suggested by Cryan & Barclay (2009) *viz.*,

The Random Collision Hypothesis, suggests that Turbines randomly sample bats flying in the airspace around them. All individuals of a particular species are equally vulnerable when occurring near turbines, regardless of sex, age, reproductive condition, or time of year.

Coincidental collision Hypothesis suggests that some aspects of bat behaviour put them at risk of colliding with turbines.

Attraction Hypothesis suggests some attractor or combination of attractors draws bats to wind turbines. Recent studies suggest that behaviours that evolved at tall trees might be the reason why many bats die at wind turbines as the tree bats are attracted to wind turbine due its resemblance with tall trees (Cryan *et al.*, 2014).

The bat mortality rate in wind farm ranges from 0 to more than 100 bats/turbine/year. For instance, study conducted at Frelampt Schillinger Berg wind farm in Germany reported 103/bats/ turbine annually. The estimated mortalities in Mid-Atlantic highlands (U.S.A) for the year 2020 (estimated on projected installed capacity) are between 33,000 and 110,000 bats per year (Kunz *et al.*, 2007). This high mortality due to wind turbine may pose serious threats to some species of bats which is already in decline.

In India, information on impacts of bat mortalities is limited. Study by Arun *et al.*, 2014 conducted in Harapanahalli wind farm (with 24 turbines), Karnataka reported 18 mortalities of Tomb bat *Taphozous melanopogon*. Another study by Pande *et al.*, 2013 at ‘Bhambarwadi Wind Farm Plateau’, Karnataka did not find any bat collisions with wind turbines, they however did report 2 Flying Fox *Pteropus giganteus* mortalities due to electrocution within the wind farm area. Although the present study was focused on the impact of wind farms on birds, bat collisions found during carcass search were also noted down and presented in the chapter 5 of this thesis.

1.2 OBJECTIVES

With this background, the present study was conducted in the wind corridor area of Kutch, Gujarat, India with the following major objectives; 1) study the avifaunal composition of the area, 2) study the changes in assemblage of land birds due to wind turbines, and 3) assess the bird mortality risk caused by wind turbines

1.3 THESIS ORGANISATION

The thesis is organised into seven thematic chapters as given below.

Chapter 1. General Introduction

This chapter gives an introduction about the impacts of wind farm on birds and it also gives a detailed scenario of this issue in the world and in India. This chapter also discusses about the various ways birds are affected by wind farms.

Chapter 2. Study Area

In this chapter, detailed notes on location, geomorphology, climate, flora and fauna are given. This chapter also deals with the various features of wind farm such as number of turbines, type of turbines and its structures.

Chapter 3. Avifaunal Composition

This chapter gives an insight into the avifauna of the study area. It also gives migratory and various conservation statuses such as IUCN, IWPA & CITES for all the species recorded. A note on significant bird sightings in the study area and nesting usage of this area by certain bird species are also discussed in this chapter.

Chapter 4. Changes in Land Bird Assemblage

This chapter discusses the difference in the species richness, diversity, composition of land birds between turbine and nearby non-turbine areas. It also discusses the various turbine and habitat variables influencing the bird species richness and diversity.

Chapter 5. Bird Mortalities

In this chapter, details about actual bird mortality, bias correction methods and use of non-parametric species richness estimators, in estimating the expected number of species which could get killed by turbines are discussed.

Chapter 6. Collision Risk of Birds and Factors Influencing Mortalities

This chapter discusses the species specific collision risk of bird species. It also provides details on factors affecting bird mortalities such as flight behaviour and morphologic characters of birds and location of wind turbines.

Chapter 7. Conclusion

In this chapter, the magnitude of the impact of turbines on birds of Kutch and various prospects of management and mitigation measures are discussed.

2 STUDY AREA

The study area is located in the Bachau Taluk of Kutch District in the state of Gujarat. The district lies between 22°44'11" and 24° 41' 25" N latitudes and between 68° 09' 46" and 71° 54' 47" E longitudes and the Tropic of Cancer cuts through this district. Kutch is largest district of Gujarat with an area of 45,652 sq.km, which is about 23 % of the total area of the State (Figure 2-1). Northern side of the Kutch district is bordered by the Great Rann of Kutch and Pakistan, in the eastern side by the Little Rann of Kutch, and the southern side by the Gulf of Kutch and on the west by the Arabian Sea. Kutch district has nine Taluks; Bhuj, Nakhatrana, Lakhpat, Abdasa, Mandavi, Mundra, Anjar, Bachau and Rapar. Kutch district is also spelt as Kachchh and Cutch, however the spelling 'Kutch' is used throughout this thesis.

The district which is mostly plain has a long coastline of 322 km and it also has small hillocks. Kutch is known for its large deposits of minerals such as lignite, bauxite, limestone. As a result there are number of industries set up in the recent years in the district. Kutch has a variable topography, though it is generally barren and rocky, it also has ranges of hills and low peaks, rugged and deeply cut river beds, shrub lands, agricultural fields, forested lands, and a number of dry rivers.

2.1 GEOMORPHOLOGY

Based on the geomorphology of the region, Kutch is categorized into four major zones 1. Coastal Zone - demarcating the southern fringe, 2. Kutch Mainland - divided into the central portion comprising rocky upland, northern hill range and coastal plains, 3. Banni Plains (less than 5 m mean sea level (msl)) - marked by raised fluvial marine sediments, mud flats and salt pans and 4. The two Ranns: Great Rann (~ 2m msl) and Little Rann, comprising vast saline wasteland. The Kutch landscape includes an array of tectono-genic geomorphic elements as uplifts and residual depressions. Mesozoic and tertiary rocks occupy the elevated landforms, whereas quaternary sediment successions occupy the residual depressions or low-lying regions. The mud-flats and salt pans are found in the Great and Little Ranns and Banni Plains (Munjpara, 2013).

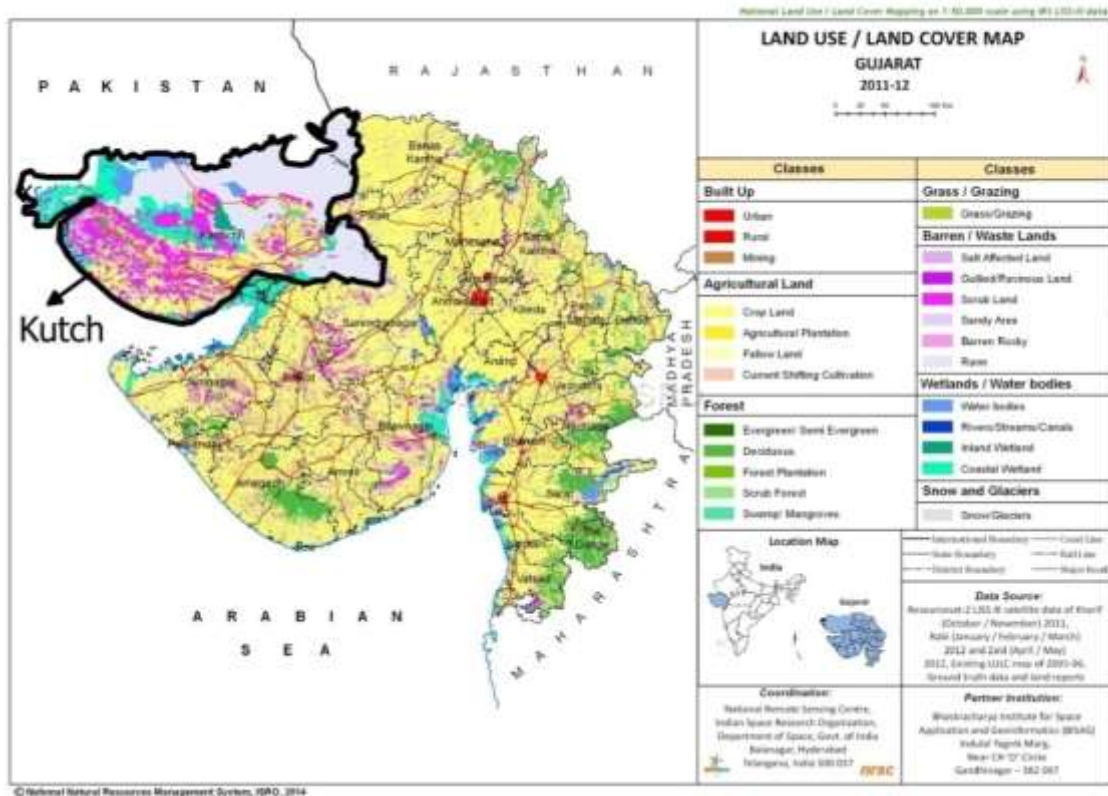
2.2 CLIMATE

The climate of the region is arid and semi-arid. The mean annual temperature is 26°C and it ranges from 10°C to 44°C. The relative humidity is less than 60 percent. The average annual rainfall is 250 to 450 mm and number of rainy days is less than 15. This is a high wind speed area ideal for wind power generation. The direction of wind is West and North West during summer and monsoon and is North during winter, with an average speed of 10-15 km (Munjpara, 2013).

2.3 FLORA AND FAUNA

The Kutch district falls in '3B Kutch Desert Bio-geographic' zone (Rodgers *et al.*, 2002). According to Champion & Seth, (1968), the Kutch region falls under "Northern tropical thorn forest" (6B/C1) and sub class "Desert thorn forest" (Figure 2-1). The predominant vegetation of Kutch district includes *Prosopis juliflora*, *Acacia nilotica*, *Acacia senegal*, *Salvadora persica*, *Salvadora oleoides* and *Euphorbia nudiflora*. There are also grassland areas dominated by *Cymbopogon*, *Aristida*, *Dicanthium* and *Chrysopogon* grasses. There are Mangrove vegetation in some coastal regions of Kutch (Munjpara, 2013). Kutch harbors a variety of wildlife including many globally threatened animals. The mammal species such as Indian Fox *Vulpes bengalensis*, Desert Cat *Felis silvestris*, Jungle Cat *Felis chaus*, Golden Jackal *Canis aureus*, Chinkara *Gazella bennettii*, and Nilgai *Bocelaphus tragocamelus* are reported from district. Indian Wild Ass *Equus hemionus* is a unique mammal of this landscape which is endemic to India, and is found in large numbers in Little Rann of Kutch.

The notable threatened species of avifauna found in Kutch include Great Indian Bustard *Ardeotis nigriceps*, Lesser Florican *Sypheotides indica*, Sarus Crane *Antegone antegone*, Indian Vulture *Gyps indicus*, White-rumped Vulture *Gyps bengalensis*, Red-headed Vulture *Sarcogyps calvus* and Egyptian Vulture *Neophron percnopterus*. The common reptiles found in Kutch district include Bengal Monitor *Varanus bengalensis*, Spiny-tailed Lizard *Uromastyx hardwiiki*, Garden Lizard *Calotes versicolor* and Saw-scaled Viper *Echis carinatus*.



(Map source: National natural resource management system, ISRO, 2014).

Figure 2-1. Land use and land cover map of Gujarat with Kutch district highlighted



Figure 2-2. Map showing the study location.

2.4 INTENSIVE STUDY AREA

The study site is located in the Samakhiali region (between 23°15' 5.18" and 23° 11' 21.72" N to 70° 30' 8.68" and 70°38' 24.68" E) of Kutch District (Figure 2-2). The total study area covers about 200 sq.km including 120 sq.km area with wind turbines and adjacent non-turbine area of 80 sq.km. The region remains dry for most part of the year and arid with mostly barren land with scattered rain-fed agricultural land patches. The few crops cultivated here includes: Sorghum *Sorghum bicolour* and Cotton *Gossypium herbaceum*. The landscape is dominated by the invasive weedy plant *Prosopis juliflora*. The Indian Wild Ass sanctuary is a part of Little Rann of Kutch (also an Important Bird and Biodiversity Area (IBA)) and borders the southern side of the study area. Important Bird and Biodiversity Areas (IBAs) are the places of international significance for the conservation of birds and other biodiversity and it is recognised world-wide as practical tools for conservation (Birdlife International, 2017). The Study area attracts variety of migratory birds as it is located along the Central Asian migratory flyway of birds.

Winter in the area commences from November and ends in February. The period from March to the first week of June is summer, followed by the southwest monsoon which lasts till the end of November. The mean temperature during summer (March to June) ranges from 17.6 to 39.5° C and 9 to 35.9°C during the rest of the year (Figure 2-3). The fifty year (1950-2000) average annual rainfall is ~ 450 mm, most of which occurs during the southwest monsoon (July-September). However from 2010-2013 the average rainfall for the study site was 753 mm with highest rainfall in 2010 (998 mm) and lowest in 2012 (182 mm) (Figure 2-4) (Data Source: Genting Energy Private Ltd.). The cold weather starts in early December and continues till the end of February. January is the coldest month of the year. The mean daily minimum temperatures varies from 9°C in January to 27°C in June and mean daily maximum temperature varies from 26.7°C in January to 39.5°C in May. May is the hottest month of the year with the mean daily maximum temperature at 39.5°C and the mean daily minimum at 25.2°C.

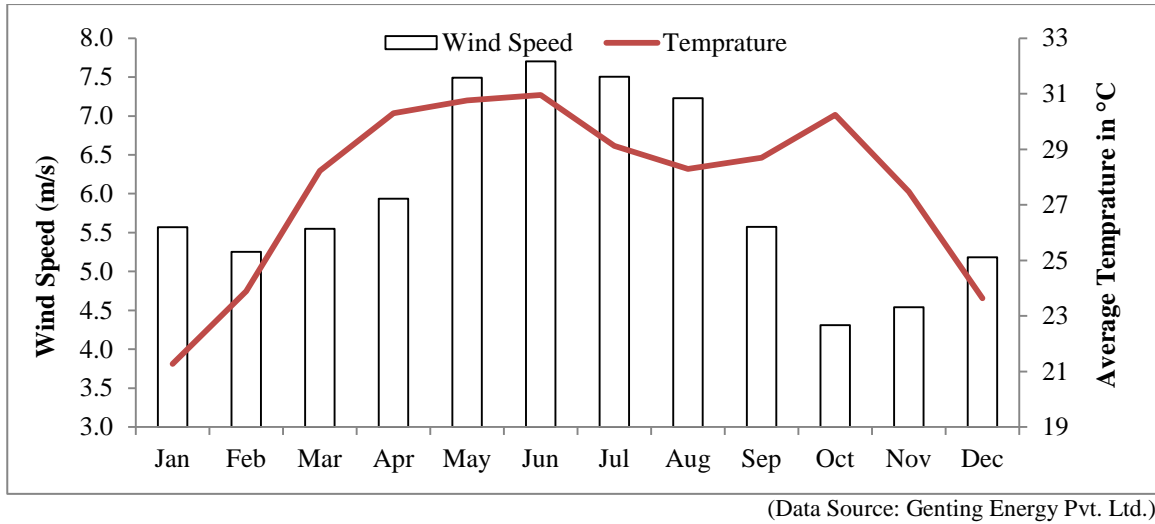


Figure 2-3. Monthly average temperature and Wind speed in the study area (from 2011 to 2014).

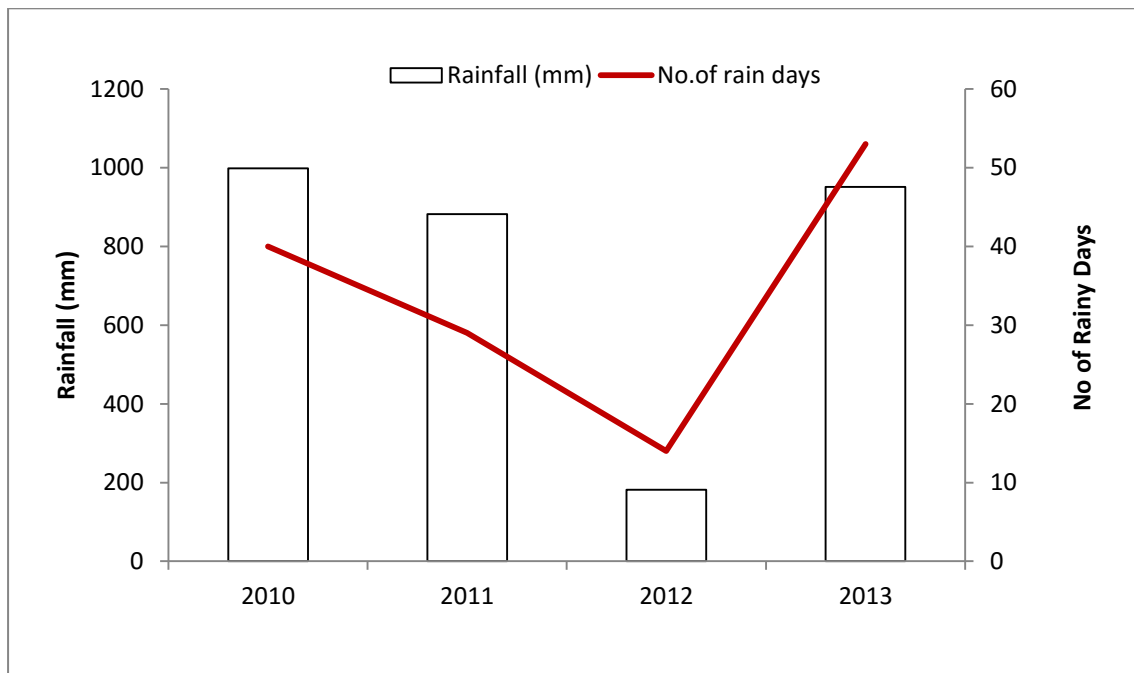


Figure 2-4. Annual rainfall and number of rainy days in the study area (from 2011 to 2013)

2.5 WIND FARM AND TURBINE STRUCTURE

The optimum wind speed prevalent in the region makes it highly suitable for wind turbine installation. The total wind farm area covered in the study is about 120 sq.km and it has

about 200 wind turbines installed since 2003. All the turbines has tubular tower and majority of the turbines are 1.8MW capacity turbines (Plate 2-1). These turbines are with a hub height of 95 m and designed for high energy production from low wind sites, with a greater rotor diameter (100 m) that enables maximum output at low wind speeds. The turbines are designed with the cut in wind speed of 3 m/s and cut out wind speed of 20 m/s, while the optimal wind speed for the turbine is 12 m/s. The turbines are scattered with minimum distance of 200 m from other turbines.



Plate 2-1. View of wind turbines from different landscapes of the study area

3 AVIFAUNAL COMPOSITION

3.1 INTRODUCTION

The Kutch district of Gujarat is one among the bird rich areas in India. With varying size of wetlands, mudflats, grass lands and arid vegetation, and also being part of Central Asian migratory flyway, it attracts large number of migratory birds. This region is also an important breeding ground for many birds. Avifauna of Kutch has been documented since 1870s. The first ever published information on the birds of Kutch was by A.O. Hume and Ferdinand Stoliczka (Hume, 1872; Stoliczka, 1872). Later, many important contributions were made by C.D Lester and Hugh Palin (Palin, 1878, 1904; Lester, 1894, 1896, 1904). The works of Sálím Ali (popularly known as ‘The Bird Man of India’) in Kutch and his book “Birds of Kutch” (Ali, 1945) has greatly enriched our knowledge on the avifauna of Kutch (Ali, 1960, 1961).

Gujarat is one of the Indian states which has many active bird watchers and avifauna of this region is well documented (Pittie, 2010). In the last decade, there were many new additions to the checklist of birds of Kutch, which have been reported mainly in the Gujarat Bird watchers’s Newsletter, “Flamingo”. The notable recent contributions include a study by Munjpara and Gadhvi (2012), which listed 177 species of birds from Naliya Grassland, Kutch district, an Important Bird Area (IBA). Similarly Gajera *et al.*, (2013) reported 252 species of birds from three mining areas in Western part of Kutch close to Narayan Sarovar Wildlife Sanctuary. Apart from checklists and distribution notes, detailed studies on the ecology of birds and other such specified studies in Kutch district are scarce (Hussain *et al.*, 1992; Munjpara, 2013). Although in the past there were many studies conducted in various parts of Kutch, there are only few studies reported from the Samakhiali region. Owing to presence of numerous wetlands and being in the path of the Central Asian Migratory Flyway, it is important to document the avifauna of this region in detail. The present chapter provides an overview of the avifauna recorded from the Samakhiali region, their conservation status and notes on the nesting of few species.

3.2 METHODS

Various methodologies were used for surveying different group of birds. An overview of different methodology used is given below and detailed notes on each methodology are discussed in the respective forthcoming chapters.

3.2.1 Land Birds except Raptors

Land bird (except Raptors) were surveyed in wind farm site and also in nearby area with no turbines (Control Site), using time constrained point counts (with 50 m radius for 10 min) from September 2012 to May 2014 (Ralph *et al.*, 1995). Totally 79 sampling points were fixed and repeated samplings were made in each point (maximum 8 and minimum 3). Surveys were conducted generally from 06:00 hrs to 10:00 hrs. More details of the survey are given in chapter 4.2.2.1.

3.2.2 Raptors

Raptors were surveyed using vantage point counts. Each count lasted for 30 minutes and all the raptors, flying within the visible range from selected vantage points were recorded. Nine rounds of surveys were conducted at 15 vantage points. Opportunistic observations were also included. Details are explained in chapter 4.

3.2.3 Water Birds

All possible areas of Samakhiali region were surveyed for the identification of wetlands and wetland birds. 55 wetlands were surveyed during the study period. Wetland birds survey was conducted by total count method (Bibby *et al.*, 2000). Counting of the water birds was made in the morning hours between 06:00 and 08:00 hrs.

3.2.4 Other Methods

Apart from these surveys, birds sighted opportunistically from the study sites as well as during carcass survey were also included in the list. Nikon 10x50 X binocular was used for the survey and birds were photographed using Sony DSC 50X Camera. Species were identified with the help of field guides and standard reference books (Ali & Ripley, 2001; Naoroji & Schmitt, 2007; Grimmett *et al.*, 2011). The nomenclature of birds were followed as in Birdlife International (del Hoyo, *et al.*, 2014) however, for few species

(which were recently upgraded from subspecies status) names were followed as in Praveen *et al.*, (2016).

3.2.5 Nests Searches

Searches were made to locate the nest of birds in all potential nesting sites like trees, bushes, buildings and towers. Ground nests were also searched in few locations where the ground nesting birds were sighted. Once a nest is located, the structure of nest-site, height of nest location and surrounding habitats were documented.

3.2.6 Data Analysis

The birds were classified into land bird and water birds according to Birdlife International's classification (Birdlife International, 2015). The migratory status of each bird such as Resident (R), Winter Visitor (WV), Summer Visitor (SV) and Passage Migrant (PM) was obtained from Grimmett *et al.*, 2011. The IUCN Red list status (IUCN, 2016) and protection status as in Indian Wildlife Protection Act (1972, amended up to 2002) were also recorded for each species. Status as per the Convention for International Trade in Endangered Species (CITES) is also collected and given along with the checklist. Birds which are near-endemic to India are listed separately based on Praveen *et al.*, (2016). Near-endemic species, which are nearly endemic to India, falls under one of the following categories of distribution: i) species, which are endemic to the larger South Asian region ii) species, which are breeding endemics to the Subcontinent, but winter extralimittally, and iii) species of small populations of which are also found just across India's borders with either China, particularly Tibet/Xizang, or Myanmar, including Preparis and Coco islands in the Bay of Bengal (Praveen *et al.*, 2016).

3.3 RESULTS

3.3.1 Bird Assemblage

During the study span, 175 bird species belonging to 47 families and 17 orders were observed (Figure 3-1, Plate 3-1). Among the 175 species recorded, only 158 species were recorded during the systematic bird surveys. The remaining 17 species were recorded through opportunistic observations. Among the 17 orders, Passeriformes dominated the list with 58 species, followed by Charadriiformes with 34 species and Falconiformes with 18 species (Figure 3-1). At the family level, maximum percentage of occurrence was

found in the families: Scolopacidae (9.20%) and Accipitridae (9.20%), followed by Anatidae (6.32%) and Ardeidae (5.75%) (Table 3-1).

Of all bird species, 56.5 % were resident, 42.2 % were winter visitor and 1 % was passage migrant. Scolopacidae accounted for maximum winter visitors (16 species), followed by Accipitridae (11 species). Among the residents, Ardeidae had maximum number of species (10 species), followed by Cysticolidae with six species. In all, 56 % were land birds; 44 % were water birds. Out of 175 species recorded, Steppe Eagle *Aquila nipalensis* was classified as Endangered, three species namely Dalmatian Pelican *Pelecanus crispus*, Common Pochard *Aythya farina* and Sarus Crane *Antigone antigone* were classified as Vulnerable and 11 species were classified as Near threatened according to IUCN Red List (IUCN, 2016) (Table 3-2, Figure 3-2). In all, 13 species of birds were near endemic to India (Table 3-3).

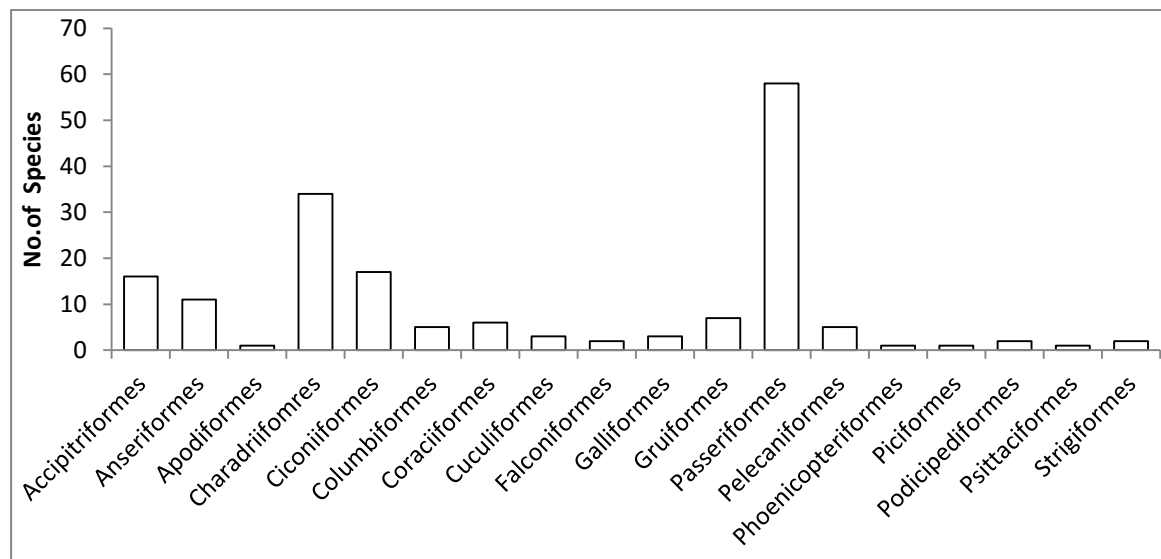


Figure 3-1. Order-wise occurrence of avifauna in the study site.

Table 3-1. Migratory status and species richness of birds in each family.

S.No.	Family	Resident	Winter Visitor	Passage Visitor	Total Number of Species (%)
1	Accipitridae	5	11	-	16 (9.14)
2	Alaudidae	4	1	-	5 (2.86)
3	Alcedinidae	3	-	-	3 (1.71)
4	Anatidae	3	8	-	11 (6.29)
5	Anhingidae	1	-	-	1 (0.57)
6	Apodidae	1	-	-	1 (0.57)
7	Ardeidae	10	-	-	10 (5.71)
8	Burhinidae	1	-	-	1 (0.57)
9	Charadriidae	4	2	-	6 (3.43)
10	Ciconiidae	2	1	-	3 (1.71)
11	Columbidae	4	-	-	4 (2.29)
12	Coraciidae	1	-	1	2 (1.14)
13	Corvidae	3	-	-	3 (1.71)
14	Cuculidae	3	-	-	3 (1.71)
15	Cysticolidae	6	-	-	6 (3.43)
16	Dicruridae	2	-	-	2 (1.14)
17	Estrildidae	2	-	-	2 (1.14)
18	Falconidae	1	1	-	2 (1.14)
19	Gruidae	1	2	-	3 (1.71)
20	Hirundinidae	3	1	-	4 (2.29)
21	Jacanidae	1	-	-	1 (0.57)
22	Laniidae	3	1	-	4 (2.29)
23	Laridae	2	6	-	8 (4.57)
24	Meropidae	1	-	-	1 (0.57)
25	Motacillidae	1	5	-	6 (3.43)
26	Nectariniidae	1	-	-	1 (0.57)
27	Passeridae	2	-	-	2 (1.14)
28	Pelecanidae	-	1	-	1 (0.57)
29	Phalacrocoracidae	1	2	-	3 (1.71)
30	Phasianidae	3	-	-	3 (1.71)
31	Phoenicopteridae	-	1	-	1 (0.57)
32	Picidae	-	1	-	1 (0.57)
33	Ploceidae	2	-	-	2 (1.14)
34	Podicipedidae	1	1	-	2 (1.14)
35	Psittacidae	1	-	-	1 (0.57)
36	Pteroclididae	1	-	-	1 (0.57)
37	Pycnonotidae	2	-	-	2 (1.14)
38	Rallidae	4	-	-	4 (2.29)
39	Recurvirostridae	1	1	-	2 (1.14)
40	Scolopacidae	-	16	-	16 (9.14)
41	Strigidae	1	1	-	2 (1.14)

S.No.	Family	Resident	Winter Visitor	Passage Visitor	Total Number of Species (%)
42	Sturnidae	3	1	-	4 (2.29)
43	Sylviidae	-	3	1	4 (2.29)
44	Threskiornithidae	4	-	-	4 (2.29)
45	Timaliidae	1	-	-	1 (0.57)
46	Turdidae	2	7	-	9 (5.14)
47	Upupidae	1	-	-	1 (0.57)
Total		99	74	2	175

In all, 16 species were listed in schedule-I, 157 species were listed in schedule-IV, and one species House crow is listed in Schedule-V under Indian wildlife protection act (amended 2002) (Figure 3-3). The Indian wildlife protection act provides maximum protection for animals coming under schedule-I category. Totally, 27 species of birds are listed in the Convention for International Trade in Endangered species (CITES) (Figure 3-4). Of which two species (Laggar Falcon *Falco jugger* and Dalmatian Pelican *Pelecanus crispus*) were listed in Appendix I, 24 species were listed in Appendix II and three species listed in Appendix III. The species which are listed in CITES appendices are threatened by illegal trading. (Figure 3-4). A family-wise list depicting common name, scientific name, IUCN status, residential status and Indian Wildlife Protection Act status are given in Appendix 1.

Table 3-2. List of Globally Threatened birds recorded in the study area

S. No	Family Name	Common Name	Scientific Name	IUCN Status	Residential Status	IWPA Schedule
1	Accipitridae	Steppe Eagle	<i>Aquila nipalensis</i>	EN	WV	I
2	Accipitridae	Pallid Harrier	<i>Circus macrourus</i>	NT	WV	I
3	Anatidae	Common Pochard	<i>Aythya ferina</i>	VU	WV	IV
4	Anhingidae	Darter	<i>Anhinga melanogaster</i>	NT	R	IV
5	Burhinidae	Greater Thick-nee	<i>Esacus recurvirostris</i>	NT	R	IV
6	Ciconiidae	Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	NT	R	IV
7	Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	NT	R	IV
8	Falconidae	Laggar Falcon	<i>Falco jugger</i>	NT	R	IV
9	Gruidae	Sarus Crane	<i>Antigone antigone</i>	VU	R	IV
10	Laridae	River Tern	<i>Sterna aurantia</i>	NT	R	IV
11	Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	VU	WV	IV
12	Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>	NT	WV	IV
13	Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>	NT	WV	IV
14	Scolopacidae	Eurasian Curlew	<i>Numenius arquata</i>	NT	WV	IV
15	Threskiornithidae	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	NT	R	IV

Table 3-3. List of Near-Endemic (to India) birds recorded in the study area.

S. No.	Family	Common Name	Scientific Name
1	Phasianidae	Indian Peafowl	<i>Pavo cristatus</i>
2	Cuculidae	Sirkeer Malkoha	<i>Taccocua leschenaultia</i>
3	Threskiornithidae	Red-naped Ibis	<i>Pseudibis papillosa</i>
4	Charadriidae	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>
5	Nectariniidae	Purple-rumped Sunbird	<i>Leptocoma zeylonica</i>
6	Motacillidae	White-browed Wagtail	<i>Motacilla maderaspatensis</i>
7	Alaudidae	Ashy-crowned Sparrow-lark	<i>Eremopterix griseus</i>
8	Cisticolidae	Rufous-fronted Prinia	<i>Prinia buchanani</i>
9	Cisticolidae	Jungle Prinia	<i>Prinia sylvatica</i>
10	Cisticolidae	Ashy Prinia	<i>Prinia socialis</i>
11	Sturnidae	Brahminy Starling	<i>Sturnus pagodarum</i>
12	Sturnidae	Bank Myna	<i>Acridotheres ginginianus</i>
13	Muscicapidae	Indian Robin	<i>Saxicoloides fulicatus</i>

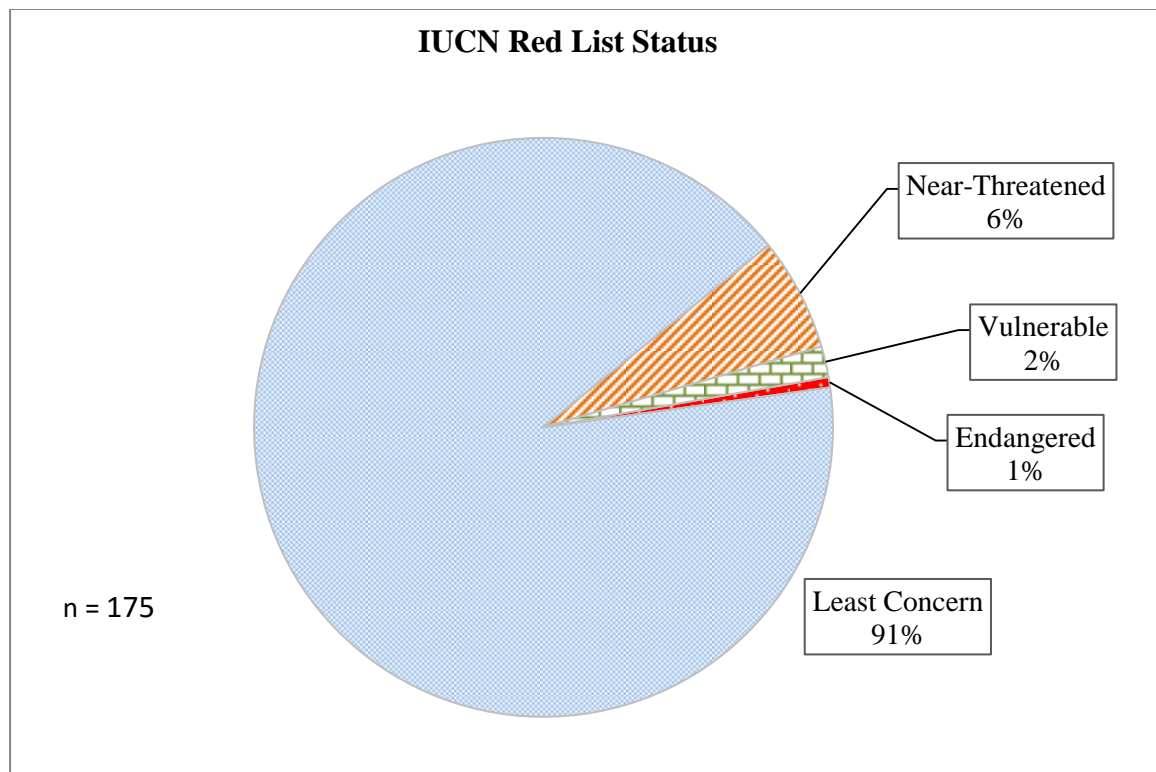


Figure 3-2. Proportion of birds under various IUCN Threatened Status

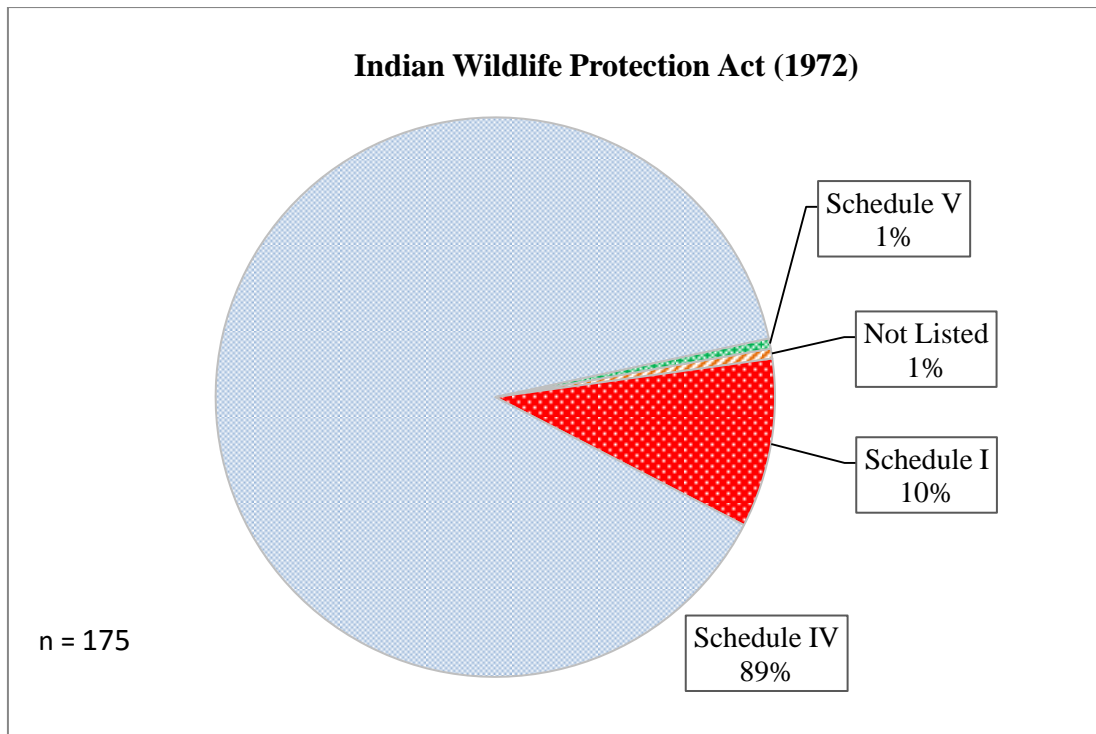


Figure 3-3. Proportion birds under various schedules of Indian Wildlife Protection Act (1972).

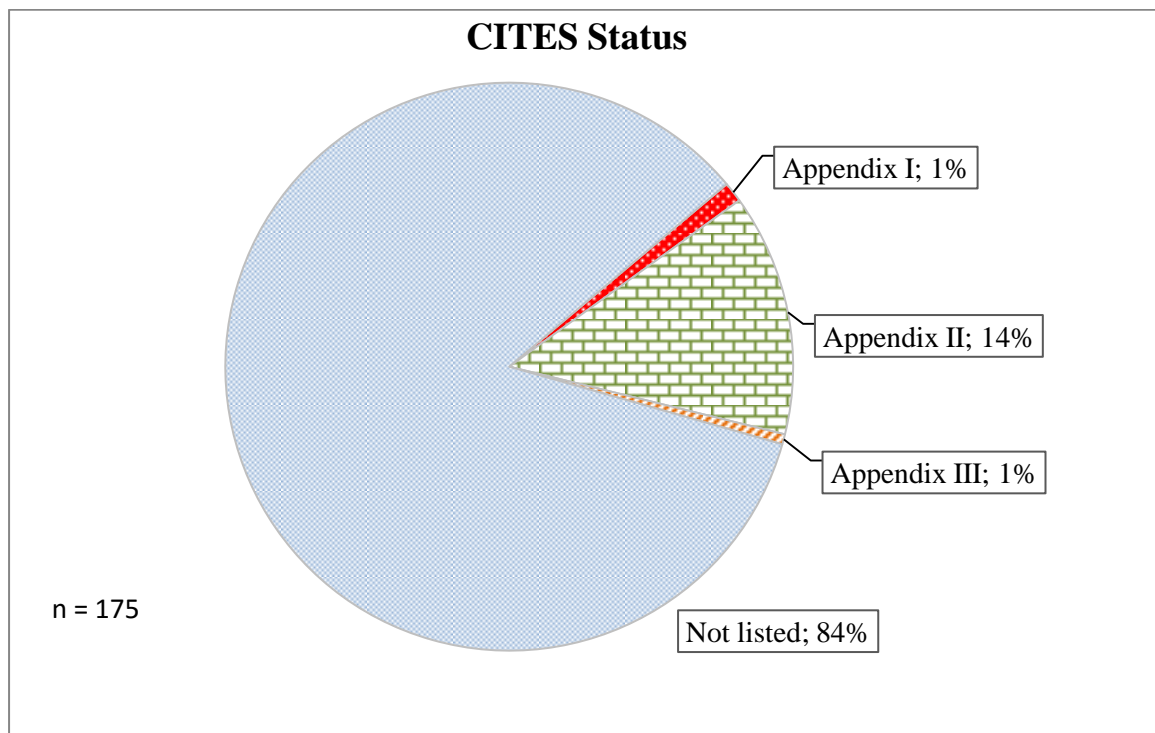


Figure 3-4. Proportion of birds listed in different category of CITES.



Dalmatian Pelican *Pelecanus crispus*



Eurasian Spoonbill *Platalea leucorodia*



Black-necked Stork *Ephippiorhynchus asiaticus*



Sarus Crane *Antigone antigone*



Common Pochard *Aythya ferina*



Greater Scaup *Aythya marila*



Steppe Eagle *Aquila nipalensis*



Greater Spotted Eagle *Clanga clanga*



Pallid Harrier *Circus macrourus*



Variable Wheatear *Oenanthe picata*



Desert Wheatear *Oenanthe deserti*



Ashy-crowned Sparrow-lark *Eremopterix grisea*



Chestnut-bellied Sand-grouse *Pterocles exustus*



White-eared Bulbul *Pycnonotus leucotis*



Asian Green Bee-eater *Merops orientalis*

Plate 3-1. Some of the birds recorded during the study

3.3.2 Nest-sites of Birds

In total, 15 bird species belonging to 11 families were found nesting in the study area. Highest number of nests were that of Rock Dove *Columba livia* (430), followed by House sparrow *Passer domesticus* (280), House Crow *Corvus splendens* (162), Red-vented Bulbul *Pycnonotus cafer* (60) and Red-rumped Swallow *Hirundo daurica* (32)

3.3.2.1 House Sparrow *Passer domesticus*

A total of 280 nests were located in the year of 2013. The nests were built in and around human habitations. Wall holes in houses and bridges, roof spaces, gaps in shutters, and unused electric meter boxes, fan cup or any such kind of places were found to be used for nesting by sparrows. In some places artificial nest boxes were also found occupied. The height of the nest locations ranged between 4 m to 18 m.

3.3.2.2 Rock Dove *Columba livia*

Totally, 430 nests were recorded in the year 2013. Rock doves constructed their nests on different made structures such as gaps in shutters of hotels and stores, holes or cavities in bridges, temple towers and ceilings of petrol bunks and other such structures. The height of the nest location varied from 6 to 17 m.

3.3.2.3 House Crow *Corvus splendens*

Crow nests were observed extensively in power transmission pylons. In 2012, the 71 pylons were searched and 34 active crow nests were found (Ali, *et al.*, 2013a). A total of 231 pylons of six types were checked, and 122 active nesting pylons with 162 house crow nests were observed in 2013. The height of occupied pylons ranged between 20 m and 50 m and location of nests on pylons varied from 15 m to 49 m. The number of nests found on a single pylon ranged from one to three: single nests were recorded on 73.8% of nest pylons, two nests on 20.5% of nest pylons and three nests on 5.7% of nest pylons.

3.3.2.4 Red-naped Ibis *Pseudibis papillosa*

In 2012, only a single nest was observed on transmission pylons due to less sampling effort (Ali *et al.*, 2013b). A total of 26 active Red-naped Ibis nest sites were recorded from four different types of pylons in 2013. The pylons used for nesting were between 20

and 30 m in height and height of the nest location on pylons varied from 15 to 29 m. Most of the nests were found on a middle console (48.5%) followed by top console (30.1%) and bottom console (21.4%) of the pylons. All the pylons carried single nest only. The Red-naped Ibis to build their nests on pylons with three electric lines (60.5%) more often than on pylons with six lines (39.5%). Most number of nests were sited on 66 kV pylons (68.4%) followed by 132 kV (21.5%) and 220 kV (10.1%). Interestingly, on 13 observations, House Crow and Red-naped Ibis nests were on the same pylons.

3.3.2.5 Red-rumped Swallow *Hirundo daurica*

A total of 32 nest sites of Red-rumped Swallows were observed under the bridges and culverts along major rural road networks in 2014. The nests were located at an average of 2.9 ± 1.27 m (range: 0.93 - 4.0 m) from the culvert openings. The nests were positioned inside the wall of culvert at an angle between 30° and 180° with a mean of 89.5°. In most cases, nest entrances were oriented towards North East followed by South West.

3.3.2.6 Other birds

Eighteen nests of Eurasian Spoonbill *Platalea leucorodia* and six nests of Glossy Ibis *Plegadis falcinellus* were recorded in a heronry (on *Prosopis juliflora*) in an area near Modpar village. Four nest-sites with 35 nests of Baya Weaver *Ploceus philippinus* were recorded on *Prosopis juliflora* plant. Two nests of the Dusky Craig-martin *Hirundo concolor* were recorded near Bachau town; they constructed oval bowl-shaped mud nests attached to the wall of a temple. The other species which nested in the study area includes Shikra *Accipiter badius*, Common Myna *Acridotheres tristis*, Indian Robin *Saxicoloides fulicatus*, Purple Sunbird *Nectarinia asiatica*, Red-vented bulbul *Pycnonotus cafer* and Brahminy Starling *Sturnus pagodarum* (Table 3-4).

Table 3-4. Bird Nests recorded in the study area in the year 2013.

S.No	Species	Scientific Name	Number of nests
1	House Crow	<i>Corvus splendens</i>	162
2	Rock Dove	<i>Columba livia</i>	430
3	Red-naped Ibis	<i>Pseudibis papillosa</i>	26
4	House Sparrow	<i>Passer domesticus</i>	280
5	Brahminy Starling	<i>Sturnus pagodarum</i>	2
6	Dusky Craig-martin	<i>Hirundo concolor</i>	2
7	Eurasian Spoonbill	<i>Platalea leucorodia</i>	18

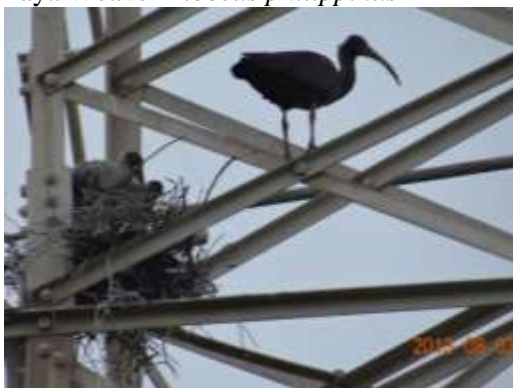
S.No	Species	Scientific Name	Number of nests
8	Glossy Ibis	<i>Plegadis falcinellus</i>	6
9	Baya Weaver	<i>Ploceus philippinus</i>	4
10	Purple Sunbird	<i>Nectarinia asiatica</i>	10
11	Red-vented bulbul	<i>Pycnonotus cafer</i>	60
12	Red-rumped Swallow (recorded in 2014)	<i>Hirundo daurica</i>	32
13	Shikra	<i>Accipiter badius</i>	2
14	Common Myna	<i>Acridotheres tristis</i>	4
15	Indian Robin	<i>Saxicoloides fulicatus</i>	30



Baya Weaver *Ploceus philippinus*



House crow *Corvus splendens*



Red-naped Ibis *Pseudibis papillosa*



Dusky Craig Martin *Hirundo concolor*



Eurasian Spoonbill *Platalea leucorodia*



Indian Robin *Saxicoloides fulicatus*

Plate 3-2. Nests of various birds recorded in the study site

3.4 DISCUSSION

Samakhiali region supports a rich avifauna. Similar to other parts of Kutch, Passeriformes are the most species rich order. Apart from this, the region supports 77 species of water birds especially ducks and waders. Migratory water birds are attracted mostly by the presence of man-made rural ponds and salt marshes. Although rain is scarce, the southwest monsoon (August–September) gives enough rain to fill the wetlands in this region and making them a good habitat for migratory wetland birds which starts arriving in October and staying till February. Many migratory birds were sighted here even during non-migratory season. For instance small flocks of Rosy starling *Sturnus roseus* were observed in non-migratory months (July-September). Many species of birds recorded in other parts of Kutch were not recorded from this area, which include threatened birds like Indian Vulture *Gyps indicus*, Red-headed Vulture *Sarcogyps calvus*, White-rumped Vulture *Gyps bengalensis*, Great Indian Bustard *Ardeotis nigriceps*, Lesser Florican *Sypheotides indicus*, Egyptian Vulture *Neophron percnopterus*, White-browed Bushchat *Saxicola macrorhynchus*, Lesser Kestrel *Falco naumanni*, Pallas's Fish Eagle *Haliaeetus leucoryphus* (Munjpara & Gadhvi, 2012; Gajera *et al.*, 2013). However, the present study added two new species to the birds of Kutch District namely Greater Scaup *Aythya marila* and Pallid Scops-owl *Otus brucei*. This is the first record of Greater Scaup *Aythya marila* from Gujarat in 40 years, and the first record to Kutch district (Ali, *et al.*, 2015). A pair (male and female) of Greater Scaup *Aythya marila* was observed in a freshwater pond in Samakhiali (23° 18'10" N; 70°30'42"E) in May 2013. Greater Scaup *Aythya marila* is a vagrant or Rare winter migrant to India (Kazmierczak, 2000; Grimmett *et al.*, 2011). Sightings of this species in India have been reported in winter from few locations including Bombay Deccan (Aspinall, 1950), Nelapattu Bird Sanctuary, Andhra Pradesh (Prashant *et al.*, 1994), Assam (Choudhury, 2000), Yamuna river (Harvey *et al.*, 2006). Last record of this species in Gujarat is by Dharmakumarsinhji (1973, 1995) in Bhavnagar district, and since then there has been no authentic record of this species from Gujarat (Kazmierczak, 2000; Rahmani & Islam, 2008). The second significant species Pallid Scops-owl *Otus brucei* recorded on 05th, February 2013 was found dead under a wind turbine at Jangi (23° 13' 52" N; 70° 34' 14" E). This sighting is the first report of this species from the political boundary of Kutch District. The Pallid Scops-owl *Otus brucei* is resident in south-eastern Arabia and Iran, and it is a rare winter visitor to north-western India (König *et al.*, 1999; Kazmierczak, 2000; del Hoyo *et al.*, 2005; Grimmett *et*

al., 2011). The records of this species elsewhere in Gujarat are by Dharmakumarsinhji (1995) in Saurashtra, Mundkur, (1986) in Rajkot and by Sangha & Malik (2010) in Zainabad of Little Rann of Kutch, Surendranagar district.

The presence of many small wetlands is a major resource for avifauna of this region. There are few threats to these wetlands, when compared to other parts of the country. The major visible anthropogenic pressure on these wetlands includes washing of cloths with detergents and excess pumping of water for agriculture purpose. During the surveys, villagers showed keen interest in conserving these migratory birds. In some villages, they even fed sacs of grains to large congregation of Demoiselle cranes *Grus virgo*. Most of the land masses other than agricultural fields are covered with *Prosopis juliflora*. Although many terrestrial birds are recorded from this area, the impacts of *Prosopis juliflora* on these birds are a concern (Nikunj *et al.*, 2011). Apart from this, birds faces threats from mining (Gajera *et al.*, 2013) and high tension electric lines (Tere & Parasharya, 2011). With the above said pressures on the avifauna, presence of large number of wind turbines in this area may also have some impact and this hypothesis is tested and discussed in the coming chapters of this thesis.

Observation of nesting of 15 species, few in large numbers also adds an additional conservational value for this area. Observation of large number of House Sparrow *Passer domesticus* nests in the area is notable as the House Sparrow *Passer domesticus* population in many parts of the country tends to decline due to various reasons (Daniels, 2008). In the study area, people had also set up many artificial nest boxes in residential areas. The successful nesting of sparrows in these artificial nest boxes were also noticed during the study period. Interesting observations of House Crow *Corvus splendens* and Red-naped Ibis nesting on the transmission pylons were noted during the study. House Crows use pylons for nesting in the study area possibly due to lack of suitable natural nest sites. The preliminary vegetation survey of the area confirmed that there are no suitable nesting trees within a 200 m radius of the pylons with nests. Although House Crow nesting on man-made structures are reported, nesting of Red-naped Ibis *Pseudibis papillosa* is usually found in large trees and the present observation is uncommon. The major factor influencing the choice of pylons for nesting is may be the lack of natural alternatives in this open, flat, food-rich agricultural landscape (Ali *et al.*, 2013a, 2013b). Another interesting observation was the nesting of Red-rumped Swallow *Hirundo*

daurica under the bridges of rural roads. It is found that there are some advantages for building nests inside bridge culverts especially in the context of plain semi-desert landscape of Kutch. Specifically, bridge culverts: (1) provide a secure placement, a constant environment and protection from extreme environments, (2) it does not allow access to terrestrial predators and encounters less anthropogenic disturbances, (3) they are typically located near water sources and cultivated lands, thus, there is no difficulty in collecting nesting materials and food (4) results in the absence of inter- and intra-specific competition for nesting (Personal observation). Extensive searches may reveal more nests of other birds.

Large congregations of water birds, presence of threatened species and nesting of many species, make this area important for conservation. The Endangered Steppe Eagle *Aquila nipalensis* was recorded frequently in the study area during winter. Similarly, about 100 individuals of Vulnerable Common Pochard *Aythya ferina* were also recorded from study area in December 2012 and January 2014. Also globally threatened Greater Spotted Eagle *Clanga clanga* and Sarus Crane *Antigone antigone* were recorded in considerable numbers. Further studies on the usage of this area by threatened birds are needed and an assessment of qualifying this area for an IBA site is also worthy due to presence of globally threatened birds. In conclusion, presence of 175 species with four globally threatened and 11 near threatened birds in the list indicates the conservational importance of this area. Hence, the anthropogenic activity threatening this habitat needs scientific management.

4 CHANGES IN LAND BIRD ASSEMBLAGE

4.1 INTRODUCTION

Birds are reported to be affected by developmental activities like roads (Benítez-López *et al.*, 2010), communication towers and power lines (Bhattacharya & Roy, 2013). Developmental activities affect bird assemblages both negatively and positively and it varies among bird species. Most studies report that developmental activities directly affect native bird species by altering its habitat (Blair, 1996, Clergeau *et al.*, 1998). Very few species thrive with these developmental activities by exploiting unique nesting and foraging opportunities that such environments provide (Beissinger and Osborne, 1982). The disturbance caused by developmental activities make most birds to move away from the anthropogenic structures. For instance, Benítez-López *et al.*, 2010 found a decline in bird density with their proximity to roads and other infrastructure. Similarly, the installation of tall structures not only leads to the collision of birds but also causes disturbance to birds which leads to the displacement (Balmori and Hallberg, 2007).

The assemblage of birds of an area is known to change after installation of wind turbines in that area. These changes may persist for years as a result of visual intrusion and also disturbance like noise and vibration which lead to habitat loss (Drewitt & Langston, 2006). The displacement of certain bird species from the wind farm have been documented in the recent years (Villegas-Patracá *et al.*, 2012, Leddy *et al.*, 1999; Pearce-Higgins *et al.*, 2009; Campedelli *et al.*, 2014). These studies also indicate that many bird species tend to avoid areas close to the turbines (100-300 m) and this effect is often long term (Villegas-Patracá *et al.*, 2012; Shaffer & Buhl, 2016). The displacement can happen during the construction and operation phase as well. The vehicle and personnel movements for turbine related activities also contribute to the displacement of birds. This displacement of birds can vary in many ways depending upon the geography, number of turbines and species involved (Drewitt & Langston, 2008).

The effects of wind turbines on grassland passerines of south-western Minnesota, USA were studied by Leddy *et al.* (1999) and it was found that the grasslands without turbines and areas located 180 m from turbines supported higher grassland birds than areas within 80 m of turbines. Similarly, study by Villegas-Patracá *et al.* (2012) in Mexico found high

species richness of birds in croplands and secondary forests, intermediate richness values at 200 m from the turbines, and lowest species richness values beneath turbines. A long term study at North Dakota and South Dakota (U.S.A.) by Shaffer & Buhl (2016) using BACI (Before After Control Impact) design showed displacement in seven of nine species studied, while one species was unaffected and one species exhibited attraction to the turbine site. They also found displacement and attraction was generally within 100 m. At times, the displacement extended even beyond 300 m. Garcia *et al.* (2015) who studied breeding passerines in wind farms found that 12 out of 15 species decreased during construction phase and 10 of them showed clear increase in the population after construction of the Valbormida wind farm in Italy.

Although, song birds are the reportedly most displaced bird group, studies found that raptors are also getting displaced from the turbine area. Garvin *et al.* (2011) found reduction in the abundance of raptors after the construction of turbines at Wisconsin, USA. Similarly, Pearce-higgins *et al.* (2009) found breeding bird densities reduced within the 500 m buffer zone of the turbines by 15–53%, with Common Buzzard *Buteo buteo* and Hen Harrier *Circus cyaneus* being the most affected species. Studies also reported that, even when no species of raptors have definitely left the wind farm area, there is a dramatic decrease in the number of raptor observations after construction of the wind farm (Campedelli *et al.*, 2014). Raptor displacement is mainly due to unfavourable conditions in the area of nesting and foraging (Madders & Whitfield, 2006). The review by Madders & Whitfield (2006) revealed that in all 20 species of raptors tested for displacement behaviour, 16 species were at lower risk, 3 species were low- medium risk and one species (Golden Eagle *Aquila chrysaetos*) was at low-high risk of displacement.

While many studies have reported displacement of birds there are few studies that have found no such effects on birds. A study by Douglas *et al.* (2011) in an upland wind farm in UK found no changes in the abundance of two species of birds Willow Ptarmigan *Lagopus lagopus* and European Golden Plover *Pluvialis apricaria* between wind farm and control sites. Similarly, a study conducted in central Apennines found no effect of wind turbines on breeding bird assemblage composed of passerines (Battisti *et al.*, 2014). Hale *et al.* (2014) observed no displacement of Dickcissel *Spiza americana*, Eastern Meadowlark *Sturnella magna*, and Grasshopper Sparrow *Ammodramus savannarum* within 750 m of wind turbines. It is known that two different species belonging to the

same family may respond differently. Stevens *et al.* (2013) found that species like Sprague’s Pipit *Anthus spragueii*, Savannah Sparrow *Passerculus sandwichensis*, and meadowlarks *Sturnella sp.* showed no evidence of displacement; in contrast, the Le Conte’s Sparrow *Ammodramus leconteii* got displaced from the turbine sites. Breeding of certain passerines are not found to be affected by the turbines. Bennett *et al.* (2014) found the proximity to the turbines did not negatively affect the nest successes of White-eyed Vireo *Vireo griseus*, Blue-gray Gnatcatcher *Poliophtila caerulea*, Northern Cardinal *Cardinalis cardinalis*, Painted Bunting *Passerina ciris*, and Lark Sparrow *Chondestes grammacus* at Wolf Ridge Wind Resource Area, Texas, USA. Similarly, the nest success of Dickcissels *Spiza americana* was also not affected by the wind turbines at the same Wolf Ridge Wind Resource Area (Hatchett *et al.*, 2013).

Table 4-1. Studies on the displacement of birds due to wind turbines

Studies	Country	Displacement	No Displacement/ Attraction
Leddy <i>et al.</i> , 1999	USA	Y	-
Pearce-higgins <i>et al.</i> , 2009	UK	Y	-
Douglas <i>et al.</i> , 2011	UK		Y
Garvin <i>et al.</i> , 2011	USA	Y	-
Villegas-Patracca <i>et al.</i> , 2012	Mexico	Y	-
Hatchett <i>et al.</i> , 2013	USA	-	Y (Nesting)
Stevens <i>et al.</i> , 2013	USA	Y(1 Sp)	Y(3 Sp)
Battisti <i>et al.</i> , 2014	Italy	-	Y
Campedelli <i>et al.</i> , 2014	Italy	Y	-
Hale <i>et al.</i> , 2014	USA	-	Y
Bennett <i>et al.</i> , 2014	USA	-	Y (Nesting)
Garcia <i>et al.</i> , 2015	Italy	Y (12 Sp.)	Y(2 Sp.)
Shaffer & Buhl, 2016	USA	Y (7 Sp.)	Y (2 Sp.)

Y-Yes, Sp-Specie, Nesting – effect on nest success

Thus, so far the studies on displacement of birds have given mixed results. A summary of these study results given in the Table 4-1. As most of the existing studies are from entirely from USA and Europe, it is essential to study the bird displacement behaviour in India. Hence, this present chapter attempt to answer the question: is there any difference in species richness, diversity and species composition of land birds between wind farm area and a carefully selected control area (lacking turbines). Secondly, the study also aimed to address the species specific differences in abundance between these two sites and to find out which species were most affected. The chapter also examines the role of habitat characteristics in influencing bird species richness and diversity.

4.2 METHODS

4.2.1 Study Design

The study area was divided into turbine site i.e. wind farm area (~120 sq. km) and control site (~80 sq. km) where there were no turbines. Both the turbine site and control site had the similar land cover and land use pattern except for the presence of turbines. The minimum distance between control site and turbine site was 1km (Figure 4-1). Climatically the area has three major seasons, winter (October-February) summer (March-June), and monsoon (July- September). However, from the avifaunal point of view, the sampling period was divided into Non migratory (March to September) and Migratory (October to February) season for data analysis and interpretation. For the sake of simplicity non-migratory season is mentioned as summer (when only resident birds use the area), and migratory season as winter (when many species of winter migratory birds visit and stay in the area). The land birds except raptors and raptors were surveyed using different methods so these two groups were dealt separately for analysis.

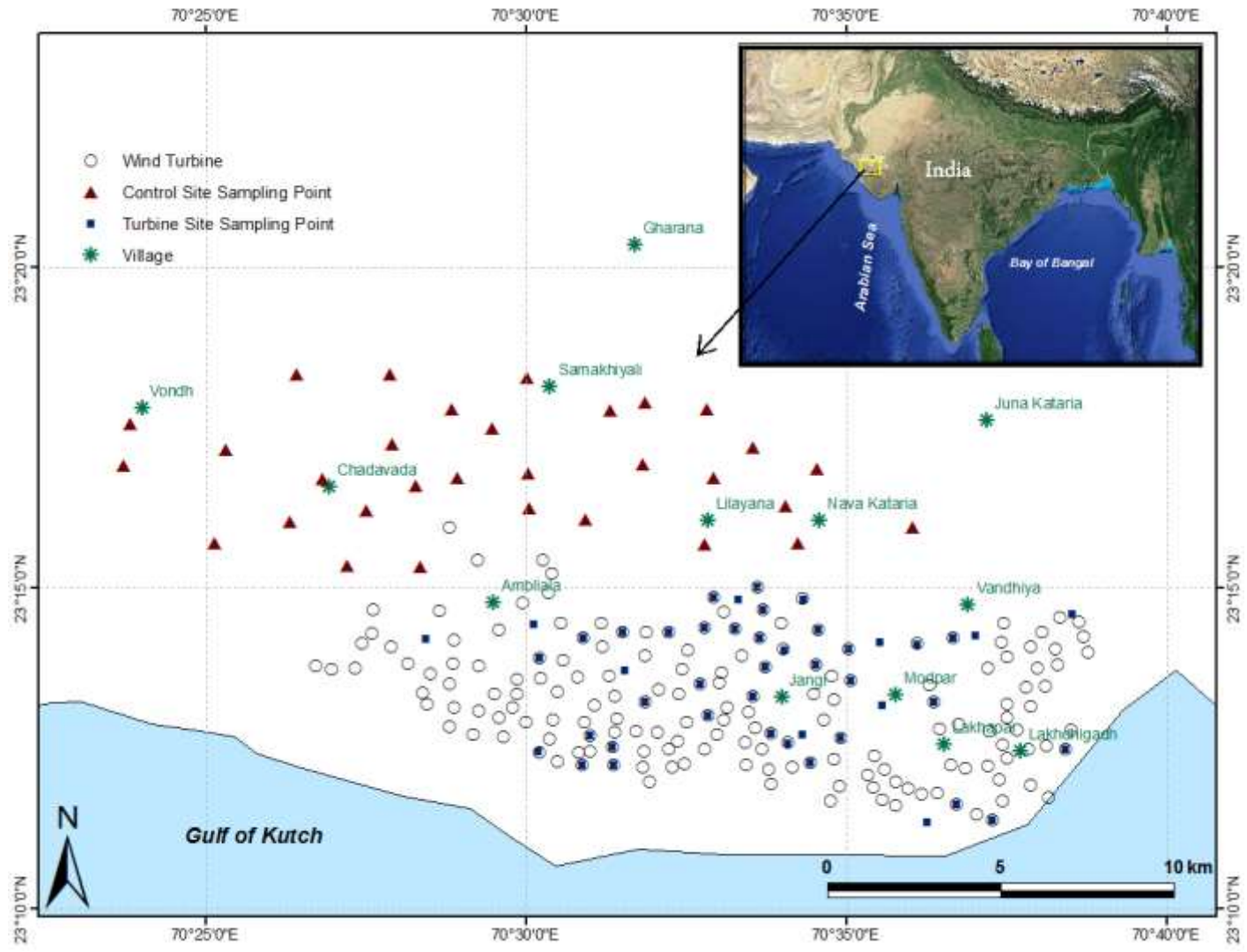


Figure 4-1. Study area map showing location of wind turbines and point counts

4.2.2 Bird Surveys

4.2.2.1 Land birds except raptors

Point counts with 50 m radius were used for the survey (Ralph *et al.*, 1995). Birds belonging to the orders Passeriformes, Columbiformes, Coraciiformes, Cuculiformes, Galliformes and Ciconiformes (only Cattle Egret *Bubulcus ibis* from ciconiformes) alone were counted during the survey. Both males and females seen within 50 m radius were counted and birds in flight were excluded. Raptors were also excluded from the count as Raptors were counted separately using vantage point surveys. During this survey White-breasted Kingfisher *Halcyon smyrnensis* and Cattle Egret *Bubulcus ibis* (water birds) were also counted as it is generally considered along with land birds. The area was stratified into turbine and control sites and a total of 79 sampling points were fixed: 48 turbine site points and 31 points in control site were fixed based on the proportion of area availability. As the area was generally open and interspersed with the thorny weed *Prosopis juliflora* and mostly rain fed agricultural fields, no further stratification on the habitat was done for fixing point counts. The control points were minimum 1 km away from the nearest wind turbine. To minimise the chance of repeated counts of same birds, a minimum of 500 m distance was maintained between sampling points. Each count lasted for 10 min covering the 50 m radius. Most of the bird counts were conducted from 0600 hrs to 0900 hrs when they were most active. Bird counts were made by a single person (Ramesh Kumar). Surveys were conducted between October 2012 and May 2014. Among eight temporal replications, five visits were made in winter and three in summer. Annual sampling were distributed as two visits in 2012 (winter: 2 visits), four in 2013 (summer: 2; winter: 2) and two in 2014 (summer: 1; winter: 1). Point counts were not conducted during extreme weather condition. Certain points were unable to be covered during the monsoon season (July-September) as the place was flooded. Totally, 430 individual point count surveys were made during the period with maximum eight and minimum of three replications at each point. Identification of birds were done using standard guides (Ali & Ripley, 2001; Grimmett *et al.*, 2011) and the nomenclature followed from del Hoyo *et al.* (2014) and Praveen *et al.*, (2016) for few species.

4.2.2.2 Raptors

Diurnal raptors were surveyed using vantage point count (Scottish Natural Heritage, 2009). In this method, all flying raptors were counted from an elevated vantage point for

30 minutes using Nikon 10 x 50 X binoculars. Doubtful individuals were photographed using Sony DSC 50 X Camera and later identified with standard books (Ali & Ripley, 2001; Naoroji & Schmitt, 2007; Grimmett *et al.*, 2011). All surveys were conducted between 0800 hrs to 1700 hrs. The days with extreme weather conditions were avoided for the surveys. Totally, 15 vantage points were fixed: eight in turbine site and seven in control site and the points were repeatedly surveyed for nine temporal cycles. Annual sampling were distributed as two visits in 2012 (winter: 2 visits), four in 2013 (summer: 2; winter: 2) and three in 2014 (summer: 2; winter: 1).

4.2.3 Statistical Analyses

4.2.3.1 Land birds other than raptors

Species accumulation curve was plotted to know the sufficiency of sampling effort landbirds. Non parametric species richness estimator (Chao-2) was used to estimate the expected number of landbird species in the area using Estimate S, 9.1 (Colwell, 2013; Chao *et al.*, 2016). The following analyses were done to explore the diversity and species richness pattern of the observed bird assemblage. The relative abundance (Ab_i = number of i^{th} species/Total number of individuals) of each species for all four assemblages (i.e. control and turbine site both in summer and winter) were calculated. Species with $Ab_i > 0.05$ was considered as dominant species (Battisti *et al.*, 2014). Species richness (S), Simpson diversity index and Simpson's measure of evenness and Shannon diversity index (H') for each assemblage were also calculated.

- Species Richness (S) = Number of species observed in each assemblage
- Simpson diversity = $1-D$, where D is the Dominance; Dominance (D) = $\sum_i \left(\frac{ni}{n}\right)^2$
- Simpson's measure of evenness = $((1/D)/S)$
- Shannon-Wiener Diversity Index (H') = $-\sum pi \ln pi$

where, pi = Proportion of individuals in the i^{th} species with respect to total sample, \ln = Natural logarithm

To assess difference in overall species composition between control and turbine sites, Non-metric Multi Dimension Scale (NMDS) analysis followed by one way

PERMANOVA (NPMANOVA) test, both using Bray-Curtis similarity measure was performed. NMDS ordines the sampling sites by their similarity in species composition. This algorithm attempts to place the data points in a two dimensional coordinate system such that the ranked differences are preserved.

PERMANOVA (Non-Parametric MANOVA, also known as NPMANOVA) is a non-parametric test of significant difference between two or more groups, based on any distance measure (Anderson, 2013). PERMANOVA calculates an F value in analogy with ANOVA. The significance is computed by permutation of group membership, with 9,999 replicates. Pair wise PERMANOVA between all groups provided as a post-hoc test. As supporting test for PERMANOVA, SIMPER (Similarity Percentage) test was performed to assess which bird species are primarily responsible for an observed difference between two groups of samples. The Simper test ranks species based on its percentage of contribution to difference between two groups.

To test, which are the species which gets most affected by wind turbines, difference in mean abundance between control and turbine site for species which had >20 sightings (including both sites) were tested using independent t-test. Data for summer and winter were tested separately. In order to treat each sampling point as independent samples, Mantel test (with 9999 permutations) was performed using Euclidean similarity measure (for distance between sampling points) and Bray Curtis similarity measure (for bird composition) to check if there is any spatial autocorrelation between sampling points. Mantel test is a permutation test for correlation between two distance or similarity matrices (Mantel, 1967, Mantel & Valand, 1970). The R value produced by this test is the Pearson's correlation coefficient between all the entries. It ranges from -1 to +1. The permutation test compares the original R to R computed from 9999 random permutations. The reported p value is one-tailed. For this analysis, mean abundance of temporal replication was taken. There was no significant spatial autocorrelation of species composition between the sampling points (Mantel test: $R = 0.028$; $p = 0.204$). Hence the assumption treatment of each sampling point as independent samples did not violate the statistical assumption.

The Generalized Linear Models (hereafter GLM) was used to infer, which factors among habitat variables influences bird species richness and diversity. Two GLMs were run one with point wise species richness (cumulative species richness at each sampling point) as

response variable and another with point wise diversity index (Shannon diversity index). The explanatory variable included turbine variables such as the density of turbines (here after referred as ‘turbine density’) and distance to the nearest wind turbine from sampling points. The turbine density (number of turbines within one km radius) for each sampling point was calculated using QGIS 2.10.1. Among the variables, ‘Turbine density’ and ‘Distance to the nearest turbine’ strongly correlated with each other, hence only turbine density was included in the analysis. Habitat variables include Normalised Differential Vegetation Index (NDVI), distance (in km) from each sampling points to the nearest fresh water body (ponds, lakes and check dams), human habitation, road (tarred) and salt marsh (salt pans).

NDVI for each sampling point corresponding to the the months in which bird samplings were done was extracted from Google Earth Engine, a repository for geospatial data (this NDVI is calculated using Landsat-7 Satellite Imagery with 30 m resolution). This NDVI is measured for every 32 days and for this analysis only values for the month in which bird survey was conducted were extracted and mean of this was included in the analysis (Mean of 8 temporal replications). NDVI is considered as the measure of plant productivity and as major determinant of bird species richness (Ding *et al.*, 2006; Qian *et al.*, 2009).

Precipitation for all the sampling points was collected from Worldclim global climatic data repository (<http://www.worldclim.org/bioclim>) (Fick and Hijmans, 2017). This precipitation data is an average of 50 yrs from 1950 to 2000. The spatial resolution of this data is 30 seconds (~ 1 sqkm) hence for the most of sampling points had separate precipitaitaion value (average of 50 yrs from 1950 to 2000). This data used to see whether precipitation play any role in the changes in the bird assemblage between sampling points. Though it may not be accurate and predicted based on the historical available data, this data set is readily available and widely used by the biologists (Loiselle *et al.* 2010, Herrick *et al.* 2013).

Other variables such as distance (in km) from each sampling points to the nearest fresh water body (Ponds, Lakes and Check dams), human habitation, road (tarred) and salt marsh (salt pans) were measured using Google Earth 2013 imagery & QGIS 2.10.1.

Analyses such as PERMANOVA, SIMPER, Mantel test, Diversity indices calculation were performed using 'Past 3.10' (Hammer *et al.*, 2001). NMDS and GLMs were performed using 'CANOCO-5' (ter Braak & Šmilauer, 2012).

4.2.3.2 Raptors

Species accumulation curve was plotted to know the sufficiency of sampling effort for raptors. Non parametric species richness estimator (Chao-2) was used to estimate the expected number of raptor species in the area using Estimate S, 9.1 (Colwell, 2013; Chao *et al.*, 2016). To assess the difference in raptor composition between control and turbine site, one-way PERMANOVA using Bray-Curtis dissimilarity distance with 9999 permutations was performed. The difference in abundance of raptor species (with >20 sightings) between control and turbine sites were analysed using independent t-test.

4.3 RESULTS

4.3.1 Land Birds except Raptors

Totally, 54 species of birds belonging to 24 families were recorded from both the sites together across seasons. The family Muscicapidae had maximum number of species (8) followed by Cisticolidae (6). Among the 54 species, 40 species were resident to the area and 12 were winter migrant and two species were passage migrant (Grimmett *et al.*, 2011). All 54 species were under the Least Concern category by IUCN (2015), however 51 out of 54 species were protected under schedule-IV of the Indian Wildlife Protection Act 1972 (Amended 2002). Species accumulation curve reached asymptote and the expected number species estimated by Chao-2 was 55 species. So it was confirmed that the sampling effort was sufficient to represent the landbird population of the area (Figure 4-2).

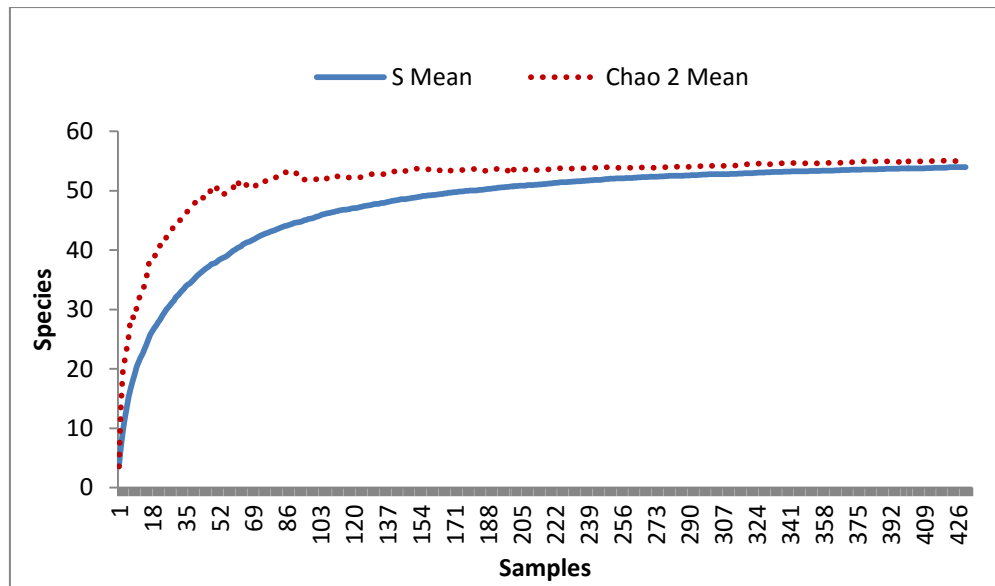


Figure 4-2. Species accumulation curve for landbirds

Of the total 54 species, 53 species were present in control site and 48 in turbine site. Species such as Greater Coucal *Centropus sinensis*, Dusky Crag-martin *Ptyonoprogne concolor*, Chestnut-shouldered Petronia *Petronia xanthocollis*, Brahminy Starling *Sturnia pagadarum*, Sykes's Warbler *Iduna rama*, Black Redstart *Phoenicurus ochruros* and Bluethroat *Luscinia svecica* were recorded only in control site. However the frequency of their sightings was less i.e. these species were sighted only <4 times during the overall survey period. The Great Grey Shrike *Lanius meridionalis* was recorded only in turbine site during the survey period (with 11 sightings during sampling).

In summer, species such as Rock Dove *Columba livia*, Grey-breasted Prinia *Prinia hodgsonii*, House Sparrow *Passer domesticus*, Red-vented Bulbul *Pycnonotus cafer* and Rosy Starling *Pastor roseus* were dominant ($Ab_i > 0.05$) in control site. Ashy-crowned Sparrow-Lark *Eremopterix grisea*, Eurasian Collared-dove *Streptopelia decaocto* and Rosy Starling were dominant in turbine site. In winter, House Sparrow *Passer domesticus*, Rosy Starling *Pastor roseus* and Common Babbler *Turdoides caudata* were dominant in control site and species like Ashy-crowned Sparrow-Lark *Eremopterix grisea*, House Sparrow *Passer domesticus* and Rosy Starling *Pastor roseus* were dominant in turbine site (Table 4-2).

Table 4-2. List of bird species recorded and their relative abundance at the control and turbine sites in summer and winter.

Family Name	Common Name	Scientific Name	Relative Frequency in Summer		Relative Frequency in Winter	
			Control (n= 35)	Turbine (n=25)	Control (n=47)	Turbine (n=43)
Alaudidae	Ashy-crowned Sparrow-Lark	<i>Eremopterix grisea</i>	0.029	0.080	0.047	0.153
Alaudidae	Crested Lark	<i>Galerida cristata</i>	-	0.008	0.002	0.008
Alaudidae	Rufous-tailed Lark	<i>Ammomanes phoenicura</i>	0.005	0.014	0.014	0.046
Alcedinidae	White-breasted Kingfisher	<i>Halcyon smyrnensis</i>	0.016	-	0.019	0.007
Columbidae	Rock Dove	<i>Columba livia</i>	0.114	0.002	0.045	0.019
Columbidae	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	0.040	0.057	0.045	0.033
Columbidae	Laughing Dove	<i>Spilopelia senegalensis</i>	0.043	0.040	0.035	0.020
Columbidae	Red Turtle Dove	<i>Streptopelia tranquebarica</i>	0.005	0.028	0.005	0.009
Coraciidae	European Roller**	<i>Coracias garrulous</i>	0.000	0.000	0.004	0.005
Coraciidae	Indian Roller	<i>Coracias benghalensis</i>	0.001	0.000	0.002	0.001
Corvidae	House Crow	<i>Corvus splendens</i>	0.044	0.024	0.028	0.014
Cuculidae	Asian Koel	<i>Eudynamis scolopaceus</i>	0.033	0.004	0.010	0.003
Cuculidae	Greater Coucal	<i>Centropus sinensis</i>	0.003	0.000	0.000	0.000
Cisticolidae	Ashy Prinia	<i>Prinia socialis</i>	0.000	0.000	0.002	0.003
Cisticolidae	Common Tailorbird	<i>Orthotomus sutorius</i>	0.005	0.000	0.003	0.002
Cisticolidae	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	0.053	0.025	0.040	0.013
Cisticolidae	Jungle Prinia	<i>Prinia sylvatica</i>	0.002	0.000	0.014	0.004
Cisticolidae	Plain Prinia	<i>Prinia inornata</i>	0.000	0.000	0.002	0.001
Cisticolidae	Rufous-fronted Prinia	<i>Prinia buchanani</i>	0.003	0.000	0.001	0.000
Dicruridae	Black Drongo	<i>Dicrurus macrocercus</i>	0.000	0.001	0.005	0.009
Estrildidae	Indian Silverbill	<i>Euodice malabarica</i>	0.004	0.038	0.010	0.000
Hirundinidae	Barn Swallow*	<i>Hirundo rustica</i>	0.004	0.000	0.017	0.005
Hirundinidae	Dusky Crag-martin	<i>Ptyonoprogne concolor</i>	0.003	0.000	0.000	0.000
Hirundinidae	Red-rumped Swallow	<i>Cecropis daurica</i>	0.019	0.003	0.017	0.008
Hirundinidae	Wire-tailed Swallow	<i>Hirundo smithii</i>	0.000	0.001	0.003	0.000
Laniidae	Bay-backed Shrike	<i>Lanius vittatus</i>	0.000	0.000	0.007	0.003
Laniidae	Long-tailed Shrike	<i>Lanius schach</i>	0.000	0.000	0.003	0.005
Laniidae	Isabelline Shrike*	<i>Lanius isabellinus</i>	0.000	0.000	0.011	0.004
Laniidae	Great Grey Shrike	<i>Lanius meridionalis</i>	0.000	0.000	0.000	0.007
Meropidae	Asian Green Bee-eater	<i>Merops orientalis</i>	0.021	0.014	0.024	0.036
Motacillidae	Paddyfield Pipit	<i>Anthus rufulus</i>	0.003	0.000	0.008	0.004
Nectariniidae	Purple Sunbird	<i>Cinnyris asiaticus</i>	0.039	0.028	0.030	0.011
Passeridae	House Sparrow	<i>Passer domesticus</i>	0.066	0.010	0.189	0.098
Passeridae	Chestnut-shouldered Petronia	<i>Petronia xanthocollis</i>	0.001	0.000	0.000	0.000
Phasianidae	Grey Francolin	<i>Francolinus pondicerianus</i>	0.008	0.033	0.000	0.011
Phasianidae	Indian Peafowl	<i>Pavo cristatus</i>	0.021	0.003	0.000	0.000
Ploceidae	Baya Weaver	<i>Ploceus philippinus</i>	0.013	0.008	0.004	0.000
Psittacidae	Rose-ringed Parakeet	<i>Psittacula krameri</i>	0.017	0.000	0.002	0.002
Pycnonotidae	Red-vented Bulbul	<i>Pycnonotus cafer</i>	0.071	0.049	0.039	0.036
Sturnidae	Brahminy Starling	<i>Sturnia pagadarum</i>	0.004	0.000	0.002	0.000
Sturnidae	Rosy Starling*	<i>Pastor roseus</i>	0.190	0.410	0.145	0.249
Sylviidae	Hume's Whitethroat**	<i>Sylvia althaea</i>	0.002	0.000	0.000	0.001
Sylviidae	Lesser White-throat*	<i>Sylvia curruca</i>	0.000	0.000	0.006	0.001
Acrocephalidae	Sykes's Warbler*	<i>Iduna rama</i>	0.000	0.000	0.003	0.000
Leiotherichidae	Common Babbler	<i>Turdoides caudate</i>	0.074	0.071	0.088	0.114
Muscicapidae	Black Redstart*	<i>Phoenicurus ochruros</i>	0.000	0.000	0.001	0.000
Muscicapidae	Bluethroat*	<i>Luscinia svecica</i>	0.000	0.000	0.005	0.000
Muscicapidae	Common Stonechat *	<i>Saxicola torquatus</i>	0.000	0.000	0.003	0.002
Muscicapidae	Desert Wheatear*	<i>Oenanthe deserti</i>	0.000	0.000	0.002	0.003
Muscicapidae	Indian Robin	<i>Saxicoloides fulicatus</i>	0.041	0.046	0.035	0.024
Muscicapidae	Isabelline Wheatear*	<i>Oenanthe isabellina</i>	0.000	0.000	0.008	0.005
Muscicapidae	Pied Bush Chat*	<i>Saxicola caprata</i>	0.005	0.000	0.009	0.002
Muscicapidae	Variable Wheatear*	<i>Oenanthe picata</i>	0.000	0.001	0.004	0.020
Upupidae	Eurasian Hoopoe	<i>Upupa epops</i>	0.000	0.000	0.005	0.002

*winter visitor; ** Passage migrant, The bold letter indicates the dominant species (with relative abundance > 0.05).

Simpson Diversity and Evenness index values were lower in turbine site than in the control site in all two seasons (Table 4-3). Overall (two season combined), species composition in both the sites were significantly different (PERMANOVA: $F = 6.531$; $p = 0.001$) and this pattern existed across the seasons (summer: $F = 6.721$; $p = 0.001$ and winter: $F = 5.883$; $p = 0.001$). In the overall (two season combined), the difference (assessed using SIMPER test) was contributed mainly by Rosy Starling *Pastor roseus* (16.88 %) and House Sparrow *Passer domesticus* (11.53 %) (Table 3-1). In Summer Rosy Starling *Pastor roseus* (12.52 %), Common Babbler *Turdoides caudata* (8.05 %) and House Sparrow *Passer domesticus* (7.92 %) were the major contributors to the difference in species composition. (Table 4-5). In winter the species which had major contribution for the difference include House Sparrow *Passer domesticus* (15.12 %), Rosy Starling *Pastor roseus* (12.12 %) and Ashy-crowned Sparrow-Lark *Eremopterix grise* (9.04 %) (Table 4-6).

Table 4-3. Diversity indices of bird assemblages of control and turbine sites in winter and summer. Sampling effort i.e. number of independent point counts surveyed for each season is given in parenthesis.

Diversity Indices	Summer (155)		Winter (275)		Overall (430)	
	Control (84)	Turbine (71)	Control (111)	Turbine (164)	Control (195)	Turbine (235)
Species Richness	35	25	47	42	53	46
Simpson Diversity Index	0.920	0.805	0.919	0.883	0.921	0.896
Simpson's Evenness	0.359	0.205	0.263	0.204	0.241	0.210
Shannon Diversity Index	2.892	2.299	3.02	2.687	3.077	2.819

Table 4-4. Bird species with major contribution for the difference in overall (two seasons combined) species composition (calculated using SIMPER test with Bray Curtis index).

Bird Species	Scientific Name	Average Dissimilarity	Percentage of Contribution	Cumulative Percentage
Rosy Starling	<i>Pastor roseus</i>	12.38	16.88	16.88
House Sparrow	<i>Passer domesticus</i>	8.463	11.53	28.41
Ashy-crowned Sparrow-Lark	<i>Eremopterix grise</i>	5.202	7.088	35.49
Rock Dove	<i>Columba livia</i>	4.745	6.465	41.96
Common Babbler	<i>Turdoides caudata</i>	4.136	5.635	47.59
Red- vented Bulbul	<i>Pycnonotus cafer</i>	2.416	3.292	50.89
Grey-breasted Prinia	<i>Prinia hodgsonii</i>	2.407	3.28	54.17
Asian Green Bee-eater	<i>Merops orientalis</i>	2.228	3.036	57.2
House Crow	<i>Corvus splendens</i>	2.168	2.954	60.16
Laughing Dove	<i>Spilopelia senegalensis</i>	2.141	2.917	63.07

Table 4-5. Bird species with major contribution for the difference in species composition in summer (calculated using SIMPER test with Bray Curtis index).

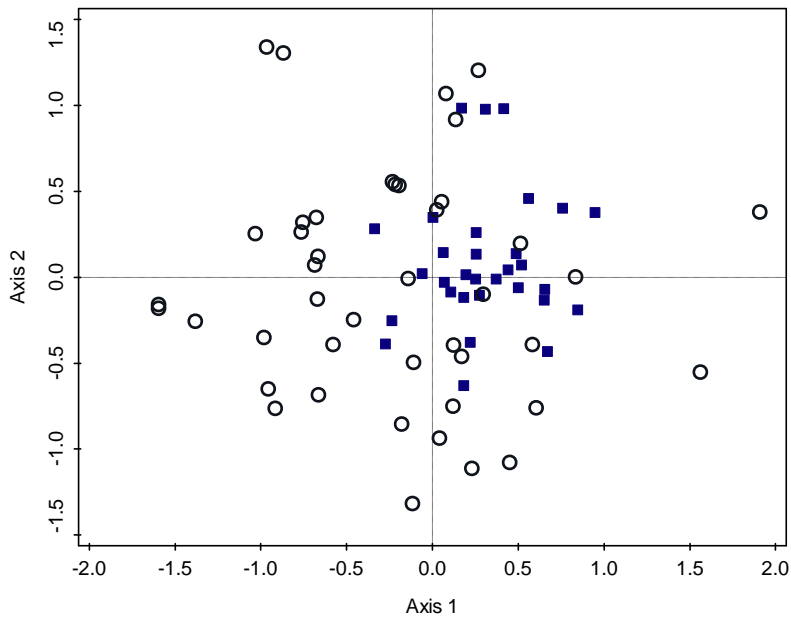
Bird Species	Scientific Name	Average Dissimilarity	Percentage of Contribution	Cumulative Percentage
Rosy Starling	<i>Pastor roseus</i>	10.44	12.52	12.52
Common Babbler	<i>Turdoides caudata</i>	6.716	8.05	20.57
House Sparrow	<i>Passer domesticus</i>	6.61	7.923	28.49
Red- vented Bulbul	<i>Pycnonotus cafer</i>	5.282	6.331	34.82
Rock Dove	<i>Columba livia</i>	5.153	6.177	41
Grey-breasted Prinia	<i>Prinia hodgsonii</i>	4.873	5.841	46.84
Ashy-crowned Sparrow-Lark	<i>Eremopterix grise</i>	4.559	5.465	52.3
Laughing Dove	<i>Spilopelia senegalensis</i>	4.394	5.267	57.57
House Crow	<i>Corvus splendens</i>	3.753	4.498	62.07
Eurasian Collared-dove	<i>Streptopelia decaocto</i>	3.576	4.286	66.35

Table 4-6. Bird species with major contribution for the difference in species composition in winter (calculated using SIMPER test with Bray Curtis index).

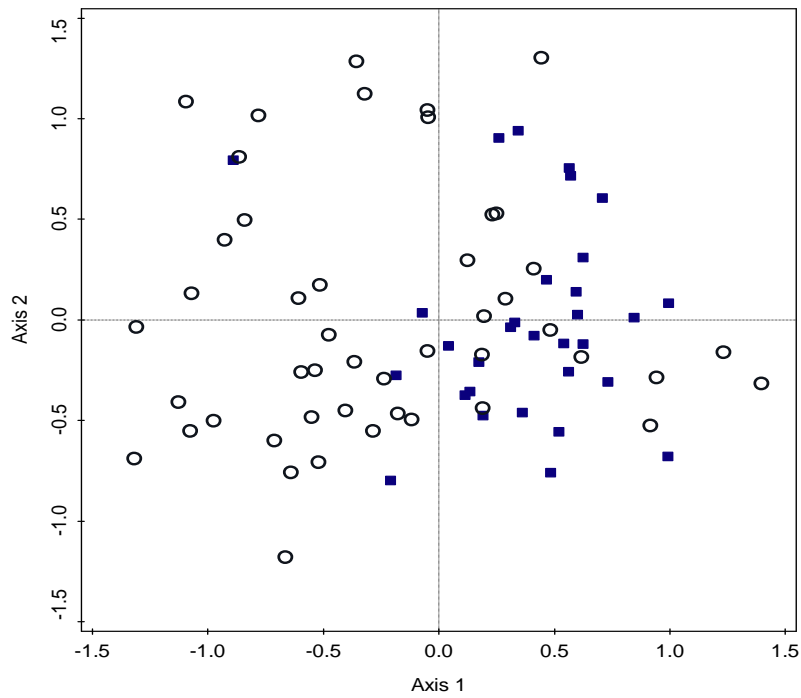
Bird Species	Scientific Name	Average Dissimilarity	Percentage of Contribution	Cumulative Percentage
House Sparrow	<i>Passer domesticus</i>	12.07	15.12	15.12
Rosy Starling	<i>Pastor roseus</i>	9.674	12.12	27.25
Ashy-crowned Sparrow-Lark	<i>Eremopterix grise</i>	7.214	9.04	36.29
Common Babbler	<i>Turdoides caudata</i>	6.452	8.085	44.37
Eurasian Collared-dove	<i>Streptopelia decaocto</i>	3.227	4.043	48.41
Grey-breasted Prinia	<i>Prinia hodgsonii</i>	3.024	3.789	52.2
Red- vented Bulbul	<i>Pycnonotus cafer</i>	2.972	3.724	55.93
Rock Dove	<i>Columba livia</i>	2.919	3.658	59.59
Asian Green Bee-eater	<i>Merops orientalis</i>	2.706	3.391	62.98
Indian Robin	<i>Saxicoloides fulicatus</i>	2.608	3.269	66.25

The first two axis of NMDS plot for summer explained 73.27 % of variation and showed distinction between the control and turbine sampling points (Figure 4-3 a). Similarly, the NMDS plot for winter explained 71.3 % of variation and it followed similar pattern as that of summer (Figure 4-3 b).

In summer, 11 species had more than 20 sightings and tested for significant difference between control and turbine site. Among these, Asian Koel *Eudynamis scolopaceus*, Common Babbler *Turdoides caudata*, Eurasian Collared-dove *Streptopelia decaocto*, Grey-breasted Prinia *Prinia hodgsonii*, House Crow *Corvus splendens*, House Sparrow, Indian Robin *Saxicoloides fulicatus*, Laughing Dove *Spilopelia senegalensis*, Purple Sunbird *Cinnyris asiaticus* and Red-vented Bulbul *Pycnonotus cafer* had significantly lower abundance in the turbine site. (Table 4-7). In winter 15 species of birds were recorded with more than 20 sightings and in this, species such as Black Drongo *Dicrurus macrocercus*, Eurasian Collared-dove *Streptopelia decaocto*, Grey-breasted Prinia *Prinia hodgsonii*, House Crow *Corvus splendens*, House Sparrow, Indian Robin *Saxicoloides fulicatus*, Laughing Dove *Spilopelia senegalensis*, Purple Sunbird *Cinnyris asiaticus* and Red-rumped Swallow *Cecropis daurica* had lower abundance in the turbine site. However, birds like Rufous-tailed Lark *Ammomanes phoenicura* and Variable Wheatear *Oenanthe picata* had higher abundance in the turbine site (Table 4-7).



a) Summer



b) Winter

Figure 4-3.a & b. Non-metric MDS plots showing overlapping of control and turbine sampling points (Circles: Turbine site sampling points; Squares: Control sampling points). The plot is created using Bray Curtis dissimilarity distance with 499 permutations.

Table 4-7. Difference in the abundance of species with more than 20 sightings between control and turbine site in summer and winter. Compared using independent t test; (n = 79 sampling points).

Common Name	Scientific Name	Summer		Winter	
		t- value	p-value	t- value	p-value
Asian Koel	<i>Eudynamys scolopaceus</i>	4.530	0.000	-	-
Ashy-crowned Sparrow-Lark	<i>Eremopterix grisea</i>	-0.355	0.724	-1.944	0.056
Black Drongo	<i>Dicrurus macrocercus</i>	-	-	2.343	0.022
Common Babbler	<i>Turdoides caudate</i>	3.577	0.001	0.661	0.511
Eurasian Collared-dove	<i>Streptopelia decaocto</i>	2.064	0.042	2.867	0.005
Asian Green Bee-eater	<i>Merops orientalis</i>			0.017	0.987
Grey-breasted Prinia	<i>Prinia hodgsonii</i>	5.804	0.000	4.991	0.000
House Crow	<i>Corvus splendens</i>	3.972	0.000	3.639	0.000
House Sparrow	<i>Passer domesticus</i>	4.651	0.000	2.573	0.012
Indian Robin	<i>Saxicoloides fulicatus</i>	3.212	0.002	3.307	0.001
Laughing Dove	<i>Spilopelia senegalensis</i>	3.634	0.001	3.482	0.001
Purple Sunbird	<i>Cinnyris asiaticus</i>	4.707	0.000	4.737	0.000
Red-rumped Swallow	<i>Cecropis daurica</i>	-	-	2.047	0.044
Red-vented Bulbul	<i>Pycnonotus cafer</i>	2.970	0.004	1.862	0.066
Rufous-tailed Lark	<i>Ammomanes phoenicura</i>	-	-	-2.056	0.043
Variable Wheatear*	<i>Oenanthe picata</i>	-	-	-3.049	0.003

* winter visitors, Bold letters indicates species with significant difference.

The Range, Minimum, Maximum, Mean, Std. Error and Std. Deviation of the independent variable used for GLM are given in the Table 4-8. The GLM model with plot wise species richness as response variable was significant ($F = 14.193$, $p = 0.001$) and it explained 43.5 % of variation. The species richness was positively influenced by NDVI ($t = 3.73$, $p = 0.001$) and negatively influenced by precipitation ($t = - 2.652$, $p = 0.009$) and turbine density ($t = - 3.630$, $p = 0.001$) (Table 4-10). The model with Shannon diversity index as response variable was also significant ($F = 3.55$, $p = 0.008$) and it explained 26 % of variation. Shannon diversity was positively influenced by NDVI ($t = 2.25$, $p = 0.027$) and negatively influenced by precipitation ($t = -2.01$, $p = 0.048$).

Table 4-8. Descriptive statistics of variables included for the GLM Analysis

Variables	Range	Minimum	Maximum	Mean	Std. Error	Std. Deviation
Altitude (m)	38.000	9.000	47.000	23.304	0.999	8.877
Distance to Turbine (km)	7.905	0.000	7.905	1.375	0.215	1.911
Density of Turbines (within 1 km radius of each sampling point)	9.000	0.000	9.000	2.570	0.290	2.580
Distance to Village (km)	4.452	0.064	4.516	1.494	0.116	1.030
Distance to fresh water body(km)	2.548	0.037	2.585	1.053	0.073	0.651
Distance to Road (km)	4.957	0.011	4.968	1.164	0.113	1.003
NDVI	0.238	0.090	0.327	0.161	0.004	0.040
Distance to Salt Pans (km)	10.989	0.273	11.262	5.764	0.301	2.673
Precipitation (mm)	35.000	397.000	432.000	417.468	0.909	8.081
Species Richness	24.000	1.000	25.000	11.785	0.635	5.647
Shannon Diversity Index	3.106	0.180	3.286	2.014	0.075	0.663

Table 4-9. Pearson Correlation matrix of Independent variables used for GLM

	Altitude	Distance to Turbine	Density of Turbines	Distance to Village	Distance to fresh water body	Distance to Road	NDVI	Distance to Salt Pans	Precipitation
Altitude		0.00	0.00	0.37	0.16	0.26	0.01	0.00	0.52
Distance to Turbine	0.46		0.00	0.02	0.01	0.00	0.15	0.00	0.00
Density of Turbines	-0.46	-0.69		0.00	0.00	0.11	0.03	0.00	0.00
Distance to Village	-0.10	-0.27	0.42		0.00	0.48	0.60	0.07	0.41
Distance to fresh water body	-0.16	-0.28	0.41	0.54		0.76	0.53	0.06	0.87
Distance to Road	-0.13	0.44	-0.18	0.08	0.04		0.88	0.56	0.00
NDVI	0.29	0.16	-0.25	0.06	-0.07	-0.02		0.08	0.06
Distance to Salt Pans	0.91	0.64	-0.64	-0.21	-0.21	-0.07	0.20		0.00
Precipitation	-0.07	-0.67	0.41	0.09	-0.02	-0.40	0.21	-0.38	

Table 4-10. GLM Models explaining the influence of turbine and habitat variables on bird assemblage. (Model 1 = Species Richness as response variable; Model 2 = Shannon diversity as response variable). Bold letters indicates P value <0.05.

Variables	Model 1 :Species Richness				Model 2: Shannon Diversity			
	AIC = 481.2, F=15.399, p = 0.001				AIC = 156.93, F=3.33, p = 0.008			
	beta	SE	t value	p -value	beta	SE	t value	p value
Intercept	7.848	2.141	3.670	0.000	11.010	4.765	2.310	0.024
Turbine Density (in 1 sq. km radius)	-0.060	0.022	-2.650	0.010	-0.036	0.043	-0.850	0.400
Distance to Human Habitation (km)	-0.025	0.041	-0.610	0.541	0.061	0.084	0.730	0.470
Distance to Ponds/Lakes (km)	-0.099	0.062	-1.610	0.112	-0.186	0.130	-1.430	0.157
Distance to Road (km)	-0.019	0.035	-0.550	0.585	-0.039	0.080	-0.490	0.629
NDVI	3.220	0.861	3.740	0.000	4.393	1.955	2.250	0.028
Distance to Salt Pans (km)	0.020	0.017	1.180	0.244	0.019	0.036	0.540	0.592
Precipitation	-0.014	0.005	-2.650	0.010	-0.023	0.011	-2.010	0.048

4.3.2 Raptors

Totally, 17 species of raptors belonging to two families (Accipitridae: 15 species, Falconidae: 2 Species) were recorded including Globally Threatened Steppe Eagle *Aquila nipalensis* (Endangered) and the Greater Spotted Eagle *Clanga clanga* (Vulnerable) see Table 3-1. Species accumulation curve reached asymptote and the expected number species estimated by Chao-2 was also 17 species. So it was confirmed that the sampling effort was sufficient to represent the raptor population of the area (Figure 4-4). Among the 17 species, six species are resident to the area and remaining 11 species are winter visitors (Grimmett *et al.*, 2011). However, during the study period only three species namely, Laggar Falcon *Falco jugger*, Black-winged Kite *Elanus caeruleus* and Shikra *Accipiter badius* were recorded in summer (non-migratory period) and 16 species were recorded in winter (Figure 4-5, Figure 4-6).

Table 4-11. List of Raptors recorded in the study area

S. No	Family	Common Name	Scientific Name	IUCN
1	Falconidae	Laggar Falcon	<i>Falco jugger</i>	LC
2	Falconidae	Common Kestrel*	<i>Falco tinnunculus</i>	LC
3	Accipitridae	Black-winged Kite	<i>Elanus caeruleus</i>	LC
4	Accipitridae	Booted Eagle*	<i>Hieraaetus pennatus</i>	LC
5	Accipitridae	Common Buzzard*	<i>Buteo buteo</i>	LC
6	Accipitridae	Griffon Vulture*	<i>Gyps fulvus</i>	LC
7	Accipitridae	Eurasian Sparrow-hawk*	<i>Accipiter nisus</i>	LC
8	Accipitridae	Greater Spotted Eagle*	<i>Clanga clanga</i>	VU
9	Accipitridae	Long-legged Buzzard*	<i>Buteo rufinus</i>	LC
10	Accipitridae	Montagu's Harrier*	<i>Circus pygargus</i>	LC
11	Accipitridae	Oriental Honey-Buzzard	<i>Pernis ptilorhynchus</i>	LC
12	Accipitridae	Pallid Harrier*	<i>Circus macrourus</i>	NT
13	Accipitridae	Shikra	<i>Accipiter badius</i>	LC
14	Accipitridae	Short-toed Snake Eagle	<i>Circaetus gallicus</i>	LC
15	Accipitridae	Steppe Eagle*	<i>Aquila nipalensis</i>	EN
16	Accipitridae	Western Marsh-harrier *	<i>Circus aeruginosus</i>	LC
17	Accipitridae	White-eyed Buzzard	<i>Butastur teesa</i>	LC

(* winter visitors)

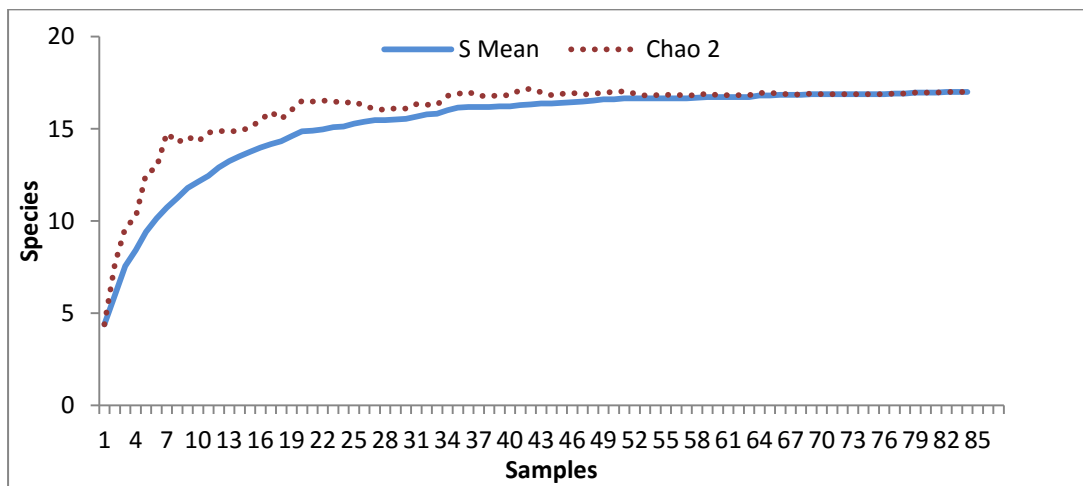


Figure 4-4. Species Accumulation Curve of Raptors in the study area.

In summer, the composition of raptors did not vary significantly between control and turbine sites (PERMANOVA: $F = 1.492$, $p = 0.235$). However in winter the composition of raptors varied significantly between two sites (PERMANOVA: $F = 4.101$, $p = 0.0378$). This difference in the winter is contributed majorly by Steppe Eagle *Aquila nipalensis* (15.58) Western Marsh-harrier *Circus aeruginosus* (14.48 %) and Black-winged Kite *Elanus caeruleus* (12.25 %) (SIMPER Test) (Table 4-12).

In summer, only Black-winged Kite *Elanus caeruleus* was recorded with more than 20 sightings and tested for significant difference between two sites. There was no significant difference in the abundance of Black-winged Kite *Elanus caeruleus* between two sites ($t = 1.211$, $p = 0.247$) in summer. During winter, four species namely Black-winged Kite *Elanus caeruleus*, Common Kestrel *Falco tinnunculus*, Steppe Eagle *Aquila nipalensis*, and Western Marsh-harrier *Circus aeruginosus* had more than 20 sightings and were tested for significant difference between two sites. Among this, abundance of Black-winged Kite *Elanus caeruleus*, ($t = 1.671$, $p = 0.118$) Common Kestrel *Falco tinnunculus* ($t = 0.078$, $p = 0.938$) and Western Marsh-harrier *Circus aeruginosus* ($t = 0.718$, $p = 0.485$) did not differ between two sites. The abundance of Steppe Eagle *Aquila nipalensis* was significantly lower in turbine site ($t = 3.371$, $p = 0.005$).

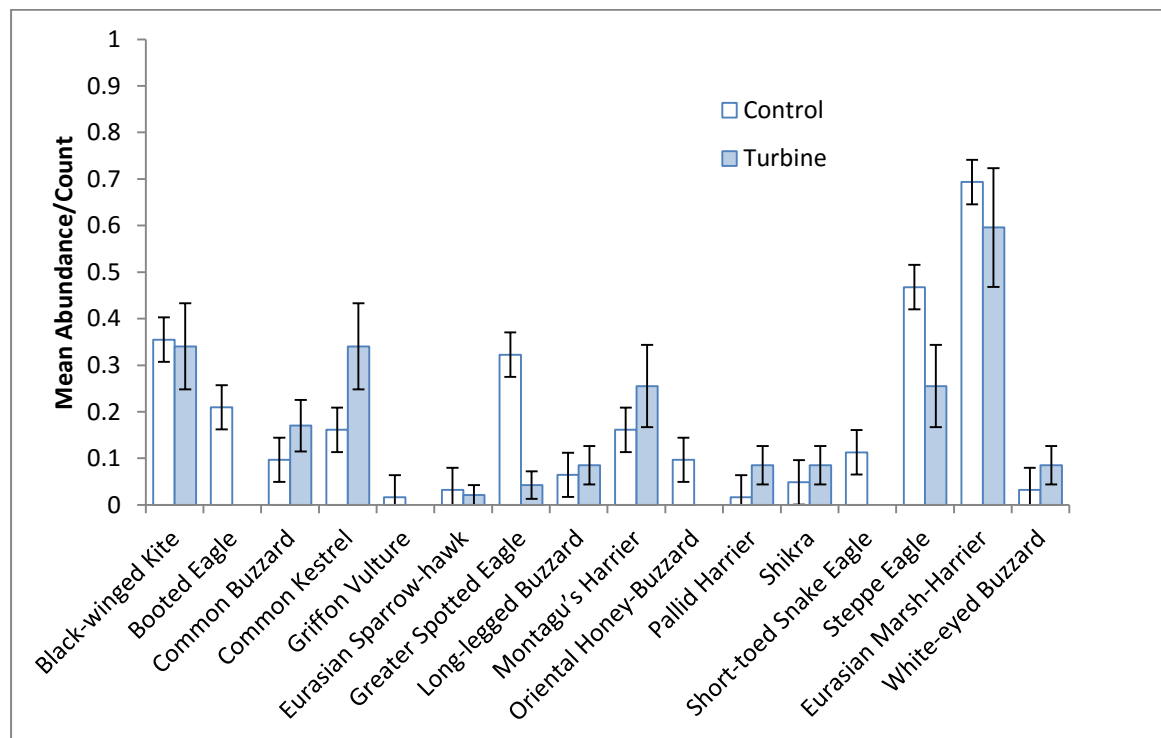


Figure 4-5. Abundance of Raptors in Control and Turbine Sites during winter.

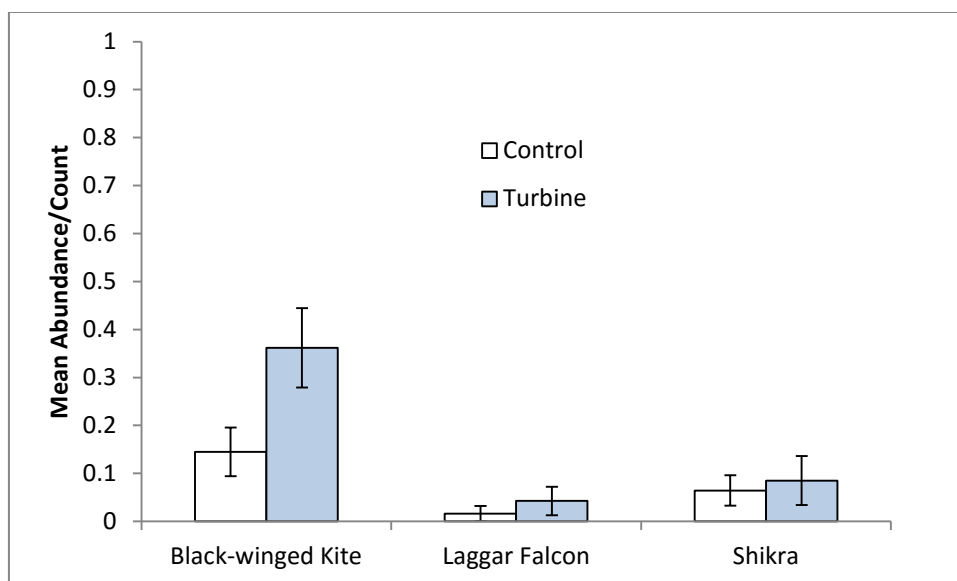


Figure 4-6. Abundance of Raptors in Control and Turbine Sites during summer.

Table 4-12. Raptor species with major contribution for the difference in species composition between control and turbine sites during winter (calculated using SIMPER test with Bray Curtis index).

Bird Species	Scientific Name	Average Dissimilarity	Percentage Contribution	Cumulative Percentage
Steppe Eagle	<i>Aquila nipalensis</i>	12.01	15.58	15.58
Western Marsh-harrier	<i>Circus aeruginosus</i>	11.93	15.48	31.07
Black-winged Kite	<i>Elanus caeruleus</i>	9.44	12.25	43.32
Greater Spotted Eagle	<i>Clanga clanga</i>	6.914	8.973	52.29
Booted Eagle	<i>Hieraaetus pennatus</i>	6.583	8.545	60.84
Common Kestrel	<i>Falco tinnunculus</i>	5.879	7.631	68.47
Common Buzzard	<i>Buteo buteo</i>	4.16	5.399	73.87
Montagu's Harrier	<i>Circus pygargus</i>	4.14	5.374	79.24
Short-toed Snake Eagle	<i>Circaetus gallicus</i>	3.253	4.221	83.46
Oriental Honey-Buzzard	<i>Pernis ptilorhynchus</i>	2.77	3.595	87.06

4.4 DISCUSSION

It was found that there is a marked reduction in the species richness, diversity and composition of the birds between wind farm area and the control area. Majority of the species showed lower abundance in the wind farm area; however a couple of species had higher abundance in wind farm. The lower species richness in wind farm area is the effect of wind turbines along with NDVI and precipitation. Unlike the other land birds, Raptor composition was similar among the two sites, except for the difference in the abundance of Steppe Eagle *Aquila nipalensis*.

The diversity of birds was lower in wind farm area as it was mainly influenced by NDVI and precipitation more than the presence of wind turbines. The presence of wind turbine negatively affected the bird assemblage to a certain level and the vegetation cover primarily attracted bird assemblage as reported by many studies (Ding *et al.*, 2006; Qian *et al.*, 2009). Regular clearing of vegetation in the turbine bases reduces the vegetation cover in the turbine area causing low species richness and diversity in the turbine area. This pattern of low species richness in wind farm in comparison to adjacent areas was also reported by Villegas-Patracca *et al.* (2012); they found increasing species richness from the base of wind turbine area.

Species richness as an indicator of habitat quality can be misleading, where degraded habitats can be occupied by generalist species thereby increasing the overall species richness (Magguran, 2016). Hence, it is recommended to consider species composition to reflect habitat quality and habitat degradation (Magguran, 2016). In the present study species composition of birds was different in turbine and control areas. Generalist species like Common babbler *Turdoides caudata*, Rosy starling *Pastor roseus*, House sparrow *Passer domesticus* were present abundantly in both the sites. However certain species of larks and wheatear including Variable Wheatear *Oenanthe picata*, Ashy-crowned Sparrow-Lark *Eremopterix grise*, Crested Lark *Galerida cristata*, Rufous-tailed Lark *Ammomanes phoenicura* were found to be more abundant in turbine area. Generally the abundance of most species except the above mentioned larks were low in turbine area. Species which prefers trees and shrubs such as Asian Koel *Eudynamis scolopaceus*, Grey-breasted Prinia *Prinia hodgsonii*, Indian Robin *Saxicoloides fulicatus*, Red-vented Bulbul *Pycnonotus cafer* and Purple Sunbird *Cinnyris asiaticus* were also found in low numbers in the turbine site. This was evident from the individual 't' test conducted for

difference in the abundance of individual species. Most species tested had lower abundance in the wind farm area. Similar avoidance of wind turbine by majority of birds was also reported from Mexico by Villegas-Patraca *et al.* (2012). From the above pattern, the regular clearing of vegetation which alters the habitat in turbine site may be one of the reasons for lower abundance of shrub preferring birds in the turbine area along with the disturbance caused by the turbine presence. This may be also the reason for high abundance of birds preferring open habitat like Larks and Wheatears in turbine site. Studies show that the increased number of Larks and Wheatears in turbine site is due to alteration of the landscape during the development of wind farms. The supply roads, trenches, cleared open areas below the turbine which had not existed before may be the causatives for this change (Hötker, 2006).

In summer, the raptor composition was similar between two sites as only three species of resident raptors were recorded. However in winter, the species richness increased and the species composition of raptors significantly varied between control and turbine sites. In winter the study area is visited by many migratory raptors. Overall the number of raptors was found low at turbine site however only Steppe Eagle *Aquila nipalensis* showed significantly low abundance in the wind farm area. But the along with Steppe Eagle *Aquila nipalensis*, the slightly low numbers of other raptors has led to the significant variation in the species composition. These findings are in agreement with the previous findings that, the displacement of raptors is generally low and species specific (Langston & Pullan, 2003; Madders & Whitfield, 2006). Among the three harriers recorded, Pallid Harrier *Circus macrourus* and Montagu's Harrier *Circus pygargus* had less number of sightings and hence the difference in abundance was not statistically compared. However, the abundance of Western Marsh-harrier *Circus aeruginosus* did not vary significantly between control and turbine site. This might be due to the flight behaviour of harriers as they usually fly close to the ground in search of prey so it naturally falls below the RSZ of wind turbine (Rotor Swept Zone). Earlier studies on Hen Harrier also found little evidence of displacement. A review by Madders & Whitfield, (2006) revealed that, Hen Harrier were not displaced due to wind turbines in many wind farms (Johnson *et al.*, 2000; Kerlinger, 2002; Schmidt *et al.*, 2003).

Steppe Eagle *Aquila nipalensis* had significantly low abundance in the turbine site. Steppe Eagle *Aquila nipalensis* has undergone extremely rapid population decline across

much of its distribution range and it is classified as Endangered by IUCN. The population decline is caused by habitat destruction, persecution, and collisions with power lines (IUCN, 2016). The present results indicate additional threats to this endangered species from wind farms in its wintering grounds. Similarly, the Greater Spotted Eagle *Clanga clanga* was also found in higher number in control than in turbine site; however, it was statistically insignificant. Its estimated global population is 3300-8800 and it is categorized as Vulnerable (IUCN, 2016). This species has also declined in population over the last three decades as a result of habitat loss and degradation. The Griffon vulture *Gyps fulvus* was recorded only once in Control site but it is known to be one of the most affected species in Europe and USA due to turbine collision (de Lucas *et al.*, 2012). It is necessary to carry out studies in other wind farms of Kutch district (Naliya Grassland Area), where the presence of Griffon vulture *Gyps fulvus* and other endangered vultures such as Indian Vulture *Gyps indicus* (Critically Endangered as per IUCN, 2016), White-rumped Vulture *Gyps bengalensis* (Critically Endangered), Red-headed Vulture *Sarcogyps calvus* (Critically Endangered) and Egyptian Vulture *Neophron percnopterus* (Endangered) are reported (Munjpara & Gadhvi, 2012).

In contrast to other raptors, Common Kestrel *Falco tinnunculus* had slightly higher abundance (statistically insignificant) in turbine site. In winter, 'wind hovering' of Common Kestrel *Falco tinnunculus* close to wind turbines were observed frequently and often (also outside vantage points) they were sitting in electric posts (8-10 m height) close to turbines. The studies by Barrios & Rodríguez, (2004) reported the flight and perching of Kestrels close to turbines and reported higher collision mortalities. This lack of turbine avoidance and its flight mechanism with intermittent gliding during hunting (Videler *et al.*, 1983) could be major reason for higher Kestrel mortality. In the present study four carcasses of Common Kestrel *Falco tinnunculus* were observed during carcass survey (chapter 5.3).

The long term impacts of the wind farm on raptors are of greater concern because they produce few offspring and have a long life expectancy. The study by Carrete *et al.*, (2009) clearly explains that wind farms is a serious threat to the long lived raptors as it decrease survival rates of this species and increasing the chance of population decline. So with mounted pressure in breeding ground of these species, the impacts of wind farm on its wintering grounds needs to investigated carefully. This study results is in concurrence

with the results of Carrete *et al.*, (2009) and emphasises the need for precautions in installing wind turbines. However, further studies including many variables, such as prey abundance, vegetation structure, vegetation cover, may give more concrete results.

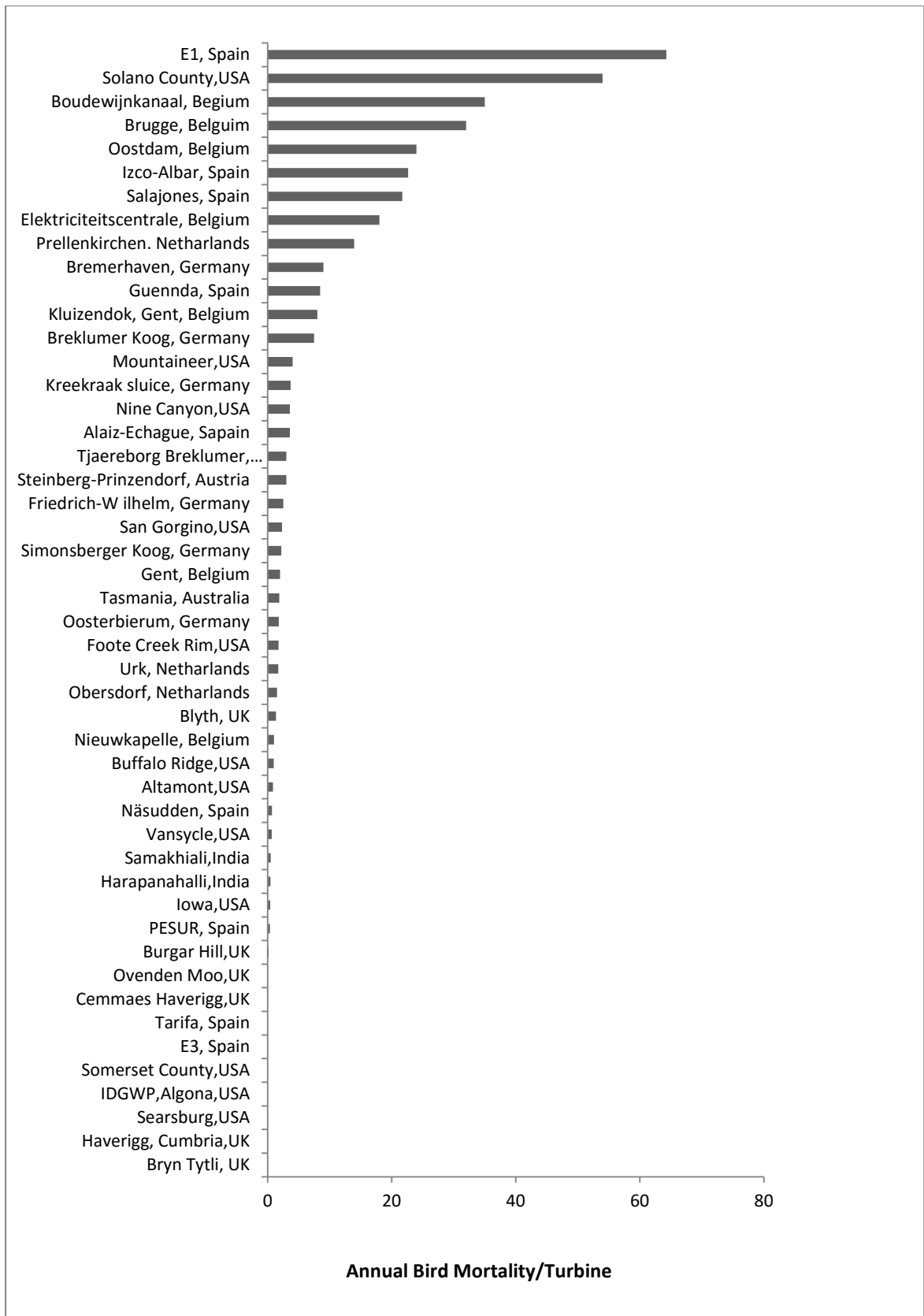
In conclusion, this study confirms that, the wind turbine has a some negative effect on the land bird assemblage of the Kutch region. The abundance most of passerine species are lower in the wind farm area. A combined effect of presence of turbine, alteration of habitats by clearing vegetation has contributed to this low abundance of bird species. Although majority of the raptors were distributed equally in wind farm and surrounding areas, it needs further scrutiny.

5 BIRD MORTALITIES

5.1 INTRODUCTION

Birds flying through the wind farm area can sometimes collide with the rotating blades of the wind turbines. Injuries to birds can also be caused from collision with towers, nacelles and associated structures of the wind farms. Studies also shows that birds can get forced to the ground and injured as a result of vortex created by the rotors (Winkelman, 1992; Drewitt & Langston, 2006). This issue of bird collisions came into light when many raptors got killed at Altamont pass of USA in early 1990s (Orloff & Flannery, 1992). Later many such collisions were reported and most of the study reports were from USA, Europe and UK. The species getting killed and number of bird mortalities varies across geographic regions, turbine types and climatic factors. The collision rate also varies according to season, for instance Howe *et al.* (2002) found that bird mortality at a wind farm in North-eastern Wisconsin (USA) was highly seasonal. The turbine structure also tends to affect the collision rate, wind turbine with lattice tower are believed to cause more bird mortalities than the tubular modern tower turbine (Orloff & Flannery, 1992).

The number of birds getting killed varied from 0 to 64 birds/ turbine annually among wind farms. Studies that shows high mortality rates includes report of 64.26 birds/turbine/year at El Perdón, Spain (Lekuona, 2001; Hötter, 2006), 54 birds/turbine/year (Erickson *et al.*, 2001) in Solano county, USA and 35 birds/turbine/year in Boudewijnkanaal te Brugge, Belgium (Everaert, 2003). In contrast to such high records of bird mortalities, studies by (Erickson *et al.*, 2001) at Green Mt, Searsburg and IDWGP Algona, USA reported zero bird mortality (Figure 5-1). Bird species like Red Kite *Milvus milvus* and Common Buzzard *Buteo buteo* were the most affected species in Germany (Hötter, 2006), whereas Red-tailed hawk *Buteo jamaicensis* and Griffon vulture *Gyps fulvus* were among the most affected species in USA and Spain (Erickson *et al.*, 2001; de Lucas *et al.*, 2012) respectively.



Source: Hötter, 2006.

Figure 5-1. Annual bird mortality rate for wind farms from various countries.

There are many bird species which are related to India (birds which had distribution range in India either wintering or residents), which were reported to be killed by wind turbines in western hemisphere. In order to find out the bird species killed so far, 20 bird species from mortality studies mainly from USA, UK and Europe were analysed. The study period of the papers selected ranged from 1998 to 2014..(Osborn *et al.*, 1998; Kingsley & Whittam, 2001; Erickson *et al.*, 2001; Johnson *et al.*, 2003; de Lucas *et al.*, 2004; Kerns & Kerlinger, 2004; Smales, 2006; Hötcker, 2006; de Lucas *et al.*, 2008; Miller, 2008; Stienen *et al.*, 2008; de Lucas *et al.*, 2012; Farfán *et al.*, 2009; Smallwood *et al.*, 2010; Zieliński *et al.*, 2010; Grünkorn, 2011; Ferrer *et al.*, 2012; Doty & Martin, 2013; Hull *et al.*, 2013; Taylor *et al.*, 2014). The result showed about 91 species were affected of which, Griffon Vulture *Gyps fulvus* is the most affected species with 632 individual followed by Rock Dove *Columba livia* (348 individuals), Horned Lark *Eremophila alpestris* (195 ind) and Golden Eagle *Aquila chrysaetos* (141 ind) Common Tern *Sterna hirundo* (112 ind) Mallard *Anas platyrhynchos* (107 ind), Common Kestrel *Falco tinnunculus* (90 ind) Black-headed Gull *Larus ridibundus* (89 ind), Common Barn-owl *Tyto alba* (87 ind), and Eurasian Buzzard *Buteo buteo* (72 ind) (Appendix-2).

Apart from USA and Europe, there are bird mortality reports from Australia (Hull *et al.*, 2013), Mexico (Villegas-Patraca *et al.*, 2012) and South Africa (Doty & Martin, 2013). In India, there are only two reported studies by Pande *et al.*, (2013) and Arun *et al.* (2014). Pande *et al.* (2013) reported mortality of five species of birds at ‘Bhambarwadi Wind Farm Plateau’ in the north Western Ghats of Maharashtra from 2008 to 2010. The affected species were Black Kite *Milvus migrans*, Bonelli’s Eagle *Hieraaetus fasciatus*, Changeable Hawk-eagle *Nisaetus cirrhatus*, Red-rumped Swallow *Hirundo daurica* and Dusky Crag-martin *Ptyonoprogne concolor*. The species with maximum casualties were Black kite *Milvus migrans* and Red-rumped Swallow *Hirundo daurica* with 3 mortalities each. Another study conducted by Arun *et al.* (2014) at Hara wind farm, Karnataka reported seven mortalities belonging to at least four species in one year period. With this background, the present chapter address the following issues 1) magnitude of bird mortalities occurring in the Samakhiali wind farm and 2) species getting involved in collision.

5.2 METHODS

5.2.1 Overview of Existing Methods

In order to find out the collision of birds, of the various methodologies used elsewhere few were found to be suitable and cost effective. To monitor bird collisions, remote tools like radar systems, Infra-red camera systems has been tested and used in certain studies (Desholm *et al.*, 2006). Apart from this, visual observation of bird collision using spotting scope, avian acoustic monitoring, Ceilometer surveys involving direct visual observation of night-migrating birds using a high-powered light, Use of laser Range finder to observe collision, moon watching technique (observing bird collisions during full or nearly full moon days) are also in practice (Desholm *et al.*, 2006). However, the collection of dead or injured birds under wind turbine site was proven to be the best method for onshore wind farms and it was used by many studies (Kerns & Kerlinger, 2004; Morinha *et al.*, 2014). Many variation of this carcass searches are used according to the field condition. For instance searches of carcass on a fixed transect where turbines are arranged in row, use of dogs for increasing the detection ability are practiced (Nicholson, 2005, Paula *et al.*, 2011). The following best suitable methodology was adopted bearing the Samakhiali wind farm condition in mind.

5.2.2 Carcass Search

Carcass surveys were conducted at selected 59 turbines from October 2011 to June 2014 at Samakhiali Wind farm. A total of 23 cycles of search was conducted at each turbine during the study span. The mean gap between two consequent searches was 40 days. The area under each selected turbine was searched within its 130-140 m radial zone from the base of the turbine while slowly walking along a spiral path outwards from the centre (Kerns & Kerlinger, 2004). The time spent to search a turbine site was about 40 minutes. When a carcass was found, data on species name, condition of carcass and distance to the turbine base were recorded. The study covered Migratory (October to March) and Non migratory (April- September) seasons.

5.2.3 Bias Correction for Carcass Detection

5.2.3.1 Searcher efficiency test

Search efficiency test was used for calculating the searcher's efficiency to detect the number of carcasses from the total number of carcasses that may be present below the turbine (Erickson *et al.*, 2004). The base of the turbines was generally bare with scattered clumps of *Prosopis juliflora*, grasses like *Dactyloctenium sp.*, *Brachiaria sp.* and crops like *Ricinus communis*. No searcher efficiency test was conducted as there was not much difficulty in locating the carcasses in most of the months except monsoon season (September–October), in which the grasses covered the base. So, the detection probability is assumed as '1' i.e. the searcher could detect all the carcasses which are available below turbine during the search.

5.2.3.2 Scavenger removal test

There are possibilities that the collided bird carcasses may be scavenged by scavengers like dogs, jackals and monitor lizards between two consequent searches. This bias can be corrected using scavenger removal tests. The scavenger removal test determines the average days that a bird carcass remains in the search area below the turbine, before being removed by scavengers (Erickson *et al.*, 2004). 10 carcasses (3 fresh; 7 decayed/scavenged) were used for this test. The mean length of time a carcass remained on a plot (T) was calculated based on the following equation (Erickson *et al.*, 2004; Kerns & Kerlinger, 2004).

$$T = \Sigma ti / S$$

Where, **ti** is the length of time a carcass remained on site; **S** is the total number of carcasses planted for the study.

The estimated number of annual bird fatalities of a wind farm (M) can be calculated using the following formula (Erickson *et al.*, 2004; Kerns & Kerlinger, 2004),

$$M = \frac{N \times I \times C}{k \times t \times e}$$

Where, 'N' is the total number of turbines, 'I' is the interval between searches in days, 'C' is the total number of carcasses found, 'k' is the number of turbines sampled, 't' is the

mean length of time carcasses remained on site before being scavenged (in days), and ‘e’ is the searcher efficiency. The mortality rates per turbine and per MW were estimated by dividing ‘M’ (estimated number of annual fatalities of the wind farms) with number of turbines present and its capacity, respectively.

5.2.4 Estimation of Expected Number of Species Killed

Non-parametric species richness estimators are generally used to estimate the number of undetected species in an assemblage based on information of rare species in a sample. This method was recently used to estimate the expected number of bird species being killed by wind turbines (Beston *et al.*, 2015). This method extrapolates species diversity out to the asymptote, beyond which additional sampling will not yield any new species. The most widely used estimators include Chao-1, Chao-2, Jack knife-1 and Jack knife-2. These four work on the concept that rare species carry the most information about the number of undetected species (Magurran, 2013). Chao-1 is a function of the ratio of singletons (number of observed species represented by single individuals) and doubletons (number of observed species represented by two individuals) (Chao, 1984; Colwell & Coddington, 1994; Magurran, 2013).

$$S_{\text{chao1}} = S_{\text{obs}} + F_1^2 / 2F_2$$

Where, S_{obs} = the number of species in the Sample, F_1 = number of observed species represented by a single individuals (Singletons), F_2 = number of observed species represented by two individuals (doubletons).

Although the Chao-2 also involves the same principle, it considers the number of species that occur in only one sample (Unique Species) and the number of species that occurs in two samples. (Chao, 1987; Colwell & Coddington, 1994; Magurran, 2013)

$$S_{\text{chao2}} = S_{\text{obs}} + Q_1^2 / 2Q_2$$

Where, S_{obs} = the number of species in the Sample, Q_1 = number of species that occurs in one sample only (Unique Species) and Q_2 = number of species that occur in two samples.

First order Jack knife (Jack knife 1) involves only the number of species that occurs in a single sample, whereas, Second order Jack knife (Jack knife 2) like Chao-2 considers

both the number of species occur in a single sample and exactly two samples (Burnham & Overton, 1978, 1979; Smith & van Belle, 1984; Magurran, 2013).

$$S_{\text{Jack1}} = S_{\text{obs}} + Q_1 (m-1/m)$$

Q_1 = the number of species that occur in one samples. m = number of samples.

$$S_{\text{Jack2}} = S_{\text{obs}} + (Q_1 (2m-3)/m - Q_2 (m-2)^2/m (m-1))$$

Q_2 = the number of species that occur in two samples. m = number of samples.

Species accumulation curve was plotted for the number of species obtained from carcass and it also estimated the number of expected species using the above said estimators (Chao-1, Chao-2, Jack-knife-1 and Jack-knife-2 methods). Each cycle of carcasses searches (that is searching of all 60 turbines) was considered as a single sample. Among 23 cycles, carcasses were detected only in ten cycles and considered for estimation. This analysis was done using Estimate S 9.1.0 (Colwell, 2013).

5.3 RESULTS

Totally, 47 bird mortalities belonging to 11 species (eight resident species and three winter visitors) including globally threatened species such as Dalmatian Pelican *Pelecanus crispus* (Vulnerable) and Painted Stork *Mycteria leucocephala* (Near-threatened) were recorded (Table 5-1, Plate 5-1) Eurasian Collared-dove *Streptopelia decaocto* had maximum number of collisions (10 individuals.) followed by Rock Dove *Columba livia* (six individuals). Common Kestrel *Falco tinnunculus*, Cattle Egret *Bubulcus ibis* and House Crow *Corvus splendens* had four mortalities each. In all 47 carcasses, only 34 carcasses were identified to species level, five carcasses were identified to family level (Accipitridae) and eight carcasses could not be identified to family level, as they were scavenged beyond recognition. The family Columbidae had maximum number of mortalities (16 individuals), followed by Accipitridae (five individuals) and Ardeidae (five individuals) (Figure 5-2). Among the 47 mortalities, 43 were recorded in migratory season or winter (from October to March) and four were recorded in non-migratory season or summer (from April to September) (Figure 5-3). Of the 59 turbines searched, 37 turbine locations had bird carcasses recorded.

All the carcasses were recorded within 80 m from the base of the turbine. Maximum numbers of carcasses (21) were recorded within 0-20 m from the base of the turbine

(Figure 5-4). Three fresh carcasses (Pallid scops-owl *Otus brucei*; Rock Dove *Columba livia* and Cattle Egret *Bubulcus ibis*) and seven scavenged carcasses (only feathers were remaining) found during search were left as such for the scavenger removal test. On an average, the fresh carcasses remained in the field for 1.3 days. However, the feathers of carcasses remained averagely for 23.7 ± 13 days. Since most of the observed carcasses were feather remains, 23.7 days was used as the residence time (mean length of time carcasses remained) for the estimation of annual mortality rate. The major scavengers seen in the study area during the surveys include Bengal Monitor Lizard *Varanus bengalensis*, Golden Jackal *Canis anthus* and domestic dog. The estimated annual bird mortality rate for Samakhiali wind farm is 0.478 birds/ turbine (1.8MW) /year.

Table 5-1. List of bird collisions at Samakhiali wind farm (between October 2011 and June 2014; from 59 turbine locations; 23 rounds of searches).

Family	Common name	Scientific Name	Resident Status	IUCN Status	No. of bird mortalities in Samakhiali
Ardeidae	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	R	LC	1
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>	R	LC	4
Dicruridae	Black Drongo	<i>Dicrurus macrocercus</i>	R	LC	1
Charadriidae	Red-wattled Lapwing	<i>Vanellus indicus</i>	R	LC	1
Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	R	NT	1
Columbidae	Rock Dove	<i>Columba livia</i>	R	LC	6
Columbidae	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	R	LC	10
Corvidae	House Crow	<i>Corvus splendens</i>	R	LC	4
Falconidae	Common Kestrel	<i>Falco tinnunculus</i>	WV	LC	4
Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	WV	VU	1
Strigidae	Pallid scops-owl	<i>Otus brucei</i>	WV	LC	1
Unidentified raptors of Family Accipitridae					5
Other unidentified taxa					8
Total					47

R-Resident; WV-Winter Visitor; LC-Least Concern; NT-Near Threatened; VU-Vulnerable

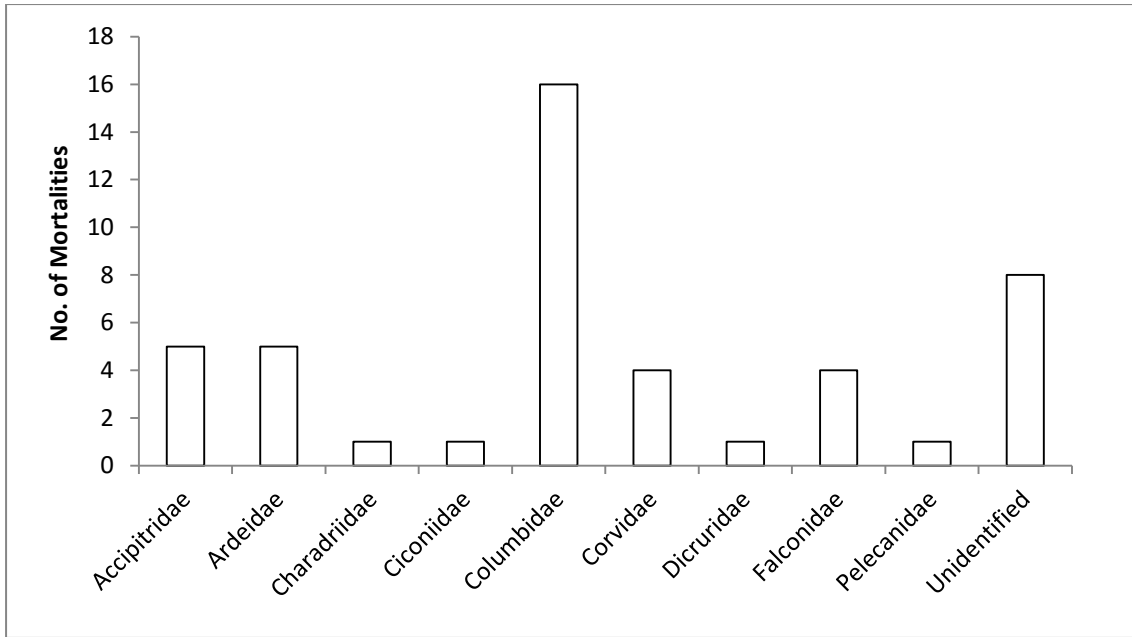


Figure 5-2. Variation of bird mortalities among different bird families

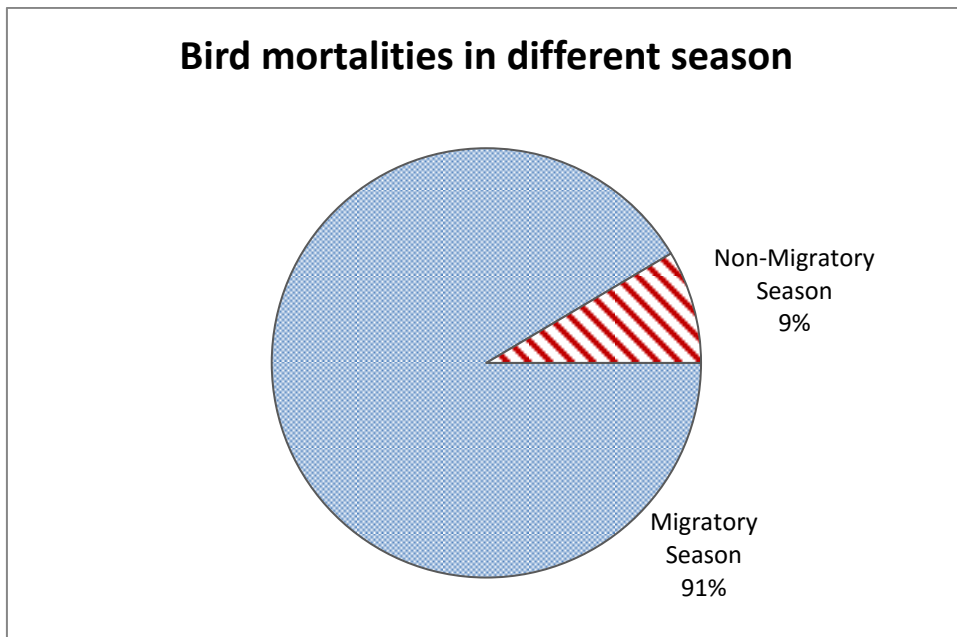


Figure 5-3. Percentage of bird mortalities recorded in non-migratory (April –September) and migratory seasons (October - March)

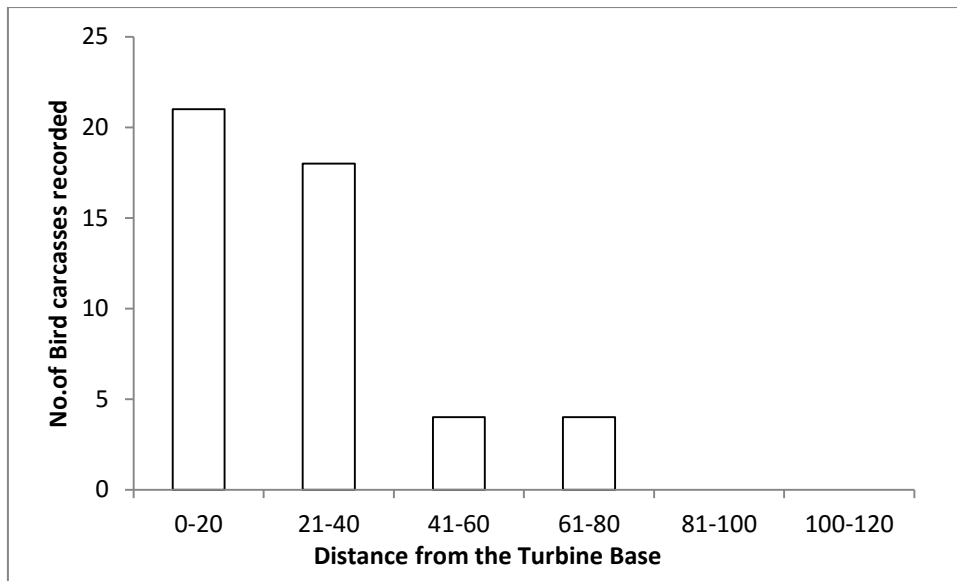


Figure 5-4. Distances from the base of turbine at which carcasses were recorded in Samakhiali wind farm.

The species accumulation curve did not reach asymptote, suggesting more carcass surveys, would have lead to additional species mortality records (Figure 5-5). The Chao-1 and Chao-2 methods estimated 20.89 ± 10.08 and 20 ± 9.2 respectively, whereas, Jack-knife-1 and Jack-knife 2 methods estimated 15.5 ± 2.1 and 19.5 ± 0 respectively, while the observed number of species to turbine mortality is 11 (Figure 5-6).

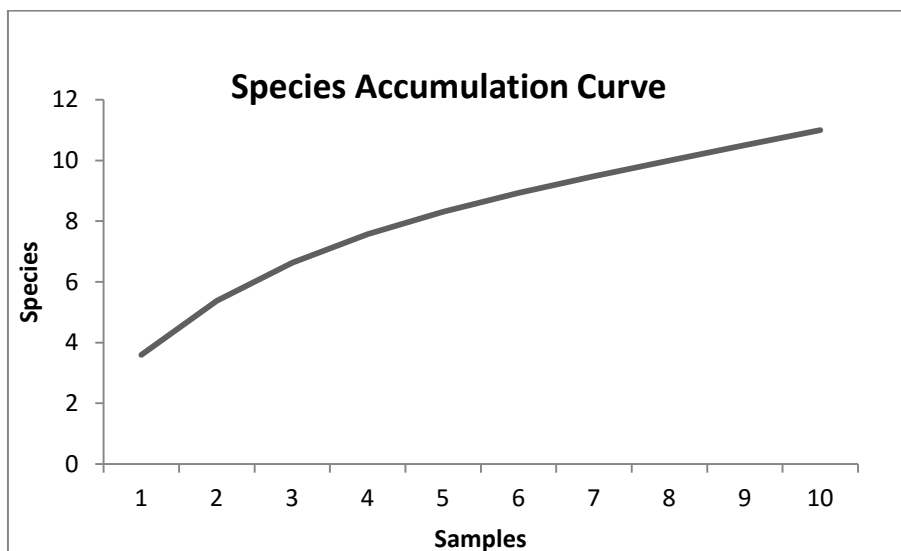


Figure 5-5. Species accumulation curve for carcass recorded at Samakhiali wind farm (with 100 randomization analysed using Estimate S).

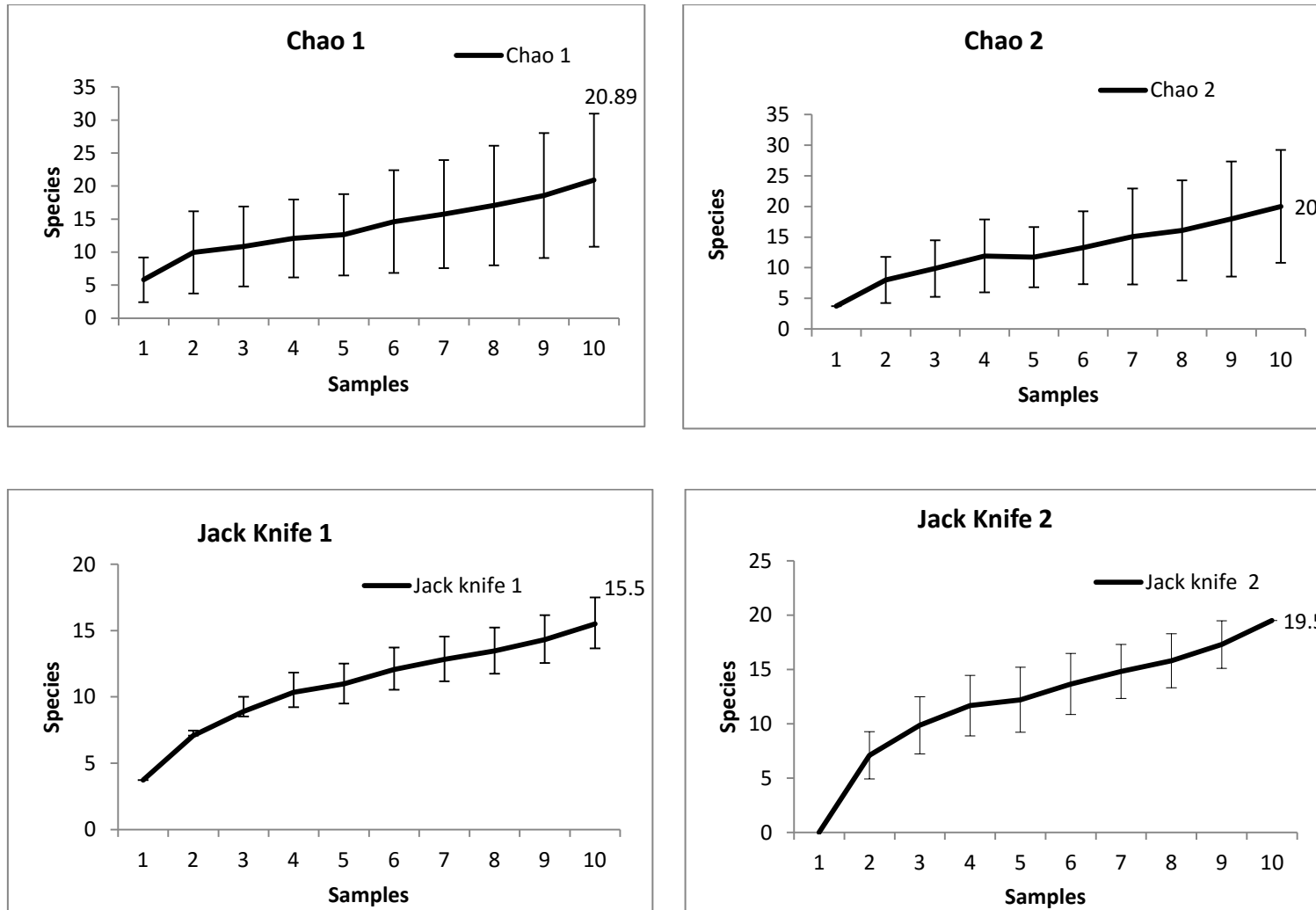


Figure 5-6. Number of expected species in carcasses at Samakhiali Wind farm calculated using various non-parametric species richness estimators (Observed number of species is 11).



Cattle Egret *Bubulcus ibis*



Pallid Scops-owl *Otus brucei*



Painted Stork *Mycteria leucocephala*



Unidentified Raptor



An injured Rock dove *Columba livia* (Note the Injuries on eye and under wings)



Plate 5-1. Some bird mortalities recorded at Samakhiali wind farm during the study

5.4 DISCUSSION

From the study it is concluded that 1) bird mortalities occur in Samakhiali wind farm, 2) the estimated bird mortalities per year is moderate when compared with other existing studies elsewhere 3) the species affected were mainly doves and raptors with few water-bird species and 4) there is high mortality during winter months than the summer months. The estimated rate of mortality, 0.478 birds/ turbine, is moderate when compared to other studies which range between 0 and 64 birds/turbine per year (Figure 5-1). Studies from other parts of the world have reported high mortalities such as 64.26 birds/turbine/year at El Perdón Spain (Lekuona, 2001; Hötker, 2006) and 54/birds/turbine/year (Erickson *et al.*, 2001) in Solano county USA. The present annual mortality rate of Samakhiali was similar to the rate observed at another Indian wind farm in Harapanahalli (0.466 birds/turbine) (Arun *et al.*, 2014), whereas Pande *et al.* (2013) predicted an estimate of 1.9 birds/turbine at Bhambarwadi wind farm, India. An average annual mortality rate of 0.265 birds/MW capacity was obtained from 0.478 birds/ turbine (1.8 MW Capacity). Based on this rate, the estimated mortality for India with an installed wind capacity of 27,151 MW (as of June 2016 (MNRE, 2016) will be 7,204 birds annually. The generalisation of the estimation is completely an approximate rate and it may vary, as mortality rate will be different according to geography, turbine structure and the bird composition in the wind farm location. However, the number is sufficient to indicate the pressures of turbines on birds; especially the type of species getting killed is of more concern than the numbers.

The recorded mortalities belonged to only 11 species of birds which are only a fraction of the actual number of bird species recorded from this region (175 species). The species accumulation curve for mortality suggests that there could be more species colliding with the turbines. Among the four methods of non-parametric species richness estimator used for estimating expected number of species being killed, Chao-1, Chao-2 and Jack-knife-2 all of them estimated almost the same number of species expected to be getting killed by blades. As these nonparametric estimators mainly rely on sample size, with more sampling number it possible to predict the number of species which gets killed more accurately.

Among the birds killed, doves (Eurasians Collared Dove and Rock dove) were the most affected species with respect to numbers. This is in accordance with few studies from

USA where high number of Rock Dove *Columba livia* mortality was also reported in many wind farms at USA (Erickson *et al.*, 2001). But in other two existing wind farms no dove mortalities were reported. (Pande *et al.*, 2013, Arun *et al.*, 2014). Next to doves raptors were the group of birds which got killed in more numbers. Four, Common Kestrel *Falco tinnunculus* were killed and five other raptors which could not be identified to species level due to the unrecognisable condition of the carcass. The mortality of raptor collision is common in most of studies reported so far (Orloff & Flannery, 1992; Carrete *et al.*, 2009). Even the other two studies from India also reported raptor mortality. In, Bhambarwadi wind farm, raptor species such as Black Kite *Milvus migrans*, Bonelli's Eagle *Hieraaetus fasciatus*, and Changeable Hawk-eagle *Nisaetus cirrhatus*, were killed (Pande *et al.*, 2013). In Karnatka an unidentified raptor was found to be killed (Pande *et al.*, 2013, Arun *et al.*, 2014). Apart from this a Critically Endangered White-backed Vulture *Gyps bengalensis* carcass was recorded in windmill site in Mawal, Pune. (Narwade, 2014).

The long term impacts of the wind farm on raptors are of greater concern, because they produce few offspring, they have a long life expectancy and they are placed in the top of food chain (Carrete *et al.*, 2009; Bellebaum *et al.*, 2013). Apart from doves and raptors considerable numbers of waterbird species (Dalmatian Pelican *Pelecanus crispus*, Painted Stork *Mycteria leucocephala*, Black-crowned Night-heron *Nycticorax nycticorax* and Red-wattled Lapwing *Vanellus indicus*) were killed in the Samakhiali wind farm. However the other two studies in India reported no water bird mortality (Pande *et al.*, 2013, Arun *et al.*, 2014). The presence of large number of wetlands in and around Samakhiali wind farms attracts large number of water birds which might have led to the collision with the wind turbines. The present study reported very less passerine mortality unlike the high passerine mortalities recorded in wind farms outside California (Erickson *et al.*, 2001). This may be due to the varied passerine species composition and geography. The low passerine mortalities in this study may also due to the long interval between the two subsequent searchers as the small sized passerine carcasses might have scavenged hence made it difficult to notice the remaining.

Out of 47, 43 carcasses were recorded during the migratory season (winter) but most of the bird carcasses (41) were of resident species. This suggests the role of parameters such as climatic conditions in determining bird mortalities apart from the bird composition of

the area. Whereas, in other two studies from India, most of the mortalities are during non-migratory (Monsoon and summer) period, indicating that the months in which birds getting killed may vary based on the geographical location of the wind farm.

In the present study, about 92 % of the carcasses were recorded within 60 m from the base of the turbine. Only 8 % of the carcasses were observed between 60-130 m from the turbine base. Arun *et al.* (2014) recorded all the bird carcasses within 60 m from the turbine base at Harapanahalli wind farm, India. Such patterns has also been observed from other countries, for instance Kerns & Kerlinger (2004) observed most of the bird carcasses within 45 m from the turbine base at Mountaineer Wind Energy Center, West Virginia USA. Hence, a search area of 100 m radius from turbine base is sufficient to record the bird carcasses in most field condition.

Apart from the collision with wind turbines, bird mortality due to other anthropogenic pressures such as power line electrocutions, communication tower collisions, road kills are reported to be a serious issue (Bujoczek *et al.*, 2011; Loss *et al.*, 2015). Similarly, during the study period there were many bird mortalities caused by the vehicular movements on the roads which connect villages in the wind farms. Common Babbler *Turdoides caudata* and House Sparrow *Passer domesticus* were the most common in mortalities. There were few incidents of electrocutions of birds due to the transmission lines within wind farm. Carcasses of Indian Peafowl *Pavo cristatus*, Rock Dove *Columba livia* and House Crow *Corvus splendens* were observed under the transmission lines and pylons. Studies report the number of bird mortality caused due to wind turbines are lower than power line collision, building and automobile related bird collisions (Loss *et al.*, 2015). In the present study no systematic documentation has been done on these mortalities and further studies are needed on comparing the mortalities caused by these various anthropogenic activities in India.

Apart from the bird mortalities, four carcasses of insectivorous bats (three Greater Mouse tailed bat *Rhinopoma microphyllum* and one unidentified species) were also recorded from the turbine base during the study period (Kumar, *et al.*, 2013). No noticeable insect and other faunal mortalities were recorded from the turbine base. This study gives an insight of the magnitude of impact of wind turbines in Samakhiali on the avifauna. More studies on different landscapes of India will reveal a clear picture of this interaction.

6 COLLISION RISK FACTORS

6.1 INTRODUCTION

There are many factors which contribute to the collision of birds with the wind turbines. The morphology of birds, its flight mechanism and other behaviours are determinants for collision mortalities. Morphological and behavioural features like large body size, gliding type of flight and flying in flocks are found to increase the risk of collision (Langston & Pullan, 2003; Kikuchi, 2008). Structural difference in the turbine also alters the bird mortality risk (Barclay *et al.*, 2007). The tall structures like communication towers are known to affect migrating birds and it is believed that the wind turbines with taller towers and guy wires may cause greater collision risk (Powlesland, 2009). Turbines with more lightings are reported to cause more bird collisions due to the trapping effect created by the lights (Drewitt & Langston, 2008; Powlesland, 2009). Old generation wind turbine blades are very small in length (3-10 m) with very high rotation speed (40-60 rpm) which leads to high collision risk (Powlesland, 2009), compared to present day turbine with long blades (~ 50 m) and slow rotation.

Location of the wind turbine is another major factor which influences bird mortalities. Migratory birds are known to follow land patterns such as coast, river and ridges. Coastal islands are known to act as resting and feeding place for large congregations of migratory birds which migrate over large water bodies (Crossland *et al.*, 2006). Wind turbines set up in such migratory pathways increases the collision risk and also cause the barrier effect to the moving birds. This increases the distance travelled and energy expenditure of the bird (Powlesland, 2009; Masden *et al.*, 2010). It is reported that turbines located in bare mountain ridges and water bodies cause more mortalities (Hötker, 2006). Apart from the location of the wind turbines, weather conditions also play a role in collision risk of birds at turbines. Generally, the weather conditions such as fog and rain that affects the visibility of the birds would increase the risk of collision (Erickson *et al.*, 2001; Kerns & Kerlinger, 2004).

Even in the same wind farm different species have different collision risks. Irrespective of the total number of birds present in the wind farm area, birds that highly using the Rotor Swept Zone (RSZ) of turbines for their flights are at higher risk of collision (Barclay *et*

al., 2007; de Lucas *et al.*, 2008). For instance, de Lucas *et al.* (2008) found that the mortality of raptors does not correlate with abundance of raptor in a wind farm at Andalusia region of southern Spain. Hence, to understand the species specific collision risk of birds it is necessary to study the usage of the Rotor Swept Zone (RSZ) of the wind turbine by the birds. The collision risk assessment studies rely on the visual observation of bird activity (Osborn *et al.*, 1998; Johnston *et al.*, 2014). Some of the recent studies also used laser rangefinders to get the exact height measurements (Stantial & Cohen 2015; Wulff *et al.* 2016). Study by Stantial & Cohen, (2015) estimated the flight heights of breeding Piping Plover *Charadrius melodu* at Atlantic coast of the United States. Similarly Wulff *et al.*, (2016) estimated the actual flight height and proportion of bird species observed at Rotor Swept Zone (RSZ) of the turbines at Southern Great Plains of Texas. They found, the flight height of 28 species matching with the RSZ, and among that 14 species had greater risk of collision as more than 25% of their flight time was spent in the RSZ.

In India, studies on the factors influencing bird mortalities on wind turbines are scarce. Pande *et al.*, (2013) studied the species specific collision risk of birds at a wind farm in Maharashtra based on their occurrence in the RSZ. They found that, out of 89 species recorded, 27 species mostly raptor species were observed in the RSZ. The collision risk estimated by Pande *et al.*, (2013) showed that the raptors are in higher risk of collision with the turbines than other bird groups and the top five species which had maximum collision risk index were Common Kestrel *Falco tinnunculus*, Red-rumped Swallow *Hirundo daurica*, Black Kite *Milvus migrans*, Bonelli's Eagle *Hieraaetus fasciatus* and Changeable Hawk-Eagle *Spizaetus cirrhatus*. Another study conducted at Harapanahalli, Karnataka by Arun *et al.*, (2014) found, four species of birds (Bonelli's Eagle *Hieraaetus fasciatus*, Short-toed Snake Eagle *Circaetus gallicus*, Black Kite *Milvus migrans* and Brahminy Kite *Haliastur indus*) out of 15 species observed were found flying in the Risk zone.

There is no further information on the above mentioned aspects from India. The present study was conducted to further contribute to the knowledge of species specific collision risk of birds from Indian condition. The potential factors influencing the wind turbine bird mortalities such as bird morphology, flight behaviour, and vertical distribution of bird and location of turbines are also analysed in this chapter.

6.2 METHODS

6.2.1 Overview of Existing Methods

Various methods are used to assess the species specific collision risk of birds. Majority of collision risk assessment studies were based on the visual observation of flight zone of the birds by keeping turbine as reference (Osborn *et al.*, 1998; Mabee *et al.*, 2006; Larsen, 2007; Pande *et al.*, 2013; Johnston *et al.*, 2014.). Few studies also used laser rangefinder to measure the exact height of bird species (Stantial & Cohen 2015; Wulff *et al.*, 2016). There are other remote techniques like radar systems, infrared cameras which can also be used for gathering information on the collision behaviour of birds. In the present study, due to practical advantage, visual observation method was preferred. Details of the methods were discussed as follows

6.2.2 Flight Activity Survey

Flight activities of all bird species flying in wind farm area were surveyed from August to December 2013. The observations were recorded from six vantage points located on the edge of the wind farm and all the points were at minimum distance of 500 m from the closest turbine. Points were located minimum 5 km apart from each other. Surveys were conducted between the time period of 0600 hrs and 1900 hrs in irregular intervals. Only single vantage point was surveyed at a given time. Totally 92 hours of observation was done with minimum of 9 hrs at all points.

The flight heights of birds were divided into three height bands, keeping wind turbine as a reference. The height of turbine from ground to tip of hub was 95 m and each blade was of 50 m length, making the total height of the turbine from ground to top most points swept by rotor blade as 145m. The ‘height band1’ was below the blades of turbine i.e. 0 to 45 m height. ‘height band 2’ or ‘Rotor Swept Zone’ or ‘RSZ’ is the region between the lowest and top most points swept by the rotor blades or the aerial height band swept by the rotor blades that is from 45m to 145m.

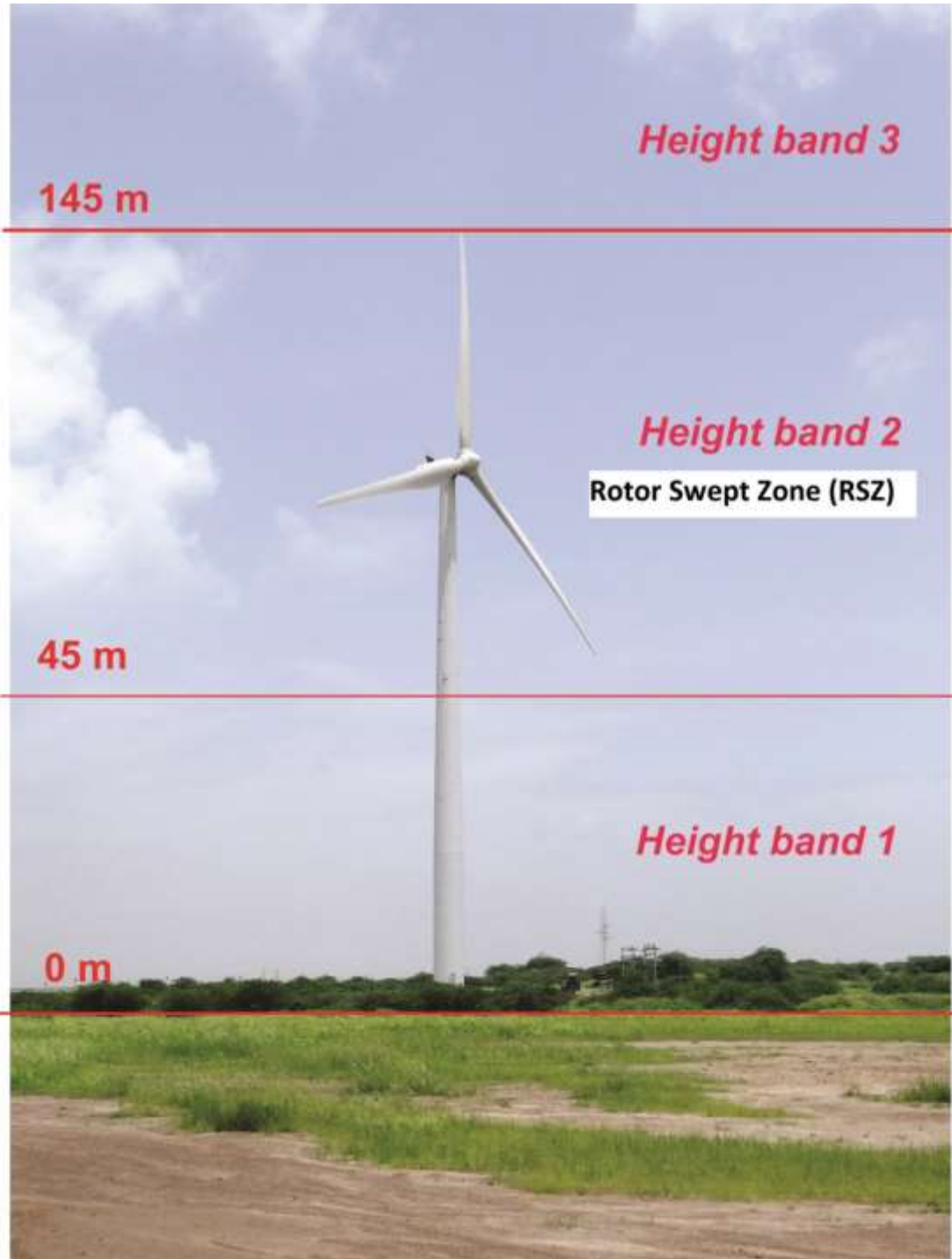


Figure 6-1. Representation of three height bands used for flight height survey

The 'height band 3' is above the RSZ i.e. above 145 m (Figure 6-1). All the birds flying in the wind farm were observed till it disappeared from the view using binoculars.

Species type, number of birds, height band in which the birds were flying and duration of the flight of each bird in different height bands were recorded. Identification of birds was done using standard field guides (Ali & Ripley 2001; Grimmett *et al.*, 2011) and the nomenclature followed is from del Hoyo *et al.*, (2014). For few species which were not listed in del Hoyo *et al.*, (2014) nomenclature from Praveen *et al.*, (2016) was followed.

6.2.3 Habitat and Bird Morphological Data Extraction

The morphological characters and flight behaviour of birds were extracted from standard books to analyse whether these factors play any role in deciding wind turbine related mortalities. The body mass of birds were extracted from Dunning (2008) and other measurements such as body length (from tip of bill to tip of tail), wing length (from carpal joint to tip of longest feather), tail length (from origin point of central tail feather to tip of the longest tail feather) were extracted from Ali & Ripley (2001). The flight types of birds were categorized into two types: gliding and non-gliding based on the keys provided by Ali & Ripley (2001). Birds such as doves which occasionally use air current to glide were also considered as gliders. Similarly flock size of birds were categorized into solitary, small flock (~ less than 20) and large flocks (~ greater than 20) based on the field flight observation data and the information provided by Ali & Ripley (2001).

6.2.4 Habitat Data Extraction

To assess the role of turbine location on bird mortalities, habitat variables for all the 59 turbine locations studied were collected. Turbine density i.e. density of turbines (number of turbines within one km radius) for each study turbine location was calculated with the help of open source GIS software QGIS 2.10.1. 2). Normalised Difference Vegetation Index (NDVI) for 59 selected turbine locations were extracted from Google earth Engine repository for geospatial data. Other variables includes, distance (in km) from each selected turbine location to the 1) nearest fresh water body (Ponds, Lakes and Check dams), 2) Human habitation and 3) Salt Marsh (Salt Pans) were measured from Google earth Imagery 2013 using QGIS 2.10.1. The altitude of turbine locations were also recorded using a GPS/Altimeter (Garmin e-Trex Vista H).

6.2.5 Statistical Analysis

The proportion of flight duration within the RSZ of each species was estimated by dividing the duration of flight in RSZ by total duration of flight observation of that species. The species with 25 % of their flight duration within RSZ were considered as those at greater risk of collision (using exact binomial test) as followed in Wulff *et al.*, (2016). Generalized linear model (GLM- Family - Poisson with log link) was performed to assess the role of morphology, flight behaviour, and flight duration of birds in causing mortalities. The model with number mortalities of bird species as response variable had explanatory variables such as wing length and body length, flight type (Gliding/Non Gliding) and Flock Size (Solitary/Small flock/Large flock). The strongly inter correlated variables such as Body and Tail length were excluded from the analysis.

To analyse the role of turbine location on deciding bird mortalities, GLM models (Family=Poisson with log link function) were performed with turbine location variables such as distance to village, distance to wetland, distance to salt marsh, NDVI and turbine density as explanatory variables. Altitude of turbine location had strong negative correlation with the distance to salt pans; hence it was not included for the analysis. Four separate models were built, using 1) all bird mortalities, 2) dove and pigeon mortalities 3) raptor mortalities and 4) wetland bird mortalities as response variable. GLMs were performed in CANOCO 5 (ter Braak & Šmilauer, 2012) and exact binomial test was performed using R (Team, 2015).

6.3 RESULTS

6.3.1 Vertical Distribution of Bird Flight Heights in the Wind Farm

Totally, 71 species of birds belonging to 32 families were found flying in the wind farm area during the 92 hour survey. Of these, 48 species were resident to the study area and 23 species were winter migrants. Family Accipitridae had maximum number of species (13) followed by Ardeidae (8). Of the 71 species, Steppe Eagle *Aquila nipalensis* is categorized as Endangered, Greater Spotted Eagle *Clanga clanga* and Dalmatian Pelican *Pelecanus crispus* as Vulnerable and Pallid Harrier *Circus macrourus*, Black-necked Stork *Ephippiorhynchus asiaticus*, Painted Stork *Mycteria leucocephala*, River Tern *Sterna aurantia*, Black-headed Ibis *Threskiornis melanocephalus* as Near Threatened as per IUCN (IUCN, 2016). In all, 28 species were used gliding type of flight and remaining

43 species did not use gliding type of flight (Figure 6-2). Among 71 species, 34 species were solitary birds, 23 species were of small flock category and remaining 14 species falls in large flock category (Figure 6-3).

Among the three height bands, height band 1 (that is below the RSZ) had maximum number of species (64) followed by RSZ (49 species). The abundance of birds was higher in ‘height band 1’ (3180 individuals) (Figure 6-4). Overall, Rosy Starling (3675) had maximum number of individual followed by Demoiselle Crane *Grus virgo* (552) and Dalmatian Pelican *Pelecanus crispus* (438) (Appendix 3). In the RSZ, Rosy Starling *Sturnus roseus* (495), Demoiselle Crane *Grus virgo* (352) and Painted Stork *Mycteria leucocephala* (131) had maximum number of individuals. Total bird flight activity irrespective of the number of species and number of individuals, was 710 minutes. Out of this, 301 minutes of flight activity was observed in the RSZ. Among the bird species, Painted Stork *Mycteria leucocephala* (186 min) had maximum flight duration in all three height bands together, followed by Cattle Egret *Bubulcus ibis* (48 min) and Steppe Eagle *Aquila nipalensis* (46 min). Similar patterns were observed in the RSZ as well, (Painted Stork *Mycteria leucocephala* (90 min), Cattle Egret *Bubulcus ibis* (31min) Steppe Eagle *Aquila nipalensis* (27min)).

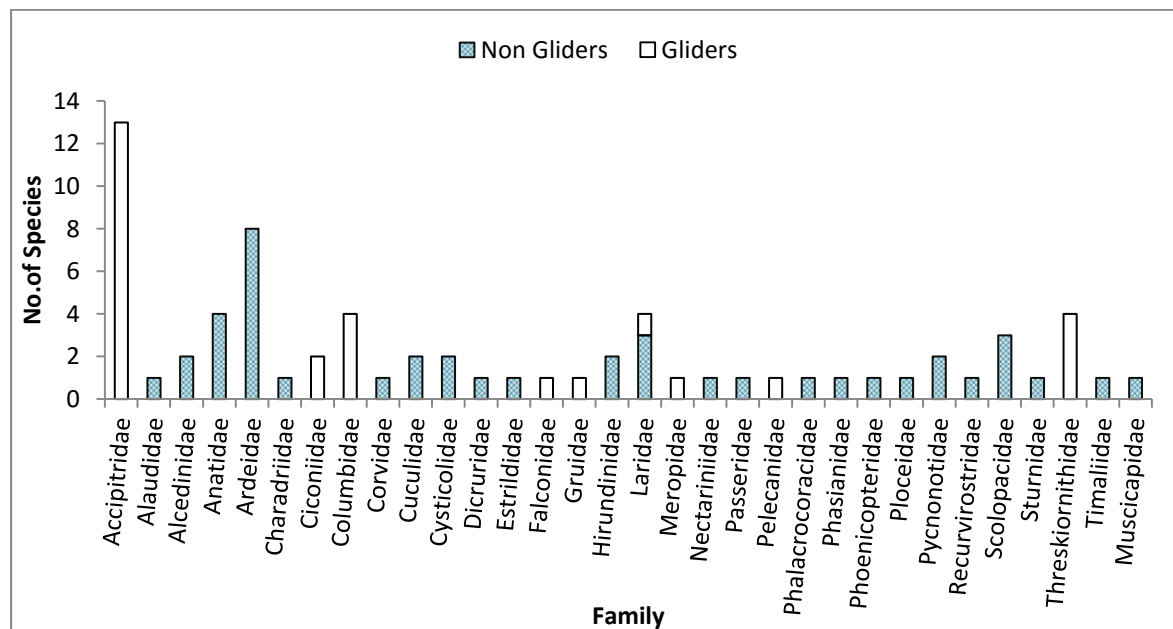


Figure 6-2. Family wise species richness and flight type of birds (n = 71)

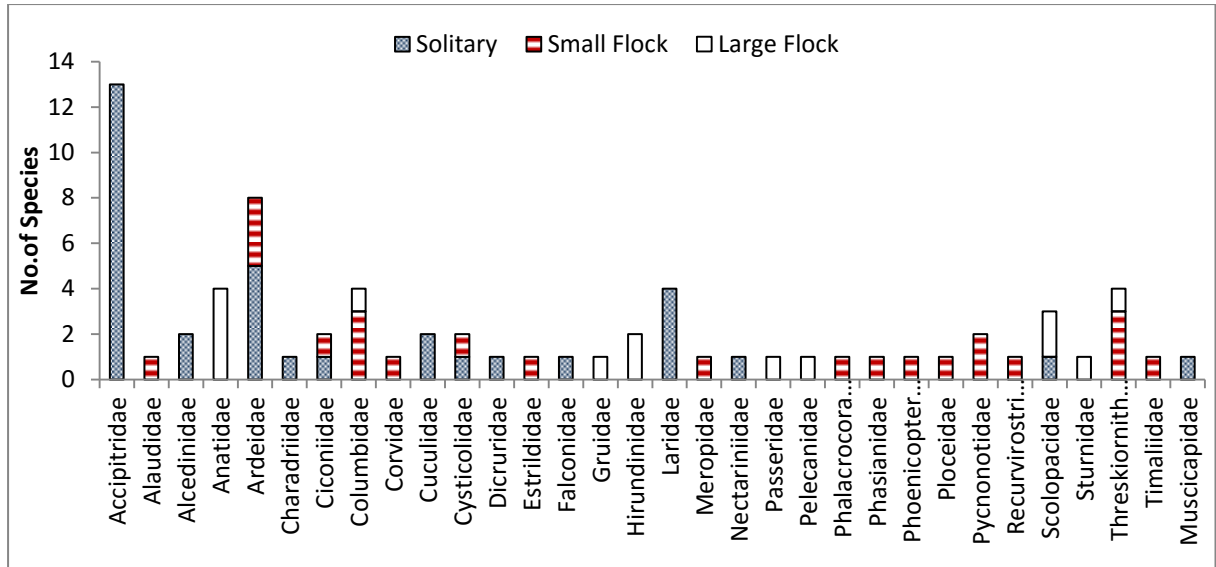


Figure 6-3. Species Richness and flock size pattern in bird families (n = 71)

Of the 71 species recorded, 36 species had more than 25 % of their flight in the RSZ and these species are considered to be at greater risk of collision (Table 6-1). Among these, 55.5 % were wetland associated species and 36 % were raptors (Figure 6-5). Three of these species are globally threatened (Steppe Eagle *Aquila nipalensis*, Greater Spotted Eagle *Clanga clanga* & Dalmatian Pelican *Pelecanus crispus*) and five are Near-threatened species (Pallid Harrier *Circus macrourus*, Black-necked Stork *Ephippiorhynchus asiaticus*, Painted Stork *Mycteria leucocephala*, River Tern *Sterna aurantia* and Black-headed Ibis *Threskiornis melanocephalus*, IUCN, 2016).

The Endangered species Steppe Eagle *Aquila nipalensis* was observed flying 24.6 minutes in the RSZ out of its 45.7 minutes total recorded flight duration. The vulnerable species Greater Spotted Eagle *Clanga clanga* and Dalmatian Pelican *Pelecanus crispus* had 18.3 min (out of 20.5 min) and 7.2 min (out of 26 min) in RSZ respectively. Bird species like Northern Pintail *Anas acuta*, Glossy Ibis *Plegadis falcinellus*, Heuglin's Gull *Larus heuglini*, White-eared Bulbul *Pycnonotus leucotis*, Rock Dove *Columba livia*, Black-headed Ibis *Threskiornis melanocephalus*, Greater Spotted Eagle *Clanga clanga*, Booted Eagle *Hieraaetus pennatus*, Common Buzzard *Buteo buteo*, Short-toed Snake Eagle *Circaetus gallicus*, Common Tern *Sterna hirundo* and Greater Flamingo *Phoenicopterus roseus* had more than 75% of their total observed flight in RSZ.

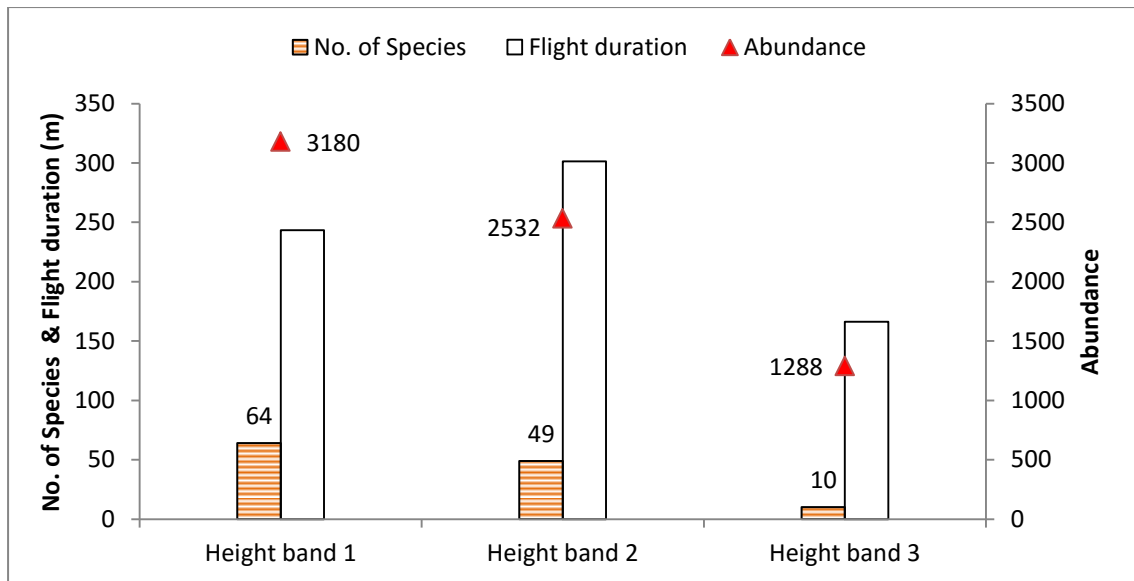


Figure 6-4. Number of species, abundance and flight duration of birds observed at three different height bands during flight height survey.

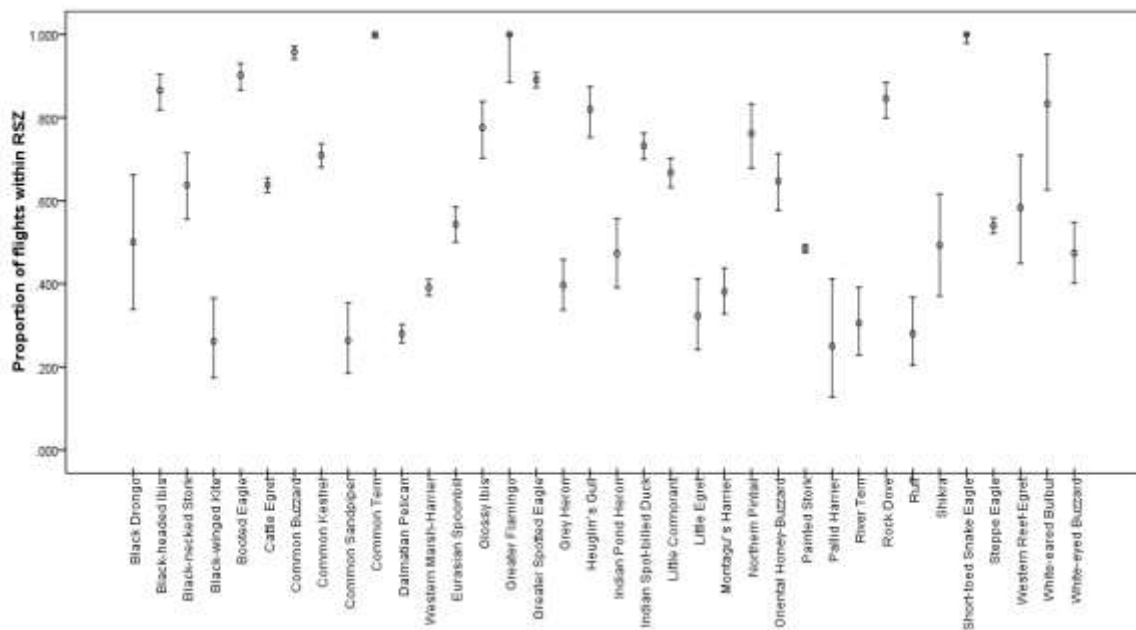


Figure 6-5. Birds with more than 0.25 proportion (25%) of their flight heights observed in RSZ (45-145 m). Black dots are the proportion of flight heights within the RSZ and the error bars are 95% confidence intervals (Units in the Y axis is 0 to 1), See. Appendix 3 for more information.

Table 6-1. List of bird species observed during the flight height survey (92 hours observation) with their duration of flight at different height band and proportion of flight at RSZ.

Family	Common name	Scientific Name	Flight time in minutes			Proportion of flight in Risk zone		
			Band 1	Band 2 (RSZ)	Height band 3	Proportion (Lower confidence level)	Actual Proportion	Proportion (Upper confidence level)
Accipitridae	Black-winged Kite	<i>Elanus caeruleus</i>	1.08	0.38	0	0.17	0.26	0.37
Accipitridae	Booted Eagle	<i>Hieraaetus pennatus</i>	0.58	5.33	0	0.87	0.9	0.93
Accipitridae	Common Buzzard	<i>Buteo buteo</i>	0.48	11	0	0.94	0.96	0.97
Accipitridae	Griffon Vulture	<i>Gyps fulvus</i>	0	0	7.02	0	0	0.01
Accipitridae	Greater Spotted Eagle	<i>Clanga clanga</i>	0	18.32	2.25	0.87	0.89	0.91
Accipitridae	Montagu's Harrier	<i>Circus pygargus</i>	3.25	2	0	0.33	0.38	0.44
Accipitridae	Oriental Honey-Buzzard	<i>Pernis ptilorhynchus</i>	1.18	2.17	0	0.58	0.65	0.71
Accipitridae	Pallid Harrier	<i>Circus macrourus</i>	0.5	0.17	0	0.13	0.25	0.41
Accipitridae	Shikra	<i>Accipiter badius</i>	0.58	0.57	0	0.37	0.49	0.62
Accipitridae	Short-toed Snake Eagle	<i>Circaetus gallicus</i>	0	2.88	0	0.98	1	1
Accipitridae	Steppe Eagle	<i>Aquila nipalensis</i>	4.17	24.67	16.87	0.52	0.54	0.56
Accipitridae	Western Marsh-harrier	<i>Circus aeruginosus</i>	17.07	16.45	8.58	0.37	0.39	0.41
Accipitridae	White-eyed Buzzard	<i>Butastur teesa</i>	1.67	1.5	0	0.4	0.47	0.55
Alaudidae	Rufous-tailed Lark	<i>Ammomanes phoenicura</i>	0.15	0	0	0	0	0.34
Alcedinidae	Pied Kingfisher	<i>Ceryle rudis</i>	0.43	0	0	0	0	0.13
Alcedinidae	White-breasted Kingfisher	<i>Halcyon smyrnensis</i>	0.85	0	0	0	0	0.07
Anatidae	Lesser Whistling Duck	<i>Dendrocygna javanica</i>	2.6	0	0	0	0	0.02
Anatidae	Northern Pintail	<i>Anas acuta</i>	0.5	1.6	0	0.68	0.76	0.83
Anatidae	Northern Shoveler	<i>Spatula clypeata</i>	3.35	0.42	0	0.07	0.11	0.16

Family	Common name	Scientific Name	Flight time in minutes			Proportion of flight in Risk zone		
			Band 1	Band 2 (RSZ)	Height band 3	Proportion (Lower confidence level)	Actual Proportion	Proportion (Upper confidence level)
Anatidae	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	3.53	9.63	0	0.7	0.73	0.76
Ardeidae	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	1.25	0	0	0	0	0.05
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>	17.35	30.52	0	0.62	0.64	0.66
Ardeidae	Grey Heron	<i>Ardea cinerea</i>	2.67	1.75	0	0.34	0.4	0.46
Ardeidae	Intermediate Egret	<i>Ardea intermedia</i>	0.53	0	0	0	0	0.11
Ardeidae	Great White Egret	<i>Ardea alba</i>	0.17	0	0	0	0	0.31
Ardeidae	Little Egret	<i>Egretta garzetta</i>	1.4	0.67	0	0.24	0.32	0.41
Ardeidae	Indian Pond Heron	<i>Ardeola grayii</i>	1.3	1.17	0	0.39	0.47	0.56
Ardeidae	Western Reef-egret	<i>Egretta gularis</i>	0.42	0.58	0	0.45	0.58	0.71
Charadriidae	Red-wattled Lapwing	<i>Vanellus indicus</i>	5.07	0.3	0	0.03	0.06	0.09
Ciconiidae	Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	0.9	1.58	0	0.55	0.64	0.71
Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	4.25	90.12	91.57	0.48	0.48	0.49
Columbidae	Rock Dove	<i>Columba livia</i>	0.77	4.18	0	0.8	0.85	0.88
Columbidae	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	21.9	2.43	0	0.09	0.1	0.12
Columbidae	Laughing Dove	<i>Spilopelia senegalensis</i>	17.17	0.25	0	0.01	0.01	0.02
Columbidae	Red Turtle-dove	<i>Streptopelia tranquebarica</i>	0.33	0	0	0	0	0.17
Corvidae	House Crow	<i>Corvus splendens</i>	34.45	7.13	0	0.16	0.17	0.19
Cuculidae	Asian Koel	<i>Eudynamys scolopaceus</i>	0.2	0	0	0	0	0.26
Cuculidae	Greater Coucal	<i>Centropus parroti</i>	0.22	0	0	0	0	0.25
Cysticolidae	Ashy-crowned Sparrow Lark	<i>Eremopterix grisea</i>	1.5	0	0	0	0	0.04

Family	Common name	Scientific Name	Flight time in minutes			Proportion of flight in Risk zone		
			Band 1	Band 2 (RSZ)	Height band 3	Proportion (Lower confidence level)	Actual Proportion	Proportion (Upper confidence level)
Cysticolidae	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	0.35	0	0	0	0	0.16
Dicruridae	Black Drongo	<i>Dicrurus macrocercus</i>	0.33	0.33	0	0.34	0.5	0.66
Estrildidae	White-throated Munia	<i>Euodice malabarica</i>	0.55	0	0	0	0	0.11
Falconidae	Common Kestrel	<i>Falco tinnunculus</i>	4.8	11.7	0	0.68	0.71	0.74
Gruidae	Demoiselle Crane	<i>Grus virgo</i>	0	3.3	20.4	0.12	0.14	0.16
Hirundinidae	Barn Swallow	<i>Hirundo rustica</i>	4.67	0	0	0	0	0.01
Hirundinidae	Red-rumped Swallow	<i>Cecropis daurica</i>	15.15	0.83	0	0.04	0.05	0.07
Laridae	Common Tern	<i>Sterna hirundo</i>	0	7.85	0	0.99	1	1
Laridae	Heuglin's Gull	<i>Larus heuglini</i>	0.5	2.27	0	0.75	0.82	0.87
Laridae	River Tern	<i>Sterna aurantia</i>	1.52	0.67	0	0.23	0.31	0.39
Laridae	Whiskered Tern	<i>Chlidonias hybrida</i>	4	1.05	0	0.16	0.21	0.26
Meropidae	Asian Green Bee-eater	<i>Merops orientalis</i>	2.13	0.08	0	0.01	0.04	0.09
Muscicapidae	Indian Robin	<i>Saxicoloides fulicatus</i>	0.33	0	0	0	0	0.17
Nectariniidae	Purple Sunbird	<i>Cinnyris asiaticus</i>	5.45	0.1	0	0.01	0.02	0.04
Passeridae	House Sparrow	<i>Passer domesticus</i>	1.98	0	0	0	0	0.03
Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	0.92	7.27	17.8	0.26	0.28	0.3
Phalacrocoracidae	Little Cormorant	<i>Microcarbo niger</i>	3.42	7.87	0.5	0.63	0.67	0.7
Phasianidae	Grey Francolin	<i>Francolinus pondicerianus</i>	0.08	0	0	0	0	0.52
Phoenicopteridae	Greater Flamingo	<i>Phoenicopterus roseus</i>	0	0.5	0	0.88	1	1
Ploceidae	Baya Weaver	<i>Ploceus philippinus</i>	0.4	0	0	0	0	0.14
Pycnonotidae	Red-vented Bulbul	<i>Pycnonotus cafer</i>	2.27	0	0	0	0	0.03

Family	Common name	Scientific Name	Flight time in minutes			Proportion of flight in Risk zone		
			Band 1	Band 2 (RSZ)	Height band 3	Proportion (Lower confidence level)	Actual Proportion	Proportion (Upper confidence level)
Pycnonotidae	White-eared Bulbul	<i>Pycnonotus leucotis</i>	0.07	0.33	0	0.63	0.83	0.95
Recurvirostridae	Black-winged Stilt	<i>Himantopus himantopus</i>	2.98	0.77	0	0.15	0.2	0.26
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	1.4	0.5	0	0.19	0.26	0.35
Scolopacidae	Green Sandpiper	<i>Tringa ochropus</i>	0.17	0	0	0	0	0.31
Scolopacidae	Ruff	<i>Philomachus pugnax</i>	1.5	0.58	0	0.2	0.28	0.37
Sturnidae	Rosy Starling	<i>Sturnus roseus</i>	20.52	4.48	0.75	0.16	0.17	0.19
Threskiornithidae	Red-naped Ibis	<i>Pseudibis papillosa</i>	7.52	2.4	0	0.21	0.24	0.28
Threskiornithidae	Eurasian Spoonbill	<i>Platalea leucorodia</i>	4.1	4.87	0	0.5	0.54	0.59
Threskiornithidae	Glossy Ibis	<i>Plegadis falcinellus</i>	0	2.02	0.58	0.7	0.78	0.84
Threskiornithidae	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	0.58	3.75	0	0.82	0.87	0.9
Timaliidae	Common Babbler	<i>Turdoides caudata</i>	1.82	0	0	0	0	0.03

6.3.2 Factors Influencing Bird Mortalities

6.3.2.1 Morphology and flight behaviour

Birds with gliding type of flight had an abundance of 656 birds in RSZ during the survey and had 28 mortalities. The non-gliding birds had 1876 individual in RSZ and had only 11 mortalities (Figure 6-6) indicating higher risk for the birds with predominantly gliding type of flight. The birds with large flock size had maximum abundance in the RSZ (1955 individuals) followed by birds with small flock size (486) and solitary birds (91) but bird mortalities were higher in small flock size (20) followed by solitary (12) and large flock size bird group (7) (Figure 6-7).

The GLM model with morphological character and flight character of birds as explanatory variable explained 33.1 % of variation ($F = 10.01$, $p = 0.001$). Among the morphological characters only the wing length significantly influenced bird mortality ($t = -1.881$, $p = 0.001$) (Table 6-3). Whereas, neither flight type nor the flock size of birds significantly influenced bird mortalities.

Table 6-2. Pearson correlation matrix for independent variable used for the model

Variabes	Body length	Body Mass	Wing Length	Tail length
Body length		0.00	0.01	0.00
Body Mass	0.85		0.12	0.00
Wing Length	0.31	0.19		0.00
Tail length	0.67	0.56	0.48	

Table 6-3. GLM model showing the influence of morphological and flight characters on bird mortality. Dependent variable: number of mortalities in each species. (AIC: 142.26, $df = 8, 62$).

Variables	B	SE	t	p(t)
(Intercept)	-1.398	0.584	-2.39	0.019
Body Mass	-0.000	0.001	-1.881	0.064
Wing length	0.004	0.001	4.301	0.001
Non-gliding Flight	-0.824	0.422	-1.94	0.055
Medium Flock Size	0.243	0.367	0.662	0.509
Large Flock Size	-12.25	144.78	-0.084	0.932

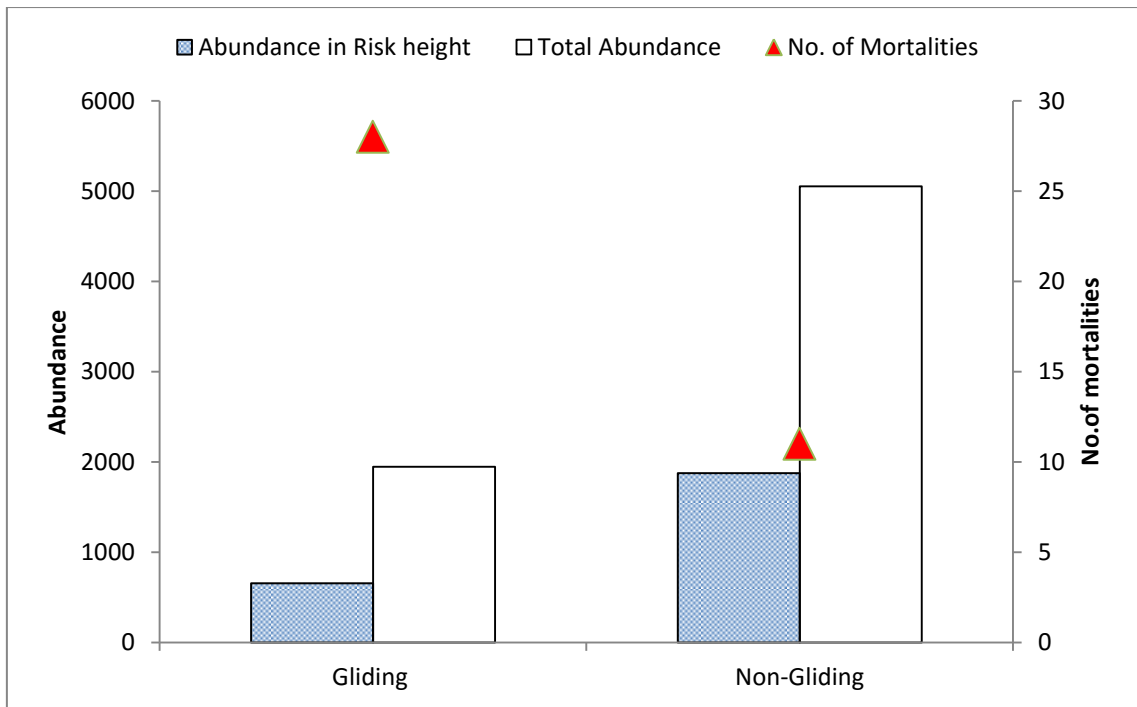


Figure 6-6. Abundance and mortalities of birds between two different flight type groups

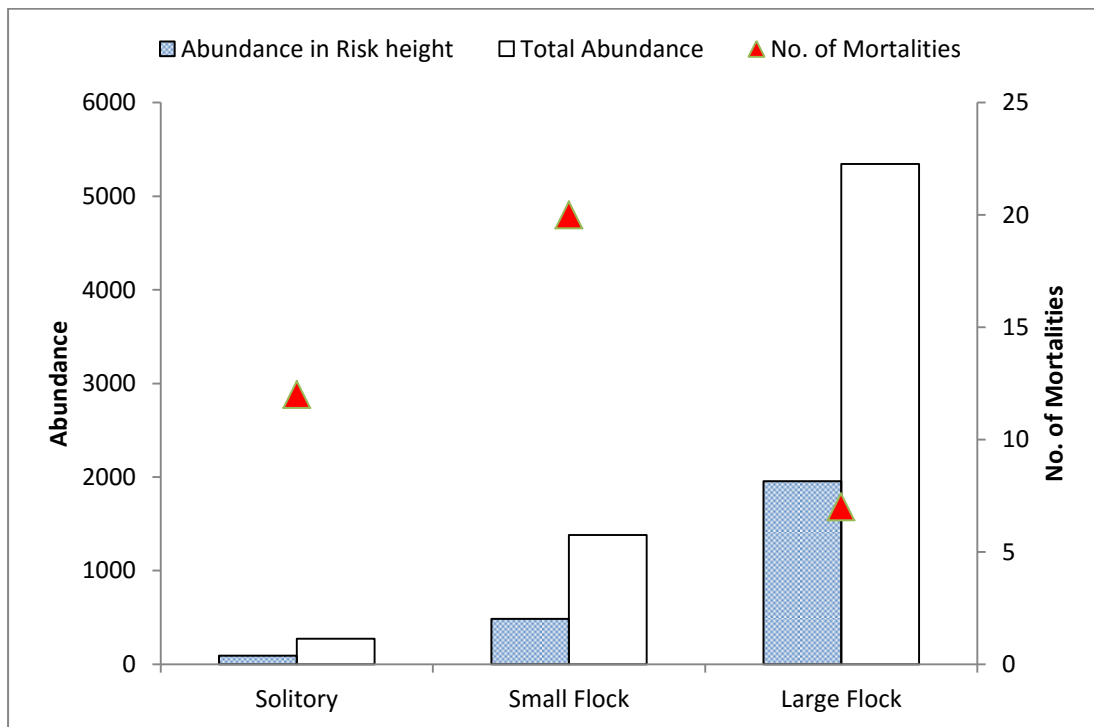


Figure 6-7. Abundance and mortalities of birds among three different flock size groups

6.3.2.2 Influence of turbine location characteristics

GLM model with all bird mortalities (n = 47) as response variable explained only 16.9 % variation and the model was not significant (F = 1.767, p = 0.135) (Table 6-5). However, this model showed the distance to village from turbines negatively influenced bird mortalities (t = -2.650, p = 0.011) i.e. the turbine located close to villages had more bird mortalities. The model with Eurasian Collared-dove *Streptopelia decaocto* and Rock Dove *Columba livia* mortalities as response variable (n = 20) explained 31 % of variation and the model was significant (F = 3.327, p = 0.01).

Distance to salt pans positively influenced doves mortality i.e. turbines located away from salt pan had more dove mortalities (t = 2.580, p = 0.013). When Eurasian Collared-dove *Streptopelia decaocto*, Rock Dove *Columba livia* and House Crow *Corvus splendens* mortalities together were treated as response variable (n = 20), the model explained 30.6 % variation and it is significant (F = 3.414, p = 0.009). This model also revealed that distance to saltpans positively influenced dove and crow mortalities (t = 2.620, p = 0.011). The model with raptor mortality as response variable (n = 9) was not significant and it explained only 15 % (F = 1.351, p = 0.257). Unlike the above said models (Poisson model with log link function) the water bird mortalities (n = 8) was analyzed using binomial with logit link function as the turbine location with water bird mortalities was binomial in nature. However this model only explained 17.8 % of variation and the model was not significant (F = 1.369, p = 0.250).

Table 6-4 Pearson Correlation Matrix of the independent variables used in the GLM models

Variables	Distance to Village	Distance to fresh water body	Distance to Salt Pans	Density of Turbines	Altitude	NDVI
Distance to Village		0.30	0.43	0.00	0.88	0.85
Distance to fresh water body	-0.14		0.06	0.11	0.12	0.28
Distance to Salt Pans	-0.11	0.24		0.04	0.00	0.24
Density of Turbines	0.38	-0.21	-0.27		0.14	0.64
Altitude	-0.02	0.20	0.92	-0.19		0.18
NDVI	-0.02	-0.14	-0.15	-0.06	-0.18	

Table 6-5. Results of five different GLM models with different response variables.

Term	Overall Bird mortalities (16.9 % variables explained) F = 1.767, p = 0.135, AIC=137.46 Poisson with log link function				Doves (31%) F = 3.102, p = 0.015, AIC=76.02 Poisson with log link function				Doves and Crows (30.6%) F = 3.3273, p = 0.01, AIC = 85.79 Poisson with log link function			
	b	SE	T	p(T)	b	SE	T	p(T)	b	SE	T	p(T)
(Intercept)	-0.028	1.341	-0.020	0.983	0.340	2.520	0.130	0.893	1.357	2.172	0.620	0.535
Distance to Village	0.470	0.177	2.650	0.011	-0.674	0.458	-1.470	0.147	-0.580	0.381	-1.520	0.134
Distance to Fresh water wetland	0.058	0.227	-0.260	0.799	-0.495	0.432	-1.150	0.257	-0.387	0.375	-1.030	0.307
Distance to Salt Pans	0.081	0.089	0.910	0.368	0.801	0.310	2.580	0.013	0.650	0.248	2.620	0.011
Turbine Density	0.044	0.093	0.480	0.633	0.035	0.171	0.210	0.837	0.011	0.151	0.070	0.944
NDVI	1.362	5.924	0.230	0.819	-24.901	15.678	-1.590	0.118	-26.184	13.400	-1.950	0.056

Term	Raptors (15%) F = 1.351, p = 0.257, AIC=57.98 Poisson with log link function				Wetland birds (17.8%) F = 1.369, p = 0.250, AIC=54.81 Binomial with logit link function			
	b	SE	T	p(T)	b	SE	T	p(T)
(Intercept)	-3.886	3.056	1.270	0.209	-4.623	4.186	1.100	0.274
Distance to Village	-0.795	0.403	1.980	0.053	-0.752	0.476	1.580	0.120
Distance to Fresh water wetland	0.087	0.489	0.180	0.859	0.446	0.733	0.610	0.545
Distance to Salt Pans	0.098	0.178	0.550	0.585	-0.369	0.261	1.410	0.164
Turbine Density	0.083	0.197	0.420	0.675	0.399	0.289	1.380	0.172
NDVI	15.032	12.131	1.240	0.221	16.887	17.685	0.950	0.344

6.4 DISCUSSION

The information available on the turbine collision risk of birds is scarce from Asia. In the present study, the information on the collision risk of 71 species including many migratory species in the Kutch region are discussed. About 70 % of the total observed species were recorded flying at heights coming within the Rotar Swept Zone (RSZ). Wetland associated bird species and raptors were at greater risk of collision with the wind turbines in the area. The high collision risk of wetland birds were in accordance with the results of the study by Wulff *et al.* (2016) in the Texas High Plains, USA. They found 15 wetland associated bird species were flying in the RSZ and seven of them had greater than 25% of their flight heights within the RSZ. They also suggested that it may be sensible to avoid installations of turbines near the wetlands to reduce the risk of turbine collisions of wetland associated species.

Among the 13 raptors observed during the survey, 12 species of birds were found flying in the risk zone and all of them had more than 25% of their observed flight within the RSZ. Griffon Vulture *Gyps fulvus* was the only raptor species, which was not recorded in the RSZ and observed flying above the RSZ in single occasion. Among the raptors, Steppe Eagle *Aquila nipalensis* accounted for maximum duration of flight (24 minutes) in the RSZ and it had 54 % of its flight within in the RSZ. Although no identified carcass of Steppe Eagle *Aquila nipalensis* (Endangered) was found during the study period, it is assumed that one of the five unidentified raptor could be of Steppe Eagle *Aquila nipalensis* as the feather features resembled it. It is interesting to note that Steppe Eagle *Aquila nipalensis* was the only species which had significantly higher abundance in the control site than in the turbine site during the raptor displacement study. This reveals that there may be more usage of control site than the turbine site by this species. From this, it is evident that the mere abundance of raptor is not the best indicator of collision risk which is also suggested by de Lucas *et al.* (2008) and Wulff *et al.* (2016). Another globally threatened species Greater Spotted Eagle *Clanga clanga* recorded during the survey had about 90% of its observed flight in the RSZ. Western Marsh-harrier, the most abundant raptor in the winter had 39 % of its flight in the RSZ and more than 40 % of observed flight is below the RSZ. Harriers generally fly in low altitudes close to ground for hunting prey, hence most of their flights comes below the RSZ and makes it less vulnerable raptor to the turbine collision (Madders & Whitfield, 2006).

Common Kestrel *Falco tinnunculus* had 71% (about 11 minutes) of its observed flight in the turbine site. In addition, hovering of Common Kestrel *Falco tinnunculus* close to rotating turbine blades and perching of this species close to wind turbines in electric lines were observed in many occasions during the study period. Higher risk of Kestrel was evident as four of 47 carcasses observed during study were that of Common Kestrel *Falco tinnunculus*. Kestrels are found to be vulnerable to turbine collision elsewhere and kestrel mortalities are also reported in wind farms of Spain (Barrios & Rodríguez, 2004) and Germany (Hötker, 2006). Hovering behaviour and use of air currents for its foraging flights may be the reason for high kestrel mortality in wind farms (Barrios & Rodríguez, 2004; Hernández-pliego, *et al.*, 2015). The Griffon Vulture *Gyps fulvus* which is one of the most affected species by collision with turbine (Carrete *et al.*, 2012; de Lucas *et al.*, 2012) was observed only once and no carcass of this species was observed in the study. The *Gyps* vulture population in Indian subcontinent has undergone rapid decline due to the diclofenac poisoning (Green *et al.*, 2004). Few species are categorised Critically Endangered and Endangered due its current low population size (IUCN 2016). Even when the vulture population recovers from the diclofenac threat, care should be taken as vultures are reported to be one the most vulnerable species to wind energy development.

The mitigation measures for raptor collision generally suggests, avoiding installation of turbines in nesting sites, migratory route and in high prey abundant areas (Teresa *et al.*, 2014; Wulff *et al.*, 2016). In Samakhiali wind farm, except for two nesting sites of Shikra, no nesting of raptors was recorded. However, this area is extensively used by winter visiting raptors during October to January making this area important for raptor conservation.

Among the 11 species identified from the recorded bird carcasses, nine species were observed in the RSZ and six of them had greater collision risk as it had 25 % of their flight within the RSZ. The Eurasian Collared-dove *Streptopelia decaocto* which had maximum number of carcasses (10) was an exceptional case as most of its flight was observed below the RSZ. It can be stated that the slight increase in its flight altitude becomes fatal for this species. It was also observed (opportunistic observation) that this species glides in circular movement in the wind farm area which may also have led to higher number of collisions. About 70% of the total bird species recorded was found flying in the RSZ which is in contrast with the results of previous studies as they found

only minor proportion of total species in RSZ. Wulff *et al.*, (2016) found only 21 % of their total species found at greater risk of collision in Texas High plains, USA. Similarly, Howe *et al.*, (2002) found 14 % of their total species in the RSZ. In India Pande *et al.*, (2013) found only 30 % of the total species in the RSZ. However, the greater collision risk of raptors and water birds in the present study is in accordance with the previous findings (Osborn *et al.*, 1998; Pande *et al.*, 2013; Wulff *et al.*, 2016).

During the study period it was observed that many birds tend to avoid turbine blades effectively even if they fly in RSZ. For instance, Rosy starlings *Pastor roseus* which fly in large flocks (in hundreds) avoids the turbine either by flying below the blades or sideways. Similar to this observation Osborn *et al.*, (1998) found most of the birds they observed avoided turbines by flying below the RSZ of the turbines. Unlike starlings, raptors showed riskier behaviour while soaring near the turbines. They were often observed to be getting dangerously close to the rotating blades and missing the blades mostly by chance. The birds avoiding entire wind farm could not be observed in the present study as no radar was used for the survey and wind turbines are scattered around ~120 sq.km and are not arranged in any specific geometrical pattern. The collision risk projected may not be uniform across different geographical location, season and time of the day.

The bird collisions with turbines were influenced by a number of factors such as location of wind turbines, species composition of the bird community of that area and other climatic factors. Among the morphological characters tested in the present study, wing length positively influenced the bird collision mortality. Birds with lengthy wings had more chance of collision with the turbines than the others. As body length is positively correlated with body length, it is evident that the large birds had more chance of collision due its low manoeuvrability (Langston & Pullan, 2003). However this may vary with the place, as small sized birds were reported to collide in greater proportion (Nicholson *et al.*, 2005). Among the 39 mortalities identified to family levels, about 71 % of them belong to gliding type of flight. The gliding type of flight was one of the main factors reported by many studies influencing the mortality, especially in wind farms where raptor mortalities are high (Langston & Pullan, 2003; Kikuchi, 2008; Katzner *et al.*, 2012).

The flock size did not influence the mortality significantly and the observed mortalities were of different flock size groups. However, birds fly in small flocks had more number

of collisions than those solitary or in large flocks. It is generally believed that birds flying in large flocks are more prone to collision as the number of birds, breadth and depth of the flock and the birds flying behind others have a reduced vision of what is in front (Kikuchi, 2008). But the present results are in contrast to this concept.

Apart from these factors, vision (eyesight) of the birds is also influence the collision which may vary to different group of birds (Kikuchi, 2008). Other bird behaviours such as courtship flights may also increase the risk of the turbine collision. For example the species like Horned Lark *Eremophila alpestris* which fly in high during their courtship display are more often killed by the turbine blades (Kerlinger & Dowdell, 2003; Kingsley & Whittam, 2005). Influence of such behaviours including flight speed on the bird mortality was not tested in the present study.

Apart from morphology and behaviour of birds the location of the turbines also plays major role in the bird mortalities. In the present study, the GLM model with the turbine location characters and overall bird mortality revealed that the turbines close to villages had more mortalities than the other turbine locations. However the dove and crow mortalities were low in the turbines located away from the salt pans. In general, birds with higher mortality such as Eurasian Collared-dove *Streptopelia decaocto*, Rock Dove *Columba livia* and House Crow *Corvus splendens* are found usually close to human habitation (Ali & Ripley, 2001). As most of the villages are located away from the salt pans; it can be considered that the human associated birds get killed by the turbines located close to the villages.

The raptor and wetland bird mortalities were not significantly influenced by the turbine location characters. It is reported that the turbines located close to water bodies cause higher bird mortalities (Hötker, 2006), however the present study did not show any such pattern. Distance from turbine location to wetlands was similar among the turbines with water bird mortality (1.23 ± 0.74 km) and without mortalities (1.20 ± 0.68 km). The number of wetland bird mortalities occurred was very low; hence further data are required to come to a concrete conclusion regarding waterbird mortality pattern.

The other major factors influencing the bird mortalities include time of the year, weather and turbine structure. 91% of the bird carcasses were observed in the winter (October - February). However, among the 33 mortalities identified, only five carcasses were of

migratory birds. From this it is evident that, apart from availability of migratory birds in winter the susceptibility of birds for collision during winter is also a major reason for higher number of bird mortality in winter. Among the three doves recorded in the flight survey, Rock Dove *Columba livia* and Eurasian Collared-dove *Streptopelia decaocto* collided in higher numbers with the turbines. One possible reason may be that as the breeding season of these two doves are between May-June and there is a possibility of juvenile birds getting killed in the winter (October to February) (Ali & Ripley, 2001).

Weather conditions is are reported to influence bird mortalities (Powlesland, 2009). For instance on a single night 27 birds mainly songbirds were killed in west Virginia on a foggy night (Kerns & Kerlinger, 2004). Similarly, 14 birds were killed by two turbines during a thunder storm in North America (Erickson *et al.*, 2001). The high number of bird mortality in winter in the present study may also be due to the poor visibility during winter months. Other features which influence bird mortalities, like structure of turbines, lighting on the turbines and rotation speed of wind turbines were not tested in this study.

7 CONCLUSION

India accounts for 4.5% of the world's greenhouse gas emissions. With the ratification of the Paris climate deal (2016) by 2030, India aims to generate 40% of its power from non-fossil sources. And it aims for a renewable energy capacity of 175GW by 2022, where solar and wind markets will be the major players. Wind farms are an inevitable part of the rapidly energy consuming world. Need for alternate forms of energy resources necessitated the readily available and abundant wind energy to be maximally tapped. This unprecedented growth in wind farms comes with major drawbacks, in which wildlife especially avifauna is affected. This thesis has highlighted the need for greater understanding of bird mortalities and displacement behaviour due to wind farms in India. Studies on this aspect are very few from India, which has emerged as a major hub for wind energy generation.

The Samakhiali region of Kutch, where this study was conducted supports diverse avifauna. As the study site is located along Central Asian Flyway, it attracts many migratory species during winter. Large congregations of water birds, presence of threatened species and nesting of many species were recorded during the study. In many occasions large congregations of Demoiselle Crane *Grus virgo* (About 1000 to 6000 individuals) were recorded, which has exceeded its 1 % biogeographical population (1000 individuals). Hence this area (Wetlands of Samakhiali) is qualified for an Important Bird and Biodiversity Area (IBA) according to A1 (Threatened Species), A4i ($\geq 1\%$ biogeographic population) criteria of IBA (Birdlife International, 2016). In conclusion, presence of 175 species with four Globally Threatened and 11 Near-threatened birds indicates the conservational importance of this area.

The study highlights the effect of wind turbines on the land birds of the Kutch region. The abundance of most passerine species was low in the wind farm area. Along with the disturbance caused by turbine, the alteration of habitat by clearing vegetation has also contributed to the low abundance of most bird species. Although majority of the raptors were distributed equally in wind farm and surrounding areas, it needs further scrutiny as even small level of impact on raptors can cause serious consequences in the overall ecosystem as they occupies top position in the food chain.

The mortality of birds at 59 turbines were studied and it was estimated that on average 97 birds die annually in the Samakhiali wind farm that has about 200 turbines. This is moderate when compared to studies elsewhere. The species affected are mainly doves and raptors along with few water-bird species and the mortality rate is higher during the migratory season of the birds. However, a large proportion of the birds that died are resident birds. Factors such as weather could also be a major factor influencing bird mortalities. The flight behaviour of birds in the turbine area has also been studied. This study also indicates that many conservationally important raptor species are flying in collision risk zone which increases the vulnerability of these species to collision. In addition, this thesis has demonstrated the effect of environmental factors which on the bird assemblages of the area. The mortality rates were found high at wind turbines located near villages and wetlands, indicating higher risk of establishing turbines in such areas.

Conservation Implications

Developmental activities in a bird rich area like Kutch should be carried out with caution. Clearing of vegetation cover and construction of roads (habitat degradation activities) should be regulated in order to minimize the displacement of passerines from turbine area. Decreasing movement of the vehicles in the turbine sites would minimize bird mortalities caused by vehicles and also reduce the disturbance to the birds. Ensuring proper insulation of electrical installations such as junctions (on Cement posts) and transformers can prevent electrocution of birds, as many of the birds use these as perching sites. Further installation of new turbines should be carried out with more caution. Selection of area close to villages and wetlands with waterbird congregation should be avoided in order to reduce the bird mortalities.

The impacts of wind farms on birds from many existing wind farms in India are unknown. Studies should be conducted in wind farms situated in various locations, for instance wind farms of Tirunelveli, Tamil Nadu (the largest wind farm site in India), wind farms adjacent to Naliya Grasslands (IBA site endangered vultures) in Gujarat and other parts of the country where wind farms have been established. The Ministry of New and Renewable Energy (MNRE) is promoting wind farms in large scale. This thesis underlines the need for these new installations to be established only after conducting detailed environmental impact assessment with special reference to avifauna. The MNRE is also in the process of large scale installation of off shore wind farms at Gulf of Kutch,

Gujarat and Gulf of Mannar (Biosphere Reserve), Tamil Nadu. The Gulf of Mannar biosphere reserve supports more than 250 species of birds and is also known for its rich diversity of marine fauna. The installation of wind turbines in sensitive areas may endanger the ecosystem of the region.

Developing strategic bird sensitivity map will play a crucial role in selecting safer locations for installation of new wind turbines and managing the existing wind farms. Such maps are available for many countries like Scotland, England, Netherland, South Africa, USA, Greece, Germany, Denmark, Slovenia, Flanders (Belgium) and Bulgaria. To prepare a bird sensitivity map of India, information pertaining to migratory flyways based on the ringing recoveries/satellite tracked birds, information on conservationally important places (such as Protected Area, Important Bird Areas, Ramsar sites) and information pertaining to important bird species (Globally threatened species, Restricted range species and species vulnerable to turbine collision) should be analyzed. This map will help in preliminary selection of location for wind farm installation. Yet, site specific bird monitoring studies should be conducted before installation of turbine to minimize the impacts. With understanding and knowledge on the impact of wind farms on avifauna, mitigation measures to control mortality and displacement due to habitat loss can be better managed. This way, conservation practices and growth of energy generation can go hand in hand.

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Appendix 1 Bird species recorded in the study area.

SI	Family	Common name	Scientific Name	IUCN	Resident Status	IWPA	CITES
1	Accipitridae	Shikra	<i>Accipiter badius</i>	LC	R	I	2
2	Accipitridae	Eurasian Sparrowhawk	<i>Accipiter nisus</i>	LC	WV	I	2
3	Accipitridae	Greater Spotted Eagle	<i>Clanga clanga</i>	LC	WV	I	2
4	Accipitridae	Steppe Eagle	<i>Aquila nipalensis</i>	EN	WV	I	2
5	Accipitridae	White-eyed Buzzard	<i>Butastur teesa</i>	LC	R	I	2
6	Accipitridae	Common Buzzard	<i>Buteo buteo</i>	LC	WV	I	2
7	Accipitridae	Himalayan Buzzard	<i>Buteo refectus</i>	LC	WV	I	2
8	Accipitridae	Long-legged Buzzard	<i>Buteo rufinus</i>	LC	WV	I	2
9	Accipitridae	Short-toed Snake Eagle	<i>Circaetus gallicus</i>	LC	R	I	2
10	Accipitridae	Western Marsh-harrier	<i>Circus aeruginosus</i>	LC	WV	I	2
11	Accipitridae	Pallid Harrier	<i>Circus macrourus</i>	NT	WV	I	2
12	Accipitridae	Montagu's Harrier	<i>Circus pygargus</i>	LC	WV	I	2
13	Accipitridae	Black-winged Kite	<i>Elanus caeruleus</i>	LC	R	I	2
14	Accipitridae	Griffon Vulture	<i>Gyps fulvus</i>	LC	WV	I	2
15	Accipitridae	Booted Eagle	<i>Hieraaetus pennatus</i>	LC	WV	I	2
16	Accipitridae	Oriental Honey-Buzzard	<i>Pernis ptilorhynchus</i>	LC	R	I	2
17	Alaudidae	Greater Hoopoe-Lark	<i>Alaemon alaudipes</i>	LC	R	IV	2
18	Alaudidae	Rufous-tailed Lark	<i>Ammomanes phoenicura</i>	LC	R	IV	-
19	Alaudidae	Ashy-crowned Sparrow Lark	<i>Eremopterix grisea</i>	LC	R	IV	-
20	Alaudidae	Crested Lark	<i>Galerida cristata</i>	LC	R	IV	-
21	Alaudidae	Greater Short-toed Lark	<i>Calandrella brachydactyla</i>	LC	WV	IV	-
22	Alcedinidae	Common Kingfisher	<i>Alcedo atthis</i>	LC	R	IV	-
23	Alcedinidae	Pied Kingfisher	<i>Ceryle rudis</i>	LC	R	IV	-
24	Alcedinidae	White-breasted Kingfisher	<i>Halcyon smyrnensis</i>	LC	R	IV	-
25	Anatidae	Northern Shoveler	<i>Anas clypeata</i>	LC	WV	IV	-
26	Anatidae	Northern Pintail	<i>Anas acuta</i>	LC	WV	IV	-
27	Anatidae	Eurasian Wigeon	<i>Anas penelope</i>	LC	WV	IV	-
28	Anatidae	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	LC	R	IV	-
29	Anatidae	Gargany	<i>Anas querquedula</i>	LC	WV	IV	-
30	Anatidae	Common Pochard	<i>Aythya ferina</i>	VU	WV	IV	-
31	Anatidae	Tufted Pochard	<i>Aythya fuligula</i>	LC	WV	IV	-
32	Anatidae	Greater Scaup	<i>Aythya marila</i>	LC	WV	IV	-
33	Anatidae	Lesser Whistling Duck	<i>Dendrocygna javanica</i>	LC	R	IV	-
34	Anatidae	Common Teal	<i>Nettapus coromandelianus</i>	LC	WV	IV	-
35	Anatidae	Knob-billed Duck	<i>Sarkidiornis melanotos</i>	LC	R	IV	-
36	Apodidae	Little Swift	<i>Apus affinis</i>	LC	R	IV	-
37	Ardeidae	Grey Heron	<i>Ardea cinerea</i>	LC	R	IV	-
38	Ardeidae	Purple Heron	<i>Ardea purpurea</i>	LC	R	IV	-
39	Ardeidae	Indian Pond Heron	<i>Ardeola grayii</i>	LC	R	IV	-
40	Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>	LC	R	IV	-
41	Ardeidae	Little Green Heron	<i>Butorides striata</i>	LC	R	IV	-

SI	Family	Common name	Scientific Name	IUCN	Resident Status	IWPA	CITES
42	Ardeidae	Great Egret	<i>Casmerodius albus</i>	LC	R	IV	–
43	Ardeidae	Little Egret	<i>Egretta garzetta</i>	LC	R	IV	–
44	Ardeidae	Western Reef-egret	<i>Egretta gularis</i>	LC	R	IV	–
45	Ardeidae	Intermediate Egret	<i>Mesophoyx intermedia</i>	LC	R	IV	–
46	Ardeidae	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	LC	R	IV	–
47	Burhinidae	Greater Thick-nee	<i>Esacus recurvirostris</i>	NT	R	IV	–
48	Charadriidae	Kentish Plover	<i>Charadrius alexandrinus</i>	LC	R	IV	–
49	Charadriidae	Little Ringed Plover	<i>Charadrius dubius</i>	LC	R	IV	–
50	Charadriidae	Lesser Sand Plover	<i>Charadrius mongolus</i>	LC	WV	IV	–
51	Charadriidae	Pacific Golden-Plover	<i>Pluvialis fulva</i>	LC	WV	IV	–
52	Charadriidae	Red-wattled Lapwing	<i>Vanellus indicus</i>	LC	R	IV	–
53	Charadriidae	Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	LC	R	IV	–
54	Ciconiidae	Asian openbill	<i>Anastomus oscitans</i>	LC	WV	IV	–
55	Ciconiidae	Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	NT	R	IV	–
56	Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	NT	R	IV	–
57	Columbidae	Rock Dove	<i>Columba livia</i>	LC	R	-	–
58	Columbidae	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	LC	R	IV	–
59	Columbidae	Laughing Dove	<i>Stigmatopelia senegalensis</i>	LC	R	IV	–
60	Columbidae	Red Turtle-dove	<i>Streptopelia tranquebarica</i>	LC	R	IV	–
61	Coraciidae	Indian Roller	<i>Coracias benghalensis</i>	LC	R	IV	–
62	Coraciidae	Eurasian Roller	<i>Coracias garrulus</i>	LC	PV	IV	–
63	Corvidae	Long-billed Crow	<i>Corvus macrorhynchos</i>	LC	R	IV	–
64	Corvidae	House Crow	<i>Corvus splendens</i>	LC	R	V	–
65	Corvidae	Rufous Treepie	<i>Dendrocitta vagabunda</i>	LC	R	IV	–
66	Cuculidae	Greater Coucal	<i>Centropus (sinensis) parroti</i>	LC	R	IV	–
67	Cuculidae	Asian Koel	<i>Eudynamis scolopaceus</i>	LC	R	IV	–
68	Cuculidae	Sirkeer Malkoha	<i>Phaenicophaeus leschenaultii</i>	LC	R	IV	–
69	Cysticolidae	Common Tailorbird	<i>Orthotomus sutorius</i>	LC	R	IV	–
70	Cysticolidae	Rufous-fronted prinia	<i>Prinia buchanani</i>	LC	R	IV	–
71	Cysticolidae	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	LC	R	IV	–
72	Cysticolidae	Plain Prinia	<i>Prinia inornata</i>	LC	R	IV	–
73	Cysticolidae	Ashy Prinia	<i>Prinia socialis</i>	LC	R	IV	–
74	Cysticolidae	Jungle Prinia	<i>Prinia sylvatica</i>	LC	R	IV	–
75	Dicruridae	Ashy Drongo	<i>Dicrurus leucophaeus</i>	LC	R	IV	–
76	Dicruridae	Black Drongo	<i>Dicrurus macrocercus</i>	LC	R	IV	–
77	Estrildidae	Indian Silverbill	<i>Euodice malabarica</i>	LC	R	IV	–
78	Estrildidae	Black-headed Munia	<i>Lonchura Malacca</i>	LC	R	IV	–
79	Falconidae	Laggar Falcon	<i>Falco jugger</i>	NT	R	IV	1
80	Falconidae	Common Kestrel	<i>Falco tinnunculus</i>	LC	WV	IV	2
81	Hirundinidae	Dusky Crag-martin	<i>Ptyonoprogne concolor</i>	LC	R	IV	–
82	Hirundinidae	Red-rumped Swallow	<i>Cecropis daurica</i>	LC	R	IV	–
83	Hirundinidae	Barn Swallow	<i>Hirundo rustica</i>	LC	WV	IV	–

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84	Hirundinidae	Wire-tailed Swallow	<i>Hirundo smithii</i>	LC	R	IV	–
85	Jacaniidae	Pheasant-tailed Jacana	<i>Hydrophasianus chirurgus</i>	LC	R	IV	–
86	Laniidae	Isabelline Shrike	<i>Lanius isabellinus</i>	LC	WV	IV	–
87	Laniidae	Great Grey Shrike	<i>Lanius meridionalis</i>	LC	R	IV	–
88	Laniidae	Long-tailed Shrike	<i>Lanius schach</i>	LC	R	IV	–
89	Laniidae	Bay-backed Shrike	<i>Lanius vittatus</i>	LC	R	IV	–
90	Laridae	Whiskered Tern	<i>Chlidonias hybridus</i>	LC	R	IV	–
91	Laridae	Brown-headed Gull	<i>Chroicocephalus brunnicephalus</i>	LC	WV	IV	–
92	Laridae	Gull-billed Tern	<i>Gelochelidon ninitica</i>	LC	WV	IV	–
93	Laridae	Heuglin's Gull	<i>Larus heuglini</i>	LC	WV	IV	–
94	Laridae	Pallas's Gull	<i>Larus ichthyaetus</i>	LC	WV	IV	–
95	Laridae	Little Tern	<i>Sterna albifrons</i>	LC	WV	IV	–
96	Laridae	River Tern	<i>Sterna aurantia</i>	NT	R	IV	–
97	Laridae	Common Tern	<i>Sterna hirundo</i>	LC	WV	IV	–
98	Meropidae	Asian Green Bee-eater	<i>Merops orientalis</i>	LC	R	IV	–
99	Motacillidae	Paddy-field Pipit	<i>Anthus rufulus</i>	LC	R	IV	–
100	Motacillidae	White Wagtail	<i>Motacilla alba</i>	LC	WV	IV	–
101	Motacillidae	Grey Wagtail	<i>Motacilla cinerea</i>	LC	WV	IV	–
102	Motacillidae	Citrine Wagtail	<i>Motacilla citreola</i>	LC	WV	IV	–
103	Motacillidae	Yellow Wagtail	<i>Motacilla flava</i>	LC	WV	IV	–
104	Motacillidae	White-browed wagtail	<i>Motacilla maderaspatensis</i>	LC	WV	IV	–
105	Nectariniidae	Purple Sunbird	<i>Cinnyris asiaticus</i>	LC	R	IV	–
106	Passeridae	House Sparrow	<i>Passer domesticus</i>	LC	R	IV	–
107	Passeridae	Chestnut-shouldered Petronia	<i>Gymnoris xanthocollis</i>	LC	R	IV	–
108	Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	VU	WV	IV	1
109	Anhingidae	Darter	<i>Anhinga melanogaster</i>	NT	R	IV	–
110	Phalacrocoracidae	Great Cormorant	<i>Phalacrocorax carbo</i>	LC	WV	IV	–
111	Phalacrocoracidae	Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	LC	WV	IV	–
112	Phalacrocoracidae	Little Cormorant	<i>Phalacrocorax niger</i>	LC	R	IV	–
113	Phasianidae	Common Quail	<i>Coturnix coturnix</i>	LC	R	IV	–
114	Phasianidae	Grey Francolin	<i>Francolinus pondicerianus</i>	LC	R	IV	–
115	Phasianidae	Indian Peafowl	<i>Pavo cristatus</i>	LC	R	I	3
116	Phoenicopteridae	Greater Flamingo	<i>Phoenicopterus roseus</i>	LC	WV	IV	2
117	Picidae	Eurasian Wryneck	<i>Jynx torquilla</i>	LC	WV	IV	–
118	Ploceidae	Streaked Weaver	<i>Ploceus manyar</i>	LC	R	IV	–
119	Ploceidae	Baya Weaver	<i>Ploceus philippinus</i>	LC	R	IV	–
120	Podicipedidae	Great-crested Grebe	<i>Podiceps cristatus</i>	LC	WV	IV	–
121	Podicipedidae	Little Grebe	<i>Tachybaptus ruficollis</i>	LC	R	IV	–
122	Psittacidae	Rose-ringed Parakeet	<i>Psittacula krameri</i>	LC	R	IV	–
123	Pteroclididae	Chestnut-bellied Sandgrouse	<i>Pterocles exustus</i>	LC	R	IV	–
124	Pycnonotidae	Red-vented Bulbul	<i>Pycnonotus cafer</i>	LC	R	IV	–
125	Pycnonotidae	White-eared Bulbul	<i>Pycnonotus leucotis</i>	LC	R	IV	–

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126	Rallidae	White-breasted Waterhen	<i>Amauormis phoenicurus</i>	LC	R	IV	–
127	Rallidae	Common Coot	<i>Fulica atra</i>	LC	R	IV	–
128	Rallidae	Common Moorhen	<i>Gallinula chloropus</i>	LC	R	IV	–
129	Rallidae	Purple Swampphen	<i>Porphyrio porphyrio</i>	LC	R	IV	–
130	Gruidae	Sarus Crane	<i>Antigone antigone</i>	VU	R	IV	2
131	Gruidae	Common Crane	<i>Grus grus</i>	LC	WV	IV	2
132	Gruidae	Demoiselle Crane	<i>Grus virgo</i>	LC	WV	IV	2
133	Recurvirostridae	Black-winged Stilt	<i>Himantopus himantopus</i>	LC	R	IV	–
134	Recurvirostridae	Pied Avocet	<i>Recurvirostra avosetta</i>	LC	WV	IV	–
135	Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	LC	WV	IV	–
136	Scolopacidae	Sanderling	<i>Calidris alba</i>	LC	WV	IV	–
137	Scolopacidae	Curlew Sandpiper	<i>Calidris ferruginea</i>	NT	WV	IV	–
138	Scolopacidae	Little Stint	<i>Calidris minuta</i>	LC	WV	IV	–
139	Scolopacidae	Common Snipe	<i>Gallinago gallinago</i>	LC	WV	IV	–
140	Scolopacidae	Black-tailed Godwit	<i>Limosa limosa</i>	NT	WV	IV	–
141	Scolopacidae	Eurasian Curlew	<i>Numenius arquata</i>	NT	WV	IV	–
142	Scolopacidae	Whimbrel	<i>Numenius phaeopus</i>	LC	WV	IV	–
143	Scolopacidae	Ruff	<i>Philomachus pugnax</i>	LC	WV	IV	–
144	Scolopacidae	Spotted Redshank	<i>Tringa erythropus</i>	LC	WV	IV	–
145	Scolopacidae	Wood Sandpiper	<i>Tringa glorioles</i>	LC	WV	IV	–
146	Scolopacidae	Common Greenshank	<i>Tringa nebularia</i>	LC	WV	IV	–
147	Scolopacidae	Green Sandpiper	<i>Tringa ochropus</i>	LC	WV	IV	–
148	Scolopacidae	Marsh Sandpiper	<i>Tringa stagnatilis</i>	LC	WV	IV	–
149	Scolopacidae	Common Redshank	<i>Tringa totanus</i>	LC	WV	IV	–
150	Scolopacidae	Terek Sandpiper	<i>Xenus cinereus</i>	LC	WV	IV	–
151	Strigidae	Spotted Owlet	<i>Athene brama</i>	LC	R	IV	2
152	Strigidae	Pallid Scoops-owl	<i>Otus brucei</i>	LC	WV	IV	2
153	Sturnidae	Bank Myna	<i>Acridotheres ginginianus</i>	LC	R	IV	–
154	Sturnidae	Common Myna	<i>Acridotheres tristis</i>	LC	R	IV	–
155	Sturnidae	Brahminy Starling	<i>Sturnia pagadarum</i>	LC	R	IV	–
156	Sturnidae	Rosy Starling	<i>Pastor roseus</i>	LC	WV	IV	–
157	Sylviidae	Sykes Warbler	<i>Iduna rama</i>	LC	WV	IV	–
158	Sylviidae	Greenish warbler	<i>Phylloscopus trochiloides</i>	LC	WV	IV	–
159	Sylviidae	Hume's Whitethroat	<i>Sylvia althaea</i>	LC	PV	IV	–
160	Sylviidae	Lesser Whitethroat	<i>Sylvia curruca</i>	LC	WV	IV	–
161	Threskiornithidae	Eurasian Spoonbill	<i>Platalea leucorodia</i>	LC	R	IV	–
162	Threskiornithidae	Glossy Ibis	<i>Plegadis falcinellus</i>	LC	R	IV	–
163	Threskiornithidae	Red-naped Ibis	<i>Pseudibis papillosa</i>	LC	R	IV	–
164	Threskiornithidae	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	NT	R	IV	–
165	Timaliidae	Common Babbler	<i>Turdoides caudata</i>	LC	R	IV	–
166	Turdidae	Indian Chat	<i>Cercomela fusca</i>	LC	R	IV	–
167	Turdidae	Bluethroat	<i>Luscinia svecica</i>	LC	WV	IV	–

SI	Family	Common name	Scientific Name	IUCN	Resident Status	IWPA	CITES
168	Turdidae	Desert Wheatear	<i>Oenanthe deserti</i>	LC	WV	IV	–
169	Turdidae	Isabelline Wheatear	<i>Oenanthe isabellina</i>	LC	WV	IV	–
170	Turdidae	Variable Wheatear	<i>Oenanthe picata</i>	LC	WV	IV	–
171	Turdidae	Black Redstart	<i>Phoenicurus ochruros</i>	LC	WV	IV	–
172	Turdidae	Pied Bushchat	<i>Saxicola caprata</i>	LC	WV	IV	–
173	Turdidae	Common Stonechat	<i>Saxicola torquatus</i>	LC	WV	IV	–
174	Turdidae	Indian Robin	<i>Saxicoloides fulicatus</i>	LC	R	IV	–
175	Upupidae	Common Hoopoe	<i>Upupa epops</i>	LC	R	IV	–

Appendix 2 Bird species mortalities related to India (migratory to India or widespread resident) in the wind farms of Europe, USA and UK. (Compiled from 24 studies).

SI.No	Common Name	Scientific Name	IUCN Status	Number of Mortalities
1	Griffon Vulture	<i>Gyps fulvus</i>	LC	632
2	Rock Dove	<i>Columba livia</i>	LC	348
3	Horned Lark	<i>Eremophila alpestris</i>	LC	195
4	Golden Eagle	<i>Aquila chrysaetos</i>	LC	141
5	Common Tern	<i>Sterna hirundo</i>	LC	112
6	Mallard	<i>Anas platyrhynchos</i>	LC	107
7	Common Kestrel	<i>Falco tinnunculus</i>	LC	90
8	Black-headed Gull	<i>Larus ridibundus</i>	LC	89
9	Common Barn-owl	<i>Tyto alba</i>	LC	87
10	Eurasian Buzzard	<i>Buteo buteo</i>	LC	72
11	Eurasian Skylark	<i>Alauda arvensis</i>	LC	70
12	Lesser Black-backed Gull	<i>Larus fuscus</i>	LC	45
13	Short-tailed Shearwater	<i>Ardenna tenuirostris</i>	LC	43
14	House Sparrow	<i>Passer domesticus</i>	LC	38
15	Lesser Kestrel	<i>Falco naumanni</i>	LC	34
16	Common Swift	<i>Apus apus</i>	LC	32
17	Short-toed Snake-eagle	<i>Circaetus gallicus</i>	LC	32
18	Cattle Egret	<i>Bubulcus ibis</i>	LC	26
19	White-tailed Sea-eagle	<i>Haliaeetus albicilla</i>	LC	26
20	White-throated Needletail	<i>Hirundapus caudacutus</i>	LC	26
21	White Stork	<i>Ciconia ciconia</i>	LC	25
22	Northern House-martin	<i>Delichon urbicum</i>	LC	19
23	Common Woodpigeon	<i>Columba palumbus</i>	LC	18
24	Eurasian Eagle-owl	<i>Bubo bubo</i>	LC	18
25	Black Kite	<i>Milvus migrans</i>	LC	16
26	Crested Lark	<i>Galerida cristata</i>	LC	16
27	Barn Swallow	<i>Hirundo rustica</i>	LC	14
28	Chukar	<i>Alectoris chukar</i>	LC	12
29	Mute Swan	<i>Cygnus olor</i>	LC	10
30	Eurasian Blackbird	<i>Turdus merula</i>	LC	9
31	Montagu's Harrier	<i>Circus pygargus</i>	LC	8
32	Winter Wren	<i>Troglodytes troglodytes</i>	LC	6
33	Hen Harrier	<i>Circus cyaneus</i>	LC	6
34	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	LC	5
35	Western Marsh-harrier	<i>Circus aeruginosus</i>	LC	5
36	Booted Eagle	<i>Hieraaetus pennatus</i>	LC	5
37	White Wagtail	<i>Motacilla alba</i>	LC	5
38	Short-eared Owl	<i>Asio flammeus</i>	LC	5
39	Eurasian Oystercatcher	<i>Haematopus ostralegus</i>	NT	4

SI.No	Common Name	Scientific Name	IUCN Status	Number of Mortalities
40	Common Stonechat	<i>Saxicola torquatus</i>	LC	3
41	Black-billed Magpie	<i>Pica pica</i>	LC	3
42	Great Cormorant	<i>Phalacrocorax carbo</i>	LC	3
43	Little Egret	<i>Egretta garzetta</i>	LC	3
44	Northern Goshawk	<i>Accipiter gentilis</i>	LC	3
45	Eurasian Sparrowhawk	<i>Accipiter nisus</i>	LC	3
46	Peregrine Falcon	<i>Falco peregrinus</i>	LC	3
47	White-bellied Sea-eagle	<i>Haliaeetus leucogaster</i>	LC	3
48	Northern Lapwing	<i>Vanellus vanellus</i>	NT	3
49	Egyptian Vulture	<i>Neophron percnopterus</i>	EN	3
50	Sand Martin	<i>Riparia riparia</i>	LC	3
51	Greater White-fronted Goose	<i>Anser albifrons</i>	LC	2
52	Common Snipe	<i>Gallinago gallinago</i>	LC	2
53	Little Tern	<i>Sternula albifrons</i>	LC	2
54	Black Stork	<i>Ciconia nigra</i>	LC	2
55	Merlin	<i>Falco columbarius</i>	LC	2
56	Eurasian Hobby	<i>Falco subbuteo</i>	LC	2
57	Northern Long-eared Owl	<i>Asio otus</i>	LC	2
58	Common Cuckoo	<i>Cuculus canorus</i>	LC	2
59	European Bee-eater	<i>Merops apiaster</i>	LC	2
60	American Pipit	<i>Anthus rubescens</i>	LC	2
61	Yellow Wagtail	<i>Motacilla flava</i>	LC	2
62	Eurasian Jay	<i>Garrulus glandarius</i>	LC	2
63	Spanish Sparrow	<i>Passer hispaniolensis</i>	LC	2
64	Gadwall	<i>Mareca strepera</i>	LC	2
65	Whooper Swan	<i>Cygnus cygnus</i>	LC	1
66	Greylag Goose	<i>Anser anser</i>	LC	1
67	Northern Shoveler	<i>Spatula clypeata</i>	LC	1
68	Common Redshank	<i>Tringa totanus</i>	LC	1
69	Grey Plover	<i>Pluvialis squatarola</i>	LC	1
70	Common Ringed Plover	<i>Charadrius hiaticula</i>	LC	1
71	Pallas's Gull	<i>Larus ichthyaetus</i>	LC	1
72	Black Tern	<i>Chlidonias niger</i>	LC	1
73	Grey Heron	<i>Ardea cinerea</i>	LC	1
74	Red-throated Loon	<i>Gavia stellata</i>	LC	1
75	Common Shelduck	<i>Tadorna tadorna</i>	LC	1
76	Eurasian Spoonbill	<i>Platalea leucorodia</i>	LC	1
77	Zitting Cisticola	<i>Cisticola juncidis</i>	LC	1
78	Little Swift	<i>Apus affinis</i>	LC	1
79	Common Chiffchaff	<i>Phylloscopus collybita</i>	LC	1
80	Wilson's Storm-petrel	<i>Oceanites oceanicus</i>	LC	1
81	Eurasian Woodcock	<i>Scolopax rusticola</i>	LC	1

SI.No	Common Name	Scientific Name	IUCN Status	Number of Mortalities
82	Little Owl	<i>Athene noctua</i>	LC	1
83	Alpine Swift	<i>Tachymarptis melba</i>	LC	1
84	Eurasian Crag-martin	<i>Hirundo rupestris</i>	LC	1
85	Upland Pipit	<i>Anthus sylvanus</i>	LC	1
86	Red-backed Shrike	<i>Lanius collurio</i>	LC	1
87	Common Crane	<i>Grus grus</i>	LC	1
88	Common Teal	<i>Anas crecca</i>	LC	1
89	Tufted Duck	<i>Aythya fuligula</i>	LC	1
90	Caspian Gull	<i>Larus cachinnans</i>	LC	1
91	Black Redstart	<i>Phoenicurus ochruros</i>	LC	1

Appendix 3. List of birds and their morphological characters recorded during flight activity survey at Samakhiali wind farm from August 2013 to December 2013

Family	Common name	Scientific Name	Migratory Status	Group	Flight Type	Flock Size	Morphological Characters				Abundance		
							Body Length (cm)	Body Mass (g)	Wing Length (mm)	Tail Length (mm)	Height band 1	Height band 2	Height band 3
Accipitridae	Black-winged Kite	<i>Elanus caeruleus</i>	R	RA	G	S	33	164	268	120	3	1	0
Accipitridae	Booted Eagle	<i>Hieraetus pennatus</i>	WV	RA	G	SF	52	834	250	190	1	1	0
Accipitridae	Common Buzzard	<i>Buteo buteo</i>	WV	RA	G	SF	53	875	250	203.5	1	3	0
Accipitridae	Griffon Vulture	<i>Gyps fulvus</i>	WV	RA	G	SF	116	7436	448.5	316	0	0	1
Accipitridae	Greater Spotted Eagle	<i>Clanga clanga</i>	WV	RA	G	S	68	2445	437.5	250	0	5	2
Accipitridae	Montagu's Harrier	<i>Circus pygargus</i>	WV	RA	G	SF	47	315.5	369.5	227	5	1	0
Accipitridae	Oriental Honey-Buzzard	<i>Pernis ptilorhynchus</i>	R	RA	G	S	68	1186.5	399.5	253.5	2	1	0
Accipitridae	Pallid Harrier	<i>Circus macrourus</i>	WV	RA	G	LF	48	388.5	346	211.5	1	1	0
Accipitridae	Shikra	<i>Accipiter badius</i>	R	RA	G	S	66	131.5	528	270	3	1	0
Accipitridae	Short-toed Snake Eagle	<i>Circaetus gallicus</i>	R	RA	G	SF	36	1699.5	191	151.5	0	1	0
Accipitridae	Steppe Eagle	<i>Aquila nipalensis</i>	WV	RA	G	S	79	2745.5	527.5	270	2	13	5
Accipitridae	Western Marsh-harrier	<i>Circus aeruginosus</i>	WV	RA	G	SF	57	711.5	490	239.5	24	10	3
Accipitridae	White-eyed Buzzard	<i>Butastur teesa</i>	R	RA	G	SF	43	325	291	174.5	3	1	0
Alaudidae	Rufous-tailed Lark	<i>Ammomanes phoenicura</i>	R	P	N	S	16	25.6	105	60.5	1	0	0
Alcedinidae	Pied Kingfisher	<i>Ceryle rudis</i>	R	W	N	S	41	84.4	151.5	108.5	4	0	0
Alcedinidae	White-breasted Kingfisher	<i>Halcyon smyrnensis</i>	R	W	N	LF	28	91.4	118.5	77.5	5	0	0
Anatidae	Lesser Whistling Duck	<i>Dendrocygna javanica</i>	R	W	N	LF	42	525	205	54	22	0	0
Anatidae	Northern Pintail	<i>Anas acuta</i>	WV	W	N	S	65	946.5	270.5	190.5	32	101	0
Anatidae	Northern Shoveler	<i>Spatula clypeata</i>	WV	W	N	LF	51	613	246	79	113	25	0
Anatidae	Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	R	W	N	LF	61	1010	270	130	44	40	0
Ardeidae	Black-crowned Night-heron	<i>Nycticorax nycticorax</i>	R	W	N	SF	58	810	282.5	102.5	1	0	0
Ardeidae	Cattle Egret	<i>Bubulcus ibis</i>	R	W	N	S	41	366	89.5	89.5	76	80	0
Ardeidae	Grey Heron	<i>Ardea cinerea</i>	R	W	N	SF	98	1443	142	172.5	6	1	0
Ardeidae	Intermediate Egret	<i>Ardea intermedia</i>	R	W	N	LF	45	462	318.5	125.5	1	0	0
Ardeidae	Great White Egret	<i>Ardea alba</i>	R	W	N	SF	96	873.5	372.5	162.5	2	0	0
Ardeidae	Little Egret	<i>Egretta garzetta</i>	R	W	N	S	63	312	273	100.5	9	7	0
Ardeidae	Indian Pond Heron	<i>Ardeola grayii</i>	R	W	N	S	46	253	275	78.5	3	2	0
Ardeidae	Western Reef-egret	<i>Egretta gularis</i>	R	W	N	SF	63	400	284	107	1	1	0

Family	Common name	Scientific Name	Migratory Status	Group	Flight Type	Flock Size	Morphological Characters				Abundance		
							Body Length (cm)	Body Mass (g)	Wing Length (mm)	Tail Length (mm)	Height band 1	Height band 2	Height band 3
Charadriidae	Red-wattled Lapwing	<i>Vanellus indicus</i>	R	W	N	SF	33	181	227.5	116.5	20	1	0
Ciconiidae	Black-necked Stork	<i>Ephippiorhynchus asiaticus</i>	R	W	G	S	135	4100	605	269	6	2	0
Ciconiidae	Painted Stork	<i>Mycteria leucocephala</i>	R	W	G	S	93	3180	500	161	44	178	131
Columbidae	Rock Dove	<i>Columba livia</i>	R	O	G	S	33	354	376.5	106	20	54	0
Columbidae	Eurasian Collared-dove	<i>Streptopelia decaocto</i>	R	O	G	SF	32	149	760	125	93	10	0
Columbidae	Laughing Dove	<i>Spilopelia senegalensis</i>	R	O	G	LF	27	101	129	113	151	4	0
Columbidae	Red Turtle-dove	<i>Streptopelia tranquebarica</i>	R	O	G	S	33	13	140.5	88	2	0	0
Corvidae	House Crow	<i>Corvus splendens</i>	R	P	N	S	43	293.5	707.5	168.5	136	20	0
Cuculidae	Asian Koel	<i>Eudynamys scolopaceus</i>	R	P	N	S	43	233	193.5	195.5	6	0	0
Cuculidae	Greater Coucal	<i>Centropus parroti</i>	R	O	N	SF	48	283	184	231	3	0	0
Cysticolidae	Ashy-crowned Sparrow Lark	<i>Eremopterix grisea</i>	R	P	N	S	13	16	77	43	17	0	0
Cysticolidae	Grey-breasted Prinia	<i>Prinia hodgsonii</i>	R	P	N	LF	11	6.4	152	52	5	0	0
Dicruridae	Black Drongo	<i>Dicrurus macrocercus</i>	R	P	N	SF	31	48.3	137.5	148	1	2	0
Estrildidae	White-throated Munia	<i>Euodice malabarica</i>	R	P	N	SF	10	12	55.5	47.5	3	0	0
Falconidae	Common Kestrel	<i>Falco tinnunculus</i>	WV	RA	G	SF	36	184	89.5	161.5	10	11	0
Gruidae	Demoiselle Crane	<i>Grus virgo</i>	WV	W	G	LF	76	2417	271.5	173.5	0	200	352
Hirundinidae	Barn Swallow	<i>Hirundo rustica</i>	WV	O	N	S	18	18.2	124.5	107.5	6	0	0
Hirundinidae	Red-rumped Swallow	<i>Cecropis daurica</i>	R	O	N	S	20	22.2	112	83.5	46	4	0
Laridae	Common Tern	<i>Sterna hirundo</i>	WV	W	N	LF	36	120	222.5	80	0	22	0
Laridae	Heuglin's Gull	<i>Larus heuglini</i>	WV	W	G	LF	60	1085	50.5	169	1	2	0
Laridae	River Tern	<i>Sterna aurantia</i>	R	W	N	S	43	112	270	203	3	1	0
Laridae	Whiskered Tern	<i>Chlidonias hybrida</i>	WV	W	N	SF	25	84	225	78.5	8	3	0
Meropidae	Asian Green Bee-eater	<i>Merops orientalis</i>	R	O	G	S	21	14.8	418.5	126.5	13	2	0
Muscicapidae	Indian Robin	<i>Saxicoloides fulicatus</i>	R	P	N	S	16	16.6	76	71.5	2	0	0
Nectariniidae	Purple Sunbird	<i>Cinnyris asiaticus</i>	R	P	N	SF	10	8.1	56	34.5	38	4	0
Passeridae	House Sparrow	<i>Passer domesticus</i>	R	P	N	S	15	24.3	432.5	55	38	0	0
Pelecanidae	Dalmatian Pelican	<i>Pelecanus crispus</i>	WV	W	G	S	183	9550	110	225	67	101	270
Phalacrocoracidae	Little Cormorant	<i>Microcarbo niger</i>	R	W	N	SF	51	427	193	139.5	78	155	6
Phasianidae	Grey Francolin	<i>Francolinus pondicerianus</i>	R	O	N	LF	33	256	95.5	87	3	0	0
Phoenicopteridae	Greater Flamingo	<i>Phoenicopterus roseus</i>	WV	W	N	SF	140	3035	273	170.5	0	2	0
Ploceidae	Baya Weaver	<i>Ploceus philippinus</i>	R	P	N	S	15	28.2	73.5	47.5	7	0	0
Pycnonotidae	Red-vented Bulbul	<i>Pycnonotus cafer</i>	R	P	N	S	20	536	96.5	87	23	0	0
Pycnonotidae	White-eared Bulbul	<i>Pycnonotus leucotis</i>	R	P	N	LF	20	23	86	75	2	1	0

Family	Common name	Scientific Name	Migratory Status	Group	Flight Type	Flock Size	Morphological Characters				Abundance		
							Body Length (cm)	Body Mass (g)	Wing Length (mm)	Tail Length (mm)	Height band 1	Height band 2	Height band 3
Recurvirostridae	Black-winged Stilt	<i>Himantopus himantopus</i>	R	W	N	SF	25	177.1	391	85	18	5	0
Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	WV	W	N	S	21	48	241	54.5	16	1	0
Scolopacidae	Green Sandpiper	<i>Tringa ochropus</i>	WV	Q	N	S	24	71.4	493.5	56.5	2	0	0
Scolopacidae	Ruff	<i>Philomachus pugnax</i>	WV	W	N	LF	25	136	181.5	83.5	44	20	0
Sturnidae	Rosy Starling	<i>Sturnus roseus</i>	WV	P	N	S	23	73.25	130.5	70	1802	1378	495
Threskiornithidae	Red-naped Ibis	<i>Pseudibis papillosa</i>	R	W	G	S	68	1500	382.5	180	18	2	0
Threskiornithidae	Eurasian Spoonbill	<i>Platalea leucorodia</i>	R	W	G	S	60	1868	167	115	30	17	0
Threskiornithidae	Glossy Ibis	<i>Plegadis falcinellus</i>	WV	W	G	SF	52	750	395	100	0	31	23
Threskiornithidae	Black-headed Ibis	<i>Threskiornis melanocephalus</i>	R	W	G	S	75	1500	356.5	139	3	3	0
Timaliidae	Common Babbler	<i>Turdoides caudata</i>	R	P	N	S	23	33.5	374	120	30	0	0

(R –Resident, WV, Winter Visitor, P-Passerine, W-Wetland associated species, RA- Raptors, O- Other species, G-Gliders, N-Non-gliders, S-Solitary, SF-Small Flock, LF- Large Flock)