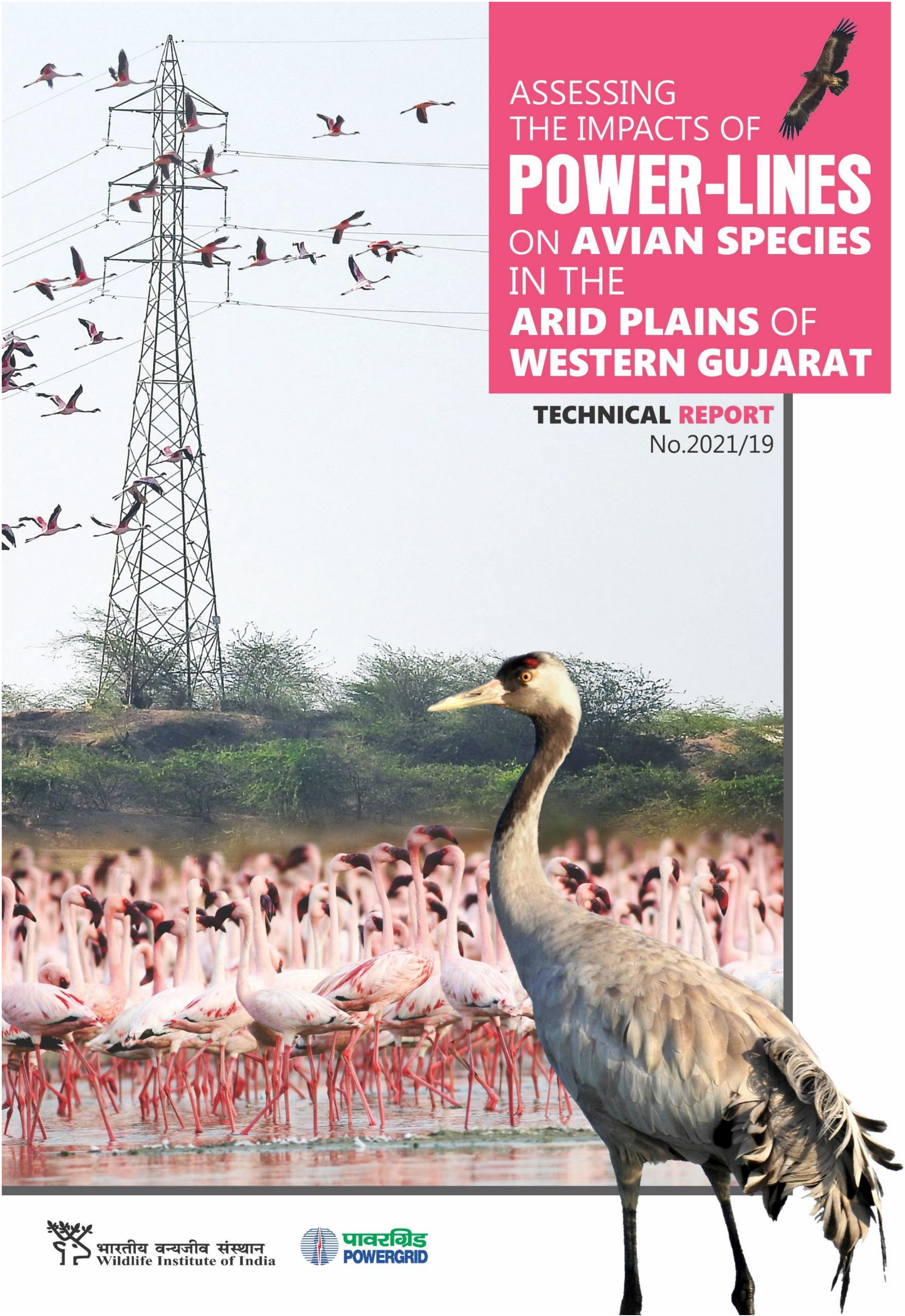

# ASSESSING THE IMPACTS OF POWER-LINES ON AVIAN SPECIES IN THE ARID PLAINS OF WESTERN GUJARAT

**TECHNICAL REPORT**
No.2021/19

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

पावरग्रिड
POWERGRID

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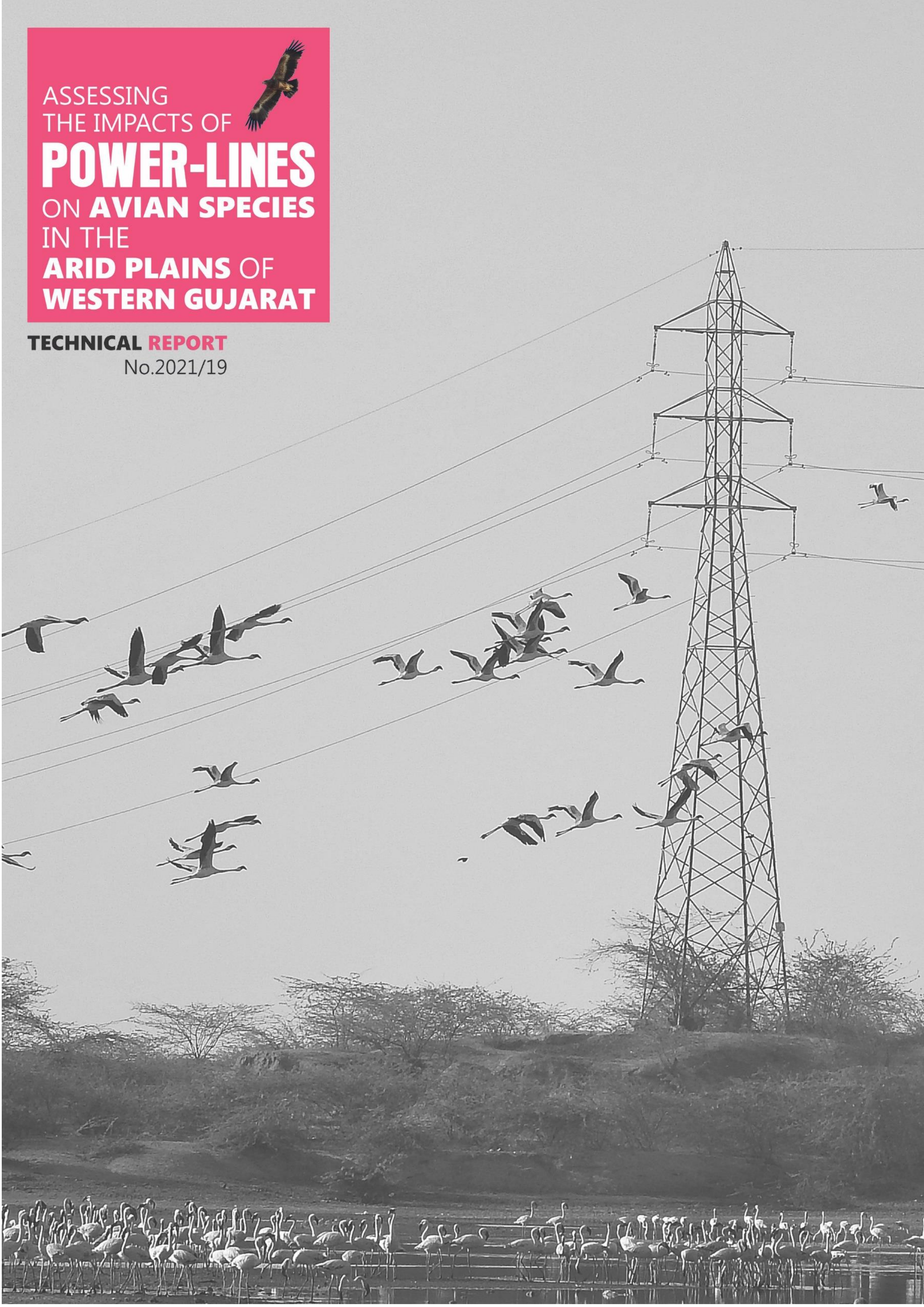

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**The citation for specific chapters is provided at the beginning of each chapter**

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**Photo credits:** Project Team

# *Contents*

# Acknowledgements

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# Summary

The Kachchh landscape in western Gujarat has witnessed rapid industrial growth in the last few decades. Also, the landscape has a high potential for wind energy generation and as a result, a number of wind farms have been established and continue to expand. Rapid industrialization and wind energy production has resulted in extensive power-line network crisscrossing the landscape. These energy infrastructures are known to pose potential risks to birds primarily those that are large-bodied in the form of collision and electrocution mortality. In lieu of this, a -four study was carried out in the Kachchh landscape to assess the impact of power-lines on large avian species in the arid plains of western Gujarat.

In order to assess the power-line collision risk, data were collected at multiple levels, which includes (1) mapping the network of transmission lines in the Kachchh district, (2) GPS telemetry of six flamingos (two Greater and four Lesser Flamingo) (3) flight behavior of cranes around power-line, and (4) mortality surveys. The distribution and abundance of migratory Raptors were studied on three selected sites across Kachchh to know the electrocution risk to raptors. Also, surveys were carried out to collect data on space use by Common Crane with respect to wind farms to study the impacts of windmills on large birds. Finally, the data were analyzed using GIS modelling and various R packages to understand the space-use by large birds and identify risky power-line stretches that could pose threats to large birds.

The analysis of Flamingo distribution surveys revealed that greater flamingos are widely distributed and occur in a much larger area than Lesser Flamingo. The analysis of tracking data showed that Flamingos make a greater number of flights during the breeding season. Further, it was documented that Lesser Flamingo use saltpans and mudflats primarily while Greater Flamingo used inland wetlands and coastal areas more often. The comparison of flight time showed that flamingos make most of the flights during night time. In the case of Cranes, Common cranes occurred in both agricultural and grassland habitats, while Demoiselle cranes were more localized and used only agricultural fields and feeding stations where local people practice food provisioning.

Flamingos tracking data helped identify two main flight corridors, one at Nanda Bet and one at Surajbari, through which they made flights. These two corridors are also the only entry points from mainland Gujarat to Kachchh and hence are the corridor for transmission lines. As a result, these transmission lines are suggested to be a potential threat to Flamingos. The overlaying of transmission lines on the suitable habitat of Flamingos and Cranes revealed that 6% and 39% of the total power-line length is falling in Flamingo and Crane suitable habitats, respectively. It was found that 84.4% and 70% of total occasions, Lesser Flamingo and Greater Flamingo crossed power-lines during night times while making long-distance flights. The flight behavior observations of Common Crane around power-lines showed that 81% of total flocks observed altered either their flight path or their flight height.

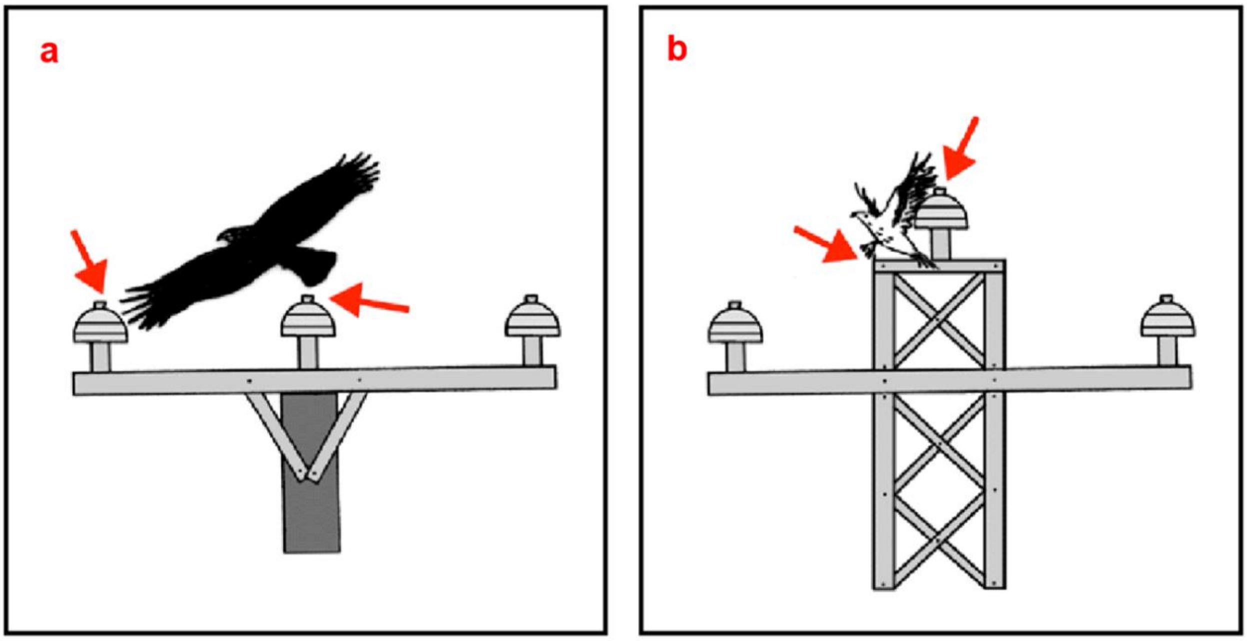
The data on raptor distribution with respect to distribution lines revealed that the Banni area has a high encounter rate (0.6 sightings/km) of raptor species and is home to several large raptors. The distribution lines in the Kachchh district do not have bird-safe spacing between conducting parts and hence can pose a potential risk to large raptors. The study investigating the impact of windmills on the space-use by Common Crane revealed that the encounter rate of Common Crane flocks in the areas dominated by windmills is six times less than in the areas with no windmills, suggesting possible functional habitat loss for the large birds due to windmills.

This study is the first detailed landscape-scale effort to assess risks by energy infrastructure on avian species that forms a baseline for any future site-specific impact assessment studies in the region. This project identified the areas where powerlines likely pose a threat to large birds such as Flamingo and Crane. This study also suggests different strategies to minimize the impacts of existing and future energy infrastructure in different habitats in the Kachchh region.

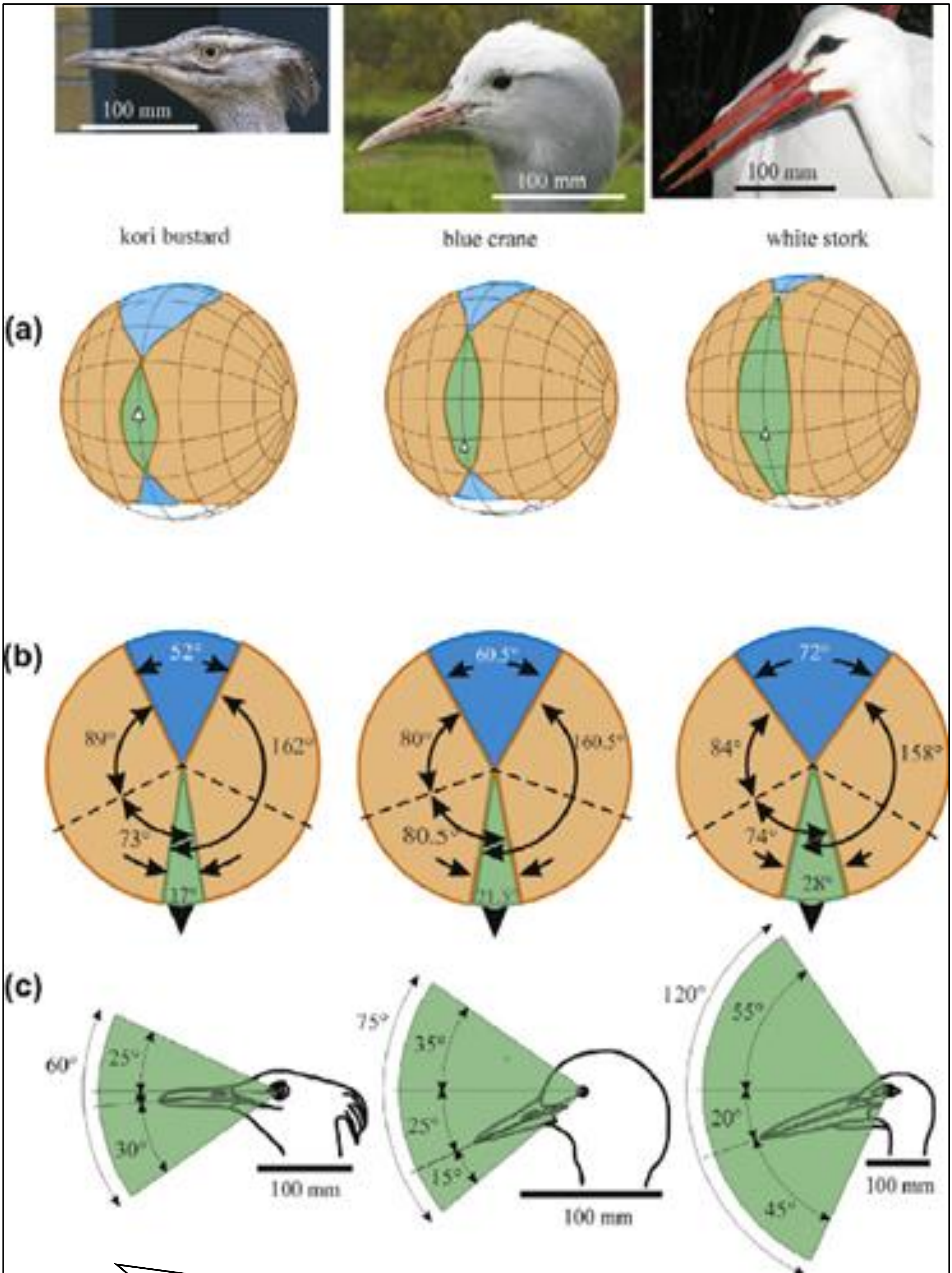
# *Energy infrastructure and its impacts on avian species*

India is one of the highest populated countries and the economy of the country is largely based on agricultural practices. The ever-increasing population, modernisation of agricultural sector and rapid industrialization require massive energy inputs. The Government of India is working to provide electricity to all households and agricultural fields in the country through various schemes such as Dindayal Upadhyay Gram Jyoti Yojana has resulted in the electrification of 98% of the total households in the country (Saubhagya.gov.in). As a result, India is now ranked third in the world in electricity production and in consumption, to meet the enormous energy demand to fuel one of the fastest-growing economies (Tripathi 2018). While this is crucial for the economic development of the country, linear power projects also have negative impacts on the natural environment. Electricity generated at power stations is transmitted by high voltage long-distance transmission lines to the distribution centres and also traverses through landscapes across the country that are generally rich in wildlife. Power-lines are also routed through ecologically sensitive areas and through forests, National Parks and Wildlife Sanctuaries that often require diversion of forest land. More importantly, power-lines pose a serious problem of electrocution and collision, specifically to birds (Ferrer 2012), which has been inadequately investigated in India so far.

Birds may safely perch on energized equipment of a power-line as long as all points of contact are at the same electric potential. Death or injury (electrocution) occurs only when birds become a pathway through which electric current flows from a higher potential (or voltage) to a lower potential (often a path to ground) of the distribution lines where the separations between conducting surfaces are relatively less. This can occur if a bird simultaneously contacts two differently energized wires (phase wires) or simultaneously contacts an energized wire and any grounded, conductive material (Avian Power Line Interaction Committee [APLIC] 2006). Bird collision, on the other hand, is primarily associated with transmission line and most often occur with the overhead earth wire, which may be less visible than energized conductors due to its smaller diameter, and affects a select group of large birds like cranes and bustards. The field of vision in large birds is narrow because of the lateral placement of eyes thereby lacking the ability to detect the obstacles from distance, making them more vulnerable to power line collisions (Martin and Shaw 2010).




Distribution lines pose the risk of electrocution due to its structural design. Electrocution happens when the bird comes in simultaneous contacts with (a) two phase wires and (b) phase wire and any conducting surface of the pole. (Source: Tinto et al. 2005)




Field of vision in Kori Bustard, Blue Crane, and White Stork (Green color: binocular sectors; orange color: monocular sectors; blue color: blind sectors) (Source: Martin and Shaw 2010)

Globally, interactions with power-lines may cause more than one billion annual bird mortalities (Hunting 2002). This extent of mortality would rank power-lines along with wind turbines and communication towers to be a major threat (Longcore et al. 2012, Smallwood 2013). Furthermore, mortality at power-lines may contribute to population declines for some species, as evidenced by studies documenting that power line-caused mortality can cause a large percentage of total mortality for species from several avian orders (Bevanger 1995, Real et al. 2001, Sergio 2004, Sundar & Choudhury 2005 McIntyre 2012). Despite an increasing number of studies that employ rigorous a priori study designs (e.g., Guil et al. 2011, Dwyer et al. 2014), much of the research published to date about bird mortality at power-lines have consisted of qualitative reviews and assessments of opportunistically collected data (Bevanger 1994, Lehman et al. 2007).

Windmills are often considered a clean energy production method, however, pose risks of direct mortality or injury to birds which is the result of a collision with rotors, towers, and associated structures. Direct mortality or severe injury of birds can result not only from collisions with rotors, but also with towers, and associated structures such as guy cables, power-lines, and meteorological masts. There is also evidence of birds being forced to the ground as a result of being drawn into the vortex created by moving rotors (Winkelman 1995). The mortalities at windmills are particularly significant for long-lived species with low productivity and slow maturation rates, especially when the species of conservation concern are affected (Drewitt & Langston 2006). In such cases, there could be significant effects at the population level (locally, regionally, or, in the case of rare and restricted species, nationally), particularly in situations where cumulative mortality takes place as a result of multiple installations. Apart from direct collision mortalities, wind farms also pose potential risks of functional habitat loss (Zimmerling et al. 2013, Marques et al. 2020)) and displacement of birds from their potential habitats (Kelsey et al. 2018).

Current and future patterns of electric power transmission and distribution lines across the country are thought to increase the potential for interference with the daily, seasonal movements of both resident and migratory birds. The power-lines and associated structures have changed the habitats and flight pathways of birds and also have altered the migration and distribution patterns as a result of avoidance of the areas adjacent to these structures. The overall impact of power-lines on bird movements, however, is not fully understood, although it has been the subject of an increasing amount of research in recent years. While there are many documented incidents of raptors, waterfowl, and other large birds found dead or injured near power-lines, the exact cause of death or injury has often been indeterminable. Electrocution and collision of birds due to power-lines is not only a topic of conservation priority but also a matter of serious economic and financial cost due to disruption to power supplies consequently becoming a cause of concern to electricity-producing and distribution companies. Appropriate routing and structure of power-lines can reduce the risks of bird collision and electrocutions by 50% or more (Prinsen et al. 2011).

While innumerable incidences of avian mortality due to power-lines and wind turbines have been in news during the recent past, barring 2-3 scientific studies on this subject, there is no study available focusing on the landscape-level assessment of impacts of these energy infrastructures on avian species in India. The mortalities of avian fauna in the country were primarily studied at western parts of the country which are the strongholds of large-sized migratory raptors and cranes. Studies done in the Thar Desert demonstrated the electrocution mortalities of birds at distribution lines (Harness et al. 2013) and collision mortalities of globally threatened Great Indian Bustard (Uddin 2021). A similar threat to Great Indian Bustard is also being identified in Kachchh district which is the last remaining stronghold for Great Indian Bustard in Gujarat. Collision mortalities of flamingos were also reported from the state of Gujarat in the study carried out by Tere and Parasharya (2011) where a total of 76 mortalities were recorded over a period of three years. Moreover, mass mortality of Flamingos happened near Khadir bet, very close to the famous Flamingo City in 2011 when more than 139 flamingos died due to 66kV power-line (Paliwal 2011).

These studies focused only on selected power-line corridors primarily from western India and the impacts of these power-lines have not been assessed at the landscape scale. Policy and management for the reduction of avian mortality should ideally be based on evidence from scientific studies that implement randomised and replicated sampling schemes. Further, the studies to assess the impacts of energy infrastructure on birds should be focused on the entire landscape and not on a small area to effectively address the issue at a larger scale and for multiple species or species groups. In addition, such estimates of mortality and comparisons among mortality threats are likely to be used for prioritizing policy and management strategies and for identifying major research needs. These estimates therefore be based on a systematic and transparent assessment of rigorously collected data.

The Kachchh district in western India is one of the important landscapes for resident as well as migratory birds such as raptors and crane that comes through Central Asian Flyway. Given the strategic location of the landscape, it has also witnessed rapid industrialisation in recent years and there has been a mushrooming of ports and harbours all along the coast. The Gulf of Kachchh is also known as the 'Gulf of Rich' due to the tremendous economic activities in this region. To meet the power demand for the ever-increasing industries, new substations and a huge network of power-lines exist in the area. This network is continuously expanding given the immense potential of renewable resources (tidal, wind, solar) in the Kachchh area. It has been estimated that Gujarat is one of the states with the highest wind energy potential, most of which is concentrated in and around the Kachchh landscape (Ministry of New and Renewable Energy 2020). Given this, multiple wind farms have been established in the district in the recent past and new wind energy projects continue to develop. The rapid growth in the energy infrastructure in the region has called for the landscape-level assessment of impacts of energy infrastructure on resident and migratory avian species.

Considering the above, a study to assess the impacts of power-lines on avian species was taken up as a collaborative effort between the Wildlife Institute of India and Power Grid Corporation of India Limited. The study has two broad objectives: *1. To assess the electrocution and collision risk to birds due to existing power-lines and wind farms, identify problematic configurations and generate comprehensive data on mortality of avifauna 2. To identify sensitive bird habitats along existing and proposed power-line and wind farm corridors in Western Gujarat.* This study is the first effort in the country to assess the risk at the landscape level and provide information in critical areas for birds and power lines passing through these areas that may pose the potential risk.

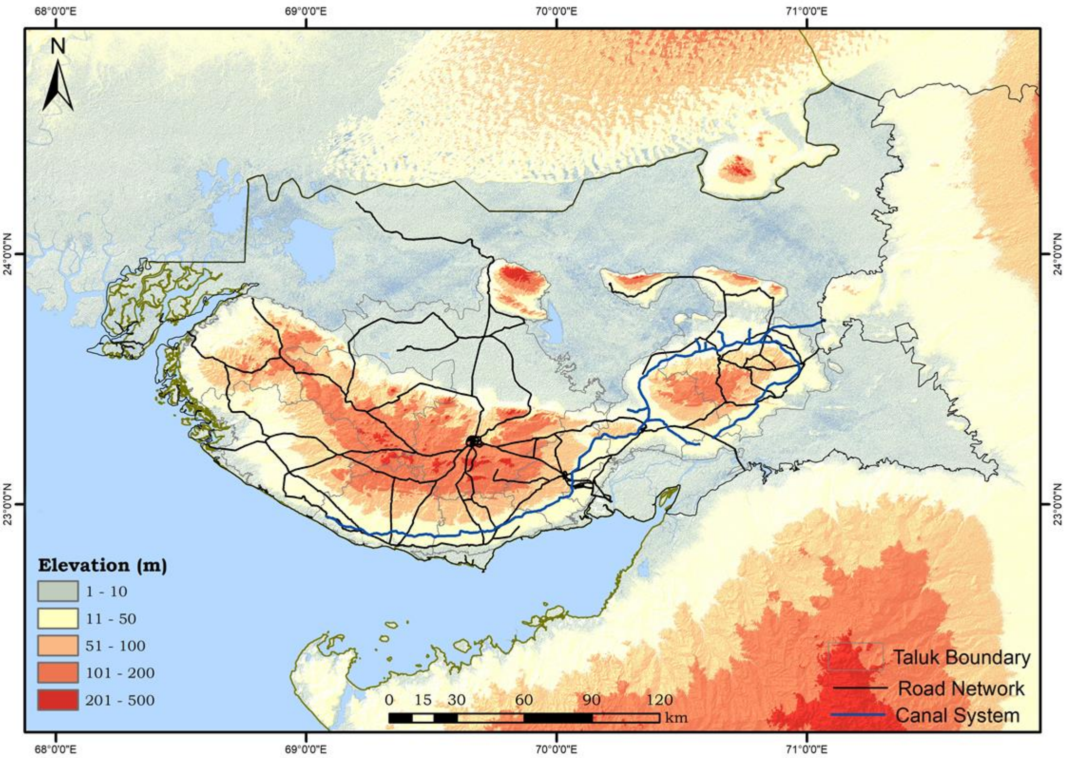
# *Kachchh Region*

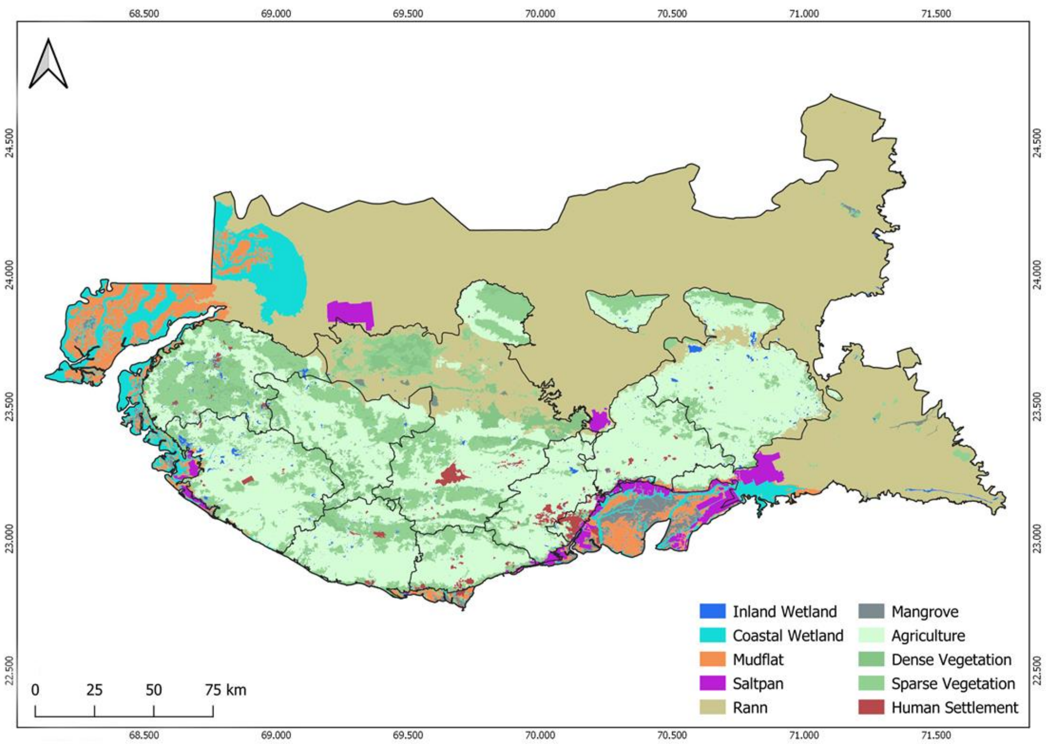
This study was carried out in the arid plains of western Gujarat which primarily falls in the administrative unit of the Kachchh district. With the Tropic of Cancer passing through this region, it is among the hottest parts of India and is categorized as a desert zone (Rodgers et al. 2000). Summers in the region are hot and dry and the temperature goes up to 46 °C while winters are cool and temperature may dip to 4 °C. The rainfalls are erratic and ranges between 300-400 mm received for only 15 days around the year and droughts are quite frequent. The landscape of Kachchh Mainland is dominated by a central highland surrounded by plains. The highland has a rugged hilly terrain in two main tracts, one from Anjar to Lakhpat and another in Rapar taluk. The lowlands are extensive alluvial agricultural plains, or mud and salt flats which is famously known as the Rann, and grassy flats of Banni (Thakkar 2017). The plains of the Kachchh also have an elevated chain of highlands comprised of Pachcham, Khadir, Bela and Chorar (Lal 2016).

The arid plains of the Kachchh district hold ecological importance as it falls under the Central Asian Flyway (Convention on the Conservation of Migratory Species of Wild Animals 2021). Also, the unique Rann system in Kachchh is globally outstanding for its biological distinctiveness and richness. This is the last remaining habitat of many threatened species. Particularly, this is the only habitat of the last surviving population of the endangered and endemic Indian Wild Ass *Equus hemionus khur*. This is also an important wintering area for the Endangered Macqueen's Bustard *Chlamydotis macqueenii*. The Kachchh region supports the largest breeding colony of the Greater Flamingo *Phoenicopterus roseus* and Lesser Flamingo *Phoeniconaias minor* in South and South East Asia and is popularly known as "The Flamingo City". It is also unique for the saline grasslands called "Banni", which support endemic salt-tolerant grasses and numerous wild relatives of commercially cultivated and economically valuable species (GEF 2009). The plains of Banni and a large number of freshwater and saline wetlands in the region become important wintering grounds for several long-distance migratory species of birds, including raptors, waterfowl and cranes.

The landscape is having vast plains and as a result, much of the area is dominated by agricultural fields. Agriculture activities in the district are rain-dependent with only 34% irrigated land (Patel 2019) cultivating primarily food crops. However, over the years with increased availability of water through canal irrigation, large tracts of the traditional dryland farms are now replaced with cash crops primarily cotton. Additionally, the demand for biofuel has also led to many parts of the region coming under castor crop production. Kachchh is also a major producer of salt in the country and contributes 78% of the total salt production in the country (Thakker 2014). The majority of the saltpans are formed across the mudflats of the Gulf of Kachchh, plains of the Little Rann of Kachchh, and a few along the edges of the Great Rann of Kachchh. The region has also seen rapid industrial growth with the development of several seaports and improved road connectivity, and to fuel these industries the area is crisscrossed by an extensive network of power-lines. Further, with the region identified as having high wind energy potential hundreds of windmills have been and continue to be established and are adding more transmission lines that transmit surplus power to other parts of the country.

In the past, several news reports of avian mortality due to collision with power lines and windmills in the Kachchh region have been reported. The landscape is an important area for several threatened, endemic and migratory species which are exposed to the risk of coming in contact with these energy infrastructures. Therefore, it became important to undertake a detailed study of the area and understand the threats to its species and their survival due to power-lines and windmills.




Maps showing the study area with elevation profile, road network and canal system (top) and Land-use/Land-cover (below)


Naliya Grassland


Banni Grassland


Agricultural Landscape


Scrubland


Wagad


Little Rann


Greater Rann

Inland Wetland

Coastal Wetland

Saltpan

Coastline

Mudflat

# *Large Avian Species of the Kachchh*

## Flamingo

Two species of resident breeding Flamingo occur in the Kachchh landscape viz. Lesser Flamingo *Phoeniconaias minor* and Greater Flamingo *Phoenicopterus roseus*. The Lesser Flamingo is the smallest of all flamingos and the Greater Flamingo is the largest. Flamingos are waders and they inhabit shallow water bodies such as saline lagoons, saltpans, and large saline or alkaline lakes, inland dams, estuaries, and coastal waterbodies. The Greater flamingo is listed as 'Least Concern' species due to its wide distribution range while the Lesser Flamingo is listed as a 'Near Threatened' species in IUCN red list due to limited breeding sites, land reclamation activities in coastal regions, water pollution and collision with powerlines. Many studies across the world regard energy infrastructures as a potential threat for flamingos. The eyes of flamingo are laterally placed which are advantageous for a filter feeder but limit long-distance vision during flight making them susceptible to powerline collisions. Specifically, power-lines crisscrossing or passing along the wetland becomes a potential threat to them.


## Migratory Cranes

The arid plains of Kachchh resemble the steppe habitat of northern Eurasia. As a result, a number of migratory birds arrive in the landscape during the winter months. Common Crane *Grus grus* and Demoiselle Crane *Anthropoides virgo* are two crane species that travel through the Central Asian Flyway to arrive in the Kachchh landscape. Here they utilize open meadows and cultivated land for foraging and wetlands for resting and roosting. Both the species are listed as "Least Concern" species in the IUCN red list due to their wide range and population. However, they are facing a potential threat by habitat loss, rapid change in agricultural practices, pesticide poisoning and energy infrastructure (IUCN, 2016). Since Cranes have a blind spot in frontal vision due to lateral placement of eyes, they are unable to detect power-line from distance (Martin and Shaw, 2010). Also, the high wing loading and flock flying behaviour does not provide them enough agility to skip the energy infrastructure falling in the flight path, making them more susceptible to collision mortality (Bavenger, 1994, 1998; Alonso and Alonso, 1999).

## Raptors

Many parts of the study area have been identified as high-priority areas for avifaunal conservation recognised as Important Bird Areas (Islam and Rahmani 2004). Several globally threatened bird species occur in the region that includes a number of raptors: five eagle species (Eastern Imperial Eagle *Aquila heliaca*, Greater Spotted Eagle *Clanga clanga* Indian Spotted Eagle *Clanga hastata*, Steppe Eagle *A. nipalensis*, and Tawny Eagle *A. Rapax*), and six vulture species (Cinereous Vulture *Aegypius monachus*, Egyptian Vulture *Neophron percnopterus*, Eurasian Griffon Vulture *Gyps fulvus*, Long-billed Vulture *G. indicus*, Red-headed Vulture *Sarcogyps calvus*, and White-rumped Vulture *G. bengalensis*). The occurrence of a large number of raptors in this region is also due to the presence of regional cattle carcass disposal sites. Given that tall trees are largely absent, anthropogenic structures such as utility poles provide tall perches used by these raptors, making them highly vulnerable to electrocution.

# *Structure of the Report*

This report details the findings of four-year study conducted in the Kachchh district. The report is structured in four different chapters, each dealing with separate aspects. The first chapter describes the distribution of flamingos and migratory cranes across the Kachchh district which forms the baseline information about the distribution and high use areas by these species. Information presented in this chapter is collected through grid-based field surveys and GPS tracking of birds during the study period. The second chapter focuses on the assessment of power-line collision risk to large birds. In this chapter, results of flight behaviour and space use by flamingos are described which provides information on critical power-line corridors and inland wetlands across the region. Also, the results of the short study on responses by Common Crane while crossing power-lines is described in this chapter which helped in understanding the influence of power-lines on the flight behaviour of Cranes.

The third chapter deals with the findings of a short study carried out in three sites across Kachchh to assess the electrocution risk to raptors. The electrocution risk assessment described in this chapter is based on the results of raptor diversity-abundance and characteristics of distribution line network across three sites in the district. The fourth chapter describes space use by Common Crane and influence of windmills on them in Bhachau taluk of eastern Kachchh.

**Citation:**

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# *Distribution of Large Avian Species in the Arid Plains of Western Gujarat*

Harindra Baraiya

Gaurav Sirola

Anju Baroth

R. Suresh Kumar

Understanding the distribution of species or species groups across space and time is crucial to understand their conservation needs. The distribution is directly influenced by the physical conditions in and around the niche of the species (Newton 2013). Climate, habitat and resource availability at the global and local scale are a few of the fairly discussed factors that affect species distribution (Telleria et al. 1992, Hurlbert & Haskell 2003, Hawkins et al. 2003, Marini et al. 2009, Campton et al. 2011, Hansen et al. 2011, Zhang et al. 2013). Moreover, anthropogenic structures such as roads, human settlements and energy infrastructure also influence the distribution of species in the form of habitat degradation, disturbance and direct mortalities (Lee et al. 2004, Jenkins et al. 2010, Khanaposhtania et al. 2019). The ultimate prediction of species distribution, thus, is determined by the interactions between multiple factors (Marra 2000, Cunningham and Johnson 2006).

In India, studies on the factors influencing birds, particularly energy infrastructure are scarce and, in the past, have focused on single species specifically the highly-threatened Great Indian Bustard *Ardeotis nigriceps* and the Vulnerable Sarus Crane *Antigone antigone* (Sundar and Choudhury 2005, Tere and Parasharya 2011, WII 2018). Further, these studies are primarily focused on select sites with relatively small areas (Ramesh et al. 2012, 2019, Harness and Juvvadi 2013, Uddin 2021). However, many bird species that face risk due to the presence of energy infrastructure, occur over larger areas. For example, the two flamingo species and the two migratory cranes are such species that occur over large areas. Therefore, to assess the threats a landscape-level study is often required.

The Kachchh landscape in western Gujarat is an important flamingo habitat worldwide. The unique saline flats of the Greater Rann of Kachchh and Little Rann of Kachchh together form the largest breeding ground for the flamingos in Asia, and are famously known as the "Flamingo City" (Tere 2005, Ali 1974). The Flamingo city is of great importance for breeding flamingos as it is one of the four main breeding sites for the lesser flamingos and has been selected as an Important Bird Area (IBA) (Birdlife International 2021). The Rann of Kachchh remains dry for most of the year, and it is only on the arrival of the monsoon it gets flooded with the ingression of saline tidal water and freshwater from rains (Gupta and Ansari 2012). During this time, it provides an ideal habitat for flamingos to breed and is extensively used by flamingos.

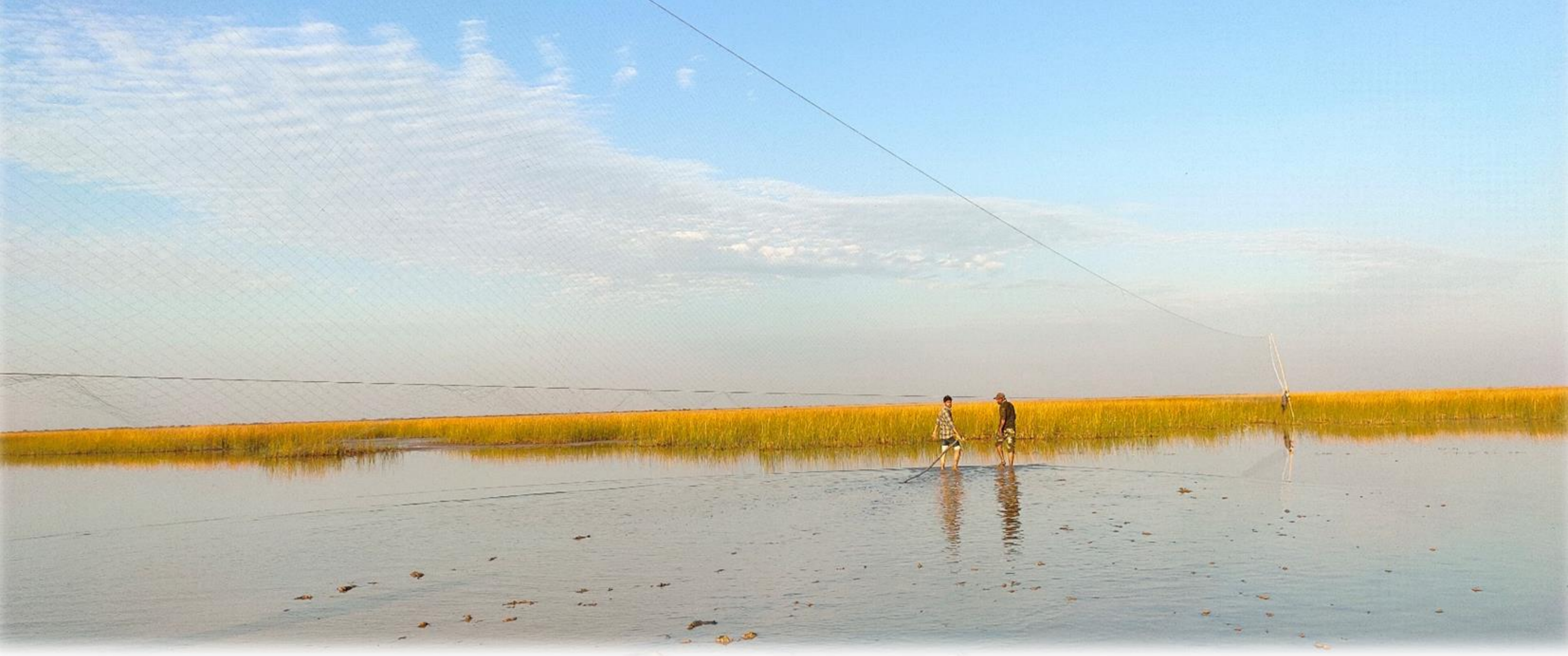
Since 1995, flamingos have been reported to breed in Rann in large numbers. The first record of Greater Flamingo breeding in Flamingo City dates back to 1893 but the first official record is from 1945 when Late Mr. Salim Ali recorded 123,245 nests and half million greater flamingos. The lesser flamingos were first recorded to be breeding in Flamingo city in 1974 by Salim Ali where he counted 2000 individuals. Since then both the flamingo species are reported to be breeding in the flamingo city. In 2020 about 10,000 nests and 60,000 Lesser Flamingo chicks were reported from Greater Rann of Kachchh which marks the importance of Rann as an important breeding site. During the non-breeding season, flamingos occur across the entire Kachchh district where they use inland wetlands, salt pans, mudflats and sea-shore for foraging and primarily feed on microalgae and aquatic invertebrates (Tere 2005).

The migratory cranes in the Kachchh landscape include Common Crane and Demoiselle Crane. Both the species breed in northern Eurasia and migrate using narrow paths to reach their wintering grounds in Africa and the Indian subcontinent (Johnsgard 1983, Higuchi et al. 2008). The arid plains of Rajasthan and Gujarat provide suitable wintering ground to migratory Crane species where a variety of habitats are available for foraging and roosting (Ali & Ripley 1987, Grimmett et al. 2011). In the agricultural fields, cranes feed on left-over crops like cereals, groundnut, pearl millet, and sorghum while in the grasslands, they forage on sedge bulbs and tubers (Tiwari and Rahmani 2002).

In the Kachchh district, few detailed studies (Tere 2005, Vyas 2014) have been carried out to understand the distribution and ecology of flamingo species. These studies were conducted primarily around the breeding season in Greater and Little Rann of Kachchh and provided no information on the species distribution during the non-breeding period. Similarly, for the distribution of migratory cranes in the Kachchh district, only one study has so far been carried out dealing with the foraging habitats of Common Crane in the Banni landscape (Tiwari and Rahmani 2002). Further, with respect to the tracking of Common crane, there is only one study conducted in 1999-2000 (Higuchi et al. 2008), where three individuals of Common Crane were successfully tagged and tracked using satellite PTTs their migration path was recorded. The gap in the efforts to assess the district-wide distribution and understand the movement pattern of Flamingo and Crane species groups in the Kachchh district necessitates answering basic questions such as where do these species occur over time? What are their high-use areas? And how do they make use of the Kachchh landscape?

One of the methods that is widely used to document the potential distribution of species and specifically over large areas is the Species Distribution Modelling (SDM) (Guisan and Thuiller 2005) which quantifies the correlation between environmental factors and the presence of the species. The derived environmental profile can be used to describe and measure the importance of specific factors and to predict species distribution across un-sampled areas (Guisan and Thuiller 2005, Miller and Rogan 2007, Elith and Leathwick 2009, Franklin 2010). The software MaxEnt is widely used to generate SDMs from presence-only data, and it is one of the most efficient techniques for predicting species distributions. (Phillips, Anderson & Schapire 2006, Elith et al. 2011). However, information on the potential distribution alone may not be sufficient to know how species use the landscape, knowledge of their fine-scale movements is also essential to know their habitat selection at local and broader scales. Therefore, the movement tracking of birds through telemetry becomes an essential aspect to know how these birds use the landscape.

We conducted this study to assess the distribution of two avian species groups: Flamingo and Migratory Crane in the Kachchh landscape. The objective of this study was to identify high use and high suitable areas for flamingos and cranes. The findings of this study served as a baseline for assessing the collision risk to these large birds discussed in chapter 3.



# Methods

***Field Surveys for collecting presence data for flamingos and cranes***

For an effective landscape-level survey, a grid-based sampling approach was adopted, wherein the Kachchh district was divided into 141 grids (Figure 1), each measuring 20 x 20 km. of these 22 grids were dropped as they fell in the restricted areas along the international border with Pakistan. Further, those grids that were inaccessible, falling either in the saline flats, Rann areas (n=42), mudflats marine habitat (n=20) and mountainous terrain (n=1) were also dropped from the survey. This resulted in a total of 56 grids that were finalized for the survey.

The Kachchh landscape is the wintering ground for two species of migratory cranes and therefore, the surveys to record Crane distribution were carried out during winter of 2018-19 and 2019-20. A vehicular road survey spanning an average of 85 km (range 45 km to 150 km) and lasting seven to eight hours was carried out in each of the 56 grids. A team of two surveyors searched on either side of the survey track for Crane flocks during the morning (0700 to 1100) and evening (1500 to 1830) hours when birds were actively foraging. On locating a Crane flock, data was recorded for species, GPS location, flock size, major flock activity and habitat. Simultaneously, to record the distribution of flamingos, all the possible wetlands in each grid were visited and data on the flamingo species, their abundance, GPS location and wetland type was recorded. Since the flamingos occur in the Kachchh landscape throughout the year, opportunistic sightings of flamingo flocks during summer and monsoon were also recorded and included in the analysis. The data was summarised for the wetland type where they occurred.

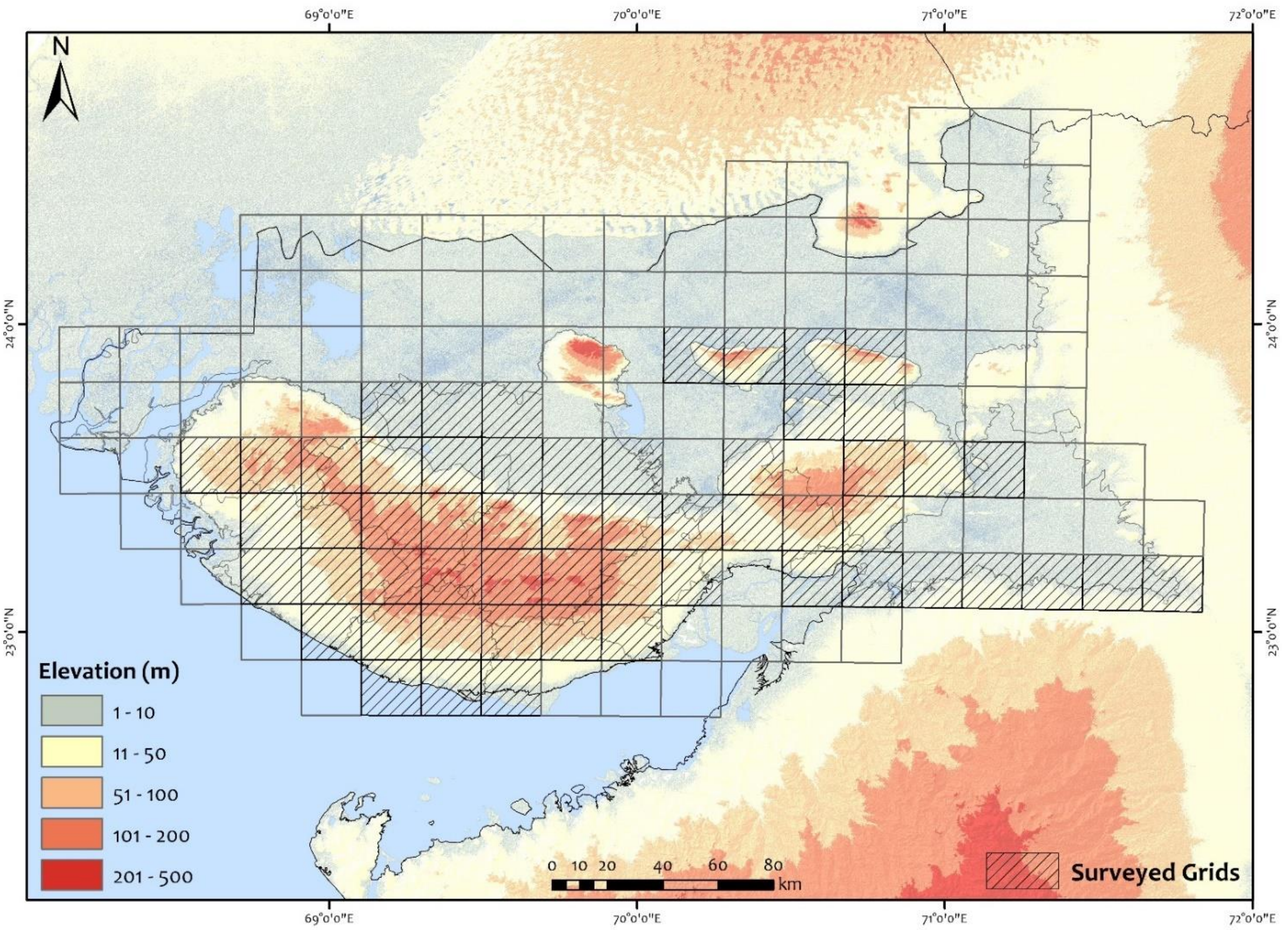



**Figure 1.** A grid-based approach was adopted where in the district was divided in 20 x 20 km grids. Of the total 141 grids, 56 grids were surveyed to record the presence of flamingos and cranes.

***Tracking fine-scale movement of Flamingo***

To track fine-scale movements Flamingo species were captured and tagged with a solar-powered GPS-GSM transmitter (OrniTrack-30 from Ornitela inc., Lithuania). The transmitters weighed 30 g (< 3% of the weight of the flamingo), and deployed as a back-pack using Teflon harness (6.5 mm). Flamingo captures were made in inland wetlands, salt pans and in coastal areas using leg noose-traps during day time and mist nets during night time.

For the analysis of tracking data, GPS locations received through the transmitters were carefully examined and any duplication in the location was removed. The movement tracks obtained were categorised as per the pre-breeding, breeding and non-breeding seasons. The breeding season was defined from the date when the Flamingo entered into the Rann habitat to the time when it moved out and not return again to the breeding location. Further, the GPS points with ground speed ≤1 kmph were selected and one location per day was randomly extracted from this data set to standardise the data for all tagged birds. This data was used to identify high-use areas or Kernel Density Estimate (KDE) and to

construct a species distribution model (methods below). These GPS locations were also used to calculate time spent in different types of wetlands during non-breeding season by Greater and Lesser Flamingo. The randomly selected locations were overlaid on the wetland layer in GIS platform and points overlapping different wetlands types were extracted. Based on the number of points overlapping in a particular wetland type percentage time was calculated.

***Tracking fine-scale movement of Common Crane***

In order to understand the movement patterns and space-use by Common Crane, attempts were made for the capture of Common cranes during 2019-20 season using traditional capture methods like leg-noose and clap-traps, and also mist nets. Due to high rainfall that year and availability of water across the Kachchh landscape cranes were dispersed making their capture extremely challenging. Therefore, we attempted the capture of cranes from the surroundings of the Kachchh district, assuming that the crane populations from nearby areas are likely to be arriving in the Kachchh landscape for foraging.

After innumerable efforts a Common crane was successfully captured and tagged on 12th March 2020 at 2015 hr at a roost site close to the Nal Sarovar Ramsar wetland. The crane was identified as an adult and weighed 4.7 kg (Sex likely to be female - Elena Ilyshenko pers. comm.). After recording select morphometric measurements, the crane was equipped with a solar-powered GPS-GSM leg-mount transmitter weighing 40 g (Model: OrniTrack-L40, Ornitela) on the left leg above knee. A yellow colour leg band with the inscription AYB along with a metal ring (L 9256 of the BNHS) was deployed on the right leg, and was released within 20 minutes of capture. The transmitter was programmed to records its location every 10 minutes on full battery power, when below 75% every half hour, less than 50% then every one hour, and when less than 25% every two hours.

***Identification of High use areas***

Kernel Density Estimates (KDE) were performed to generate home ranges and core areas and 95% and 50% isopleth of the home range (Worton 1989) were extracted. Fixed kernel with smoothing parameter estimated by Plug-in ‘bandwidth’ was selected to generate KDE and analysis was performed in R studio using 'ks' package. For each season a separate KDE was constructed.

***Species Distribution Modelling (SDM)***

To identify high suitable areas, the Kachchh landscape for both flamingos and cranes, Species Distribution Models were constructed using Maximum Entropy modelling (MaxEnt). For the SDM of Flamingo, the presence data point from GPS telemetry were used. Publicly available variables such as NDWI, BioClim variables, and altitude were used as predictor variables with a resolution of 1 sq.km. Since the frequency of recording data points varies with the battery charge percentage of the transmitters, one GPS point per day was randomly selected to standardize the sample size. Additionally, presence locations recorded during the field surveys were used to generate SDM.

Similarly, for migratory Crane species, an SDM was created using sighting locations recorded during field surveys. Further, the presence data from eBird was used in the construction of SDM to ensure the spatial spread of the data in the area where surveys were not conducted due to inaccessibility. Both, Common and Demoiselle Crane use open meadows and agricultural areas in this landscape (Khachar et al. 1987, Soni et al. 1993, Tiwari and Rahmani, 2002) and therefore Land Use Land Cover (LULC) was used as a predictor variable along with NDVI and BioClim layers with the resolution of 1 sq.km.

To train the distribution model, we used 70% of the total presence locations for both the cranes and flamingos and the remaining 30% were used to test the model. On the generation of the SDMs for the two species groups, the relationship between presence points and predictor variables was calculated using the response curve method and the performance of the models was assessed using the Area under curve (AUC) values. To assess the model performance, receiver operating characteristics (ROC) was undertaken. Further, the model output was classified according to the presence probability and we designated the regions with the probability of 0.5 and more as suitable areas.

# Results

From May to August 2018, rapid surveys were conducted across the Kachchh landscape, with Flamingo sightings recorded along the survey route. With the commencement of the winter season, 56 grids were surveyed in 2200 man-hours, resulting in a total survey effort of 4500 km to document the presence of migratory Crane species across the Kachchh landscape. Following that, 125 wetlands were visited to record the presence of Flamingo. In addition, while commuting in field sites, opportunistic sightings of target bird species were recorded.

***Distribution of Flamingo***

From the 125 wetlands surveyed across 56 grids, 101 were inland wetlands, 12 saltpans and 12 coastal wetlands. During the surveys, Greater Flamingo was recorded from 42 inland wetlands, eight saltpans and six coastal wetlands while Lesser Flamingo was recorded from five inland wetlands, two saltpans and only one coastal wetland (Table 1). A total 187 flocks of Greater Flamingo and 72 flocks of Lesser Flamingo were recorded in 35 and 13 grids, respectively.

The average flock size of Greater Flamingo was 314 and ranged from a single individual to 5000 individuals. The average flock size of Lesser Flamingo recorded was 1639 with the range of 20 to 25000 individuals. Large congregations of both the species were recorded from Surajbari creek, inland wetlands of Ratnal and Mithirohar, and saltpans of Gandhidham, Tuna and Jakhau where the flocks of more than 500 birds were recorded.

**Table 1.** The table shows the presence of Greater and Lesser Flamingo in different type of wetlands

| S. No. | Types of Wetlands | No. of surveyed Wetlands | Greater Flamingo presence | Lesser Flamingo presence |
|---|---|---|---|---|
| **1** | Inland Wetland | 101 | 42 | 5 |
| **2** | Saltpans | 12 | 8 | 2 |
| **3** | Coastal Wetland | 12 | 6 | 1 |
| | **Total** | **125** | **56** | **8** |

The sighting data obtained during field surveys were used to generate Kernel Density Estimation (KDE) to identify high-use areas by the two flamingo species. KDE revealed that the two species of Flamingo occur differently in the Kachchh. Greater Flamingo in this landscape occurred in a total of 3123 sq.km (95% KDE) while Lesser Flamingo occurred in a comparatively smaller area of 1335 sq.km (95% KDE). The difference was also recorded in the area of high occurrence (50% KDE) where the Greater Flamingo high occurrence area measured a total of 222 sq.km while Lesser Flamingo high occurrence area measured 266 sq.km (Figure 2). The inland wetland of Ratnal and salt-pans of Tuna were identified as high occurrence areas for the Greater Flamingo and inland wetlands of Ratnal and Mithi-rohar and salt-pans of Kandala and Tuna were found to be high occurrence areas for lesser flamingos.

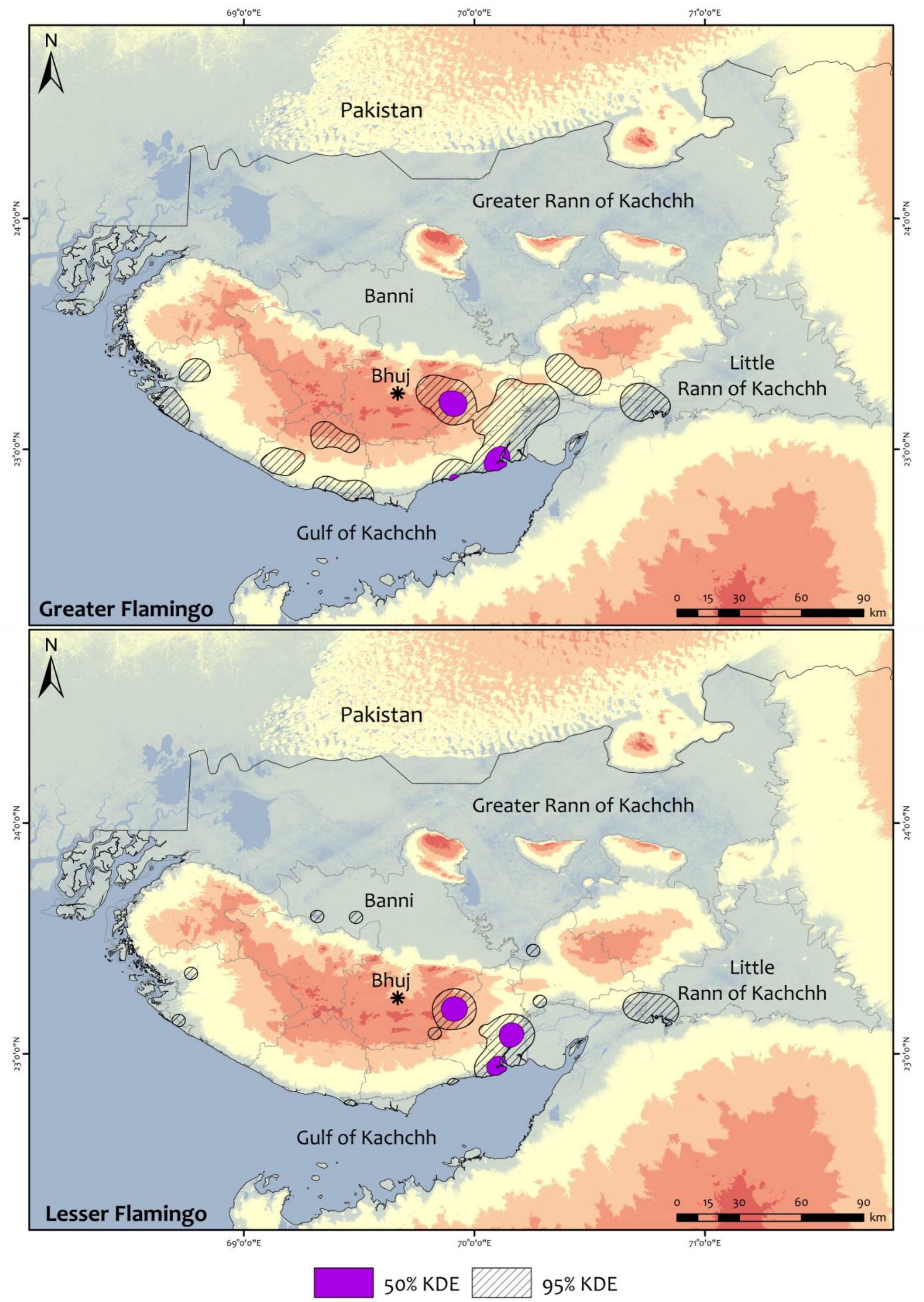



**Figure 2**. Maps of 50% (high-use area) and 95% Kernel Density contours for Greater and Lesser Flamingo across the Kachchh district.

*Tracking the movement of Flamingos*

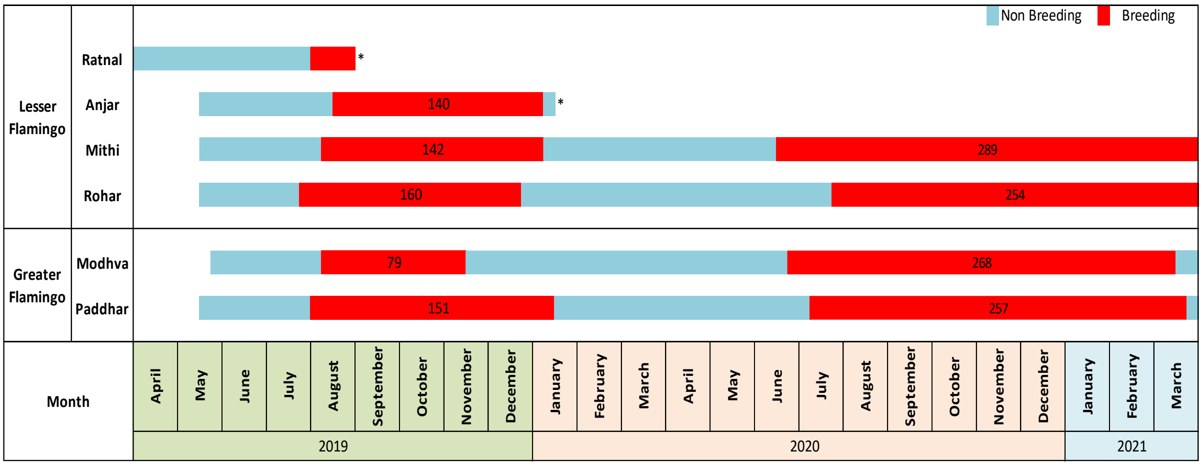
Between April and May 2019, a total of six flamingos (four Lesser Flamingo, two Greater Flamingo) were captured and deployed with the OrniTrack 30 transmitter. The flamingos were captured from across sites in the Kachchh district to cover populations from different habitats. The flamingos were named after the village or location from where they were captured (Lesser Flamingo: Anjar, Mithi, Rohar, Ratnal; Greater Flamingo: Modhva and Paddhar). The Lesser Flamingo Ratnal stopped transmission after 160 days of deployment (Technical failure), and another named Anjar died after 249 days (cause of death unknown and the tag was recovered), while all other tagged flamingos continue to transmit (Table 2).

**Table 2.** Summary of the tracking effort of the four lesser flamingos and two greater flamingos tracked between April 2019 to May 2021.

| Name of Flamingo | Weight (g) | Date of tagging & release | Date of the last location | Total Duration tracked | Number of locations received |
|---|---|---|---|---|---|
| **Lesser Flamingo** | | | | | |
| Ratnal | 1910 | 03/04/2019 | 10/09/2019 | 160 | 17201 |
| Anjar | 1245 | 12/05/2019 | 15/01/2020 | 249 | 35260 |
| Mithi# | 1900 | 14/05/2019 | 26/04/2021 | 713 | 78038 |
| Rohar# | 1735 | 14/05/2019 | 03/05/2021 | 720 | 81178 |
| **Greater Flamingo** | | | | | |
| Modhva# | 4198 | 09/05/2019 | 03/05/2021 | 726 | 44826 |
| Paddhar# | 3590 | 13/05/2019 | 26/04/2021 | 715 | 54535 |

#Tag active and transmitting locations

It was observed that the tagged Flamingos primarily stayed within the Kachchh region for most part of their tracking period. The lesser flamingos limited themselves to the eastern parts of the Kachchh while greater flamingos used the western parts and the coastline extensively. With the arrival of the monsoon in 2019 (late July), both flamingo species began migrating to the Rann habitat for breeding and spent an average of four months there. However, one of the Greater Flamingo (Paddhar) returned to its non-breeding site after 79 days (Figure 3). In the breeding season of 2020 flamingos visited Rann by June end and spent a much longer duration in the breeding ground (average 8 months). Further, the greater and lesser flamingos used different sites for breeding in the Rann. Greater flamingos used western part of the Greater Rann of Kachchh (Flamingo City) on the other hand lesser flamingos used eastern areas of the Greater Rann and Little Rann of Kachchh.

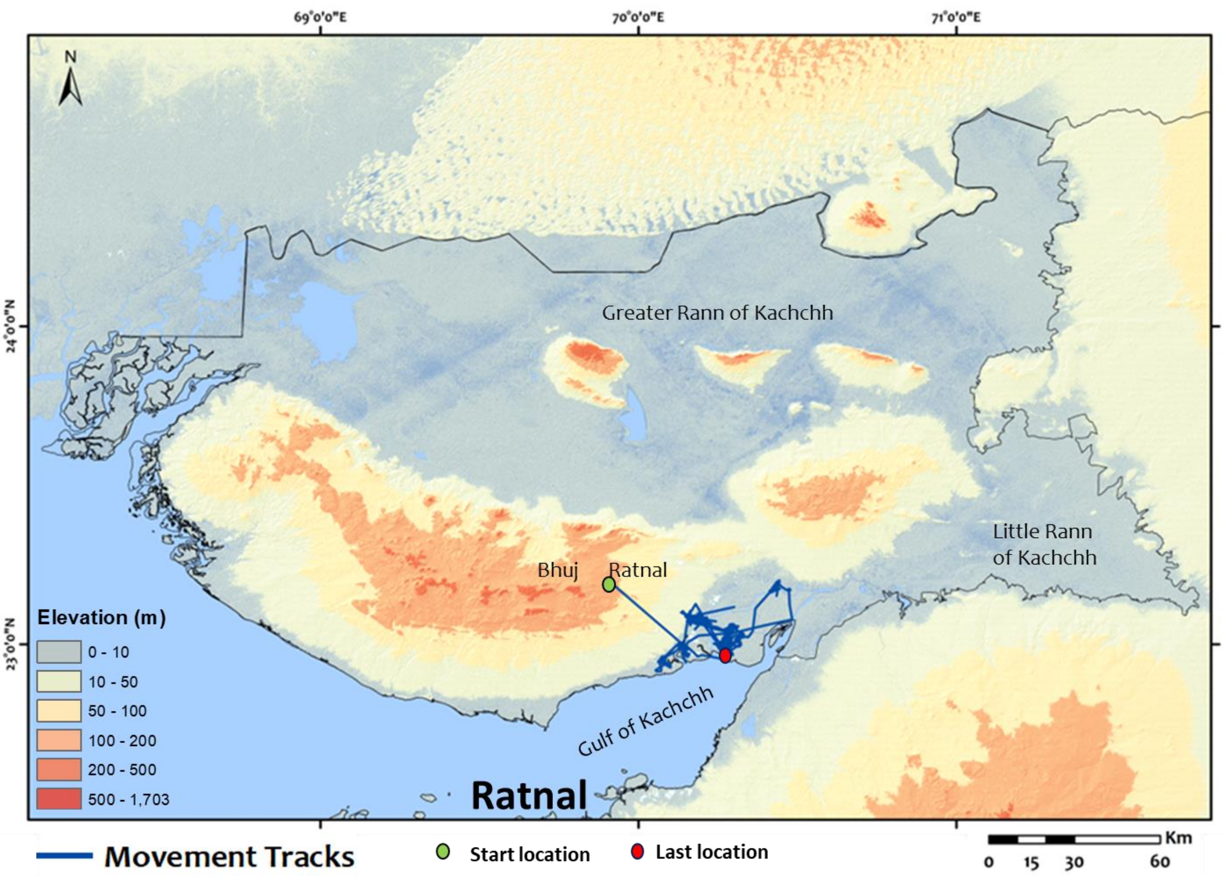



* Tag stopped working

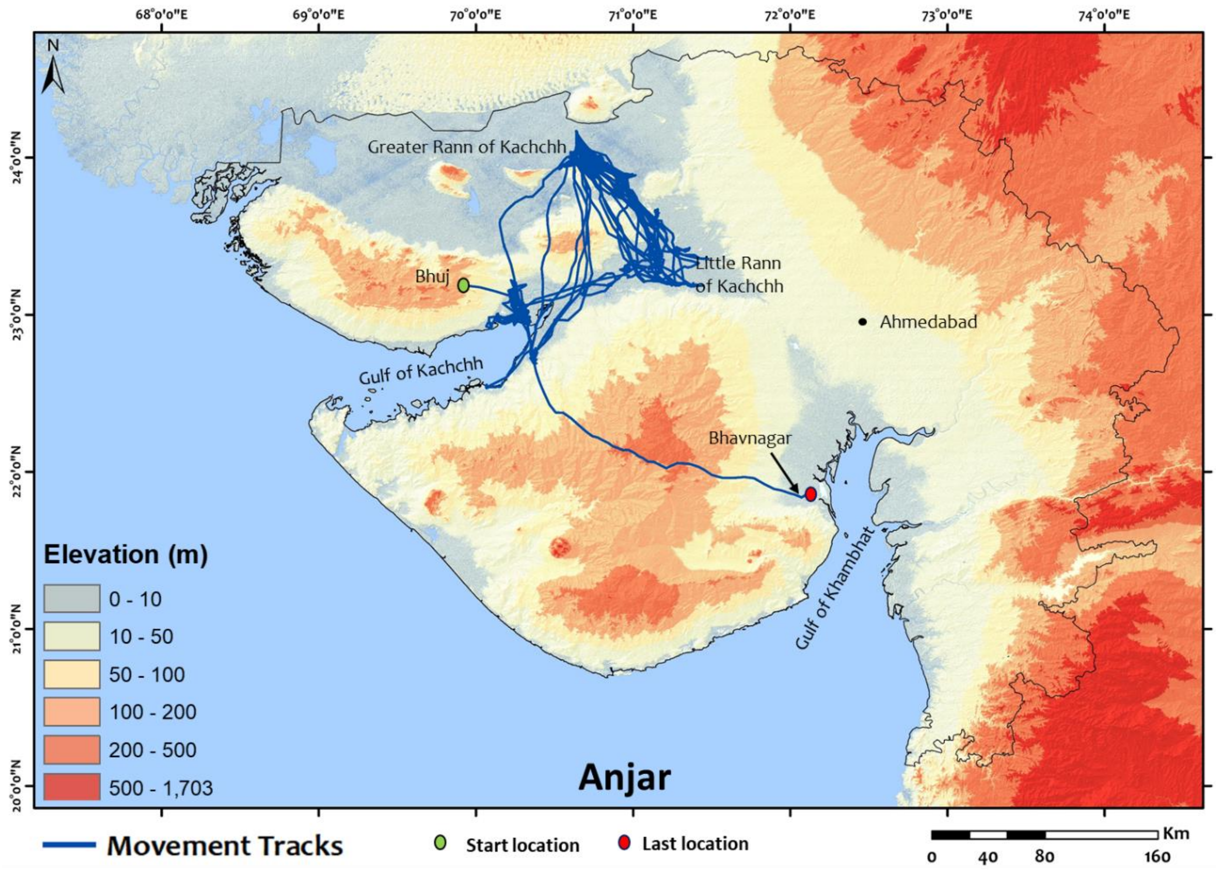
**Figure 3.** The residency period of flamingos at breeding and non-breeding sites during the tracking period (May 2019- March 2021).

***The individual movement of the tracked flamingos is described below-***

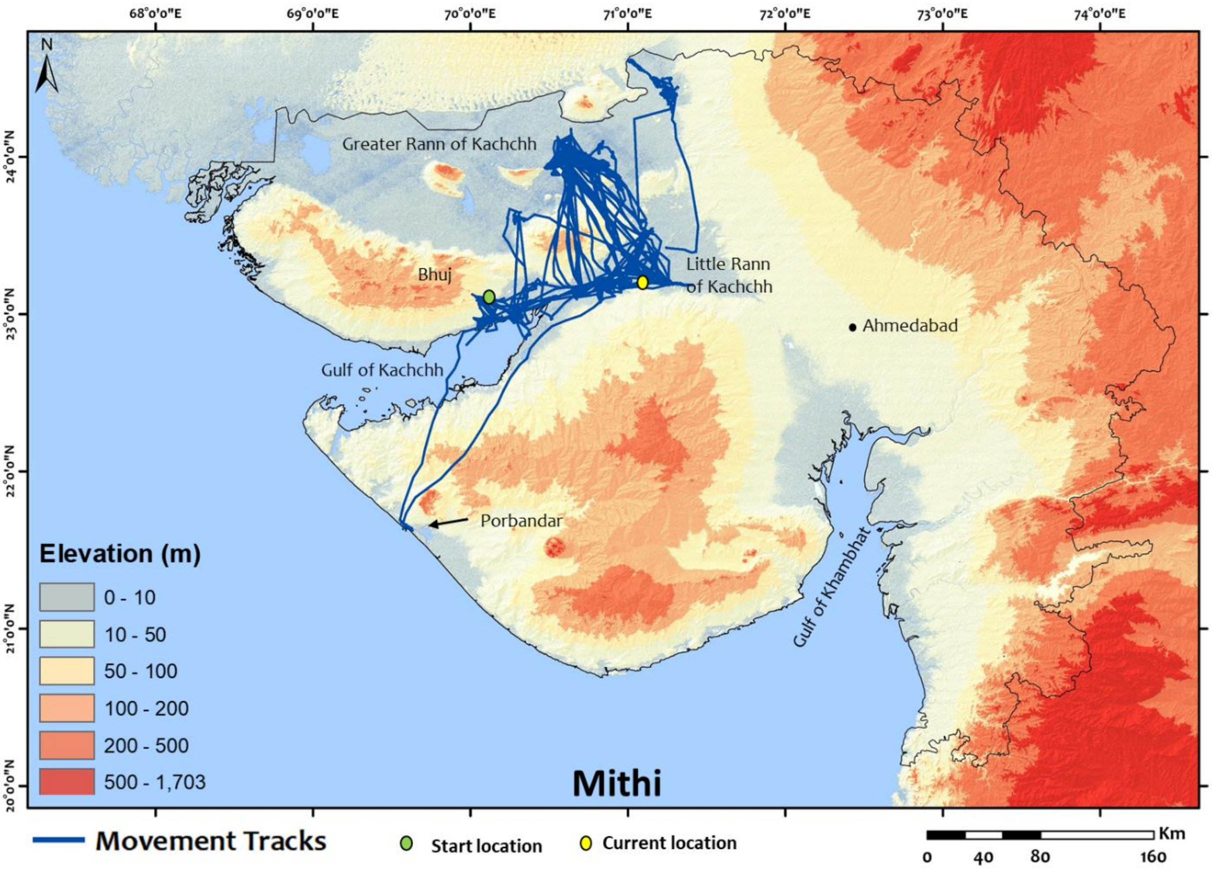
**Ratnal-** Ratnal was captured from an inland wetland located near Ratnal village in Anjar taluk. Shortly after tagging it spent a few days at Ratnal wetland and then moved to saltpans near Gandhidham. From Gandhidham saltpans, it moved to Mithi-Rohar, an inland wetland near Gandhidham and spent around three months in that particular wetland during its stay Ratnal continuously moved between surrounding saltpans and the mudflats of the Gulf of Kachchh. With the arrival of the monsoon (August) Ratnal went to mudflats of the Gulf of Kachchh from where the transmitter stopped functioning on 10th September 2019.



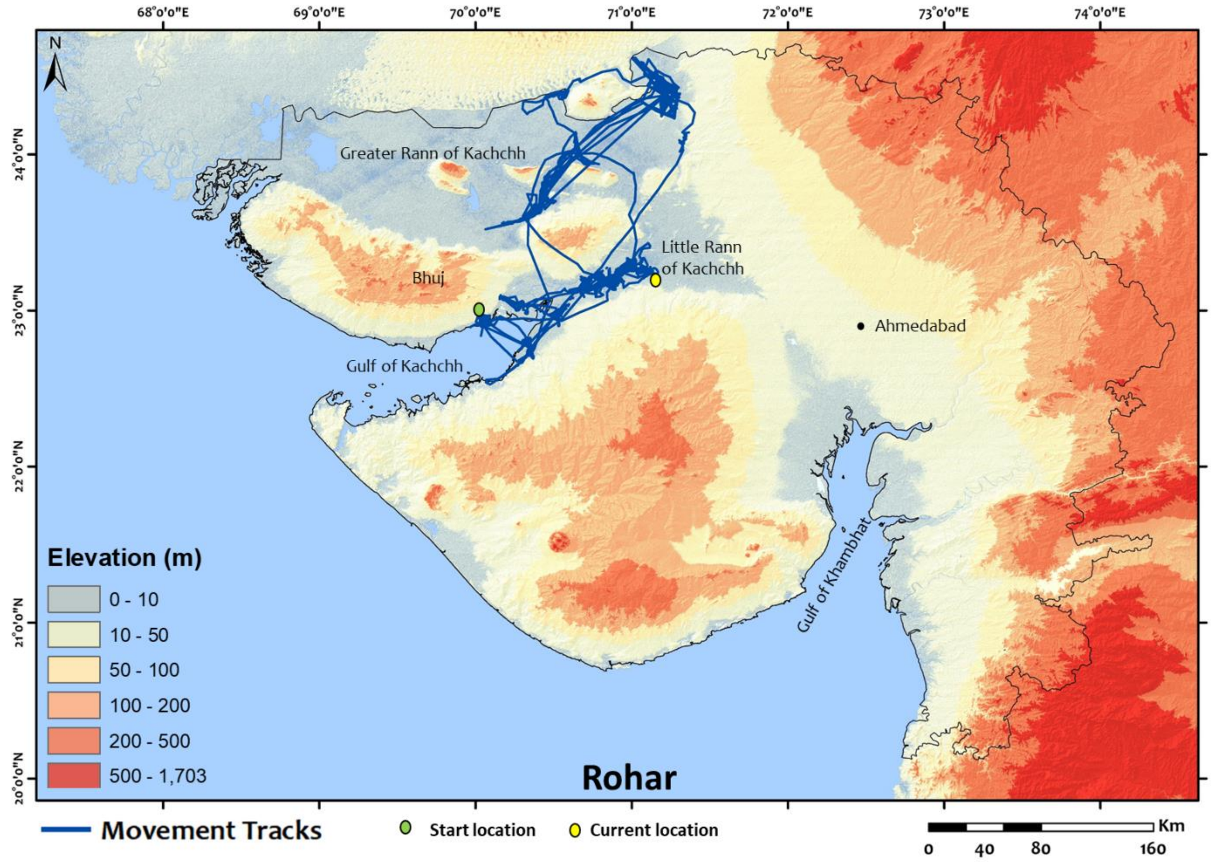
**Anjar**- Anjar was tagged from an inland wetland near Ratnal village. Post-release Anjar went straight to the saltpans and mudflats of the Gulf of Kachchh and spent 3 months in that habitat from May till the first week of August. On 7th August, Anjar left the Gulf of Kachchh and visited Little Rann from where it finally entered Great Rann of 16th August and breed there. During its stay in Rann, it frequently made flights between the Greater Rann and the Little Rann and followed water channels for movement. Anjar spent a total of 140 days at the breeding site. In the first week of January, Anjar left the Greater Rann and arrived at the salt pans near Maliya on the Southern coast of the Gulf of Kachchh. On 10th January it started its longest journey and reached saltpans near Bhavnagar town on the Gulf of Khambhat. During this journey, it travelled a distance of 183 km and then stopped transmitting data on 15 January 2020.



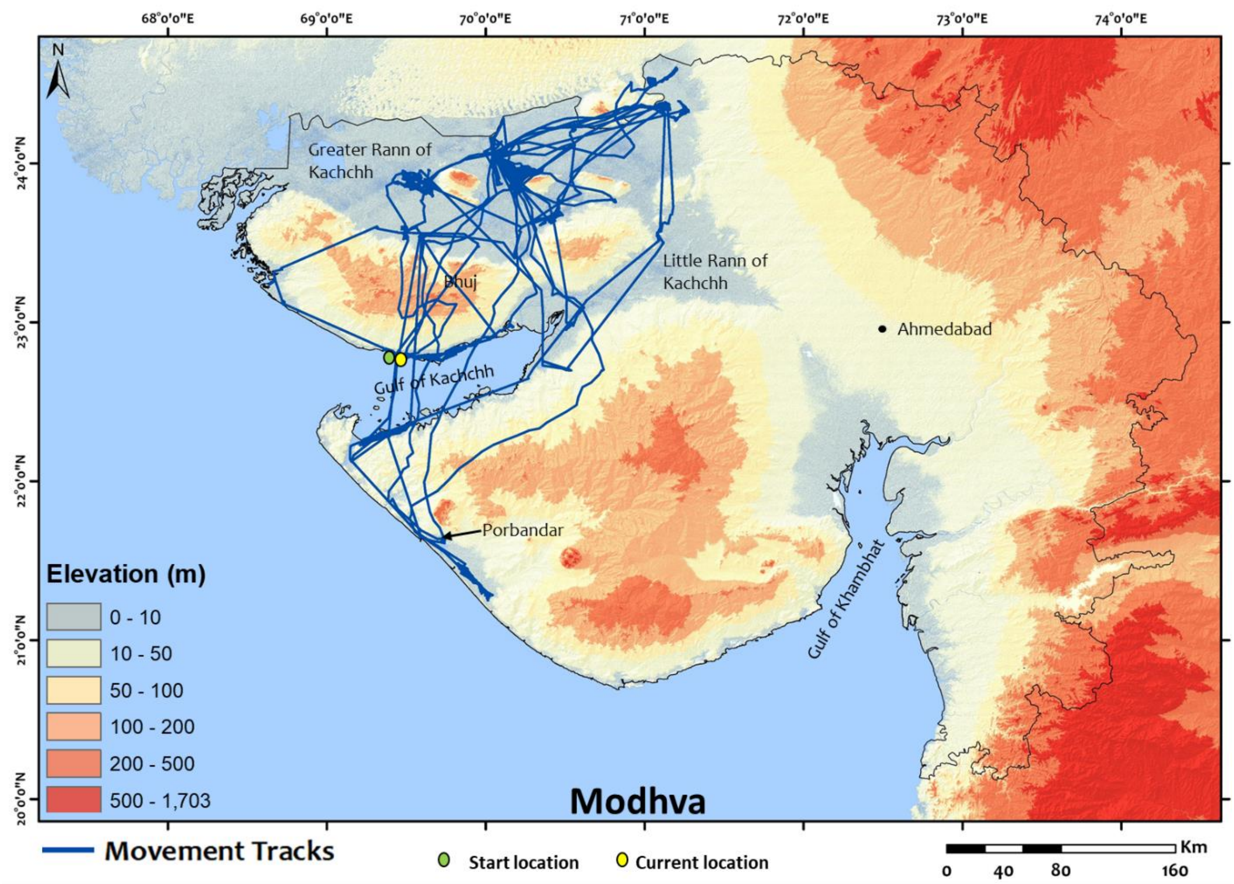
**Mithi-** Mithi was captured from an inland wetland Mithi-Rohar. Post-release Mithi went straight to Gandhidham-tuna saltpans and kept using the area for around three months. During this time, it kept moving between the Sang River stretch near Anjar town, saltpans and mudflats of the Gulf of Kachchh. With the arrival of the monsoon, it moved to the Surajbari Creek from where it moved to the Little Rann and finally to the Greater Rann of Kachchh on 13th August (North of Balasar) and bred at Bela in 2019 breeding season. In September and October, Mithi remained at its breeding site and didn't move out of the Greater Rann, but only in November and December, it frequently visited Little Rann of Kachchh. On 2nd January 2020 Mithi left the Greater Rann after spending 142 days and returned to the Gulf of Kachchh and spent a month. In February it made a 9-day visit to Porbandar and returned to Gandhidham-Tuna saltpans and spend three months there. In mid-June 2020, Mithi visited Little Rann from where it went to Balasar breeding site and spent around 6 months there. Mithi returned to Little Rann in the last week of January 2021 and since then has been spending all of the time in Little Rann.



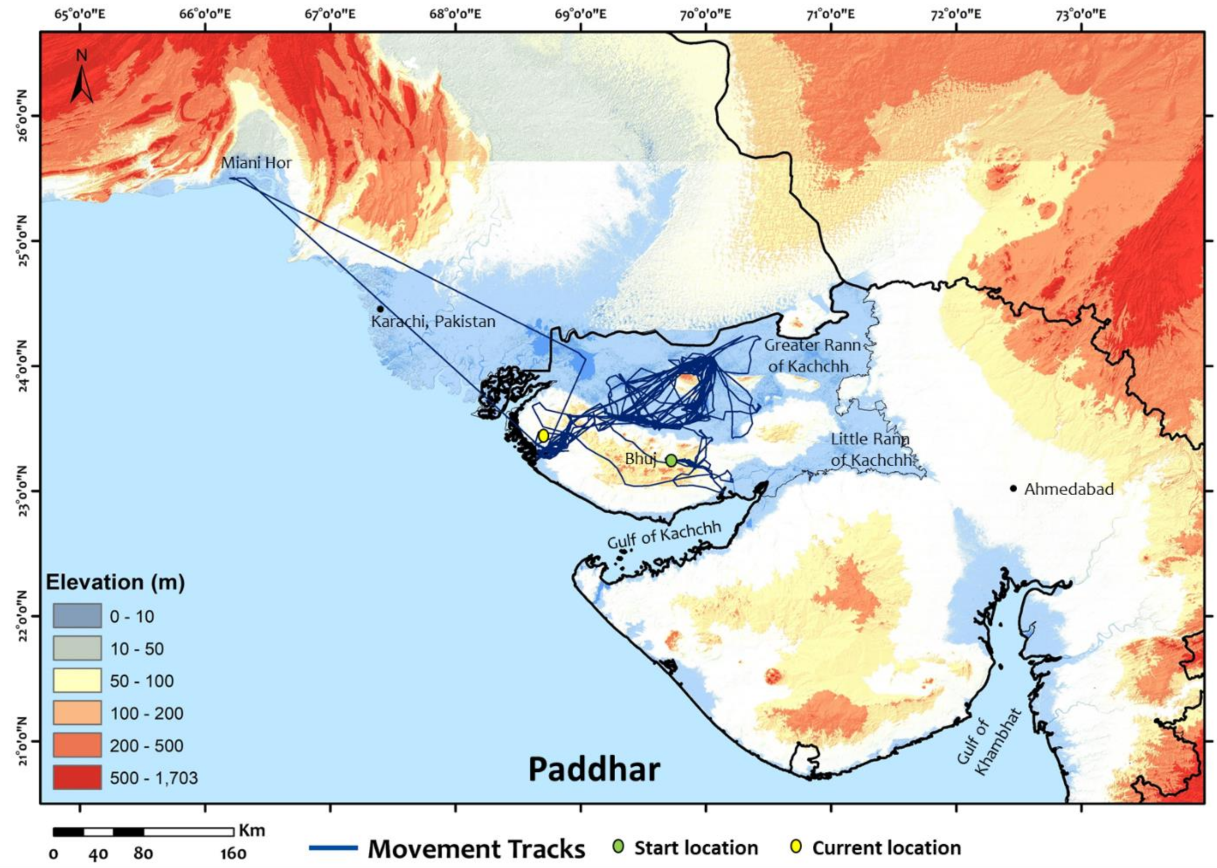
**Rohar**- Rohar was captured from an inland wetland Mithi-Rohar. Rohar kept using Mithi-Rohar for around three months during which it frequently kept visiting nearby saltpans and mudflats near Gandhidham. With the onset of monsoon, it moved to Surajbari Creek and spent the whole breeding season of 2019 (August-December), during this period it kept moving between mudflats in Little Rann of Kachchh and saltpans of Surajbari. In January 2020 it moved back to the Gandhidham-Tuna salt pans and kept using the area for six months. During this period, it spent its daytime feeding at saltpans and used the inland wetland near Sanghad village for night roosting. In July 2020 it again moved to the Little Rann from where it went to Greater Rann and spent five months and then again returned to Little Rann in January 2021.



**Modhva**- Modhva was tagged from the coastline near Mandvi. Post-release it kept using the coastline between Mundra and Mandvi for three months however on the commencement of monsoon it moved Banni. On 24th August 2019, Modhva left Banni and entered the western part of Greater Rann of Kachchh. For two months it remained in Rann habitat and bred here. During it stay at Rann, Modhva once visited the easternmost reach of Greater Rann of Kachchh and returned. On 11th September it left Rann habitat and moved to the Southern coastline of the Gulf of Kachchh and used those coastal wetlands near Javar for two and half months. On the second February, Modhva returned to the northern coastline of the Gulf of Kachchh and then remained there till June 2020. In the last week of June, it moved to the breeding area, and then for the next four months, it keep moving between the breeding site in Rann, Coastline of Kachchh and coastal wetlands of Porbandar and Madhavpur. On 18 October 2020, it finally visited the northern fringes of Rann and spent two months there and then moved to the flamingo city in December. Paddhar breed at the flamingo city and moved out of the Rann in March 2021.



**Paddhar-** Paddhar was tagged from an inland wetland near Bhuj city. Post breeding limited itself to the inland wetlands of Kachchh and kept shifting from one wetland to another. During the breeding season of 2019, it went to the inland wetlands of the Banni landscape and bred there. After spending four months in the breeding site, Paddhar moved near Jakhau in the western Kachchh from where it once made a short visit to a coastal wetland named Miani Hor along the Arabian Sea coast in Pakistan on second February 2020. This wetland is located 95 KM west of the city Karachi and returned to the western parts of Kachchh after staying there for 11 hours, during this visit it covered a distance of 273 Km. Paddhar kept using the inland wetlands of Western Kachchh for the next four months and as the breeding season approached it moved to Banni on 8th July 2020. It used the Banni area for the next 6month during which it made some visits to the non-breeding area and the famous breeding site 'flamingo city'. On 1st January 2021, Paddhar moved to Greater Rann and spent 27 days at flamingo city and then returned to Banni on 13th March 2021.



***High-use areas of tagged flamingos***

A Kernel Density Estimates (KDE) performed to identify the high use areas by tagged flamingos revealed that Lesser Flamingo uses a much larger area as compared to Greater Flamingo. The core utilized area (50% KDE) for Lesser Flamingo on an average during the pre-breeding season was found to be 8.7 (SD ± 9.9) $km^{2,}$ which increased to 301.5 (SD ± 387.3) $km^2$ during the breeding season of 2019 and then again decreased to 50.5 (SD ± 48.79) $km^2$ during the post-breeding season and in the breeding season of 2020 it was 244 (SD ± 120.2) $km^2$. The core utilized area for Greater Flamingo during the pre-breeding season was 0.3 (SD ± 0.1) $km^2$, in the breeding season of 2019 area increased to 35 (SD ± 29,7) $km^2$ and decreased to 4 (SD ± 1.4) $km^2$ during the post-breeding season and was maximum during the breeding season of 2020 i.e. 788 (SD ± 939) $km^2$. The area utilized during the breeding season increased for both the flamingo species (Table 3). The greater flamingos used Banni and western parts of Greater Rann during the breeding season while lesser flamingos extensively used eastern parts of Greater Rann (North of Bela) and the Little Rann (Figure 4).

**Table 3.** Table showing 95% and 50% utilization distribution during different seasons by tagged flamingos

| Species | Bird Name | Pre breeding (2019) (sq km) | | Breeding (2019) (sq km) | | Post Breeding (2020) (sq km) | | Breeding (2020) (sq km) | |
|---|---|---|---|---|---|---|---|---|---|
| | | **95% KDE** | **50% KDE** | **95% KDE** | **50% KDE** | **95% KDE** | **50% KDE** | **95% KDE** | **50% KDE** |
| Lesser Flamingo | Ratnal | 33 | 0.7 | 177 | 27 | | | | |
| | Anjar | 274 | 20 | 4080 | 849 | | | | |
| | Mithi | 388 | 14 | 2092 | 302 | 482 | 85 | 1611 | 159 |
| | Rohar | 6 | 0.1 | 331 | 28 | 249 | 16 | 2814 | 329 |
| Greater Flamingo | Modhva | 4 | 0.4 | 876 | 56 | 70 | 5 | 8997 | 1452 |
| | Paddhar | 0.7 | 0.2 | 99 | 14 | 56 | 3 | 1377 | 124 |

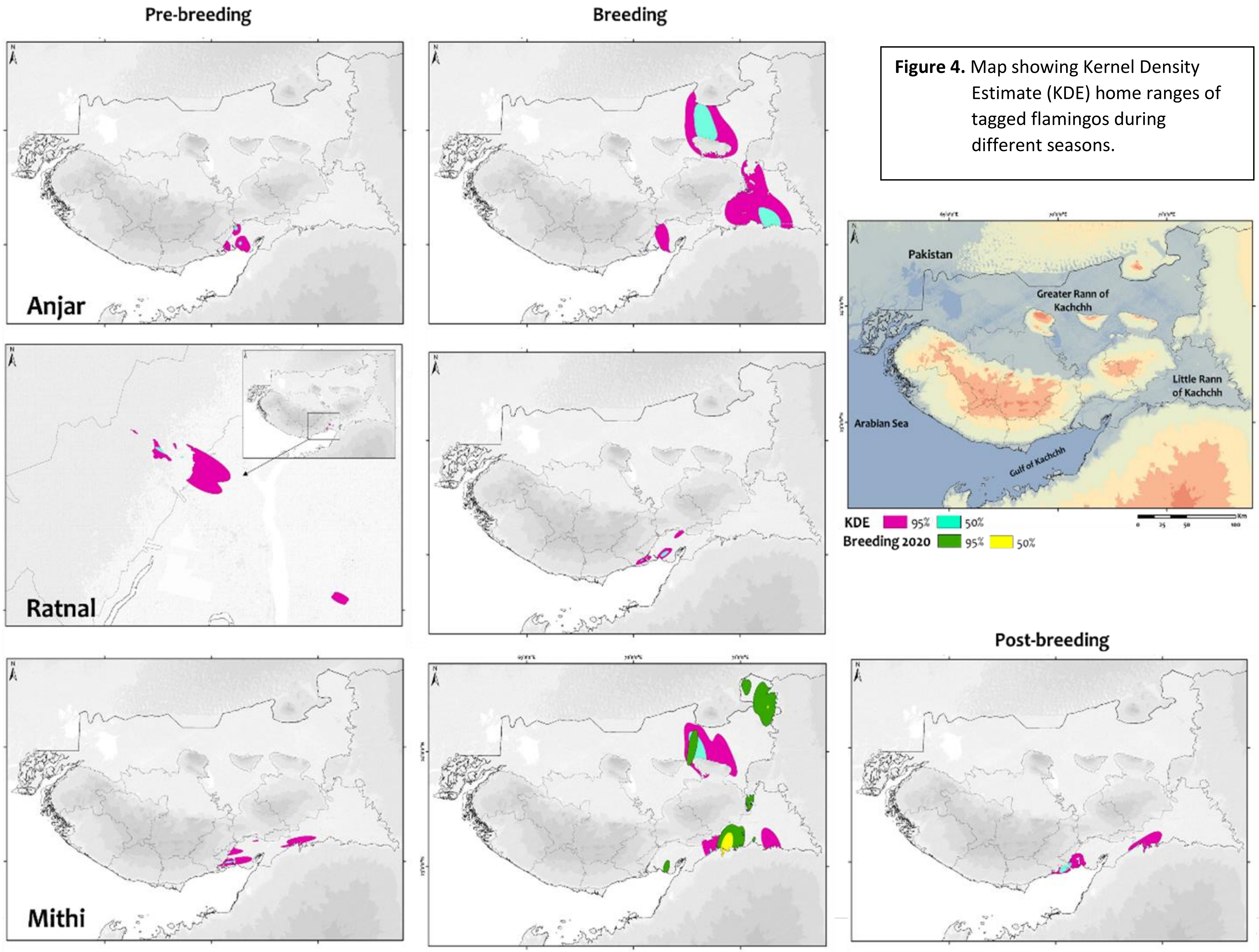
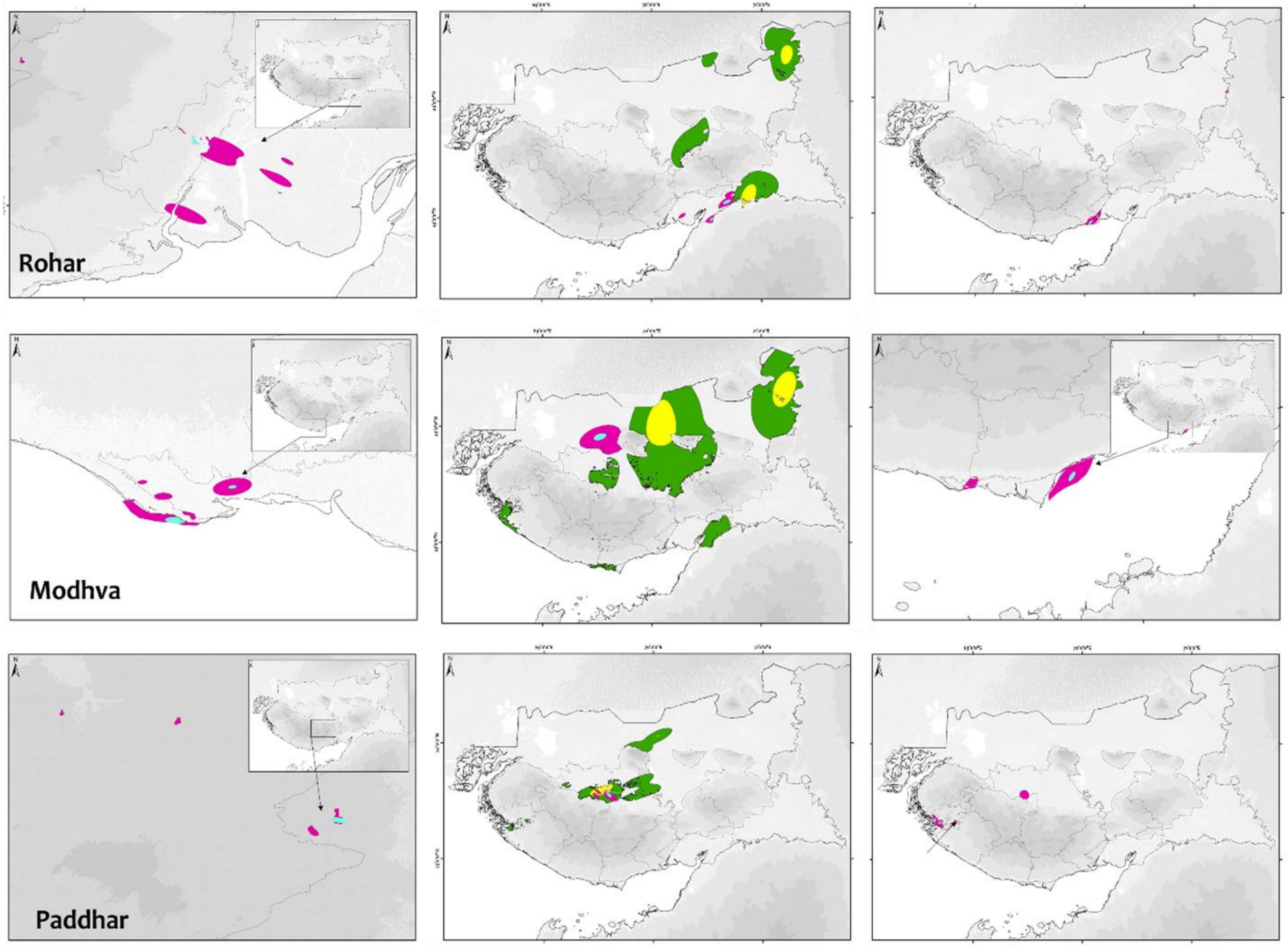



**Figure 4.** Map showing Kernel Density Estimate (KDE) home ranges of tagged flamingos during different seasons.


Rohar
Modhva
Paddhar

***Wetland types used by tagged flamingos during non-breeding season***

The wetlands used by Flamingos can be categorized as coastal wetlands, inland wetlands, saltpans, and the Rann. Coastal wetlands comprise intertidal mudflats, coastline, and areas with mangroves. Inland wetlands include fresh and saline water bodies, check dam and river stretch. Tagged flamingos used all these wetlands and it was found that there were differences in both species. The lesser flamingos primarily used saltpans (49%) and coastal wetlands (29%) on the other hand the two greater flamingos used less of the salt pans (1%) utilized inland (49%) and coastal wetlands (50%) extensively (Figure 5).

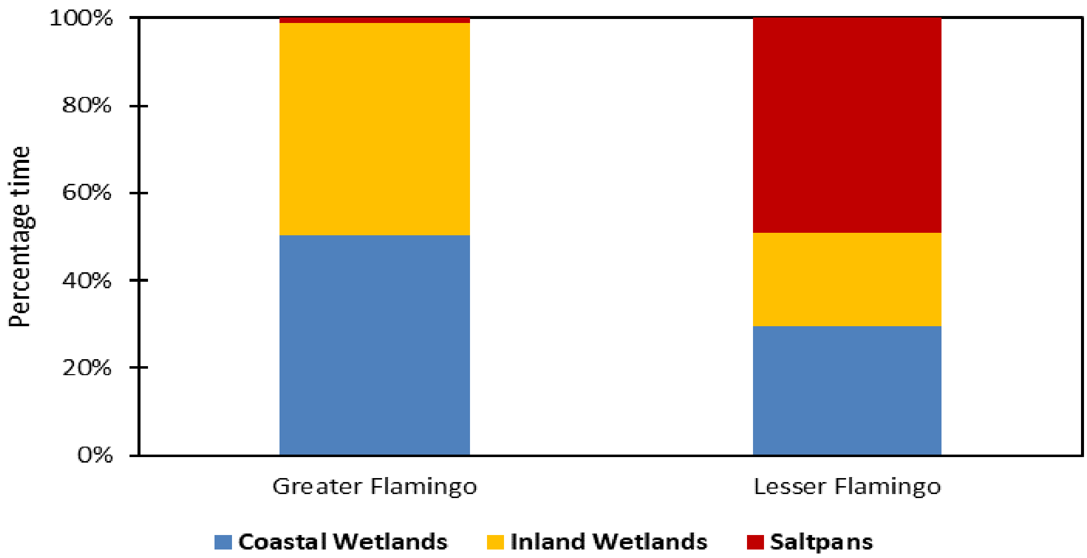



**Figure 5.** Stacked graph showing percentage time spent in different wetland types by tagged flamingos in Kachchh landscape during the non-breeding periods.

Individual variation in the wetland used by the tagged flamingos was also found. Among lesser flamingos, Mithi equally used the saltpans and coastal wetlands whereas Rohar spent more of its time in saltpans (57%). The two greater flamingos were also different in the wetlands they utilized. Modhva extensively used coastal wetland (coastline) whereas Paddhar spent all of its time in the inland wetlands (Figure 6).

**Table 4.** Table showing point locations of tagged flamingos in different types of wetlands in Kachchh landscape during non-breeding season.

| Wetland Type | Lesser Flamingo | | Greater Flamingo | |
|---|---|---|---|---|
| | Mithi | Rohar | Modhva | Paddhar |
| **Inland** | 39 | 72 | 0 | 251 |
| **Coastal** | 106 | 42 | 217 | 2 |
| **Saltpan** | 100 | 154 | 0 | 5 |
| **Total** | **245** | **268** | **217** | **258** |

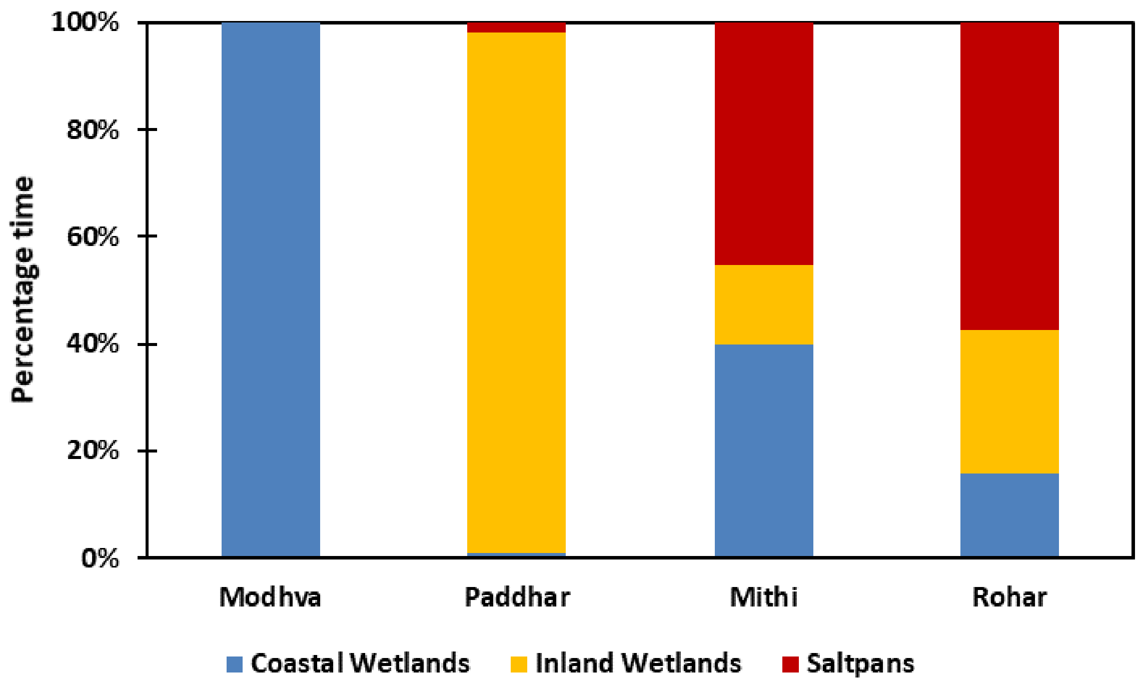



**Figure 6.** Stacked graph showing percentage time spent by tagged flamingos in in different wetland types of Kachchh landscape during the tracking period.

***Species Distribution Model (SDM) of Flamingo species***

A SDM was constructed based on 2181 locations of flamingo movement, comprising 1922 locations recorded by GPS transmitters and 259 locations recorded during field surveys. The AUC value of the SDM was 0.819, meaning that the model was highly accurate. The SDM showed a total of 6000 sq.km area as high suitable habitat for the flamingos. The, areas identified as high suitable through modelling coincided significantly with the tracking locations of Flamingo.

Areas with ≥50% probability of finding Flamingo were largely falling in Greater and Little Rann of Kachchh. In the Greater Rann of Kachchh, the areas which were north of the Banni grassland and Bela hills were identified as highly suitable for Flamingo. These are the areas that were visited by flamingos during the breeding season. In the case of Little Rann of Kachchh, the south-western parts of the Rann, adjoining with the creek of Gulf of Kachchh were identified as a highly suitable area (Figure 7).

Along with two Ranns, the mudflats and saltpans along the coastline of Gandhidham and Bhachau taluks were also identified as high suitable areas. These are the areas where flamingo flocks were observed during the non-breeding season. In the western Kachchh, saltpans of Jakhau port were also identified as highly suitable areas for flamingos. The mean temperature of the driest quarter, altitude, and annual precipitation were three main variables (more than 15% contribution) that were used for constructing the SDM for the flamingos.

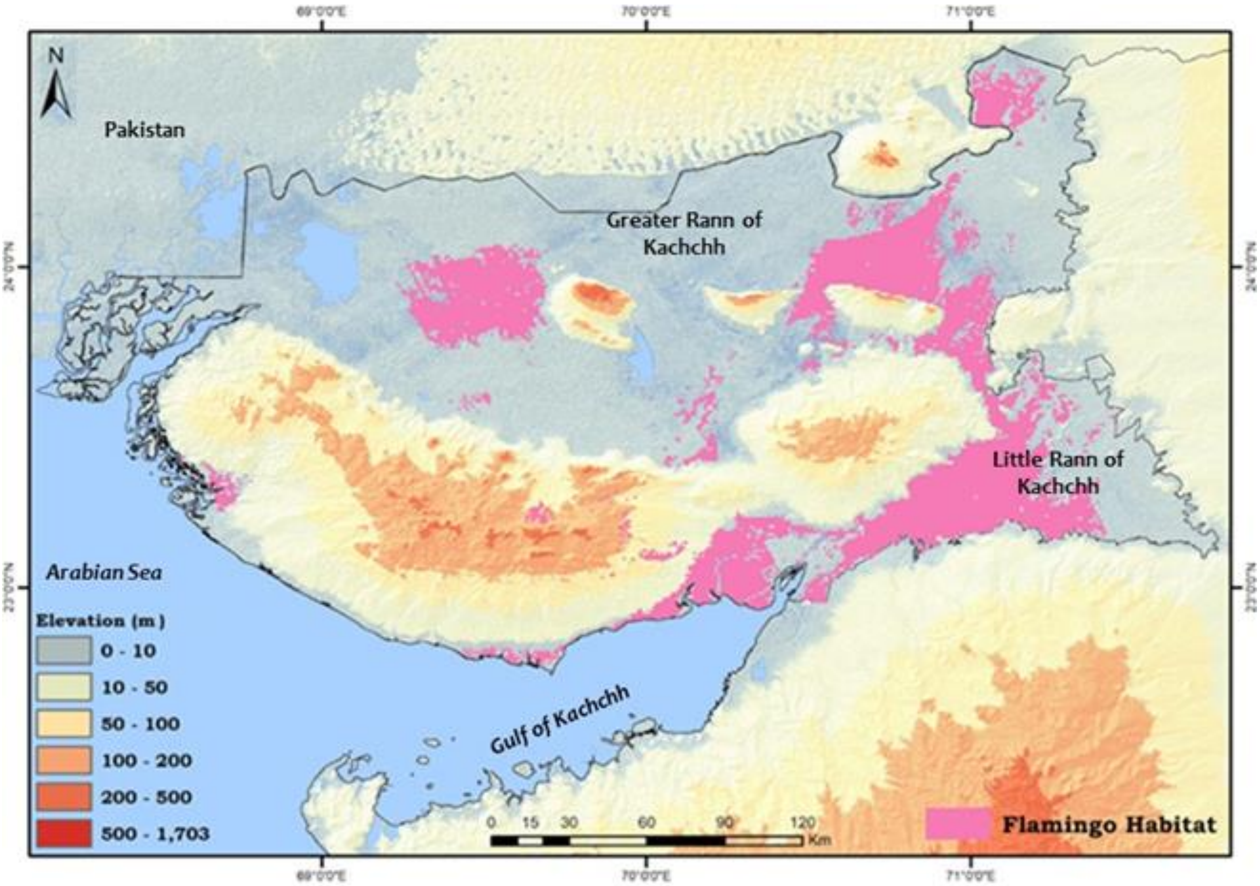



**Figure 7.** The figure shows highly suitable areas (Pink) (more than 50% probability) for Flamingo species across the Kachchh district.

***Distribution of migratory Cranes***

During the study period, a total of 238 and 24 flocks of Common and Demoiselle Crane were recorded from 27 and 7 grids, respectively. The average flock size of Common Crane was 70 with the range of 1 to 850 individuals, whereas, the average flock size of Demoiselle Crane recorded was 192 with the range of 1 to 500 individuals. The data showed that Common Crane was mostly found in small flocks (55%) while Demoiselle Crane was mostly found in large flocks (86%). Additionally, six roost sites for Common and eight for Demoiselle Crane were recorded across the Kachchh with Chhari Dhandh and Rampar having the highest roosting population of Common and Demoiselle Crane, respectively.

Flocks of Common Crane were recorded in the agricultural landscape also during foraging and in eight of the ten taluks with Mandavi having the highest number of flocks (41%) followed by Bhuj (24%) and Anjar (14%). In the case of Demoiselle Crane, flocks were recorded foraging in only three taluks, falling in eastern Kachchh with Bhachau having the highest number of flocks (58%) followed by Rapar (25%) and Anjar (17%).

***High occurrence areas of Common Crane***

The Kernel Density Estimation showed a large part of the Kachchh landscape being used by the species. Three high occurrence areas (50% KDE) for Common Crane were identified in Mandvi, Anjar and Banni regions, measuring 576 sq km, 68 sq.km and 282 sq km respectively. 95% KDEs showed Banni grassland as one of the high occurrence landscapes covering the area of 2190 sq km while another high occurrence area was found to be an agricultural landscape of the Kachchh district. The largest 95% KDE in the agricultural landscape measured 4933 sq.km covering the parts of Abdasa, Mandvi, Mundra, Bhuj and Anjar taluk, followed by Bhachau (886 sq.km) and Rapar (632 sq km). A small area of 37 sq km in LRK also came out as a high occurrence area for the Common Crane (Figure 7).

In the case of Demoiselle Crane Bhachau taluk measuring 70 sq.km in the area and Rapar taluk measuring 17 sq.km emerged as high occurrence areas using 50% KDE. As per the 95% KDE results, Bhachau taluk covers an area of 505 sq.km followed by 160 sq.km and 150 sq.km (both in Rapar taluk) and only one area from Anjar taluk around Ratnal village, having an area of 108 sq.km emerged as high occurrence areas for the Demoiselle Cranes (Figure 8).

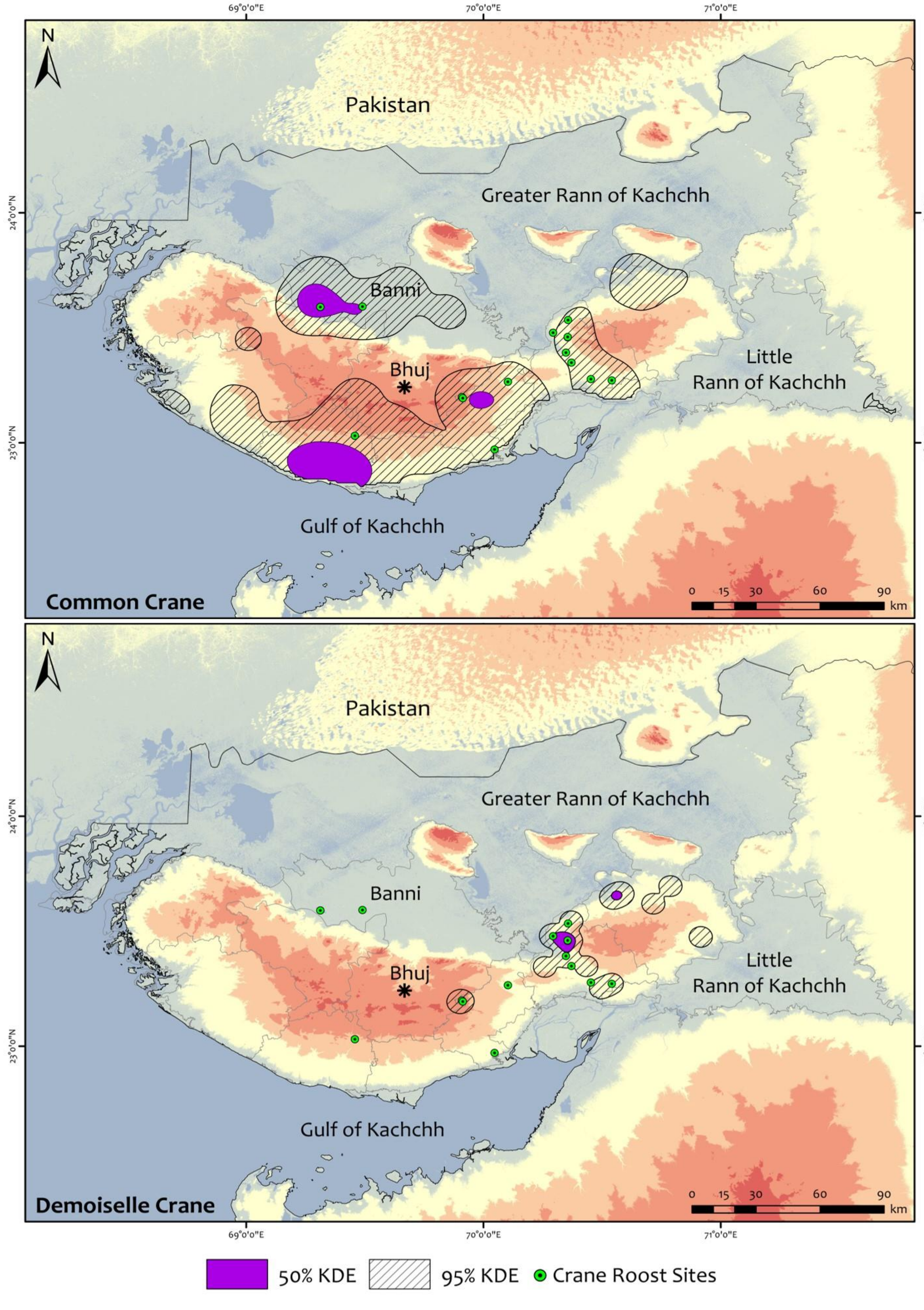



**Figure 8.** The map showing 50% (Purple) and 95% (shaded) KDE for Common Crane based on Crane flock locations recorded during the study period. The Green dots show roosting sites for cranes.

*Species Distribution Model of migratory Crane species*

A SDM model was also created for the migratory cranes based on 881 locations comprising 623 locations recorded in eBird and 258 locations recorded during field surveys. The AUC value of the model was 0.849, meaning that the model was highly accurate. The SDM showed 5200 sq.km area as high suitable Crane habitat, falling in the agricultural landscape of Mandvi, Mundra, Anjar and Bhachau taluk and in parts of Banni and Little Rann of Kachchh (Figure 9). Temperature seasonality (bio_4), land-cover and altitude were three major variables that contributed to the SDM construction for migratory cranes.

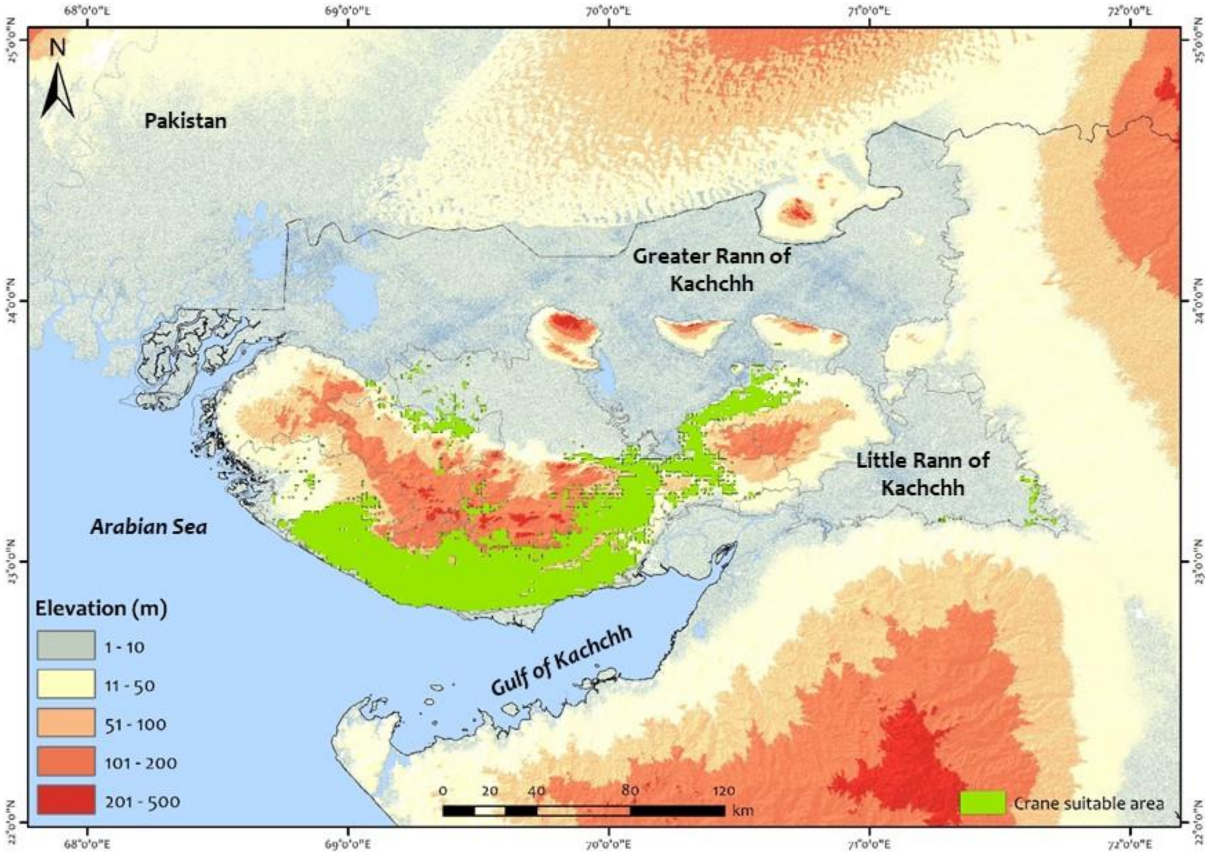



**Figure 9.** The figure showing highly suitable areas (Green) (more than 50% probability) for migratory Crane species across the Kachchh district.

***Outcomes of tracking effort during the year 2022***

***Greater Flamingo tagged at Thol Wildlife Sanctuary***

Tracking Flamingos from the arid plains of Gujarat provided crucial insight into their spatial use and the flight corridors. The flamingo population tracked was found to be a resident breeding population as they never moved out of Western Gujarat during tracking. The flamingo population exponentially increases during breeding season in Kachchh; however, their origin, spatial use and migratory paths are unknown. Given this, the research team planned to tag Greater Flamingo for locations outside Kachchh. Hundreds of Flamingos visit Thol Lake Wildlife Sanctuary every year, and the information about where they arrive and breed is not known. Therefore, to determine their spatial use and migratory route, two Greater Flamingos from Thol were tagged in May 2022 (Table 5).

In May 2022, two Greater Flamingos were captured and tagged with solar-powered GPS-GSM transmitter from Thol Ramsar Site.

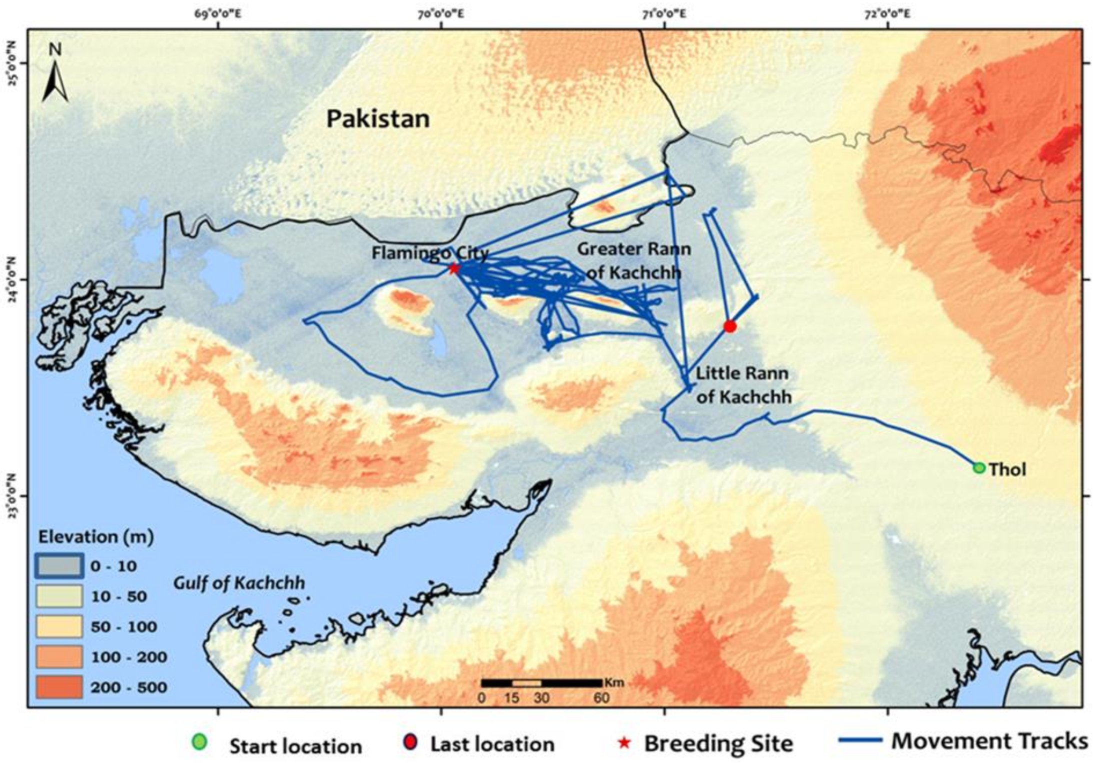
**Table 5.** Summary of the tracking effort of the two greater flamingos captured and tagged in May 2022.

| Name of Flamingo | Weight (g) | Date of tagging & release | Number of locations received |
|---|---|---|---|
| Thol# | 2750 | 11/05/2022 | 10974 |
| Hanj# | 4000 | 19/05/2022 | 6065 |

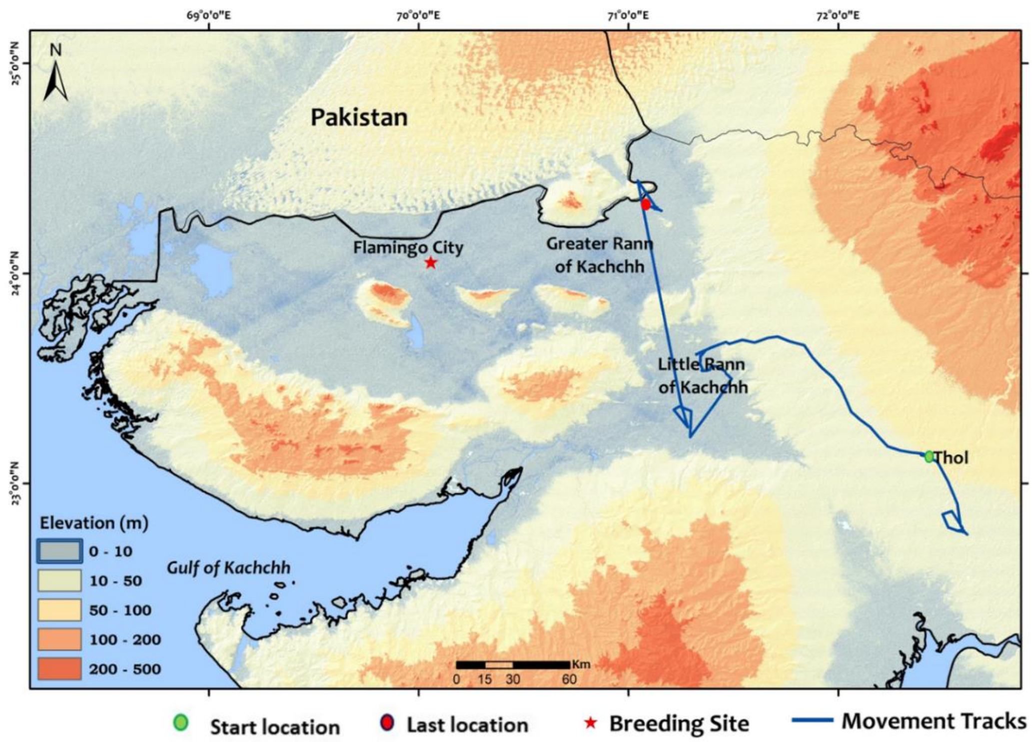
#Tag active and transmitting locations

***The individual movement of the tracked flamingos is described below-***

**Thol**- Thol was captured and tagged at the Thol Ramsar site. This greater flamingo spent its whole non-breeding season in Thol. During its stay at the wetland, Thol used the western part for foraging while the eastern fringes of the wetlands were used as root sites. Thol started its journey to Rann on 8th July, and it went straight to Little Rann of Kachchh and spent three days there. On 11th July, Thol moved to the wetland surrounding Nanda Bet, stayed there for four days, and then moved to Greater Rann of Kachchh near the Bela region. From Bela, Thol moved to the Banni landscape on 25th July, from where it went to Flamingo city to breed. After finishing its breeding, Thol moved out to Nanda Bet on 31st December 2022 and continues to use wetlands in that area.



**Hanj-** Hanj was also captured and tagged from Thol. Post-release, Hanj spent 13 days at Thol wetlands and then moved to an inland wetland near Navgram due to a fall in water level at Thol. After staying there for 20 days, Hanj returned to Thol wetland on 14th June. It spent the next 27 days at Thol and started its journey to the Rann on 11th July. During its journey to the Little Rann, Hanj covered a distance of 150 km. In October, it went to the Nada Bet area and transmitted the last location from the area on 7th November 2022.




### *High-use areas of tagged flamingos*

The use areas (KDE) by tagged flamingos at Thol was similar to the Greater flamingos tagged in Kachchh as they used a much smaller area during the non-breeding season (Table 6). The core utilized area (50% KDE) for Thol during the pre-breeding season was found to be 0.052 km² which increased to 355 km² during the breeding season of 2022. While Hanj's core area during the pre-breeding season was 0.518 km², KDE for the breeding season cannot be performed due to a lack of data.

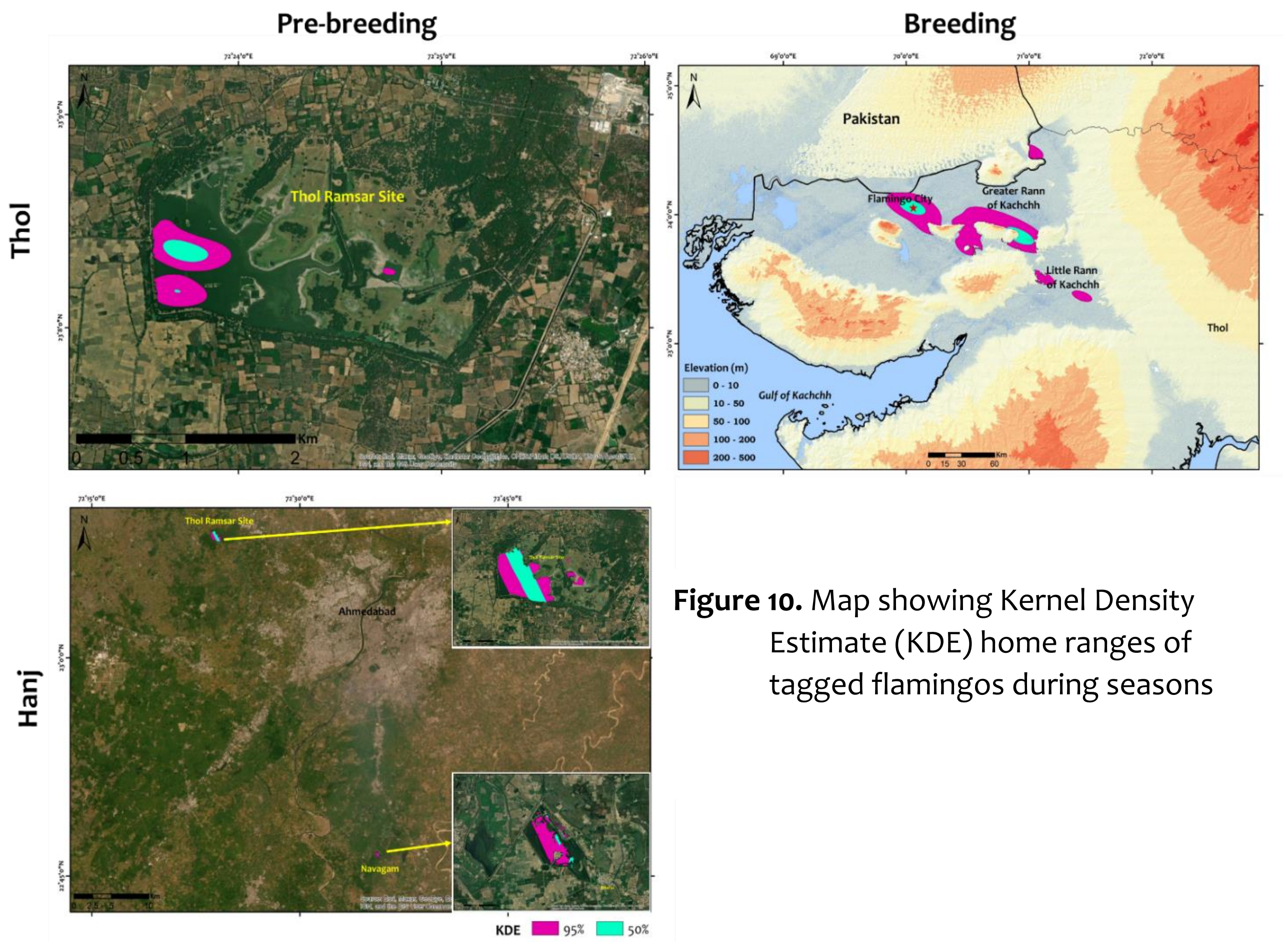



**Figure 10.** Map showing Kernel Density Estimate (KDE) home ranges of tagged flamingos during seasons

**Table 6.** Table showing 95% and 50% utilization distribution during different seasons by tagged flamingos

| Species | Bird Name | Pre-breeding (2022) (sq km) | | Breeding (2022) (sq km) | |
|---|---|---|---|---|---|
| | | 95% KDE | 50% KDE | 95% KDE | 50% KDE |
| Greater Flamingo | Thol | 0.293 | 0.052 | 2726 | 335 |
| | Hanj | 1.357 | 0.518 | NA | NA |

***Common Crane***

As part of this study, a total of eight Common Cranes (one in 2020 and seven in 2022) were captured and tagged with a solar-powered GPS-GSM leg-mount transmitter weighing 40 g (Model: OrniTrack-L40, Ornitela) on the left leg above knee. All the cranes were captured and tagged at Thol and Nal Sarovar Ramsar sites, Gujarat, India (Table 7). The Common Crane tagged in 2020 (named Vadla) migrated to Kazakhstan and completed one migration cycle i.e., from Gujarat to south-western Siberia and then returned to Gujarat. However, the crane seized transmitting data in April 2021 when it was on its return migration again. Of the seven Common Cranes tagged in 2022, four cranes (namely, Gani, Sanand, Nal and Bhal) completed their migration cycle i.e. from Gujarat to south-western Siberia and then returned to Gujarat. One Common Crane (named Bhaskar) seized data transmission due to tag failure while the tag of another crane (named Thol) fell off due to mechanical issue in deployment. The last Common Crane (named Lothal) was captured by local villagers in Barmer, Rajasthan following the suspicion of it being a spy bird from Pakistan. The following table details the information on all tagged cranes as part of the project.

**Table 7.** A table detailing the information on timings of tagging, tagged crane identification and last locations of tagged Cranes

| S. No. | Name of the Crane | Date of tagging | Tagging location | Tag No. | Metal Ring No. | Plastic Band No. | Current location |
|---|---|---|---|---|---|---|---|
| 1 | Vadla | 12-03-2020 | Vadla Wetland (22.922671 N; 71.958432 E) | 182378 | L-9256 | AYB | Data transmission seized |
| 2 | Thol | 02-02-2022 | Thol Ramsar Site (23.136826 N; 72.391072 E) | 182376 | L-9258 | AYA | Transmitter fell off |
| 3 | Gani | 10-02-2022 | Thol Ramsar Site (23.139794 N; 72.405048 E) | 182377 | L-9259 | AYC | Thol Ramsar Site (23.139794 N; 72.405048 E) |
| 4 | Sanand | 22-02-2022 | Thol Ramsar Site (23.135603 N; 72.401336 E) | 182379 | L-9260 | AYD | Miani Hor Ramsar site, Pakistan (25.617531 N; 66.369482 E) |
| 5 | Bhaskar | 04-03-2022 | Vadla Wetland (22.918991 N; 71.96749 E) | 182380 | L-9261 | AYF | Data transmission seized |
| 6 | Nal | 04-03-2022 | Vadla Wetland (22.918991 N; 71.96749 E) | 182381 | L-9262 | AYI | Iran Afghanistan Border (34.673800; 60.978200 E) |
| 7 | Bhal | 05-03-2022 | Vadla Wetland (22.910345 N; 71.984059 E) | 182382 | L-9263 | AYV | Vadla Wetland (22.910345 N; 71.984059 E) |
| 8 | Lothal | 05-03-2022 | Vadla Wetland (22.918991 N; 71.96749 E) | 182383 | L-9264 | AYZ | Deceased |

***Home ranges and movements of the tagged Common cranes during winter***

A total of five Common cranes were successfully tracked for the entire winter season i.e. from November to March. Of the five, one Common Crane named Vadla was tracked for the winter season 2020-21 and rest four were tracked during the winter season 2022-23. During their stay in wintering ground here in Gujarat, the tagged birds used Little Rann of Kachchh, Vadla wetland complex, Nal Sarovar Bird Sanctuary, Thol Wildlife Sanctuary and Blackbuck National Park, Velavadar. In the case of Little Rann of Kachchh and Blackbuck National Park, birds utilised open meadows and bare fields for foraging while in the other areas, cranes utilised agricultural fields.

Of the five Common Crane tracked, Bhal used largest area (95% KDE = 385 sq.km) followed by Sanand (95% KDE = 276 sq.km) while Vadla used the smallest area (95% KDE = 11 sq.km). When looking into a core area use (50% KDE), Sanand had the largest core area (30 sq.km) followed by Bhal (15 sq.km) while Vadla had the smallest core area (1 sq.km) (Figure 11 - 14). The core areas of the tagged birds were generally the areas where Cranes visit regularly for foraging that also overlaps with or in the close proximity of the roosting wetland.

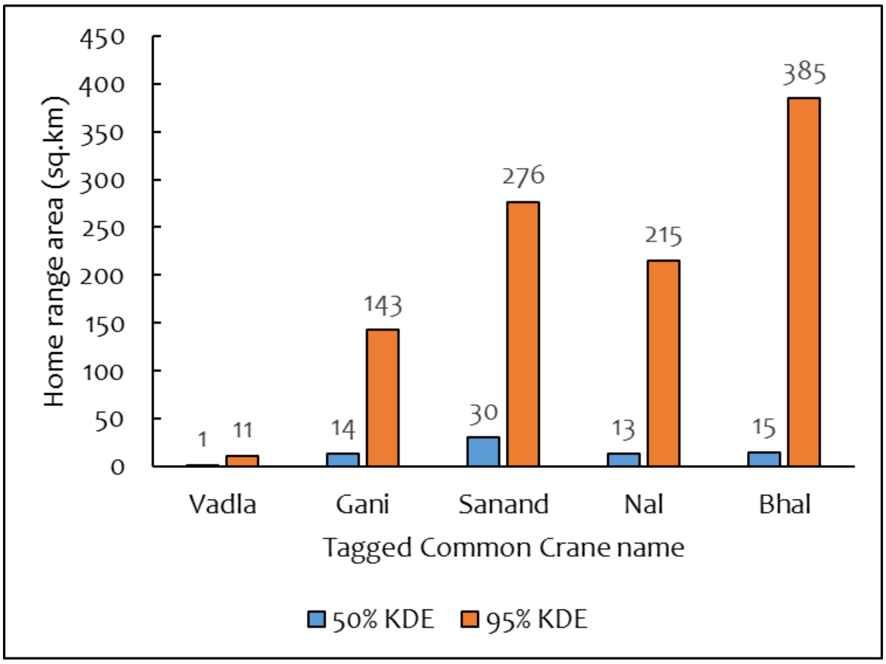
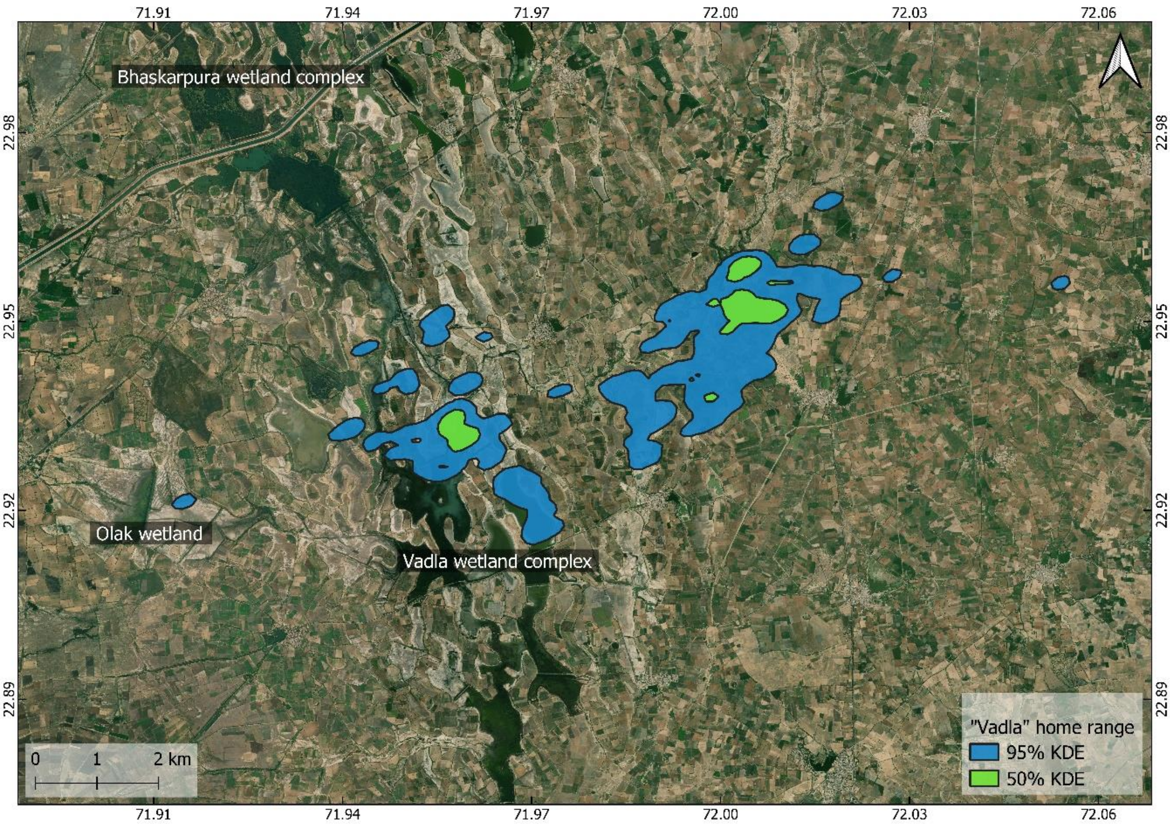



**Figure 11.** A graph comparing the core area (50% KDE) and over all home range (95% KDE) of the five Common Cranes tracked.



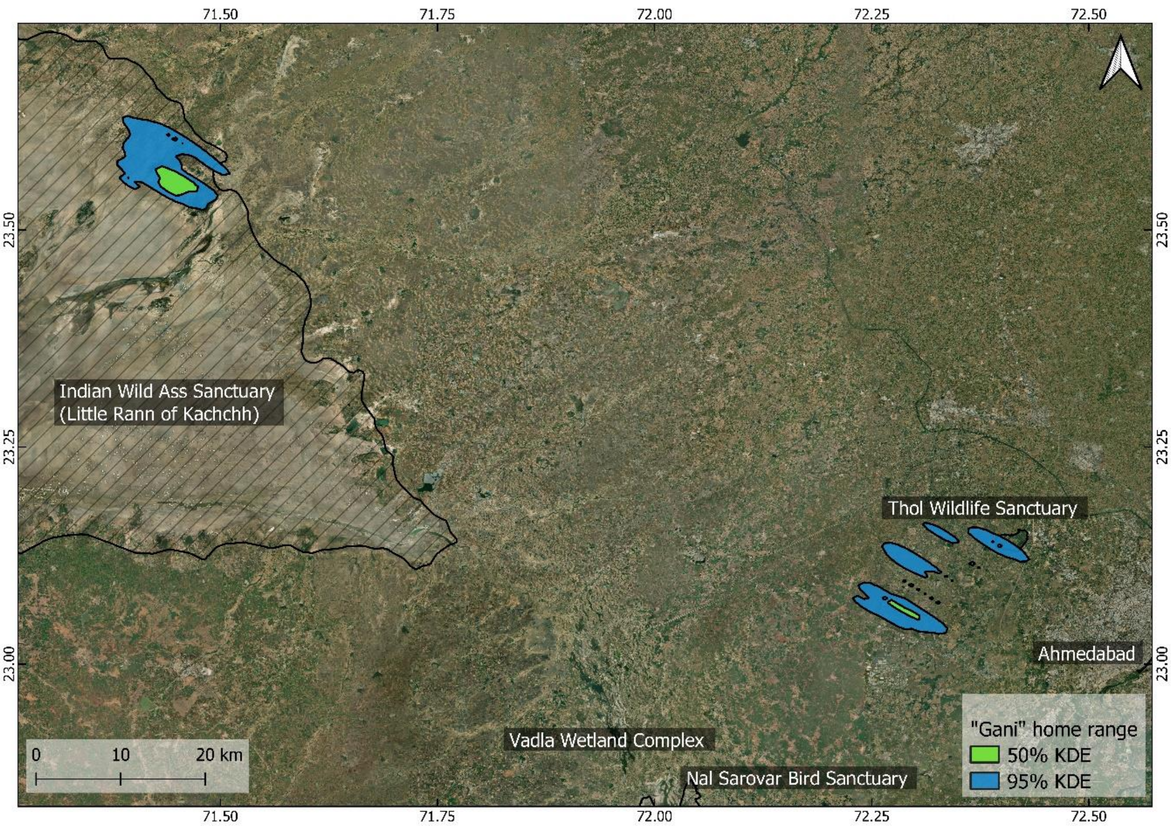




**Figure 12.** Maps showing the home ranges of two Common cranes: Vadla (above) and Gani (below)

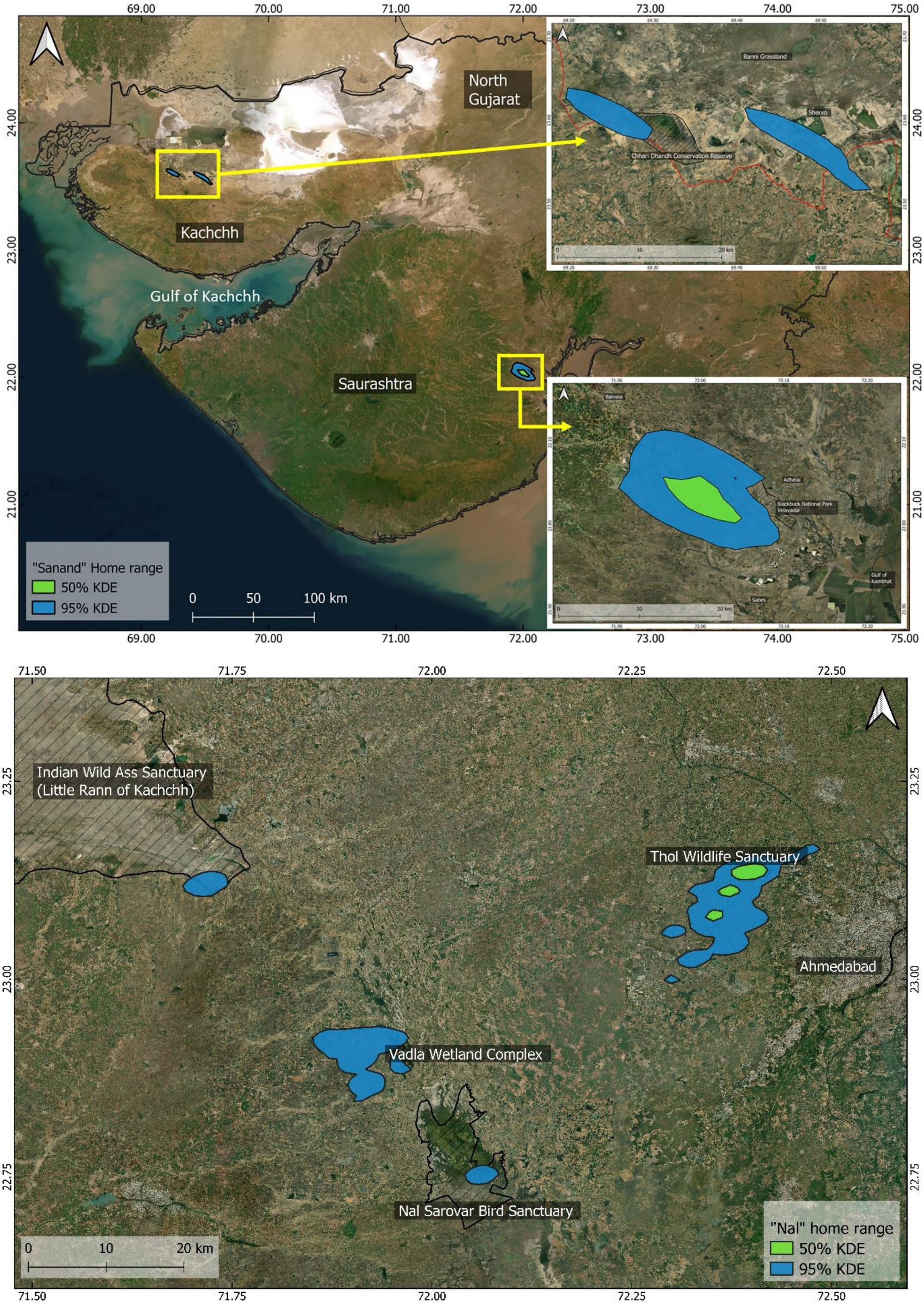



**Figure 13.** Maps showing the home ranges of two Common cranes: Sanand (above) and Nal (below)

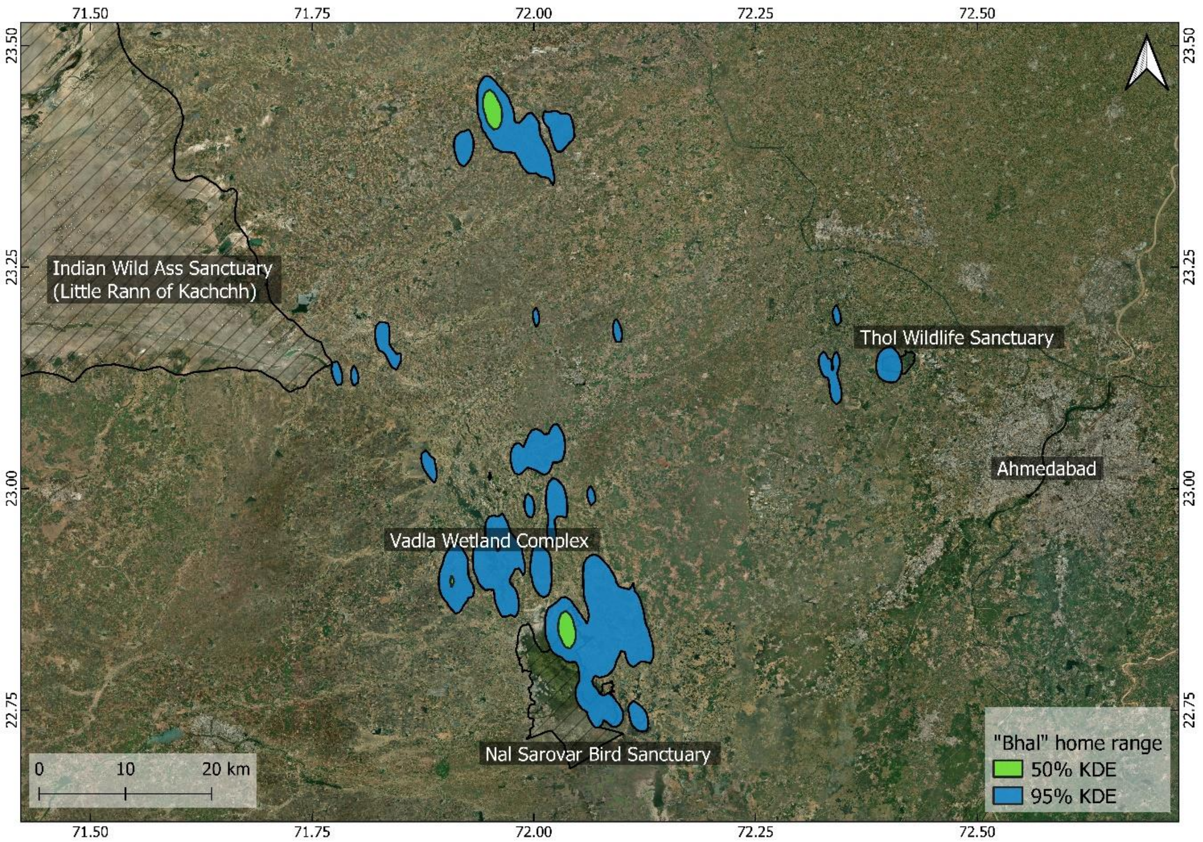



**Figure 14.** Map showing the home ranges of a Common Crane named Bhal

**Migration of Common Crane**

The Common Crane tagged in 2020 (name: Vadla) migrated to Kazakhstan and completed one migration cycle i.e. from Gujarat to Kazakhstan and then returned to Gujarat. However, the crane seized transmitting data in April 2021. Of the seven Common Cranes tagged in 2022, four cranes successfully completed one migration cycle in 2022. The mean length of spring migration routes of five tagged cranes (one in 2020 and four in 2022) was 4938 km (SD ± 155; Range: 4707 km – 5066 km) which was completed in 15 to 26 days. The cranes travelled only during the day time and stopped over in oasis and agricultural fields for night roost. Vadla did not make stopovers during the day time whereas rest four cranes made stopover for one to eight days. During the migration journey, cranes crossed seven countries before entering in the south-western Siberia region. The migratory flyway of tagged cranes is largely consisted of deserted landscape of Pakistan (Kharan desert), Afghanistan (Margow desert) and Turkmenistan (Karakum desert) and agricultural landscape of Uzbekistan and Kazakhstan (Figure 15). The Karakum desert and the shoreline of Aral Sea are important stop-over sites where the tagged cranes made day roosts.

The cranes started on their Autumn migration in the last week of September 2022 and first week of October 2022. Bhal and Nal started their Autumn migration on 28th September, Gani started the migration on 29th September and Sanand started the migration on 5th October. Cranes followed largely the same route as Spring migration, however, with no day roosts. It is noteworthy that Nal took only eight days to enter in India through Kachchh-Pakistan border. However, it stopped over in LRK for six days before arriving in Vadla wetland. Bhal and Gani took 12 and 9 days respectively to enter in India through the same region as Nal. The tracking of migratory journey of the five cranes have revealed the breeding sites of the population of the species that uses arid plains of western Gujarat.


**Figure 15.** Map showing migratory routes of the five tagged Common Cranes along the Central Asian Flyway

## Discussion

Flamingos being primarily associated with water occurs across all the wetlands in the Kachchh however the two flamingo species used the landscape differently. The Greater flamingos use the entire Kachchh Landscape while lesser flamingos are concentrated on the eastern Kachchh. These differences in the distribution of the two flamingo species may be attributed to the differences in their diet spectrum. The greater flamingos are generalist filter feeders and feed on crustaceans, molluscs, and larval aquatic insects, seeds of marsh grasses, algae, diatoms, and small fishes (Johnson et al. 2007). The lesser flamingos are specialized filter feeders and feed primarily on microscopic blue-green algae and benthic diatoms (Krienitz 2018, Jerkin 1957). *Arthrospira* which is the main food of Lesser flamingo (Krienitz 2018) requires moderate salinity (22-66%) for its optimum growth which is available only in selected sites. The narrow spectrum of the diet of Lesser Flamingo forces them to use coastal areas along the Gulf of Kachchh in search of foraging sites with optimal resources.

The flamingos of Kachchh region were distributed across different types of wetlands (inland, coastal wetlands and saltpans) and move to Rann habitat on the arrival of breeding season. The source of water in these wetlands is either rain-fed rivers or tides, and this wetland system is quite different from the wetlands used by flamingos in Africa. In Africa, the wetlands used by flamingos are volcanic in origin and are referred to as soda lakes which are fed through rivers, rainfall and hot springs. The salinity in these soda lakes is a result of the mixing of volcanic ash with the water (Krienitz 2018, Vareschi 1978) which promote the growth of alkaliphilic, halo and thermotolerant microorganisms and are used by flamingos both for foraging and nesting (Grant 2004, Johnson and Cezilly 2007).

Across the three years of tracking of the flamingos mostly remained in the Kachchh suggesting that they may be from the resident breeding population. Further the two tagged Greater Flamingos used the Kachchh differently. One extensively used the inland wetlands while other limited itself to the coastal wetlands of the Gulf of Kachchh. These two habitats are quite different tin term of the availability of food resources which suggests that they belong to two different population of Greater Flamingo which are habitat specific. The large congregations of flamingos were observed prior to the breeding season which appears to be a migrant population arriving in the Kachchh only before the breeding season and then moving to the Rann for breeding. This was confirmed by the Greater Flamingos tagged in Thol which arrived in Little Rann of Kachchh before moving into Greater Rann of Kachchh for breeding. Further research is required to better understand the use of Kachchh landscape by a migrant population of flamingos.

During the breeding season tagged flamingos used the Rann differently. The Greater Flamingos used remote Flamingo City surrounded by water in the Greater Rann of Kachchh. On the other hand, the tagged lesser flamingo used areas around Bela taluk/district and Little Rann near Surajbari creek as breeding areas which also has been reported to be the major breeding sites for lesser flamingos (Parasharya et. al 2010, Vyas 2014). The Kernel home ranges obtained using the tracking data revealed that the area of utilization increases for both species during the breeding season when they use Rann. This difference may be due to the reduced availability of suitable food resources in Rann habitat as the negative correlation between the home ranges and food availability has been observed in many other studies in different parts of the world (Albert et. al. 2013, Corriale et. al. 2013, Maude et. al. 2019).

The Rann gets inundated by water only during the monsoon and the depth is influenced by the amount of rainfall. During the three years of study there were differences in the rainfall pattern, 2018 was a drought year followed by a good monsoon in 2019 and excessive rainfall in 2020 (IMD, 2020). Hence it may be concluded that the tagged Greater flamingo could not breed in the Flamingo City in 2019 breeding seasons as the adequate water level was not available. The correlation between rainfall and breeding season for greater flamingos has been extensively studied across the breeding sites in Africa and it was found that breeding shows an exponential increase with a rise in the water levels (Johnson and Cezillt 2007, Cezillt et. Al 1995). The water levels also dictate the breeding of Lesser Flamingo which requires moderate rains, wet soil for building a nest and shallow water in adjacent areas. Flooded areas are not preferred for nesting (Krienitz 2018). These conditions were met during the breeding season of 2019, and two tagged lesser flamingos bred in Bela (Greater Rann). The influence of water on the distribution of Flamingos was also established by the SDM where the precipitation (22.8%) was one of the most contributing factors in the model. The precipitation determines the water depth and salinity of a wetland and is the governing factor that influences the number of flamingos (Krienitz 2018, Vyas 2014).

The field surveys for Crane presence showed that Common Crane occurs widely in the Kachchh district compared to the Demoiselle Cranes. It was observed that in the winter season 2018-19, Common Cranes occurred primarily in the agricultural landscape while in the winter season 2019-20, they were mostly recorded from the open meadows in the Banni landscape. This may be attributed to the amount of rain received in the monsoons. 2018 was marked as a drought year making the meadows dry and scarce of food and as a result, Common Crane used agricultural fields for foraging. Demoiselle cranes were mostly found in the agricultural fields and unlike Common Crane; they were never recorded form the Banni landscape. This may be attributed to the foraging habit of Demoiselle Cranes who forage primarily on grains and readily accept food provided by local people. However, the space-use and foraging habits of both Common and Demoiselle Crane is not fully understood till date and therefore, many questions regarding their spatial ecology remains unanswered.

The SDM suggested that temperature seasonality, LULC and altitude influences the distribution pattern of cranes. These are migratory species and arrive in the Kachchh landscape during winter and therefore, the temperature can play a vital role in their arrival, stay, and departure timings. The cranes use agricultural fields and open meadows for foraging and hence the LULC will define where the cranes will possibly occur. Earlier, Tiwari and Rahmani (2002) studied the distribution and diet of Common Crane in the Kachchh landscape and reported that the species feeds on *Cyperus* tubers in Banni and left-over seeds in agricultural fields. This was also observed by Khacher et al. 1993, from the Saurashtra region of the Gujarat state. The LULC, however, is defined by the altitude at a given point. For instance, the high-altitude areas (more than 100 m) will largely be dominated by scrubland and devoid of agricultural fields, and as a result, cranes are very less likely to occur at an altitude higher than 100 m in this landscape.

The tracking effort of five Common Crane is proved to be the first step in understanding the movement pattern and space-use by the species in wintering ground here in Gujarat. The crane populations roosting in the wetlands surrounding Kachchh landscape were thought to be commuting to Kachchh for foraging. Contradictory to this, the tracking data revealed that Common Crane population of Nal Sarovar and Thol remain confined to the area and does not commute to the Kachchh landscape except the eastern fringes of Little Rann of Kachchh. However, there can be differences in movement patterns and commuting distances for foraging across the different populations as they use dynamic agricultural landscape. Therefore, the tracking of more number of cranes from different populations may provide detailed insight in their space-use in different areas.

The tracking of migratory journey revealed fine-scale route of Common cranes wintering in and around Nal Sarovar. This effort has added in our knowledge of crane migration strategy where the crucial information on the timings and duration of migration, daily flight behaviour during migration and stopover locations were recorded that were never fully known before for the Common Crane population that winters in Gujarat. The only other attempt to track Eurasian cranes was from the Kachchh region that dates back in 1999-2000 when three cranes were successfully tracked to their breeding grounds at

Chelyabinsk and Isim in Russia, and Kokalaat in Kazakhstan using satellite tags (Argos PTT – 45 g) (Higuchi et al. 2008). This pioneering effort did provide information on the breeding origin of these wintering cranes however, given the tracking technology of the time detailed information on their movement path, and arrival and departure from stop-over and or roosting sites was limited.

This study has revealed that flamingos widely occur in the mainland Kachchh and Rann habitat but at different times of the year. The migratory cranes in this landscape are largely found in the agricultural fields, and the distribution of the species group is wider and also dynamic with the amount of rainfall. The results of the current study will serve as the baseline data for the distribution of four large bird species across the Kachchh district and help in the assessment of the risks posed by energy infrastructures. However, this study is based on the limited number of tagged birds and a lot more individuals are required to tagged and tracked which will give us the more detailed insight on the use of the landscape by them.

**Citation:**

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# *Collision Risk to Large Avian Species due to Transmission Lines in the Arid Plains of Kachchh*

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Gaurav Sirola
Anju Baroth
R. Suresh Kumar

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Collision with the power lines occurs when birds in flight crash with the earth wire located at the top of transmission lines, causing serious injury or death (APLIC 2006). Earth wires alone are reported to be responsible for the majority (86%) of collision-related bird mortalities (Murphy et al. 2009). The earth wire, whether present single or in pairs, is a non-energized wire that is thinner than conductors, making it difficult for many bird species to detect it during flight. Large birds such as bustards, cranes, swans, pelicans, storks and herons, have a blind spot in their frontal vision due to their body weight and lateral positioning of eyes, making it much more difficult to detect the wire or obstruction and hard to manoeuvre swiftly during flight (Jenkins et al. 2010, Martin and Shaw 2010, Martin 2011). Mortalities due to power-line collision may have population-level impacts (Bevanger and Broseth 2004) and can even push certain bird species (Crane, Bustard, Flamingo) to the verge of extinction (Prinsen et al. 2011). Further, it is reported that collision mortalities may even lead to changes in the migratory paths of birds as in the case of Great Bustard *Otis tarda* (Palacin et al. 2017).

Power-lines passing through highly suitable habitats and major wintering and breeding congregation sites like wetlands, coastal areas and grasslands may pose a serious threat of collision (Faanes 1987, Andriushchenko and Popenko 2012, Bernardino et al. 2018). Birds tend to use specific mountain ranges, valleys, river stretches, and coastal areas as their flight corridors during migration. Placement of power-lines in such extensively used passages increases the risk of collisions (Bavenger 1994, Newton 2010). A six-year study conducted in the subalpine region of Norway from 1989 to 1995 found that the collision rate of birds was 5.3 birds per km power line, and establishing a power-line in an open area was the leading cause of the collision (Bevanger et al. 2004).

The number of cables and the vertical distance between wires also influence the rate of bird collisions. The bundle of cables is much more visible than a single wire and hence poses a lesser risk to the bird as it will be visible from a distance (APLIC 2012). The transmission lines with multiple strata pose a higher risk as they may appear like an inescapable wall for a bird in flight. Reports suggest that a transmission line with two vertical levels is 72% less risky than power-lines with three vertical levels of conductors (Prinsen et al. 2011). The tall pylons of the transmission line pose a greater risk of collision as the bird collisions are found to be positively correlated to tower height Neves (2005).

The flight behaviour of birds additionally influences collision risks as long-distance migratory birds fly at a much higher altitude; hence are at lower risk while local birds are more prone to collision (Newton 2010) due to more frequent flights. The birds flying in a flock are more susceptible to collisions, e.g., cranes tend to form large flocks, which reduces the time and space to manoeuvre around unexpected obstacles for trailing birds (Alonso and Alonso 1999). A study by Pandey et al. (2008) reported power-line collisions of waterfowl and shorebirds mostly occur during low visibility between 9 p.m. to 10 p.m. and again around 4 a.m. indicating that the risk of collisions is higher for a nocturnal bird. Younger birds are reported to be more prone to collisions that are attributed to their less manoeuvrability especially in unfamiliar habitats with power-lines (Sundar and Chaudhary 2005, Fransson et al. 2019). Further, weather conditions also affect the visibility, which influences the flight behaviour of birds, as heavy fog, rainfall, snow, and cloudy weather force birds to fly at low altitudes and windy weather may hamper the manoeuvrability of birds while approaching power-lines (Bevanger 1994, APLIC 2006, Savereno et al. 1996).

Recently, the number of studies assessing the impact of power-lines on avifauna has increased significantly around the globe, however, only 6.1% of the studies are conducted in Asian countries (Bernardino et al. 2018). In India, studies on the impact of power-lines have been confined only to a few species. Sundar and Choudhury (2005) studied the power-line collision mortalities of the Sarus crane in the Gangetic flood plains of North India and found 35 dead and 8 injured birds over a period of three years. The impact of power-lines on Flamingos was studied by Tere and Parasharya (2011) in Gujarat where they recorded 76 collision mortalities during the study period (2002-2005). A study by Uddin et al. (2021) indicated that the power-line collision makes the only viable population of Great Indian Bustard vulnerable in the Thar Desert, Rajasthan as the population-level mortality of ~16%/year is caused by power-lines. Further detailed studies on the power-lines collision are required to be taken up at the landscape level as India is one of the power-line collision hotspots in the African-Eurasian region (Prinsen 2011).

Studies on the impacts of power-lines can help in the identification of risky stretches in an area and can reduce the collision of birds if suitable mitigation measures are adopted. Such mitigation methods include modification, rerouting, undergrounding and marking transmission lines. The effectiveness of these mitigation measures depends on several factors and varies across the regions. Efficacy studies on mitigation measures found that removal of earth wires can reduce collision risk by 80% (Beranger 2001) whereas banding wires with neoprene bands reduced bird mortality up to 76% (Janss and Ferres 1998). Also, bird diverters on earth wire can significantly reduce collision rates (Crowder 2000, Anderson 2002, De la Zerda and Roselli 2003). Moreover, it is highly recommended to underground all existing power-lines passing through the habitats that are highly used by birds (Prinsen et al. 2011).

The arid plains of Kachchh are a stronghold for large bird species like migratory cranes and Flamingos. Every year thousands of migratory cranes and Flamingos visit Kachchh for wintering and breeding, respectively. The Great Rann of Kachchh is a major breeding site for Flamingo in the whole of Asia. This landscape also attracts numerous other migratory birds, such as it falls in the Central Asian Migratory Flyway. In the recent past, the increased establishment of industries in Kachchh has enhanced the energy demand, which resulted in the expansion of the transmission line network in this region (GETCO 2017). Numerous transmission lines crisscross through the open landscape of Kachchh and continue to expand.

There have been only a few studies carried out in the region to assess the impacts of power-lines on birds. However, these studies primarily focused on single species or species groups such as Great Indian Bustard (WII 2018) and Flamingo (Tere and Parasharya, 2011) and addressed the problem of power-lines only for small regions in Kachchh. A large number of Flamingo mortalities due to collision with powerlines are recorded every year from across the distribution range. In December 2011, around 400 Lesser Flamingo mortalities were reported from Kadhir Bet (Gupta 2017), 27 mortalities from Bhavnagar in 2018 (Indian Express 2018) and five Greater Flamingo deaths in Ahmednagar, Maharashtra in 2016 (Kurhade 2017). To the best of our knowledge, studies on the impact of transmission lines at the landscape level and to identify high-risk power-line corridors have not been conducted in this region. This is the first such study aimed to assess the collision risk and identification of sensitive habitats for large bird species like flamingos and migratory cranes across the Kachchh district in Gujarat.

High mortality of lesser flamingos due to collision with transmission line (66 kV) recorded during 2011 at Khadir Bet (Source- https://www.downtoearth.org.in/coverage/killing-ground-34618)

# Methods

### 1. *Mapping and characterization of transmission lines*

We obtained GPS locations of the transmission line pylons from Gujarat Energy Transmission Corporation (GETCO) and converted point locations to line networks using Arc GIS. The ground-truthing of each line was performed and new lines missing from GETCO data were added by manual mapping using satellite imagery in Google Earth. The mapped power-lines were then characterized, during which select pylons from each line were visited by the researcher and data on the type of pylon, the capacity of line, number of vertical levels (strata), number of conductors in each bundle, and number of earth-wire, were recorded. The height of the pylon was measured using a rangefinder.

### 2. *Flight data analysis*

#### *(i) Flamingos*

To understand the flight behaviour of two flamingo species in the area, the span of tracking data was examined when the flamingos were in flight. Based on the ground speed recorded by transmitter, tracks were categorized into flight and non-flight tracks. For this segregation all the GPS points with ground speed of < 1 kmph was marked as non-flight locations and > 1 kmph flight. The flight locations were then converted into line tracks in

GIS platform. Only flight data with GPS fixes at the 10-minute intervals were used for this study.

The flight tracks were further classified into three flight classes:

1. **Local flights** - distance covered within 10 km (birds moved within the same wetland or surrounding wetlands)
2. **Medium-range flights**- the distance between 10 to 25 km (birds moved from inland wetlands to surrounding saltpans or mudflats for foraging or roosting)
3. **Long-range flights**- distance greater than 25km (birds invariably travelled far, primarily during the breeding season, between the Greater Rann and the Little Rann habitat).

The medium and long-distance flights were then plotted in ArcMap, and the power-line network was overlaid for analysing powerline crossings during the flights. Additionally, to analyse flight time, all the flights between 5 Am to 7 Pm were marked as day flights while from 7 Pm to 5 Am were marked as night flights.

***(ii) Cranes***

Flight behaviour of Common Crane was carried out at the southern fringes of Bhachau taluk of Kachchh. The total study area is around 316 km$^2$ through which about 271km long transmission lines pass. The habitat is dominated by agricultural fields, supported by two water canals (main and feeder canal) originating from river Narmada. Vehicular road surveys were carried out throughout the day (0700 hr. to 1200 hr. and 1600 to 1900) from mid-January to February end of 2019 for searching crane flocks. The flight behaviour of Common Crane was observed by two observers and the flights were video recorded for analysis. Following observation parameters were recorded for analysis a) flight time, location of the observer, weather conditions, power-line capacity, flock size, flight origin, flock's responses to power-lines, the total number of attempts made by the flock, and the crossing positions. Responses included splitting the flock, increased flight height, change in flight direction, flare, and stalling.

The flocks were categorized into four categories based on their size: Family flock (1 to 4), Small flock (5 to 20), Medium flock (21 to 50), and Large flock (more than 50). The number of attempts, i.e., the flock's total interactions with power-lines, was summed for each sample, resulting in a maximum number of four interactions observed. Flight origin was categorized into three distance classes: within 200 m, 200 to 500 m, and more than 500 m. For further analysis, crossing attempts were compared with the flock category, flight origin (distance to power-lines), and flight behaviour.

### *3. Identification of transmission lines in high suitable habitats for Flamingos and Cranes*

To identify sensitive power-lines that cross an important wetland, all inland wetlands were mapped using Sentinel and Google Earth imagery. Based on their area, wetlands were categorized as small (0-5 ha), medium (5-50 ha), and large (>50 ha) and were surveyed to record the presence of flamingos. Mapped wetlands were exported to ArcMap, and a buffer of 100 m was created. The transmission line network was overlaid over these wetlands, and transmission lines falling within or cutting across the area including the 100 m buffer were clipped and analysed.

The identification of critical transmission lines in Kachchh district was performed by overlaying powerline network on high suitable areas for Flamingo and migratory cranes in the GIS platform. Power-lines falling in the high suitable areas were separated and summarized which helped in calculating the length of different capacity lines and other transmission line characteristics.

### *4. Mortality Surveys*

The power-line collision mortality surveys were also performed in Bhachau where a total of 22 km power-line stretches, running parallel to the feeder canal were selected. To record power-line collision mortality in saltpans and mudflat habitats, a 12 km long stretch of the Surajbari bridge area was selected. Due to the presence of water and vast mudflats, this area is highly preferred by birds such as Flamingos, Pelicans, Storks, Herons, Egrets and other Waders.

The mortality surveys around the selected power-lines were carried out on a two-wheeler at the speed of 10-20 km/hr., and frequent stops were made to search around the area for evidence of bird carcasses. These surveys were carried out twice a week. During the survey, both sides (50 m on each side) of the power-line were searched for the mortalities, thus making it a 100 m wide stripe survey. When a carcass was spotted, time, location, species, condition of the carcass, a sign of collision or electrocution, distance from nearest power-lines, power-line capacity, number of earth wire, and phase wires were recorded. Along with systemic surveys, opportunistic data on mortalities due to power-line during field visits across Kachchh was recorded.

# Results

### *Transmission line network*

Transmission line networks of six different voltages were mapped forming a total length of 5482 km across the Kachchh landscape (Figure 1). The transmission line network comprises of 185 lines of 66 kV (2472 km), 29 lines of 220 kV (1329 km), 13 lines of 400 kV (1282 km) and one line each of 132 kV (22 km), 500 kV (210 km) and 765 kV (161 km). The majority of these lines are distributed in the eastern region of the Kachchh in Bhachau (1015 km), Anjar (856 km), Bhuj (854 km) and Rapar (492 km) taluks where all capacity power-lines are present. In the western taluks (Lakhpat, Abdasa and Nakhatrana), fewer number of power-lines with lower voltages (66kV) are present (Figure 2). All the power-lines enter Kachchh from two areas; Nanda Bet and Surajbari Creek, forming two critical powerline-corridors in the region.

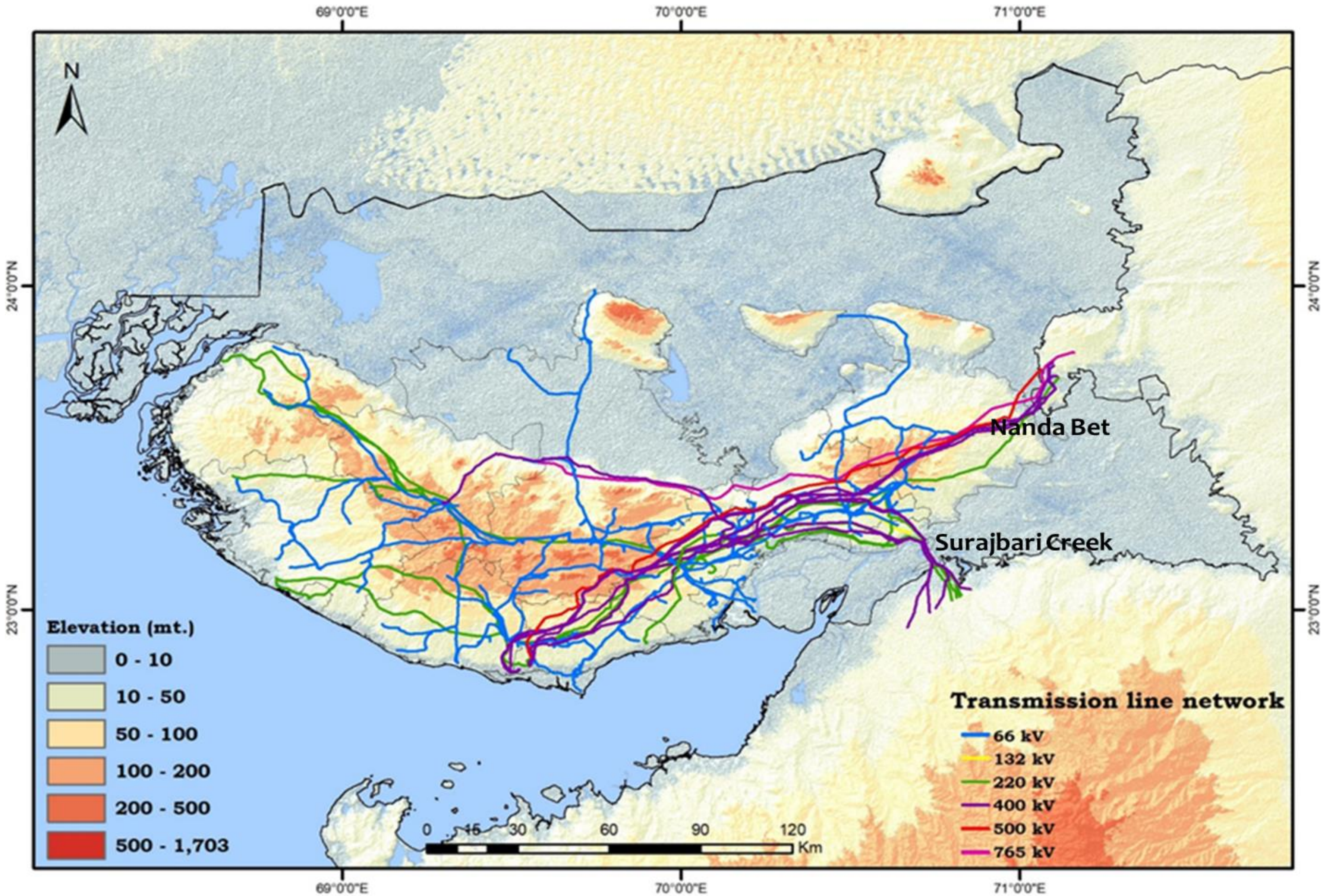



**Figure 1.** The transmission lines network clearly shows that 66kV lines are spread across the landscape, whereas higher kV lines are concentrated towards the Eastern parts of the Kachchh, forming major power-line corridors.

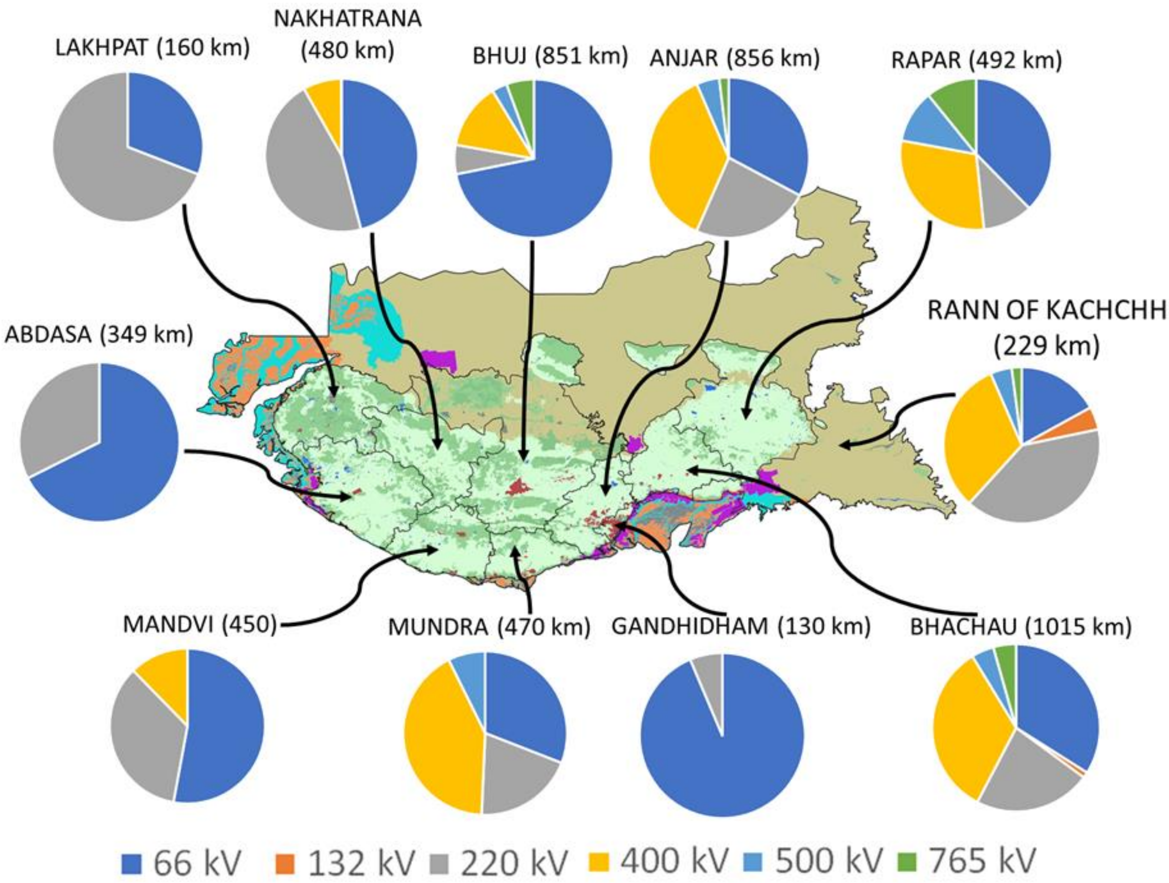



**Figure 2.** Length of Transmission lines in different taluks of Kachchh district.

765 kV transmission lines pylons in the landscape have maximum height (80 m) and largest vertical steel lattice structure with two peaks carrying two earth wires. The pylon has a double circuit, three strata and six wires in each bundle of conductor. The 500 kV pylons have 40 m high horizontal steel lattice with two peaks carrying two earth wires. Pylon had only one strata with two phases and four wires in bundle of conductors. The pylons of 400kV transmission line are 55 m high lattice with two peaks. The pylons have a double circuit, three strata with two or four wires in each bundle of conductor. The 220 kV pylons had lattice with two heights i.e., 70 m and 35 m. The pylons with 70 m height have a double circuit, six strata and two wires in each bundle of conductor while 35 m high pylons have a double circuit and three strata with one wire on each side. On both types of pylons, only one earth wire was present (Table 1).

The pylons of 132kV had a height of 25 m with three strata carrying six conducting wires (3 on each side) and having one earth wire on the top. The pylons of 66kV line pylons had two structures, H-shaped and steel lattice. Steel lattice pylons had 25 m height with a double circuit, three strata carrying six conducting wires (3 on each side) and having one earth wire on the top. H-shaped pylons had 10mt height with single circuit one strata and three conducting wires without any earth wire.

**Table 1.** The height of pylons varied with the capacity of the transmission lines. 66kV line had a minimum height of 10 m and 765 kV line had pylons with a maximum height of 80 m.

| S. No. | Capacity (kV) | Type of Pylons | Height (m) | Number of strata | Conductor wires | Number of earth wires |
|---|---|---|---|---|---|---|
| 1 | 66 | 2 | 10, 25 | 1,3 | 3,6 | 0, 1 |
| 2 | 132 | 1 | 25 | 3 | 6 | 1 |
| 3 | 220 | 2 | 35, 70 | 3,6 | 6,12 | 1 |
| 4 | 400 | 1 | 55 | 3 | 12,18,24 | 2 |
| 5 | 500 | 1 | 40 | 1 | 8 | 2 |
| 6 | 765 | 1 | 80 | 3 | 36 | 2 |


The images depicting the structural differences in the pylons of transmission line of different voltage capacities observed in the Kachchh landscape during the study period

***Transmission line network and suitable Flamingo habitat***

The high suitable area for Flamingo was found to be crisscrossed by a number of transmission lines. A total 313 km length which is 6% of all the transmission lines, passes through high suitable Flamingo habitat (Table 2). The majority of these lines are located near the Gandhidham-Tuna saltpans, Surajbari Creek, and Nanda Bet. The 66 kV lines have a maximum length (144 km) and number(n=40) of all the capacities of lines passing through the flamingo habitat. Other capacity transmission lines are 400kV (n=10) with a length of 79 km, 220kV (n=12) with a length of 72 km, and one line each of 500 and 700 kV with a length of 10km, 8km respectively. A 7 km stretch of 66kV transmission line located in the Greater Rann of Kachchh between Dholavira and Bela has been undergrounded (Figure 3).

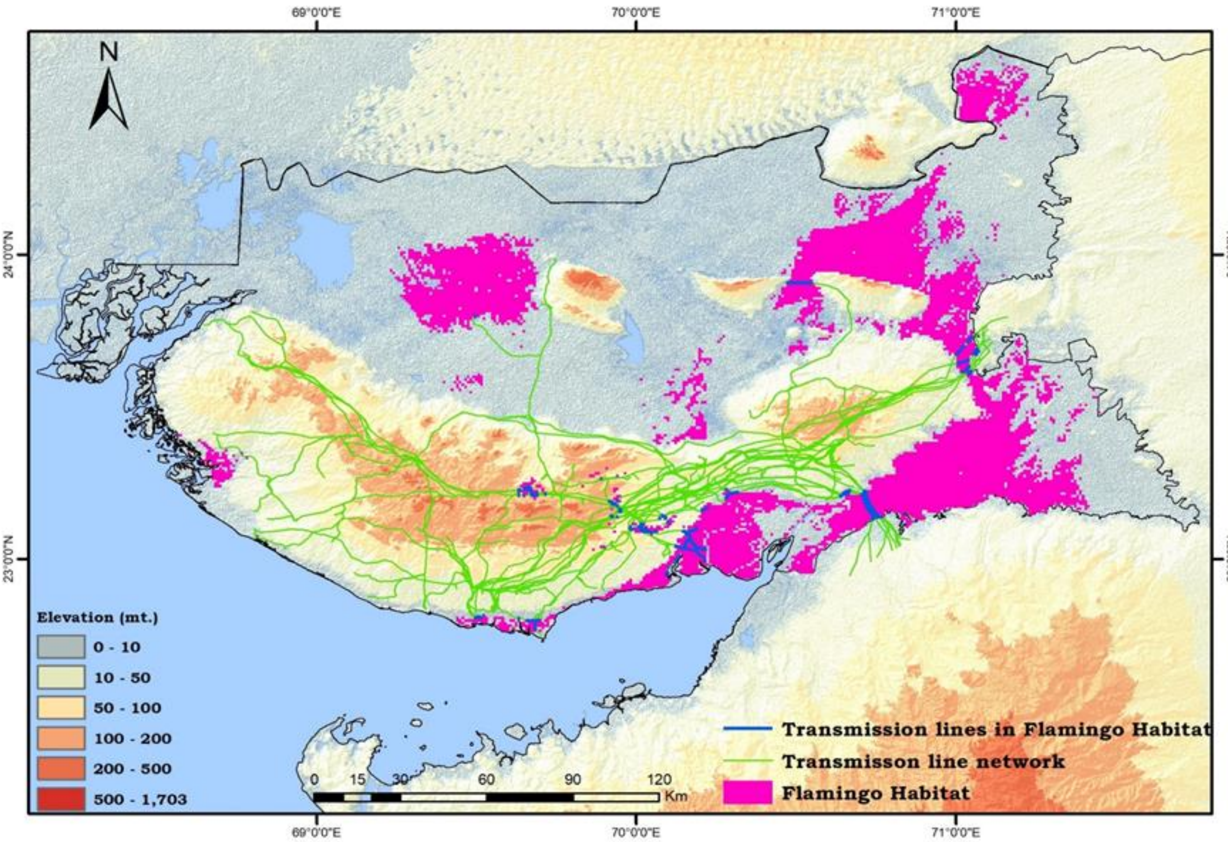



**Figure 3**. Map showing transmission lines (blue color) passing through suitable flamingo habitat (pink color) across Kachchh district.

**Table 2.** The percentage length of the different transmission lines together accounts for 6% of all the lines in the Kachchh landscape that pass through the high suitable flamingo area.

| S. No. | Capacity (kV) | Total length of line (km) | Length of lines in Flamingo habitat (km.) | Percentage of line length in flamingo habitat |
|---|---|---|---|---|
| 1 | 66 | 2472 | 144 | 6 |
| 2 | 132 | 22 | 0 | 0 |
| 3 | 220 | 1329 | 72 | 5 |
| 4 | 400 | 1282 | 79 | 6 |
| 5 | 500 | 210 | 10 | 5 |
| 7 | 765 | 167 | 8 | 5 |
| | **Total** | **5482** | **313** | **6** |

The transmission line corridors at Surajbari creek span a total length of 9 km with four lines of 400 kV and three lines of 220 kV running parallel to each other. Transmission lines in this corridor are closely placed and are separated by a distance that ranges from 50m to 545 m and the total width is 1.2km (Figure 4a).

The length of the transmission line corridor at Nanda bet ranges from 3 km to 11 km and three lines of 400 kV and one line each of 220 kV, 500kV and 765kV pass through this corridor. The transmission lines in this corridor are sparsely placed and are separated by a distance that ranges from 90 m to 4200m and the total width is around 8km (Figure 4b).

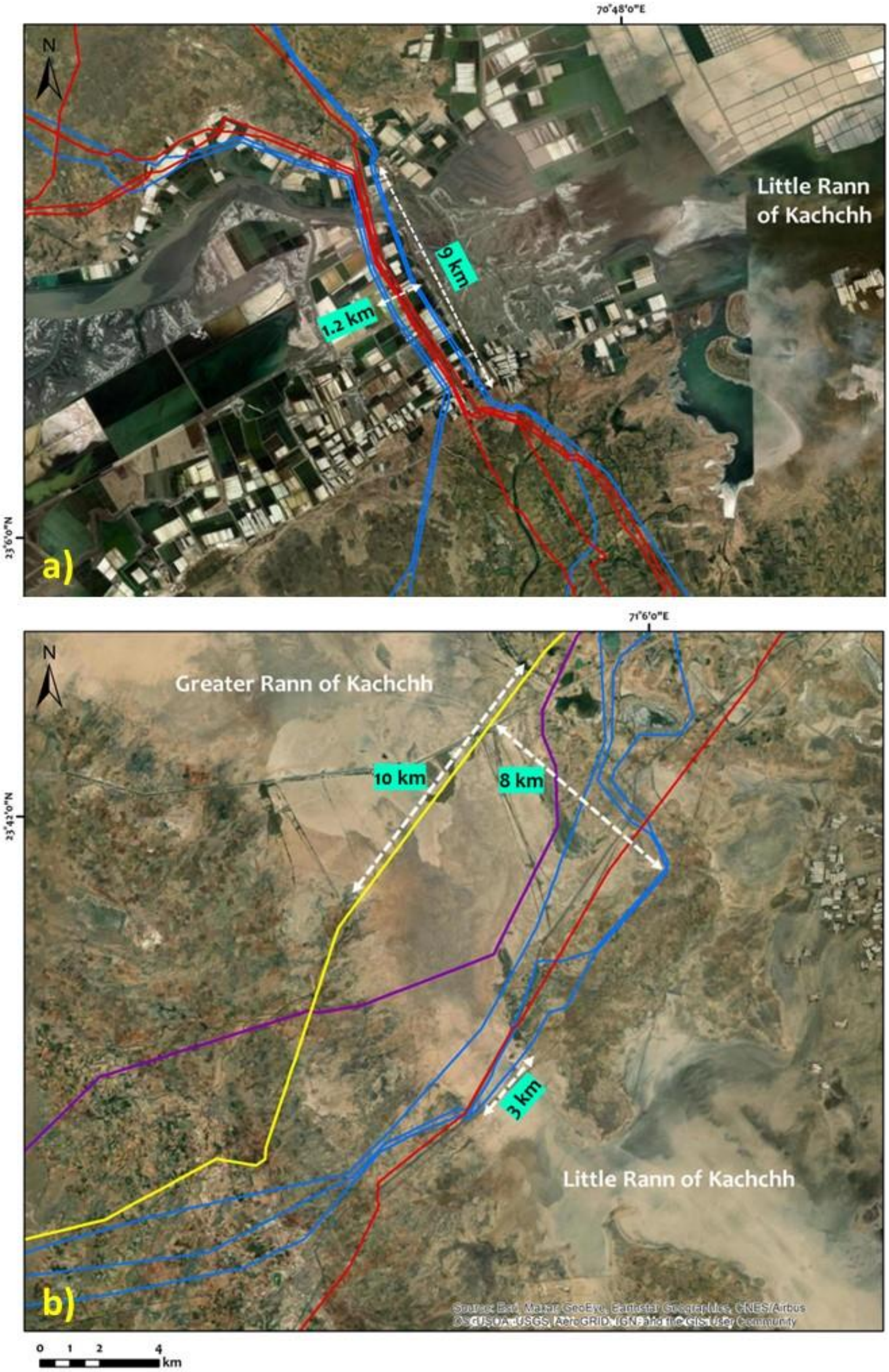



**Figure 4.** Map showing two powerline corridors at Surajbari Creek bridge (a) and Nanda Bet (b) from where multiple high-capacity transmission lines enter Kachchh mainland.

*Flight behaviour of Flamingos*

The flight data of tagged Greater Flamingo (n=2) and Lesser Flamingo (n=4) was examined in detail from May 2019 to March 2021 to know the flight behaviour. It was found that the tagged lesser flamingos showed higher movement than greater flamingos. Lesser Flamingo made a total of 201 medium range (10-25 km) and 125 long range flights (>25km), whereas Greater Flamingo made only 90 medium and 42 long range flights (figure 5). Lesser flamingos made a higher number of flights during the breeding season of 2019 and frequently moved between the Greater Rann and the Little Rann. While during the breeding season of 2020 only a few flights between the two Ranns were observed.

Greater Flamingo made few flights during the breeding season of 2019, they moved to Greater Rann at the start of the breeding season and moved out only at the end of the breeding season. However, they showed higher movement during the breeding season of 2020 as they regularly moved from inland wetland and mudflats to Flamingo city. Lesser flamingos were found to maintain their flight path close to water predominantly, while no such pattern in the flight path was observed in the case of greater flamingos and flew directly over the mainland of Kachchh to travel from breeding areas to the non-breeding areas.

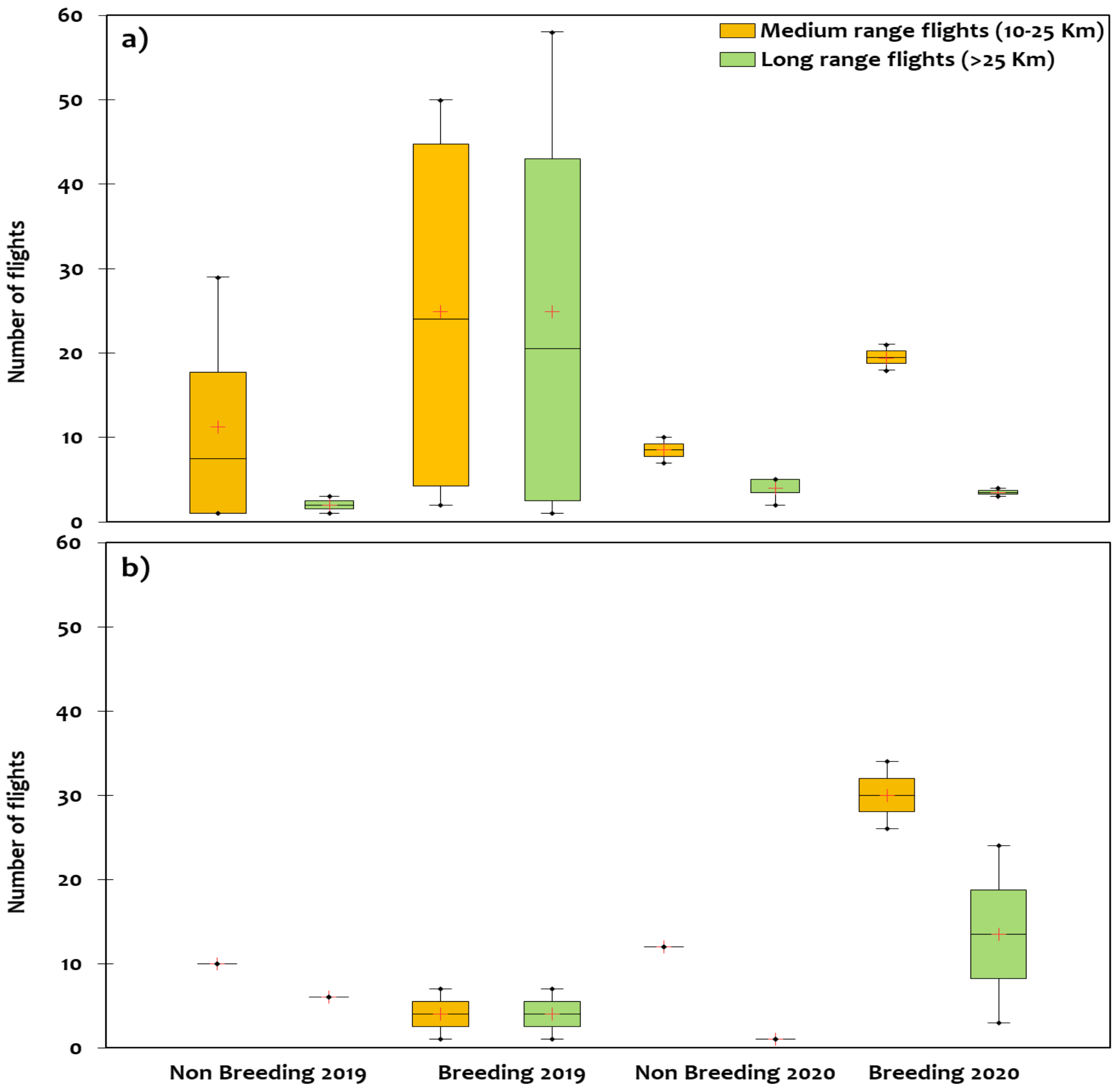



**Figure 5.** Boxplot showing variability in flight number during breeding and the non-breeding season is tagged (a) Lesser Flamingo (n=4) and (b) Greater Flamingo (n=2).

The tracking data also revealed that across all seasons, flamingos made a significant number of nocturnal flights (Figure 6). The majority of medium (60%) and long-range flights (81%) by Lesser Flamingo were made during the night while Greater Flamingo made only long-range flights at night time.

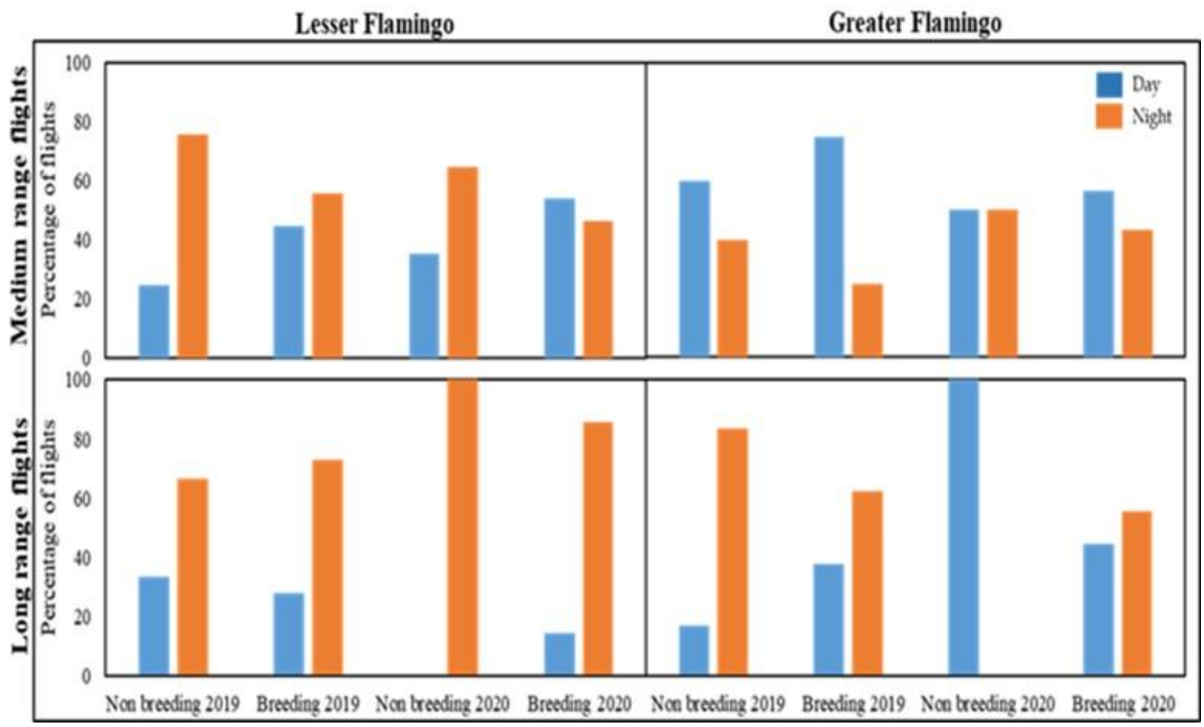



**Figure 6**. Tagged Lesser Flamingo made higher number of nocturnal flights but tagged greater flamingos made more diurnal medium-range flights and nocturnal long-range flights in the year 2019.

***Flights and transmission line network***

On overlaying transmission line network and medium and long-range flight tracks, it was found that tagged Lesser Flamingo crossed transmission lines 959 times out of which 244 crossings were made during medium and 715 during long-range flights. A total of 23% medium and 58% of long-range flights involved crossing transmission lines by tagged Lesser Flamingo. Most of these crossings occurred during the breeding season of 2019 (n=544) at Surajbari and Nanda bet region of the Kachchh district (Figure 7). On further analysis, it can be deduced that across all seasons, most of the transmission lines were crossed by the tagged Lesser flamingo during the night (85.6%) and only a few in day time (14.4%) (Figure 8).

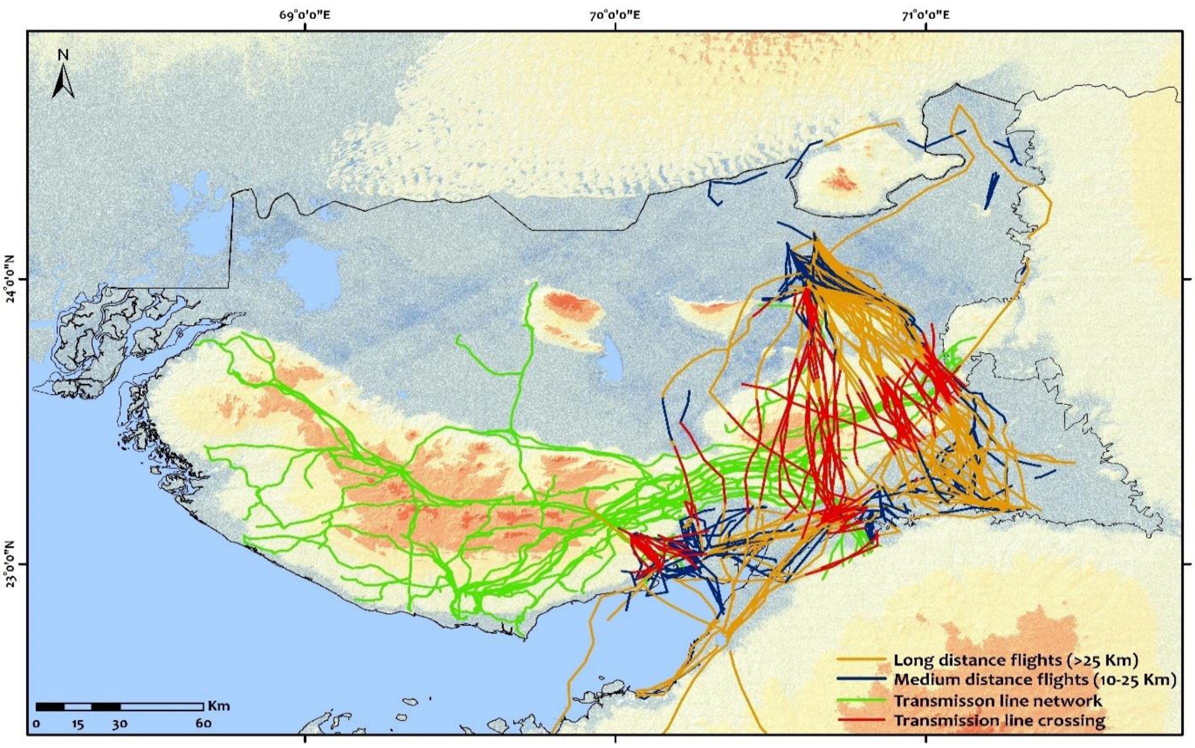



**Figure 7.** Map showing transmission line crossing (red color) by tagged Lesser Flamingo (n=4). The majority of the transmission line crossing events in tagged lesser flamingos (n= 715) occurred during long-range flights (orange color) in the eastern region of Kachchh.

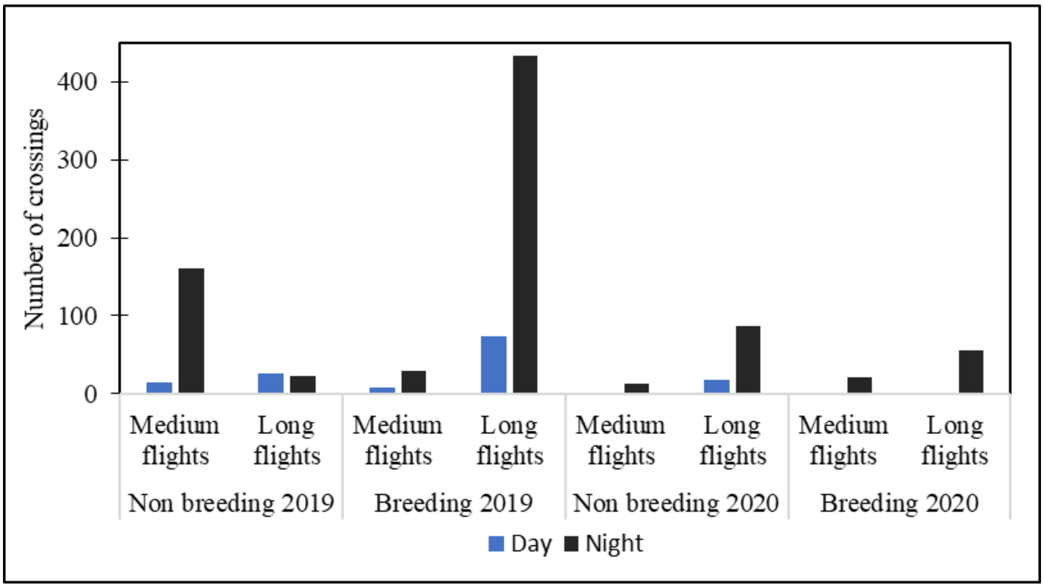



**Figure 8.** Transmission line crossing events at night (n=745) were more than a day (n=138). Additionally, more crossings were observed during medium-range flights than in long-range flights in the non-breeding season of 2019.

The transmission line crossing events involve crossing of power-lines of different capacity. During the tracking period of tagged Lesser Flamingo a total 50 lines of 66 kV, 30 lines of 220 kV, ten lines of 400 kV and one line each of 132 kV ,500 kV and 765 kV were crossed during medium and long-range flights (Figure 9).

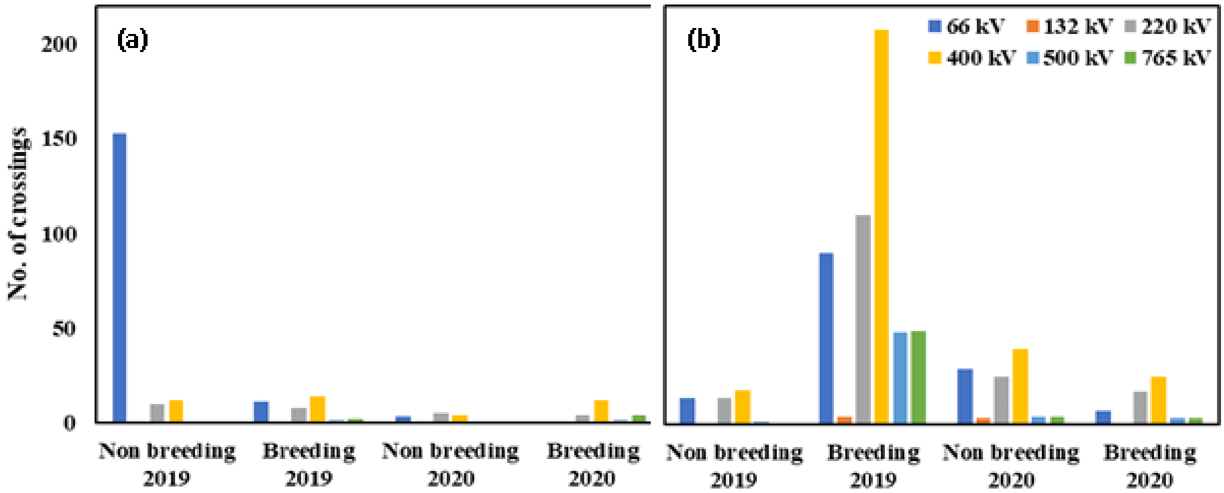



**Figure 9.** Transmission line crossing by tagged Lesser Flamingo during medium-range flights (a) was maximum for low-capacity lines (66kV, n=153) in the non-breeding season. Long-range flights (b) showed more transmission line crossings of higher capacity lines (400kV, n=207) in the breeding season of 2019.

Greater Flamingo crossed the power-line 333 times, out of which 69 crossings were during medium and 264 during long-range flights. A total of 34% medium and 48% of long-range flights involved crossing transmission lines by tagging Greater Flamingo (Figure 10). Most of these transmission line crossing events occurred during the non-breeding seasons of 2019 (n=119) when tagged greater flamingos used inland wetlands and in breeding season of 2020(n=113). The majority of crossings were made during the night (70%) (Figure 11).

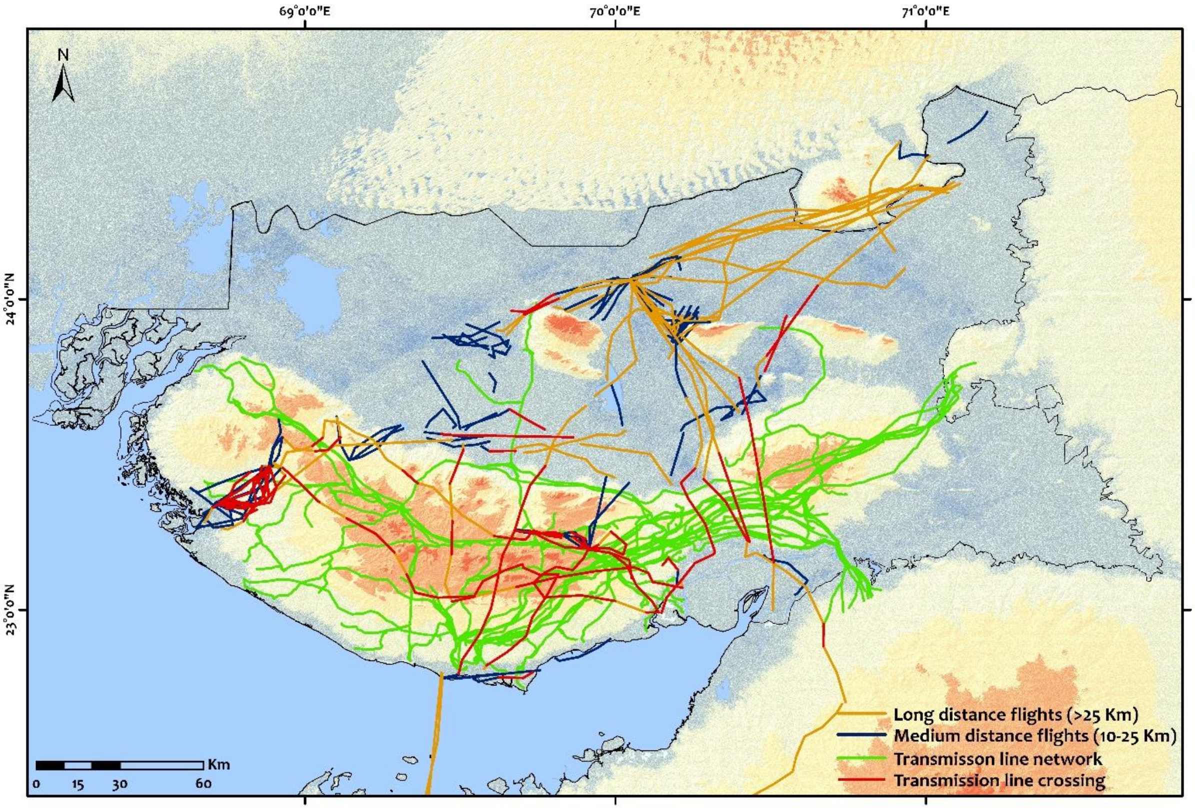



**Figure 10.** Map showing transmission line crossing (red color) by tagged Greater Flamingo (n=2).

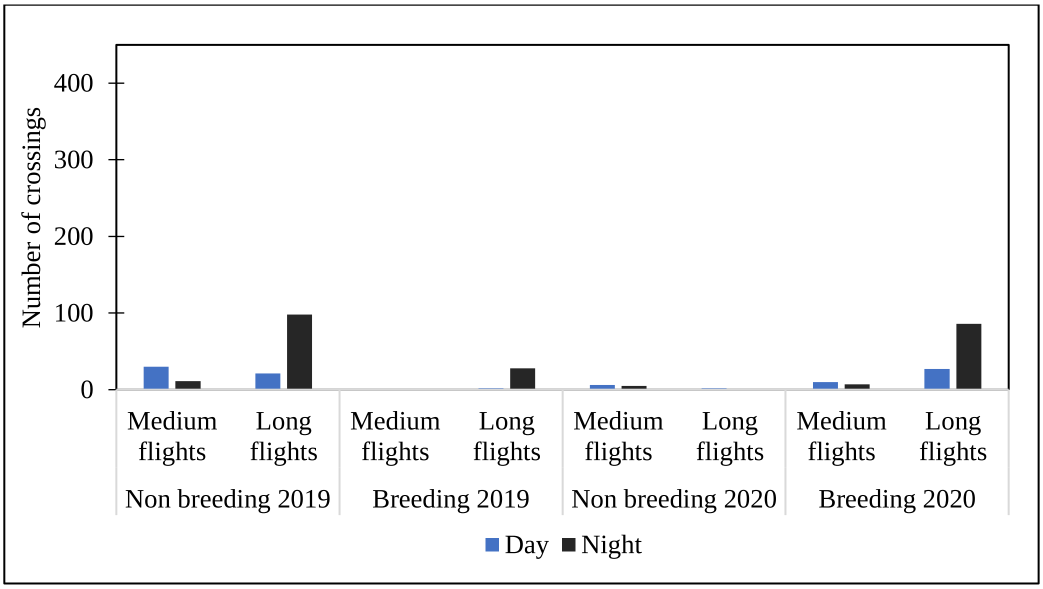



**Figure 11.** Most of the power-line crossings (n=235) by tagged Greater Flamingo were made during nighttime.

During the tracking period of tagged Greater Flamingo, a total 61 lines of 66 kV, 19 lines of 220 kV, 14 lines of 400 kV, and two lines of 500 kV and one 765 kV line was crossed during medium and long-range flights (Figure 12).

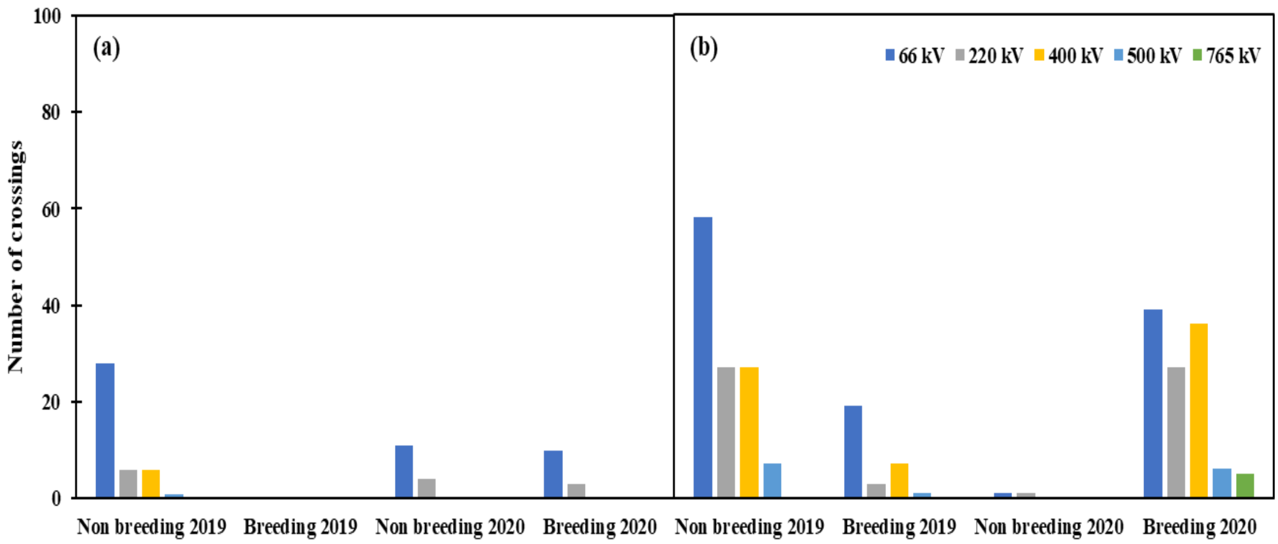



**Figure 12.** Transmission line crossing by tagged Greater Flamingo during medium-range flights (a) was maximum for 66 kV line (n=28). Long-range flights (b) again showed more transmission line crossings of 66 kV line (n=58).

*Critical Power-line stretches in Crane habitat*

The power-line network of the district was overlaid with high suitable areas for migratory cranes which revealed that 39% of total power-line network of the landscape pass through the high suitable areas. Further analysis based on particular capacity line length falling in suitable areas revealed that of the total 400 kV line network, 50% of it falling in the high suitable areas followed by 500 kV line where 44% of total 500 kV length falls in high suitable areas. Other transmission lines falling in suitable areas are 220 kV (39 % of total 220 kV length), 66 kV (34 % of total 66 kV length) and 765 kV (26 % of total 765 kV length) (Table 3).

**Table 3**. The table showing different capacity transmission lines falling in suitable areas for cranes. The percentage length falling in suitable area is calculated for each line and cumulative percentage are given in the last row.

| S. No. | Capacity (kV) | Total length of line (km) | Length of line in suitable areas (km) | % Length in suitable areas |
|---|---|---|---|---|
| 1 | 66 | 2472 | 852 | 34 |
| 2 | 132 | 22 | - | - |
| 3 | 220 | 1329 | 517 | 39 |
| 4 | 400 | 1282 | 638 | 50 |
| 5 | 500 | 210 | 93 | 44 |
| 6 | 765 | 167 | 44 | 26 |
| | **Total** | **5482** | **2144** | **39** |

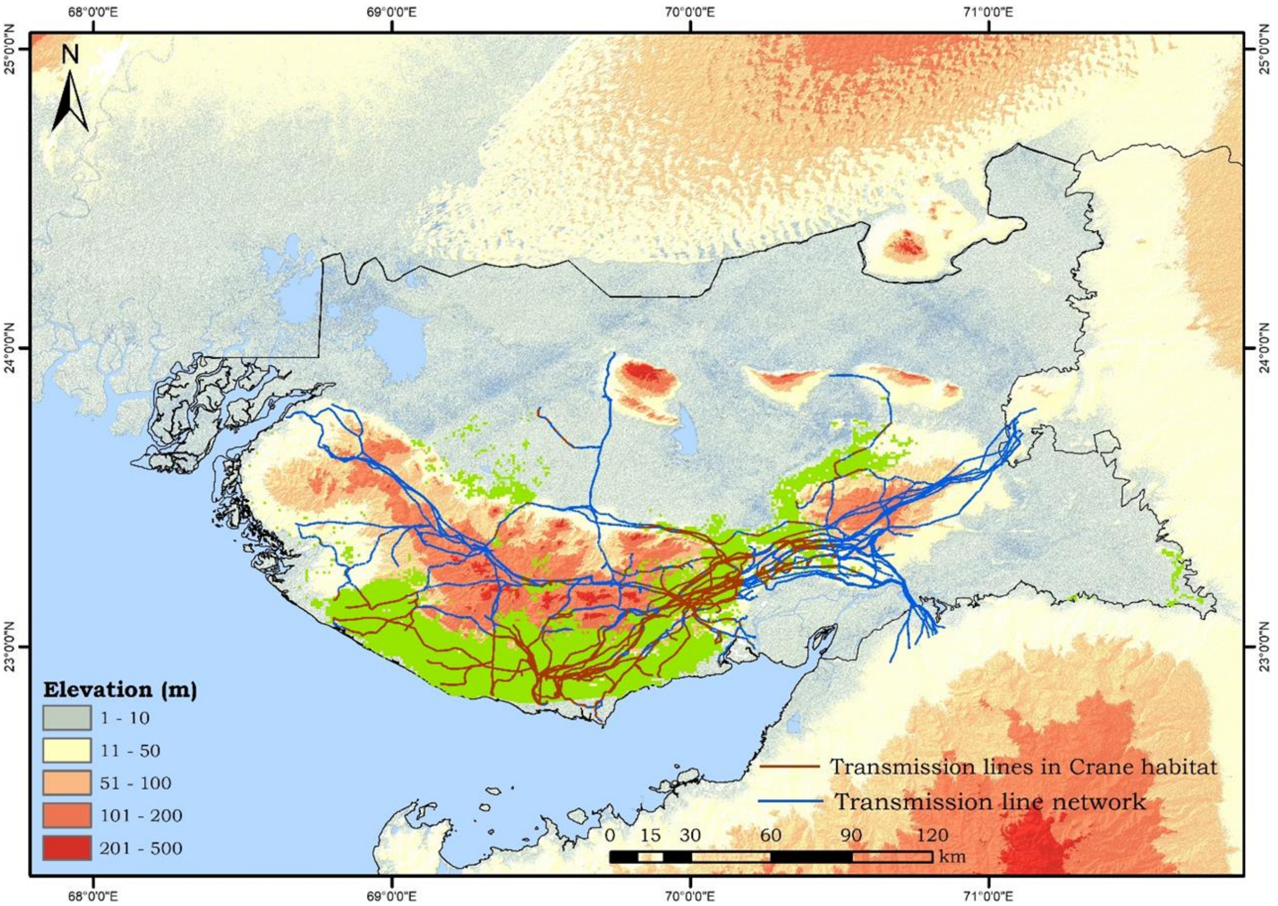



**Figure 13.** The map showing critical transmission lines in the high suitable areas for migratory cranes. The majority of the crucial transmission lines are falling in Mandvi, Mundra, Anjar and Bhachau taluk where extensive agricultural fields are located.

***Common Crane flight behaviour***

During 250 man-hr. of effort, responses of 79 Common Crane flock flights were observed. The flock size of observed Crane flights ranged from 1 to 200 with a mean flock size of 38.1 (± 45.3) comprising a total 904 individuals. While approaching transmission lines, around 81% of crane flocks showed a response while 19% flocks did not respond at all. The responses recorded in 64 flocks were: gaining flight height (n=38), changing flight course (n=14) and splitting (n=12) (Figure 14). On observing the position of transmission line crossings, it was found that 51% of crossing were made above the earth wire, 39% crossing were between the earth wire and conductors and 10% were below the lowest conductor.

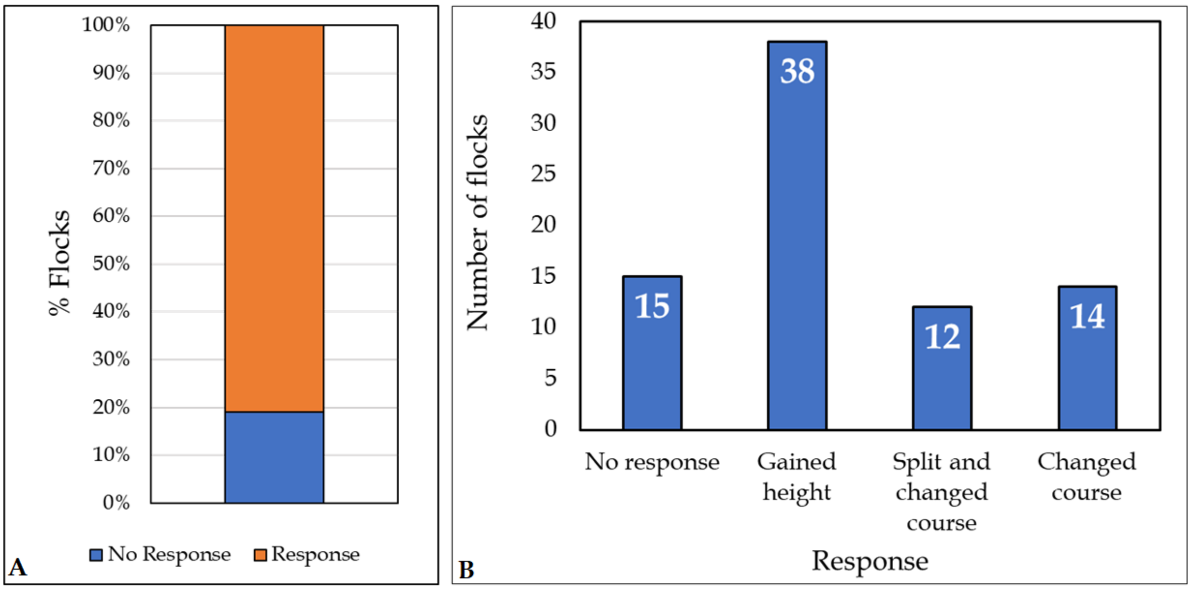



**Figure 14**. A. Majority of flocks (81%) showed response to the power-lines during the flight. B. A graph showing number of flocks responding in different type of response.

Common cranes in all the flock size catagories showed gaining of flighe height type of response predominently. Change in flight course type of response was majorly observed in very large flock size (44%) followed by small flocks (24%), family flocks (15%) and large flocks (%). The split and change course type of response was recorded mostly in lerge flocks (14%) followed by small flocks (7%) while observed nigligible numbers of occasions in family flocks (1%) and very large flocks (2%) (Figure 15).

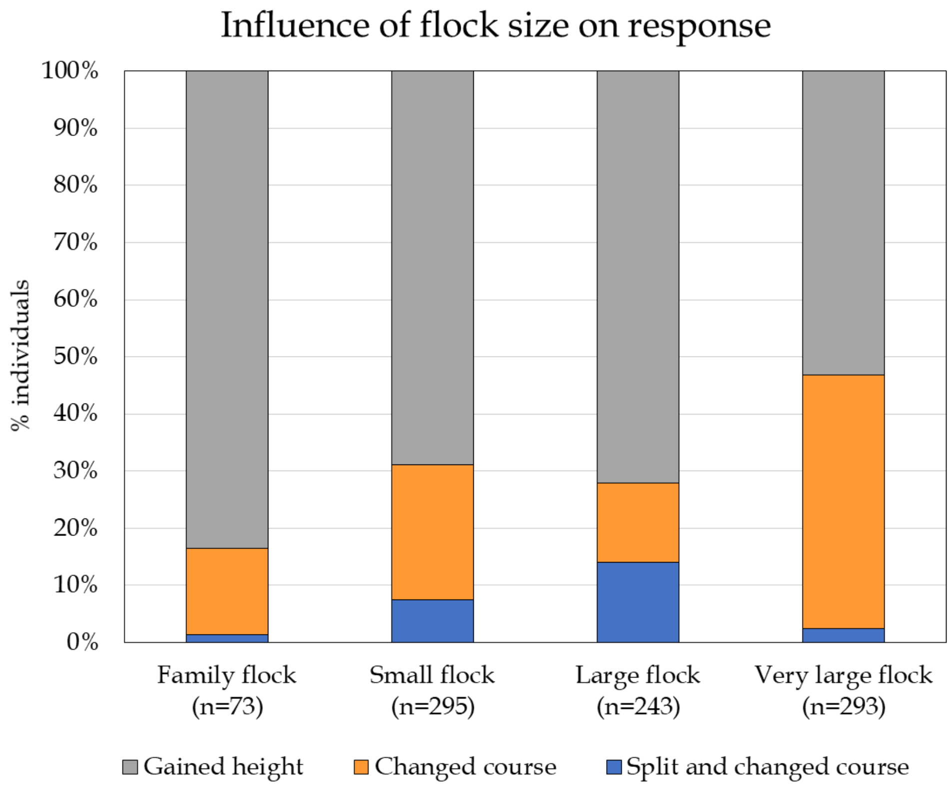



**Figure 15.** Frequency distribution of different type of responses shown by family flock, small flock, large flock and very large flock.

The analysis of flight origin distance and type of response revealed that when the flight origin is within 200 m distance from the transmission lines, majority of flocks gained height (69%) followed by change in flight course (26%) and split and changed course (5%). A similar pattern was observed when the fight origin distance was between 200 to 500 m, however, when the origin of flight was beyond 500 m, cranes showed only gain in height (79%) and change in course (21%) (Figure 16).

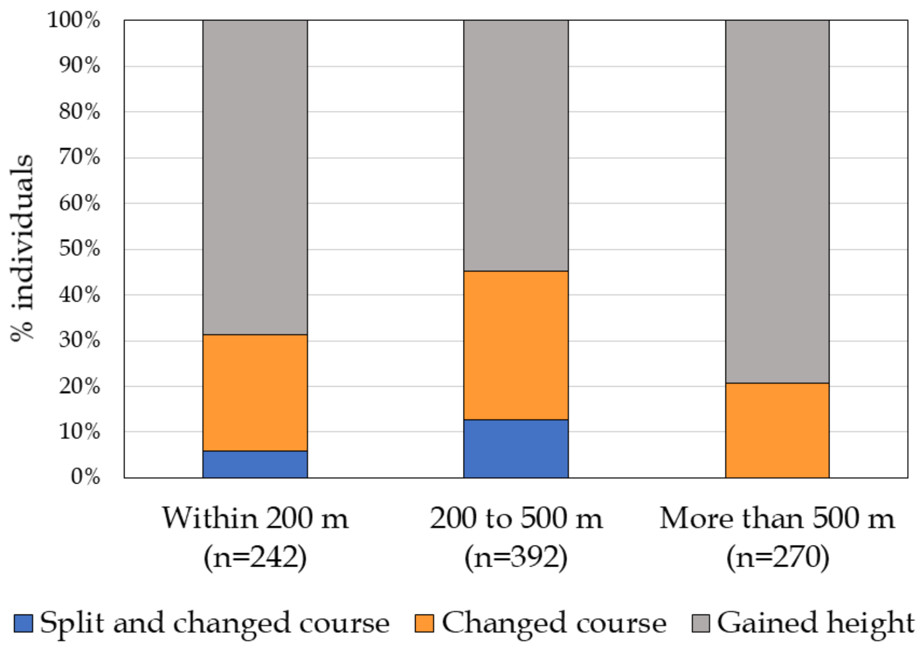



**Figure 16.** Frequency distribution of different type of responses when flight originated from with 200 m distance, 200 to 500 m distance and more than 500 m distance.

The analysis of respone to differnet capacity transmission lines revealed that for lower capacity transmission lines (66- 220kV) around 95% Common Cranes gained height and 5% spit and changed course whereas while crossing 400kV transmision lines 63% cranes gained height, 30 % changed course and 7% split and changed course (Figure 17).

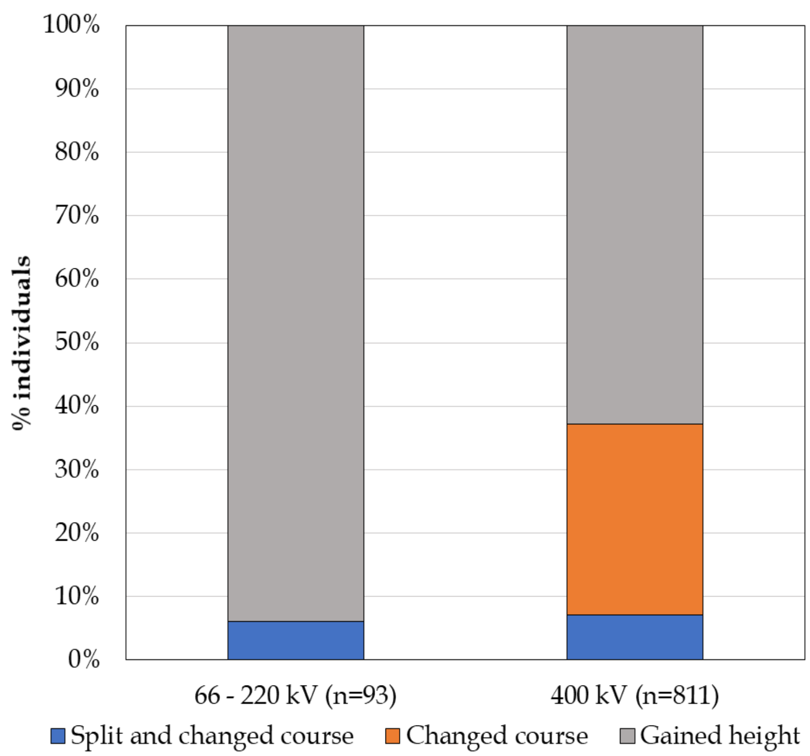



**Figure 17.** Frequency distribution of different type of responses at different capacity power-lines. Responses to 66 kV and 220 kV were clubbed as both the kV power-lines are of similar configurations.

***Mortalities of birds due to powerline collision***

During systemic mortality surveys at Surajbari, four 400 kV and three 220 kV transmission line forming a total length of 30 km was surveyed five times while at Bhachau one 220kV and 400 kV line with a total length of 22 km was surveyed. During these surveys a total of five power-line collision mortalities (two Greater Flamingo, one Eurasian Spoonbill, Eurasian Curlew and Dalmatian Pelican) were recorded from Surajbari (Table 4). At Bhachau two Common Crane carcasses were recorded which appeared to be a collision mortality.

Along with the systemic surveys, opportunistic power-line collision mortalities across the Kachchh landscape were also recorded. Over a duration of one and half year, 22 power-line collision mortalities were found, with Flamingos (n=7) being most affected birds followed by pelicans (n=5). Of the total 18 bird carcasses, 13 carcasses were found under transmission lines while 9 carcasses were found under distribution lines (Table 5).

**Table 4.** The table showing details of bird carcass attributed to collision mortality at Surajbari Bridge area*.

| S. no | Date | Time | Species | No. of Carcass | Condition of Carcass | Sign of collision | Distance from power line (m) | Line Capacity (kV) |
|---|---|---|---|---|---|---|---|---|
| 1 | 07-01-2019 | 08:30 | Eurasian Spoonbill | 1 | Old | Leg broken | 6 | 220 |
| 2 | 24-02-2019 | 09:32 | Eurasian Curlew | 1 | Old | Hanging on earth wire | 0 | 400 |
| 3 | 24-02-2019 | 10:26 | Greater Flamingo | 1 | Old | Leg broken | 19 | 400 |
| 4 | 13-03-2019 | 18:26 | Greater Flamingo | 1 | Old | Broken leg and neck | 40 | 400 |
| 5 | 13-03-2019 | 18:30 | Dalmatian Pelican | 1 | Old | Broken leg and neck | 41 | 400 |

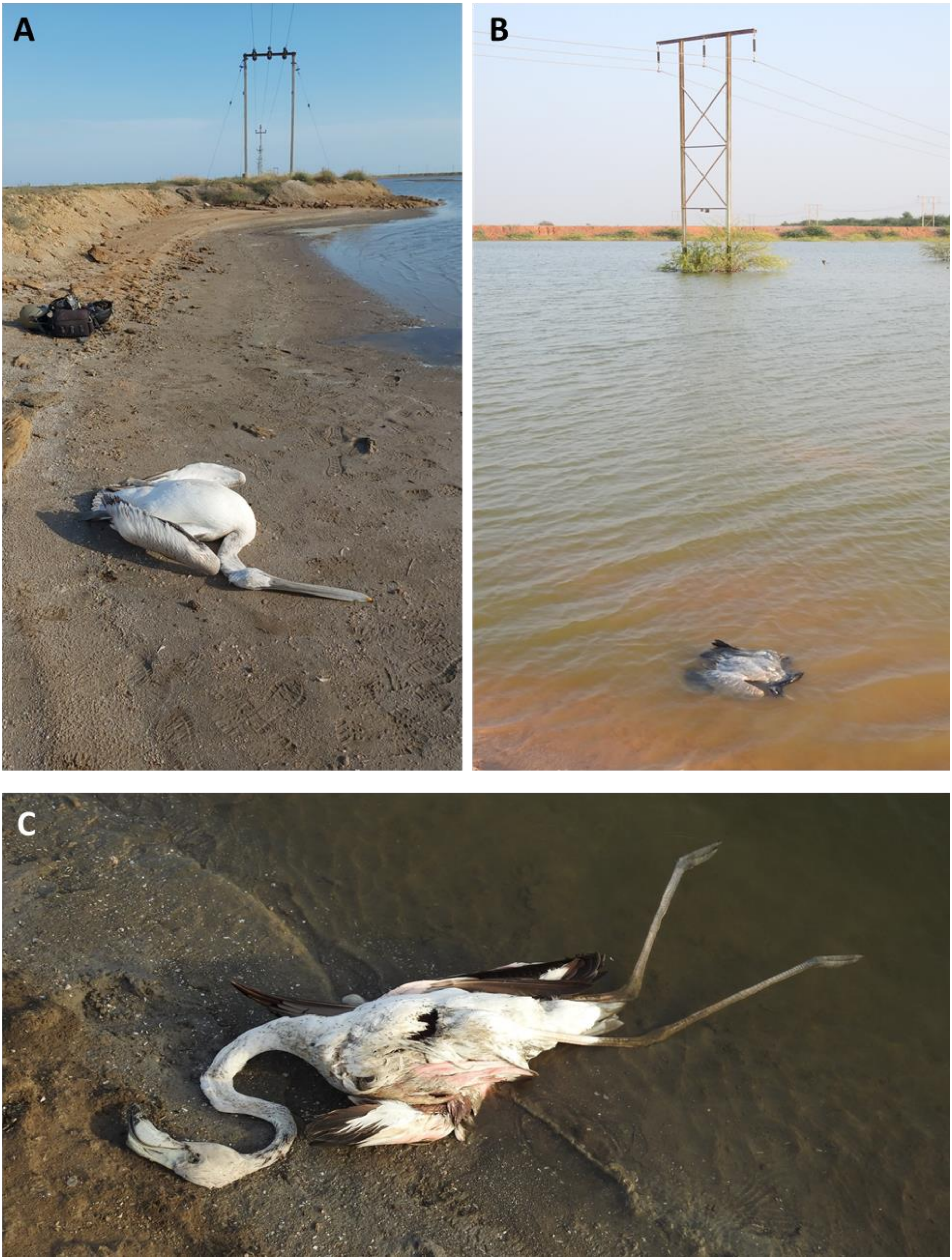
Two Eurasian Spoonbill were found dead due to collision with transmission line.

**Table 5.** Bird mortalities recorded near or below power lines across the Kachchh landscape during the study

| S. No | Date | Species | No. of carcass | Condition of carcass | Sign of collision | Distance from power line (m) | Line Capacity (kV) |
|---|---|---|---|---|---|---|---|
| 1 | 04-06-2018 | Eurasian Spoonbill | 1 | Old | Hanging, Leg broken, entangled with earth wire | 0 | 220 |
| 2 | 19-06-2018 | Greater Flamingo (Sub-adult) | 3 | Fresh | Injury in wings. One severed wing found 10 m away | 30 | 66 |
| 3 | 12-07-2018 | Cattle Egret | 1 | Old | Hanging on middle conductor, Neck broken | 0 | 132 |
| 4 | 30-07-2018 | Common Pigeon | 2 | Fresh | Injuries in neck and belly | 10 | 132 |
| 5 | 01-08-2018 | Lesser Flamingo | 1 | Old | Hanging on conductor | 0 | 66 |
| 6 | 07-08-2018 | Eurasian Spoonbill | 1 | Old | Legs Broken | 13 | 220 |
| 7 | 07-08-2018 | Lesser Flamingo | 1 | Old | Wings and neck broken | 20 | 220 |
| 8 | 07-08-2018 | Grey Heron | 1 | Fresh | Hanging on earthed wire | 0 | 400 |
| 9 | 26-10-2018 | Common crane | 1 | Fresh | Wings and neck broken | 15 | 66 |
| 10 | 30-10-2018 | Great White Pelican | 2 | Fresh | Injuries in wing and neck | 10 | 11 |
| 11 | 07-12-2018 | Greater Flamingo | 1 | Fresh | Injuries in wing and neck | 0 | 11 |
| 12 | 30-10-2019 | Dalmatian Pelican | 1 | Fresh | Leg broken; feathers observed sticking to the power-line | 0 | 11 |
| 13 | 30-10-2019 | Painted Stork | 1 | Old | Wings broken | 0 | 11 |
| 14 | 02-12-2019 | Demoiselle Crane | 1 | Fresh | Wings broken | 15 | 66 |

| S. No | Date | Species | No. of carcass | Condition of carcass | Sign of collision | Distance from power line (m) | Line Capacity (kV) |
|---|---|---|---|---|---|---|---|
| 15 | 10-12-2019 | Dalmatian Pelican | 1 | Old | Neck broken | 10 | 11 |
| 16 | 10-12-2019 | Dalmatian Pelican | 1 | Old, scavenged | Wings and neck broken | 2 | 11 |
| 17 | 10-12-2019 | Greater Flamingo | 1 | Old, scavenged | Neck, legs broken | 2 | 11 |
| 18 | 10-12-2019 | Great Cormorant | 1 | Old, scavenged | Wings and neck broken | 3 | 11 |

*The exact cause of the bird mortalities for most cases recorded during this study has not been verified through any forensic or autopsy study. Further, none of these lines were equipped with Line Marking Devices.




Mortalities of large avian species due to power-line collision recorded in Kachchh during the study period. A. Dalmatian Pelican, B. Demoiselle Crane and C. Greater Flamingo

*Wetlands and Transmission line network*

A total of 1274 inland wetlands were mapped in the Kachchh district of which, 557 wetlands are small, 657 are medium, and 60 are large. Rapar taluk has the highest number of wetlands (n=240) and Gandhidham taluk has the lowest number of wetlands (n=17). It was found that transmission lines cut across 58 wetlands, while in 40 wetlands power-lines pass within 100 m buffer. Abdasa and Bhachau taluk has the maximum number (n=10 each) of wetlands crisscrossed by transmission lines, followed by Rapar and Anjar (n=7 each). 125 segments of 78 different transmission lines pass through and around 98 wetlands. Out of these 78 lines, 49 are of 66 kV capacity, 17 of 220 kV, nine of 400 kV, and one each of 500 kV and 765 kV (Table 6). On further analysis, it was found that the total length of segments of 66 kV lines cutting across wetlands is maximum (40 km), which forms 2% of the entire length of 66 kV lines in Kachchh (Table 7). Survey data reveals that 6 out of 98 wetlands cut across by power-lines are being used by the flamingos and cranes.

**Table 6.** The table showing details of small, medium, and large-sized wetlands in different taluks and extent of power-lines passing through and around these wetlands.

| S. No. | Taluk | No. of Small wetlands | No. of Medium wetlands | No. of Large wetlands | No. of Total wetlands | Power-line cutting across the wetland | Power-line passing within 100 m buffer |
|---|---|---|---|---|---|---|---|
| 1 | Abdasa | 109 | 94 | 13 | 216 | 10 | 8 |
| 2 | Anjar | 25 | 36 | 2 | 63 | 7 | 4 |
| 3 | Bhachau | 47 | 75 | 2 | 124 | 10 | 11 |
| 4 | Bhuj | 49 | 70 | 10 | 129 | 2 | 2 |
| 5 | Gandhidham | 8 | 7 | 2 | 17 | 3 | 1 |
| 6 | Lakhpat | 80 | 137 | 12 | 229 | 2 | 2 |
| 7 | Mandvi | 76 | 66 | 3 | 145 | 8 | 4 |
| 8 | Mundra | 19 | 14 | 0 | 33 | 5 | 2 |
| 9 | Nakhatrana | 36 | 38 | 4 | 78 | 4 | 3 |
| 10 | Rapar | 108 | 120 | 12 | 240 | 7 | 3 |
| | **Total** | **557** | **657** | **60** | **1274** | **58** | **40** |

**Table 7.** The table showing lengths of different capacity transmission lines passing through inland wetlands.

| S. No | Capacity (kV) | Length of Segment crossing wetlands (km) | % Length over Wetlands |
|---|---|---|---|
| 1 | 66 | 40 | 2 |
| 2 | 132 | 1 | 8 |
| 3 | 220 | 25 | 2 |
| 4 | 400 | 12 | 1 |
| 5 | 500 | 2 | 1 |
| 6 | 765 | 1 | 0.4 |
| | **Total** | **81** | **2** |

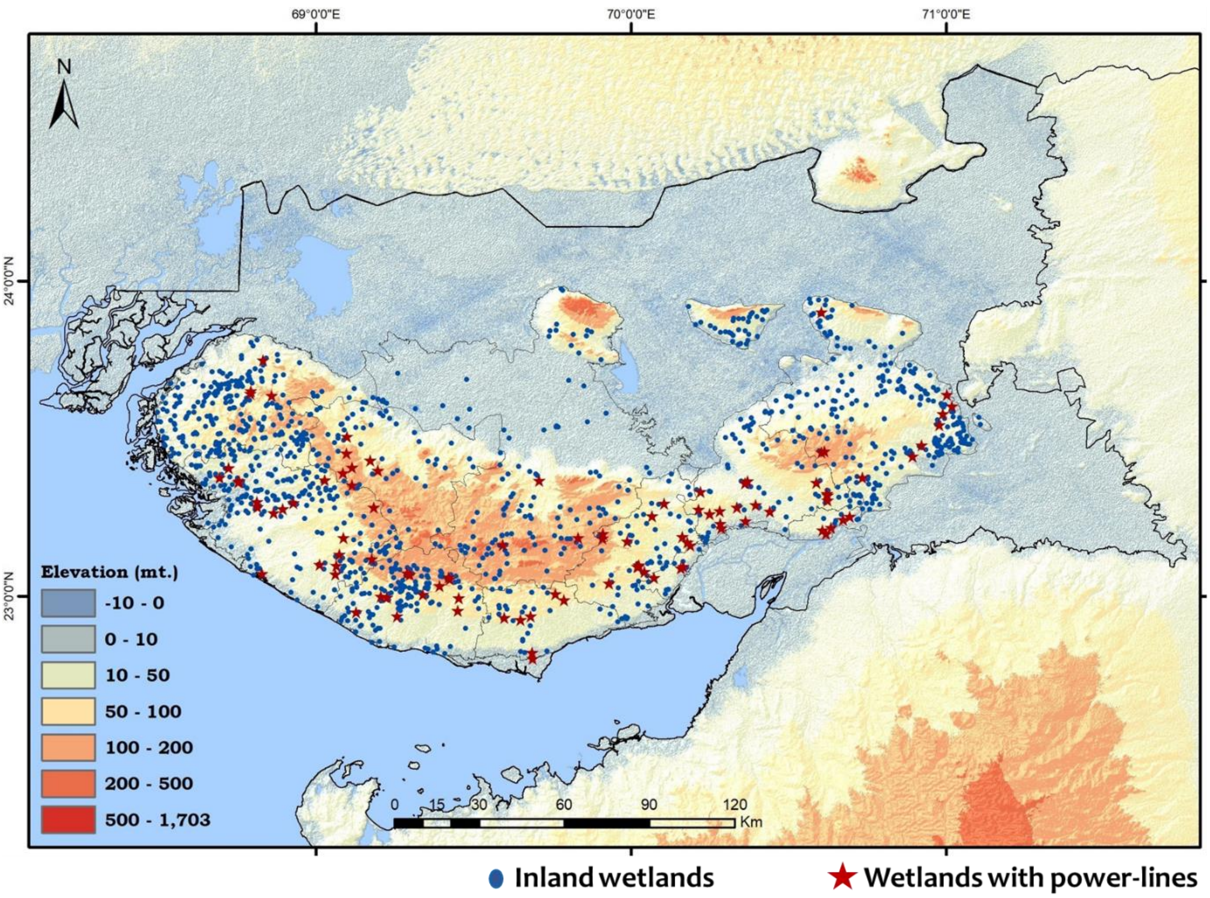



**Figure 18.** Map showing inland wetlands with the power-lines passing through or within 100 m buffer of wetland.

Apart from inland wetlands, power-lines also cut across a complex of saltpans, mudflats, and coastal areas. A total of 29 segments which comprises eight lines of 66 kV and six lines each of 200 and 400 kV, forming a total length of 162 km passes through saltpans, mudflats and coasts. Most of these areas are located near Gandhidham and Surajbari creek and have a network of low and high-capacity transmission lines respectively.

***Critical Wetlands for Flamingos based on tracking data***

During the tracking period, all tracked visited 38 inland wetlands and spent a considerable amount of time (more than a week) in 15 wetlands. On further analysis, it was found that a 66 kV transmission lines cut across two wetlands, Ratnal and Mithi-Rohar, which are located in Anjar and Gandhidham taluk, respectively (Figure 19). Wetland in Ratnal was used by two Lesser Flamingo (Anjar, Ratnal) and one Greater Flamingo (Paddhar), whereas Mithi-Rohar was used by Lesser Flamingo (Anjar, Ratnal and Mithi) only. These two wetlands were also found to support a large number of flamingos and other large birds during the systemic grid surveys hence are the critical habitats where the power-line may pose a high collision risk.

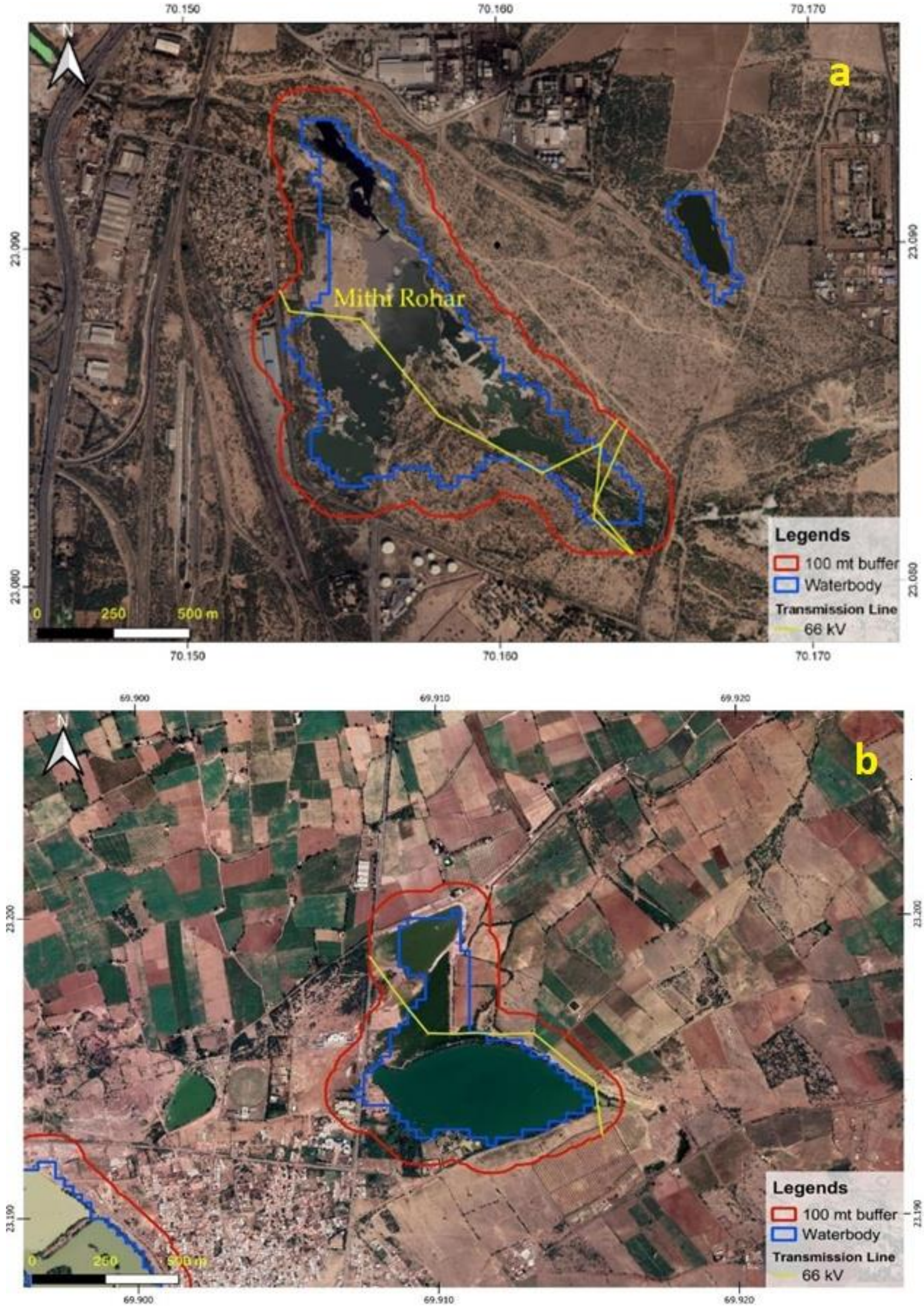



**Figure 19.** Map showing power-lines cutting across two wetlands extensively used by tagged Flamingos (a- Mithi-Rohar, b- Ratnal)

*Outcomes of tracking effort during the year 2022*

**Greater Flamingo**

***Flight behaviour of Flamingos***

During the tracking period, Thol made 38 flights (Figure. 20) and had almost an equal number of long and medium-range flights; on the other hand, Hanj made 11 flights, of which seven were medium-range. If we see the time of flights, both individuals made a greater number of flights during the day (Figure 21).

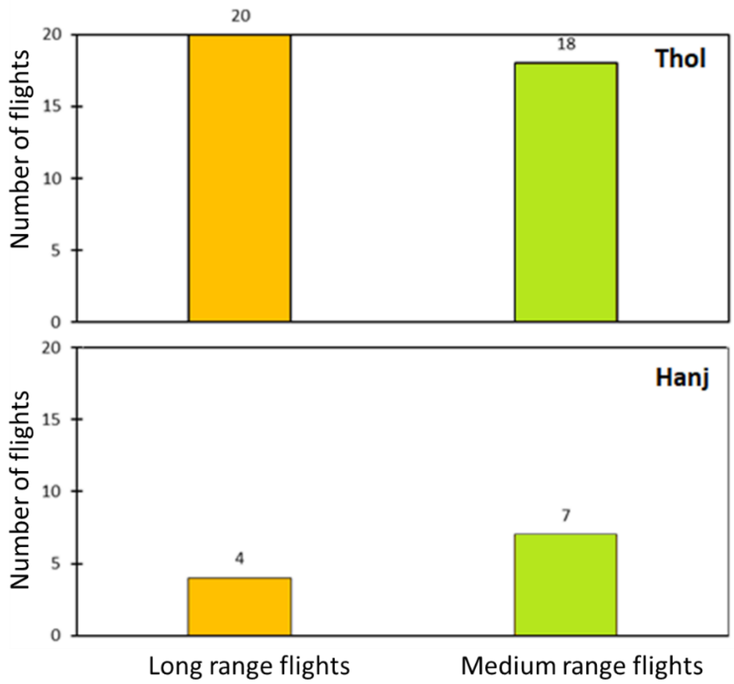



**Figure 20.** Bar Graph showing variability in flight number during breeding and the non-breeding season.

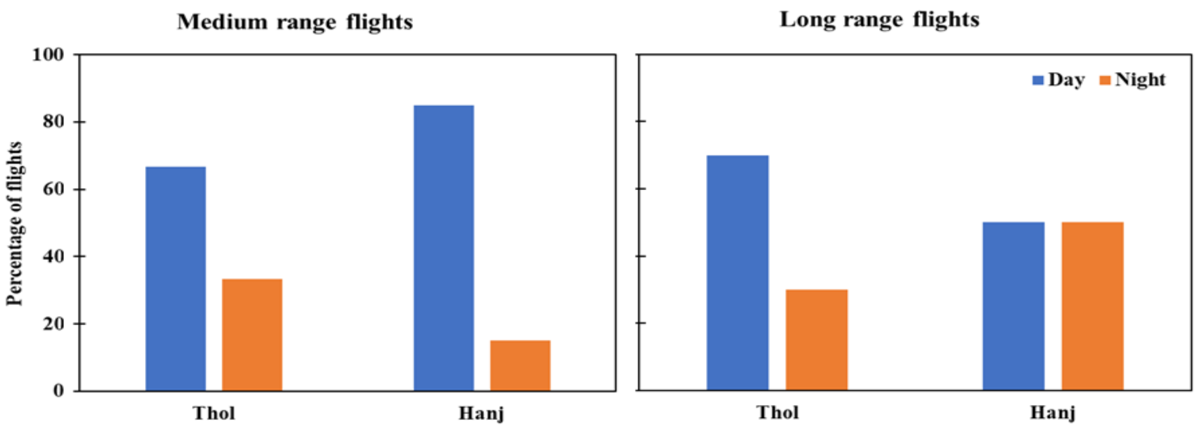



**Figure 21.** Bar graph showing that both the individuals of tagged Greater flamingo made more flights during day time.

***Flights and transmission line network***

The transmitters high-resolution (10min interval) data was used to identify the segments of the transmission lines crossed by tagged flamingos. It was found that flamingos made a total of 46 crossings. Most of these crossings were made during the long flights of daytime (Figure 22) when flamingos moved from non-breeding to the breeding area. During these crossings, 66 kV transmission lines were crossed the maximum times (n=21), followed by 400 kV lines (Figure 23).

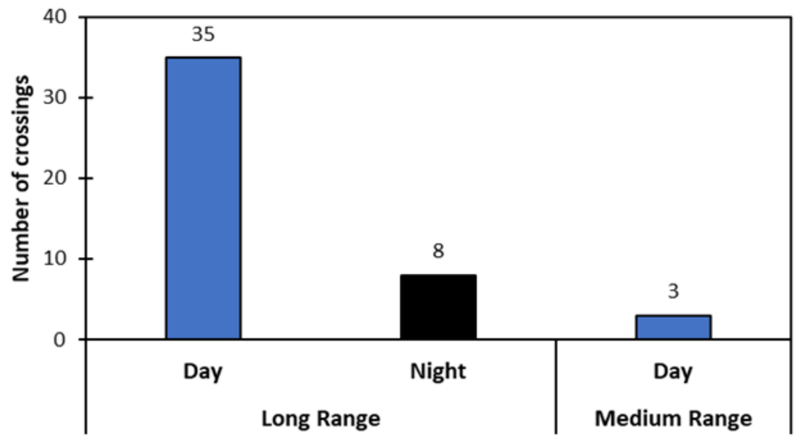



**Figure 22**. Most of the transmission line crossing were made during long-range flights

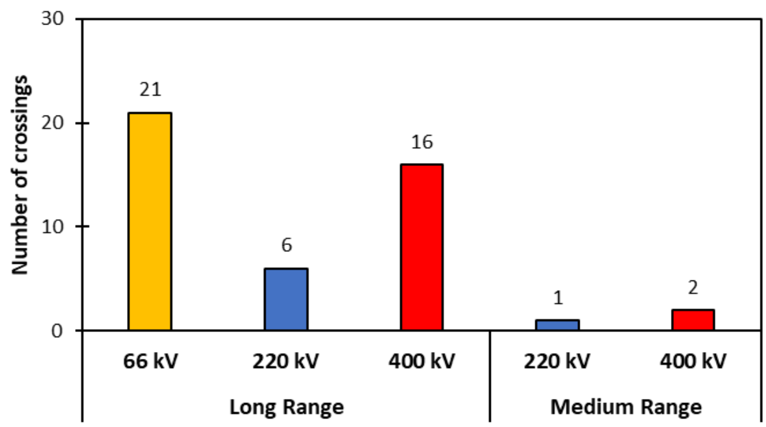



**Figure 23**. Graph showing number of different capacity transmission line crossing by tagged Greater flamingos during long and medium range flights.

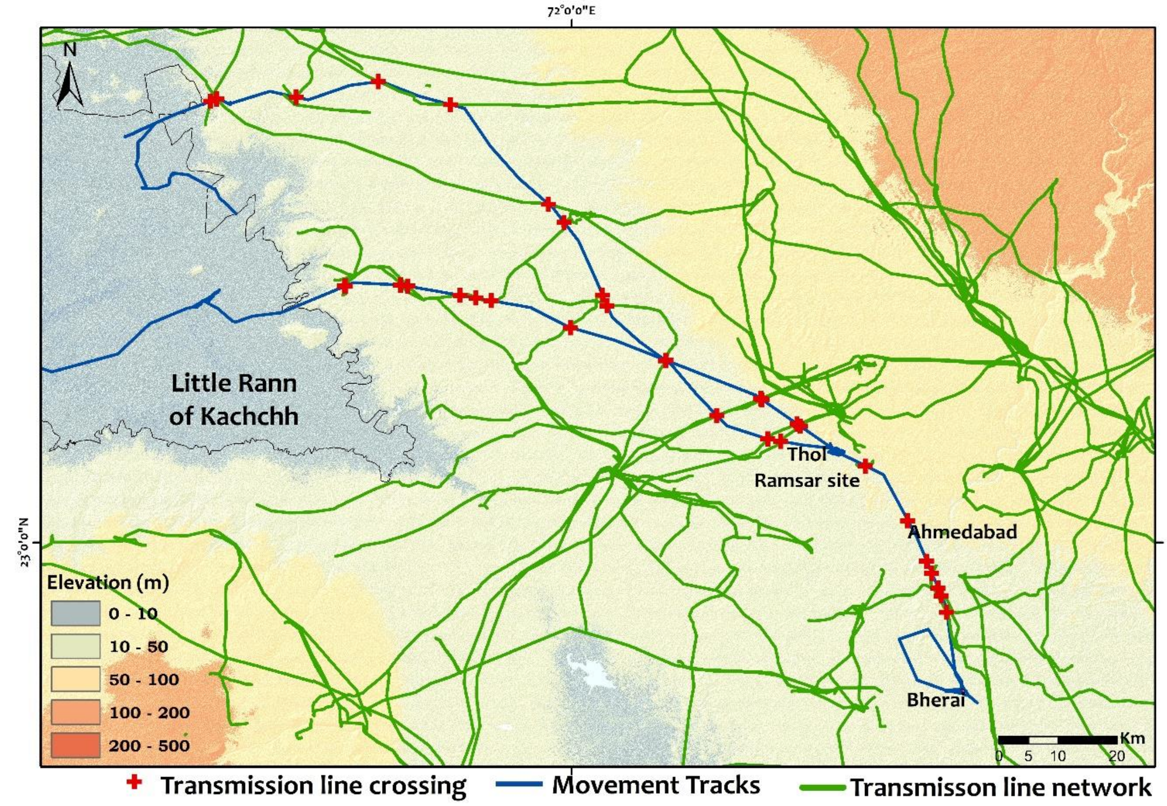



**Figure 24.** Map showing the segments of transmission lines crossed by tagged flamingos.

***Common Crane***

***Daily movements of the tagged Common cranes***

The tagged Common Cranes showed regular movements between roosting wetlands and foraging fields. The cranes departed for the foraging fields in the morning between 0600 to 0700 hrs and returned to the roosting wetland either during the mid-day or in the evening after 1800 hrs. For the round trip from roosting wetland to foraging field, the highest mean daily distance travelled was by Nal (mean = 27.25 km, SD ± 21.72, range = 4.48 – 156.97 km) followed by Gani (mean = 26.93 km, SD ± 24.93, range = 6.99 – 141.32 km) while the lowest mean daily distance travelled was by Sanand (mean = 19.76 km, SD ± 24.80, range = 6.04 – 275.96 km). Bhal and Vadla travelled mean daily distance of 25.65 km (SD ± 19.08, range = 6.04 – 275.96 km) and 20.31 km (SD ± 6.21, range = 6.04 – 275.96 km) respectively (Figure 25).

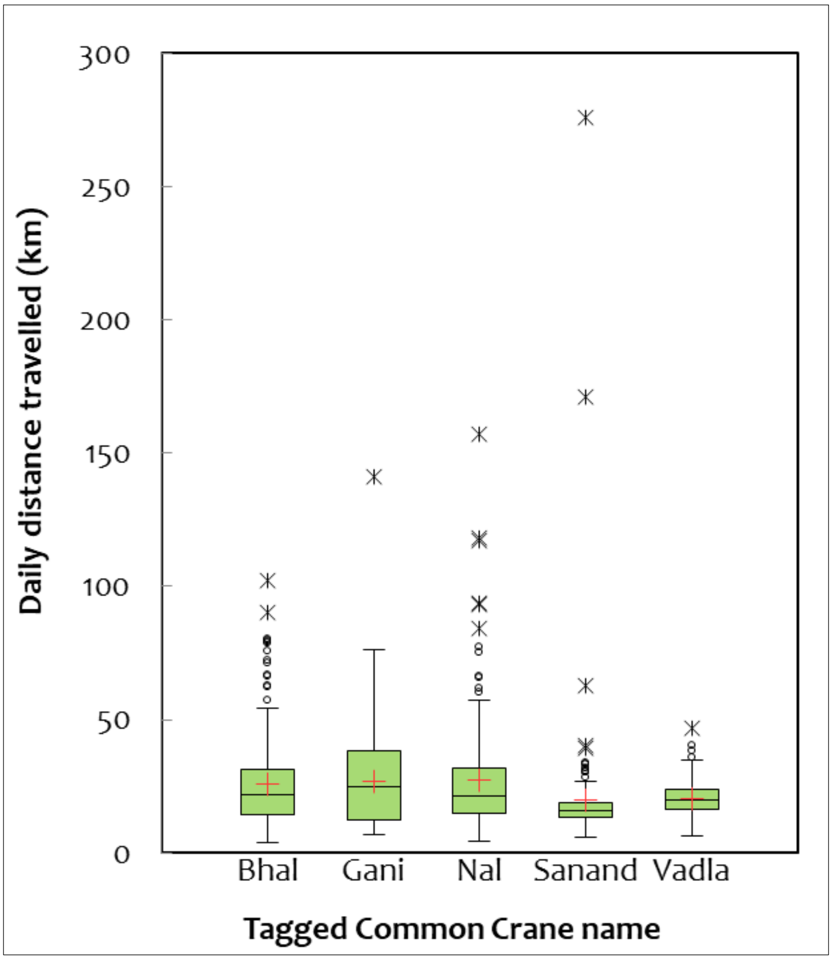



**Figure 25.** A box plot showing the daily distance travelled by five tagged Common cranes during their stay in wintering grounds in Gujarat

*Transmission lines crossed by tagged Common cranes*

The intersection analysis revealed the locations from where the tagged cranes crossed transmission lines in the region. A total of 667 transmission line crossings were recorded on all six different capacity transmission lines. The crossings were primarily recorded near Nal Sarovar Bird Sanctuary, Thol Wildlife Sanctuary and near Viramgam town adjoining to Little Rann of Kachchh (Figure 26). No crossings were recorded when the cranes were inside the Little Rann of Kachchh.

Of the six different capacity transmission lines, 66 kV line was crossed for the maximum times (n = 321) followed by 400 kV lines (n = 195) and 220 kV lines (n = 148). The 132 kV, 500 kV and 765 kV lines were crossed only one time (Figure 27). The transmission line crossings were happened only during the day time as birds are usually don't make flight in the night.

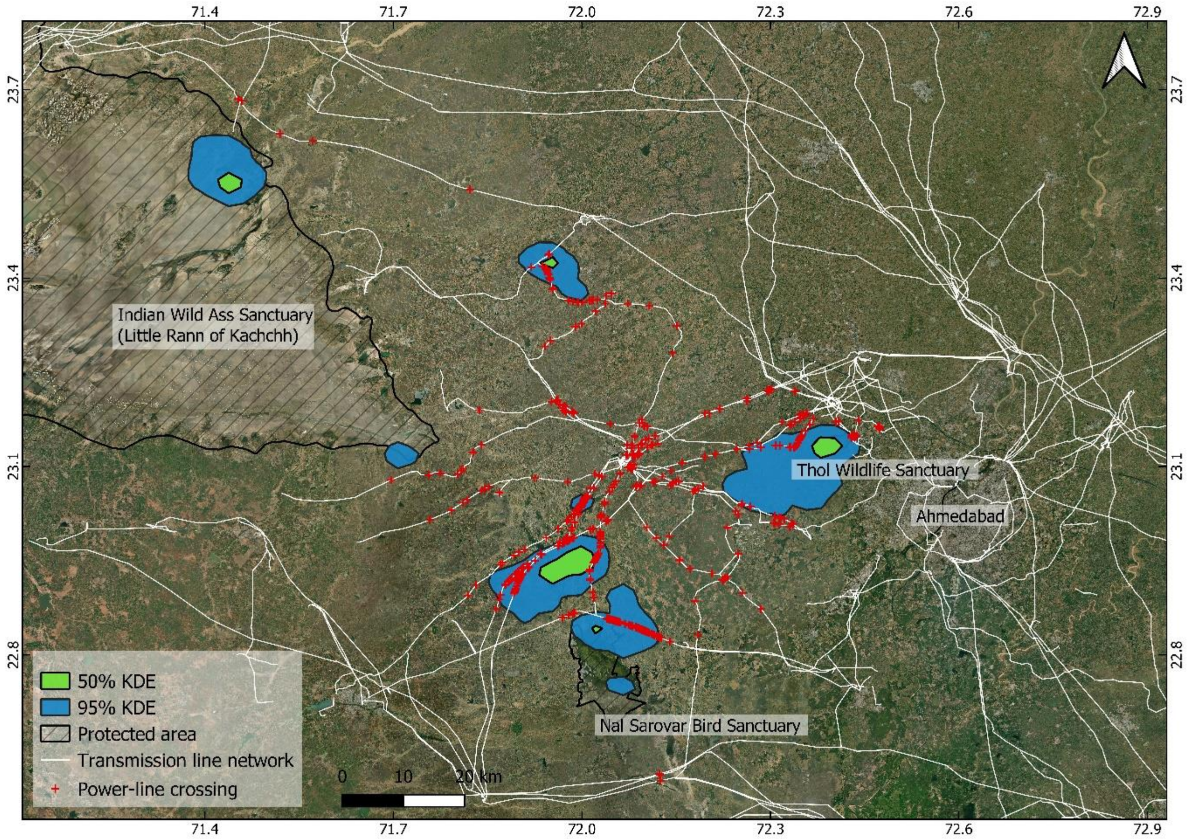



**Figure 26.** Map showing cumulative home range of all five tagged common cranes and the locations from where the cranes crossed the transmission lines

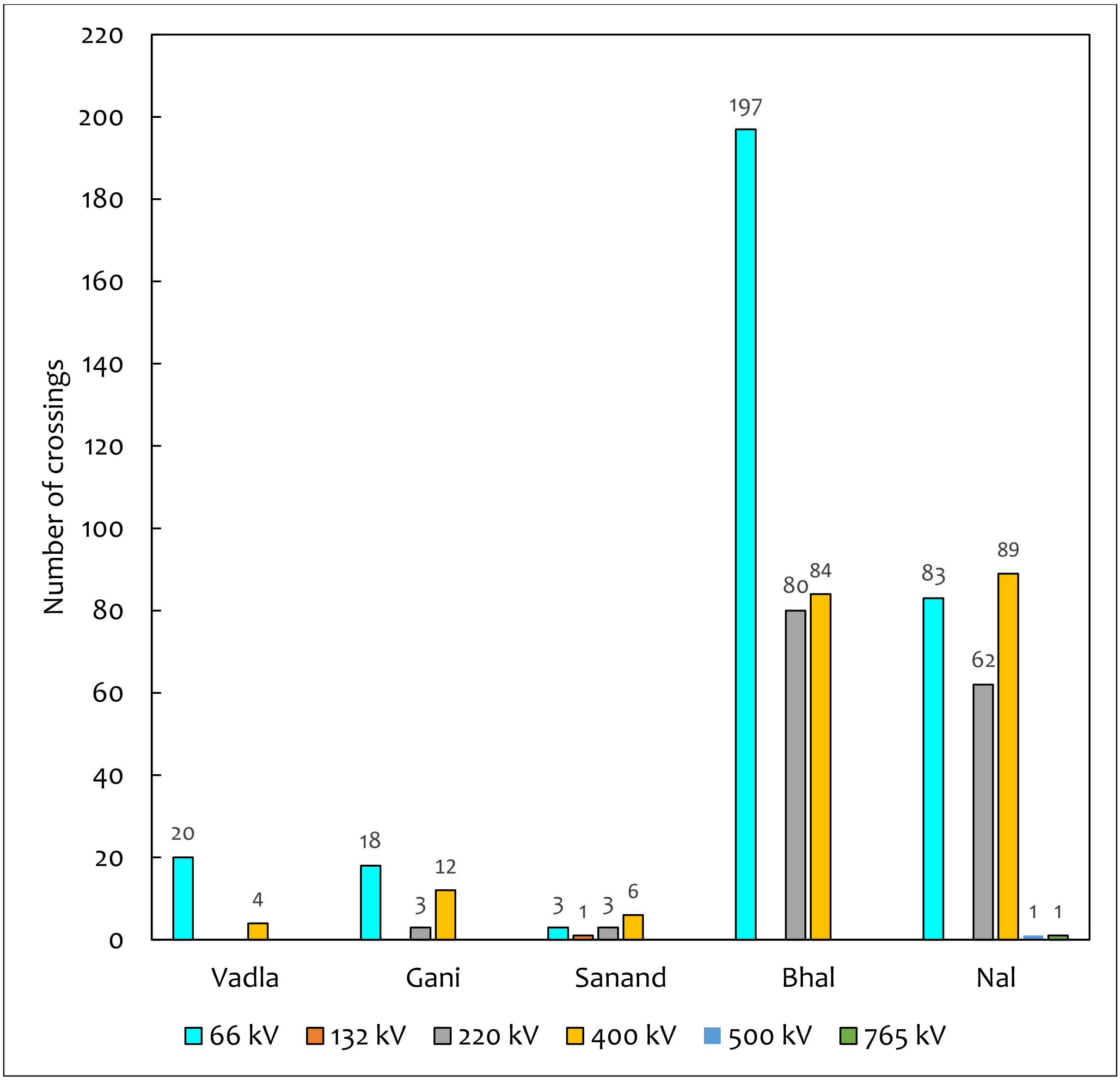



**Figure 27.** A graph comparing different capacity transmission lines by five tagged Common cranes

# Discussion

This study assessed collision risk posed to large birds like flamingos and migratory cranes by transmission lines. A total of 5482 km transmission lines of different carrying capacity were mapped across the Kachchh district. Around 60% of the transmission lines are concentrated in Anjar, Bhachau, Mundra and Gandhidham taluka. These four talukas happen to be highly industrialized, with the introduction of the Special Economic Zone Act-2004, 12 Special Economic Zones have been established in this area. Additionally, three industrial parks have also been established in Mundra, Gandhidham and Samakhiyali (IC 2007). Industries require a lot of energy, and to fulfil this energy demand network of transmission lines has increased in Kachchh (GETCO 2017) and has resulted in a high transmission line network in the eastern Kachchh. Additionally, the Mundra port facilitates the 4000 MW Tata Mundra Ultra Mega Power Plant, which is the biggest thermal power plant in India (nsenergybusiness.com) and provide electricity to five states.

The transmission lines mapping revealed that power transmission in Kachchh is through two major corridors located at Surajbari Creek and Nanda Bet. These areas provide narrow land connectivity to mainland Kachchh, and this area is surrounded by the two largest protected areas of India (Greater and Little Rann). The Rann has an extremely saline environment and is covered with water for around five months, making construction and maintenance activity uneconomical hence all transmission lines have to pass these corridors.

The tagged lesser flamingos extensively used the eastern parts of the Kachchh and were found to move from the Gulf of Kachchh to Little Rann and then to the Greater Rann following the watercourse during the breeding season. And, lesser flamingos also made regular flights between the breeding sites at Greater Rann and foraging sites in the Little Rann of Kachchh.  Which resulted in crossing of the transmission line corridors of Surajbari and Nanda Bet multiple times by tagged lesser flamingos. Two Greater Flamingo tracked in 2022 also crossed the transmission line corridor of Nanda Bet. However, due to battery malfunctioning, the exact time of and location of these crossings could not be determined.

The flamingos are crossing power-lines corridors during the night, making them more susceptible to transmission collisions. Many studies have reported high collision rates in nocturnal birds (Crowder 2000; Pandey et al. 2008) as power-lines are less visible at night. Further, these transmission corridors cut across the high suitable habitats of both flamingo species and studies have found that powerline passing through high-use areas pose a risk of collision (APLIC 2012).  The transmission lines in power-line corridors are of high capacity having three strata, which further add to the risks posed by these lines as powerline with more than one strata pose a higher risk of collision (Prinsen et al. 2011). The mortality surveys in the Surajbari Creek didn't provide sufficient evidence on the threat posed by transmission lines, as only few collision mortalities were recorded. The low detection of mortalities may be attributed to the fact that flamingos make nocturnal flights and the area surrounding transmission lines is submerged into water, so any collision mortality at night may remain undetected as, by morning carcasses of dead birds would be carried away by the creek's water.

The transmission lines falling in the flamingos fight path are required to be mitigated to avoid any future collision mortalities. Bird diverters and polycarbonate flappers are quite effective in preventing collisions (Anderson 2002); a spiral device with fluorescent light has been used to reduce flamingo collisions in South Africa (Eskom 2003; Eskom Transmission 2009). Considering the nocturnal flight behaviour of flamingo installation of illuminated bird diverters with flashing LEDs are recommended. Further Avian Collision Avoidance

System (ACAS) which illuminates a power-line have the potential to reduce the collision risk at night (Dwyer 2019) however efficacy of such techniques is required to be tested before large-scale implementation.

Few wetlands in this region are found to support a population of many birds and occur outside any protected area. The wetlands like Ratnal and Mithi-Rohar located in Anjar and Gandhidham taluk are important pre-breeding congregation sites, and up to 20000 flamingos forage in these wetlands. It is observed that few power-line mortalities happen here; hence transmission line crisscrossing these wetlands may be rerouted. Additionally, any future transmission lines are recommended to be placed at least 100 m away from wetlands as it is a zone where most collisions with power-line are reported (APLIP 2012).

The migratory cranes use much larger landscape and occur in three major hotspots. The threat posed by transmission lines to cranes is not specified to a particular area as cranes are distributed across Kachchh. Tracking data clearly showed the high use of agricultural fields which are situated in non-protected areas where the power-line network is extensive. Studies suggest that Common cranes are one of the 13 crane species impacted by powerline collision out of 15 (Dwyer et al. 2019). In this study it was observed that location of powerline influences the collision risk of common cranes differently. The transmission line near the foraging and roosting poses a risk as in these areas crane fly at much lower height and had to gain height while approaching such powerlines. In Kachchh cranes used the agricultural fields extensively, and 40% of the transmission lines passes thorough the areas which are most suitable for cranes. Power lines crossing agricultural

fields with seasonally attractive crops or residue can contribute to collision risks (APLIP 2012) therefore all such powerlines may be mitigated to increase the visibility and reduce collision risks.

This study has assessed the collision risk across the Kachchh landscape using telemetry data and field observations. Across the landscape, two power-line corridors have been identified which may pose a potential collision risk to Flamingo and associated large water birds. Additionally, several wetlands have been identified through which, the transmission lines are cutting across, making them risky for flamingos, cranes and other large birds inhabiting these wetlands. Based on the information provided in this study, a detailed guideline to avoid and mitigate the possible impacts of powerlines have been prepared and provided at the end of the report (Page no. 141)


**Citation:**

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# *The risk of Electrocution to Avian Species in the Arid Landscape of Kachchh*

Harindra Baraiya

Anju Baroth

R. Suresh Kumar

Mortalities due to electrocution have been identified as one of the serious threats for avian species worldwide which is the consequence of birds' biology, ecology and power-line structures (Bevanger 1998, Janss 2000). The electrocution risk is primarily associated with distribution lines and affects large birds as they use the line poles for perching and often come in simultaneous contact. This results in the birds coming in contact with a) two energised wires b) energised wire and cross arm or c) energised wire and earthed wire while perching on pole, thus completing the electric circuit resulting in sudden death due to shock (APLIC 2006). The mortalities due to electrocution have been recorded in a variety of avian species that uses low voltage power-line poles as resting or nesting surface (APLIC 2006, Tobolka 2014). The risk of electrocution is particularly a serious threat to raptor species inhabiting in open habitats like grasslands where the absence of trees encourages raptors to use distribution line poles as vantage points, resting, roosting and nesting sites (Infante and Peris 2003, Sánchez-Zapata et al. 2003, Karyakin et al. 2005, Lehman et al. 2007).

Mortalities in raptors due to electrocution has been reported worldwide and many studies have shown impacts on certain raptor species in Europe (López-López et al. 2011, Guil et al. 2015), America (Harness and Wilson 2001, Lehman et al. 2010), Africa (Kruger et al. 2004; Boshoff et al. 2011, Angelov et al. 2013), Asia (Goroshko 2011, Harness et al. 2013) and Oceania (Fox and Wynn 2010). It is reported to be the prime cause of population decline in many raptors such as Bonelli's Eagle in Spain and France (Real and Manosa 1997, Real et al. 2001) and in the Eurasian Eagle Owl in France (Bayle 1999) and Italy (Rubolini et al. 2001).

The population decline of Egyptian Vulture in East Africa has also been attributed to the electrocution of the species in a high number (Nikolause 1984, 2006).

Factors that are influencing the risk of electrocution mortalities to birds are as follows:

1) Habitat and topography around the distribution lines also influence the rate of electrocution. For example, Golden Eagle in shrub-steppe regions of the Intermountain West, US are at higher risk as the natural perches in the region are not available thus compelling the species to perch on distribution lines. In contrast, Bald Eagle is adapted to forested habitats where natural perches are abundantly available, thus making the species safer compared to Golden Eagle (Lehman et al. 2007). Another study suggests that raptors mostly perch on the poles that are comparatively at a higher elevation than others, thereby, ending up posing a higher risk of electrocution to Raptors at those points (Boeker and Nickerson 1975, Nelson and Nelson 1976, Benson 1981).

2) Structural design and materials used on the electric poles are one of the prime reasons that influence the level of mortality due to electrocution in raptors. Electrocution is more common on distribution lines since the separation of conducting structures is much closer than on transmission lines (APLIC 2006). In countries like USA, distribution lines are made up of wood, thereby reducing the risk of electrocution of small birds and posing risk primarily to large raptors like eagles and vultures. However, poles with transformers are hazardous even for medium and small-sized raptors in this region, as the number of conducting structures is relatively more (Harness and Wilson 2001, APLIC 2006). In Europe and Mongolia, nearly all the distribution lines are supported by steel or reinforced concrete, making raptors of all sizes more susceptible to electrocution (Janss and Ferrer 1999, Janss 2000, Dixon et al. 2020).

3) Size of the species, gender, sex ratio and life stage are the other crucial factors influencing the electrocution risk to raptors (Lehman et al. 2007). In a study on Spanish Imperial Eagle, 78% of electrocution mortality was recorded in females due to their larger wing length as compared to the males (Ferrer and Hiraldo 1992). Studies on

Golden Eagle in North America indicated that immature individuals are electrocuted more frequently as they are less experienced in landing and taking off, thus more susceptible to the electrocution risk (Lehman et al. 2007). A study on Saker Falcon in Mongolia revealed a higher number of female electrocutions in the juvenile population and a higher number of male mortalities in the adult population which was due to female-biased sex ratio in juveniles and male-biased sex ratio in adults (Dixon et al. 2020).

The arid landscape of western India is an important habitat for migratory raptors (Islam and Rahmani, 2004) as it resembles the steppe habitat of northern latitudes where these raptors breed. Given the habitat suitability, several globally threatened raptor species are resident to this region as well as use this as wintering ground, including four eagle species and six vulture species. However, a large number of raptors winter in this landscape, electrocution mortality assessment studies are scarce. One such study has been carried out in Thar Desert, Rajasthan, by Harness et al. (2013), which revealed a high number of mortalities of raptors and many other medium-sized birds.

One of the important raptor habitats in western India is the Kachchh landscape, where notable raptor diversity is observed. Having the mosaic of unique Rann habitat, grasslands and agricultural fields and different types of wetland habitats, the arid plains of Kachchh is home to as many as 39 raptor species (eBird 2021). However, no scientific studies are available focusing on the electrocution risk to raptors in this landscape. In this study, we assess the electrocution risk with respect to raptor diversity and abundance. For this purpose, we identified three sites across the arid plains of Kachchh to systematically record raptor distribution and abundance. In addition, structural design of the distribution line poles was also done to assess the electrocution risk

## Study Area

A primary survey was conducted to select the study sites (Figure 1) based on the distribution of raptors across the Kachchh district. These sites were selected from the following three taluk

1. Bhachau
2. Banni and
3. Naliya

The network of distribution lines in these areas is installed and operated by Paschim Gujarat Vij Company Limited (PGVCL). Bhachau is located at the eastern part of Kachchh, sharing borders with the Little Rann of Kachchh and the Indian Wild Ass Sanctuary. The region is characterized by flat terrain where the agricultural fields cover most of the area. However, the region has witnessed a spurt in industrial development over the last few decades, making it more populous and thus requiring an increase in distribution line network. Due to proximity to the Little Rann of Kachchh, this region becomes a critical habitat for migratory Raptor species during the winter season.

Banni, the vast mosaic of grassland and marshes, is located in the southern reaches of Great Rann of Kachchh and north of Bhuj city. The landscape is a flat terrain, devoid of tall trees spread across 2600 sq.km of an area having fewer villages than Bhachau and Naliya.

Dabadghao and Shankarnarayan (1973) have classified Banni grasslands as Dichanthium-Cenchrus-Lasiurus type where the predominant vegetation is grasses and herbs with few species of sedge (GUIDE and GSFD 2010). The wetland-grassland mosaic of the landscape resembles the steppe grasslands of northern Eurasia, making it an ideal habitat for migratory raptors during the winter season. The absence of tall trees in this landscape makes distribution line poles a potential perch site for the raptors, making them vulnerable to electrocution risk.

Naliya, the only stronghold for the Great Indian Bustard in Gujarat, is located in Abadasa taluk, which is in the south-western part of Kachchh district. The principal habitat types of the area include grasslands and agricultural fields with numerous perennial and temporary water bodies. The west-most part of the area has saltpans and mudflats along the Gulf of Kachchh shoreline. The famous Great Indian Bustard Sanctuary is near Naliya town, making it the legally protected home for migratory raptors. At the same time, a high number of villages in the landscape requires an intensive network of distribution lines, thus increasing the risk of electrocution for the raptors.

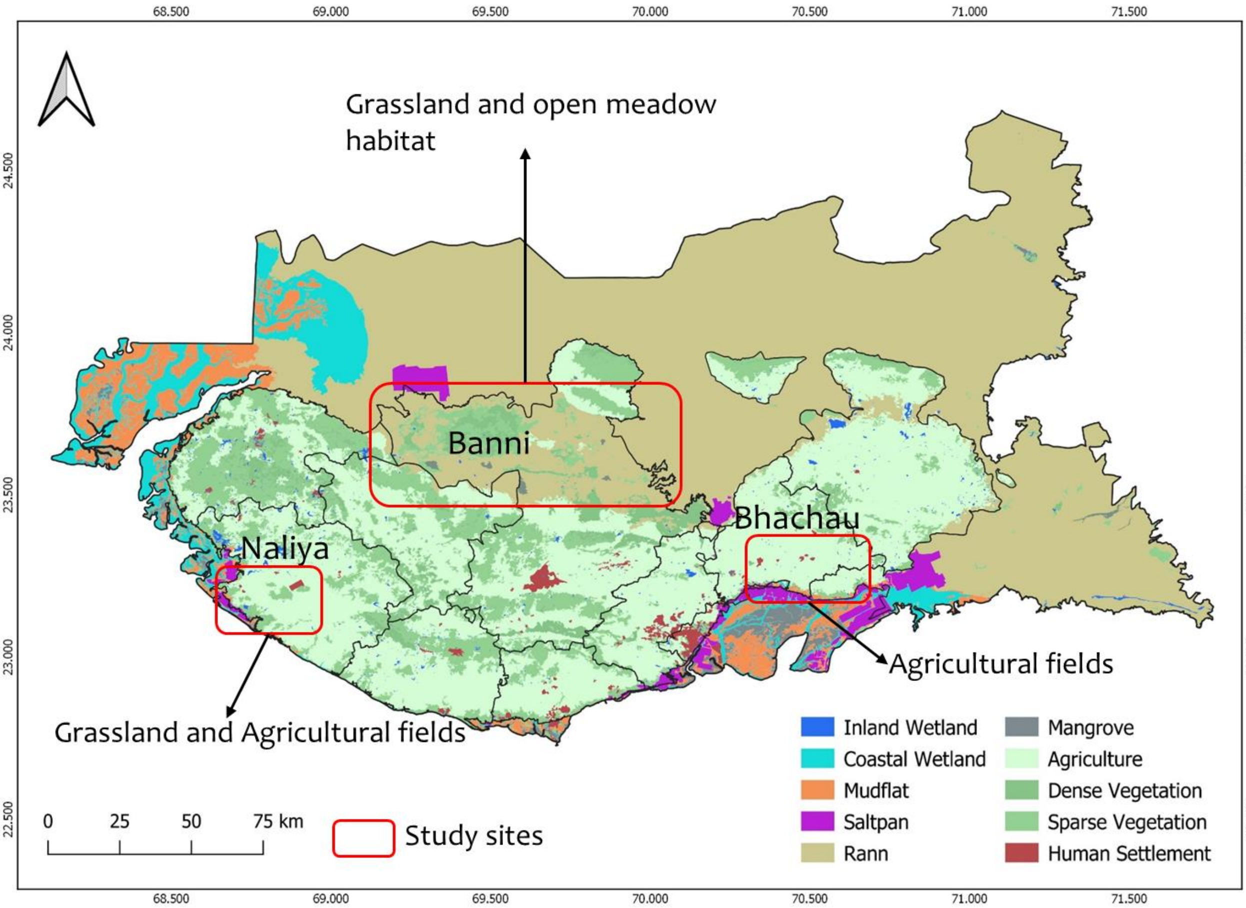


**Figure 1.** A map showing the Kachchh district and three select sites where surveys were carried out to record the raptor distribution.


Agricultural fields of Bhachau


Open meadows of Banni


Grasslands of Naliya

## Methods

The distribution line network in all the three study sites was mapped using Google Earth and its characterisation was done during the field surveys. Distribution lines in these areas run parallel to the existing roads, making the vehicular road survey method suitable for recording the electrocution mortality along with the diversity and abundance of Raptor species. The systematic surveys were conducted during winters of 2018-19 and 2019-20 when the migratory raptors are present in the landscape. The surveys were carried out by two researchers riding on a motorbike on existing roads, observing the areas around the distribution line to record mortalities. Simultaneously, the presence of Raptor species around the surveyed lines was also recorded. Data on time, GPS location, species, numbers, habitat type, and perching surface were recorded upon sighting a Raptor.

The Raptor data was summarised according to the species group and size. The Raptors were categorised in three classes according to their body size: small (up to 45 cm), medium (46 to 60 cm) and large (more than 60 cm) using Grimmett et al. 2011. Further, the encounter rate per km was used to compare the relative presence of Raptors across sites. Electrocution risk to the raptors was assessed by comparing the distribution line's configuration with the raptor species utilizing that area.

# Results

***Distribution Line Mapping and Characterization:***

34 distribution line stretches were surveyed across three study sites, totalling 363 km in length, with maximum number of distribution lines (n=14) being surveyed in Naliya and lowest in Banni (n=7). The longest surveyed distribution line network was in Naliya (160 km), followed by Banni (130 km) and Bhachau was the shortest (73 km) surveyed network of distribution lines (Table 1). Similarly, the shortest surveyed line stretch was 1.5 km in length while the longest was 30 km in length, both located in the Naliya region.

On characterizing the distribution lines configurations, the average cross arm length was found to be 100 cm while the vertical distance between the top conductor and cross arm was 60 cm and oblique distance between the top conductor and lower conductor was 80 cm (Table 2 and Figure 3). The cross arms of these lines were primarily in two shapes: straight cross arms made of iron and U-shaped cross arms made of iron and composite plastic. Insulators on these lines were found to be made of either porcelain or fiberglass covered with polymer sheds.


**Figure 2.** Different types of cross-arms and insulators recorded in the distribution lines in the Kachchh district.

**Table 1.** Details of surveyed distribution lines in three study sites

| Study site | No. of lines | No. of Poles | Total length (km) | Shortest line stretch (km) | Longest line stretch (km) |
|---|---|---|---|---|---|
| Bhachau | 13 | 1250 | 73 | 2 | 14 |
| Banni | 7 | 2175 | 130 | 4 | 26 |
| Naliya | 14 | 2470 | 160 | 1.5 | 30 |
| **Total** | **34** | **5895** | **363** | | |

**Table 2.** Comparison of configuration of distribution lines in Kachchh with suggested sufficient separation line as per APLIC guidelines (APLIC 2006)

| **Attribute** | **Sufficient separation (cm)** | **Separation in distribution lines in Kachchh (cm)** |
|---|---|---|
| Cross arm length | 240 | 100 |
| Cross arm to top phase wire | 140 | 65 |
| Diagonal Distance between lower and top phase wire | 150 | 80 |
| Distance between phase wire and cross-arm (pin insulator length) | 61 | 35 |

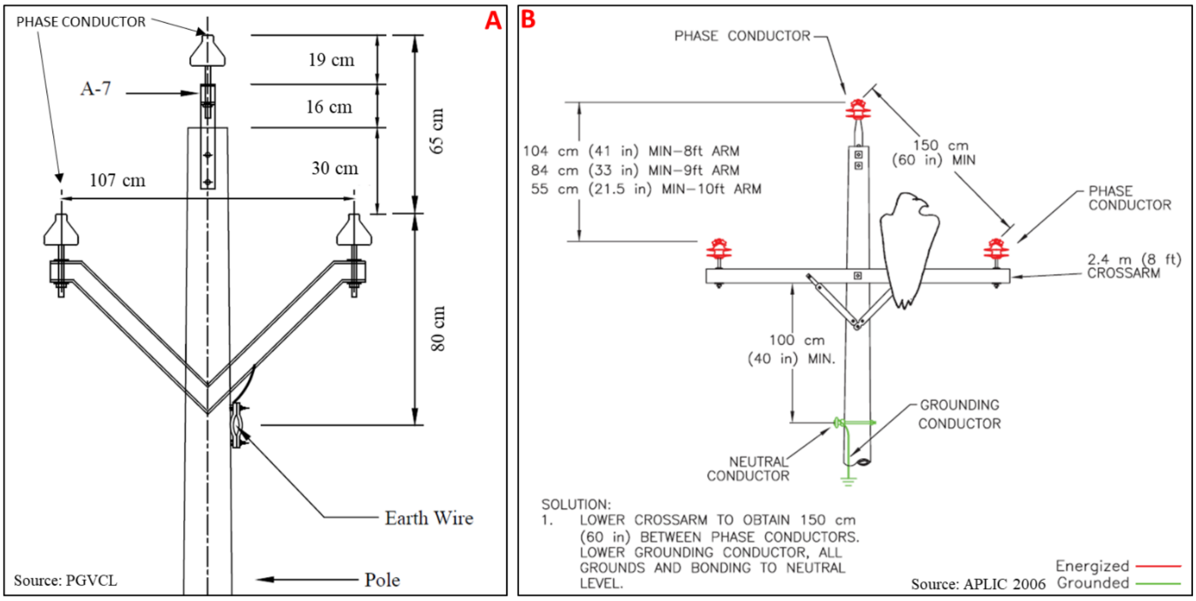


**Figure 3** The comparison between the conducting parts separations of the distribution lines in (A) Kachchh and (B) as suggested by APLIC 2006

***Raptor Diversity and Distribution***

A survey effort of 1530 km, 424 km and 660 km was made across Bhachau, Banni and Naliya sites respectively to record the Raptor diversity and electrocution mortalities along powerline stretches. During this survey effort, a total of 407 Raptor sightings were made (Banni>Bhachau>Naliya) out of which, the highest number of sightings were recorded from Banni landscape (n=246) while the lowest number of sightings were recorded from Naliya (n=54) (Figure 4 and 5). In terms of the number of species (Bhachau>Banni≃Naliya), we recorded highest number of species at Bhachau (n=23) while equal number of species (n=18) were recorded in Banni and Naliya. Eagles were the most sighted species group at all the sites followed by Harrier and Buzzard (Figure 6).

The encounter rate analysis (Banni>Naliya>Bhachau) revealed that the Banni area has the highest encounter rate (0.6 sightings/km) while the Bhachau area has the lowest encounter rate (0.07 sightings/km) (Figure 7). Summarisation of raptors sightings as per body size (Banni>Bhachau>Naliya) showed that the large raptors were found maximum in Banni landscape (51.6%) followed by Naliya (35.1%) and Bhachau (26.1%) (Table 3 and 4). Further, across three sites, 20%, 27% and 24% of total raptors sighted in sitting position were perched on distribution lines at Bhachau, Banni and Naliya, respectively.

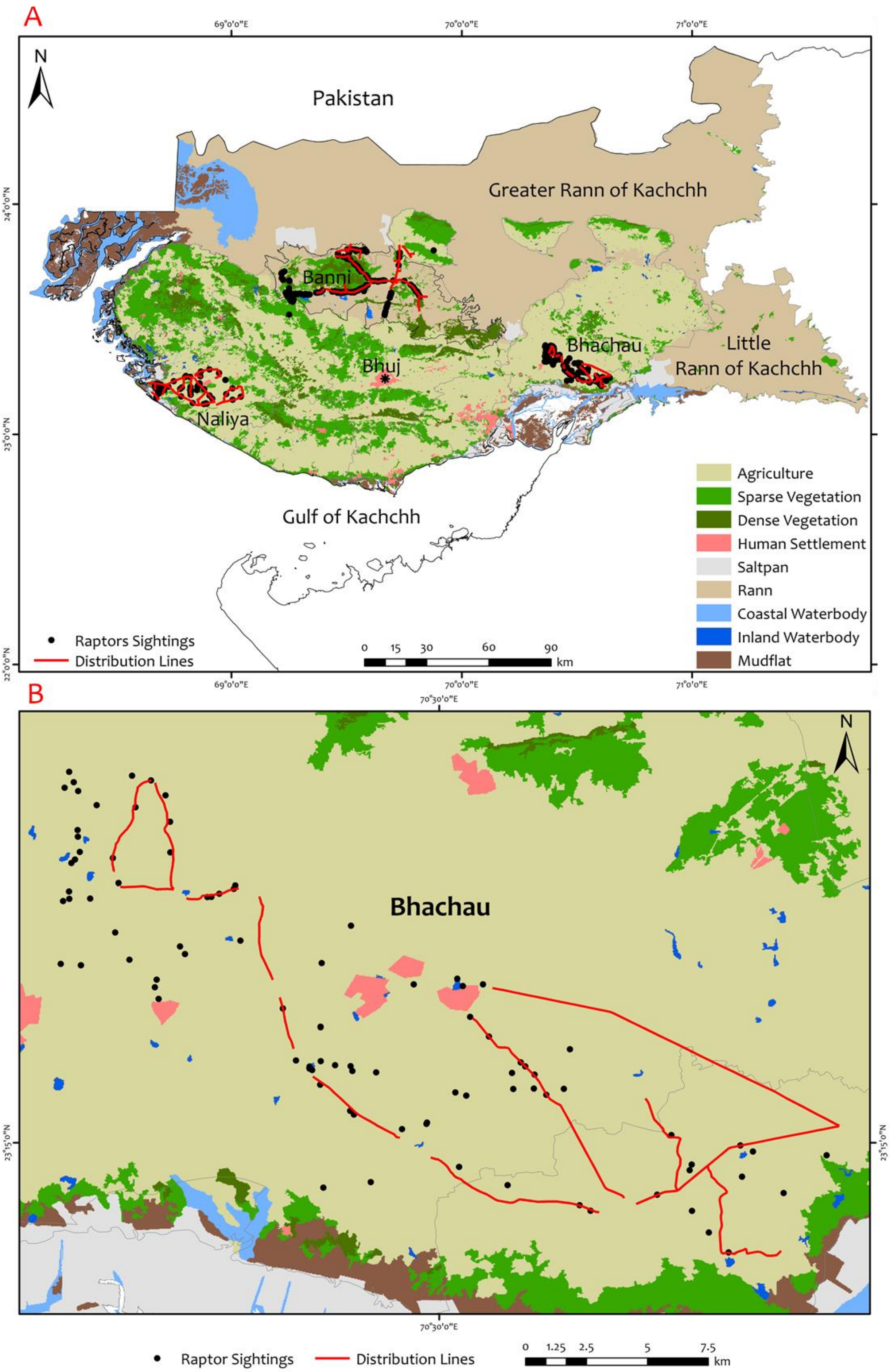


**Figure 4.** Maps showing the surveyed distribution line network and raptor sightings across Kachchh (A) and in Bhachau study site (B)

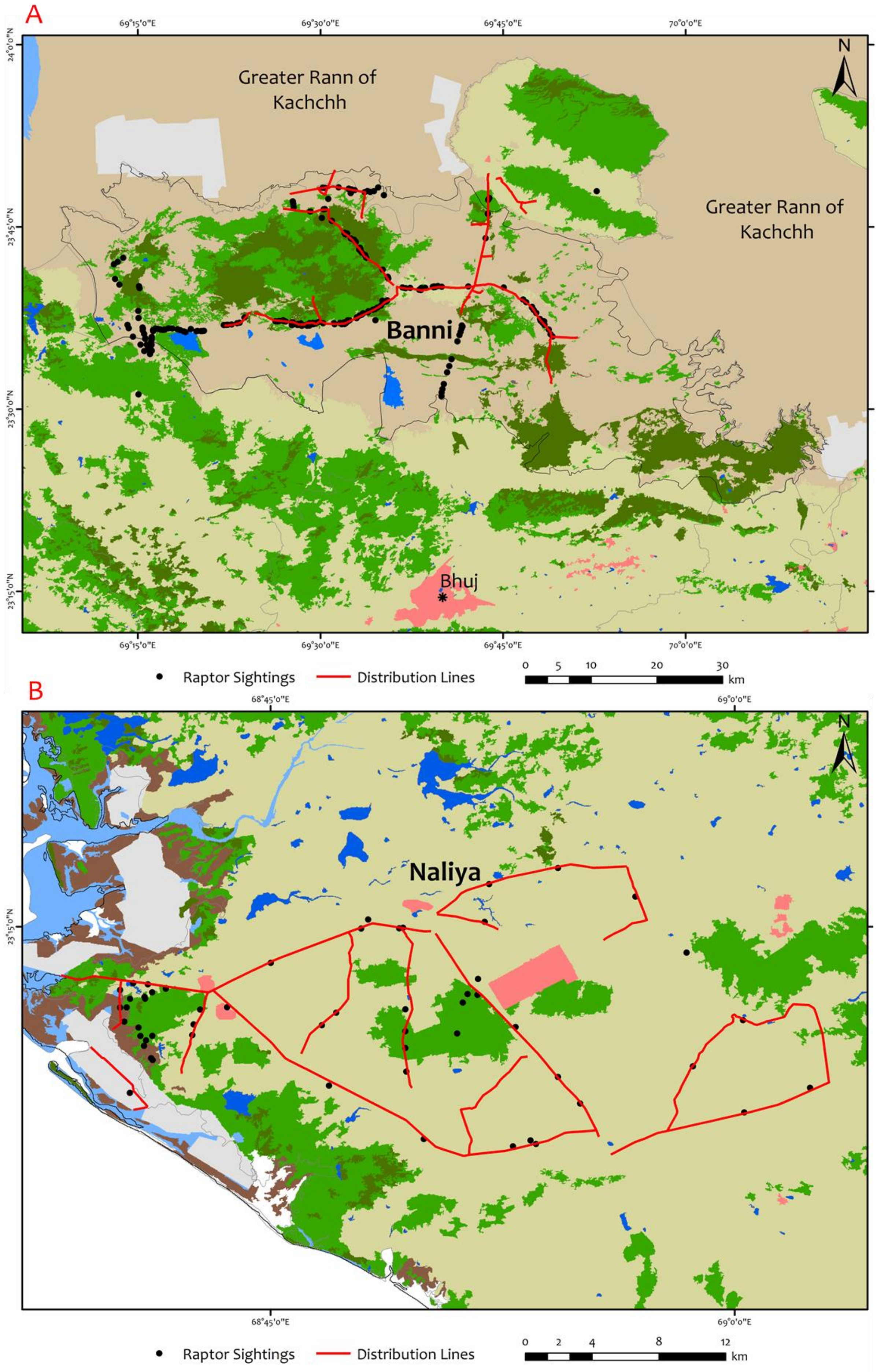


**Figure 5.** Maps showing surveyed distribution line network and raptor sightings in Banni and Naliya

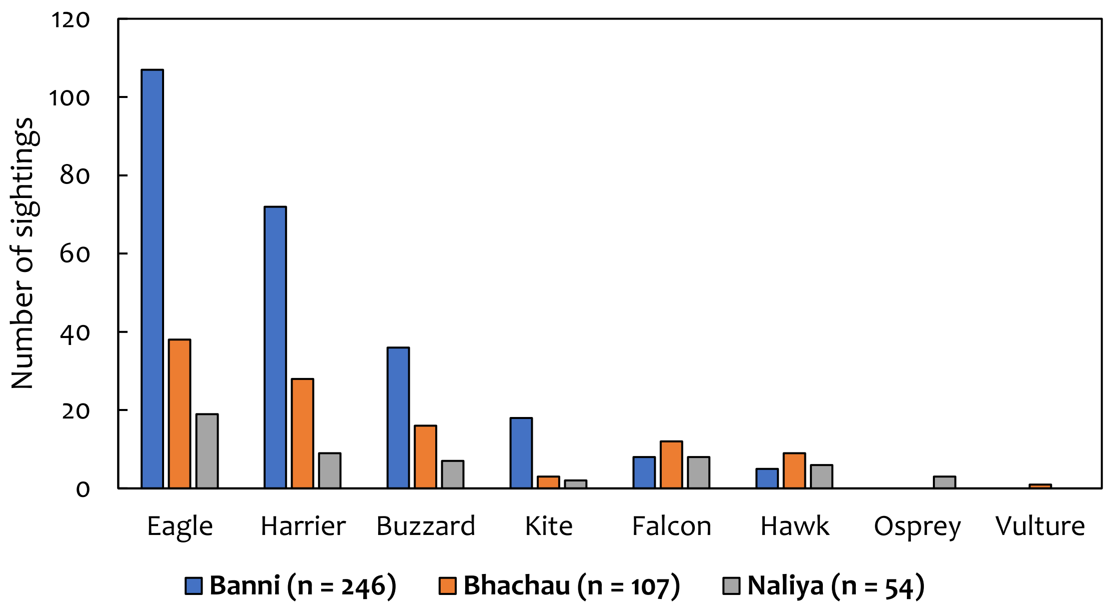


**Figure 6.** Sightings of different raptor species groups across three study sites in the Kachchh landscape.

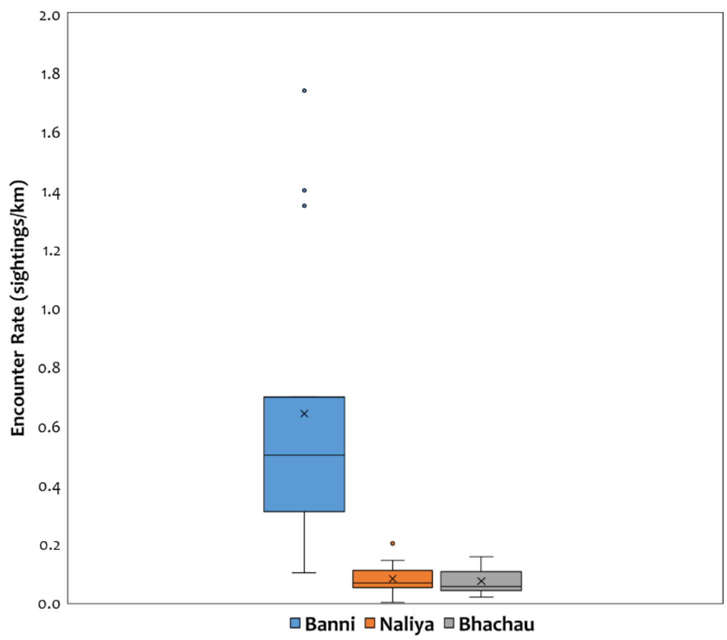


**Figure 7.** Box plots comparing the encounter rate of Raptors (sightings per km) at all three sites. The Banni landscape showed the highest mean encounter rate (0.6 sightings/km) while Bhachau showed the lowest mean encounter rate (0.07 sightings/km).

**Table 3**. Summary of Raptor sightings in each size class across three study sites. Banni landscape had a maximum number of total as well as large-bodied raptor sightings while Naliya showed the least number of sightings.

| S. No. | Size Class | Study Sites | | | Overall (n=407) |
|---|---|---|---|---|---|
| | | Banni (n=246) | Bhachau (n = 107) | Naliya (n=54) | |
| 1. | Large Body (>60 cm) | 51.6 % (n =127) | 26.1 % (n=28) | 35.1 % (n=19) | 42.7 % (n=174) |
| 2. | Medium Body (46-60 cm) | 35.7 % (n=88) | 53.2 % (n=57) | 37.0 % (n=20) | 40.5 % (n=165) |
| 3. | Small Body (up to 45 cm) | 12.6 % (n=31) | 20.5 % (n=22) | 27.7 % (n=15) | 16.7 % (n=68) |

**Table 4**. Body length and wingspan of select raptor species observed in the Kachchh landscape

| Species | Body Length (cm) | Wing-span (cm) |
|---|---|---|
| Cinereous Vulture | 68-120 | 250-310 |
| Eastern Imperial Eagle | 68-90 | 176-220 |
| Steppe Eagle | 60-89 | 250-262 |
| Osprey | 50-66 | 150-180 |
| Montagu's Harrier | 43-47 | 97-115 |
| Peregrine Falcon | 28-38 | 94-117 |

During the survey, only one bird carcass of Osprey was recorded under the distribution line at salt pans of Naliya. Three carcasses of electrocuted birds including one Eurasian Collared Dove and two Rosy Starling were recorded opportunistically.

A carcass of an Osprey, lying under the distribution line. The burn of wing feathers suggested the electrocution mortality.

## Discussion

This study revealed the presence of high raptor diversity in the Kachchh landscape that includes four globally threatened eagles and three Vulture species, indicating the importance of this landscape for raptors. The mosaic of habitats that includes unique Rann system, grasslands, agricultural fields, scrubland, and open meadows makes the landscape suitable for migratory and resident raptors. As a result, raptors from northern latitudes migrate to the Kachchh through Central Asian Flyway and winters here. A few rare raptor species such as Saker falcon, Lesser Kestrel and Merlin, which are otherwise found in this landscape, could not be recorded during the survey period. This could be because our survey efforts were primarily concentrated in the agricultural landscape and grasslands of Kachchh while these rare species are mostly observed in the Little Rann of Kachchh.

Among all the raptors recorded in the landscape, highest numbers were of large bodied (length ≥65 cm) raptors, indicating the importance of this region for large raptors. The large raptors use the thermal uplift (Marques 2019) to soar in search of food and the

Kachchh landscape, being open flat terrain, provides suitable thermals to these birds, making it a crucial landscape for migratory large raptors. This study also confirms the Banni area's importance as indicated by the high encounter rate of raptors in the landscape. The higher numbers of the species in the Bhachau area (23 species) may be attributed to the geographical location of the area. The Bhachau area is located between two important raptor habitats in the Kachchh district: Little Rann of Kachchh and Banni.

The Banni landscape is characterized by flat terrain dominated by grass species (GUIDE 2010). Therefore, it resembles the steppe habitat of northern latitudes, making it a suitable area for wintering large raptors. However, the landscape does not provide natural tall perches to the Raptors due to the lack of tall trees. Studies have shown that in the open habitats, raptors use distribution line poles to take advantage of wider field of view (Boeker and Nickerson 1975, Nelson and Nelson 1976) and the regular use of these poles increases the risk of electrocution of raptors in an open habitat (Benson 1981). Additionally, Banni is the home for greater number of raptors when compared to other areas: Bhachau and Naliya, which increases the probability of Raptors using distribution line poles as a perching substrate. The studies have shown that in this type of scenario, installing additional perches can mitigate the electrocution risk (Dixon 2019, Sánchez 2020). Therefore, it is anticipated that the raptors are at higher risk of electrocution in Banni.

The distribution lines in Naliya and Bhachau can also pose potential risk of electrocution for raptors. These areas are predominantly agricultural landscape with high human population density when compared to Banni and the distribution line network is comparatively intensive in these areas. The studies have indicated that the electrocution risk is directly influenced by the density of distribution line poles, as higher density of poles provides more opportunity to raptors for perching (Tinto et al. 2010, Dwyer et al. 2020). Though fewer raptors are encountered in these areas, the dense network of distribution lines makes the habitats in Naliya electrocution-prone for Raptors.

During the study period, we recorded four mortalities due to electrocution around Jakhau, Naliya and Bhuj. The low mortality detection may be attributed to the low detectability, as many survey lines were passing over thick blanket of *Prosopis juliflora* bushes. Also, the high density of natural scavengers like Dog, Golden Jackal, House Crow and rodents in the landscape quickly scavenge away the carcasses. As suggested by Ponce at al. (2010), the detection of carcass in any landscape is influenced by removal of the carcass by the scavengers, detectability and the observer's abilities. Therefore, mortality recorded in this study may not truly represent the magnitude of electrocution risk in the Kachchh region.

Further, the raptors in the area appear to be dispersed and large congregations were not recorded during the survey period as the area lacks huge cattle carcass dumpsites, which attracts large raptors. The major cattle carcass dumps in this region are mostly located in the city outskirts, while in rural areas, the cattle carcasses are dumped wherever the open land is available. As the raptors are dispersed, any mortalities happening are also scattered and may often go unnoticed.  The study carried out by Harness et al. (2013) in the Thar Desert, Rajasthan showed high number of mortalities (161 avian carcasses of 13 different species) associated with electrocution. This was attributed to the open, scrub-less habitat that enhances the detectability of carcasses and the proximity of distribution lines to the Jorbeer cattle dumping site, thus attracting raptors and other scavenging birds.

Our study was carried out for a relatively shorter period, yet it has shown the importance of this landscape as a wintering ground for migratory raptors. The Banni landscape with high raptor use requires special attention with respect to electrocution risk mitigation. Currently, the density of distribution lines is less in the Banni due to low and nomadic population of the landscape, unlike Bhachau and Naliya. However, the future electrification of the area will bring more number of distribution lines in the landscape, increasing the electrocution risk. Given this, the existing lines are recommended to be mitigated either by covering the conductors near poles with an insulator or by installing the additional elevated perches for raptors (APLIC 2006).

The Kachchh landscape has high Raptor diversity that includes globally threatened species. Therefore, the future distribution lines in the landscape may be having bird-safe separation of conductors to avoid electrocution mortality. The current distribution line configuration followed by in the area have insufficient separation between any two conducting parts on the pole, which can pose a risk to raptors. Given this, the separation between conducting parts requires to be according to the globally accepted standards to make them bird-safe. The detailed information on the mitigation measures is included at the end of the report.


**Citation:**

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# *Distribution of Migratory Common Crane with respect to Wind Energy Infrastructure*

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Palak Joshi

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Anju Baroth

R. Suresh Kumar

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The development of renewable energy infrastructure, particularly windmills, has witnessed a boost worldwide to reduce human-induced carbon emission while meeting the energy requirement for rapidly increasing human population (GWEC 2018, Sawin et al. 2016). Though the wind energy is regarded as 'clean energy' or 'green energy' source, it has been identified as one of the serious threat to the wild fauna in the form of collision mortalities, especially of bats and birds (Drewitt and Langston 2006, Saidur et al. 2011, Schuster et al 2015). Mortalities happen when the species come in sudden contact with rotors or associated structures, resulting in injuries and sometimes death (Drewitt and Langston, 2006). The concerns regarding bird mortalities at windmills is increasing and a result, monitoring and research on bird mortalities at windmills are in focus in recent years (Drewitt and Langston 2006, Krijgsveld *et al.* 2009, Marques *et al.* 2014).

Mortalities due to windmills can cause population level consequences for the species of conservation priority, for example large and long-lived birds with low breeding and maturation rates (Drewitt and Langston 2006, Carrete et al. 2012, de Lucas et al. 2012). However, mortalities rates are highly variable with worldwide range of zero to 40 deaths per windmill per year (Sovacool 2009) as the collision probabilities are site and species specific (Thaxter et al. 2017). There are multiple factors that influence mortality rates, including species-specific factors, site-specific factors, and windfarm-specific factors (Marques et al. 2014). The species with high wing loading and narrow frontal vision are particularly at risk of collision (Janss 2000, Herrera-Alsina et al. 2013). The collision risk is also depending on the topography and suitability of habitat for birds and the placement of windmills in these habitats (Marques et al. 2014).

Apart from the bird mortalities, windmills also pose threat to birds in form of habitat loss and degradation and displacement of birds (Schuster et al. 2015, Marques et al. 2020). The studies on the soaring birds suggested that birds avoid the use of areas dominated by windmills (May 2015). Further, the study-based evidence suggests that the number of large birds decreases in proximity to windmills (Pearce-Higgins et al. 2009, Barrios & Rodriguez 2004), which is the result of avoidance behaviour by these birds (Villegas-Patraca et al. 2014). The studies have also suggested functional habitat loss, particularly for raptors that tend to avoid soaring in the areas where windmills are constructed (Marques et al. 2020). However, these studies are largely focused on raptors and study areas are mostly the migratory bottlenecks or breeding habitat.

The grasslands and agricultural fields of western India resembles to the steppe habitat of northern Eurasia and as a result a number of migratory bird winter in this landscape including Common Crane. Common cranes predominantly occur in Rajasthan and Gujarat where they use vast agricultural fields and grasslands for foraging (Ali and Ripley 1987, Tiwari and Rahmani 2002). The Kachchh landscape in western Gujarat is one of the strongholds for the wintering Common Crane in India which is also the highly suitable landscape for the wind energy production. Therefore, in last decade, the Kachchh landscape has witnessed spurt in the windfarms, primary falling in the agricultural areas where cranes are occurring in large numbers. Given this, a study was conducted in the Kachchh region to record the distribution of Common Crane in and around windfarms. The objective of the study was to see if there is change in the distribution pattern of Common Crane in windmill area and no-windmill area. For this, two area adjoining to each other, were selected in Bhachau taluk and surveys were carried out to record the distribution of Common Crane in both the areas.

## Study area and Methods

A primary survey was conducted from 1st January to 15th January, 2019 in Bhachau taluk, covering 331 km in 50 hours. Based on the primary surveys two sites: with and without windmills were selected with the area of 140 sq km and 191 sq km respectively. The windmill area was selected as it consists of 240 windmills with no particular pattern of installation and the majority habitat of the area was dry agriculture. The windmill area had windmills operated by three different companies, viz. Vestas, Suzlon and Neg Micon. The Suzlon S82 wind turbines had a tower height of 78.8 m, a rotor diameter of 82 m and single turbine capacity of 1.5 MW. Vestas V110 wind turbine had a tower height of 80 m, rotor diameter of 110 m and single turbine capacity of 2 MW and Neg Micon had a tower height of 50 m, rotor diameter of 48.2 m and single turbine capacity of 750 KW.

The site without windmills was selected in proximity to the windmill site and had both majorly dry agriculture with few cultivated fields irrigated through two canals. Both the areas had almost similar habitat and topographic characteristics and was largely dominated by agricultural fields which is the prime foraging habitat for Common Crane in this landscape.

***Field sampling for Common Crane presence***

Given the targeted species for the study are large enough to be detected from a considerable distance, vehicular (2-wheelers) road survey method was adopted to record the locations of Cranes. The study areas and survey tracks were mapped using Google Earth Pro to ease the vehicular field surveys. A total of six tracks were mapped out of which, three were in Windmill area measuring 55.7 km in total length, and three were in no-windmill area having a total length of 86.5 km (Figure 1). The tracks identified crisscrossed the study region, ensuring spatial coverage. The survey was conducted in the morning (0800 to 1300 hrs) and evening (1500 to 1900 hrs). The six tracks were repeated ten times during the study with the uniform speed of 20-30 kmph. The survey was carried out by two persons to minimize observer bias. GPS location, time, flock size, habitat, activity, and distance to nearest windmill were recorded upon locating the flock. The GPS locations of other large birds, whenever observed, were also recorded.

In order to assess the overlap between wind farms and Crane-use areas, existing windmills across the Kachchh district were mapped using Google earth imageries. Further, areas with high wind energy potential were mapped as identified by the Ministry of New and Renewable Energy (2020). Both, existing windmills and area of high wind energy potential were overlaid with the suitable areas for cranes identified through SDM and crane distribution range identified using 95% KDE (for more details of SDM and KDE, see section one of the report) to know the potential risk zones for cranes.

***Mortality Surveys***

In order to record the avian mortality due to windmill collision, the entire area was searched during 14th February to 1st March 2019. During this period, a total of 183 windmills were visited randomly and under each windmill, active carcass search was conducted. Upon locating a carcass, carcass location, time, species or remains (primary or secondary feathers) and windmill number were recorded. Due to time constraints windmills were covered only once for the mortality survey. The windmills were selected in such a way that no part of the Windmill area remained uncovered.

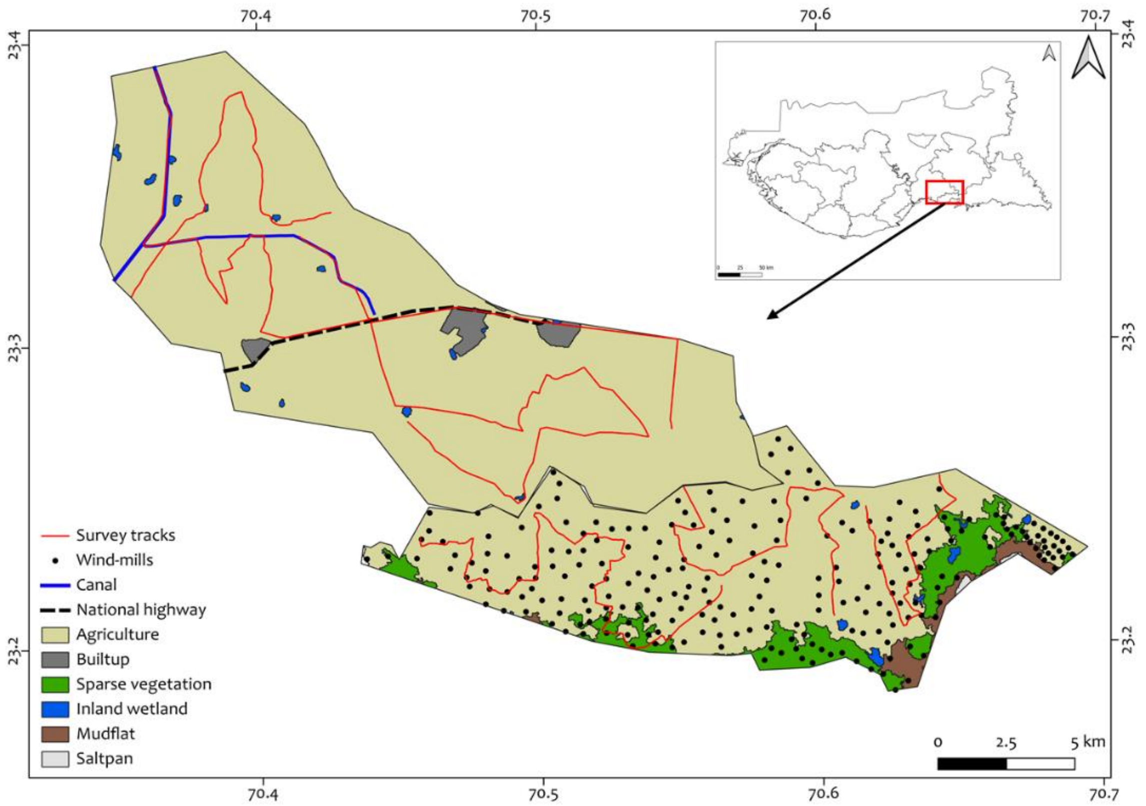


**Figure 1.** Study area map showing survey tracks in the areas with and without windmills.

## Findings of the study

A total of 500 hours were spent surveying 1425 km tracks to record the Common Crane flocks during which 50 flocks were recorded. Of these, 44 flocks were recorded form the control area while only six flocks were recorded in the windmill area (Figure 2). The mean flock sizes of Common Crane flocks were 13 (SD ± 15) and 11 (SD ± 10) in control and windmill sites respectively. The encounter rate (ER) showed that the area without windmill had the mean ER of 0.06 (SD ± 0.05) flock per km while windmill area had the mean ER of 0.01 (SD ± 0.03) flock per km (Figure 3). The Crane flocks were recorded in only two pockets in the windmill area and were not evenly distributed across the area.

The results showed that the areas with windmill had six times less encounter rate than the area without windmill, which may be attributed to the disturbance caused by windmills. However, the study conducted in the winter following the dry monsoon of 2018 might have forced Cranes near the Narmada canal in the study area. In the following year when there was adequate rainfall, most of the Common cranes were recorded from the Banni grassland, suggesting that the space-use by Common cranes is highly variable and is also governed by environmental factors. The Common Crane flocks recorded in the windmill area were towards the edge of the windfarm suggesting the avoidance of deeper areas of the windfarm. This indicate that the windmills might be forcing them to displace from the area, resulting in the functional habitat loss.

The functional habitat loss due to windmills was previously studied in Black Kite where the GPS tracking revealed that the species avoided the potentially suitable habitat with windmills (Marques et al. 2020). Avoidance of windmill dominated areas is also recorded for other soaring birds as reported by Cabrera-Cruz & Villegas-Patraca (2016) wherein they observed continuous change in migration trajectory with increasing wind farms falling in bird migration paths in Mexico. The Common crane space use investigated in this study was in the wintering ground where the Cranes forage in agricultural fields. Apparently, due to the region's high potential of wind energy production, huge wind farms are established in agricultural fields, resulting in conflict with Crane space use.

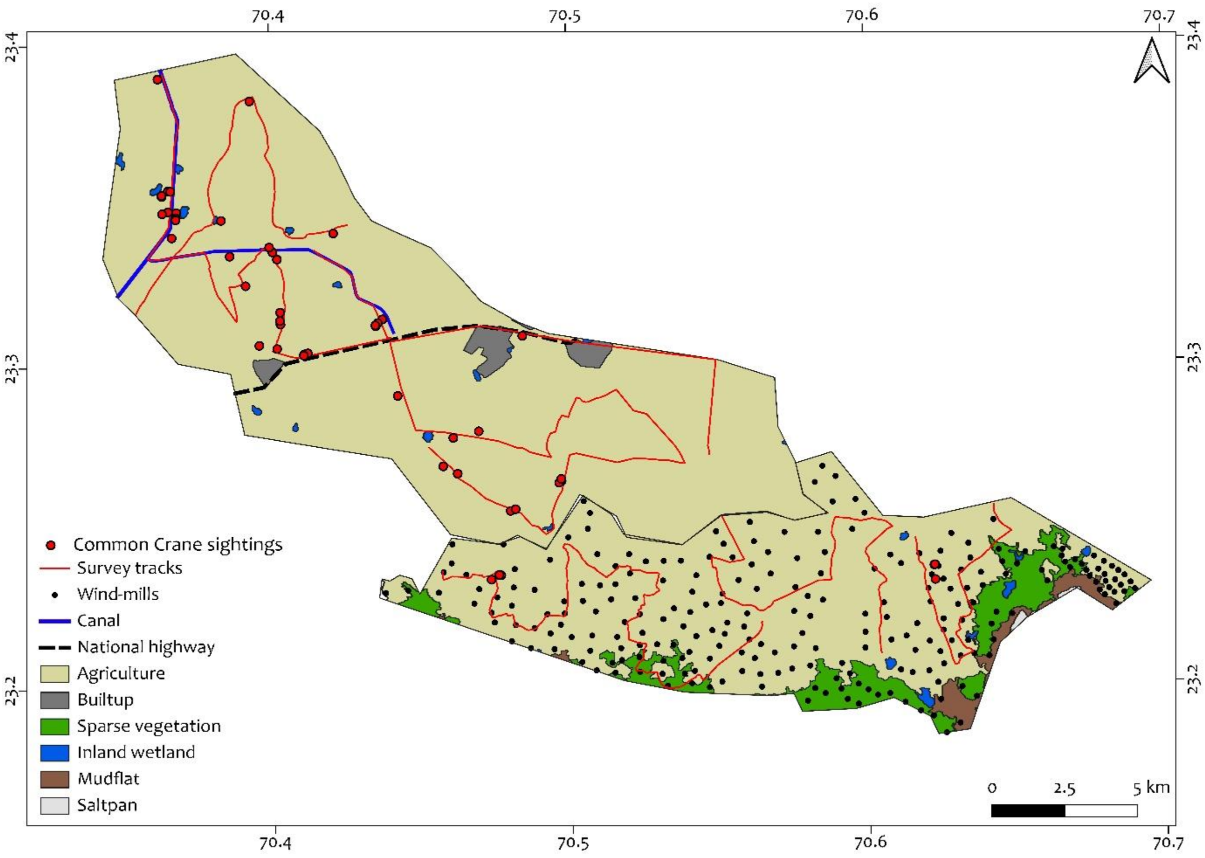


**Figure 2.** A map showing the spatial distribution of Common Crane flocks in the study area.

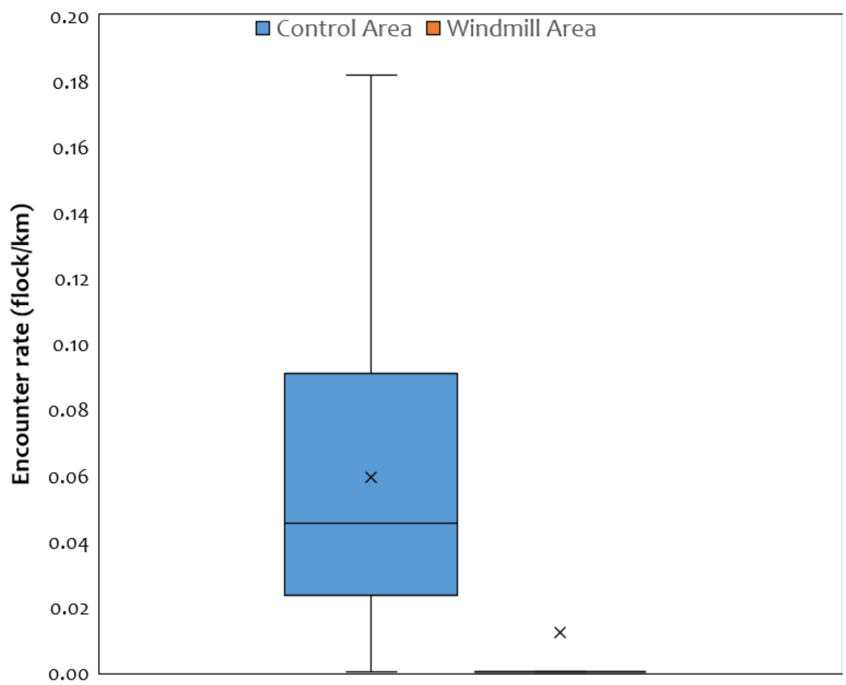


**Figure 3.** A box plot showing the encounter rate in control and windmill areas.

Surveys in search of bird carcasses were conducted covering a total of 183 out of 240 windmills in 9 days. During this, no direct evidence of Common Crane mortality due to the windmills could be recorded. Feathers and body parts of Cattle Egret and Blue Rock Pigeons were found on five occasions in the premises of windmills. However, it was quite difficult to conclude the windmill collision mortality as the feathers and body parts were scattered and were not enough to show the sign of collision.

The absence of Common Crane mortality in the windmill site further indicates that the Cranes are not using the area frequently. Other carcasses found around the windmills were of Egret species and Blue Rock Pigeon, which are found in relatively high numbers in the area. The study conducted by Kumar et al. 2012 in the same area recorded six avian carcasses including Blue Rock Pigeon, Corvus species, Egret species and Dove species. However, the mortality of birds due to windmills is influenced by multiple factors such as weather, bird abundance and placement of windmills in the area (Marques et al. 2014). Therefore, the short-term studies may fail to show the actual magnitude of bird mortality due to windmills.

Further, a total of 1606 windmills were mapped across the Kachchh district and additional 4813 sq.km area mapped is identified as the high wind energy potential area (Ministry of New and Renewable Energy-Wind Energy Division 2020). It was found that 23 % of existing windmills and 24% of potential wind energy area is falling in the suitable habitat for cranes. Whereas, 36 % and 46 % of existing windmills and potential wind energy area overlapped with crane distribution range respectively (Table 1, Figure 4). The current study has indicated that the existing windmills are possibly displacing large birds like Common Crane from their suitable habitat. The displacement of cranes due to windmills can be better understand by tracking the fine scale movement using the telemetry across multiple wintering seasons.

**Table 1.** A table detailing the existing windmills and proposed wind farms in and outside crane suitable areas and crane distribution range in the Kachchh district.

| S. No. | Area | Number of existing windmills (N = 1606) | High wind energy potential area (sq km) (total = 4813 sq km) |
|---|---|---|---|
| 1 | Inside Crane suitable areas (identified through SDM) | 365 (23 %) | 1139 (24 %) |
| 2 | Outside Crane suitable areas (identified through SDM) | 1241 (77 %) | 3674 (76 %) |
| 3 | Inside Crane distribution range (95% KDE) | 581 (36 %) | 2118 (44 %) |
| 4 | Outside Crane distribution range (95% KDE) | 1025 (64 %) | 2695 (56 %) |

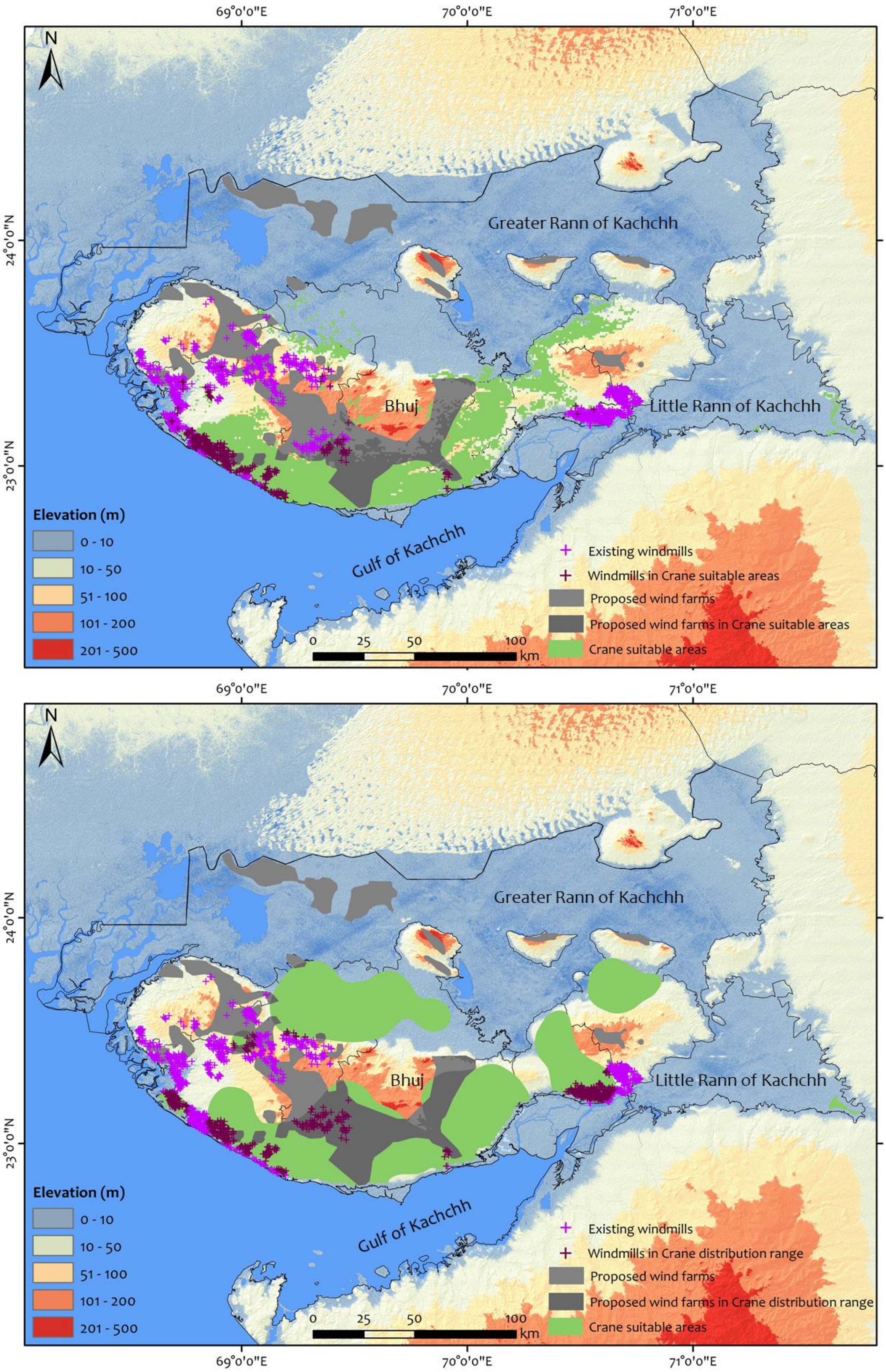


**Figure 4.** A map of the Kachchh district showing existing windmills and proposed wind farms falling in high suitable areas (above) and in total occurrence areas (below) for cranes.

**Citation:**

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# Suggested Guidelines for minimizing risks posed by energy infrastructure to birds

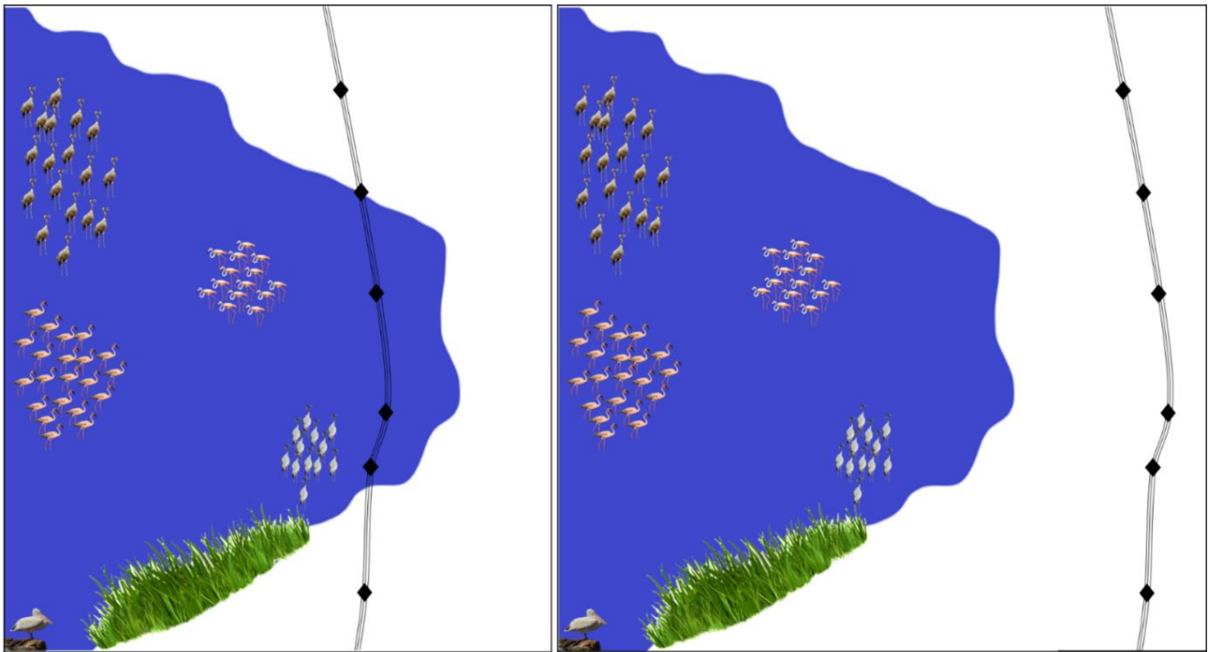
Anju Baroth
R. Suresh Kumar

*The threats posed by energy infrastructure vary with the type of habitat, whether terrestrial or aquatic, and the species occurring there. For this study, the impact of power-lines was assessed on two avian species groups, one associated with aquatic habitats: Greater and Lesser Flamingo and the other associated with terrestrial habitats: the migratory Common Crane, Demoiselle Crane and Raptors. The following is a set of guidelines for mitigating impacts posed by power-lines and windmills for the above-mentioned species occurring in the Kachchh district in western Gujarat. The measures suggested here follows the guidance document "Eco-friendly measures to mitigate impacts of linear infrastructure on wildlife" (WII, 2016), and others such as APLIC (2006, 2012) and Prinsen et al. (2012). Many of these suggested measures or actions are widely adopted world over. The agencies dealing with energy infrastructure may consider the mitigatory measures given here and adopt appropriate measure in consultation with state forest department.*

**Collision Risk**

1. **Undergrounding power-lines:** The first and foremost mitigation strategy for collision risk with transmission lines is to place them underground, completely eliminating the risks. In the case of Kachchh landscape, an 8 km stretch of 66 kV power-line connecting Rapar taluk and Khadir bet was undergrounded following the high mortality of flamingos in 2011. This was the successful mitigation measure that completely stopped further collision mortalities. Therefore, it is recommended that the undergrounding of select power-line stretches (both transmission and distribution) bisecting critical bird habitats be considered following the guidelines of Central Electricity Authority.

2. **Non-placement or routing of power-lines away from high use areas**: In the cases where undergrounding is not possible, an appropriate routing of power-lines can minimise the risk to birds. Bird collisions mostly happen during sudden take-off and landing by birds. Therefore, the power-lines placed around high-use areas should consider leaving buffer distance for birds to take off and landing. The routing of power-lines is site-specific and should consider the birds behaviour as in which direction birds are mostly entering in the area. However, it is essential to have accurate data and demarcation of such high-use areas and migratory bird paths across the country. This information will enable agencies responsible for energy infrastructure, especially transmission and distribution utilities, to make informed decisions and avoid these areas during their project planning process. In the cases where the high use area is situated near human settlements or industrial areas, power-lines may be placed along the edge of the settlement where the possibility of bird activity will be very low. This study identified critical high-use areas for all focal avian species groups across the Kachchh landscape, including inland wetlands, saltpans, mudflats, agricultural fields, and grasslands. In these areas, existing power-lines are recommended to be rerouted, and any future power projects should avoid routing through these areas (Figure 1).



A. Risk situation: Power-line passing through a high-use wetland

B. Reduced risk situation: Power-line routed away from high-use wetland

**Figure 1.** Routing away the power-lines from high bird use areas to reduce the risk of bird collision with power-line

3. **Placing lines as powerline corridors**: The interline distance between two power-lines influences the level of risk birds may face. It is suggested that placement of the power-lines next to one another may pose less risk to birds. In a clustered line situation, birds only have to make one ascent and descent to cross the lines while in distantly-placed power-line situation, birds will have to make more ascent and descents, thus increasing the collision risk (APLIC 2012). Further, the power-line cluster will be confined to a smaller area and will be more visible to birds when compared to distantly placed power-lines. Presently the inter-line distances of the power-lines at the Surajbari creek range from 50 m to 550 m, while at Nanda Bet range from 90 m to 4800 m. Since these two are the high use area providing passage between the Gulf of Kachchh and Rann to flamingos and other large water birds, power-lines in these areas pose a greater risk to them. Therefore, it is recommended that the placement of new transmission lines here and other critical areas may be clustered with the existing lines to reduce collision risk (Figure 2).

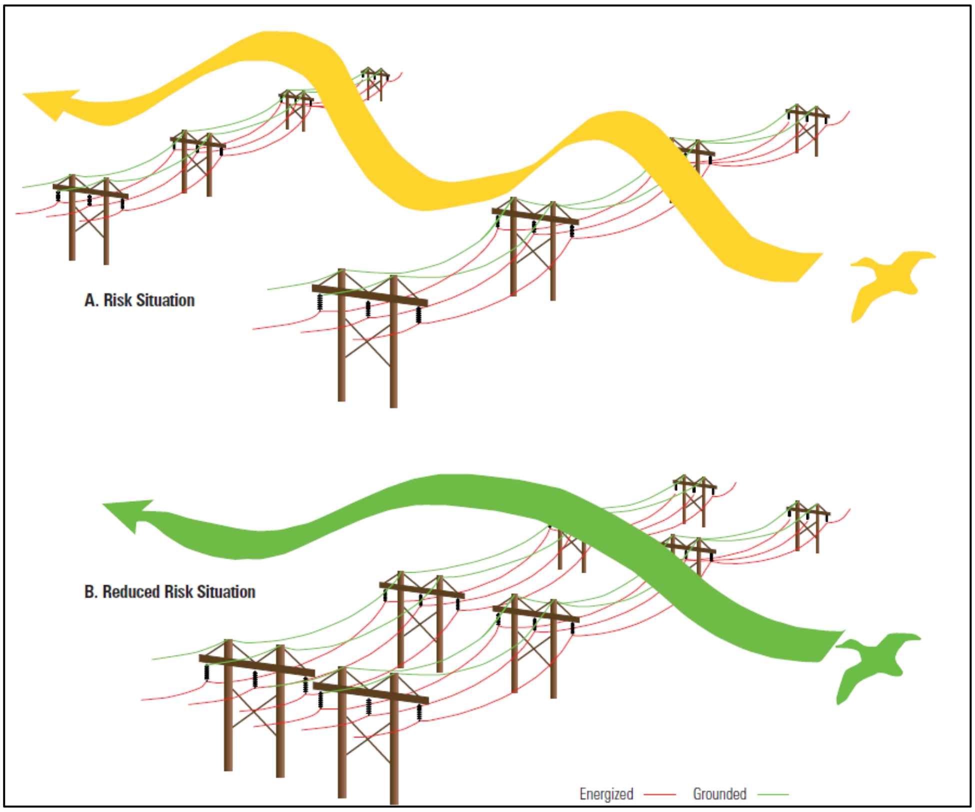



**Figure 2.** Recommended placement of power-lines to reduce the risk of bird collisions (After Thompson 1978) (Source: APLIC 2012)

4. **Optimization of existing Power-line infrastructure:** The Surajbari creek and Nanda Bet in particular were identified as important flight corridors for flamingos and it is these areas where large numbers of transmission lines cutting across. Given that these areas are having existing power-lines, optimising the use of these infrastructure may effectively reduce the number of new power-line being added in the area. Currently, there are a total of eight and six power-lines passing through Surajbari creek and Nanda bet, respectively. The possibilities of merging new power-lines with existing power-lines may be explored to optimize the use of existing pylons in these two areas and other critical habitats. Further, these power-lines are being owned by different companies and government sectors, increasing the number of lines in the area. Therefore, centralizing the power infrastructure development regardless of owner company may allow merging power-lines and using the infrastructure at its optimum capacity, thus decreasing the number of lines and risk to birds.

5. **Line marking devices (LMD):** In a situation where the power line cannot be rerouted or placed underground then to mitigate the risk of collision, LMDs such as spheres, swinging plates, spiral vibration dampers, bird flappers, flags, and crossed bands are used to make power-lines visible. This is not a permanent mitigation measure as the diverters require to be monitored and maintained periodically. Bird collisions with power lines are reported to occur with the earth wires frequently, and it is this wire that is generally marked with line marking devices (APLIC 2012). This is particularly the case in western countries and in terrestrial habitats where few species of large birds occur and in low densities. This is unlike the case in tropical regions like in Kachchh where there are number of large-bodied migratory species that congregate there and likely encounter transmission lines more often and as a result become vulnerable to both earth and conductor wires. Also, large avian species such as flamingos make nocturnal flights when no phase conductors and earth wire are visible. Therefore, for the Indian region, it is suggested to mark all wires in the transmission line spans.

   Technical specifications for deployment of Bird Flight Diverters (BFD) on transmission lines have been produced by the Central Electricity Authority (CEA) in India (Anonymous, 2022). It is specified that in transmission lines with two or more conductors per phase (bundle conductors) BFD be placed on Earth wire(s). Additionally, in transmission lines with single conductor in each phase, then BFD be placed on the phase conductors as well on the Earth wire(s). Further, it is suggested that BFD shall be placed on central 80% span of the line and at an interval of 10 m.

In line with this, we further suggest that BFD be installed at every 10 m on the earth wire and one BFD be installed at every 15 m on conductor wires in a staggered pattern, thereby, the power line will have effectively one diverter at every 5 m to 6 m (Figure 3). It is recommended that the BFDs used be of the glow-in-dark type, ensuring its effectiveness at night as well in low light conditions. This is particularly important in the context of Kachchh landscape where the two species flamingos and cranes tracked for their movements were found to be making significant number of flights at night.

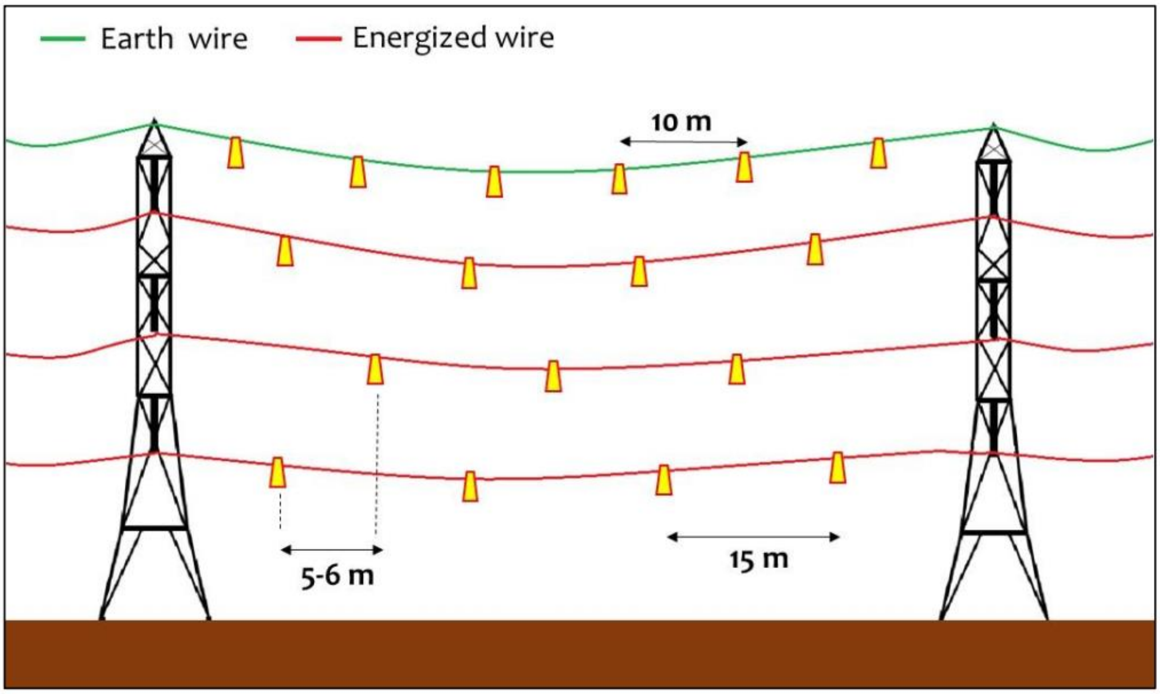



**Figure 3.** Schematic diagram showing the deployment of line marking devices on earth wire and conductors to reduce risk of bird collisions.

Further, Saltpans and mudflats are also being used by large numbers of birds and currently most of these areas are devoid of transmission lines. However, the distribution line network providing electricity to saltpans were found to be posing a collision risk to large birds like flamingos and pelicans. It is recommended that distribution lines in salt pans where high bird use is observed may also be fitted with LMDs to reduce collision risk.

6. **Avian Collision Avoidance System (ACAS):** Recently, the ACAS developed in America is reported to be effective in reducing bird collision mortalities (Sandhill Crane) up to 98% (Dwyer at al. 2019). The ACAS devices are currently installed on H frame pylons of 15m height and emit near-ultraviolet lights at such an angle that conductors can be illuminated which can also be installed on EHV lines (Dwyer at al. 2019). The ACAS is reported to be particularly useful along river stretches and wetland sites where natural features channel birds into relatively narrow flight corridors. The use of this system in the Kachchh landscape may be explored.

The Avian Collision Avoidance System (ACAS) during night. Photo by James Dwyer, EDM International (Source: American Ornithological Society 2019)

**Electrocution risk**

7. **Rerouting or undergrounding the distribution lines**: Measures suggested to mitigate electrocution risks to birds, which is associated with distribution lines is generally again rerouting or undergrounding of problematic sections. This is a long-term measure and provides complete bird safety. However, the distribution lines are unavoidable in many places because of the human settlement. Therefore, the undergrounding of lines is the best option, especially in the areas like Banni where comparatively lesser number of lines are present. In situations where these two mitigation measures are not possible retrofitting existing power lines specifically the configuration of the power pole design is recommended to be taken up.

8. **Pole design**: Structural configuration of distribution line should primarily consider providing sufficient separation between energized conductors or phases and grounded hardware. The separation distances can be increased by increasing cross-arm length, lowering the position of cross-arm on pole, or installing fibreglass pole extension to elevate the top conductor (Figure 4) (APLIC 2006). Installation of phase wires below the cross arms, using suspension insulators is said to reduce electrocution risk.

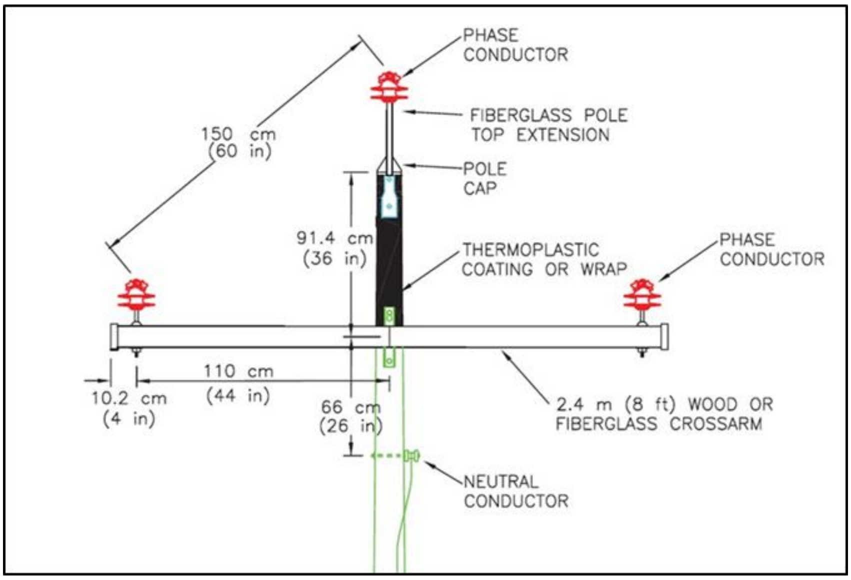



**Figure 4.** Sufficient separation between phase wires and grounded surfaces on the power pole as shown in the image here is said to minimize electrocution risk. (Source: APLIC 2006)

9. **Insulation**: As an immediate solution to minimize bird electrocution, insulating the conducting part is also suggested to be effective. To prevent electrocutions, it is suggested that the energized conductor wires, jumper wires and other conducting surfaces be covered by a non-conductor insulation material. Additionally, use fuse cut-out covers, arrester caps and insulation riser termination where necessary. These will require periodic monitoring and maintenance as the insulation material do weather over time and the line may once again pose electrocution risks.

10. **Perch discourager:** A short-term measure can be adopted to discourage birds from perching on distribution line power poles. For this, perch discouragers such as brush, spikes and pointed deterrents can be mounted on the cross-arms. However, the installation of perch discouragers may displace birds to other poles where there are no perch discouragers, and therefore should only be used where there are natural perches available in the area. This again will require regular monitoring and maintenance.

**Windmill risk**

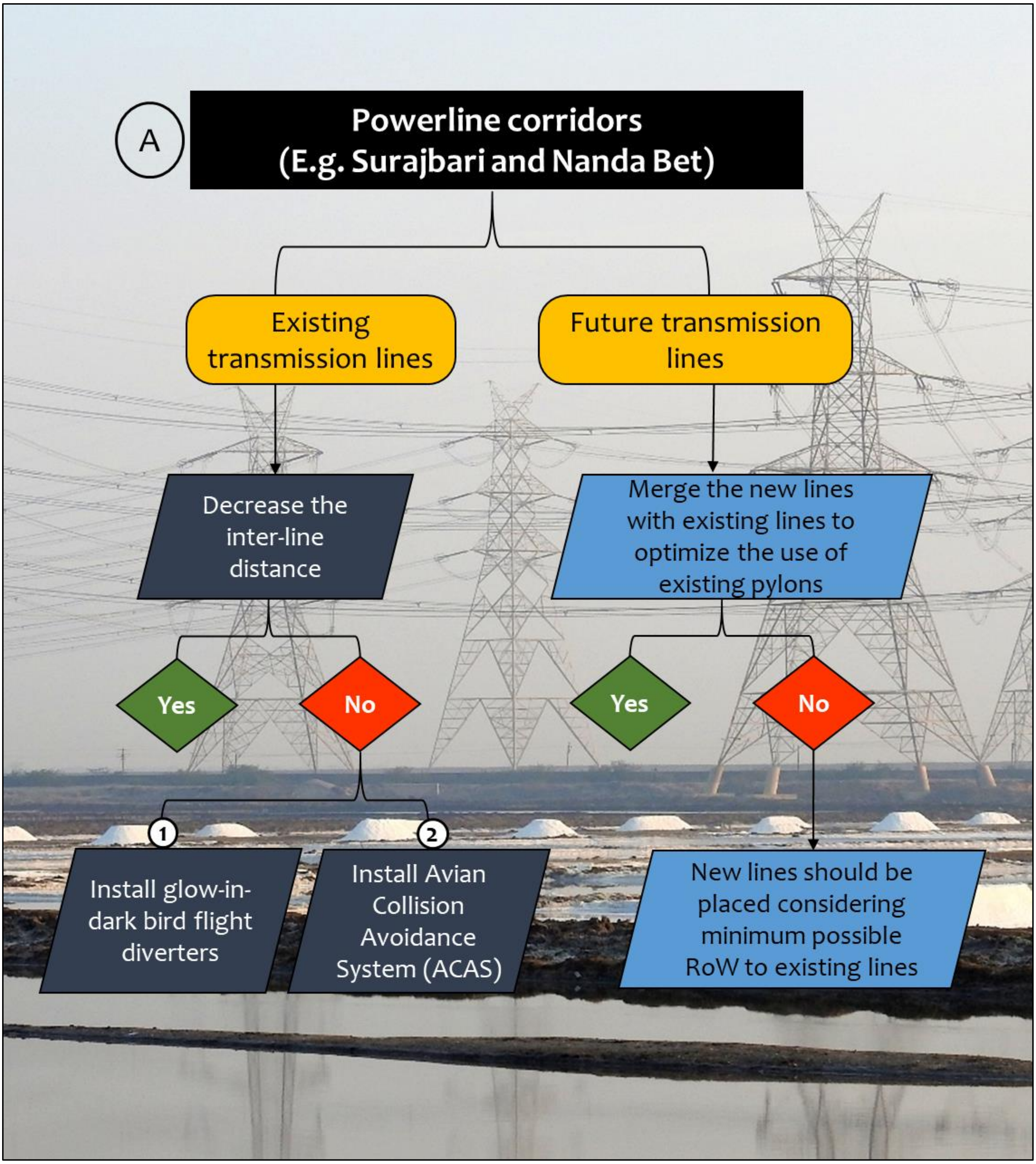
11. **Location of windfarm:** The location of a windfarm influences magnitude of risk to birds. Windfarms in and around high bird-use areas and along migratory flyway pose significant collision risk to birds. Windfarms not only pose collision risk; they also force birds to move to another area. Therefore, it is suggested that the placement of windfarms should avoid the high bird-use areas. The Kachchh landscape has high potential for wind energy production and as a result, the landscape has witnessed high number of wind energy projects which continues to expand and this overlaps with high-use areas for birds. Therefore, it is recommended that the areas highly suitable for large birds such as cranes be avoided for future wind energy projects in the Kachchh district.

12. **Marking windmill blades:** Given the situation where windmills are already installed in high bird-use areas, it is suggested that the visibility of rotors should be enhanced. This can be achieved by painting the rotors with black color in a staggered manner. This is a mitigation strategy adopted in Norway where it was observed that collision fatalities associated with windmills are reducing up to 70% (May et al. 2020). The other mitigation measure suggested is installing reflectors and applying UV coating on rotors (Marques at al. 2014). These mitigation measures have varying efficacy and depends on the bird species and thus, the efficacy studies are required after adopting the mitigation measure.

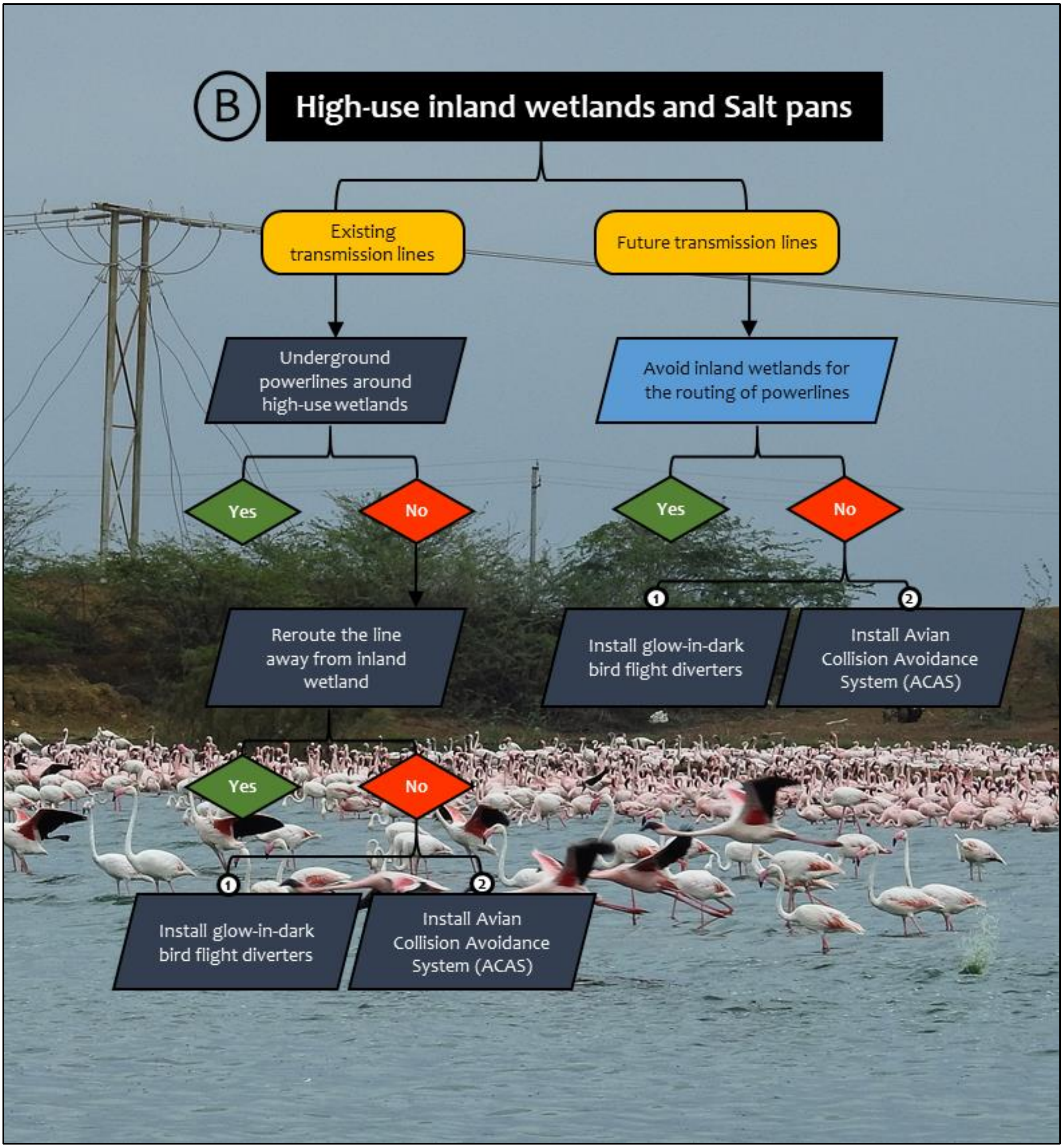
Given the potential of the Kachchh landscape for renewable energy production, many new wind and solar farms might be established in the region. The locations of these projects should be first evaluated and measures to minimise their impacts on avifauna should be considered. Further, the new power-lines adding to the landscape due to these projects should be routed considering the high use areas mentioned in this document. The flowchart is provided below which will be helpful in adopting the mitigation measures for existing as well as future energy infrastructure.

*It is to be highlighted here that the mitigation measures suggested are based on this four-year study that had both drought and wet year conditions, and tracking data from only a small number of flamingos. Therefore, the observations made may not truly depict the risk posed by energy infrastructure to birds in the landscape, and the mitigatory measures suggested may be adopted accordingly. Further, the guidelines include many mitigation measures of which, few are long term approaches while few are short-term approaches. Short-term approaches like installing line marking devices, insulator covers, and Avian Collision Avoidance System (ACAS) require continuous monitoring and maintenance. Also, the efficacy of these measures depends on the habitat, location and bird species. Therefore, long term research studies on the efficacy of different mitigation measures will further help in selecting appropriate measures specific to the region.*

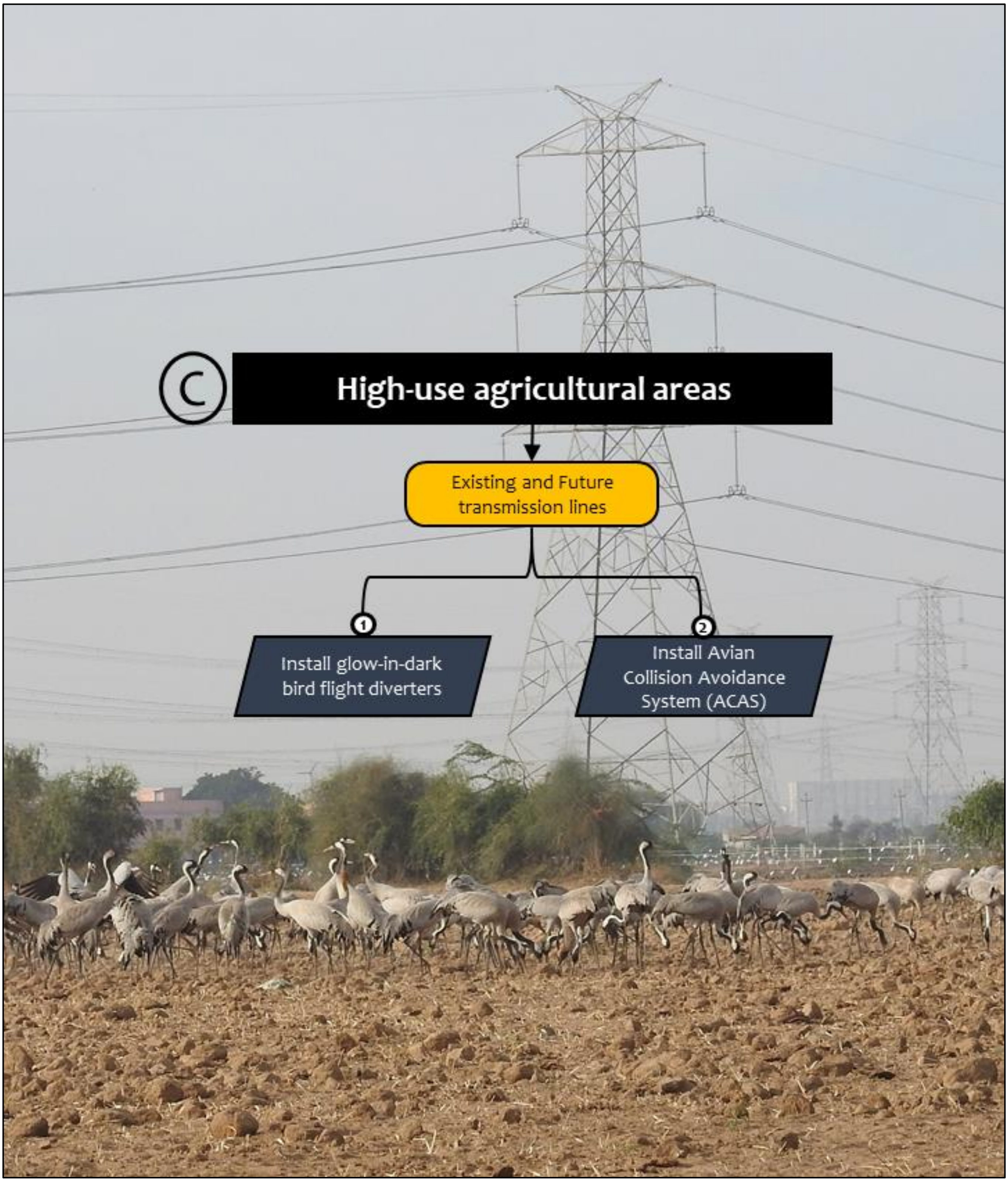
Flow-chart of guidelines to minimize impacts of power-lines on large bird species where power-lines are placed in the form of corridors in the Kachchh district



Flow-chart of guidelines to minimize impacts of power-lines on large bird species in inland wetlands and salt pans of the Kachchh district



Flow-chart of guidelines to minimize impacts of power-lines on large bird species occurring in the agricultural landscape of the Kachchh district



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## Annexure 1

**The list of birds recorded in the Kachchh landscape during study.**

(Risks: C = collision, E = Electrocution, B = Both, UN =Unknown) (IUCN categories: LC = Least Concern, VU = Vulnerable, NT = Near Threatened, EN = Endangered, CR = Critically Endangered)

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Order: Anseriformes** | | | | | |
| | **Family: Anatidae** | | | | | |
| 1 | Lesser Whistling Duck | *Dendrocygna javanica* | C | LC | IV | II |
| 2 | Knob-billed Duck | *Sarkidiornis melanotos* | C | LC | IV | II |
| 3 | Ruddy Shelduck | *Tadorna ferruginea* | C | LC | IV | II |
| 4 | Common Shelduck | *Tadorna tadorna* | C | LC | IV | II |
| 5 | Cotton Pygmy Goose | *Nettapus coromandelianus* | C | LC | IV | II |
| 6 | Garganey | *Spatula querquedula* | C | LC | IV | II |
| 7 | Northern Shoveler | *Spatula clypeata* | C | LC | IV | II |
| 8 | Gadwall | *Mareca strepera* | C | LC | IV | II |
| 9 | Eurasian Wigeon | *Mareca penelope* | C | LC | IV | II |
| 10 | Indian Spot-billed Duck | *Anas poecilorhyncha* | C | LC | IV | II |
| 11 | Mallard | *Anas platyrhynchos* | C | LC | IV | II |
| 12 | Northern Pintail | *Anas acuta* | C | LC | IV | II |
| 13 | Common Teal | *Anas crecca* | C | LC | IV | II |
| 14 | Common Pochard | *Aythya ferina* | C | VU | IV | II |
| 15 | Ferruginous Duck | *Aythya nyroca* | C | NT | IV | I |
| 16 | Tufted Duck | *Aythya fuligula* | C | LC | IV | II |
| | **Order: Galliformes** | | | | | |
| | **Family: Phasianidae** | | | | | |
| 17 | Indian Peafowl | *Pavo cristatus* | B | LC | I | |
| 18 | Common Quail | *Coturnix coturnix* | UN | LC | IV | II |
| 19 | Rain Quail | *Coturnix coromandelica* | UN | LC | IV | |
| 20 | Black Francolin | *Francolinus francolinus* | UN | LC | IV | |
| 21 | Grey Francolin | *Francolinus pondicerianus* | UN | LC | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Order: Phoenicopteriformes** | | | | | |
| | **Family: Phoenicopteridae** | | | | | |
| 22 | Greater Flamingo | *Phoenicopterus roseus* | C | LC | IV | II |
| 23 | Lesser Flamingo | *Phoeniconaias minor* | C | NT | IV | II |
| | **Order: Podicipediformes** | | | | | |
| | **Family: Podicipedidae** | | | | | |
| 24 | Little Grebe | *Tachybaptus ruficollis* | UN | LC | IV | |
| 25 | Great Crested Grebe | *Podiceps cristatus* | UN | LC | IV | |
| 26 | Black-necked Grebe | *Podiceps nigricollis* | UN | LC | IV | |
| | **Order: Columbiformes** | | | | | |
| | **Family: Columbidae** | | | | | |
| 27 | Rock Pigeon | *Columba livia* | E | LC | IV | |
| 28 | Eurasian Collared Dove | *Streptopelia decaocto* | E | LC | IV | |
| 29 | Red Collared Dove | *Streptopelia tranquebarica* | E | LC | IV | |
| 30 | Spotted Dove | *Streptopelia chinensis* | E | LC | IV | |
| 31 | Laughing Dove | *Streptopelia senegalensis* | E | LC | IV | |
| 32 | Yellow-footed Green Pigeon | *Treron phoenicopterus* | E | LC | IV | |
| | **Order: Pterocliformes** | | | | | |
| | **Family: Pteroclidae** | | | | | |
| 33 | Chestnut-bellied Sandgrouse | *Pterocles exustus* | C | LC | IV | |
| 34 | Painted Sandgrouse | *Pterocles indicus* | C | LC | IV | |
| | **Order: Otidiformes** | | | | | |
| | **Family: Otididae** | | | | | |
| 35 | Great Indian Bustard | *Ardeotis nigriceps* | C | CE | I | |
| 36 | Macqueen's Bustard | *Chlamydotis macqueenii* | C | VU | I | II |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Order: Cuculiformes** | | | | | |
| | **Family: Cuculidae** | | | | | |
| 37 | Greater Coucal | *Centropus sinensis* | E | LC | IV | |
| 38 | Sirkeer Malkoha | *Taccocua leschenaultii* | E | LC | IV | |
| 39 | Pied Cuckoo | *Clamator jacobinus* | E | LC | IV | |
| 40 | Asian Koel | *Eudynamys scolopaceus* | E | LC | IV | |
| 41 | Common Hawk Cuckoo | *Hierococcyx varius* | E | LC | IV | |
| | **Order: Caprimulgiformes** | | | | | |
| | **Family: Caprimulgidae** | | | | | |
| 42 | Indian Nightjar | *Caprimulgus asiaticus* | UN | LC | IV | |
| 43 | Savanna Nightjar | *Caprimulgus affinis* | UN | LC | IV | |
| | **Family: Apodidae** | | | | | |
| 44 | Alpine Swift | *Tachymarptis melba* | UN | LC | IV | |
| | **Order: Gruiformes** | | | | | |
| | **Family: Rallidae** | | | | | |
| 45 | Common Moorhen | *Gallinula chloropus* | UN | LC | IV | |
| 46 | Eurasian Coot | *Fulica atra* | C | LC | IV | |
| 47 | Grey-headed Swamphen | *Porphyrio poliocephalus* | UN | LC | IV | |
| 48 | White-breasted Waterhen | *Amaurornis phoenicurus* | UN | LC | IV | |
| | **Family: Gruidae** | | | | | |
| 49 | Sarus Crane | *Antigone antigone* | C | VU | IV | II |
| 50 | Demoiselle Crane | *Anthropoides virgo* | C | LC | IV | II |
| 51 | Common Crane | *Grus grus* | C | LC | IV | II |
| | **Order: Charadriiformes** | | | | | |
| | **Family: Burhinidae** | | | | | |
| 52 | Indian Thick-knee | *Burhinus indicus* | UN | LC | IV | |
| 53 | Great Thick-knee | *Esacus recurvirostris* | UN | NT | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Recurvirostridae** | | | | | |
| 54 | Black-winged Stilt | *Himantopus himantopus* | UN | LC | IV | II |
| 55 | Pied Avocet | *Recurvirostra avosetta* | UN | LC | IV | II |
| | **Family: Haematopodidae** | | | | | |
| 56 | Eurasian Oystercatcher | *Haematopus ostralegus* | UN | NT | IV | II |
| | **Family: Charadriidae** | | | | | |
| 57 | Grey Plover | *Pluvialis squatarola* | UN | LC | IV | II |
| 58 | Pacific Golden Plover | *Pluvialis fulva* | UN | LC | IV | II |
| 59 | Yellow-wattled Lapwing | *Vanellus malabaricus* | UN | LC | IV | II |
| 60 | Red-wattled Lapwing | *Vanellus indicus* | UN | LC | IV | II |
| 61 | White-tailed Lapwing | *Vanellus leucurus* | UN | LC | IV | II |
| 62 | Lesser Sand Plover | *Charadrius mongolus* | UN | LC | IV | II |
| 63 | Greater Sand Plover | *Charadrius leschenaultii* | UN | LC | IV | II |
| 64 | Kentish Plover | *Charadrius alexandrinus* | UN | LC | IV | II |
| 65 | Little Ringed Plover | *Charadrius dubius* | UN | LC | IV | II |
| | **Family: Rostratulidae** | | | | | |
| 66 | Greater Painted-snipe | *Rostratula benghalensis* | UN | LC | IV | |
| | **Family: Jacanidae** | | | | | |
| 67 | Pheasant-tailed Jacana | *Hydrophasianus chirurgus* | C | LC | IV | |
| | **Family: Scolopacidae** | | | | | |
| 68 | Whimbrel | *Numenius phaeopus* | C | LC | IV | II |
| 69 | Eurasian Curlew | *Numenius arquata* | C | NT | IV | II |
| 70 | Bar-tailed Godwit | *Limosa lapponica* | C | NT | IV | II |
| 71 | Black-tailed Godwit | *Limosa limosa* | C | NT | IV | II |
| 72 | Ruddy Turnstone | *Arenaria interpres* | C | LC | IV | II |
| 73 | Great Knot | *Calidris tenuirostris* | UN | EN | IV | I |
| 74 | Ruff | *Calidris pugnax* | UN | LC | IV | II |
| 75 | Broad-billed Sandpiper | *Calidris falcinellus* | UN | LC | IV | II |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| 76 | Curlew Sandpiper | *Calidris ferruginea* | UN | NT | IV | II |
| 77 | Temminck's Stint | *Calidris temminckii* | UN | LC | IV | II |
| 78 | Sanderling | *Calidris alba* | UN | LC | IV | II |
| 79 | Dunlin | *Calidris alpina* | UN | LC | IV | II |
| 80 | Little Stint | *Calidris minuta* | UN | LC | IV | II |
| 81 | Common Snipe | *Gallinago gallinago* | UN | LC | IV | II |
| 82 | Terek Sandpiper | *Xenus cinereus* | UN | LC | IV | II |
| 83 | Red-necked Phalarope | *Phalaropus lobatus* | UN | LC | IV | II |
| 84 | Common Sandpiper | *Actitis hypoleucos* | UN | LC | IV | II |
| 85 | Green Sandpiper | *Tringa ochropus* | UN | LC | IV | II |
| 86 | Spotted Redshank | *Tringa erythropus* | UN | LC | IV | II |
| 87 | Common Greenshank | *Tringa nebularia* | UN | LC | IV | II |
| 88 | Marsh Sandpiper | *Tringa stagnatilis* | UN | LC | IV | II |
| 89 | Wood Sandpiper | *Tringa glareola* | UN | LC | IV | II |
| 90 | Common Redshank | *Tringa totanus* | UN | LC | IV | II |
| | **Family: Turnicidae** | | | | | |
| 91 | Barred Buttonquail | *Turnix suscitator* | UN | LC | IV | |
| | **Family: Dromadidae** | | | | | |
| 92 | Crab-plover | *Dromas ardeola* | UN | LC | IV | II |
| | **Family: Glareolidae** | | | | | |
| 93 | Cream-coloured Courser | *Cursorius cursor* | C | LC | IV | |
| 94 | Indian Courser | *Cursorius coromandelicus* | C | LC | IV | |
| 95 | Small Pratincole | *Glareola lactea* | UN | LC | IV | |
| | **Family: Laridae** | | | | | |
| 96 | Slender-billed Gull | *Chroicocephalus genei* | C | LC | IV | II |
| 97 | Black-headed Gull | *Chroicocephalus ridibundus* | C | LC | IV | |
| 98 | Brown-headed Gull | *Chroicocephalus brunnicephalus* | C | LC | IV | |
| 99 | Pallas's Gull | *Ichthyaetus ichthyaetus* | C | LC | IV | |
| 100 | Caspian Gull | *Larus cachinnans* | C | LC | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| 101 | Lesser Black-backed Gull | *Larus fuscus* | C | LC | IV | |
| 102 | Little Tern | *Sternula albifrons* | UN | LC | IV | II |
| 103 | Gull-billed Tern | *Gelochelidon nilotica* | UN | LC | IV | |
| 104 | Caspian Tern | *Hydroprogne caspia* | UN | LC | IV | |
| 105 | Whiskered Tern | *Chlidonias hybrida* | UN | LC | IV | |
| 106 | Common Tern | *Sterna hirundo* | UN | LC | IV | |
| 107 | River Tern | *Sterna aurantia* | UN | VU | IV | |
| 108 | Lesser Crested Tern | *Thalasseus bengalensis* | UN | LC | IV | II |
| | **Order: Ciconiiformes** | | | | | |
| | **Family: Ciconiidae** | | | | | |
| 109 | Asian Openbill | *Anastomus oscitans* | C | LC | IV | |
| 110 | White Stork | *Ciconia ciconia* | C | LC | I | II |
| 111 | Black-necked Stork | *Ephippiorhynchus asiaticus* | C | NT | IV | |
| 112 | Painted Stork | *Mycteria leucocephala* | C | NT | IV | |
| | **Order: Suliformes** | | | | | |
| | **Family: Anhingidae** | | | | | |
| 113 | Oriental Darter | Anhinga melanogaster | C | NT | IV | |
| | **Family: Phalacrocoracidae** | | | | | |
| 114 | Little Cormorant | *Microcarbo niger* | C | LC | IV | |
| 115 | Great Cormorant | *Phalacrocorax carbo* | C | LC | IV | |
| 116 | Indian Cormorant | *Phalacrocorax fuscicollis* | C | LC | IV | |
| | **Order: Pelecaniformes** | | | | | |
| | **Family: Pelecanidae** | | | | | |
| 117 | Great White Pelican | *Pelecanus onocrotalus* | C | LC | IV | |
| 118 | Dalmatian Pelican | *Pelecanus crispus* | C | NT | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Ardeidae** | | | | | |
| 119 | Grey Heron | *Ardea cinerea* | C | LC | IV | |
| 120 | Purple Heron | *Ardea purpurea* | C | LC | IV | |
| 121 | Great Egret | *Ardea alba* | C | LC | IV | |
| 122 | Intermediate Egret | *Ardea intermedia* | C | LC | IV | |
| 123 | Little Egret | *Egretta garzetta* | C | LC | IV | |
| 124 | Western Reef Egret | *Egretta gularis* | C | LC | IV | |
| 125 | Cattle Egret | *Bubulcus ibis* | C | LC | IV | |
| 126 | Indian Pond Heron | *Ardeola grayii* | C | LC | IV | |
| 127 | Black-crowned Night Heron | *Nycticorax nycticorax* | C | LC | IV | |
| | **Family: Threskiornithidae** | | | | | |
| 128 | Glossy Ibis | *Plegadis falcinellus* | B | LC | IV | II |
| 129 | Black-headed Ibis | *Threskiornis melanocephalus* | B | NT | IV | |
| 130 | Red-naped Ibis | *Pseudibis papillosa* | B | LC | IV | |
| 131 | Eurasian Spoonbill | *Platalea leucorodia* | C | LC | I | II |
| | **Order: Accipitriformes** | | | | | |
| | **Family: Pandionidae** | | | | | |
| 132 | Osprey | *Pandion haliaetus* | B | LC | I | II |
| | **Family: Accipitridae** | | | | | |
| 133 | Black-winged Kite | *Elanus caeruleus* | E | LC | I | II |
| 134 | Egyptian Vulture | *Neophron percnopterus* | B | EN | IV | I |
| 135 | Oriental Honey Buzzard | *Pernis ptilorhynchus* | B | LC | I | II |
| 136 | Cinereous Vulture | *Aegypius monachus* | B | NT | IV | I |
| 137 | White-rumped Vulture | *Gyps bengalensis* | B | CE | I | I |
| 138 | Indian Vulture | *Gyps indicus* | B | CE | I | I |
| 139 | Short-toed Snake Eagle | *Circaetus gallicus* | B | LC | I | II |
| 140 | Indian Spotted Eagle | *Clanga hastata* | B | VU | I | II |
| 141 | Greater Spotted Eagle | *Clanga clanga* | B | VU | I | I |
| 142 | Booted Eagle | *Hieraaetus pennatus* | B | LC | I | II |
| 143 | Tawny Eagle | *Aquila rapax* | B | VU | I | II |
| 144 | Steppe Eagle | *Aquila nipalensis* | B | EN | I | I |
| 145 | Eastern Imperial Eagle | *Aquila heliaca* | B | VU | I | I |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| 146 | Bonelli's Eagle | *Aquila fasciata* | B | LC | I | II |
| 147 | White-eyed Buzzard | *Butastur teesa* | B | LC | I | II |
| 148 | Western Marsh Harrier | *Circus aeruginosus* | B | LC | I | II |
| 149 | Pallid Harrier | *Circus macrourus* | B | NT | I | II |
| 150 | Montagu's Harrier | *Circus pygargus* | B | LC | I | II |
| 151 | Shikra | *Accipiter badius* | E | LC | I | II |
| 152 | Eurasian Sparrowhawk | *Accipiter nisus* | E | LC | I | II |
| 153 | Black Kite | *Milvus migrans* | B | LC | I | II |
| 154 | Brahminy Kite | *Haliastur indus* | B | LC | I | II |
| 155 | Common Buzzard | *Buteo buteo* | B | LC | I | II |
| 156 | Long-legged Buzzard | *Buteo rufinus* | B | LC | I | II |
| | **Order: Strigiformes** | | | | | |
| | **Family: Strigidae** | | | | | |
| 157 | Indian Eagle Owl | *Bubo bengalensis* | B | LC | IV | |
| 158 | Spotted Owlet | *Athene brama* | E | LC | IV | |
| 159 | Short-eared Owl | *Asio flammeus* | B | LC | IV | |
| | **Order: Bucerotiformes** | | | | | |
| | **Family: Upupidae** | | | | | |
| 190 | Common Hoopoe | *Upupa epops* | UN | LC | IV | |
| | **Order: Coraciiformes** | | | | | |
| | **Family: Alcedinidae** | | | | | |
| 161 | Common Kingfisher | *Alcedo atthis* | UN | LC | IV | |
| 162 | White-throated Kingfisher | *Halcyon smyrnensis* | UN | LC | IV | |
| 163 | Pied Kingfisher | *Ceryle rudis* | UN | LC | IV | |
| | **Family: Meropidae** | | | | | |
| 164 | Green Bee-eater | *Merops orientalis* | UN | LC | IV | |
| 165 | Blue-cheeked Bee-eater | *Merops persicus* | UN | LC | IV | |
| 166 | Blue-tailed Bee-eater | *Merops philippinus* | UN | LC | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Coraciidae** | | | | | |
| 167 | European Roller | *Coracias garrulus* | E | LC | IV | I |
| 168 | Indian Roller | *Coracias benghalensis* | E | LC | IV | |
| | **Order: Piciformes** | | | | | |
| | **Family: Megalaimidae** | | | | | |
| 169 | Coppersmith Barbet | *Psilopogon haemacephalus* | UN | LC | IV | |
| | **Family: Picidae** | | | | | |
| 170 | Eurasian Wryneck | *Jynx torquilla* | UN | LC | IV | |
| | **Order: Falconiformes** | | | | | |
| | **Family: Falconidae** | | | | | |
| 171 | Common Kestrel | *Falco tinnunculus* | E | LC | IV | II |
| 172 | Red-necked Falcon | *Falco chicquera* | E | NT | I | II |
| 173 | Amur Falcon | *Falco amurensis* | E | LC | IV | II |
| 174 | Eurasian Hobby | *Falco subbuteo* | E | LC | IV | II |
| 175 | Laggar Falcon | *Falco jugger* | E | NT | I | II |
| 176 | Peregrine Falcon | *Falco peregrinus* | E | LC | I | II |
| | **Order: Psittaciformes** | | | | | |
| | **Family: Psittaculidae** | | | | | |
| 177 | Rose-ringed Parakeet | *Psittacula krameri* | UN | LC | IV | |
| | **Order: Passeriformes** | | | | | |
| | **Family: Campephagidae** | | | | | |
| 178 | White-bellied Minivet | *Pericrocotus erythropygius* | UN | LC | IV | |
| 179 | Small Minivet | *Pericrocotus cinnamomeus* | UN | LC | IV | |
| | **Family: Oriolidae** | | | | | |
| 180 | Indian Golden Oriole | *Oriolus kundoo* | UN | LC | IV | II |
| | **Family: Vangidae** | | | | | |
| 181 | Common Woodshrike | *Tephrodornis pondicerianus* | UN | LC | IV | II |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Aegithinidae** | | | | | |
| 182 | Common Iora | *Aegithina tiphia* | UN | LC | IV | |
| 183 | Marshall's Iora | *Aegithina nigrolutea* | UN | LC | IV | |
| | **Family: Dicruridae** | | | | | |
| 184 | Black Drongo | *Dicrurus macrocercus* | UN | LC | IV | |
| 185 | Ashy Drongo | *Dicrurus leucophaeus* | UN | LC | IV | |
| | **Family: Laniidae** | | | | | |
| 186 | Red-tailed Shrike | *Lanius phoenicuroides* | UN | LC | IV | |
| 187 | Isabelline Shrike | *Lanius isabellinus* | UN | LC | IV | |
| 188 | Brown Shrike | *Lanius cristatus* | UN | LC | IV | |
| 189 | Bay-backed Shrike | *Lanius vittatus* | UN | LC | IV | |
| 190 | Long-tailed Shrike | *Lanius schach* | UN | LC | IV | |
| 191 | Great Grey Shrike | *Lanius excubitor* | UN | LC | IV | |
| | **Family: Corvidae** | | | | | |
| 192 | Rufous Treepie | *Dendrocitta vagabunda* | | LC | IV | |
| 193 | House Crow | *Corvus splendens* | E | LC | V | |
| 194 | Large-billed Crow | *Corvus macrorhynchos* | E | LC | IV | |
| | **Family: Paridae** | | | | | |
| 195 | White-naped Tit | *Machlolophus nuchalis* | UN | VU | IV | |
| | **Family: Alaudidae** | | UN | | | |
| 196 | Greater Hoopoe Lark | *Alaemon alaudipes* | UN | LC | IV | |
| 197 | Rufous-tailed Lark | *Ammomanes phoenicura* | UN | LC | IV | |
| 198 | Ashy-crowned Sparrow Lark | *Eremopterix griseus* | UN | LC | IV | |
| 199 | Singing Bushlark | *Mirafra cantillans* | UN | LC | IV | |
| 200 | Indian Bushlark | *Mirafra erythroptera* | UN | LC | IV | |
| 201 | Greater Short-toed Lark | *Calandrella brachydactyla* | UN | LC | IV | |
| 202 | Sand Lark | *Alaudala raytal* | UN | LC | IV | |
| 203 | Oriental Skylark | *Alauda gulgula* | UN | LC | IV | |
| 204 | Crested Lark | *Galerida cristata* | UN | LC | IV | |

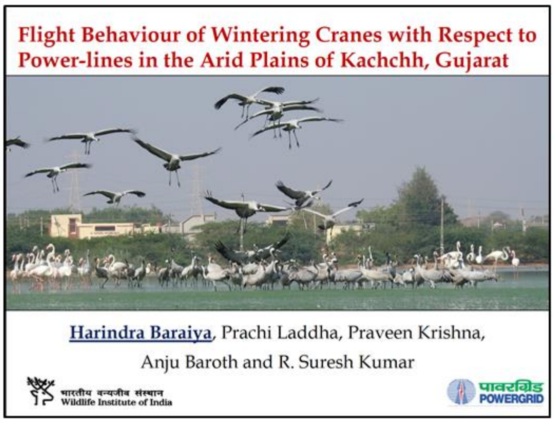
| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Cisticolidae** | | | | | |
| 205 | Common Tailorbird | *Orthotomus sutorius* | UN | LC | IV | II |
| 206 | Rufous-fronted Prinia | *Prinia buchanani* | UN | LC | IV | II |
| 207 | Grey-breasted Prinia | *Prinia hodgsonii* | UN | LC | IV | II |
| 208 | Ashy Prinia | *Prinia socialis* | UN | LC | IV | II |
| 209 | Plain Prinia | *Prinia inornata* | UN | LC | IV | II |
| 210 | Zitting Cisticola | *Cisticola juncidis* | UN | LC | IV | II |
| | **Family: Acrocephalidae** | | | | | |
| 211 | Booted Warbler | *Iduna caligata* | UN | LC | IV | II |
| 212 | Sykes's Warbler | *Iduna rama* | UN | LC | IV | II |
| 213 | Clamorous Reed Warbler | *Acrocephalus stentoreus* | UN | LC | IV | II |
| | **Family: Hirundinidae** | | | | | |
| 214 | Dusky Crag Martin | *Ptyonoprogne concolor* | UN | LC | IV | |
| 215 | Barn Swallow | *Hirundo rustica* | UN | LC | IV | |
| 216 | Wire-tailed Swallow | *Hirundo smithii* | UN | LC | IV | |
| 217 | Red-rumped Swallow | *Cecropis daurica* | UN | LC | IV | |
| 218 | Streak-throated Swallow | *Petrochelidon fluvicola* | UN | LC | IV | |
| | **Family: Pycnonotidae** | | | | | |
| 2019 | Red-vented Bulbul | *Pycnonotus cafer* | UN | LC | IV | |
| 220 | White-eared Bulbul | *Pycnonotus leucotis* | UN | LC | IV | |
| | **Family: Phylloscopidae** | | | | | |
| 221 | Common Chiffchaff | *Phylloscopus collybita* | UN | LC | IV | II |
| | **Family: Sylviidae** | | | | | |
| 222 | Lesser Whitethroat | *Curruca curruca* | UN | LC | IV | II |
| 223 | Eastern Orphean Warbler | *Curruca crassirostris* | UN | LC | IV | II |
| | **Family: Zosteropidae** | | | | | |
| 224 | Indian White-eye | *Zosterops palpebrosus* | UN | LC | IV | II |

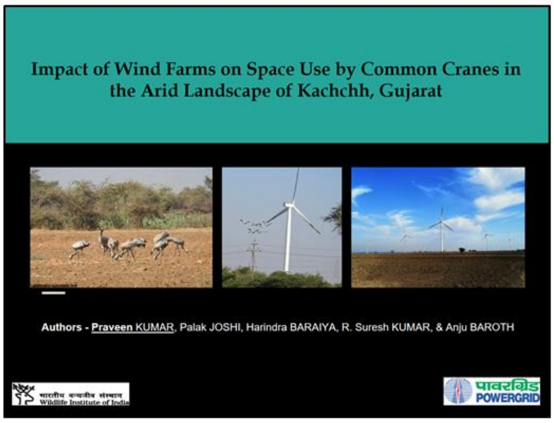
| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Leiothrichidae** | | | | | |
| 225 | Common Babbler | *Argya caudata* | UN | LC | IV | II |
| 226 | Large Grey Babbler | *Argya malcolmi* | UN | LC | IV | II |
| | **Family: Sturnidae** | | | | | |
| 227 | Rosy Starling | *Pastor roseus* | E | LC | IV | |
| 228 | Brahminy Starling | *Sturnia pagodarum* | E | LC | IV | |
| 229 | Common Myna | *Acridotheres tristis* | E | LC | IV | |
| 230 | Bank Myna | *Acridotheres ginginianus* | E | LC | IV | |
| | **Family: Muscicapidae** | | | | | |
| 231 | Rufous-tailed Scrub Robin | *Cercotrichas galactotes* | UN | LC | IV | II |
| 232 | Indian Robin | *Copsychus fulicatus* | UN | LC | IV | II |
| 233 | Oriental Magpie Robin | *Copsychus saularis* | UN | LC | IV | II |
| 234 | Bluethroat | *Luscinia svecica* | UN | LC | IV | II |
| 235 | Red-breasted Flycatcher | *Ficedula parva* | UN | LC | IV | II |
| 236 | Rufous-tailed Rock Thrush | *Monticola saxatilis* | UN | LC | IV | II |
| 237 | Blue Rock Thrush | *Monticola solitarius* | UN | LC | IV | II |
| 238 | Stoliczka's Bushchat | *Saxicola macrorhynchus* | UN | VU | IV | II |
| 239 | Siberian Stonechat | *Saxicola maurus* | UN | LC | IV | II |
| 240 | Pied Bushchat | *Saxicola caprata* | UN | LC | IV | II |
| 241 | Isabelline Wheatear | *Oenanthe isabellina* | UN | LC | IV | II |
| 242 | Desert Wheatear | *Oenanthe deserti* | UN | LC | IV | II |
| 243 | Brown Rock Chat | *Oenanthe fusca* | UN | LC | IV | II |
| 244 | Variable Wheatear | *Oenanthe picata* | UN | LC | IV | II |
| | **Family: Nectariniidae** | | | | | |
| 245 | Purple Sunbird | *Cinnyris asiaticus* | UN | LC | IV | |
| | **Family: Ploceidae** | | | | | |
| 246 | Streaked Weaver | *Ploceus manyar* | UN | LC | IV | |
| 247 | Baya Weaver | *Ploceus philippinus* | UN | LC | IV | |

| S. No. | English Name | Scientific Name | Risk | IUCN Category | WPA Schedule | CMS Appendix |
|---|---|---|---|---|---|---|
| | **Family: Estrildidae** | | | | | |
| 248 | Indian Silverbill | *Euodice malabarica* | UN | LC | IV | |
| | **Family: Passeridae** | | | | | |
| 249 | House Sparrow | *Passer domesticus* | UN | LC | IV | |
| | **Family: Motacillidae** | | | | | |
| 250 | Grey Wagtail | *Motacilla cinerea* | UN | LC | IV | II |
| 251 | Western Yellow Wagtail | *Motacilla flava* | UN | LC | IV | II |
| 252 | Citrine Wagtail | *Motacilla citreola* | UN | LC | IV | II |
| 253 | White-browed Wagtail | *Motacilla maderaspatensis* | UN | LC | IV | II |
| 254 | White Wagtail | *Motacilla alba* | UN | LC | IV | II |
| 255 | Paddyfield Pipit | *Anthus rufulus* | UN | LC | IV | II |
| 256 | Long-billed Pipit | *Anthus similis* | UN | LC | IV | II |
| 257 | Tawny Pipit | *Anthus campestris* | UN | LC | IV | II |
| | **Family: Emberizidae** | | | | | |
| 258 | Black-headed Bunting | *Emberiza melanocephala* | UN | LC | IV | |
| 259 | Red-headed Bunting | *Emberiza bruniceps* | UN | LC | IV | |
| 260 | Grey-necked Bunting | *Emberiza buchanani* | UN | LC | IV | |
| 261 | Striolated Bunting | *Emberiza striolata* | UN | LC | IV | |

## Annexure 2

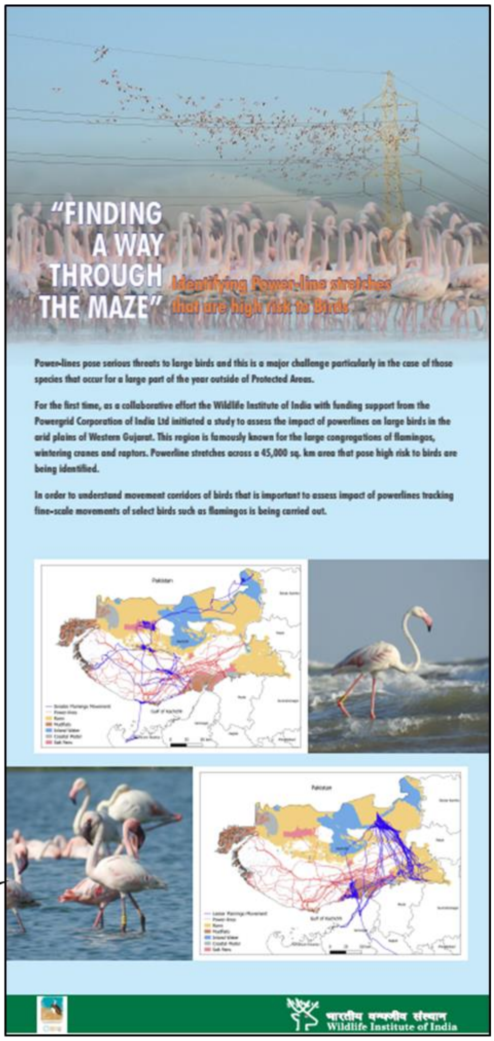
The findings of this project were presented in different national and international conferences/symposium/seminars in the form of oral presentations and posters as listed below:



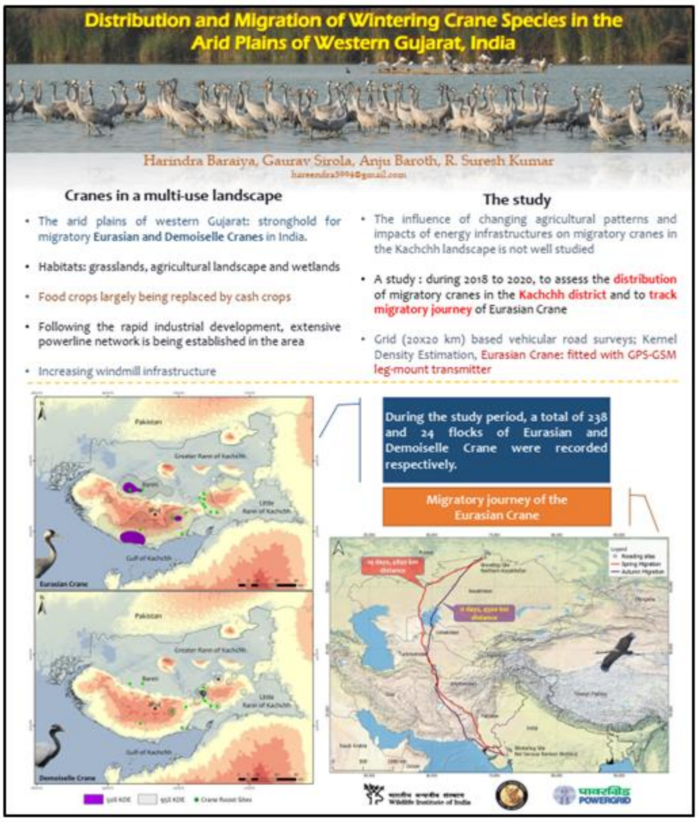



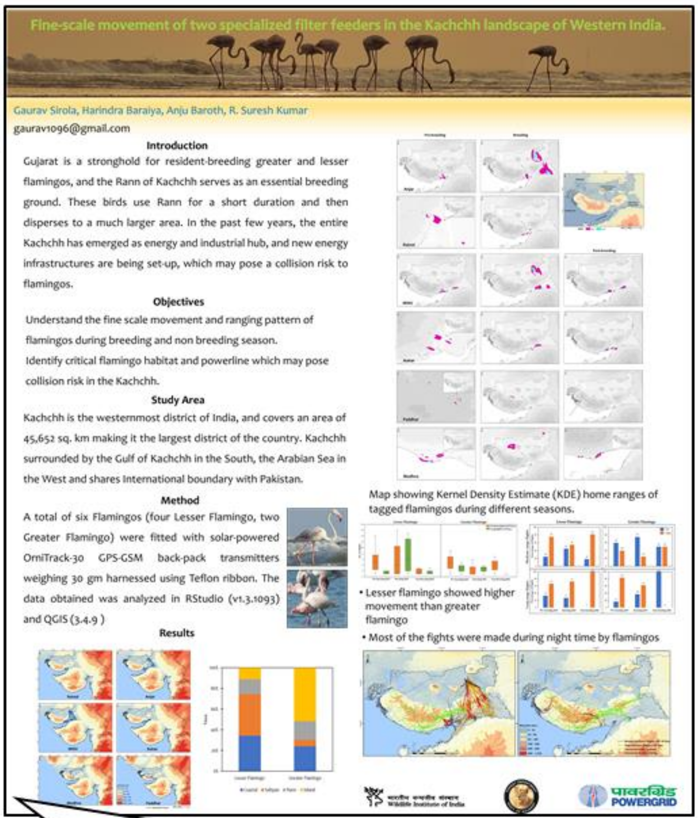

Two oral presentations were made at the 1st International Conservation Conference, Aligarh Muslim University and Wildlife Institute of India, Aligarh, Uttar Pradesh(October 21-23, 2019)


Oral talk presented at the International Conference on Wetlands and Migratory Waterbirds organized by Bombay Natural History Society, Mumbai(18-22 November, 2019)




Poster presented at CMS COP 13, Gandhinagar, Gujarat (17-22 February, 2020)




Two poster presentations were made at the National Symposium on Avian Biology, Department of Zoology and Environmental Science, Gurukul Kangari (Deemed to be University) (March 30-31, 2021, Haridwar)


Oral talk presented at the Waterbird Society 45th Annual Meeting, organized by Waterbird Society (8-12 November, 2019, Online)

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