HABITAT IMPROVEMENT AND CONSERVATION BREEDING OF

GREAT INDIAN BUSTARD

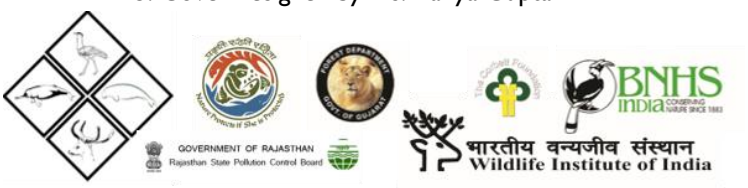
: AN INTEGRATED APPROACH



Annual Progress Report II
(March 2017 - April 2018)

Wildlife Institute of India

Project title:	**Habitat improvement and conservation breeding of the Great Indian Bustard: An Integrated Approach**
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Project report period:	March 2017 – April 2018
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Collaborating agencies:	(1) Bombay Natural History Society (2) The Corbett Foundation (3) Humane Society International
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Photo credits:	1. Cover page with GIB male in display © Anoop K.R. 2. Tagged GIB © Devesh Gadhavi 3. Mother GIB with chick © Dr. G.S. Bharadwaj 4. Three bustards at backdrop of development © Yogendra Shah 5. Cover designed by Ms. Tanya Gupta



Executive Summary

The Great Indian Bustard (GIB) is critically endangered with only about 100-150 individuals left in wild that need urgent recovery actions. The project "Habitat Improvement and Conservation Breeding Program of Great Indian Bustard" is a holistic and collaborative effort to aide in the species' recovery by a) securing a captive population as insurance, b) assessing where, how and what mitigation measures should be implemented, c) sensitizing stakeholders to garner public support and train agencies in conservation efforts, and d) develop pilot habitat management strategies.

The following progress has been made on these main components in 2017–18.

1. The project team travelled to various successful conservation breeding centers across India such as the Western Tragopan in Sarahan, Himachal Pradesh, Vulture Conservation Breeding Centre in Pinjore, Haryana, and to Houbara bustard breeding center in Abu Dhabi for exposure to breeding techniques. The Memorandum of Understanding (MoU) between Ministry of Environment, Forest and Climate Change (MoEFCC), Government of Rajasthan, and Wildlife Institute of India (WII) has been approved by Government of Rajasthan and communicated. Deliberations towards designing the facility has been commenced.
2. Under applied research component, the annual GIB survey was conducted in Thar (March 2017) and Maharashtra (October 2017), and additionally the Pokhran Field Firing Range was resurveyed in April 2018 with special permission from the Indian Army. Based on 3053 km surveys in 361 cells (36 sq km dimension) spread over 9252 sq km area (a subset of Thar landscape that encompasses recent distribution of GIB), we estimated the current population size to be 128 (SE 19) individuals. The survey in Maharashtra did not yield any GIB detection and population was estimated to be less than 8 birds (appendix 5). The national lesser florican survey was jointly conducted by the project team with partner agencies in July - September 2017 that yielded a conservative estimate of 264 male territories across the range; highlighting the critical status of this species. Two GIBs were radio-tagged in Kutch, out of which one died due to powerline collision, and the telemetry information is aiding in prioritizing powerlines (main threat) for mitigation. Carcass surveys under power lines in Thar showed mortality of three GIB, and an estimated death of ~1 lakh birds (all species) annually in the ~4000 sq km priority GIB habitat. Radio tagging of free-ranging dogs showed that an unsustainable 33% of chinkara population is cropped annually, and indicates potential negative impacts on the associated GIB. Behavioral

observations on GIB at the interface of anthropogenic disturbances are also been undertaken to inform management.

3. The social engagement aspect has seen our team visit several villages in Jaisalmer district to assess livelihood concerns and conservation attitude of the local population. We intend to involve the local population as stakeholders in GIB conservation to create goodwill, and these social surveys will help in developing outreach programs. Publicity materials such as brochures for power agencies and other stakeholders have been prepared and widely disseminated. The team met with representatives of power agencies as well as senior government officials to sensitize them on the critical issue of powerline mitigation for GIB conservation. Meetings with Rajasthan state government for institutionalizing the GIB conservation breeding program and local communities in Kutch were carried out.
4. The project has procured bird diverters for power lines and arranged their pilot implementation with the help of power agencies in Thar and is continuing advocacy to implement this action on a larger scale to prevent bird mortality. In consultation with the Director, Desert National Park, the Eco sensitive zone of Thar landscape was delineated and disseminated to Rajasthan Forest Department and National Green Tribunal for necessary actions. Free-ranging dog population assessment was carried out to understand the level of problem and sterilization programs to control their population have been planned with Humane Society International (HSI) and The Corbett Foundation (TCF) in the coming months. We also conducted training workshops on population, habitat and threat surveys involving Forest Department staff and volunteers in bustard range states, and additional training program on quantitative conservation methods for project staff and partner agencies in WII. This report provides a detailed description of our activities for the year 2017 - 2018.

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INTRODUCTION

1.1. PROJECT OBJECTIVES

1. CONSERVATION BREEDING
2. APPLIED RESEARCH
3. CAPACITY-BUILDING AND AWARENESS
4. PILOT IMPLEMENTATIONS FOR SURGICAL HABITAT MANAGEMENT

Chapter I – Introduction

The Great Indian Bustard *Ardeotis nigriceps* (hereafter GIB) is one of the rarest birds in the world. With ~150 individuals left, almost exclusively in India, the species is listed as Critically Endangered (IUCN 2011) and lies within Schedule I (the highest protection status) of the Wildlife (Protection) Act, 1972. Their populations have steadily declined by 75% in last 30 years and are facing imminent extinction risk unless serious management interventions are applied (Dutta et al. 2011). Historically, GIB was distributed throughout the western half of India, but, currently they are found in five fragmented pockets. According to our recent population assessment (Dutta et al. 2016), the largest population of 140±53 birds occurs in Thar landscape of Rajasthan (Desert National Park in Jaisalmer alongside Jodhpur). The other populations are <15 birds each, occurring in Gujarat (Lala-Naliya Sanctuary and its neighbourhood in Kachchh), Maharashtra (Bustard Sanctuary in Solapur, alongside Chandrapur and Nagpur), Andhra Pradesh (Rollapadu Sanctuary and its neighbourhood in Kurnool) and Karnataka (Bellary) (Dutta et al. 2011).

The species has declined due to compounding effects of direct and indirect human exploitation on their slow life-history traits. They were subjected to exhaustive hunting and egg collection in the past that reduced their population to ~1260 birds in 1969 (Dharmakumarsinhji 1971). However, their contemporary decline is largely due to prevailing habitat loss as dry grasslands have been marginalized as 'unproductive wastelands' and progressively converted to other land uses since colonial times. Recent developments in irrigation and farming technologies have intensified agriculture in bustard habitats and changed cropping practices from seasonal to year-round, intensive crops. This change has led to food scarcity for bustards, pesticide contamination, and habitat loss. Development activities like infrastructural growth (electricity, road and irrigation networks), industries, power projects, and wind turbines have caused severe habitat degradation and disturbance to birds. Being low and heavy flyers, they face a high risk of fatal collisions with power-lines, which are difficult to detect from afar. Populations of free-ranging dogs have increased in bustard habitats, and along with native predators (fox, mongooses, and cats), they have increased predation pressure on nests and chicks and reduced recruitment. Past efforts of banning human activities to create bustard Sanctuaries over large human-use landscapes, without appropriate settlement of land rights, have generated bitterness among local people, leading to lack of conservation support. These factors have in turn caused local extinctions from some Sanctuaries. Local people and managers are not sufficiently aware of the conservation benefits of grasslands and the scientific ways to manage them. Whereas, traditional ways to manage these habitats are eroding due to rapid socio-ecological changes driven by state policies (Dutta et al. 2013). Although most remaining breeding habitats are protected to some level, vast movements of bustards expose them to the threats mentioned above in the non-breeding habitats, defeating the purpose of protecting small breeding reserves. Since these large bustard landscapes cannot be freed from human uses, a mixed approach of Protected Area based conservation of breeding habitats and coexistence with compatible human land uses by mitigating survival threats in adjoining landscapes best suits the situation.

Our team liaised with the Commanding Officer of the Indian Army and was granted a special permission for the year 2017 - 2018 to access the Pokhran Field Firing Range (PFFR) to survey. This official survey informed our efforts greatly. The PFFR has stretches of untouched grasslands that are critical for bustards. The lack of substantial human interference lends this area to be the most conducive to GIB proliferation. We hope that in the future we will continue the positive relationship with the Armed Forces and with their cooperation be able to survey more of the range and in close detail. With a total area of close to

3000 sq km, the range offers a valuable insight into the last remnants of the species as well as to serve as an iconic representation of what grasslands look like in India.

Effective conservation of bustard habitats would require information on species' ranging patterns, relative magnitudes and distribution of threats, and ways to reconcile species' ecological needs and livelihood concerns that are poorly known. Furthermore, management authorities in many areas exhibit poor enforcement ability due to inadequate staff and infrastructure, lack of motivation, and inaccessibility. Concerned about the extinction crisis of GIB, Indian conservation circles have proposed strategic recovery plans for the species as a flagship of dry grasslands. The National Guidelines for Bustard Recovery Plans developed by Ministry of Environment, Forest and Climate Change (Dutta et al. 2013) strongly recommend filling research gaps, mitigating threats, improving habitat, improving enforcement capacity, and engaging communities in conservation. However, the implementation of *in situ* conservation measures require some gestation time, but, the population size of GIB (with no birds in captivity) is too small to sustain such delays. Thus, a captive population needs to be secured for supplementing wild populations and reintroducing birds into restored habitats in favourable times.

This project aims at integrating all these components into a holistic conservation plan for the priority bustard landscapes of Rajasthan, Gujarat, and Maharashtra. The proposed activities will be undertaken in collaboration with State Governments, local NGOs, and research organizations so as to pool knowledge/expertise and ensure timely and effective implementation. Since both the endangered bustards of dry grasslands – GIB and lesser florican (*Sypheotides indicus*) – share some habitats, these activities will supplement and complement each other's needs. By doing so, habitats that support a plethora of other endangered wildlife, such as the spiny-tailed lizard *Saara hardwickii*, chinkara *Gazella bennettii*, foxes *Vulpes* spp, wolf *Canis lupus* pallipes, caracal *Caracal* caracal and blackbuck *Antelope cervicapra* will be restored.

1.1. Project objectives

The broad goals and objectives of this project are as follows:

1. **Conservation Breeding**

   Developing and running Conservation Breeding Centre to secure captive populations of GIB and (if needed) lesser florican as insurance against extinction and (if possible) subsequent reintroduction/supplementation into restored habitats.

2. **Applied research**

   Undertaking targeted research for:

   a) Prioritizing conservation areas,

   b) Characterizing threats,

   c) Monitoring populations and habitats to assess the effectiveness of management actions,

   d) Assessing local communities' livelihood concerns and willingness to adopt bustard-friendly land uses,

   e) Comprehensive understanding of population genetics to inform conservation management

3. **Capacity-building and awareness**
    a) Improving protection enforcement through training of Forest staff and implementation of technology aided patrolling,
    b) sensitizing decision-makers, managers and local communities on bustard conservation,
    c) raising public awareness and support for bustard conservation through awareness materials,
    d) Incentivizing local land users to adopt bustard-friendly land uses
4. **Pilot implementations for surgical habitat management**

    Demonstrating best practices for habitat improvement through pilot/experimental surgical interventions that will be subsequently replicated by State Forest Departments.



Image 1 - View of typical Thar Desert landscape © Tanya Gupta



PROJECT ACTIVITIES

2.1. CONSERVATION BREEDING
2.2. APPLIED RESEARCH
2.3. CAPACITY-BUILDING AND OUTREACH
2.4. PILOT IMPLEMENTATIONS FOR SURGICAL HABITAT MANAGEMENT

Chapter 2 - Project activities

2.1. Conservation breeding

1. A Project Scientist, project veterinarian and a project associate were recruited for conservation breeding programme of GIB in October 2017.
2. Meetings to operationalize GIB conservation breeding program. To involve appropriate consultation and expert technical support in *ex-situ* conservation actions for GIB, the Project Investigator corresponded with national and international bustard scientists and captive breeders. These meetings significantly aided in informing future.
3. Dr. Sutirtha Dutta, co-investigator of the Bustard Conservation Project visited the Houbara Bustard Breeding Centre at Saih Al Salam (SAS) in United Arab Emirates on 28 April 2018 (Fig 1). The objective of the visit was to gain better understanding of the bustard breeding processes that will aide in developing the Indian bustard breeding facility. A report of this visit is attached in the appendix 1.



Figure 1 - Dr. Sutirtha Dutta along with experts from the IFHC Houbara Breeding Center in Abu Dhabi, April 2018 © WII photo library

4. The staff of the conservation breeding programme visited the Vulture Conservation Breeding Centre (VCBC), Pinjore, Haryana in January and had a meeting with Dr. Vibhu Prakash, Deputy Director, BNHS and in-Charge of vulture programme and Mrs. Nikita Prakash, Avian Egg Incubation Expert. Management protocols, egg incubation protocols along with enclosure designs were discussed with VCBC staff. The project staff had a tour of the VCBC facility to understand the requirement of long term conservation breeding programme.
5. The conservation breeding staff had a meeting in November 2017 with Dr. Sushil Sood, Veterinary Officer at Department of Forest Farming and Conservation, Kufri, Himachal Pradesh. Discussions on viable breeding options of the GIB, specifically the assisted reproduction of the species in the future along with other assisted reproduction programs and their success were discussed. The

staff also interacted with Dr. Laxminarasimha, Biologist (Forest Department) and Head of the Western Tragopan Pheasantry and Breeding Centre, Sarahan, Himachal Pradesh. Enclosure designing, incubation techniques and husbandry techniques implemented in their centre were discussed.

6. Project representatives engaged in dialogue with Dr. GV Reddy, APCCF and Chief Wildlife Warden of Rajasthan in February 2018 to assist in the smooth movement of the approval for the Memorandum of Understanding (MoU) to begin construction of the Bustard Conservation Breeding Centre and implementation of the collaborative breeding programme. The team also met Mr. Yogendra Kumar Dak, Secretary to the Ministry of Environment and Forest, Rajasthan with respect to expediting the MoU. The present situation of the understanding between the parties is that of an agreement, indicating next steps that include the construction of the conservation breeding centre at an appropriate location. Subsequently, we received the MoU vetted by Rajasthan Government in June 2018.
7. In March 2018, we hosted Dr. Juan Carlos Alonso who is a collaborator in this project from the National Museum of Natural Sciences, Spanish Council for Scientific Research and gave a talk on "Sexual selection and its biological consequences in Great Bustards" in WII (Fig 2).
8. The conservation breeding staff compiled a review of literature and synthesized documents of bustard care and husbandry within the context of Great Indian Bustard Captive Breeding and Management as well as one describing the potential diseases to be managed (see appendix).
9. An egg hatching incubator and a chick brooder including accessories such as a humidifying machine were purchased by the team. We shall begin experimental egg hatching of Specific Pathogen Free (SPF) eggs soon to establish a running protocol for the future when bustard eggs will be hatched.
10. Drafts of egg incubation protocol and plan for conservation breeding centre have been developed which will be updated after receiving inputs from concerned subject experts. These will also be informed internally based on the experience of the project team.



Figure 2 - Dr. Juan Carlos Alonso while giving a talk on "Sexual selection and its biological consequences in Great Bustards" at WII © Sujit Narwade

2.2. Applied research

2.2.1. Population and habitat surveys

2.2.1.1. Status assessment of GIB, associated fauna and habitat in Thar

Since 2014, Wildlife Institute of India and Rajasthan Forest Department have been conducting joint surveys to understand the current status, distribution patterns, and local contexts of key conservation-dependent species in Thar to develop scientific management plan. This report contains findings of the 2017 survey and focuses on recent spatio-temporal trends in the population of key species, the habitat and threats. Persistence of GIB critically depends on Thar, where ~75 % of the global population resides.

The project team assessed the status of native and conservation-dependent species such as the GIB, chinkara and desert fox. Non-native and 'problem' species such as free-ranging dogs, pigs and Nilgai (*Boselaphus tragocamelus*) that live alongside the habitat of the GIB, in addition to anthropogenic pressures across 19,728 sq km of potential bustard landscape in Thar spanning Jaisalmer, Jodhpur and small parts of Bikaner and Barmer districts of Rajasthan were also assessed. Systematic surveys were conducted in 144 sq km cells from slow-moving vehicle along $29.2 \pm 8.0_{SD}$ km transects to record species detections, habitat characteristics in sampling plots, and secondary information on species occurrences (Fig 3). Multiple teams comprising field biologists and Forest Department staff simultaneously and rapidly sampled 121 cells along 3529 km transects (extensive surveys) with additional 635 km transects in five GIB occupied cells (intensive surveys). Extensive surveys provide information on bustard occurrence across the landscape and intensive surveys provide information on bustard density in occupied cells. Additionally, extensive surveys provide information on abundance of associated species. Great Indian bustard and other key species detection data were analysed in Occupancy (McKenzie et al 2006) and Distance Sampling (Thomas et al 2010) framework to estimate proportion of sites occupied and density/abundance.

During the last four surveys, 38 (2014), 40 (2015), 37 (2016) and 37 (2017) great Indian bustards were detected. Their detection/non-detection in 2-km transect segments (spatial surveys) across cells (2017) showed that $6.7 \pm 2.9_{SE}$ % of sites were occupied (naive occupancy 5%). Bird density was estimated at $0.48 \pm 0.10_{SE}$ /100 sq km across all sites and $7.49 \pm 1.63_{SE}$ /100 sq km in used sites (cells where at least one bird was detected during 2017). Abundance was estimated at $95 \pm 21_{SE}$ individuals in the 19728 sq km landscape, pooling data across 2016-17 (Table 1, Figs 6 & 7). The current abundance estimate was lower than the past estimate ($140 \pm 53_{SE}$ in 2015-16); this could be partly due to inadequate intensive surveys in high-density sites within the Field Firing Range (Fig 4). Hence, Wildlife Institute of India's great Indian bustard conservation project team conducted follow-up distance based line transect surveys in the subset of landscape where the species is distributed (western Thar: 4068 km^2 area, and Pokhran Field Firing Range: 5184 km^2 area) jointly with Indian Armed Forces in March–April 2018, to refine the past estimate. Based on these surveys, abundance was estimated at $128 \pm 19_{SE}$ individuals in 9252 km^2 great Indian bustard distribution area in Thar. But, there might be a real decline in numbers, as comparison of species' encounter rate across years, keeping sampled sites constant, indicated a non-significant but declining trend between 2014-15 ($1.00 \pm 0.41_{SE}$ /100km) and 2016-17 ($0.83 \pm 0.30_{SE}$ /100km). Additional ancillary information based on power-line carcass surveys (2 mortalities in 20 km high-tension power-lines surveyed seven times) indicated that about 18 birds were expected to have died because of the 152 km high-tension lines distributed across bustard occupied sites.

Chinkara was found in 89 % of sites and its density at landscape-scale was estimated at $205 \pm 14_{SE}$ animals/100 sq km, yielding abundance of $40{,}442 \pm 2811_{SE}$ in 19,728 sq km landscape (2017). Desert fox was found in 41 % of sites, at densities of $15.03 \pm 2.39_{SE}$ /100sq km, and abundance of $2965 \pm 471_{SE}$ individuals in 19,728 sq km landscape (Figs 5-7 & Table 1).

Our threat surveys showed anthropogenic expansion across survey years, wherein the proportion of sampling plots with water source, power-lines, farm-huts and wind turbines had increased annually by 0.12, 0.09. 0.07, and 0.03, respectively, over the last three years. Correspondingly, population of free-ranging dogs showed a remarkable expansion over these years, wherein the proportion of sites occupied increased from $0.15 \pm 0.04_{SE}$ (2014) to $0.61 \pm 0.09_{SE}$ (2017), and their encounter rate increased from $4.32 \pm 1.77_{SE}$ to $23.11 \pm 9.39_{SE}$ /100km in sites that were monitored across all years.

Our study provides robust abundance estimates of key native / conservation dependent as well as non-native / 'problem' species in Thar. It provides recent trends of species' distribution and abundance vis-à-vis habitat and threat intensity across space and time, to alarm managers about the changing dimensions of Thar landscape and guide site-specific management and policy. The expansion of power-lines and the expected mortality rate of bustards is unsustainable given that this population cannot sustain human-induced death of >2 birds/yr. (see Dutta *et al.* 2011). This survey captured snapshots of GIB distribution that needs to be augmented with satellite telemetry-based information on seasonal landscape use to mitigate threats.

Based on our results and from field knowledge, we strongly recommend:

a) Expeditiously mitigating power-lines by undergrounding all lines within high priority areas (this is the only fool proof measure for conserving the great Indian bustard), and marking lines with bird diverters in medium priority areas,
b) b)Improving great Indian bustard recruitment in existing enclosures using predator-proof-fences and nest-predator removal,
c) Creating more enclosures or conservation/community reserves in priority conservation cells,
d) Smart and intensive patrolling to control poaching and generate management information,
e) Targeted research to understand local ecology of great Indian bustard, characterize threats, and ranging patterns,
f) Balancing local livelihood concerns with conservation goals through social research and incentivized bustard-friendly land-uses, and
g) Engaging local communities to monitor and protect wildlife through outreach and incentive programs.

A detailed report of the great Indian bustard status assessment in Thar is available as appendix 2.

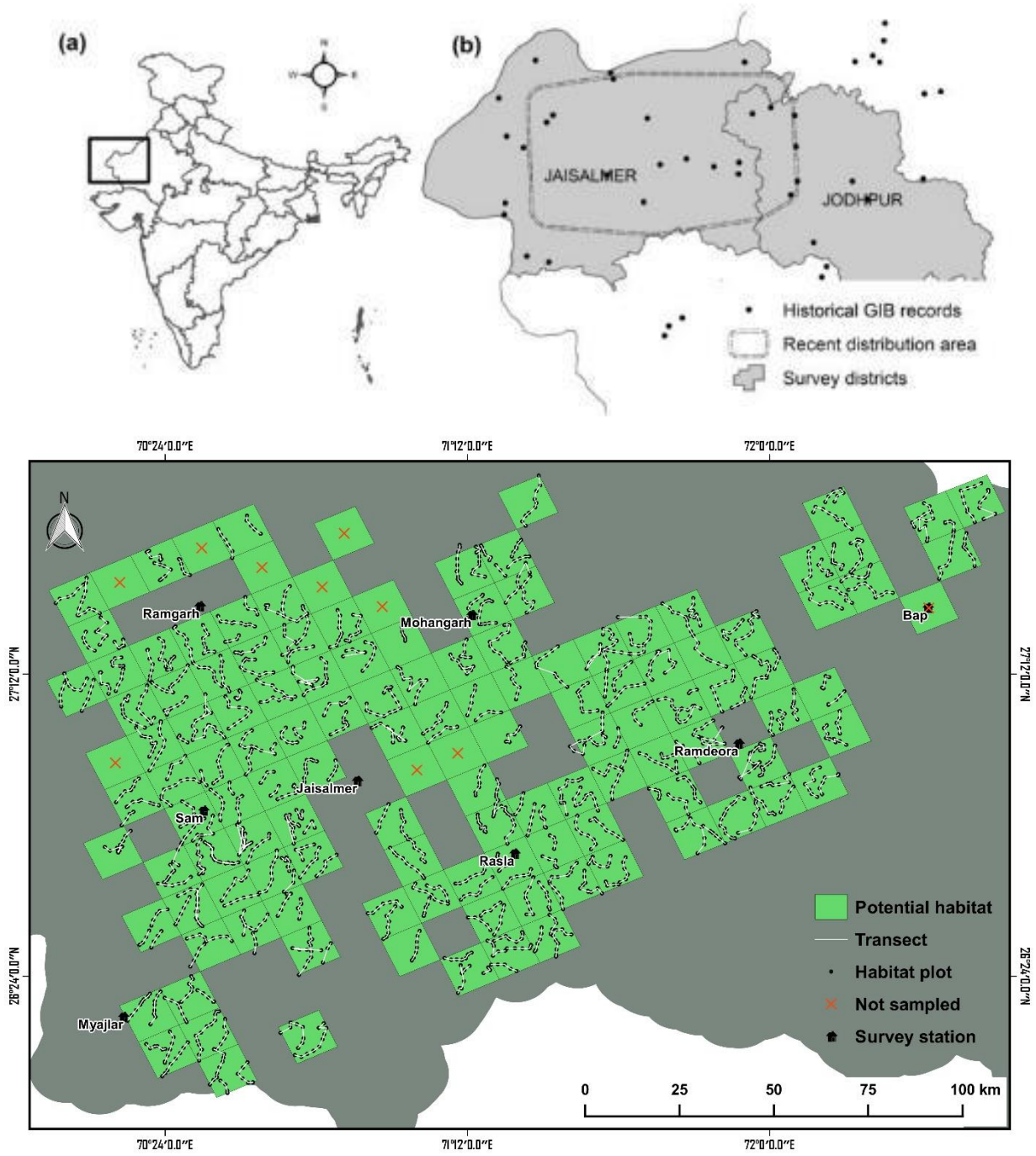


Figure 3 - Sampling design for Great Indian Bustard, associated species and habitat assessment in Thar landscape: location of study area (a); delineation of bustard landscape from existing information on species' occurrence; and (c) survey efforts in 2017

Table 1 - Population status of Great Indian Bustard and associated native fauna of Thar landscape during 2017

Species	***Trn***	***Eff***	***Obs***	$\widehat{ESW}$	$\widehat{D}$ **(# km^{-2})**	$\widehat{\psi}$	$\widehat{\psi}.A$	$\widehat{N}$
Great Indian Bustard (2016-17) *A. nigriceps*	575 158*	7493 1846*	65	401 (24)	0.005 (0.001) 0.075 (0.016)*	0.067 (0.029)	1322	95 (21) 97 (48)*
Chinkara (2017) *G. bennettii*	293	3583	1036	169 (7)	2.05 (0.14)	0.79 (0.04)	15625	40442 (2810)
Desert fox (2017) *V. vulpes pussilla*	293	3583	77	82 (9)	0.150 (0.024)	0.68 (0.13)	13415	2965 (471)

Trn = Number of transects/trails sampled
Eff = Total length of transects/trails, or efforts in kilometers
Obs = Number of individuals detected on transects/trails
$\widehat{ESW}$ = Mean (SE) Effective Strip Width in meters, indicating the distance from the transect within which you effectively detect birds (see ref)
$\widehat{D}$ = Mean (SE) density of birds in numbers km^{-2}, representative of the entire Thar landscape.
$\widehat{N}$ = Mean (SE) Number of individuals in the landscape (19,728 km^2) or abundance
$\widehat{\psi}$ = Mean (SE) occupancy probability, or proportion of cells (144 km^2) occupied by the species, correcting for imperfect detection
$\hat{p}$ = Mean (SE) species detection probability, or the probability of detecting the species in a survey if it is present in the cell
$\widehat{\psi.A}$ = Occupied area, estimated as the product of landscape area (19,728 km^2) and occupancy probability
Values marked as (*) are representative of seven (07) cells that were occupied by Great Indian Bustard



Image 2 GIB does not know geographical boundaries © Sujit Narwade

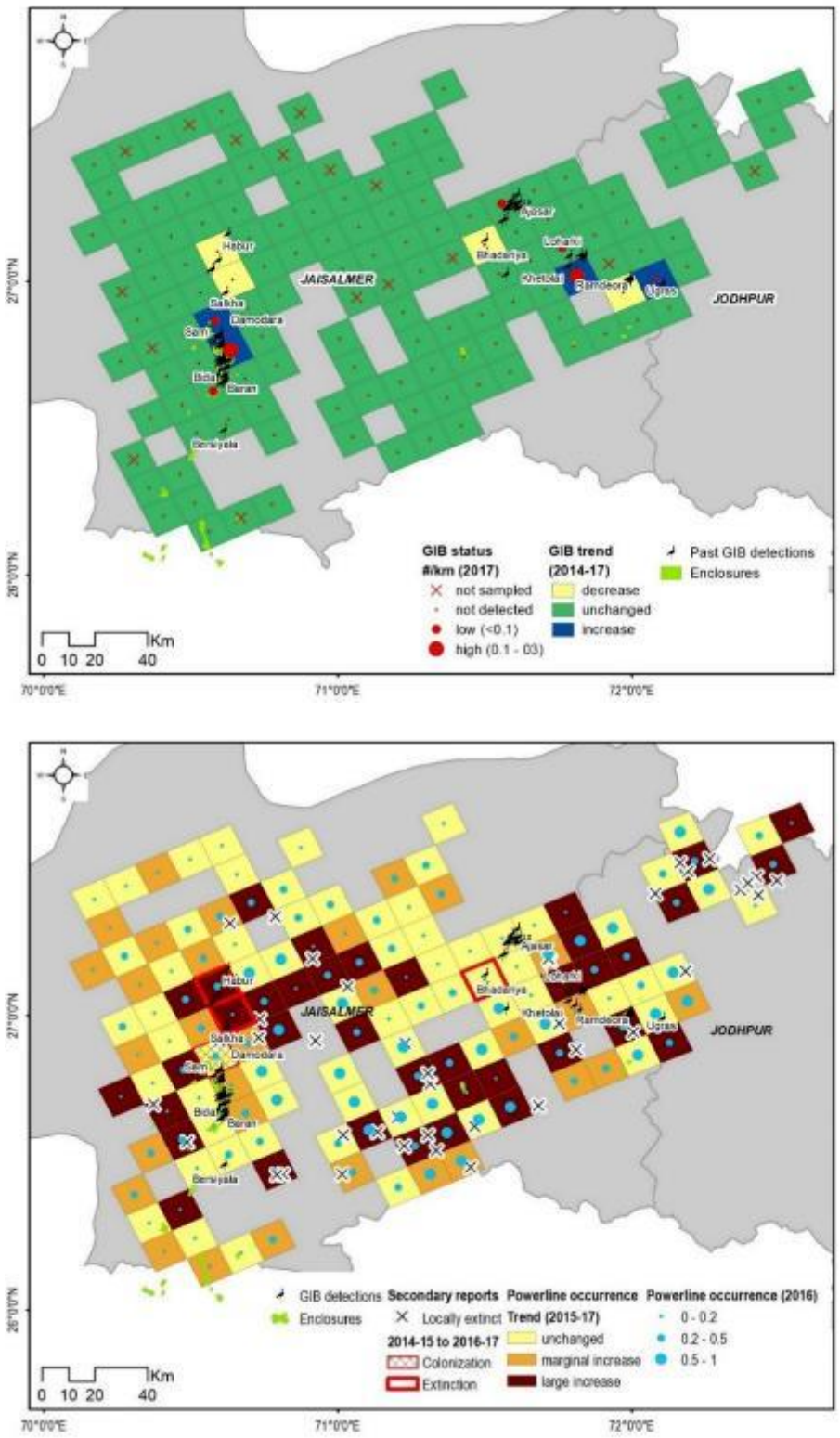


Figure 4 - Status, distribution and trend of Great Indian Bustard population (top) against the distribution and trend of power-line networks (bottom) in Thar landscape (2014-17)

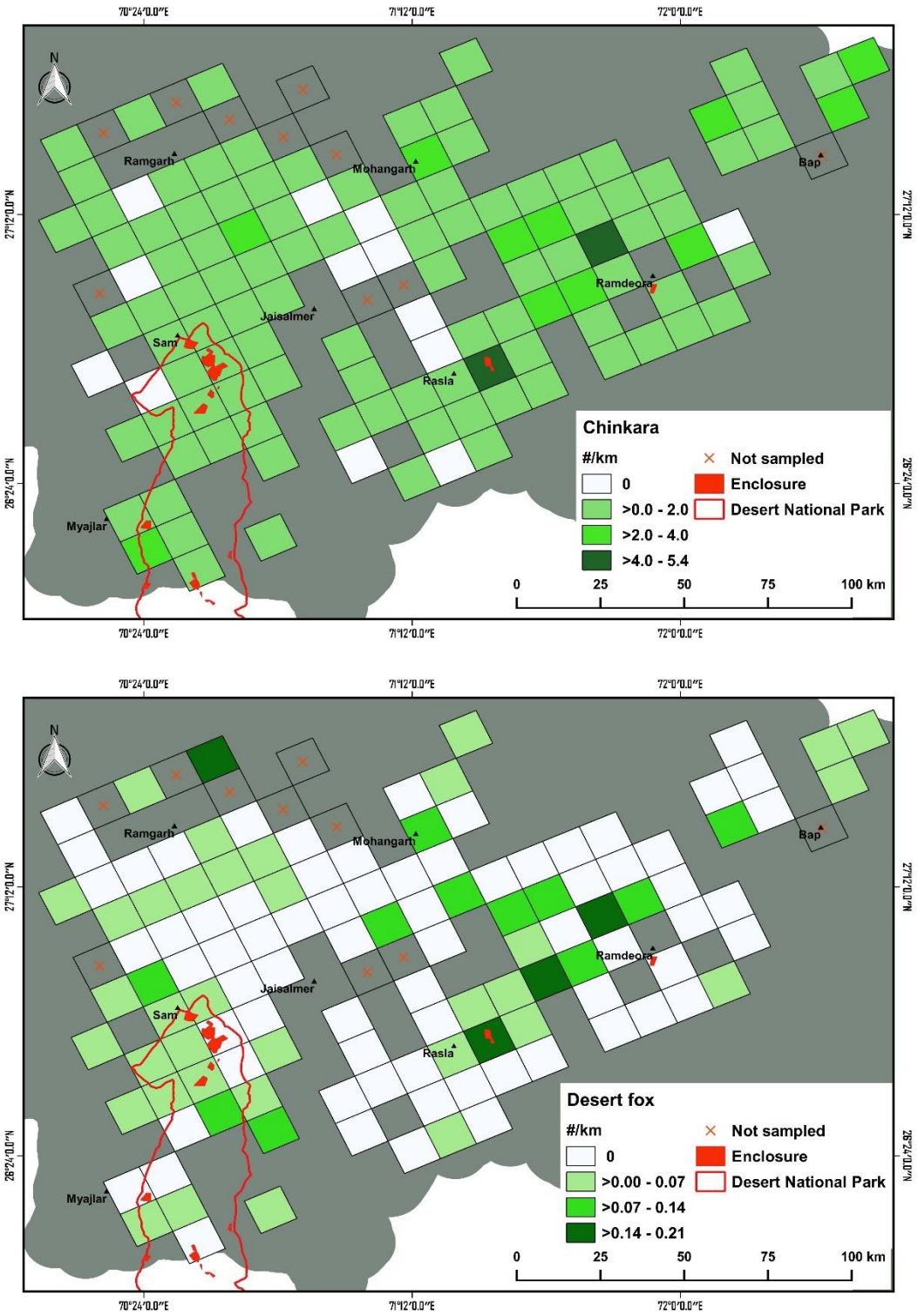


Figure 5 - Status and distribution of key species associated with Great Indian Bustard in Thar landscape (2017)

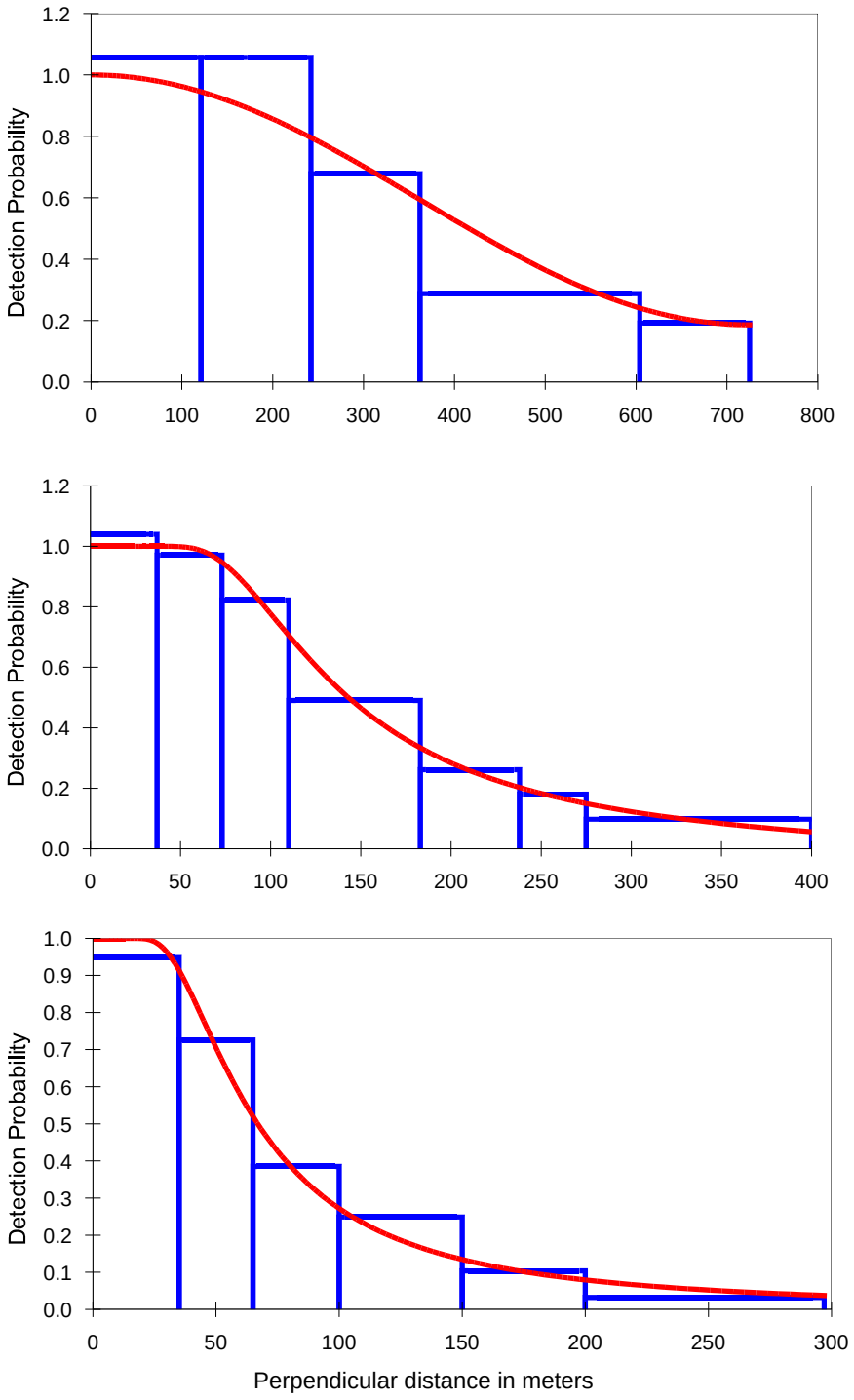


Figure 6 - Detection function (probability of detecting an animal along distance from transect) of Great Indian Bustard (top), Chinkara (center) and Fox (bottom) in Thar landscape during 2017

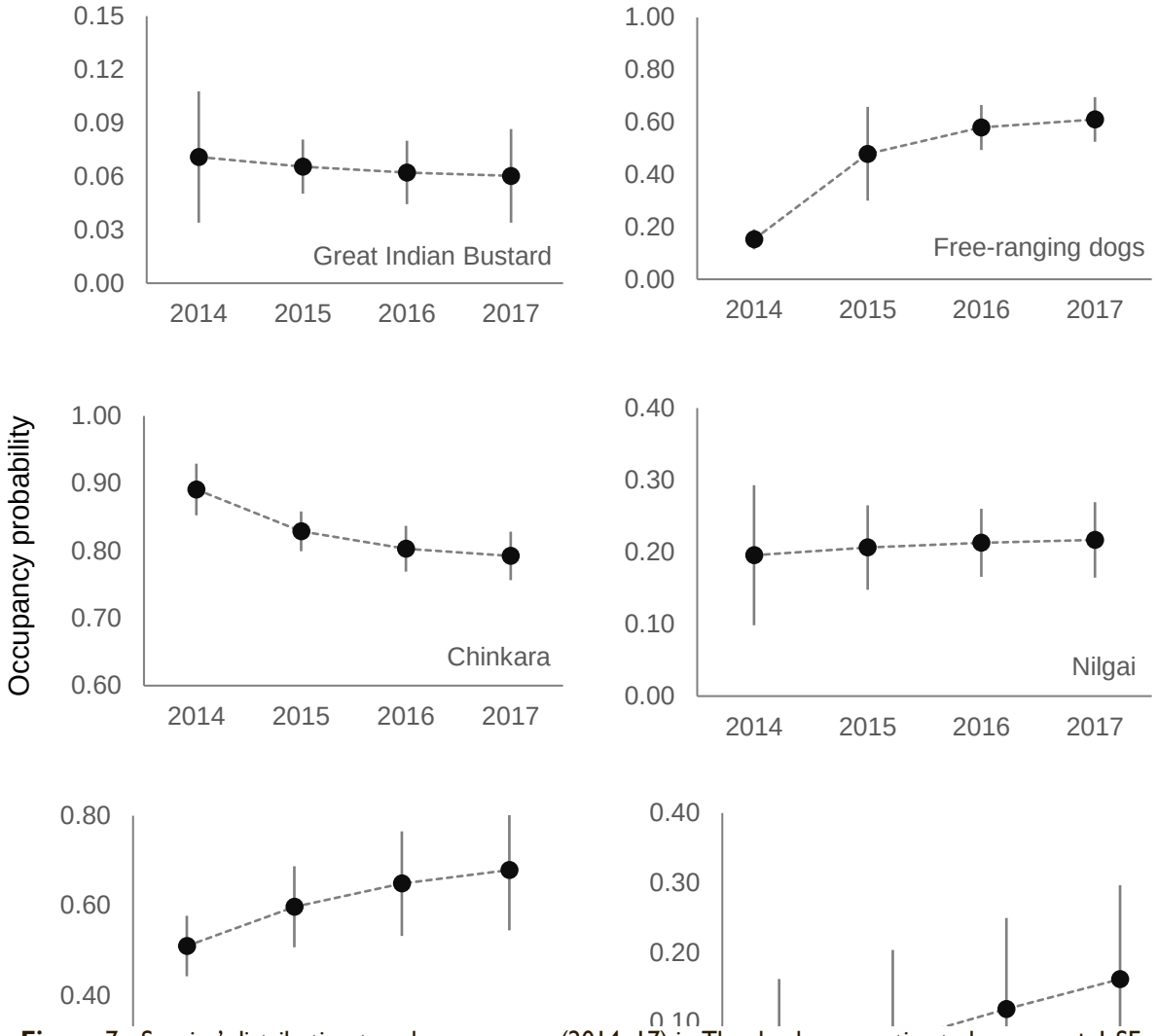


Figure 7 - Species' distribution trend across years (2014–17) in Thar landscape, estimated as mean + 1 SE proportion of sites occupied using dynamic occupancy models, for native / 'important' (left) and non-native / 'problem' species (right)

2.2.1.2 National Lesser Florican Status Assessment

Lesser Florican (*Sypheotides indicus*) is an endangered agro-grassland bird whose ecology and status are poorly known that impedes conservation efforts. To fill this gap, a national status survey was designed by the Endangered Species Recovery Program (ESRP) of Wildlife Institute of India and was jointly implemented with Bombay Natural History Society (BNHS), The Corbett Foundation (TCF) and State Forest Departments across the species' breeding range. This report documents the methodology of this exercise, and presents its findings on lesser florican's distribution, abundance, habitat characteristics, threats and their implications for conservation.

We delineated the lesser florican's breeding range using informed digitization with the aid of Maxent species' distribution model (that analyses species' presence locations against environmental covariates to generate habitat suitability map, see Elith et al 2010), and inputs from local experts. We assessed the species' status based on displaying males, using spatially representative sampling and analytical design that accounted for imperfect detection. Our assessment used hurdle modelling approach, where we: a) first estimated the species' occupancy in 36 sq km cells using vehicle observation points (stop-overs), and b) estimated the species' abundance at detected sites (subset of occupied sites) using line transect distance sampling. c) We quantified habitat characteristics (land cover, vegetation structure and anthropogenic pressures) systematically along occupancy and distance surveys. d) We explored and developed statistical relationships between habitat covariates and occupancy/abundance. e) We mapped the species' distribution, local densities and threats, to generate a conservation priority map. We drew inferences at the scale of breeding range and eco-geographically defined regions and landscapes (Ajmer: Shokaliya-Kekri; Rajasthan rest: Shahpura, Jalore, Pratapgarh; Gujarat: Kutch, Saurashtra; Madhya Pradesh: Ratlam; Maharashtra: Akola-Washim).

The status survey was conducted during the breeding season (July–September, 2017) with a team of 121 observers, who were trained on the standard data collection protocol through state-level workshops at Bhavnagar, Ujjain, Ajmer and Akola. Lesser florican occupancy was assessed at 428 sites (36 sq km) spread across ~20,000 sq km range, using 5400 stop-overs, and density was assessed in 32 sites (where the species was detected) using 488 km transect-walks that yielded 70 sightings (64 males, 6 females) in 218 transects (table 2).

Lesser florican occupied 13+3SE % sites or 1908 sq km area, at ecological density of 0.25+0.06SE territorial males sq km. The population size was estimated to be 340 (162–597, 95%CI) territorial males, with a conservative estimate of 264 individuals that indicates ~80% population decline in last 3–4 generations (since 2000). Regional assessments indicated that the population was largely restricted to: Velavadar (Bhavnagar, Gujarat) having 96–115 territorial males and Shokaliya-Bhinai (Ajmer, Rajasthan) having 110–136 territorial males. The species' response to habitat exhibited regional plasticity, with occupancy favoured by grassland cover in Gujarat, and by agricultural cover in Ajmer (Fig 9). However, density in occupied sites was an increasing function of grassland cover, indicating that males congregated in large contiguous grasslands. Birds were dispersed over a large agricultural expanse at low density in Ajmer (~800 sq km) and clustered at high density in a small grassland reserve in Bhavnagar (~100 sq km). This inverse density-occupancy relationship perhaps resulted from their flexible social/spatial organization, implying that, a contiguous grassland would achieve the same conservation outcome as a much larger agricultural area would. Finally, we prioritized sites and quantified threat levels across landscapes and regions (Figs 8 & Figs 10-16), to guide conservation investments.

Our methodology for estimating lesser florican numbers assumes that expected abundance at occupied sites where species was not detected (but present) was similar to that where species was detected. If this assumption is violated (which is likely when the species is missed in sites with fewer than average individuals) then the estimated global population size will be positively biased. To avoid

this issue, we emphasize on the 'minimum population size' of 264 individuals as a conservative estimate of the population.

We also developed conservation recommendations for each landscape (see 2.2.1.2.1in Annexure- National Lesser Florican Status Report) to guide species' recovery actions, based on prior knowledge (Dutta et al. 2013) and our collective observations. Highlighting that lesser florican population might have dwindled by ~80% over last 3–4 generations, we call for immediate scaling up of efforts for the species' conservation. The priority sites for conservation actions are Shokaliya and Saurashtra landscapes followed by Kutch and Kekri landscapes, followed by Ratlam, Shahpura and Akola landscapes.

Our key recommendations for priority sites (see 2.2.1.2.1 in Annexure- National Lesser Florican Status Report for further details) are to:

1. provide protection to priority lesser florican sites by creating conservation areas and implementing strict patrolling by Forest Department and local communities,
2. regulating intensive land uses such as infrastructural, industrial and salt pan developments, and mitigation of existing infrastructure such as power-lines,
3. implementing scientific grasslands management by consolidating relatively large contiguous grasslands, restricting livestock grazing for monsoon months (June–September), restoring habitats by removing exotic shrub/tree plantations,
4. incentivizing florican-friendly agricultural practices by promoting scattered organic farming and stall-feeding of livestock in monsoon months against compensations,
5. consolidation networks of local people or 'florican friends' who can report and prevent detrimental activities,
6. reducing nest/chick predation by free-ranging dogs by undertaking a holistic dog population control program in neighbouring villages,
7. generating scientific information on lesser florican ecology particularly the non-breeding season to aid conservation management using satellite telemetry and associated surveys,
8. advocacy and outreach programs to generate support among multiple stakeholders for lesser florican conservation, and,
9. Finally, given the potential decline of the species, gaps in our knowledge regarding their key threats, and inherent difficulties in implementing urgent conservation actions in their vast unprotected habitats, a conservation breeding program should be implemented urgently to secure a captive population for insurance and possible reintroduction in future. Given the current numbers, there is still a window of opportunity for recovery of the lesser florican.
10. This status assessment protocol and its inferences, including the spatial prioritization needs to be refined over next two years, and should thereafter be implemented periodically to monitor the pulse of the endangered lesser florican and its dwindling habitats. In the imminent future, we plan to refine our status assessment protocol and conduct consultative meetings at regional levels to prepare site-wise conservation plans.

Table 2 - Occupancy sampling and distance sampling results of Lesser Florican survey across the landscapes

Area		Occupancy sampling				Density (distance) sampling			
Region	Landscape	Sites	Stop-overs (surveys)	Detected stop-overs	Detected sites	Sites	Transects	Efforts (km)	Male sightings
Ajmer	Kekri	37	444	4	2	3	19	39	15
	Shokaliya	51	711	21	17	17	112	244	15
Rajasthan rest	Jalore	20	254	1	1	1	5	9	0
	Pratapgarh	15	140	1	1	1	5	11	2
	Shahpura	48	555	3	3	4	30	72	0
Gujarat	Kutch	30	407	5	4	4	29	78	1
	Saurashtra	105	1450	14	3	2		35	31
Maharashtra	Akola-Washim	50	649	0	0				
Madhya Pradesh	Ratlam-Sardarpur	72	790	0	0				
Total		428	5400	49	31	32	218	488	64



Image 3 Pan-India survey of Lesser Florican conducted after a decade. A nice rangoli of Lesser Florican was designed by a college student during a workshop conducted in MDS University, Ajmer © Sujit Narwade

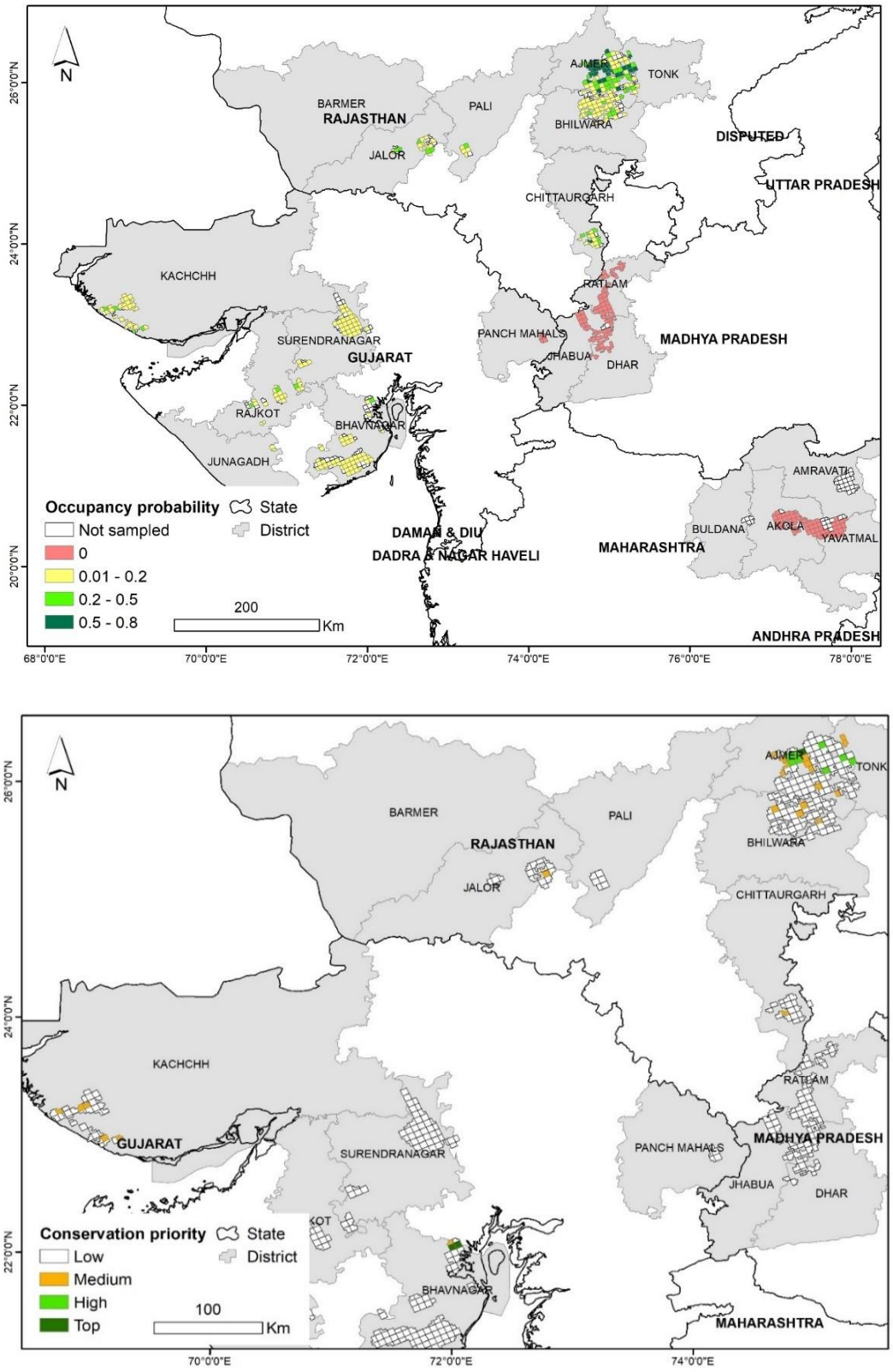


Figure 8 - Occupancy probability of lesser florican and conservation importance of sites (36 sq km cells) across breeding range during July–September 2017. Note that this map is preliminary and needs to be refined using data from at least three breeding cycles sinc

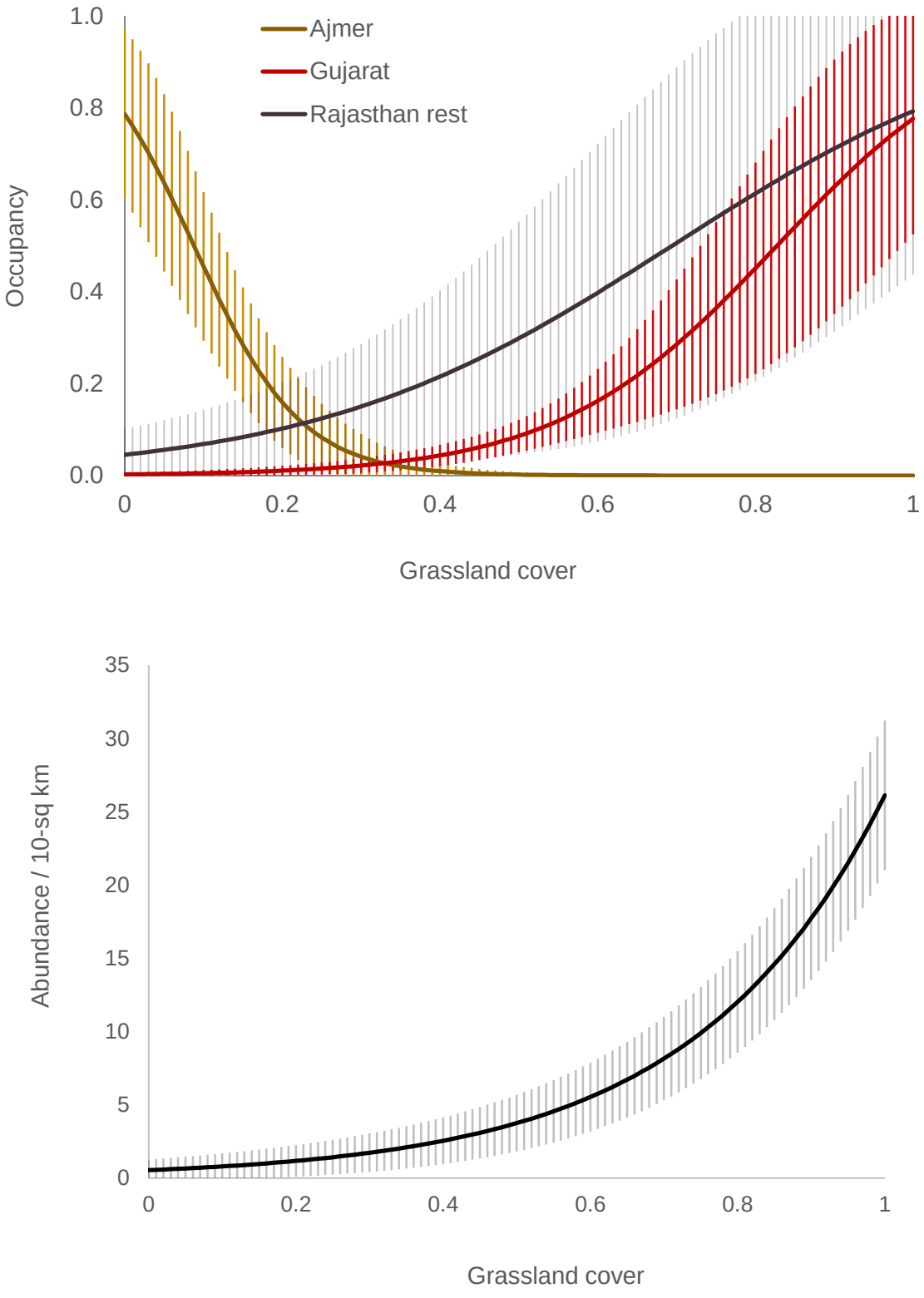


Figure 9 - Relationships between occupancy probability and proportional grassland cover across regions (top), and mean abundance /10 sq km vs. proportional grassland cover across sites occupied by lesser florican in the breeding range during July–September 2017.

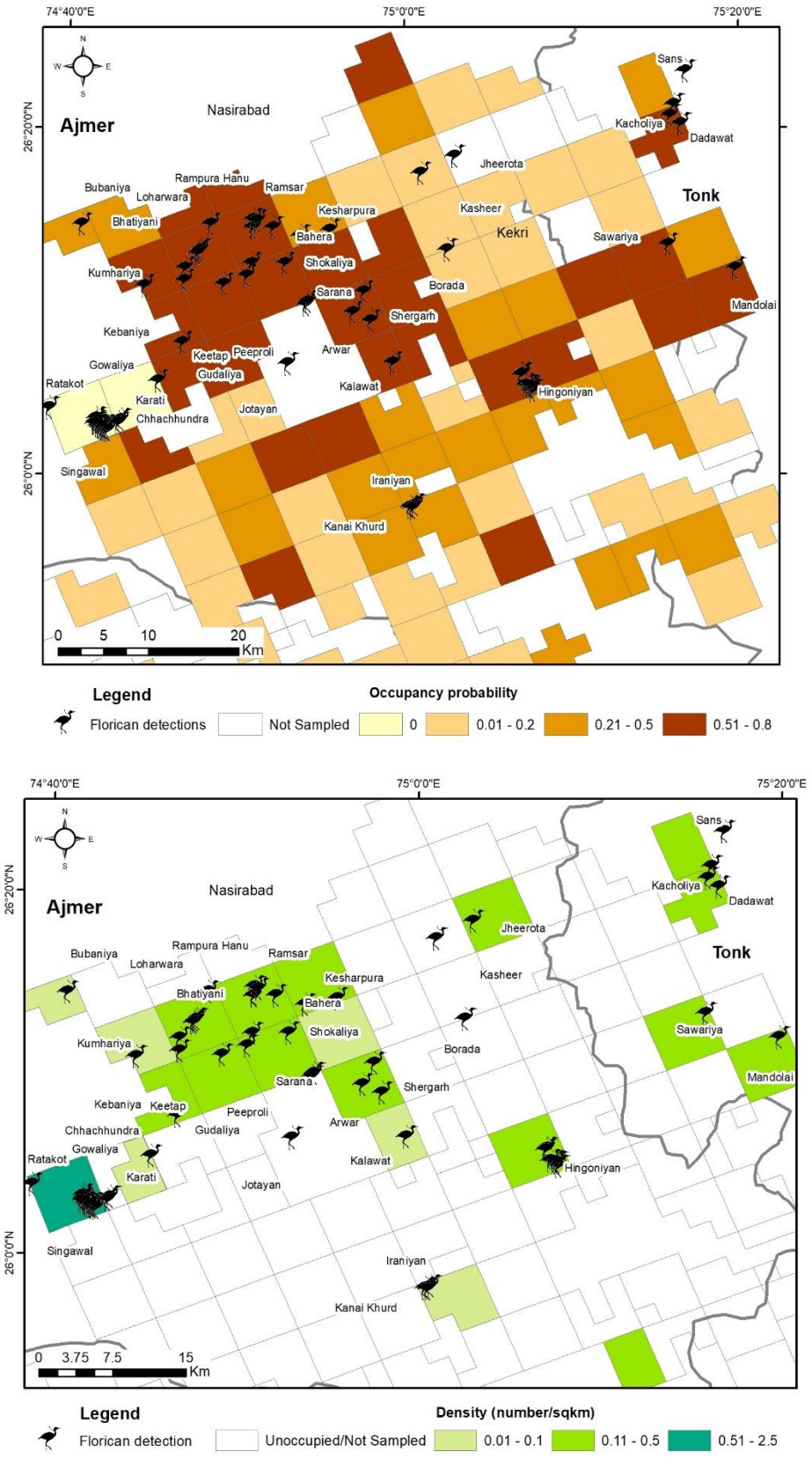


Figure 10 - Occupancy probability and density of Lesser Florican in Shokaliya landscape, Ajmer, Rajasthan - a priority conservation area for the species - in 2017

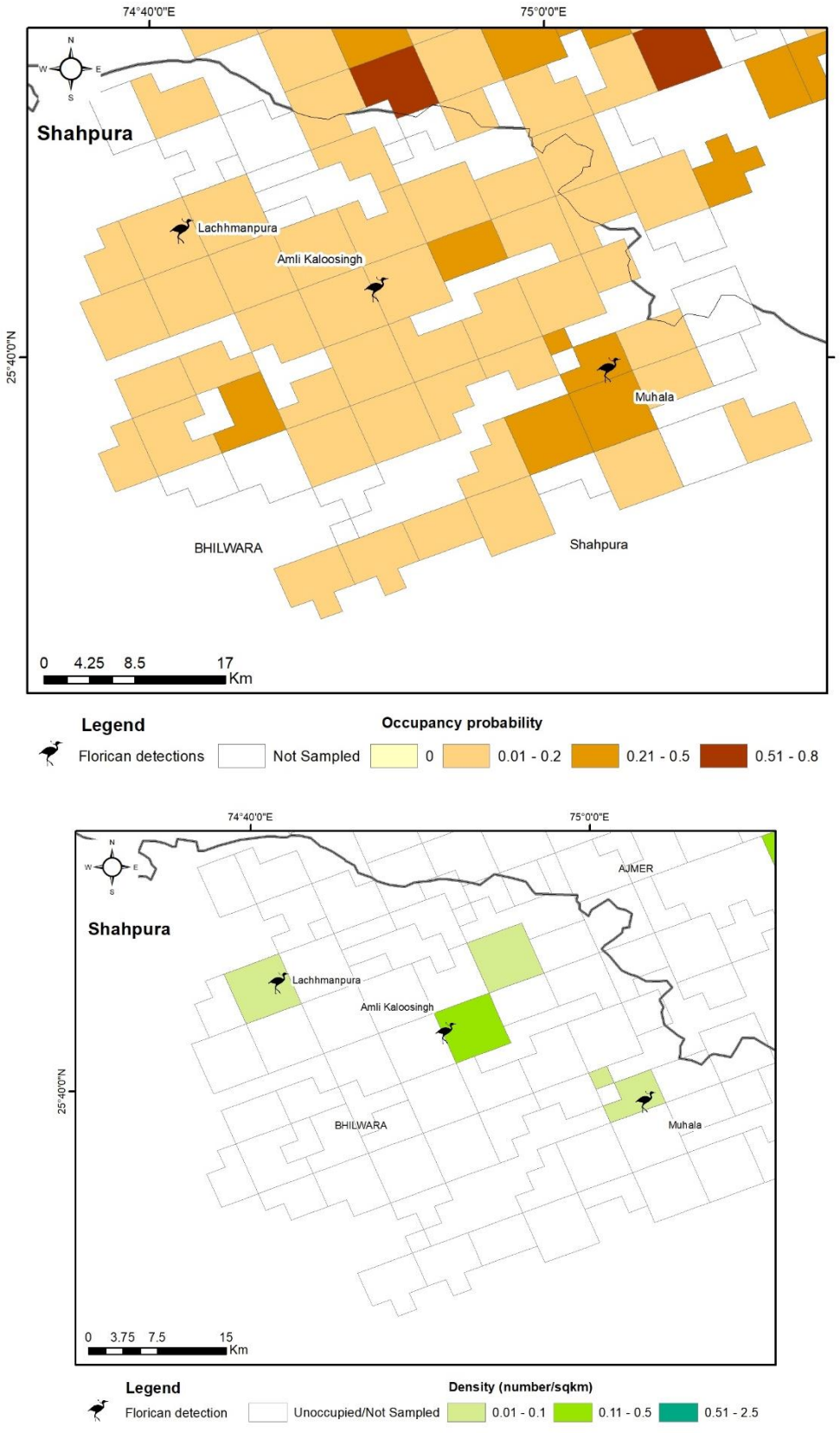


Figure 11 - Occupancy probability and density of Lesser Florican in Shahpura landscape, Bhilwara, Rajasthan in 2017

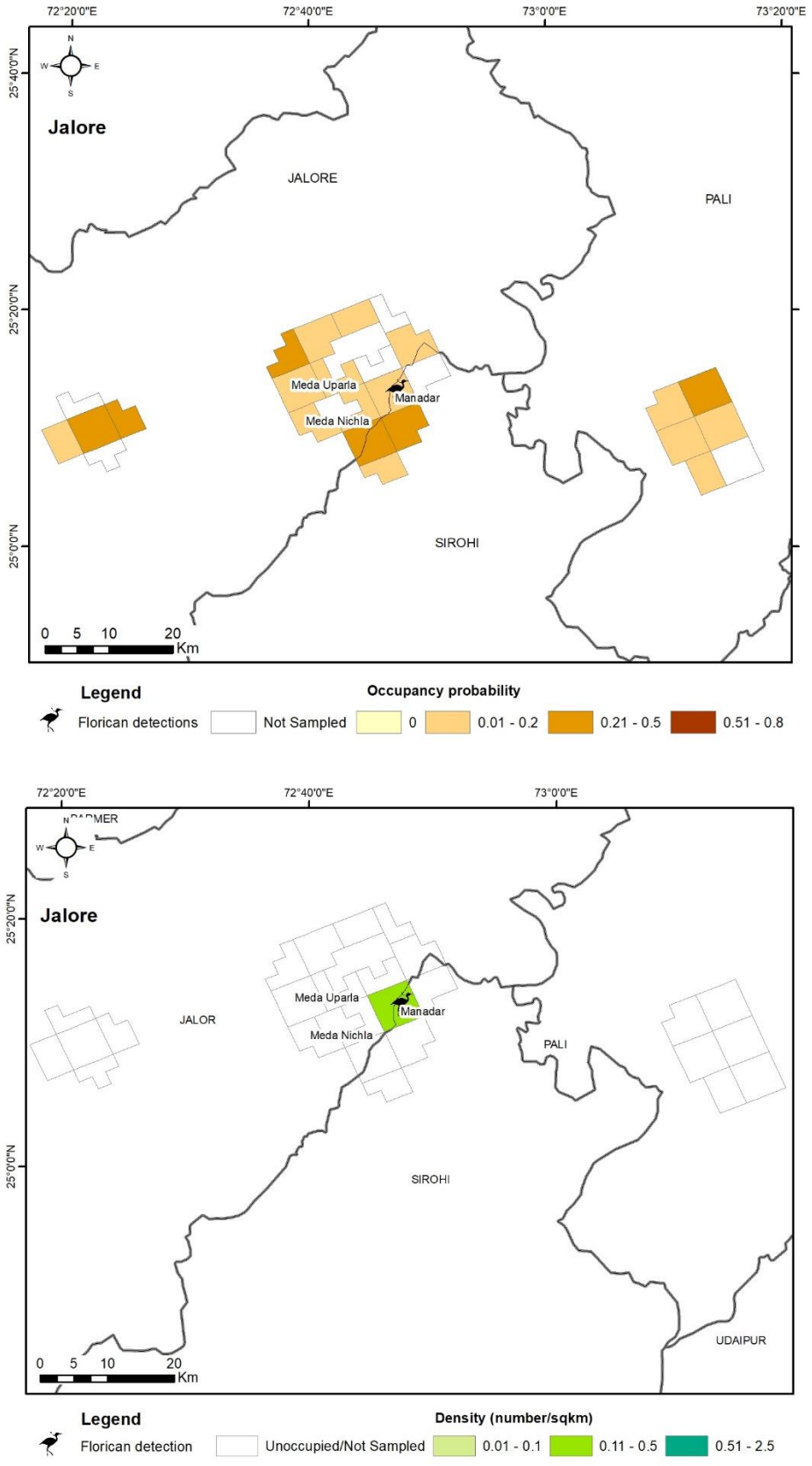


Figure 12 - Occupancy probability and density of Lesser Florican in Jalore landscape, Rajasthan in 2017

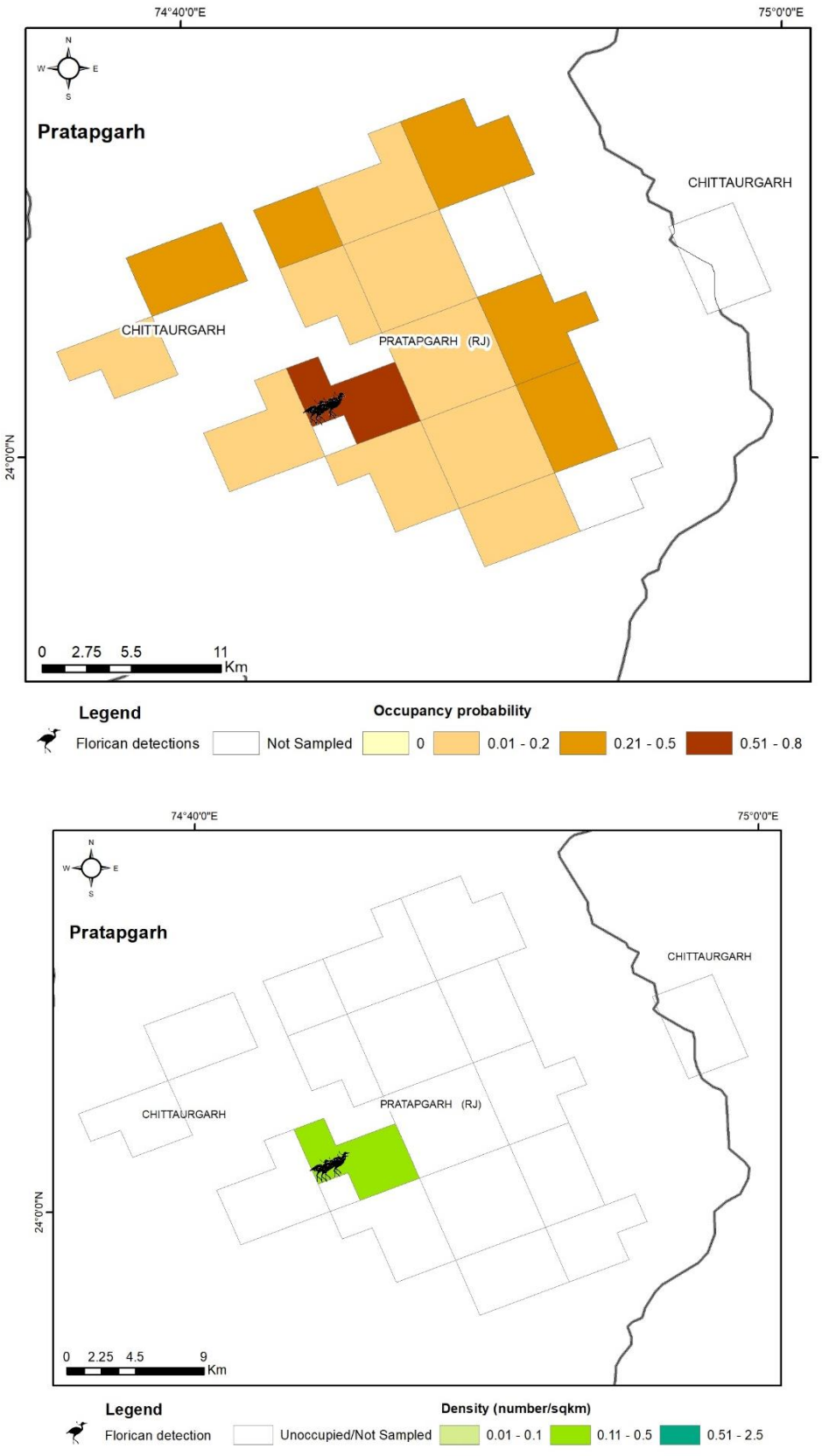


Figure 13 - Occupancy probability and density of Lesser Florican in Pratapgarh landscape, Rajasthan in 2017

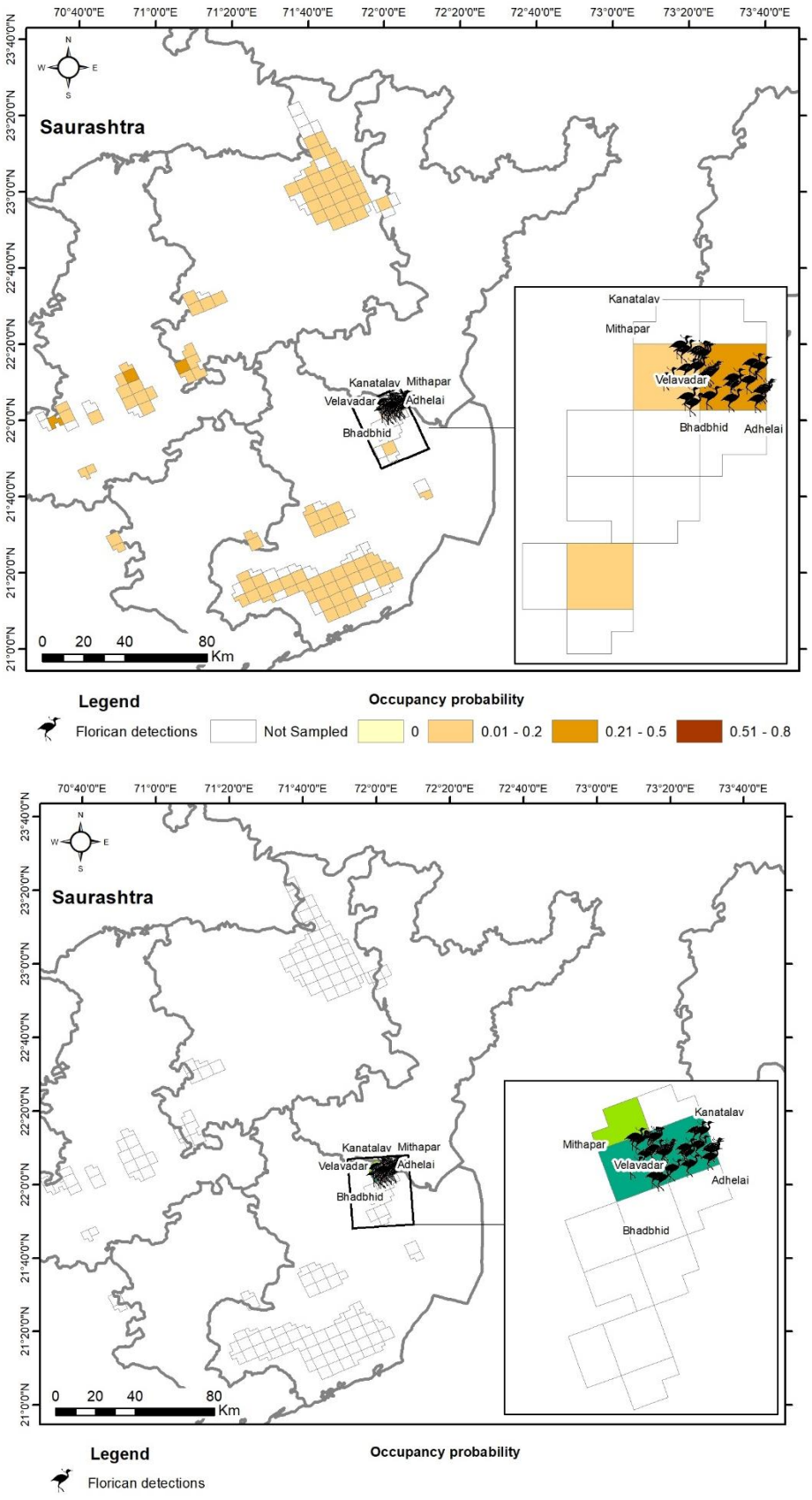
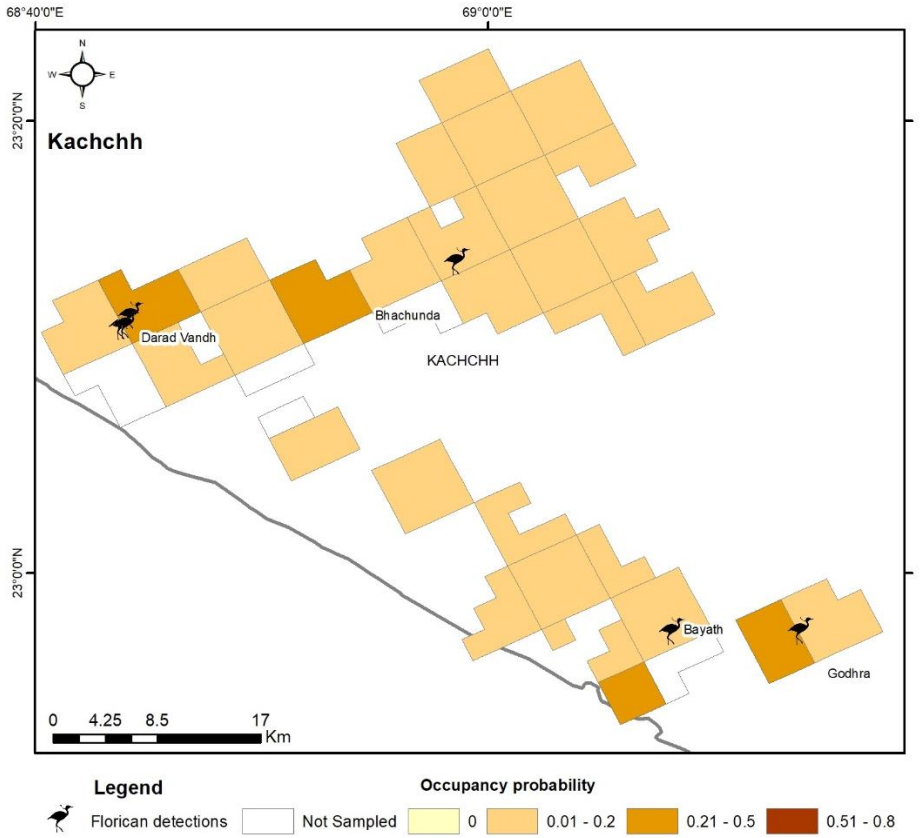


Figure 14 - Occupancy probability and density of Lesser Florican in Saurashtra landscape, Gujarat - a priority conservation area for the species - in 2017



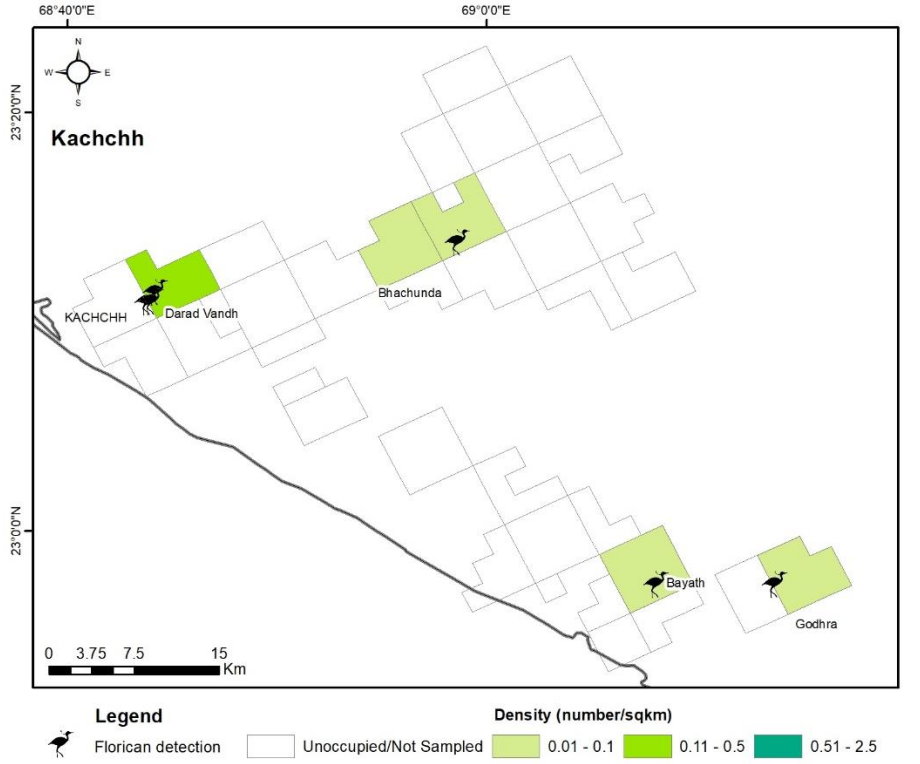


Figure 15 - Occupancy probability and density of Lesser Florican in Kutch landscape, Gujarat - a priority conservation area for the species - in 2017

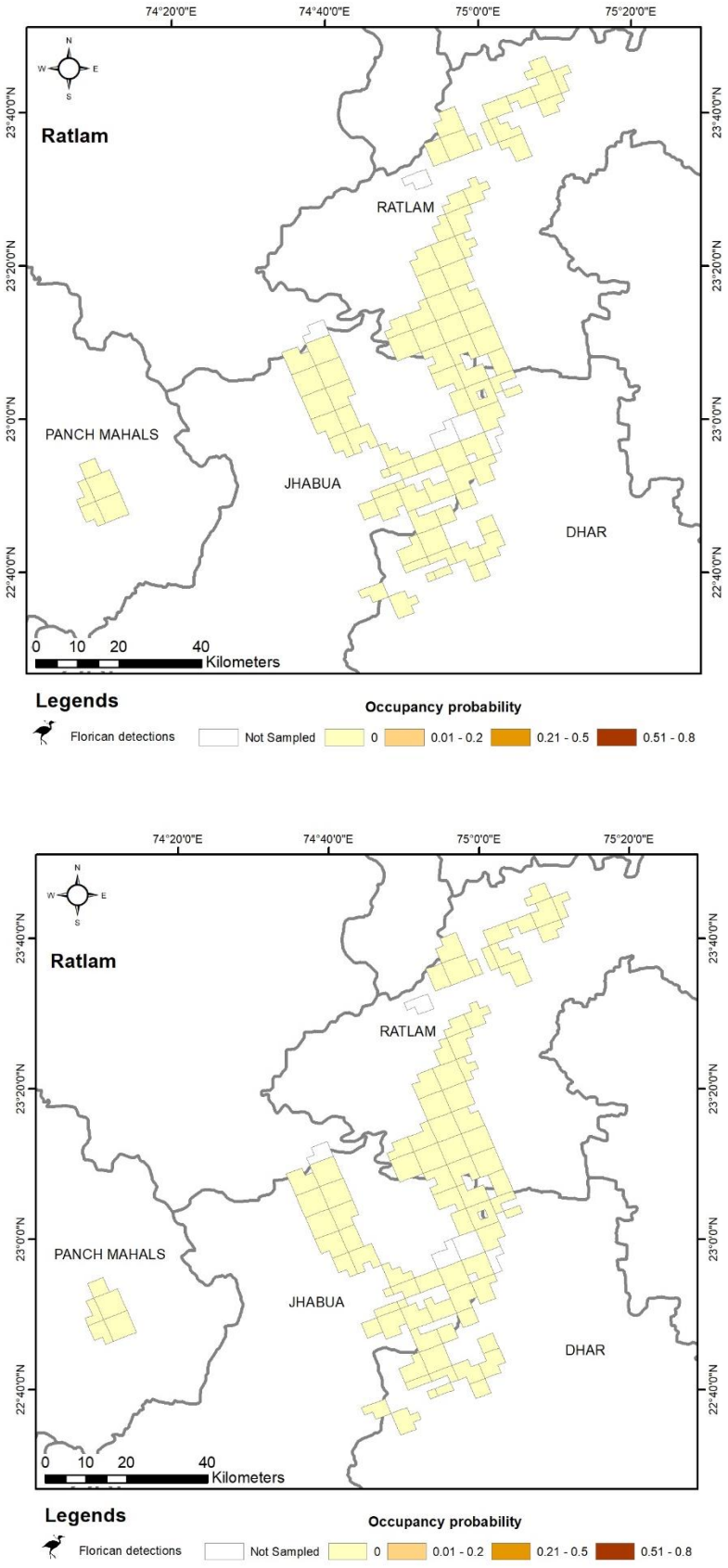


Figure 16 - Occupancy probability of Lesser Florican in Ratlam landscape (Madhya Pradesh) and Akola landscape (Maharashtra)

2.2.1.2.1 Conservation recommendations - Landscape-wise summary

Sr. No.	Conservation action	Task	Priority/ process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
1.	Reduce nest/chick predation by dogs	1. Removal of free-ranging dogs from breeding grounds 2. Sustained sterilization of dogs from villages buffering breeding grounds 3. Garbage management in villages around breeding grounds	High/ Continuous	All priority lesser florican conservation sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with Swachh Bharat abhiyan	~ Rs. 10 lakh for community awareness per village ~ Rs. 20 lakh for dog sterilization programme to be carried out at each site (4-5 villages) for 2-3 months per year for 1000 dogs ~ Rs. 10 lakh for garbage management per village	This action will improve recruitment rate of florican population
2.	Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	High/ Continuous	1. Shokaliya 2. Velavadar 3. Kachchh	1. Radio tracking of ~10 birds in Rajasthan and Gujarat to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas	1. Rs. 4 lakh for marking 1 km of power lines with bird diverters 2. Cost of undergrounding 1 km power - line is Rs. 35 lakh for high tension line and Rs. 20 lakh for low tension line	This action will help reduce mortality of birds
3.	Develop Conservation Breeding Program	Develop a national conservation breeding centre with State Forest Depts., MoEF&CC and scientific organization (WII / BNHS) as partners and international bustard breeders as collaborators	High	1. Sorsan 2. Velavadar / Kachchh	1. Signing of MoU between partners 2. Permission to collect eggs and tag birds 3. Development of centre 4. Execution of program following scientific protocol	Rs. 25 crores for construction and running CBC for ten-fifteen years	This action will secure an insurance population against imminent extinction risk
4.	Promote florican friendly farming	Promotion of florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	High/ Continuous	All agricultural areas in priority conservation sites of 1. Shokaliya 2. Kachchh 3. Akola	1.Collaboration/engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bio remedies 3. Marketing florican-friendly crops at higher prices as an incentive to farmers	1. Rs. 1 lakh for farmer training program per site 2. Rs. 2 lakhs for certification of land of one farmer who wish to get associated with the scheme	Action will balance livelihood concerns and florican conservation Land will be monitored for three years

Sr. No.	Conservation action	Task	Priority/ process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
5.	Grazing regulation in unprotected grasslands	Stop/partition livestock grazing in non-PA, private/village owned florican breeding grasslands during July–August (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	High/ Continuous	Grasslands > 5 sq km area, particularly in 1. Kachchh, 2. Dahod 3. Saurashtra, 4. Pratapgarh 5. Ratlam	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 3. Incentivized stall-feeding of livestock during monsoon	1. Rs. 1 lakh per site for engaging two local people to enforce grazing restriction during 2-3 monsoon months. 2. Cost of incentive needs to be computed based on livestock holding in a site	This action will help in increasing herbaceous biomass, which is critical for lesser florican breeding, and provide fodder for livestock in the lean period (winter through summer)
6.	Research and monitoring	**1. Satellite telemetry** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology which are all poorly known 2. Understand the impact of land-use change on lesser florican	High/ immediate	1. Shokaliya 2. Velavadar 3. Kachchh 4. Pratapgarh	1. Necessary permissions from government agencies to capture and tag birds 2. Purchase and deployment of tags 3. Research and monitoring exercise Effects of intensification of agricultural practices, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis	Rs. 3 lakhs per PTT x 5 PTTs / site + Rs. 2 lakh for field expenses required for installing PTT per site Rs. 10 lakhs for field monitoring, image processing and other expenses per year per site	This action will help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions
7.	Create positive publicity for florican conservation	Outreach programme for Forest staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for florican conservation	High/ Continuous	All florican conservation sites, particularly 1. Shokaliya 2. Velavadar 3. Kachchh	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	1. Rs. 1 lakh per workshop 2. Rs. 25,000 for each follow up event	This action will generate public support for lesser florican conservation
8.	Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	High/ once in every two years	1. Shokaliya 2. Sailana (Ratlam) 3. Abdassa (Kachchh) 4. Bhal area including Velavadar BBNP	Collaborative implementation through Forest departments and concerned agencies	Rs. 1000-1500/- per acre for uprooting a plant using mechanization method (JCB/Pokland)	This action will create more optimal habitats for the species

Sr. No.	Conservation action	Task	Priority/ process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
9.	Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**PA rationalization** Rationalization of boundaries of the WLS and defining the Eco-Sensitive Zone (ESZ)	High/ priority	1. Sailana WLS 2. Sardarpur WLS	There is need to take decision on revenue land falling under Sanctuary areas and demarcation of the core areas	Chain link fence cost Rs. 7 lakh / km and gates as per requirements With additional cost for predator proof concrete foundation	To avoid public antagonism against land-use restrictions and livelihood in areas adjoining PAs that can damage Lesser Florican conservation
		Relief from crop-raiding Compensation policy to be designed to address the issue of crop raiding by large herbivores like Nilgai	Medium/ Priority	1. Sailana 2. Sardarpur 3. Velavadar NP 4. Akola	Nilgai and pigs, crop-raiding animals, use PAs containing Lesser Floricans as a refuge. This association causes antagonism towards Lesser Florican conservation.	Rs 20,000 per farmer per Ha for damage of more than 50% of the crop	
		Protection to marginal conservation areas Focusing on existing and unprotected Lesser Florican breeding sites	High	All non-protected Lesser Florican sites	1. Regulation of intensive land-uses (mining, salt pans, infrastructure, intensive farming) 2. Incentivizing local people for implementing Lesser Florican-friendly land-uses 3. Land ownership should remain with the people.	Rs. 20 lakhs per year per site	This action will balance livelihood concerns and Lesser Florican conservation
		Preventing disturbances to breeding birds Preventing human disturbances, hunting and livestock grazing by patrolling in PAs	High/ Continuous	All known breeding sites of Lesser Florican	1. Identifying and engaging poachers or other interested local people as protectors and forest guards to create a parallel protection force for four months 2. Adequate training and logistic/fund support for the training	Rs. 10 lakhs per site	
10.	Regulate tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for Lesser Florican	High/ Continuous	All florican breeding sites, particularly 1. Shokaliya 2. Velavadar 3. Kachchh 4. Pratapgarh	1. Develop guidelines of eco-tourism that does not disturb breeding birds but generates income for local people 2. Identify local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not being detrimental to conservation	Rs. 50,000 for training programme for nature guides	This action will help generate local income and awareness about lesser florican
11.	Developing Community Conservation Areas	Developing an organizational structure for Community Conservation Areas (CCA)	High/ priority	1. Shokaliya 2. Kachchh	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	1. Rs. 50,000 for workshop for CCA stakeholders. 2. Rs. 30 lacs as incentives for the people involved in conservation	This action will help to develop a pilot habitat model apart from a protected area governed by local people

2.2.2. ECOLOGY AND RANGING PATTERNS

2.2.2 Satellite telemetry

While population and habitat surveys of GIB provide coarse-scale information on species' distribution, finer-scale information on landscape use, ranging patterns, and critical habitat requirements are needed to develop effective and detailed conservation action plans. These information can be generated precisely through biotelemetry, and the most important application of this exercise is to mitigate threats in areas intensively used by the birds. The project has requested granting permission to tag birds in Thar and Kutch, and have received the permission from MoEF&CC. Gujarat Government issued the permission to tag two birds in 2017. However, permission from Rajasthan Government is still awaiting despite multiple requests.

The Wildlife Institute of India team comprising of Project Investigator Dr. Y. V. Jhala, Co-Project Investigator Dr. S. Dutta, Project Associate Mr. Bipin C.M., Veterinary Doctor Mr. Sarvesh Rai, and international bustard expert and collaborator Dr. J.C. Alonso successfully tagged two juvenile GIB with the help of BNHS bird trapping team on May 1, 2017. These birds were fitted with solar-powered PTTs that remotely transmit GPS locations. The juvenile female (*Raheva*) moved 200 km within 48 days at daily speed of 4 (SD = 3) km day^{-1}. During these movements, it crossed hostile infrastructure such as power lines between grassland patches such as Naliya, Kothara, and Sindhori-Ranpur-Vamori. Bird locations and movements have been overlaid on ground digitized power-line networks to indicate the extent of threats (Fig 17-19). The bird's transmitter stopped functioning on June 29 and through field visits it was confirmed that this bird had died due to power-line collision.

Another tagged bird, *Alfin,* was tracked for 386 days from 1 May 2017 to 6 June 2018 (and still continuing). The bird has moved 7.2 (SD = 4.2) km on a daily basis, ranging from 0.1 to 29.9 km, covering a total distance of 2787 km during this time. The Minimum Convex Polygon estimator indicated a home range of 429 sq km. However, the intensively used area covered a cumulative ~45 sq km area (Fig 17).



Image 4 A tagged bird, *Alfin,* was tracked for more than one year and still providing crucial data of its movement © Devesh Gadhavi

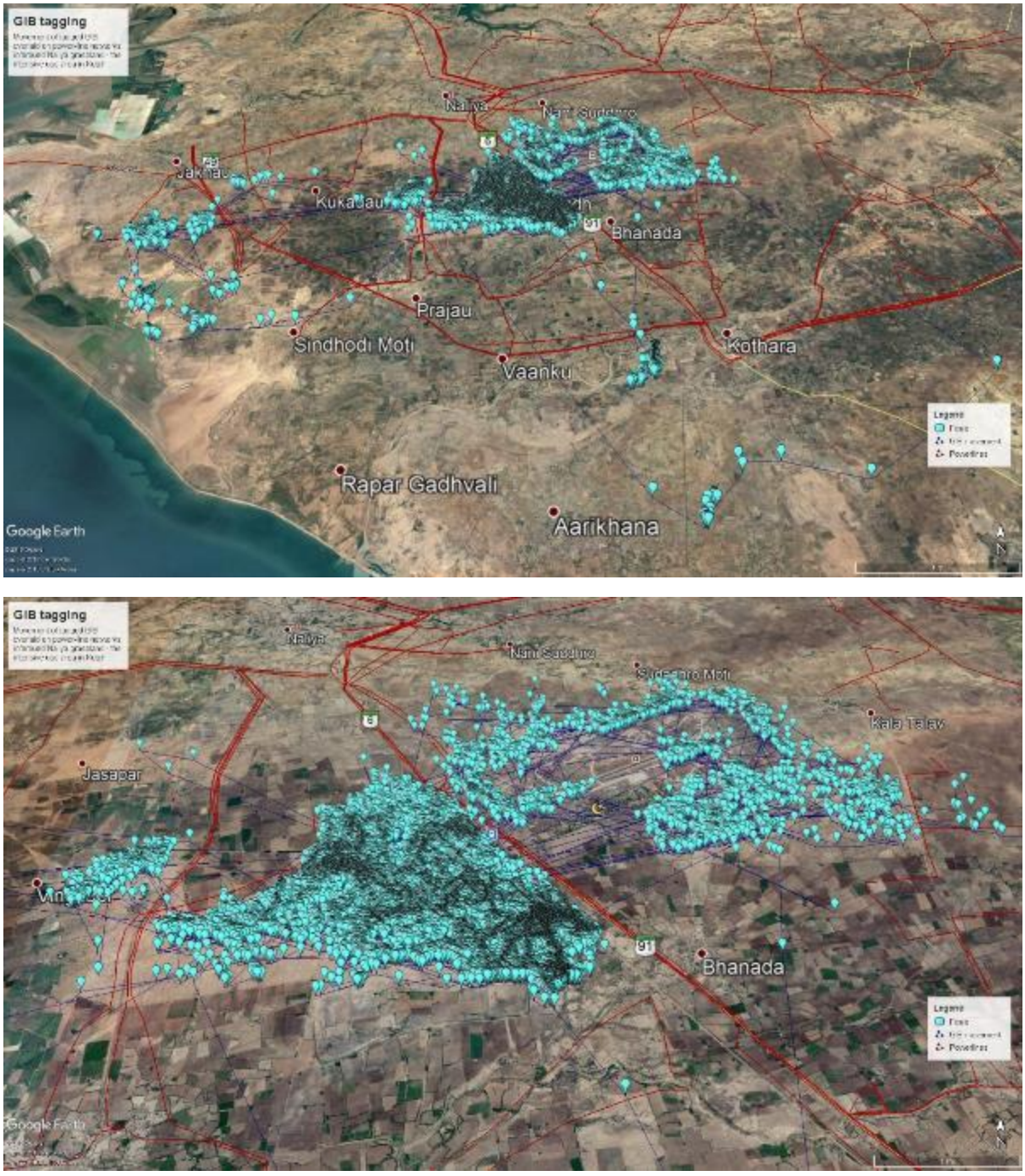


Figure 17 - Movement of tagged Great Indian Bustard overlaid on network of power lines in Kutch; showing usage of the larger landscape (top) and intensive use in Naliya and adjoining areas (bottom)

2.2.2.1 Report on the mortality of tagged Great Indian Bustard due to collision with 33 KV transmission line near Kachchh Bustard Sanctuary, Lala – July 10, 2017

Within months of tagging two Great Indian Bustard *Ardeotis nigriceps* in Naliya grassland of Abdassa, Kachchh, one tagged bird died due to collision with power-line. This section provides information on the tagged bird movements, mortality incident, joint assessment by Gujarat Forest Department and Wildlife Institute of India team, and the follow-up actions to mitigate power-lines for GIB conservation.

MORTALITY OF TAGGED BIRD

The transmitter on one female juvenile, Raheva, stopped functioning on June 29. This tag transmitted GPS fixes after a lag of few days, and the reception of information was further delayed by some technical problems. On reaching the last movement locations of the bird in the tracking record (June 17–20, 2017), it was observed that the locations (23.17451^0 N, 68.76067^0 E) were exactly under a 33 KV high-tension line within 500 m from village Lala, and within 1 km of Kachchh Bustard Sanctuary. Dr. Dutta and his team recovered remains of the tagged GIB right underneath the power-line that included large number of feathers, bones, decomposed meat and skin. Additionally, a feather with some tissue was still attached to the earth-wire. Later, these samples were confirmed to be that of the tagged bird based on genetic identification at WII lab. It was clear that the bird, while moving from Ranpur grasslands to the west, which it used intensively, towards Naliya grasslands in east, had collided with the power line most likely on June 17, 2017. The bird might have died from the instant impact of collision or have sustained serious injuries and was subsequently predated or scavenged by dogs or other carnivores. Subsequent locations till June 20 were within 100 m of this collision point which were likely because the bird was predated or dragged by carnivores. Despite this collision-induced-death occurring in private farms adjacent to village Lala, the bird carcass went undetected perhaps because the remains were washed by rain, got mixed with soil, and became inconspicuous. The dead bird could be traced only because it was tagged with a GPS PTT.

JOINT ASSESSMENT & EVIDENCE COLLECTION

On finding evidence of bird death, Dr. Dutta informed the local Forest Department staff and carried out joint assessment of the situation as well as collection of evidence at the accident spot. The staff led by RFO Mr. Sodha, and including Forest guards Mr. Ashvin Jadeja and Mr. Maheshwari prepared evidence report in presence of local villagers (Fig 20). Bird remains such as feathers and bones were collected using surgical gloves and stored in zip-lock bags and tissue and skin samples were stored in vials with 95% alcohol and were labelled with date-time-location tags. Bird remains were distributed in clusters spread over 70 m radius from the collision spot (Fig 20). Samples were immediately sent to Forensic cells of Wildlife Institute of India and Gujarat Forest Department and was genetically confirmed to be that of the tagged bird.

Subsequently, Mr. B. Suchindra, Deputy Conservator of Forests (Kachchh west circle), Mr. Patel, Assistant Conservator of Forests (Kachchh west circle) along with officials from GETCO and PGVCL reached the accident spot to carry out a joint assessment of the bird mortality incident. Deputy Engineer of PGVCL, Mr. Sadhu verified that the power-line is connected to wind-turbines and is owned by Suzlon Company. Mr. Ahmad, ex-sarpanch of Lala was also present at the site and showed images of an earlier mortality of GIB due to collision with the same 33 KV transmission line on September 12, 2014. These power-lines pass within hundred meters of the Kachchh Bustard Sanctuary at some points, and have been installed without No Objection Certificate from the Forest Department; hence illegal. Mr. N. K. Solanki, Superintending Engineer (TR) of GETCO, Anjar region opined that undergrounding of 33 KV transmission lines is technically feasible and Suzlon Company can be pressurized to underground this cable. Dr. S. Dutta pointed out that the power-lines are particularly detrimental because they cut across frequent movement paths of GIB, and are vertically aligned in three parallel towers each with six conductors and one earth wire ranging from 18 m to 30 m in height from ground that increases the chance of fatal collisions such as the current accident (Fig 20). Considering these technical opinions and the fact that the power-lines run within 1 km of the Sanctuary, Deputy Conservator of Forests (Kachchh west) drafted a letter to request the District Collector to enforce immediate undergrounding of this entire power-line that runs for 15 km from Sindhori to Jakhau, to avoid future mortalities. This letter incorporates technical opinions of Dr. Dutta, Mr. Solanki and Dr. Suchindra, and was communicated to the District Collector.

WAY AHEAD

During the joint assessment it was realized and suggested that a central directive to mitigate power-lines in priority bustard habitats is essential, and needs to be implemented through joint stakeholder workshops. Since the bustard landscape in Kachchh has high density of power-lines and it is impracticable to underground all lines, Wildlife Institute of India will develop priority maps based on surveys and tagging study to suggest undergrounding of very critical power-line segments and marking of moderately critical power-line segments with Bird Diverters. The report provided by WII should also include short-term, medium-term and long-term measures to mitigate threats of power-lines to GIB, and provide designs, costs, required features and vendors of Bird Diverters for marking lines. Although a detailed report on the above aspects will be communicated by WII in due course of time, the most critical power-lines in the GIB habitat, which must be undergrounded, have been highlighted based on existing knowledge of species' landscape-use (Fig 21). These power-line segments are: a) the 33 KV transmission line between Sindhori and Jakhau that is responsible for two GIB collision-induced-deaths, b) the distribution lines between Naliya-Jakhau road and Parjau, c) the power-lines along the railway track on Naliya-Kothara road, and d) the new power station and radiating 220 KV power-lines next to Dhufi enclosure in Kunathia grassland.

While human-induced loss of every individual can increase total extinction risk for the Critically Endangered Great Indian Bustard, mortality of this tagged bird provides the opportunity to sensitize power agencies and institutionalize cross-departmental joint decision-making in bustard habitats.



Figure 18 - Locations (black dots) and movements (light green lines) of tagged Great Indian Bustard in Kachchh during May 5 – June 20, 2017 overlaid on power-line networks (red lines). The dark green track indicates the movement from Ranpur grasslands toward Lala village.



Figure 19 - Tagged Great Indian Bustard locations (black dots) during June 17-20, 2017 overlaid on power-line networks (power-lines where the bird collided in thin white track and other power-lines in red track), showing the collision spot between Kachchh Bustard Sanctuary and Lala village.



Figure 20 - The 33 KV transmission lines connected to wind turbines with three parallel towers each having 6 conductors and 1 earth wire that led to fatal collision of tagged Great Indian Bustard, and the ground visit by project team in collaboration with Gujarat Forest department © WII Photo library

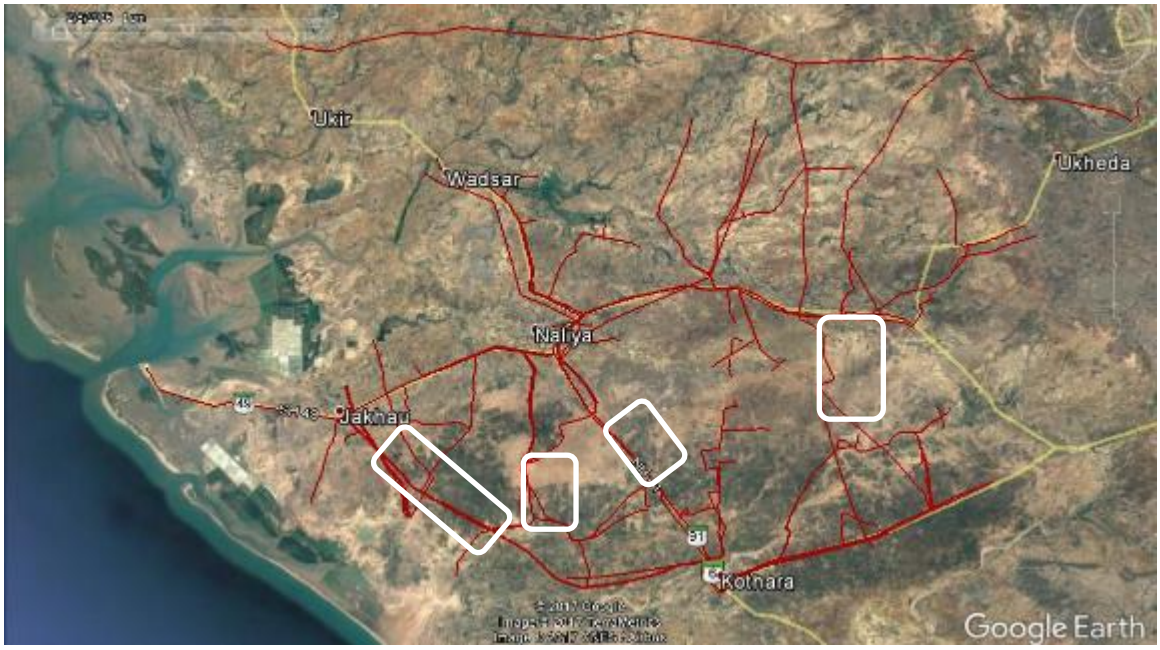


Figure 21- Partially ground-digitized power-line maps (in red lines) in bustard habitat of Kachchh, where the most detrimental power-lines are highlighted (in white boxes) that must be undergrounded to conserve the remaining Great Indian Bustard in Kachchh

As a consequence of this incident and sensitization activities jointly undertaken by Gujarat Forest Department, Wildlife Institute of India and The Corbett Foundation, the State Government directed the power agency GETCO to underground the entire 15 km stretch of the powerline that resulted in the bird mortality. District Collector passed this directive; however, implementation of this action is still pending.

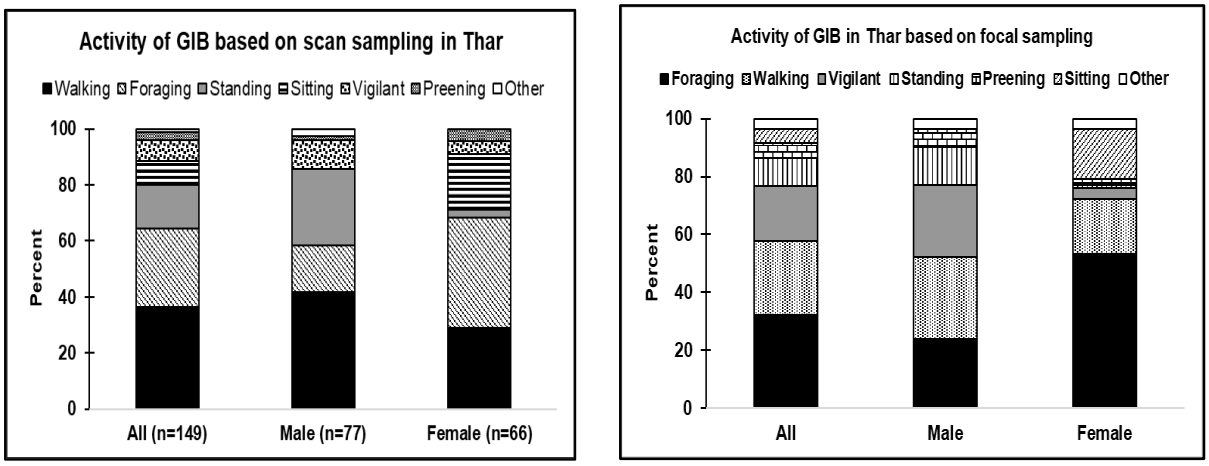
2.2.2.2. GIB phenology and behavioural ecology

Understanding of Great Indian Bustard (GIB) phenology and behavioural ecology (habitat use, response to disturbances etc.) are essential for managing breeding habitats. The objectives are to understand their daily activity budget, seasonal landscape use, foraging and breeding behaviour and intraspecific interactions in/around Desert National Park (DNP), a priority area for their conservation. This research component will quantify the influence of anthropogenic activities such as people and vehicular movement, livestock grazing, tourism activities and land use types as well as predator presence, on GIB. It will also determine the benefit of enclosures to GIB conservation, and recommend measures to improve the management of enclosures if required, to increase usage by birds. The dietary requirements and availability will be quantified so as to suggest measures to ensure forage availability inside enclosures during resource lean period. Encounters with nest predators (dogs, pigs, mongooses and foxes) will be quantified so that measures to control predator population can be undertaken.

Behavioural observations of GIB were carried out in and around four enclosures viz, Sudasari, RKVY, Gajaimata and PPC. Observations were recorded in enclosures inside Desert National Park and surrounding agricultural fields (Fig 24). Behavioural observations were recorded using scan (1minute) and focal (5 and 10 minutes) sampling methods. Data on daily activity patterns of solitary and flocking individuals were collected. Additionally, human activities such as people and vehicular movement, livestock grazing, tourism activities, presence of predators (dogs, foxes, mongooses, and pigs) in the vicinity as well as weather were recorded. Faecal samples were collected *ad-libitum*.

A total of 135 scan and 109 focal samples were carried out. Since majority of the scan samples were of displaying males (43%), after discarding these observations walking (36%) was the predominant

activity followed by foraging, standing, sitting, vigilant, and preening (Fig 22a). Foraging was the predominant activity observed in females (39%), whereas for males it was walking (42%).



a) (b)

Figure 22 - Daily activity budget, based on preliminary observations of Great Indian Bustard in Thar using scan and focal sampling in 2017-18.

Similarly, for focal sampling after discarding the samples of the displaying males which constitute for 39% of the observations, the predominant activity observed was foraging (32%) followed by walking, vigilant, standing, preening and sitting (Fig 22b). As observed in scan sampling, foraging was the predominant activity recorded in females (53%), whereas for males it was walking (28%).

Two males were seen displaying courtship behaviour standing apart at a distance of 700-800m from each other for a period of 7 days. The males would vocalize 3-5 times/ minute with the rate increasing in the presence of females and vocalization of the other male. One male was seen mating with females on three occasions, twice in the evenings and once early morning. During full moon nights, one male would display till 1AM in the night. In one instance, a dog was observed chasing 2 GIB males drinking water and the birds flew away and on another occasion, an Indian fox and a male GIB were chasing each other which ended with GIB chasing the fox away after three minutes. During summer, GIB were observed feeding mostly on Ker *Capparis decidua* fruits and, on termites particularly during the days when early morning temperature would drop below 25°C which would start termite activity.

During scan sampling, livestock (mostly cattle) were observed within 500m of the birds (61%), whereas humans (13%) and vehicles (13%) were recorded within 500m of GIB (Fig 23). Observations inside the enclosures suggest that the birds are very wary of human activity within 400-500m and their behaviour immediately changes particularly with presence of humans. If human presence is detected visually within 200-300m, their ongoing activity is disrupted, and they become vigilant or/and hide or/and walk away or/and take flight. Interestingly, in agriculture fields, the birds react to human presence (vehicles and shepherds) at shorter distances (100-200m) and more observations are required to confirm this behaviour (Fig 24).

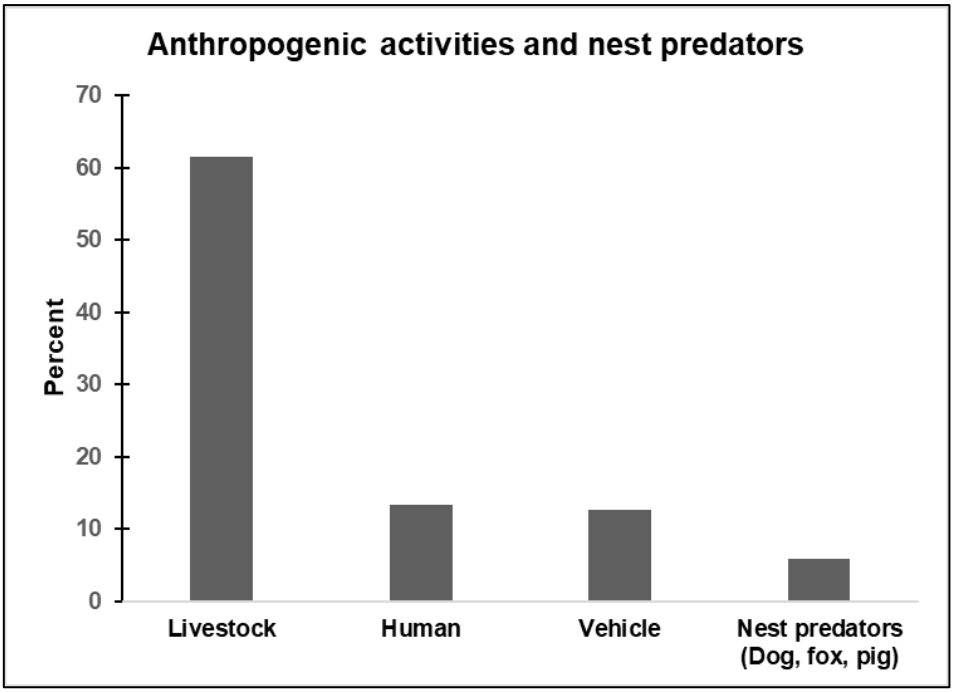


Figure 23 - Anthropogenic activities and nest predators within 500m of Great Indian Bustard in Thar observed during scan sampling in 2017-18



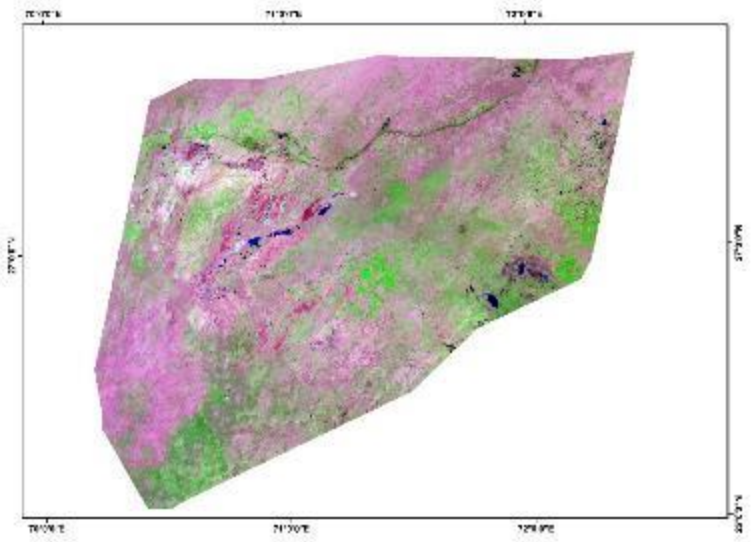
Image 5 – Foxes are predators of eggs and chicks of ground nesting birds like GIB © Sujit Narwade



Figure 24 - Great Indian Bustard behaviour in Desert National Park during 2017-18 (top row from left) female/s- drinking water, standing in the shade, vigilant; (second row from left) female/s- walking, foraging; (third row from left) male- foraging, standing in the shade, vigilant; (fourth row from left) male- sitting in the shade, displaying; and (bottom row from left) interactions between the sexes before mating © Bipin C. M.

2.2.2.3 Thar desert landscape land use/land cover (LULC) classification for GIB habitat

Classification of the Thar Desert landscape LULC was necessary for identifying the Grassland and Savanna areas as they are the preferred habitat for the species of interest, GIB. The 27,488 sq. landscape consists of the following broad LULC categories - grassland, grassland Savanna, scrubland, woodland, shrub land, sparse vegetation/open land, agriculture and few settlements. Apart from the dense grassland and Savanna, all other vegetation types have sparse chlorophyll content and are woody in nature, causing enormous pixel mixing with sparse vegetation areas and open land areas.



The efforts for classification of the Thar Desert landscape may be divided into three phases of differing approaches. The first phase was a multistep hybrid approach combining unsupervised and supervised classification methods. The second phase attempted use of several spectral indices to arrive at a layer with intersection of the range of spectral values with respect to the mean spectral reflectance values of grassland/Savanna. In the third phase, a 'random forest' machine learning approach was used on the principle component dimensions of the spectral indices to identify the grassland/Savanna pixels.

METHODOLOGY IN PHASE 1:

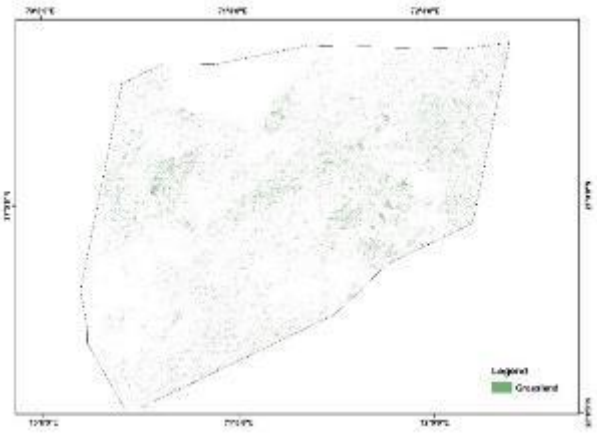
1. A false colour composite (FCC) with Short wave Infrared (SWIR), Infrared (IR) and Green bands of Landsat 8 OLI data of August 2015 was used as this combination is best suited for desert landscapes.

2. Ground reference points for the land cover categories collected during the GIB surveys were categorised into 9 classes based on their habitat composition: sparse (less than 20% grass and 20% wood), moderate grassland (20-50% grass and less than 20% wood), dense grassland (more than 50% grass and less than 20% wood), Savanna (50% grass and 20-50% wood), tree dominated woodland (no grass, 40% shrub and 40% tree), mixed woodland (less than 20% grass, less than 40% shrub and less than 40% tree), open scrubland (20-50% grass and 20-50% wood), dense scrubland (20-50% grass and more than 50% wood) and agriculture. 50% of the points were used for training and the other 50% were kept for testing.

3. Using the ground reference points and google earth imagery as reference, the FCC was used for supervised classification. In the initial phase, several trial and error steps were performed during which the supervised classification was attempted with 300, 400, 500, 600 classes and with different iteration (10-20). In spite of fragmenting the landscape into 600 classes, pure classes with either only habitat classes (grass and Savanna) or pure classes with only non-habitat classes (scrub/shrub/agriculture/sparse) could not be achieved.

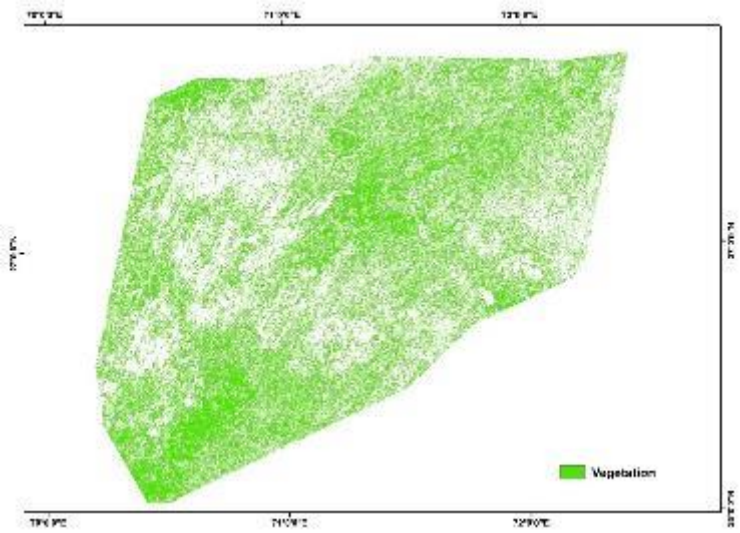
4. At this stage it was necessary to remove all the pixels from the image which were not necessary to be included in classification. Hence, all the agriculture fields and settlements were digitized manually with help of Science Pvt. Ltd.

5. While the digitizing of the agriculture fields was being carried out, simultaneously an unsupervised classification on the FCC was carried out to produce 500 classes. From these 500 classes of the unsupervised file, each class was examined and referenced with google earth imagery closely, and divided into vegetation and non-vegetation layers.



6. A vegetation only layer was extracted from the FCC. This vegetation layers has excluded (to an extent) all the sand dune areas, sparse vegetation areas, thorny scrub and woody areas.

7. The raster file of this extracted vegetation layer was converted to shape file for FCC extraction of the vegetation areas.



8. Now we had an FCC image which was an extract of only vegetation areas.

9. The digitized agriculture layer was used for clipping out the agricultural areas from the vegetation layer. This gave a false colour composite which had classes - grassland, grass/Savanna, shrub land, and scrubland.

10. This FCC with four classes was further classified into 500 classes using supervised classification.

11. Each of the 500 classes were closely examined with reference of google earth imagery. Pure classes containing only grass/Savanna (GIB habitat) and classes with mostly grass/Savanna and little mixing from other classes were extracted.

The layer resulting from the above steps covered grassland/Savanna but also displayed noise from other land cover classes. In an effort to remove the noise, a spectral indices approach was adopted. The following methodology was used in this second phase:

SPECTRAL INDICES USING BAND INFORMATION FROM LANDSAT 8 OLI IMAGES OF AUGUST 2015:

Please see Fig 25 for further details.

1. Modified Chlorophyll Absorption in Reflectance Index (MACRI) which is sensitive to variations in chlorophyll

$$\frac{1.5[2.5(R_{800}-R_{670})-1.3(R_{800}-R_{550})]}{\sqrt{(2R_{800}+1)^2-(6R_{800}-5\sqrt{R_{670}})-0.5}}$$

2. Modified Soil Adjusted Vegetation Index (MSAVI) which is used as a soil brightness correctness factor

$$\frac{1}{2}[2R_{800}+1-\sqrt{(2R_{800}+1)^2-8(R_{800}-R_{670}]}$$

3. Moisture Stress Index (MSI) which indicates water content and stress in plant canopy
   MSI = R1650 / R830
4. Normalised Difference Vegetation Index (NDVI) which indicates the amount and vigour of vegetation
   NDVI = (R800 - R670) / (R800 + R670)
5. Soil and Atmospherically Resistant Vegetation Index (SARVI) which minimizes canopy background and atmospheric effects by incorporating a constant soil adjustment factor

$$\text{SARVI} = \frac{(1+L)\times(R_{800}-R_{rb})}{R_{800}+R_{rb}+L}$$

$$\text{Where } R_{rb} = R_r-\gamma(R_b-R_r)$$

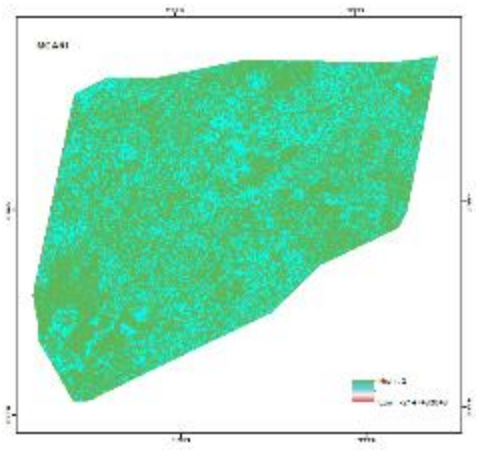
6. Transformed Normalised Difference Vegetation Index (TNDVI) which shows the NDVI of plant cover adjusted to adjacent soil
   SQRT ((NIR - RED) / (NIR + RED) +.5)
7. Ratio Vegetation Index (RVI) RED / NIR
8. Renormalized Normalised Difference Vegetation Index (RNDVI)

$$\text{RDVI} = \frac{(R_{800}-R_{670})}{\sqrt{(R_{800}+R_{670})}}$$

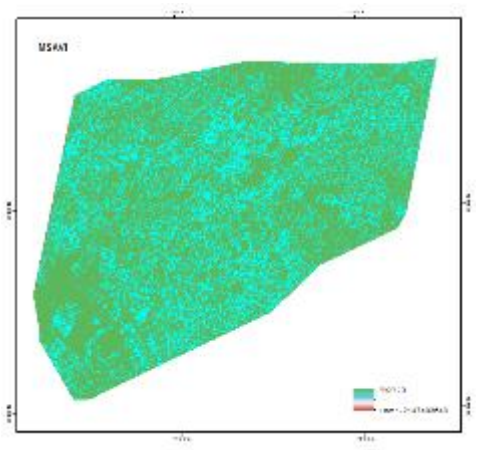
9. Normalised Burn Ratio (NBR) which discriminates between healthy and burned vegetation
   (R800 - R2215) / (R800 + R2215)
10. Modified Triangular Vegetation Index (MTVI) which is sensitive to variations in chlorophyll

$$\frac{1.5[1.2(R_{800}-R_{550})-2.5(R_{670}-R_{550})]}{\sqrt{(2R_{800}+1)^2-(6R_{800}-5\sqrt{R_{670}})-0.5}}$$

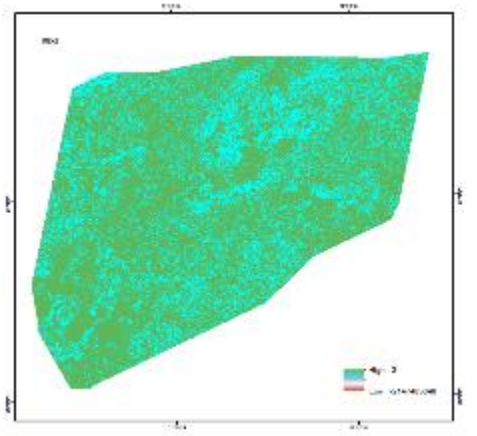
11. Mid Infrared (MidIR) which indicates soil moisture
    R1650 / R2215



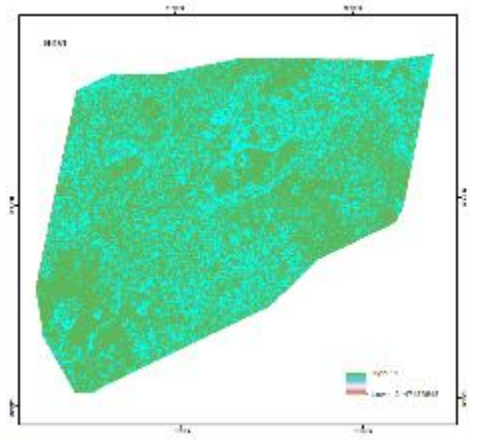
(i)



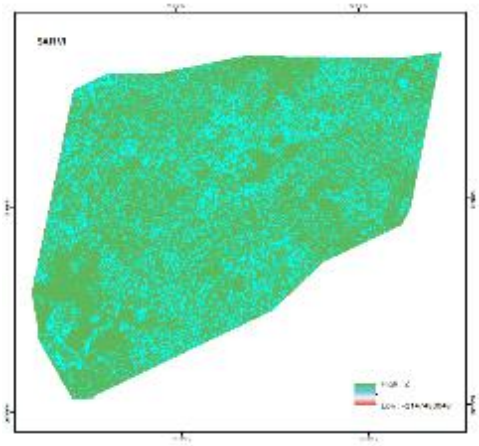
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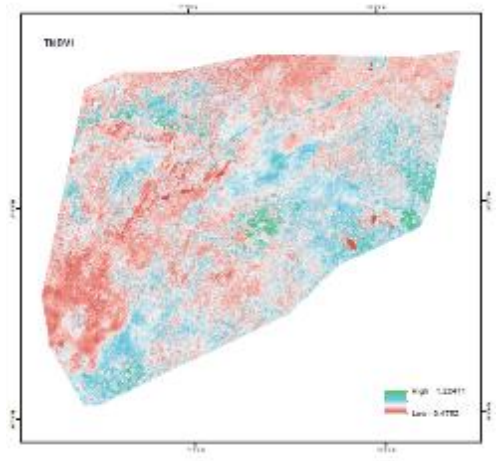
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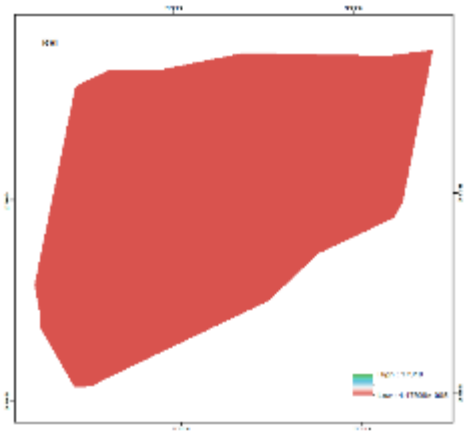
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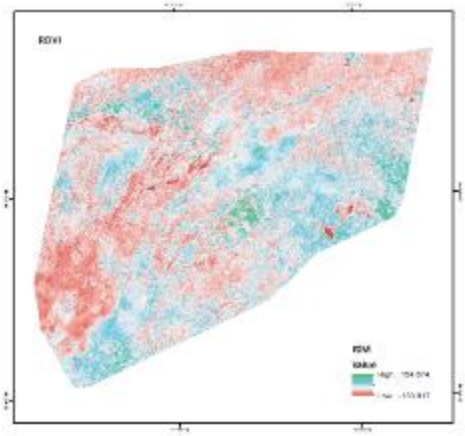
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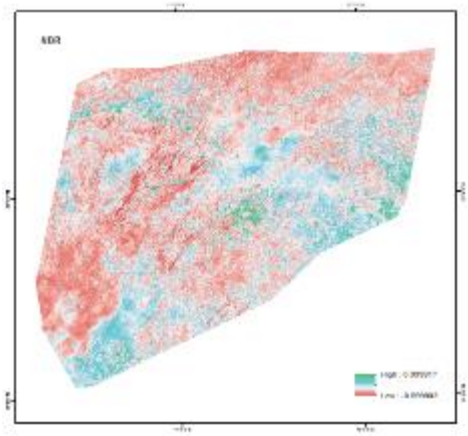
(vi)



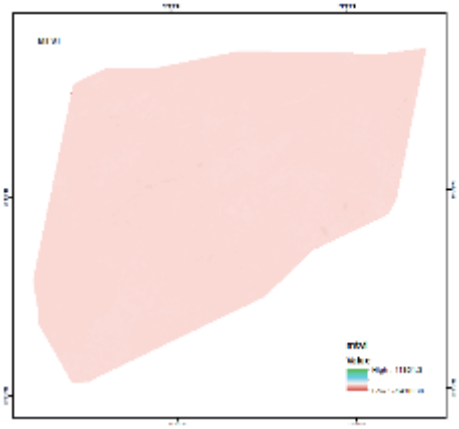
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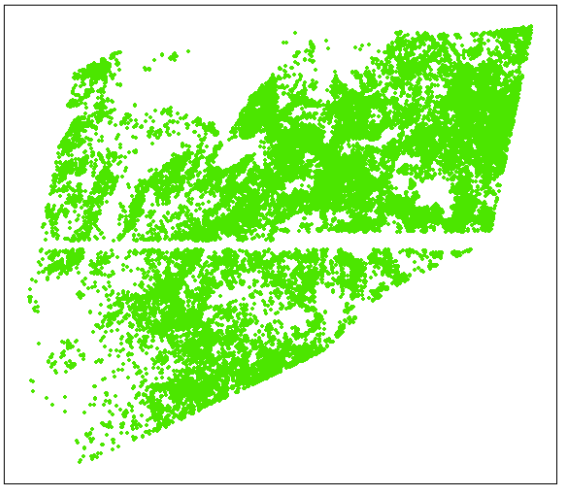
Figure 25 - (i) Modified Chlorophyll Absorption in Reflectance Index (ii) Modified Soil Adjusted Vegetation Index (iii) Moisture Stress Index (iv) Normalised Difference Vegetation Index (v) Soil and Atmospherically Resistant Vegetation Index (vi) Transformed Normalis

The values of each of the above calculated spectral indices were attached to the ground truth points for grassland and Savanna. Mean, standard deviation and coefficient of variation for each index value of the grassland/Savanna points was calculated. The coefficient of variation was used to determine the variability in the data and indices with less than 20% coefficient of variation were selected to define a range of index values. The range of the values of the spectral indices was calculated using deviation around the mean values. They are mentioned in the **Table 3** below:

All pixels falling within the range of spectral index values were selected and a layer with intersection of the pixels from all the indices were made. However, when this layer was resampled on a 1km x 1km grid, it was found that the dense habitat areas achieved through this method was missing out on important and vast areas of grasslands and Savanna.

Table 3 Mean, SD and coefficient of variation for each index value of the grassland/Savanna points

Spectral Index	Mean	Standard Deviation	Coefficient of Variation	Range of values
MCARI	0.198	0.087	0.43	0.111 to 0.285
MSAVI	0.282	0.075	0.265	0.207 to 0.357
MSI	0.975	0.094	0.096	0.881 to 1.069
NDVI	0.1668	0.049	0.29	0.1178 to 0.2158
SARVI	0.1449	0.096	0.66	0.0489 to 0.2409
TNDVI	0.814	0.043	0.052	0.771 to 0.857
RVI	0.715	0.079	0.11	0.636 to 0.794
RDVI	31.57	9.08	0.287	22.49 to 40.65
NBR	0.111	0.057	0.51	0.054 to 0.168
MTVI	0.1987	0.087	0.43	0.117 to 0.2857
MidIR	1.19	0.078	0.65	1.112 to 1.268



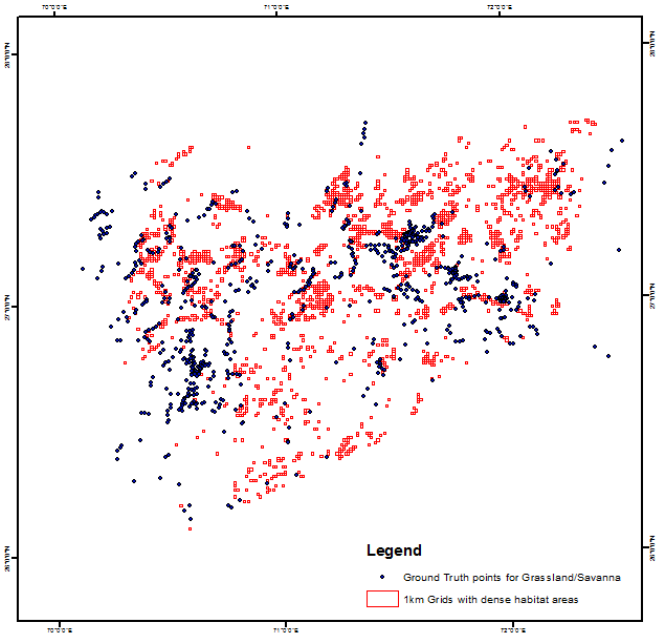


Figure 26 - Image showing intersection of all pixel values falling under the range of index values for habitat

At this stage, it was necessary to adopt a third approach to the classification of the satellite data for identification of grassland and Savanna areas in the Thar Desert landscape (Fig 26).

METHODOLOGY USED IN THE THIRD PHASE OF CLASSIFICATION:

A Linear Discriminant Analysis (LDA) was attempted on the spectral index values of the grassland and Savanna points. It was observed that the indices had very high collinearity amongst each other. Hence a Principle Component Analysis (PCA) was performed on the spectral indices. The principle components resulting from the PCA were used for LDA. 75% of the ground truth points were used for training and 25% were kept aside for testing the classification output. 67% accuracy could be achieved in discriminating the grassland and Savanna (habitat) pixels versus the non-habitat pixels. Hereafter, a PCA was performed on entire raster layers of all the spectral indices.

With the principle components of the spectral layers, classification algorithms using supervised classification, LDA and random forest were attempted. The dataset was trained with 75% of the ground truth points and tested with 25% of the points. 70% accuracy in discriminating habitat pixels as against non-habitat pixels could be achieved through this method.

The Land-use land-cover map produced by this exercise will be used for understanding habitat use and distribution of grassland associated species, and to monitor changes in the status of grassland/savannah habitat (Fig 27).



Image 6 Need to monitor changes in the status of grassland/savannah habitat is necessary © Sourav Supakar

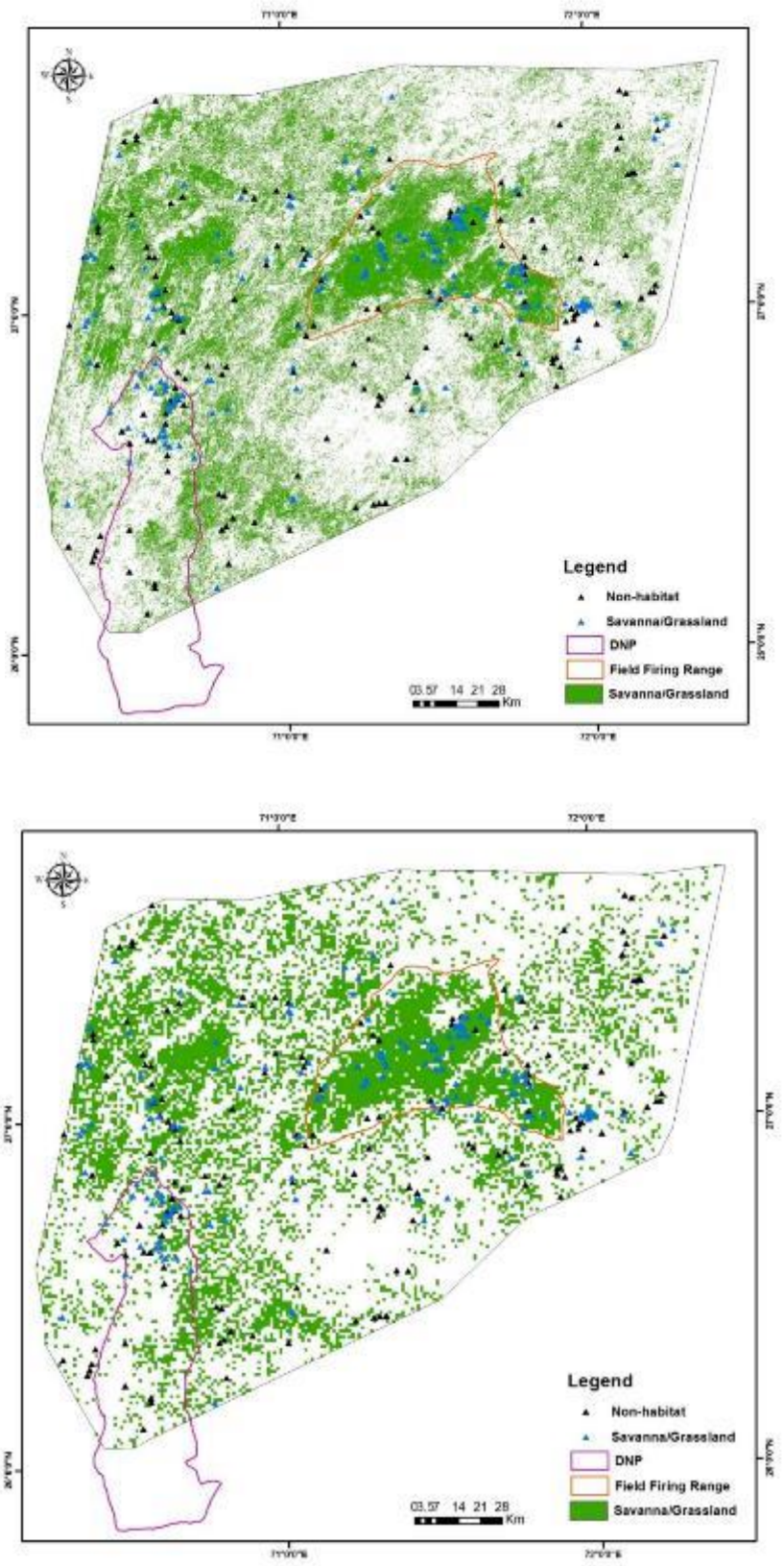


Figure 27 – Classified images of Grassland and Savanna habitat layer (top) and the same layers resampled to 1 km grid size

2.2.3. Assessment of threats

2.2.3.1. Population assessment of free-ranging dogs

The GIB landscape in Thar holds a large population of free-ranging dogs that partially depend on village-based resources but also depredate wildlife, including GIB nests, thereby being an important threat that needs to be urgently managed. To manage this problem, we assessed population status of free-ranging dogs in/around Desert National Park. Subsequently, a comprehensive study was undertaken that included the following activities:

Count surveys: Dogs were counted in 2 settlements, wherein observers walked on predesigned route recording the number of dogs present with consistent effort of ~ 8 km walk in 2 hours per square km of settlement area. Age and sex class of dogs were recorded. This activity generated crude counts of dogs in all settlements dispersed across GIB habitat in/around Desert National Park.

Mark-recapture surveys: A fraction of these settlements – 6 villages (Sam, Salkha, Lakhmano, Kuchhri, Neemba and Beeda)) and a Dog telemetry area – were targeted for estimation of dog abundance in mark-recapture framework which is robust to imperfect detection. An 83X point 10 shoot digital camera and zoom lens smartphone was used to photo-capture and sightings of dogs were recorded based on distinguishable natural marks (flanks, head, tail, other body marks). Four sessions were completed for each selected settlement and photographs were compared to find the number of initial marked sample which were included in subsequent samples. Capture recapture data of dogs were used to estimate non-detection corrected abundance in these settlements. Count and mark-recapture abundance estimates in these settlements would yield a correction factor that can be used to estimate dog abundance in all settlements using double sampling approach.

Vehicle transects: To assess density and distribution of free-ranging dogs in wildlife habitats, home range of radio tagged dogs (Fig 28) were obtained by modelling Minimum Convex Polygon (MCP) using 24 hour telemetry data from January to December 2018. Home range of dogs were surveyed using slow moving vehicles on pre decided tracks. Data will be analysed in Density Surface Modelling framework to generate spatially explicit density of dogs across GIB habitat in Thar.

This activity will generate baseline information on numbers and distribution of dogs in GIB habitat of Thar that will help us in planning sterilization/removal programs and monitor the effectiveness of these programs in reducing the number of dogs within manageable limits.

2.2.3.2. RANGING PATTERNS AND RESOURCE UTILIZATION BY FREE RANGING DOGS

To understand the impacts of free-ranging dogs on wildlife, we carried out field activities to determine ranging patterns and resource utilization of dogs using biotelemetry.

Radio tracking: 6 dogs were fitted with radio-collars and tracked daily on vehicle for 112 days (Fig 28). GPS locations, time and associated variables (habitat type, activity of animal and associated individuals) were recorded at every 15 minutes (Fig 28 and 29). Spatial locations of radio-collared dogs will be analysed using Minimum Convex Polygons (MCP) and Kernel methods to estimate home range size and habitat use. Time and location data will be analysed to assess temporal activity pattern, proportion of time and periods spent in settlement vs. wildlife habitats, and time-activity budgets.



Figure 28 - Field activities related to understanding and management of the impact of free-ranging dogs on wildlife in/around Desert National Park © Monisha Mohandas and Devendradutta Pandey

Behavioural sampling: Each radio tracked dog was observed using focal animal sampling for ~150 hours, including continuous 24 hours monitoring for 5 days, to determine their activity patterns, feeding habits and inter-specific interactions. Data on scavenging, active predation and interactions with conspecifics and potential competitors (fox, cat, raptor etc.) were recorded (Fig 28). Radio tagging of free-ranging dogs showed that an unsustainable 33% of chinkara population is cropped annually

Carcass availability assessment: To assess carcass availability in the area used by radio-tracked dogs, the combined MCP with 2 km buffer was converted into ninety four 1 sq km grid-cells, realized on ground using handheld GPS unit. A fixed zigzag route of 127 km were digitized using Google Earth™ in the same area that was surveyed once every 15 days to record carcasses. Data on condition, distance of carcass from trail, and presence of scavengers around the carcass were collected. This field activity will yield information on predation rates of wild prey and livestock by dogs.

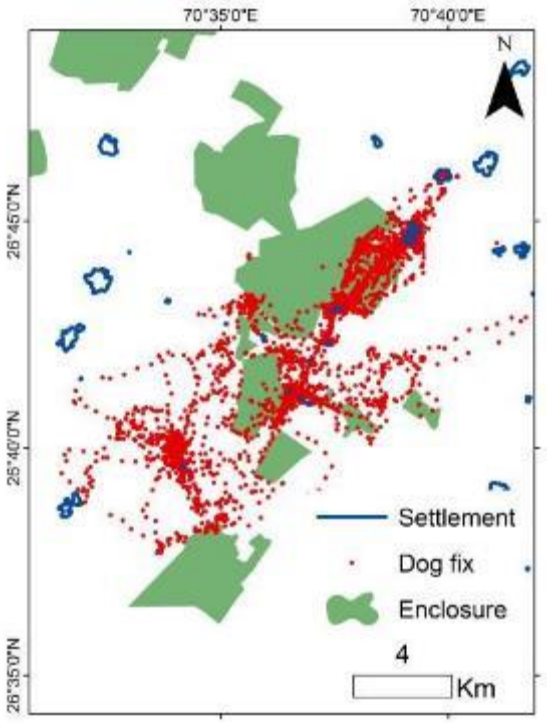


Figure 29 - Radiolocations of free-ranging dogs (n=9) overlaid on enclosures and settlements in Desert National Park during 2017-18



Image 7 Free ranging dogs are now hunting Chinkara in packs © Devendradutta Pandey

2.2.3.2. Assessment of bird mortality due to power-lines

Expanding networks of power-lines in wildlife habitats are causing fatal collision of birds in general and bustards in particular as the latter have low and heavy flight with small frontal vision because of which they fail to detect these thin structures from afar and collide. As recommended by bustard recovery plans (Dutta et al. 2013), Rajasthan Forest Department and project representatives have engaged with power-line agencies to install bird diverters on power-lines in priority GIB habitats. Simultaneously, to estimate bird collision rates and future effectiveness of mitigation measures (installation of bird diverters or undergrounding of cables), we assessed movement rate of bustard and other birds across power-lines, and their collision rates with power lines.

First, to compare the natural mortality rate of birds with that due to power lines, we surveyed (Fig 30) power line segments (n=50) and random belt transects of similar dimension (2000 m x 60 m) laid in natural environment without power line (n=20), once in January 2017. Bird carcasses were not detected under any random transect (n=20 transects), indicating the relatively low natural prevalence of bird mortality (Fig 30 and 31).

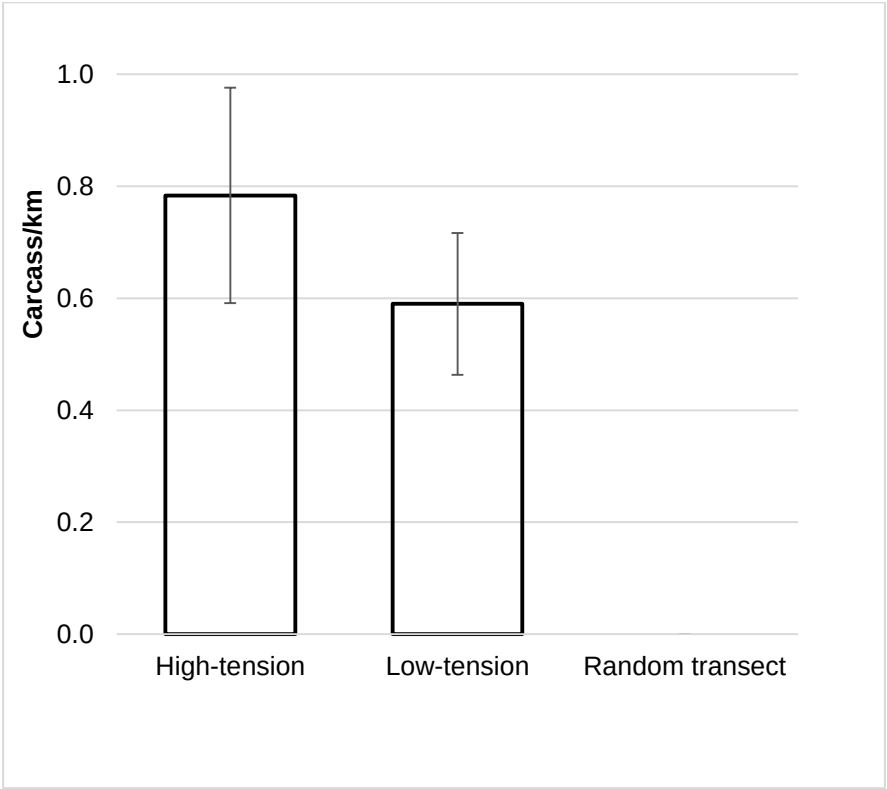


Figure 30 - Mean and standard error of carcass encounter rate under power line and random transects in Thar landscape during 2017-18.

To assess collision rates of birds, forty 2 km power-line segments (20 high-tension and 20 low-tension) were randomly selected in prime GIB habitat and 30-m band on either side of these power-lines were sampled for bird carcasses (Fig 32) on a monthly basis from March to December 2017 for 6 times. All bird carcasses were removed prior to sampling.

In total we collected 289 bird carcass samples out of which 25 % carcasses were visually identified at the time of collection and tissue/feather sample were collected for rest of 75% carcasses to further identify them genetically. Genetic identification of collected samples is still under process.

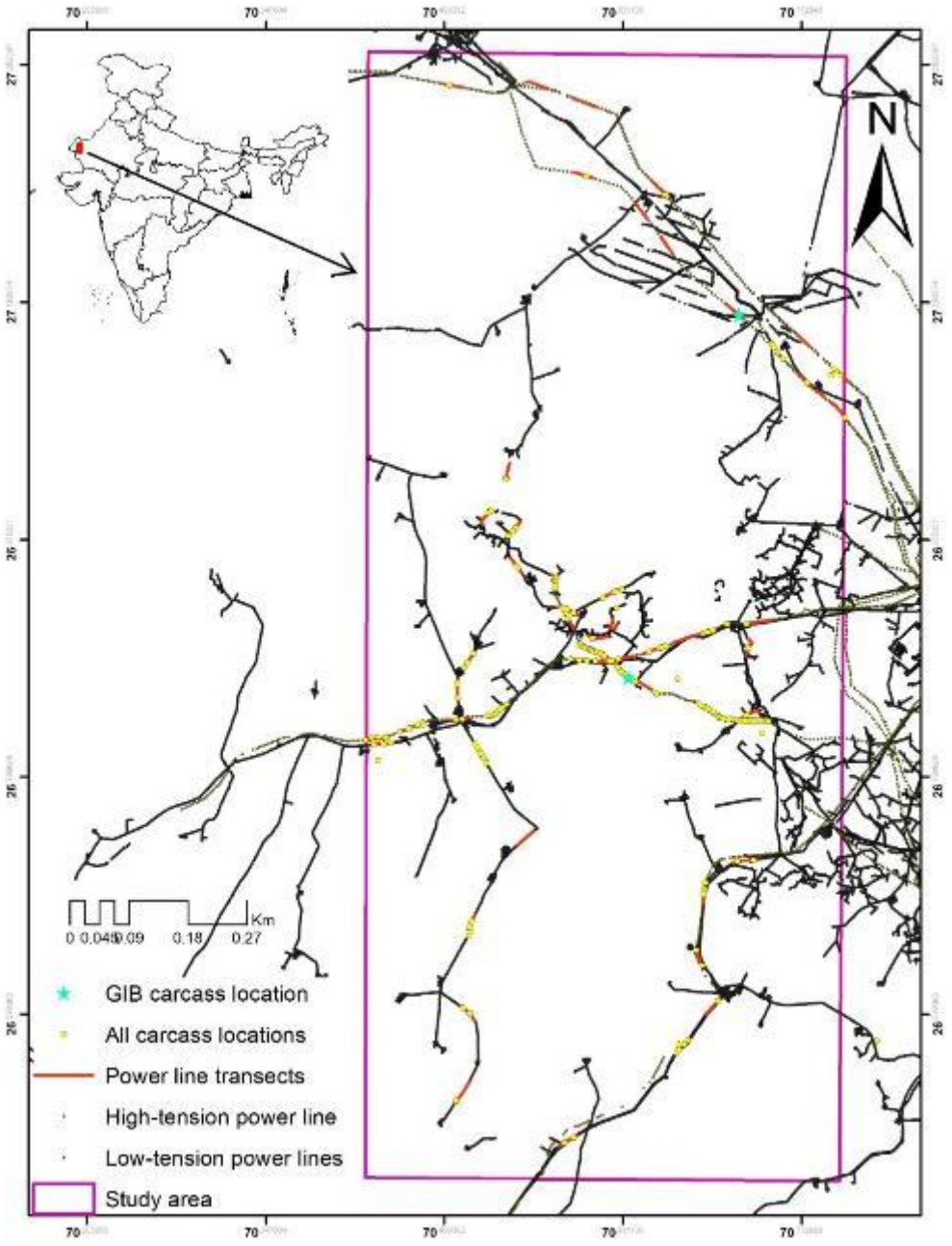


Figure 31 - Map showing power line study area, high-, low-tension power lines, transects, carcass location of great Indian bustard and other birds found on power line transects in Thar landscape during 2017-18.

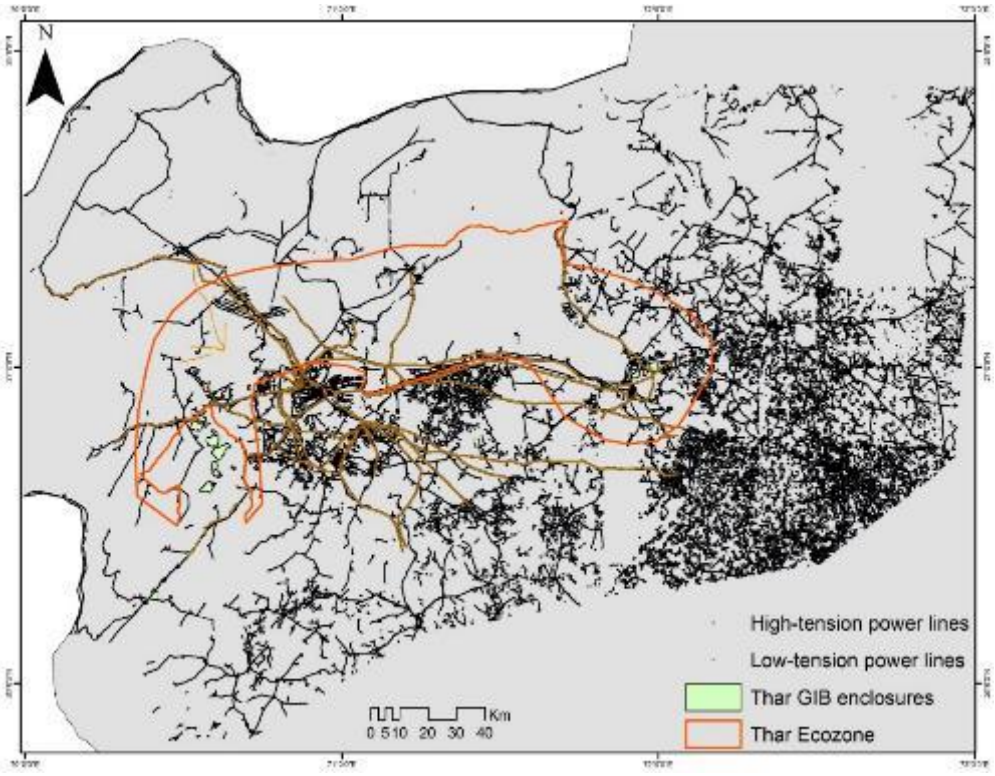


Figure -32 Map showing power line network in Thar landscape

Since, birds found under power-lines do not represent true mortality as a fraction of carcasses can go undetected or decomposed prior to survey, we conducted four experiments to incorporate detection and decomposition rates of carcasses. For carcass decomposition / disappearance experiments we used 80 fresh bird carcasses of various size (50 – 5000 g) and placed them under 10 randomly selected power-line segments and monitored them on days 2, 3, 5, 7, 10, 15, 30 and 60 since placement, and recorded if the carcass persisted or disappeared (Fig 32 and 35). For carcass detection experiment, we used 56 fresh/old carcasses of different sizes (50 – 5000 g) and placed them at random locations under six randomly selected power-line segments. Three/four observers surveyed these power-line segments to detect these carcasses in a blind trial. Our experiments resulted that the probability of carcass detection increased asymptotically with body mass of bird. Probability of carcass detection for birds weighing<100g, 100-1000 g and >1000 g was estimated at 0.43, 0.84 and 0.97, respectively (Fig 34). The probability of carcass persistence declined asymptotically with time and depended on bird body mass (Fig 33). Probability of carcass persistence for birds <100g was estimated at 0.09 till 2 days and 0.04 from 2 to 5 days since carcass placement, and 0 thereafter. The probability of carcass persistence for birds weighing 100-1000g was estimated at 0.36 till 2 days and 0.04 till 30 days since carcass placement. The probability of carcass persistence for birds weighing >1000g was estimated at 0.78 till 2 days, 0.39 till 20 days and 0.17 on the 30th day since carcass placement.

Mean monthly encounter rate of bird carcasses was 0.29, 0.37 and 0.27 birds / km for small, medium, and large birds, respectively (Table 4). We found a significant difference between mean monthly carcass encounter rate in high- and low- tension power lines (Table 4). For high-tension power lines it was 0.25, 0.22 and 0.22 birds / km and for low-tension power lines it was 0.4, 0.15 and 0.5 birds / km for small, medium, and large birds, respectively. However, carcass detection probability of small birds was low (0.43) compared to that of medium (0.84) and large (0.97) birds. Similarly, mean probability of carcass persistence through 30 days preceding our survey was lower for small (0.08) and medium birds (0.16) compared to large birds (0.48). Correcting for these biases, the true collision rate was

estimated at 7.74 small bird, 1.70 medium sized birds and 0.47 big bird mortalities km^{-1} $month^{-1}$, yielding an estimated 8,013 bird mortalities/month in the 4,200 Sq km landscape of Thar GIB habitat (Table 4).

High-tension power lines alone cause 4,955 bird mortalities/month, compare to that low-tension power lines contributes relatively low 2,949 bird mortalities/month. We found two great Indian bustard carcasses during these surveys (Fig 36), extrapolation of our findings on total high-tension power lines under prime GIB habitat of Thar indicates that ~18 Great Indian Bustards/year dying due to power line casualties. To come up with a final estimate, after genetic identification data will be analysed and number of birds dying from power line collision per km per month will be updated to assess taxa/size wise bird mortality due to power-lines.

To quantify bird crossing across power lines, we observed movement of birds at 10 randomly selected 2 km power-line segments which include 5 low tension power lines and 5 high tension power lines in prime GIB habitat. We tried to cover a maximum of 850 m from a point observing bird movements across power lines for 12 hours a day. We conducted this exercise in winter, summer and post monsoon to capture seasonal differences in bird composition. Bird movements across power line, flight height from wires, and use of wires, poles and pylons for perching/roosting were recorded, and segregated into taxa/size groups. Collision events during these observations, if any, were recorded. During bird flight activity observations, we recorded a total of 6732 individuals of 49 species. The most numerous species was Eurasian collared doves (27.59% of total individuals), followed by Lark (19.38%), green bee-eater (7.07%) and white eared bulbul (6.01%) etc. Our initial results show that comparison of crossing *vs.* collision rates indicated *Ploceidae, Anatidae* and *Charadriidae* as the most collision-prone families.



Image 8 Number of new renewable projects such as wind mills and solar power plants in Thar Desert © Sujit Narwade

Table 4 - Mean monthly collision rates (birds / km with 95% confidence intervals) of birds in different weight classes in Thar landscape during 2017-18. Collision rates were adjusted for biases in a stepwise fashion i.e., mean carcass encounter rate was corrected for detection probability and persistence probability to estimate true bird mortality / km / month.

		<100 (g)	100-1000 (g)	>1000 (g)
High-tension	Mean carcass/km	0.08	0.07	0.07
	SE carcass/km	0.03	0.02	0.03
	Mean encounter rate	0.25	0.22	0.22
Low-tension	Mean encounter rate	0.02	0.08	0.03
	SE encounter rate	0.01	0.02	0.01
	Mean encounter rate	0.04	0.15	0.05
Class mid weight (g)		50.00	550.00	4750.00
Probability (detection)		0.43	0.84	0.97
Mean probability (persist)		0.08	0.16	0.48
High-tension	True carcass/km	7.74	1.70	0.47
Low-tension	True carcass/km	1.23	1.13	0.10
High-tension	Km power line	500.00		
Low-tension	Km power line	1200.00		
High-tension	bird mortality/month	3868.50	852.27	234.15
Low-tension	bird mortality/month	1475.52	1350.79	122.39
High-tension	bird mortality/year	60284.78		
Low-tension	bird mortality/year	35875.80		
Total bird mortality/month 8013.38 Total bird mortality/year 96160.58				

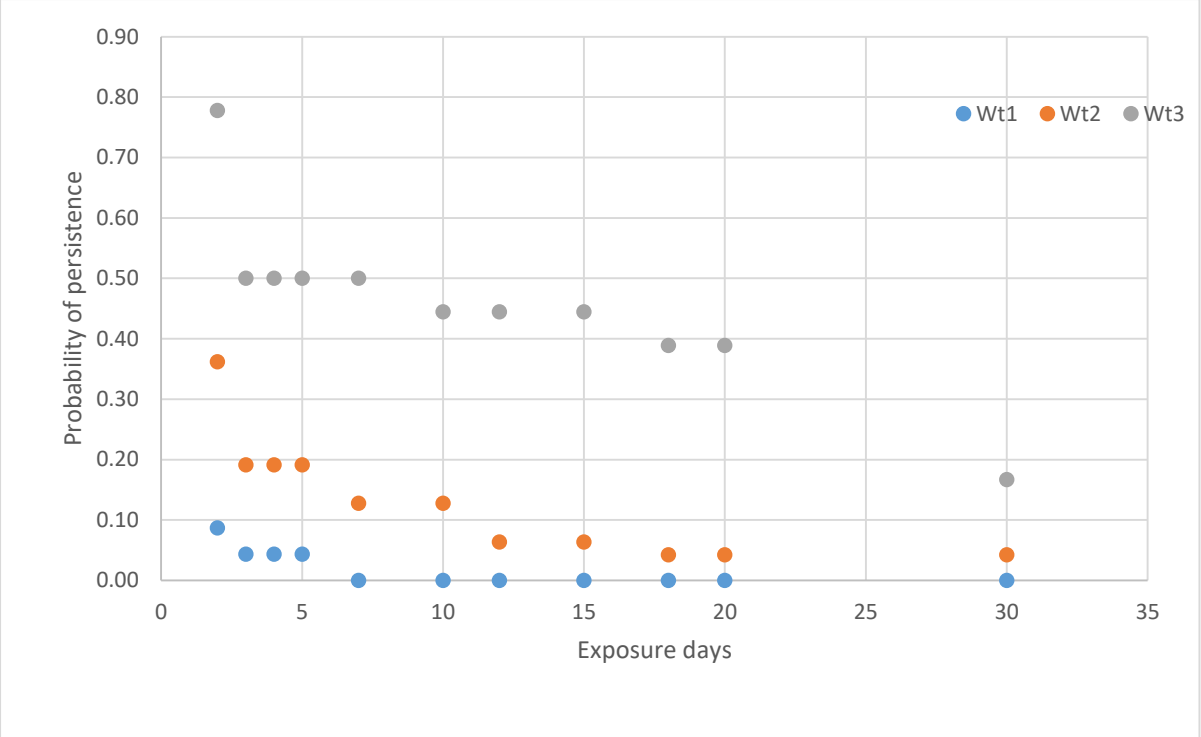


Figure 33- Probability of carcass persistence along time since placement under power lines for small (<100 g), medium (100-1000 g) and large (>1000 g) birds in Thar landscape during 2017-18.

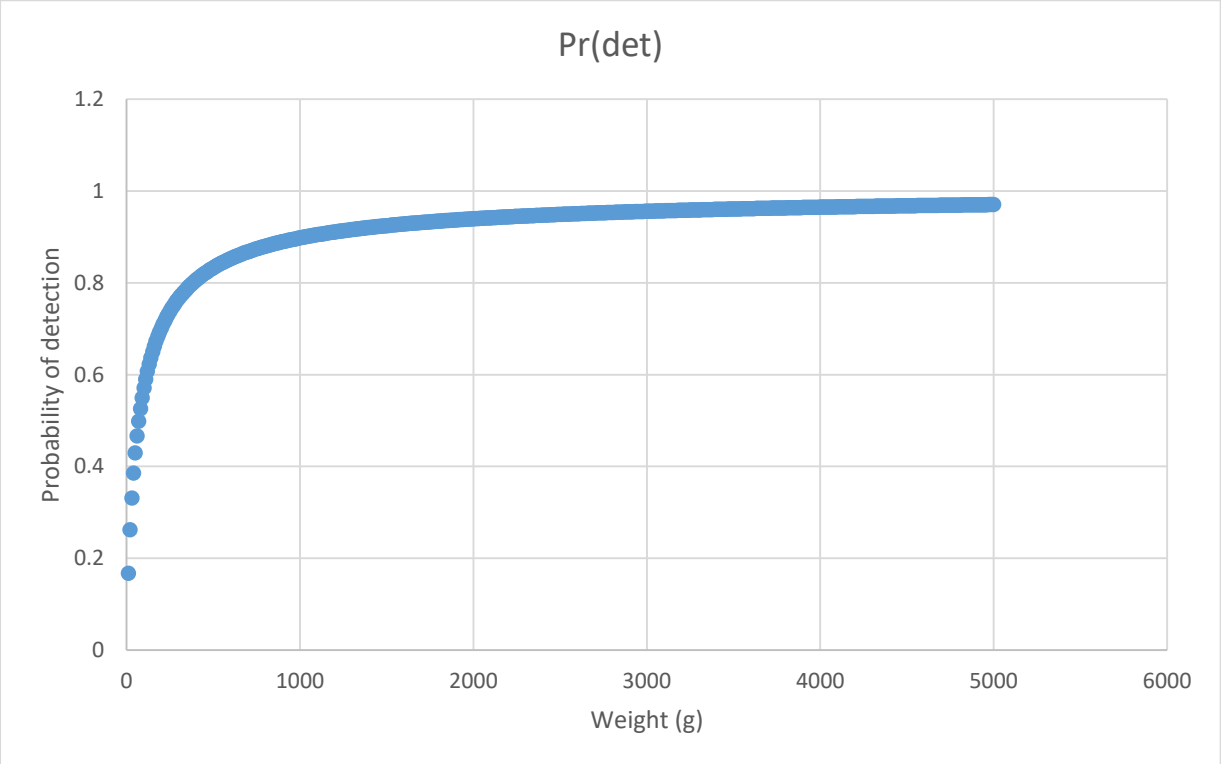


Figure 34 - Probability of detection along body mass of birds estimated from carcass detection experiment in Thar landscape during 2017-18.



Figure 35 - Field activities related to assessment of bird mortality caused by power-line collisions (left, centre) and power line observations (right) in Thar during 2017-18 © Mohib Uddin



Figure 36 - Carcass of great Indian bustard found during power line surveys in Thar landscape in May 2017 © Bipin C.M.

2.2.3.3. Assessment of nest predators using camera trap

As per the recommendations of the national bustard recovery plans (Dutta, et al., 2013), the Forest Department enclosures in Thar are managed with the objective of improving GIB recruitment. The eggs and chicks of bustard are known to face high mortality due to predation and other causes (Morales et al. 2002).

It is important to assess the abundance of potential nest/chick predators in and around the enclosures so that subsequently their population could be controlled for the improvement of GIB recruitment rate. To do so, we deployed camera traps following the Random Encounter Model sampling framework

(Rowcliffe et al. 2008) inside and outside those enclosures in Thar which had previous GIB breeding records (Fig 37). For camera-trapping inside the enclosures, we systematically placed one camera trap at the centres of 500m X 500m grid-cells. For placing camera traps outside the enclosures similar 500m X 500m grids were placed around the enclosure after leaving a buffer of 1km. We placed Reconyx HC500 Hyperfire Semi-covert passive infrared camera-traps at the height of 0.18–0.23 m from ground. The cameras were operated for 30-40 days at each location. Since the commencement of the camera trap work in December, 2016 till May, 2018 camera-trapping has been done at 12 different locations which includes 9 enclosures and 3 areas outside enclosures; with ~300 unique camera placements we have covered an area 80 square kilometre (Table 5).

Table 5 Camera trapping efforts across enclosures for assessment of nest predator population status in Thar landscape during 2016–17

S. No.	Name of Enclosure	Cameras Placed	No. of Photos
1.	Sudasari	60	138,065
2.	Kanoi	36	83,575
3.	RKVY	37	196,202
4.	Gajaimata	15	84,969
5.	Ramdeora	26	162,871
6.	Chauhani	16	47,086
7.	Gajaimata_PPC	8	10,434
8.	Rasla	17	63,050
9.	Rasla outside	19	101,199
10.	Sudasari outside	32	101,199
11.	Miajalar	23	86416
12.	Miajalar outside	24	72,183

We obtained photo-captures of potential nest predators (fox, mongoose, cats and dogs), bustard, chinkara, Nilgai, wild pigs, and livestock. Photo-capture data will be analysed using Random Encounter Modelling approach that uses independent capture rate and speed to estimate abundance. To enable this, calibration exercises were carried out at the time of camera-trap placement to characterize camera viewing frames that would be used to generate triaxle location, distance from camera, and speed from animal photo-captures.





Figure 37 - Camera-trapping to assess great Indian bustard egg/chick predator abundance and species photo-captures in systematically placed camera-traps in and around Desert National Park enclosures during 2017-18 © WII photo library

2.2.4. Conservation genetics to aide protection and conservation management

Sample collection and DNA extraction:

Great Indian Bustard samples were collected from Rajasthan and Gujarat as part of collaring and deaths due to electrocution and natural deaths during last one year (April 2017-March 2018). All the samples were either collected in zip locks filled with silica or ethanol and shipped to conservation genetics lab for further storage at -20°C. DNA was isolated from tissue, molted feathers using DNeasy blood and tissue kit (Qiagen), and egg membranes using Bush et al. (2005) protocol. All the extractions were carried out in batches in a dedicated room and included negative controls to monitor for any potential contamination during extractions (Fig 38).

Methods and Genetic analysis:

Species identification was done using conserved primers to amplify mtDNA sequences containing either a 323 bp fragment of control region II (L438 and H772; Wenink et al. 1993) or a 399 bp fragment of the cytochrome b gene (LCyt-B4 and LCyt-B6; Broderick et al. 2003) and compared the sequences using available genebank sequences. Misidentification of samples with other birds is highly possible; therefore, a species identification step is carried out before any other genetic analysis. The same mtDNA sequences generated can be used to identify the haplotypes and compare with existing (Ishtiaq et. al. 2011). Nuclear microsatellites were also used (n=13) to identify individuals and various genetic analyses. Multi tube approach was used to amplify all the microsatellites in four panels. Negative controls were included in all PCR's to monitor for any contamination.

DESIGNING OF MTDNA CR AND CYTB PRIMERS

As the portion of targeted mtDNA sequences is very small in comparison to the whole Control region (Singh et.al. 2017) and Cytochrome b regions (Kocher et. al. 1989), we targeted to amplify the whole sequence regions by designing internal primers which can amplify shorter fragments in both the invasive and non-invasive samples. Moreover, it is also useful in determining the level of genetic variation, phylogenetic and phytogeography with a high level of accuracy.

Initially we amplified whole CYTB and CR sequences using good quality tissue samples and then we designed internal primers by aligning all the sequences. The primers designed can also be used to amplify in Houbara bustard and Lesser Florican. The amplification was carried out in a 20 ll reaction volume containing 1 ul of the extracted DNA, 100 uM of dNTPs, 4 pmol of each primer, 1.5 mM MgCl2, 0.5 units of AmpliTaq Gold (Life Technologies) and 1 ul PCR buffer (10 mM Tris–HCl, pH 8.3, and 50mM KCl). The PCR conditions were the following: initial denaturation at 95 oC for 10 min, followed by 35 cycles of denaturation at 95 oC for 45 s, annealing at 56 oC for 45s and extension at 72 oC for 90s. The final extension was at 72 oC for 10 min. Finally, the PCR products were electrophoresed on 2% agarose gel, stained with ethidium bromide (0.5mg/ml) and visualized under a UV trans illuminator. The PCR products were sequenced directly in 3130 Genetic Analyser (Applied Bio systems) in both directions.

Results:

Amplifiable DNA was achieved from all the collected samples. MtDNA sequences after comparison with GenBank sequences showed presence of Houbara and other bird species from the collected samples and finally GIB positive samples were further used for genetic analyses. No new haplotypes were found apart from existing three haplotypes in GIB positive samples. Microsatellites (n=8) are polymorphic with number of alleles ranged from 2-8 and remaining microsatellites (n=2) were found

to be monomorphic. Range of allelic dropouts and false alleles (0-10%) confirming the presence of no major genotyping errors in the data.



Figure 38 - Lab activity under Conservation Genetics Component © WII photo library

Primers designed:

Primer sequences for the amplification of control region and CytB regions of bustard species and expected length of their amplicons.

Control region Primer combination and expected length	
YSF1+YSR1	320 bps
YSF2+YSR2	420 bps
YSF3+YSR3	217bps
YSF4+YSR4	300bps
YSF5+YSR5	510 bps
YSF6+YSR6	450bps
Cytochrome B region primer combinations and expected length	
YSCYTBF1+YSCYTBR1	350bps
YSCYTBF2+YSCYTBR2	400bps

2.3. Capacity-building and outreach

2.3.1. Meetings and workshops

Various meetings and workshops were organised under capacity building and outreach programme as given below.

SN	Date	Place	Topic/Issue	Attendee
1	Mar-17	Jaisalmer	Training programme for Bustard Survey	WII Project team
2	28-Apr-17	Aranya Bhawan, Jaipur	Project implementation meeting with focus on conservation breeding programme	Hon. Chief Minister, Rajasthan; Forest Minister; Forest Department, Rajasthan; Rajasthan State wildlife board; Project team.
3	02-May-17	Van Bhawan, Bhuj	Meeting on immediate actionable plans in GIB habitat of Kutch, Bhuj	Dr. A Rahmani, Dr. Juan Carlos Alonso, Dr. Y.V. Jhala, Dr. Sutirtha Dutta, Mr. Bipin CM, CCF-Kutch
4	Jul-17	Lala, Kutch	Meeting with Gujarat forest department on immediate actionable points to mitigate powerlines post tagged bird mortality	DFO- Kutch, APCCF-Gujarat, CCF-Kutch, Devesh Gadhvi, Dr. Sutirtha Dutta, Representative of SUZLON and GETCO
5	16-17 July 2017	Bhavnagar	Training workshops for lesser Florican status assessment with state forest department, partner NGOs and volunteers	WII project team
6	24-Jul-17	Ujjain	Training workshops for lesser Florican status assessment with state forest department, partner NGOs and volunteers	WII project team
7	2-3 August 2017	Ajmer	Training workshops for lesser Florican status assessment with state forest department, partner NGOs and volunteers	WII project team
8	Aug-17	Kheechan, Jodhpur	Site visit to bustard conservation area for powerline impact assessment and mitigation	WII project team
9	Aug-17	Gandhinagar	Meeting with CWLW, Gujarat for permission	CWLW, Dr. Sutirtha Dutta
10	29-Aug-17	Jaipur	Review meeting of project updates with RSPCB (Co-funder) and meeting with CWLW on project updates.	Dr. Sutirtha Dutta
11	17-Sep-17	Akola	Training workshops for lesser Florican status assessment with state forest department, partner NGOs and volunteers	WII project team
12	Oct-17	Dehradun	Post Lesser Florican survey workshop to prepare report	BNHS, TCF and WII project team members

SN	Date	Place	Topic/Issue	Attendee
13	Oct-17	Naliya	Meeting with Gujarat forest department and local communities to sensitize the latter on convergence between bustard conservation and livelihood	Dr. Sutirtha Dutta made a presentation
14	Nov-17	Khetolai, Rajasthan	Meeting with sarpanch Khetolai and forest department guards regarding collaborative conservation in Khetolai.	Project team members
15	Nov-17	Jaisalmer	Meeting with DFO-Jaisalmer to discuss project activities	WII-Project team
16	Nov-17	Gir National Park	Meeting on Lesser Florican conservation status and action plan organized by Gujarat forest department	Dr. Sutirtha Dutta presented on national Lesser Florican status assessment and conservation plan
17	11 to 13 Nov 2017	Sarahan, Himachal Pradesh	Visit to the Western Tragopan Conservation Breeding Center and consultation on various breeding and husbandry protocols for GIB	Dr. Laxminarsimha, Arjun Awasthi and Dr. Tushna Karkaria
18	10-Nov-17	Shimla, Himachal Pradesh	Consultation on various breeding and husbandry options for GIB	Dr. Sushil Sood, Arjun Awasthi and Dr. Tushna Karkaria
19	11- 17 December 2017	Dehradun	Training workshops for project partners on quantitative conservation tools	WII project team, BNHS
20	07-Jan-18	Pinjore, Haryana	Recce of the Conservation breeding center and consultation on breeding and husbandry practices	Dr. Vibhu Prakash, Mrs. Nikita Prakash, Dr. Sujit Narwade, Arjun Awasthi and Dr. Tushna Karkaria
21	11-Jan-18	Jodhpur	Meeting with CCF on project activities and immediate action plans	Dr. Sutirtha Dutta; Mr. Mohib Uddin; CCF, Jodhpur
22	11-Jan-18	Jodhpur	Meeting on mitigation of high tension power line in Thar eco sensitive zone	CCF-Jodhpur, representatives of RVPNL, SUZLON, Jodhpur Discom powerline companies; WII- Project team, DFO-Desert national park.
23	20 January 2018- 10 February 2018	Thar, Rajasthan	Permission & support for Dog Neuterization in the villages around GIB habitat	Sarpanch -Sam, Luno ki basti, Ganga, Kanoi, Salkha, Bida, Nimba, Lolai, Faledi, Chauhani, Jamda, Balanio ki Dhani, sipla, Barna, Bheelo ki basti – Mr. Devendradutta Pandey
24	28-Mar-18	WII, Dehradun	Sexual selection in Great Bustard- by Dr. Juan Carlos Alonso	,Dr. Sutirtha Dutta, Bipin C.M., Dr. Sujit Narwade and Dr. Tushna Karkaria

SN	Date	Place	Topic/Issue	Attendee
25	Apr-18	Pokhran	Meeting with Indian Armed forces on the need and importance of GIB conservation and follow-up status surveys in Pokhran field firing range.	WII project team, Col. Anshuman
26	Apr-18	Jaisalmer	Meeting with collector on harmonizing project activities with government outreach programmes	WII-Project team
27	Apr-18	Gandhinagar	Meeting on project activities and tagging permissions	Dr. Y.V Jhala; CWLW-Gujarat; Other forest department officers
28	28-Apr-18	Abu Dhabi	Participation in Bustard conservation conference in Birdlife Flyway Summit at Abu Dhabi and visit to Houbara bustard breeding center on appraisal on artificial breeding techniques	Dr. Sutirtha Dutta
29	18-May-18	Aranya Bhawan, Jaipur	Permission for arthropods collection from DNP	Dr. Reddy, Ms. Monika,

2.3.2. Awareness materials

1. Brochures on information about GIB and ongoing activities of the project (Fig 39)
2. Brochures on mitigating measures (power-line) for GIB conservation to sensitize power agencies was distributed (Fig 40)
3. Brochure to sensitize Indian Armed Forces on GIB conservation and gain permission to monitor the GIB population in Field Firing Range is under progress

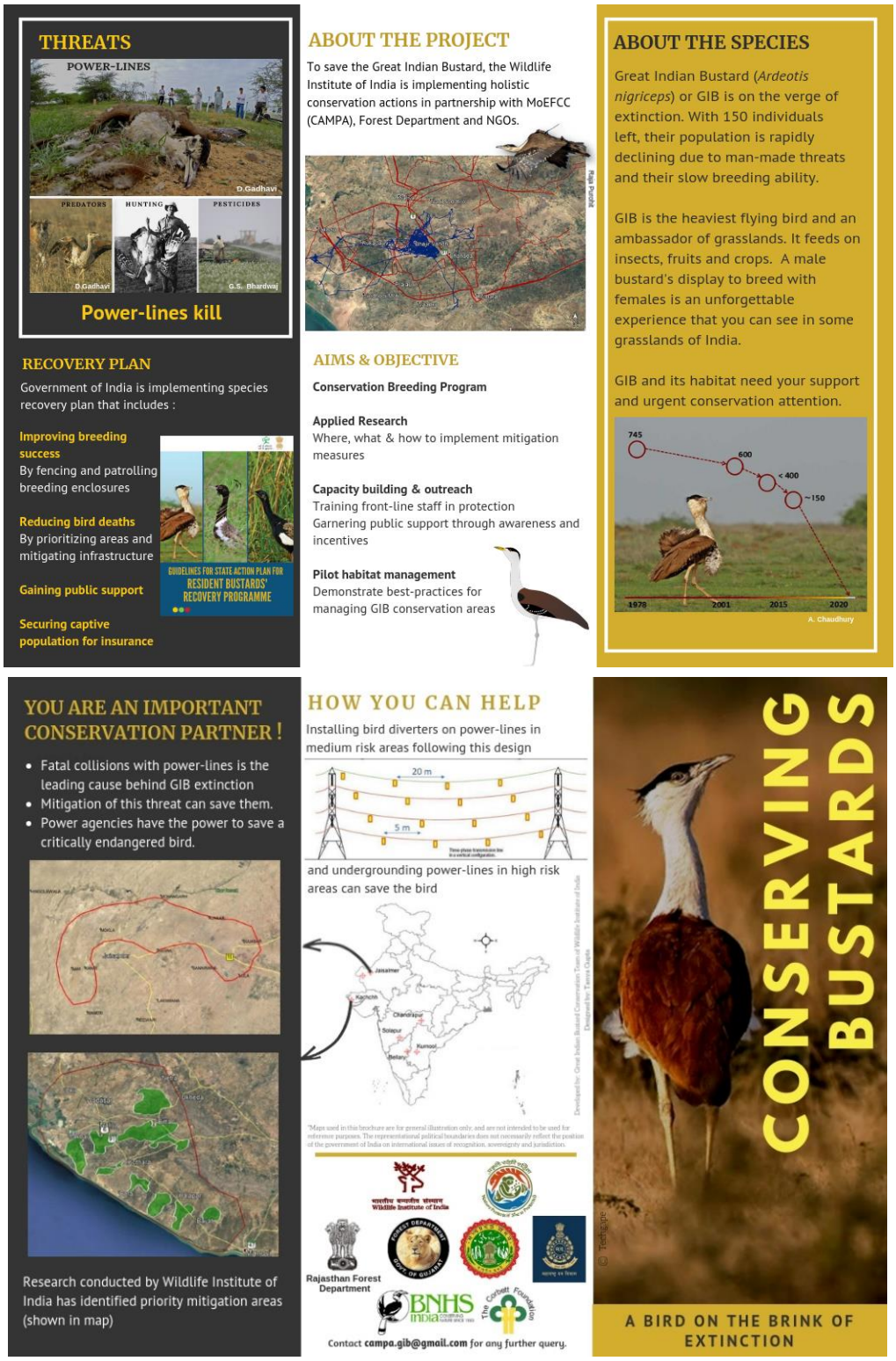


Figure 39 - Brochure on mitigating measures (power-line) for Great Indian Bustard conservation to sensitize power agencies



Figure 40 - Brochure to sensitize Indian Armed Forces on GIB conservation and gain permission to monitor the GIB population in Field Firing Range is under progress



Figure 41 - Cover page of notebooks to be distributed among school children in study area

2.3.3. Relevant publications

Publications

1. M.Sc. dissertation titled "Has conservation gone to the dogs? Ecological aspects of free-ranging dogs in the Thar"
2. M.Sc. dissertation titled "Assessing threats to birds from power-lines in Thar with special emphasis on Great Indian Bustard"
3. Collar et al (2018). Approaching extinction of Asian bustards. *Forktail* 33(2017):1-26
4. GIB report 2017-18. Dutta, S., Bipin C.M., Anoop, K.R., Uddin. M., Shekhawat, R.S., Jhala, Y.V. 2017. Status and trend of Great Indian Bustard, Associated Wildlife and Threats in Thar. Wildlife Institute of India, Dehradun and Rajasthan Forest Department, Jaipur.
5. Lesser Florican survey report 2017. Dutta, S., Narwade, S., Bipin, C.M., Gadhavi, D. Uddin, M., Mhaskar, M., Pandey, D., Mohan, A., Sharma, H., Iyer, S., Tripathi, R., Verma, V., Varma, V., Jangid, A., Chakdar, B., Karulkar, A., Lambture, B., Khongsai, N., Kumar, S., Gore, K., Jhala, D., Vaidya, N., Horne, B., Chittora, A., Annigeri, B.S., Trivedi, M. and Jhala, Y.V. (2018) Status of the Lesser Florican Sypheotides indicus and implications for its conservation. Wildlife Institute of India; Bombay Natural History Society and The Corbett Foundation.
6. Dutta, S. 2018. Greener on neither side: socio-ecological crisis of grasslands in India. In Umesh Srinivasan and Nandini Velho (eds) Conservation from Margins. Orient Blackswan, Hyderabad.

News articles

1. Bustard, Wires, and the Flight to Extinction. Conservation India, January 2018 (URL - uhttp://www.conservationindia.org/articles/bustard-wires-and-the-flight-to-extinction)
2. The New Forest Policy Is a Lesson in Missing the Wood) s for the Trees. (https://thewire.in/environment/the-new-forest-policy-is-a-lesson-in-missing-the-woods-for-the-trees

Media coverage of the project

1. This draft national forest policy too gives short shrift to grasslands (URL - https://india.mongabay.com/2018/04/13/this-draft-national-forest-policy-too-gives-short-shrift-to-grasslands/)
2. Green Energy, Red Tape & Last Stand of the Poor Bustard! (URL - https://www.thequint.com/news/india/great-indian-bustard-extinction)
3. 19,000 birds die due to high-tension wires every month in Jaisalmer-Barmer region (URL - https://timesofindia.indiatimes.com/city/jaipur/19k-birds-die-due-to-high-tension-wires-every-month-in-jaisalmer-barmer-region/articleshow/64535449.cms)
4. India Is Paying the Price for Losing Its Grasslands (URL - https://www.thequint.com/news/environment/india-is-paying-the-price-for-losing-its-grasslands)
5. Power lines killing the last remaining Great Indian Bustards in India (URL - https://news.mongabay.com/2017/12/video-power-lines-killing-the-last-remaining-great-indian-bustards-in-india/)
6. The bustard and the windmill (http://www.thehindu.com/sci-tech/energy-and-environment/the-bustard-and-the-windmill/article19608564.ece)
7. The skies are no longer safe... (Read more at: https://www.deccanherald.com/content/657772/skies-no-longer-safe.html)
8. National survey on Great Indian Bustard to start on March 17 (URL - https://timesofindia.indiatimes.com/city/ajmer/national-survey-on-gib-to-start-at-dnp-on-march-17/articleshow/57471349.cms)
9. Put satellite tag on GIBs for tracking movements' (URL - https://timesofindia.indiatimes.com/city/jaipur/put-satellite-tag-on-gibs-for-tracking-movements/articleshow/64564302.cms)

10. 1st GIB breeding centre to come up in Baran (https://timesofindia.indiatimes.com/city/jaipur/1st-gib-breeding-centre-to-come-up-in-baran/articleshow/64346415.cms)
11. Bustards: Down to the wire (https://www.thehindubusinessline.com/blink/cover/bustard-down-to-the-wire/article24054698.ece
12. Great Indian Bustard breeding centre to come up at Sorsan (https://www.hindustantimes.com/jaipur/great-indian-bustard-breeding-centre-to-come-up-at-sorsan/story-7zBjHAqxdXJMrDBfgL12yK.html)
13. Great Indian Bustard breeding centres in Kota & Jaisalmer soon (https://timesofindia.indiatimes.com/city/jaipur/great-indian-bustard-breeding-centres-in-kota-jaisalmer-soon/articleshow/58428144.cms)
14. Rajasthan to set up bustard breeding centre (http://www.thehindu.com/news/national/other-states/rajasthan-to-set-up-bustard-breeding-centre/article18350355.ece)
15. Great Indian Bustard breeding centre to be set up in Kota (https://www.hindustantimes.com/jaipur/great-indian-bustard-breeding-centre-to-be-set-up-in-kota/story-69snVE7h2qYAvv9xwDFGjP.html)
16. The bird that could have become India's national bird but for that spelling! 21-01-2018 (https://www.dailyo.in/variety/the-great-indian-bustard-wildlife-renewable-energy-extinction-endangered-gib-/story/1/21879.html)
17. The bustard and the windmill SEPTEMBER 02, 2017 16:22 (http://www.thehindu.com/sci-tech/energy-and-environment/the-bustard-and-the-windmill/article19608564.ece)
17. Green Energy, Red Tape & Last Stand Of The Great Indian Bustard January 13, 2018 (http://www.indiaspend.com/cover-story/green-energy-red-tape-last-stand-of-the-great-indian-bustard-92598)

2.3.4. Social Engagement

A significant part of the project is to engage with the local people that reside in and around prime Great Indian Bustard (GIB) habitat. Working with people is essential to create buy-in and goodwill for the long-term success of both the in-situ and ex-situ conservation efforts to save the Great Indian Bustard. We started this process by engaging with the people who live in and around the Desert National Park where a significant portion of the last remaining GIB populations resides.

1. Currently our team has been able to speak to representatives from all the villages within the Desert National Park. We have created survey questionnaires that was used to interview villagers. This survey serves to inform us about specific attitudes that the people have, their motivations, their needs, and their sensitivity towards the species that they coexist with. The surveys were conducted by the sociologist in our team. The information collection and attitude assessments will continue on into the second year of the project. We prepared two priority lists for social surveys based on GIB habitat conservation prioritization. The questionnaire that was used for conducting interviews during 2017 - 2018 is enclosed in the appendix.

2. We believe that by educating children we can help change attitudes and bring about a generational shift in sensitivity towards species, especially awareness surrounding the GIB. Our goal is to create programming for children that is sustainable, can be easily carried out repeatedly in the future, and will have the positive affect of including a large section of the society in Jaisalmer in community conservation efforts. We have designed books to be distributed among school children. Our intention is to conduct workshops that will have elements such as movie screenings, drawing competitions, and games, all wildlife themed and leading into talking to children about the GIB. These activities are planned for the month of September 2018 onwards.

3. There are many youths in the villages that are educated and have degrees as well, and yet do not have job skills to be gainfully employed. The economy in the Thar Desert predominantly functions due to and relies heavily on the tourism season which lies between October to January. This creates a peak income period for individuals associated with the tourism industry. The rest of the year individuals must rely on the income that they earn during this tourism period. The youth are not exposed to and cannot engage in job skills workshops or state government sponsored trainings because of the scarcity of resources available for them to travel to areas where the training would take place. Moreover, many individuals have never had an experience of working at a full-time job since they have half or more of the year off. This is an opportunity for our team to bridge the gap and create goodwill in the community by assisting these youth to achieve gainful employment and to train them on relevant skills that can increase their chances of employability. This is a challenge and to understand the problem better and how to mitigate this issue our social engagement team met with the District Magistrate of Jaisalmer, Mr. Kailash Chand Meena in the month of April. He connected us with the Rajasthan State Skill Development & Livelihood Development officer for the district of Jaisalmer Mr. Hasan Khan. We have initiated dialogue and will work closely with RSLD office to accomplish our goals of social engagement with communities. These activities are planned for the month of September 2018 onwards.

As a part of community outreach we are also committed to disseminate information regarding our programming and activities that we are undertaking in the conservation of the GIB. Dr Sutirtha Dutta, the co-Principal Investigator on the Great Indian Bustard project was published in *Conservation India*, where he wrote about the collisions of GIB with power lines and how mitigation efforts by using power line diverters can significantly lower the risk of mortalities caused by collisions (Dutta 2018). Our project also received coverage in several publications such as *The Times of India* (Bhatia 2018), *IndiaSpend* (Bindra 2018), and several other publications of national repute. By improving the knowledge base of the general public, we hope to create a stronger dialogue for GIB conservation and to gain the trust and support for the Wildlife Institute of India's efforts to protect, gather vital information on, and inform our decisions when it comes to the conservation breeding of the GIB.

2.3.4.1 Questionnaire Survey

We prepared two priority lists for social surveys based on GIB habitat conservation prioritization. We collected a list of household heads village wise from census report and selected number of households for the interviews with equi - proportional sample sizes, according to total number of households. The research team conducted all the interviews during March and April. We randomly selected 5% of the total household per village to conduct interviews following under the framework of equi- proportional sampling design. In total we have surveyed 158 households across 20 villages and 10 Dhanis from the first priority list. These surveys will yield information on the local livelihood concerns, conservation perceptions, scope of alternate livelihoods, and ways to minimize the antagonism among local people towards conservation. It will also help us in designing our outreach programs to sensitize local people.

Surveys conducted in villages - Bida, Dhoba, Kumhar Kotha. Chauhani, Faledi, Lolai, Doojasar, Khabha, Tejsi, Jajeeya, Salkha, Kanoi, Jamra, Sipla, Neembha, Koriya, Dhuliya, Barna, Kuchhri, Ganga (Fig 42).

We have conducted an exploratory survey to understand human livelihoods, perceptions toward grassland degradation, conservation attitude, and issues that pose threat to grassland. We now wish to conduct further focused surveys to assess their present knowledge, attitude and practices towards grassland and to understand change(s) in their attitude after outreach programs are undertaken during the project study period.

This detailed questionnaire has been designed to collect further information based on the findings of the exploratory survey. Questionnaire is divided into 4 sections.

1. Section I - Socioeconomic profile

This part of the questionnaire was designed to understand human livelihoods and natural resource dependencies in villages within GIB habitats. Knowledge about current livelihood can help in identifying areas and means of introducing GIB-friendly alternative livelihoods. For pastoralists, we would like to know where they are obtaining their grazing resources from (grasslands/market fodder/harvested crops) so that we can compute their economy and the scope of community fodder farms. This will provide better nourishment to the cattle and we'll be able to create a better relation with the local community which will turn out to be benefit for conservation.

2. Section II - Human-animal conflict
   To win over local community for bustard conservation, we would like to know the current status of human animal conflict, in particular the severity of problem of free ranging dogs and wild pig in the target area so that we can implement problem animal population control measure to reduce this conflict.
3. Section III – Pastoralism and institutional arrangements
   We also aim to understand past pastoral practices and if they have changed currently. In case of change, we will try to understand the causes behind the change. In particular, we would try to know if there is reduction in livestock holding/ nomadism/ herding. If pastoralists reported pastoral reduction behind the change, we would like to examine if pastures that have better institutional arrangement/ enforcement have suffered less change. In such case, institutional arrangements can be invoked in grassland conservation.
4. Section IV - Additionally, how much veterinarian support they are getting from the government and if they are satisfied with that, so as to know the difference in livestock health and survival between aided and non-aided villages. If there is a difference that can be gauged by better veterinary facilities from the project, will pastoralists forgo the surplus livestock against better veterinarian services? We would like to know the scope of this intervention. We will also need to find the site where livestock can be trans-located if such intervention succeeds.
5. Section V - Local Communities' Attitudes and Perceptions
   Perception studies among communities in areas neighbouring the protected area are valuable due to their ability to disclose awareness regarding conservation and existing attitudes toward conservation efforts. Gaining a better understanding of human behaviour manifested towards the protected area and properly incorporating them in future management could increase conservation effectiveness

   It is important to know the attitudes and perceptions of people towards wildlife, local species conservation, and purpose of Protected Areas and towards the FD which is the regulatory body to understand the extent of antagonism and the level of awareness and the possibilities on reconciling communities can be understood.

   a. To know whether they are open to alternative income sources and if they have the infrastructural and skills for those livelihoods. So that we can offer alternate livelihood programme to reduce their dependency on grassland resources n also win them over for conservation.
   b. to understand the spectrum of problems they are facing to neutralize the current park vs people narrative
   c. grazing pressure on grassland
   d. saving the grassland

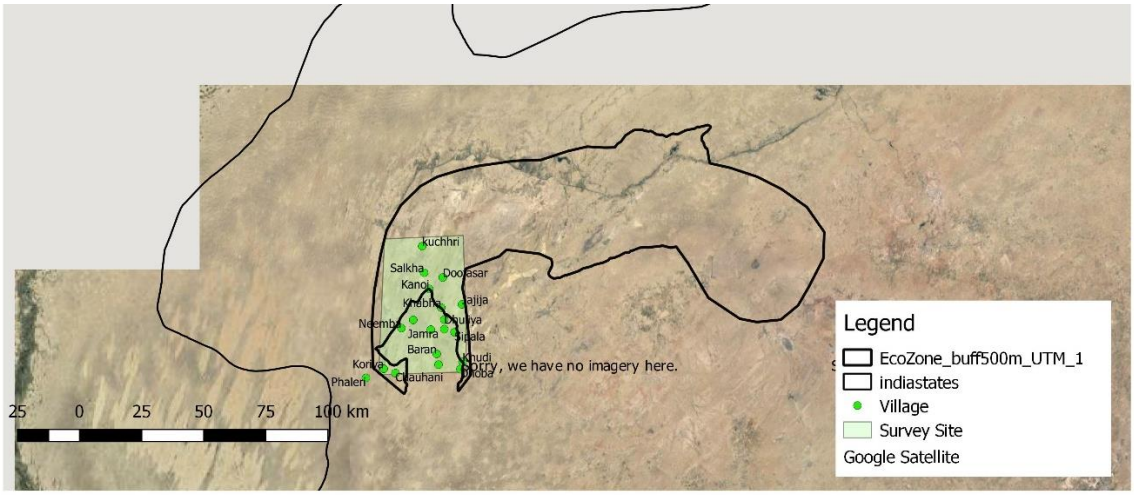


Figure 42 - Map showing villages where household surveys were conducted in Thar landscape



Image 9 Socio-economic culture of Thar is unique in India © Tanya Gupta

2.3.5. Training of Forest Department staff and volunteers in implementing population and habitat surveys for GIB and lesser florican

GIB population assessment survey was conducted in Thar landscape during 17-26 March 2017, wherein 53 volunteers and 58 Forest Department staff were trained in survey methods, instruments such as GPS, Range finder, Suunto compass and navigation using Google maps, sampling protocol for occupancy sampling and line transect based distance sampling along with data collection and recording techniques before the survey. Additionally, resurvey was conducted in and around Pokhran Field Firing

Range in Jaisalmer District during 5-20 April 2018. Seven volunteers and ten forest guards were trained in survey methods before the survey.

Lesser florican population assessment is feasible within a small window of 45–75 days as displaying males can be spotted only during July-September and across five states including Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh. Joint surveys through collaborative efforts of Wildlife Institute of India (WII), Bombay Natural History Society (BNHS) and The Corbett Foundation (TCF) along with range State Forest departments and local NGOs/institutions were conducted during July-September 2017. To train surveyors on the standardized population assessment approach and data collection protocol, two-days training workshops were organized, one at each survey State (Fig 43) in collaboration with BNHS and TCF along with range state forest departments and local NGOs/institutions:

1. Gujarat – Department of Marine Science, Department of Zoology, Sir P.P. Institute of Science, M.K. Bhavnagar University and Blackbuck National Park, Velavadar in Bhavnagar on 16-17 July 2017
2. Madhya Pradesh – Office of the Chief Conservator of Forests, Ujjain and Sailana Wildlife Sanctuary in Ratlam on 24 July 2017
3. Rajasthan – Department of Environment, MDS University, Ajmer and Shokaliya Conservation Reserve, Nasirabad on 2-3 August 2017
4. Maharashtra – Vankuti, Divisional Forest Office, Akola on 17 September 2017

During the course of the survey, 120 Forest Department staff and 60 volunteers were trained in survey methods, instrumentation and sampling protocols for population and habitat surveys.



Image 10 Post survey workshop conducted for participants of Wildlife Institute of India (WII), Bombay Natural History Society (BNHS) and The Corbett Foundation (TCF) at WII © WII photo library



Image 11 Field training was provided to all survey participants including staff of forest department © Devendradutta Pandey



Figure 43 - Training workshop of the National status assessment of endangered lesser florican and its breeding habitats survey held at (a) Bhavnagar, (b) Ujjain, (c) Ajmer (d) Akola © BNHS and WII photo library



Image 12 Training to newly recruited staff of the project and collaboaring agency BNHS coducted at WII © Tanya Gupta



Image 13 – Field training to newly recruited staff of the project and collaboaring agency BNHS coducted at Rajaji National Park © BNHS photo library

2.4. Pilot implementations for surgical habitat management

This project component aims at facilitating, informing and, in cases, directly implementing surgical habitat management measures in priority Great Indian Bustard conservation areas. We targeted Thar landscape, the most important area for the species' conservation. Earlier, we held meetings with field officers of Rajasthan Forest Department to discuss the designs of effective predator-proof fencing. Our design entails thin-mesh chain-link fencing, 6 ft tall from ground that is reinforced with one feet underground concrete foundation at the base, and angled out fence at the top. Following this design, enclosures in Chowani Predator Proof Closure was developed by Rajasthan Forest Department. Our radio tagging of free-ranging dogs suggested that this design was far more effective than the other enclosures in keeping free-ranging dogs away. In the current year, our team focused on mitigating powerlines by mapping infrastructure, sensitizing power agencies, and pilot installation of power-lines in Thar.

2.4.1. Mapping of infrastructures in Thar

Arid grasslands and desert are regarded as 'unproductive wastelands' and targeted for power generation; resulting in rapid increase of wind turbines, solar power projects, and power-lines in GIB habitats. Power-lines pose one of the critical threats to this low flying heavy bird with poor frontal vision. Our surveys shows that power lines are on top among major causes of decline in the current population of GIB. We attempted to map power-lines in GIB habitats so that mitigation measures can be implemented in identified priority areas for species conservation. To target high priority areas for immediate conservation actions we digitized an ecological boundary of prime GIB habitat (GIB Arc) based on past 10 years GIB movement information in Thar and proposed that area as an eco-sensitive zone.

The GIB landscape in Thar, extending across 20,000 sq km area, is too vast to map infrastructure manually. Therefore, low and high tension power-lines, wind and solar power projects, roads, and settlements were digitized from very high resolution satellite imagery available with Google Earth™. This task was outsourced to M/S. Science Pvt. Ltd. and maps have been generated. We did ground truthing of digitized power lines (Fig 44) and wind turbines, and updated the information. We identified power lines and wind turbines with their owner companies, and mapped them accordingly (Fig 45). We identified infrastructures and their agencies to target high priority power lines and sensitize the concerned authorities for mitigating this critical threat (Table 6).

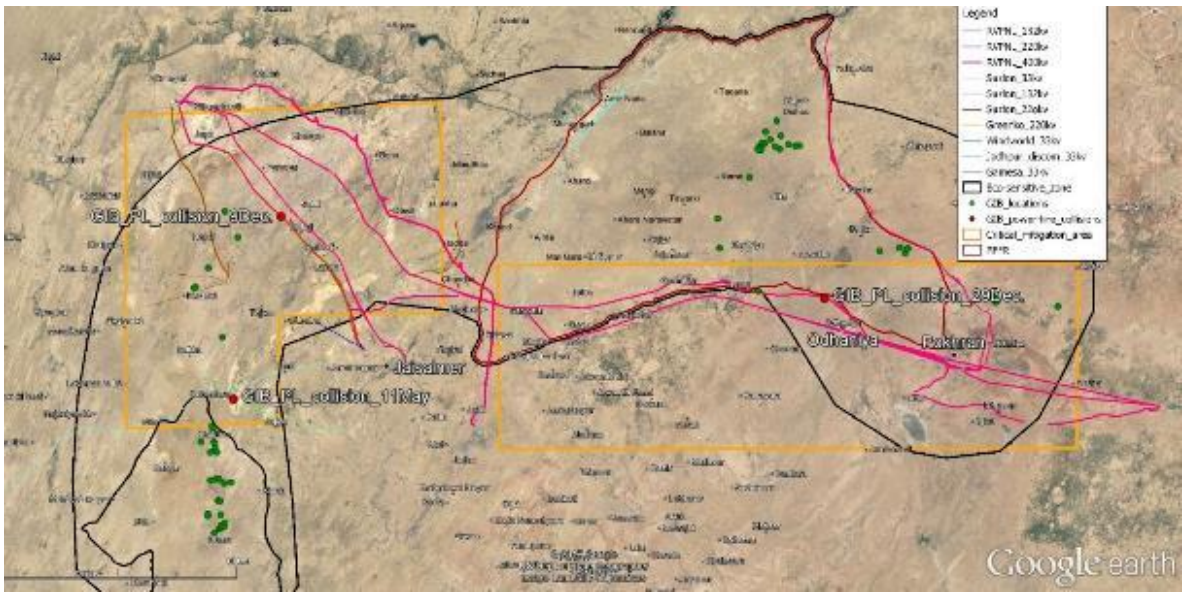


Figure 44 - Map of infrastructure (high-tension power-lines) in Thar with high priority mitigation areas (2017-18)

Table 6. Details of high-tension power lines present in priority Great Indian Bustard habitat of Thar landscape that needs to be mitigated

Name of Power-line Company	Power in KV	Name of Line	Length in KMs
Rajasthan Vidyut Prasaran Nigam Limited (RVPNL)	132	132kv Jaisalmer – Ramgarh - 1	40
	132	132kv Jaisalmer – Ramgarh - 2	40
	132	132kv Askandra	50
	220	220kv Amarsagar – Ramgarh	40
	220	220kv Amarsagar - Lilo	5
	220	220kv Amarsagar - Phalodi	125
	220	220kv Amasagar - Dechu	120
	400	400kv Akai - Ramgarh	55
Total	475 KMs		
Suzlon	33	33kv Small pylons Kuchri	20
	33	33kv Big pylons Kuchri - Habur	20
	132	132kv Kaladungar	20
	220	220kv Habur - Ramgarh	35
	220	220kv Amarsagar - Mokal	20
Total	115 KMs		
Jodhpur Discom	33	Sam - Dhanana	40
	33	-	60
Total	100 KMs		
Wind World	33	Kanoi - Salkha	20
Total	20 KMs		
Greenko	220	Amarsagar - Ramgarh	40
Total	40 KMs		
Gamesa	33	Amarsagar - Ludarva	4
Total	4 KMs		

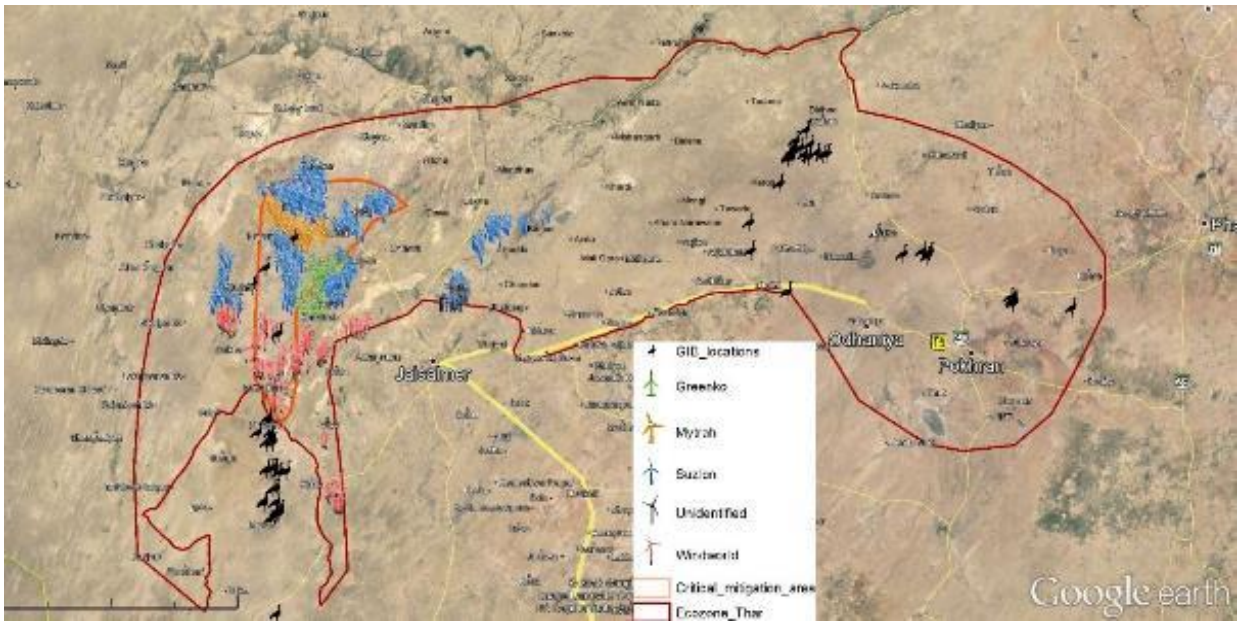


Figure 45 - Maps of infrastructure (wind turbines) in Thar landscape (2017–18)

2.4.2. Pilot installation of bird diverters on power lines in Thar Landscape

These infrastructure maps and areas identified for mitigation measures have been shared with State Forest Departments and power agencies for mitigation measures. Meetings with forest department and representatives of power line companies were held on 11 January 18. 35 diverters were handed over to them which were later installed in a 1km stretch of high tension power line in Khetolai, near Pokhran Field Firing Range on 9th February 2018 (Fig 46). Another batch of diverters were installed in the power lines in Mokla on 13 January 2018.



Figure 46 - Pilot installation of bird diverters on power lines in Mokhla and Khetolai – apriority areas for mitigating power lines for Great Indian Bustard conservation © Sourav Supakar and Mohib Uddin

2.4.3. Delineation of Thar Eco-sensitive Zone – technical inputs

In consultation with the Director, Desert National Park, the Project team delineated the Eco sensitive Zone of Thar encompassing critical conservation areas for the Great Indian Bustard and disseminated the map to Rajasthan Forest Department and National Green Tribunal Bhopal for necessary actions and implementation (Fig 47). This zone is to act as a buffer between human activity and the home range of the bustard and other animals in the DNP. The zone will restrict specific activities such as construction and grazing to create a smooth transition between different habitats. With fewer human disturbances the buffer zone will also develop into a better habitat. This will ideally lead to the maintenance if not growth of the core conservation area of the DNP.

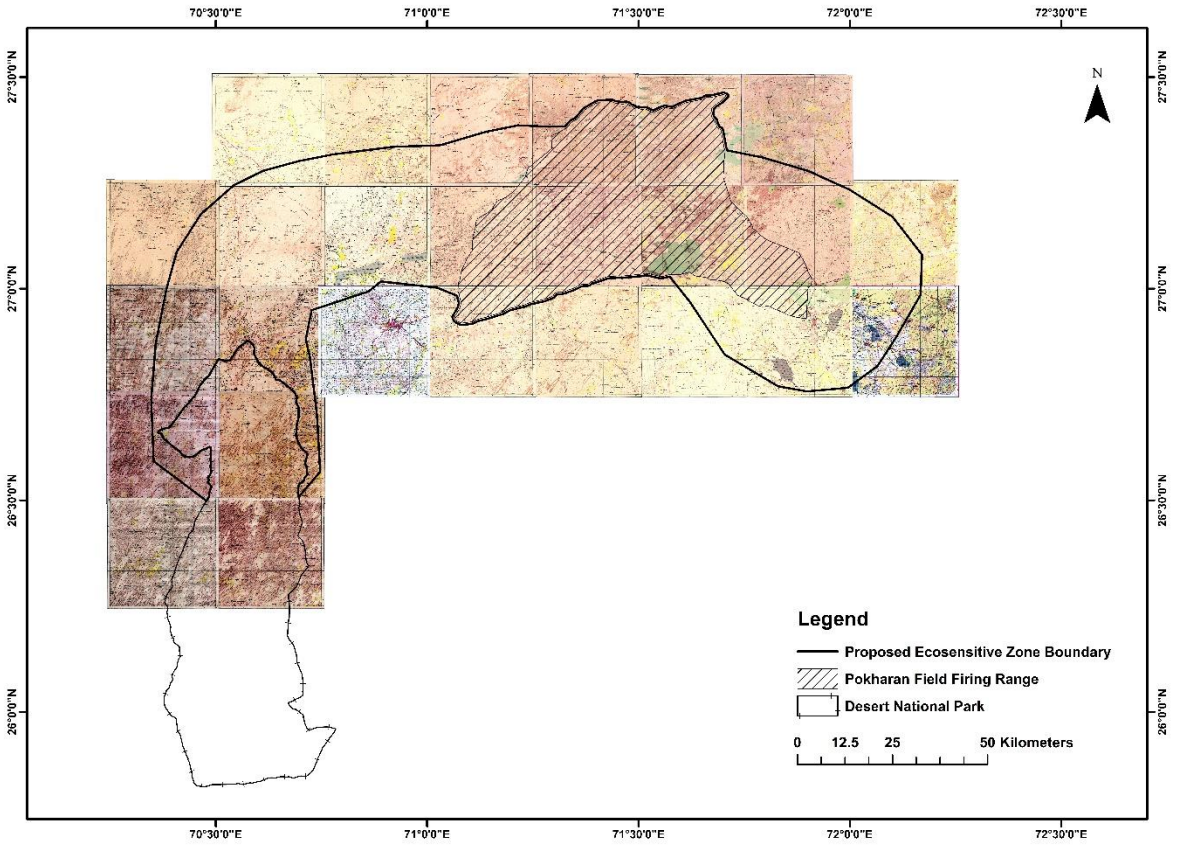


Figure 47 Proposed Eco-sensitivity Zone in Thar Desert

2.4.4 Nest Predator Management

1. The stray dog populations were assessed at ~1000 individuals in ~20 villages within the prime Great Indian Bustard habitat in/around Desert National Park, based on our study (See section 2.2.3.1). Humane Society International (HSI) has agreed to collaborate with WII on sterilizing dogs in GIB habitat of Rajasthan. The proposal had been drafted and agreed upon by both the parties. Permission was obtained from Chief Conservator of Forests (Jodhpur) for implementing this activity. Although the pilot phase of dog sterilization was planned in April–June, 2018, HSI was unable to implement the exercise during this time, and has committed to undertake the exercise in September 2018. The *sarpanch* of the villages which fall in and around the activity area have been informed by the project team about the sterilization program, and have provided their written consents to this exercise.

2. The need for relocation of the nest predators from the Thar enclosures has been communicated to the Director Desert National Park, and has been taken up for permission from competent authority.

Project team has initiated communication with subject expert, Mr. Kartikeya Singh Chauhan, for implementing this activity, and is awaiting formal permission.

2.4.5. Status assessment of enclosures in Desert National Park

We mapped the enclosures in Desert National Park through ground truthing, collected their details including; year of creation, year of recreation, current condition, area, location, and assessed their current status (Fig 48 & Table 7). This information will help us in understanding the effect of these enclosures along with time on the biodiversity of enclosures, the effect of controlled grazing and the effect of water provisioning on animals.

Table 7 Details of enclosures in Desert National Park and their current status

S. N	Updated name	Area (Ha.)	Latitude	Longitude	Status	Old name of the enclosure	Area in Ha.	Project	Village/ Cluster	Year of creation	Age
1	AC closure	800	26.81336	70.54229	Good	Sam/Ganga A	700		Sam, Ganga	1980	37
						Sam C	100		Sam, Kanoi	1990	27
2	Sam_RKVY	100	26.85903	70.56457	Good	Sam RKVY	100		Kanoi	2012	5
3	Sudasri_ACD	1515	26.73744	70.61618	Good	Sudasari A	700		Jamda	1980	37
						Sudasari C	350		Jamda, Nimba	1987	30
						Sudasari D	465		Jamda	1991	26
4	Sudasari_B	350	26.72848	70.63774	Good	Sudasari B	350		Jamda	1986	31
5	Sudasri_EF	150	26.71018	70.59462	Good	Sudasari E	50		Jamda	2007	10
						Sudasari F	100		Jamda	2008	9
6	Gajaimata	485	26.68631	70.59709	Good	SPP Gajai Mata	50	RFBP-II	Jamda	2015	2
						Gajaimata Mandir	20	RFBP-II	Jamda	2013	4
						Gajai Mata	415	GIB	Jamda	2015	2
7	RKVY	1435	26.77545	70.59011	Good	Sudasari G/Closure G/B Sudasari	250	GIB	Nimba, Ganga	2014	3
						Sudasari RKVY	200	RKVY	Ganga	2012	5
						Ganga A	100	CSS	Ganga, Nimba	2009	8
						Ganga B/Closure CSS Sudasari	70	CSS	Ganga, Nimba	2010	7
						Digga Magra	330	GIB	Nimba, Ganga	2014	3
						SPP Digga	50	GIB	Nimba, Ganga	2014	3
						Gada Magra	435	GIB	Nimba, Ganga	2015	2
8	Miajlar_B	100	26.29332	70.40543	Good	Miajlar B	100	RKVY	Miajlar	2011	6
9	Phulia	400	26.39958	70.50476	Good	Phulia	400	GIB	Phulia	2014	3
10	SP Dav/Dav_B	307	26.43003	70.51383	Good	SP Dav	307	CSS	Dav	2016	1
11	SP Chauhani_A	122	26.65525	70.61191	Good	SP chauhani A	122	CSS	Chouhani	2016	1
12	SP Chauhani_B	25	26.66003	70.61706	Good	SP chauhani B	25		Chouhani	2016	1

S. N	Updated name	Area (Ha.)	Latitude	Longitude	Status	Old name of the enclosure	Area in Ha.	Project	Village/ Cluster	Year of creation	Age
13	Chauhani	800	26.62095	70.57568	Good	Chouhani CM	200	CM	Chouhani	2011	6
						Chouhani TFC	400	TFC	Chouhani	2011	6
						Chouhani campa	200	CAMPA	Chouhani	2012	5
14	Chelasar_nadi _50ha.	50	26.67388	70.63499	Good	Chelasar nadi	50	GIB	Barna, Chouhani	2014	3
15	Chelasar_nadi _50ha.	50	26.67885	70.63166	Good	Chelasar nadi	50	GIB	Barna, Chouhani	2014	
16	Chouhani_PP C	100	26.66566	70.60347	Good	Chouhani PPC	100	GIB	Chouhani	2015	2
17	Sipla	100	26.68081	70.65657	Good	Sipla	100	GIB	Sipla	2015	2
18	SP_sipla	73			Good	SP sipla	73	CSS	Sipla	2016	1
19	Ramdeora_AB C	883	27.00321	71.98412	Good	Ramdeora A	360		Ramdeora	1987	30
						Ramdeora B	315		Ramdeora	1987	30
						Ramdeora C	208		Ramdeora	1991	26
20	Ramdeora G	200	26.98471	71.96209	Good	Ramdeora G	200	CM	Ramdeora	2012	5
21	Ramdeora_R KVY	675	26.97958	71.92599	Good	Ramdeora H	225	GIB	Ramdeora	2015	2
						Ramdeora E	200	GIB	Ramdeora	2013	4
						Ramdeora F	150	GIB	Ramdeora	2013	4
						Ramdeora RKVY	100	RKVY	Ramdeora	2012	5
22	Khara	50	27.05873	72.03158	Good	Khara	50	GIB	Khara	2014	3
23	Loharki	100	27.13078	71.75722	Good	Loharki	100	GIB	Loharki	2015	2
24	Nath Ji ka Tanka	5	27.1654	71.87328	Good	Nath Ji ka Tanka	5	GIB	Loharki	2013	4
25	Guddi	150	26.78727	71.80534	Good	Guddi	150	GIB	Guddi	2013	4
26	20- Ha.	20	26.68525	70.62295	Good	20- Ha.	20				
27	Kanoi_B	400	26.83703	70.55879	Need maintainance	Sam/kanoi B	400		Sam	1980	37
28	Kanoi_first	200	26.82151	70.57026	Need maintainance	Sam D/Kanoi-I	200		Sam	1994	23
29	Miajlar_A	500	26.27714	70.40639	Need maintainance	Miajlar A	500		Miajlar	1981	36
30	Bandhara_A	235	26.09082	70.55318	Need maintainance	Bandhara A	235		Bandhara	1981	36
31	Bandhara_B.	422	26.10311	70.55032	Need maintainance	Bandhara B	422		Bandhara	1981	36
32	Kundal	250	26.18597	70.66051	Need maintainance	Kundal	250		Kundal	1983	34
33	Sundara_A	700	26.16733	70.55378	Need maintainance	Sundara A	700		Sundara	1981	36
34	Sundara_B	50	26.15114	70.53601	Need maintainance	Sundara B	50		Sundara	1993	24
35	Piparli_260ha.	260	26.11825	70.55248	Need maintainance	Piparli	260		Piparli	1983	34
36	Piparli_260ha.	260	26.13477	70.54666	Need maintainance	Piparli	260		Piparli	1983	34

S. N	Updated name	Area (Ha.)	Latitude	Longitude	Status	Old name of the enclosure	Area in Ha.	Project	Village/ Cluster	Year of creation	Age
37	Bhoo_ka_par _A	235	26.09082	70.55318	Need maintaina nce	Bhoo ka par A	235		Bhoo Ka Par	2003	14
38	Bhoo_ka_par _B	100	26.03719	70.60329	Need maintaina nce	Bhoo ka par B	100		Bhoo Ka Par	2008	9
39	Manihari_A	40	26.06966	70.5704	Need maintaina nce	Manihari A	40		Manihari	1983	34
40	Manihari_B	80	26.06773	70.56624	Need maintaina nce	Manihari B	80		Manihari	1986	31
41	Sankhli	100	26.05032	70.59133	Need maintaina nce	Sankhli	100		Sankhli	2007	10
42	Khabdala_A	350	26.0895	70.40828	Need maintaina nce	Khabdala A	350		khabdala	1986	31
43	Khabdala_B	450	26.05701	70.4067	Need maintaina nce	Khabdala B	450		khabdala	1987	30
44	Dagari_A	400	26.05826	70.36744	Need maintaina nce	Dagari A	400		Dagari	1988	29
45	Dagari_B	350	26.06755	70.34862	Need maintaina nce	Dagari B	350		Dagari	1993	24
46	Ujlan	350	26.81152	71.97221	Need maintaina nce	Ujlan	350		Oojla	1987	30
47	Rasla A	500	26.75303	71.43368	Need maintaina nce	Rasla A	500		Rasla	1988	29
48	Rasla B	110	26.74111	71.43934	Need maintaina nce	Rasla B	110		Rasla	1991	26
49	Dhudsar	200	26.84249	71.99312	Need maintaina nce	Dhudsar	200		Dhursar	1994	23
50	Kanoi	220			No fence	Kanoi	220	GIB	Kanoi	2014	3
51	Koria	450			No fence	Koria	450		Koria	1988	29
52	Dabdi	475			No fence	Dabdi	475		Dabdi	1988	29
53	Bersiala	450			No fence	Bersiala	450		Bersiala	1987	30
54	Dav	143			No fence	Dav	143		Dav	1988	29
55	Ramdeora D	200			No fence	Ramdeora D	200		Ramdeora	1994	23

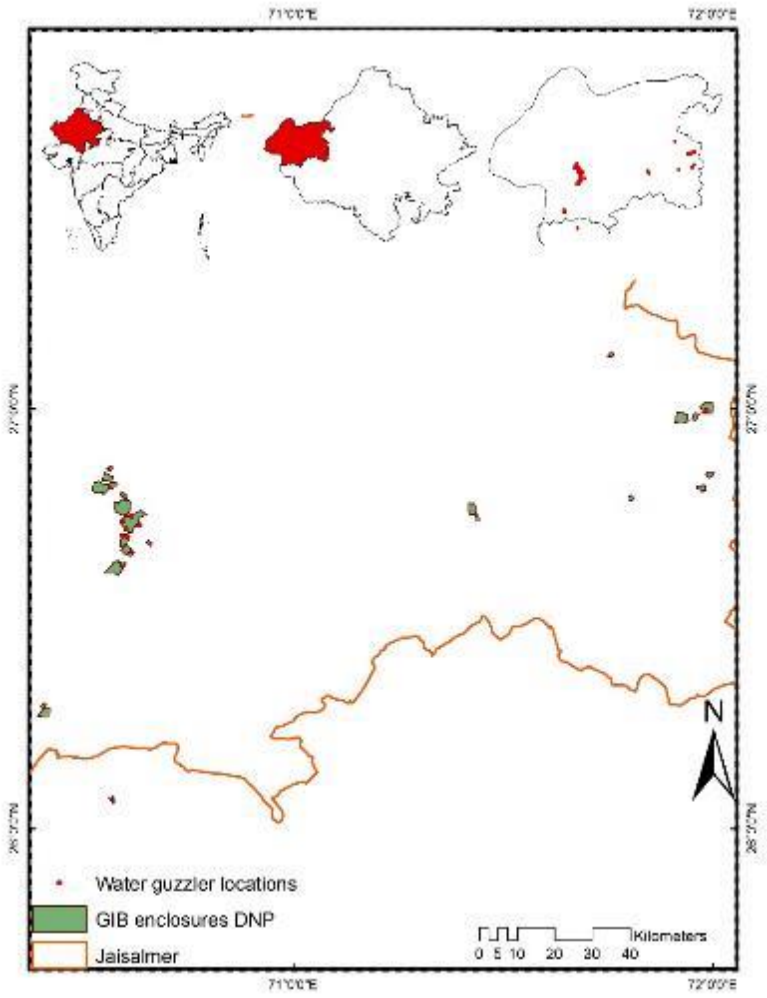


Figure 48 - Enclosure and water guzzlers of Desert national park – Thar

2.4.6. Assessment of the effect of livestock grazing on physical and chemical properties of soil in arid Thar ecosystem

Over the past thirty years, the area of Indian Thar has witnessed one of the fastest demographic growths in the country. This landscape is thickly populated in comparison to other hot deserts of the world. The human density in Thar landscape is 83 inhabitants per sq. Km. Thar holds a large livestock population, and extensive grazing by livestock is an important process contributing to the deterioration of desert environment (Rahmani and Soni, 1997). The human: livestock ratio is almost 1:2 in the desert districts (Sharma, 2008; Mehra, 2008).

In order to protect the fauna and flora of the Thar Desert, the Government of India in the late 1970s started planning the establishment of a large sanctuary or a park of various age (time since establishment/maintenance) and size, for wildlife where human pressure could be kept to a minimum and the wildlife could be given maximum security from hunters as well as from habitat alteration (Barve et al., 2005). This management measure has created a sharp contrast between intensively grazed and relatively un-vegetated areas vs. moderately (illegally) grazed and relatively vegetated areas. This situation provides an opportunity to assess how soil properties recover from grazing exclusion/regulation. Desert National Park (DNP) was the result of this planning. One of the main purposes of establishing this Park was to protect the Great Indian Bustard (GIB) (*Ardeotis nigriceps)* (Rahmani, 1988). The major objective of the Park is to develop core areas (enclosures) in which human

interference is kept to a minimum and livestock grazing is totally banned. In the initial stages, Sam, Sudasari, Phulia, and Miajalar enclosures were established. Every year, the Forest Department is adding new enclosures. But a very limited quantitative research has been carried out in the arid Thar Desert, to the effects of livestock grazing on soil properties, despite the fact that uncontrolled livestock grazing has been regarded as an important cause of desertification.

In light of these issues, this study aims to assess the effect of livestock grazing on soil properties of grazing exclusion areas (Gajai Mata, Sudasari, and Rashtriya Krishi Vikas Yojana (RKVY) enclosures) as compared with the adjacent grazed area. Soil sampling was done from centroid point of enclosures and surroundings by using the systematic method at each site (Fig 49).



Image 14 – Impact of livestock grazing in GIB areas needs to be assessed © Sujit Narwade

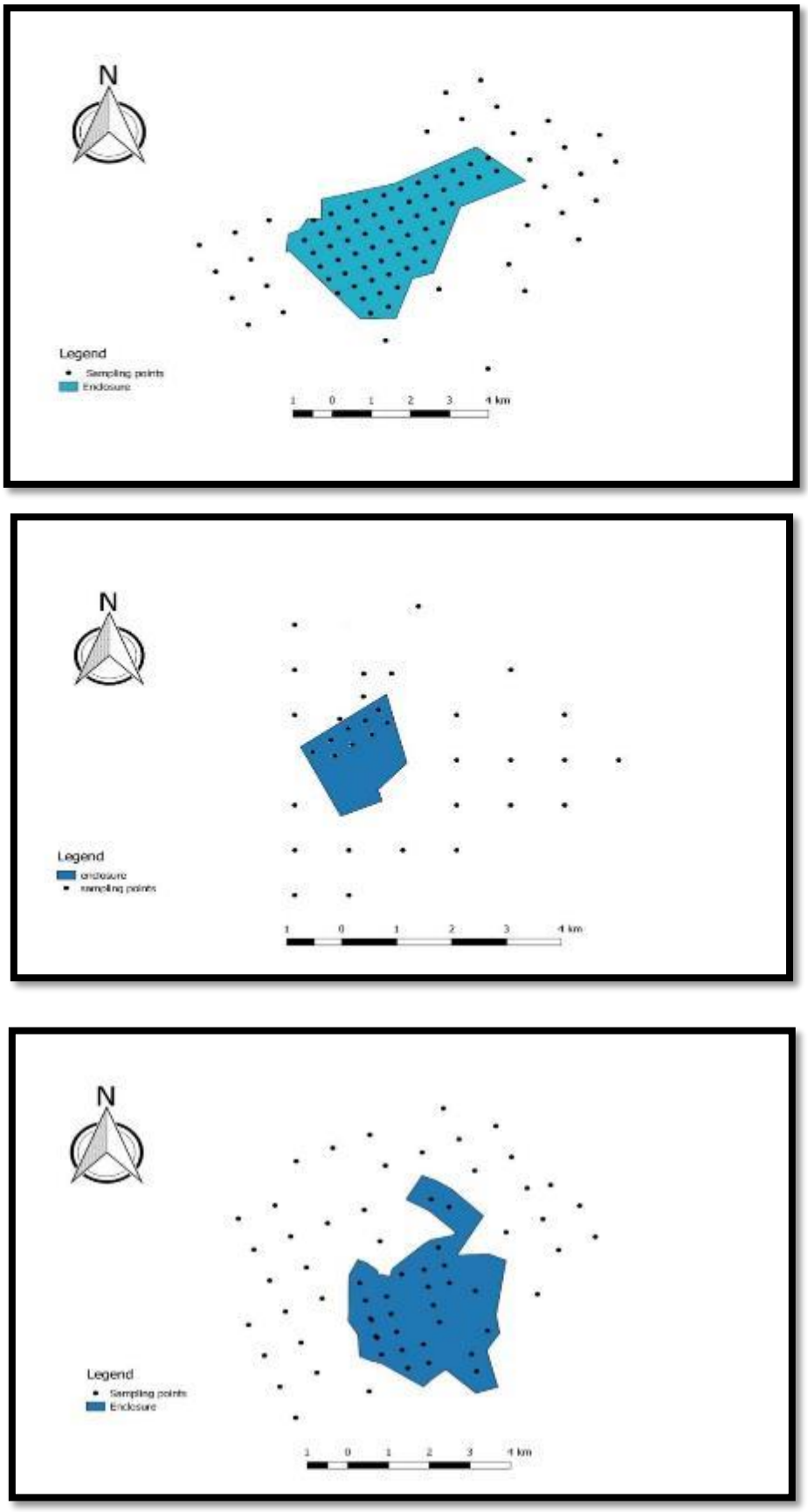


Figure 49 - Map showing the soil sampling points in (a) Sudasari, (b) Gajaimata and (c) RKVY Enclosure and its surrounding by systematic sampling design with one sample per 500m^2 inside the enclosure and one sample per 1sq km outside enclosure.

Major soil parameters include pH, Electrical Conductivity (EC), Sodium (Na), Potassium (K), Bulk Density (B.D), Porosity, Moisture Content, Total Organic Carbon (TOC), Total Kjeldahl Nitrogen (TKN), Carbon: Nitrogen and Basal Soil respiration. A number of samples (n=200) were collected and analysed as per the standard methodologies.

The result of soil quality analysis is presented in **Table** 8. The major nutrients parameters were in the range of 0.043 to 0.058 % (TOC), 0.023 to 0.035 % (TKN), 4.49 to 5.96 ppm (K), 1.84 to 3.22 ppm (Na) and 110.6 mg CO_2 (Soil respiration).

Table 8 - Physicochemical properties of top soil collected from different enclosures and its surrounding. Result presents average and standard error of each parameter.

Parameters	**Mean ± SE of physiochemical variables across sites**					
	Gajai Mata Enclosure	Gajai Mata Surrounding	RKVY Enclosure	RKVY Surrounding	Sudasari Enclosure	Sudasari Surrounding
pH	8.11±0.04	8.10±0.06	8.02±0.03	8.07±0.03	8.03±0.03	8.01±0.03
EC (dS/m)	0.074±0.01	0.067±0.00	0.062±0.01	0.071±0.00	0.093±0.02	0.073±0.00
Na(ppm)	2.60±0.53	2.38±0.70	2.04±0.31	3.22±0.25	1.84±0.08	3.19±0.05
K (ppm)	5.96±0.58	4.49±0.35	4.59±0.48	4.89±0.29	5.61±0.35	5.11±0.47
B.D. ($g/cm^{2)}$	**1.14±0.02**	**1.13±0.02**	**1.17±0.01**	**1.10±0.01**	**1.21±0.01**	**1.15±0.01**
Porosity (%)	0.56±0.01	0.56±0.01	0.54±0.004	0.57±0.003	0.53±0.00	0.56±0.004
Moisture content (%)	**0.12±0.023**	**0.23±0.058**	**0.11±0.02**	**0.22±0.03**	**0.15±0.01**	**0.19±0.034**
TOC (%)	0.043±0.01	0.053±0.01	0.058±0.01	0.046±0.01	0.057±0.01	0.055±0.01
TKN (%)	0.023±0.01	0.035±0.00	0.035±0.00	0.030±0.00	0.029±0.00	0.032±0.00
C:N ratio	2.41±0.40	2.42±0.61	1.87±0.282	2.09±0.28	2.58±0.34	2.82±0.70
Basal Soil Respiration	107.8±0.79	106.4±2.65	108.3±1.43	110.6±1.22	100.87±0.79	108.51±2.69

The result suggested higher bulk density and lower moisture content of soil inside enclosures than surroundings. The TOC, TKN and soil respiration content was found to be maximum in RKVY and Sudasari enclosure. Whereas Gajai Mata has lower amount of total organic carbon due to fragmented vegetation & fewer plant covers or it may be due to the large area covered under the dunes. The reason behind the higher or close TOC values in the surrounding is because of the moderate grazing with breaking plant material and litter decomposition, the soil increases the soil organic carbon. K was higher in Gajaimata enclosure and Na was higher in the surrounding areas of RKVY and Sudasari, which may be due to the excessive grazing practice and absence of vegetation cover that causes high

evaporation rates and promote the accumulation of salts in the topsoil because of the upward movement of water and soluble salts from salinized deep horizons.

The effect of livestock grazing on biodiversity is a debatable conservation issue with studies showing positive as well as negative effects of grazing on plant and animal richness and abundance. Unregulated livestock grazing can alter soil properties by increasing soil compaction, reducing water retention capacity, and reducing organic contents that can negatively impact vegetation growth and species richness. Results of the study show that there is a significant difference in bulk density and moisture content between enclosures and surroundings. Bulk density is higher inside enclosures while moisture content is higher in surroundings because of agro-pastoral practices. Livestock grazing and seasonal agricultural practices significantly affect soil properties. However, we did not find consistent difference in soil properties between enclosure and surroundings that could pin down the effect of agro-pastoral practices on soil. This could be because the sampled enclosures represent a gradient of age, and the effect of agro-pastoral exclusion on soil properties can be a function of time. To manage Great Indian Bustard habitat appropriately, these changes should be identified to avoid unwanted and harmful ecosystem changes. Considering this point, further study is under process to assess the effect of excluding agro-pastoral uses on soil properties in other enclosures and their surroundings that represent a gradient of time since establishment of enclosure.

2.4.7. Effect of grazing regulation on arthropod (GIB food) recovery and implications for management

Does Great Indian Bustard cantered conservation management benefit other associated taxa? This question has important implications on management of habitat and enclosures for desert biodiversity in general. Several conservation actions have been implemented in the Thar landscape cantered on GIB. One of these actions is chain-link fencing to reduce consumptive human uses and regulate/exclude grazing pressure, for the regeneration of grassland vegetation in crucial bustard breeding habitats. We are examining the effects of this action on other taxa, such as arthropods, which are also the food for GIB. Spiders (family *Arachnida*) that feed on other arthropods, is a candidate surrogate species and good indicator of habitat quality and insect abundance. Hence, we assessed the density and richness of spider families based on visual observation in different enclosures and their surrounding areas of the Thar landscape, to generate baseline information on the spider diversity status and the effect of enclosure on their density and richness. Permission has been requested for collection of arthropod samples for species-level identification and inferences.



Eresidae (Velvet Spider) in an enclosure of Desert National Park © Rishikesh Tripathi

We surveyed 11 enclosure and surrounding pairs (Sudasari, Gajaimata, Chauhani PPC, Chauhani TFC, Sipla, Manihari, Miajlar, Ramdeora, Loharki, Guddi, Rasla), to visually count spiders and recorded their families in 2–8, 0.25sq km grids per site. Spiders were sampled in each grid along five diagonal points of 5 m radius each that were segregated by 100 m.

Results: We found 4032 spiders belonging to 21 families from 680 points in 136 grids spread across 11 enclosure and surrounding pairs. The family richness and density of individuals 78.5/sq m in plot is plotted across enclosure-surrounding pairs (Fig 50). Preliminary results indicate higher family richness (t=1.87, DF=10, p=0.05) and density (t=1.87, DF=10, p=0.04) per plot in enclosures compared to surroundings.

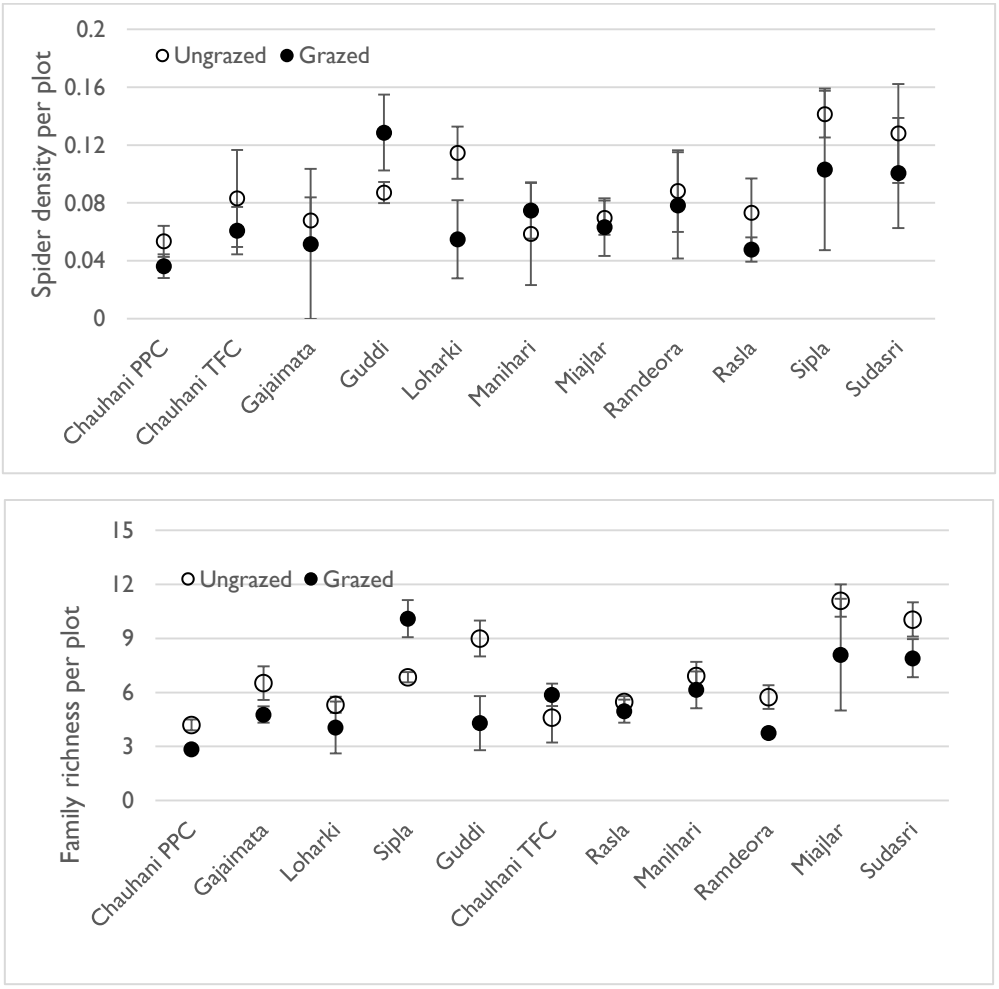


Figure 50 - Mean (SE) of spider density and family richness per plot in grazed and unglazed areas of Thar landscape in 2017-18

This preliminary study indicates a positive effect of enclosures on density and richness of spider families in this important landscape. Complete study at the species level would be instrumental to shed insights on how spiders - a surrogate of arthropod community – the chief food item for Great Indian Bustard, will response to exclusion/regulation of livestock grazing.



PROPOSED PROJECT ACTIVITIES DURING 2018-19

Chapter 3. Proposed project activities during 2018-19

Sr. No.	Project component	Proposed activity	Prerequisites
1.	Conservation breeding	A) signing of MOU, B) training of centre staff, C) design and commencement of centre construction, D) development of standard operating protocols for the facility in consultation with bustard breeding experts	Depends on agreement with Rajasthan Government and IFHC
2.	Applied research	A) countrywide population status assessment of lesser florican, B) great Indian bustard population surveys in Thar especially Field Firing Range and Kutch, C) satellite tagging of great Indian bustard in Thar and Kutch D) camera trapping to assess nest predator density D) phonological/behavioural observations of great Indian bustard in Thar, e) powerline mortality surveys in Kutch	permission from CWLW Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh Permission from CWLW Rajasthan and Gujarat
3.	Capacity building and outreach	A) questionnaires for livelihood concerns and conservation attitude in Thar, B) village outreach programs, C) continuation of publicity materials (brochures, diaries, posters and a film), D) meetings and sensitization workshop with Armed Forces, E) continued sensitization of powerline agencies through national-level meeting and follow-ups	Support from local community and other stakeholders
4.	Pilot habitat management	A) procurement and distribution of third batch of bird diverters, B) spay neuter program for free-ranging dogs in thar (collaboration with HSI) and Kutch (collaboration with TCF), C) collaborative conservation actions with communities and forest department in Khetolai (thar)	Initiative by power companies

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Appendices

Appendix 1 - Report on Visit to IFHC Abu Dhabi Houbara Breeding Centre, UAE

by Sutirtha Dutta on 28 April 2018

Background: Dr. Sutirtha Dutta, Faculty Wildlife Institute of India and co-supervisor of the Bustard Conservation Project (Endangered Species Recovery Program funded by National CAMPA, Ministry of Environment, Forests and Climate Change) visited the Houbara Bustard Breeding Center at Saih Al Salam (SAS) in United Arab Emirates on 28 April 2018 during 08:30 – 14:30 hours. The objective of the visit was to gain better understanding of the bustard breeding processes that will aide in developing the Indian bustard breeding facility.

The facility: The Saih Al Salam Center for *Chlamydotis macqueenii* captive breeding is run by Reneco Wildlife Consultants working under the umbrella of International Fund for Houbara Conservation, with the headquarter at Abu Dhabi. The Facility has an expanse of 3.9 km^2 area in the Arabian desert, between Sweihan and Al Ain, United Arab Emirates, and is fortified by a concrete wall of 1.5 m with barbed wire fencing reinforced on angled-in rods of another 0.5 m height. The facility is also planted with dates and other native shrubs along the boundary. The visit was arranged by IFHC after the Global Flyway Summit at Abu Dhabi on 23–27 April 2018. The visit was coordinated by Mr. Toni Chalah of Reneco/IFHC, Director of the SAS Center. Dr. Dutta first visited the office of Bustard Breeding Center, and discussed current issues related to great Indian bustard and lesser florican conservation, and the prospect of collaborating with IFHC/Reneco to implement the bustard breeding program at India. Both parties exchanged ideas on the breeding program, related to designing the facility, developing protocols and other details subject to the required scale of operations. The Facility follows assisted reproduction techniques, where each individual and its ejaculate/egg is identified and tracked by a unique id printed on their cage, leg ring, mark on the egg etc. that helps in monitoring individual histories for research and stock management.

Biosecurtiy: The Facility is surrounded by poultry farms, natural populations of birds, and receive human visitors daily who can be vectors of diseases. Therefore, the Facility has multiple barriers of biosecurity, with visitors' vehicles being washed two-three times at different gates using different disinfectants on alternate days to avoid resistance of disease causing agents to these remedies. Additionally, staff and visitors have to clean their shoe soles, change into sleepers, clean and dry their hands with soap, disinfectant and tissue paper (preferable over towel for hygienic reasons), and wear aprons over clothes which are cleaned every day, before entering any bird chamber. Captive birds were also vaccinated against New Castle, Avian Flu and Pox virus, as these were not the most virulent and damaging diseases.

Breeding chamber: There are eight breeding chambers in the Facility, each with several birds. Male and female houbaras are housed in separate chambers/housings. The male chamber contains ~300 cells made of Teflon and 2x2 m^2 in dimension, the specifications of which were decided based on research. Some males were displaying, as the breeding season continues from January through May. As a male displays, the keeper places a dummy female and lets the male mount and ejaculate, placing a Petri dish to collect the ejaculate (few microliters) at the right time. The ejaculate is then transferred to the Research laboratory by 'runners'. The male cell has litter of small stone chips that are cleaned of fecal pellets on a daily basis. All breeders are imprinted to reduce stress of handling. Two males are not put in the same cell to reduce aggressive encounters. The litter is changed once in a year, and the entire male chamber is completely cleaned and disinfected after the breeding season, in June, when breeders are moved out into the tunnels (see later). The male cell is fitted with feeders which is weighed at the end of each day to measure the individual's food intake. Food consumption is monitored

and overeating is avoided as this can lead to fat deposition which can induce trauma and physiological stress. The chamber is indoors, and therefore, light period, temperature and humidity are maintained using an automated program, with these environmental parameters being monitored using data loggers in the chamber. Toni emphasized that either birds can be housed outdoors with less maintenance, or they can be housed indoors with intensive maintenance of these parameters, depending on the extremity of weather conditions. The temperature and photoperiodism that induce males to display must be studied intensively in the field, for this purpose. There are similar but separate chambers for females, which was not visited as the females were being prepared for hatching.

Research laboratory: The research lab, placed in the same building as breeding chamber, examines the ejaculate that is brought to them from males to evaluate: a) the volume/quantity using a pipette, b) the motility (movement) by scoring under microscope, and other parameters using basic methods. This data is entered into computers by lab technicians, and are collated using programs that are developed by in-house programmers using access database programs. Based on the sperm quality, the department manager decides how many dosage can be made of the ejaculate. The ejaculate is placed on a shaker to reduce chance of coagulation and sedimentation, and increase spermatozoa survival rate. Subsequently, this sperm is stored in cold tank using liquid nitrogen to form a central sperm bank that is used to inseminate females when none of the existing males have produced ejaculates at the time when females are inceptive. The ejaculate is also subjected to genetic analysis to find compatible females based on pedigree (avoiding close relatives) and to maximize the center genetic diversity. The spermatozoa is injected in the female vagina when the latter is inceptive. This timing is crucial, and is known after intensively monitoring wild females, weighing them frequently and examining when they decide to breed. These information are used in captivity to decide the timing of injection. Although female birds can store spermatozoa for a certain period, injecting the semen within a conducive window ensures higher fertilization rate. Even if some males do not ejaculate frequently, or some females do not breed frequently, they are still retained in the founder stock, and whatever reproductive materials are produced by them, are used, to retain the initial genetic diversity of the captive stock. All equipment used in the lab and founder chamber are daily disinfected by washing and sterilizing.

Egg processing facility: This facility has several chambers segregated by function. The first chamber is for egg handling, where eggs that are laid by founders and collected by 'runners', are transported. Each egg is wiped to clear the fecal and dust materials that may have adhered in the mother cell, and are then fumigated for disinfection. Then these eggs are transferred to incubation room with several incubators. Eggs are weighed after every 3 days, and depending on their weight loss regime, they are rearranged into different incubators, each with a certain setting compatible with the developmental trend of the egg. Eggs are kept in incubators for 19 days, and are then shifted to the hatchery cell. Candling of eggs to examine fertility and embryonic development of eggs are also undertaken to aide in this decision. Hatchery has similar incubator machines, but the temperature and turning conditions of these machines are maintained to stimulate the eggs for hatching. These conditions are also based on intensive studies, where wild females are closely monitored using sensors to estimate these parameters. After the eggs hatch, the chicks are kept in brooder chamber for first two hours. These brooder chambers have small cardboards with bulb heating. Subsequently, these chicks are shifted to chick rearing chamber.

Chick rearing facility: This is the most important and heavily staffed sector of the center, where chicks are segregated into age-specific cardboard pens. There is a research informed diet regime for chicks, and young chicks are coaxed to feed on a meal of alfalfa, mealworms and processed pellets. This process requires patience and staff if the number of chicks are large. Subsequently, the chicks are taken to a preparation cell where they are prepared for transfer to the final stage – the tunnel.

Bird preparation facility: After 3 months' age, juveniles are transferred to tunnels that are arrays of long semicircular cages made of netlon material that are laid in the open but provides shade. Here, similar aged cohorts are kept in batches of 12-24 individuals. Keepers feed them once by scattering the food across the tunnels (30 x 5 sqm dimension) such that youngs learn finding food items. Young juveniles are imprinted on humans, but because of decreased association over time, older juveniles avoid human and show feral traits. There are 1500 tunnels in 5 patches each with the capacity of 12-24 juveniles in Saih Al Salam Center. The food to be provided in the tunnel is processed at the food processing and washing chamber. All diseased/dead birds are removed from tunnels by a daily visit.

Staff: The facility has 400 staff from 30 nationalities, who stay in the housing within the facility premises. Staff maintain the data of operations on daily basis, this data is entered instantaneously, and daily, weekly, monthly and yearly reports are produced through data management and analysis programs Staff discipline is extremely important and is ensured through a hierarchical administrative structure where bottom up and top bottom communications are ensured. The Center has several departments such as genetic management, chick development, assisted reproduction etc., each headed by a coordinator how reports to the Center Director. The designing of the facility was done by a cell within Reneco that has specialized personnel for this task.

Appendix 2 – Questionnaire for local people

Village: Community Name:

Q1.Total members of the family living in your household:

Sex	Education level	Occupation

Q2. Agricultural economics (average for 2-3 years)

Crops	Total production	Market (quantity)	Income	Expenditure

Q3. What is the size of your field? _____

Q4. Where is your main market for buying and selling products?

_____

Q5. Livestock economics (average for 2-3 years)

Livestock	Number	Commodity	Quantity		Income	Expenditure		
			Household	Trade		Fodder	Daily wage	Vet. services
Cattle								
Buffalo								
Goat								
Sheep								
Camel								

Q6. Fodder requirement is filled from - grasslands / agricultural fields / purchase from market / other

Q7. Grazing area for livestock (in kms) and Area name:

Q8. If fodder is not available from grasslands or fields how would you meet the fodder demand?

Q9. How many young were born in last 2-3 years? _____calves &_____fawns

Q10. How many survived till 3rd year _____ & how many recruits did you sell in last 3years? _____

Labor/Employment economics

Q11. What kind of labour work you do? _____& where? _____

Q12. How much salary or daily wage do you get? _____ & for how many days in a year _____

Q13. Wealth and assets (visual assessment of household)

Item	Presence
Bicycle/ Motorcycle/ Car	
Mobile	
T.V.	
Solar Panel	
Tractor	
Farm Implements	
Other	

Q14. Number of livestock lost in last 2 years:

Cause of mortality	Livestock type	
	Cattle / buffalo	Sheep / goat
Natural death (age)		
Disease outbreak		
Depredation		
Road kill		

Q15. Name the wild animals that depredate your livestock/ or raid your fields. _____

Q16. How many times in a month do they depredate your livestock/fields? _____

Q17. Wild animal living and frequenting croplands can be a problem?

If yes, why is it a problem?

Q18. Do you face problems of animals attacking humans or livestock – in particular, dogs? YES/NO

Q19. Compared to 10 years back, how productive are village pastures now?

Q20. Do you access pasture &water of the other village in bad years? _____ and do they allow you?_____

If yes, how much do you spend?

Duration? Location?

If no, do you gave to a nomadic pastoralist?

Q21. Do you pay money to the pastoralist?

If yes-, how much (no. of livestock*rate/day/livestock* no. of days) *

Q22. To whom do you complain/address about land tenure issues that threatened your livelihoods?

Do they listen to your issues?

Q23. How often do you obtain veterinary services? Quarterly/ Biyearly/ Yearly/ Never

Q24. In what form do you receive veterinary services?

Camps at your village [ ] nearby village (what distance) [ ] Jaisalmer [ ]

Q25. In general, are you satisfied with the veterinary services that you receive?

Q26. Is there adequate veterinary services to respond to serious livestock – disease outbreak in your area?

Q27. Are you willing to exchange the present livestock with less number of high yielding animals with better veterinary care?

Q28. Do you make any profits from tourism and seasonal fair? Yes/No

If yes, what is the nature of your activity as it relates to tourism?

Q29. What is the main purpose of DNP according to you?

Tourism [ ] Nature protection/ biodiversity conservation [ ] Don't know [ ] Other _____

Q30. What are the most important benefits from the existence of the national park?

Q31. What are the issues or problems you are currently facing?

	Least Imp				Most Imp
Drinking water	1	2	3	4	5
Food grains/vegetables	1	2	3	4	5
Electricity	1	2	3	4	5
School	1	2	3	4	5
Hospitals	1	2	3	4	5
Veterinary hospitals	1	2	3	4	5
Grazing field	1	2	3	4	5
Depletion of grassland	1	2	3	4	5
No direct revenue from DNP's management	1	2	3	4	5
Local resident's minimal or no involvement in the management	1	2	3	4	5

Little or no access to natural resources within DNP	1	2	3	4	5
Other (specify)	1	2	3	4	5

Q32.If these problems continue, would you think of getting resettled outside the Park? If no, explain the reasons.

_____

_____

If yes, what are your demands from government? _____

Q33. Have you seen decline/increase in the number of wild animals in your area? (e.g. Chinkara, GIB, Spiny tailed lizard) Yes / no/ No idea

If yes, what do think is the cause for decline

_____

Q.34. Are you open to alternative income sources? Yes/No

If yes, please
suggest_____

_____

Q35. What alternative source of income would you like to undertake in future?

_____

_____

Q36. Are you interested in saving grassland/pastures? Yes/No

Q37. Do you think that there is a decline of grasslands/pastures? If yes, what are the reasons behind this loss?

_____

_____

Q38. Would you accept the following alternates to reduce the grazing pressure on the grasslands?

Reduce the number of livestock [ ] grow fodder [ ] purchase from the market [ ] move to other place [ ]

other (specify) _____ [ ]

Appendix 3 - GIB survey report 2017-18

Appendix 4 - Lesser Florican survey report 2017

Appendix 5 – Maharashtra GIB Status Survey Report 2018

Appendix 6 - Masters Dissertation Thesis on Impacts of Free Ranging Dogs on Native Fauna of Thar

Appendix 7 - Masters Dissertation Thesis on Impact of power lines on bird mortality in Thar

Appendix 8 - Masters Dissertation Thesis on effect of livestock grazing on physical and chemical properties of soil in the arid thar ecosystem"

Status and Trend of

GREAT INDIAN BUSTARD

Associated Wildlife and Threats in Thar



SURVEY REPORT
2017-18

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Status and trend of Great Indian Bustard, Associated Wildlife and Threats in Thar

2017–18

Wildlife Institute of India,

Dehradun Rajasthan Forest

Department, Jaipur

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Executive Summary

Arid ecosystems of India support unique biodiversity and traditional agro-pastoral livelihoods. However, these habitats are highly threatened due to their historical marginalization in conservation planning and large-scale land-use changes. The Critically Endangered great Indian bustard *Ardeotis nigriceps* acts as a flagship and indicator of this ecosystem, and is the focus of current conservation efforts implemented by the Government to protect these ecosystems. Persistence of this species critically depends on Thar landscape, where ~75 % of the global population resides. Since 2014, Wildlife Institute of India and Rajasthan Forest Department are conducting joint surveys to understand the current status, distribution patterns, and local contexts of key conservation-dependent species in Thar, for developing scientific management plan. This report contains findings of the 2017 survey, and focuses on recent spatio-temporal trends in the population of key species, habitat and threats.

This study assessed the status of native and conservation-dependent species such as great Indian bustard, chinkara and fox, non-native and/or 'problem' species such as free-ranging dogs, wild pig and nilgai alongside their habitat and anthropogenic pressures across 19,728 km² of potential bustard landscape in Thar spanning Jaisalmer, Jodhpur and small parts of Bikaner and Barmer districts of Rajasthan. Systematic surveys were conducted in 144 km² cells from slow-moving vehicle along 29.2 $\pm$ 8.0$_{SD}$ km transects to record species' detections, habitat characteristics in sampling plots, and secondary information on species' occurrences. Multiple teams comprising field biologists and Forest Department staff simultaneously and rapidly sampled 121 cells along 3,529 km transects (extensive surveys) with additional 635 km transects in five great Indian bustard occupied cells (intensive surveys). Extensive surveys provided information on bustard occurrence across the landscape and intensive surveys provided information on bustard density in occupied cells. Additionally, extensive surveys provided information on abundance of associated species. Great Indian bustard and other key species' detection data were analyzed in Occupancy and Distance Sampling framework to estimate proportion of sites occupied and density/abundance.

During the last four surveys, 38 (2014), 40 (2015), 37 (2016) and 37 (2017) great Indian bustards were detected. Their detection/non-detection in 2-km transect segments (spatial surveys) across cells (2017) showed that 6.7 ± 2.9$_{SE}$ % of sites were occupied (naive occupancy 5%). Bird density was estimated at 0.48 $\pm$ 0.10$_{SE}$ /100 km² across all sites and 7.49 $\pm$ 1.63$_{SE}$ /100 km² in used sites (cells where at least one bird was detected during 2017). Abundance was estimated at 95 $\pm$ 21$_{SE}$ individuals in the 19728 km² landscape, pooling data across 2016-17. The current abundance estimate was lower than the past estimate (140 $\pm$ 53$_{SE}$ in 2015-16); this could be partly due to inadequate intensive surveys in high-density sites within Pokhran Field Firing Range. Hence, Wildlife Institute of India's great Indian bustard conservation project team conducted follow-up distance based line transect surveys in the subset of landscape where the species is distributed (western Thar: 4068 km² area, and Pokhran Field Firing Range: 5184 km² area) in March–April 2018, to refine the past estimate. Based on these surveys, abundance was estimated at 128 $\pm$ 19$_{SE}$ individuals in 9252 km² great Indian bustard distribution area in Thar. Additional ancillary information based on power-line carcass surveys (2 mortalities in 20 km high-tension power-lines surveyed seven times) indicated that about 18 birds were expected to have died because of the 152 km high-tension lines distributed across bustard occupied sites.

Chinkara density was estimated at 205 ± 14_{SE} animals/100 km², yielding abundance of 40,442 ± 2811_{SE} in 19,728 km² landscape (2017). Desert fox density was estimated at 15.03 ± 2.39_{SE} /100km², and abundance of 2965 ± 471_{SE} individuals in 19,728 km² landscape.

Our threat surveys showed an expansion of human artifacts across survey years, wherein the proportion of sampling plots with water source, power-lines, farm-huts and wind turbines had increased annually by 0.12,
0.09. 0.07, and 0.03, respectively, over the last three years. Correspondingly, population of free-ranging dogs showed a remarkable expansion over these years, wherein the proportion of sites occupied increased from
0.15 ± 0.04_{SE} (2014) to 0.61 ± 0.09_{SE} (2017), and their encounter rate increased from 4.32 ± 1.77_{SE} to 23.11 ± 9.39_{SE} /100km in sites that were monitored across all years.

Our study provides robust abundance estimates of key native / conservation dependent as well as non-native / 'problem' species in Thar. It provides recent trends of species' distribution and abundance vis-à-vis habitat and threat intensity across space and time, to alarm managers about the changing dimensions of Thar landscape and guide site-specific management and policy. The expansion of power-lines and the expected mortality rate of bustards is unsustainable given that this population cannot sustain human-induced death of
>2 birds/yr (see Dutta *et al.* 2011).

Thar supports the largest global population of great Indian bustard and offers the best hope for its persistence. This survey captured snapshots of great Indian bustard distribution that needs to be augmented with satellite telemetry based information on seasonal landscape use to mitigate threats. Based on results and field knowledge, we strongly recommend: a) expeditiously mitigating power-lines by undergrounding all lines within high priority areas (this is the only foolproof measure for conserving the great Indian bustard), and marking lines with bird diverters in medium priority areas, b) improving great Indian bustard recruitment in existing enclosures using predator-proof-fences and nest-predator removal, c) creating more enclosures or conservation/community reserves in priority conservation cells, d) smart and intensive patrolling to control poaching and generate management information, e) targeted research to understand local ecology of great Indian bustard, characterize threats, and ranging patterns, f) balancing local livelihood concerns with conservation goals through social research and incentivized bustard-friendly land-uses, and g) engaging local communities to monitor and protect wildlife through outreach and incentive programs.

1. Introduction

The great Indian bustard (*Ardeotis nigriceps*) is Critically Endangered (IUCN 2011) with less than 300 birds left, largely in India. Rajasthan holds the largest population and prime hope for saving the species (Dutta et al. 2011). As the range States across the country are implementing recovery plans for great Indian bustard (Dutta et al. 2013), information on current status and recent trends of their population, habitat characteristics, and threats are scanty. Such information are essential for conservation planning and subsequently assessing the effectiveness of management actions. Great Indian bustard inhabit open, arid &semi-arid agro-grass habitats that support many other species like chinkara *Gazella bennettii*, desert fox *Vulpes vulpes pusilla*, Indian fox *Vulpes bengalensis* and spiny-tailed lizard *Saara hardwickii* that are data deficient and threatened. This study was aimed at generating information on population and habitat status of these species for the crucial bustard landscape of western Rajasthan.

Great Indian bustard are cryptic and vagile birds occupying large landscapes without distinct boundaries that make complete enumeration of population impractical and unreliable. Their population status has to be estimated using robust sampling and analytical methods that incorporate imperfect detection, allow statistical extrapolation of estimates to non-sampled areas, and are replicable. However, the extreme rarity of bustards makes precise estimation of population abundance difficult and logistically demanding. Through repeated surveys from March 2014 to 2016, we have attempted to develop a protocol for monitoring the population status of great Indian bustard and associated wildlife in Thar and other bustard landscapes across the country, and conducted a survey following this approach in March 2017.

Our survey covered the potential great Indian bustard habitat in Jaisalmer and parts of Jodhpur, Bikaner and Barmer districts, Rajasthan (hereafter, Thar landscape). Ground data was collected by researchers, volunteers and Forest Department staff who were trained through workshops and field exercises prior to the survey. This report provides robust abundance estimates of the aforementioned species, recent population trends, along with spatially explicit information on the status and trends of key ecological parameters (habitat and anthropogenic threats) to guide managers in implementing *in-situ* management actions as prescribed by the bustard recovery plans (Dutta et al. 2013).

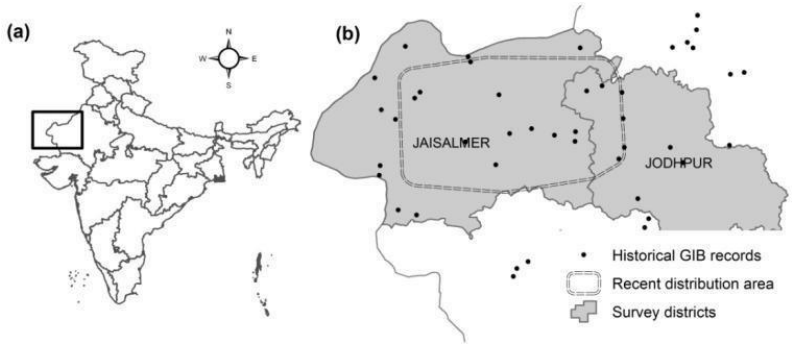
2. Thar landscape

We identified the potential great Indian bustard landscape in Thar in a stepwise manner during the past surveys. Recent historical records (post 1950s) of great Indian bustard in western Rajasthan were collated (Rahmani 1986; Rahmani and Manakadan 1990) and the broad distribution area was delineated that was further streamlined using recent information on species' absence from some historically occupied sites (sources: Rajasthan Forest Department, Ranjitsinh and Jhala 2010). Herein, extensive sand dunes, built-up and intensive agriculture areas were considered unsuitable based on prior knowledge (Dutta 2012). These areas were identified from the combination of land-cover maps procured from NRSC (ISRO), Digital Elevation Model and night-light layers in GIS domain, Google Earth imageries, and extensive ground validation surveys during 2014-2015. The remaining landscape, an area of 19,728 km^2, was considered potentially habitable for great Indian bustard and subjected to sampling (figure 1).

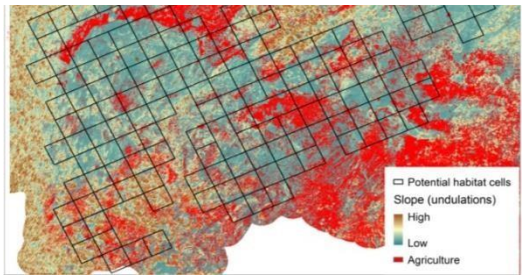
The study area falls in Desert Biogeographic Zone (Rodgers et al. 2002) with arid (Jodhpur) to superarid (Jaisalmer and Bikaner) conditions. Rainfall is scarce and erratic, at mean annual quanta of 100-500 mm that decreases from east to west (Pandeya et al. 1977). The climate is characterized by very hot summer (temperature rising up to 50^{o}C), relatively cold winter (temperature dropping below 0^{o}C), and large diurnal temperature range (Sikka 1997). Broad topographical features are gravel plains, rocky hillocks, sand-soil mix, and sand dunes (Ramesh and Ishwar 2008). The vegetation is Thorny Scrub, characterized by open woodlot dominated by *Prosopis cineraria*, *Salvadora persica* and exotic *Acacia tortilis* trees, scrubland dominated by *Capparis decidua*, *Zizyphus mauritiana*, *Salvadora oleoidis*, *Calligonum polygonoides*, *Leptadenia pyrotechnica, Aerva pseudotomentosa*, *Haloxylon salicornicum* and *Crotolaria bhuria* shrubs, and grasslands dominated by *Lasiurus sindicus* and *Dactyloctenium sindicum*. Notable fauna, apart from the ones mentioned before, include mammals like desert cat *Felis silvestris*, birds like Macqueen's bustard *Chlamydotis macqueenii* (not available during survey period), cream-coloured courser *Cursorius cursor*, sandgrouses *Pterocles* spp., larks, and several raptors.

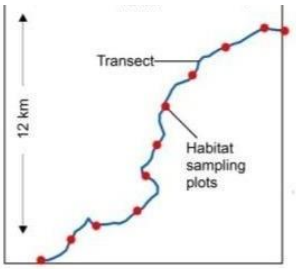
Thar is the most populated desert, inhabited by 85 persons/km^2 that largely stay in small villages and *dhanis* (clusters of 2-8 huts), and depend on pastoralism and dry farming for livelihoods. A fraction of this landscape (3,162 km^2) has been declared as Desert National Park (Wildlife Sanctuary), which is not inviolate and includes 73 villages (Rahmani 1989). As a result of such human dependence and governmental policies of diverting this landscape to renewable energy production, we are noticing an expansion of human artifacts in this landscape that may potentially impact the native wildlife, and were monitored as part of this survey.

Figure 1 Sampling design for great Indian bustard population and habitat assessment in Thar landscape (2014-2016): location of study area (a); delineation of bustard landscape from existing information on species' occurrence (b), remotely sensed habitat information and reconnaissance surveys (c); distribution of transects in 144 km² cells overlaid on potential habitat (d); and habitat sampling plots at 2 km interval on transect (e)

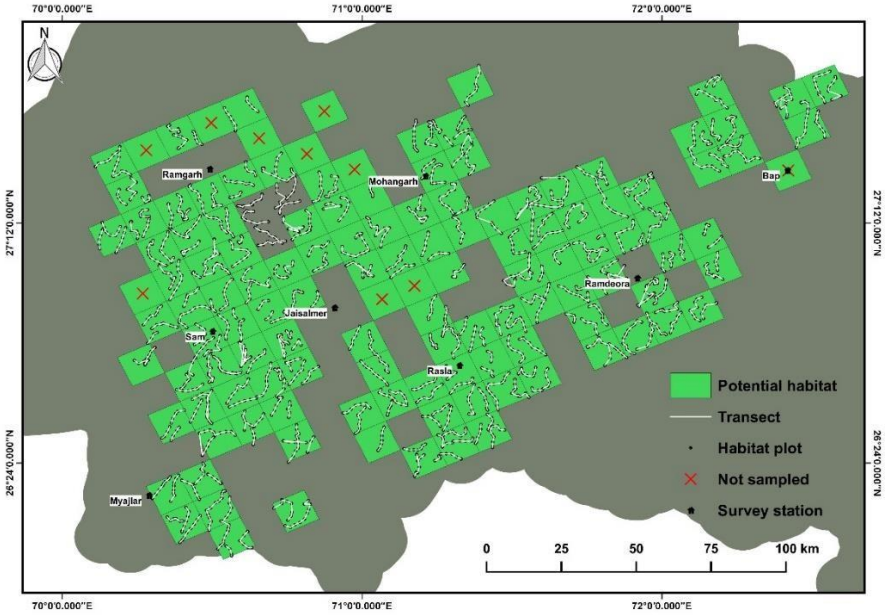


(c)





(d)



3. Methods

3.1. Organization of survey

The potential great Indian bustard landscape in Thar was divided into seven sampling blocks (Ramgarh, Mohangarh, Bap, Ramdeora, Rasla, Myajlar, and Sam-Sudasari) which were simultaneously surveyed by 52 teams during March 18-23, 2017. Similar exercise was carried out in the past with the help of 18 teams during March 22-26, 2014, 17 teams during March 21-25, 2015, and 40 teams during March 15-19, 2016. Each sampling block was surveyed by separate teams, enabling us to cover such large expanse within brief time period in order to minimize bird/animal movements between survey areas. Each team comprised of a researcher/volunteer, one Forest Department guard adept with the locality, and one rugged-terrain vehicle. Field activities in a sampling block were supervised by a research biologist from the Wildlife Institute of India with several years of field experience on wildlife surveys. Team members were trained through workshops and rigorous field exercises on a standardized data collection protocol for two days prior to block surveys. Data collected by teams were collated after the completion of surveys and analyzed.

3.2. Sampling design

Species and habitat status were assessed using vehicle transects in a systematic sampling design. A grid of 137* cells, each 144 km^2 (12 km x 12 km) in dimension, were overlaid on the landscape of interest (19,728 km^2 area) and realized on ground by handheld GPS units and Google Earth imageries. Sampling was carried out in two phases: extensive surveys at first, where we randomly sampled 121 cells in 2017. Cells were surveyed along dirt trails of $29.2 \pm 8.0_{SD}$ km length (two or three transects) from a slow moving (10-20 km/hr) vehicle. Surveys were conducted in early morning (0600-1000) and late afternoon (1600-1900), when bird/animal activity was highest. This sampling scheme was chosen to optimize our target of ≥70 % area coverage and logistic constraints (man-power, six days, eight hours/day) (details in Dutta et al. 2014). Secondly, intensive surveys were conducted, wherein cells occupied by great Indian bustard (during the extensive survey) were intensively sampled along multiple transects of $14.6 \pm 6.6_{SD}$ km length, totaling to $127 \pm 13.5_{SD}$ km efforts in a cell, following similar protocol as above. Intensive surveys provided more robust and spatially representative estimate of great Indian bustard population status in occupied areas.

3.3. Data collection

3.3.1. Species' information

Data on great Indian bustard, key associated species (desert fox, Indian fox, chinkara, nilgai *Boselaphus tragocamelus* and pig), and biotic disturbances (feral dogs and livestock) were collected in 2 km segments along transect (data sheet in appendix 1). Corresponding to these species' sightings, number of individuals, GPS coordinates, and perpendicular distances from transect were collected. Perpendicular distance was measured from the distance and angle of sighting, using a Bushnell/Hawke Laser Range-finders and Suunto Compass, respectively, when animals were sighted along roughly linear segments of the transect, or as the closest approach distance (Hiby and Krishna 2004) when animals were sighted around curving path. Corresponding to bustard sightings, associated terrain, substrate, land-cover and three dominant plant species were also recorded.

3.3.2. Habitat information

Habitat features that could potentially influence species' distribution, such as, land-cover, terrain, substrate, vegetation structure, and human artifacts were recorded at 2 km intervals along transect (see

data sheet in appendix 2). Dominant land-cover type barren/agriculture/grassland/shrubland/woodland), terrain type (moderately or extremely flat/sloping/undulating), and substrate type depending on soil characteristics (rock/gravel/sand/soil) were recorded within 100 m radius of the point. Vegetation structure was recorded as percentage of ground covered by short grass and herb (<30cm), tall grass and herb (>30cm), shrub (<2m) and tree (>2m) within 20-m radius of the point. These covariates were recorded in broad class- intervals (0-10, 10-20, 20-40, 40-60, 60-80, and 80-100 %) to reduce inconsistency of observation errors between teams. Vegetation composition was recorded as three dominant plant taxa within 100m radius of the point. Presence of human structures (settlement/farm-hut/metal-road/power-lines/wind-turbine/water-source) was recorded within 500-m radius of the point. Status of spiny-tailed lizard, another key associate of bustard with a relatively small activity range (Dutta and Jhala 2014), was recorded as occurrence of their burrow(s) within 10 m radius of the point.

3.3.3. Community surveys

Community surveys were conducted in 99 randomly selected villages, by opportunistically interviewing 131 residents (appendix 3). Village-level information on reports of bustard (present and ten years back) and associated species' (chinkara, fox, nilgai and crane) occurrences in village areas were collected.

3.4. Data analysis

3.4.1 Population status

Occupancy and density/abundance are commonly used parameters to assess population status.

We estimated occupancy or proportion of cells occupied by great Indian bustard from extensive survey data using dynamic/multi-season occupancy modes (Mackenzie et al. 2006). This approach corrects for the probability of missing species at a site during a season/year using detection data from repeated surveys, and can estimate occupancy (probability of patch occupied), colonization (probability of an unoccupied patch being occupied in next time period) and extinction (probability of an occupied patch being unoccupied) probabilities. We used species' sightings in 2 km transect segments to generate detection/non-detection matrix (spatial surveys) for sampled cells across survey years 2014, 2015, 2016 and 2017 (primary seasons). We fitted dynamic occupancy models that assumed a) occupancy to be constant across years
$psi(.)$ or varying between years, because of b) constant extinction $ext(.)$ and colonization $col(.)$ probabilities or c) temporally varying extinction $ext(t)$ and colonization $col(t)$ probabilities, while assuming detection probability to be d) constant across sites and surveys $p(.)$ or e) varying between years $p(t)$ (MacKenzie et al. 2006). We compared these models using Information Theoretic approach Burnham and Anderson (2002), and derived year-wise occupancy estimates from the least AICc (Akaike 1974) model in R (R Core Team 2017).

Species' density was estimated using Distance analysis in program DISTANCE (Thomas et al. 2010). This approach models the declining probability of detecting individual(s) along increasing distances from transect, wherefrom effective detection/strip width ($\widehat{ESW}$) and effective sample area ($\widehat{A}$) are derived. This metric is used to convert encounter rate into density estimate ($\hat{D}$) (demonstrated in the footnote, also see Buckland et al. 2001). Since extensive transects were random samples, species' abundance was estimated as the product of density and landscape area. We used this framework to assess population size of chinkara and desert fox. For other species, we provided mean $\pm$ SE estimates of encounter rates.

However, great Indian bustard sightings were too few and spatially clustered for robust modeling of detection function and for obtaining an unbiased, precise estimation of density/abundance in this framework. To circumvent this issue, we supplemented extensive surveys with intensive surveys in sites where great Indian bustard was detected (known occupancy). Thereafter, landscape-scale abundance was estimated by pooling extensive and intensive survey data to model detection function, compute density at

each cell, and estimate the landscape-scale density/abundance as the average of cell-wise (replicates) densities in program DISTANCE. Since, we could not intensively sample the Pokhran Field Firing Range due to access issues in 2017 survey, Wildlife Institute of India's Great Indian Bustard Conservation Project team conducted follow-up distance based line transect surveys in the subset of landscape where the species is distributed (western Thar: 4068 km² area, and Pokhran Field Firing Range: 5184 km² area) in March–April 2018, to refine the past estimate in a similar analytical framework.

Our current estimation of great Indian bustard numbers is a refinement over our earlier approach (2014-15 assessment, see Dutta et al. 2015), where information on density came only from extensive surveys. We expect our current estimation to be less biased since information on density from intensive and spatially exhaustive sampling will be more representative.

3.4.2. Habitat status and use

Habitat characteristics of a cell were summarized from covariate data collected at $16.5_{Mean} \pm 4_{SD}$ sampling plots along extensive transects of 2017. a) For categorical covariates (land-cover and substrate types), frequency of occurrence of each category was estimated. b) For interval covariates (vegetation structure), mid-values of class-intervals were averaged across plots. c) Vegetation composition was quantified as the mean dominance score of plant taxa across plots (dominant: 3 – not dominant: 1). c) Disturbance covariates were quantified as frequency occurrence of settlement, farm hut, metal road, power lines, wind turbines, solar plant and water body. Thereafter, these values were averaged across plots to generate disturbance indices for each cell. Mean $\pm$ SE estimates of covariates were computed across sampled cells to describe landscape characteristics.

3.4.3. Spatial and temporal trends of species, habitat and threats

We generated spatially explicit information on status and trend of species, habitat, and threats to understand how the landscape is changing and to aid managers in targeting conservation actions. We estimated species' encounter rates across years using data from cells that were sampled across all years, for meaningful comparison. We mapped current encounter rates of focal species along with their recent trends, by estimating the linear regression slope of encounter rates across years in a cell, to depict temporal change rate at the site-level. We generated surface maps of habitat covariates from their mean values in sampled cells. All mapping was carried out in program ArcMap (ESRI 1999-2008). Finally, we assessed the temporal trend in habitat and threat variables, by estimating the annual frequency occurrence of various threats (e.g., farm hut and power lines), proportional cover of land-cover types (e.g., agriculture and grassland) and percentage ground cover of vegetation structure (e.g., short grass and tall grass), and computing their temporal change rates, as above .

3.4.4. Community responses

We estimated the proportion of respondents who reported occurrences of the focal species in their village areas, and generated occurrence maps based on secondary reports. We also mapped the areas where great Indian bustard was reported to be present 10 years back but was currently absent (i.e., locally extinct) at the village-level. We compared the mean and 95% confidence interval of intensity and trend of power- lines between great Indian bustard occupied, unoccupied, and locally extinct sites to test the effect of power- lines on bird distribution and extinction risk.

ESW: perpendicular distance within which that many individuals are missed as are detected outside ESA = Transect length x 2*ESW
Density = Number / ESA

4. Results

4.1. Population status

Our extensive surveys covered 121 cells (17,424 km² area) along 3,529 km transect in 2017, with additional 635 km transects in six great Indian bustard occupied cells (figure 1). Data generated from these surveys provided estimates of species' occupancy, density and abundance. In the past, we sampled 108 cells along 1,697 km transect in 2014, 77 cells along 1,246 km transect in 2015, and 120 cells along 2,273 km transect in 2016.

4.1.1. Great Indian Bustard

Surveys conducted during 2014, 2015, 2016 and 2017 recorded minimum 38, 40, 37 and 37 unique great Indian bustards respectively, comprising observations along transects and those *en route* sampling cells. Extensive surveys during 2017 detected great Indian bustard in six cells or 5 % of sites (naïve occupancy). Probability of detecting great Indian bustard in a 2 km trail segment (if present in the cell) was estimated at
0.09 ± 0.03_{SE}; showing that the probability of detecting the species if present in a site was ~0.8 on average. Correcting for such imperfect detection, proportion of sites occupied by great Indian bustard was estimated at 6.7 ± 2.9_{SE} % of sites in 2017. Pooling extensive and intensive surveys of 2016-17, we detected 65 flocks with mean flock size of 1.63 ± 0.11_{SE} individuals. Distance data of these observations was best explained by uniform detection function with cosine series expansion (least AICc value; goodness of fit: $\chi 2$=0.65, df=5, p=0.99). This model estimated effective strip width at 401 ± 26_{SE} m (figure 2), based on which, great Indian bustard density was estimated at 0.48 ± 0.10_{SE} birds/100km² for all cells and 7.49 ± 1.63_{SE} birds/100km² in occupied cells (fig 3). Landscape-scale abundance was estimated at 95_{Mean} ± 21_{SE} individuals (table 1). Our traditional approach, where great Indian bustard encounter rate was computed only from extensive surveys of 2017, yielded abundance estimate of 135 birds.

Follow-up survey (2018) results

Follow-up surveys conducted in December – January 2017 in western Thar: 4068 km² area, and March – April 2018 in Pokhran Field Firing Range: 5184 km² area, to refine the past estimate involved 3052 km search efforts, yielding 35 detections. Distance data was best explained by uniform detection function (X^2 = 1.53, df=4, p=0.82), and effective strip width was estimated to be 447 ± 48_{SE} m. Bird density of the entire area (9252 km²) was estimated to be 1.4 ± 0.20 (1.0 – 1.9 $_{95\%\ CI}$) birds/100 km², yielding abundance estimate of 128 ± 19_{SE} individuals.

4.1.2. Chinkara

Extensive survey in 2017 yielded detection of 1036 chinkara herds at encounter rate of 29 + 2.3_{SE} herds/100km and mean herd size of 2.49 ± 0.07_{SE} individuals. Distance data of these observations was best explained by hazard-rate detection function with simple polynomial series expansion (truncated at 420m) (least AICc and GOF-p=0.99) that estimated herd effective strip width at 169 ± 7_{SE} m (figure x). Chinkara density was estimated at 205 + 14_{SE} animals/100km², yielding abundance estimates of 40,442 ± 2810_{SE} animals in the landscape (table 1).

4.1.3. Desert fox

Extensive survey in 2017 yielded detection of 77 desert fox at encounter rate of 2.15 ± 0.26_{SE} individuals/100km, and group size of 1.09 ± 0.04_{SE} individuals. Distance data of these observations (truncated at 228 m) was best explained by half-normal detection function with cosine series expansion (least AICc and GOF-p: 0.91) that estimated effective strip width at 82 ± 9_{SE} m (figure x). Desert fox density was estimated at 15.03 ± 2.39_{SE} individuals/100km², yielding abundance of 2965 ± 471_{SE} animals in the landscape (table 1).

* Detectability experiments using dummy birds (June 2014 and March 2016) yielded a similar effective strip width of 402 ± 34_{SE} m.

4.1.4. Other fauna

Extensive survey in 2017 also yielded sightings of Indian fox (encounter rate 0.22 ± 0.08_{SE} animals/100km), nilgai (3.93 ± 1.11_{SE} animals/100km), wild pig (1.98 ± 0.75_{SE} animals/100km), and domestic livestock (484.49 ± 62.84_{SE} cattle/100km and 2065.83 ± 138.8_{SE} sheep-goat/100km) (table 3). Spiny-tailed lizard burrows were detected in 8.2 ± 1.5 % plots.

Table 1 Population status of Great Indian Bustard and associated native fauna of Thar landscape during 2017

Species	***Trn***	***Eff***	***Obs***	$\hat{\boldsymbol{\delta}}$***W***	$\hat{D}$ ***(# km^{-2})***	$\hat{\psi}$	$\hat{\psi}$***. A***	$\hat{N}$
Great Indian Bustard (2016-17) *A. nigriceps*	575 158*	7493 1846*	65	401 (24)	0.005 (0.001) 0.075 (0.016)*	0.067 (0.029)	1322	95 (21) 97 (48)*
Chinkara (2017) *G. bennettii*	293	3583	1036	169 (7)	2.05 (0.14)	0.89 (0.04)	15625	40442 (2810)
Desert fox (2017) *V. vulpes pussilla?*	293	3583	77	82 (9)	0.150 (0.024)	0.68 (0.13)	13415	2965 (471)

Trn = Number of transects/trails sampled

Eff = Total length of transects/trails, or efforts in kilometers

Obs = Number of individuals detected on transects/trails

$\hat{\boldsymbol{\delta}}$ = Mean (SE) Effective Strip Width in meters, indicating the distance from the transect within which you effectively detect birds (see ref)

$\hat{D}$ = Mean (SE) density of birds in numbers km^{-2}, representative of the entire Thar landscape.

$\hat{N}$ = Mean (SE) Number of individuals in the landscape (19,728 km^2) or abundance

$\hat{\psi}$ = Mean (SE) occupancy probability, or proportion of cells (144 km^2) occupied by the species, correcting for imperfect detection

$\hat{p}$ = Mean (SE) species detection probability, or the probability of detecting the species in a survey if it is present in the cell

S = Naïve occupancy, or proportion of cells (144 km^2) where the species was detected

$\hat{\psi}$. A = Occupied area, estimated as the product of landscape area (19,728 km^2) and occupancy probability

Values marked as (*) are representative of six cells that were occupied by great Indian bustard

Figure 2 Detection function (probability of detecting an animal along perpendicular distance from transect) of Great Indian Bustard (top), Chinkara (center) and Fox (bottom) in Thar landscape during 2017

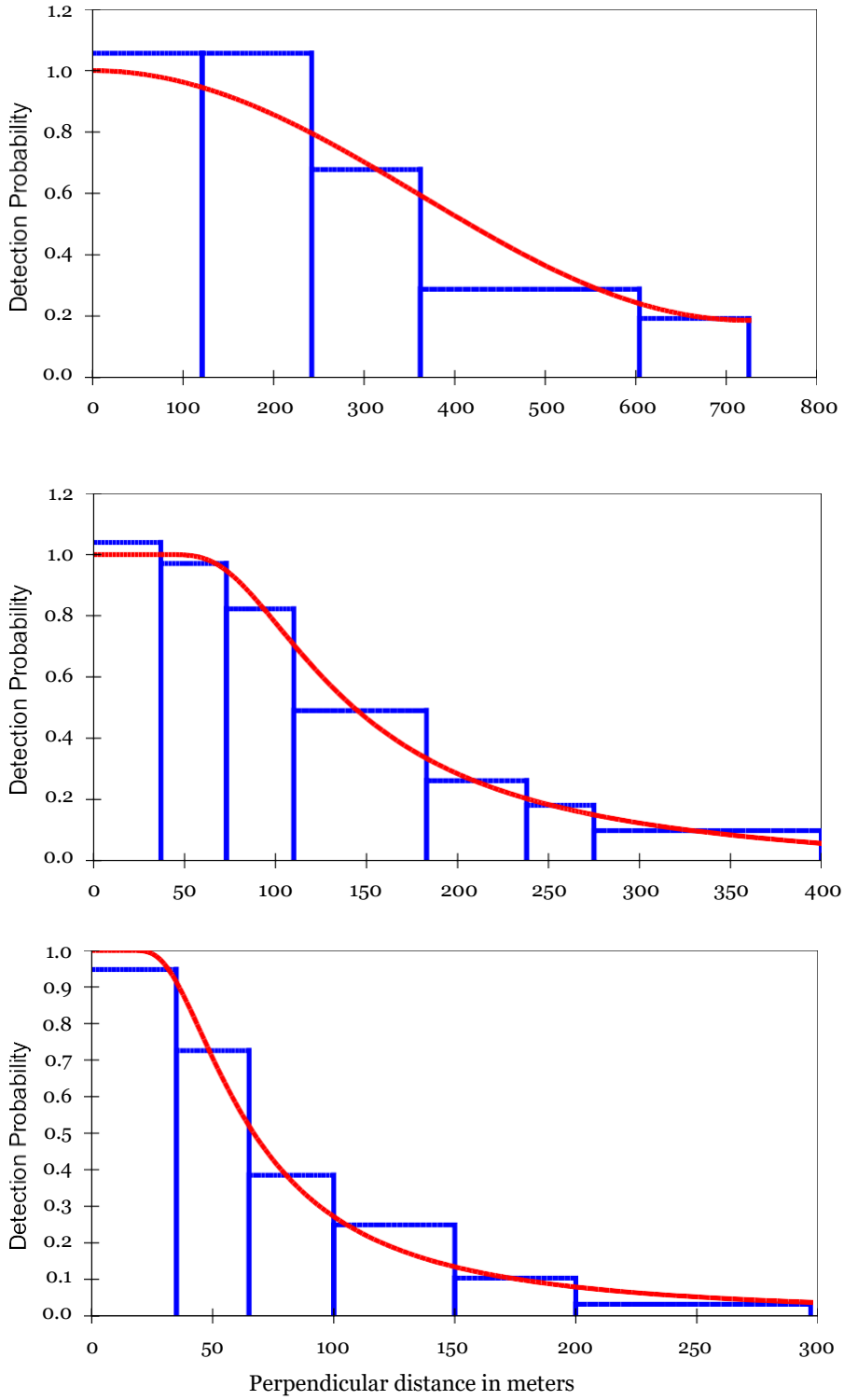


Figure 3 Status (2017) and trend (2014–2017) of Great Indian Bustard in Thar landscape

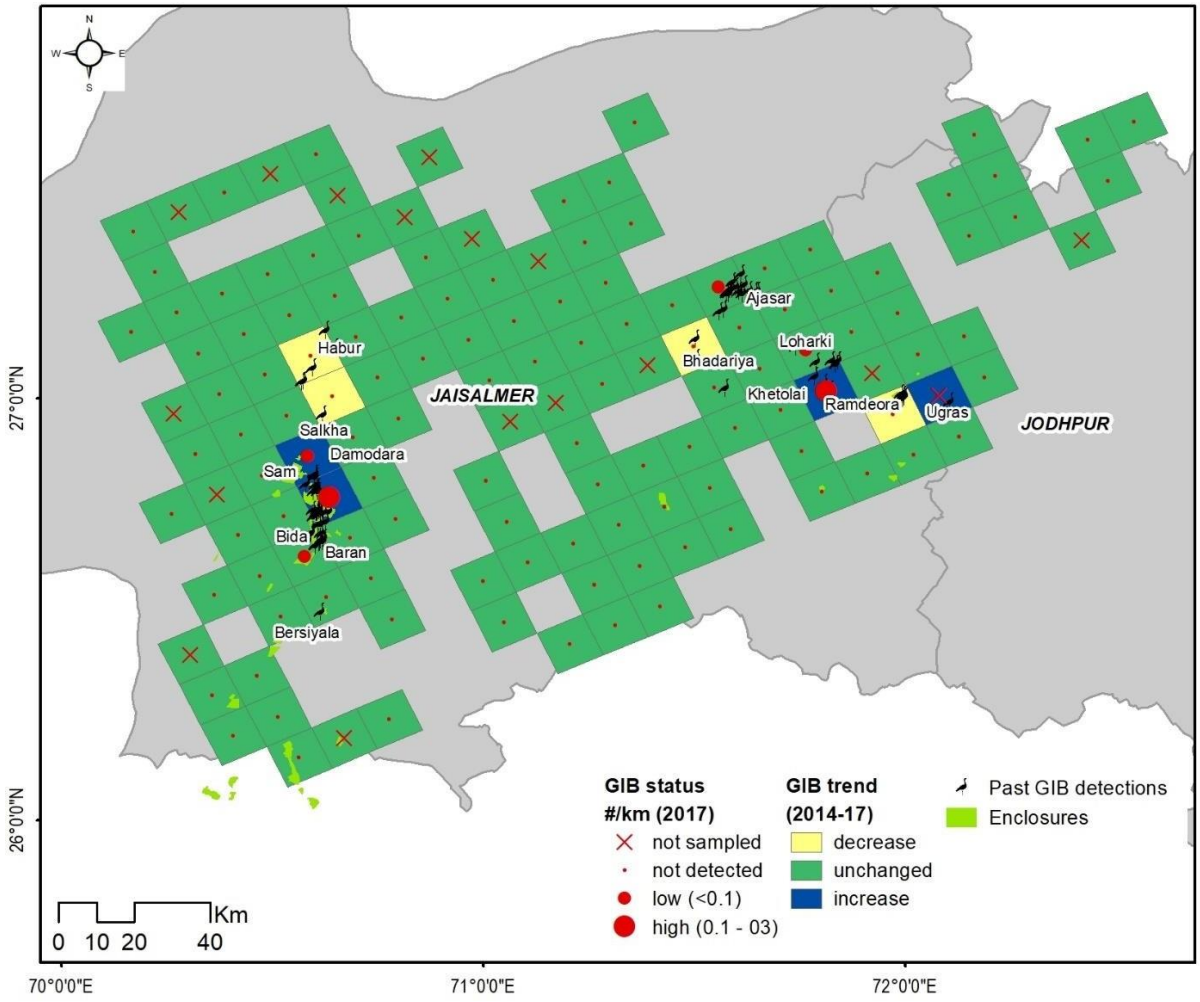


Figure 4 Status (2017) and trend (2014–2017) of Chinkara (top) and Desert fox (bottom) in Thar landscape

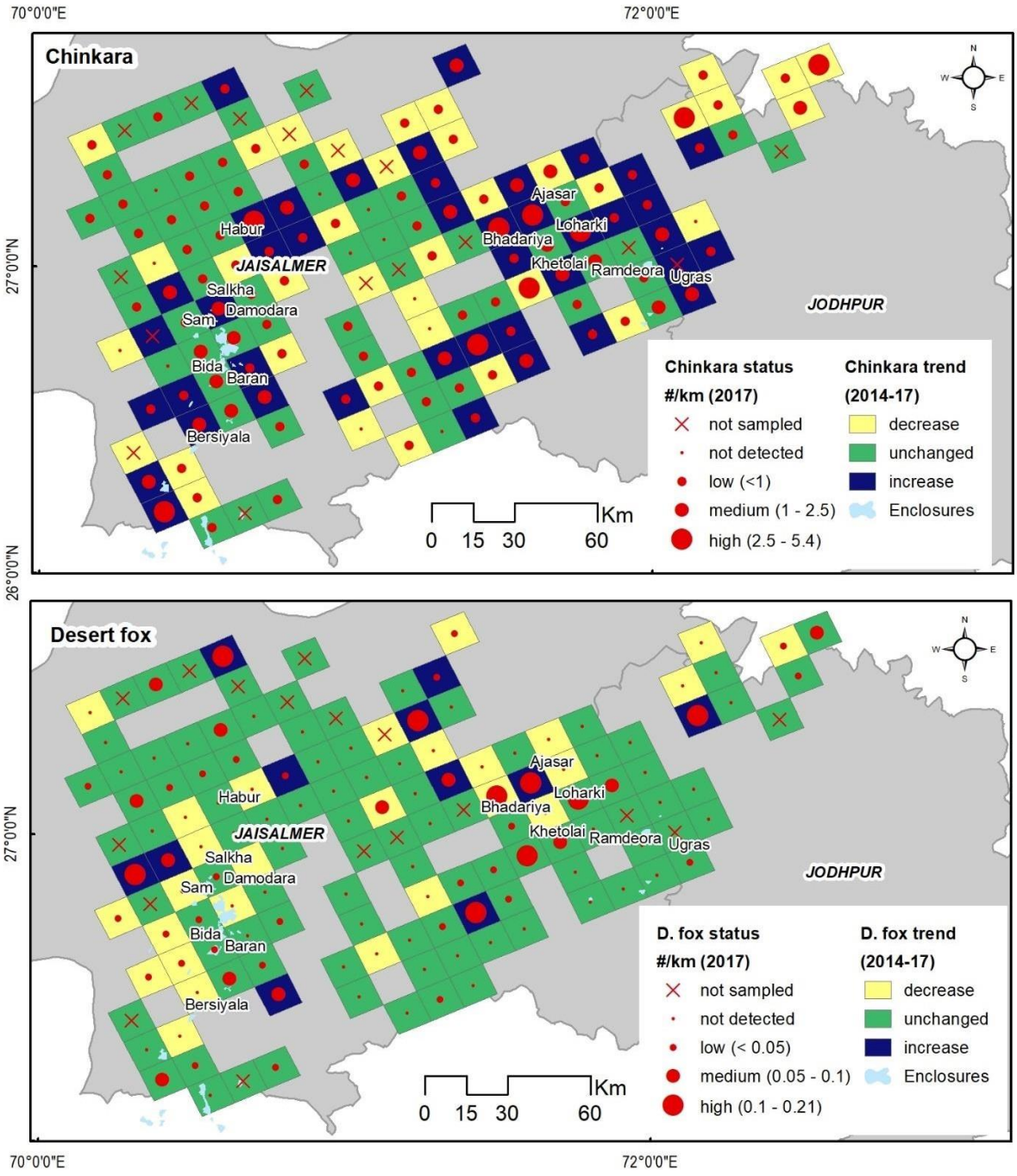
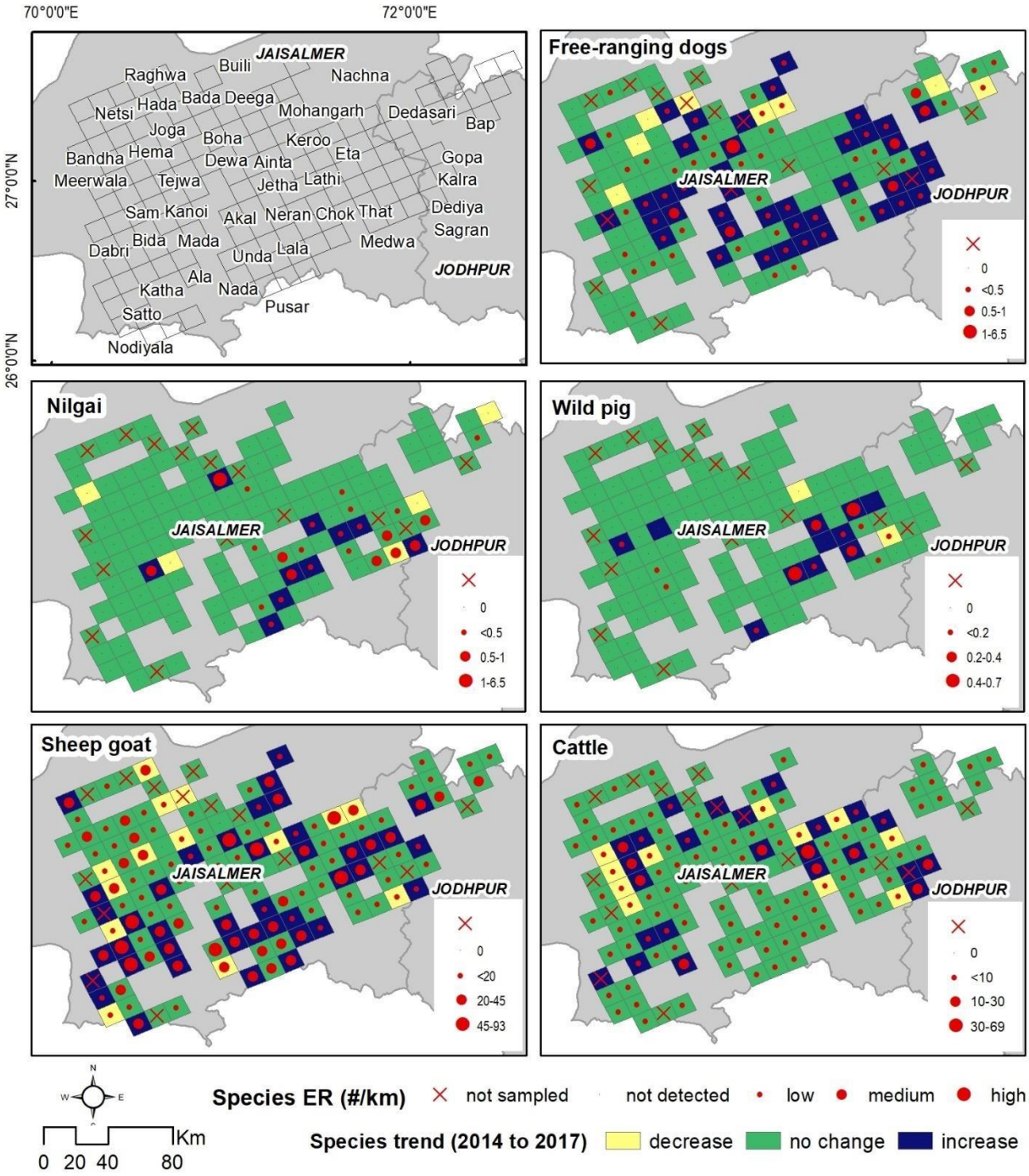


Figure 5 Status (2017) and trend (2014–2017) of non-native / domestic species in Thar landscape



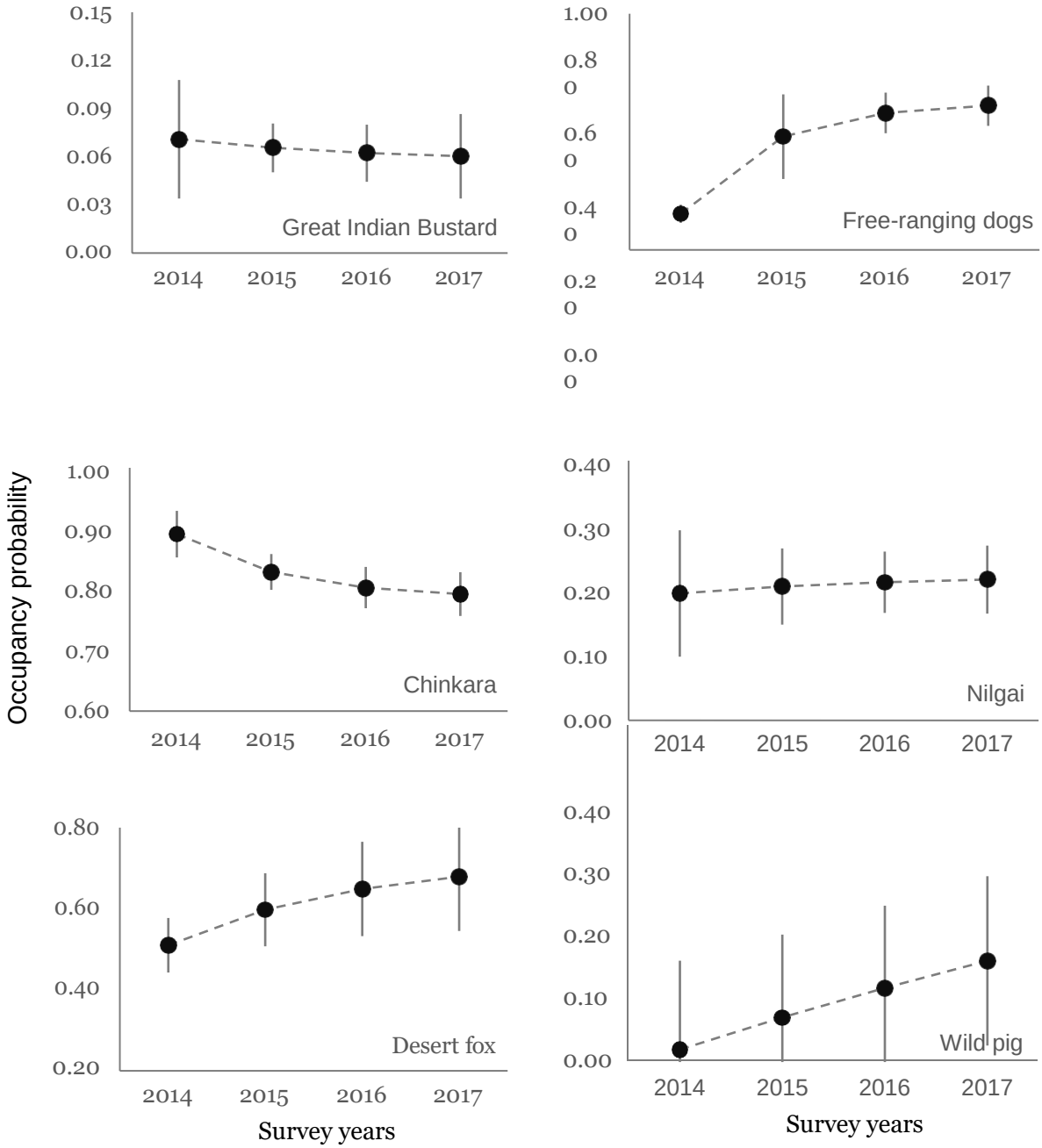
4.1.5. Species' population trends

For meaningful comparison of population trends for our focal species, we computed mean ± 1 SE animal encounter rates/100 km across cells, which were surveyed in all years (table 2). Additionally, annual occupancy estimates were derived from our dynamic occupancy models to infer trends (figure z). These results showed a rapid increase of free-ranging dogs, an increasing trend of sheep and goat, and a non-significant but declining trend of great Indian bustard that needs to be ascertained in subsequent surveys.

Table 2 Species' population trend across years (2014–2017) in Thar landscape, estimated as mean (SE) number of animals 100km^{-1}. For each species, encounter rates have been computed for all cells sampled in a year (first row) and the subset of cells sampled in all years (same cells)

Species	Sample	2014	2015	2016	2017
Great Indian Bustard	All cells	0.82 (0.32)		0.59 (0.2)	
	Same cells	1 (0.41)		0.83 (0.3)	
Chinkara	All cells	83.44 (11.98)	85.58 (14.94)	60.71 (7.44)	80.75 (8.8)
	Same cells	78.72 (15.31)	85.48 (17.6)	59.93 (10.86)	79.37 (12.78)
Desert fox	All cells	3.56 (0.61)	2.64 (0.81)	1.87 (0.38)	2.76 (0.4)
	Same cells	3.29 (0.79)	3.06 (0.98)	2.27 (0.54)	2.64 (0.52)
Indian fox	All cells	0.21 (0.12)	0.1 (0.1)	0.29 (0.15)	0.22 (0.08)
	Same cells	0.26 (0.19)	0.12 (0.12)	0.28 (0.22)	0.18 (0.09)
Dog	All cells	3.47 (1.15)	5 (1.22)	5.08 (0.92)	18.6 (5.44)
	Same cells	4.32 (1.77)	4.59 (1.28)	5.46 (1.24)	23.11 (9.39)
Nilgai	All cells	3.07 (1.42)	4.88 (1.8)	9.28 (3.15)	3.93 (1.11)
	Same cells	4.41 (2.38)	5.06 (2.08)	5.63 (2.03)	5.42 (1.8)
Wild pig	All cells	0.85 (0.85)	1.28 (0.91)	2.33 (0.93)	1.98 (0.75)
	Same cells	1.45 (1.45)	0.89 (0.89)	2.92 (1.35)	2.26 (1.22)
Cattle	All cells	217.5 (32.18)	687.9 (194.62)	465.09 (67.15)	484.49 (62.84)
	Same cells	237.79 (43.93)	558.58 (166.01)	450.43 (83.28)	469.53 (101.8)
Sheep goat	All cells	1252.6 (124.76)	1539.42 (209.83)	2187.03 (228.66)	2065.83 (138.8)
	Same cells	1389.71 (165.7)	1622.77 (248.21)	2146.63 (291.9)	1868.28 (137.6)

Figure 6 Species' distribution trend across years (2014–17) in Thar landscape, estimated as mean ± 1 SE proportion of sites occupied using dynamic occupancy models, for native / 'important' (left) and non-native / 'problem' species (right)



4.1.6. Habitat status and trends

Habitat characterization along transects during 2017 survey showed that the landscape was dominated by: a) flat followed by undulating terrain; b) soil followed by sand substrate; c) grassland/savanna followed by agriculture and shrubland land-cover; and d) short grass and crops interspersed with tall grass and shrub as the vegetation cover. Woody vegetation was dominated by *Capparis* > *Calotropis* > *Leptadenia* > *Aerva* > *Zizyphus* > *Calligonum* > *Crotolaria* in the shrub layer, and *Acacia* > *Prosopis cineraria* ~ *Salvadora* in the tree layer (table 3). Whilst the herbaceous vegetation was dominated by *Dactyloctenium* > *Lasiurus* (grasses) and *Fagonia* > *Haloxylon* (herbs). Among human artifacts (threats), power-lines were most common followed by water sources and farm huts.

Table 3 Descriptive statistics of habitat covariates in 144 km² cells of Thar landscape (2017)

Feature	Units	Habitat variable	Mean (SE)
Disturbances	Occurrence probability (500-m radius plot)	Power-lines	0.42 (0.03)
		Water body	0.39 (0.02)
		Hut	0.36 (0.02)
		Settlement	0.25 (0.02)
		Metal road	0.14 (0.01)
		Wind turbines	0.13 (0.02)
		Solar plant	0.02 (0.01)
Landcover	Proportional cover	Grassland	0.36 (0.02)
		Agriculture	0.26 (0.02)
		Shrubland	0.19 (0.02)
		Barren	0.13 (0.02)
		Woodland	0.06 (0.01)
Substrate	Proportional cover	Soil	0.78 (0.03)
		Sand	0.11 (0.02)
		Gravel	0.07 (0.02)
		Rocky	0.04 (0.01)
Terrain	Proportional cover	Flat	0.53 (0.02)
		Undulating	0.14 (0.02)
		Sloping	0.1 (0.01)
Vegetation composition (dominance score 1-3)	Grass	*Dactyloctenium*	0.91 (0.07)
		Lasiurus	0.45 (0.05)
	Herb	*Fagonia*	0.3 (0.03)
		Haloxylon	0.17 (0.03)
		Senia	0.16 (0.03)
	Shrub	*Capparis*	0.71 (0.05)
		Calotropis	0.59 (0.06)
		Leptadenia	0.44 (0.04)
		Aerva	0.39 (0.05)
		Zizyphus	0.26 (0.04)
		Calligonum	0.13 (0.03)
		Crotolaria	0.1 (0.02)
	Tree	*Acacia*	0.21 (0.03)
		Prosopis cineraria	0.09 (0.01)
Vegetation stratification	Ground cover (%)	Crop cover	26.02 (2.22)
		Short grass	20.91 (1.31)
		Tall grass	12.28 (0.9)
		Shrub	10.12 (0.7)
		Tree	5.61 (0.44)

We also observed sharp increase in the proportion of sampling plots with human artifacts, especially water sources, power-lines, farm-huts and wind-turbines across the survey years. However, land-cover composition and vegetation stratification did not show any discernible trend over the years. The rapid expansion of the above-mentioned human artifacts is concerning as they have far-reaching ecological consequences. Expansion of water sources and human presence may be the reason behind the expansion of 'undesirable' species such as free-ranging dogs in this landscape. Whilst, power-lines can have strong negative impacts on bustard by reducing their numbers through collision related mortality. Our ancillary surveys of power-lines for bird carcasses (2 mortalities in 20 km high-tension power-lines surveyed seven times) indicate that about 18 birds have likely died because of the 152 km unmitigated high-tension lines that are present in bustard occupied sites. Analyzing great Indian bustard occupancy and local extinction, based on secondary reports, against the current status and recent trend of putative habitat variables indicated higher trend of power-line intensity in extinct cells compared to occupied cells, and significantly positive trend of power-line incidence in occupied cells (table) that was a significant conservation concern, given the high mortality rate due to power-lines.

4.1.7. Secondary reports

Information provided by agro-pastoralists about the past and present occurrences of great Indian bustard and current occurrence of associated species were used to estimate the proportion of village areas where the occurrence of a particular species was confirmed by at least one respondent. Results indicated that great Indian bustard distribution was more widespread 10 years back (25 $\pm$ 5$_{SE}$ % village-areas) than present (16 $\pm$ 4$_{SE}$ %). The species was not reported from 64% of village areas, and in last ten years, 19% of village areas lost the species, whereas, 11% of village areas were newly occupied / colonized. Among the most commonly reported species were, chinkara (92%) > fox (78.1%) > spiny-tailed lizard (75%) > nilgai (66%) > crane (41%). Jackal, which is rare (if at all present) in the area was reported very less (6.8% village-areas), indicating the authenticity of the reports.

Figure 7 Spatial gradients of key putative factors influencing Great Indian Bustard distribution: (clockwise) terrain flatness, grassland cover, settlements and power-lines

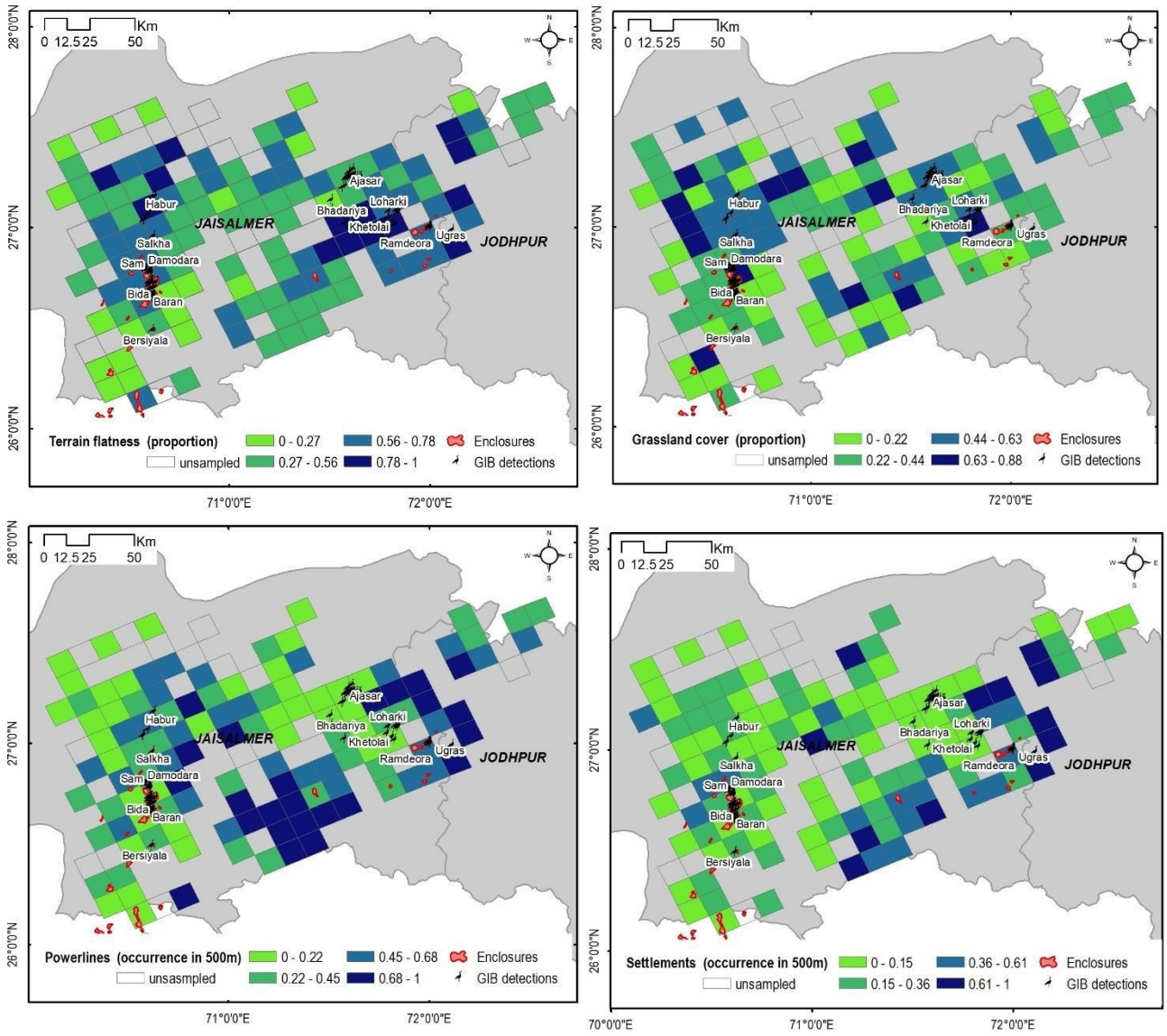


Figure 8 Occurrence probability of human artifacts in sampling plots across Thar landscape from 2015 to 2017. Error bars are 1 SE across 144-km² cells, and values in parentheses are regression slopes against years that are indicative of temporal trends. Also shown are land-cover and vegetation structure variables that, expectedly, do not show strong temporal trends

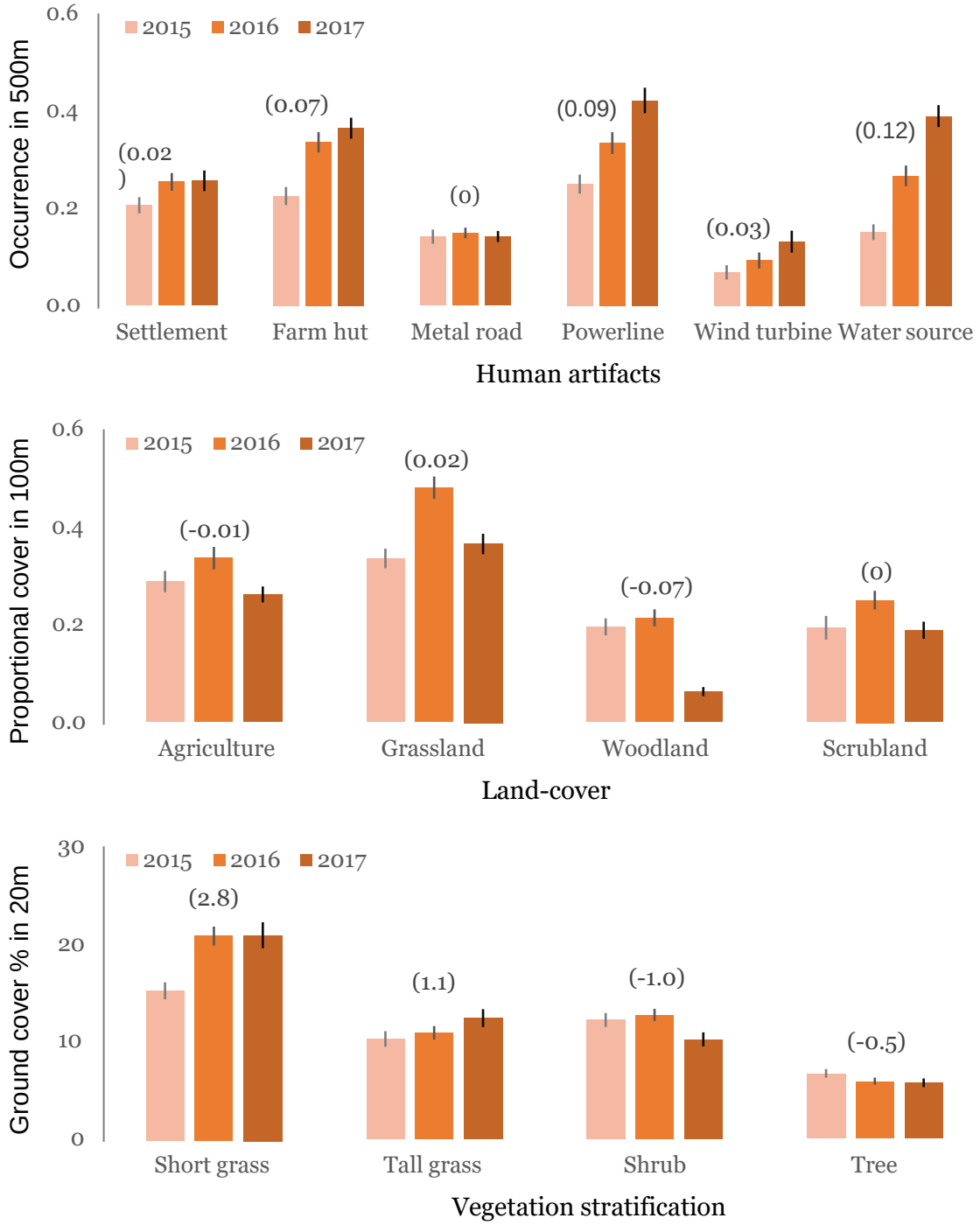


Figure 9 Great Indian Bustard distribution and local extinction in the past decade (based on secondary reports) and from 2014-15 to 2016-17 (based on occupancy surveys) overlaid on the occurrence (2016) and recent trend (2015-17) of power-line expansion across Thar landscape

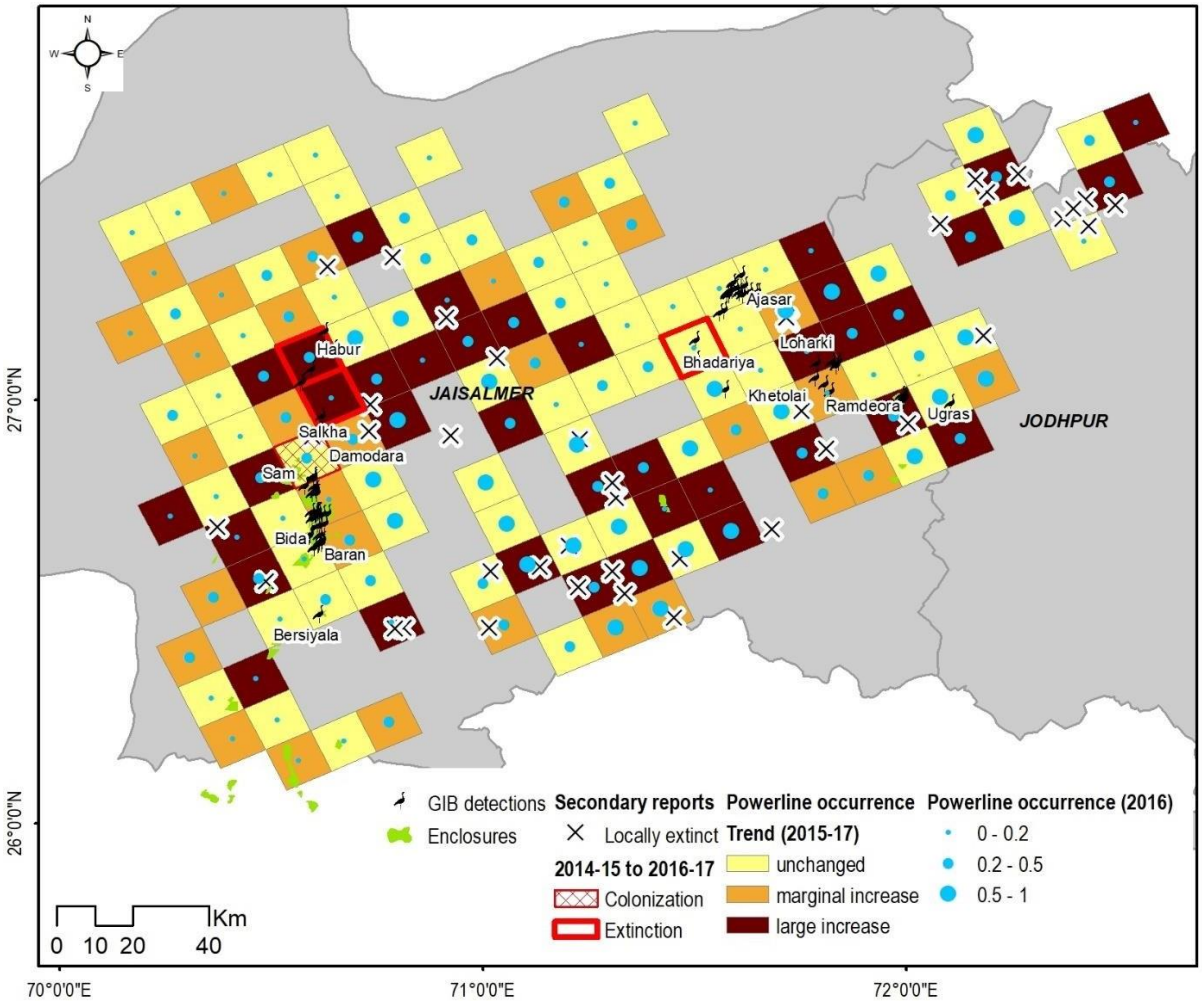
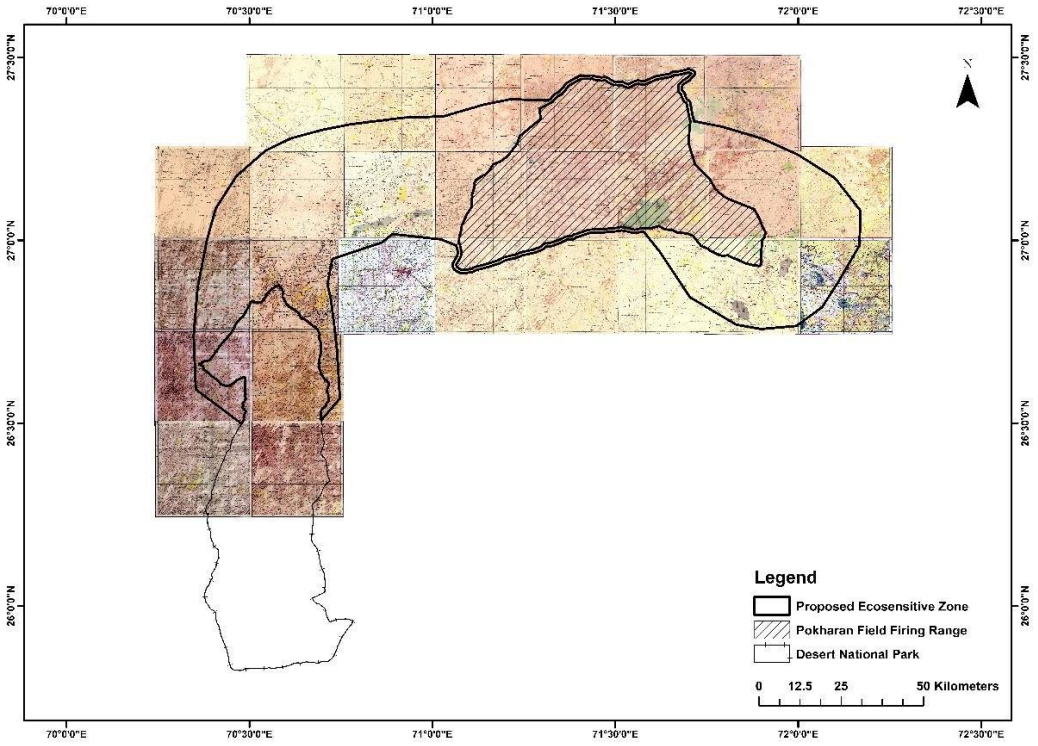


Table 4 Mean (95% CI) of current status and recent trend of putative habitat variables in 144 km² cells where great Indian bustard currently occurs (occupied), occurred 10 years back but not now (extinct) and never occurred (unoccupied) in Thar landscape, based on secondary reports during 2016-17 surveys

	Variables	Measurement	Extinct	Occupied	Unoccupied
Current status	Flatness	Frequency occurrence (proportion) in sampling plots	0.58 (0.5–0.66)	0.56 (0.47–0.64)	0.46 (0.37–0.55)
	Agriculture		0.28 (0.21–0.36)	0.25 (0.19–0.31)	0.22 (0.17–0.28)
	Grassland		0.36 (0.27–0.45)	0.38 (0.3–0.46)	0.31 (0.23–0.4)
	Settlement		0.32 (0.22–0.42)	0.24 (0.18–0.31)	0.22 (0.15–0.28)
	Power-lines		**0.53 (0.41–0.65)**	0.4 (0.31–0.49)	0.4 (0.3–0.5)
	Wind turbines		0.19 (0.07–0.31)	0.11 (0.04–0.18)	0.11 (0.03–0.19)
Rate of change	Settlement	Proportional change per year during 2015–2017	-0.02 (-0.11–0.08)	0.01 (-0.04–0.07)	-0.02 (-0.09–0.04)
	Power-lines		0 (-0.08–0.08)	**0.06 (0.01–0.1)**	0.02 (-0.03–0.07)
	Wind turbines		0.02 (-0.04–0.07)	0.01 (-0.01–0.04)	0.02 (-0.02–0.06)

Figure 10 Proposed ecosensitive zone to conserve great Indian bustard and associated fauna and habitat of Thar landscape



5. Discussion and recommendations

This report is an outcome of the long-term annual collaborative surveys of Wildlife Institute of India and Rajasthan Forest Department to monitor the population status of the critically endangered great Indian bustard and its associated fauna, habitat and threats in 19,728 km² potential bustard habitat of Thar landscape. This exercise follows a standardized, spatially representative sampling and analytical design that accounts for imperfect species' detection, thereby allowing robust spatio-temporal comparisons. During three initial survey years (2014-16), we have tried and tested various modifications over our basic sampling and analytical designs. The key refinement is a two-phase sampling to assess great Indian bustard abundance, wherein, extensive surveys across the landscape generates information on proportion of cells occupied by the species, and intensive surveys generates information on density in occupied cells, together providing abundance estimate in the landscape. For comparison with past estimates, we have reported the density/abundance estimated using the traditional approach; however, our current approach yields more realistic estimate.

Comments on the population enumeration technique

Thar landscape extends over a vast area with little barrier to bird/animal movements, thereby rendering total population counts impractical and unreliable. Comparing great Indian bustard numbers observed in conventional surveys to that reported by local informants, Rahmani (1986) speculated that only 10–20 % of population might be detectable. This impeded earlier efforts of assessing their population status with confidence, which we circumvent using line transect distance sampling approach. To obtain unbiased abundance estimate of an area, line transects should be randomly placed with respect to (1) animals and (2) the general habitat that can influence animal density gradient. For logistical practicality without violating the first assumption, we laid our transects on dirt and cross-country tracks, to which great Indian bustard did not show avoidance/preference, according to earlier studies (Dutta 2012) and absence of evasive movements in our long-term distance data. To adhere to the second assumption, we estimated animal density by sampling occupied cells in a spatially intensive and representative manner. This refinement generated more realistic population estimate than the earlier (2014-15) exercise. Our approach involves modeling of detection function using distance data of observations. We demonstrated that the effective detection widths based on actual bird detections (2014–17) matched very closely with that based on dummy birds (2014 and 2016). Hence, we recommend using dummy birds in blind trials to correct for imperfect detection when actual observations in a survey are inadequate. Our earlier exercise (2014-15) also lacked precision for great Indian bustard population estimation, as can be expected for a species with tiny population and patchy distribution across large area. Implementing two phase sampling that makes use of intensive data from sites used by species and pooling samples from consecutive years (without much difference in encounter rates) have provided reasonable precision in the current exercise.

For the purpose of monitoring, we recommend replicating our intensive surveys on a seasonal basis in great Indian bustard used areas in west (Chawani–Habur) and east (Bhadaria–Ajasar–Pokhran) Thar landscape that would allow reliable inferences on local population trend and seasonality. A complete landscape-scale survey, spanning summer (March-April) and winter (October-December) seasons can be conducted once every 2-4 years to detect changes in overall population status. Finally, the current species' density/abundance estimates should not be compared to that reported in Dutta et al. (2014, 2015) because of our methodological refinements. Instead, encounter rates based on consistently sampled cells should be used for inferences on temporal species' trends.

Is there a decline in population?

Although our estimate based on 2017 surveys (95 $\pm$ 21 individuals) indicated a decline in Great Indian Bustard numbers, inadequate sampling of the species' prime habitat – Pokhran Field Firing Range, could have biased the estimate. Our follow-up surveys, where the Great Indian Bustard Conservation Project team surveyed western Thar landscape and Pokhran Field Firing Range, yielded more refined estimate of 128 $\pm$ 19 individuals. Although we cannot infer trend in the population in a meaningful way because of the poor precision of the past (2014–16) estimates, managers should take cognizance of the mounting evidence of powerline mortalities in this landscape. Our carcass surveys covering 80 km low and high tension powerlines across ~4000 sqkm area on six occasions spread over a year estimated ~18 Great Indian Bustard deaths, based on three recorded mortalities (two during and one outside surveys). Although the initial years of monitoring shows a stable population of Great Indian Bustard in Thar, such high human- induced mortality rate is unsustainable for a long lived species; would eventually lead to their decline, and is necessary to be mitigated in an expeditious manner.

Conservation implications

Rahmani (1986) assessed great Indian bustard status in this landscape, but direct comparison between the two studies is not possible as the survey methods differ considerably. However, numbers and area of use have seemingly declined in these three decades. Typical number of birds seen by respondents in their localities has also reduced from earlier times. Local peoples' responses to our questionnaires indicated that great Indian bustard distribution was more widespread ten years back than it is currently. Local extinction reports were concentrated around Phalodi-Bap (north-east Thar) and Reewari-Bhimsar-Rasla-Sadrasar (south-central Thar) areas that corroborated our field observations.

Our earlier results on species-habitat relationships (Dutta *et al* 2016) indicated that disturbance was the prime factor influencing distribution in this region. Great Indian bustard did not use areas with high incidence of humans or infrastructure. Their occurrence also depended on protection and declined with distance from protected enclosures. Hence, reduction of anthropogenic pressures in great Indian bustard occupied cells by creating enclosures and/or providing alternate arrangements to local communities should be the priority conservation action. The recent (late 2013) installation of wind-turbines and high tension power-lines between Sam-Sudasiri and Salkha areas is a severe threat to the survival of great Indian bustard population as they increase the risk of electrocution and fatal collisions of the locally migrating birds in western Thar. Thar landscape has already lost great Indian bustard from Mokla grasslands following the installation of wind-turbines and high tension power-lines between near Mokla in early 2011. At least three instances of great Indian bustard mortality through collision with power-lines associated with wind-turbines have been reported from our power-line surveys and anecdotal evidence in Thar in the last year, and it is estimated that about 18 birds may die each year due to power-lines. Recent deliberations and decision that no more over-head power-lines and wind turbines should be installed in the priority great Indian bustard habitat, and existing power-lines will be mitigated, will greatly benefit the species. Based on our long-term understanding of this landscape, an eco-sensitive zone boundary has been proposed (fig 10) to facilitate this process. However, these actions need to be expeditiously implemented as the current level of power-line mortality is too high for this small population to sustain, and the increasing trend of power-lines in great Indian bustard occupied cells is particularly concerning in this context.

Effective conservation in Thar would require a multi-pronged approach that includes the Forest Department, Indian Army, local communities and research/conservation agencies. Apart from protecting key breeding areas as enclosures, conservation funds should be utilized on activities to maintain anthropogenic pressures below species' tolerance threshold by involving communities in participatory-planning that balances conservation and livelihood concerns. This includes activities such as regulated ecotourism that can improve the local economy, mitigation of infrastructural development, and bustard-friendly agro- pastoral practices (Dutta et al. 2013).

Since great Indian bustard usage is spread across large expanse of Thar, comprehensive insights into their ranging patterns are required for fine-tuning these conservation actions. Currently, two distinct population clusters are noticeable – one in western Thar extending from Chowani in south to Habur in north, and another in eastern Thar, in/around Pokhran Field Firing Range. Secondary occurrence reports of great Indian bustard from Bada-Nehdai-Dewa-Mandhau-Ainta villages in northern Thar indicate possible connectivity between these western and eastern populations. However, the actual corridors can only be determined through biotelemetry studies, and although capturing of a few birds involve an element of risk, this risk is unavoidable to conserve the species as a whole.

Key recommendations

The great Indian bustard population and habitats are declining drastically across its distribution range. Thar landscape is the only remaining habitat supporting a viable (and the largest) breeding population but is also experiencing a rapid increase in anthropogenic disturbances in terms of human presence in remote interiors, power-lines, wind turbines, and water provisioning – all of which are detrimental to the persistence of great Indian bustard. To recover great Indian bustard population by restoring habitats in this landscape, we recommend:

a) Consolidating existing enclosures where bustard breeds using predator-proof chain-link fences (in Sam, Sudasari, Gajaimata, Rasla and Ramdeora) as the current fencing is inadequate to keep predators away in most cases.

b) Active management of free-ranging dogs, pigs and native nest predators (foxes, mongoose and monitor lizards) from breeding enclosures (~25 km^2 cumulative area) to improve nesting success and chick survival of great Indian bustard, by routine translocation of these predators outside the enclosures, and the use of nest repellents (Pavlovian experiments) using dummy eggs. This management is unlikely to affect the population of these predators as the area of intervention is miniscule in comparison to their ubiquitous distribution.

c) Mitigating ill-effects of wind-turbines and overhead power-lines in priority conservation cells, particularly the great Indian bustard ranging arc between Sudasari-Sam-Salkha-Mokla-Mohangarh-Bhadariya- Ajasar-Ramdeora (figure x) to reduce obstruction to local bird movements. New power-lines should be made underground and existing ones should be marked with Bird Flappers/Diverters to make them visible and minimize collision risk (Silva et al. 2014). WII has already supplied pilot diverters, which have been installed in select lines by power agencies (Suzlon and RVPNL). Similar products need to be imported or locally made and deployed on priority power-lines across the eco-sensitive zone (fig 10) in an expeditious manner by power/energy agencies.

d) Transferring lands in priority conservation cells (e.g, habitats near Kanoi-Salkha-Habur, Nathoosar, Chanani, Ugras, Galar, Chhayan, Ajasar-Keroo, Bhadariya, Mohangarh and Dhaleri) to Forest Department for creating new protective enclosures, and where this strategy is unfeasible or undesirable, conservation areas can be jointly managed by local communities and Forest Department.

e) Adaptive management of breeding enclosures to accommodate the critical foraging needs of bustard during the nesting phase, apart from protection to nests/chicks. To achieve this objective, dietary supplementation by cultivating ~10% of enclosure area in patches of ~1 ha with local food crops can be planned. Enclosures can be seasonally opened to livestock grazing (October through March), not exceeding ecological carrying capacity of 10 Animal Units / km^2 (1 Animal Unit is equivalent to one adult female cow and 4 sheep and goat), so that the benevolent effects of livestock grazing on vegetation structure and the availability of dung beetles (an important food for bustard) are maintained. This management is ideal for older enclosures such as Sudasari and not in more recent enclosures which are recovering from the impacts of excessive grazing.

f) Smart and intensive patrolling to generate management information and control poaching. This entails recruiting more staff, building their capacity through tools and training, and providing performance based incentives.

g) Targeted research on great Indian bustard to characterize threats spatio-temporally, understand landscape use patterns using biotelemetry, and objective monitoring of their population status by involving research organizations.

h) Involving local people in conservation by addressing their livelihood concerns (e.g., regulated ecotourism), and encouraging them to monitor bustard occurrence and report illicit activities using rewards and incentives. A coordinated outreach program must be implemented that understands the needs and concerns of local people in the great Indian bustard conservation area (fig 10), sensitize them on desert/grassland conservation in general and the need of conserving great Indian bustard in particular, and provide alternate livelihood solutions that are socio-ecologically compatible. Baseline information on community composition, livelihoods and village livestock holdings, generated from our questionnaires (Dutta et al. 2016) can aide in designing such outreach programs.

i) Conducting regular outreach programs with other stakeholders such as Indian Army personnel and energy sector to sensitize them on the need and required actions for bustard conservation.

Conclusion:

The key to conserve this vital landscape is to implement a combination of stringent protection measures to control poaching, expeditious mitigation of infrastructure such as power-lines, and disallowing detrimental infrastructure in the larger great Indian bustard conservation area, but provisioning of basic amenities and livelihood options to local people (e.g., regulated ecotourism), and scientific habitat management of breeding enclosures. These recommended actions needs to be collaboratively implemented by Rajasthan Forest Department, Wildlife Institute of India and partner conservation agencies.

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Appendix 1: Datasheet for Great Indian Bustard and associated species' sightings

Date:_____Cell-ID:_____Team:_____(Obs.) Trail-length:____(km)

GPS at every 2-km		Sighting information				Associated habitat characteristics (Great Indian Bustard)			
SN	**Latitude, Longitude**	**Species**	**Number**	**Perp. Dist.**	**Projected Lat, Long**	**Terrain (100m)**	**Substrate (100m)**	**Landcover (100m)**	**Vegetation (3 dominant sp)**
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	
						F / S / U (M / V)	R / G / S / s	B / A / G / W / S	

Notes:

Species to record: Great Indian Bustard, Chinkara, Blackbuck, Nilgai, Wildpig, Fox, Dog, Sheep & Goat, Cattle

Perpendicular distance classes: 0-10, 10-25, 25-50, 50-100, 100-150, 150-200, 200-300, 300-400, 400-600 & 600-1000 meters

Appendix 2: Datasheet for habitat characterization at every 2-km along transect route

Date:_____Cell-ID:_____Team:_____(Obs.)

SN	Latitude dd—mm—ss	Longitude dd—mm—ss	Time (hrs)	Terrain (100 m radius)	Substrate (100 m radius)	Land-cover (100 m radius)	Vegetation composition (% area in 20m radius)					3 dominant plants (100m radius)	*Sandha* Pr (10m radius)	Human structure (100m radius)
							Short grass/ herb(<30 cm)	Tall grass (>30cm)	Shrub (<2 m)	Tree (>2 m)	Crop (name)			
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P
				F / S / U (M / V)	R / G / S / s	B / A / G / W / S							1 / 0	S / H / R / E / W / P

Notes:

Abbreviations: **Terrain** – **F** (flat**)** / **S** (sloping) / **U** (undulating) with qualifier **M** (moderately) / **V** (very)
Substrate – **R** (rock) / **G** (gravel) / **S** (sand) / **s** (soil)
Land-cover – **B** (barren) / **A** (agriculture) / **G** (grassland) / **W** (woodland) / **S** (scrubland)
Human structure – **S** (settlement) / **H** (farm hut) / **R** (metal road) / **E** (electricity lines) / **W** (wind turbine) / **P** (water-source)

Vegetation composition classes: 0-10, 10-20, 20-40, 40-60, 60-80, 80-100 %.

Appendix 3: Datasheet for secondary information on Great Indian Bustard occurrence

Date:_____Cell-ID:_____Team:_____(Obs.)

Village	Respondent Name	Latitude, Longitude	Q1. How many GIB have you seen in last 3	Q2. When & where was the last that you have	Q3. Is there a threat to GIB from a) hunters, b) development and c) agriculture here?	What other species occur here?
1)	1)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	2)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	3)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
2)	1)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	2)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	3)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
3)	1)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	2)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha
	3)				a) b) c)	Chinkara / Blackbuck / Nilgai / Wild pig / Fox / Sandha

Status of the

LESSER FLORICAN

Sypheotides indicus and implications for its conservation



Survey report 2017-2018

Wildlife Institute Of India

ABBREVIATIONS

BNHS	Bombay Natural History Society;
BBNP	Blackbuck National Park;
FD	Forest Department;
GIB	Great Indian Bustard;
LF	Lesser Florican;
MDS University	Maharshi Dayanand Saraswati University, Ajmer;
MoEFCC	Ministry of Environment, Forest and Climate Change;
NP	National Park;
PA	Protected Area;
RF	Reserve Forest;
TCF	The Corbett Foundation;
WII	Wildlife Institute of India, Dehradun;
WLS	Wildlife Sanctuary

PLACES MENTIONED IN REPORT

Kutch and Kachchh & Jalore and Jalor are same places.

*Maps used in this brochure are for general illustration only, and are not intended to be used for reference purposes. The representational political boundaries does not necessarily reflect the position of the government of India on international issues of recognition, sovereignty and jurisdiction.

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

BNHS INDIA CONSERVING NATURE SINCE 1883

The Corbett Foundation

सत्यमेव जयते
Rajasthan Forest Department

FOREST DEPARTMENT GOVT. OF GUJARAT

Ministry of Environment, Forest and Climate Change
Government of India

STATUS OF THE LESSER FLORICAN

SYPHEOTIDES INDICUS AND IMPLICATIONS FOR ITS CONSERVATION

SURVEY REPORT 2017 - 2018

Implementing agencies

Wildlife Institute of India (Endangered Species Recovery Program), Dehradun
Bombay Natural History Society, Mumbai
The Corbett Foundation, Kutch

Partner agencies

Rajasthan State Forest Department
Gujarat State Forest Department
Madhya Pradesh State Forest Department
Maharashtra State Forest Department

Supporting institutions

Maharaja Krishnkumarsinhji Bhavnagar University, Gujarat
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SUMMARY

1. Lesser Florican *(Sypheotides indicus)* is an endangered agro-grassland bird whose ecology and status are poorly known that impedes conservation efforts. To fill this gap, a national status survey was designed by the Endangered Species Recovery Program of Wildlife Institute of India and was jointly implemented with Bombay Natural History Society, The Corbett Foundation and State Forest Departments across the species' breeding range. This report documents the methodology of this exercise, and presents its findings on lesser florican's distribution, abundance, habitat relationships, threats and their implications for conservation.

2. We delineated lesser florican' breeding range using informed digitization with the aid of MaxEnt distribution model, and inputs from local experts. We assessed the species' status based on displaying males, using spatially representative sampling and analytical design that accounted for imperfect detection. Our assessment used hurdle modeling approach, where we: a) first estimated the species' occupancy in 36 sq km cells using vehicle observation points (stop-overs), and b) estimated the species' abundance at detected sites (subset of occupied sites) using line transect distance sampling. We c) quantified habitat characteristics (land cover, vegetation structure and anthropogenic pressures) systematically along occupancy and distance surveys, d) explored and developed statistical relationships between habitat covariates and occupancy/abundance. & e) mapped the species' distribution, local densities and threats, to generate conservation priority map. We drew inferences at the scale of breeding range and eco-geographically defined regions and landscapes (Ajmer: Shokaliya-Kekri; Rest of Rajasthan : Shahpura, Jalore, Pratapgarh; Gujarat: Kutch, Saurashtra; Madhya Pradesh: Ratlam; Maharashtra: Akola-Washim).



3. The status survey was conducted during the breeding season (July–September, 2017) with a team of 121 observers, who were trained on the standard data collection protocol through state-level workshops at Bhavnagar, Ujjain, Ajmer and Akola. Lesser florican occupancy was assessed at 428 sites (36 sq km) spread across ~20,000 sq km range, using 5564 stop-overs, and density was assessed in 32 sites (where the species was detected) using 479 km transect-walks that yielded 70 sightings (64 males, 6 females).



4. Lesser florican occupied 13 (3SE) % sites or 1908 sq km area, at ecological density of 0.25 (0.06SE) territorial males per sq km. The population size was estimated to be **340 (162–597 95%CI) territorial males**, with a conservative estimate of **264 individuals** that indicates ~80% population decline in last 3–4 generations (since 2000). Regional assessments indicated that the population was largely restricted to: Velavadar (Bhavnagar, Gujarat) having 96–115 territorial males and Shokaliya-Bhinai (Ajmer, Rajasthan) having 110–136 territorial males. The species' response to habitat exhibited regional plasticity, with occupancy favoured by grassland cover in Gujarat, and by agricultural cover in Ajmer. However, density in occupied site was an increasing function of grassland cover, indicating that males congregated in large contiguous grasslands. Birds were dispersed over a large agricultural expanse at low density in Ajmer (~800 sq km) and clustered at high density in a small grassland reserve in Bhavnagar (~100 sq km). This inverse density-occupancy relationship perhaps resulted from a flexible social/spatial organization, implying that, a contiguous grassland would achieve the same conservation outcome as a much larger agricultural area would. Finally, we prioritized sites and quantified threat levels across landscapes and regions, to guide conservation investments.

5. Our methodology for estimating lesser florican numbers assumes that expected abundance at occupied sites where species was not detected (but present) was similar to that where species was detected. If this assumption is violated, which is likely when the species is missed in sites with fewer than average individuals, then the estimated global population size will be positively biased. To avoid this issue, we emphasize on the 'minimum population size' of 264 individuals as a conservative estimate of the population.



6. We also developed conservation recommendations for each landscape to guide species' recovery actions, based on prior knowledge (Dutta *et al*. 2013) and our collective observations. Highlighting that lesser florican population might have dwindled by ~80% over last 3–4 generations, we call for immediate scaling up of efforts for the species' conservation. The priority sites for conservation actions are Shokaliya and Saurashtra landscapes followed by Kutch and Kekri landscapes, followed by Ratlam, Shahpura and Akola landscapes. Our key recommendations for priority sites are to: a) provide protection sites by creating conservation areas and implementing strict patrolling by Forest Department and local communities; b) regulating intensive landuses such as infrastructural, industrial and salt pan developments, and mitigate existing infrastructure such as power-lines; c) implementing scientific grasslands management by consolidating relatively large contiguous grasslands, restricting livestock grazing for monsoon months (June–September), restoring habitats by removing exotic shrub/tree plantations; d) incentivizing florican-friendly agricultural practices by promoting scattered organic farming and stall-feeding of livestock in monsoon months against compensations; e) consolidating networks of local people or 'florican friends' who can report and prevent detrimental activities; f) reducing nest/chick predation by free-ranging dogs by undertaking a holistic dog population control program in neighbouring villages; g) generating scientific information on lesser florican ecology particularly during the non-breeding season to aid conservation management using satellite telemetry and associated surveys; and h) advocacy and outreach programs to generate support among multiple stakeholders for lesser florican conservation. i) Finally, given the potential decline of the species, gaps in our knowledge regarding their key threats, and inherent difficulties in implementing urgent conservation actions in their vast unprotected habitats, a conservation breeding program should be implemented urgently to secure a captive population for insurance and possible reintroduction in future. Given the current numbers, there is still a window of opportunity for recovery of the lesser florican.

7. This status assessment protocol and its inferences, including the spatial prioritization needs to be refined over next two years, and should thereafter be implemented periodically to monitor the pulse of the endangered lesser florican and its dwindling habitats. In the imminent future, we plan to refine our status assessment protocol and conduct consultative meetings at regional levels to prepare site-wise conservation plans.

List I: Participants of the lesser florican status survey 2017

SN	Wildlife Institute of India	Bombay Natural History Society	The Corbett Foundation
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29	Jat Sadiq Kasam		

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	Mr. S. J. Vanda (Round Forester, Kundhda)		
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7	Mr. Uday Vora (Retd. Chief Conservator of Forest)	Gujarat Forest Department	
8	Mr. Viral Joshi	Individual, Amreli	
9	Mr. Nirav Bhatt	Individual, Surendra Nagar	
10	Mr. Yogendra Shah	Individual, Surendra Nagar	
11	Mr. Shatrughna Jebaliya	Individual, Surendranagar	
12	Mr. Ajay Desai	Prakrti Mitra Mandal, Dadhod	
13	Mr. Ashok Mashru	Individual, Rajkot	
14	Mr. Mukesh Bhatt	Individual	
15	Mr. Ajay Gadikar	Individual	Madhya Pradesh
16	Mr. Govind Pande	Forest Department, Akola	Maharashtra
17	Mr. Kaustubh Pandharipande (President)	SAMVEDANA	

List IV: Officers who helped in lesser florican status survey 2017 logistics

SN	Rajasthan	Gujarat	MP	Maharashtra
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7		Shri P. A. Vihol (DCF, Kutch East)		
8		Shri B. Suchindra (DCF, Kutch West)		
9		Shri Mohan Ram (DCF, Bhavnagar)		
10		Shri T. Karuppasamy (DCF, Dhari)		
11		Smt. Sakkira Begum (DCF, Amreli)		
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13		Shri R. M. Parmar (ACF, Bariaya)		
14		Shri Mahesh Trivedi, (ACF, Velvadar NP)		



THE SPECTACULAR AERIAL DISPLAY BY A MALE FLORICAN TO ATTRACT FEMALES .

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INTRODUCTION



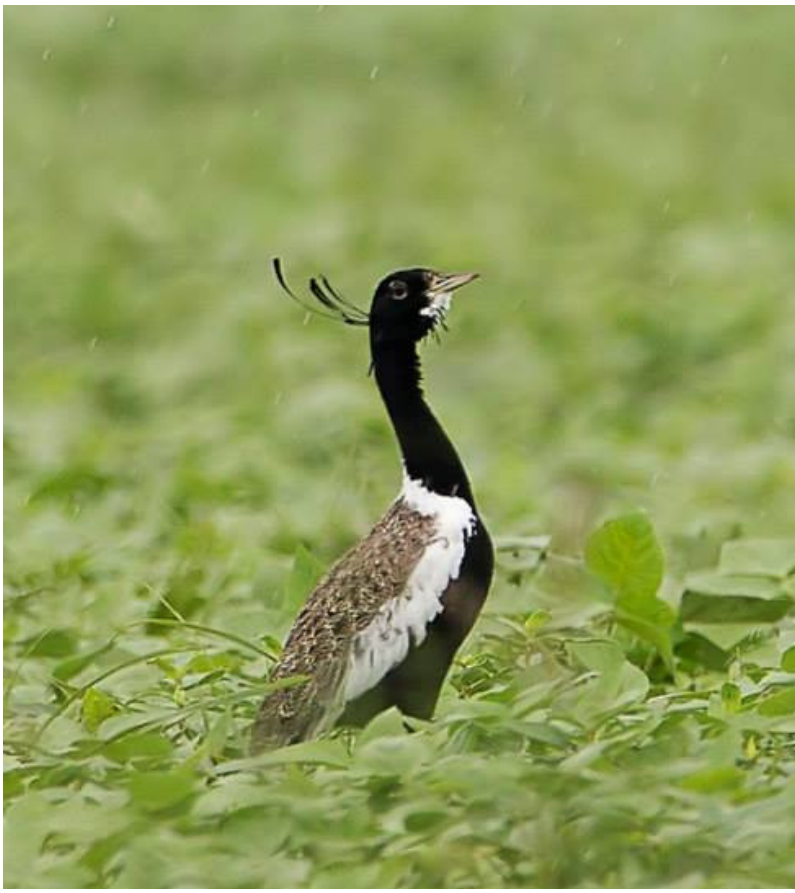


1.2 Need for status survey

Endangered species conservation entails regular and objective assessment of their distribution, abundance, current threats to identify priority habitats, develop conservation strategies, and routinely assess management effectiveness. However, The last population assessment of the lesser florican was conducted in 2006 by late Ravi Sankaran, following which a distribution survey was carried out by the Wildlife Institute of India in 2010 (Bhardwaj *et al.* 2011). Since then, there is paucity of information on the species' status and conservation contexts that impedes current recovery efforts. Additionally, the species' biology and ecology are poorly understood, especially in the non-breeding season due to their elusive nature. To fill these information gaps, a status assessment exercise across the breeding range following a standardized protocol is needed that can be replicated across years.

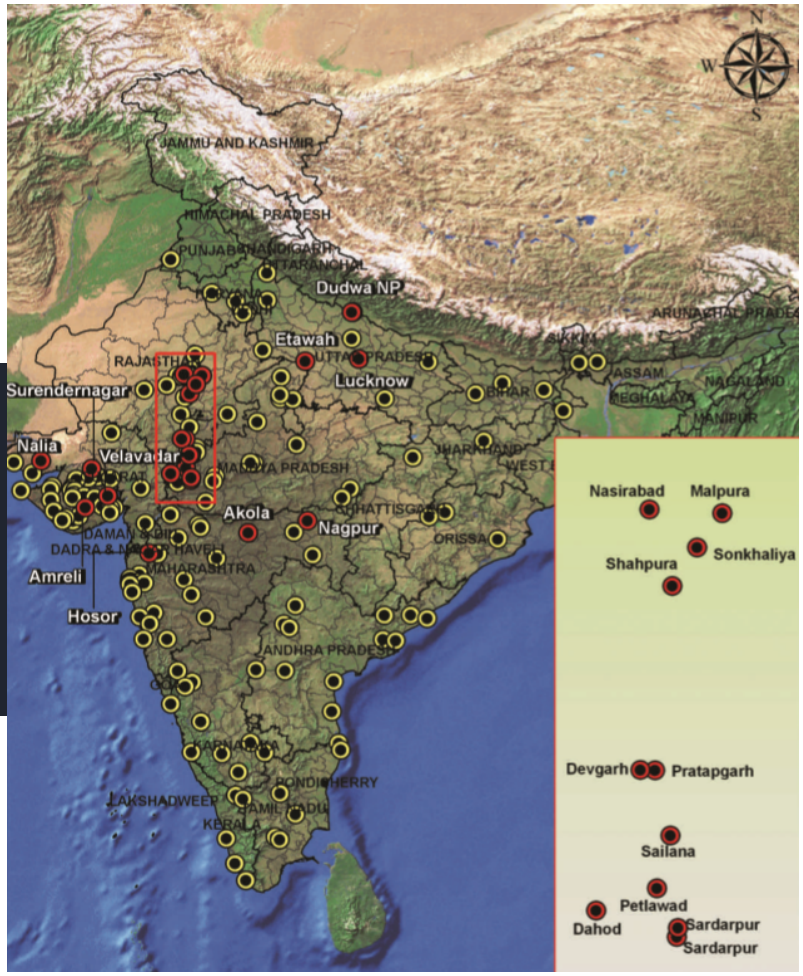
1.1 About lesser florican (*Sypheotides indicus*)

Lesser florican (*Sypheotides indicus*) is the smallest bird of the bustard family (*Otididae*). It is endemic to this country and is one of the four bustard species of India, all of which are threatened (IUCN), Though lesser florican has been given the highest degree of protection under Schedule-I of the Wildlife (Protection) Act 1972, its numbers have declined, necessitating its declaration as an Endangered species in the IUCN Red list. Subsequently, it has been included as a priority species in the Species Recovery plan by the Ministry of Environment, Forest and Climate Change, Government of India (Dutta *et al*. 2013).



1.3 Distribution of lesser florican in India

Lesser florican is virtually endemic to India (Ali 1981, BirdLife International 2001) and is distributed in the lowland open plains (Goriup and Vardhan 1982). Historically, it occurred from Gujarat and Rajasthan in west to West Bengal and Orissa in east, and from Saharanpur as well as Mainpuri districts (Gopi Sundar 2006) of Uttar Pradesh in north to Thiruvananthapuram (Kerala) in south (Ganguli Lachungpa and Rahmani 1990; Baker 1922-1930; BirdLife International 2001; Sankaran 1993). It also occurred in Terai region of Nepal, Pakistan and vagrantly in Bangladesh and Myanmar. The main breeding areas were probably in the districts of Nashik, Ahmednagar and Solapur of Maharashtra, eastern Haryana and the Kathiawar Peninsula of Gujarat (Anon. 1908, Goriup and Karpowicz 1985).



Past (Yellow) and Present (Red) distribution of lesser florican in India
Source: Threatened Birds of India (Year 2012)

The current breeding distribution is restricted to:
1) Rajasthan, in the districts of Ajmer (Shokaliya Community Reserve), Bhilwara, Tonk, Pali and Pratapgarh (Bharadwaj *et al*. 2011);
2) Gujarat, in the districts of Dahod, Bhavnagar (Blackbuck NP, Velavadar) (Gadhvi and Shah 2008), Amreli, Surendranagar and Kutch (Lala-Naliya WLS) (Fulljames 1837; Bharadwaj *et al*. 2011);
3) Madhya Pradesh, in the districts of Ratlam (Sailana WLS) (Ganguli-Lachungpa 1985), Dhar (Sardarpur WLS), Jhabua and Sheopur (Kuno WLS);
4) Maharashtra, in the districts of Yavatmal, Akola (Kasambe and Gahale 2010), Washim (Pandhripande pers. comm.), Chandrapur (Narwade *et al*. 2015) and Nashik (Raha and Prakash 2001); and
5) Andhra Pradesh, in the district of Kurnool (Rollapadu WLS) (Ganguli-Lachungpa and Lachungpa 1986).
Post-breeding, birds migrate to peninsular- (Dharmakumarsinhji 1950) and north- India (Sankaran pers. comm.). Note that, the sites mentioned in parantheses are Protected Areas in each landscape, where lesser florican occurs.

1.4 GENERAL ECOLOGY

HABITAT USE

Lesser florican breeds in rain-fed grasslands (>2 ha in area) with ample ground cover (>55% grass and herb cover), moderately tall grasses (~50 cm) like *Sehima*, *Chrysopogon*, *Dicanthium* and *Cymbopogon* spp., and scattered shrubs (<50/ha density) like *Zizyphus* and *Acacia* spp. (BirdLife International 2009; Sankaran 2000). Use of croplands for breeding is not common, but has been recorded in soybean (*Glycine max*), groundnut (*Arachis hypogea*), and less frequently in sorghum (*Sorghum vulgare*), maize (*Zea mays*), sugarcane (*Saccharum*), rice (Oryza sativa), mustard (*Brassica campestris*), and wheat (*Triticum vulgare*) crops (Sankaran 2000), as well as grasslands within forest plantations. Hilly terrain, wetland, dense forest, and deserts are avoided. Moderately high grassland biomass, an indicator of low grazing pressure, and remoteness from human settlements (>2.6 km away) are additional important predictors of their occurrence (Dutta and Jhala 2014; Sankaran 1997b). Dutta and Jhala (unpublished data) found that breeding male territories have more heterogeneous ground vegetation structure than the general habitat, possibly to accommodate diverse life-history needs (food, concealment and advertisement). Sankaran (1997a) reported that in intensively grazed grasslands, species tends to be found more frequently in croplands, and in years of good rainfall when grasslands are covered with tall (>1.5m) grass, males shift to shorter vegetation, such as soybean fields. During nonbreeding season, the species sometimes uses lightly wooded areas, grasslands and Zizyphus dominated scrubland (Sankaran 2000).



BEHAVIOUR

Individuals are relatively solitary and extremely elusive, except during the breeding season. Birds conceal themselves in ground vegetation by lying low, and are flushed when the source of disturbance is within few meters. Their flight is similar to other bustards, characterized by rhythmic strokes of broad wings, neck outstretched and legs tucked under body, although their wing-beats are faster than other bustards.

FOOD

The species is omnivorous, feeding on insects such as grasshoppers, beetles (families *Cantharidae, Chrysomelidae, Buprestidae* and *Scarabidae*), ants and caterpillars, amphibians, and plant parts like seeds, herbs, fruits and plant shoots (Ali *et al.* 1986; Baker 1922–1930; BirdLife International 2001; Sankaran and Rahmani 1986b). Birds forage in relatively open areas in early morning and evening, and retire into thicker cover during mid-day. They commonly feed in short grasses and low crops; typically by walking 5–10 m before pausing and scanning for prey as well as threats, thereafter either dashing at or snapping up or creep-stalking prey items in the manner of an egret (Ali *et al*. 1986). On reaching their breeding grounds in lean condition, birds feed throughout the day; however, with the advancement of season, males are observed to feed and display alternatively. Availability of insects is considered as an important factor in the reproductive success of female lesser floricans.

BREEDING

Breeding behaviour of lesser florican has been extensively studied in the past (Dharmakumarsinhji 1950; Dharmakumarsinhji 1953; Goriup and Karpowicz 1985; Sankaran 1997c; Sankaran and Manakadan 1990; Sankaran and Rahmani 1986a). The species exhibits an exploded lek mating system, where males establish territories of 2–3 ha, spaced at 200–500 m from each other (Sankaran 1994). Sankaran (1994) reported an average 4.7 territories per sq km, while a more recent study (Dutta and Jhala 2012) estimated an average 1.5 males per sq km in grasslands of Kutch. Breeding coincides with the timing and intensity of south-west monsoon, beginning from May through September. During this time, birds immigrate to breeding grounds, where males acquire breeding plumage and establish territories within first few weeks (Sankaran 1994). They perform an aerial display from specific spots within their territories (Sankaran and Rahmani 1986a), where they leap up to two meters in air, rapidly beating their wings and paddling their legs, thereafter falling swiftly back to the ground with their wings and legs tucked in. They also emit a frog-like rattle from the friction of their primaries that can be heard from 300–400 m distance. Males perform this display after every 50 seconds on an average (Ridley *et al.* 1985, Dutta and Jhala unpublished data) and up to 500–600 times a day. Display rates are generally higher during the latter part of breeding season, early morning and cloudy/rainy weather. It serves the dual function of territorial and sexual advertisements. Females visit male arenas exclusively for mating, and nest outside or at the periphery of their territories (Sankaran 1994), raising the offsprings alone.



Image 1
Lesser florican displaying male (left) and elusive female (right)
© Mukesh Bhatt

Females prefer tall grass cover for nesting, and lay 4–5 eggs (49 x 41 mm size and olive-brown, mottled, streaked and blotched pattern) on bare ground (Gadhvi 2003; Sankaran 1994). She incubates these eggs for 21 days sitting cautiously still to avoid detection. They remain highly vulnerable to predators and poachers during this time. The newly hatched precocious chicks stay with their mother for roughly over 15–30 days. Females and chicks stay in breeding grounds for at least a month longer than males. Breeding in cultivation is not frequent, but does occur in short crops like soybean and groundnut, and less frequently in the taller ones like cotton, sorghum, maize and sugarcane (Sankaran 2000). Grasslands in southern India are possibly used for breeding only when conditions are unfavorable in the usual breeding range (Sankaran and Manakadan 1990). At the end of the breeding season around October/November, birds have been reported to return to the southeastern and northern regions (Dharmakumarsinhji 1950, Sankaran 1997b).

RANGING PATTERNS

The species is a local migrant in India, and their ranging patterns are poorly known. Life-history information is scanty, but recovery of one winged bird showed that their life span could exceed four years (Dharmakumarsinhji 1943). Their local movements are considered partial and opportunistic, with birds tending to concentrate in regions that have received good rainfall in the current year, and sporadically elsewhere. Dutta and Jhala (2012) reported much lower breeding bird density in drought year (~0.6 males/sq km) than years with average rainfall (~1.5 males/ sq km) in grasslands of Kutch. However, it is yet to be concluded whether this pattern is due to lower display rate (primary detection cue) or abandonment of the area in droughts. Dharmakumarsinhji (1950) observed males returning to the same breeding sites every year for >20–30 years, and speculated that breeding site fidelity is strong. However, ringing records (involving 18 of 489 birds) revealed moderate levels of site fidelity, as only 10 of these birds were recaptured in the ringing site while the remaining were found >50 km away (Dharmakumarsinhji 1950).

1.5 Threats and conservation issues

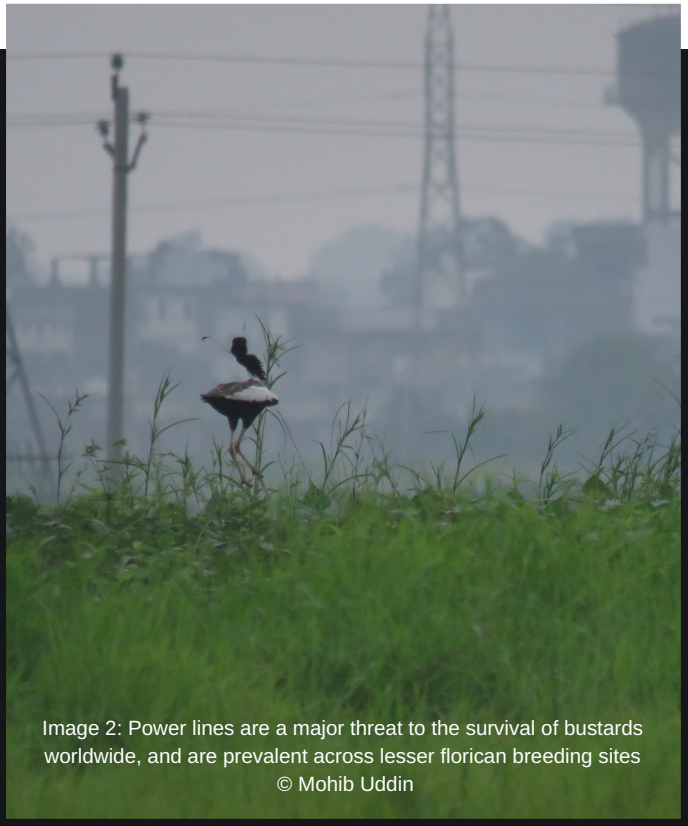


Image 2: Power lines are a major threat to the survival of bustards worldwide, and are prevalent across lesser florican breeding sites © Mohib Uddin

Major threats to the species include habitat loss and mismanagement due to the lack of a holistic grassland conservation policy and scientific management . Paucity of ecological information, particularly for non-breeding habitats, also impedes their conservation. A detailed list of threats and conservation issues is as follows:

1. Poaching, trapping, and egg collection.
2. Pesticide usage in breeding grounds that can potentially deplete insect biomass and increase environmental toxicity.
3. Land use changes involving agricultural intensification, changes in cropping patterns, diversion of grasslands for infrastructure (wind-turbines and power-lines), industries/housing, and salt pans particularly in Bhal region of Gujarat.
4. Mismanagement of agro-grasslands through untimely grass harvest, excessive livestock grazing, plantation of harvest of shrub/tree species.
5. Mining projects in prime breeding areas, especially the open caste mines.
6. Free ranging dogs in prime breeding habitats, and possibly nest or chick predation caused by them.
7. Renewable energy projects such as installation of wind turbines in open habitats and expansion of power-lines have resulted in loss of habitat and (possibly) bird mortality due to collision or electrocution.
8. Excessive livestock grazing in breeding grounds during monsoon is a major threat as the species avoids grazed areas because of disturbances and the depletion of cover.
9. Poorly planned plantations of shrub/tree species such as *Prosopis juliflora* by the Forest Departments has made several historically used sites suboptimal for the species.
10. Erratic and changing precipitation patterns induced by climate change in the lesser florican range can potentially affect breeding success and population recovery.
11. Prevalent disturbance from unethical photography results in stress to the breeding birds.
12. Lack of awareness regarding importance of grasslands and lesser florican among locals in the species range.
13. Finally, paucity of ecological and conservation information, including inadequate knowledge of current distribution, abundance, demography, ranging patterns and non-breeding habitat use impedes effective conservation strategies.



METHODS

2.1 BACKGROUND

Lesser florican population have been assessed in the past by late Ravi Sankaran (Sankaran, 1990; Sankaran et al., 1992; Sankaran, 1996b; Sankaran, 2000). This approach entailed visits to a sample of agro-grassland sites during the breeding season (July – September), counting all male floricans displaying in the site by intensive/combing foot search, doubling this count assuming equal sex ratio, and extrapolating the estimate to include unsampled sites. This protocol was used to monitor lesser florican population status for five cycles between 1982 and 2006 (Collar, 1982; Sankaran, 1990; Sankaran *et al*., 1992; Sankaran, 1996; Sankaran, 2000). Since then, there has been discontinuity in monitoring lesser florican population, and the habitat/conservation contexts have also changed drastically across the species' breeding range.

A few concerns regarding this traditional approach of counting lesser florican are that, the protocol is not exactly replicable and is not robust to non-detection of birds in surveys. The problem of non-replicability is related to sampling objectivity: unless sampling efforts are standardized across space and time, or detections are corrected for variable efforts, abundance estimates cannot be compared meaningfully. Since sampling efforts per site (number and experience of observers, intensity of search, spatial representation etc.) are not explicit in the earlier survey reports, it is difficult to replicate this method and yield meaningfully comparable results. The problem of non-detection can negatively bias abundance estimates, and make comparisons across space and time difficult if detectability varies simultaneously. The count statistic in lesser florican surveys is based on displaying males, and factors affecting the detection of display, such as display rate (which is a function of environmental conditions – local rainfall/resources, weather and time of day), habitat characteristics, and observer experience can strongly vary across space and time. Hence, there is a need to correct for missing individuals in the survey. In our current study, we attempted to develop a monitoring protocol that, notwithstanding the need of further refinements, addresses these issues.

2.2 DELINEATION OF SAMPLING FRAME

To assess the range-wide status of lesser florican, we first defined our area of interest or the sampling frame. This is particularly difficult for bustards, especially lesser florican, because of their behavioural plasticity and use of contrasting habitats in different landscapes. We delineated the sampling frame by expert/knowledge based digitization of potential lesser florican breeding sites from very high-resolution satellite imagery. Researchers at the Wildlife Institute of India with multiple years' experience of working in varied lesser florican landscapes manually digitized agro-grass-scrub habitats that can be potentially occupied by the species in Google Earth, based on prior knowledge of breeding sites, habitat use (Sankaran, 2000; Bhardwaj *et al.* 2011), and ground conditions (fig 1).

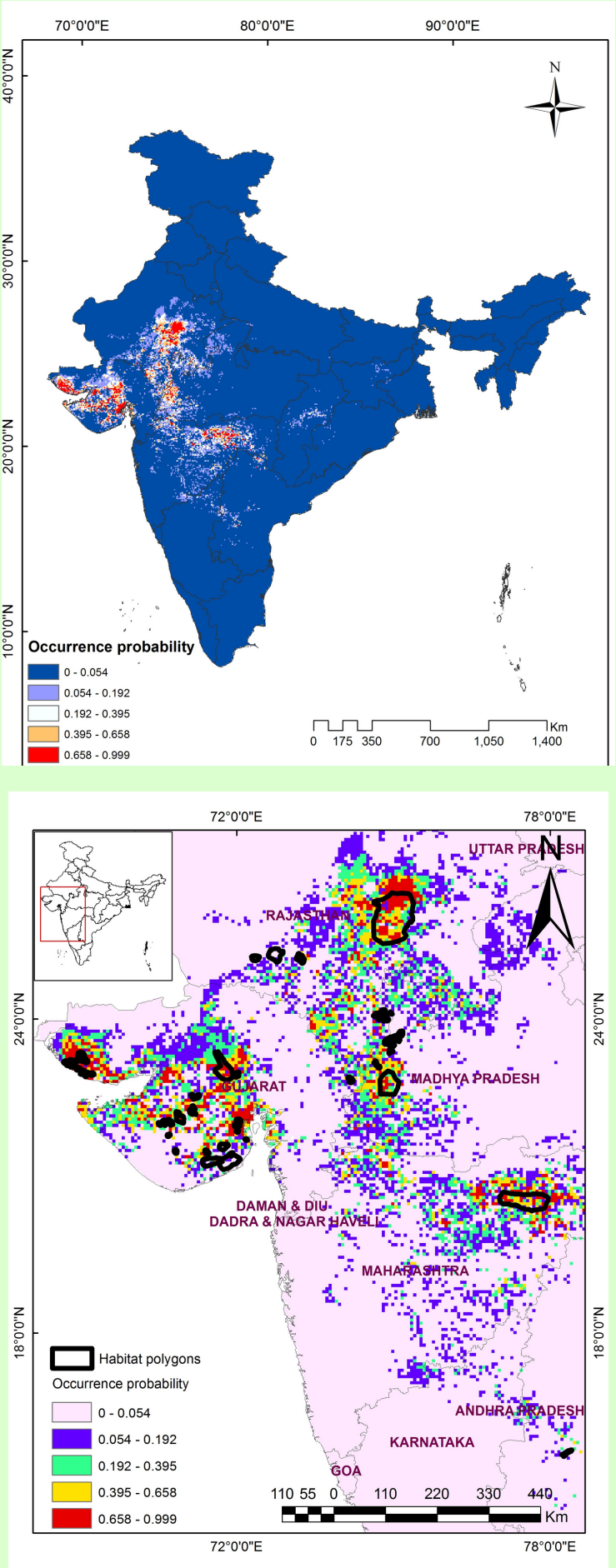


Figure 1:
Habitat suitability map showing occurrence probability of lesser florican across its breeding range based on MaxEnt modeling (top) along with digitzed habitat polygons (bottom)

To verify if our digitization has covered the potential distribution range of lesser florican, we developed a MaxEnt habitat suitability model (Ferrier *et al*., 2006) based on recent occurrences (post 1980s) and environmental variables such as, a) monthly maximum normalized difference vegetation index (NDVI) of 10 day composite from January through December 2013 (source: SPOT Vegetation NDVI accessed from spotImage/http://probav.vgt.vito.be/en/product-tools) at 1 sq km grain-size, b) elevation, c) slope, and d) compound topographic index (source: Hydro-1K dataset accessed from USGS 2001) and e) 19 bioclimatic variables (Hijmans *et al*., 2005, Stockwell and Nobel 1992, Stockwell and Peterson 2002). We used default settings for parameters such as prevalence, regularization multiplier, and density of background sampling, for creating multiple replicate models. We used MaxEnt based niche models since their outputs are known to be more accurate than comparable techniques (Ferrier *et al*., 2006); however, it can overpredict the distribution. The output is shown in figure 1. Areas that were predicted to be potentially suitable by MaxEnt were reviewed by researchers based on recent occurrence information and local habitat characters, and the digitization was refined when required. Finally, we circulated this map to local subject experts that included NGO partners, birdwatchers and State Forest Departments in each landscape (see contributors in list I–III), who refined the habitat polygons further. To be on the safer side, we added a buffer of 1 km to these habitat polygons.Thus, we delineated the potential breeding distribution map of lesser florican, hereafter referred to as the 'breeding range'. Given the historically widespread distribution of lesser florican and its occasional vagrant movements, some unknown and sporadic breeding sites may be left out from this mapping. However, we believe that the excluded area will not exceed 10% of the species' breeding range.

We classified the breeding range into following regions and landscapes based on ecogeographical criteria: Ajmer region (Shokaliya and Kekri landscapes), rest of Rajasthan (Shahpura, Jalore and Pratapgarh), Gujarat (Kutch and Saurashtra), Madhya Pradesh (Ratlam-Sardarpur), Maharashtra (Akola-Washim) (fig 2), and Kurnool (Rollapadu) .

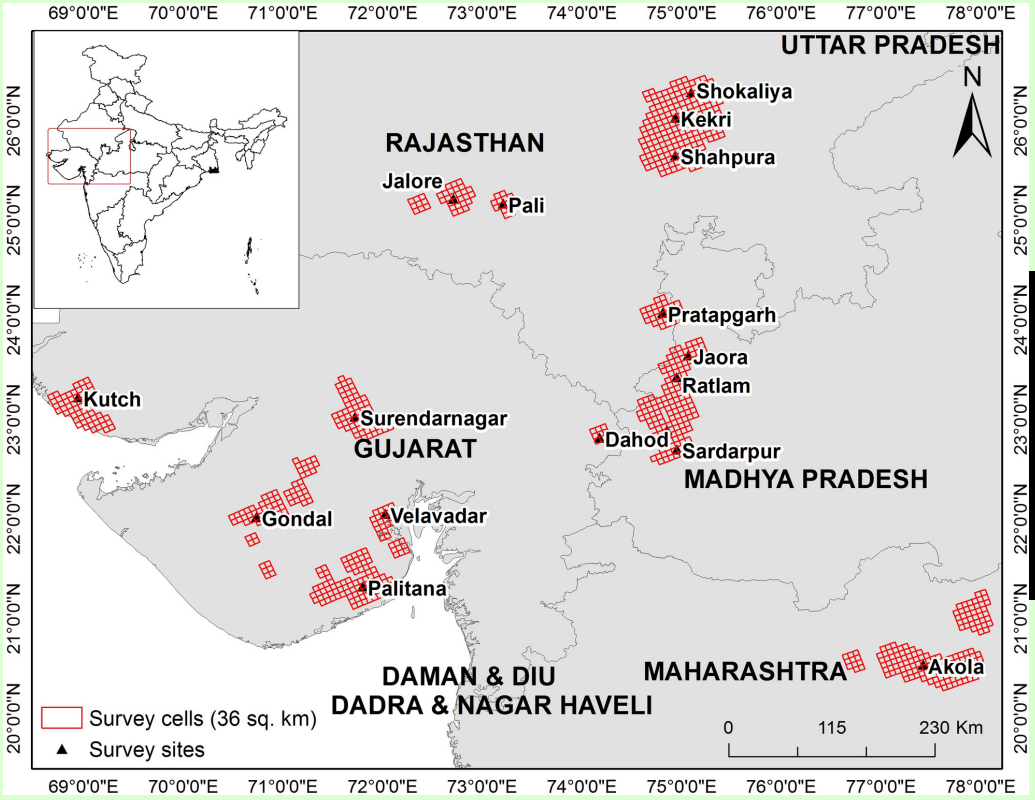


Figure 2: Lesser florican breeding range classified into survey regions, landscapes and sites

2.3 SAMPLING APPROACH

Our sampling approach was analogous to hurdle modelling (Hu *et al*. 2011), wherein we decomposed the lesser florican abundance into two components: proportion of sites occupied and abundance in occupied sites. We assessed these measures using two metrics: occupancy (probability of a sampled site being occupied) and density (mean abundance per sq km in occupied site). These metrics are independently useful in monitoring two important ecological aspects: breeding distribution and ecological density (clustering) of lesser florican. Additionally, population abundance can be inferred from the product of these two metrics, which we introduce below and critically discuss later.
Our sampling units, hereafter 'sites', were 6 x 6 sq km cells, overlaid on the breeding range. Sites with >33% habitat area were retained and ~75% sites were sampled, with equiproportional representation from all regions (fig 2). We preferred grid-cells to habitat-patches for sampling, because the transition between habitats and non-habitats is not clear-cut here (unlike forested systems) that complicates statistical extrapolation of population metrics. Conversely, fixed cells facilitate multiple-year comparisons of population status at sites. We selected this site dimension because it is sufficiently large to contain exploded lek(s) (Sankaran, 1997b; Dutta and Jhala, 2014). These studies have shown that lesser florican occurs in agro-grass patches generally >1 sq km in area and males occupy ~5 ha territories but can shift territories within breeding season in response to grazing and habitat changes.

We sampled sites in two phases: Occupancy surveys (Mackenzie *et al*., 2002) in the first phase and Line Transect surveys (Ralph *et al*., 1993) in the second phase.

2.3.1 OCCUPANCY SURVEYS

We assessed site occupancy using spatially replicated surveys following Mackenzie et al. (2002). We sampled 75% of sites in each landscape. We sampled a site along a route, digitzed prior to the survey in Google Earth, passing through optimal lesser florican habitats that covered at least three 4-sq km cells (hereafter 'sub-units') nested in the site (30% coverage). A team of two trained observers surveyed these routes on two or four wheel vehicles, recording lesser florican detections in one or two ~10 min observation points per sub-unit that were at least 1 km apart, to ensure adequate dispersion of surveys (fig 3). To maximize detections, we laid observation points in relatively optimal habitats (for e.g., dense scrubs with low use- or detection-probability were avoided), and also recorded lesser florican(s) that were detected in the kilometre following a stopover, although such detections were negligible (<5% relative frequency). Surveys were conducted during 06:30–10:30 and 17:00–19:00 hours because males display most frequently in early morning and late evening hours, leaping in the air and producing a 'rattle' once per minute that is usually audible up to 500 m (Sankaran, 1996; Dutta and Jhala, 2012). Hence, if a lesser florican is present within 500 m of a observation points, we are likely to detect it within 10 minutes. Based on a pilot analysis of detection history from 20 sites in Shokaliya-Kekri landscape in program GENPRES, we sampled each site with at least five stopovers, to achieve the desired precision (<20% CV) in our global occupancy estimate. Since time of day, wind-speed and weather conditions could potentially influence the production and reception of the sexual signal, inducing heterogeneity in detection probability, we also recorded these covariates at each stopover. Since we were interested in identifying factors influencing the probability of occurrence, we recorded the land-cover, ground vegetation cover and height in 100 m radius, and anthropogenic disturbances in 200 m radius of observation points (Annexure 1).

2.3.2 LINE TRANSECT SURVEYS

If a site was occupied (at least one detection), we assessed lesser florican density in it, using intensive and spatially representative line transect distance sampling. Line transects of approximately 2-km length were placed along the diagonal of 4- sq km cells/sites (fig 3). Two trained observers walked each transect once during 06:30–10:30 and 17:00–19:00 hours, the peak activity period, to count displaying lesser floricans. Observers used binoculars to detect birds and recorded the sighting distance and angle of each detection, using laser range finder and compass, respectively. Since we were also interested in abundance-habitat relationships, we quantified habitat variables that could potentially influence lesser florican numbers, at every 250 m along the transect. We recorded terrain and land-cover in 100-m radius, vegetation structure and composition in 50-m radius, and anthropogenic disturbances in 200-m radius plots. (Annexure 2) We preferred: a) line transect to point counts since the latter is more prone to biases due to animal movements and observer disturbance, and b) foot transect to vehicle transect since lesser florican's sexual signals can get masked by the noise of the vehicle, reducing detection.

We realized sites, sub-units, occupancy routes, and transects on ground using Google Map applications in smart phones or handheld GPS units (see Annexure 4). We recorded data in standardized data sheets (see annexures 1 and 2) and entered field data on daily basis in online spreadsheets that were subsequently collated, processed and analysed.

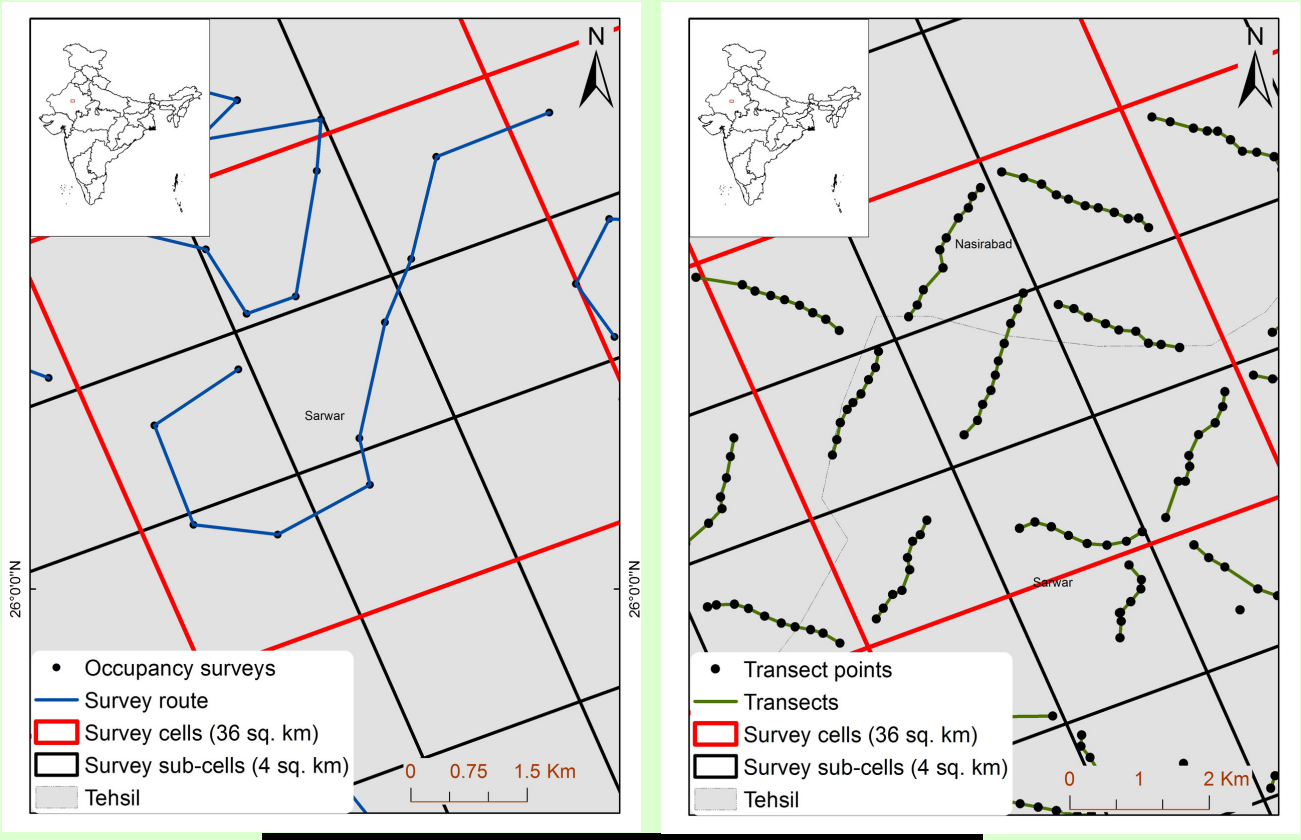


Figure 3
Graphical representation of point-count based occupancy and line transect based distance sampling for status assessment of lesser florican across the breeding range in 2017

2.4 INSTITUTIONAL COLLABORATION

Lesser florican population assessment is feasible within a small window of 45–75 days as displaying males can be spotted only during July-September. Hence, large human and financial resources were needed to conduct the range-wide survey. To mobilize such resources, it was decided to conduct joint surveys through collaborative efforts of Wildlife Institute of India (WII), Bombay Natural History Society (BNHS) and The Corbett Foundation (TCF) along with range State Forest Departments and local NGOs/institutions. We identified agencies working in each landscape and having overlapping goals, and approached them for collaboration. State Forest Department also provided logistic support for the exercise. Such collaboration facilitated sharing of knowledge and coordination between potential partner agencies to prepare site-specific lesser florican conservation plans in line with the National Species Recovery Plan (Dutta et al. 2013). We hope that this collaborative exercise will also help leverage funding for the implementation of site level recovery projects.

COLLABORATION AND TRAINING

To train surveyors on the standardized population assessment approach and data collection protocol, we organized two-days training workshops, one at each survey State:

1. **Gujarat** – Department of Marine Science, Department of Zoology, Sir P.P. Institute of Science, M.K. Bhavnagar University and Blackbuck National Park, Velavadar in Bhavnagar on 16-17 July 2017

2. **Madhya Pradesh** – Office of the Chief Conservator of Forests, Ujjain and Sailana Wildlife Sanctuary in Ratlam on 24 July 2017

3. **Rajasthan** – Department of Environment, MDS University, Ajmer and Shokaliya Conservation Reserve, Nasirabad on 2-3 August 2017

4. **Maharashtra** –Vankuti, Office of Divisional Forest Officer, Akola

We also organized a post survey workshop at Wildlife Institute of India, Dehradun on 12-13 October 2017, where representatives of partner agencies and core survey teams participated to discuss and collate learnings from varied landscapes. This workshop resulted in refinement of breeding range maps, better understanding of logistic requirements, and development of conservation problems and solutions at the landscape-level.

2.5 DATA ANALYSIS

2.5.1 OCCUPANCY ESTIMATION

To assess occupancy, we analysed detection history (1/0) from spatial surveys (observation points) at 36 sq km cells, to estimate the proportion of sites occupied by lesser florican after correcting for imperfect detection. We first modeled the species' detection probability in a survey, by comparing a) a model with constant detection probability, against models where b) detection probability was assumed to vary with local abundance (Royle et al. 2004), or c) regions, capturing regional variations in lesser florican density and habitat characteristics, d) wind speed and e) weather, capturing weather effects on reception of signal. Since, we were evaluating factors that influenced detection in this step, we fitted the above models by retaining the same state model, where occupancy was a function of region. We compared these models using Information Theoretic approach (Burnham and Anderson, 2002), and selected the least AICc model to characterize the detection process (Akaike, 1974)

We estimated range-level occupancy, by assuming occupancy to be constant across sites. We extrapolated the estimate to unsampled sites, to assess the number of sites occupied and area of occupancy. To examine spatial variation in occupancy, we modelled occupancy on regions: Ajmer, rest of Rajasthan, and Gujarat. These regions represented different habitat characteristics and conservation contexts that could influence occupancy. We removed Maharashtra and Madhya Pradesh from this analysis since there was no detection in these regions. We built and compared occupancy models using the package unmarked in program R (Mackenzie *et al.*, 2002) (see Annexure 3 for R script).

2.5.2 DENSITY ESTIMATION

To assess lesser florican density in occupied sites, we used conventional distance sampling (Strindberg & Buckland, 2004) that models detectability as a function of perpendicular distance of sightings. After diagnosing the distance data for evasive bird movements (close to the line) and peaking of observations (at further distances), we fitted half–normal and hazard–rate detection functions to it. We selected the best detection model using AICc (Akaike, 1974) and goodness–of–fit tests, to estimate detection probability. Using this estimate, we corrected counts along spatially replicated transects to obtain site-level densities. We estimated the mean global density in occupied sites by averaging site-level densities.

2.5.3 POPULATION SIZE

Finally, we estimated range-level (hereafter 'global') abundance from the product of number of sites occupied by lesser florican and the mean abundance at a site. We generated bootstrapped geometric mean and 95% confidence intervals of global abundance by sampling site occupancy and density from normal distributions specified by respective mean and SE estimates in program R (see annexure 3 for R script). This formulation assumes that expected abundance at occupied sites where species was not detected (but present) was similar to that where species was detected. If this assumption is violated, which is likely when the species is missed in sites with fewer than average individuals, then the estimated global population size will be positively biased. To avoid this issue, we emphasize on a conservative estimate of global abundance based only on those sites where the species was detected, representing a 'minimum population size'.

2.5.4 HABITAT RELATIONSHIPS

To generate baseline information on habitat characteristics in lesser florican breeding range, we summarised habitat variables at sites sampled for occupancy and sub-units sampled for density. Using this data, we assessed regional- and landscape- scale habitat differences, by comparing mean and 95% confidence intervals of habitat variables. We identified habitat selection of lesser florican by modelling occupancy at sites on grassland cover, sward biomass (ground-vegetation height * cover) and disturbances, as additive and interactive effects of regions. Then, we identified factors influencing site abundance by modelling density at sub-units on grassland-prevalence, terrain flatness, sward- cover and structural heterogeneity, crop- cover and structural heterogeneity, and anthropogenic disturbances, as additive or interactive effects of regions.



We postulated that habitat selection would differ by region (interactive effect) because the species exhibited prominent behavioral plasticity in their habitat responses across regions, probably because of the vast differences in their conservation and habitat contexts. We built occupancy and density models using generalized linear models of binomial and Poisson families, respectively, and compared models using Information Theoretic approach in program R (see annexure 3 for R script). Unless mentioned otherwise, we used only male lesser florican detections in the above statistical analyses, because female detections were too few for meaningful inferences.

2.5.5 CONSERVATION PRIORITIZATION AND THREAT ASSESSMENT

We mapped lesser florican detections, habitat variables, predicted occupancy and density across sites using program ArcGIS version 10.2.2 (ESRI 2014). We generated a conservation priority map, where the importance of a site for lesser florican conservation (W) was assessed from the region's contribution to the global population (wr) and the expected/predicted abundance of lesser florican in that site (Ns), as: W = wr*Ns. This ranking valued contiguous large sub-populations over small-fragmented populations for species conservation.

We carried out comparative assessment of anthropogenic threats to lesser florican across landscapes. To quantify threats, we used proxy variables that were collected from occupancy surveys and were quantified as the proportion of observation points in a landscape with a particular threat. We averaged this value across sites in a landscape, to estimate the mean occurrence probability of the threat. This metric was scaled to the maxium occurrence probability for that threat across landscapes, to generate a relative threat index for each landscape. A composite threat index was generated by weighted average of various threat indices, wherein certain threats (e.g., industrial/infrastructural development and excessive livestock grazing) were given higher weightage than others (e.g., agricultural activities and road networks), based on prior conservation understanding. Although, relativizing threat prevalence enabled comparison across threats and developing the composite index, it was not useful in comparing the status of a threat across time. Hence, we also reported the actual mean occurrence probability of each threat across landscapes. Finally, landscapes were ranked using the composite threat index, to make informed decisions on where/how to invest conservation funds given the priority and threats. Details of the, proxies and weightages are presented on page 45.

Datasheets for occupancy (Annexure 1) and line transect surveys (Annexure 2) are provided.



P. juliflora prolification is a major cause of habitat loss for floricans.

Results & Findings





3.1 EFFORT

We conducted the exercise with 121 surveyors (see list I–III). Breeding range of lesser florican encompassed 576 sites (36-sq km cells). We assessed the species' occupancy in 506 sites (18,206 sq km area), out of which, 428 sites (75% of available sites) were adequately sampled (see criteria in methods), each with 13 (5SD) (range 5-32) spatial surveys or observation points. We detected lesser florican in 31 sites. Subsequently, we assessed lesser florican density in these sites by sampling each site with 7 (2SD, range 3-9) spatially replicated transects of length 2.3Mean (0.6SD)(range 0.5–3.8) km. Cumulatively, we walked 218 transects covering 478.8 km, and detected 70 lesser floricans, out of which, 64 observations were of males – with 45 observations based on visual cues and 19 observations based only on auditory cues. Only six observations were of females, which were discarded from the analysis (Table 1).

Habitat variables were quantified during occupancy and line transect surveys, and were used to describe site characteristics across breeding range (Table 2) and sites occupied by lesser florican (Table 3).

Table 1
Sampling efforts at regional and landscape levels for assessing lesser florican occupancy and density across the breeding range in 2017

Area		Occupancy sampling				Density (distance) sampling			
Region	Landscape	Sites	Stop-overs (surveys)	Detected stop-overs	Detected sites	Sites	Transects	Efforts (km)	Male sightings
Ajmer	Kekri	37	444	4	2	3	19	39	15
	Shokaliya	51	711	21	17	17	112	244	15
Rajasthan rest	Jalore	20	254	1	1	1	5	9	0
	Pratapgarh	15	140	1	1	1	5	11	2
	Shahpura	48	555	3	3	4	30	72	0
Gujarat	Kutch	30	407	5	4	4	29	78	1
	Saurashtra	105	1450	14	3	2		35	31
Maharashtra	Akola-Washim	50	649	0	0				
Madhya Pradesh	Ratlam-Sardarpur	72	790	0	0				
Total		**428**	**5400**	**49**	**31**	**32**	**218**	**488**	**64**

Table 2:
Mean (SE) of habitat variables at sites sampled for lesser florican occupancy across the breeding range based on occupancy survey habitat quantification in 2017

Region	Units	Ajmer		Rajasthan (rest)			Gujarat		Madhya Pradesh	Maha-rashtra
Landscape		Kek	Sho	Jal	Prt	Sha	Kut	Sau	Rat	Ako
Agriculture	% cover	64 (2.2)	70.1 (2.2)	46.5 (4.3)	71 (5.6)	55.7 (3)	32.2 (2.9)	58.1 (2.1)	53.2 (2.4)	64.5 (2.8)
Grassland		19.4 (2)	12.1 (2)	27.1 (3)	23.6 (5.8)	21.5 (3.1)	45.1 (2.7)	24.6 (2)	38.7 (2.2)	14.2 (2)
Scrub/wood		16.7 (1.6)	17.7 (1.4)	26.4 (4.1)	5.4 (1.7)	22.8 (2.1)	22.6 (1.5)	17.4 (1)	8.1 (1)	21.3 (2.4)
Ground veg height	cm	45.4 (1.6)	41 (1.3)	35.3 (1.8)	36.9 (1.7)	38.5 (1.5)	35.2 (1.5)	43.7 (1)	28.6 (1.2)	55.9 (1.4)
Ground veg cover	% cover	57.1 (1.9)	67.4 (1.3)	58.6 (2.4)	50.3 (2.9)	68 (1.1)	66.2 (1.4)	68.2 (0.8)	66.9 (1.1)	59.1 (2.5)
Active disturbance	index (intensity)	0.46 (0.02)	0.45 (0.02)	0.37 (0.04)	0.62 (0.05)	0.47 (0.02)	0.34 (0.03)	0.44 (0.01)	0.45 (0.02)	0.42 (0.02)
Passive disturbance		0.25 (0.02)	0.23 (0.02)	0.18 (0.03)	0.53 (0.04)	0.25 (0.02)	0.26 (0.02)	0.33 (0.01)	0.31 (0.02)	0.29 (0.02)

Landscapes include Kekri (Kek), Shokaliya (Sho), Jalore (Jal), Pratapgarh (Prt), Shahpura (Sha), Kutch (Kut), Saurashtra (Sau), Ratlam-Sardarpur (Rat) and Akola-Washim (Ako)

Table 3:
Mean (SE) of habitat variables at sites occupied by lesser florican across the breeding range based on distance survey habitat quantification in 2017

Habitat variables		Units	Ajmer	Gujarat	Rajasthan (rest)
Land cover	Agriculture	% cover	73.2 (2.1)	34.1 (4.5)	66.6 (4.9)
	Grassland		14 (1.5)	43.5 (4.3)	16.8 (4)
	Scrub/wood		12.8 (1.3)	22.4 (2.7)	16.5 (3.1)
Natural vegetation	Ground veg cover	% cover	30.6 (1.5)	81.1 (4.8)	36.9 (3.1)
	Ground veg height	cm	33.2 (0.5)	34.8 (1.4)	31.7 (1.7)
	Woody cover	% cover	8.5 (0.6)	16.9 (2.9)	11.5 (1.3)
Cropping characteristics	Crop cover	% cover	58.4 (1.8)	25.9 (3)	50.8 (4.6)
	Crop height	cm	67.6 (2.1)	42.5 (3.1)	60.1 (3.8)
	Crop richness	number/plot	1.17 (0.03)	0.54 (0.07)	0.95 (0.09)
	Sorghum	occurrence (%)	50.6 (2.1)	17.9 (3.8)	21 (3.3)
	Sesame		4.1 (0.8)	8.1 (2.3)	13.6 (3.2)
	Blackgram		15.4 (2.2)	0 (0)	34.3 (6.3)
	Greengram		31.5 (2.8)	5.9 (1.9)	16 (4.6)
Disturbances	Active disturbance	index (intensity)	0.7 (0.04)	0.7 (0.09)	0.74 (0.1)
	Passive disturbance		0.57 (0.05)	0.74 (0.1)	0.59 (0.11)

3.2 OCCUPANCY

We detected male lesser florican in only 6.3% of sampled sites (naïve occupancy) at the range-level. However, the probability to detect a lesser florican during a survey, if it was present in the site, was <<1. Further, comparison of alternate models showed that region and weather conditions influenced detection probability (model 2 in Table 4a). Detectability of the species was higher in Gujarat than Ajmer and rest of Rajasthan (fig 4), and this trend reflected regional variations in lesser florican density (see section 3.4). Using the best detection model and assuming constant occupancy (model 18 in Table 4a), we estimated range-level occupancy at 13 (2.6SE) % of sites, equivalent to 1908 sq km occupied area. This estimate is representative of Ajmer, rest of Rajasthan, and Gujarat regions only (n = 306 sampled sites out of total 380 sites), as Maharashtra and Madhya Pradesh were excluded from the analysis since lesser florican was not detected there, and these regions were assumed to be entirely unoccupied. Assuming occupancy to vary across regions (model 17 in table 4a), we estimated the occupancy probability to be higher in Ajmer ($\hat{\psi}$ = 40.6 (SE 12.1) % sites) than Gujarat ($\hat{\psi}$ = 4.9 (SE 1.9) % sites), but could not precisely estimate occupancy for rest of Rajasthan (20.6 (38.2) % sites) due to very few observations (fig 4).

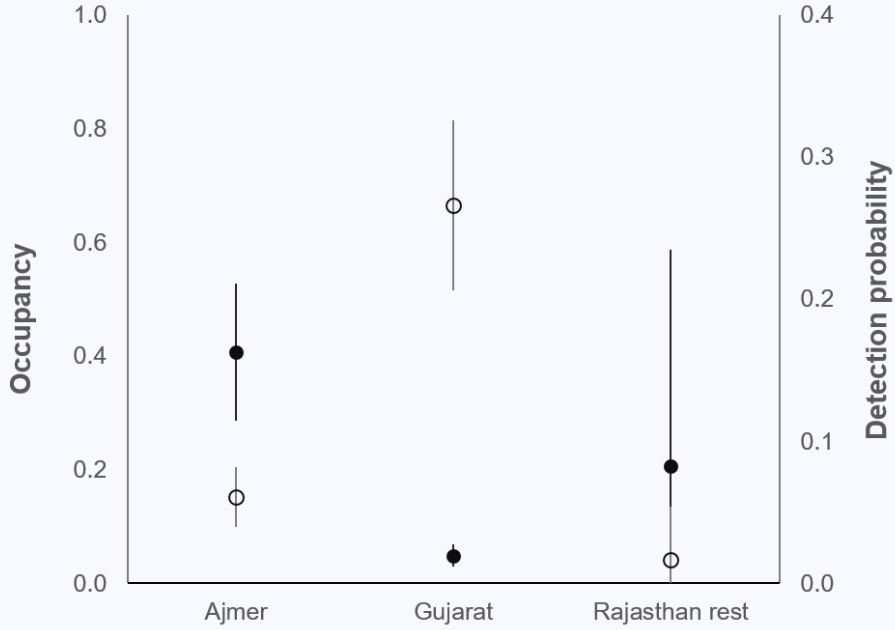


Figure 4: Regional occupancy probability (closed circles) and species' detection probability (open circles) of lesser florican across regions in the breeding range in 2017. Error bars are 1 SE.

3.3 OCCUPANCY-HABITAT RELATIONSHIPS

Habitat quantification in potential breeding sites showed that agricultural cover was maximum in Ajmer (Shokaliya > Kekri) and Maharashtra (Akola-Washim) regions, followed by rest of Rajasthan (Pratapgarh > Shahpura > Jalore), Madhya Pradesh (Ratlam-Sardarpur), and Gujarat (Saurashtra > Kutch), while grassland cover followed an inverse trend (Gujarat ≈ Madhya Pradesh > rest of Rajasthan > Maharashtra ≈ Ajmer). Despite grassland availability, ground vegetation height was considerably low in Madhya Pradesh followed by Kutch and rest of Rajasthan, while being highest in Akola-Washim followed by Saurashtra and Ajmer. Active (human presence) and passive (human artifacts) disturbances were particularly intense in Pratapgarh landscape. Mean and 1 SE of these habitat variables are reported in Table 3, as baseline information for future monitoring. However, as these variables were quantified at spatial locations which were optimal for lesser florican use/detection, this habitat characterization are not truly representative of general habitat; but can be used as a relative measure for spatial and temporal comparisons.

Comparison of alternate hypotheses on factors influencing lesser florican distribution found maximum support for regional effects of grassland cover (model 9 in Table 4a), wherein occupancy probability increased with grassland cover in Gujarat but decreased with grassland cover in Ajmer (fig 5). Occupancy probability also increased with grassland cover in rest of Rajasthan, but the relationship was not precise due to inadequate observations (Table 5a). We generated spatially explicit occupancy probability of lesser florican from this model (fig 6).



Lesser Florican in agricultural field. Florican prefers grasslands with good cover but may use crop fields where grasslands are not available.

Table 4:
Ranking of candidate models explaining lesser florican (a) occupancy and detection probability across the breeding range and (b) density (mean abundance per 10 sq km) across occupied sites in 2017

(a)

No.	Model	W_i	ΔAICc	AICc	Deviance	K
1	ψ (.) p(.)	-	-	446.76	442.72	2
	Candidate models for detection probability with occupancy modeled on region					
2	ψ (Rgn) p(Rgn + Wthr)	0.73	0.00	411.71	397.34	5
3	ψ (Rgn) p(Rgn + Wind + Wthr)	0.27	2.01	413.72	397.24	6
4	ψ (Rgn) p(Rgn)	0.00	10.86	422.57	410.29	4
5	ψ (Rgn) p(Wthr)	0.00	14.68	426.40	416.20	4
6	ψ (Rgn) p(Wind + Wthr)	0.00	15.59	427.30	415.02	5
7	λ (Rgn) p(.) Royle-Nichols	0.00	24.10	435.81	427.68	3
8	ψ (Rgn) p(.)	0.00	48.94	460.65	452.52	3
	Candidate models for occupancy with detection probability modeled on region and weather					
9	ψ (Rgn*Grsl) p(Rgn + Wthr)	0.44	0.00	394.56	373.82	10
10	ψ (Rgn*Grsl + Vhet) p(Rgn + Wthr)	0.16	2.06	396.62	373.73	11
11	ψ (Rgn*Grsl + Pdtb) p(Rgn + Wthr)	0.16	2.08	396.65	373.75	11
12	ψ (Rgn*Grsl + Vhgt*Vcov) p(Rgn + Wthr)	0.08	3.39	397.96	370.71	13
13	ψ (Rgn*Grsl + Pdtb + Adtb) p(Rgn + Wthr)	0.08	3.45	398.01	372.95	12
14	ψ (Rgn*Grsl + Pdtb + Vhet) p(Rgn + Wthr)	0.05	4.17	398.74	373.67	12
15	ψ (Rgn*Grsl + Pdtb + Vhgt*Vcov) p(Rgn + Wthr)	0.03	5.57	400.13	370.69	14
16	ψ (Rgn*Grsl + Pdtb + Adtb + Vhet + Vhgt*Vcov) p(Rgn + Wthr)	0.00	9.03	403.59	369.71	16
17	ψ (Rgn) p(Rgn + Wthr)	0.00	17.15	411.71	397.34	7
18	ψ (.) p(Rgn + Wthr)	0.00	35.15	429.72	419.52	5
19	ψ (Grsl) p(Rgn + Wthr)	0.00	37.13	431.70	419.42	6

(b)

SN	Model	W_i	ΔQAICc	QAICc	Deviance	K
1	Grassland + Woody cover	0.44	0.00	46.55	157.68	3
2	Grassland + Woody cover + Active disturbance + Passive disturbance	0.34	0.55	47.10	134.61	5
3	Grassland	0.22	1.38	47.93	174.83	2
4	Active disturb	0.00	15.12	61.67	233.36	2
5	Woody cover	0.00	15.34	61.89	234.30	2
6	*Null*	0.00	15.91	62.47	247.24	1
7	Grassland + Woody cover + Active disturb	0.00	16.74	63.29	229.01	3
8	Active disturb + Passive disturb	0.00	18.27	64.82	246.79	2

Model covariates include: Region (Rgn), Grassland cover (Grsl), Ground vegetation height heterogeneity (Vhet), Ground vegetation height (Vhgt), Ground vegetation cover (Vcov), Prevalence of passive disturbances (Pdstb), Prevalence of active disturbances (Adtb) as site covariates; and Weather (Wthr) and Wind speed (Wind) as survey covariates

Table 5:
Effect of habitat variables on lesser florican (a) occupancy (logit-transformed occurrence probability) and (b) density (logtransformed number per 10 sq km) across breeding range in 2017

(a)

Parameter	Effect size	SE	z-stat
Intercept	1.31	1.09	1.20
Gujarat	-7.27	1.88	-3.86
Rajasthan (rest)	-4.35	1.66	-2.62
Grassland cover	-14.85	6.66	-2.23
Gujarat * Grassland	22.07	7.25	3.04
Rajasthan (rest) * Grassland	19.24	7.20	2.67

(b)

Parameter	Effect size	SE	z-stat
Intercept	1.06	0.97	1.09
Grassland cover (proportion)	3.88	1.01	3.86
Woody cover (proportion)	-14.69	10.23	-1.44

3.4 DENSITY

We detected 64 males in 28 out of 218 transects across 32 occupied sites. Although the total area of a site was 36 sq km, the habitat area in a site where transects were actually laid was 29 sq km on average the rest of the site being ' non- habitat'. Half normal detection function fitted the distance data best ($\chi 2$=0.26, df=3, p=0.97), and yielded estimates of effective half-strip width (ESW = 277, SE 27, 95% CI 227–338 m) and detection probability (p = 0.53, 0.43–0.65). Correcting for imperfect detection, lesser florican density in occupied sites was estimated to be 0.25 (0.06SE) (95% CI 0.15–0.42) males per sq km. At regional level, density tended to be higher in Gujarat (0.50, 0.18SE, 0.24–1.02 per sq km) than Ajmer (0.18, 0.07, 0.09–0.37 per sq km) and rest of Rajasthan (0.04, 0.04, 0.01–0.20 per sq km) (fig 6 and 7).

3.5 DENSITY-HABITAT RELATIONSHIPS

Lesser florican density (n = 32 sites) was modelled as mean abundance per 10 sq km on habitat variables, which were collected from sampling plots on transects and averaged for the site. More intensive and representative habitat quantification at sites where lesser florican density was assessed, corroborated that agricultural attributes (coverage, height and crop richness in a plot) were higher in Ajmer and rest of Rajasthan compared to Gujarat, while grassland cover followed an inverse trend. Ground vegetation cover, but not height, was markedly higher in Gujarat than Ajmer and rest of Rajasthan. Passive disturbance intensity was relatively higher in Gujarat than other regions. Mean and 1 SE of these habitat variables are reported in Table 3, and represent an unbiased characterization of the occupied sites; hence, will allow more robust spatial and temporal comparison of habitat in occupied sites.

Habitat variables were strongly cross-correlated (|r|>0.4) that could complicate the interpretation of parameters in density models. Hence, we removed less important variables based on prior ecological understanding to ensure satisfactory variance inflation factors (<2 units) of parameter estimates (see Annexure 3 for R script), and >6 observations per parameter in the full model. Based on histograms of response along with residual diagnosis and dispersion parameters ($\hat{c}$) of the full model, we concluded that lesser florican density followed a zero-inflated Poisson distribution that was best modelled as a quasi-Possion distribution using generalized linear models.

Comparison of alternate hypothesis explaining density-habitat relationships found maximum support for models (1-3 in Table 4b) including grassland cover with/without woody cover and disturbance variables. We selected the least QAICc model (Wi = 0.44) for inference that showed a strong positive effect of grassland cover on lesser florican density (Table 5b), where density was particularly high in contiguous/extensive grassland sites (fig 5). Spatially explicit density was generated from the least AICc model for sites where lesser florican occupancy was detected (fig 6).

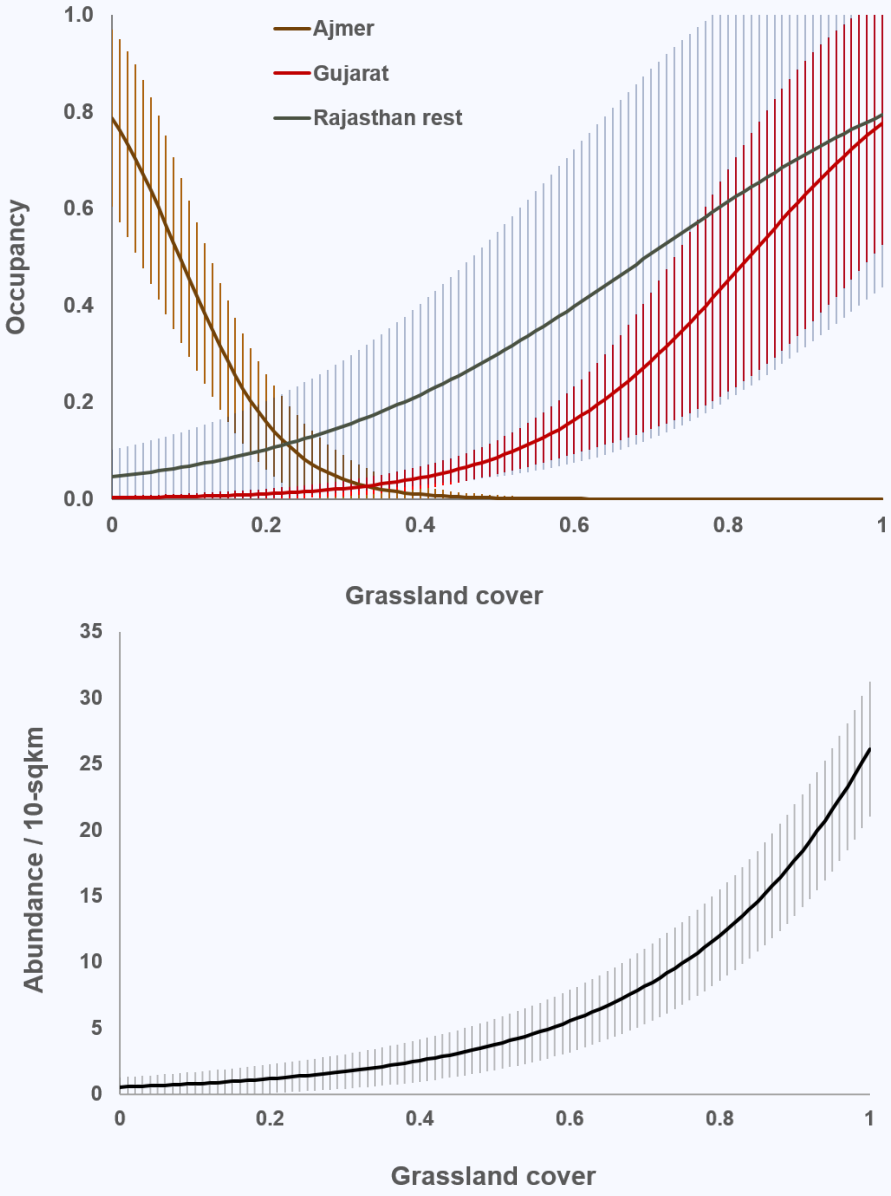
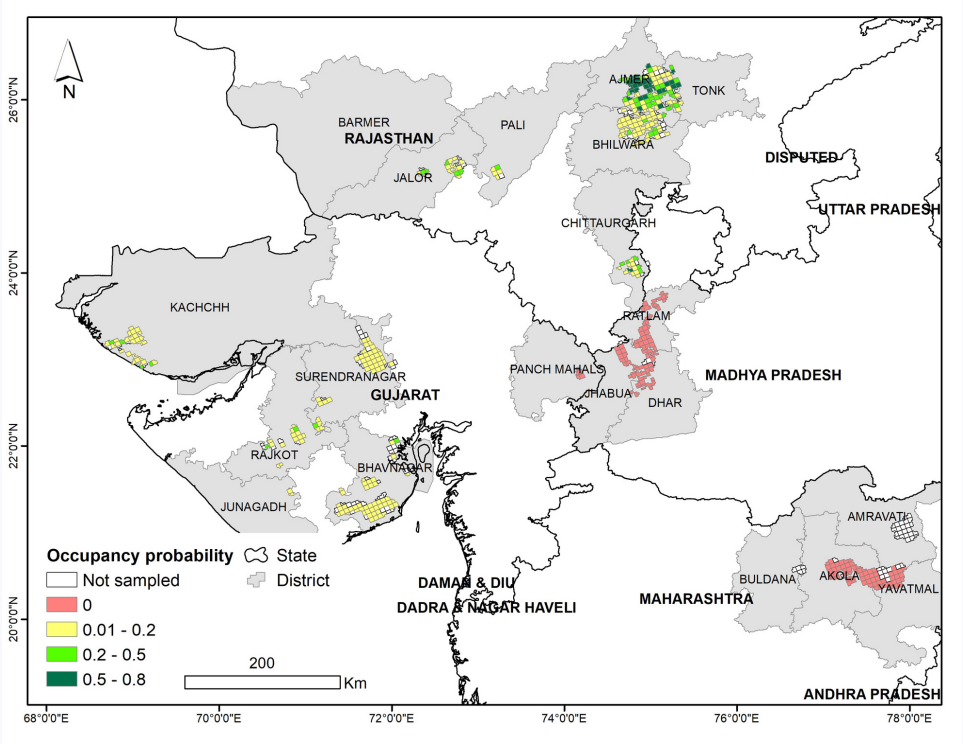


Figure 5
Relationships between occupancy probability and proportional grassland cover across regions (top), and mean abundance per 10 sq km vs. proportional grassland cover across sites occupied by lesser florican in the breeding range in 2017. Error bars are 1 SE.



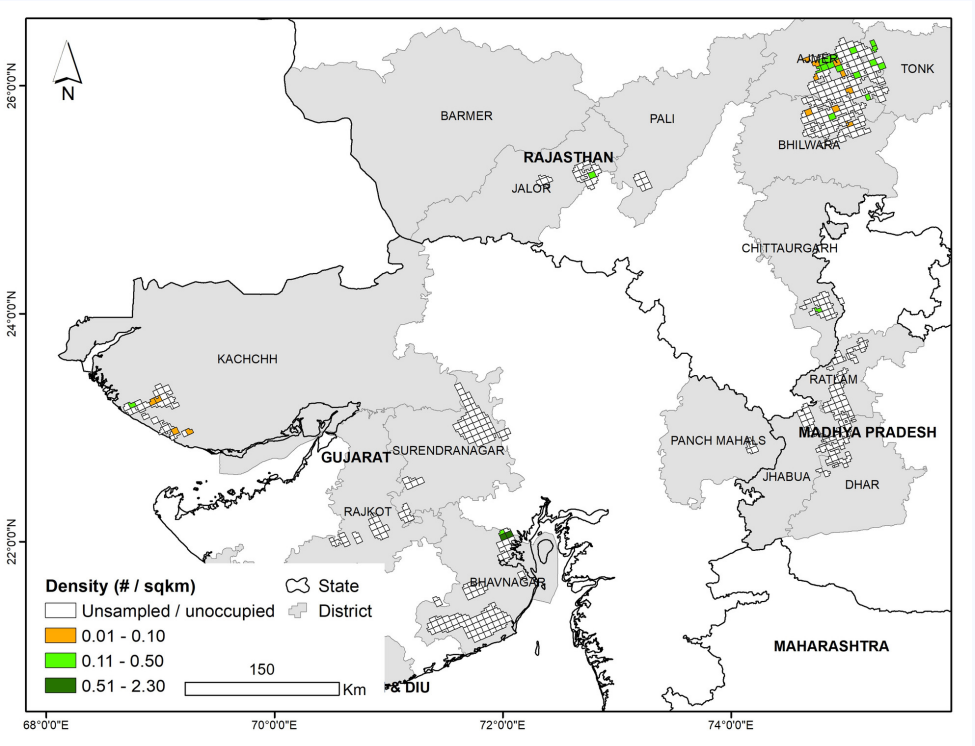


Figure 6 :
Model-predicted lesser florican occupancy probability (top) and mean number per sq km (bottom) in sites (36 sq km cells) across breeding range in 2017.

3.6 POPULATION ABUNDANCE

Based on the proportion of sites occupied (0.13, 0.03 SE) and mean abundance at an occupied site 7.25 (1.74SE), we estimated the geometric mean number of breeding male lesser florican to be 340 (95% CI 162–597) individuals. This estimate includes the potential breeding habitat in sites (mean area 29 sq km) across Rajasthan (Ajmer and Rest of Rajasthan) and Gujarat states, while that of Madhya Pradesh and Maharashtra were ignored as lesser florican was not detected, and only a few males if at all, were likely to occur there. Abundance of male lesser florican across sites where their occupancy was detected (i.e., naïve occupancy of 6.5% sites, without any extrapolation to undetected but possibly occupied sites) was estimated to be 264 (66SE), (95% CI 157–442) individuals. We propose this figure as a conservative estimate of the global population of the male breeding pool. Due to logistic constraints, we could not conduct surveys in Rollapadu WLS, where 6 males were reported in 2017 (Prudhviraj and Vaibhav Mupadi, pers. comm.).

As expected, detection probability in occupancy surveys (fig 4) surrogated the density gradient reasonably well (fig 7), when compared across regions.We observed an inverse occupancy-density relationship across breeding regions that suggested regional differences in the species' social/spatial organization (fig 7). Male lesser florican arenas were dispersed across a larger area at very low density in Ajmer region; while their arenas were concentrated in a few sites at relatively high density in Gujarat (Saurashtra) region. Thus, Ajmer and Saurashtra represented two extremes of the species' exploded lek mating system, from very loose congregation in agriculturally dominated landscape to very tight congregation in grassland dominated landscape. The process(es) behind this pattern needs to be examined because of their strong implications in the species' sociobiology and conservation, as grasslands are being converted to agriculture across India.

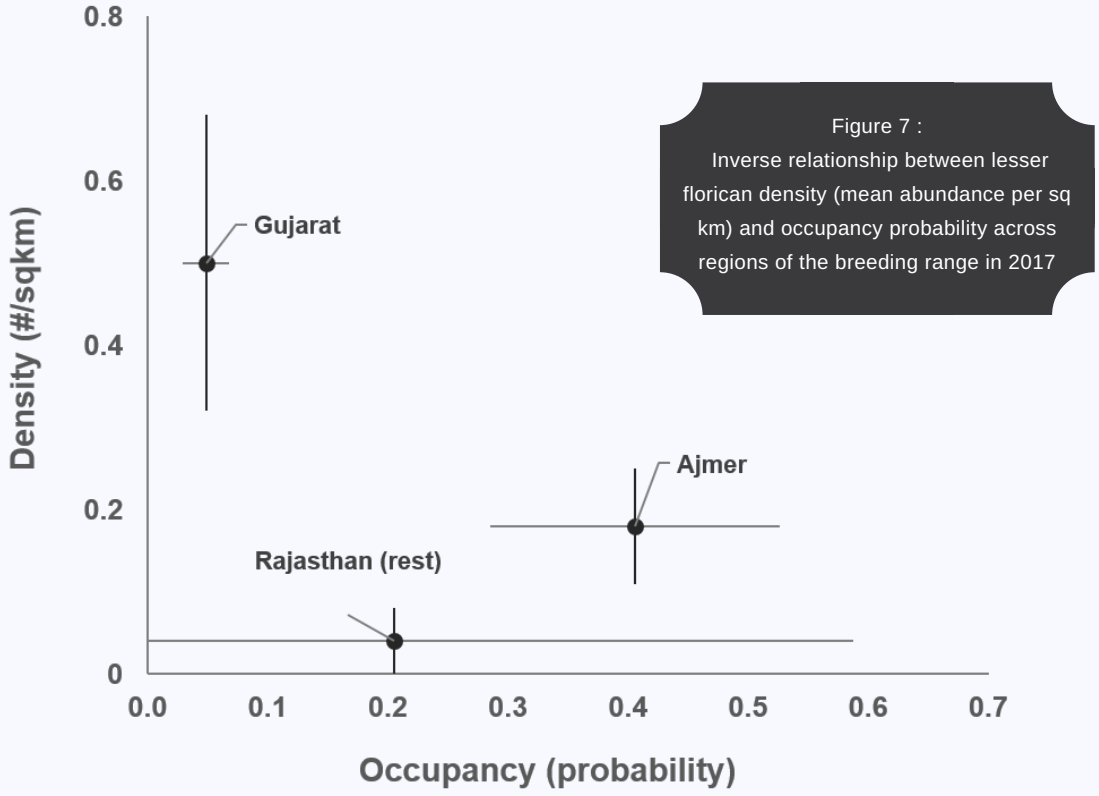


Figure 7 :
Inverse relationship between lesser florican density (mean abundance per sq km) and occupancy probability across regions of the breeding range in 2017

3.7 CONSERVATION MAPPING

Conservation priority rank, computed from expected lesser florican abundance at sites weighted by relative contribution of the regional population to the global pool, indicated that the priority conservation areas are clustered in two areas. The Blackbuck National Park, Velavadar and its adjoining area in Bhavnagar district, Gujarat held about 96 (model-predicted)–115 (empirically estimated) male lesser floricans in two sites. Here, males congregate in the well-managed grasslands, and occasionally use surrounding agricultural areas particularly during late breeding season that are also used by nesting females (Indra Gadhvi pers. obs). Another 110 (model-predicted)–136 (empirically estimated) male lesser floricans were found in Ajmer extending from Bhinai in west through Shokaliya Conservation Reserve, Nasirabad and adjoining areas to Malpura, Tonk in the east. As mentioned above, males are spread out at low density across estimated 22 sites comprising of agricultural fields here; with one site near Bhinai (26.0443 N, 74.6975 E) having relatively flat, unobtrusive, low-impact agriculture holding substantially high density (1.8 males per sq km) that resembles an agro-grass mosaic. Although our conservation prioritization is intended to guide managers to allocate conservation efforts, we caution readers that this exercise is a preliminary representation, and needs to be refined using data from at least two-three breeding cycles since this species is known to shift breeding grounds in response to local rainfall patterns (fig 8).

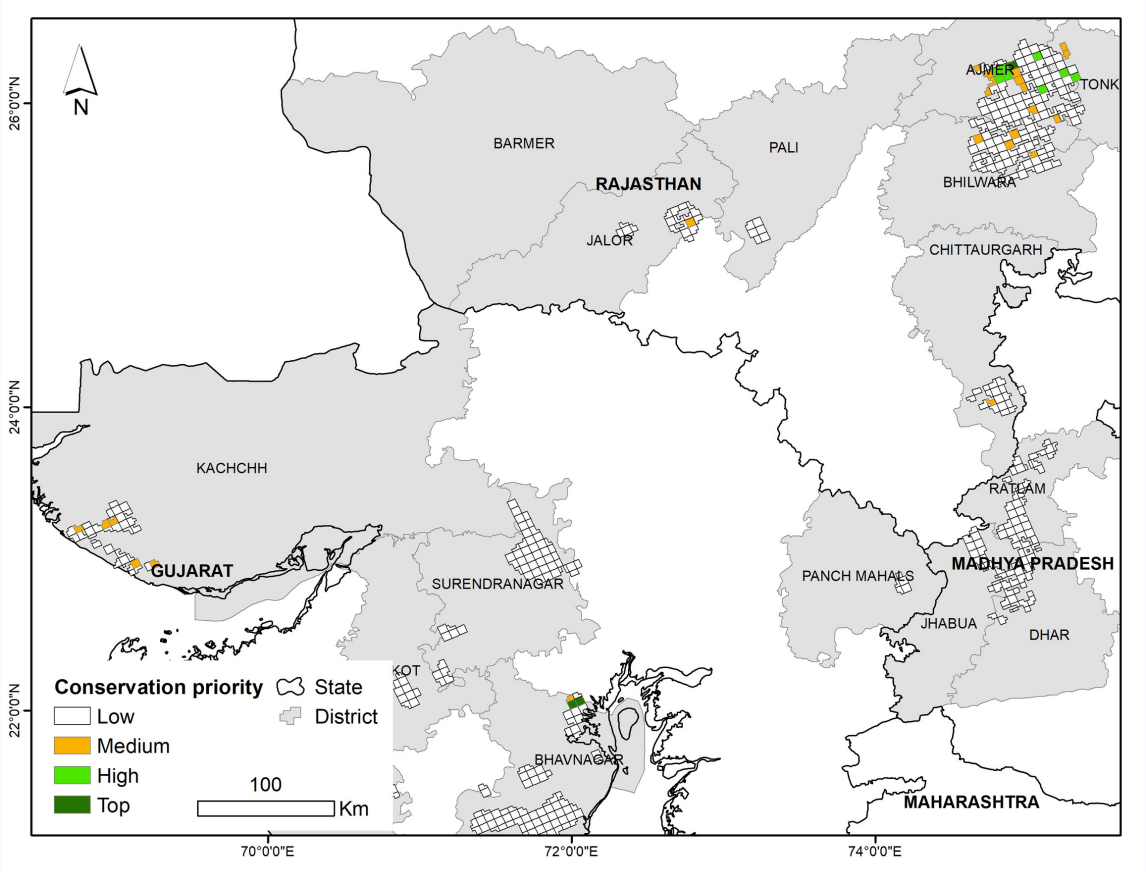


Figure 8
Importance of sites (36 sq km cells) for lesser florican conservation across breeding range in 2017. Note that, this map is preliminary and needs to be refined using data from at least three breeding cycles since lesser florican is known to change their spatial distribution in response to local rainfall patterns.

3.8 THREATS

Our comparative threat assessment with the focus on lesser florican indicated that Ratlam-Sardarpur (region Madhya Pradesh) > Shokaliya–Kekri (Ajmer) > Akola-Washim (Maharashtra) were the most threatened landscapes, whereas Jalore and Shahpura (region rest of Rajasthan) were relatively less threatened. Agricultural activities were highest in Shokaliya–Kekri; urbanization and infrastructural development was highest in Ratlam-Sardarpur; industrialization was maximum in Akola-Washim and Shokaliya; livestock grazing was highest in Ratlam-Sardarpur; and free-ranging dogs were highest in Kutch (Table 6 and 7).



Interfering Wings!

Wind turbines affect florican population by degrading habitat and suppressing the sound of the displaying males.

Table 6:
Comparative threat assessment across landscapes, based on proportions of occupancy observation points with a particular threat across sites (values in top row), scaled to the maximum value across landscapes (values in bottom row and parantheses) in the lesser florican breeding range in 2017

			Landscape								
Threats	**Proxy**	**Weight**	**Sho**	**Kek**	**Sha**	**Jal**	**Rat**	**Kut**	**Sau**	**Ako**	**Mean**
Agricultural activities	Agriculture	0.5	0.66 (1)	0.63 (0.95)	0.56 (0.85)	0.44 (0.66)	0.58 (0.87)	0.33 (0.5)	0.59 (0.88)	0.65 (0.98)	0.56
	Human	0.5	0.76 (0.95)	0.81 (1)	0.77 (0.96)	0.68 (0.84)	0.81 (1)	0.62 (0.77)	0.8 (0.99)	0.61 (0.75)	0.73
Urbanization	Settlement	1.0	0.16 (0.42)	0.21 (0.55)	0.18 (0.48)	0.18 (0.49)	0.38 (1)	0.23 (0.61)	0.17 (0.44)	0.25 (0.67)	0.22
Infrastructure development	Powerlines	0.8	0.42 (0.59)	0.44 (0.61)	0.43 (0.61)	0.5 (0.7)	0.65 (0.91)	0.63 (0.88)	0.72 (1)	0.47 (0.66)	0.53
	Road	0.5	0.31 (0.65)	0.38 (0.79)	0.4 (0.84)	0.33 (0.69)	0.48 (1)	0.28 (0.58)	0.45 (0.94)	0.41 (0.85)	0.38
	Industries	1.0	0.05 (0.9)	0.02 (0.39)	0.01 (0.2)	0.03 (0.45)	0.01 (0.22)	0.01 (0.1)	0.03 (0.55)	0.06 (1)	0.03
Overgrazing	Livestock	1.0	0.39 (0.88)	0.42 (0.95)	0.4 (0.9)	0.32 (0.73)	0.44 (1)	0.25 (0.57)	0.34 (0.77)	0.41 (0.92)	0.37
Nest predation	Dog	1.0	0.15 (0.54)	0.09 (0.33)	0.14 (0.51)	0.16 (0.59)	0.16 (0.57)	0.28 (1)	0.15 (0.53)	0.2 (0.72)	0.17
Cumulative threat index			**0.72**	**0.65**	**0.62**	**0.62**	**0.78**	**0.62**	**0.72**	**0.82**	
Threat rank *			**3**	**5**	**7**	**8**	**2**	**6**	**4**	**1**	
Conservation importance **			**1**	**2**	**3**	**4**	**3**	**2**	**1**	**4**	

Landscapes include Kekri (Kek), Shokaliya (Sho), Jalore (Jal), Shahpura (Sha), Kutch (Kut), Saurashtra (Sau), Ratlam-Sardarpur (Rat) and Akola-Washim (Ako)

* Landscapes are ranked in descending order of threats; lower ranks indicating higher threat levels

** Landscapes are ranked in descending order of conservation importance; lower ranks indicating higher conservation value

A SPECIES ON ITS PATH TO EXTINCTION





DISCUSSION AND RECOMMENDATIONS

This report presents the protocol developed as part of the Endangered Species Recovery Program of WII, to assess the population status of lesser florican across its breeding range, along with the outcomes of its first implementation through collaborative efforts of WII, BNHS, TCF, State Forest Departments and other local institutions/indiviudals. We estimated a global population of 340 (95% CI 162–597) male territories distributed across ~2000 sq km area. However, this estimate would be unbiased only if density in sites where the species was detected was representative of sites where the species occurred but was not detected. Since this assumption can be violated, we recommend the use of the conservative 'minimum population size' estimate of 240 individuals. Meanwhile, we are attempting to refine our analytical approach to generate more robust estimate on the lines of the two-phase adaptive sampling proposed by Conroy et al. (2006). It is extremely difficult to assess female numbers, and earlier studies have typically assumed equal sex ratio. However, we avoid making such assumptions and have reported only the male territory numbers. Notably, this estimate is considerably lower than the last estimate of 3530 individuals or 1765 territories in 1999 (Sankaran 2000). This difference would imply a probable population decline of 81% over three-four generations. However, this conclusion can be premature as a few annual status assessments are required to confirm their current status. But, to be cautious, conservation managers should take cognizance of the probable decline and scale up efforts for the species' conservation.







Our surveys also showed that the lesser florican population is largely concentrated in two areas: Shokaliya and Velavadar. Although these areas hold similar numbers, birds are densely clustered in a few (at least two) sites in Velavadar – a contiguous grassland area, as opposed to being widely dispersed over many (estimated to be 22) sites in Shokaliya – an uniformly agricultural area. One possible explanation to such ecologically contrasting spatial organizations, is the likely difference in resource dispersion between the two habitats, although this hypothesis is yet to be tested. The conservation implication of this finding is that, although lesser florican may breed in agricultural landscape, it would require hundreds of square kilometers of agricultural area to achieve the same population outcome as a ten square kilometer contiguous grassland patch.

We provide some broad recommendations to conserve lesser florican in the current contexts, while detailed landscape wise recommendations are provided later (Section 5).



4.1. Key Recommendations

1. Protection to lesser florican conservation sites :

All priority conservation sites, mapped by us (figure 8) and to be refined in future status assessments that are outside Protected Areas, must be consolidated under some form of flexible yet legal protection status such as community reserve or conservation reserve, so that detrimental land-uses can be disallowed and lesser florican-friendly subsistence land-uses can be promoted in these areas. However, local people should retain land-ownership in these areas, to avoid public antagonism towards lesser florican conservation.

2. Land-use regulation in lesser florican conservation sites :

Our surveys show intense anthropogenic disturbances in lesser florican conservation sites in the form of infrastructural (settlements, power-lines and roads), industrial (mining and wind energy), agricultural (intensive inorganic agriculture) and salt pan developments, particularly in Bhal region of Gujarat. Although lesser florican is more tolerant to human presence than the great Indian bustard and other bustards, their conservation is incompatible with intense disturbances. Therefore, the following land-uses should be disallowed in priority conservation sites: mining, wind energy production, expansion of power lines [while existing power lines should be mitigated by undergrounding or marking overhead cables with bird diverters following Jans and Ferrer (1998)], and plantation of shrub/tree species by Forest Department.

The following land-uses should be regulated/modified in priority conservation sites: use of pesticides in agriculture and free-ranging lilvestock grazing during the four monsoon months June–September.

3. Scientific grassland management and restoration :

Although lesser florican can breed and survive in agricultural landscapes, our findings show that they prefer and occur at much higher densities in grasslands that are large, contiguous and with adequate herbaceous biomass. Very few protected grasslands are currently managed in this form with the only exception of Blackbuck National Park, Velavadar. Therefore, PA managers should target consolidating relatively large (>10–20 km2) grasslands and manage them as contiguous habitats that are freed from livestock grazing during four monsoon months (June–September). These grasslands should not be planted with shrub/tree species such as *Prosopis* and *Glyricidia*, while existing plantations should be removed and planted with native grasses, to restore grassland habitats.

4. Promotion of florican-friendly agricultural practices :

Since a large proportion of lesser floricans are breeding in cropfields, there is need to promote florican-friendly agricultural practices. A long-term sustainable agricultural scheme should be launched through partnerships between conservation agencies and local farmers that reduces pesticide usage (to boost insect resources and reduce environmental toxicity) and compensates for the foregone production cost by marketing these organic conservation products at higher prices. This scheme should be integrated into ongoing bustard recovery programs.

5. Strengthening of local people's participation in conservation :

Lesser florican inhabits human-use landscapes with negligible control of Forest Department; the federal conservation agency in India. Although the response of local people to lesser florican conservation varies from antagonism to mild support across sites, the majority lacks awareness and is neutral to the species. Hence, there is significant scope of launching outreach programs that raises local awareness on the need, requirement and benefits of lesser florican conservation, and recruits local nature enthusiasts to form a network of 'florican friends' who can provide active protection to the species and inculcate conservation values in their localities.

6. Nest/chick predator control :

Although there is no hard evidence of nest/chick predation by free-ranging dogs, wild pig and other nest/chick predators, given the recent human-induced population increase of these species, there is an urgent need of controlling these populations through a mix of strategies including active removal and sterilization of these nest predators, and regulation of garbage disposal in priority conservation sites.

7. Conservation research and monitoring :

Current conservation plans for lesser florican are entirely based on their breeding ecology and distribution, while their non-breeding ecology and distribution remain completely unknown. These information are vital for effective conservation planning, as threats during non-breeding season can play vital role(s) behind their ongoing decline. For instance, note the occasional rescues of female lesser floricans from human-dominated areas during non-breeding season (appendix III). Therefore, biotelemetry research to understand the species' non-breeding ecology and ranging patterns, is urgently needed. Additionally, their status needs to be assessed regularly (annually for the first three years to refine/streamline the monitoring protocol and once every three years since then) following the protocol demonstrated in this report.

8. Conservation breeding as an insurance policy :

For continued persistence of the species, a national level conservation breeding programme should be commenced immediately, and implemented with adequate and long-term financial, physical and technological resources

9. Advocacy and policy intervention :

Finally, there is an urgent need of strong multi-agency advocacy to influence policy-makers that lesser florican conservation sites are conservable ecosystems and not unproductive 'wastelands', to ensure that policy safeguards to implement the conservation actions recommended above are in place.

4.2. Future plan of work

1. To refine our status assessment protocol and generate robust inference on the current numbers and distribution, breeding range surveys need to be conducted following similar collaborative and standardized approach in successive two years (July-September of 2018 and 2019).

2. Consultative meetings at the regional levels need to be organized to prepare site-wise conservation plans, strengthen the networks of local people, and consolidate collaborations between national conservation agencies, local conservation groups, and State Forest Departments for joint implementation of recovery actions.



Conservation recommendation for lesser florican population recovery

Sr. No.	Conservation action	Task	Priority/ Process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
1	Reduce nest/ chick predation	Removal of free-ranging dogs from lesser florican breeding sites Sustained sterilization of dogs from villages buffering lesser florican breeding sites Garbage management in villages around lesser florican breeding sites	High/ Continuous	All priority lesser florican conservation sites	Awareness among local communities about issues/threats of free-ranging dogs Collaboration with concerned agencies for removal and sterilization programs Linking this programme with Swachh Bharat abhiyan	~ Rs. 10 lakh for community awareness per village ~ Rs. 20 lakh for dog sterilization programme to be carried out at each site (4-5 villages) for 2-3 months per year for 1000 dogs ~ Rs. 10 lakh for garbage management per village	To improve recruitment rate of lesser florican population
2	Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	High/ Continuous	1. Shokaliya 2. Velavdar 3. Kutch	1. Radio tracking of ~10 birds in Rajasthan and Gujarat to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas	1. Rs. 4 lakh for marking 1 km of power lines with bird diverters 2. Cost of undergrounding 1 km poweline is Rs. 35 lakh for high tension line and Rs. 20 lakh for low tension line	Tol help reduce mortality of birds
3	Develop Conservation Breeding Program	Develop a national conservation breeding center (CBC) with State Forest Depts., MoEFCC and scientific organization (WII / BNHS) as partners and international bustard breeders as collaborators	High/ Long-term (20 years)	1. Sorsan 2. Velavdar / Kutch	1. Signing of Memorandum of Understanding between partners 2. Permission to collect eggs and tag birds 3. Development of conservation breeding center 4. Execution of program following scientific protocol	Rs. 40 crores for construction and running CBC for 20 years	To secure an insurance population against imminent extinction risk
4	Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	High/ Continuous	Agricultural areas in priority conservation sites of 1. Shokaliya 2. Kutch 3. Akola	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	1. Rs. 1 lakh for farmer training program per site 2. Rs. 2 lakh/ person for certification of land of farmer who wish to get associated with the scheme	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years

Sr. No.	Conservation action	Task	Priority/ Process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
5	Grazing regulation in unprotected grasslands	Stop/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	High/ Continuous	Grasslands > 5 km^2 area, particularly in 1. Kutch, 2. Dahod 3. Saurashtra, 4. Pratapgarh 5. Ratlam	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 3. Incentivized stall-feeding of livestock during monsoon	Rs. 1 lakh per site for engaging two local people to enforce grazing restriction during 3-4 monsoon months. Cost of incentive needs to be computed based on livestock holding in a site	To help in increasing herbaceous biomass, which is critical for lesser florican breeding, and provide fodder for livestock in the lean period (winter through summer)
6	Research and monitoring	**1. Satellite telemetry** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology that are all poorly known. Also understand the impact of land-use change on lesser florican ecology 2. **Monitoring** Distribution and population status assessment following the protocol demonstrated here.	1. High/ immediate 2. High/ (During 2018, 2019 thereafter once every three years)	1. Shokaliya 2. Velavadar 3. Kutch All lesser florican landscapes	1. Necessary permissions from government agencies to procure tags and capture and tag birds 2. Effects of agricultural intensification, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis. Necessary permissions and logistical support from government agencies to conduct surveys and collaborative efforts from all concerened agencies	Rs. 3 lakhs per PTT x 5 PTTs / site + Rs. 2 lakh for field expenses required for installing PTT per site Rs. 10 lakhs for field monitoring, image processing and other expenses per year per site	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions
7	Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	High/ Continuous	All lesser florican conservation sites, particularly 1. Shokaliya 2. Velavadar 3. Kutch	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	1. Rs. 1 lakh per workshop 2. Rs. 25,000 for each follow up event	To generate public support for lesser florican conservation
8	Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	High/ once in every two years prior to monsoon (May–June)	1. Shokaliya 2. Sailana 3. Kutch 4. Bhal including Velvadar	Collaborative implementation by Forest departments and concerned agencies	Rs. 1000-1500/- per acre for uprooting a plant using mechanization method such as excavators (JCB/Pokland)/ bulldozers	To create more optimal habitats for lesser florican

Sr. No.	Conservation action	Task	Priority/ Process	Regions/ Sites	Requirement	Estimated fund requirement (per programme per site in INR)	Justification
9	Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**PA rationalization** Rationalization of boundaries of the Wildlife Sanctuaries (WLS) and defining the Eco-Sensitive Zone (ESZ)	High/ priority	1. Sailana WLS 2. Sardarpur WLS	There is need to take decision on revenue land inside Sanctuary areas and demarcation of the core areas	Chain link fence cost Rs. 7 lakh / km (approx) and gates as per requirements With additional cost for predator proof concrete foundation	To avoid public antagonism due to restrictions on land-use and livelihoods in areas adjoining Protected Areas (PAs) that can be detrimental to lesser florican conservation
		Relief from crop-raiding Compensation policy to be designed to address the issue of crop raiding by large herbivores like Nilgai	Medium/ Priority	Sailana Sardarpur Velavadar NP Akola	, Crop-raiding by nilgai and wild pigs, in/around PAs demarcated for lesser florican causes antagonism towards lesser florican conservation.	Rs 20,000 per farmer per ha for damage of more than 50% of the crop	
		Protection to marginal conservation areas Focusing on existing and unprotected lesser florican breeding sites	High	All non-protected lesser florican sites	1. Regulation of intensive land-uses (mining, salt pans, infrastructure, intensive farming) 2. Incentivizing local people for implementing lesser florican-friendly land-uses 3. Land ownership should remain with the people.	Rs. 20 lakhs per year per site	To balance livelihood concerns and lesser florican conservation Capacity building and involvement of local people in lesser florican conservation
		Preventing disturbances to breeding birds Preventing human disturbances, hunting and livestock grazing by patrolling in PAs	High/ Continuous	All known breeding sites of lesser florican	1. Identifying and engaging poachers or other interested local people as protectors and forest watchers to create a parallel protection force for four months 2. Adequate training and logistic/fund support for the training 3. Deploy local villagers as 'Florican friends' during June-September (lesser florican breeding season)	Rs. 10 lakhs per site Rs. 5000 per person per year per site x 40 sites	
10	Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	High/ Continuous	All lesser florican breeding sites, particularly 1. Shokaliya 2. Velavadar 3. Kutch	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people 2. Identify and train local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not detrimental to conservation	Rs. 50,000 for training programme for nature guides	To help improve local revenue and awareness about lesser florican
11	Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	High/ priority	1. Shokaliya 2. Kutch	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	1. Rs. 50,000 for workshop for CCA community 2. Rs. 30 lacs as incentives for the people involved in conservation	To help develop a pilot habitat model apart from a conservation area governed by local people





REGION CHAPTERS



We have segregated the breeding range of lesser florican into regions and landscapes that have similar ecogeographical and conservation settings. Here, we provide information on these regions and landscapes, such as their geo-political location (http://districts.nic.in/), bio-geographic zone (Rodgers et al. 2000), vegetation type (Champion and Seth 1968), climate, topography, major land cover/ use, human population density (Census of India 2011), livestock population density (Livestock Census 2014), major livelihoods, major crops, and protected/ conservation- areas. We also report lesser florican occupancy and density maps along with conservation recommendations for each landscape that will be particularly useful for local field conservation practitioners.

5.1 REGION: AJMER

SHOKALIYA AND KEKRI

Attribute	Ajmer	Tonk
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern tropical dry deciduous forests (5B)	Northern tropical dry deciduous forests (5B)
Annual rainfall (2012-16)	Min.- 462 mm (2015), Max.- 612 mm (2012), Average- 562mm	Min.- 607 mm (2015), Max.- 793 mm (2013), Average: 722 mm
Elevation (range)	316-870 m above mean sea level	316-870 m above mean sea level
Temperature (2011)	Min.- 3.3°C, Max.- 46.6° C	Min.- 3.3°C, Max.- 46.6°C
Topography	Mostly plains with some undulating areas	Mostly plains with some undulating areas
Major land cover/ use	Mainly crop fields and highly degraded scrub forests	Mainly crop fields and highly degraded scrub forests
Tehsils surveyed	Nasirabad, Kishangarh, Sarwar, Kekri and Bhinay	Malpura, Toda Raisingh, Devli (Tonk District)
Human population density (2011)	305/ km^2	198/ km^2
Livestock population density (2012)	232/ km^2	168/ km^2
Major livelihoods	Farming, animal husbandry and mining (minerals- feldspar, quartz, mica, limestone, marble and masonry stone)	Farming, animal husbandry and mining (minerals- feldspar, quartz, granite, silica, masonry stone and limestone.)
Major crops	Sorghum, wheat, maize, groundnut, pearl millet, bengal gram and green gram	Sorghum, wheat, maize, groundnut, pearl millet, bengal gram and green gram
Protected/ Conservation- Areas/ Important sites for conservation	Shokaliya closed area (17 km^2) – Established in 1980, with few patches of grasslands protected as reserve forests. More than 80 Great Indian Bustards (GIB) used to breed in crop fields in this landscape during 1980s' (Rahmani and Manakadan 1988), while lesser florican were reported to visit this area regularly during monsoon (Sankaran *et al.* 1992)	Grasslands (Bheed/Bir/Charagah) in Malpura Tehsil, Bisalpur Conservation Reserve- 48 km^2. Lesser floricans have been reported from Kurad and Lamba Harisingh villages in Malpura Tehsil (Bhardwaj et al. 2011)

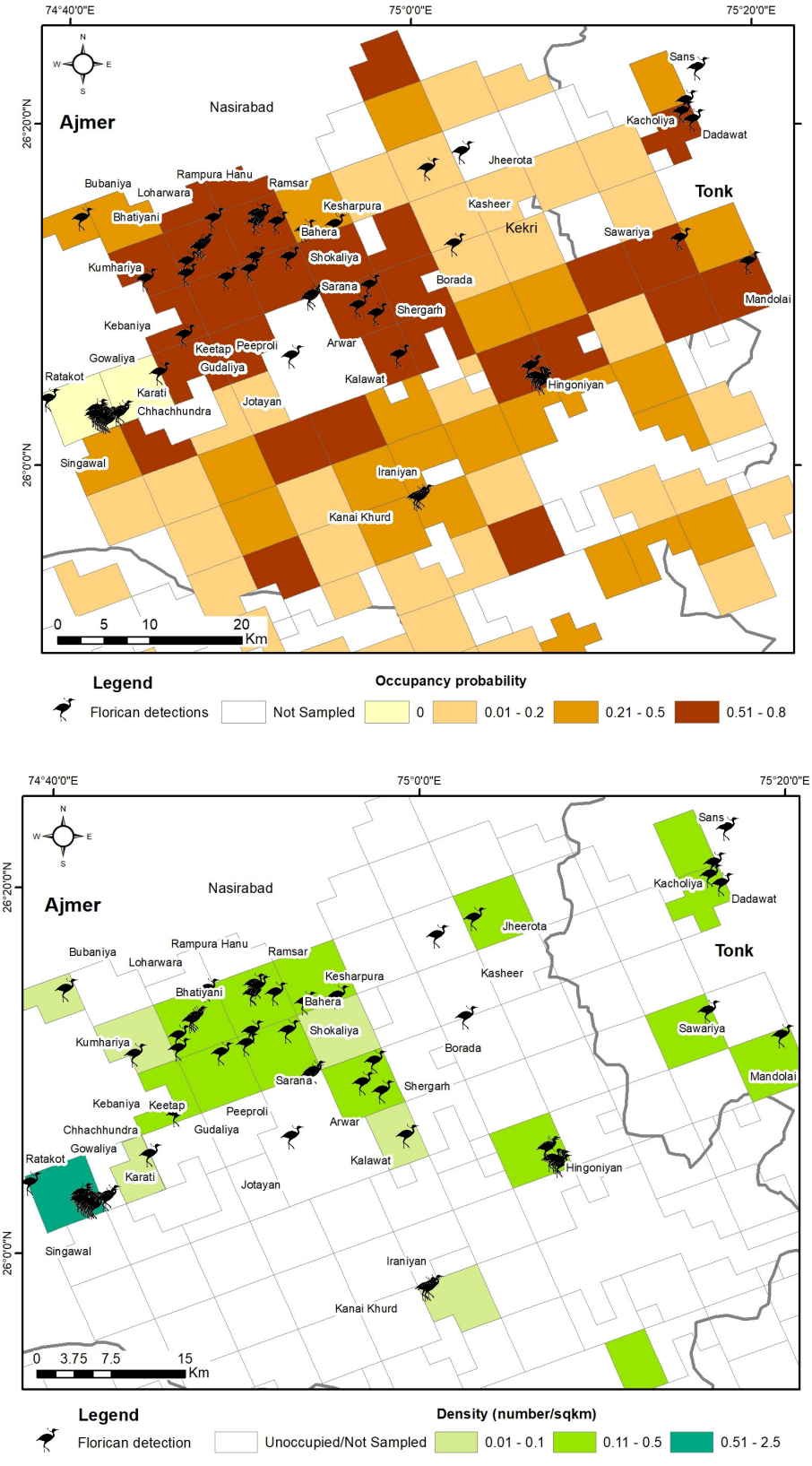


Figure 9: Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Ajmer region

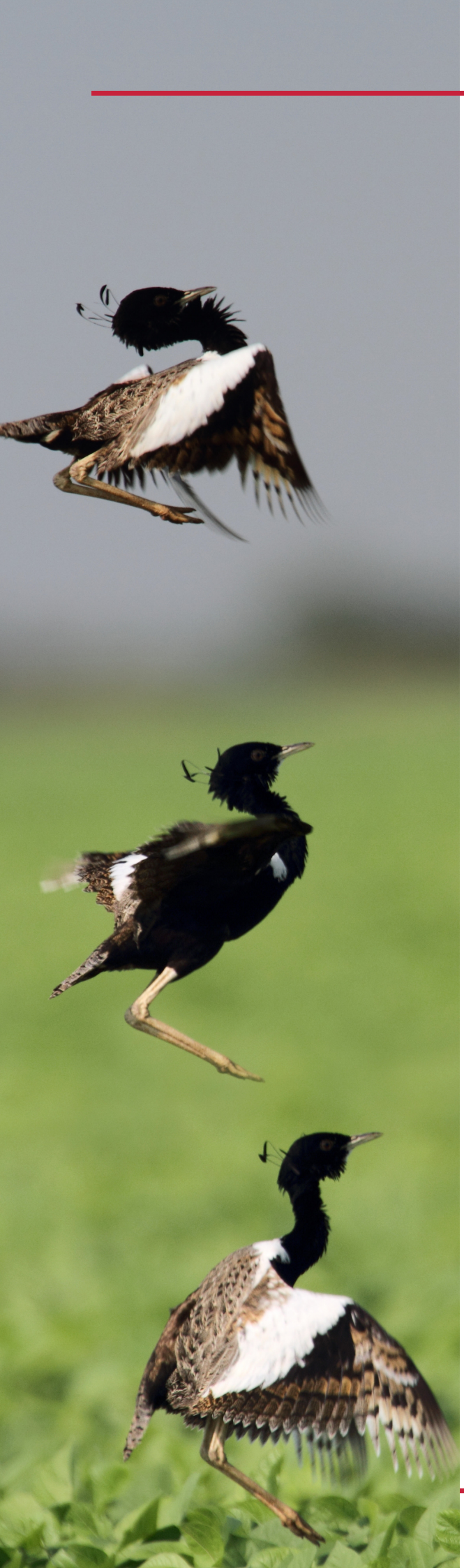
CONSERVATION RECOMMENDATIONS:

URGENT REQUIREMENT OF COMMUNITY CONSERVATION AREA

A strategy needs to be devised and implemented to deal with mining and protection of lesser floricans as well their habitat in Shokaliya landscape (Narwade et al. 2017). During the survey, mining activities were seen across this landscape, for major minerals such as feldspar, quartz, mica stone quarries, etc. as well as minor minerals such as marble and masonry stone, etc. A number of abandoned, non-functional and operational mines have resulted in disturbances and fragmentation of the area. We compiled location data of mines that were encountered during surveys, and additional information on the proposed mines were received through the Office of the Deputy Conservator of Forests (DCF), Ajmer as well as the reports of District Level Environment Impact Assessment Authority (DEIAA) and District Level Expert Appraisal Committee (DEAC). The existing and upcoming mining projects in Shokaliya landscape were mapped and overlaid on the lesser florican distribution maps for prioritizing projects that need to be mitigated (Table 7 and fig 10).

Except few Reserve Forests, there are no lesser florican Protected Areas in Shokaliya landscape. Therefore, we tried to identify potential areas that could be managed as lesser florican conservation areas (Fig 10). Restoration of all Reserve Forest patches to grasslands should be a long-term strategy in Nasirabad, Bhinay, Sarwar, Malpura, Kishangarh, Toda Raisingh and Kekri tehsils. Management of lesser florican conservation areas should be based on the following prescription.





1. Protection of lesser florican sites – All lesser florican distribution sites outside Protected Areas can be declared as Lesser florican community reserves, with small core areas of 100 ha and larger buffer area or Eco-Sensitive Zone (ESZ) of few square kilometres.

2. Special criteria to be adopted for lesser florican community reserves-

a. Ownership of the land will remain with the people except areas under control of the Forest Department

b. Small core areas should be given full protection, especially during breeding season of lesser floricans

c. Sustainable/ traditional agriculture practices should be promoted in buffer areas

d. Regulation in buffer zone for habitat alteration, mining, industrialization and establishment of non-renewable energy projects and installation of power lines

3. Promotion of lesser florican friendly agricultural practices - Since, majority of the lesser floricans are found breeding in crop fields, there is need to promote lesser florican friendly agricultural practices. Lesser florican recovery programme should have a component of sustainable agriculture scheme. Farmers, who get associated with the lesser florican friendly agricultural practices, can get training and certificate from concerned agencies for availing better market price for their crop yield.

4. Habitat restoration – Because of mismanagement, almost all grasslands under Reserve Forests have become unsuitable habitat for lesser floricans, and need to be immediately restored by removing the plantations of invasive *Prosopis juliflora.*

5. Rotational grazing – To avoid overgrazing by livestock, some of the plots can be managed by rotational grazing

Table 7: List of mines in Shokaliya landscape

S. No.	Mine Lease No.	Village	Tehsil	Latitude	Longitude
DEAC DEIAA mines					
1	6|99	Shokaliya	Sarvar	26°14'42"	74°50'20"
2	24|09	Derathu	Nasirabad	26°17'15"	74°46'00"
3	9|92	Bhudwasa	Nasirabad	26°10'55"	74°44'00"
4	10|09	Rambadi	Nasirabad	26°20'10"	74°53'28"
5	41|06	Chat	Nasirabad	26°14'40"	74°44'40"
6	25|95	Loharwada	Nasirabad	26°14'31"	74°46'30"
7	211|05	Ramsar	Nasirabad	26°14'10"	74°50'55"
8	48|05	Ramsar	Nasirabad	26°14'1"	74°50'35"
9	1|96	Ramsar	Nasirabad	26°14'3"	74°50'30"
10	41|09	Loharwada	Nasirabad	26°15'52"	74°47'27"
11	88|09	Sanod	Nasirabad	26°17'30"	74°48'04"
12	22|96 R	Shokaliya	Sarwar	26°12'15"	74°50'32"
13	86|11	Bhatiyani	Nasirabad	26°13'35"	74°44'40"
14	73|01	Sarana	Sarwar	26°16'15"	74°54'15"
15	139|08	Ramsar	Nasirabad	26°15'23"	74°52'10"
16	109|11	Mavasiya	Nasirabad	26°16'47"	74°55'45"
17	9|99	Derathu	Nasirabad	26°15'55"	74°45'8"
18	156|07	Ramsar	Nasirabad	26°18'40"	74°52'20"
19	9|01	Sarana	Sarwar	26°10'35"	74°53'20"
SEIAA mines					
20	3|05	Sarana	Sarwar	26°8'30"	74°50'30"
21	24|99	Piproli	Sarwar	26°11'50"	74°50'00"
22	445|05	Sanod	Nasirabad	26°17'8"	74°48'27"
23	6|92	Saneed	Nasirabad	26°18'35"	74°48'50"
24	184|07	Chat	Nasirabad	26°14'20"	74°44'50"
25	5|96	Sanod	Nasirabad	26°17'40"	74°48'30"
26	1|96	Ramsar	Nasirabad	26°14'35"	74°50'30"
27	47|2000	Sanod	Nasirabad	26°17'27"	74°49'00"
28	352|08	Rampura	Nasirabad	26°13'45"	74°47'45"
29	347|08	Rampura	Nasirabad	26°13'45"	74°47'45"
DEIAA mines					
30	75|02	Bhagwantpura	Sarwar	26°13'7"	74°55'47"
31	48|07	Bavdi	Sarwar	26°12'25"	74°56'15"
32	321|04	Kesarpura	Sarwar	26°9'42"	74°50'46"
33	549|05	Kesarpura	Sarwar	26°9'50"	74°51'4"
34	443|05	Lakshmipura	Nasirabad	26°15'05"	74°53'15"
35	85|11	Kesarpura	Nasirabad	26°14'45"	74°52'20"
Other mines					
36	31|97	Bavdi	Sarwar	26°12'15"	74°55'45"
37	16|93	Piproli	Sarwar	26°11'50"	74°50'20"
38	44|2000	Arwad	Sarwar	26°10'20"	74°55'10"
39	4|04	Kebaniya	Sarwar	26°11'00"	74°45'56"
40	316|05	Sanod	Nasirabad	26°16'42"	74°47'50"
41	2|91	Loharwada	Nasirabad	26°16'15"	74°47'50"
42	539|05	Ramsar	Nasirabad	26°15'00"	74°51'52"
43	52|08	Ramsar	Nasirabad	26°14'57"	74°51'42"
44	23|03	Bhatiyani	Nasirabad	26°12'45"	74°44'50"
45	245|06	Hanuliya	Nasirabad	26°11'55"	74°49'40"
46	309|08	Ramsar	Nasirabad	26°19'5"	74°53'30"
47	468|05	Derathu	Nasirabad	26°17'25"	74°46'55"
48	348|05	Rampura	Nasirabad	26°13'45"	74°47'45"
49	515|05	Bhudasa	Nasirabad	26°11'15"	74°43'12"
50	379|05	Bhudasa	Nasirabad	26°10'55"	74°43'20"
51	11|09	Rambadi	Nasirabad	26°20'00"	74°53'20"

Table 8 Areas proposed as lesser florican conservation reserve in Shokaliya landscape

S. No.	Villages falling under block	Area (in Ha)
1.	Sawaipura, Ratakot, Mathaniya	2090
2.	Gwaliya, Gopalpura	210
3.	Gopalpura	79
4.	Ratanpura	151
5.	Kebaniya	102
6.	Bhatiyani	219
7.	Loharwara	198
8.	Rampura Hanu, Jaswantpura, Hanwantiya	134
9.	Shokaliya, Kesharpura	136
10.	Kumaria Khdea, Kotdi	477
11.	Ganeshpura, Arwar, Sarana	400
	Total area	**4196**

Shokaliya and Kekri landscapes: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce nest/ chick predation	1. Removal of free-ranging dogs from lesser florican breeding sites 2. Sustained sterilization of dogs in villages around lesser florican breeding sites 3. Garbage management in villages around lesser florican breeding sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with “Swachh Bharat abhiyan”	Priority sites (map)	High / continuous	FD, HSI - WII	To improve recruitment rate of lesser florican population
Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	1. Satellite tracking of ~10 birds to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas and using bird diverters/ reflectors	Priority sites (map)	High / first 5 years	FD, BNHS, WII	To help reduce mortality of birds
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers.	Priority sites (map)	Medium / continuous	FD, BNHS	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years. More sites could be added with additional information from successive surveys.
Grazing regulation in unprotected grasslands	Reduce/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	Restore grazing lands by removing invasive *Prosopis* and planting native grasses Develop community fodder farms or allow grazing in one-third of grazing lands while sparing the rest for lesser florican. Incentivize stall-feeding of livestock during monsoon	Priority sites (map)	Medium/ continuous	FD,BNHS, local people	To help increase herbaceous biomass in breeding sites, which is critical for lesser florican breeding. Provide fodder for livestock in the lean period (winter through summer)
Research and monitoring	**1. Satellite telemetry:** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology that are all poorly known. Also understand the impact of land-use change on lesser florican ecology 2. **Monitoring:** Distribution and population status assessment following the protocol demonstrated in this report	1. Necessary permissions from government agencies to procure tags, capture and tag birds. 2. Effects of agricultural intensification, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis. 3. Logistical support from government agencies to conduct surveys and collaborative efforts from all concerned agencies	All sites	High / first 5 years	WII,BNHS, FD	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	Priority sites (map)	Medium / continuous	WII,BNHS, FD	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	Veedis and grazing lands in all sites	High / first 5 years	FD, local people	To create more optimal habitats for lesser florican
Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	Focusing on existing and unprotected Lesser Florican breeding sites Reducing human disturbances, hunting and livestock grazing by patrolling in protected breeding sites	**Protection to marginal conservation areas** 1. Regulation of intensive land-uses (mining, salt pans, infrastructure) 2. Incentivizing local people for implementing lesser florican-friendly land-uses 3. Land ownership should remain with the people. **Minimizing disturbances to breeding birds** 1. Identifying and engaging poachers or other interested local people as protectors and forest watchers to create a parallel protection force for four months 2. Adequate training and logistic/fund support for patrolling staff 3. Deploy local villagers as 'Florican friends' during June-September (lesser florican breeding season)	Priority conservation sites (map)	Medium / continuous	FD, BNHS, local people	To balance livelihood concerns and lesser florican conservation. More sites could be added with additional information from successive surveys. Capacity building and involvement of local people in lesser florican conservation.
Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people 2. Identify and train local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not detrimental to conservation	Shokaliya	Medium / continuous	BNHS, FD, local people	To help improve local revenue and awareness about lesser florican
Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	Shokaliya, Sarana, Malpura, Kumhariya, Ratakot, Bhinai	Medium / continuous	FD, BNHS, local people	To help develop a pilot habitat model apart from a conservation area governed by local people

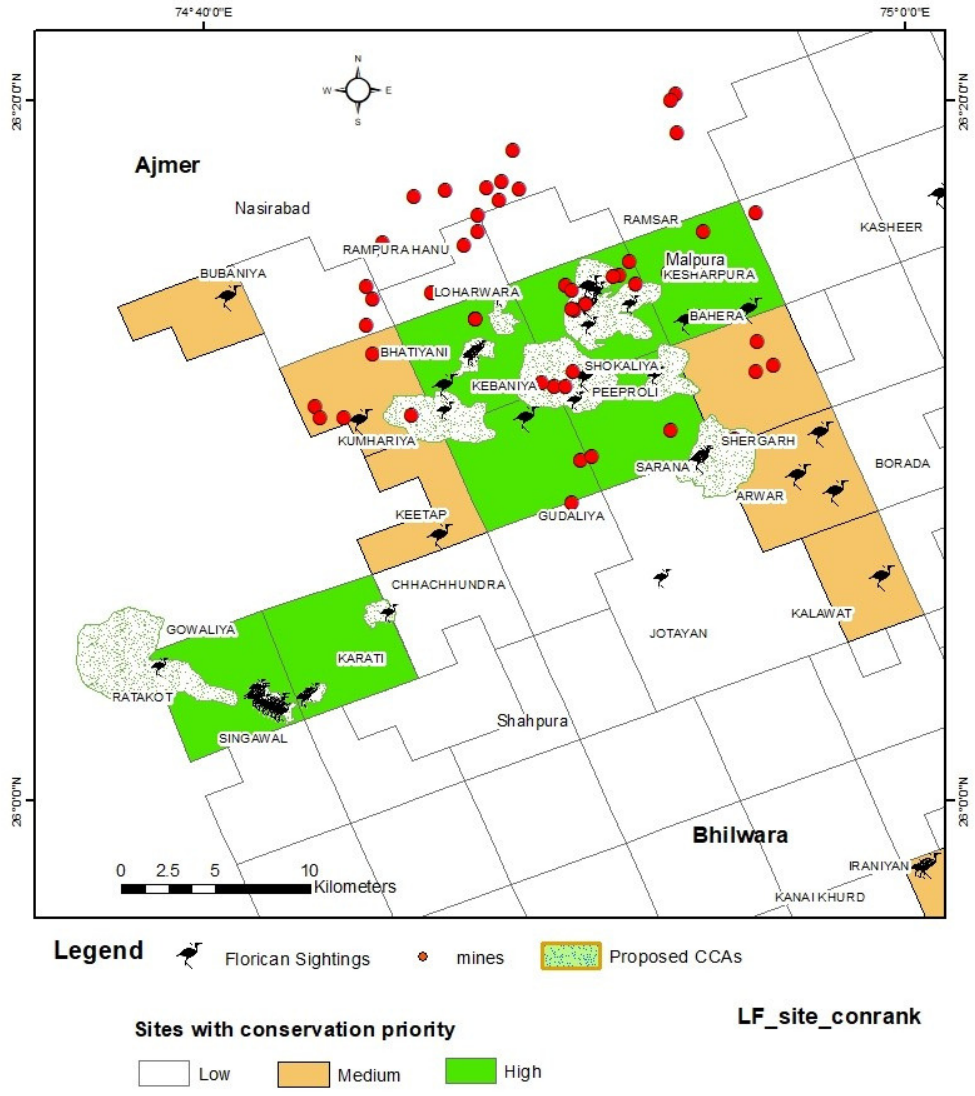


Figure 10: Locations of mines overlaid on priority conservation sites and lesser florican detections, and the proposed Community Conservation Areas (CCAs) in Shokaliya landscape of Ajmer region

5.2 Region: Rest of Rajasthan

5.2.1 SHAHPURA

Attribute	Details
District	Bhilwara
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern tropical dry deciduous forests (5B)
Annual rainfall (2012-16)	Min.- 548 mm (2015), Max.- 934 mm (2016), Average- 712 mm
Elevation (range)	305-822m above mean sea level
Temperature (2011)	Min- 2.3°C, Max- 45.8°C
Topography	Mostly open plains and some undulating areas
Major land cover/ use	Mainly crop fields and highly degraded scrub forests
Tehsils surveyed	Shahpura, Gulabpur, Jahazpur, Banera, Kotri (Bhilwara District)
Human population density (2011)	230/ km^2
Livestock population density (2012)	234/ km^2
Major livelihoods	Farming, animal husbandry and mining (minerals- feldspar, soapstone, Iron ore, mica, masonry stone, marble, granite)
Major crops	Sorghum, wheat, maize, groundnut, pearl millet, bengal gram, green gram and black gram
Protected/ Conservation-Areas/ Important sites for conservation	Grassland (Charagah/bheed/bir) near Bhatera village. Lesser floricans have been reported from Loolas/Kalsas, Shopura, Arni Ghoda, Khamora, and Mataji ka Kheda villages (Sankaran, 1999, Bhardwaj et al. 2011)

Shahpura landscape: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	1. Satellite tracking of ~10 birds to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas and using bird diverters/ reflectors	All breeding sites	High / first 5 years	FD, WII	To help reduce mortality of birds
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	Lachhman-pura, Amli Kaloosingh, Muhala, Bhatera villages	Medium / continuous	FD, BNHS	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years. More sites could be added with additional information from successive surveys.
Grazing regulation in unprotected grasslands	Reduce/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. c. Incentivized stall-feeding of livestock during monsoon	Lachhman-pura, Amli Kaloosingh, Muhala, Bhatera villages	Medium/ continuous	FD,BNHS, local people	To help increase herbaceous biomass in breeding sites, which is critical for lesser florican breeding. Provide fodder for livestock in the lean period (winter through summer)
Research and monitoring	**1. Satellite telemetry:** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology that are all poorly known. Also understand the impact of land-use change on lesser florican ecology 2. **Monitoring:** Distribution and population status assessment following the protocol demonstrated here	1. Necessary permissions from government agencies to procure tags and capture and tag birds. 2. Effects of agricultural intensification, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis. 3. Necessary permissions and logistical support from government agencies to conduct surveys and collaborative efforts from all concerned agencies	All sites	High / first 5 years	WII,BNHS, FD	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	Lachhman-pura, Amli Kaloosingh, Muhala, Bhatera villages	Medium / once every three years	WII,BNHS, FD	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	Veedis/beeds/ birs/charagah in all sites	High / first 5 years	FD, local people	To create more optimal habitats for lesser florican
Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	Lachhman-pura, Amli Kaloosingh, Muhala, Bhatera villages	Medium / continuous	FD, BNHS, local people	To help develop a pilot habitat model apart from a conservation area governed by local people

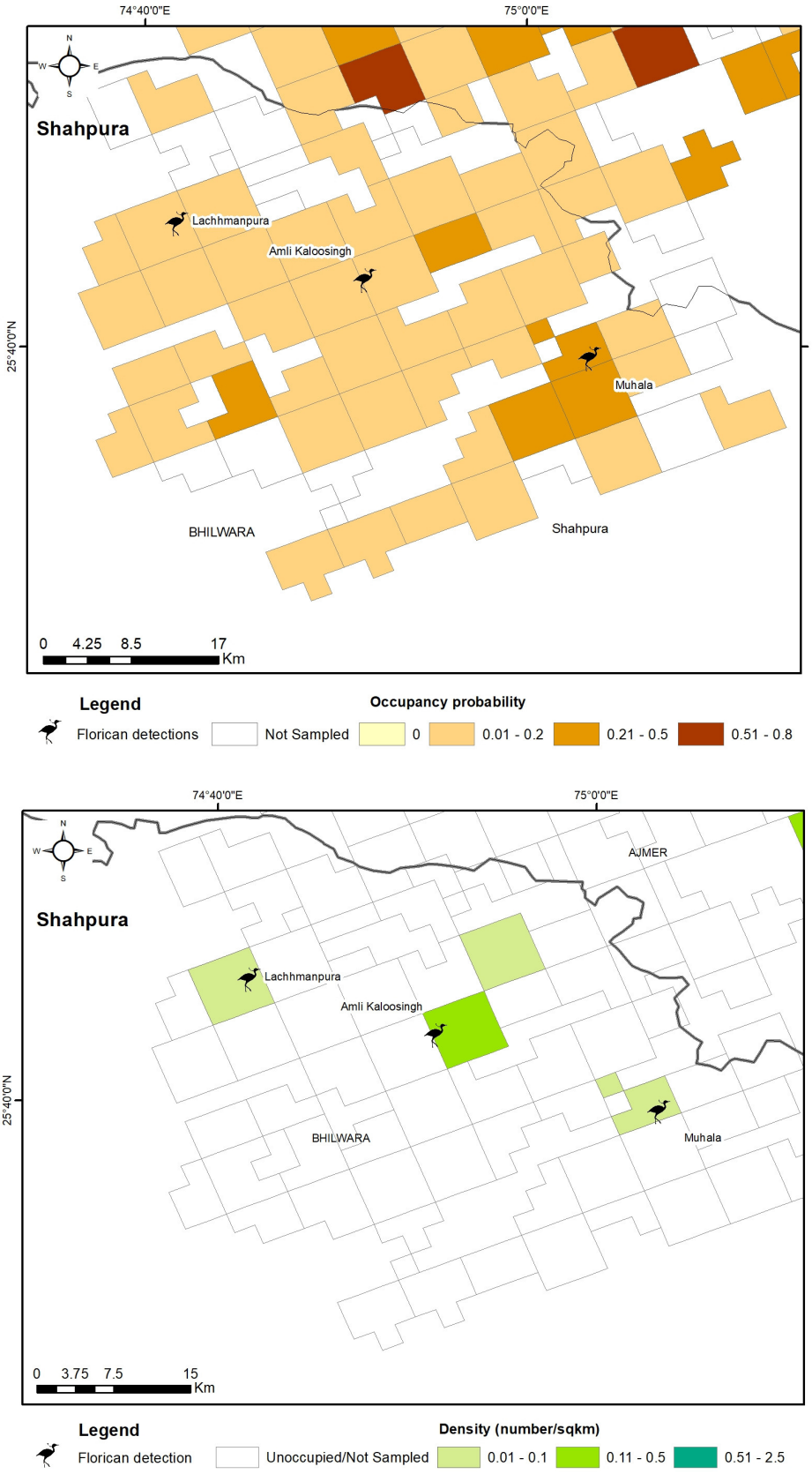


Figure 11: Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Shahpura landscape

5.2.2 JALORE

Attribute	Jalore	Sirohi	Pali
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern tropical dry deciduous forests (5B)	Northern tropical dry deciduous forests (5B)	Northern tropical dry deciduous forests (5B)
Annual rainfall (2012-16)	Min.- 283 mm (2012), Max.- 690 mm (2015), Average- 484 mm	Min.- 723 mm (2014), Max.- 1134 mm (2015), Average- 912 mm	Min.- 506 mm (2012), Max.- 882 mm (2016), Average- 607 mm
Elevation (range)	180-991m above mean sea level	184- 1722m above mean sea level	180-991m above mean sea level
Temperature (2011)	Min.- 5.6°C, Max.- 47.2 °C	Min.- -5.4°C, Max.- 47 °C	Min.- 1.8°C, Max.- 45.4 °C
Topography	Mostly open plains and some undulating areas	Open plains, undulating areas and hills	Undulating plains and scattered hills
Major land cover/ use	Mainly crop fields and highly degraded scrub forests	Mainly crop fields, dry deciduous and highly degraded scrub forests, pastures	Mainly crop fields, pastures, dry deciduous and highly degraded scrub forests
Tehsils surveyed	Jalore, Bhinmal, Ahor	Shivganj	Bali
Human population density (2011)	172/ km^2	202/ km^2	164/ km^2
Livestock population density (2012)	153/ km^2	175/ km^2	186/ km^2
Major livelihoods	Farming, animal husbandry and mining (minerals- fluorite, gypsum, masonry stone and granite)	Farming, animal husbandry and mining (minerals- limestone, marble, calcite, masonry stone, and granite)	Farming, animal husbandry, manufacturing and mining (minerals- - limestone, quartz, feldspar, masonry stone and granite)
Major crops	Sorghum, wheat, maize, groundnut, pearl millet, Bengal gram and green gram	Sorghum, wheat, maize, castor, pearl millet, sesame and green gram	Sorghum, wheat, maize, groundnut, pearl millet, green gram and sesame
Protected/ Conservation- Areas/ Important sites for conservation	Sundha Mata Conservation Reserve-117 km^2	Mount Abu Wildlife Sanctuary- 326 km^2	Lesser floricans were reported in 1996 from Boya, Birolia and Omkali villages (Vyas and Sharma 2013). Jawai Bandh Conservation Reserve- 19 km^2, Tadgarh Raoli Wildlife Sanctuary- 495 km^2, Kumbalgarh Wildlife Sanctuary - 608 km^2, Phulwari KI Nal Wildlife Sanctuary - 692 km^2

5.2.3 PRATAPGARH

Attribute	Details
District	Pratapgarh
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern tropical dry deciduous forests (5B)
Annual rainfall (2012-16)	Min.- 712 mm (2015), Max.- 1319 mm (2016), Average- 1022mm
Elevation (range)	180-991m above mean sea level
Temperature (2011)	Min.- 2.3°C, Max.- 45.8 °C
Topography	Mostly undulating with some open plains
Major land cover/ use	Mainly crop fields and highly degraded scrub forests
Tehsils surveyed	Pratapgarh
Human population density (2011)	195/ km^2
Livestock population density (2012)	172/ km^2
Major livelihoods	Farming, animal husbandry and mining (minerals- soapstone, red ochre, masonry stone, marble)
Major crops	Wheat, maize, soya bean, groundnut, red lentil and black gram
Protected/ Conservation- Areas/ Important sites for conservation	Lesser floricans were reported in 2008 from Ratniyakhedi, Kariabad, Siddhpura, Bajrangarh and Mowdikhera villages (Bhardwaj 2010). While, in the same landscape Sankaran (2000) counted 28 males in year 1999. Sita Mata Wildlife Sanctuary- 422 km^2

Pratapgarh and Jalore landscape: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce nest/ chick predation	1. Removal of free-ranging dogs from lesser florican breeding sites 2. Sustained sterilization of dogs from villages buffering lesser florican breeding sites 3. Garbage management in villages around lesser florican breeding sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with "Swachh Bharat Abhiyan"	Naulakha beed, Police line, Chiklad, Ratniya kheri (Pratapgarh)	High / continuous	FD, HSI, WII	To improve recruitment rate of lesser florican population
Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	1. Satellite tracking to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas and using bird diverters/ reflectors	Naulakha beed	High / continuous	FD, WII	Tol help reduce mortality of birds
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bio remedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	Bajrang garh, Peeplikhera (Pratapgarh)	Medium / continuous	FD, BNHS	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years
Grazing regulation in unprotected grasslands	Stop/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 3. Incentivized stall-feeding of livestock during monsoon	Naulakha beed	High / continuous	FD, BNHS	Tol help in increasing herbaceous biomass, which is critical for lesser florican breeding, and provide fodder for livestock in the lean period (winter through summer)
Research and monitoring	**Monitoring:** Distribution and population status assessment following the protocol demonstrated here	3. Necessary permissions and logistical support from government agencies to conduct surveys and collaborative efforts from all concerened agencies	Naulakha beed	High / continuous	FD, WII, BNHS	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	Pratapgarh, Pali and Jalore	Medium / continuous	FD, WII	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	Jalore, Pali	High / continuous	FD, Local people	Tocreate more optimal habitats for lesser florican
Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**Protection to marginal conservation areas** Focusing on existing and unprotected Lesser Florican breeding sites	1. Regulation of intensive land-uses (mining, salt pans, infrastructure, intensive farming) 2. Incentivizing local people for implementing Lesser Florican-friendly land-uses 3. Land ownership should remain with the people.	Naulakha beed of Pratapgarh	High / continuous	FD, Local people	To balance livelihood concerns and Lesser Florican conservation. Capacity building and involvement of local people in Lesser Florican conservation
Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people 2. Identify and train local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not detrimental to conservation	Pratapgarh	Medium / continuous	FD, BNHS, WII	To help improve local revenue and awareness about lesser florican
Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	Pratapgarh	High / continuous	FD, WII	To help develop a pilot habitat model apart from a conservation area governed by local people

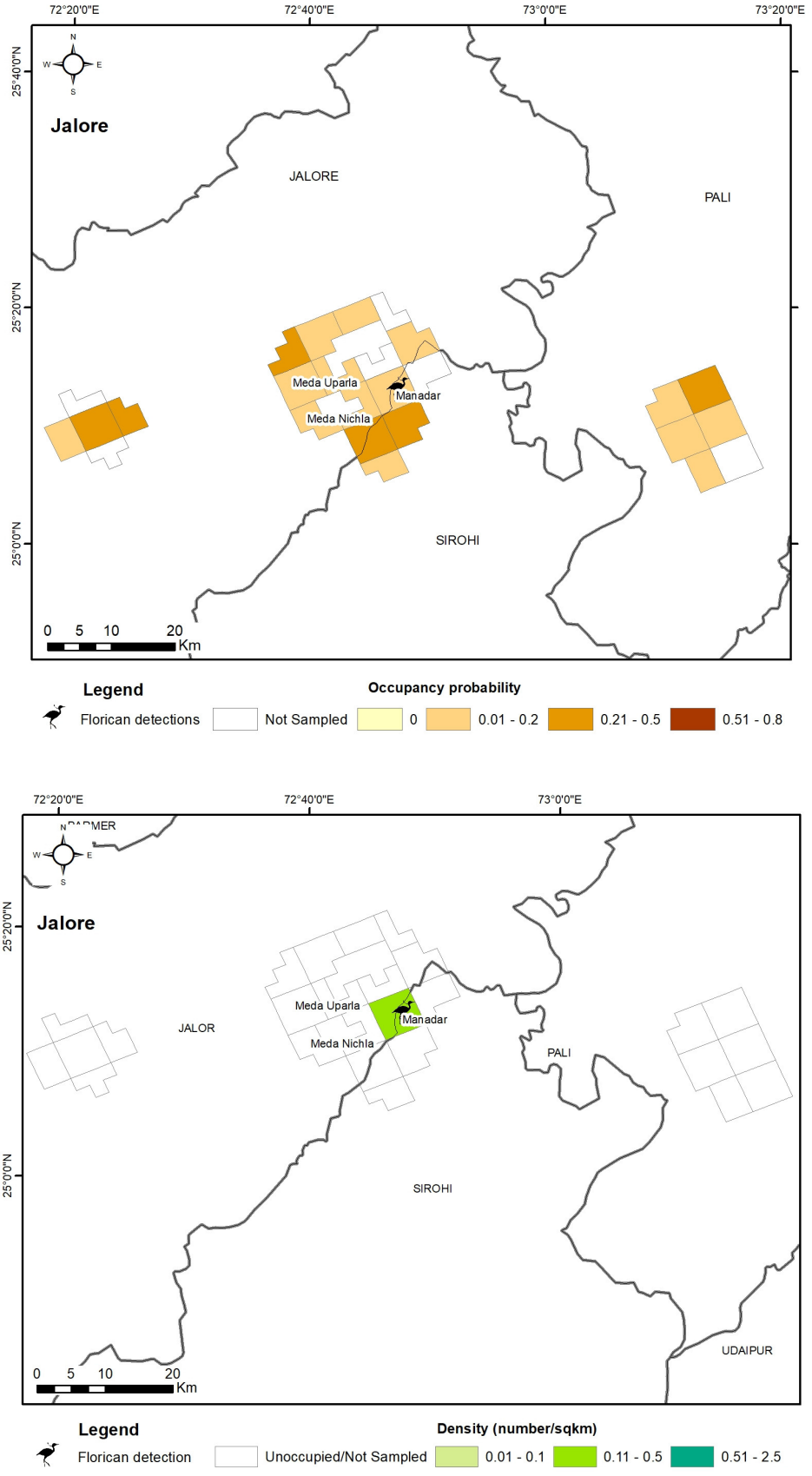
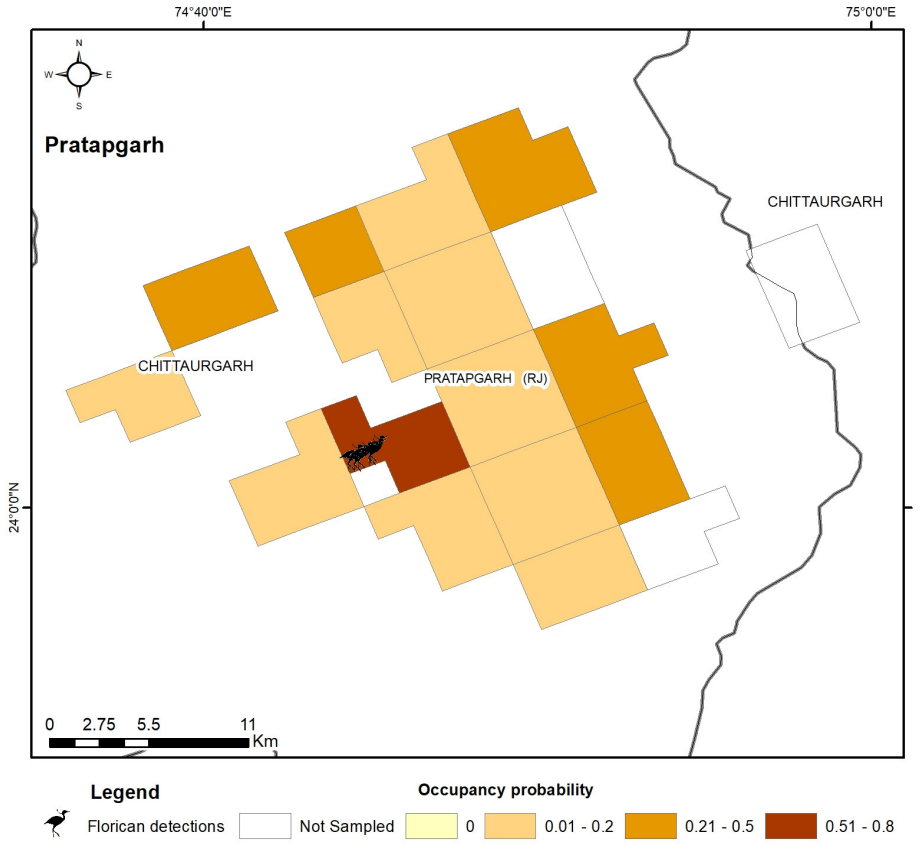


Figure 12: Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Jalore landscape



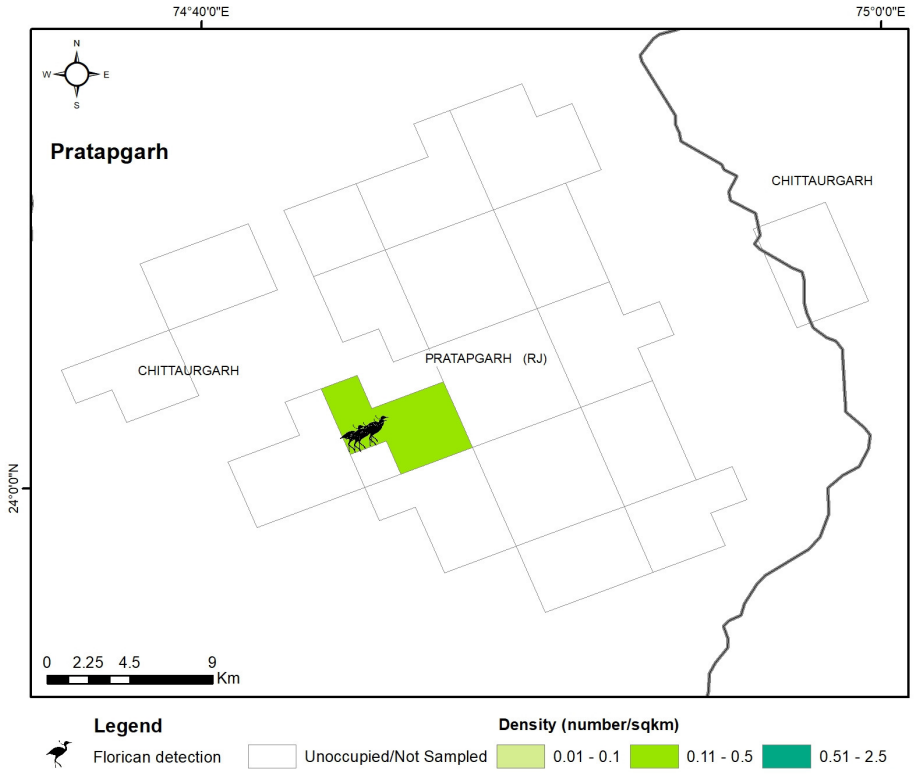


Figure 13 Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Pratapgarh landscape

5.3 GUJRAT

5.3.1 SAURASHTRA

Attribute	Bhavnagar	Amreli
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern Tropical Thorn Forest (6B)	Northern Tropical Thorn Forest (6B)
Annual rainfall (2012-16)	Min.- 382 mm (2012), Max.- 933 mm (2013), Average- 602 mm	Min.- 348 mm (2012), Max.- 901 mm (2013), Average- 651 mm
Elevation (range)	1-501m above mean sea level	5-649m above mean sea level
Temperature (2011)	Min.- 9.7°C, Max- 43.6 °C	Min.- 7.2°C, Max. -42.8 °C
Topography	Open plains and some undulating areas	Open plains, undulating areas and hills
Major land cover/ use	Mainly crop fields and highly degraded scrub forests	Mainly crop fields and highly degraded scrub forests
Tehsils surveyed	Bhavnagar, Ghogha, Vallabhipur, Talaja, Mahuva, Sihor, Palitana, Gariyadhar	Savar Kundla, Lilia, Kunkavav Vadia
Human population density (2011)	287/ km^2	205/ km^2
Livestock population density (2012)	119/ km^2	147/ km^2
Major livelihoods	Farming, animal husbandry, fisheries, manufacturing and mining (minerals- dolomite, lignite, masonry stone, moulding sand, salt)	Farming, animal husbandry, fisheries, manufacturing and mining (minerals- limestone, natural clay, marl)
Major crops	Cotton, wheat, maize, sesame, pearl millet, groundnut, sorghum, sugarcane	Cotton, wheat, pearl millet, groundnut, sugarcane, maize
Protected/ Conservation-Areas/ Important sites for conservation	Blackbuck National Park, Velavadar-34 km^2, Grass/grazing lands (*Vidi*s). In early 1990s, lesser floricans were recorded in almost all tehsils of Bhavnagar. Around 50-60 lesser florican males used to be seen till year 2000. In recent years, they are sighted only in and around Blackbuck National Park during monsoon.	Paniya Wildlife Sanctuary-39 km^2, Mithiyala Wildlife Sanctuary-18 km^2, Krakanch grassland- Lilia tehsil and Grass/grazing lands (*Vidi*s). Two male floricans have been reported from small grasslands patches of around 50 Ha area each near Manikpura and Nana Liliya villages.

Attribute	Surendranagar	Junagadh	Rajkot
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana,	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Northern Tropical Thorn Forest (6B)	Northern Tropical Thorn Forest (6B), Northern tropical dry deciduous forests (5B)	Northern Tropical Thorn Forest (6B)
Annual rainfall (2012-16)	Min.- 331 mm (2012), Max.- 672 mm (2013), Average- 453 mm	Min.- 430 mm (2012), Max.- 1192 mm (2013), Average- 810 mm	Min.- 341 mm (2012), Max.- 1028 mm (2013), Average- 609 mm
Elevation (range)	7-366 m above mean sea level	5-1174 m above mean sea level	1-314 m above mean sea level
Temperature (2011)	Min.- 11°C, Max.- 46 °C	Min.- 12°C, Max.- 39 °C	Min.- 7.5°C, Max.- 44.5 °C
Topography	Mostly open plains and some undulating areas	Open plains, undulating areas and hills	Open plains, undulating areas and hills
Major land cover/ use	Mainly crop fields, pastures and degraded scrub forests	Mainly crop fields, pastures and mixed deciduous forests	Mainly crop fields, pastures and scrub forests
Tehsils surveyed	Dhrangadra, Dasada, Wadhwan, Chotila, Lakthar	Visavadar, Bhesan	Rajkot, Jasdan, Kotda Sangani, Gondal, Wankaner, Jam Kandorna, Jetpur
Human population density (2011)	168/ km^2	311/ km^2	340/ km^2
Livestock population density (2012)	117/ km^2	139/ km^2	123/ km^2
Major livelihoods	Farming, animal husbandry, manufacturing and mining (minerals- silica sand, fireclay)	Farming, animal husbandry, fisheries, manufacturing and mining (minerals- limestone, natural clay)	Farming, animal husbandry, manufacturing and mining (minerals- fireclay, silica sand, limestone)
Major crops	Cotton, wheat, pearl millet, groundnut, sugarcane, sorghum	Cotton, wheat, pearl millet, groundnut, sugarcane, sorghum, mango	Cotton, wheat, pearl millet, groundnut, sugarcane, sorghum, mango
Protected/ Conservation-Areas/ Important sites for conservation	Wild ass Wildlife Sanctuary- 4953 km^2, Nalsarovar Wildlife Sanctuary-120 km^2, Vidis. Lesser floricans have been recorded from the fringe areas of LRK, *vidis* of Rajpara and Mandav, Anantpur areas which are privately managed.	Gir National Park-258 km^2, Gir Wildlife Sanctuary- 1153 km^2, Girnar Wildlife Sanctuary-178 km^2, Grasslands in Visavadar, Grass/grazing lands (*Vidi*s)	Wild ass Wildlife Sanctuary- 4,953 km^2, Rampura Vidi Wildlife Sanctuary- 15 km^2, Grass/grazing lands (*Vidi*s)

5.3.2 KUTCH

Attribute	Details
District	Kutch
Bio geographic zone	Desert (3B)- Katchchh
Vegetation	Northern Tropical Thorn Forest (6B)-Desert Thorn Forest (6B/C1)
Annual rainfall (2012-16)	Min.- 253 mm (2012), Max.- 652 mm (2013), Average- 395 mm
Elevation (range)	3-458 m above mean sea level
Temperature (2011)	Min.- 7.5°C, Max.- -45.6 °C
Topography	Mostly open plains
Major land cover/ use	Mainly crop fields, pastures and degraded scrub forests
Tehsils surveyed	Naliya, Mandvi
Human population density (2011)	46/ km^2
Livestock population density (2012)	42/ km^2
Major livelihoods	Farming, animal husbandry, fisheries, manufacturing and mining (minerals- lignite, clay, salt, limestone, laterite, bauxite)
Major crops	Cotton, wheat, pearl millet, groundnut, sorghum, green gram, fruits
Protected/ Conservation-Areas/ Important sites for conservation	Kutch bustard Sanctuary- 2 km^2, Kutch Desert Wildlife Sanctuary- 7506 km^2, Narayan Sarovar Wildlife Sanctuary- 442 km^2, Chharidhand Conservation Reserve-227 km^2, Banni grasslands. Lesser floricans are mainly seen in Kutch bustard Sanctuary, Naliya grasslands, Bhanada, Kunathiya, Vinga ber, Parjau, Nani Duphi, Bhachunda, Khirsara and adjoining areas of Abdasa. They are also seen in Dedhiya, Godhra, Layja and adjoining areas of Mandvi tehsil. These areas are also inhabited by GIB.

Saurashtra and Kutch landscape: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce nest/ chick predation	1. Removal of free-ranging dogs from lesser florican breeding sites 2. Sustained sterilization of dogs from villages buffering lesser florican breeding sites 3. Garbage management in villages around lesser florican breeding sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with Swachh Bharat Abhiyan	Great Indian Bustard (GIB) Core Area (100 sq km) in Kutch, Blackbuck National Park (BBNP) and villages of Bhal	High Priority, should be done in 2 years	FD, TCF, DNCS, WII, concerned Govt. Dept.	To improve recruitment rate of lesser florican population
Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	1. Satellite tracking to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas	Kutch, BBNP Velavadar Bhal area	High and continuous for 5 years	FD, WII, TCF, DNCS, FD, GETCO, Suzlon, concerned Govt. Dept	Tol help reduce mortality of birds
Develop Conservation Breeding Program	Develop a national conservation breeding center (CBC) with State Forest Depts., MoEFCC and scientific organization (WII / BNHS) as partners and international bustard breeders as collaborators	1. Signing of Memorandum of Understanding between partners 2. Permission to collect eggs and tag birds 3. Development of conservation breeding center 4. Execution of program following scientific protocol	Mandvi in Kutch and BBNP in Bhavnagar	High/ should be done within 1 year	WII, FD, TCF, DNCS	To secure an insurance population against imminent extinction risk
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	GIB Core area with ~40 villages in Abdasa, and BBNP & its surrounding villages in 20 km radius, in Bhavnagar	High/ continuous	TCF, FD, WII, DNCS,Local NGOs	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years
Grazing regulation in unprotected grasslands	Stop/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 3. Incentivized stall-feeding of livestock during monsoon	GIB Core area with ~40 villages in Abdasa, and BBNP & its surrounding vilages in 20 km radius, in Bhavnagar	Medium/ should be done in 3 years	FD,TCF, DNCS, Local NGOs, Panchayat, BMCs	Tol help in increasing herbaceous biomass, which is critical for lesser florican breeding, and provide fodder for livestock in the lean period (winter through summer)
Research and monitoring	**Satellite telemetry:** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology that are all poorly known. Also understand the impact of land-use change on lesser florican ecology **Monitoring:** Distribution and population status assessment following the protocol demonstrated here	1. Necessary permissions from government agencies to procure tags and capture and tag birds 2. Effects of agricultural intensification, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis. 3. Logistical support from government agencies to conduct surveys and collaborative efforts from all concerened agencies	Kutch & BBNP Velavadar	High/ Continuous	WII, FD, DNCS, TCF	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	GIB Core area with ~40 villages in Abdasa, and BBNP & its surrounding vilages in 20 km radius, in Bhavnagar	High/ continuous	TCF, DNCS, WII, FD, Local NGOs	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	GIB Core Area (100 sqkm) in Kutch, Blackbuck National Park (BBNP) and villages of Bhal	High/ continuous for 5 years	FD	To create more optimal habitats for lesser florican
Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**Protection to marginal conservation areas** Focusing on existing and unprotected Lesser Florican breeding sites **Preventing disturbances to breeding birds** Preventing human disturbances, hunting and livestock grazing by patrolling in PAs	1. Identification and transfer of Revenue Dept. lands that are important for lesser florican to Forest Department, to prevent encroachment. 2. Regulation of intensive land-uses (mining, salt pans, infrastructure, intensive farming) 3. Incentivizing local people for implementing lesser florican-friendly land-uses in their private lands protection force for four months 4. Adequate training and logistic/fund support 5. Identify and deploy local villagers as 'Florican friends' during June-September (lesser florican breeding season)	GIB Core area with about 40 villages in Abdasa Kutch, and in Bhavnagar BBNP & its surrounding vilages within 20 km radius	High and continuous, should be done in a year	FD, TCF, WII, DNCS and concerned Govt. Dept.	To balance livelihood concerns and lesser florican conservation. Capacity building and involvement of local people in Lesser Florican conservation
Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people 2. Identify and train local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not detrimental to conservation	Great Indian Bustard (GIB) Core Area (100 sqkm) in Kutch, Blackbuck National Park (BBNP) and villages of Bhal	Medium/ continuous	TCF, FD, DNCS, Local NGOs	To help improve local revenue and awareness about lesser florican
Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	GIB Core area with about 40 villages in Abdasa Kutch, and in Bhavnagar BBNP & its surrounding vilages within 20 km radius	High	TCF, FD, WII, DNCS, Local NGOs	To help develop a pilot habitat model apart from a conservation area governed by local people

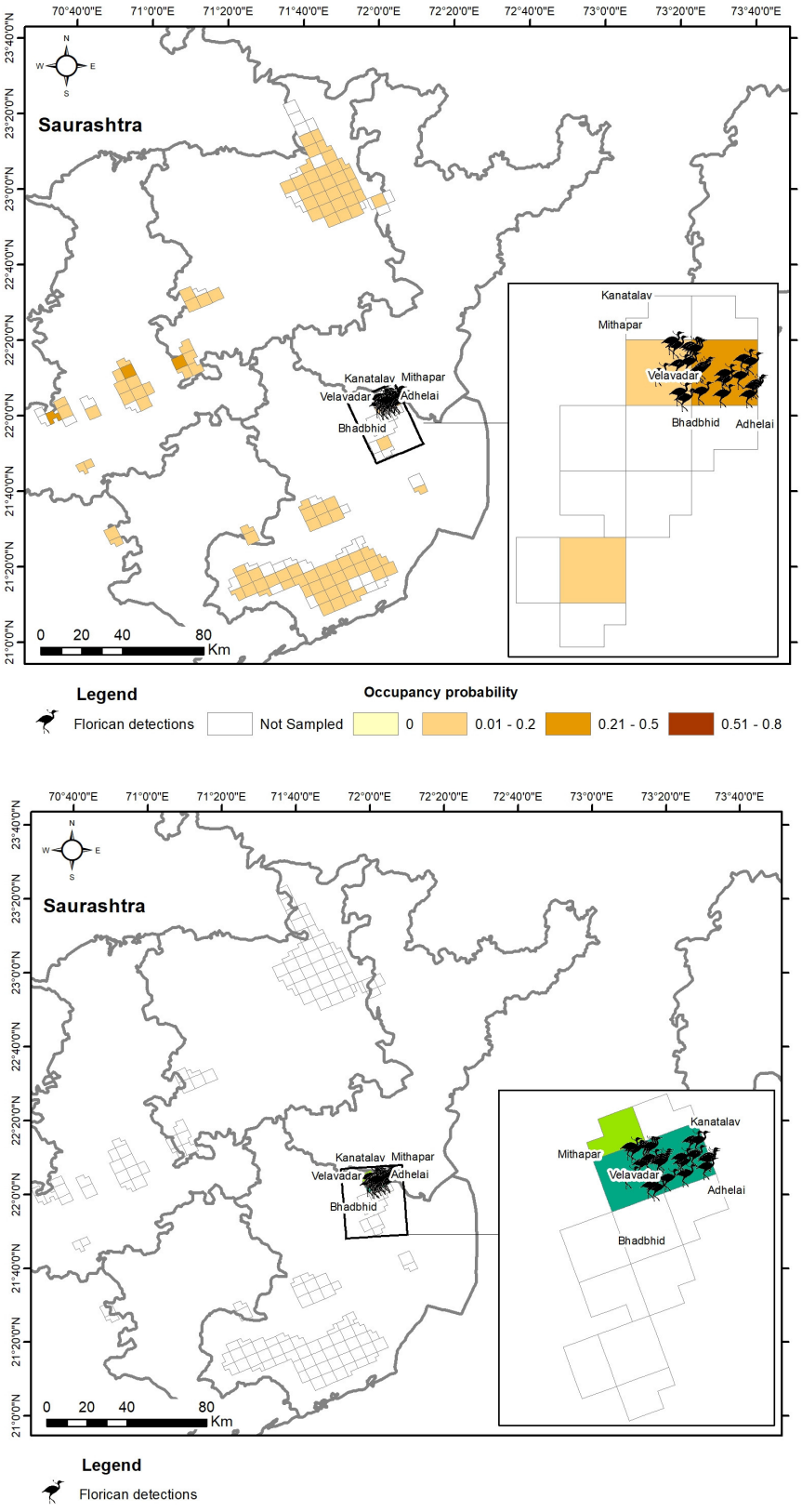


Figure 14 Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Saurashtra landscape

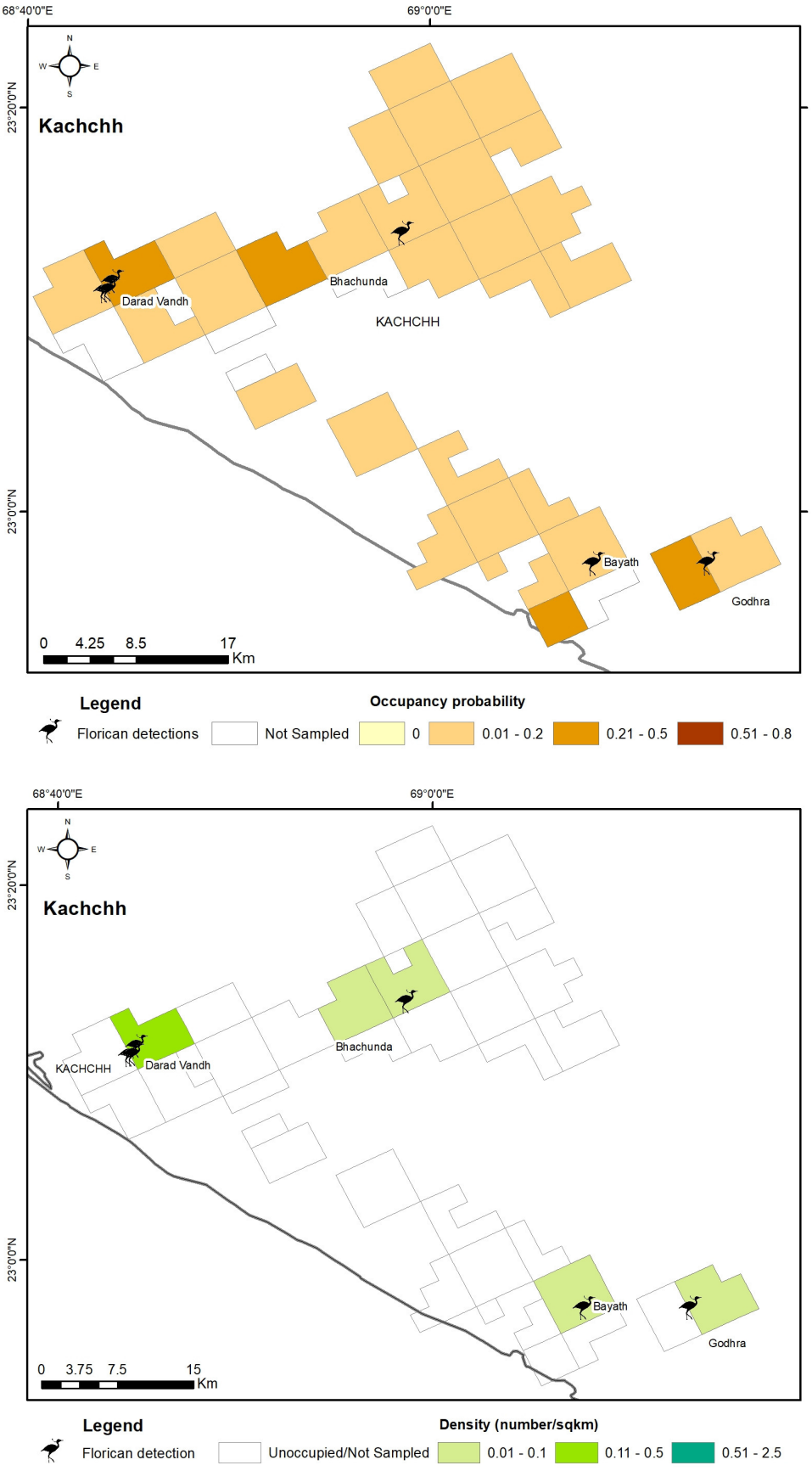


Figure 15: Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Kutch landscape

5.4 MADHYA PRADESH AND MAHARASHTRA

5.4.1. RATLAM – SADARPUR

Attribute	Ratlam (Madhya Pradesh)	Dhar (Madhya Pradesh)
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Southern tropical dry deciduous forests (5A)	Southern tropical dry deciduous forests (5A)
Annual rainfall (2012-16)	Min.- 614 mm (2014), Max.- 1354 mm (2016), Average- 1115 mm	Min.- 736 mm (2014), Max.- 1297 mm (2013), Average- 955 mm
Elevation (range)	305-640 m above mean sea level	150-751 m above mean sea level
Temperature (2011)	Min.-7.9°C, Max.- 42.4 °C	Min.-10°C, Max. -45.0 °C
Topography	Mostly open plains with some hilly areas	Mostly open plains with some hilly areas
Major land cover/ use	Mainly crop fields, forests and pastures	Mainly crop fields and forests
Tehsils surveyed	Sailana, Ratlam, Jaora	Sardarpur, Kukshi, Badnawar
Human population density (2011)	299/ km^2	268/ km^2
Livestock population density (2012)	144/ km^2	155/ km^2
Major livelihoods	Farming, animal husbandry, and manufacturing	Farming, animal husbandry, and manufacturing
Major crops	Wheat, maize, cotton, soya bean, opium	Wheat, soya bean, maize, cotton
Protected/ Conservation-Areas/ Important sites for conservation	Sailana Wildlife Sanctuary- 12.96 km^2, Jaora grasslands. Shikarwadi compartment comprises 354 ha area (grassland in 200 ha and remaining crop fields and grazing lands). Amba compartment is almost 1000 ha area. The area is known for the cyclic dry phases leading to fluctuation in of population of lesser floricans (Sankaran and Rahmani 1990, Sankaran 1991). In 2015, the lesser florican count was 20 birds which dropped to four in year 2016 and two in 2017.	Lesser florican Wildlife Sanctuary, Sardarpur - 348 km^2 with 628 hectares of grassland. In newly developed grassland area of Panpura plot (50 ha), a male lesser florican was sighted displaying during 2015 and 2016.

Attribute	Jhabua (Madhya Pradesh)	Dahod (Gujarat)
Bio geographic zone	Semi-arid (4B) Gujarat-Rajputana	Semi-arid (4B) Gujarat-Rajputana
Vegetation	Southern tropical dry deciduous forests (5A)	Southern tropical dry deciduous forests (5A)
Annual rainfall (2012-16)	Min.- 776 mm (2015), Max.- 1293 mm (2013), Average- 991 mm	Min.- 439 mm (2015), Max.- 802 mm (2013), Average- 663 mm
Elevation (range)	150-751 m above mean sea level	174-400 m above mean sea level
Temperature (2011)	Min.- 11.3°C, Max.- 39.5 °C	Min.- 4.1°C, Max.-43.0 °C
Topography	Mostly open plains with some hilly areas	Mostly open plains with some hills
Major land cover/ use	Mainly crop fields and forests	Mainly crop fields, forests and pastures
Tehsils surveyed	Jhabua, Petlawad, Thandla, Jobat	Dahod, Jhalod, Limkheda
Human density (2011)	285/ km^2	584/ km^2
Livestock density (2012)	217/ km^2	478/ km^2
Major livelihoods	Farming, animal husbandry, and fisheries	Farming, animal husbandry, and manufacturing
Major crops	Wheat, soya bean, maize, cotton, black gram	Paddy, wheat, groundnut, green gram, maize, soya bean, ginger
Protected/ Conservation- Areas/ Important sites for conservation	Petlawad Reserve Forest. Lesser florican presence has been reported from Ratamba forest patch since year 2011. This forest patch comprises 525 hectares of grassland, and the entire area is fenced to protect the birds from disturbance (Gadikar 2015). Lesser floricans are also sighted in Tarkhedi beat in Bani, Morjheria and Samarkundia villages.	Rampara Vidi (grassland) includes three protected grasslands of 1987.81 ha total area (a) Kali Talai (858.68 ha) b) Muvalia (750.43 ha), Razam (378.40 ha). Forest Department protect these grassland from late June to December., Ratanmahal WLS, Grass/grazing lands (*Vidis*).

Ratlam-Sadarpur landscape: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce nest/ chick predation	1. Removal of free-ranging dogs from lesser florican breeding sites 2. Sustained sterilization of dogs in villages around lesser florican breeding sites 3. Garbage management in villages around lesser florican breeding sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with Swachh Bharat Abhiyan	Sailana, Sardarpur, Petlawad	High / continuous	FD, HSI - WII	To improve recruitment rate of lesser florican population
Reduce mortality factors for adult birds	1. Identify and characterize fatal threats (e.g. wind turbines and power lines) in breeding habitats 2. Develop effective mitigation measures to reduce these threats	1. Satellite tracking of ~2 birds to understand mortality factors 2. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 3. Undergrounding power lines in critical areas and using bird diverters/ reflectors.	Sailana	High / continuous	FD, WII	Securing rapidly declining population of Lesser Florican
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	Sailana, Sardarpur, Petlawad	Medium / continuous	FD, BNHS, BAIF Foundation	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years
Grazing regulation in unprotected grasslands	Stop/ partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a. Developing community fodder farms b. Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 3. Incentivized stall-feeding of livestock during monsoon	Sardarpur, Sailana	High / continuous	FD, BNHS, Samvedana, BAIF Foundation	To reduce egg trampling by cattle
Research and monitoring	**1. Satellite telemetry:** Satellite tracking of lesser florican to understand their movement patterns, critical nesting and non-breeding habitat requirements, and basic biology that are all poorly known. Also understand the impact of land-use change on lesser florican ecology 2. **Monitoring:** Distribution and population status assessment following the protocol demonstrated here	1. Necessary permissions from government agencies to procure tags and capture and tag birds. 2. Effects of agricultural intensification, new renewable energy projects, and habitat fragmentation due to industrialization on lesser florican need to be assessed through long-term research using land-cover change trend analysis. 3. Logistical support from government agencies to conduct surveys and collaborative efforts from all concerned agencies	Sailana, Sardarpur, Petlawad	High / continuous	WII, FD and other NGO's	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders	Sailana, Sardarpur, Petlawad	Medium / Continuous	WII, FD, BNHS	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	Sailana, Sardarpur, Petlawad	High / first 5 years	FD, local people	Tocreate more optimal habitats for lesser florican
Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**PA rationalization** Rationalization of boundaries of the Wildlife Sanctuaries (WLS) and defining the Eco-Sensitive Zone (ESZ) **Relief from crop-raiding** Compensation policy to be designed to address the issue of crop raiding by large herbivores like Nilgai **Protection to marginal conservation areas** Focusing on existing and unprotected Lesser Florican breeding sites **Preventing disturbances to breeding birds** Preventing human disturbances, hunting and livestock grazing by patrolling in PAs	There is need to take decision on revenue land inside Sanctuary areas and demarcation of the core areas Crop-raiding by nilgai and wild pigs, in/around PAs demarcated for lesser florican causes antagonism towards lesser florican conservation 1. Regulation of intensive land-uses (mining, infrastructure, intensive farming) 2. Incentivizing local people for implementing lesser florican-friendly land-uses 3. Land ownership should remain with the people. 1. Identifying and engaging poachers or other interested local people as protectors and forest watchers to create a parallel protection force for four months 2. Adequate training and logistic/fund support for the training 3. Deploy local villagers as 'Florican friends' during June-September (lesser florican breeding season)	Sailana WLS, Sardarpur WLS Shisa, Masa, Borgaon-Manju villages and adjoining areas Of Maharashtra	Medium / continuous	FD, BNHS, local people	To balance livelihood concerns and Lesser Florican conservation. Capacity building and involvement of local people in Lesser Florican conservation To secure safe breeding habitat for birds
Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people	Sailana, Petlawad	Medium / continuous	BNHS, FD, local people	To help improve local revenue and awareness about lesser florican

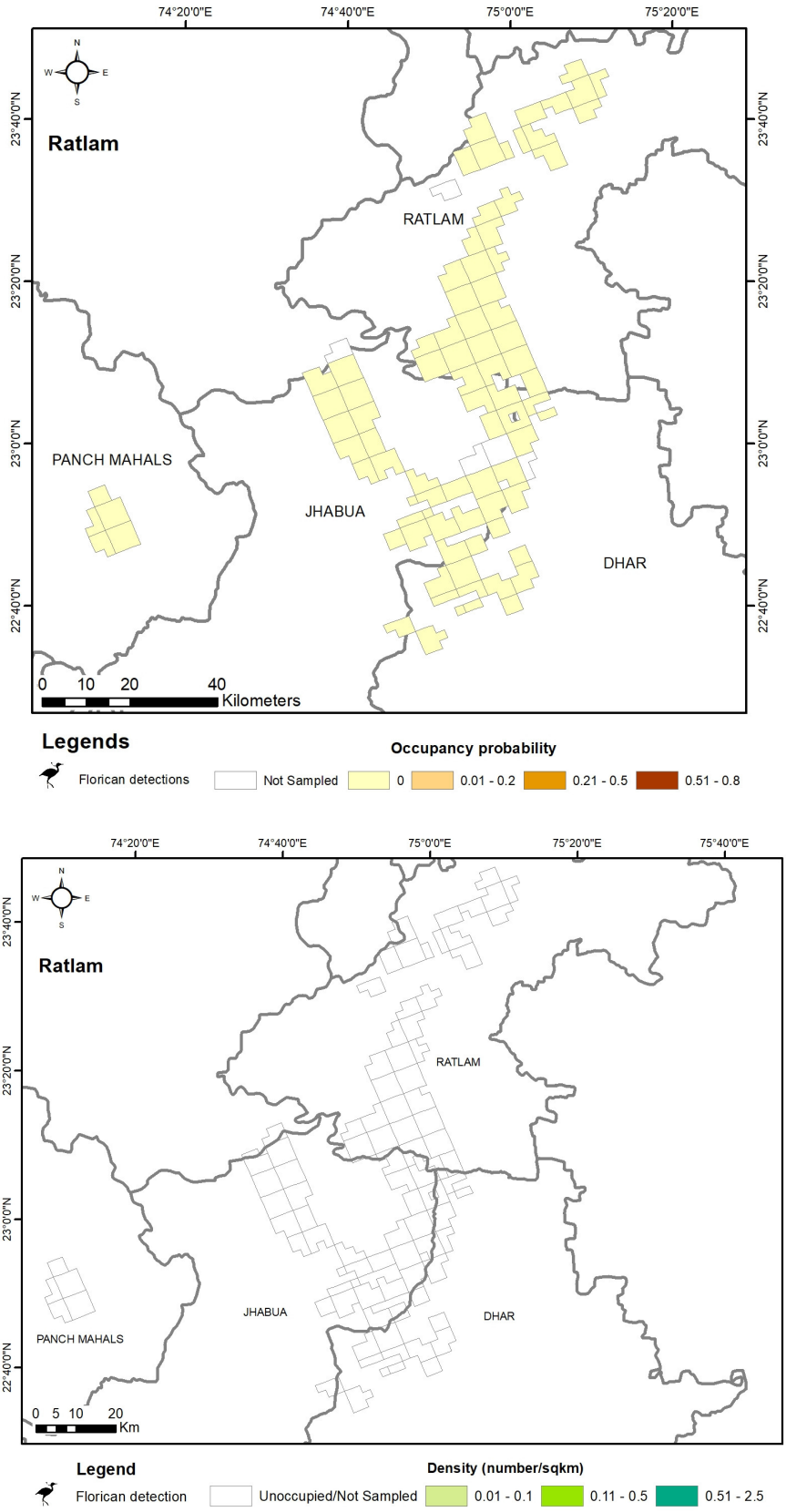


Figure 16: Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Madhya Pradesh region

Although our surveys did not detect florican in Madhya Pradesh, few birds were reportedly using the landscape (source: Ajay Gadikar)

5.4.2..AKOLA – WASHIM

Attribute	Akola	Washim	Yavatmal
Bio geographic zone	Deccan Peninsula (6D) Central Plateau	Deccan Peninsula (6D) Central Plateau	Deccan Peninsula (6D) Central Plateau
Vegetation	Southern Tropical Dry deciduous forests (5A)	Southern Tropical Dry deciduous forests (5A)	Southern Tropical Dry deciduous forests (5A)
Annual rainfall (2012-16)	Min.- 798 mm (2014), Max- 1335 mm (2013), Average- 929 mm	Min- 702 (2014), Max- 1330mm (2013), Average- 920 mm	Min.- 763 (2014), Max.- 1317mm (2013), Average- 953 mm
Elevation (range)	250-940 m above mean sea level	261-549 m above mean sea level	261-549 m above mean sea level
Temperature (2011)	Min.- 8.0°C, Max.- 48.0 °C	Min.- 8.0°C, Max.- 47.0 °C	Min.- 8.0°C, Max.- 47.0 °C
Topography	Mostly plains with some undulating areas	Mostly plains with some undulating areas	Mostly plains with some undulating areas
Major land cover/ use	Mainly crop fields, degraded forests and pastures	Mainly crop fields, degraded forests and pastures	Mainly crop fields, forests and pastures
Tehsils surveyed	Akola, Barshi Takali, Murtizapur	Washim, Karanja Lad	Darwha, Ner
Human population density (2011)	320/ km^2	244/ km^2	204/ km^2
Livestock population density (2012)	82/ km^2	94/ km^2	84/ km^2
Major livelihoods	Farming, animal husbandry, and manufacturing (cotton industry)	farming, animal husbandry, and manufacturing (cotton industry)	Farming, animal husbandry, mining (minerals- coal, limestone) and manufacturing (cotton industry)
Major crops	Cotton, wheat, sorghum, sugarcane, green gram, pigeon pea	Soya bean, cotton, wheat, green gram, pigeon pea, sorghum	Soya bean, cotton, wheat, green gram, pigeon pea, sorghum
Protected/ Conservation-Areas/ Important sites for conservation	Lesser florican has been reported from Borgao Manju (Kasambe & Gahale 2010). Grasslands near Shisa, Masa villages, Akola telsil and near Vadala village Barshi Takali tehsil. During 2016, 4-5 males were reported from this area. Katepurna Wildlife Sanctuary- 73 km^2, Narnala Wildlife Sanctuary- 12 km^2	Karanja Reserve Forest, Karanja Sohol Blackbuck Sanctuary- 18 km^2.	Lesser florican has been recorded from Darwha, in Yavatmal District (Kasambe & Gahale 2010) Reserve Forests in Ner and Darwha Tehsils, Tipeshwar Wildlife Sanctuary- 148 km^2, Painganga Wildlife Sanctuary- 324 km^2.

Akola – Washim landscape: conservation recommendations

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Reduce nest/ chick predation	1. Removal of free-ranging dogs from lesser florican breeding sites 2. Sustained sterilization of dogs in villages around lesser florican breeding sites 3. Garbage management in villages around lesser florican breeding sites	1. Awareness among local communities about issues/threats of free-ranging dogs 2. Collaboration with concerned agencies for removal and sterilization programs 3. Linking this programme with Swachh Bharat abhiyan	Shisa, Masa, Borgaon-Manju villages and adjoining areas	High / continuous	FD, HSI - WII	To improve recruitment rate of lesser florican population
Reduce mortality factors for adult birds	Develop effective mitigation measures to reduce these threats	1. Mapping of potential threats (e.g. power lines and wind turbines) and identifying mitigation areas 2. Undergrounding power lines in critical areas	Shisa, Masa, Borgaon-Manju villages and adjoining areas		WII, FD, BNHS	Securing rapidly declining population of lesser florican
Promote lesser florican friendly farming	Promotion of lesser florican-friendly agricultural practices, including sparing of grasslands between crop fields, mixed cropping of different heights, and replacement of pesticides and chemicals with bio-remedies	1.Collaboration/ engagement with farmers and agriculture department 2. Create awareness about health benefits of organic farming and provide alternate bioremedies 3. Marketing lesser florican-friendly crops at higher prices as an incentive to farmers	Florican distribution sites inTehsils Akola, Barshi Takali and Murtizapur and GIB Sanctuary, Solapur	Medium / continuous	FD, BNHS, Samvedana, BAIF Foundation	To balance livelihood concerns and lesser florican conservation. To ensure sustenance of program, land will be monitored for three years
Grazing regulation in unprotected grasslands	Stop / partition livestock grazing in non PA, private/village owned lesser florican breeding grasslands during June–September (breeding season) by encouraging herders to stall feed livestock through dialogue or legal restrictions	1. Engagement with grassland owners (individuals or village panchayats) to develop joint management plans that may include: a.) Developing community fodder farms b.) Allowing grazing in one-third of a grassland while sparing the rest for lesser florican. 2. Incentivized stall-feeding of livestock during monsoon	Florican distribution sites inTehsils Akola, Barshi Takali and Murtizapur and GIB Sanctuary, Solapur	High / continuous	FD, BNHS, Samvedana, BAIF Foundation	To reduce egg trampling by cattle
Research and monitoring	**Monitoring:** Distribution and population status assessment following the protocol demonstrated here	Necessary permissions and logistical support from government agencies to conduct surveys and collaborative efforts from all concerened agencies	Florican distribution sites inTehsils Akola, Barshi Takali and Murtizapur and GIB Sanctuary, Solapur	High / continuous	WII, FD, BNHS	To help develop effective conservation plans, refine population monitoring exercise, fill information gaps on non-breeding ecology and distribution, and prioritize conservation actions

Conservation action	Task	Requirement	Sites	Priority / process	Implementing agencies	Remarks
Create positive publicity for lesser florican conservation	Outreach programme for Forest Department staff, local communities and other stakeholders (Revenue, Agricultural & Veterinary Depts.) on the need and requirements for lesser florican conservation	1. Identification of stakeholders 2. Develop & disseminate outreach materials on ecological/conservation values of lesser florican and their habitats in vernacular languages 3. Conduct multiple stakeholder sensitization workshops 4. Arrange nature education programme	Florican distribution sites inTehsils Akola, Barshi Takali and Murtizapur and GIB Sanctuary, Solapur	Medium / once every alternate year	WII, BNHS, FD, Samvedana	To generate public support for lesser florican conservation
Habitat restoration	**Invasive weed management** Removal of *Prosopis juliflora* and other invasive plants from breeding sites	Collaborative implementation by Forest departments and concerned agencies	Newly developed florican grassland by Akola Division	High / first 5 years	FD, local people	To create more optimal habitats for lesser florican
Reduce public antagonism by integrating lesser florican conservation with local livelihood issues	**Relief from crop-raiding** Compensation policy to be designed to address the issue of crop raiding by large herbivores like Nilgai **Protection to marginal conservation areas** Focusing on existing and unprotected Lesser Florican breeding sites **Preventing disturbances to breeding birds** Preventing human disturbances, hunting and livestock grazing by patrolling in PAs	Crop-raiding by nilgai and wild pigs, in/around PAs demarcated for lesser florican causes antagonism towards lesser florican conservation 1. Regulation of intensive land-uses (mining, infrastructure, intensive farming) 2. Incentivizing local people for implementing lesser florican-friendly land-uses 3. Land ownership should remain with the people. 1. Identifying and engaging poachers or other interested local people as protectors and forest watchers to create a parallel protection force for four months 2. Adequate training and logistic/fund support for the training 3. Deploy local villagers as 'Florican friends' during June-September (lesser florican breeding season)	Florican distribution sites inTehsils Akola, Barshi Takali and Murtizapur Shisa, Masa, Borgaon-Manju villages and adjoining areas	Medium / continuous	FD, BNHS, local people, Samvedana	To balance livelihood concerns and Lesser Florican conservation. Capacity building and involvement of local people in Lesser Florican conservation, to secure safe breeding habitat for birds
Promote regulated lesser florican tourism	Regulated, ethical tourism can be promoted to generate alternate income for local livelihoods and increase the conservation support for lesser florican	1. Develop guidelines of eco-tourism that does not disturb breeding birds and generate income for local people 2. Identify and train local people interested in this alternate livelihood and develop required facilities 3. Implement in collaboration with Forest Department to ensure that tourism is not detrimental to conservation	Shisa, Masa, Borgaon-Manju villages and adjoining areas	Medium / continuous	BNHS, FD, Samvedana, local people	To help improve local revenue and awareness about lesser florican
Developing Community Conservation Areas (CCAs)	Developing an organizational structure for Community Conservation Areas	1. High intensity of engagement, first 2 years 2. Handholding for institutionalization of the programme	Shisa, Masa, Borgaon-Manju villages and adjoining areas	High / continuous	BNHS, FD, local people	To help developp a pilot habitat model apart from a conservation area governed by local people

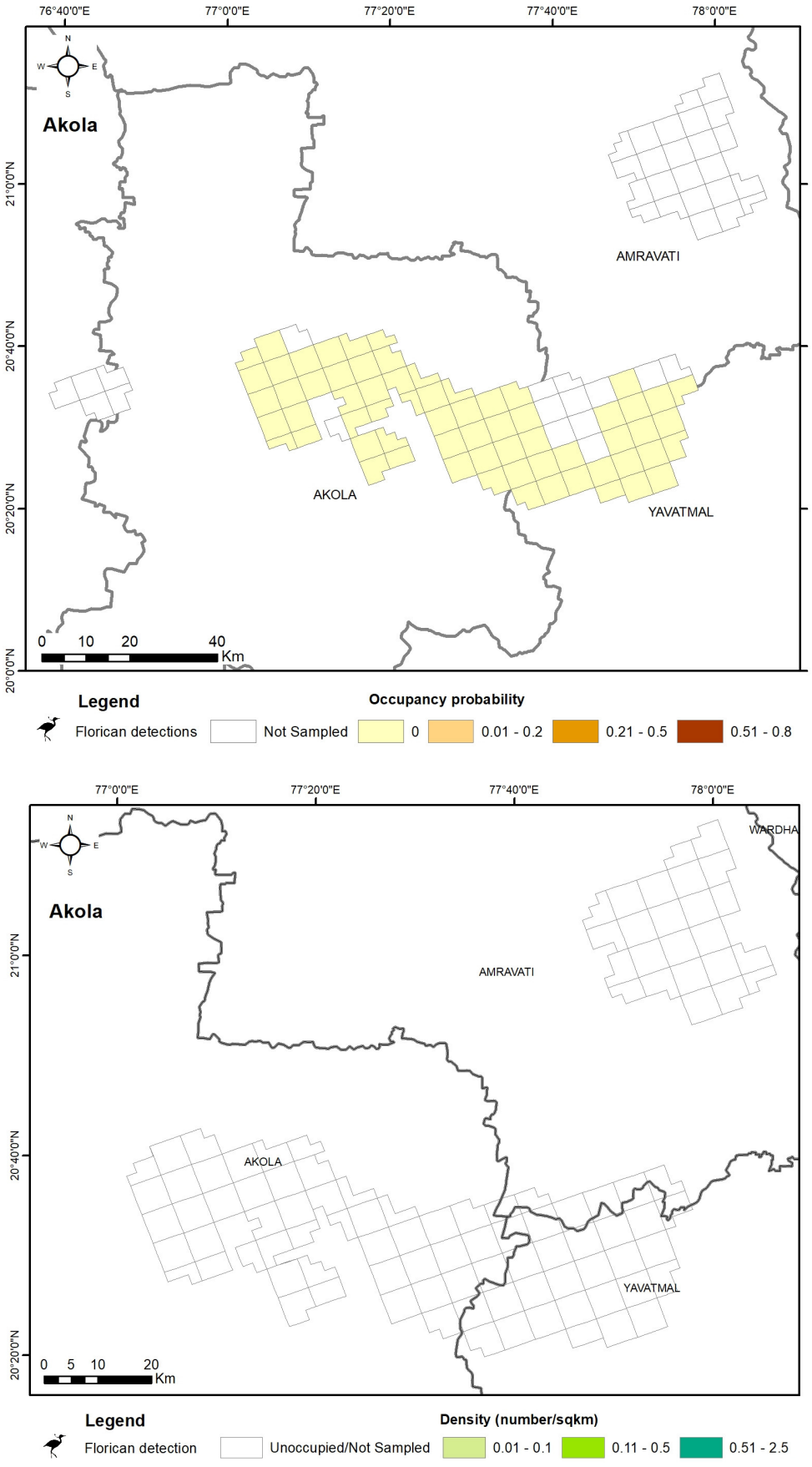


Figure 17 Predicted occupancy probability (top) and density (bottom) along with detections of lesser florican in sites (36 sq km cells) across Maharashtra region

Although our surveys did not detect florican in Maharashtra, some birds were reportedly using the landscape (source: Kaustubh Pandharipande)

APPENDICES

APPENDIX I - MAPS OF PROTECTED AREAS WHERE LESSER FLORICAN OCCUR

Gujarat



Image 3: Blackbuck National Park, Velavdar, Bhavnagar, Gujarat



Image 4: Kutch bustard Sanctuary, Lala, Kutch, Gujarat

Madhya Pradesh

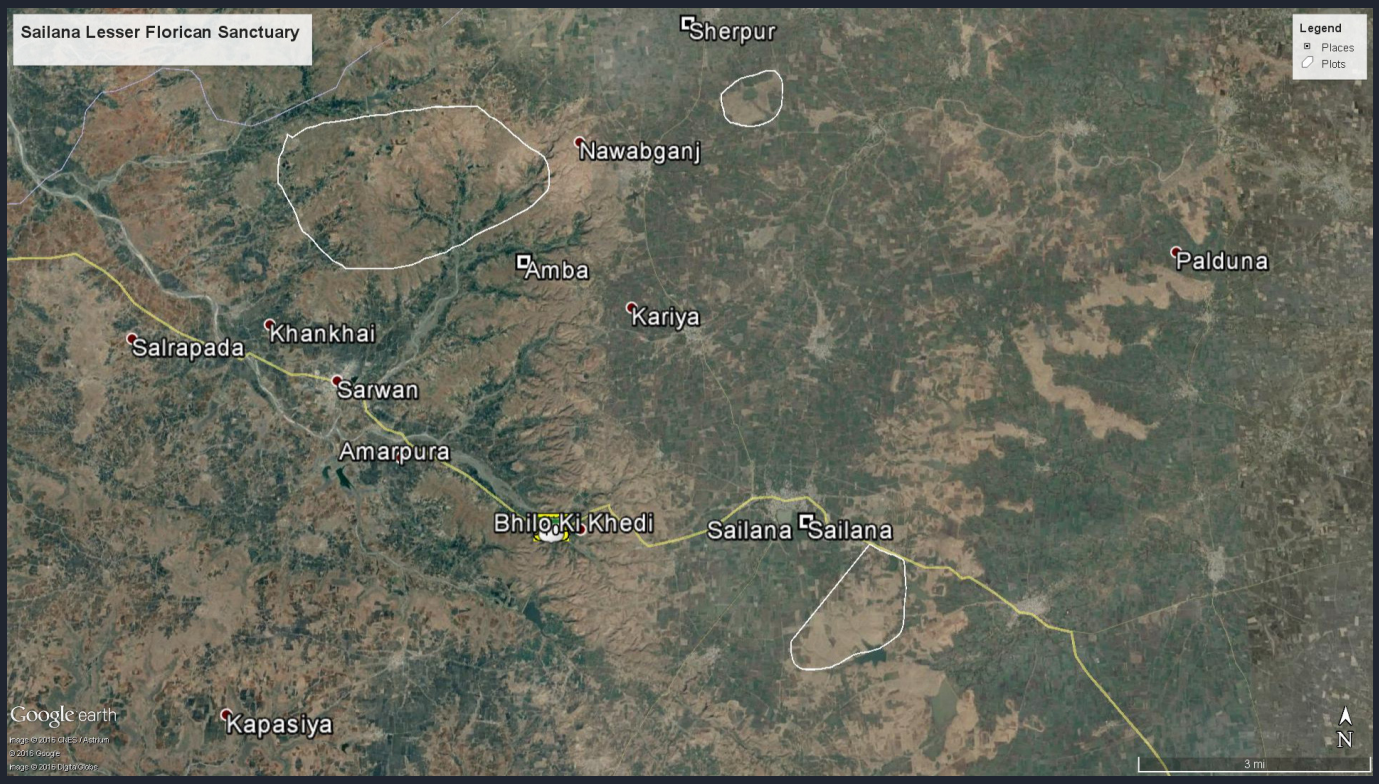


Image 5: Important breeding sites of lesser florican in Sailana WLS, Ratlam, Madhya Pradesh

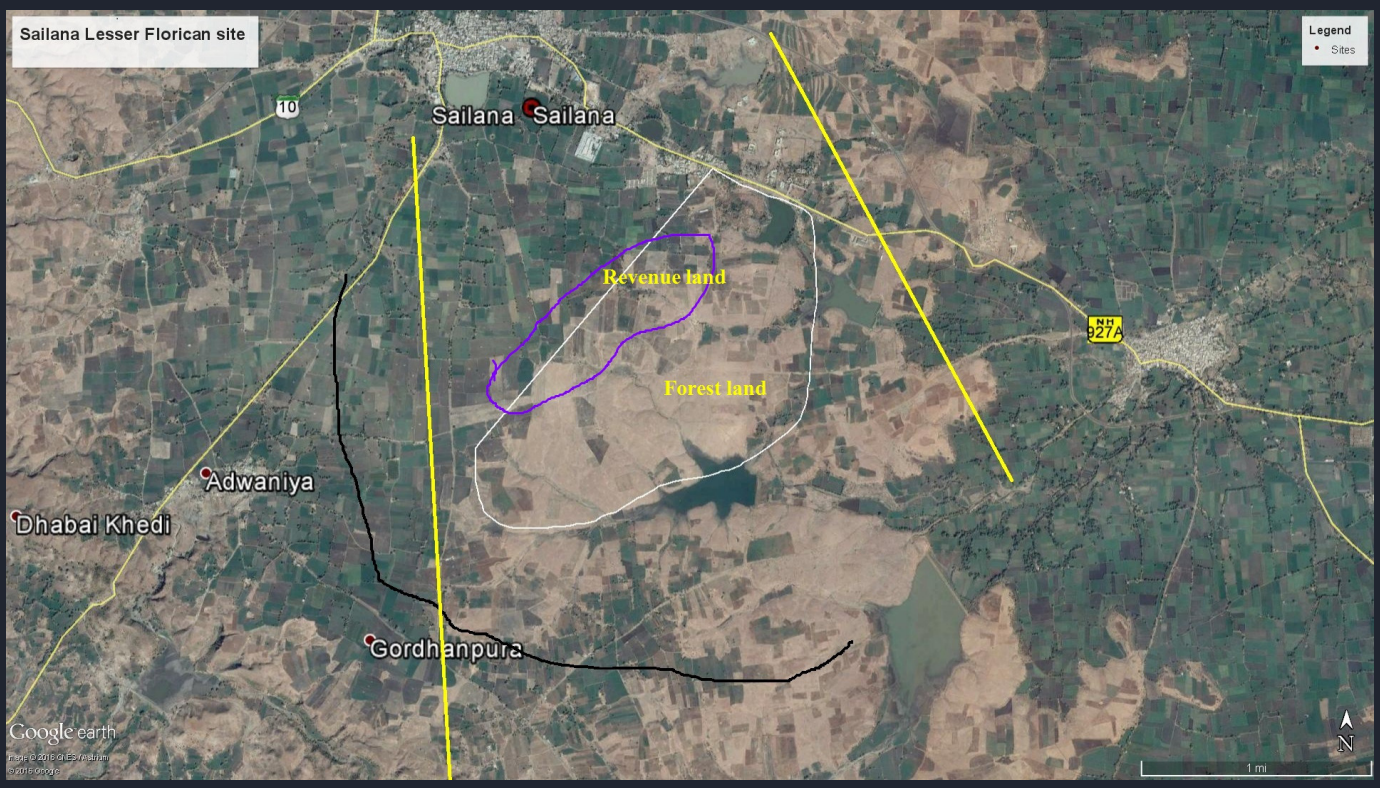


Image 6: Shikarwadi core area (black: wind turbines, yellow: high tension power lines) in Sailana WLS, , Ratlam, Madhya Pradesh

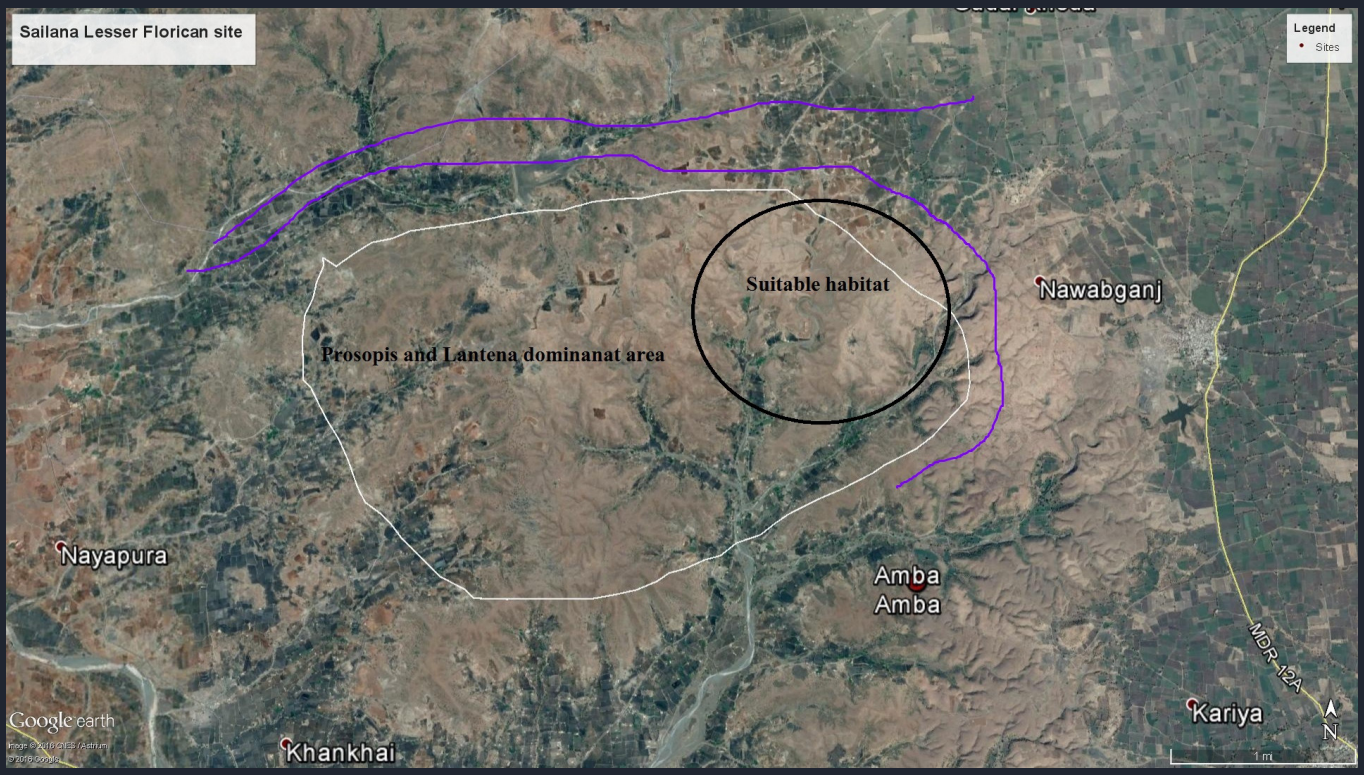


Image 7: Amba lesser florican site (black boundary: suitable habitat, purple lines: wind turbine areas) in Ratlam, Madhya Pradesh

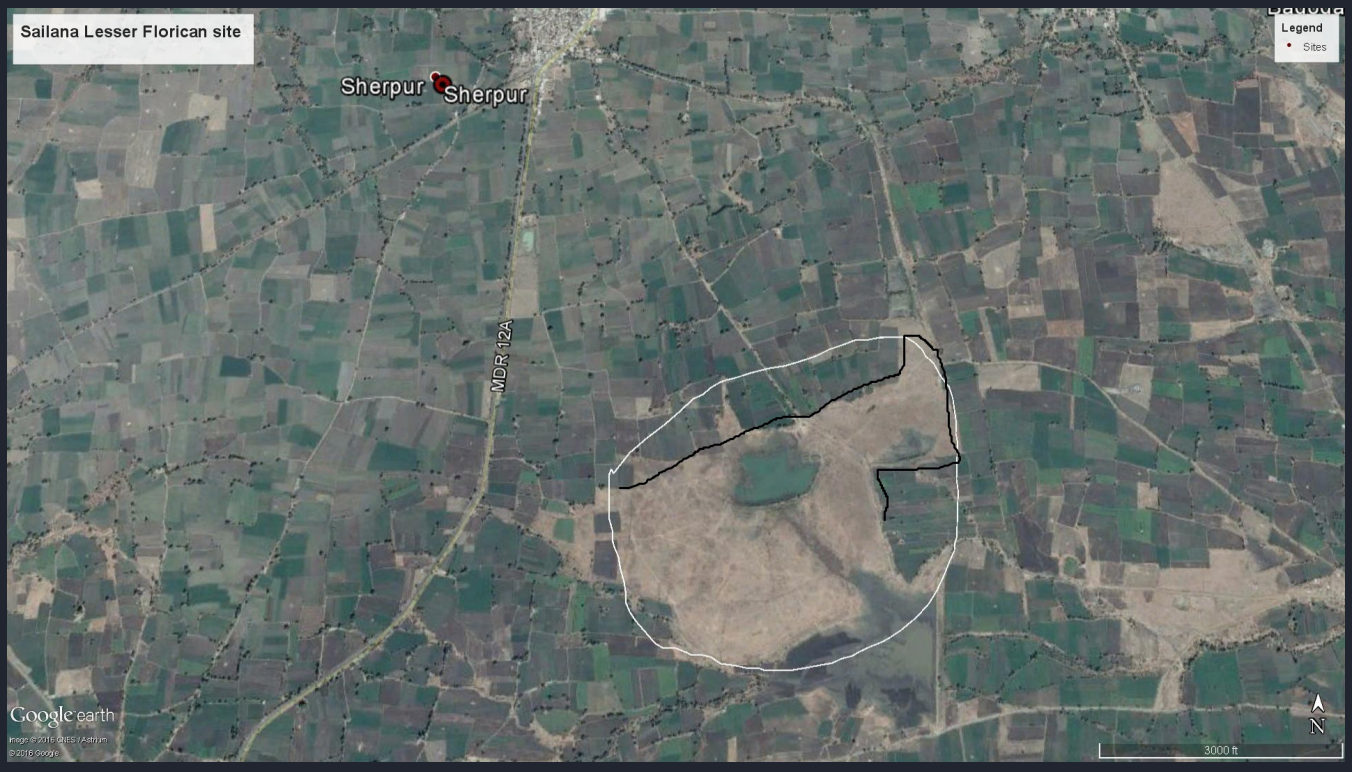


Image 8: Sherpur lesser florican site with conservation exclosure of <100 ha in Ratlam, Madhya Pradesh

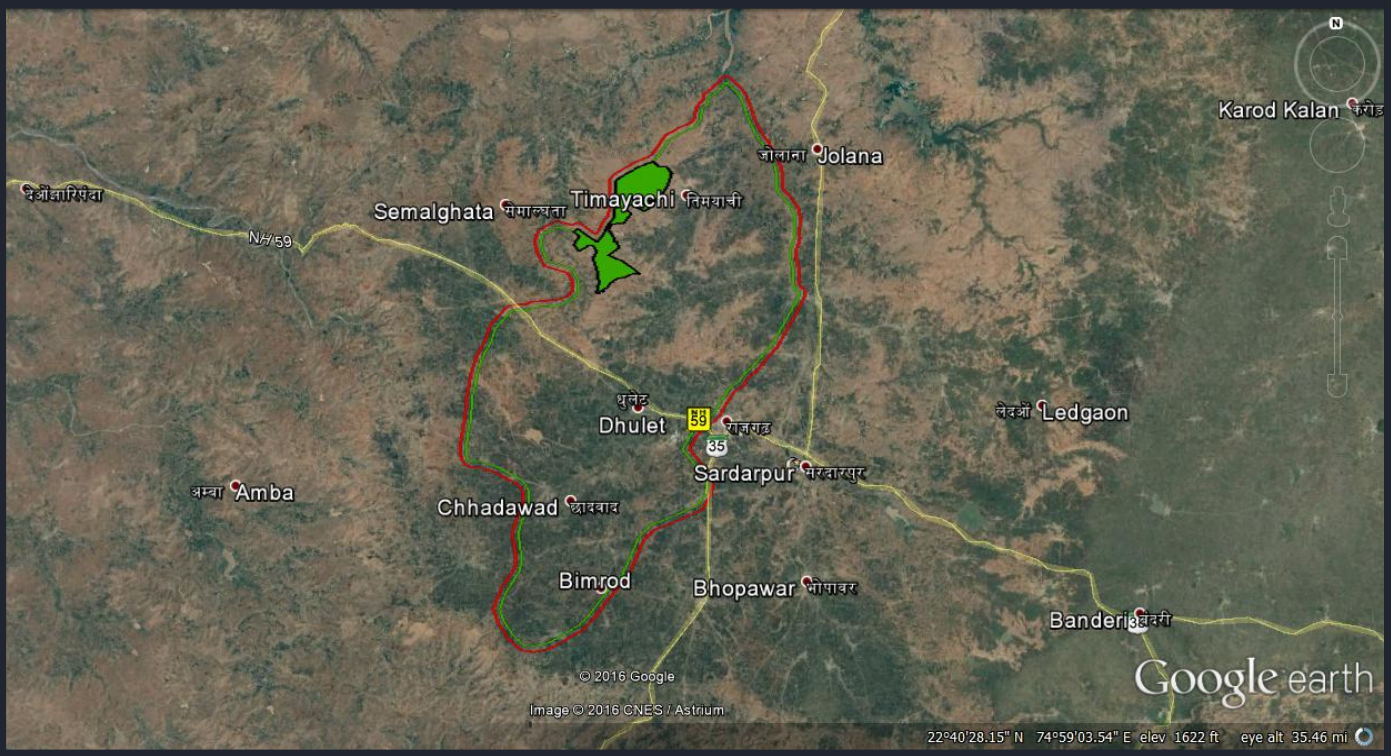


Image 9: Sardarpur WLS spread across 350 km2 area (polygons showing core areas) in Sardarpur, Madhya Pradesh

APPENDIX II FIELD AND HABITAT PHOTOS



Image 10: Typical lesser florican habitat with mosaic of grassland and agriculture in Sailana, Ratlam, Madhya Pradesh in 2017 © Sujit Narwade



Image 11: Habitat degradation due to invasive Lantana and Prosopis in lesser florican site of Amba, , Ratlam, Madhya Pradesh in 2017 © Sujit Narwade



Image 12: Installation of wind turbines near lesser florican breeding sites are a source of disturbance due to power-lines and noise © Sujit Narwade



Image 13: Lesser florican breeding habitat in Sardarpur WLS, Sardarpur, Madhya Pradesh © Sujit Narwade



Image 14: Kutch Bustard Sanctuary, Gujarat surrounded by wind turbines © Balasaheb Lambture



Image 15 : View of Rampura grassland area during monsoon in Dahod, Gujarat © Ameya Karulkar



Image 16: Habitat of lesser florican and great Indian bustard in Naliya grassland, Kutch, Gujarat © Ameya Karulkar



Image 17: Pesticide spraying in agricultural fields in Shokaliya landscape, Ajmer, Rajasthan © Sujit Narwade



Image 18: Farmers working in mixed crop field in lesser florican breeding site in Shahpura landscape, Bhilwara, Rajasthan © Biswajit Chakdar



Image 19: Interaction with local farmers at florican site of Pratapgarh, Rajasthan © Mohib Uddin



Image 20: Lesser florican breeding site near Bhatera village, Shahpura landscape, Bhilwara, Rajasthan © Biswajit Chakdar



Image 21: Breeding habitat of lesser florican in Shokaliya landscape, Ajmer, Rajasthan © Sujit Narwade



Image 22: Lesser florican breeding site in Pratapgarh, Rajasthan © Mohib Uddin



Image 23: Remaining grassland patches of Jalore, Rajasthan © Mohib Uddin

Appendix III - Note on lesser floricans rescued and released in year 2017

A total of five lesser floricans were rescued and released during September to December 2017, in various parts of the India.

1. Maharashtra (2 birds) - One female lesser florican with wing injury was found (18.2971°N 74.7464°E) near grasslands of Bhigwan village, Tehsil Indapur, District Pune on 19 September 2017(S. Jared, pers. comm). It was kept at his home for two days, treated with turmeric, and released on 22 September 2017. One juvenile lesser florican was rescued by a group of birdwatchers (Mr. Sandeep Valvi and Mr. Akshay Akki) from an open ground at Police headquarters, Solapur city (17.6659°N 75.9192°E) on 25 November 2017. According to the sources (M. Shete, pers. comm.) the bird was feeding on insects under light lamps in the evening and a police officer on duty noticed bird and followed it. The disturbed bird ran and was trapped in an auditorium from where it was rescued and handed over to the Office of Range Forest Officer, Great Indian Bustard Sanctuary, Nannaj, Solapur. The bird was perfectly fine and kept in custody of Forest Department for deployment of satellite transmitter. Forest Department staff released the bird on 30 November 2017, in grasslands of Nannaj (Source, Office of the Range Forest Officer, GIB Sanctuary).

2. Karnataka – One female lesser florican was rescued by local birdwatchers near Hubli city on 17 November 2017 and released in city outskirts on 18 November 2017.

3. Gujarat – One bird was rescued near Vadodara, ringed by BNHS and Gujarat Forest Department team and released in Rampura grassland, Dahod on 2 November 2017.

4. Rajasthan – One abandoned chick of lesser florican was rescued by a villager in Kacholia, Malpura tehsil, District Ajmer (26.3545°N, 75.2698°E) on 11 October 2017 which was released at the same place the next day.
The sighting of birds mostly from areas outside its known range and during non breeding season highlights the immediate need of radio telemetry studies for conservation of non-breeding habitats of this species.

Appendix IV- Photos of training workshop, field surveys and interactions during lesser florican status assessment, 2017



Image 24: Training workshop conducted at MK University, Bhavnagar, Gujarat © Balasaheb Lambture



Image 25: Training workshop conducted at Ujjain, Madhya Pradesh © Balasaheb Lambture



Image 26: Training workshop conducted at MDS University, Ajmer, Rajasthan © Forest Division, Ajmer



Image 27: Training workshop conducted at Akola, Maharashtra © BNHS photo library



Image 28: Post survey workshop organised at WII, Dehradun © WII photo library



Image 29: Regional universities and NGOs were involved in the lesser florican survey © Parul Sen



Image 30: Training about using advance tools and technologies such as GPS, range finders and mapping was given to survey participants before starting actual surveys © Sujit Narwade



Image 31: Combination of researchers, volunteers and staff of Forest Department was very instrumental in conducting landscape level surveys © Sujit Narwade



Image 32: Survey team conducting line transect sampling to assess lesser florican status © Sutirtha Dutta



Image 33: Interactions of survey team with local people during field surveys © BNHS photo library

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  District data - http://districts.nic.in/

ANNEXURES

Annexure 1: Datasheet for site-occupancy assessment of lesser florican using occupancy surveys

Site..... Visit..... Date..... Observers..... Track ID.....(GPS) Tr-len .....(km)

Point SN 1-km	Cell ID	Latitude dd-mm-ss	Longitude dd-mm-ss	Time (hh:mm) start – end	Weather	Wind speed	Land-cover 100m radius	Ground veg 100m radius		Active disturbance 200m	Passive disturbance 200 m	Florican count			Activity	Secondary data (farmers/herders)	
								Height (0-3)	Cover (0-3)			M	F	Total		Seen Likh this season here?	When was Likh last seen here?
1					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
2					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
3					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
4					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
5					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
6					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
7					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
8					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
9					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
10					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
11					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
12					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
13					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
14					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
15					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		

Abbreviations Weather: S (Sunny) / B (Bright) / C (Cloudy) / R (Rainy); Wind speed: N (None) / M (Mild) / S (Strong); Land-cover: G (Grassland), A (Agriculture), S (Scrubland), W (Woodland); Active disturbance: H (Human), D (Dog), L (Livestock), O (Others); Passive disturbance: S (Settlement), E (Electric lines), R (Road), I (Industrial uses); Sex: M (Male) / F (Female); Activity: D (Display) / F (Foraging) / A (Aerial/flight)

Annexure 2: Datasheet for population and habitat assessments of lesser florican using line transect surveys

Site..... Visit..... Date..... Observers..... Track ID.....(GPS) Tr-len .....(km)

Point SN 1-km	Cell ID	Latitude dd-mm-ss	Longitude dd-mm-ss	Time (hh:mm) start – end	Weather	Wind speed	Land-cover 100m radius	Ground veg 100m radius		Active disturbance 200m	Passive disturbance 200 m	Florican count			Activity	Secondary data (farmers/herders)	
								Height (0-3)	Cover (0-3)			M	F	Total		Seen Likh this season here?	When was Likh last seen here?
1					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
2					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
3					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
4					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
5					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
6					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
7					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
8					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
9					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
10					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
11					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
12					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
13					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
14					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		
15					S/B/C/R	N/M/S	G/A/S/W			H/D/L/O	S/E/R/I				D/F/A		

Abbreviations Weather: S (Sunny) / B (Bright) / C (Cloudy) / R (Rainy); Wind speed: N (None) / M (Mild) / S (Strong); Land-cover: G (Grassland), A (Agriculture), S (Scrubland), W (Woodland); Active disturbance: H (Human), D (Dog), L (Livestock), O (Others); Passive disturbance: S (Settlement), E (Electric lines), R (Road), I (Industrial uses); Sex: M (Male) / F (Female); Activity: D (Display) / F (Foraging) / A (Aerial/flight)

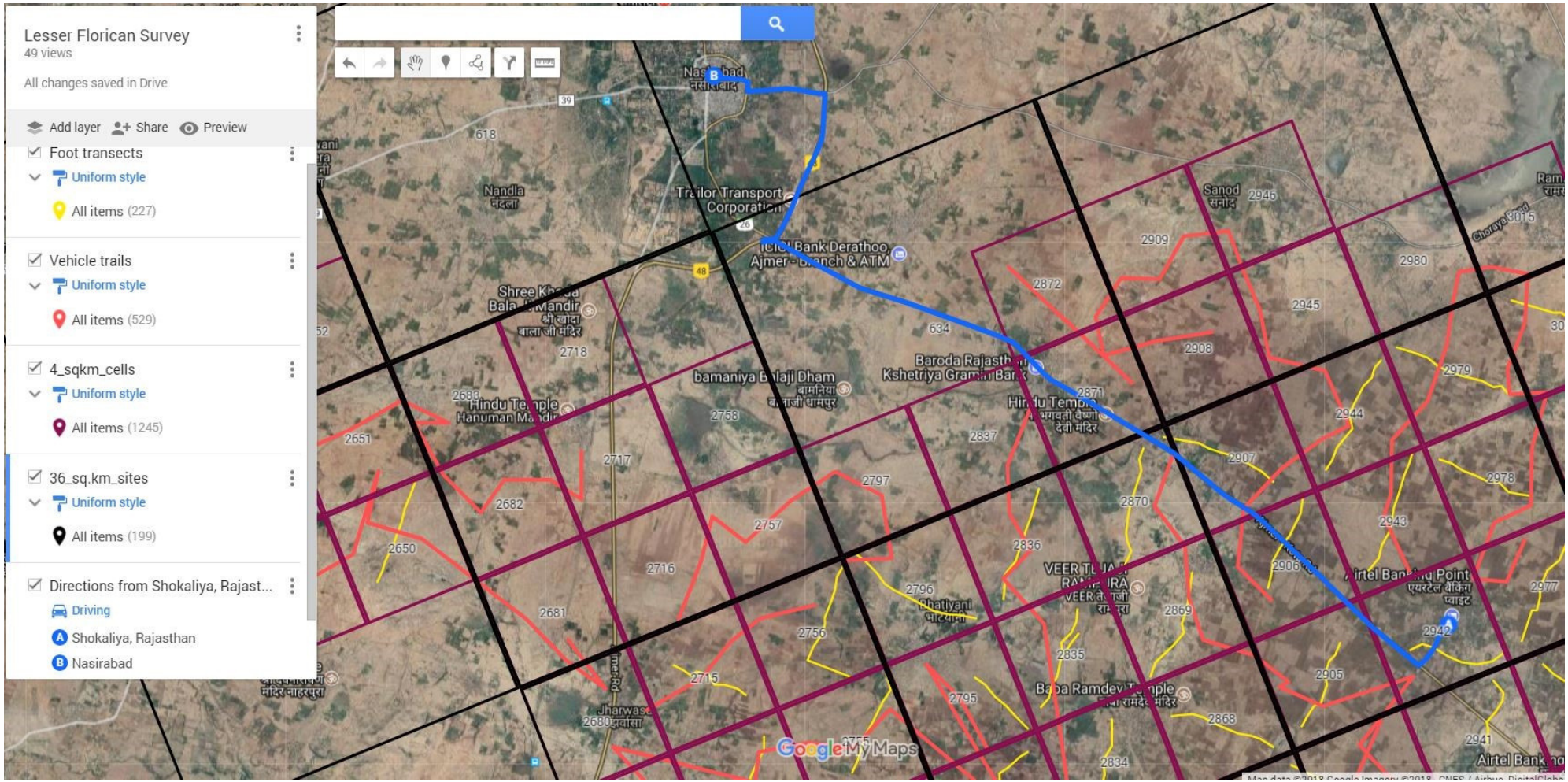
ANENXURE 3: R SCRIPT FOR ANALYZING LESSER FLORICAN SURVEY DATA

```
library(unmarked)
library(MuMIn)
data <- read.csv("LF_occ_2017_all.csv")
names(data)
data$Lndscp <- as.factor(data$Lndscp)
data$Rgn <- as.factor(data$Rgn)
summary(data)
# checking for multicollinearity
habdat <- data[,63:71]
cor <- cor(habdat)
corr <- ifelse(cor>0.4, round(cor,2),0)
corr
# Pull out occupancy matrix - all sites
y.all <- data[,2:57]
x.all <- data[,58:71]
# Make unmarked frame - all sites
umf.all <- unmarkedFrameOccu(y=y.all,
  siteCovs=data.frame(x.all))
head(umf.all)
# Pull out occupancy matrix - sites in occupied landscapes
drgnr <- read.csv("LF_occ_2017_rgnr.csv")
names(drgnr)
drgnr$Lndscp <- as.factor(drgnr$Lndscp)
drgnr$Rgn <- as.factor(drgnr$Rgn)
summary(drgnr)
y.rgnr <- drgnr[,2:57]
x.rgnr <- drgnr[,58:71]
# Make unmarked frame - sites in occupied landscapes
umf.rgnr <- unmarkedFrameOccu(y=y.rgnr,
  siteCovs=data.frame(x.rgnr))
head(umf.rgnr)
# Pull out occupancy matrix - sites in occupied regions
drgnl <- read.csv("LF_occ_2017_rgnl.csv")
names(drgnl)
drgnl$Lndscp <- as.factor(drgnl$Lndscp)
drgnl$Rgn <- as.factor(drgnl$Rgn)
summary(drgnl)
y.rgnl <- drgnl[,2:57]
x.rgnl <- drgnl[,58:71]
# Make unmarked frame - sites in occupied landscapes
umf.rgnl <- unmarkedFrameOccu(y=y.rgnl,
  siteCovs=data.frame(x.rgnl))
head(umf.rgnl)
# Run occupancy models
## all data  to estimate range-level occupancy
occ_null = occu(~1 ~1, data=umf.all)
occ_RN = occuRN(~1 ~1, K=72, data=umf.all)
# Compare basic models
list(AIC(occ_null, occ_RN))
backTransform(occ_null, type="state")
## occupied region data  to estimate range and region level occupancies
# modeling detection probability with occupancy modeled on regions
occ_null. = occu(~1 ~1, data=umf.rgnl)
occ_null.rgnl = occu(~1 ~Rgn, data=umf.rgnl)
occ_RN.rgnl = occuRN(~1 ~Rgn, K=72, data=umf.rgnl)
occ_drgn.rgnl = occu(~Rgn ~Rgn, data=umf.rgnl)
occ_dcova.rgnl = occu(~Wthr+Wndspd ~Rgn, data=umf.rgnl)
occ_dcovb.rgnl = occu(~Wthr ~Rgn, data=umf.rgnl)
occ_drgncova.rgnl = occu(~Rgn+Wthr+Wndspd ~Rgn, data=umf.rgnl)
occ_drgncovb.rgnl = occu(~Rgn+Wthr ~Rgn, data=umf.rgnl)
# model selection and inference
occrngl_sel = model.sel(occ_null.,occ_null.rgnl, occ_RN.rgnl,occ_drgn.rgnl,
occ_dcova.rgnl,occ_dcovb.rgnl,occ_drgncova.rgnl, occ_drgncovb.rgnl)
write.csv(occrngl_sel,"detection_models.csv")
occrngl_sel
```

```
summary(occ_drgncovb.rgnl)
# estimate regional occupancies
Rgn = c("Ajm","Guj","Rajr")
Wthr = mean(drgnl$Wthr)
newdat1 = data.frame(Rgn,Wthr)
occrgn_prd = predict(occ_drgncovb.rgnl , newdata=newdat1, type="state",
se.fit=TRUE)
detrgn_prd = predict(occ_drgncovb.rgnl , newdata=newdat1, type="det",
se.fit=TRUE)
occ_est_rgn = data.frame(newdat1,occrgn_prd, detrgn_prd)
occ_est_rgn
write.csv(occ_est_rgn,"regional_occupancy.csv")
# modeling occupancy on habitat covariates with best detection model
occu1 = occu(~Rgn+Wthr ~ 1, data=umf.rgnl) # to estimate range-level occupancy
occu2 = occu(~Rgn+Wthr ~ Rgn, data=umf.rgnl)
occu3 = occu(~Rgn+Wthr ~ Grsl, data=umf.rgnl)
occu4 = occu(~Rgn+Wthr ~ Rgn*Grsl, data=umf.rgnl)
occu5 = occu(~Rgn+Wthr ~ Rgn*Grsl+Psv_dstb, data=umf.rgnl)
occu6 = occu(~Rgn+Wthr ~ Rgn*Grsl+Psv_dstb+Act_dstb, data=umf.rgnl)
occu7 = occu(~Rgn+Wthr ~ Rgn*Grsl+Grndvg_het, data=umf.rgnl)
occu8 = occu(~Rgn+Wthr ~ Rgn*Grsl+Grndvg_ht*Grndvg_cov, data=umf.rgnl)
occu9 = occu(~Rgn+Wthr ~ Rgn*Grsl+Grndvg_het+Psv_dstb, data=umf.rgnl)
occu10 = occu(~Rgn+Wthr ~ Rgn*Grsl+Grndvg_ht*Grndvg_cov+Psv_dstb,
data=umf.rgnl)
occu11 = occu(~Rgn+Wthr ~
Rgn*Grsl+Grndvg_het+Grndvg_ht*Grndvg_cov+Psv_dstb+Act_dstb, data=umf.rgnl)
occmodsel = model.sel(occ_null.,
occu1,occu2,occu3,occu4,occu5,occu6,occu7,occu8,occu9,occu10,occu11)
occmodsel
write.csv(occmodsel,"occupancy_models.csv")
summary(occu4)
# Generate response curves
Wthr = rep(mean(drgnl$Wthr),303)
Grsl = rep(seq(0,1,0.01),3)
Rgn = rep(c("Ajm","Guj","Rajr"), each=101)
newdat2 = data.frame(Rgn,Grsl,Wthr)
newdat2
occmod_pred = predict(occu4, newdata=newdat2, type="state", se.fit=TRUE)
occmod_est = data.frame(newdat2,occmod_pred)
occmod_est
write.csv(occmod_est,"occupancy_prediction.csv")
# Density estimated in Distance sampling
# Calculate geometric mean & 95% CI of population abundance
# run for range-level
psi = 0.13
psi.se = 0.026
sites=380
D = 0.25
Ns = 0.25*29
N.se = Ns*0.24
# start iterations
iter=10000
N = as.data.frame(matrix(0,ncol=4,nrow=iter))
colnames(N) = c("occ","Ns", "Abun", "lnAbun")
for(n in 1:iter){
N[n,1] = rnorm(1, psi, psi.se)*sites
N[n,2] = rnorm(1, Ns, N.se)
N[n,3] = N[n,1]*N[n,2]
N[n,4] = log(N[n,3]+1)}
arith = mean(N$Abun)
geo = mean(N$lnAbun)
# Computing lf male abundance estimates
mean = exp(geo)-1
tlc = quantile(N$lnAbun, probs = 0.025)
tuc = quantile(N$lnAbun, probs = 0.975)
lc = exp(tlc)-1
uc = exp(tuc)-1
est = c(mean, lc, uc)
```



ANNEXURE 4: GOOGLE MAP APPLICATION IN ANDROID DEVICE USED IN LESSER FLORICAN STATUS SURVEY 2017



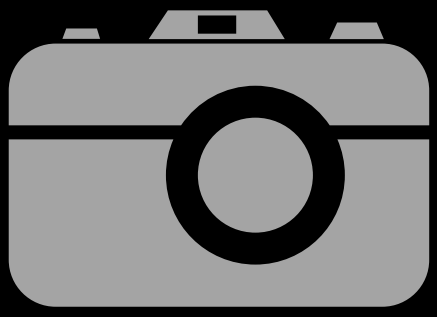


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STATUS OF GREAT INDIAN BUSTARD AND ASSOCIATED SPECIES IN THE STATE OF MAHARASHTRA

APRIL 2018

STATUS SURVEY REPORT 2018

STATUS OF GREAT INDIAN BUSTARD AND ASSOCIATED SPECIES IN THE STATE OF MAHARASHTRA

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Executive Summary



The Great Indian Bustard (hereafter GIB) are magnificent, large flying bird and was previously found throughout India and parts of Pakistan (Islam & Rahmani, 2002). In India, it was distributed throughout the grasslands of North India and the Deccan Landscape (Rahmani, 1989), but in last three decades there has been a drastic change in its former range. Only about 250 individuals survive today in the parts of India, with no breeding range outside the India. (Dutta et al., 2011). The largest population of 100-150 birds is found in the state of Rajasthan (Rahmani, 2006) followed by less than 35 individuals in the states Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh (BirdLife International, 2015). GIB is listed under Schedule 1 species as per Wildlife (Protection) Act 1972, and listed as Endangered or Appendix 1 species of CITES.

As a part of the project titled 'Tracking of Great Indian Bustard (*Ardeotis nigriceps*) and mapping its potential habitat across the Deccan Landscape, Maharashtra' funded by the Forest Department, Govt. of Maharashtra, three GIBs were fitted with GPS transmitters and their movement was tracked for one year. The tracking data has helped in identifying suitable areas for GIB conservation beyond the protected area system in Maharashtra. In order to ascertain status of GIB and its potential habitat in Maharashtra, a landscape level survey was conducted in September, 2017 in collaboration with Maharashtra Forest Department.

The GIB is nomadic in nature and uses large areas without distinguished boundaries, and therefore, requires robust sampling method to evaluate its status and distribution. Since the present status of GIB is not known beyond the designated bustard areas, a probability distribution map for GIB covering an area of 55,000 km^2 was developed through probability distribution modeling (Phillips et al., 2006) using locations of tagged GIB across the across the landscape to survey potential GIB habitat in Maharashtra.

This survey revealed the status of GIB, Blackbuck and Chinkara in potential GIB habitat which is mostly in human dominated landscape of Maharashtra. A systematic survey was conducted in 372 grids of 12 x12 km across the State. Vehicle based species and habitat survey were conducted from 25th - 30th September, 2017 by 31 teams (1 researcher, 1 - 2 volunteer and 2 - 3 forest officials). Grids were surveyed along road trails of 3.03 ± 1.74 km length (single continuous or multiple broken transects) in a slow moving (10 - 20 km/hr) vehicle. At every 1 km interval along the transect, habitat characteristics that potentially influence species distribution were recorded. To overcome the issue of low detection owing to very low population size and their ecology, a blind test using life-size GIB dummies was conducted to know the possibility of detection in sampling grids by the sampling team. The dummies were placed in the sampling grids were placed by a separate team. The sampling team was unaware of the location of the dummy GIB.

Questionnaire survey were conducted by opportunistically interviewing up to three residents per grid with a semi-structured questionnaire. Respondents were asked whether they knew or could identify the bird, and about reports or sightings of GIB in their vicinity. Information about the occurrence of associated species from these areas was also collected.

A total of 238 groups of Blackbuck were recorded across 2117 line transects covering a distance of 6436.6 km (mean length 3.03 ± 1.74 km)

in 372 grids. Density of Blackbuck in potential GIB habitat was found to be 0.74 ± 0.11 /km² and total population was found to be 37,690 ± 5626. 19 groups of Chinkara were recorded across 2117 line transects covering a distance of 6436.6 km (mean transect length 3.03 ± 1.74 km) in 372 grids. Density of Chinkara in potential GIB habitat was found to be 0.02 ± 0.01 /km² and total population was found to be 1481 ± 577. The data was left-truncated at 20 m, so that the model was not constrained by the limited number of Chinkara observed on or close to the transect.

During the survey, no GIB was sighted. However, out of 1401 respondents 72 confirmed GIB presence in their area within the last 4 days to 6 months. We used this information along with locations of tagged birds in Maharashtra to identify 87 out of 372 grids as conservation priority areas for GIB. These grids constituted 11 clusters spread across 12 forest divisions of Maharashtra covering an area of 12,528 km² dominated by kharif crops and open areas.

Out of the 30 GIB dummies placed, only 4 were detected by the respective sampling teams. The detection probability was found to be 13% which is within the range of previous studies (Rahmani, 1986). Power analysis on detection probability (13%) and occupancy (8.06%) of dummy life-sized GIB showed that 8 replicates required in 180 grids of detecting 53% change in occupancy. This would mean that, if the population of GIB ranges from 8 to 10, there is a chance of detecting one GIB with a minimum sampling effort of 8 temporal replicates for each transect considering that detection probability of dummy GIB and live GIB are the same. During the survey, no GIB was sighted, which implies that the number of GIB might be less than 8 in Maharashtra.

Eleven clusters in 12 forest divisions has been identified important for GIB conservation in the state of Maharashtra. Most of these areas are dominated by kharif crops (sorghum, peanut, groundnut, seed oils), preferred by GIB as foraging grounds. The following recommendations are made on the basis of the findings of the landscape level GIB survey for conservation of GIB in the state:

- The 11 identified clusters should be monitored for a duration of 1-2 years continuously at least 2-3 times a year.
- Department-owned areas within such grids should be managed as bustard habitats by removing invasive species.
- There is an urgent need for awareness in these identified clusters with option to promote traditional cropping patterns. Any changes in these areas will be critical for GIB conservation.
- Traditional cropping patterns need to be promoted by involving other line departments and need to have awareness and capacity building for the same.
- There is a need to put reflectors on power-lines in such areas.
- Dog population needs continuous monitoring and measures should be taken to control the growth of dog populations in such areas.
- GIB conservation in Maharashtra is only possible if traditional cropping and land sparing is promoted and incentivized.



Introduction

India is a globally important biodiversity region harboring four biodiversity hotspots (Myers et al., 2000). It also harbors nearly 1.2 billion people, experiencing rapid development and population expansion, creating various challenges for conservation of different taxa (Velho et al., 2012). Many anthropogenic factors affect species ecology leading to their extinction (Morrison et al., 2007). Large animals by virtue of their size and home range are relatively more susceptible to extinction as a consequence of fragmentation and degradation of habitat (Schaller 1967). The effect is more pronounced on species which share their habitat with humans. The Great Indian Bustard *Ardeotis nigriceps* (hereafter GIB) is one such species. GIB is a critically endangered (IUCN 2017) and Schedule 1 species as per the Wildlife (Protection) Act, 1972. GIB belongs to the family Otitidae of the Order Otidiformes and is considered among the largest flying birds in the world. GIB had its share of fame when it became a candidate for the National bird of India. The renowned Indian ornithologist Salim Ali strongly recommended for it, but it was over-ruled in favor of the Indian Peafowl (Ali, 1961). GIB is a large, charismatic bird once found throughout India and parts of Pakistan. Until the end of the 19th century, GIBs were seen in large flocks across the grasslands of India and Pakistan. Within India, they were distributed throughout the grasslands of North India and the Deccan Landscape (Rahmani, 1989), However, in the last three decades, there has been a drastic change in its former distribution range and even a flock of three individuals is a rare sight (Islam and Rahmani, 2002). The species' total population was estimated to be less than 300 individuals in 2008, and these were confined to only certain parts of India with no breeding range outside India (Dutta et al., 2011). The most recent estimate places the population at a range between 50-249 mature individuals (BirdLife International, 2015). The largest population of 100-150 birds is found in Rajasthan (Rahmani, 2006) and less than 35 individuals in the states Gujarat, Madhya Pradesh, Maharashtra, Karnataka and Andhra Pradesh (BirdLife International, 2015). Earlier studies conducted in Maharashtra during the 1980s revealed that there were 60 individuals, which then decreased to 36 adult individuals by 2006 (Anon, 2006). The current population is believed to be less than 8 – 10 birds.

The recent decline in GIB numbers has been recorded from all regions in the present distribution range, including Rajasthan and Gujarat (Dutta et al., 2011), having completely disappeared from the state of Haryana, Punjab, Orissa, Madhya Pradesh, Tamil Nadu and Uttar Pradesh (Anon, 2015). The current populations of Maharashtra, Karnataka and Andhra Pradesh are considered to be at the risk of local extinction. The sparse population status of GIB across its range necessitates baseline data collection data of its status, distribution and habitat parameters. This information is very essential for conservation planning and subsequently assessing the effectiveness of management actions.

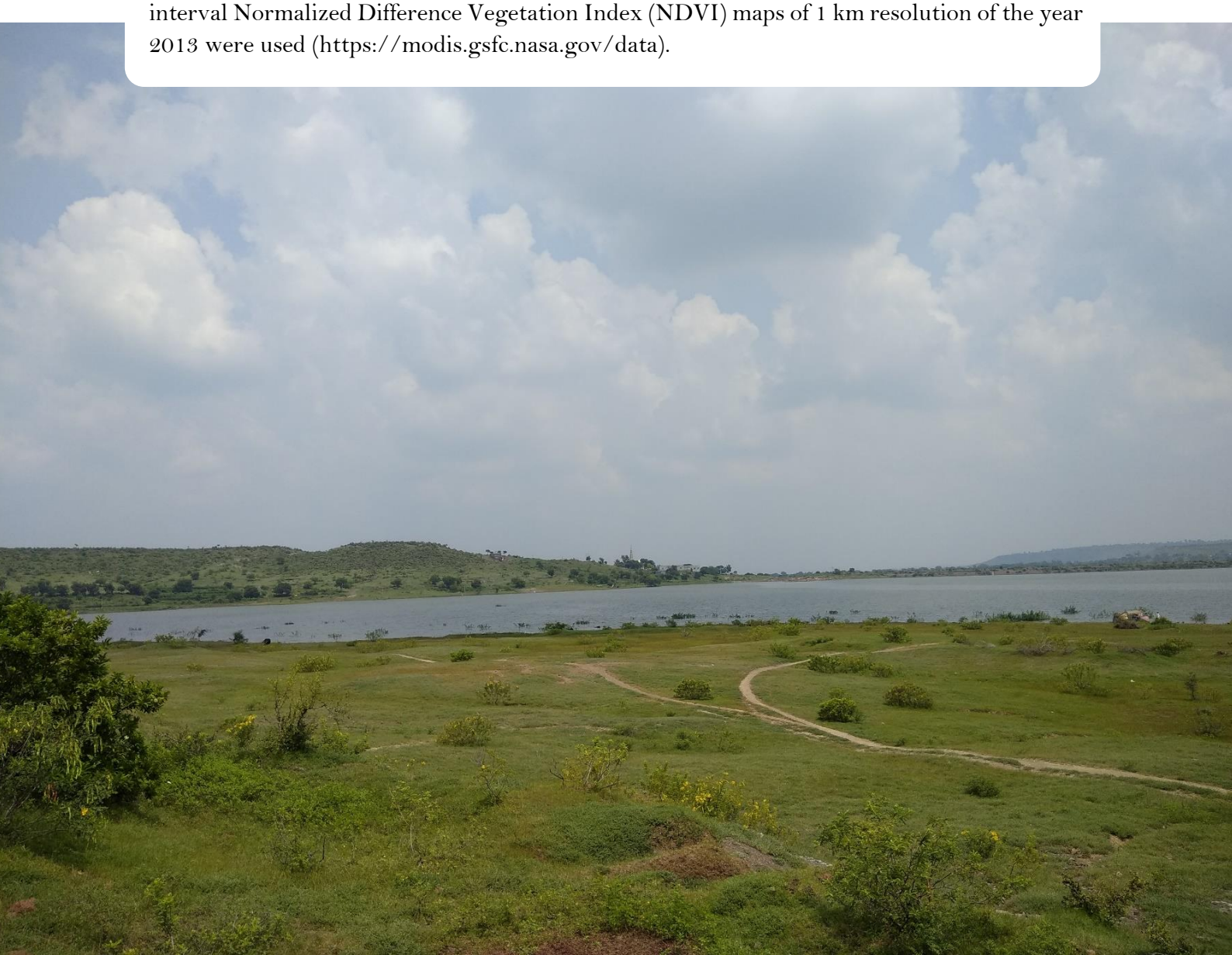
The GIB is nomadic in nature and uses large areas without distinguished boundaries, and therefore, requires robust sampling methods to evaluate its status and distribution. Since the present status of GIB is not known beyond the designated bustard areas, a probability distribution map for GIB covering an area of 55,000 km^2 was developed through probability distribution modeling (Phillips et al., 2006) using locations of tagged GIB across the across the landscape to survey potential GIB habitat in Maharashtra.

The identified potential habitat was divided into 372 grids of 12 x 12 km. 31 field survey teams consisting of researchers from Wildlife Institute of India, volunteers and forest officials of Maharashtra State Forest Department were trained through workshops prior to the survey. Each team collected data for 12 adjacent grids through 20 km vehicle transects in each grid, and recorded data on GIB, its habitat and associated grassland species viz., Blackbuck *(Antilope cervicapra)*, Chinkara (*Gazella bennettii)*, Indian Fox (*Vulpes bengalensis)* and Indian Wolf (*Canis lupus*).

Materials and Methods

Mapping potential GIB landscape in Maharashtra

To develop potential GIB distribution map for the state of Maharashtra, the GPS locations of three tagged birds were used. The birds were tagged as a part of project entitled 'Tracking of the Great Indian Bustard and mapping its potential habitat in Deccan landscape of Maharashtra'. The birds were captured using noose traps and fitted with 70-gram Solar Argos/GPS PTT (Microwave Telemetry Inc.). The instrument recorded GPS locations daily at 05:00, 07:00, 09:00, 11:00, 17:00, 19:00 and 21:00 hours and Argos locations on alternate days. We collected a total of 2923 locations from all the three birds. Using these locations, we predicted the probability distribution map of GIB using MaXent model (Phillips et al., 2006); http://www.cs.princeton.edu/wschapire/maxent/) (Figure: 1). For this, 16 days interval Normalized Difference Vegetation Index (NDVI) maps of 1 km resolution of the year 2013 were used (https://modis.gsfc.nasa.gov/data).



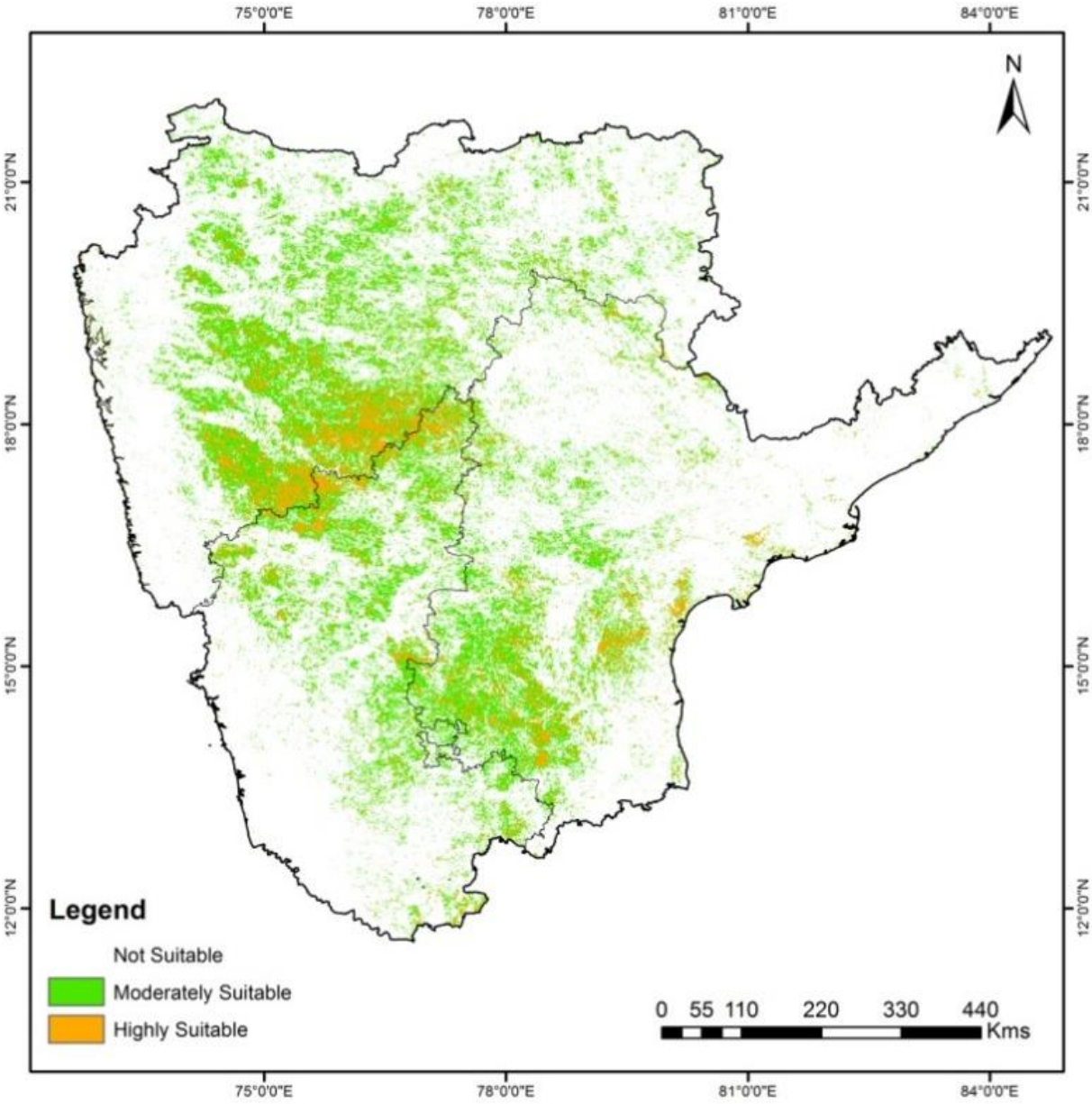


Figure 1: Probable GIB distribution in the states of Maharashtra, Andhra Pradesh and Karnataka

Survey Design

12 x12 km grids were overlaid on the probability distribution map (Figure 2) and 372 grids were selected for sampling. A workshop for trainers was conducted at Wildlife Institute of India on 21st September, 2017. Subsequently, each of these trainers conducted workshops at their respective field sites to train forest staff and volunteers. Each team was assigned 12 adjacent grids to cover in 6 days from 25th - 30th September 2017 (two grids per day). In each grid, multiple vehicle transects of minimum 2 km length totaling 20 km were traversed to collect data on GIB, its associated species and habitat parameters.

The objectives of the survey were:

- To identify areas used by GIB in the state of Maharashtra,
- To evaluate the status of GIB and associated species, and threats to their conservation in the state of Maharashtra,
- To develop management strategies to conserve critical grassland habitats in the state of Maharashtra.



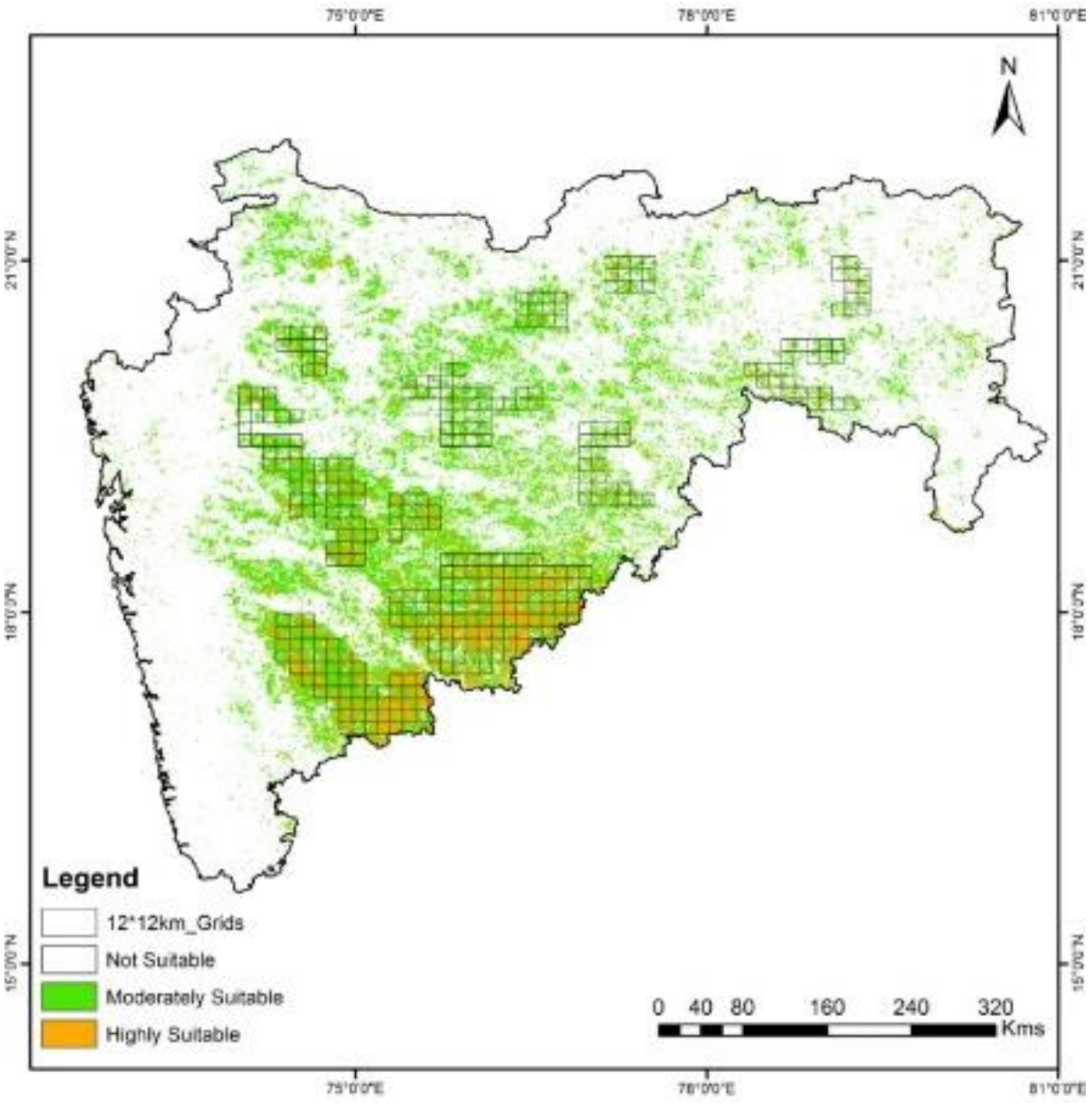


Figure 2: Probable GIB distribution map in Maharashtra with sampling grids

Sampling Design

Species and habitat status were assessed using systematically designed vehicle transects. 372 grids were overlaid on the potential GIB habitat (covering 55000 sq. km). Sampling was carried out from 25th - 30th September, 2017 with the help of 31 teams (1 researcher, 1-2 volunteers and 2-3 forest officials). Grids were surveyed along road trails of 3.03 ± 1.74 km length (single continuous or multiple broken transects) in a slow moving (10-20 km/hr) vehicle. Each team covered 12 grids in six consecutive days, one grid in the morning (0600-1000 h) and one in the evening (1600-1900 h), when animal activity is expected to be highest. Each team collected data on GIB presence and associated species (Blackbuck, Chinkara, feral dogs, Nilgai, Wild Pig, Indian Fox and Indian Wolf). The teams also recorded important habitat characteristics such as land cover, substrate and human disturbances at 1 km interval, on each transect. Secondary information on occurrence and perceived threats to GIB and associated species was also collected through a semi-structured questionnaire survey of the local people from different villages in each grid.

Data Collection

Data on GIB presence and its associated species was collected along transects. For each direct sighting of GIB and associated species, number of individuals, GPS coordinates, transect bearing, animal bearing and sighting distance were recorded using rangefinder and compass. Information on physical parameters such as terrain, soil substrate, land cover etc. were also recorded.

Habitat Characteristics

At every 1 km interval along the transects, habitat characteristics that potentially influence species distribution, such as land cover, terrain, soil substrate, and human disturbances were recorded. The dominant land-cover type (barren/agriculture/grassland/shrub land/woodland), terrain type (flat/sloping/undulating-moderate or very), and substrate type depending on soil characteristics (rock/gravel/sand/soil) were recorded within a radius of 100 m of the point. Vegetation structure was recorded as percentage of ground covered by grasses (tall, medium, short), herbs, shrubs (<2m) and tree within 20 m radius of the point. These covariates were recorded in broad class-intervals (0-10, 10-20, 20- 40, 40-60, 60-80, and 80-100 %) to reduce inconsistency of observation errors between teams. Vegetation composition was recorded as three dominant plants within 100 m radius of the point. Presence of human structures (settlement/ farm-hut/ metalled-road/ electric-lines/ wind-turbine/ water-source) was also recorded within 100 m radius of the point.

Questionnaire Survey

Questionnaire surveys were conducted by opportunistically interviewing up to three residents per grid with a semi-structured questionnaire. Respondents were asked whether they knew or could identify the bird, and about reports or sightings of GIB in their vicinity. Information about the occurrence of associated species from these areas was also collected.

Results

Density estimation of GIB associated species

Blackbuck (*Antilope cervicapra*)

A total of 238 groups of Blackbuck were recorded across 2117 line transects covering a distance of 6436.6 km (mean length 3.03 ± 1.74 km) in 372 grids. Density of Blackbuck in potential GIB habitat was found to be 0.74 ± 0.11 /km^2 and total population was found to be 37,690 ± 5626 (Table 2).

Table 2: Density estimate for Blackbuck in surveyed areas of Maharashtra, India

Parameter	Point Estimation	Standard Error	% Co-efficient of Variation	95% Confidence of Interval	
DS	0.14	0.01	12.24	0.11	0.17
E(S)	5.29	0.45	8.54	4.47	6.26
ESW	131.70	9.26	7.04	114.67	151.25
D	0.74	0.11	14.93	0.55	0.99
N	37690	5625.8	14.94	28168	50431

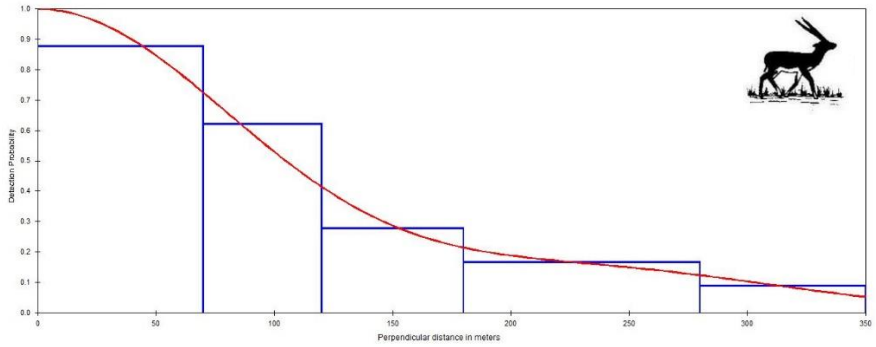
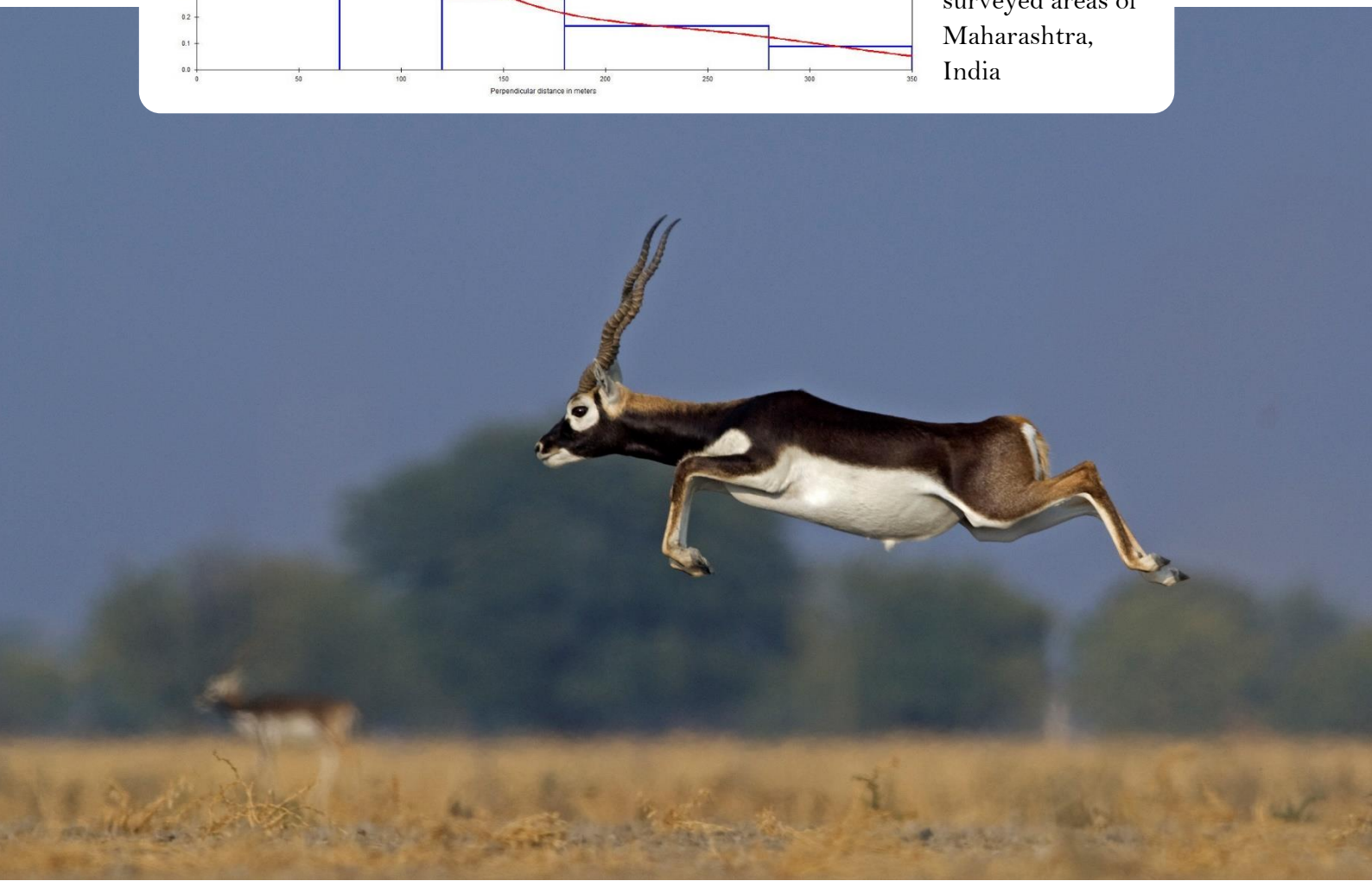


Figure 3: Detection probability plot for Blackbuck in surveyed areas of Maharashtra, India



Chinkara *(Gazella bennettii)*

A total of 19 groups of Chinkara were recorded across 2117 line transects covering a distance of 6436.6 km (mean transect length 3.03 ± 1.74 km) in 372 grids. Density of Chinkara in potential GIB habitat was found to be 0.02 ± 0.01 /km^2 and total population was found to be 1481 ± 577 (Table 3). The data was left-truncated at 20 m, so that the model was not constrained by the limited number of Chinkara observed on or close to the transect (Figure 4).

Table 3: Density estimate for Chinkara in surveyed areas of Maharashtra, India

Parameter	Point Estimation	Standard Error	% Co-efficient of Variation	95% Confidence of Interval	
DS	0.01	0.003	32.25	0.005	0.01
E(S)	2.68	0.58	21.91	1.70	4.24
ESW	135.88	29.26	21.53	86.87	212.53
D	0.02	0.01	38.99	0.01	0.05
N	1481	577.49	38.99	702.0	3128.0

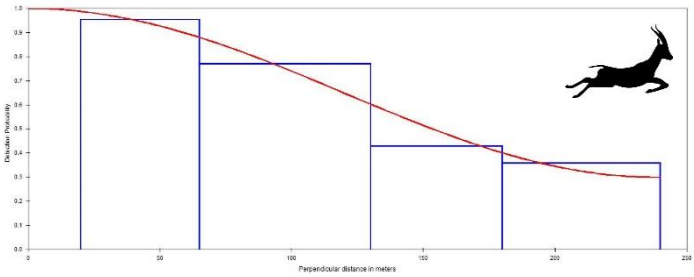
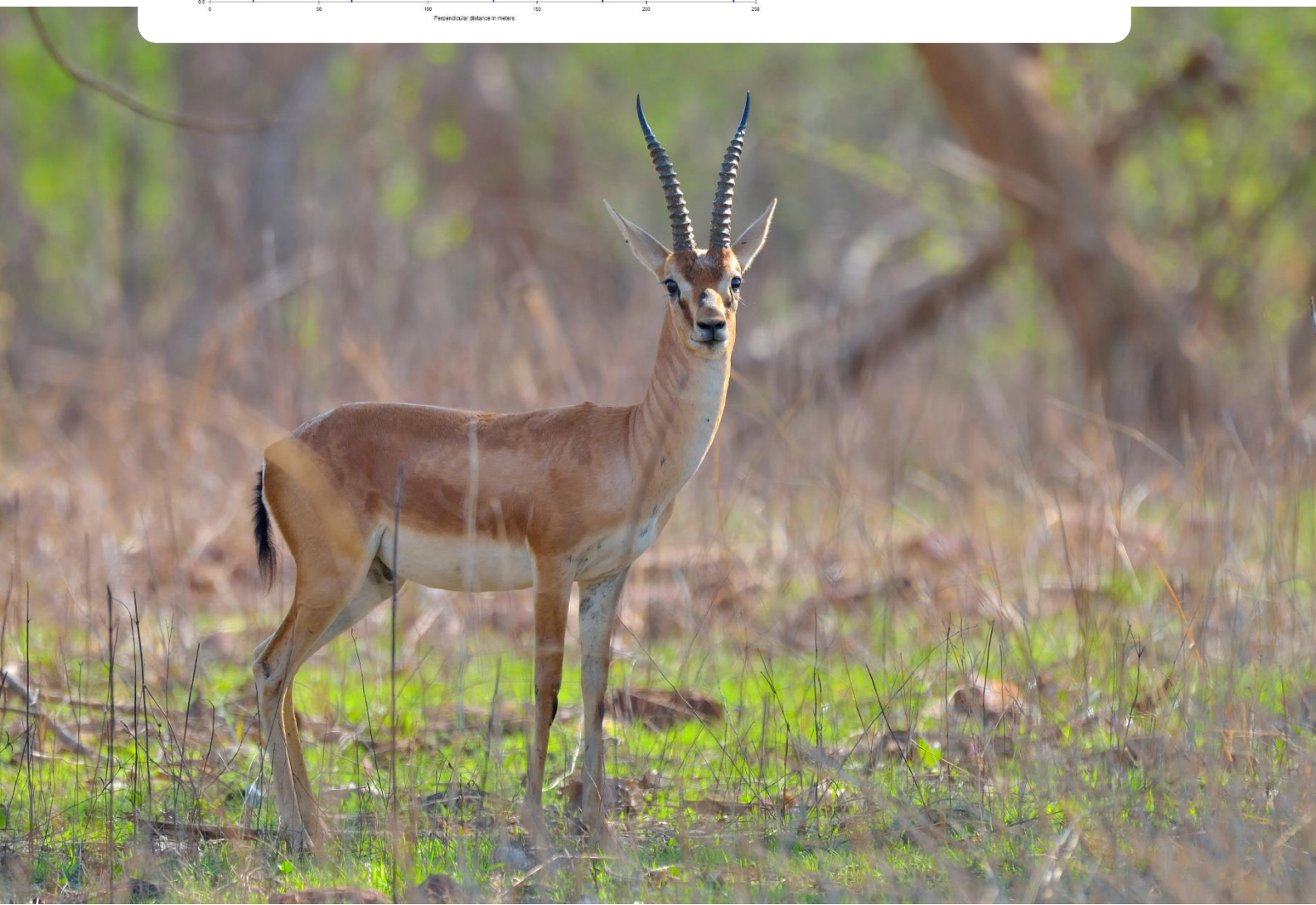


Figure 4: Detection probability plot for Chinkara in surveyed areas of Maharashtra, India



Distribution of associated species in potential GIB habitat

The state of Maharashtra harbors good populations of Blackbuck, Chinkara, Indian Fox and Indian Wolf that are distributed outside the protected area of the landscape as well. During the survey, Blackbuck were reported from most of the forest divisions except Chandarpur and Pandharkawada Forest Divisions (Figure 5). Chinkara were reported from Aurangabad, Ahmadnagar, Beed and Sangli Forest Divisions (Figure 6). Figure 7 shows, Blackbuck and Chinkara overlap and exclusive areas surveyed in the landscape.

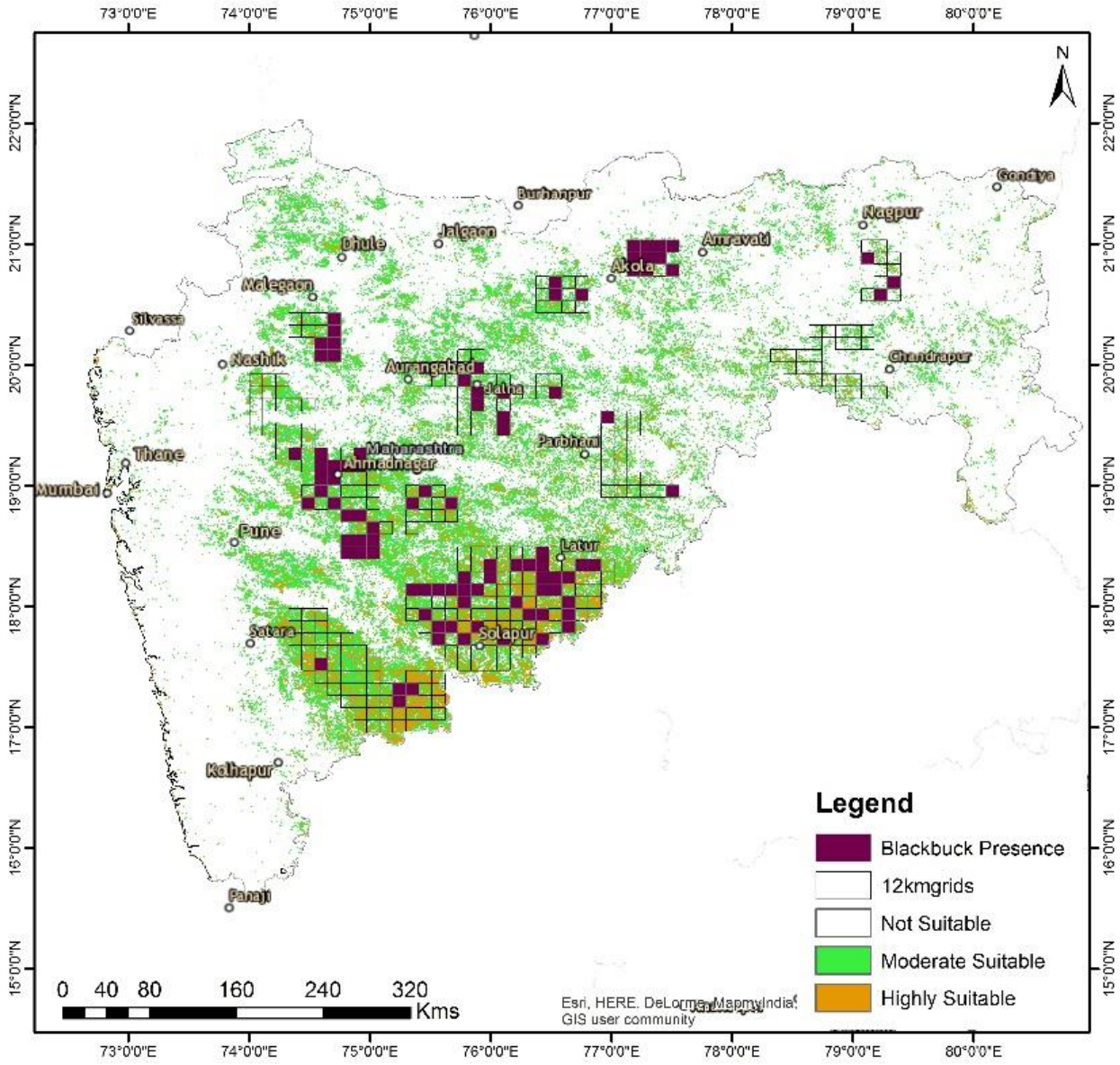


Figure 5: Map showing grids with Blackbuck presence across surveyed grids in Maharashtra, India

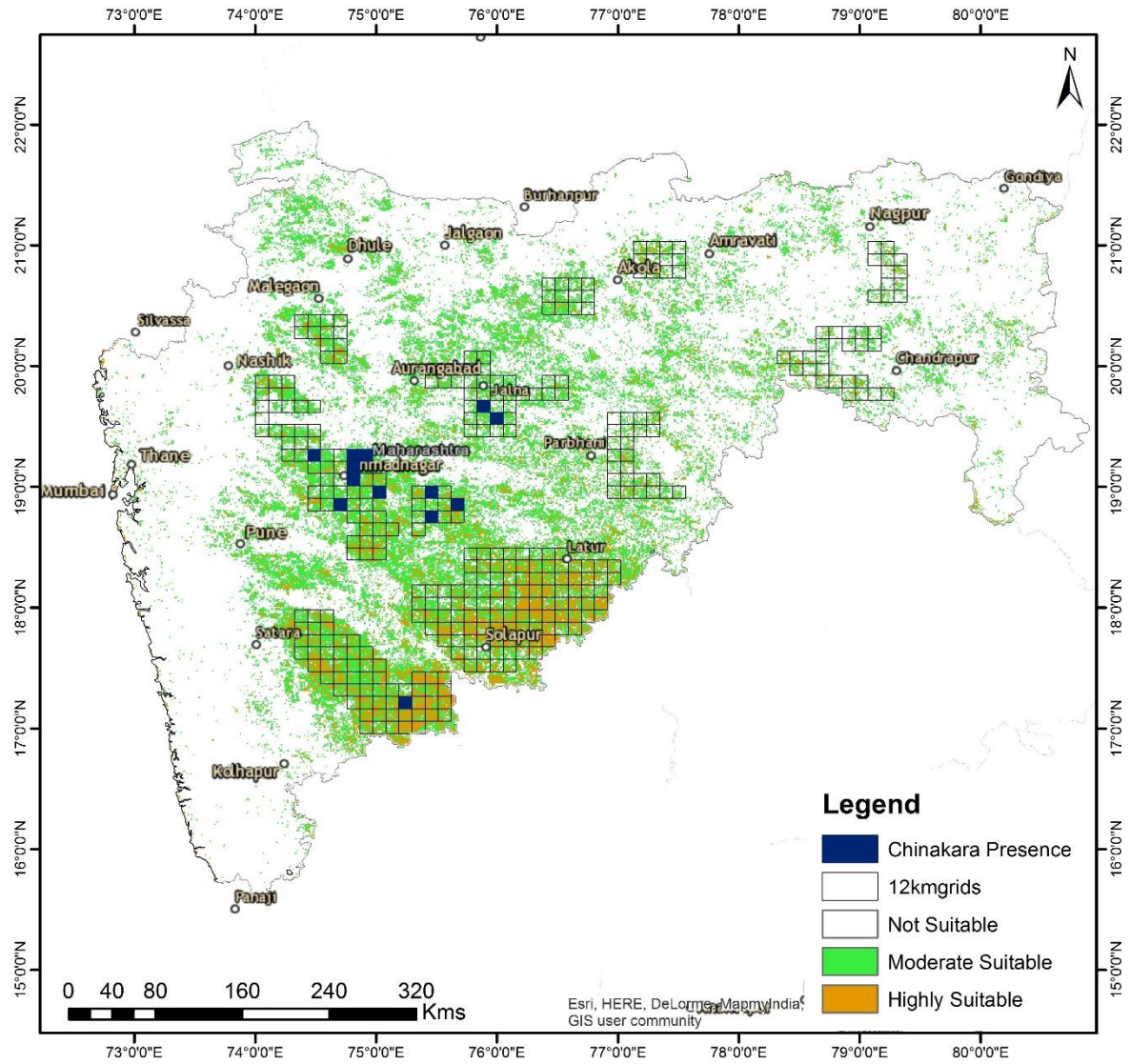


Figure 6: Map showing grids with Chinkara presence across surveyed grids Maharashtra, India



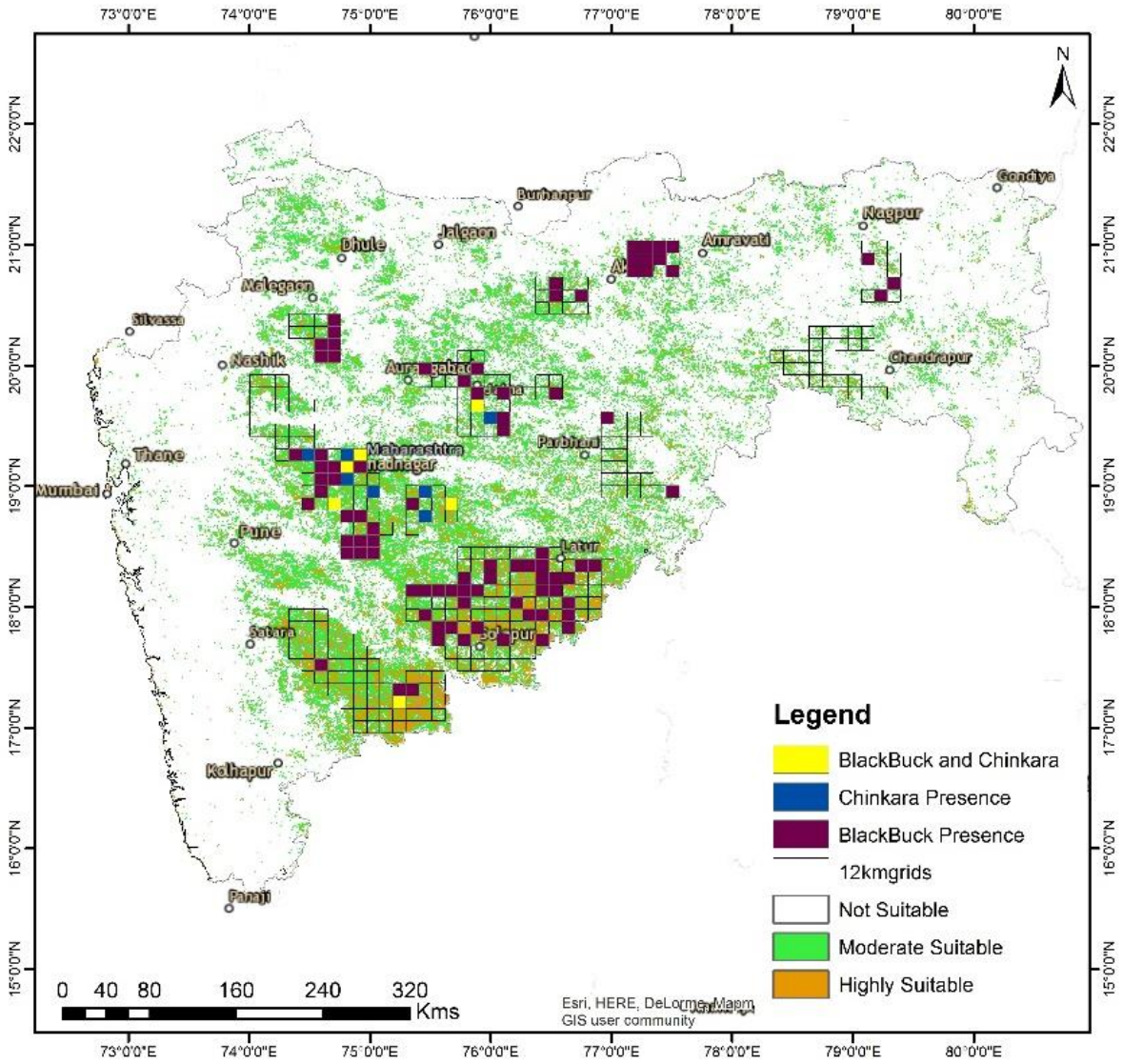


Figure 7: Map showing grids with Blackbuck and Chinkara presence and their overlaps across surveyed grids in Maharashtra, India





GIB occurrence during landscape survey

During the survey, no GIB was sighted. However, out of 1401 respondents 72 confirmed GIB presence in their area within last 4 days to 6 months. We used this information along with locations of tagged birds in Maharashtra to identify 87 out of 372 grids as conservation priority areas for GIB. These grids constituted 11 clusters spread across 12 forest divisions of Maharashtra covering an area of 12,528 km². The important GIB areas like Nannaj and Warora are part of these priority clusters. Figure 8 shows GIB priority areas across Maharashtra

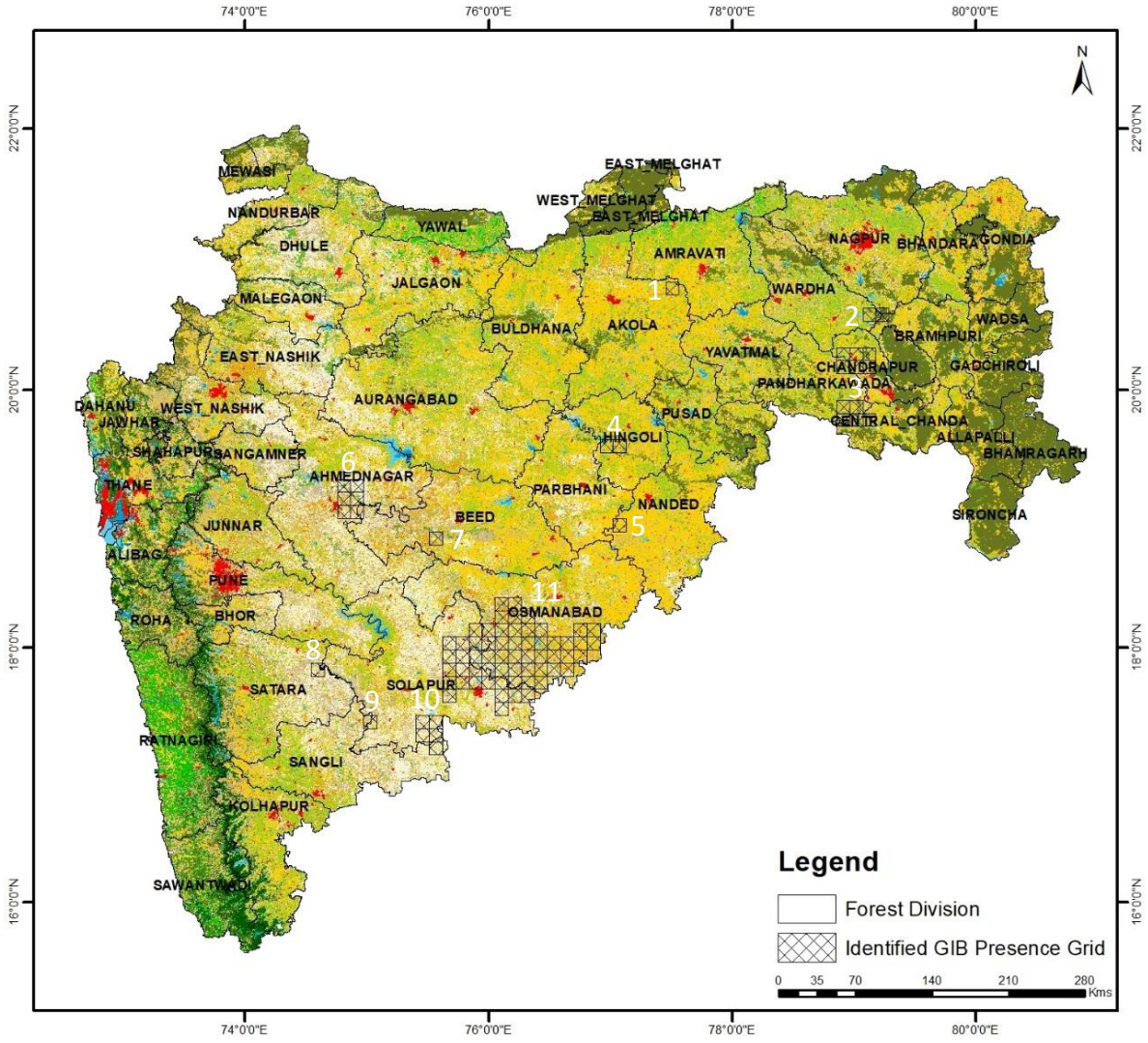


Figure 8: Map showing 11 clusters for priority conservation in Maharashtra, India

Cluster 1: Grid-A (Near Murtizapur of Akola Forest Division)

This cluster has one 12 x 12 km grid covering an area of 144 km² area. Grid A12 within this cluster falls near Murtizapur of Akola Forest Division. The overall land use is dominated by kharif crops followed by mixed crops. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 4 and corresponding map is given in Figure 9. GIB presence in this grid was confirmed to be within the last 1 month.

Table 4: Table showing areas under different land use categories

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	1.88	Deciduous Forest	1.42
Kharif Crop	85.27	Degraded Forest/ Forest	0.11
Rabi Crop	1.68	Wasteland	2.58
Zaid Crop	0.007	Waterbody Max	2.30
Double/Triple Crop	23.63	Waterbody Min	0.06
Current Fallow	6.52		

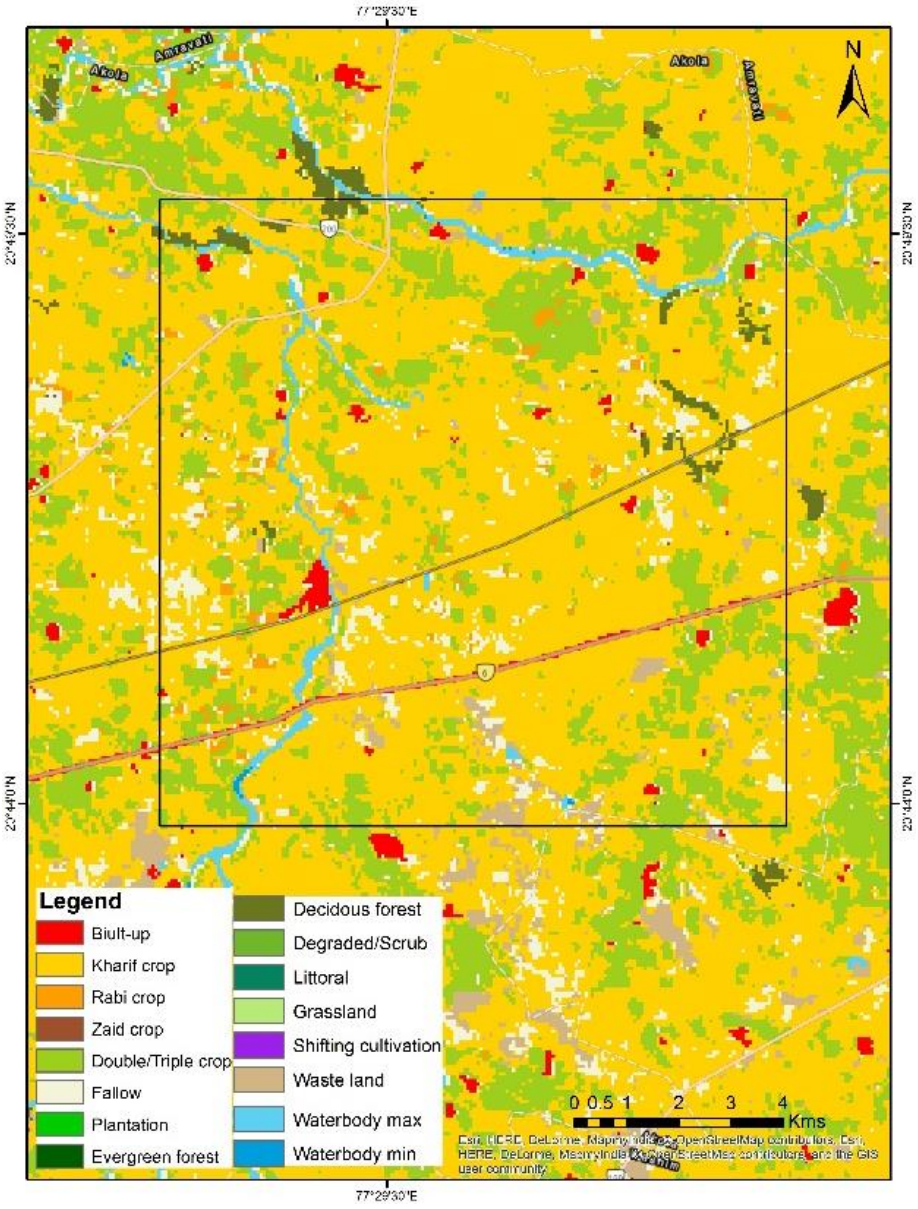


Figure 9: Potential GIB habitat grid identified during landscape survey in Akola Forest Division, Maharashtra, India

Cluster 2: Grid-C (Near Arvi and Pimpalgaon of Wardha Forest Division)

This cluster has one 12x12 km grid covering an area of 144 km² area. Grid C10 within this cluster falls near Arvi and Pimpalgaon of Wardha Forest Division. The overall land use is dominated by kharif crops and mixed crop. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 4 and corresponding map is given in Figure 10. GIB presence in this grid was confirmed to be within the last 6 months.

Table 5: Table showing areas under different land use categories

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	0.60	Deciduous Forest	13.85
Kharif Crop	42.07	Degraded Forest/ Forest	1.84
Rabi Crop	0.48	Wasteland	11.10
Double/Triple Crop	41.23	Waterbody Max	3.04
Current Fallow	8.81	Waterbody Min	0.01
Plantation	0.07		

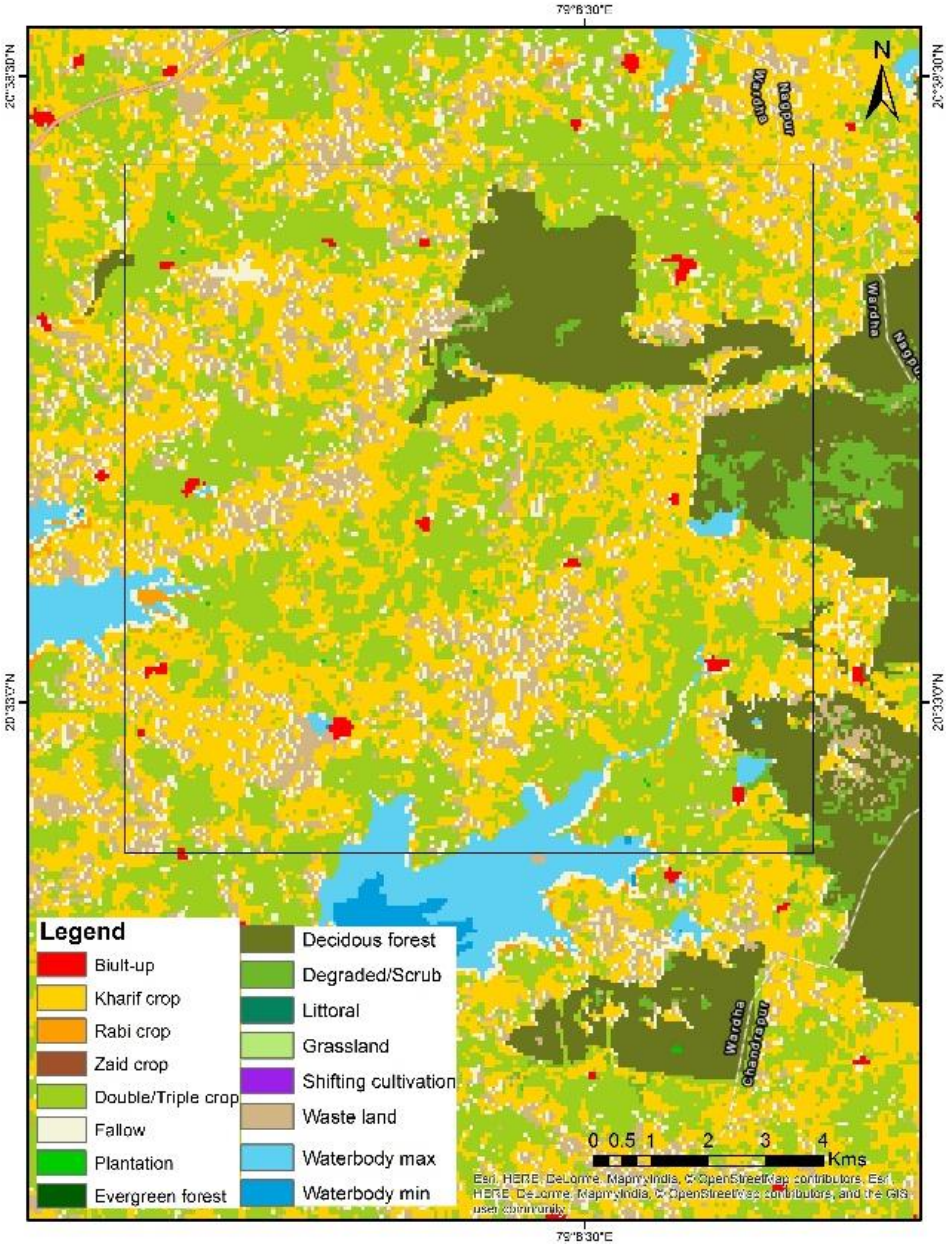


Figure 10: Potential GIB habitat grid identified during landscape survey in Wardha Forest Division, Maharashtra, India

Cluster 3: Grid-E (Near Warora and Wani of Chandrapur and Pandharkawada Forest Division)

This cluster has eight 12x12 km grid covering an area of 1152 km² area. Grids E1-3, E7-11 within this cluster falls near Warora and Wani of Chandrapur and Pandharkawada Forest Division. The overall land use is dominated by kharif crops followed by mixed crops. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 6 and corresponding map is given in Figure 11. GIB presence in this grid was confirmed to be within the last 1 month.

Table 6: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	33.94	Plantation	0.15
Kharif Crop	543.75	Deciduous Forest	90.58
Rabi Crop	3.93	Degraded Forest/ Forest	41.78
Zaid Crop	0.064	Wasteland	99.38
Double/Triple Crop	438.37	Waterbody Max	22.63
Current Fallow	71.45	Waterbody Min	3.62

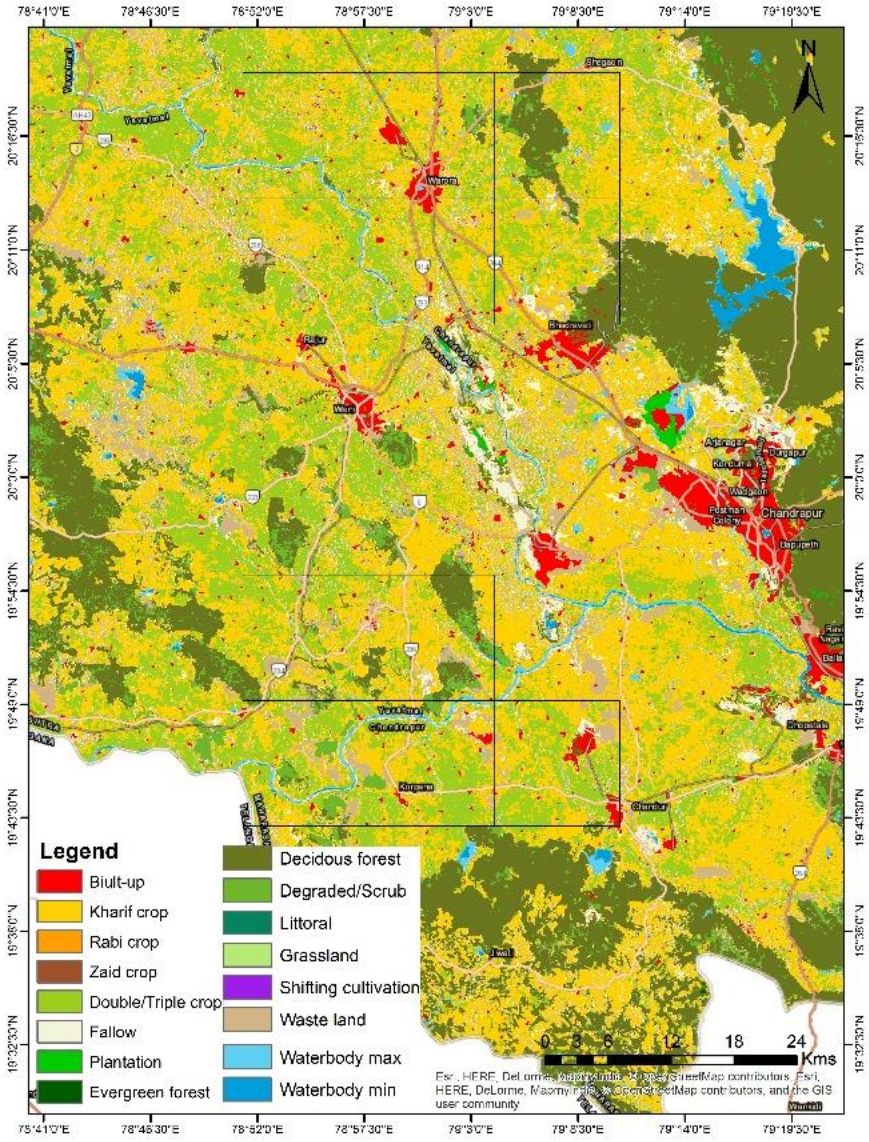


Figure 11: Potential GIB habitat grid identified during landscape survey in Chandrapur and Pandharkawada Forest Division, Maharashtra, India

Cluster 4: Grid-J (Hingoli Forest Division)

This cluster has two 12x12 km grid covering an area of 288 km² area. Grids J1 and J2 within this cluster falls near Hingoli of Hingoli Forest Division. The overall land use is dominated by kharif crops followed by wastelands and Deciduous forest. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 7 and corresponding map is given in Figure 12. GIB presence in this grid was confirmed to be within the last 1 month.

Table 7: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	2.79	Deciduous Forest	16.86
Kharif Crop	125.88	Degraded Forest/ Forest	4.66
Rabi Crop	0.08	Wasteland	22.26
Double/Triple Crop	55.66	Waterbody Max	5.16
Current Fallow	11.11	Waterbody Min	8.97
Plantation	0.76	Plantation	0.76

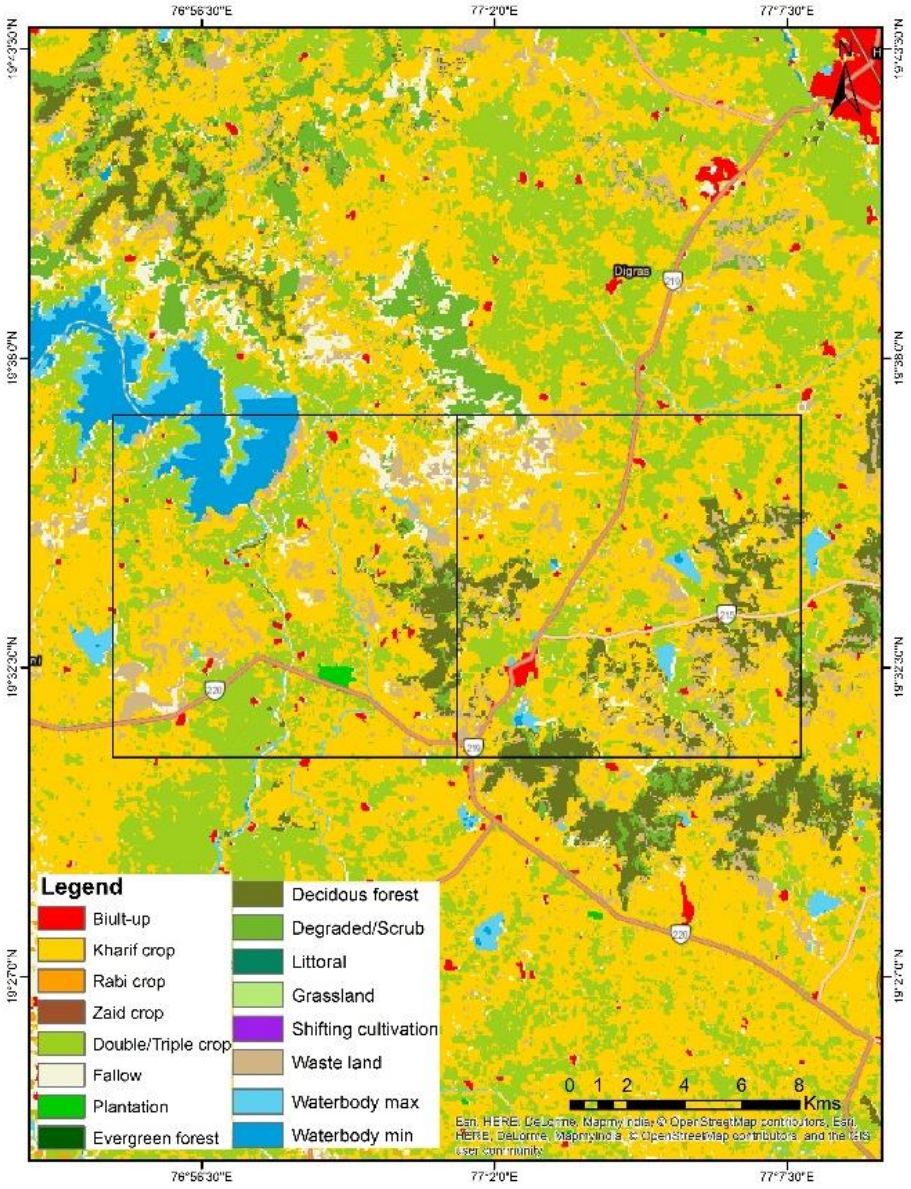


Figure 12: Potential GIB habitat grid identified during landscape survey in Hingoli Forest Division, Maharashtra, India

Cluster 5: Grid-K (Near Loha of Nanded Forest Division)

This cluster has one 12x12 km grid covering an area of 144 km² area. Grid K8 within this cluster falls near Loha of Nanded Forest Division. The overall land use is dominated by kharif crops followed by wastelands and deciduous forest. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 8 and corresponding map is given in Figure 13. GIB presence in this grid was confirmed to be within the last 1 month.

Table 8: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	2.78	Deciduous Forest	16.86
Kharif Crop	125.88	Degraded Forest/ Forest	4.66
Rabi Crop	0.08	Wasteland	22.26
Double/Triple Crop	55.66	Waterbody Max	5.16
Current Fallow	11.11	Waterbody Min	8.97
Plantation	0.76	Plantation	0.76

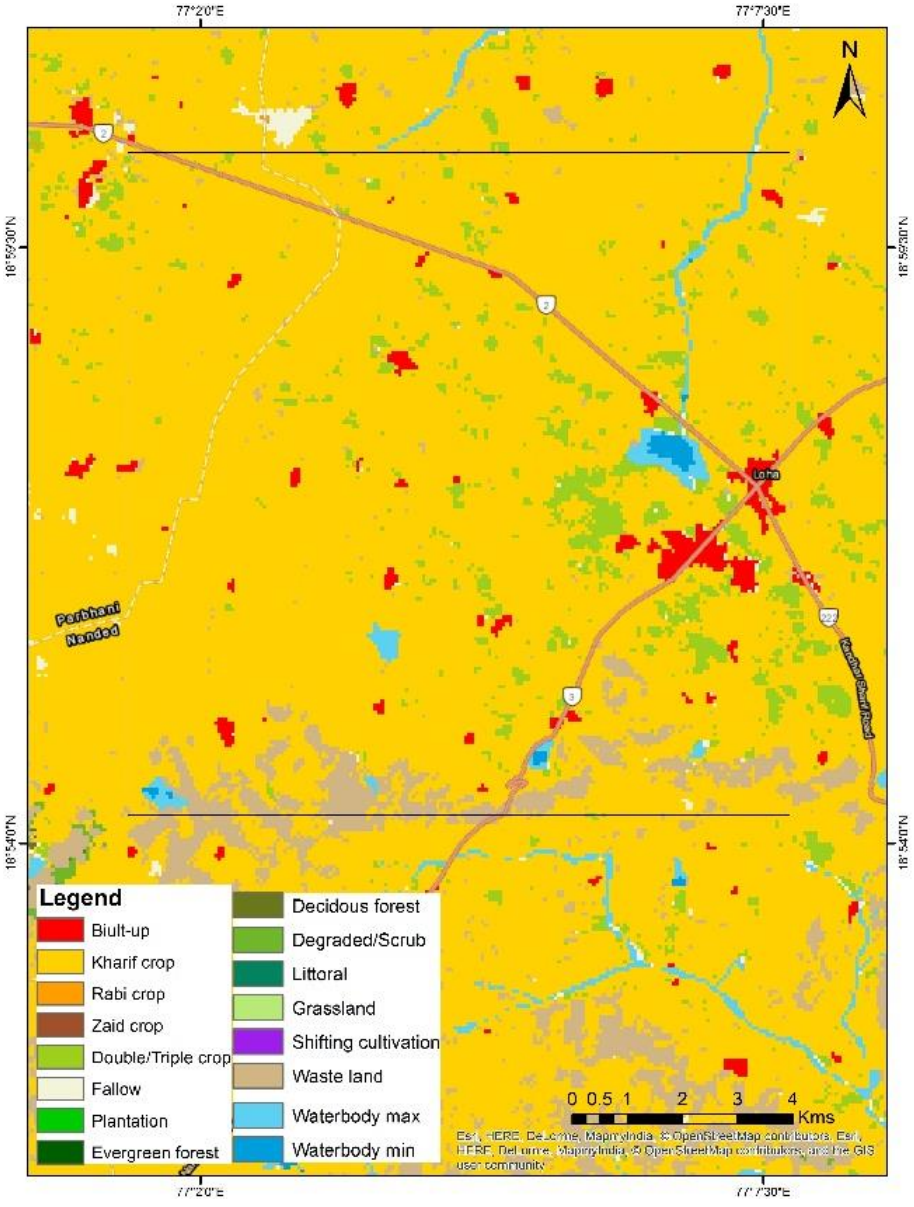


Figure 13: Potential GIB habitat grid identified during landscape survey in Nanded Forest Division, Maharashtra, India

Cluster 6: Grid-O (Ahmadnagar Forest Division)

This cluster has six 12x12 km grid covering an area of 864 km² area. Grids O1-6 within this cluster falls near Ahmadnagar of Ahmadnagar Forest Division. The overall land use is dominated by fallow lands followed by wasteland and major crops types are kharif crops and Rabi crops. The areas under each land use category is provided in Table 9 and corresponding map is given in Figure 14. GIB presence in this grid was confirmed to be within the last 1 month.

Table 9: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	17.30	Plantation	0.88
Kharif Crop	88.97	Deciduous Forest	22.05
Rabi Crop	72.55	Degraded Forest/ Forest	29.72
Zaid Crop	0.23	Wasteland	133.15
Double/Triple Crop	18.56	Waterbody Max	7.59
Current Fallow	393.99	Waterbody Min	0.06

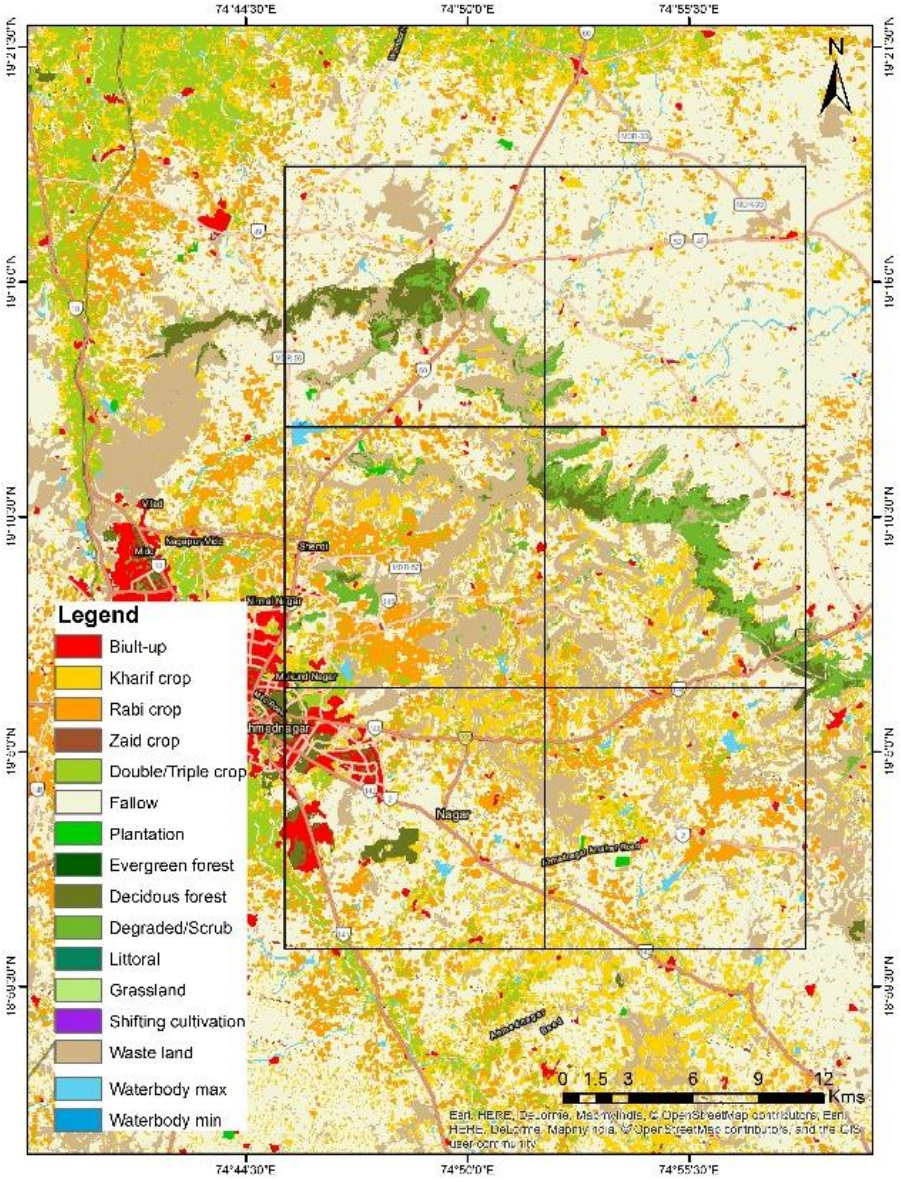


Figure 14: Potential GIB habitat grid identified during landscape survey in Ahmadnagar Forest Division, Maharashtra, India

Cluster 7: Grid-Q (Near Patola and Borkhed of Beed Forest Division)

This cluster has one 12x12 km grid covering an area of 144 km² area. Grid Q6 within this cluster falls near Patola and Borkhed of Beed Forest Division. The overall land use is dominated kharif crops followed by fallow lands. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 10 and corresponding map is given in Figure 15. GIB presence in this grid was confirmed to be within the last 2 months.

Table 10: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	0.90	Plantation	0.27
Kharif Crop	28.30	Deciduous Forest	2.13
Rabi Crop	22.75	Degraded Forest/ Forest	7.83
Zaid Crop	0.003	Wasteland	33.79
Double/Triple Crop	9.34	Waterbody Max	1.87
Current Fallow	23.39	Waterbody Min	0.18

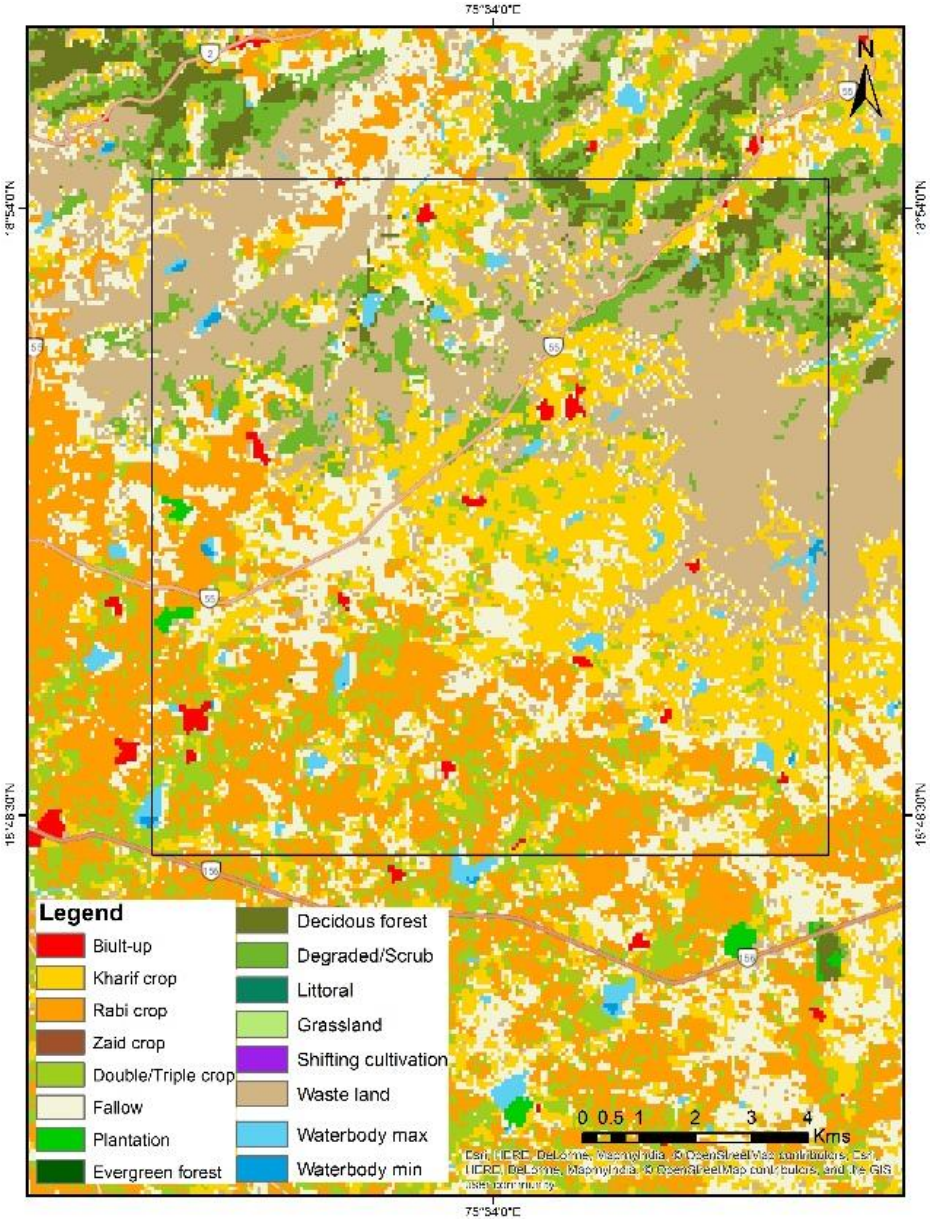


Figure 15: Potential GIB habitat grid identified during landscape survey in Beed Forest Division, Maharashtra, India

Cluster 8: Grid-R (Near Phaltan and Pimpari of Satara Forest Division)

This cluster has one 12x12 km grid covering an area of 144 km² area. Grid R6 within this cluster falls near Phaltan and Pimpari of Satara Forest Division. The overall land use is dominated fallow land followed by wasteland. The areas under each land use category is provided in Table 11 and corresponding map is given in Figure 16. GIB presence in this grid was confirmed to be within the last 1 month.

Table 11: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	1.22	Deciduous Forest	0.12
Kharif Crop	12.24	Degraded Forest/ Forest	1.84
Rabi Crop	3.74	Wasteland	44.69
Zaid Crop	0.02	Waterbody Max	1.59
Double/Triple Crop	1.54	Waterbody Min	0.03
Current Fallow	65.30	Current Fallow	65.30

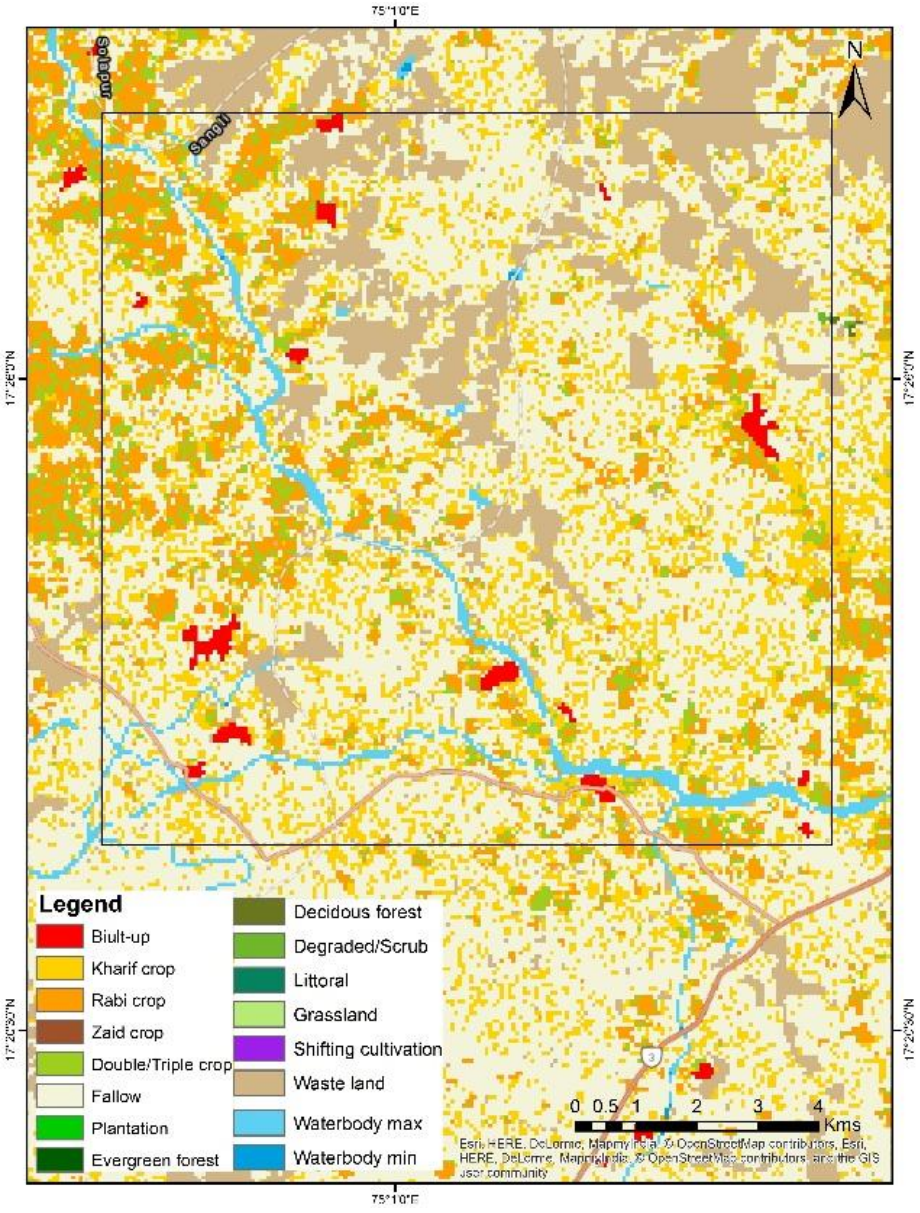


Figure 16: Potential GIB habitat grid identified during landscape survey in Satara Forest Division, Maharashtra, India

Cluster 9: Grid-T (Near Atpadi and Sangola of Sangli Forest Division)

This cluster has one 12x12 km grid covering area of 144 km² area. Grid T5 within this cluster falls near Atpadi and Sangola of Sangli Forest Division. The overall land use is dominated by fallow land followed by kharif crops. The agriculture practice in the area is traditional. The areas under each land use category is provided in Table 12 and corresponding map is given in Figure 17. GIB presence in this grid was confirmed to be within the last 2 months.

Table 12: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	1.39	Deciduous Forest	0.007
Kharif Crop	25.10	Degraded Forest/ Forest	0.02
Rabi Crop	12.68	Wasteland	16.17
Double/Triple Crop	5.66	Waterbody Max	3.50
Current Fallow	68.50	Waterbody Min	0.02

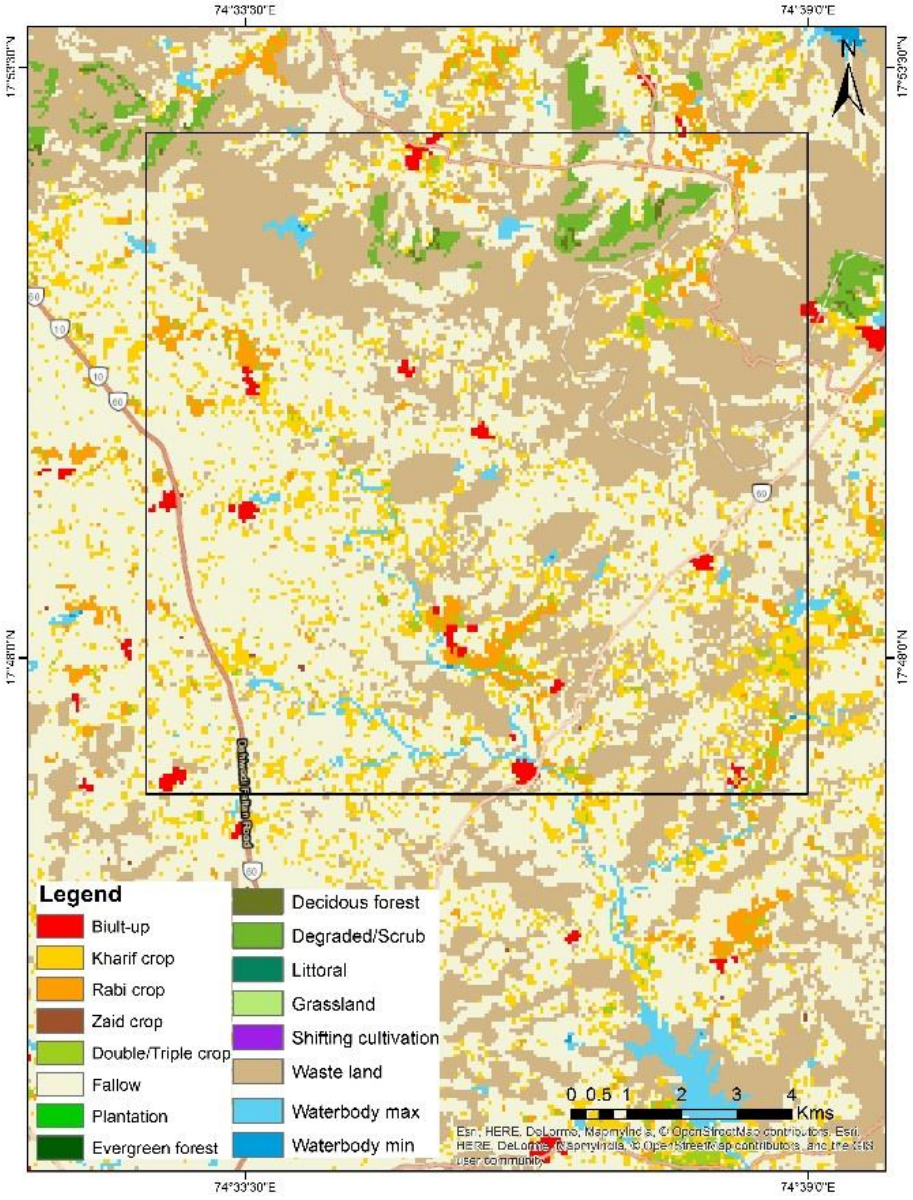


Figure 17: Potential GIB habitat grid identified during landscape survey in Sangli Forest Division, Maharashtra, India

Cluster 10: Grid-T (Near Mangalwedha and Nandeshwar of Solapur Forest Division)

This cluster has five 12x12 km grid covering an area of 720 km² area. Grids U2, U3, U5, U6 and U9 within this cluster falls near Mangalwedha and Nandeshwar of Solapur Forest Division. The overall land use is dominated by fallow lands followed by kharif crops and wastelands. The areas under each land use category is provided in Table 13 and corresponding map is given in Figure 18. GIB presence in this grid was confirmed to be within the last 6 months.

Table 13: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	3.52	Plantation	0.85
Kharif Crop	116.08	Deciduous Forest	0.43
Rabi Crop	9.54	Degraded Forest/ Forest	0.52
Zaid Crop	0.079	Wasteland	73.74
Double/Triple Crop	5.85	Waterbody Max	9.79
Current Fallow	409.62	Waterbody Min	0.49

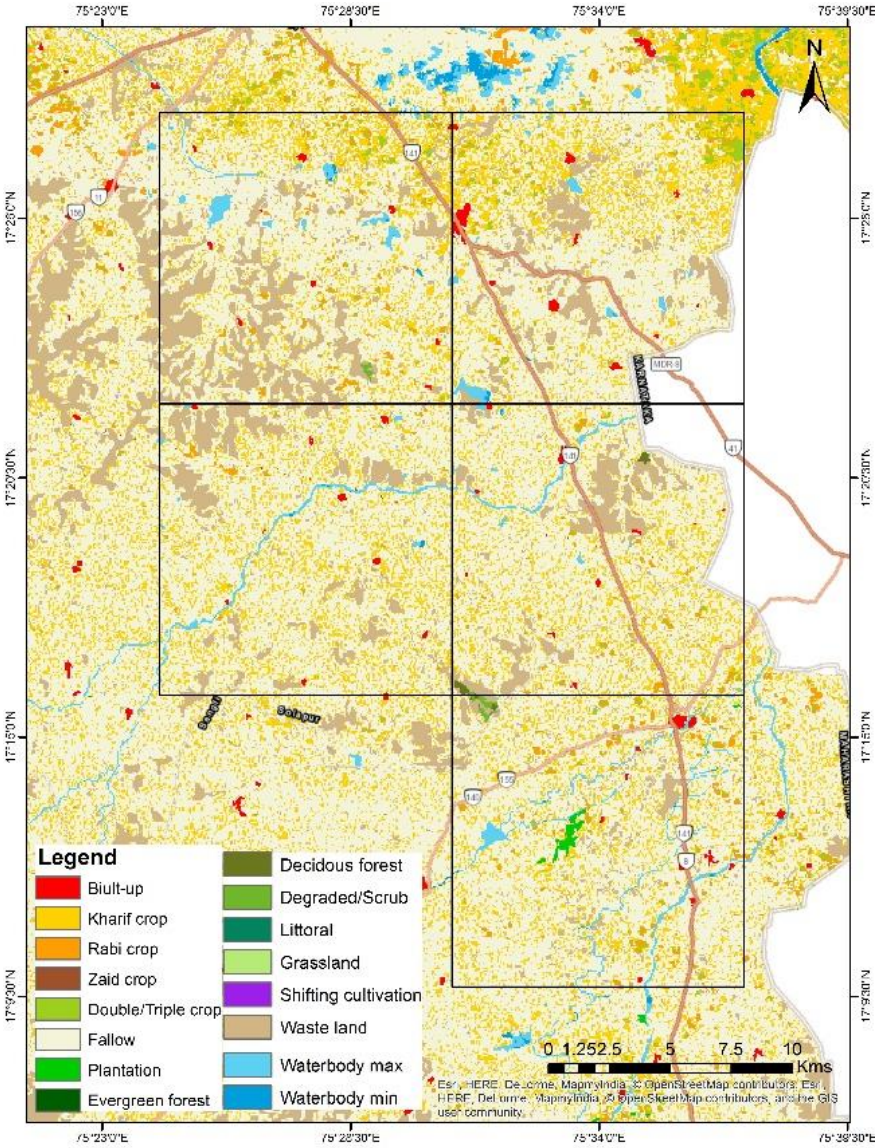


Figure 18: Potential GIB habitat grid identified during landscape survey in Solapur Forest Division, Maharashtra, India

Cluster 11: Grid- W, X, Y, Z, AA, AB, AC and AE (Near Solapur, Tuljapur, Osmanabad, Latur and Ausa of Solapur and Osmanabad Forest Division)

This cluster has fifty-nine 12x12 km grid covering area of 8496 km² area. Grids W8, W12, X5, X9, X10, Y10-12, Z1, Z2, Z4-12, AA1-12, AB1-12, AC3-12, AE1-5, and AE9 within this cluster falls near Solapur, Tuljapur, Osmanabad, Latur and Ausa of Solapur and Osmanabad Forest Division. The overall land use is dominated by kharif crops followed by mixed crops. The areas under each land use category is provided in Table 14 and corresponding map is given in Figure 19. GIB presence in this grid was confirmed to be within the last 4 days to 8 months.

Table 14: Table showing areas under different land use category

Landuse type	Area in sq. km	Landuse type	Area in sq. km
Built-up	155.84	Plantation	15.56
Kharif Crop	2538.0	Deciduous Forest	13.39
Rabi Crop	555.76	Degraded Forest/ Forest	9.12
Zaid Crop	0.67	Wasteland	927.81
Double/Triple Crop	496.28	Waterbody Max	200.90
Current Fallow	2703.65	Waterbody Min	40.75

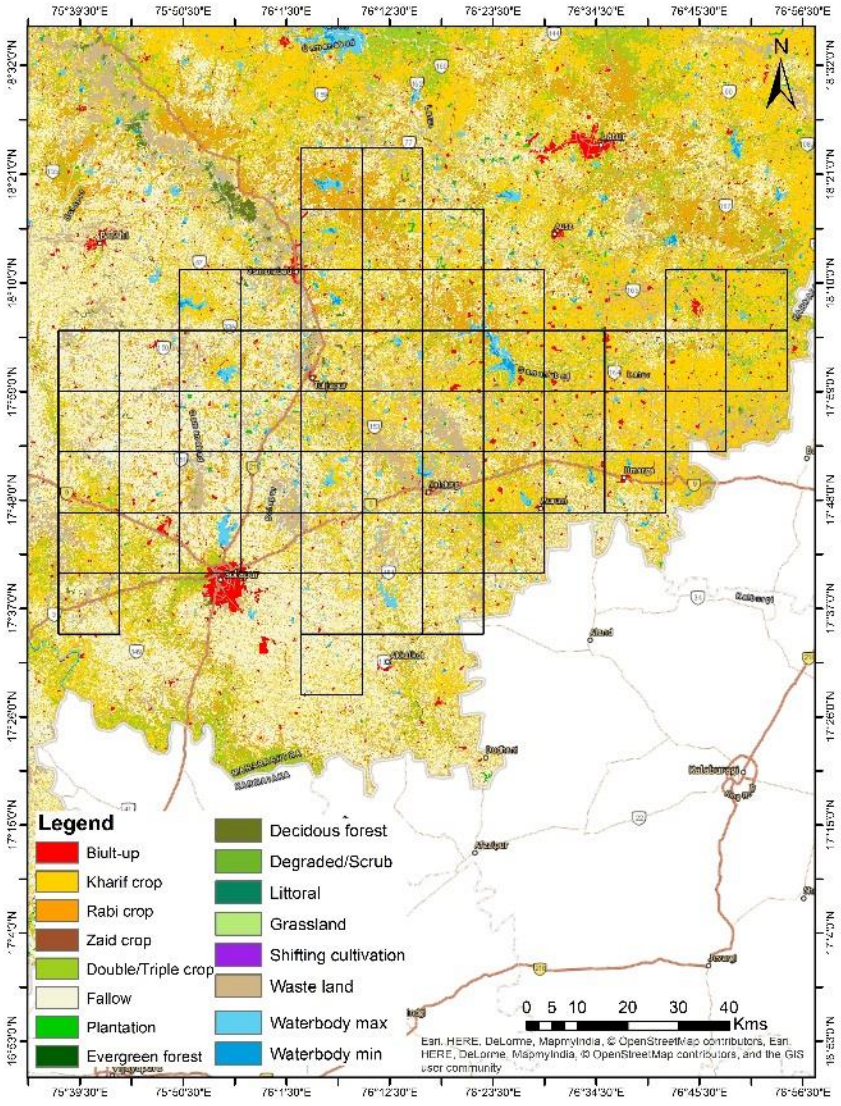


Figure 19: Potential GIB habitat grid identified during landscape survey in Solapur and Osmanabad Forest Division, Maharashtra, India

Questionnaire Survey

The questionnaire survey data (n=1401 respondents) revealed that 53.82% of respondents had no idea about the bird, 37.26% knew but had never seen a GIB. 2.28% of respondents had seen GIB in last 6 months (April – September, 17) (Figure 20). The 72 respondents who knew about or had seen GIB were asked about the perceived reasons of decline of GIB. 59.72% of respondents had no idea, 18.06% respondents believed that change in cropping pattern is the reason of decline, 8% believed electric lines are responsible for the decline and 4.17% believed development is the main reason (Figure 21).

Figure 20: Graph showing respondents' knowledge of GIB presence in their area

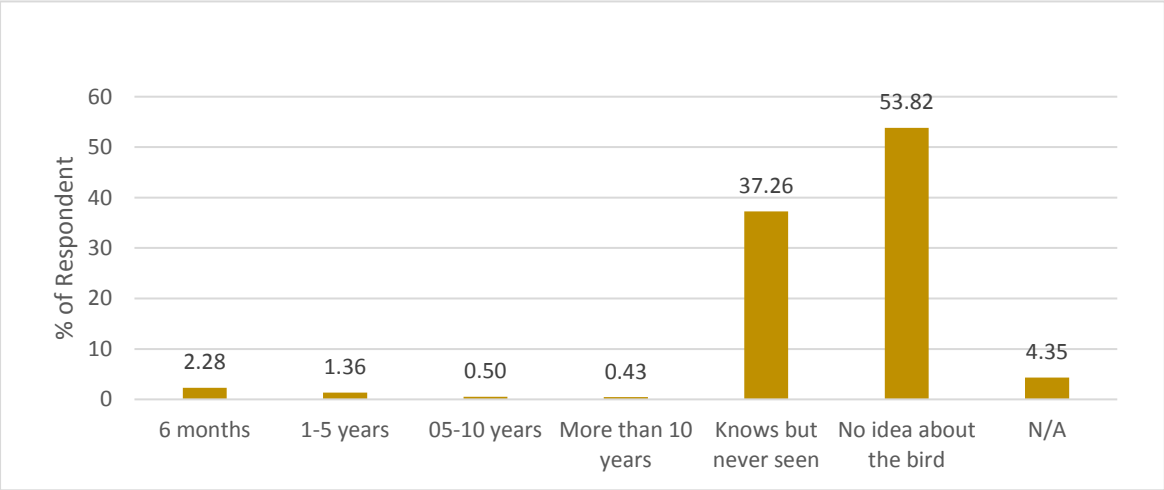
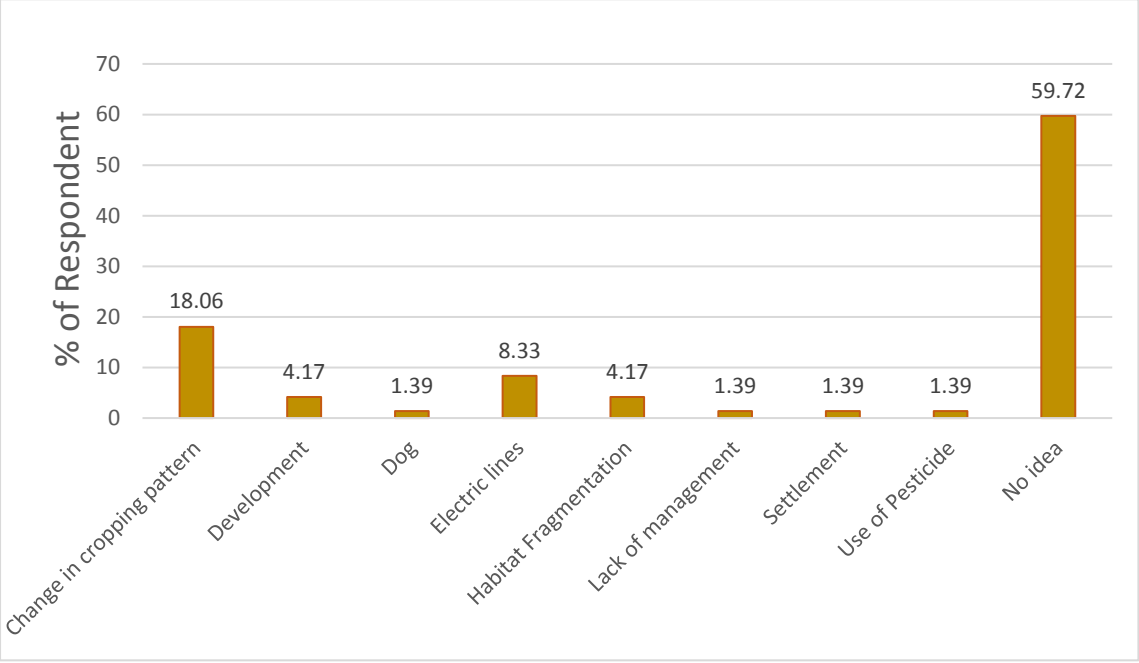


Figure 21: Graph showing perceived reasons of GIB decline in various part of Maharashtra according to questionnaire survey



Blind Test using life-size dummy

GIB prefers arid and semi-arid grasslands with scattered short scrub, bushes and low intensity cultivation in flat or gently undulating terrain. They congregate in traditional grassland patches (mostly identified) with low disturbance, to breed during mid-summer and monsoon. In non-breeding season, it makes local and possibly long distance nomadic movements in response to various factors, using areas rich in food resources and surrounded by natural grass-scrub habitat for easy navigation. It requires different microhabitat envelope for different activities, such as grasslands with relatively tall vegetation (25-100 cm), high insect resources and less grazing pressure, for nesting; short sparse vegetation (<25 cm) on slightly elevated grounds for display; sparse vegetation (<25 cm) with minimal scrub for roosting; and moderate (25-50 cm) vegetation shade for resting (Rahmani, 1989; Dutta, 2012). Because of their ecology and low population in Maharashtra probability to see one GIB is very low. To overcome this, a blind test using life-size GIB dummies was conducted (Figure 22) to know the possibility of detection in sampling grids by the sampling team. The dummies were placed in the sampling grids by a separate team. The sampling team was unaware of the location of dummy GIB. The placement of the dummies GIB across grids is shown in the Figure 23.

Placement of life-sized dummy GIB

The study extended over a large area and each team was assigned to cover an area of 1728 sq. km. One dummy GIB was placed for each team in one of the 12 grids without informing the teams about its location. A total of 30 dummy GIBs were placed across the area sampled in Maharashtra to evaluate the chance of detection of GIB (Figure 23). The detection probability of dummy GIB and live GIB were assumed to be same.

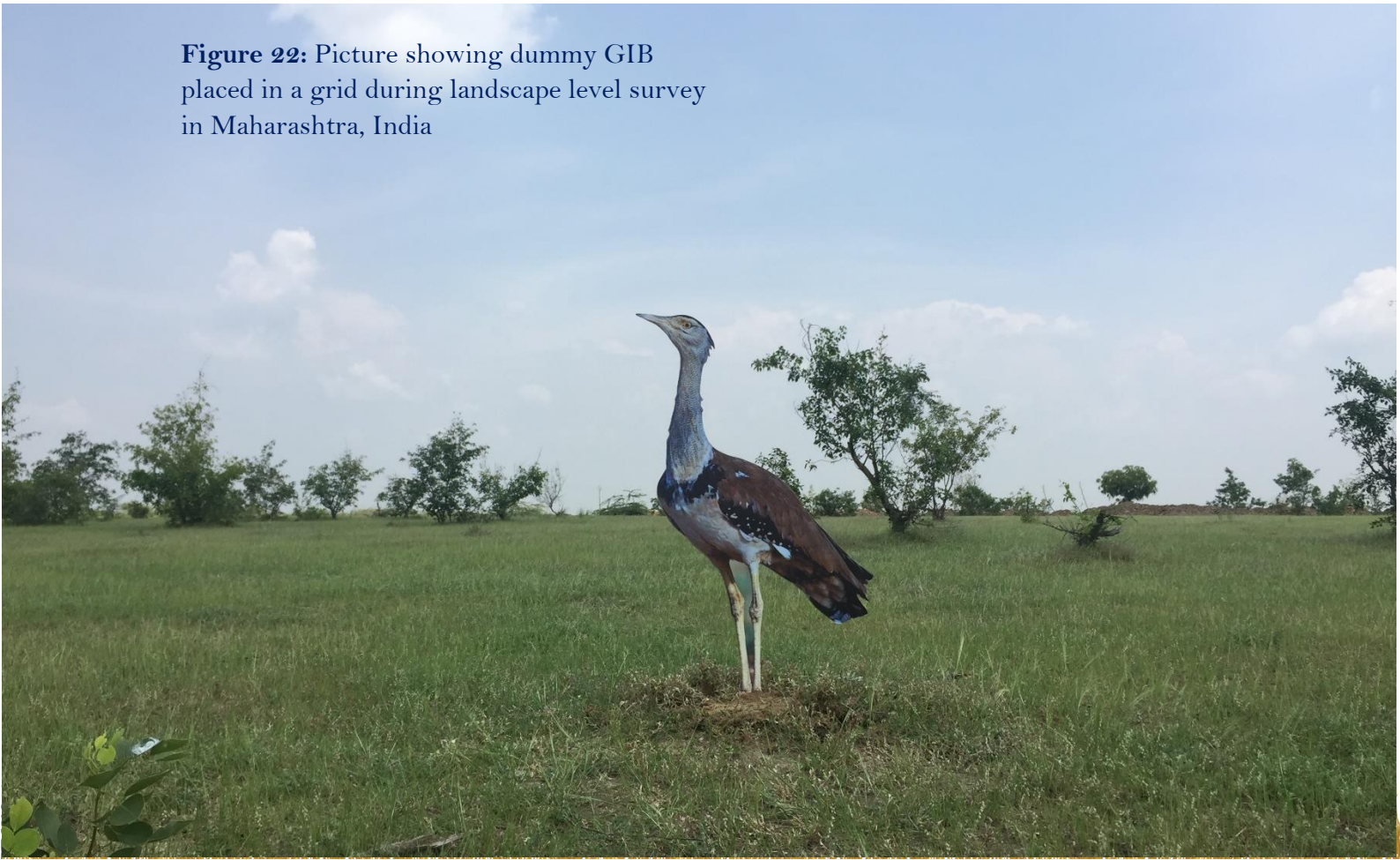


Figure 22: Picture showing dummy GIB placed in a grid during landscape level survey in Maharashtra, India

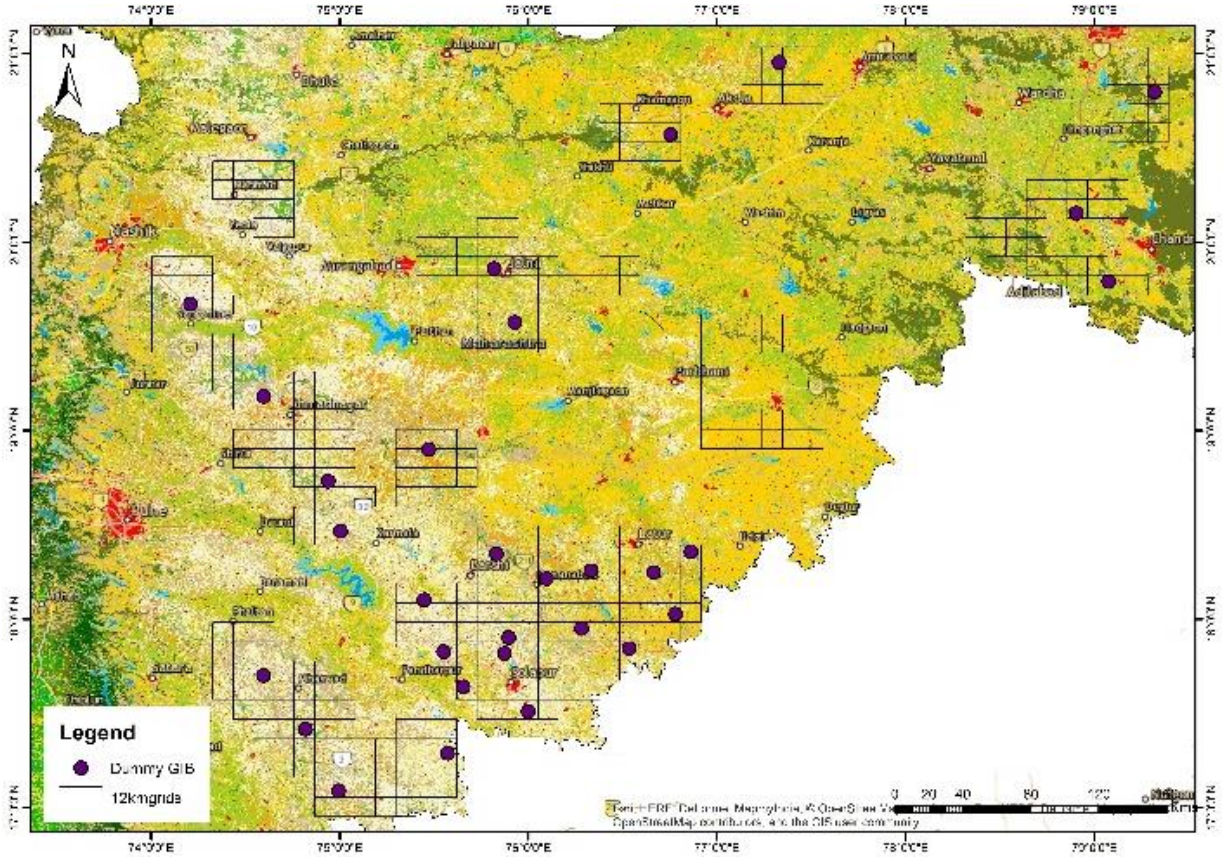


Figure 23: Map showing the locations of dummy GIBs placed in grids

Random points were generated across potential GIB distribution map for placement of dummy birds. The area was further scrutinized and dummies were placed at suitable areas where chances of GIB occurrence was assumed to be high. 30 life-size dummies were placed in grids so as to ensure that each team would have at least 1 dummy in their respective grids.

Outcomes and Conclusion

Out of the 30 dummies placed, only 4 were detected by the respective sampling teams. The detection probability was found to be 13% which is within the range of previous studies (Rahmani, 1986). This would mean that, if the population of GIB ranges from 8 to 10, there is a chance of detecting one GIB with a minimum sampling effort of 8 temporal replicate for each transect considering that detection probability of dummy GIB and live GIB are the same. During the survey, no GIB was sighted which implies that the number of GIB might be less than 8 in Maharashtra.

The number of sampling occasion required the determine species presence at occupied sites based on blind test (dummy life-size of GIB) varied accordingly to designed confidence level. Based on our estimate of occupancy (8.06%) and detectability (13%) of dummy GIBs. Power analysis showed, that there is 80% chance of detecting a 53% change in occupancy with sampling effort of 8 replicates in 200 grids (Barata et al., 2017). This can also be achieved by sampling 140 - 150 grids with 10 replicates (Figure: 24). This indicates need for intensive sampling for detecting any population change in Maharashtra.

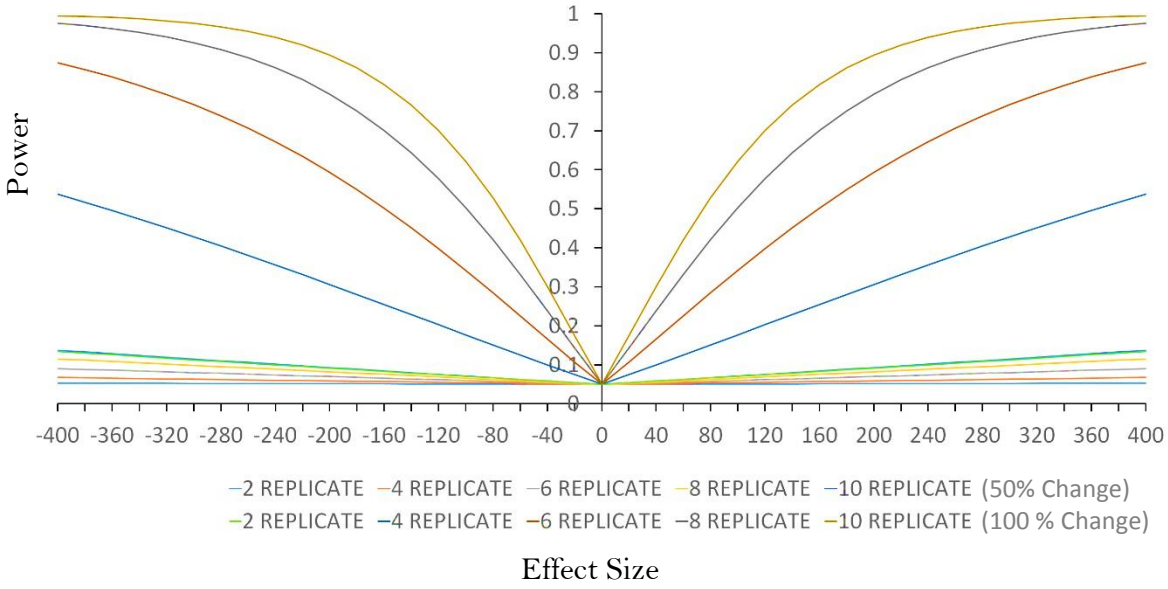


Figure 24: Statistical power as function of change in occupancy under different sampling designs (number of replicates and grids)



Discussion

India has experienced a significant loss in grassland habitats over the last few hundred years due to expansion of agriculture as well as human settlements (Tian et al., 2014). In addition, farmers have been shifting to cash crop production from traditional cultivation of pulses and oil seed (Nalawade et al., 2010; Seethalakshmi, 2010; Kadapatti, and Bagalkoti, 2014). This shift from the traditional agricultural pattern is mainly due to increase in demand and high economic value of cash crops. The rapid conversion of grasslands and shrub lands into agricultural lands, excessive use of insecticides and pesticides, over grazing and human disturbance are the major contributing factors in the decline of GIB populations.

GIBs were once distributed throughout the grasslands of northern India and the Deccan Landscape in around 11 states (Rahmani, 1989), but are now confined to only 7 states with less than 250 individuals (Dutta et al., 2010). The aim of this survey was to provide an overview of suitable areas for GIB in Maharashtra and identify potential areas for future planning. The GPS locations from tagged birds revealed habitats preferred by GIB in the state of Maharashtra. It was earlier considered that GIB only used grasslands (Simcox, 1913; Tyabji, 1952; Dangre, 1966; Rahmani, 1987; Thosar et al., 2007) but telemetry data has revealed that they spend most of their time in agricultural fields and fallow lands for foraging and congregate at grasslands for breeding. The tagged birds were seen to be utilizing an area of more than 14,000 km^2. These findings make it clear that conserving habitats outside the protected area system is critical for GIB conservation in the state of Maharashtra.

Maharashtra harbors a good population of Blackbuck outside the protected area; their density was found to be 0.74 ± 0.11 km^2, and total population was found to be 37690 ± 5625. The density of Chinkara was found to be very low (0.02 ± 0.01 km^2) and total population was found to be 1481 ± 577. This is probably our grids were in potential GIB habitat. Chinkara generally prefers arid areas, including sand deserts, flat plains and hills, dry scrub and open forests (Rahmani, 1990; Jaipal, 2015; IUCN, 2017).

Unfortunately, no GIBs were sighted during the survey, However, indirect information of their presence in known areas was collected through questionnaire survey and probable new areas were identified. The authenticity of this information was confirmed by showing pictures of Wooly Necked Stork *(Ciconia episcopus)* to respondents as this species is one of the closest species in the area with whom GIB is confused by the local people. Once people confirmed the presence of GIB, information about areas where GIB has been seen and approximate time of such sightings was collected. Using this information, 11 clusters (87 grids) were identified. Most of these grids fall outside protected grassland areas with crop fields dominated by kharif crops and open areas. These grids need proper monitoring for further validation.

The blind test experiment conducted by placing dummy GIBs has revealed low detection of these birds which can be further confounded by low population size, nomadic movement and use of large agricultural landscape for foraging without distinguished boundary. Out of the 30 dummies placed, only 4 had been detected by survey teams. Power analysis on detection probability (13%) and occupancy (8.06%) of dummy life-sized GIB showed that 8 replicates required in 180 grids of detecting 53% change in occupancy. Considering this, it would

require 8 temporal replicates for each transect across the landscape to detect one GIB if the population size is 8-10. This indicates that the probable population size of GIB is less than 8 birds in the state of Maharashtra. It is recommended to survey the 11 identified clusters in a more rigorous way in the coming year.

Conservation Implications

GIBs are large flying birds, which generally take low flights resulting in mortality due to collision with electric lines. Dogs are another major threat to them. The habitat selection of GIB changes throughout the year in response to food availability. The telemetry data has indicated that GIB prefers open grasslands and agricultural fields of sorghum, groundnuts, and pigeon pea. In this context, both the agricultural and land sparing practices are to be well managed for GIB conservation in Maharashtra. Awareness raising programs should be initiated and measures should be taken to protect traditional agricultural practices.

Management of Potential GIB Clusters in Maharashtra

There are 11 clusters in 12 different forest divisions which are important for GIB conservation in the state of Maharashtra. Most of these areas are dominated by kharif crops (sorghum, peanut, groundnut, seed oils), preferred by GIB as foraging grounds. The following recommendations are made on the basis of the findings of the landscape level GIB survey:

- The 11 identified clusters should be monitored for a duration of 1-2 years continuously at least 2-3 times a year.
- Department-owned areas within such grids should be managed as bustard habitats by removing invasive species.
- There is an urgent need for awareness in these identified clusters with option to promote traditional cropping patterns. Any changes in these areas will be critical for GIB conservation.
- Traditional cropping patterns need to be promoted by involving other line departments and need to have awareness and capacity building program for the same.
- There is a need to put reflectors on power-lines in such areas.
- Dog population needs continuous monitoring and measures should be taken to control the growth of dog populations in such areas.
- GIB conservation in Maharashtra is only possible if traditional cropping and land sparing is promoted and incentivized.

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HAS CONSERVATION GONE TO THE DOGS?

Ecological aspects of free-ranging dogs in the Thar

Dissertation submitted to Saurashtra University, Rajkot in partial fulfillment of Master's Degree in Wildlife Science (June 2017)

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Destroyed buildings can be rebuilt; destroyed works of art may possibly be replaced by new creations; but every animal and every flower which becomes extinct is lost forever in the most absolute of all deaths.

Joseph Wood Krutch

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For all those who have not forgotten to follow their passion…

Monisha S Mohandas
20th June 2017

ABSTRACT

1. One of the few mammals to have a near-global distribution, dogs (*Canis familiaris*) are an introduced mammalian predator. Dogs have contributed to 11 vertebrate extinctions and are a potential threat to 188 threatened species globally. This study investigates population sizes, ranging patterns, behavioural activity, and resource utilisation of free-ranging dogs in Thar landscape, Rajasthan.

2. Using double sampling framework, I calibrated effort-standardized counts (C) with mark-recapture based abundances ($\widehat{N}$) that was used to estimate dog abundances within human habitation. Landscape-scale dog abundance was estimated using vehicle transect based distance sampling. Home ranges of nine free-ranging dogs was determined using locations from radio-telemetry. Resource use was quantified as feeding durations on various food items based on continuous monitoring. Resource availability was quantified as wild prey and livestock carcass density using line transect based distance sampling.

3. The calibrated relationship [$N = (1.65 \pm 0.05_{SE})$ x C] estimated a total of $761 \pm 109_{SE}$ dogs in human habitation with the total number of dogs averaging at $1804 \pm 462_{SE}$ dogs in 1008 km^2 area. Home range (95% MCP) of free-ranging dogs averaged at $19.81 \pm 4.79_{SE}$ km^2 with no difference between males and females. Space-use was two-fold closer to enclosures (prime wildlife resource patches) and threefold closer to settlements (human-derived resource patches) than expected under random use.

4. Activity budget and temporal activity pattern obtained from 156-hours continuous monitoring per dog showed that dogs were crepuscular, mostly active during 0600-0900 and 1800-2100 hours, and resting for 75% of the day.

5. Prey densities (individuals/km^2) were estimated to be 7 $\pm$ 1.22_{SE} chinkara, 0.46 $\pm$ 0.23_{SE} nilgai, 4681 spiny tailed lizard and 2861$\pm$ 203_{SE} jird. Goat and sheep carcasses contributed most to the diet (54% feeding time) and were also most selected (Ivlev's index = 0.96_{goat} and 0.95_{sheep}) followed by predation on nilgai and chinkara. I estimated potential predation rates of chinkara and nilgai to be 9.67 and 10.95 dog^{-1} $year^{-1}$ respectively albite with a small sample.

6. **Synthesis and applications.** This study provides information on important aspects of free-ranging dog ecology and their impacts in Thar landscape. It provides the basis required for implementing dog control programs in the landscape focusing on the flagship and critically endangered great Indian Bustard *Ardeotis nigriceps*.

Keywords: activity pattern, Canis familiaris, double sampling, home range, population, predation rate

CHAPTER 1

INTRODUCTION

1.1 General Introduction

In today's world, a 14,000 years bond that has been maintained, if not strengthened by man in every generation, is now being put to the test. For the dog or for wildlife? *Man's best friend* are descendants of the charismatic grey wolf (Doherty et al. 2017), which was domesticated by man at least 14,000 years ago to save their lives and livestock from wolves itself (Frantz et al. 2016). 14,000 years later, dogs have invaded most parts of the world and expanded their niche with their abundance continually increasing (Lenth et al. 2008).

About 1 billion domestic dogs have been estimated worldwide, of which, this population is composed of pets, free-ranging and feral dogs (Gompper 2014). The term free-ranging dogs refer to dogs that are not owned by humans but depend on human derived food resources as well as occasionally on wild prey (Lenth et al. 2008, Vanak 2008). These include stray dogs and owned farm and pastoral companion dogs (Vanak 2008). However, feral dogs are considered to be wild and partially dependent of human derived food resources (Nesbitt 1975; Green and Gipson 1994).

Since free-ranging dogs have to survive on their own, they tend to kill livestock of villagers in the rural areas, go through garbage bins in urban, semi urban or rural areas and occasionally hunt wildlife as prey (Hughes and Macdonald 2013). This scenario provides a loss to villagers, increases disease transmissions, and causes free-ranging dogs to be a threat to wildlife (Hughes and Macdonald 2013; Belo et al. 2015).

According to the Living Planet Index (LPI) of 2016, about 10% of the decline in wildlife population globally is due to invasive/introduced species and disease transmissions (World Wide Fund for Nature, WWF 2016). Considering the fact, that dogs carry transmissible pathogens for diseases such as rabies and canine distemper virus, they can often decrease the population of native species of wildlife (Woodroffe 1999; Young et al. 2011; Vanak et

al. 2007). Transmission of zoonotic diseases are very possible especially when these free-ranging dogs are found in close proximity to humans (Salb et al. 2008; Young et al. 2011).

1.2 Current situation with free-ranging dogs in Thar landscape

This is an emerging crisis in Thar landscape which is an important arid biodiversity area of India. The Thar landscape provides an appropriate platform to study this crisis because of the intersection between endangered native biodiversity and human dominance with the highest human density recorded across any desert. The landscape has a relatively large dog population that depends on village resources, tourist resorts, livestock, and native wildlife (Dutta pers. communication & Hiby *et al.* 2016). The large dog population in this landscape might be because of the additional availability of water via the Indira Gandhi canal and/or the alternative food availability aforementioned. This raises a conservation outcry as native species of Desert National Park (a protected area in Thar) are now introduced to a new competitor and/or predator. Thar, with its severe arid conditions that result in typically low ungulate and native predator densities, might not be able to sustain such additional pressure in terms of a non-native formidable predator.

To effectively understand and mitigate this crisis, it is imperative to study dog abundance, their impact on wildlife as well as factors affecting their numbers, distribution and behaviour in the wild. This is of pivotal importance because the Indian government has started implementing grassland recovery plans with emphasis on great Indian bustards as a flagship species and the Thar landscape holds the largest yet precariously surviving population of these critically endangered birds (Dutta et al. 2016). With the increase of free-ranging dogs and their partial dependence on wild diet, the naïve Great Indian bustards would most likely be under utmost threat from these formidable predators.

1.3 Current literature

1.3.1 Population Estimation

Studies have shown that free-ranging dogs, are known to have a negative impact on local people as well as native wildlife. These negative impacts can occur through different ways such as predation on wildlife (Ritchie et al. 2014), competition with native species (Vanak

et al. 2014), disease transmission (Furtado et al. 2016) and hybridization (Bassi et al. 2017). To understand this, estimating the population of these dogs is the most crucial aspect.

Extensive empirical work has been conducted to estimate populations of species. This took a forward leap with the introduction of capture, mark and recapture technique introduced by Johannes Petersen in the 19th century. This technique was named the Lincoln-Petersen estimator and assumed that the study population is 'closed' whereby no births, deaths, immigration, and emigration has occurred during the mark recapture sampling. Mark recapture techniques on canids have used ear tags, radio collars, dyes, and physiological markers such as radioactive isotopes as means of marking individuals (Kruuk et al. 1980; Roemer et al. 1994; Hein and Andelt 1995; Schauster et al. 2002).

In India, the mark recapture technique has been used to estimate the population of free-ranging dogs. Currently, the closest literature available in India are Pal (2001) on the population ecology of free-ranging dogs in West Bengal, Punjabi et al. (2012) in suburban Mumbai and Hiby et al. (2011) in estimating dog population in Rajasthan. Pal (2001) explains that there was a seasonal variation in population density of 185 ± 19 dogs per km^2 and the sex ratio of 1.37:1, was skewed to males. Punjabi et al. (2012) used a mark-resight framework to estimate dog abundance and reported a total of 680.64 ± 34.06 dogs in Aarey Milk Colony, Mumbai which borders Sanjay Gandhi National Park while Hiby et al. (2011) estimated dog abundance using mark resight surveys in three cities in Rajasthan (36,580 dogs in Jaipur, 24,853 in Jodhpur and 2,962 in Jaisalmer) for the purpose of dog sterilization.

1.3.2 Ranging Patterns

Research on ranging patterns of canids in India has been going on since the early 1980s (Johnsingh 1981 on ecology and behaviour of dhole with reference to predator-prey relations; Venkataraman et al. 1995 on movement patterns of two dhole packs; Aiyadurai and Jhala 2006 on habitat use of golden jackals; Vanak and Gompper 2010 on spatial ecology of Indian foxes in a human-dominated dry grassland ecosystem). Understanding

the ranging patterns of species is essential in determining their home ranges and territory as well as factors that affect their habitat selection.

Home ranges and territory size explains the functional role of a species and individuals in a system. Publications such as List and Macdonald (2003) and Jhala et al. (2009), have used radio telemetry to understand the home ranges of mammalian species while a publication has used GPS-collars to study the movement patterns of leopards in a human dominated landscape (Odden et al. 2014). Beside this, literature on the application of radio telemetry on free-ranging dogs to study ranging patterns in India is currently not present.

Though, across the globe, there have been many studies on free-ranging dog ecology. Research such as number of threatened species due to dogs as invasive (Bellard et al. 2016), ecology of feral dogs in Alabama (Scott and Causey 1973) and role of roads in facilitating dog access to primary habitats (Doherty et al. 2015) are a few of the publications present.

Understanding behaviour of a species provides intricate details on the 'how' and 'why' questions. Temporal activity pattern and time activity budget of a species answers such a question. It portrays information regarding the 24-hour cycle of an animal in terms of its activity and the average time spent in each activity. Such literature is extensively available in India especially for large carnivores, in understanding their movement patterns in accordance with prey (Johnsingh 1983; Karanth and Sunquist 2000; Majumder et al. 2011).

1.3.3 Resource Utilisation

Diet, most fundamental in understanding ecology of any species, is a primary resource governing all other attributes. Therefore, diet studies are imperative in understanding range-use, habitat-needs, predation effects and competition (Karanth and Sunquist 1995 on prey selection by tigers, leopards and dholes in tropical forests; Jethva and Jhala 2004 on food habits of Indian wolves in Gujarat by analyzing scats and monitoring radio-tagged wolves; Aiyadurai and Jhala 2006 on foraging and habitat use by golden jackals in Gujarat). However, in India, this study is only partially explored for free-ranging dogs (Vanak and Gompper 2009 looked at the dietary niche separation between free-ranging domestic dogs and Indian foxes and discovered that dogs survived largely on human-derived foods while

Home et al. 2017 explained that most small-bodied livestock was predated upon by dogs in the Upper Spiti landscape, Himachal Pradesh). Considering how free-ranging dogs have become inimical in India, there are limited studies on their impact on wildlife (but see Vanak et al. 2007; Bhardwaj and Dutta 2015).

1.4 Present Study

1.4.1 Broad Objective

The rationale behind this study is to understand the dependency of free-ranging dogs on anthropogenic resources and their impact on wildlife in Thar to create conservation awareness about the same and provide information relevant to their management.

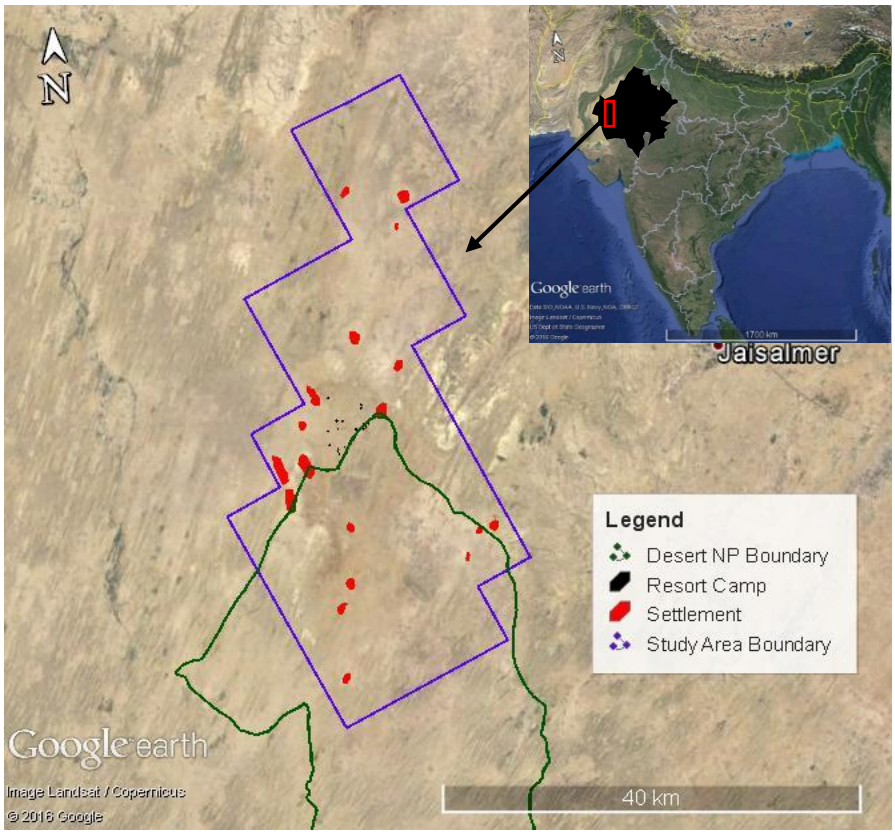
1.4.2 Main Objectives

- To assess the population status of dogs in the study area.
- To determine the ranging patterns of free-ranging dogs in Thar landscape.
- To assess temporal activity patterns of free-ranging dogs in Thar landscape.
- To obtain time activity budgets of free-ranging dogs in Thar landscape.
- To study the resource utilisation of free-ranging dogs in Thar landscape

CHAPTER 2

STUDY AREA

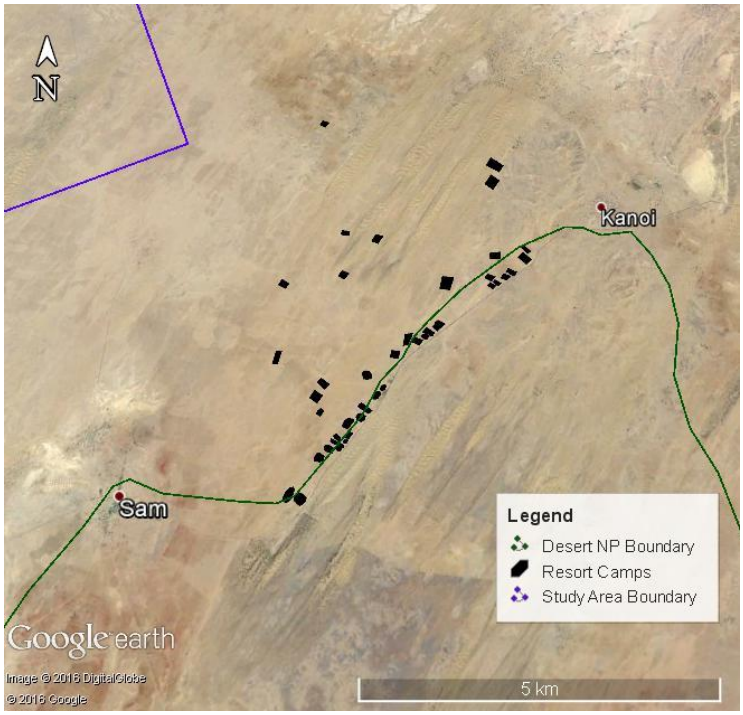
My study was conducted in Thar landscape, west of Rajasthan, India from December 2016 to April 2017 (**Map 1**).



Map 1. Study area map. The relative location of Rajasthan in India and the position of the study area in the state.

Thar landscape is under biogeographic zone 3 (Indian desert) per the classification provided by Rodgers et al. 2002. It is one of the most populated deserts in the world inhabited with 85 humans/km^2 (Rahmani 1989). My study area comprises of the northern part of Desert National Park (hereafter DNP) with 18 human settlements (7 within the NP and 11 at the periphery) and about 70 resort camps as well as the arid landscape outside the protected area.

My study area includes the tourism zone comprising of resort camps, wilderness and traditional agro-pastoral area since I expected dog densities to respond to tourism waste deposits. The resort camps providing concrete and tented accommodation are situated between Sam and Kanoi and only open during the tourist season which is November to February (**Map 2**). During this season, dogs are seen close by and feed on the leftovers thrown in dumps behind the resort camps. Hence, this area is considered an important stratum in my study area.



Map 2. The tourist area between Sam and Kanoi which is open from November to February only

DNP is the largest national park in India with an area of 3162 km^2 (Sharma et al. 2013). It was officially notified in 1980 and is part of the Thar landscape. It is situated in the state of Rajasthan extending over two districts, that of Jaisalmer and Barmer (Sharma et al. 2013).

The southern half of my study area (**Map 1**) is dotted with Dhanis where local pastoral communities stay in thatched huts through the year or on seasonal basis to graze their livestock in adjoining habitats. In the same area, the Forest Department has created enclosures for Great Indian Bustard conservation that harbours other wildlife. This combination, results in free-ranging dogs in biodiversity rich habitats whose impacts can be potentially detrimental to wildlife conservation.

My study area of about 1008 km^2, a typical desert landscape was chosen due to high records of Great Indian Bustards (*Ardeotis Nigriceps*) and native wildlife (Dutta et al. 2016, **Figure 1**). Some native wildlife which are potential prey for free-ranging dogs in this area are nilgai, chinkara, Indian fox, desert fox, desert cat, great Indian bustard, spiny-tailed lizard and Indian desert jird. Local people, although agnostic towards free-ranging dogs, occasionally feed them. The area is a mosaic of grassland, gravel and sand dune habitats interspersed with human habitation and agricultural patches providing an ideal setting for studying free-ranging dog ecology especially interactions between dogs and wildlife.

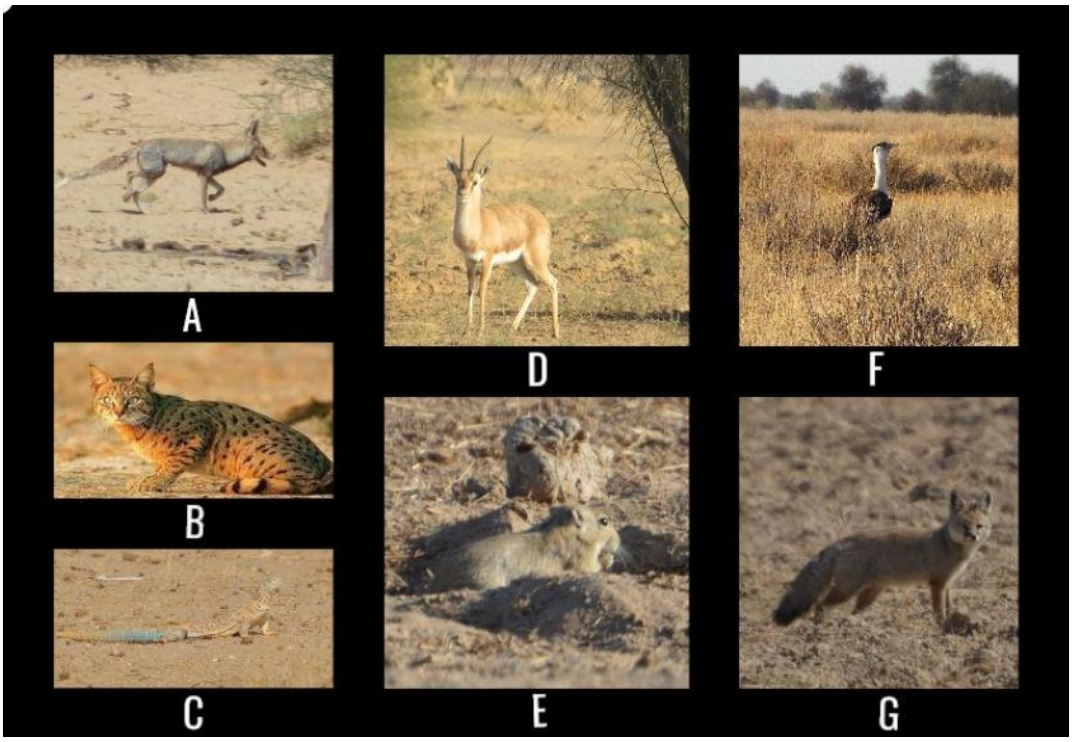


Figure 1. Some major wild fauna found in Thar landscape, Rajasthan. A. Desert fox (*Vulpes vulpes pusilla*), B. Desert cat (*Felis silvestris*) © Ramki Sreenivasan, C. Spiny tailed lizard (*Saara hardwickii*), D. Chinkara (*Gazella bennettii*), E. Indian desert jird (*Meriones hurrianae*), F. Great Indian Bustard (*Ardeotis Nigriceps*) and G. Indian fox (*Vulpes bengalensis*)

This landscape harbours grasslands dominated by *Lasiurus sindicus* and *Dactyloctenium sindicum*, scrublands dominated by *Zizyphus mauritiana*, *Capparis decidua*, *Haloxylon salicornicum* and *Crotolaria bhuria* shrubs as well as thorny scrubs (Dutta et al. 2016). Rainfall is minimal and infrequent with an average of 100-500 mm yearly that declines in an east to west gradient (Pandeya et al. 1977). During the summers (April to June), temperatures rise to ≥50˚C while in the winters (November to February) temperatures drop below 0˚C (Sikka 1997).



Figure 2. Topographical features in Thar landscape. A. Grasslands, B. Settlements, C. Sandy scrub, D. Agriculture, E. Sand dunes and F. Dhani

CHAPTER 3

METHODS

Ethics Statement

All permissions to carry out the research work were obtained from the Office of the Chief Wildlife Warden, Rajasthan State (Letter no: F3(02)/CWLW/2015/1/97, dated:23 November 2016) under provisions of the Wildlife (Protection) Act, 1972, Government of India. Permission for radio-collaring dogs were obtained from the office of the Deputy Conservator of Forest and Director, Desert National Park and carried out under the supervision of a veterinary official from Jodphur. The dissertation committee of Wildlife Institute of India which also considers the ethics of research methods approved the study.

3.1 Population Estimation

I estimated dog numbers in settlements and tourism area using a double sampling approach (Cochran 1977), where crude counts of dogs were calibrated with mark-recapture based abundance. I also estimated landscape-scale dog abundance using vehicle transect based distance sampling. While conducting count surveys, the sociodemographic (religion) and socio-economic factor (number of livestock holding) of settlements were recorded.

- **Field methods**

Dog Count Survey

To count dogs in human settlements, I mapped settlements in the study area via Google Earth and ground-truthed them using surveys. Eighteen settlements (consisting of at least 15 houses) were noted (see Chapter 2, **Map 1**). I, then created trails passing through the settlements using Google Earth (see Appendix, **Figure A1**). The putative trail length was 10km per 1km^2 settlement area. For the dog count survey, one observer walked through the settlements on the digitised trails and counted the number of dogs while recording their age (pup or adult) and gender with minimal deviation from the created path. These counts

were done only once in all settlements within my study area. Although this approach did not account for imperfect detection, it generated a logistically easy index of abundance.

Mark-Recapture

To estimate detection-corrected abundance of dogs, I conducted mark recapture sampling in six settlements and the tourism resort area that were selected based on count surveys to represent the entire range of the population count spectrum (low to high dog counts). The six settlements were *Bida, Kuchhri, Lakhmanon ki basti, Neemba, Salkha* and *Sam* and the tourism area between Sam and Kanoi.

During the mark recapture sampling, my field assistant and I (navigator and observer) walked through the settlement on the same trail but maximized capture probability by intensively searching for dogs (deviating from the trails when required). For the tourism area, mark recapture sampling was conducted on a slow-moving vehicle (20km/h) with an open top. The left and right flank and the front side of each dog were photographed and its gender was recorded for identification. The images were captured using a Samsung SM101C smartphone with 10x optical zoom which had an installed OSM Tracker application (OSM Tracker, Hiby 2016) configured for the mark recapture sampling of dogs (see Appendix for details, **Figure A2**). Each session was of four occasions for all sites except for settlement, *Lakhmanon ki basti,* where sampling was done for three occasions due to issues with logistic constraints. The mark recapture and count surveys for Sam and Salkha were obtained from an earlier pilot survey conducted in September 2016 and reported in Hiby et al. (2016).

Vehicle Transect

To estimate landscape-scale dog abundance using distance sampling, the entire study area was divided into 28 grids, each of 6 x 6 km using ArcGIS 9.3 (ESRI). Each grid, had a random point and I digitised transects on Google Earth passing through the random point by following visible dirt trails (see Appendix, **Figure A3**). The length of each transect was 8.14 $\pm$ 0.07 km and if a settlement was present the transect passed through it. During

vehicle transect exercise, species, count, perpendicular distance and GPS locations were recorded using handheld LASER rangefinder (make:Bushnell), magnetic compass (SUUNTO see through) and GPS Garmin etrex30 (Appendix, **Figure A4**). Each transect was surveyed through twice on a slow-moving vehicle (speed ≤20 km/h), once each in winter (January-February 2017) and summer (March 2017).

- **Analytical methods**

Mark Recapture

For mark recapture based abundance estimation, I identified individual dogs from the photographs using gender, pelage patterns and natural markings (like scars, wounds and ear-cuts) (see Appendix, **Figure A5**). I removed duplication of same individuals (if any) within a session. The first session was compared with the next session and individuals that were detected in both sessions were given the same identity code (ID). The process was repeated for subsequent sessions. A detection history '1 0' X-matrix was generated for each site (Otis et al. 1978). The entire mark recapture process for six settlements and tourism area was completed within two months.

I tested for population closure using Pradel models, where an unconstrained model with survival (phi), recruitment (f) and recapture parameter estimates was compared with a constrained model where phi and f were fixed at 1 and 0 respectively to assume no loss or gain. I considered the population closed if the constraint model found more support than the unconstrained model in terms of AIC and likelihood ratio test (Cooch and White 2009).

For closed population abundance estimation, I modeled detection parameters as constant (null model: M_0), time-variant (M_t), variable between individuals (M_h) and variable with time and individual (M_{th}) using Huggins model in Program Mark (White and Burnham 1999). The behaviour model, M_b was not run because we did not physically capture dogs for marking. Hence, we did not expect a behavioural response of trap shyness and trap happiness by dogs during recaptures. However, time model, M_t was tested because the capture probability of dogs in the settlements partially depended on their movements away from settlements to food resource areas such as tourism areas and carcass sites within the

day. Heterogeneity model, M_h with 2 mixtures was tested with an assumption that there might be a difference in behavioural or personality between individual dogs. I diagnosed model parameters for convergence issues and removed models with convergence errors from candidate set. I ranked remaining models using AICc scores and selected the least AICc model for inferring. If two models had similar support (ΔAICc<2), then I used the simpler model for inference.

Dog Count Survey

To calibrate the relationship of counts with abundance, $\widehat{N}$ (obtained from mark-recapture analysis), dog abundance was modeled with count in the six settlements using linear regression in R version 3.3.1 software (R Core Team). Dog abundances in the remaining 12 villages were then predicted by fitting counts to the calibrated equation. For tourism area, I computed the ratio of count to $\widehat{N}$ in one block and used that ratio to correct counts into abundance in other two tourism blocks. Standard errors in predicted abundance was generated by bootstrapping.

Vehicle Transect

Vehicle transect data consisting of dog sightings, spatial location, angle and distance was analysed in Distance 7.0 software (Thomas et al. 2010) to estimate density of free-ranging dogs in a landscape-scale. I fitted half-normal, uniform and hazard rate models with cosine, hermite polynomial and simple polynomial series expansion and estimated effective strip width and density based on the model with least AIC and satisfactory goodness of fit following Buckland et al. (2015).

3.2 Ranging Patterns

I constructed a home range map using minimum convex polygon and fixed kernel densities. I obtained GPS locations through radio-telemetry data of five dogs and using commercial vehicle tracking satellite tags on four dogs.

- **Field methods**

To capture and radio-collar free-ranging dogs, baits (using carcasses from natural-mortalities) and track-and-dart techniques were used. Some dogs (n=3) were trapped on a carcass using soft-padded foot-hold traps. Upon being trapped, a gas-powered dart delivery system was used. Other dogs (n=6) were darted directly by following them on foot or a 4-wheel drive. Telonics MOD 400 VHF radio transmitter collars were then placed on the captured free-ranging dogs (N=9, 5 Males, 4 Females) in Desert National Park. These collars weighed on an average of 400g (~1-2% of the dog's weight).

Although, one male dog's transmitter was removed by a villager, 25 days after collaring it, 26 locations were obtained prior to the collar being removed and thus data was still used for computing ranging patterns.

Table 1. Details of the dogs collared in the wild (inside Desert National Park)

S. No	Collaring Batch	Sex	Individual Names	Details
1.	First	Female	WII-6	Mother with 5 pups. In a pack with WII-5 and WII-9.
2.	First	Male	WII-5	In a pack with WII-6 and WII-9.
3.	First	Male	WII-7	Slightly more tolerant towards humans compared to the rest
4.	First	Male	WII-8	The individual whose VHF collar was removed after 25 days by a villager and died on 16th February 2017.
5.	First	Male	WII-9	In a pack with WII-5 and WII-6 but seen alone too.
6.	Second	Female	WII-1	Mother with 4 pups
7.	Second	Female	WII-2	Mother with 3 pups
8.	Second	Female	WII-3	Mother with 4 pups
9.	Second	Male	WII-4	Seen alone or sometimes with a brown female dog

Each radio-collared dog was located by actual sighting and homing in (White and Garrott 1990) systematically across different times of the day from vehicle using either a three element Yagi or H antenna with a handheld receiver (Habit model HR 2600/ Telonics TR-

4). The activity of the dog, GPS location, associated individuals and time were recorded daily for each individual.

Commercial vehicle tracking satellite tags (make: SPOT Trace) (weighing ~88 g) were placed on 4 collared individuals in addition to the MOD 400 collar to provide remotely accessible location data at a very fine resolution (5-minute interval). The SPOT data were downloaded from the website: https://login.findmespot.com/spot-main-web/auth/login.html.

- **Analytical methods**

All data explorations were done using MS Excel 2016 (Microsoft Inc.).

Minimum Convex Polygons (MCP) were created for each dog from the GPS locations using ArcGIS 9.3 (ESRI) and Biotas 2.0α (Ecological Software Solutions LLC).

Home ranges were estimated using area accumulation plots wherein 20% - 100% MCP were digitised (Harris et al. 1990). The point after which the area enclosed reached an asymptote despite an increase in MCP percentage, was taken as the home range.

I, also, used fixed kernel estimators in Hawths Tools (White and Garrott 1990) in ArcGIS 9.3 (ESRI). For each dog, kernel home range areas corresponding to 15%-95% contours or isopleths were derived and the mean proportion of area enclosed by isopleths relative to the maximum (95% contour area) was plotted. The isopleth corresponding to inflection point in the graph where home range area increased rapidly or exponentially indicated the area. I compared the distances of nearest enclosure and settlement to dog radio-locations with 1000 random points in the combined dog MCP area, using frequency distribution and t-test.

3.3 Resource Utilisation

From 24-hour continuous monitoring data, I constructed an activity pattern and time budget. I used Ivlev's Index to understand prey preference by free-ranging dogs and computed the number of chinkara and nilgai kills annually by dogs found in the wild in my intensive study area.

- **Field methods**

Behaviour

Initially, I followed four radio-collared dogs on foot and/or four-wheel drive to understand the starve-feed cycles, distinguish between predation and scavenging events and develop a behaviour sampling protocol (**Table 2**).

Table 2. The total time spent continuously monitoring each dog.

Individual Names	Total time spent on continuously monitoring dogs (hours)
WII-6	216
WII-5	156
WII-7	156
WII-9	156
WII-2	96

Hence, a total of 876 hours of continuous monitoring data was recorded during the study period. Data collected were time, belly score, activity, GPS location, presence and interaction of associated individuals, presence and interaction of prey (goats, sheep, chinkara and nilgai), presence and interaction of competitors (wild pig and vultures) and presence and interaction of humans (see Appendix, **Figure A6**).

During the study, dogs were kept in view or within 50 to 150 meters from the observer's, day and night. Prior to continuous monitoring, we habituated the dogs to our presence and the usage of flashlight at night for two weeks. The dogs were tolerant to our presence within 50m without any obvious alteration in their behaviour. At night, a flashlight was used at every 10 minute intervals to confirm dog location apart from radio signals. All predation and scavenging events by dogs were recorded during continuous monitoring. The

behavioural states and events were also recorded to assess temporal activity pattern and time activity budget (**Table 3**).

Table 3. Definition of different key activities used in the study for assessing time activity budgets in free-ranging dogs (modified after Schaller 1972, Creel and Creel 2002).

States	Definition
Alert	Either standing on fours or sitting on twos or all down while scanning the surroundings and being alert. Face muscles are tight, mouth is closed and ears cocked up.
Feeding	Feeding on carcass (predated or scavenged) gauged by direct observations. Includes drinking (lapping) of water.
Grooming	Scratching ears and nose, licking genitals and other parts of the body and using plants or other materials as a means of cleaning themselves.
Interaction	When two dogs are seen in close proximity (touching) with each other. For instance, suckling, licking, sniffing, playing and aggression.
Hunting	The act of predation which comprises of stalking, chasing, actual act of bringing down prey (usually done when there are two dogs for large mammals but for small animals only one individual is present). Includes, digging to get Spiny tailed lizard and Desert jird out from their burrow.
Moving	Travelling from one point to another alone or with the presence of associative individuals or pups. Face is open mouthed with relaxed muscles and is usually silent.
Resting	Sitting or lying in a relaxed posture with the head pointing downwards and the mouth either loosely closed or lower jaw drooping. Also, lying flat on one side with flank, head and legs resting on the ground.
Wallowing	Cooling the body by sitting or lying in water or mud for a period of time.

Events	Definition
Barking	Vocalisation with slightly raised muzzles and includes growling, howling, whimpering and barking.
Excretion / Scent Marking	Stopping at intervals while moving and urinating while standing with hind limb up (characteristic of dominant male canids) or by squatting (both males and females) and defecating.
Sniffing	The nose is pointed towards the ground while moving or when stationary.
Regurgitate	Contents from the stomach is removed via the mouth.

Resource Quantification

To quantify resources available for free-ranging dogs in this area, I estimated prey and carcass density by using the following methods:

i) Based on GPS locations obtained from collared dogs, a 100% MCP was created with a 2km buffer around it. In the first method, this area was divided into 94 grids of 1km x 1km and in each grid, a diagonal 1km line transect was laid (see Appendix, **Figure A7**). Two observers walked on the 1km line transect. While the first observer, upon encountering wild prey, recorded the species, count, transect bearing, animal bearing, distance and GPS location, the second counted and recorded the number of active jird and spiny tailed lizard burrows in the first 500m x 2m belt of the transect (see Appendix, **Figure A8**).

ii) To estimate the number of available carcasses, a route of 127km was digitised on Google Earth (see Appendix, **Figure A9**). The route was sampled at 16 day intervals, recording carcass of cow, nilgai, chinkara, goat and sheep, the condition of carcass (fresh, partially eaten, completely eaten), presence of scavengers, GPS location, closest distance from the route and approximate size of the carcass (see Appendix, **Figure A10**). Carcasses that were previously recorded were not noted down in subsequent surveys.

- **Analytical methods**

Behaviour

Behavioural data of 876 hours collected during 24-hour continuous monitoring sessions was used to understand temporal activity pattern. I divided the time of the day into eight periods of three hours each and calculated proportional time spent on these activities for each period. Mean and standard error of proportion time spent on activities was estimated across dogs. I calculated the average of total time spent for each activity by free-ranging dogs, by dividing the time spent for each activity per dog, by the total hours of observation for each dog to obtain a time activity budget. A graph depicting the type of prey (livestock carcass and wild prey) and the quantity fed upon by dogs in both seasons was generated.

Resource Quantification

Wild prey (chinkara and nilgai) data was analysed using Distance 7.0 software (Thomas et al. 2010) by fitting half normal, uniform and hazard rate models with cosine, hermite polynomial and simple polynomial series expansion to distance data and estimating effective strip width and density based on the least AIC model with satisfactory goodness of fit. Since spiny tailed lizards live solitarily, the number of active burrows accounts for the number of individuals following Dutta and Jhala (2007). Density of jird was calculated from burrow counts using the calibration model developed by Ramesh (2011).

Carcass density was computed using Distance 7.0 (Thomas et al. 2010) based on relative size (>50kg was categorised as big (cattle and nilgai) and <50kg as small (chinkara, goat and sheep)) and based on each route and its replicate (N=4). From the prey items fed by free-ranging dogs during the 24-hour continuous monitoring, the amount utilised by free-ranging dogs from what was available was derived. Since there were no actual weights of prey eaten by dogs, which was difficult to enumerate in field, time spent on carcasses were taken as surrogates of biomass consumed. With the data obtained, Ivlev's index was used to understand the preference of prey items by free-ranging dogs in Thar landscape, Rajasthan. The biomass of wild prey was based on Dutta (unpublished data), Ramesh (2011) and Menon (2014).

Predation rate

Predation rates of chinkara and nilgai were obtained from continuous monitoring data and expressed as numbers killed/days observed for each dog. This rate was averaged across all monitored dogs. The number of dogs found in the intensive study area of 94km^2 (see Chapter 4, section 4.3), was multiplied with the number of kills per dog in a year to determine the average number of chinkara and nilgai individuals that are potentially predated annually.

Data was processed using MS Excel 2016 (Microsoft Inc.) and the softwares specified above.

CHAPTER 4

RESULTS

4.1 Population Estimation

- **Dog abundance in settlements and tourism area**

I estimated mark recapture based dog abundance in four settlements (Bida, Kuchhri, Lakmanon and Neemba) and the tourism area. I used the results on dog abundance of two additional settlements (Sam and Salkha) from Hiby et al. 2016. Closure test using Pradel models indicated that all four settlements were closed populations **(Table 4)**.

Table 4. Models for closure test in four settlements in Thar landscape, Rajasthan with their corresponding number of parameters (K), AICc values, difference in AICc values between the jth model and the model with the lowest AICc value (ΔAICc) and deviance.

Settlement	Model Name	K	AICc	ΔAICc	Deviance
Bida	{phi(1) f(0)}	1	83.99	0	9.12
	{phi(.) f(.)}	2	85.81	1.82	8.73
Lakmanon	{phi(1) f(0)}	1	64.11	0	15.39
	{phi(.) f(.)}	3	68.22	4.11	14.69
Kuchhri	{phi(1) f(0)}	2	279.30	0	44.62
	{phi(.) f(.)}	4	281.60	2.30	42.66
Neemba	{phi(1) f(0)}	1	385.56	0	20.84
	{phi(.) f(.)}	3	388.05	2.49	19.21

phi – survival parameter
f – recruitment parameter
(1) – present
(.) – constant
(0) – absent

Heterogeneity models for all four settlements did not converge and were removed from model comparison. Null model (M_0) found maximum support for Bida and Kuchhri while, time model (M_t) found maximum support for Neemba (**Table 5**). For, Lakmanon time (M_t) and null model found equal support (ΔAICc =0.04) and I selected the M_0 model (**Table 5**).

Table 5. Models for closure test in four settlements in Thar landscape, Rajasthan with their corresponding number of parameters (K), AICc values, difference in AICc values between the jth model and the model with the lowest AICc value (ΔAICc) and deviance.

Settlement	Model Name	K	AICc	ΔAICc	Deviance
Bida	Mo	1	83.95	0	70.47
	Mt	4	90.30	6.35	70.20
Lakmanon	Mt	3	64.01	0	72.24
	Mo	1	64.05	0.04	76.73
Kuchhri	Mo	1	204.40	0	323.04
	Mt	3	207.27	2.87	321.79
Neemba	Mt	4	378.31	0	476.88
	Mo	1	385.55	7.24	490.25

Salkha had the highest dog abundance, $\widehat{N}$ with 125 ± 8.75 individuals while Bida had the lowest dog abundance with a $\widehat{N}$ of 16 ± 0.54 individuals (**Table 6**). During dog count survey, number of dogs recorded for Salkha was 76, Sam was 65, Neemba was 48, Kuchhri was 36, followed by Bida and Lakmanon at 16 and 12 respectively.

Table 6. Number of dogs counted within a settlement and the estimated population size ($\widehat{N}$) of dogs for six settlements in Thar lansdscape, Rajasthan with standard errors (SE).

Settlement	Count	M_{t+1}	$\widehat{N}$	SE
Bida	16	16	16	0.54
Kuchhri	36	52	60	3.88
Lakmanon	12	16	18	1.68
Neemba	48	71	74	2.03
Salkha	76	103	125	8.75
Sam	65	82	115	10.35

- **Estimated population size with dog counts**

When population size was plotted against dog counts, the abundance of dogs increased linearly with an increase in count (N=6, y=1.65x, R^2=0.99, p<0.05, **Figure 3**). The intercept was forced at the origin for Figure 3 because y-intercept was insignificant (encompassing zero) indicating that when no dogs were counted the dog abundance was a negative value. Using the equation, y=1.65x, the dog population was modelled for all settlements in my study area (**Table 7**).

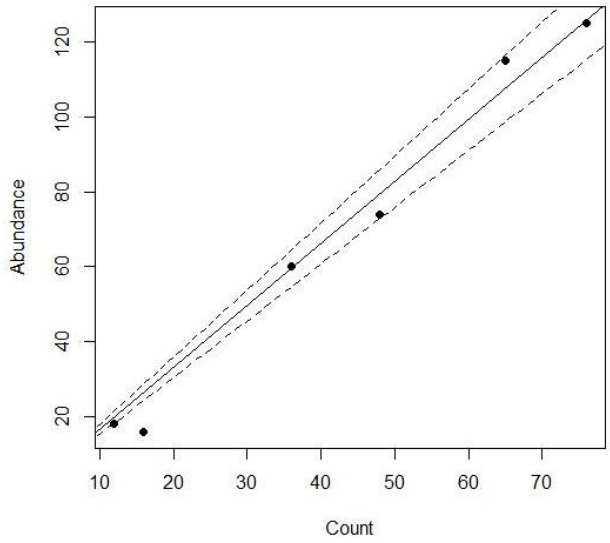


Figure 3. Estimated population size ($\widehat{N}$) of dogs plotted against dog counts in six settlements.

Table 7. Predicted population of dogs in 12 settlements with respective standard errors (SE).

Settlement	Count	Predicted $\widehat{N}$	SE
Balanio Ki Dhani	3	5	0.02
Ganga	12	20	0.08
Ghuriya	22	36	0.14
Ishaniyon Ki Basti	16	26	0.10
Jamra	6	10	0.04
Kangar Ki Dhani	2	3	0.01
Kanoi	71	117	0.45
Keshovon Ki Basti	23	38	0.14
Lolai	6	10	0.04
Loonoon Ki Basti	0	0	0
Rojani Ki Basti	4	7	0.03
Sagroan Ki Basti	1	2	0.01

Closure test using Pradel model indicate that tourism area block 1 was an open population. For tourism area, I estimated the initial population size and superpopulation using POPAN model in program Mark (White and Burnham 1999) was used to estimate the initial population or the super-population. The best model assumed a time constant survival parameter, zero probability of entering the population from the super-population (surrounding wild and settlement area) and time-constant recapture parameter (**Table 8**). The initial population size which was same as the superpopulation size was estimated at 44 $\pm$ 3.86 individuals. On an independent count survey in tourism area block 1, I counted 10 dogs and computed count abundance ratio of 4.40. Using this ratio, I corrected counts in the entire tourism area (block 1, block 2 and block 3) to abundance estimate of 79 $\pm$ 6.95 dogs.

Table 8. Models for population estimation of dogs in tourism area in Thar landscape, Rajasthan with their corresponding number of parameters (K), AICc values, difference in AICc values between jth model and the model with the lowest AICc value (ΔAICc) and deviance.

Model Name	K	AICc	ΔAICc	Deviance
{Popan (phi=(.) pent=0 N0=(.)}	3	164.34	0	0
{Popan (phi=(.) pent=(.) N0=(.)}	3	26986.86	26822.52	26803.11

phi – survival parameter
pent – probability of entry
N0 – initial population size
(.) – constant
(0) – absent

- **Socio-demographic and socio-economic factors with dog abundance**

Dog abundance was not affected by religion (Hindu and Muslim) of settlements (t-stat=0.106, df=7, p>0.05, **Table 9**). Moreover, there was no correlation between livestock holding on dog abundance (R=0.10, N=15, p>0.05).

Table 9. Mean dog abundance in settlements based on the majority ethnic group with respective standard errors (SE).

Religion of settlements	Mean dog abundance/household	SE
Hindu	0.13	0.05
Muslim	0.14	0.04

- **Dog Density in study area**

The dog density was also estimated in the larger landscape inclusive of wilderness habitats and areas without settlements and tourism between January to March 2017. Half normal-cosine adjustment model was selected based on least AICc score and satisfactory goodness fit (χ^2 =0.46, df=3, p=0.93) with an effective strip width of 85.78 $\pm$ 6.40 meters (see Appendix, **Figure A11**). Dog density of 1.79 individuals per km^2 was estimated from January to March 2017, yielding an abundance estimate of 1804 dogs in my study area (**Table 10**). Since, there was no difference in detection function between seasons, I pooled both seasons to estimate detection function more robustly and precisely. 28% of the dog observations in winter were of pups while in summer it was 16% indicating that there were 0.12 dogs less in summer per dog observed in winter.

Table 10. Number of dogs (N), density (individual/km^2) (D), encounter rate (DS) and cluster size (ES) with standard errors in Thar landscape based on season.

Season	Parameters	Estimate	SE
Winter	N	2265	634.89
	D	2.25	0.63
	DS	1.46	0.38
	ES	1.53	0.16
Summer	N	1381	517.64
	D	1.37	0.51
	DS	0.87	0.31
	ES	1.57	0.16
Winter and Summer	N	1804	461.76
	D	1.79	0.46
	DS	1.16	0.31

4.2 Ranging Patterns

- **Home range of free-ranging dogs**

The average home range size (95% MCP) irrespective of sex-classes for nine collared dogs were 19.81 ± 4.79 km^2 in Thar landscape, Rajasthan. Meanwhile, for 95% KDE it was 31.89 ± 3.03 km^2 and for 85% KDE it was 18.67 ± 4.82 km^2. The average home range size of male dogs was 20.24 ± 5.94 km^2 (N=5) while for females it was 19.26 ± 8.85 km^2 (N=4). Home range size was similar between male and female dogs. The average area of overlap between males was 49.60 ± 7.58 % while between females it was 42.92 ± 15.63 %.

Table 11. Number of GPS location, 95% MCP, 95% KDE, 85% KDE for each radio-collared dog.

Individual	Number of GPS locations	95% MCP (km^2)	95% KDE (km^2)	85% KDE (km^2)
WII-1	2578	9.85	24	15
WII-2	2364	10.65	26	16
WII-3	2680	45.82	47	22
WII-4	2887	38.41	38	20
WII-5	91	21.93	36	24
WII-6	104	10.73	27	16
WII-7	105	2.68	18	10
WII-8	26	13.54	31	20
WII-9	82	24.65	40	25

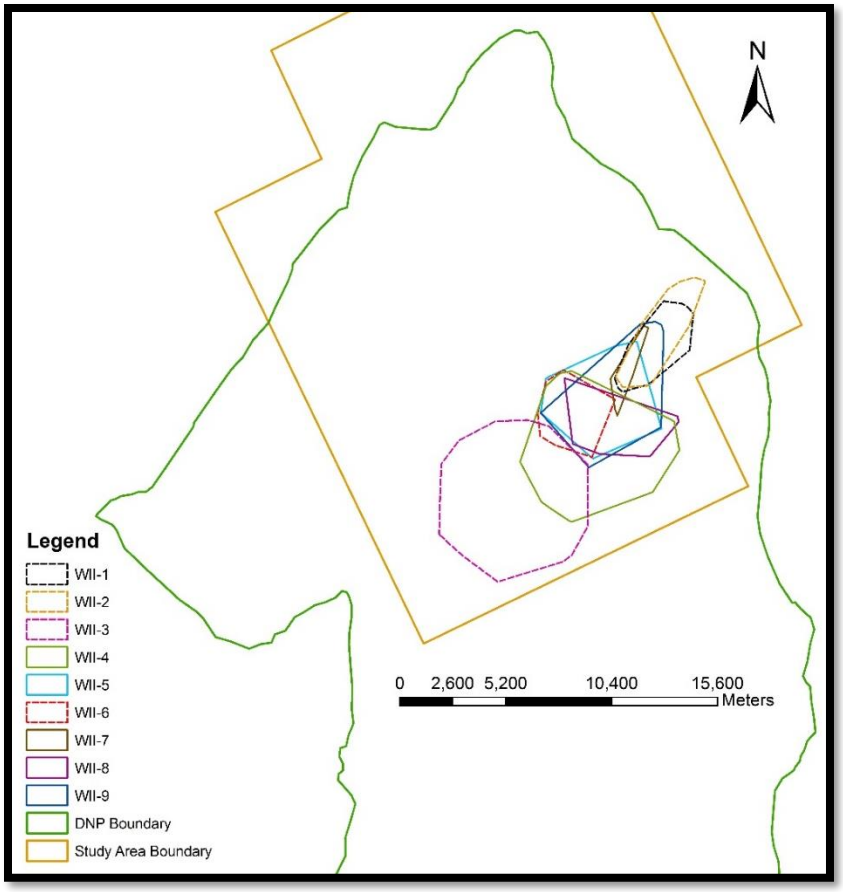


Figure 4. 95% MCP home ranges (km^2) of free-ranging dogs in Thar landscape, Rajasthan from January to April 2017. The home ranges indicated by dotted lines refer to females while the solid lines refer to males.

Kernel home range analysis shows that beyond 85% fixed kernel, the isopleth area increment was exponential indicating the latter to be caused by exploratory forays and movements outside the usual ranges of the individual (**Figure 5**). Hence, 85% was used to indicate home range of dogs in Thar landscape, Rajasthan. The average area for males was 19.80 ± 2.65 km^2 **(Figure 6**) while for female dogs it was 17.25 ± 1.60 km^2 (**Figure 7**).

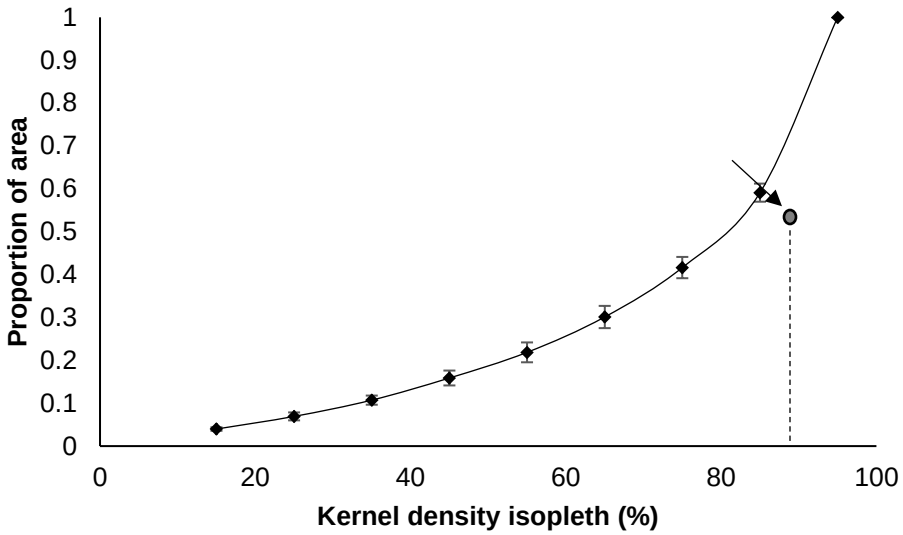


Figure 5. Proportion of home range area of free-ranging dogs against different kernel density isopleths with respective standard errors.

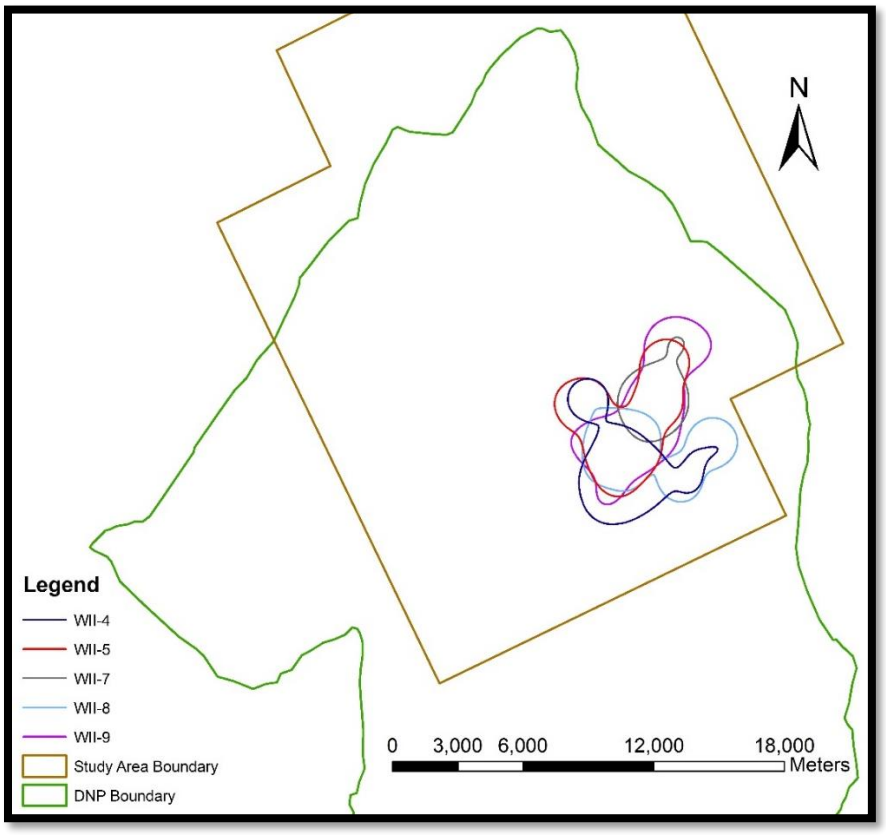


Figure 6. 85% fixed kernels showing home range (km^2) of male radio-collared dogs in Thar landscape, Rajasthan from January to April 2017.

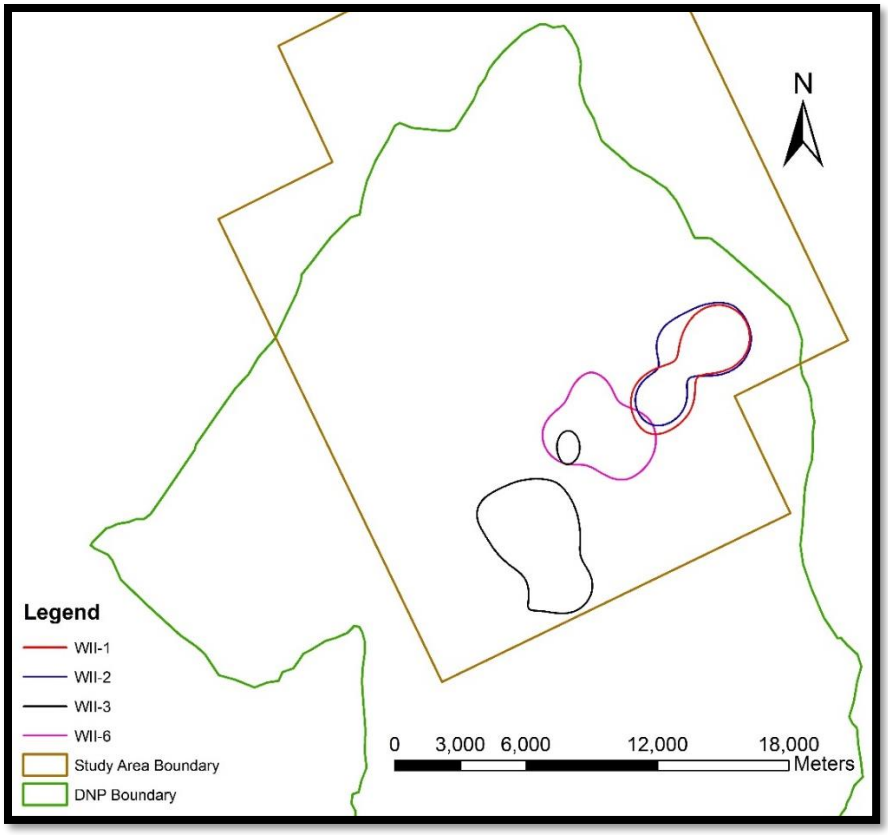


Figure 7. 85% fixed kernels showing female home range (km^2) of radio-collared dogs in Thar landscape, Rajasthan from January to April 2017.

- **Distance of home range to nearest enclosure and settlement**

Dogs were two-fold closer to enclosures (x=746 m, CI=16, n=11083) and three-fold closer to settlement (x=599 m, CI=14) than random locations (distance to enclosure = 1699 m, CI=101, n=1000 and distance to settlement = 1828, CI=65) (**Figure 8** and **Figure 9**).

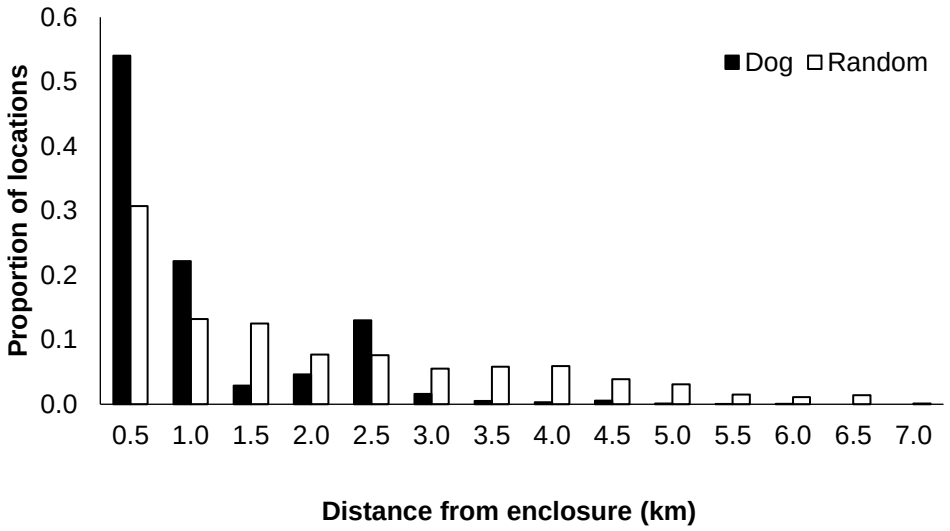


Figure 8. Proportion of dog and random locations with distance from enclosure.

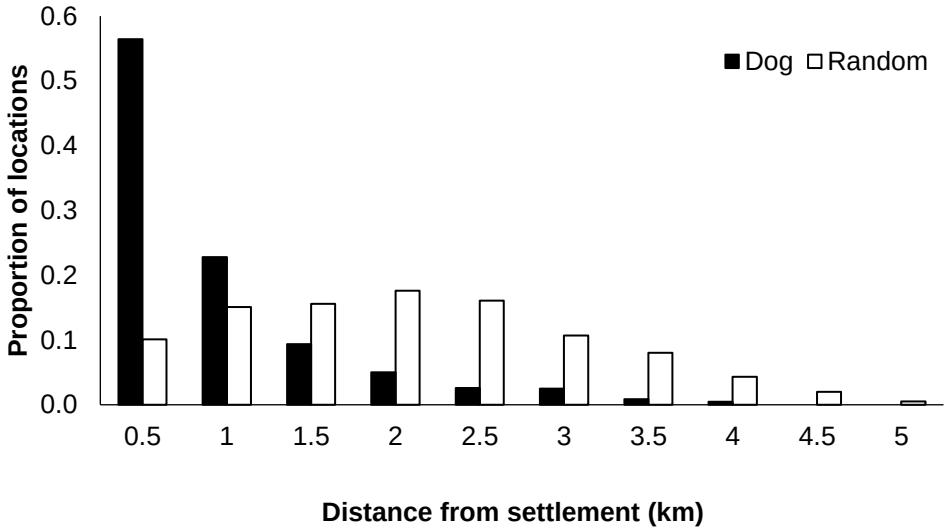


Figure 9. Proportion of dog and random locations with distance from settlement

4.3 Resource Utilisation

- **Time Activity Budget**

Free-ranging dogs spent 75% of the day resting followed by 11% moving, 10% being alert, 2% for feeding and the remaining 2% in other activities such as social interaction, hunting and auto-grooming (**Figure 10**).



Figure 10. Time activity budget of free-ranging dogs from 24-hour continuous monitoring in Thar landscape, Rajasthan. The error bars represent standard errors with dogs as samples.

- **Temporal Activity Pattern**

A temporal activity pattern was generated based on 4 key behavioural states (**Figure 11**). Free-ranging dogs are crepuscular showing maximum activity during 0600-0900 hours and 1800-2100 hours when time allocation to resting was minimal. Dogs were observed resting in mid-day (0900-1800 hours) and mid-night (2100-0300 hours). Movements peaked between 0300-0600 hours and 1800-2100 hours. Feeding mostly occurred between 0600-0900 hours and 1800-2100 hours. Dogs were more alert in the early morning between 0600-0900 hours and became less alert in the afternoon and evening.

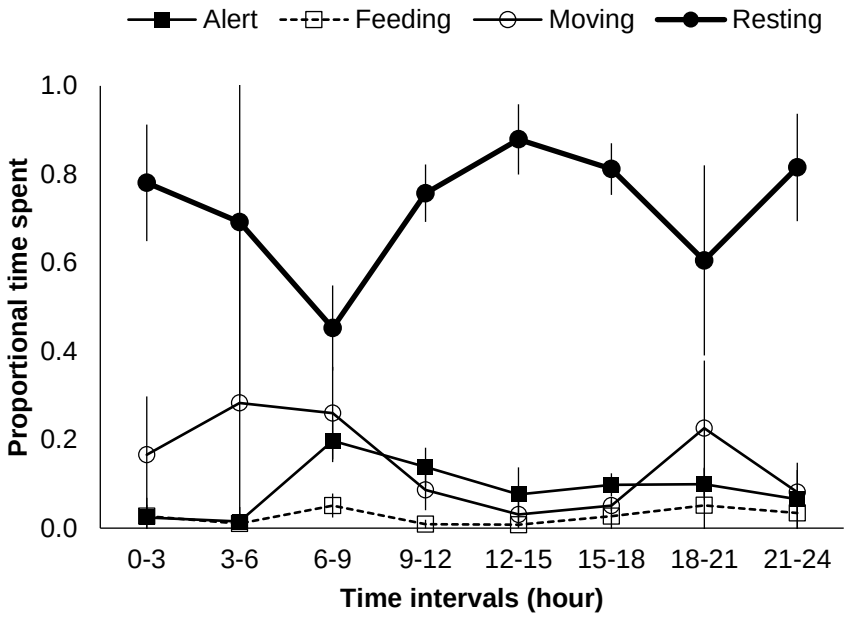


Figure 11. Temporal activity pattern of free-ranging dogs obtained from 24-hour continuous monitoring in Thar landscape, Rajasthan. The error bars represent standard errors with dogs as samples

Wild Prey Density

Analysis of detection data for chinkara showed support for uniform model with cosine adjustment. The model had satisfactory goodness of fit ($\chi^2 = 0.65$, df= 5, $p_{chinkara} = 0.99$) (**Table 12** and see Appendix, **Figure A12**). Due to small sample size of nilgai individuals, uniform model found maximum support ($\chi^2 = 0.18$, df= 2, $p_{nilgai} = 0.91$) (**Table 12** and see Appendix, **Figure A13**). **Table 13** shows the herbivore biomass per km^2 of wild prey (chinkara, jird, nilgai and spiny-tailed lizard). Spiny tailed lizard density was estimated at 4680.85 individuals per km^2. Density of jird burrows was estimated at 25925.53 per km^2 which yielded individual density estimates of 2860.66 per km^2.

Table 12. The effective strip width (ESW) (m), number of individuals (N), density (D) (individual/km^2), cluster size (ES) and encounter rates (DS) of the best model relating detections versus distance classes with respective standard errors for chinkara and nilgai.

Species	Parameters	Estimate	SE
Chinkara	ESW	180.16	12.14
	N	660	114.95
	D	7.02	1.22
	ES	2.17	0.21
	DS	3.24	0.47
Nilgai	ESW	357.76	0*
	N	43	21.64
	D	0.46	0.23
	ES	2.91	0.88
	DS	0.16	0.06

* effective strip width is equivalent to maximum width in a uniform model. Estimated with certainty.

Table 13. Herbivore biomass, density and biomass density of chinkara, jird, nilgai and spiny-tailed lizard.

Herbivore	Biomass (kg)	Density (individual/km^2)	Biomass density (kg/ km^2)
Chinkara	19	7.02	133.38
Jird	0.075	2860.66	214.55
Nilgai	110	0.46	50.6
Spiny-tailed lizard	0.225	4680.85	1053.19

- **Carcass Density**

Free-ranging dogs feed on carcasses for 51% of the feeding time from February to April 2017. Carcass densities decreased with days (N=4, R^2=0.86, p<0.05) showing a decrease in carcasses from winter through summer (**Figure 12**). Best model relating carcass detection and distance classes was selected based on satisfactory goodness of fit and least AICc score as a half-normal cosine (χ^2 = 0.67, df= 3, p = 0.88). There was no difference in detection function of carcasses in terms of size, thus, I pooled all carcass types to estimate detection function more robustly and precisely (**Table 14** and see Appendix, **Figure A14**).

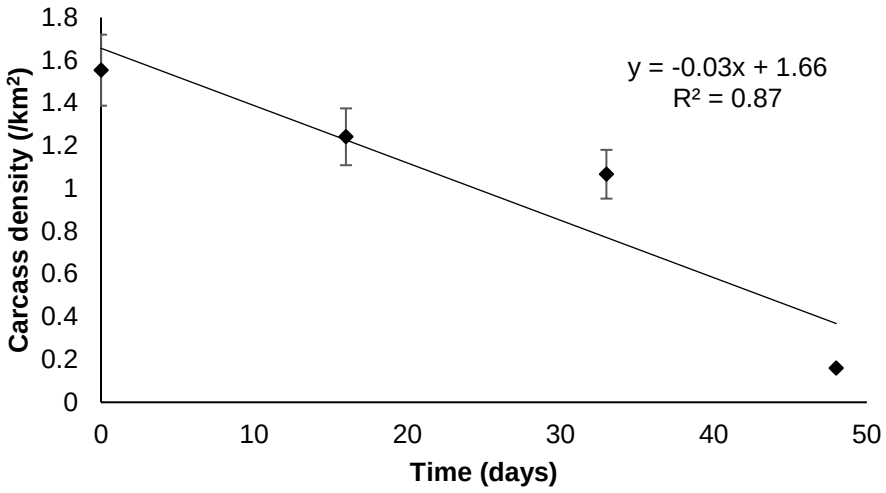


Figure 12. Carcass density of prey plotted against time with the line equation and coefficient R^2 value and respective standard errors in Thar landscape, Rajasthan.

Table 14. The effective strip width (ESW) (m), density (D) (individual/km^2) and number of carcasses (N) from March to April 2017 with respective standard errors.

Parameters	Estimate	SE
ESW	19.83	3.06
D	1.29	0.44
N	121	41.06

- **Food preference**

Livestock carcasses were fed upon more compared to wild prey in winters while in summer, more wild prey was fed upon (**Figure 13**). Ivlev's index computed on proportion time spent on different food items and their density in the wild, showed that the most preferred prey item was goat (0.96), followed by sheep (0.95), nilgai (0.46), chinkara (0.25) and cattle (0.12) (**Figure 14**). On the other hand, spiny-tailed lizard (-0.64) was not preferred.

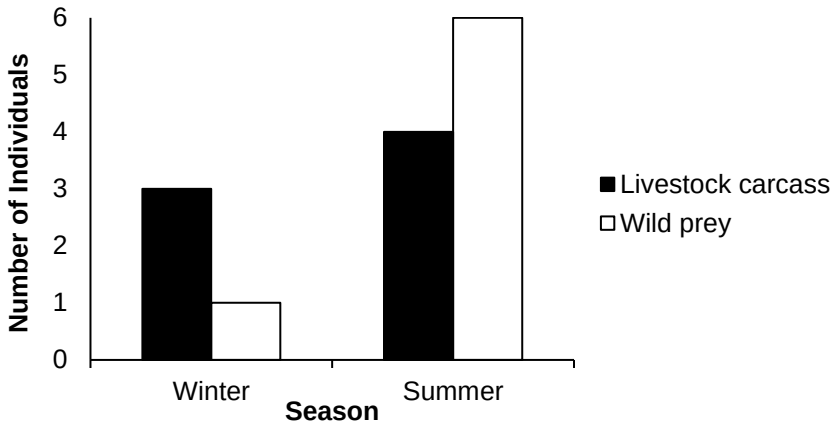


Figure 13. Comparing the number of livestock carcasses and wild prey fed upon in winter and summer for free-ranging dogs.

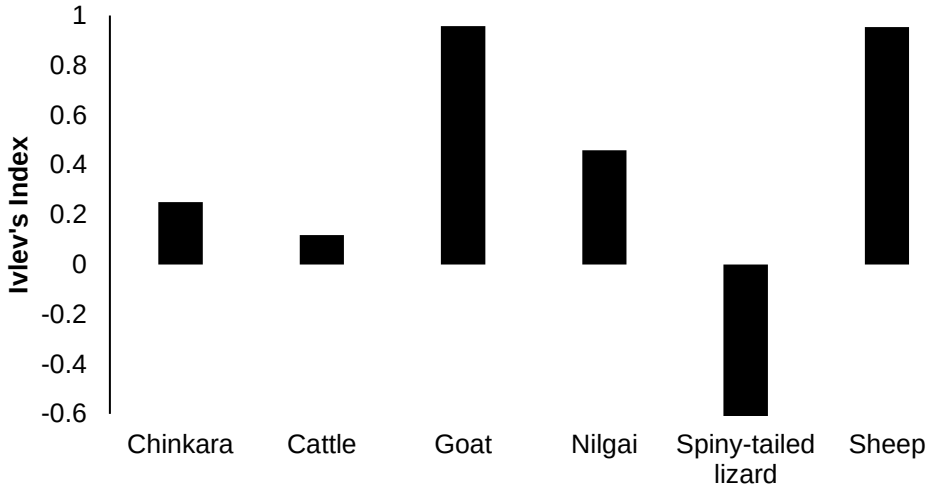


Figure 14. Ivlev's selectivity index for different prey items of free-ranging dogs in Thar landscape, Rajasthan.

- **Predation rate**

The average number of kills of chinkara and nilgai per day among the radio-collared dogs were 0.05 and 0.09 individuals respectively. In my intensive study area of 94km^2, there are about 21 dogs in total including the eight radio-collared ones. Continuous monitoring and *ad libitum* observations indicated that typical group size of dogs hunting nilgai and chinkara were 3 and 2 respectively. Predation rates of chinkara and nilgai extrapolated to these hunting dog packs indicated that 203.07 chinkara and 235.83 nilgai individuals were at potential risk from dog predation annually.

CHAPTER 5

DISCUSSION

5.1 Studying free-ranging dogs in Thar landscape

In my study, I developed a double sampling based approach to calculate dog abundance. This approach can be used to rapidly assess dog numbers for establishing baselines and monitor effectiveness of population management measures in and around Desert National Park. I explored the spatial distribution of free-ranging dogs inside Desert National Park looking at their home ranges to discern their space pattern usage. Lastly, I assessed the interactions of a sample of free-ranging dogs with potential prey, competitors and conspecifics to comprehend their potential impacts on wildlife.

5.2 Population Estimation

A double sampling method is a practical technique used in field by incorporating two methods that are an index to abundance (Eberhardt and Simmons 1987). Using double sampling approach that calibrates effort-standardized counts with mark recapture based abundances, I estimated 682 (SE=0.05) dogs in 18 settlements distributed across 1008 km^2 landscape in Thar. Double sampling approach was introduced by Neyman (1938) and applied to assess population status of several species such as white-tailed deer (Ryel 1971) and nesting birds (Bart and Earnst 2001)**.** This approach is ideal for cases where within a short time frame, and an extensive area to cover a cost effective and logistically as well as scientifically robust method is required. In our case, use of double sampling approach allowed dog population to be estimated at a reasonably large scale with confidence and less funds. I estimated that mark recapture in all settlements would cost 193250 INR (3004 USD) as compared to 107142.50 INR (1665 USD) in the current assessment framework (see Appendix, **Table A1** and **Table A2**). Also, the residual standard error of predicted dog numbers in six settlements where actual dog numbers were also available was 6.31, indicating that abundance could be estimated with reasonable confidence using this approach at large scales.

Since dog counts are sensitive to survey efforts, with counts increasing asymptotically with efforts, efforts should be standardized across villages, such as 10 km per km^2 village area in our case. If efforts are not standardized across villages, then count-abundance relationship would be weak and confounded with detectability and unequal survey efforts. For future studies on dogs in this landscape, since villages are similar in structure and hence detection process of dogs should be similar, I recommend counting dogs in all settlements in one occasion with a minimal survey effort of 10 km per km^2 village area, and predicting dog numbers based on my calibration model (Population size=1.65 (SE=0.05) * dog counts). However, for other landscapes with different settlement structure and hence different detection process, this model should not be transferred, rather a locally suited calibration model should be developed from a subset of doubly sampled settlements.

Implemented at large scales, this approach can generate baselines that can be monitored over years to understand dog demography, assess if management measures such as sterilization programs are being effective in reducing population size, and importantly, understanding factors influencing dog abundance patterns such as resource availability and social tolerance. In this landscape, dog abundance in Hindu dominated settlements were similar to those in Muslim dominated settlements. Moreover, there was no correlation between settlement livestock holding on dog abundance. This may be because dog population is not limited by livestock availability inside settlements as dogs can range widely to access food. Another possibility is that livestock count obtained for each settlement through questionnaires may not be depicting the true abundance of livestock, and needs to be verified with actual livestock censuses in villages by survey teams.

Dog densities in winter was much higher than that in summer. A possible explanation is vehicle transects based distance sampling in winter were conducted from January to February which coincided with the birth of pups increasing the number of dogs in the landscape but this only explains about 12% of the increase in dog abundance during winter as shown in the findings. The proportion of pups seen in winter were much higher than summer due to pup mortality. Another explanation would be that higher per-capita food resources in tourism areas in winter encouraged dogs to locally immigrate and the pleasant

ambient weather in winter increased dog activity, hence more use of the landscape (Ables 1969; Kavanau and Ramos 1972; Scott and Causey 1973; Geffen and Macdonald 1993). This means that we might have underestimated the dog abundance in summer because of inactive dogs that are resting.

5.3 Ranging Patterns

Home range size for both male and female dogs averaged at 19.81 ± 4.79 km^2. As the metabolic needs of a carnivore increases, so does its home range size (Gittleman and Harvey 1982). Food and water availability do have a strong influence on a carnivore's home range. Carnivores' home ranges depend on the distribution of their prey allowing them to have higher hunting success and prevent shortage of food (Frame et al. 1979). For free-ranging dogs in Thar landscape, enclosures set up by the Forest Department has a higher wild prey density (chinkara and nilgai) than surrounding unprotected areas. Probably because of such high resources inside enclosures, home ranges of all dogs usually encompassed these enclosures. Livestock carcasses, a frequent food source for free-ranging dogs were dumped in open areas by people living in Dhanis. These carcasses were dispersed across the study area such that they were not a predictable resource and had to be actively searched by dogs. However, the open areas used for carcass dumping were frequently near enclosures.

In terms of the high variability in home range size of dogs, it was noticed that home ranges of individuals that were much larger (WII-3 and WII-4), although encompassing part of the enclosures, they were the furthest from enclosures compared to other dogs. This is a possible explanation that the home ranges were much larger to encompass a part of the enclosure. Being a semi-arid state, water is a critical-resource for the animals (Gittleman and Harvey 1982). Waterholes in enclosures and water tanks in Dhanis were a crucial resource for these dogs as they mostly drank after feeding which was once a day.

The enclosures set up by the Forest Department were accessible to dogs and aided the dogs in their hunting prowess. The dogs usually got inside enclosures via 1) holes on the fence that were cut by people living in Dhanis to allow their livestock to forage in enclosures and

2) by digging the ground below the fence and squeezing through. During hunting, dogs used the enclosure fence as a physical barrier for wild prey. Hunting in packs, they would drive their prey towards the fence and before their prey can cross over, they would attack the rear to paralyse the prey and then aim for the neck followed by evisceration. This hunting strategy by dogs is similar to most canids such as dholes, Indian wolves and African wild dogs (Jhala 1993; Creel and Creel 2002).

Based on *ad libitum* observations and continuous monitoring, it was observed that lactating females used Dhanis as a refuge for their pups. The potential reason could be because of secure water source, shelter and occasional human-derived food resources that can improve pup recruitment. Studies have shown that lactating female wolves and foxes drink water more often and therefore, their denning sites are always less than 2km from a water source (Jhala et al. 2003; Maurya 2012). In account of this fact, all Dhanis had a personal water tank which was accessible by these dogs.

From continuous monitoring, observations showed that dogs did not only depend on Dhani's as a water source, but they used Dhani's as a resource hold. Multiple Dhani owners, were of the notion that they owned the same dog and that their dogs did not harm wildlife but protected their poultry from other dogs and thus, fed these dogs. Yet, our radio-telemetry data indicated otherwise showing that these dogs moved from Dhani to Dhani after staying for several days and did indeed hunt wild prey. On top of this, the dogs obtained free food from Dhani owners. This indicates that free-ranging dogs are closer to both wild resources as well as human derived resources, thus, utilizing the rural and wild niches to the fullest.

5.4 Resource Utilisation

To delve into the behavioural ecology of a species, causes an explosion of questions that requires extensive research and large sample sizes. Nevertheless, it is this first step which is crucial to perceive a species and its surroundings for the purpose of management and conservation of that very species and the ecosystem itself (Caro 2007).

To understand the behaviour of free-ranging dogs, I investigated the activity budget and temporal activity pattern of radio-collared dogs. Free-ranging dogs spent most of their day resting (~75%) which is normal in carnivores (usually canids and felids) for them to digest rich protein diet and conserve energy (Zepelin and Rechtschaffen 1974). I found that there was no difference between the proportion of time spent in different activities between males and females. However, proportion of time spent in various activities differed considerably with time of day. Like other large canids such as dholes (*Cuon alpinus)* and coyotes *(Canis latrans)*, free-ranging dogs too were crepuscular with activity peaking during 0600-0900 hours and 1800-2100 hours. Free-ranging dogs moved both during the day and the night for hunting and/or searching for prey carcasses to feed on (Johnsingh 1982; Andelt 1985).

Free-ranging dogs were mostly alert at the peak feeding time. A*d libitum* observations and continuous day-night monitoring indicated that such alertness was probably to prevent kleptoparasitism from other scavengers such as ravens (*Corvus corax*), Egyptian vultures (*Neophron percnopterus*), Cinereous vulture (*Aegypius monachus*) and wild pigs (*Sus scrofa*). Our observations on interactions between dogs and wildlife showed 1.9 interactions with competitors per dog day, and 50% of these occasions involved aggressive response of free-ranging dogs and flight response of kleptoparasites. This observation is in concurrence with studies on other canids, such as Gorman et al. 1998 showing that African wild dogs are vulnerable to kleptoparasitism; Caro and Stoner 2003 showing that kleptoparasitism increases time cost for carnivores; and Stahler et al. 2006 showing that wolves in Yellow National Park lose significant amounts of biomass from their kill to scavengers.

Results of resource use-availability analysis showed that, free-ranging dogs preferred carcasses (sheep and goat) more than hunting wild prey (nilgai and chinkara). That is why feeding on livestock was documented only as scavenging events on carcasses, and no active predation was observed. This is probably because of the availability of carcasses as free meals, which does not require dogs to spend extra cost (time and energy) to hunt (Stephens

and Krebs 1986). According to optimal foraging theory (MacArthur and Pianka 1966), predators tend to maximize their net rate of food intake while foraging, and to do so, benefits and cost are weighed. Thus, feeding on carcasses maximizes the net rate of food intake by free-ranging dogs (cost is the search time) as compared to wild prey (cost is the search time and handling time). However, it was seen that in summer, dogs fed more on wild prey than livestock carcasses. The probable explanation is that carcass densities were decreasing in summer as shown in my findings which made dogs hunt wild prey. Dogs did not show preference towards spiny-tailed lizard and jird probably because the energy to dig them out of their burrows was too costly compared to the energetic gains from consuming these small animals.

Moreover, chinkara and nilgai density within a 94km^2 area was 7.02 $\pm$ 1.22 and 0.46 $\pm$ 0.23 individuals/km^2 respectively which was considerably high compared to the report by Dutta et al. (2016) which estimated density for chinkara and encounter rate for nilgai in the larger Thar landscape as 1.88 $\pm$ 0.25 individuals/km^2 and 0.09 $\pm$ 0.03 individuals/km respectively. The high densities of chinkara and nilgai are because of the five enclosures that are a part of this 94km^2 area. These enclosures have higher densities of the mentioned species than other open areas in the landscape.

The total herbivore biomass in the intensive study area is 1451.72 kg/km^2. This area has one of the lowest estimates of herbivore biomass in the country as studies show that Mudumalai Tiger Reserve had an estimate of 2117.15 kg/km^2 (Venkataraman 1995), Kanha including domestic prey had 2450 kg/km^2 (Schaller 1967) and Bandipur National Park had 3320 kg/km^2 (Johnsingh 1982). Ranthambore Tiger Reserve and Gir National Park, despite being a semi-arid region, the biomass density was 6263 and 1646 kg/km^2 respectively (Bagchi et al. 2004; Khan 1997). However, comparing my study area to that of deserts around the world, Thar landscape has a higher herbivore biomass density. Namib desert has a herbivore biomass density of 520kg/km^2 while the Kalahari desert is 439kg/km^2 based on large herbivores only (Williamson and Williamson 1981; Southgate et al. 1996). A probable reason that Thar is higher compared to Namib and Kalahari desert is that underground dwellers mainly jird and spiny tailed lizard contributed the most while

for the other two deserts, rodents and reptiles were not a part of the herbivore biomass density estimate.

To synthesise the outcomes of my study, I calculated predation rates on chinkara, a native conservation-dependent species within my intensive study area of 94km^2. Based on the five collared dogs, the number of chinkara individuals that are at potential risk from predation per dog year is 9.67. Continuous monitoring and *ad libitum* observations indicated that there were another 13 dogs that lived within the 94km^2 area apart from the ones radio-collared by us and also, typically a pack of two dogs hunted chinkara. Therefore, predation rates of chinkara extrapolated to a total of 21 dogs indicated 203.07 chinkara individuals were at potential risk from dog predation in a year, which is a substantial 31% of the chinkara population. However, this data is based on a small sample size which can be augmented through longer continuous monitoring sessions.

5.5 Methodological issues and study limitations

Closed mark recapture models assume closure of population to gains (births and immigration) and losses (deaths and emigration) of individuals (Otis et al. 1978). In this study, mark recapture surveys in a settlement were completed within 7 days. This time window was short enough to assume minimal chance of death and pups were not considered as they might be born within the sampling period. However, the possibility of local emigration and immigration to and from adjacent settlements could not be negated as home range diameter of dogs (mean = 5 km for 9 collared dogs) exceeded the distance between adjacent settlements. Therefore, I performed formal test for closure using Pradel models (Cooch and White 2009). Results of closure test indicated that dog populations in all sampled villages were closed population.

However, the tourism area was an open population, where individuals left the initial population linearly with time, and no new individual entered the population. This pattern was perhaps because tourism intensity, and hence, food resources in tourism resorts, declined from early to late January, and visitation of dogs from adjacent settlements reduced with time. Thus, the population available in each count was a subset of the

superpopulation, and count to abundance ratio of tourism area was much smaller than other settlements. Hence, I estimated dog abundance in tourism area separately from villages, by correcting counts in the entire tourism area by the ratio of count to superpopulation abundance (in this case, the initial population size) in a subset of the tourism area – the western tourism block. Since the superpopulation was not restricted to one tourism block although the counts in one survey were, my assessment of dog abundance in the tourism area could be overbiased. A better approach would be to estimate dog abundance for the entire tourism area by mark recapture approach that was not possible due to logistic constraints of this study.

Detection probability of dogs estimated by our models did not vary with time or in response to prior capture in most settlements. This was expected because dogs were not physically captured or baited that could change their behavior, and surveys were done by the same observers under similar conditions (time and weather) and following a standard protocol. However, in one settlement, Neemba, there was community interference which prevented us from completing the second survey, because of which the time model (M_t) found more support unlike the other settlements. As expected, this model estimated much lower recapture probability in the second occasion compared to the other occasions.

It should be noted that the detection probability estimated by mark recapture models in this study is a confounding effect of local availability (probability of presence within settlement) and detection probability (probability of detection if presence within settlement). Given our intensive search during mark recapture surveys within a settlement, I speculate that dogs were missed during a survey mostly because of their foraging bouts away from the settlement, i.e., local unavailability, rather than non-detection *per se*. In vehicle transect based distance sampling for assessing landscape scale dog abundance, majority of detections were obtained from settlements. There was visible difference in density and also detectability within and outside settlements, and for more robust density estimation, ideally, these differences should be partitioned in multicovariate detection and density surface modeling framework (Miller et al. 2013).

CHAPTER 6

CONCLUSION

My study shows that free-ranging dogs act as the apex predator in the Thar landscape. Compared to other apex predators, they occur at much higher densities, to the tune of 1.79 ± 0.46 individuals per km^2, resulting in 1804 dogs in 1008km^2. The double sampling method used in this study was statistically robust and logistically cost-effective as well as feasible (R^2=0.99). For future studies in this landscape, the calibrated model (Population size = (1.65 ± 0.05) * dog counts) can be used to estimate dog abundances.

Dogs in this landscape, not only used Dhani's as a water source but also as a resource hold. The free-ranging dogs, apart from staying near Dhani's and obtaining food from them, used Dhani's as a hotspot for hunting wild prey. Thus, both wild and human derived resources were used to the fullest.

The wild resources that dogs hunted were chinkara, nilgai and spiny-tailed lizards. Dogs selected livestock (goat and sheep) carcasses more than wild prey. Among 21 free-ranging dogs in the intensive study area, the potential predation rates of chinkara are 203 individuals in a year which is 31% of the chinkara population.

Thar landscape has a higher herbivore biomass density than other deserts. This is probably because underground dwellers were a part of this estimate while for Kalahari and Namib desert only mammalian herbivores biomass density was estimated.

Impacts of free-ranging dogs on wildlife including predation and competitive interactions are substantial and needs to be managed. Management solutions such as a sustained sterilization program at settlement level, constant removal of dogs from enclosures, and predator-proofing of enclosures must be enforced to resolve the growing free-ranging dog crisis in this landscape. This step can help in bridging the gap between conservation agencies and local communities, who want the dogs in their settlement to be relocated (based on personal observations and communications).

This thesis is only the first step in a long-term goal of free-ranging dog management in India. There are many further aspects and questions that should be answered in the future for better understanding of free-ranging dog ecology. This is an imperative step to curb the free-ranging dog issue which is affecting conservation efforts for our native wildlife.

After all, at the end of the day, we humans, can make changes in our environment for the better, we can save many of these extraordinary, highly evolved species, if we only stop to think and act on it in time.

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APPENDIX



Figure A1. Trails digitized using Google Earth to carry out dog count surveys within human settlement areas in Thar desert

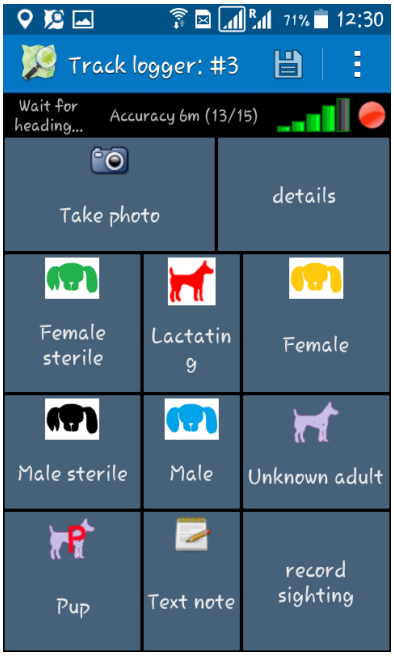


Figure A2. The OSM tracker app used in the smartphone for mark recapture survey of dogs within human settlements and tourism areas in Thar desert.

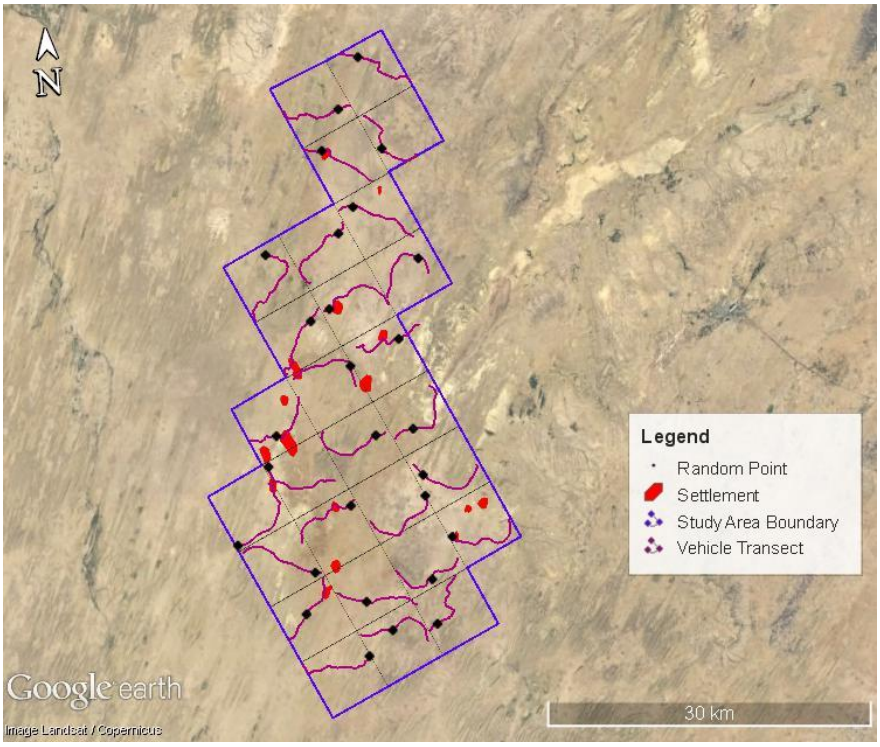


Figure A3. Vehicle transect created using Google Earth based on a random point generated in a 6km x 6km grid using ArcGIS within the intensive study area of Thar desert

Group Name: _____ Date: _____ Start Time: _____ End Time: ___ _____

Begin GPS Lat: _____ (N), Long: _____ (E) End GPS Lat: _____ _____(N), Long: _____ _____(E)

Transect ID: _____ Total Length: _____ km Weather Condition: Cloudy / Clear Sky / Rain

Seg No.	GPS Coordinates	Animal Species	Total Number	Total					Transect Bearing	Sighting Distance and Angle		GPS Location
				M	F	SM	SF	Young		*Animal Bearing	Distance	

M- male, F- female, SM - sub adult male, SF - sub adult female

Figure A4. Data collection sheet used for vehicle transects in study area.



Figure A5. Three photographs showing the same dog due to similar individual markings on the face and limbs.

Start Date: End Date: Weather:

Observer: Individual Name:

Time	GPS Location	Activity	Associated Individuals					Prey					Competitor					Humans				Remarks
			IC Time	OC Time	Resp-Obs_dog	Resp-Ass_Ind	Desc	IC Time	OC Time	Resp-Obs_dog	Resp-Prey	Sps	IC Time	OC Time	Resp-Obs_dog	Resp-Comp	Sps	IC Time	OC Time	Resp-Obs_dog	Resp-Humans	

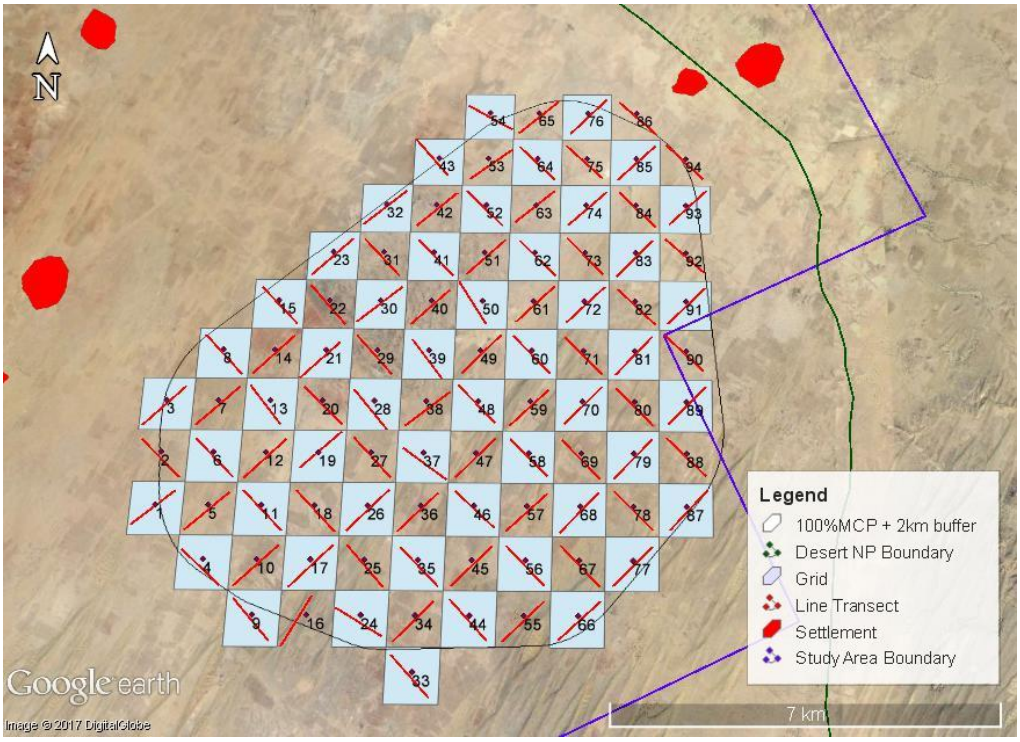


Figure A7. Ninety-four grids of 1km x 1km with a 1km line transect within each grid for sampling prey in the intensive study area of Thar desert

Transect ID: _____ Observer: _____ Date: _____ Time: _____ – _____

Weather: Clear / Cloudy / Rainy Bearing: _____ Effort: _____ (km)

Segment (500 m)	Latitude dd.ddddd	Longitude dd.ddddd	Species	Number	Sighting distance (m)	Sighting angle	Proj. Sp. Latitude dd.ddddd	Proj. Sp. Longitude dd.ddddd	Remarks	Spiny-tailed lizard burrows in 500 x 2 sqm	Jird burrows in 500 x 2 sqm

Track ID:

Figure A8. Data collection sheet used in line transects for estimating density of wild prey within home range and 2km buffer of radio-collared dogs

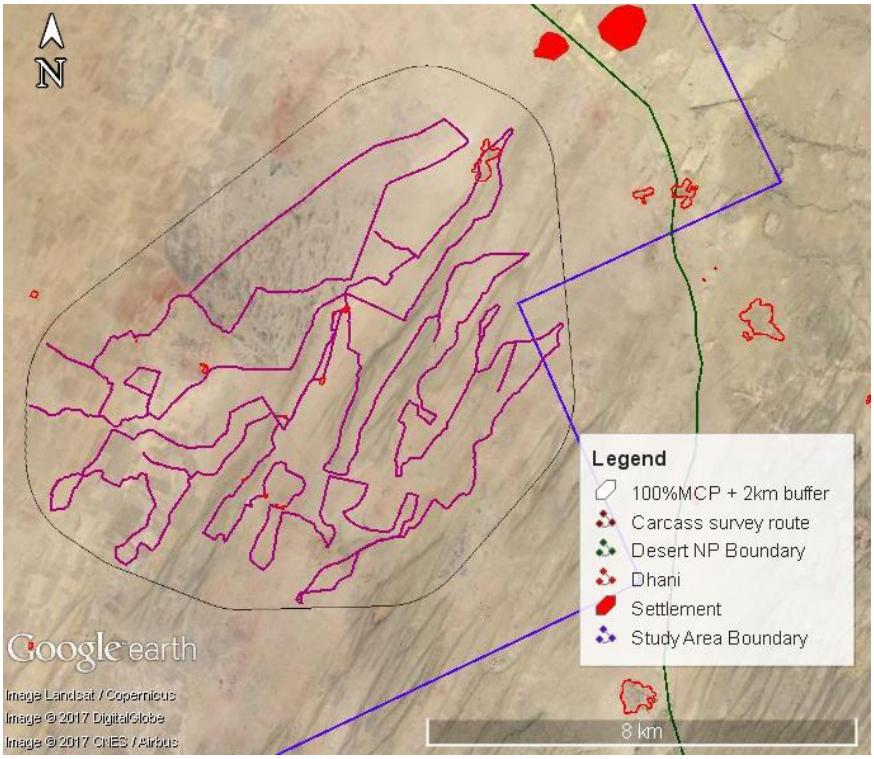


Figure A9. Vehicle transects to quantify carcass density within home range and 2km buffer of radio-collared dogs

Observer: _____ Date: _____ Start GPS Location: _____ N _____E

Start Time: _____ Sector: Wild End GPS Location: _____ N _____E

End Time: _____ Length of trail: _____km Weather: Clear sky / Sunny / Breezy / Rain / Cloudy

No.	Species				Condition of carcass			GPS Coordinates	Approx size	Scavengers present?	Closest app dist from route	Picture No.
	Cow	Goat	Sheep	Others	Fresh	Partially eaten	Completely eaten					

Figure A10. Data collection sheet used during the carcass survey

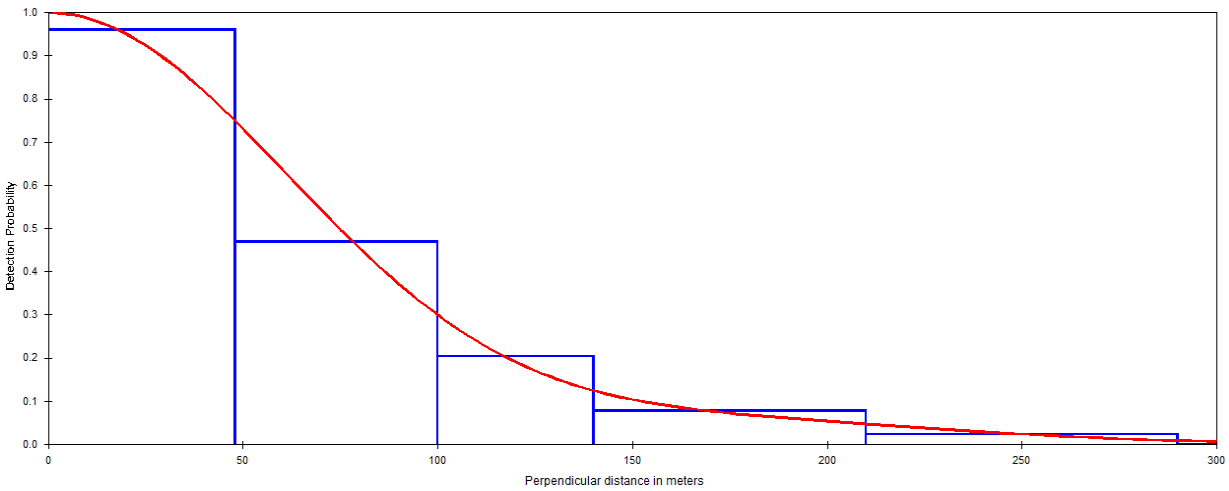


Figure A11. Model fit curve graph for dog density in study area.

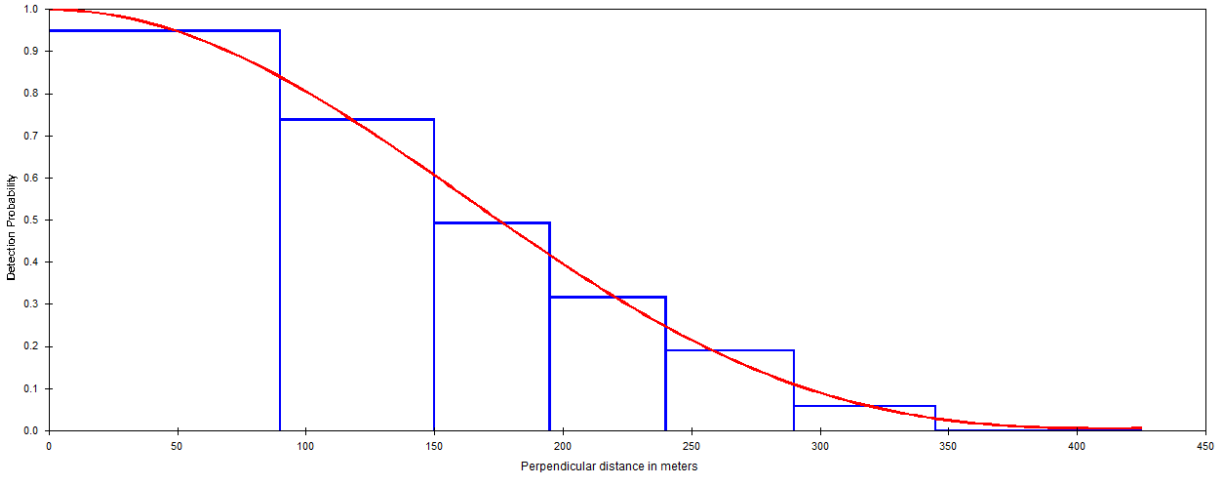


Figure A12. Model fit curve graph for chinkara in intensive study area.

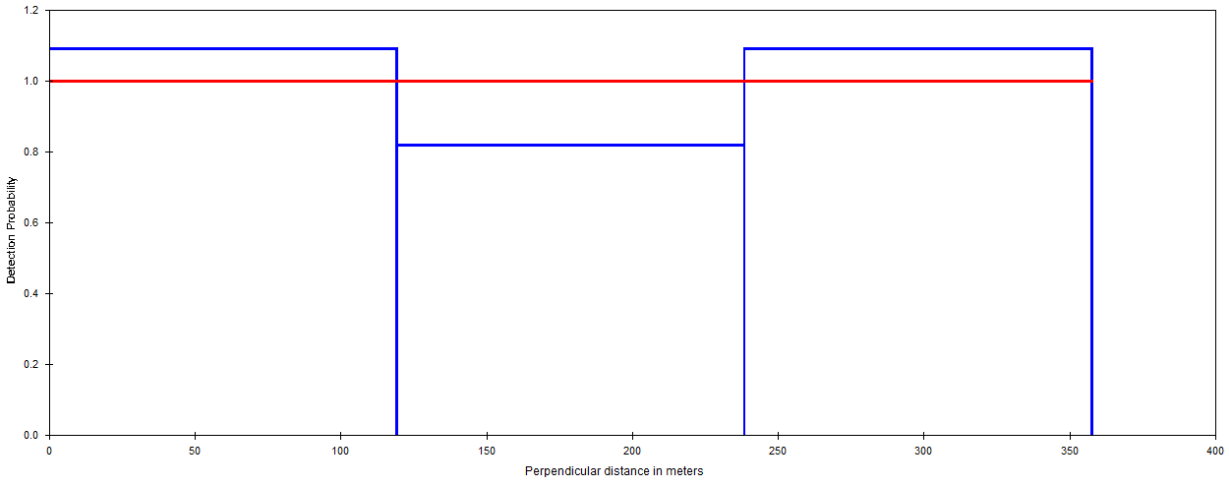


Figure A13. Model fit curve graph for nilgai in intensive study area.

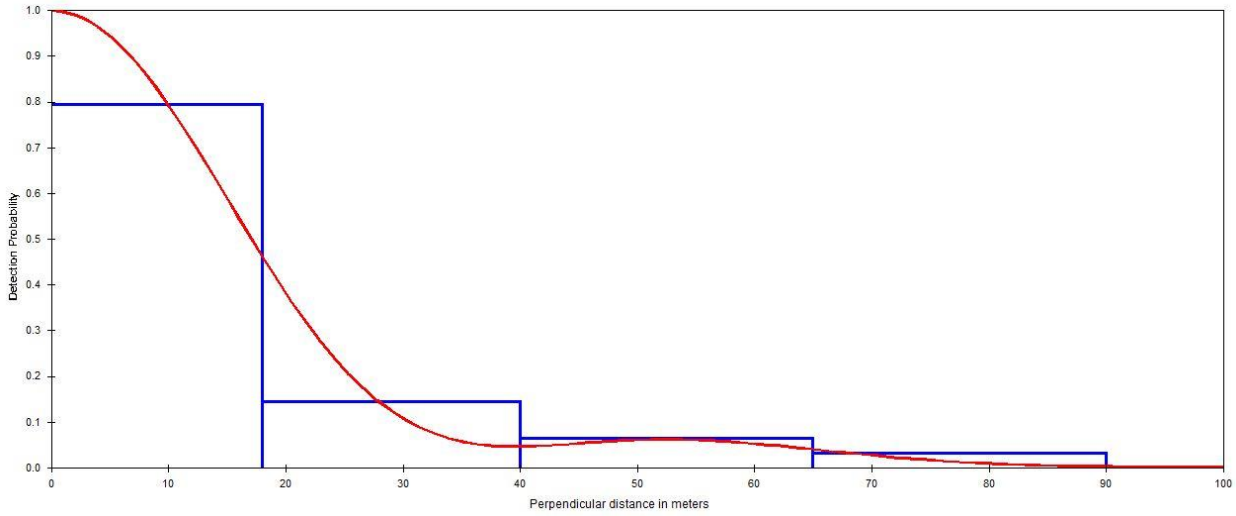


Figure A14. Model fit curve graph for carcasses in intensive study area.

Table A1. Total cost spent for mark recapture in all locations without a double sampling approach.

Type of cost	Amount (INR)	Quantity	Days	Number of locations	Total (INR)
Vehicle rent	1100	1	4	21	92 400
Fuel	65	6.5 litres	4	21	35 490
Labour	270	2	4	21	45 360
Equipment	20 000	1	4	21	20 000
				GRAND TOTAL:	**193 250**

Table A2. Total cost spent in using double sampling approach

Type of cost	Amount (INR)	Quantity	Days	Number of locations	Purpose	Total (INR)
Vehicle rent	1100	1	1	21	CS	23 100
Fuel	65	6.5 litres	1	21	CS	8 872.50
Labour	270	1	1	21	CS	5 670
Vehicle rent	1100	1	4	6	CMR	26 400
Fuel	65	6.5 litres	4	6	CMR	10 140
Labour	270	2	4	6	CMR	12 960
Equipment	20 000	1	4	6	CMR	20 000
				GRAND TOTAL:		**107 142.50**

CS- count survey
CMR- capture mark recapture



Plate 1. Radio-collaring free-ranging dogs in Thar landscape, Rajasthan



Plate 2. Homing in on one of the radio-collared dogs using a three-element Yagi antenna with a handheld receiver (Habit model HR 2600)



Plate 3. Walking line transects of 1km each for prey assessment in intensive study area.

Assessing threats to birds from power-lines in Thar with special emphasis on Great Indian Bustard

A Thesis

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Executive summary

Power line collision is an increasing concern for bird conservation. Number of power lines are increasing speedily covering ecologically important areas. Thar landscape holds high avian diversity as well as increasing network of power lines. This necessitates comprehensive assessment of the impact of power lines on birds. I conducted this study in/around Desert National Park to collect baseline data on power line mortality and assess their impact on birds. To assess power line mortality, I conducted surveys in 100 km of power lines using belt transects and compared it with natural mortality assessed from randomly selected belt transects without power lines. I repeated surveys on a monthly basis to know the seasonal effect of power lines on mortality. I conducted carcass detection and persistence experiment to correct mortality rate for non-detection and decomposition biases. To know the movement rate across power lines I observed 10 segments of power lines in different areas and collected information about bird power line interactions. I have not detected bird carcasses in random transects and found high carcass encounter rate in power line transects (0.784 and 0.590 carcass / km, respectively for high- and low-tension power lines). I recorded one power line mortality of great Indian bustard and 97 casualties of other birds during power line transects in three surveys in which highest number was of Egyptian vulture and common pigeon. I extrapolated my results and found that ~18700 birds are dying per month in GIB habitats of Thar landscape. Collision per crossing was higher for high tension power lines with multiple wires. I have observed 5796 individuals of 49 species crossing power lines. Highest crossing rate was of *Columbidae* (24.25 bird / km / hr). Small birds (<100g) have crossed maximum times (60.70 crossing / km / hr) because they are more abundant in nature. Crossing rate was higher in winter possibly due to migration season. I found large variation between families in terms of collision vulnerability, estimated as collision per crossing that was not related to body mass differences but other biological attributes. As my result shows that power lines are affecting wide range of bird species, it is necessary to develop bird friendly infrastructures to fulfil human requirements without endangering birds as well as implementing a regular power line mortality monitoring program to assess the effectiveness of these measures.

1. INTRODUCTION

In this modern era energy is a key requirement. Energy is the origin of life and has fuelled growth in livelihood standards and economic development. Human demand for energy has increased exponentially in the industrial era, and the ability to transport energy from its source to the consumer has become one of the clearest indicators of how our societies have progressed. Power lines have become essential feature of our modern landscape and are today vital for transporting energy. Infrastructural development is one of the foremost needs of humans to fulfil their necessities.

The network of power line that transmit energy from production centres to substations (hereafter transmission lines) and the line that then distribute energy to costumers (hereafter distribution lines) reach out in the vast spider's web like grids across the landscape. Transmission line loop between large pylon or towers, over 30 meter high that aside from the conductors, often have another cable on top - known as groundwires –to protect conductors by earthing pylons in the event of being hit by lighting. This unavoidable state of affairs generates a series of environmental costs that bring out into the open the classic conflict between the efficient running of electrical infrastructure and the conservation of biodiversity.

Electric power transmission lines are known to be a cause of bird mortality through collision. Most accidents occur with the groundwire, which is thinner than the conductors and therefore more difficult for flying birds to see (Alonso et al. 1994). Electrocution can occur when a bird perches on a cross-arm and completes an electrical circuit with two or more body parts. Electrocution can also happen when the bird comes between two energized components or an energized and an earthed (also called 'grounded') component of the pole structure. Collisions, on the other hand, happen when birds fly directly into electrical lines, poles and pylons. Either the bird is instantly killed when it collides with such obstructions and the subsequent impact with the ground, or it dies from the resulting injuries (Bevanger 1994, APLIC 2006). Avian collisions with and electrocution by power lines have been documented since the early 1900s, but it was not until the 1970s that biologists and engineers began to realize the extent of these events and to study mitigation measures (Bevanger 1998; APLIC 2006; Lehman et al., 2006). The number of power lines is increasing worldwide at 5% per year (Jenkins, Smallie, & Diamond, 2010). This percentage applies to both power distribution (generally 2.4 kV to 60 kV) and transmission lines, which carry >69 kV of electricity (APLIC 2006).

Increase in numbers of power lines has generated increasing concern due to the negative effect it may have on some species that are particularly vulnerable to collision and electrocution (Alonso, 1994). Worldwide it is estimated that bird collisions with power structures, including transmission and distribution lines that result in fatalities could approach 1 billion annually (Hunting 2002). Until an assessment of the cumulative effects of bird mortality from power lines is conducted, the magnitude of such mortalities will remain uncertain (Manville 2009).Bird mortality from collisions with power lines and other electric-utility structures has been documented for nearly 350 species of birds (Manville 1999). Healthy populations can normally compensate for additional mortality due to unusual causes, but may be seriously affected when these acts on a reduced population, hence collisions with power lines are the most important mortality source for some endangered species of birds (Manville 2009).

One of the most endangered bird taxa, bustards (*Otididae*) are also highly prone to fatal collisions with power-lines because of their biological attributes and the human-dominated landscapes that they inhabit. Bustards are heavy birds with small frontal vision that make them oblivious to thin power-lines that criss-cross their habitats, resulting in fatal collisions (Martin & Shaw, 2010). Out of the 25 species of bustards, India is home to three residents and one migrant species; all threatened with extinction (IUCN).The great Indian bustard *Ardeotis nigriceps* (GIB) is most critically endangered (IUCN, 2017) with about 200 birds left, 75% of which occurs in Thar (Dutta et al 2016).The GIB have been wiped out from 90% of its former range (Rahmani and Manakadan 1990).Their habitat is under anthropogenic pressure from industrialization and conversion to intensive agricultural fields. Even within the Thar Desert of Rajasthan, the population has been declining due to hunting, fatal collision with power-lines, nest predation by feral dogs, and destruction of habitats due to transformation of desert/grassland into agriculture fields under irrigation schemes such as Indira Gandhi Canal, drilling for gas and petroleum, mining, stone quarrying, industries, and renewable power projects. Remaining grasslands are subjected to high grazing pressure from domestic livestock (Dutta & Jhala 2014). Among these threats, fatal collision with power-lines is perhaps the most critical threat (S. Dutta pers comm.) since the extreme slow life-history traits of the species cannot sustain any additional human-induced loss of adult birds at this stage. Thus, understanding of threats to great Indian bustard from power-lines and effective mitigation of these structures is crucial for their conservation. Since bustards are now targeted as flagships for grassland/desert conservation, and much of grassland/desert wildlife suffer from similar

threats as GIB, there is an urgent need to assess power-line related mortality for birds, in general, and identify group specific vulnerabilities.

With this aim, I studied power-line related bird mortality in the unique landscape of the Indian Thar Desert, This is one of the smallest and most densely populated deserts of the world and occupies nearly 9% of India's geographical area and covers 208,751km^2, in Rajasthan alone. Due to its geographical location which is the juxtaposition of the Palaearctic, Oriental and Saharan region and falls in the flyway of migratory birds, it has high avian and plant diversity. Nearly 300 bird species have been identified in this landscape (Rahmani & Soni, 1997).

The ecological context of this area is rapidly changing due to intensification in human population, and their occupied area. Survival of wild species is becoming harder in the presence of men made structures like human settlements and industrial development. Big web of wind mills and power lines is one of the main cause of loss in avian diversity of the area as well as expansion of agriculture, overgrazing by livestock, change in cropping pattern, development of seepage wetlands and introduction of exotic plants have greatly affected desert birds such as the most critically endangered Great Indian Bustard *Ardoetis nigriceps*, the migratory Houbara Bustard *Chlamydotis undulate* and the endemic White-browed Bushchat *Saxicola macrorhyncha* (Rahmani & Soni, 1997). This area deserves more concern because of the existence of the flagship species of grassland i.e. Great Indian Bustard which is one of the most critically endangered species of birds and facing a high risk of extinction which requisite extra effort for conservation.

In the present study, field data were gathered on the distribution of bird collision and movement rate in power line corridor in Thar Desert to

i. Assess mortality rate of birds due to power line collision.

a) To compare mortality rate of birds due to power line collision with natural causes of bird mortality.
   My research hypothesis is that power line is a large additive cause behind bird mortality. Hence, my prediction is that carcass counts under power lines exceed the carcass counts in natural conditions.

b) To know the effect of power line characteristic (high-, low-tension power line / number of wires) on mortality rate.

My research hypothesis is that high tension power lines with more numbers of wires can cause higher mortality, but they also form barrier to bird movements leading to less bird crossings. Therefore, I predict that bird mortality may not vary between high- and low-tension power lines.

c) To know the difference of mortality rate in different season (winter & summer).
My research hypothesis is that, bird numbers/availability vary between seasons with winter being the peak migration time. Therefore, my research prediction is that collision rate will be higher in winter comparison to summer.

d) To know the influence of habitat on mortality rates.
My research hypothesis is that, mortality will be higher in areas with higher bird numbers. Since bird species diversity is high in heterogeneous habitats, I predict that collision rate will be high in heterogeneous habitats.

ii. To quantify movement rate of birds across power lines.

a) To know the effect of power line characteristics on bird movement rates
My research hypothesis is that high-tension power lines forms barrier to bird movements due to their large vertical distribution. Therefore, I predict that movement rate will be higher in low tension power line.

b) To know the difference in movement rate of birds according to their size
My research hypothesis is that small birds will be more abundant than large birds following the mass-abundance relationship (Nee Sean, Read Andrew F., 1991), and hence crossing rates at power lines will be proportional to bird numbers. Therefore, I predict that frequency of bird crossing would depend on their size, with movement rate being negatively correlated with bird size.

c) To know the difference in movement rate of birds, according to their family.
My research hypothesis is that bird taxa differ in their flight
Different family prefer different kind of time and flight height, therefore movement rate across power line will be different for families.

d) To know the difference in movement rate of birds in terms of seasons.
My research hypothesis is that winter is peak migration season, therefore movement rate will be high in winter.

iii. To quantify taxa specific vulnerability to power line collisions.

a) To know the difference in vulnerability to power line collision within families.
My research hypothesis is that flight behaviour of birds depends on their biological attributes viz. their frontal vision, wing load etc. Therefore, I predict that vulnerability to power line collision will be different for families.

b) To know the difference between vulnerability to power line collision within different size classes.
My research hypothesis is that large bodied birds have large wingspan due to that they are more prone to collision, therefore I predict vulnerability to power line collision will be high in large sized birds.

2. STUDY AREA

2.1 Location

I carried out this study in the part of Thar Desert which is located in western Rajasthan between 23◦04–30◦11N and 69◦29 –78◦17E. Thar is the eastern extension of the vast Iranian-Arabian Desert, which joins the great Sahara Desert. It is about 640 km long and 160 km wide and covered by several metres of sand which is constantly being shifted by winds blowing from the south-west (Krishnan, 1982). The Thar Desert extends into Pakistan but nearly 62% is situated in 11 districts of western Rajasthan. Surveyed area for this study was 3,103 km^2 distributed in prime habitat of *Ardiotis nigriceps* which includes some parts of Desert National Park.

2.2 Climate

Though moisture-bearing winds of the south-west monsoon blow over Rajasthan for 4 months (June to September) of the year, there are no hills across the direction of the winds to impede their progress and precipitate some rain. The Aravalli Mountains are aligned parallel to the direction of the winds and do not form a serious obstacle to their course across Rajasthan (Krishnan, 1982). Thus, the climate is characterized by low rainfall with erratic distribution. Rainfall in Thar Desert varies from less than 150 mm in parts of Jaisalmer in the extreme west to 400 mm in the east towards the Aravalli Mountains. Droughts lasting 3 to 4 years are common. Nearly 85% of the rainfall is received during the monsoon period with most rain falling during only a few days. Total precipitation shows large inter-annual variations, with a coefficient of variation of 70%. Thar Desert experiences extremes of diurnal and annual temperatures, low humidity and high wind velocity, characteristic of warm-dry continental climates. The year can be divided into three seasons: winter (October to February), summer (March to June) and monsoon (July to September). June is the hottest month and January the coldest. The temperature varies from 0°C in winter to 50°C in summer (Ghosh, 1996).

2.3 Habitat and flora

The major part of Thar Desert is occupied either by dry open grassland or by grassland interspersed with trees and thorny bushes (Gupta 1975). The land-cover types can be classified into grasslands/savannahs, bare sand dunes, stabilized sand dunes, barren flatlands or *magras*,

and agricultural areas(Agarwal, Goyal, & Qureshi, 2015). The vegetation falls under the category 'thorn forest type' or 'scrub forest type' (Mathur 1960; Champion and Seth 1968). Dominant grasses are *Lasiurus indicus, Desmostachya bipinnata, Dactyloctenium aegyptium* and *Eragrostris ciliaris*, and the main sedge is *Cyperus rotundus* (Gupta, 1975; Bhandari, 1990; Shetty, 1994). Most of other vegetation consists of stunted, thorny or prickly shrubs and perennial herbs which are resistant to drought such as *Capparis decidua, Calotropis procera, Calligonum polygonoides, Acacia senegal, Prosopis cineraria, Aerva javanica, Aristidaadescensionis* and other psammophytic species (Shetty 1994). Sand dunes form 58% of the desert. The Indira Gandhi Nahar Project Rajasthan has produced many new aquatic habitats in the form of small ponds and swampy areas. Indira Gandhi Canal and Oil Exploration have also caused severe habitat alterations in some places (K.K. sharma, & S. P. mehra, 2008)Major agricultural crop of the area is pearl millet or bajra (*Pennisetum typhoides*) cultuvated in monsoon. The other common crops are mong (*Phaseolus radiatus*), moth (*Vigna aconitifolia*), guar (*Cyamopsis tetragonoloba*) and til (*Sesamum indicum*). In the irrigated areas of IGNP,these traditional crops are being replaced by cash crops such as groundnut (*Arachishypogea*), cotton (*Gossypium* spp.), rice (*Oryza sativa*), sugarcane (*Saccharumofficinarum*), wheat (*Triticum sativum*) and barley (*Hordeum vulgare*) (Chatterji &Saxena, 1988, Rahmani & Soni, 1997).

2.4 Fauna

Thar Desert supports a variety of avifaunal species due to the presence of various habitat types. A total of 272 species of birds, belonging to 17 Orders and 55 Families have been recorded from this region (Sivaperuman et al. 2007). Out of these, 223 species are resident and 49 are migrants. Out of 55 families found in this region, 26 were recorded during this study including some of the endangered species, which includes critically endangered great Indian bustard (*Ardeotis negriceps*), white-rumped vulture (*Gyps bengalensis*), red-headed vulture (*Sarcogyps calvus*) and Indian vulture (*Gyps indicus*) that are vulnerable to power line collisions.

The mammalian fauna of Thar is highly diverse, comprising of at least 68 species, which constitute about 18% of the total Indian mammalian fauna. Two major carnivores, the Asiatic lion *Panthera leo persica* and the Asiatic cheetah *Acinonyx jubatusvenaticus*, have become extinct in Rajasthan during the last 100 years. The wild ass *Equus hemionus khur*, although suspected to have become extinct during the last four decades, has recently been sighted by

Sangha (2003). The desert cat (*Felis sylvetris*), desert fox (*Vulpes vulpes pusilla*), Indian fox (*Vulpes bengalensis*), caracal (*Feliscaracal*), wild pig (*Sus scrofa*), Indian desert gazelle or chinkara (*Gazella bennettii*), blackbuck (*Antilope cervicapra*) and blue bull (*Boselaphus tragocamelus*) are some of the prominent mammalian species still found in Thar desert.
Among mammals, Chiropterans are vulnerable to power line collisions. In India, 114 species of bats are found (17 megabats and 97 microbats). Out of this, Thar desert is home to eleven microbats, viz., *Rhinopoma microphyllum, Rhinopoma hardwickii, Taphozous perforatus, Taphozousnudiventris, Rhinolophus lepidus, Scotophilus heathii, Pipistrellus mimus (tenuis), Megaderma lyra, Hipposideros fulvus, Tadarida aegyptiaca* and *Pipistrellus dormeri*, and three mega-chiropteran species viz., *Pteropus giganteus, Cynopterus sphinx* and *Rousettus leschenaulti* in its recent past (Purohit & Senacha, 2004).

2.5. Human dimension

Thar is one of the most densely populated deserts in the world. The human density is 83 inhabitants per sq. km. Thar holds a large livestock population, and extensive grazing by livestock is an important process contributing to the deterioration of desert environment. The human : livestock ratio is almost 1:2 in the desert districts (K.K. sharma, & S. P. mehra, 2008). Human settlements are increasing with the improvement in the drainage system of the desert. Infrastructural development is quite common throughout the landscape. Vertical belt of wind turbines is creating a big barrier in flyways of birds. One of the biggest threats to avifauna in this area is power lines which becomes a mist net in aerial ways of birds. These infrastructure are continuously increasing in desert area for fulfilling the demands of human population. Rapidly changing land use pattern and use of intensive agriculture is affecting habitat diversity, which is also a cause for decreasing floral and faunal diversity in Thar. Tourism is increasing day by day in Thar, to say it's an eco-friendly event for human society to give exposure about wild areas. However ground reality is not the same, Thar is facing excessive load of tourism which is creating another threat for wild animals and big increasing concern for conservation of desert areas.

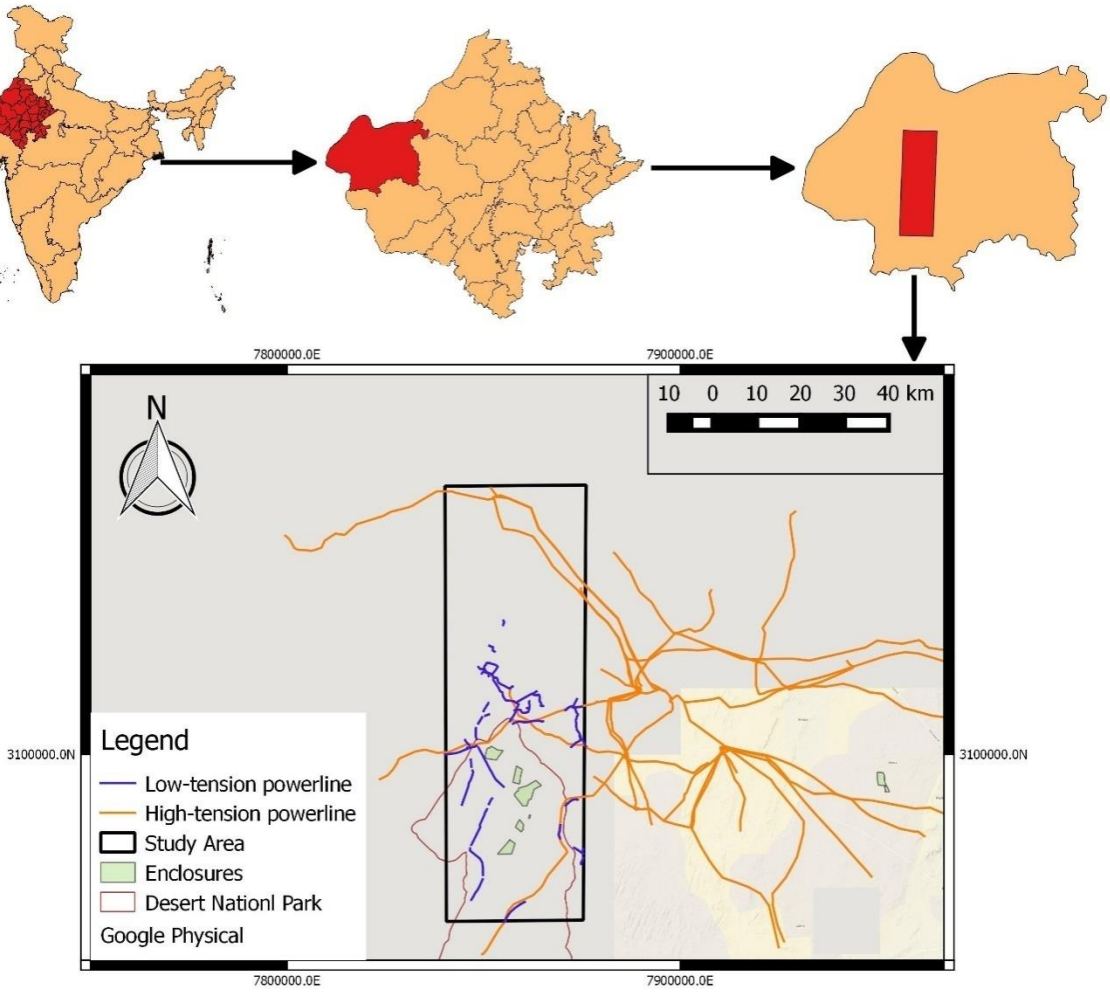


Figure 1. Map of the study area showing the geographic location (Jaisalmer, Rajasthan, India from right to left in the inset) and power line structures in Thar landscape 2017.



Figure 2. Images of Infrastructures in Thar landscape during January-April 2017 (High- and low-tension power line, wind turbines from top to bottom).

3. METHODOLOGY

3.1. Field surveys

3.1.1. Surveys to assess power line collision rate

To assess the mortality rate of birds due to collision and electrocution with power lines, I surveyed power line corridors in my study area (Bevanger, 1999), the prime habitat for *A. nigriceps*. To select samples for this survey, I digitalised low- and high- tension power lines within my study area with the help of very high resolution satellite imagery in Google Earth. I generated 25 random points each on low- and high- tension power lines with the help of QGIS 10.0. I laid fixed transects of~2000 m length at each of these points. Two observers, including me, surveyed these power line segments by walking along straight lines at 15 m distance on either side of the wire, searching for bird carcasses within 15 m strip on either side of the observer; thereby counting all carcasses within 60 m belt along the power line. Observers attempted to record carcasses up to species level, and where this was difficult due to carcass decomposition, they recorded the finest possible taxonomic group (genus/family/order, such as raptors, cranes, bustard, doves/pigeons and passerines). Some carcasses were represented by highly degraded bones and feathers that could not be assigned to any taxa, and were recorded as 'unidentified'. To correctly identify taxa of carcasses *a-posteriori*, observers collected tissue and feather samples of carcasses in ethanol vials and zip locks, respectively, along with recording calibrated photographic evidence of the carcass. Evidences of 10 feathers or less were not considered as mortality as they could be blown by wind or deposited by birds during roosting/preening.

I followed the following sampling designs to address my objectives. First, to compare the natural mortality rate of birds with that due to power lines, I surveyed power line segments (n=50) and belt transects of similar dimension (2000 m x 60 m) laid in natural environment without power line (n=20), once in January 2017.

Second, to estimate annual bird mortality due to power lines, and the influence of power line characteristics, season and habitat on mortality rates, I surveyed these low- (n=20) and high- (n=20) tension power line segments in March 2017 and April 2017. I removed all carcasses from power line segments one month prior to these surveys to estimate monthly mortality rate. Corresponding to carcass sighting, observers recorded the geographic location, condition and

distance of carcass from wire. Observers visually assessed habitat characteristics within 60 m radius plots at 200 m intervals under power line. Variables that were recorded at these plots included geographic location, land-cover (agriculture, barren, grassland, shrubland, woodland or scrubland), terrain (flat, sloping or undulating) and substrate (rocky, gravel, sand or soil).

3.1.2. Experiments to correct carcass decomposition and detection biases

Carcass count, thus obtained, is an underestimate of true mortality due to power lines because some carcasses, particularly of smaller birds, are decomposed and scavenged before the survey (persistence / disappearance probability); and all available carcasses are not necessarily detected (detection / non-detection probability). To correct for these biases, I conducted two experiments to estimate the probability of carcass persistence over time and that of detection following (Ponce, Alonso, & Carrasco, 2010).

For carcass persistence experiment, we placed 34 fresh carcasses of birds under the area of 10 randomly selected power line segments (5 low- and 5 high- tension) and monitored them after 2, 5-7, 10, 15-18, 20-25, 30 and 60 days since placement following (Ponce et al., 2010). I recorded if the carcass persisted or disappeared on these days by searching 30 m radius around the placement location to avoid any chance of missing carcasses that were dragged during predation but still lay within the power line area. I considered a carcass to have disappeared if it was not found or <10 feathers remained. Since smaller birds would disappear faster than larger birds through decomposition and scavenging, I used carcasses ranging from 15 to 8500 g to represent the body mass spectrum. These carcasses included wild birds that were detected very fresh, estimated at $\leq$1 day old (n=15 birds), as well as domesticated country chicken that were purchased from *Dhani* owners (who keep few individuals for self-consumption) without coercion and euthanized (n=18 birds). These domesticated birds do not have odour typical of intensive poultry farming as they are raised in non-captive environment, and therefore would mimic wild birds in terms of attracting predators.

For carcass detection experiment, I used 18 bird carcasses covering body mass range from 50 to 5000 g, to capture the effect of size on detection, and estimate size-specific detection probabilities. The project investigator placed these carcasses under six randomly selected power line segments following completely randomized placement decision (number and location of carcasses under each power line).Three observers, including me, separately searched for these carcasses in a blind test, by walking at slow, regular pace parallel to the wire

and at a distance of 15m from it, searching 15 m strip on either side; thereby mimicking actual power line surveys.

3.1.3. Behavioural observations of birds across power line to assess the movement rate

For quantifying the movement rate of birds across power lines, I observed birds activities at low- (n=5) and high- (n=5) tension power lines in prime *A. nigriceps* habitat. Two observers, including me, observed bird movement by sitting under power lines and observing bird activities within a distance of 60-884 m ahead of us. To avoid altering bird movements due to the presence of observer, we used a mobile camouflaged hide for these observations.

To compare the movement rate between seasons, I conducted this exercise once in winter from 14th to 25th February and once in summer from 25th April to 3rd of May 2017.

Observers recorded bird activity at power lines from daybreak to sunset, and to avoid observer fatigue, observers rested for 30 minutes after every two hours of observation. Observers used Bushnell 8*42 and Hawk 8*42 binoculars for observation and a Canon SX60HS bridge camera to capture fast moving birds for identification. Temperature and wind velocity were also recorded with the help of anemometer once every hour to understand the effects of temperature and wind velocity on bird activity. Species identification followed Birds of the Indian subcontinent (Grimmett R, Inskipp C, Inskipp T. 2007). Observers recorded the following variables corresponding to bird sighting: position of bird with respect to wire (above, below, through line), vertical distance of bird from wire (<1, 1-5, 5-10, 10-20 m), horizontal distance of bird from observer measured as the distance class between the proximate and distant pole/pylons through which the bird has crossed, number of wires in power line, heights of lowest and upper wire, and the usage of power line by the bird (perching, crossing, chasing).

3.2. Data analysis

3.2.1. Detection probability

To estimate the proportion of bird carcasses detected during power line surveys, I used data on number of carcasses (trials) which were detected (success) in my detection experiment, to model carcass detection probability (response) on log-transformed bird weight (predictor) using binomial generalized linear model in program R. I used this model to predict mean and standard error of carcass detection probability based on mid-values of low (0-100 g), medium (100 – 1000 g) and high (1000 – 8500 g) weight classes.

3.2.2. Probability of persistence

To estimate the proportion of carcasses deposited in the month leading to a survey that would be available for detection, I computed the proportion of carcasses that were not completely decomposed/ removed along increasing exposure times (2, 5, 7, 10, 15, 20, 30, 60 days) in my decomposition experiment. Since bird carcass could be deposited on any of the 30 days leading to a survey, I estimated the persistence probability of an average carcass as the mean of proportions of carcasses persisting on 0, 1, 2 … 30^{th} day.

3.2.3. Assessment of bird mortality rate and patterns

To estimate bird mortality due to power lines, I computed mean and standard error of carcass encounter rates (carcass/km) across power line samples by pooling monthly survey data, and segregating birds into low (<100 g), medium (100-1000 g) and high (>1000 g) weight classes. I estimated actual bird mortality / km / month in each of these weight classes as the carcass encounter rate divided by the product of carcass detection probability and persistence probability. I obtained total bird mortality / km / month by adding actual mortalities of different weight classes. I extrapolated this estimate to the linear length of power lines in our landscape of interest, digitized using Google Earth imagery, to obtain expected monthly bird mortalities due to power lines.

I compared mean and 95% confidence intervals of bird carcass / km under power lines to that under natural environment to test if power lines contributed significantly more to bird mortality than the natural prevalence.

To estimate the difference in mortality rate in winter and summer season, I compared mean and 95% confidence interval of carcass encounter rates (carcass / km) between seasons, segregated by power line type (high vs. low tension).

To assess the influence of power line and habitat characteristics on bird mortality , I modelled mean monthly carcass count in 2 km power line samples on number of wires, habitat heterogeneity – measured as Shannon-Weiner's diversity index from land-cover categories across plots, and prominent habitat gradients extracted by principle component analysis, using Poisson generalized linear model in program R. I built candidate models (alternative hypotheses) explaining bird mortality patterns, and ranked models using Akaike's Information Criterion (AIC). Important factors and their effects on bird mortality were inferred from parameter estimates of the minimum AIC model (Quinn and Keough, 2002).

3.2.4. Assessment of bird crossing rate and patterns

To estimate bird crossing rate at power lines, I estimated mean and 95% confidence intervals of crossings / km / hr for birds as whole and also segregated by families and weight-classes.

To incorporate imperfect detection of birds and effect of bird size on detectability, I compared bird crossing / m along increasing distance classes with that in the first distance class, separately for each power line, assuming that observers detected all birds crossing the first distance class and bird activity was uniform across distance classes, akin to the principles of point transect distance sampling (Buckland et al. 2001). I found evidence of declining detectability along increasing distance classes for small (<100 g) and medium (100 – 1000 g) size birds, but not for large (>1000 g) birds. Under the above assumptions, I computed the number of birds / m crossing a distance class relative to that crossing the first distance class, truncating all values to 1 (maximum), to estimate the proportion of birds detected along increasing distance classes for each power line and bird weight class. This correction factor was used to estimate actual number of birds crossing each distance class which were summed up to estimate total crossings / km / hr.

To assess the effects of power line type and season on bird movements, I compared mean and 95% confidence interval of bird crossings / km / hr between low- and high- tension power lines, and between summer and winter surveys. To compare crossing rates, and therefore exposure

to collision risk, between bird sizes, we compared mean and 95% confidence intervals of crossings / km estimate the movement rate according to season I compared the corrected crossing rate of bird in both winter and summer season.

To estimate the difference in movement rates according to bird size, and therefore their exposure to collision risk, I segregated birds into low (<100 g), medium (100 – 1000 g) and high (>1000 g) weight classes, and compared their mean and 95% confidence intervals of crossings / km / hr, separately for winter and summer seasons.

3.2.5. Assessment of vulnerability to collision

To assess the vulnerability of bird families and weight classes to power line collision, I computed the ratio of collision to crossing rates at power lines for families and weight classes. To estimate ratio of collision to crossing rate, I divided carcass / km / month by crossing / km / month.

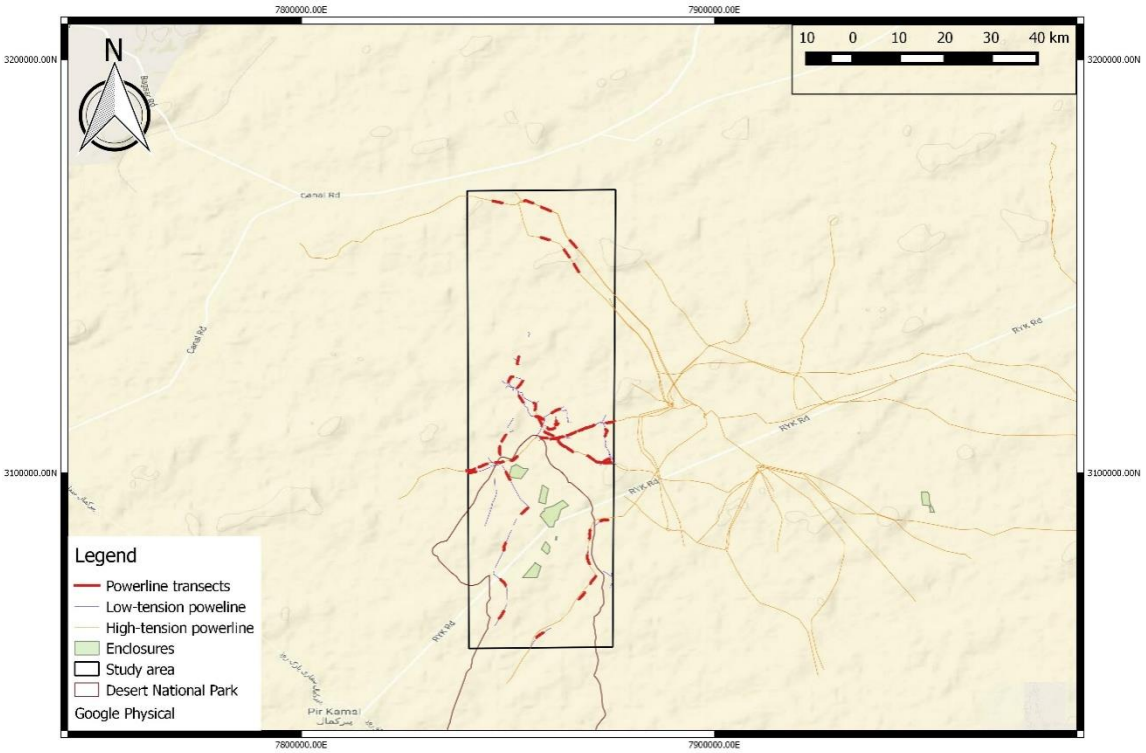


Figure 3. Map showing power line transects laid in Thar landscape during January - April 2017.

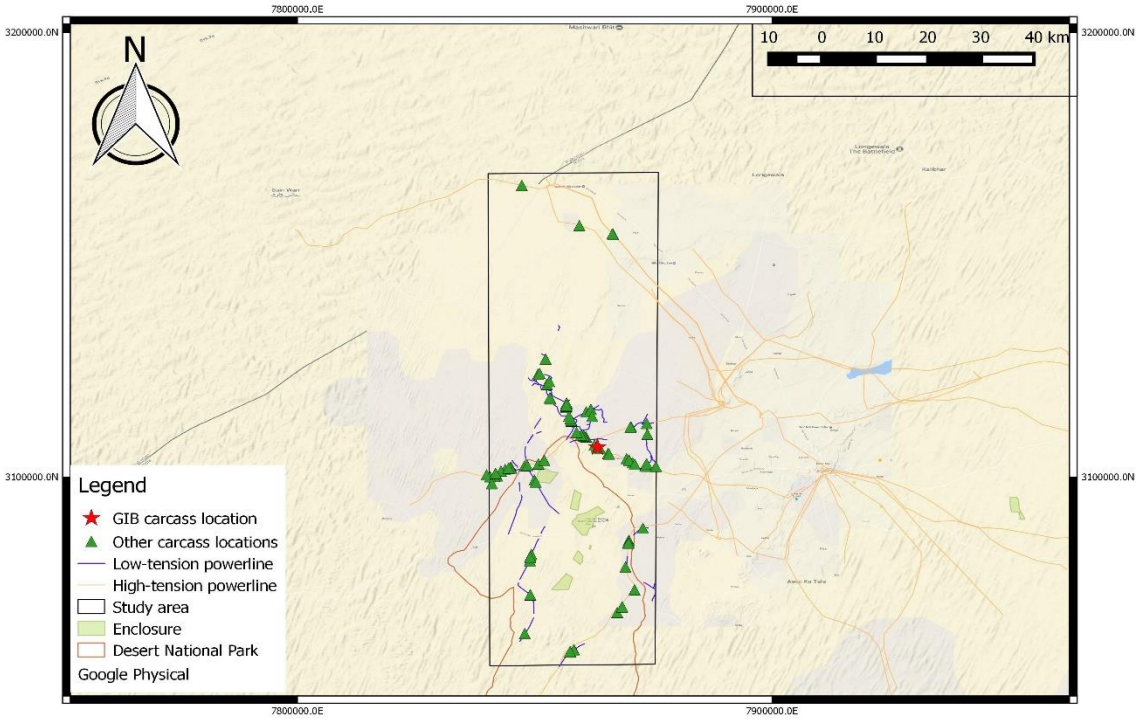


Figure 4. Map showing carcass location of great Indian bustard and other birds found on power line transects in Thar landscape during January - April 2017.

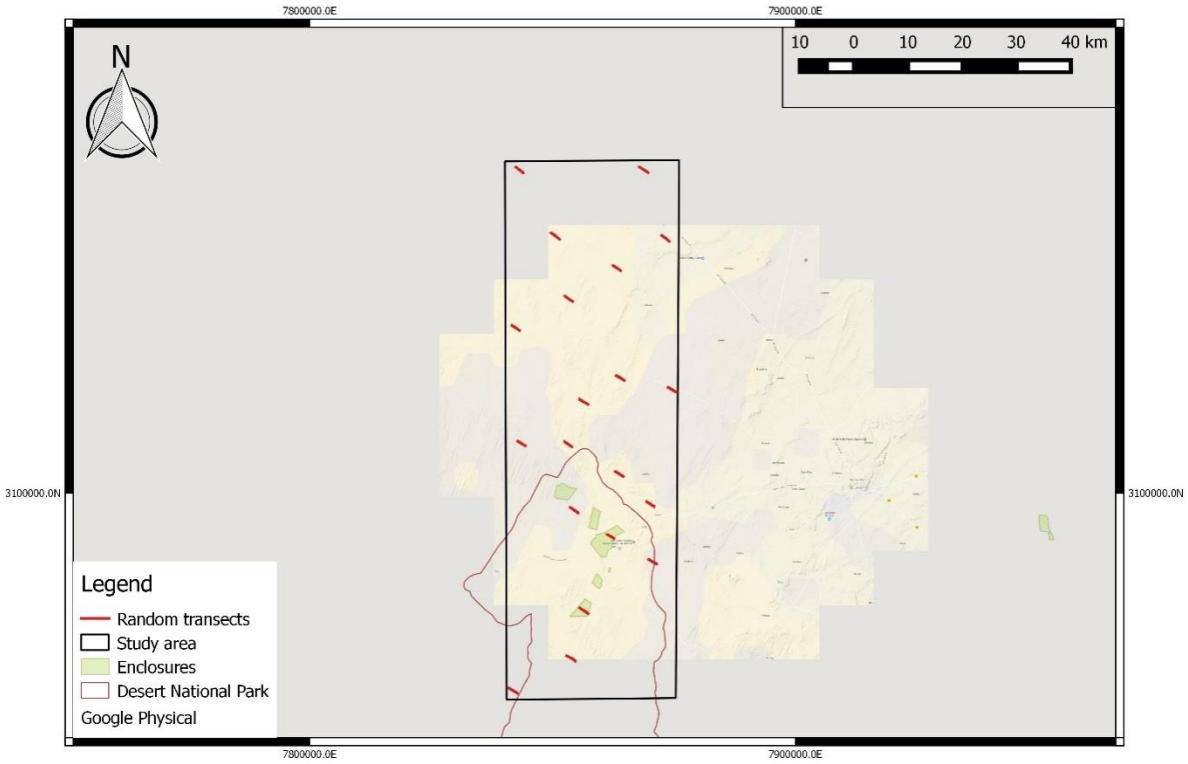


Figure 5. Map showing random transects laid in Thar landscape February 2017.



Figure 6. Bird carcasses used for carcass decomposition experiment during January-April in Thar landscape 2017 (Eurasian griffon vulture (left upper), common teal (right upper), red naped ibis (middle), long-legged buzzard (right lower), country chicken (left lower).

4. RESULTS

In total, I surveyed 100 km of power line on foot, and found 97 bird casualties. Out of this 45.68% of birds were identified and they comprised of 11 families and 14 species. This total includes carcasses found in base survey (when carcasses were not removed prior to survey) and seasonal surveys (one survey in winter and summer each when old carcasses were removed one month prior to surveys). Highest number of carcasses was that of *Acciptridae* (14.43% of total casualties), followed by *Columbidae* (10.30%), *Glareolidae* (4.12%), *Gruidae* (4.12%), *Anatidae* (2.06), *Corvidae* (2.06%), *Strigidae* (1.03%), *Coraciidae* (1.03), *Falconidae* (1.03%), *Acrocephalidae* (1.03%) and *Ploceidae* (1.03%) (Table 1).

Table 1. Summary of carcasses found during power line surveys in Thar landscape during January - April 2017.

Species	**Scientific name**	**Family**	**Carcasses**	**Relative abundance (proportion)**
Egyptian vulture	*Neophron percnopterus*	*Accipitridae*	7	0.072
Eurasian Griffon Vulture	*Gypf fulvus*	*Accipitridae*	6	0.062
Long legged buzzard	*Buteo rufinus*	*Accipitridae*	1	0.010
Common Teal	*Anas crecca*	*Anatidea*	2	0.021
Blyth's Reed Warbler	*Acrocephalus dumetorum*	*Acrocephalidae*	1	0.010
Common pigeon	*Columba livia*	*Columbidae*	7	0.072
Eurasian collared dove	*Streptopelia decaocto*	*Columbidae*	3	0.031
Indian Roller	*Coracias benghalensis*	*Coraciidae*	1	0.010
House Crow	*Corvus splendens*	*Corvidea*	2	0.021
Laggar Falcon	*Falco jugger*	*Falconidea*	1	0.010
Cream coloured courser	*Cursorius cursor*	*Glareolidae*	4	0.041
Demoiselle crane	*Grus virgo*	*Gruidea*	4	0.041
Baya Weaver	*Ploceus philippinus*	*Ploceidae*	1	0.010
Spotted Owlet	*Athene brama*	*Strigidae*	1	0.010
Unidenified	-	-	56	0.577

4.1 Is carcass encounter rate higher under power lines than natural environment?

Bird carcasses were not detected under any random transect (n=20 transects), indicating the relatively low natural prevalence of bird mortality. In contrast, bird carcass encounter rate was higher in power-line transects (mean=0.784 carcass/km, SE=0.192, n=25 in high-tension power-line and mean=0.590 carcass/km, SE=0.127, n=25 in low-tension power line) (fig 7)

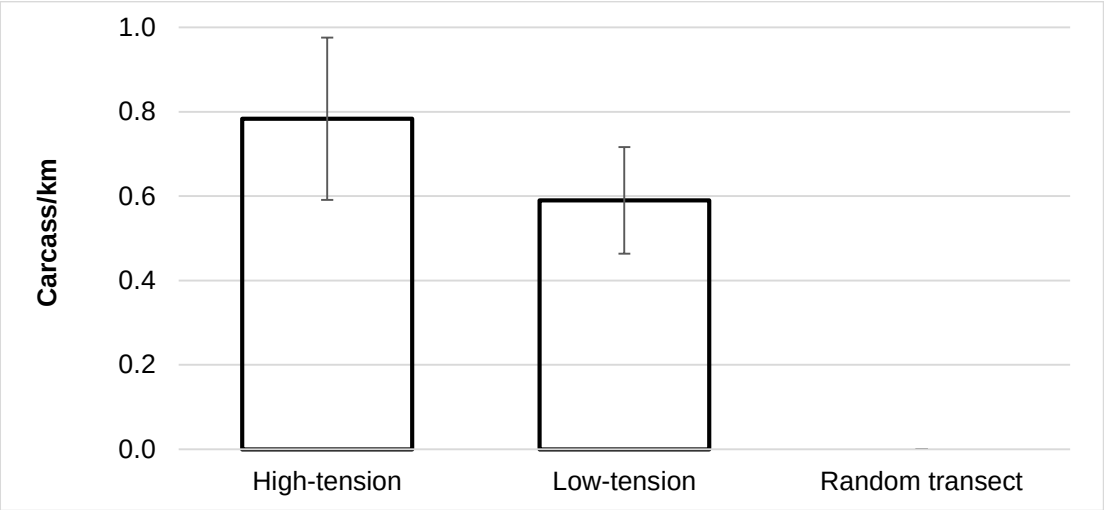


Figure 7. Mean and standard error of carcass encounter rate under power line and random transects in Thar landscape during January - April 2017

4.2 Persistence of carcasses

The probability of carcass persistence declined asymptotically with time and depended on bird body mass (fig 8). Probability of carcass persistence for birds <100g was estimated at 0.20 till 2 days since carcass placement, and 0 thereafter. The probability of carcass persistence for birds weighing 100-1000g was estimated at 0.35 till 2 days, 0.12 from 2 to 20 days and at 0.06 from 20 to 30 days since carcass placement. The probability of carcass persistence for birds weighing >1000g was estimated at 1.00 till 2 days, 0.78 till 20 days and 0.70 on the 30^{th} day since carcass placement.

Table 2.Details of bird carcasses used for carcass decomposition / persistence experiment in Thar landscape during January - April 2017

Weight class	Species	Number of carcasses
<100g	Country chicken	4
	Blyth's reed warbler	1
100-1000g	Country chicken	9
	Red naped ibis	2
	Common teal	2
	Common pigeon	2
	Eurasian collared dove	1
>1000g	Eurasian griffon vulture	5
	Egyptian vulture	1
	Punjab raven	1
	Long-legged buzzard	1
	Peafowl	1
	Country chicken	4

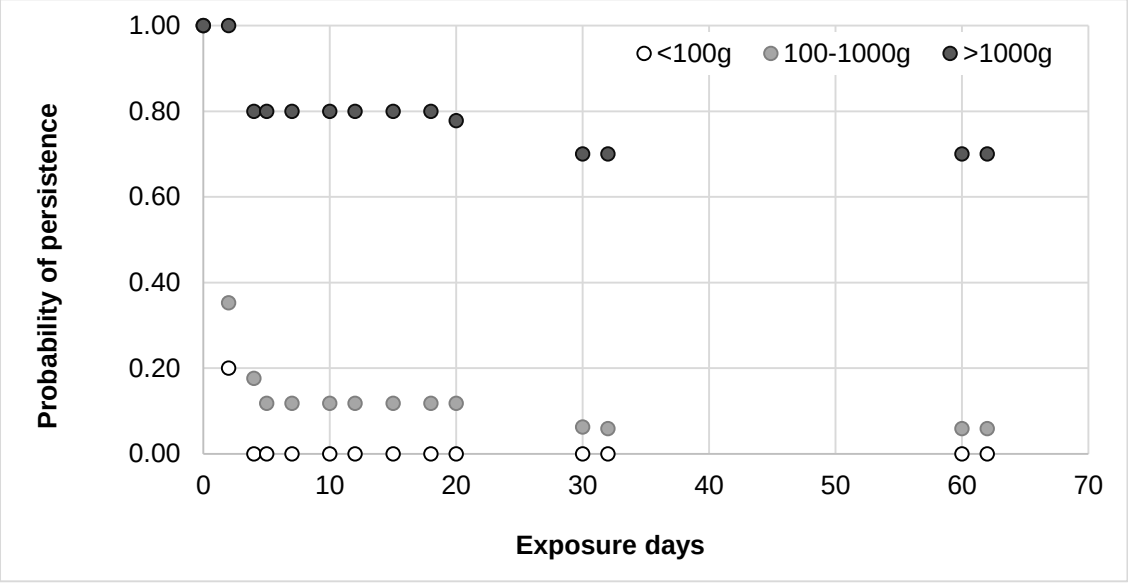


Figure 8. Probability of carcass persistence along time since placement under power lines for small (<100 g), medium (100-1000 g) and large (>1000 g) birds in Thar landscape during January - April 2017.

4.3 Detectability of carcasses

The probability of carcass detection increased asymptotically with body mass of bird. Probability of carcass detection for birds weighing<100g, 100-1000 g and >1000 g was estimated at 0.497, 0.899 and 0.976, respectively. (fig 9).

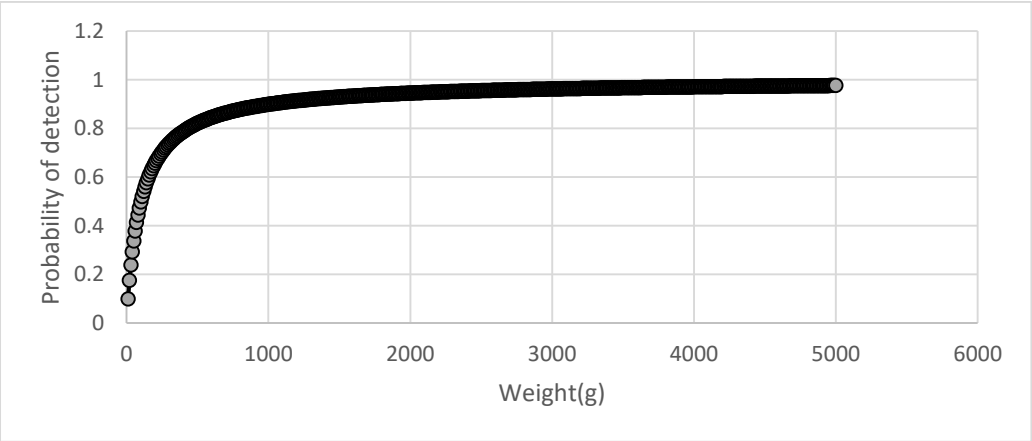


Figure 9. Probability of detection along body mass of birds estimated from carcass detection experiment in Thar landscape during April 2017.

4.4 Bird mortality rate due to power line collision

Mean monthly encounter rate of bird carcasses was 0.02, 0.09 and 0.09 birds / km for small, medium, and large birds, respectively. However, carcass detection probability of small birds was low (0.34) compared to that of medium (0.83) and large (0.98) birds. Similarly, mean probability of carcass persistence through 30 days preceding my survey was lower for small (0.01) and medium birds (0.12) compared to large birds (0.78). Correcting for these biases, the true collision rate was estimated at 4.17 birds/km/month for small birds, 0.93 birds/km/month for medium birds, 0.13 birds/km/month for large birds. Extrapolating this collision rate to 3600 km of power line, I estimated that 18778 birds are killed by power line collision in my study area in a month (table 3).

Table 3. Mean monthly collision rates (birds / km with 95% confidence intervals) of birds in different weight classes in Thar landscape during March–April 2017. Collision rates were adjusted for biases in a stepwise fashion i.e., mean carcass encounter rate was corrected for detection probability and persistence probability to estimate true bird mortality / km / month.

	Weight class		
	<100g	100-1000g	>1000g
Mean encounter rate (/ km)	0.02	0.09	0.09
Detection probability	0.34	0.83	0.98
Persistence probability	0.01	0.12	0.78
True carcass encounter rate (/km)	4.17	0.93	0.13
Total power line(km)	3600.00		
Bird mortality/month	14996	3332	450
Total bird mortality in a month	18778		

4.5 Does carcass encounter rate differ with power line type and season?

Carcass encounter rate at high-tension power lines (mean=0.265 carcass / km, SE=0.724, n=20) was higher than that at low-tension power lines during summer (mean=0.100 carcass / km, SE=0.052, n=20).However, carcass encounter rate at high-tension power line (mean=0.206 carcass / km, SE=0.077, n=20) was not different from that at low tension power line during winter (mean=0.250 carcass / km, SE=0.089, n=20) (fig. 10).

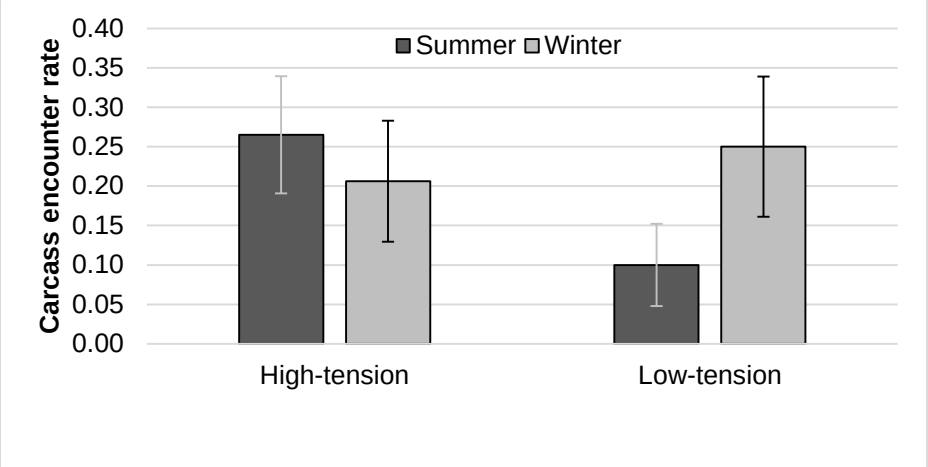


Figure 10. Mean and standard error of carcass encounter rate in high-tension power line and low-tension power line across winter and summer surveys in Thar landscape during March – April 2017.

4.6 Does mortality rate depend on habitat heterogeneity and number of wires?

Carcass encounter rate was positively and precisely related with number of wires (appendix 1), indicating that collisions are more likely where power lines have larger number of wires. Carcass encounter rate was positively but not precisely related with habitat heterogeneity (table 4).

Table 4. Parameter estimates of best-fit Generalised Linear Model examining the effects of habitat heterogeneity and number of wires on bird mortality due to power line collisions in Thar landscape during January and April 2017.

Variable	Estimate	Standard error	P
Intercept	-1.156	0.509	0.023
Wires	0.141	0.033	<0.01
Habitat heterogeneity	0.665	0.424	0.116

4.7 Crossing rate of birds across power lines

During bird flight activity observations, I recorded a total of 5796 individuals of 49 species. The most numerous species was Eurasian collared doves (33.86% of total individuals), followed by white eared bulbul (10.05%), lark (9.33%), green bee-eater (6.02%), common pigeon (5.79%), house sparrow (5.53%), common babbler (4.76%), house crow (4.10%), and southern grey shrike (3.07%) (Table 5).

Table 5. List of species with family and number of individuals detected during flight observation at power lines in Thar landscape in February-May 2017.

Species	**Scientific name**	**Family**	**Individuals detected**
Asian desert warbler	*Sylvia nana*	*Sylviidae*	2
Barbary falcon	*Falco pelegrinoides*	*Falconidae*	1
Barn swallow	*Hirundo rustica*	*Hirundinidae*	7
Black bellied sandgrouse	*Pterocles orientalis*	*Pteroclididae*	10
Black drongo	*Dicrurus macrocercus*	*Dicruridae*	10
Brahminy starling	*Sturnia pagodarum*	*Sturnidae*	1
Chestnut bellied sandgrouse	*Pterocles exustus*	*Pteroclididae*	145
Chestnut shouldered petronia	*Petronia xanthocollis*	*Passeridae*	33
Cinereous vulture	*Aegypius monachus*	*Accipitridae*	6
Clamorous reed warbler	*Acrocephalus stentoreus*	*Acrocephalidae*	4
Comman starling	*Sturnus vulgaris*	*Sturnidae*	1
Common babbler	*Turdoides caudata*	*Leiothrichidae*	276
Common kestrel	*Falco tinnunculus*	*Falconidae*	1
Common pigeon	*Columba livia*	*Columbidae*	336
Cream coloured courser	*Cursorius cursor*	*Glareolidae*	1
Desert wheatear	*Oenanthe deserti*	*Muscicapidae*	23
Desert white throat	*Sylvia minula*	*Sylviidae*	3
Eastern imperial eagle	*Aquila heliaca*	*Accipitridae*	3
Egyptian vulture	*Neophron percnopterus*	*Accipitridae*	52
Eurasian collared dove	*Streptopelia decaocto*	*Columbidae*	1963

Species	**Scientific name**	**Family**	**Individuals detected**
Eurasian griffon vulture	*Gyps fulvus*	*Accipitridae*	22
Eurasian marsh harrier	*Circus aeruginosus*	*Accipitridae*	1
Green bee eater	*Merops orientalis*	*Meropidae*	349
Himalayan griffon vulture	*Gyps himalayensis*	*Accipitridae*	5
House crow	*Corvus splendens*	*Corvidae*	238
House sparrow	*Passer domesticus*	*Passeridae*	321
Indian silverbill	*Euodice malabarica*	*Estrildidae*	50
Laggar falcon	*Falco jugger*	*Falconidae*	135
Lark	*Alaudidae*	*Alaudidae*	541
Laughing dove	*Spilopelia senegalensis*	*Columbidae*	68
Long legged buzzard	*Buteo rufinus*	*Accipitridae*	2
Merlin	*Falco columbarius*	*Falconidae*	5
Pallid harrier	*Circus macrourus*	*Accipitridae*	2
Pied bushchat	*Saxicola caprata*	*Muscicapidae*	7
Plain prinia	*Prinia inornata*	*Cisticolidae*	9
Punjab raven	*Corvus corax*	*Corvidae*	39
Purple sunbird	*Cinnyris asiaticus*	*Nectariniidae*	89
Red rumped swallow	*Cecropis daurica*	*Hirundinidae*	1
Red vented bulbul	*Pycnonotus cafer*	*Pycnonotidae*	117
Red wettled lapwing	*Vanellus indicus*	*Charadriidae*	2
Rosy starling	*Pastor roseus*	*Sturnidae*	14
Shikra	*Accipiter badius*	*Accipitridae*	2
Short toed snake eagle	*Circaetus gallicus*	*Accipitridae*	2
Southern grey shrike	*Lanius meridionalis*	*Laniidae*	178
Tawny eagle	*Aquila rapax*	*Accipitridae*	2
Variable wheatear	*Oenanthe picata*	*Muscicapidae*	126
White eared bulbul	*Pycnonotus leucotis*	*Pycnonotidae*	583
White eyed buzzard	*Butastur teesa*	*Accipitridae*	1
White rumped vulture	*Gyps bengalensis*	*Accipitridae*	7

Mean bird crossing rates / km / hr were estimated for each family. Most numerous family which crossed power line was *Columbidae* (mean =24.25 bird / km / hr, SE=0.37), followed by *Pycnonotidae* (mean=15.51 bird / km / hr, SE=0.27), *Alaudidae* (mean=7.04 bird/km/hr, SE=0.36), *Meropidae* (mean=4.78 bird / km / hr, SE=0.38) and *Passeridae* (mean=3.49 bird / km / hr, SE=0.45) (fig. 11).

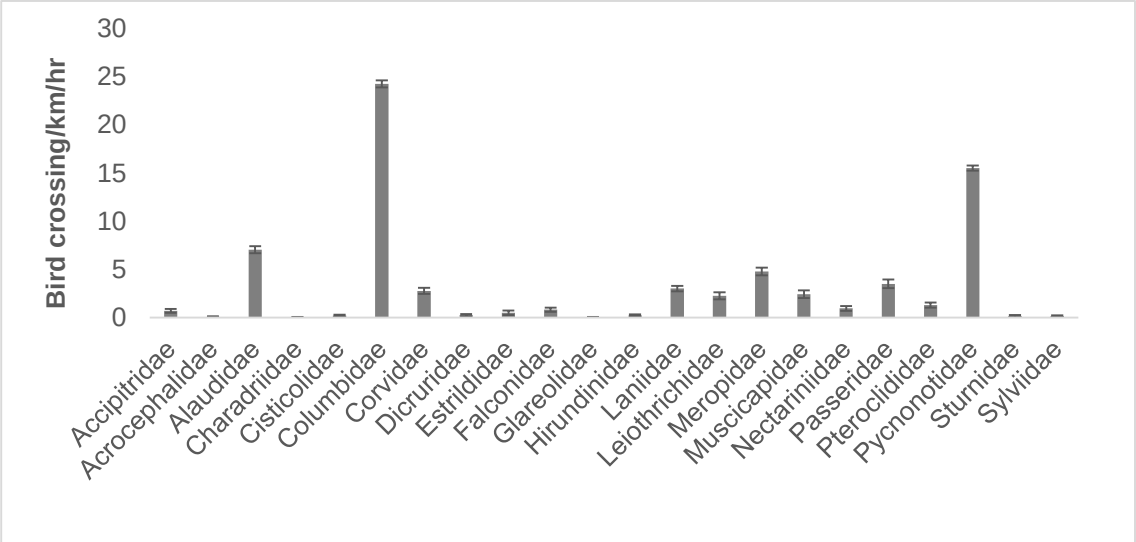


Figure 11. Mean and standard error of power line crossing rates (number / km / hour) across taxonomic families in Thar landscape in February - May 2017.

4.8 Does crossing rate (i.e., availability of birds) depend on size?

Power line crossing rate was higher for small birds (mean=60.70 crossing / km / hr, SE=3.75) followed by medium (mean=33.83 crossing / km / hr, SE=2.56) and large birds (mean=2.51 bird / km / hr, SE=0.45), indicating that small birds were more numerous/available (fig 12).

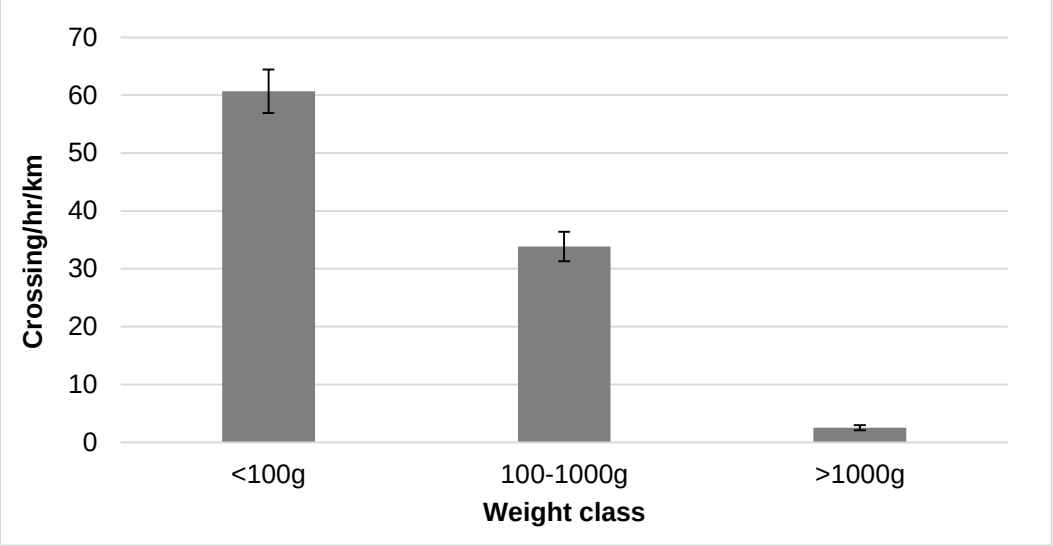


Figure 12. Mean and standard error of power line crossing rate (birds / km / hr) for small (<100 g), medium (100-1000 g) and large (>1000 g) birds in Thar landscape during February - May2017.

4.9 Does crossing rate (i.e., availability of birds) depend on season?

Power line crossing rate was higher in winter (mean=178.52 crossing / km / hr, CI=95%) than summer (mean=78.14 crossing / /km / hr, CI=95%), indicating that birds were more numerous/available in winter the peak migratory season (fig. 13).

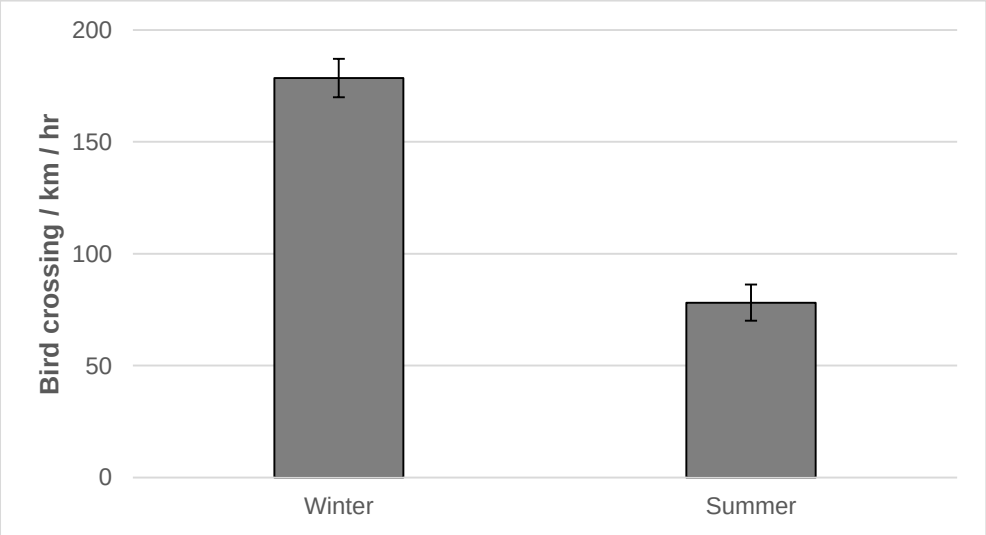


Figure 13. Mean and standard error of power line bird crossing / km / hr for winter and summer season in Thar landscape in 2017.

4.10 Does vulnerability to power line collision differ between taxa?

Based on collision rate relative to crossing rate, five bird families were identified to be more prone to power line mortality (*Ploceidae, Anatidae, charadriidae, gruidae, acrocephalidae*), whereas, 11 families were found to be less prone to power line mortality (*alaudidae, corvidae, falconidae, laniidae, leiothrichidae, meropidae, muscicapidae, nectariniidae, passeridae, pteroclididae*) (fig. 14). However, vulnerability to power line mortality did not depend on bird weight class (fig 15).

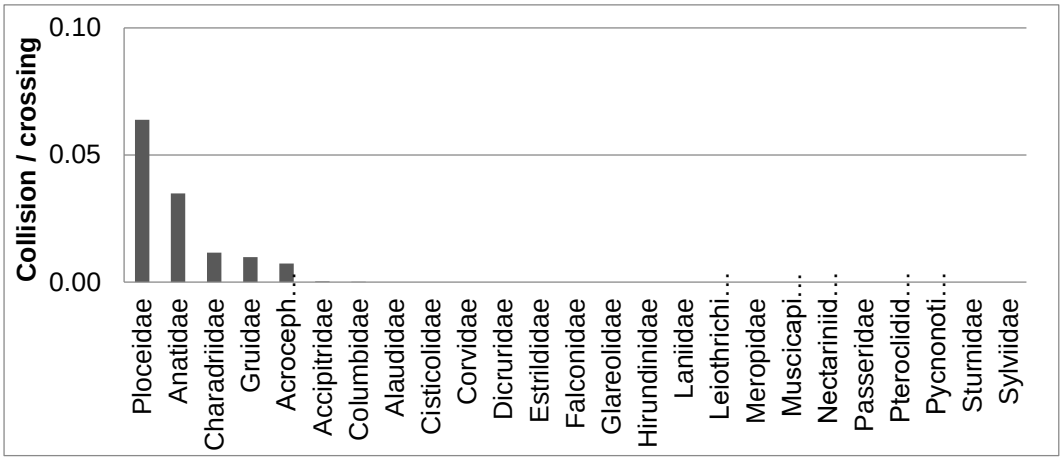


Figure 14. Ratio of collision to crossing rates at power lines for various bird families in Thar landscape during February - May 2017

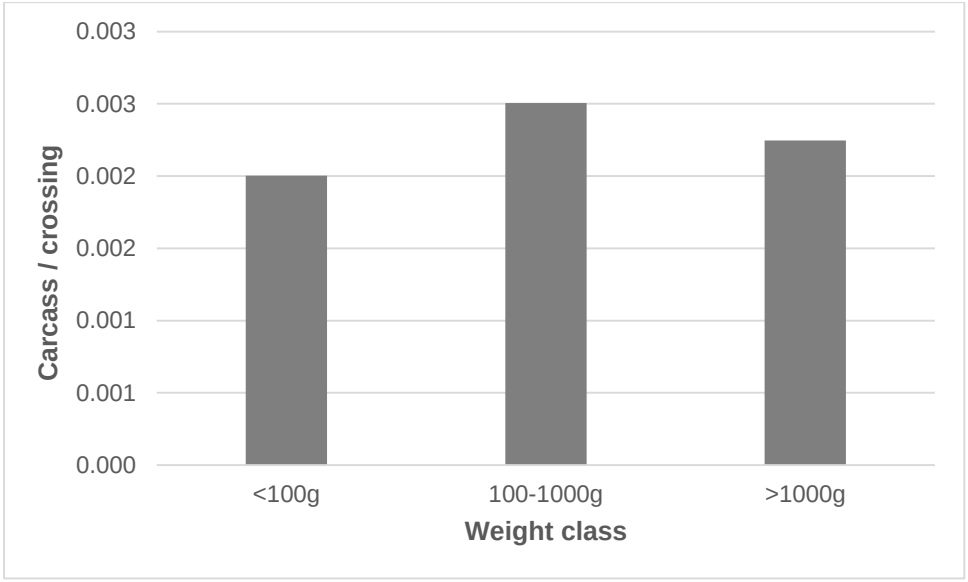


Figure 15. Ratio of collision to crossing rates at power lines for various bird size classes in Thar landscape during February - May 2017.



Figure 16. Carcass of great Indian bustard found during power line surveys in Thar landscape in May 2017.



Figure 17. Carcass of blyth's reed warbler found in power line surveys (with high-tension power line) in Thar landscape during January-April 2017.



Figure 18. Carcass of baya weaver found in power line surveys (with the mark of collision on forehead) in Thar landscape during January-April 2017.



Figure 19. Cream coloured courser with mark of collision with wire found in power line collision survey in Thar landscape during January-April 2017.



Figure 20. Field activities of power line survey in Thar during January-April 2017.

5. DISCUSSION

Power line mortality is an important and increasing concern for bird conservation worldwide (Bevanger, 1998).Studies on bird collision/electrocution have been carried out in several countries in recent past, but such information are largely lacking from India. My study attempts to fill this information gap as power line networks are expanding in remote landscapes of India, which are also prime wildlife habitats, to meet basic needs of rural populace. Conducted in Thar Desert, a landscape of high avian diversity (Rahmani & Soni, 1997), this study finds particular importance in the conservation context of the critically endangered great Indian bustard *Ardeotis nigriceps*. I found a power line mortality of great Indian bustard in the fourth survey, which couldn't be completed within my dissertation tenure, and results were not included in this thesis. However, one casualty of great Indian bustardin100 km survey within 4 months is considerable given that < 200 individuals of the species survive, 75% of it in Thar Desert, and indicates the severity of power line collision/electrocution to this declining population (Dutta et al 2016). Besides great Indian bustard, I found that power lines were affecting several other species, inclusive of threatened birds.

I estimated the number of birds dying from power lines in my study area by extrapolating monthly carcass encounter rate, corrected for detection and persistence biases, to the length of power lines. Results indicated that ~18,000 birds probably succumb to power line collision/electrocution per month in this important conservation area. This figure mostly comprised of small birds followed by medium and large birds.

Egyptian vulture (Endangered, IUCN 2017) and common pigeon (Least Concern, IUCN 2017) represent 7.21 % each of the total bird fatalities followed by Eurasian griffon vulture (Least Concern, IUCN 2017) (6.18 %), demoiselle crane (Least Concern, IUCN 2017) and cream coloured courser (Least Concern, IUCN 2017) (4.21%). This indicates that power lines affect a wide variety of species from small to large birds.

I hypothesized that power lines are a substantial additive cause of bird mortality, and as expected, I found significantly higher carcass encounter rate under power lines compared to natural environment. High mortality rate in power lines and no record of mortality in natural environment shows the dominant role of power line collisions in reducing bird numbers and diversity.

As hypothesized, bird crossing rate reduced with number of wires (high crossing rate in low-tension), indicating that high tension lines or multiple strata of power lines act as barrier to bird movements. Despite higher crossing rates across low-tension power lines, carcass encounter rate was similar between low- and high-tension power lines. This implies that more birds die per crossing at high-tension lines. Thus, high-tension lines or areas with multiple strata of power lines are doubly dangerous to birds, by creating a movement barrier and increasing mortality chances.

I hypothesized that mortality rate will vary between seasons due to difference in bird numbers. Expectedly, I found significantly higher bird crossing and carcass encounter rates in winter - the peak migration time. This affects local migrants like vultures, coursers and cranes as well as long-distance migrants like common teal.

I hypothesized that mortality rate will be high in heterogeneous habitat due to more bird richness/abundance. My result indicated a weak and imprecise positive effect of habitat heterogeneity on bird mortality. This could be because the scale at which we measured habitat heterogeneity (100m plots) was smaller compared to the scale at which habitat heterogeneity affects bird numbers, and thereby mortality rates.

As hypothesized, crossing rate of small birds at power lines was higher than that of large birds. This is because small birds are naturally more abundant following the energy equivalence hypothesis that leads to a negative relationship between species' mass and abundance in nature (Nee Sean, Read Andrew F., 1991). Small birds also use power line structures for perching / food searching more frequently than large birds (personal observations).

I hypothesized that bird families will differ in their vulnerability to power line collision which may be because of their weight differences, as heavy flyers might be more prone to collision (Jeremy M. V. Rayner 1988), or other biological attributes such as low frontal vision of some birds (Janss, 2000). My results did not show any effect of bird biomass on vulnerability. However, there was large variation between families in terms of collision vulnerability, which indicates that biological attributes related to flight such as frontal vision, flight height and wing load, and not mass, are critical.

5.1 Methodological issues

This study covered a period of 4 months; however, to come up with more authentic results at least one full year cycle is required since bird activity differ considerably between seasons. Sampled area also needs to be extended across the Thar landscape to cover spatial variability in bird usage and to identify extremely affected areas in terms of power line collisions. Carcass counts at power lines underestimate the number of bird casualties, the bias being higher for smaller birds. In this study, mortality estimates are corrected for detection and persistence biases based on experiments. However, detection probability obtained from fresh carcasses, as in this study, might be an overestimate since fresh carcasses are easier to detect and might not represent carcasses in various conditions that are detected during actual power line surveys. To come up with more reliable estimate, equal proportion of fresh and old carcasses should be used in the detectability experiments.

5.2 Management recommendations

Risk of power line collision to birds is very high in Thar landscape as power lines are spread in and around the preferable habitat, particularly in the prime habitat of Great Indian Bustard outside of Desert National Park. Due to the big size and low frontal vision, bustard are more prone to collision with power line. My results show alarming rate of collisions in the study area, inclusive of species that are endangered or vulnerable. Thus, efforts to reduce such mortality will have substantial conservation value. Though energy is essential for human community, there is an urgent need to mitigate energy operations so as to fulfil human needs without harming birds. The use of bird-friendly structures is needed. In terms of mitigation, I recommend that all existing overhead power lines in priority great Indian bustard habitats should be marked with bird diverters. New power lines in and around prime habitat of great Indian bustard should be undergrounded. A long term monitoring programme of sample power lines in Thar and other important areas should be implemented in order to gain crucial information on collision rates. Effectiveness of bird diverters need to be assessed by comparing crossing and collision rates before and after marking (BACI design) following (Alonso, 2016). Simultaneously, priority habitats should be identified through research and safeguarded from power line operations. Power line companies need to be sensitized to avoid such areas while planning power line routes. Thus, a combination of research, action, outreach and policy is urgently needed to mitigate the crisis of power line mortality of birds.



Figure 21. Carcasses of common pigeon (left) and Egyptian vulture (juvenile & adult, right) found in power line survey in Thar landscape during January-April 2017.



Figure 22. Carcasses of Eurasian collared dove, spotted owlet and short-toed snake eagle (from right to left) found in power line survey in Thar landscape during January-April 2017.



Figure 23. Images showing use of mobile hide in bird crossing observations in Thar landscape during February-May 2017.



Figure 24. Birds using power line structures in Thar landscape during January-April 2017 (long-legged buzzard & Eurasian collared dove, upper) (short-toed snake eagle & laggar falcons, lower right to left)



Figure 25. Cinereous vulture soaring through high-tension power line in Thar landscape during January-April 2017.

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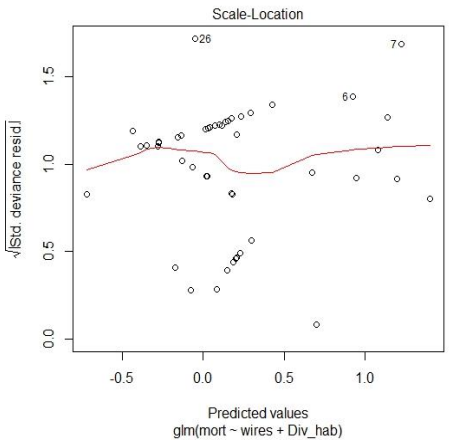
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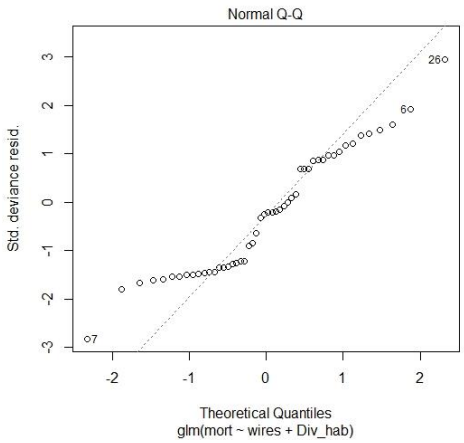
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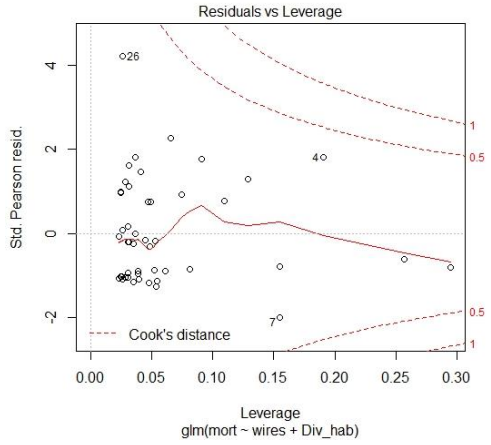
Appendix 1. Diagnosis of best-fit Generalised Linear Model examining the effects of habitat heterogeneity and number of wires on bird mortality due to power line collisions in Thar landscape during January - April 2017.(a) scale-location plot, (b) normal quantile–quantile plot, (c) residuals vs. leverage plot, and (d) residual vs. fitted plot fitted vs. observed response plot (columns)

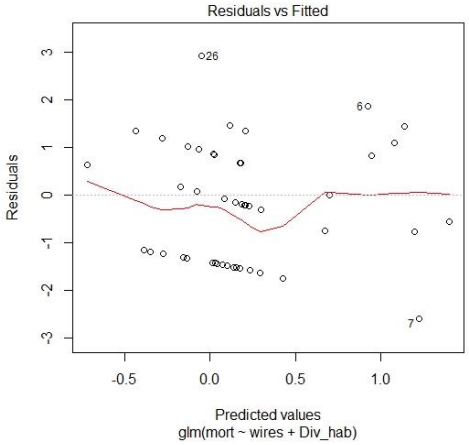
a) b)





c) d)





"EFFECT OF LIVESTOCK GRAZING ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL IN THE ARID THAR ECOSYSTEM"

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By

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M.Sc. 4th Semester: 2017

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Certificate

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This is to certify that **Ms. Pratima Kumari,** School of Environmental & Natural Resources has completed her dissertation entitled **"study on the effect of livestock grazing on physical and chemical properties of soil in the arid Thar ecosystem"** in partial fulfilment for the award of the Degree of Master of Science in Environmental Science (Environmental Studies) under my supervision.

I also certify that:

1. The dissertation compiles original piece of work carried out by her during IV semester, 2017.
2. The work is neither published nor submitted to any other University/Institution in India for award of any Degree or Diploma.

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CANDIDATE'S DECLARATION

I hereby declare that the study entitled ***"EFFECT OF LIVESTOCK GRAZING ON PHYSICAL AND CHEMICALS PROPERTIES OF SOIL IN THE ARID ECOSYSTEM OF THAR, RAJASTHAN"*** being submitted by me in the partial fulfilment of the requirement for the award of ***MASTER OF ENVIRONMENTAL SCIENCE by DOON UNIVERSITY, DEHRADUN*** is an authentic record of my own work carried out during a period from Feb 2017- June 2017 under the supervision of ***Dr. Surendra Singh Suthar (Supervisor), Dr. Sutirtha Dutta and Mr. Vineet Singh (Co-supervisors).***

I declare that all the information and facts furnished in this project report are based on my intensive findings.

Dated **(PRATIMA KUMARI)**

M.Sc. EVS 4th SEM

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EXECUTIVE SUMMARY

Soil is one of the most important factors affecting production potential and utilization of rangelands (Schuma et al., 2002). Rangeland ecosystem processes are largely influenced by livestock grazing, the assessment of which is generally based on soil and vegetation conditions. Livestock grazing affects grassland dynamics, changing the species colonisation and extinction relationships via consumption, mechanical disturbance, seed dispersal and altered soil fertility due to dung-borne nutrient input. Fragile arid ecosystem of India support high livestock density, of in beyond carrying capacity, and the effect of livestock grazing on soil properties of these arid ecosystems are poorly known. To access the effects of livestock grazing on soil properties of an important conservation landscape, Thar Desert, soil sampling was carried out in different enclosures (***Gajai Mata, Rashtriya Krishi Vikas Yojana and Sudasari***) and surroundings in March 2017. Soil samples were collected from enclosures which are relatively free of grazing and agriculture and their surroundings that experience livestock grazing and agriculture. Soil samples were taken at the depths of 0-15 cm using the systematic sampling method and were collected in zip poly bags. All samples were then transferred to the laboratory to estimate soil parameters such as Electrical conductivity, pH, Soil Organic Matter, Total Nitrogen, Potassium, Sodium, Bulk density, Soil Porosity, moisture content, and basal soil respiration.

Bulk density was higher and porosity and moisture content were lower in enclosures compared to surroundings. Whereas, the difference in basal soil respiration and sodium between enclosure and their surrounding was not consistent across enclosures. Sodium and pH were higher in Gajai Mata compared to other enclosures. Whereas, electrical conductivity, moisture content, and bulk density were higher and porosity was lower in Sudasari enclosure. However, total nitrogen, total organic carbon and C:N ratio did not differ between enclosures and their surroundings or even between enclosures. Sudasari being the oldest enclosure has recovered from agro pastoral exclusion/regulation which is evident in more compaction of soil, whereas soil is less compact because of trampling induced erosion and ploughing in surrounding areas and new enclosures.

In general, it can be said that livestock grazing and seasonal agricultural practices significantly affects the soil properties. To manage a rangeland ecosystem, these changes should be identified to avoid unwanted and harmful ecosystem changes.

Key Words: Enclosures, seasonal agricultural practice, livestock grazing, C:N ratio, soil properties, soil compaction, arid ecosystem, Thar landscape.

CHAPTER - *1*
INTRODUCTION

Livestock grazing is essential for the management and growth of many important wildlife habitats (Krausman et al., 2009). Grassland, shrub land all require some grazing to maintain the structure and composition upon which a variety of plants and animals depend for their survival. Livestock grazing plays a key role in maintaining species-rich habitats by controlling more aggressive species which would otherwise dominate these areas and by preventing scrub encroachment (Browning and Archer, 2011). The selection of certain plant species in preference to others by livestock is an important factor determining the structure and floristic composition of the vegetation of various habitats (Hendricks et al., 2005). Livestock grazing removes plant material more gradually than cutting or burning and gives mobile species a better chance to move to other areas within the habitat (Boakye et al., 2013).

The presence of herbivores in a natural ecosystem can determine various properties including soil compaction (Soil compaction is the process of increasing dry bulk density of soil, reducing the pore space by expulsion of air through applied pressure on a soil body), break-down and decrease in aggregate stability, reduction in the amount of available moisture, change in soil and vegetation type and finally the physical and chemical characteristics of the soil (Nawaz et al., 2013). Most changes, especially changes in a soil's physical properties, are a result of soil compaction or density increase caused by trampling (Mulholland and Fullen, 1991). During compaction, soil particles become closer together, undergoing a reduction in porosity and an increase in density (Nawaz et al., 2013). This causes reduction in the amount of water penetration in the soil, thus decreasing its moisture content. With increasing grazing intensity, acidity and calcium carbonate may increase, whilst the amount of organic matter and electrical conductivity will significantly decrease.

Quantitative assessments of the effects of livestock grazing on ecosystem and soil over a broad range of environments may provide a basis for evaluating and modifying theoretical models, provide insight and perspective into the results of empirical studies, and be rephrase for global changes in land use and climate (Milchunas and Lauenroth, 1993).

Agriculture alters the natural cycling of nutrients in soil. Intensive cultivation and harvesting of crops for human or animal consumption can rephrase (Batey, 2009). Pastoralism on communal areas is the livelihood activity across most of the Thar Desert (Singhvi and Kar, 2004). The grazing land available is, however, shrinking as more is sold to private owners. This leads to increase in grazing intensity as more livestock are dependent on smaller pastures that causes detrimental changes in soil properties, at least in the short term, and longer-term changes in the balance between shrubs and grasses.

Over the past thirty years, the Indian Thar has witnessed one of the fastest demographic growths in the country. This landscape is thickly populated in comparison to other hot deserts of the world. 17.44 million People and 23.33 million livestock are recorded from the region (Singhvi and Kar, 2004). These populations exert pressure on the biological resources of the Thar Desert causing a lack of sustainability and necessitate conservation of biodiversity actions. . Thar is a home to the critically endangered wild species Great Indian Bustard *(Ardeotisnigriceps),* Desert Cat *(Felissilvestris)* and populations of these wild fauna have been declining within the Thar Desert over the last few decades due to destruction of habitats, indiscriminate hunting, and increase feral dog, human and livestock population in their habitats and the transformation of desert grassland into agriculture fields under irrigation schemes of Rajeev Ghandhi Canal, drilling for gas and petroleum, mining, stone quarrying, growth of industries, and power projects along with the expansion of roads, putting up electric poles, wind turbines and many remaining grasslands are subjected to high grazing pressure from domestic livestock and intensive harvesting by local communities consequently the Rajasthan's state bird Great Indian Bustard (GIB) has become enormously rare now. Animal and plants species of economic or conservation value have become either threatened or endangered (*Commiphora wightii* and *Tecomella undulata*). Other endemic species have ecological requirements and need to multiply, and be conserved (Dutta et al., 2011).

The study related activities would be taken up in the Gajai Mata, Sudasari, and Rashtriya Krishi Vikas Yojana (RKVY) enclosures and their surroundings. The detailed characteristics of these sites are given below:

Sudasari: Sudasari enclosure was established in 1980-1991. Its maintenance started around in the year of 2013-2015. It spread over an area of 15.2 sq. km. It is 40 km south-west to Jaisalmer and lies at 26°43'10.29" N latitude and 70°35'43.58" E longitudes (Awasthi, 2002).

The habitat is plain ground which is cover with 65% *Lasiurus sindicus* (Sewan grass) and bushes out of which 16% is less than 25cm grasses, 30% of grasses are of 25-50cm height and 12.5% are of 50-100cm. It is a core area that surrounded by wire fencing and divided into six blocks. Agricultural and grazing activities are prohibited in this area. It is one of the oldest enclosure in Thar Desert. It is an ideal habitat for the state bird (GIB) of Rajasthan. It has 7 Guzzlers to provide water to wild animals. Most of the study site area is supported by a grass, *Lasiurus sindicus* and remaining area is occupied by other vegetation like *Caparis decidua, Prosopis cineraria, Salvadorapersica, Calotropisprocera, Ziziphusnummularia, Leptadeniapyrotechnica, Lyciumbarbarum*. GIB (*Ardeotisnigriceps*) along with Desert Cat (*Felissilvestris*), Desert Fox, Indian Fox, Chinkara *(Gazellabennetti)*, Desert Hare *(Lepus tibetanus)* and Nilgai (*Boselaphus tragocamelus*) were noticed from this site (Gehlot , 2016).

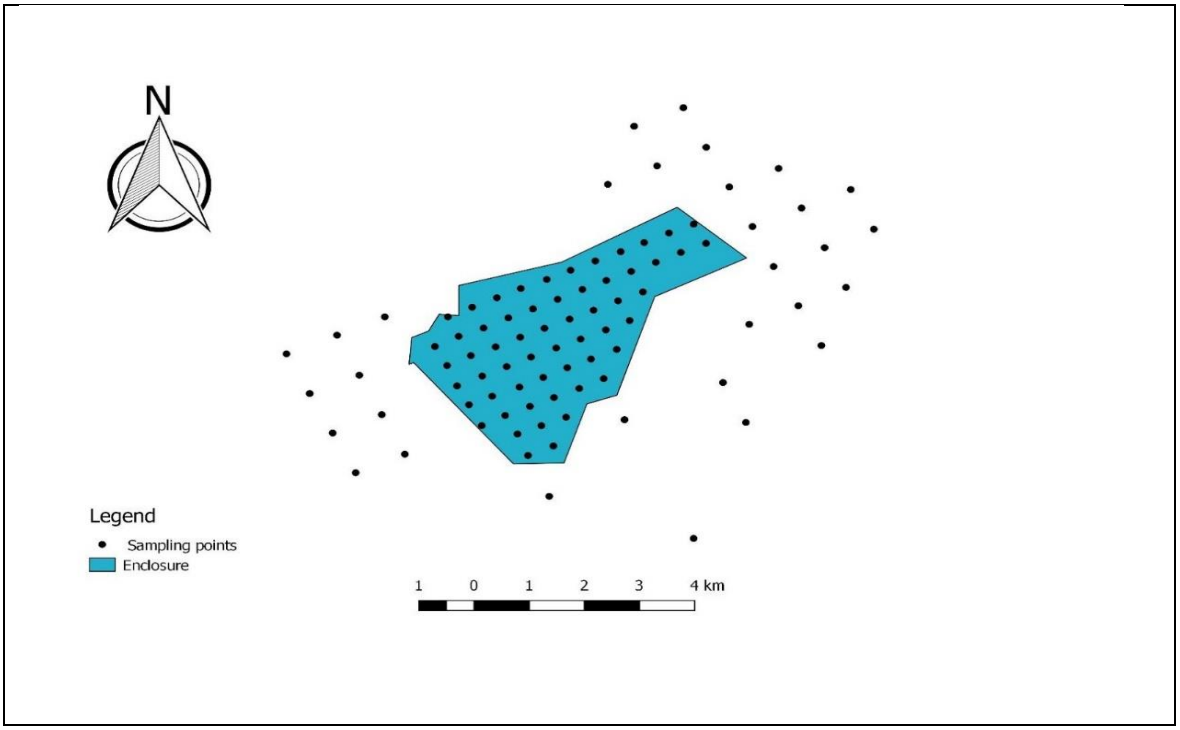


Figure 1: Map showing the soil sampling points in Sudasari Enclosure and in its surrounding by systematic sampling design with one sample per 500m inside enclosure and one sample per 1km outside enclosure.

Gajai Mata- It was established in 2015-2016. It is spread over an area of 4.7 sq. km (450ha). It lies at 26°39’ N latitude and 70°35' E longitudes. It has 1 guzzler to provide water to wild animals. This study area is dominantly covered by *Lasiurus sindicus* and *Dactyloctenium aegyptium* grasses. Since this is the new enclosure of Thar Desert so Agricultural and grazing activities are prohibited in this area.

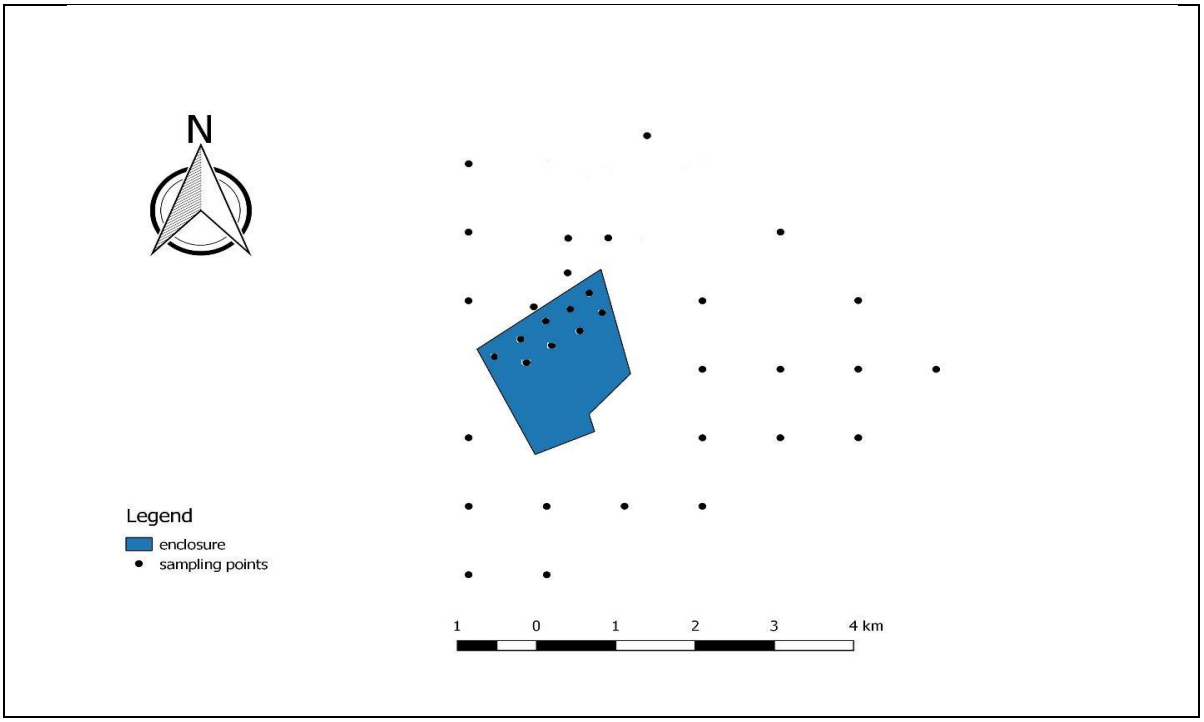


Figure2: Map showing the soil sampling points in Gajai Mata Enclosure and its surrounding by systematic sampling design with one sample per 500m inside enclosure and one sample per 1km outside enclosure.

RKVY- It was also established in 2009-2016 and it covers 14.7 sq.km (1500ha) of total land cover of Thar Desert. Ganthiya, sewan (*Lasiurus sindicus*), Dhamasa grasses are mainly found in this enclosure. It lies at 26°45' N latitude and 70°35' E longitudes.

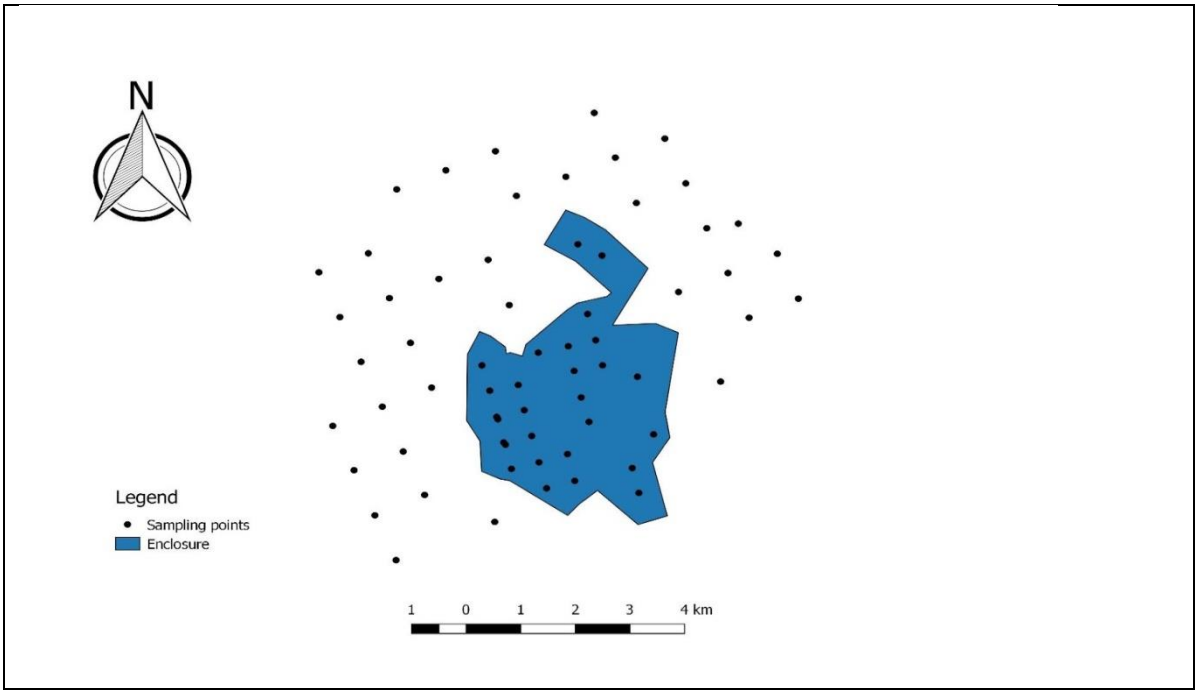


Figure3: Map showing the soil sampling points in RKVY Enclosure and its surrounding by systematic sampling design with one sample per 500m inside enclosure and one sample per 1km outside enclosure.

In the arid Thar Desert, very limited quantitative research has been carried out as to the effects of livestock grazing on soil properties, despite the fact that livestock grazing has been regarded as an important cause of desertification (Jeddi, Chaieb, 2010). In light of these issues, my study aims at the effect of livestock grazing on soil properties of Thar ecosystem.

My Objectives are as follows:

1. Use of quantitative techniques to compare the impacts of grazing on physical and chemical properties of soil and plant communities in relation to various grazing, abiotic, and ecosystem variables following grazing exclusion as compared with the adjacent grazed area.

   My research hypothesis is,

   - There is a significant difference in soil variables of enclosures and surroundings which is because of agro-pastoral practices in surrounding areas.
   - Livestock grazing significantly affects the carbon contents, nitrogen contents, and moisture content of enclosure and surroundings.

Owing to the importance and necessity of identifying soil properties in arid rangeland management, and the variable effects of different kinds of herbivores on soil, this study compares some of the physical and chemical properties of soil between enclosures and surroundings experiencing livestock grazing in the desert rangelands of Thar in Rajasthan.

CHAPTER - 2
REVIEW OF LITERATURE

Grazing effects soil properties directly and indirectly. Direct effects relate to animal trampling and excretion, while indirect effects are mediated by changes in vegetation structure and function (**Taboada et al. 2011**). The effect of livestock grazing on biodiversity is a contentious conservation issue with studies showing positive as well as negative effects of grazing on plant and animal richness and abundance. Unregulated livestock grazing can alter soil properties by increasing soil compaction, reducing water retention capacity, and reducing organic contents that can negatively impact vegetation growth and species richness.

Milchunas and Lauenroth (1993) studied the quantitative effects of grazing on vegetation and soils over a global range of environments in which multiple regression analyses were performed on a worldwide 236-site data set compiled from studies that compared species composition, aboveground net primary production (ANPP), root biomass, and soil nutrients of grazed vs. protected, un-grazed sites. The objective was to quantitatively assess factors relating to differential sensitivities of ecosystems to grazing by large herbivores. Results showed that Percentage differences in ANPP between grazed and un-grazed sites decreased with increasingly long evolutionary histories of grazing and increased with increasing ANPP, levels of consumption, or years of treatment. Although most effects of grazing on ANPP were negative, some were not, and the statistical models predicted increases in ANPP with grazing under conditions of long evolutionary history, low consumption, few years of treatment, and low ANPP for grasslands-plus-shrublands. The data and the models support the controversial hypothesis that grazing can increase ANPP in some situations. Similar to species variables, percentage differences in ANPP between grazed and un-grazed treatments were more sensitive to varying ecosystem-environmental variables than to varying grazing variables. Within levels not considered to be abusive "overgrazing," the geographical location where grazing occurs may be more important than how many animals are grazed or how intensively an area is grazed.

Lavado et al. (1996) carried out a study on a grassland of the Flooding Pampa (Argentina) to analyse the effect of grazing on the status and spatial variability of soil organic matter, nitrogen and phosphorus. Geostatistical methods were used to study the spatial dependence of these soil properties. Organic carbon (OC) and total nitrogen (TN) showed spatial structure

only in the un-grazed area with a similar range of dependence (39 m and 36 m respectively). The occurrence of litter in this area lead to a large and spatially homogeneous C input to the soil, which would be the key factor of the spatial structure of organic carbon and total nitrogen. Mineral nitrogen content [(NO3-)-N + (NHd+)-N] was higher in the ungrazed area on both sampling dates. The mineral N content showed a large short-range variahility (nugget variation) independent of grazing history. A significant decrease in the extractable P (Bray & Kurtz #l) in the grazed area was found. The extractable P exhibited spatial structure only in the ungrazed area. However, its spatial pattern was different from those of organic carbon and total nitrogen: the range of dependence was higher (57 m) and the spatial structure exhibited a great irregularity. The differences between C, N, and P variability were possibly related to their dynamics in the soil. No evidence of effects of animal excreta on nutrient content or spatial variability was found.

Hiernaux et al. (1998) determined the effects of grazing by livestock on soil surface. Four year grazing experiment was carried out in Sadore H, Niger. Grazing treatments were a factorial arrangement of two stocking rates (62·5 and 125 kg live weight ha~1) and four sheep: goat ratios (0:6, 2:4, 4:2 and 6:0 animals per pasture), with two pastures per treatment and two un-grazed controls. Observations were also made in a fallow subjected to 9 ye

ars of intense and uncontrolled mixed grazing, and in a site that had been protected from grazing for 15 years. Result showed that the soil infiltration index slightly increased with moderate grazing, but decreased at higher stocking rates. Compaction due to trampling was observed in the topsoil beneath the shrub canopy and also in vegetated patches, but only under intense grazing pressure. Soil bulk density was not affected by grazing except for an increase observed below 10 cm depth at the understorey of shrubs which is therefore unlikely due to trampling. When compared to the un-grazed control, pH, organic C and N concentrations, and to lesser extent P concentration, decreased after 4 years of grazing. Soil P and pH further decreased after 9 years of very high grazing pressure. However, neither N nor organic C decreased further.

Peco et al. (2006) analysed changes to floristic composition, species richness and heterogeneity as well as soil and light resources in relation to grazing abandonment in two characteristic topography-related types of dehesa habitat (upper slope and lower slope grasslands). The results showed an effect of grazing on resource availability. In general there was a smaller proportion of fine matter (clay), organic matter, total nitrogen, assimilable

potassium and readily available water in abandoned as opposed to grazed zones. Whereas, did not find any effect of grazing on phosphorous availability. Abandonment reduces light availability at ground level in lower slope grasslands (wet meadows) but does not produce a significant reduction in upper slope (driest) grasslands, although there is an increased spatial heterogeneity in the availability of light associated with the presence of scattered shrubs. While the total number of species in abandoned zones did not significantly differ from grazed zones, floristic composition changed dramatically with abandonment in both habitat types, with less than 50% of common species. Also, floristic heterogeneity at the small scale increased with abandonment.

Pei et al. (2007) studied soil properties and plant characteristics in a typical degraded area in desert steppe of Alxa. Focused on the effects of grazing on soil properties and vegetation changes under three management regimes: continuous year-long livestock grazing (FG), grazing excluded for 2 years (2EX) and grazing excluded for 6 years (6EX). Results showed that exclosure enhanced soil organic carbon (SOC) and total N accumulation, and decreased pH and bulk density. Soil organic carbon and total N in the 0–20 cm soil increased significantly with exclosure period, with 22% higher SOC, and 14% higher N in 6EX as compared with FG. Data indicated a considerable difference in soil particle size distribution between the exclosure and grazed area, and soil coarse sand fraction (>0.25 mm) in the grazed area was 16–26% higher than that in the exclosure. Plant cover was ranked according to 6EX > 2EX > FG, with a high of 46% (6EX) to a low of 31% (FG). Plant biomass was similarly ranked and vegetation diversity increased with increasing exclosure period.

Stavi et al. (2008) examined the soil properties associated with flock trampling routes and rock fragment clusters, as well as those associated with the remainder of the intershrub area and shrub patches in the northern Negev region of Israel. Moisture content, organic carbon content, bulk density and calcium carbonate content of the soil were determined inside and outside long-term grazing exclosures. Results showed that Grazing did not have a significant effect on soil properties at the whole-plot scale, but there were highly significant interactions between grazing and type of cover. Compared with the former trampling routes in the exclosures, the active trampling routes outside them had higher bulk density and lower moisture and organic carbon contents. The intershrub area had higher moisture and organic carbon contents under grazing than in the exclosures. Grazing increased the spatial

heterogeneity of the soil properties examined via the creation of a network of trampling routes on the hillsides.

Eldridge and Whitford (2009) suggested that Domestic grazing animals that congregate around watering points in arid rangelands create clearly-defined trampling-induced grazing gradients. Grazing and trampling alter soil and vegetation condition, often leading to substantial reductions in ecological function

Al-Seekh et al. (2009) investigated the effect of excluding grazing on soil properties and soil moisture content after many years of severe overgrazing for two sites (Sorif and BaniNoem). The sites represent two different environmental conditions in the southern part of West Bank. The ungrazed pastures showed low bulk density (3 % and 12 %) in BaniNoem during 2004 and 2005, respectively. In addition, significantly higher O.M % in grazed area (2.89, 3.31) compared to ungrazed areas (1.86, 2.42) in BaniNoem during 2004 and 2005 study years, respectively, and there was inconstancy of EC, P, and available nitrogen (NO3- and NH4+) between grazed and ungrazed plots. Soil moisture significantly increased by excluding grazing during 2004 and 2005 at Sorif site and during 2005 at BaniNoeim site. In addition, the results showed ($P< 0.05$) higher soil moisture content (23 % and 33 %) at Sorif site compared to (10 % and 23 %) BaniNoem site in April of 2004 and 2005, respectively.

Lin et al., (2010) studied how grazing intensity affected the spatial patterns of vegetation and soil fertility at scales ranging from 0.1 to 18.7 m in a desert steppe in Inner Mongolia, China. Increasing grazing intensity decreased the range of spatial autocorrelation of plant aboveground biomass at the fine scale (<2 m), indicating that vegetation patches were more fragmented under higher grazing pressure. Spatial heterogeneity of soil water content and organic C concentration decreased along the gradient of increasing grazing intensity at the fine scale. Light grazing increased soil NH_4^+ availability and its overall variability. Soil NO_3^- only had significant cross-correlation with aboveground biomass in un-grazed plots at the fine scale, suggesting that the spatial correlation between plant and soil fertility was affected by grazing. Spatial patterns of studied variables did not respond to grazing intensities at a coarse scale (1–18 m). Our results demonstrated that the grazing intensity altered fine scale processes in this desert steppe and caused divergent responses of spatial distribution of vegetation and soil fertility.

Taboada et al. (2011) studied the Grazing Impacts on Soil Physical, Chemical, and Ecological Properties in Forage Production Systems and concluded that Grazing changes soil physical properties by defoliation and treading. Defoliation decreases ground cover, which increases topsoil temperature and evaporation rates, and causes salinization in salt-affected areas. Animal treading often results in shallow compaction when soil is trampled moist, and causes paddling when soil is trampled wet. Structural damage by grazing can be restored by natural regenerative processes, which may take many years in dry climates. Faster responses are possible in temperate climates, because of the action of frequent wetting and drying cycles, freezing and thawing cycles, and vigorous pasture root growth. Grazing alters litter decomposition and the functioning of the soil microbial community, and these effects are to a large extent mediated by plant community turnover. Several lines of evidence suggest that grazing effects on soil carbon and nutrient cycling may vary predictably along habitat moisture/ fertility gradients. The partitioning of nutrients between dung and urine differs among nutrients and grazing systems. Nitrogen is excreted in a rather equivalent proportion in dung and urine, whereas most P returns to soil in dung paths. Grazing alters N and P cycling by accelerating returns via animal depositions, and by increasing N outputs through volatilization and leaching. Rotational grazing is an effective practice to increase forage utilization efficiency and reduce the fraction of dung and urine deposited on the soil, thus reducing field heterogeneity. However, rotational grazing has less clear consequences on the recovery of soil physical properties and carbon stocks. Soil protection by vegetation is most important in semiarid and desert grasslands, where decreased infiltration rates by grazing are closely associated with bare ground areas. This objective can be attained by excluding grazing for several years (rest periods). However, restoration of soil organic matter in degraded arid rangelands would take exceedingly long (and economically unsustainable) periods of livestock exclusion.

Zarekia et al. (2012) studied short-term effects of grazing management on some of the physical and chemical characteristics of soil in steppe rangelands of Saveh (Markazi Province of Iran) in which features such as phosphorus, potassium, nitrogen, organic carbon, electrical conductivity, acidity and soil bulk density have been studied within two projects of range management; the Nemati rangeland with a rest-rotation grazing system for 10 years (moderate grazing intensity) and the Shirali rangeland with continuous grazing during the year (severe grazing intensity). Studies showed that elements such as phosphorus and potassium in the Shirali rangeland are more than the other two regions. However, nitrogen and organic carbon,

pH and soil bulk density were not significantly different in these three areas. The results indicate that enclosure and rest-rotation grazing system with moderate grazing intensity leads to small changes in some of the physical and chemical characteristics of soil. Therefore, the effect of management on soil properties requires a longer time in the steppe rangelands.

Jafaria et al. (2014) compared some of the physical and chemical properties of soil between two regions experiencing livestock and wildlife grazing in the desert rangelands of Kalmand-Bahadoran in Yazd province. The results indicated that physical properties of the soil such as clay and moisture percentage showed no significant differences. Bulk density in the region of livestock grazing revealed a highly significant increase compared to the area under wildlife grazing ($P<0.01$). Calcium carbonate, acidity and electrical conductivity parameters also saw a significant increase from 18.33%, 8.47% and 1.46% in the region with livestock grazing to 14.91%, 8.36% and 1.35% on the wildlife grazing site respectively ($P<0.01$). In terms of organic matters there was no significant difference between the two study sites. Overall, changes in soil properties have occurred as a result of wildlife grazing from halophyte and shrub species and from less grazing pressure at the site.

Fayez & Riahi (2014) investigated that soil carbon (c) storage and quality in rangeland ecosystems mar change as a result of long term heavy grazing, especially in upland arid and semi-arid rangelands characterised by low soil organic C contents. The impact of grazing exclosure on soil carbon stock and mineralisation, microbial biomass carbon and the activities of invertase and alkaline phosphatase involved in C and P cycling as soil ecological indicators were studied in woody and non-woody rangeland ecosystems of two sites (Sabzkouh with woody cover and Boroujen with non-woody cover) located in Zagros Mountains, Central Iran. Results demonstrated that soil organic carbon and Nitrogen contents, and C:N ratios were not affected by grazing regime Boroujen, while un-grazed rangelands had higher C(17%) and N (19%) contents compared with heavily grazed rangelands at Sabzkouh. Grazing exclosure increased soli C mineralisation (44.7-73.6%) and turn over (24-64%) at both study sites. Soil invertase activity was significantly higher (1.3-2.1 times) in un-grazed than heavily grazed rangelands at both sites.

CHAPTER - 3
MATERIALS AND METHODOLOGY

3.1 STUDY AREA DESCRIPTION

3.1.1 Location

I carried out my study in Sudasari, Gajai Mata and RKVY enclosures and their surroundings which is situated in The Desert National Park (DNP) that covers an area of 3162 km² of which 1900 km² is in Jaisalmer district and remaining 1262 km² is in Barmer district of Rajasthan State (Mathur et al., 1992). The study area falls in Desert Biogeographic Zone with arid condition. It supports the highest human population among deserts that depends on agro-pastoral livelihoods. It is Located between 25°51'N to 26°52'N and 70°18'E to 70°34'E in the Thar Desert (the Great Indian Desert, forms a vast arid land, like a sea of sand, which is situated between 23°04' N to 30°11'N latitude and 69°29' E to 78°17'E longitude in the western Rajasthan) (Sinha et al., 2003). Desert National Park is situated very close to the India-Pakistan border in Rajasthan and DNP was gazetted in the year 1980 (Islam and Rahmani, 2011).

3.1.2 Climatic condition

Across the landscape of Jaisalmer, altitudes are low, ranging from 210-300m above mean sea level (Pandey et al., 2009). The Thar Desert has tropical desert climate. It is very humid with temperature ranges from 45 degrees to a maximum of 60 degrees in daylight and cools down at night in summer. In winter the days are warmer and the nights are very chilly. It is because the sand gets heated up fast in the day and cools down quickly at night (Bollasina and Niga, 2011). April, May and June are the hottest months with average maximum and minimum temperatures 41 centigrade to 24 centigrade respectively, while December, January and February are the comparatively coldest months with average maximum and minimum temperatures 28 centigrade to 9 centigrade respectively. The Aravalli Mountains are aligned parallel to the direction of the winds and do not form a serious obstacle to their course across Rajasthan (Krishnan, 1982). Thus, the climate is characterized by low rainfall with erratic distribution. Rainfall in Thar Desert varies from less than 150 mm in parts of Jaisalmer in the extreme west to 400 mm in the east towards the Aravalli. The monsoon winds which come from the Bay of Bengal loose almost all the moisture by the time they reach here. As a result this part remains dry and has no rains. It has turned this fertile land into a barren desert (Singhvi and Kar, 2004).

3.1.3 Habitat and Flora

The major part of Thar Desert is occupied either by dry open grassland or by grassland interspersed with trees and thorny bushes (Gupta 1975). The land-cover types can be classified into grasslands/savannahs, bare sand dunes, stabilized sand dunes, barren flatlands or magras, and agricultural areas (Agarwal, et al., 2015). There are few local tree species suitable for planting in the desert, which are slow growing. Therefore, exotic tree species were introduced for plantation. Many species of Eucalyptus, Acacia, Cassia and other genera from Israel, Australia, US, Russia, Zimbabwe, Chile, Peru and Sudan have been tried in Thar Desert (Rahmani and Soni, 1997). The state Forest Department has planned Acacia tortolis surrounding the whole enclosure.

The vegetation of major part of the arid region of the Thar falls under thorn forest type (Champion and Seth, 1968). Khejri *Prosopis cineraria* is commonly found, which is revered and protected by the local communities specially the '*Bishnois*' (Kaushik et al., 2003). The vegetation of DNP is quite sparse with open grassland, throny bushes, plantation and dunes as the broad habitat types. One-sixty eight plant species belonging to 48 families have been reported from this area (Pandey *et al.* 1985). Tree species *viz. Commiphora wightii,, Ammannie desertorum, Acacia spp., Dipcadi erythraem, Enneatogon, Ephedra foliata, Glossonema varians, Helitropium rariflorum, Limeum indicum,* Tecomella undulata brachystachyus *Moringa concanensis, Rhynchosia schimpari, Seddera latifolia, Sesuvium sesuvioides, Tephrosia falciformis, Tribulus rajasthanensis and Ziziphus truncate provide sustenance to the desert* fauna. Grass species also abound the region; these are dominated by: ratarda, Cenchrus ciliaris, Schima maryosus, Chesris barbata. iseolema laxum, Dicanthium annnlarum, Chryopason montanus, cynadon Dactylon, etc. (Daehler et al., 2005).

3.1.4 Fauna

Sixty species of mammals, 8 species of amphibians, 51 species of reptile are known from the Thar (Baqri and Kankane 2001). The endemic reptile species of the Thar Desert are Laungwala Toad-headed Agama *Bufoniceps laungwalansis, Sindh Awl-headed Snake Lytorhynchus paradoxus are also found* in DNP (Macey et al., 2006). Many more endemic and endangered mammal, bird and reptile species are found in DNP. Fourteen species of lizards and 7 species of snakes have been recorded from this area (Agarwal 2007). Records of important reptile species such as Indian Spiny-tailed Lizard *Uromastyx hardwickii* Dwarf Gecko *Tropiocolotes persicus euphorbiacola*, Persian Gecko *Hemidactylus*

persicus, Desert Monitor *Varanus griseus* and Saw-scaled Viper *Echis carinatus sochureki* have been established based on recent studies (Agarwal, 2009). More than 100 bird species have been listed from DNP including a good population of the Great Indian Bustard (locally called *Godawan*) (Kalra *et al.* 2006) and is a home for migrant Houbara Bustard. The important mammal species of the area includes Chinkara *Gazella bennetti*, Desert Fox *Vulpes vulpes*, Indian Fox *Vulpes bengalensis*, Desert Cat *Felis silvestris*, Hairy-footed Gerbil *Gerbillus gleadowi*, Desert hare *Lepus nigrricollis dayanus* and Long-eared hedgehog *Hemeichinus auritus* (Home and Jhala, 2009).

3.1.5 Soil and its characteristics

The terrain is dominantly sandy, with sand dunes of 10-30 m average height, interspersed with inter dune plains of different sizes covering more than 60% area (Hanley et al., 2014). The soils are dominantly sandy, with 60-90% fine sand and 2-10% of silt-clay in the topsoil. This type of soil has poor clay content and also lacks in moisture content. Desert soils are generally of brown, light brown or reddish colour. Due to the arid conditions, leaching of soil is almost absent in the desert soils and thus evaporation is quite rapid. Therefore, these soils are in general saline. Further, in some low level areas, the salt content in the desert soils is really high. In fact, it is so high that common salt is obtained by evaporating the saline water collect from such areas (Orlando et al., 2010). In Rajasthan Desert, south – west monsoon is relatively strong during summer season. These strong dust storms and winds carry fine dust and leave behind bigger sand particles. As a result, the soils in the west of the Aravalli Mountain Ranges become more and more sandy and thus are infertile (Middleton, 1986). The DNP is barren with several sand dunes and a few hills in the north-western region. The Park forms a vast sandy and undulating terrain (Picard, 1917). Desert soils are basically poor in nitrogen, which is an important nutrient required for the plantation purpose. These soils when irrigated properly produce rich crops. The soils of the arid zone actually are sandy to sandy loamy in texture. The depth and consistency vary according to the topographical features (Woche et al., 2005).

3.1.6 Human dimension

In Thar landscape, the human density is 83 inhabitants per sq. km. Thar holds a large livestock population, and extensive grazing by livestock is an important process contributing to the deterioration of desert environment (Rahmani and Soni, 1997). The human: livestock ratio is almost 1:2 in the desert districts (sharma, and mehra, 2008).

In order to protect the fauna and flora of the Thar Desert, the Government of India in the late 1970s started planning the establishment of a large sanctuary or a park of various age (time since establishment/maintenance) and size, for wildlife where human pressure could be kept to a minimum and the wildlife could be given maximum security from hunters as well as from habitat alteration (Barve et al., 2005). This management measure has created sharp contrast between intensively grazed and relatively un-vegetated areas vs. moderately (illegally) grazed and relatively vegetated areas. This situation provides an opportunity to assess how soil properties recover from grazing exclusion/regulation. The Desert Wildlife Sanctuary (popularly called Desert National Park) was the result of this planning. It is among the one of the three protected areas of the Thar Desert (Rahmani, 1997). It was notified in 1984 and it was planned to gradually upgrade it to a Park, hence its popular name Desert National Park. One of the main purposes of establishing this Park was to protect the Great Indian Bustard (*Ardeotis nigriceps)* (Rahmani, 1988). The major objective of the Park is to develop core areas (enclosures) in which human interference is kept to a minimum and livestock grazing is totally banned. In the initial stages, Sam, Sudasari, Phulia, and Miyajlar enclosures were established. Every year, the Forest Department is adding new enclosures. Presently, there are 28 enclosures. Besides the enclosures within the Park, there are six enclosures outside the boundary, which are called satellite conservation areas (Rahmani, 1997).

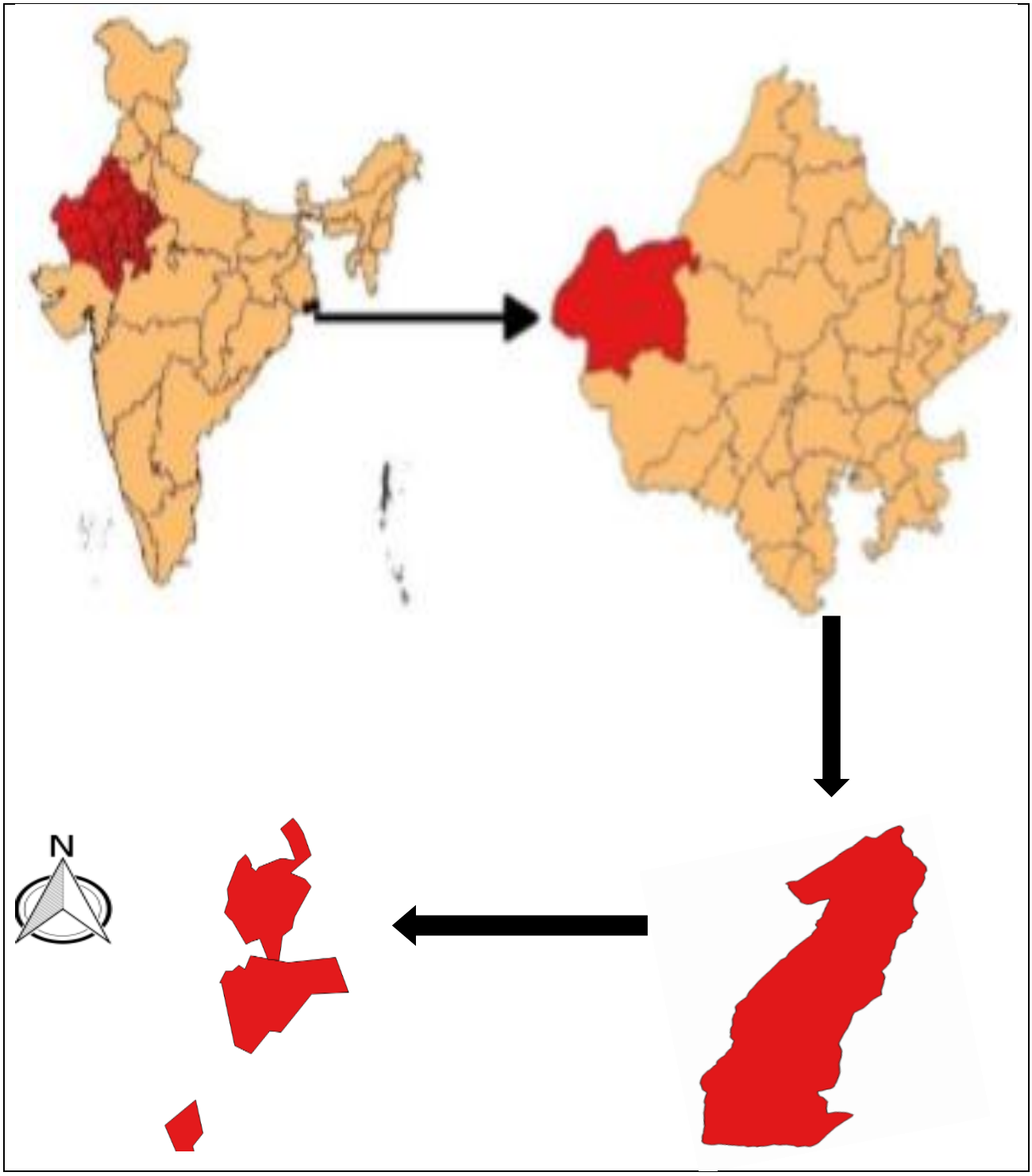


Figure4: Map of the study area showing the geographic location (Enclosures, Desert National Park, Jaisalmer, Rajasthan, India from right to left in the inset).



Figure 5: Images of different Enclosures and equipments used during GIB survery in and soil sampling in Thar landscape in March 2017 (from top to bottom).

3.2 METHODOLOGY

3.2.1 Field method

To assess the effect of livestock grazing on soil properties of Thar Ecosystem, Firstly, the study area was determined using topographic maps, GPS location and field investigation. Soil Sampling was performed on 2 areas of the above described enclosures i.e. in the protected area and the other outside area under livestock grazing (sheep, cow and goat) i.e. surroundings of Thar Desert. The two regions are flat and their climatic and topographic conditions- slope, aspect and height- are the same. Depending on vegetation type and condition, soil sampling was done from centroid point of enclosures and surroundings by using the systematic method on each site.

For soil sampling, sample taken from the centroid point of Sudasari, Gajai Mata and Rastriya Krishi Vikas Yojana enclosures in March 2017. I collected 200 soil samples using a shovel or spade from 0-15 cm soil depth of the topsoil (89, 65, and 45 soil samples was from Sudasari, RKVY and Gajai Mata and its surroundings respectively) in a systematic sampling design with one sample per 500m inside enclosure and one sample per 1km outside exclosure i.e. Surroundings and collected soil samples in zip-locks and properly transported to the Doon University, Dehradun for analyse them in laboratories.

3.2.2 Laboratory/Analytical analysis

Finally, having 200 samples from 3 enclosures and surroundings, the pH was measured in 1:10(w/v) aqueous solution (deionized water) using a digital pH meter and Electrical conductivity was measured by digital conductivity meter for a saturated soil past using distilled water. Bulk density and porosity determined by weighing bottle method. Gravimetric methods (Gardner, 1965) were used for soil moisture content. Total Organic carbon (TOC) was determined by using Walkley and Black (1934) method. Kjeldahl acid-digestion method was used to determine total Kjeldahl Nitrogen (TKN), respectively. Soil potassium and sodium were determined by using flame photometer. Soil basal respiration was determined by alkali absorption method.

1. Bulk density and porosity

The mass of the soil is determined by weighing the oven dry soil sample. Bulk density is calculated from the mass and volume of the soil.

Weigh an empty 25 ml beaker. Fill the beaker with oven dry soil upto the brim by tapping and weigh it. Empty the bottle and determine its exact volume using burette.

Calculation:

$$\text{Bulk density (g/cm3)} = \frac{\text{oven weight soil (g)}}{\text{Volume of beaker (cm3)}}$$

$$\text{Porosity (\%)} = 1 - \frac{\text{bulk density}}{2.65}$$

2. Moisture content

Moisture content in soil was measured by gravimetric method.

a) Weigh empty 50ml beaker.
b) Place 1gm moist soil sample in the beaker and weight it again.
c) Place the beaker in an oven at 105°C for 24 hours.
d) Remove the sample from the oven, and place the beaker in the desiccators until it is cool.
e) Take final weight of the beaker.

Calculation

$$\text{Moisture content (\%)} = \frac{Y-Z}{Z-X} \times 100$$

Where, X = Mass of empty beaker (gm)

Y= Mass of beaker + Moist soil sample (gm)

Z= Mass of beaker + oven dry soil sample (gm)

3. pH

The pH was measured using a digital pH meter in 1:10 (w/v) aqueous solution (deionized water).

a) Weigh 3 g air-dry soil and put in 100 ml beaker, add 30 ml distilled water.
b) Put the beaker on electric shaker for 1 hour at 150 rpm.
c) Read the conductivity of test solution by pouring electrode in solution.

d) Record the temperature of soil water suspension during the test.

4. Electrical Conductivity (EC)

The electrical conductivity of water extract of soil gives a measure of soluble salt content of the soil. It is measured on a conductivity meter and normally reported in dS/m.

a) Weigh 3 g air-dry soil and put in 100 ml beaker, add 30 ml distilled water.
b) Put the beaker on electric shaker for 1 hour at 150 rpm.
c) Read the conductivity of test solution by pouring electrode in solution. EC is expressed as (dS/m).
d) Dip the conductivity cell in distilled water when not in use.
e) Record the temperature of soil water suspension during the test.

5. Sodium

The sodium is estimated by flame photometer.

a) Take 3gm air dry soil sample in 100ml beaker and add 30ml distilled water in it.
b) Shift the beaker on electrical shaker for 1 hour at 150 rpm.
c) Filter the sample solution through Whatman 1 filter paper.
d) Determine the potassium concentration of filtrate by use of the flame photometer.
e) Feed the working standard solution and prepare a standard curve.
f) If the sample reading is not found within the standard reading range in that case the appropriate dilution of the filtrate may be made to bring the reading within standard range.
g) Note down the reading from the display of flame photometer.

6. Potassium

Potassium in soil is determined by flame photometer and measured in ppm.

a) Take 3gm air dry soil sample in 100ml beaker and add 30ml distilled water in it.
b) Shift the beaker on electrical shaker for 1 hour at 150 rpm.
c) Filter the sample solution through Whatman 1 filter paper.
d) Determine the potassium concentration of filtrate by use of the flame photometer.
e) Note down the reading from the display of flame photometer.

7. Total Organic Carbon (TOC)

a) Weigh 1 gm. of soil sample into dry 500 ml conical flask. Add 10 ml of $K_2Cr_2O_7$ into the flask with micro pipette and swirl.
b) Add rapidly with a burette 20 ml conc. H_2SO_4 and swirl gently until soil and reagents are mixed then more vigorously for one minute.
c) Allow the reaction to proceed for 30 min on asbestos sheet to avoid burning of table due to release of intense heat due to reaction of sulphuric acid.
d) Add slowly 200 ml of distilled water, 10 ml of 85% orthophosphoric acid (H_3PO_4) and add about 0.2 gm NaF (one small teaspoon). The H_3PO_4 and NaF are added to complex Fe^{3+} which would interfere with the titration endpoint.
e) Just before titration add 10 drops (1 ml) ferroin indicator into the conical flask. Titrate the excess $K_2Cr_2O_7$ with 0.5 N ferrous ammonium sulphates till the colour flashes from yellowish green to greenish and finally brownish red at the end point.
f) Simultaneously blank test is run without soil.

Calculation

Organic carbon (%)= [(B-S) x 0.0006/m] x 100

Where, B = mL of titrant [$Fe(NH_4)(SO_4).6H_2O$] used to titrate blank

S= mL of titrant [$Fe(NH_4)(SO_4).6H_2O$] used to titrate sample

m= weight of sample

8. Total Kjeldahl Nitrogen in soil

The organic matter in the soil is oxidized by $KMnO_4$ in presence of NaOH. The ammonia released during oxidation is absorbed in boric acid to convert the ammonia to ammonium borate. The ammonium borate formed is titrated with standard H_2SO_4. From the volume of standard H_2SO_4 required for the reaction with ammonium borate, the N is calculated.

a) 1 gm soil sample was taken in digestion tube.
b) Added digestion mixture (i.e. sodium sulphate and copper sulphate in 5:1 ratio) to the sample.
c) Added 10 ml conc. Sulphuric acid to the tube.
d) The samples were digested for 2 hours in digestion system.

e) Separated the sample from system and allowed the mixture to cool.
f) Diluted the samples from one by one adding 10ml distilled water.
g) Diluted samples were kept in distillation system.
h) After distillation process, the receiver solution was taken out for titration.
i) The receiver solution was titrated with 0.1 conc. HCL by using methyl red indicator. At end point the pink colour appear.

Calculation

$$TKN\ (\%) = \frac{1.401 \times (T-B) \times N \times D.F.}{\text{Wt. of sample}}$$

Where, T = mL of titrant used to titrate sample

B = mL of titrant used to titrate blank

N = normality of HCL

D.F. = dilution factor

9. Soil basal respiration by alkali absorption method

Soil respiration rate was measured by alkali absorption method. 100 gm fresh soil was taken in 500ml beaker and 50 ml of 0.25 NaOH solution was kept in 100 ml beaker and made air tight three replicates were made for all the samples. After 24 hours the alkali was titrate with 0.25 HCL solution using phenolphthalein indicators.

CO_2 absorbed from the soil was calculated as following:

$Mg\ CO_2 = V \times N \times 22$

V = volume of the acid

N = normality of the acid

3.2.3 Statistical analysis

After chemical analysis, the descriptive statistics of data sets including the Mean, Standard deviation was performed. All other data were also subjected to statistical analysis on Excel 2016 Software.

CHAPTER - 4
RESULTS AND DISCUSSION

The physicochemical parameters of the soil of the study area are listed in T able 1.

Table 1: Physicochemical properties (mean ± SEM) of top soil collected from different enclosures and its surrounding. Result presents average and standard error of each parameter.

Parameters	**Sampling sites**					
	Gajai Mata Enclosure	**Gajai Mata Surrounding**	**RKVY Enclosure**	**RKVY surrounding**	**Sudasari Enclosure**	**Sudasari Surrounding**
pH	8.11 ± 0.04	8.10 ± 0.06	8.02 ± 0.03	8.07 ± 0.03	8.03 ± 0.03	8.01 ± 0.03
EC (dS/m)	0.074 ± 0.01	0.067 ± 0.00	0.062 ± 0.01	0.071 ± 0.00	0.093 ± 0.02	0.073 ± 0.00
Na (ppm)	2.60 ± 0.53	2.38 ± 0.70	2.04 ± 0.31	3.22 ± 0.25	1.84 ± 0.08	3.19 ± 0.05
K (ppm)	5.96 ± 0.58	4.49 ± 0.35	4.59 ± 0.48	4.89 ± 0.29	5.61 ± 0.35	5.11 ± 0.47
B.D. ($g/cm^{3)}$	1.14 ± 0.02	1.13 ± 0.02	1.17 ± 0.01	1.10 ± 0.01	1.21 ± 0.01	1.15 ± 0.01
Porosity (%)	0.563 ± 0.01	0.565 ± 0.01	0.54 ± 0.004	0.57 ± 0.003	0.53 ± 0.00	0.56 ± 0.00
Moisture Content (%)	0.12 ± 0.023	0.23 ± 0.06	0.11 ± 0.02	0.22 ± 0.03	0.15 ± 0.01	0.19 ± 0.03
TOC (%)	0.043 ± 0.01	0.053 ± 0.01	0.058 ± 0.01	0.046 ± 0.01	0.057 ± 0.01	0.055 ± 0.01
TKN (%)	0.023 ± 0.01	0.035 ± 0.00	0.035 ± 0.00	0.030 ± 0.00	0.029 ± 0.00	0.032 ± 0.00
C:N ratio	2.41 ± 0.40	2.42 ± 0.61	1.87 ± 0.282	2.090 ± 0.28	2.58 ± 0.34	2.82 ± 0.70
Basal Soil Respiration (Mg CO_2)	107.8 ± 0.79	106.4 ± 2.65	108.3 ± 1.43	110.6 ± 1.22	100.87 ± 0.79	108.51 ± 2.69

4.1 BULK DENSITY

Average Bulk Density of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 1.14, 1.17, 1.21, 1.14, 1.11 and 1.15 g/cm^3 respectively (Figure 6). The result demonstrated that bulk density was highest in enclosures compared to its surrounding because the soil of enclosure is more compacted with less pore space, and this kind of soil have a higher bulk density. RKVY and Gajai Mata enclosure also have the sand dunes in it and sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils. This might be the reason of its higher bulk density.

The bulk density varies indirectly with total pore space present in the soil and gives a good estimate of porosity of soil.

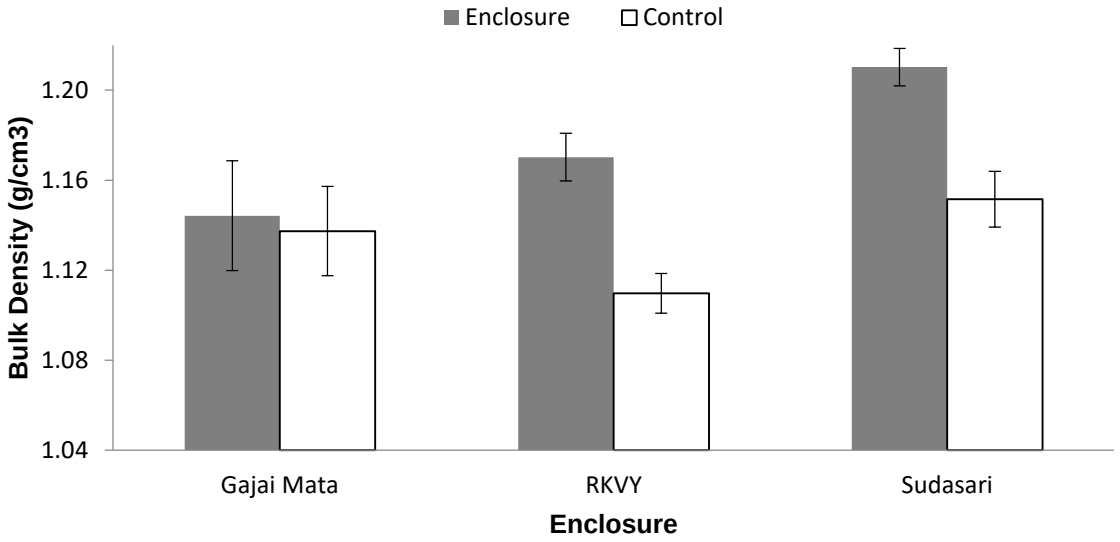


Figure 6: Mean and standard error of Bulk Density (g/cm3) for Gajai Mata, RKVY, Sudasari enclosures with respect to their surroundings.

4.2 POROSITY

Average porosity of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 0.563, 0.54, 0.54, 0.56, 0.58 and 0.56 % respectively (figure 7). Soil porosity is inversely proportional to the measurement of bulk density, which means that porosity decreases as bulk density increases and vice-versa**.** Therefore figure 6 follows a reverse trend as comparison to Bulk density that shows Porosity was highest in Gajai Mata and lowest in Sudasari enclosure.

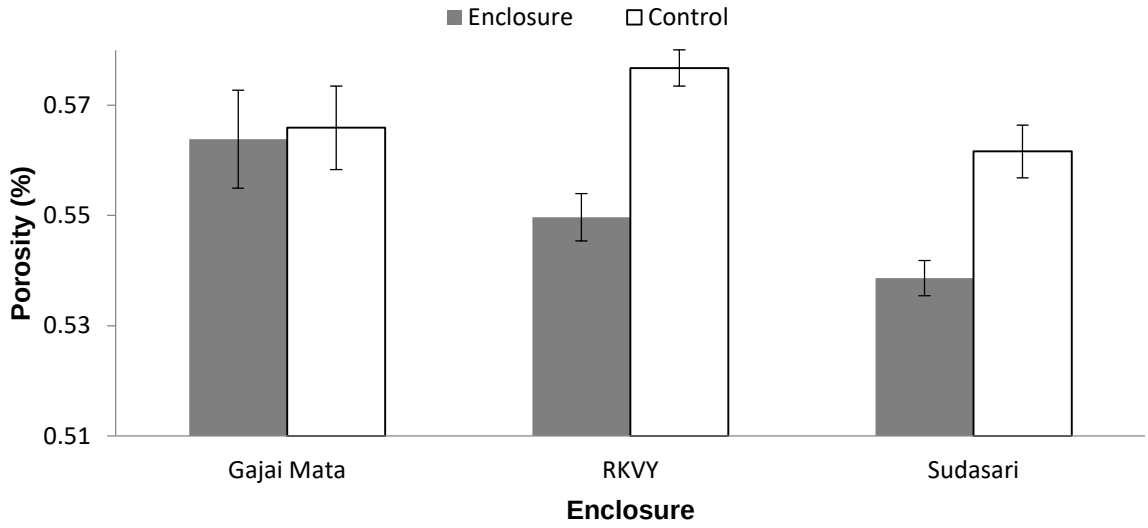


Figure 7: Mean and Standard error of porosity in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.3 MOISTURE CONTENT

Figure 8 showed that Average moisture content of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 0.12, 0.11, 0.16, 0.24, 0.28, and 0.19 % respectively. Moisture content was found higher in Sudasari enclosure because of it has more vegetation cover compared to other enclosures and lower in RKVY enclosure. Although moisture content was higher in Gajai Mata's surrounding compared to Gajai Mata and other enclosures.

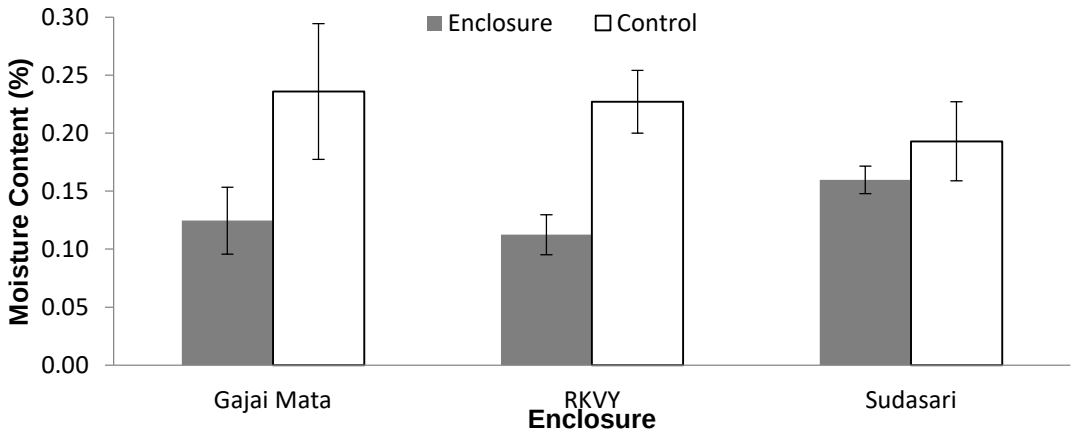


Figure 8: Mean and Standard error of moisture content in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.4 pH

Average pH of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 8.11, 8.02, 8.03, 8.10, 8.07, and 8.01 respectively(Figure 9). Result demonstrated that soil pH in the 0–15 cm depth was higher in Gajai Mata enclosure (newer enclosure) and lower in RKVY and Sudasari enclosures. The pH value increases with increasing the grazing intensity (Amezaga et al., 2004).

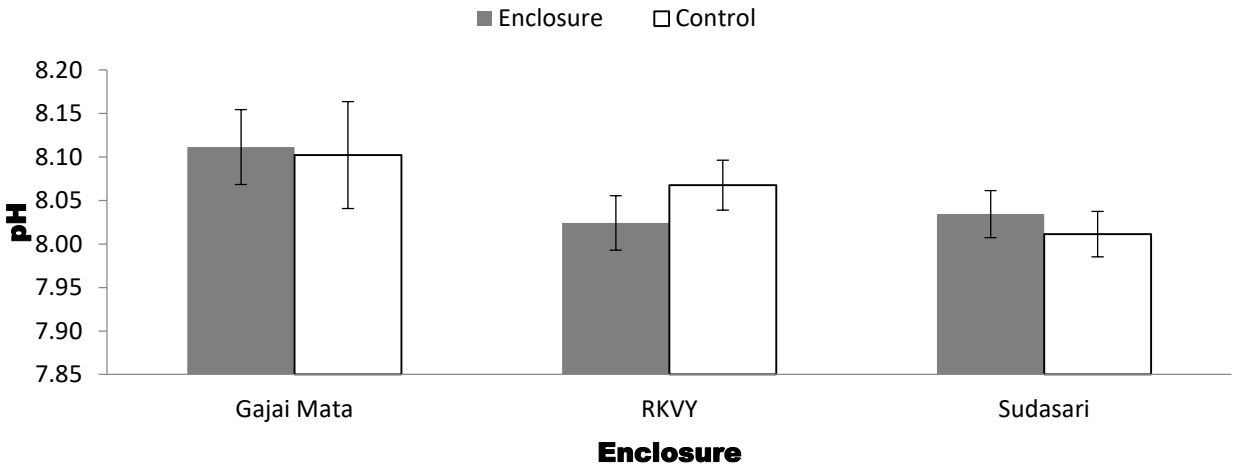


Figure 9: Mean and Standard error of Basal pH in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.5 ELECTRICAL CONDUCTIVITY

Average electrical conductivity of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 0.07, 0.06, 0.09, 0.06, 0.07, and 0.07 dS/m respectively (figure 10). The result presented in this study demonstrated that there was a slightly higher amount of electrical conductivity (EC) in the Sudasari enclosure compared to its surrounding and two other enclosures.

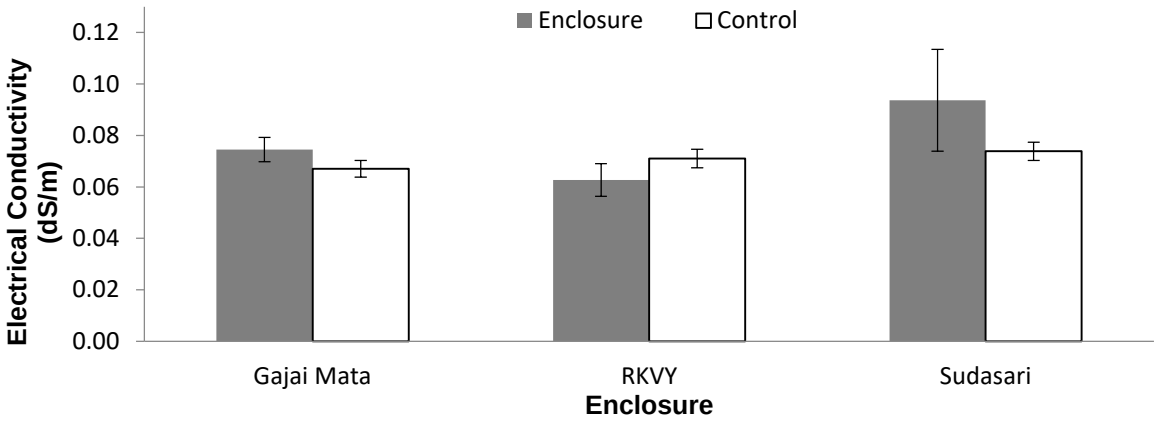


Figure 10: Mean and Standard error of Electrical conductivity in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.6 SODIUM

Average sodium content of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 2.60, 2.04, 1.84, 2.38, 3.22, and 3.12 ppm respectively (figure 11). The result showed that sodium content of soil was affected by grazing and the value of it in the Gajai Mata enclosure was higher than other enclosures. High evaporation rates under grazing may promote the accumulation of salts in the topsoil because of the upward movement of water and soluble salts from salinized deep horizons (Lavado, Taboada, 1987).

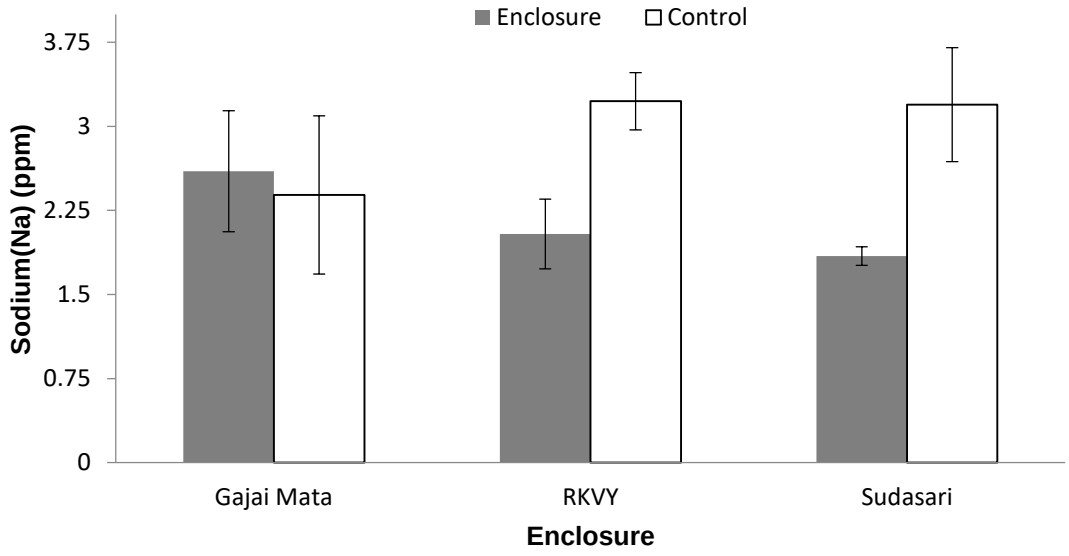


Figure 11: Mean and Standard error of sodium in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.7 POTASSIUM

Average Potassium content of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 5.96, 4.59, 5.61, 4.49, 4.89 and 5.11 ppm respectively (figure 12). The higher amount of K was observed in Gajai Mata enclosure due to the absence of vegetation cover. Due to this, high evaporation rates and less vegetation cover may promote the accumulation of salts in the topsoil because of the upward movement of water and soluble salts from salinized deep horizons (as earlier mentioned in the case of Sodium).

On the other hand, RKVY enclosure demonstrated lower content of soil potassium compared to other enclosures and surrounding. Zarekia et al., (2012) mentioned that the increase in K may have been related to livestock's positive effect on accumulation of K via trampling and their excreta.

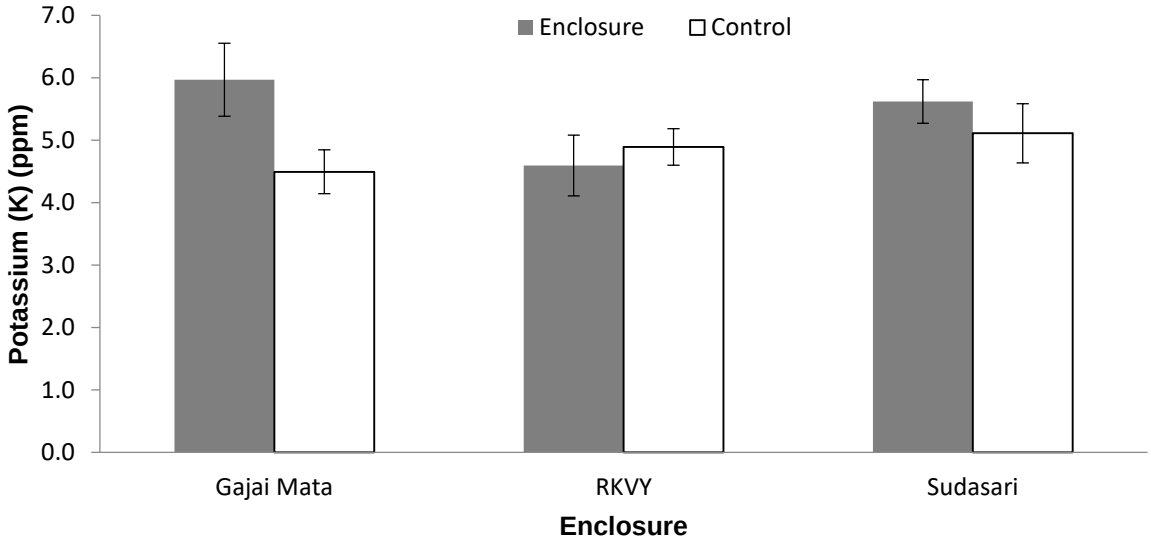


Figure 12: Mean and Standard error of Potassium in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.8 TOTAL ORGANIC CARBON (TOC)

Average total organic carbon of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 0.04, 0.06, 0.06, 0.05, 0.05 and 0.05 % respectively (figure 13). The amount of TOC was higher in RKVY and Sudasari enclosures than in Gajai Mata enclosure. Gajai Mata has lower amount of total organic carbon due to fragmented vegetation & less plant covers or it may be due to the large area covered under the sand dunes. The reason behind the higher or close TOC values in the surrounding is because of the moderate grazing with breaking plant

material and litter decomposition to the soil increases the soil organic carbon Zarekia et al., (2012).

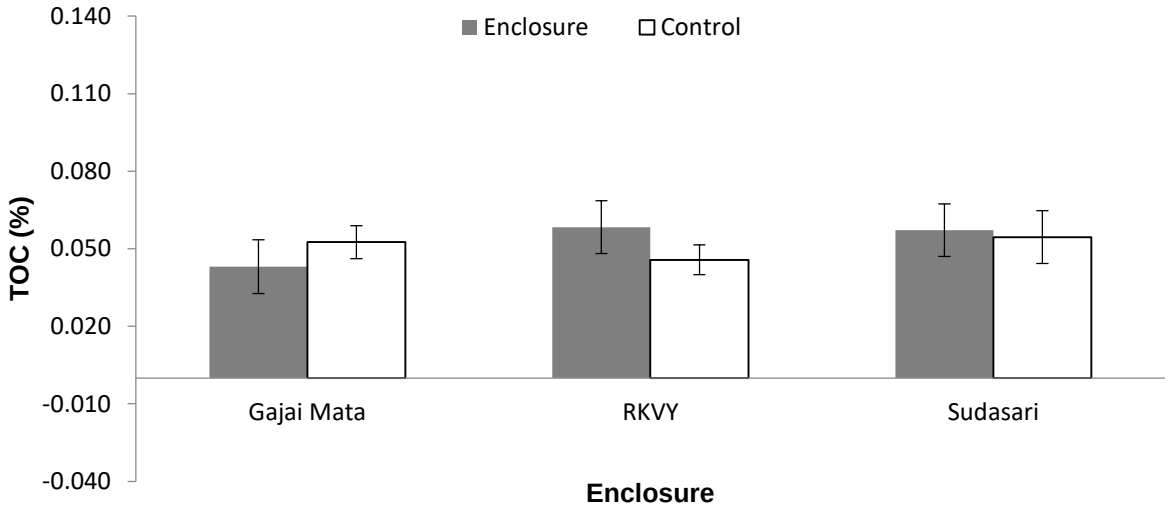


Figure 13: Mean and Standard error of total organic carbon in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings

4.9 TOTAL KJELDHAL NITROGEN (TKN)

Total nitrogen of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 0.02, 0.04, 0.03, 0.04, 0.03, and 0.03 % respectively (figure 14). The amount of total nitrogen in the Gajai Mata enclosure was lower and higher in RKVY enclosure compared to enclosures and surroundings.

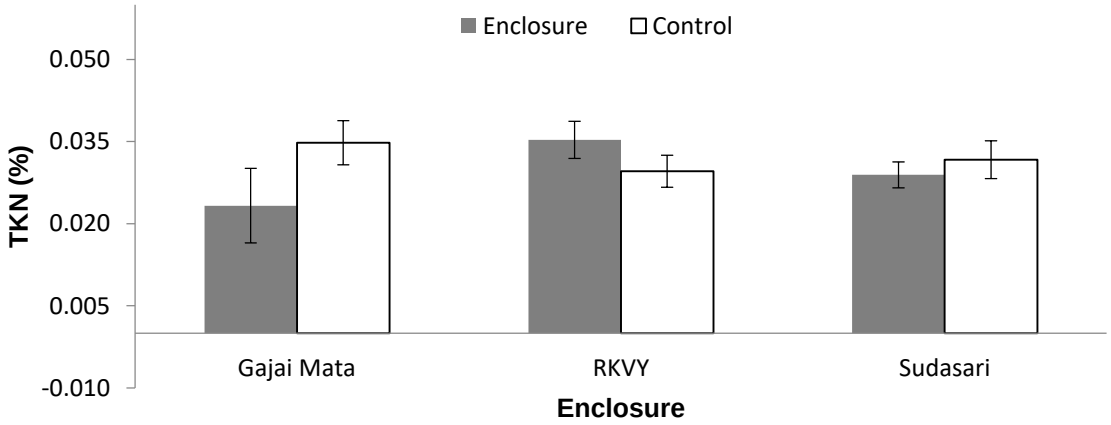


Figure 14: Mean and Standard error of total Nitrogen in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings.

4.10 C:N ratio

Average C:N ratio of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 2.41, 1.87, 2.58, 2.42, 2.09 and 2.82 respectively (Figure 15). C/N ratio of arid soil was slightly higher in the Sudasari enclosure compared to other enclosures. Whereas, relatively low compared to its surrounding. While it was approximately same in Gajai Mata enclosure and its surrounding.

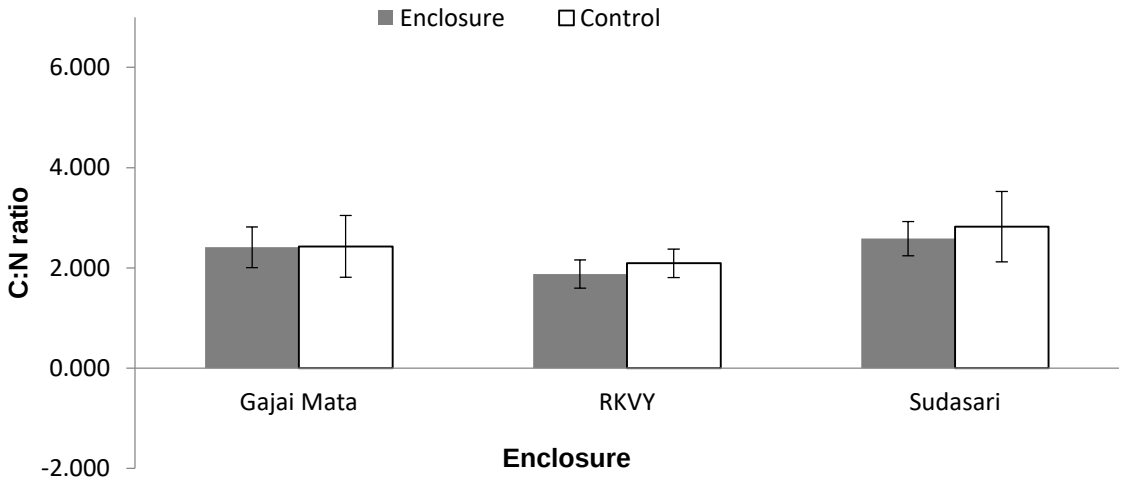


Figure 15: Mean and Standard error of C:N ratio in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings

4.11 Basal soil respiration

Average Basal soil respiration of Gajai Mata, RKVY, Sudasari enclosures and its surroundings were 107.80, 108.30, 100.87, 106.48, 110.66, and 108.51 mg CO_2 respectively (figure 16). The result demonstrated that basal soil respiration was higher in RKVY enclosure and lower in Sudasari enclosure.

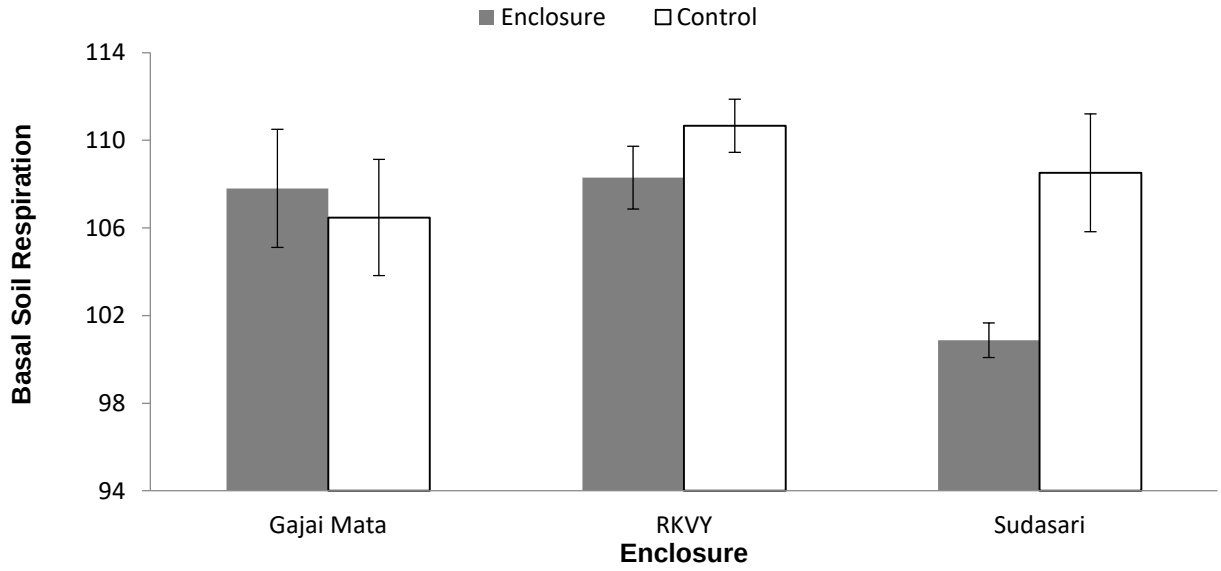


Figure 16: Mean and Standard error of Basal soil respiration in Gajai Mata, RKVY, and Sudasari Enclosures and their surroundings

DISCUSSION

Livestock grazing affects soil attributes, which inturn impacts the ecosystem function (Bagchi and Ritchie, 2005). In many cases, soil loss on grazed rangeland is greater than on ungrazed rangeland (Todd et al. 1998). Soil inside protected areas had a greater vegetation cover, woody debris, litter and high levels of micro topography and these condition had a major impact on soil properties.

The results presented in this study demonstrate that the ungrazed pastures (Sudasari and RKVY) showed an increasing trend in bulk density, moisture content, TOC, TKN and electrical conductivity as time of grazing exclusion increased. While there was an opposite trend for Sodium, Potassium concentration and pH values.

The increase of soil pH in Gajai Mata enclosure and its surroundings compared to other enclosures, which was observed in the present study, confirms with the relevant report by Shaltout et al. (1996) in eastern Saudi Arabia. This increase in pH might be related to increasing evaporation and soil erosion in the new enclosure free grazing site. In this area, the loss of foliage and litter cover lead to an increase in the exposure of the soil surface to radiation and compaction, and facilitate the rapid conduction of heat through the soil (Yates et al., 2000).

Since Gajai Mata is a new enclosure with less vegetation cover, might be the reason of high Sodium and Potassium content in this enclosure, confirms with the relevant study of Lavado and Taboada (1987) investigated that high evaporation rates under grazing may promote the accumulation of salts in the topsoil because of the upward movement of water and soluble salts from salinized deep horizons Salts did not accumulate at the soil surface in the absence of grazing because a thick layer of litter reduced evaporative losses and thus decreased the upward flux of water and salts.

Contrary to other studies (Beylich et al., 2010) the degree of soil compaction, as measured by bulk density, depends on the soil texture as well as on the soil moisture at the time of grazing and on the level of organic matter in the soil surface This explained why the bulk density of grazed humid areas was higher than the ungrazed areas. However, the arid rangeland data showed conflicting results; some reported that there are no differences in bulk density between grazed and ungrazed areas, while others reported that there are

consistent high bulk density values for grazed areas (Bossdorf et al., 2000). In this study Bulk density was higher in Sudasari where grazing is excluded since long time.

The result demonstrated that ungrazed enclosure has higher moisture content and this result is supported by Al-Seekh et al., (2009) that studied the effect of excluding grazing on soil properties and soil moisture content after many years of severe overgrazing for two sites (Sorif and BaniNoem) in 2004 and 2005. Data showed that, excluding grazing significantly increase the soil moisture content in Sorif site at 15 cm soil depth during all measurement dates. On the other hand, no significant difference in soil moisture content between grazed and ungrazed areas at BaniNoem site in 2004, while excluding grazed plot significantly had a higher soil moisture content compared to grazed plot in 2005.

CHAPTER - 5
CONCLUSION

The effect of livestock grazing on biodiversity is an argumentative conservation issue with studies showing positive as well as negative effects of grazing on plant and animal richness and abundance. Unregulated livestock grazing can alter soil properties by increasing soil compaction, reducing water retention capacity, and reducing organic contents that can negatively impact vegetation growth and species richness. In this regard a study was conducted in Desert National Park, Thar Desert, Rajasthan, which is the habitat of state bird of Rajasthan and declared 'Critically Endangered' by International Union for Conservation of Nature (IUCN) ***The Great Indian Bustard (GIB).*** The results of the study shows that there is a significant difference in soil variables of enclosures and surroundings which is because of agro-pastoral practices in surrounding area. Moreover livestock grazing and seasonal agricultural practices alters the soil properties such as bulk density, porosity, moisture content, electrical conductivity which render serious consequences for plant growth in a dry Mediterranean climate where water is a scarce resource. These results represent only the change after few years of excluding grazing in new enclosures, and more conclusive results are required many years under such conditions. To manage a rangeland ecosystem, these changes should be identified to avoid unwanted and harmful ecosystem changes. Grazing management plans and subsequent operational decisions should be included both economic and biological considerations. More studies to better assess the time scale of exclusion and more soil samplings in enclosures and surroundings are also needed to understand better the ecology of this fragile ecosystem.

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CHAPTER 6
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