Status and Trend of

GREAT INDIAN BUSTARD

Associated Wildlife and Threats in Thar

SURVEY REPORT
2017-18

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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

Survey Team

Coordinators: Sutirtha Dutta, Bipin C. M. & Anoop K. R.

Researchers:

2017 survey

A. Mohan, Aaranya Gayathri, Abhishek Thakur, Aditya Bisht, Akshay Jain, Amandeep Ruhela, Anugraha Chandekar, Arun Purohit, Avinash Yadav, Basavaraj Mulage, Bhargava M. Singh, Devendradutta Pandey, Dinesh Kumar, Divyrajsinh Jadeja, Durgesh Bali, Genie Murao, Idris Ahmed, Jyoti Dhandhukia, Karmavir Bhatt, Kishan Gopal Suthar, Lakshit Sharma, Malyasri Bhattacharya, Mamta Choudhary, Mariyam Nasir, Pawan Pareek, Pooja Pawar, Prasath S., Pratiksha Kothule, Pratima Singh Rajpoot, Dr. Prayag H. S, Preeti Pandey, Priyamvada Bagaria, Rachana Rao, Rahul Rana, Rishika Dubla, Rishikesh Tripathi, Rizwan Ali Khan, Rupesh Gawde, Shailesh Kumar Gupta, Sumit Kumar Bawalia, Tanerav Singh, Tungala Suresh, Vaishali Rawat, Vanya Joshi, Dr. Veena H. F. Ammanna, Vijay Patel, Dr. Vikas Verma, Vineet Singh, Viral Vadodariya, Yogesh Patel

2018 follow-up survey

Anjali Nagar, Arjun Awasthi, Devendradutta Pandey, Hemlata Joshi, Hrishika Sharma, Rishikesh Tripathi, Shikha Jasrrotia, Sweta Iyer, Sohan, Sourav Supakar, Tanerav Singh, Tanya Gupta and Tushna Karkaria

Forest Staff: Ashok Bishnoi, Babu Khan, Barkat Khan, Bhawani Singh, Bhawani Singh Akal, Bhanwar Singh, Chaen Singh, Chotu Ram, Devi Singh, Bhuri, Durga Ram, Ghuman Singh, Giridhari Lal, Hameer Singh, Hanuman Ram, Hari Singh, Harish Bishnoi, Jitendra Singh, Jograj Singh, Joita Ram, Kalyan Singh Jodha, Kamlesh Kumar, Kareem Khan, Kesha Ram, Khem Chand B, Khem Chand G, Kishan Gopal, Mahendra Vishnoi, Mangu Dan, Mehra Ram, Mehra Ram, Mohan Ram Banta, Mukesh Meena, Mukhtyar Khan, Narayan Singh, Narpat Singh, Pema Ram, Pemp Singh, Pokar Ram, Pukhraj Dudhi, Pushta, Pushpa Kanwar, Pushpa Mali, Rakesh Kumar, Ram Hari Meena, Ram Prasad Meena, Ram Swaroop, Rohit Kumar, Sadeek Khan, Saroj, Shyam Singh Bhati, Surendra Singh, Suresh Kumar, Teejon, Tejpal Singh, Ummed Singh, Vikas, Vinod Kumar.

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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 $6.7 \pm 2.9_{SE}$ % 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 $205 \pm 14_{SE}$ animals/100 km^2, yielding abundance of $40{,}442 \pm 2811_{SE}$ in 19,728 km^2 landscape (2017). Desert fox density was estimated at $15.03 \pm 2.39_{SE}$ /100km^2, and abundance of $2965 \pm 471_{SE}$ individuals in 19,728 km^2 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 $0.15 \pm 0.04_{SE}$ (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).

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).

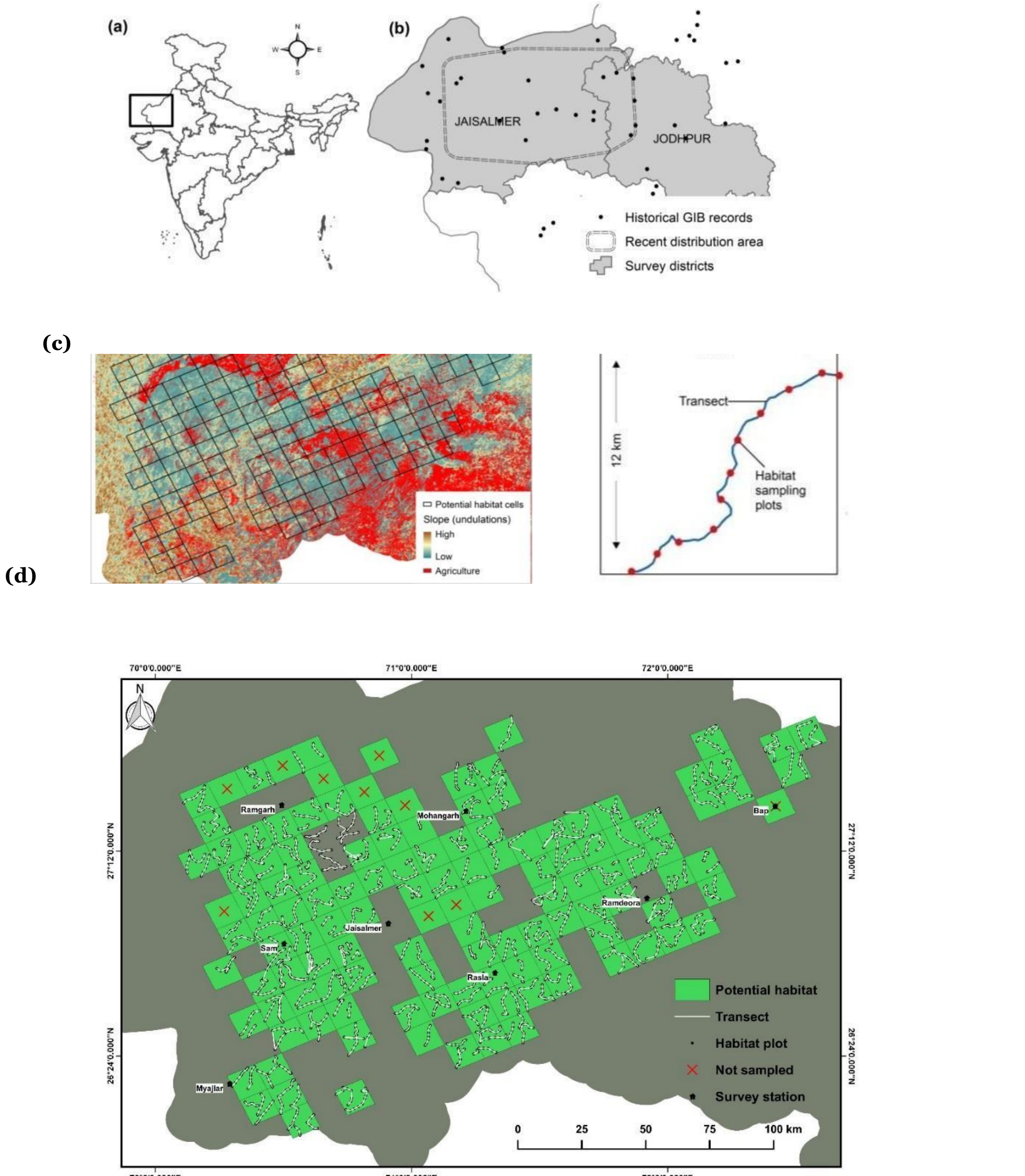
2. Thar landscape

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)



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 ($\overline{ESW}$) and effective sample area ($\overline{ESA}$) are derived. This metric is used to convert encounter rate into density estimate ($\overline{D}$) (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 km^2 area, and Pokhran Field Firing Range: 5184 km^2 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

$0.09 \pm 0.03_{SE}$; 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 $6.7 \pm 2.9_{SE}$ % of sites in 2017. Pooling extensive and intensive surveys of 2016-17, we detected 65 flocks with mean flock size of $1.63 \pm 0.11_{SE}$ individuals. Distance data of these observations was best explained by uniform detection function with cosine series expansion (least AICc value; goodness of fit: $\chi2=0.65$, df=5, p=0.99). This model estimated effective strip width at $401 \pm 26_{SE}$ m (figure 2), based on which, great Indian bustard density was estimated at $0.48 \pm 0.10_{SE}$ birds/100km² for all cells and $7.49 \pm 1.63_{SE}$ birds/100km² in occupied cells (fig 3). Landscape-scale abundance was estimated at $95_{Mean} \pm 21_{SE}$ 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 $447 \pm 48_{SE}$ 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 $128 \pm 19_{SE}$ 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 $2.49 \pm 0.07_{SE}$ 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 $169 \pm 7_{SE}$ m (figure x). Chinkara density was estimated at $205 + 14_{SE}$ animals/100km², yielding abundance estimates of $40{,}442 \pm 2810_{SE}$ 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 $2.15 \pm 0.26_{SE}$ individuals/100km, and group size of $1.09 \pm 0.04_{SE}$ 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 $82 \pm 9_{SE}$ m (figure x). Desert fox density was estimated at $15.03 \pm 2.39_{SE}$ individuals/100km², yielding abundance of $2965 \pm 471_{SE}$ animals in the landscape (table 1).

* Detectability experiments using dummy birds (June 2014 and March 2016) yielded a similar effective strip width of $402 \pm 34_{SE}$ 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*	$\hat{ES}W$	$\hat{D}$ (# 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

$\hat{ES}$ = 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

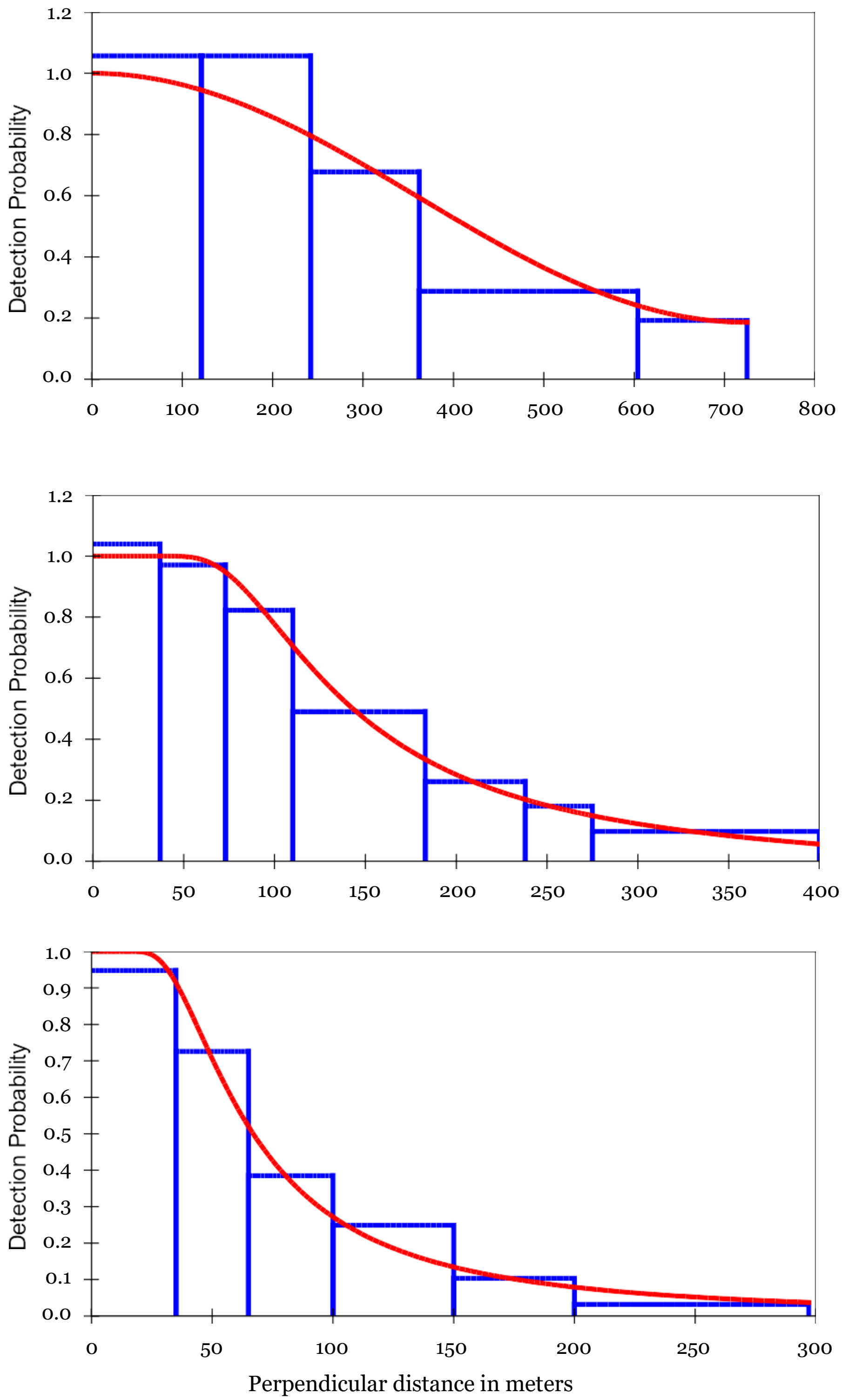


Figure 3 Status (2017) and trend (2014–2017) of Great Indian Bustard in Thar landscape

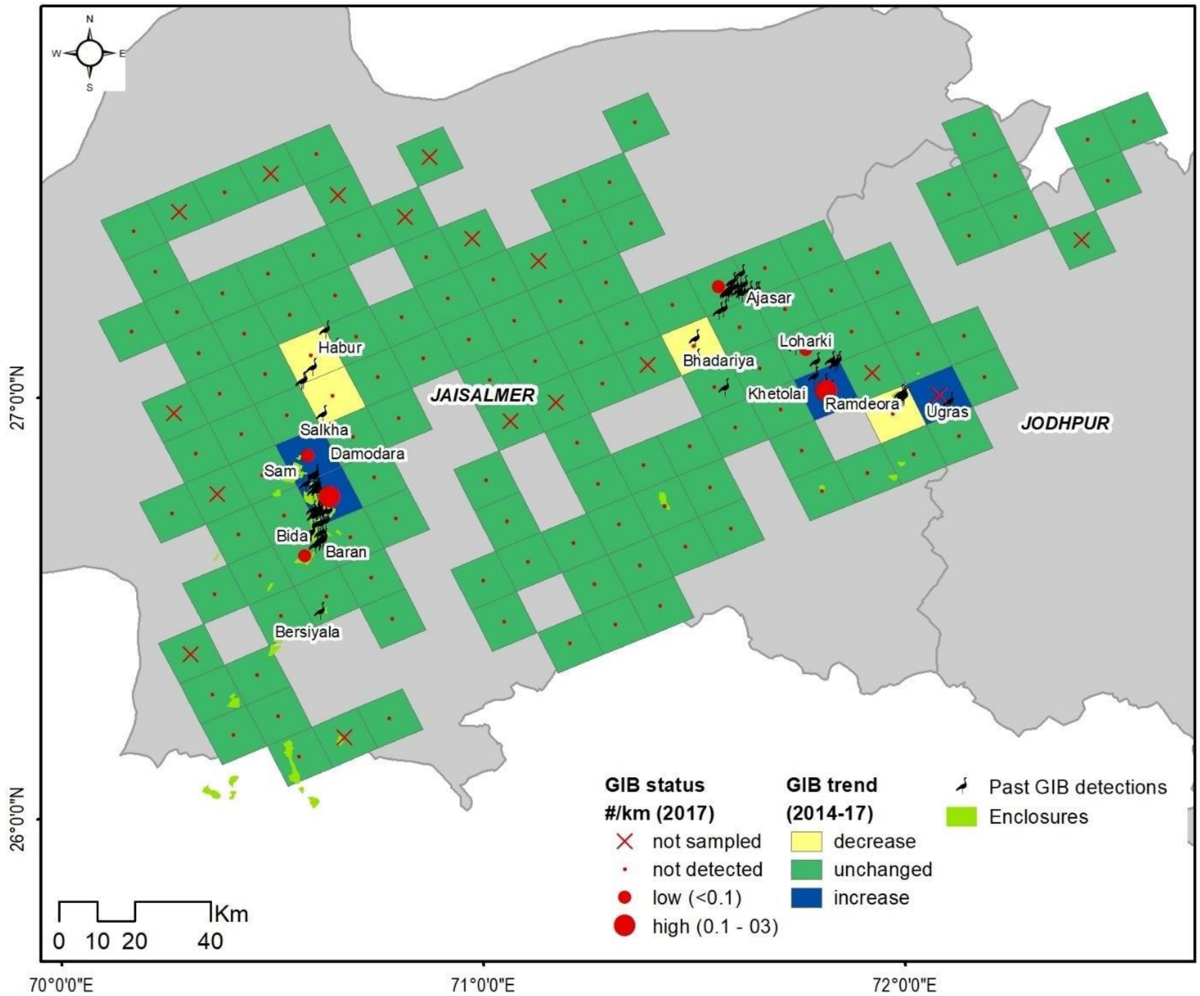


Figure 4 Status (2017) and trend (2014–2017) of Chinkara (top) and Desert fox (bottom) in Thar landscape

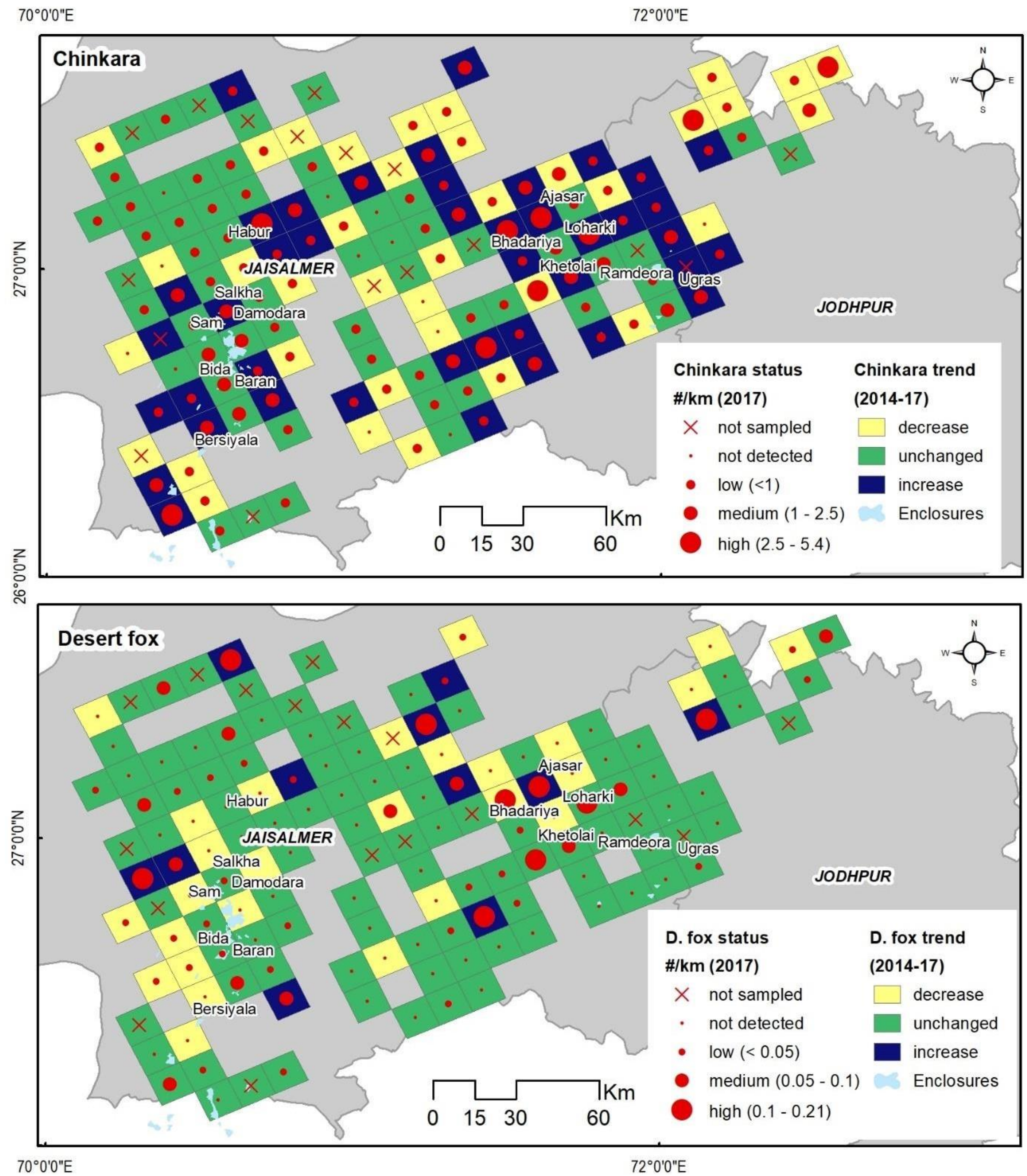
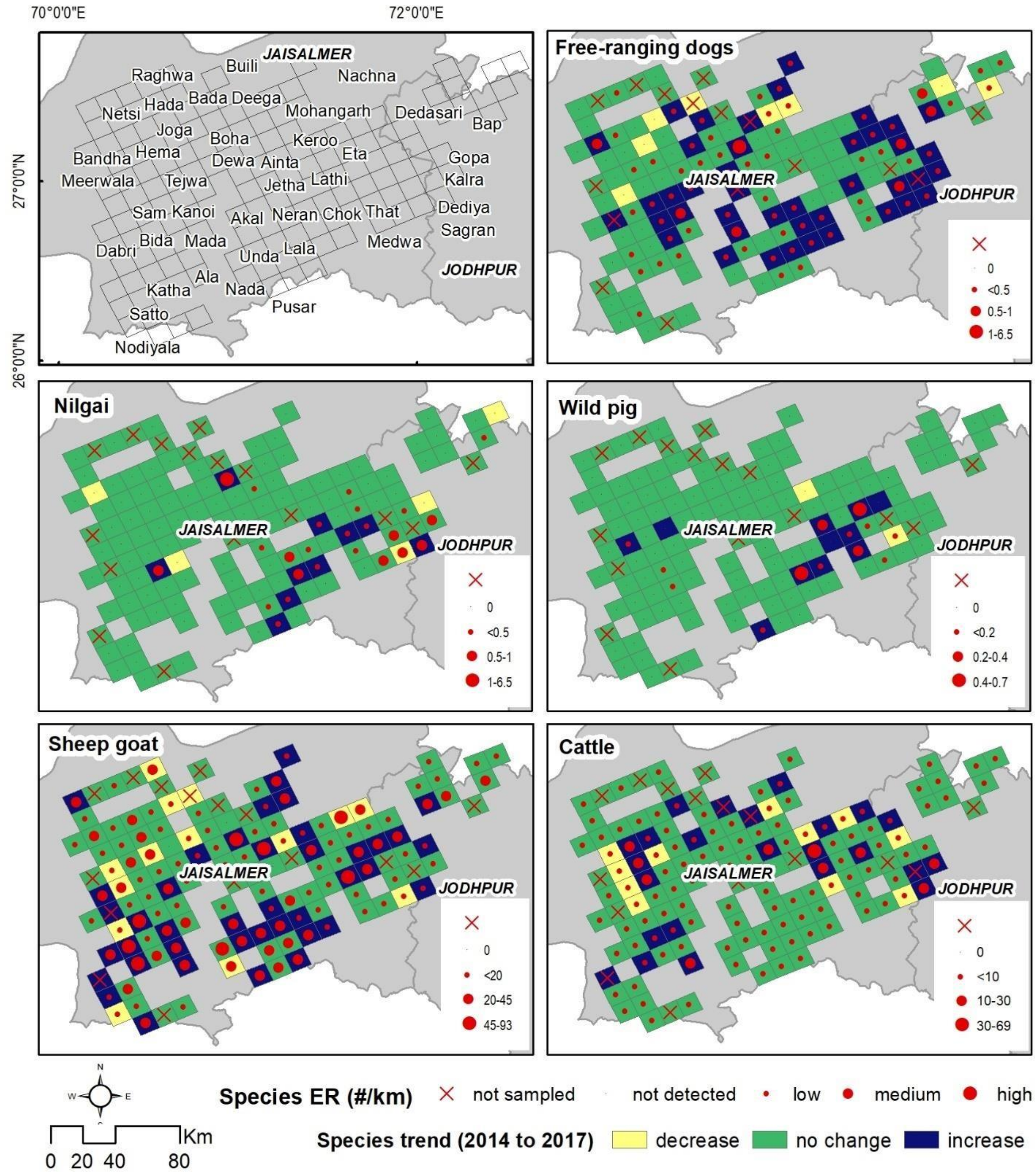


Figure 5 Status (2017) and trend (2014–2017) of non-native / domestic species in Thar landscape



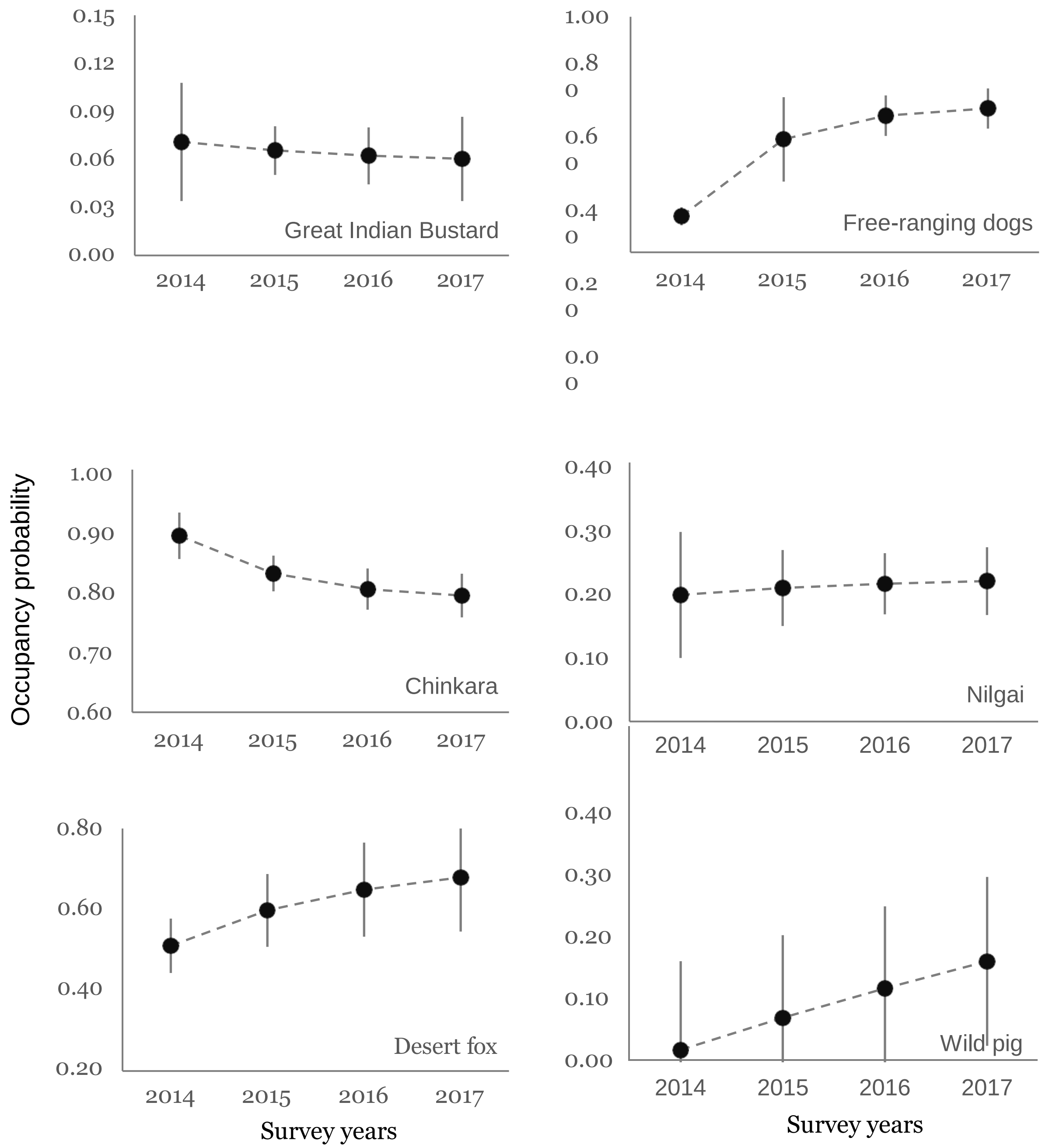
4.1.5. Species' population trends

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

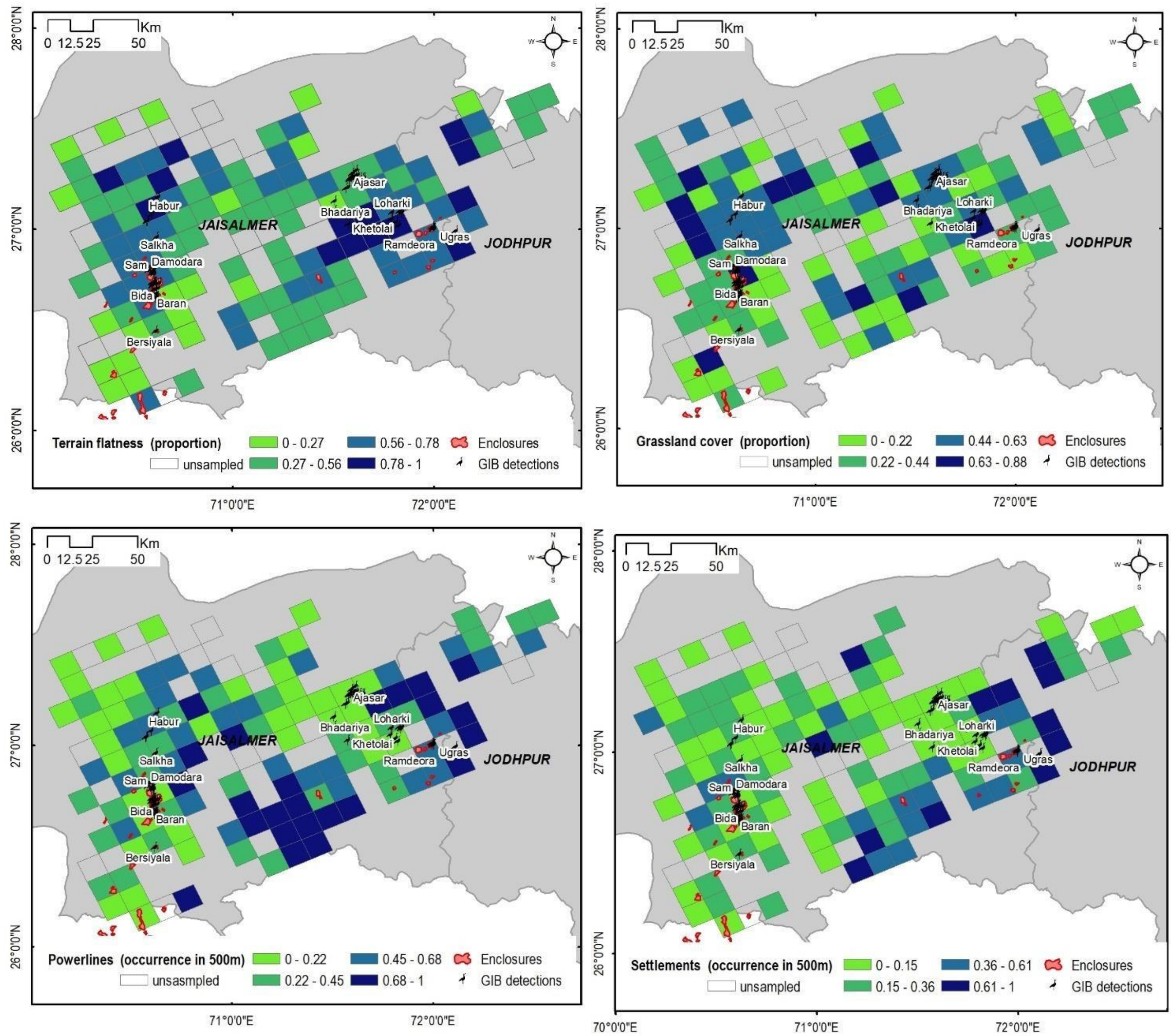


Figure 8 Occurrence probability of human artifacts in sampling plots across Thar landscape from 2015 to 2017. Error bars are 1 SE across 144-km² cells, and values in parentheses are regression slopes against years that are indicative of temporal trends. Also shown are land-cover and vegetation structure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

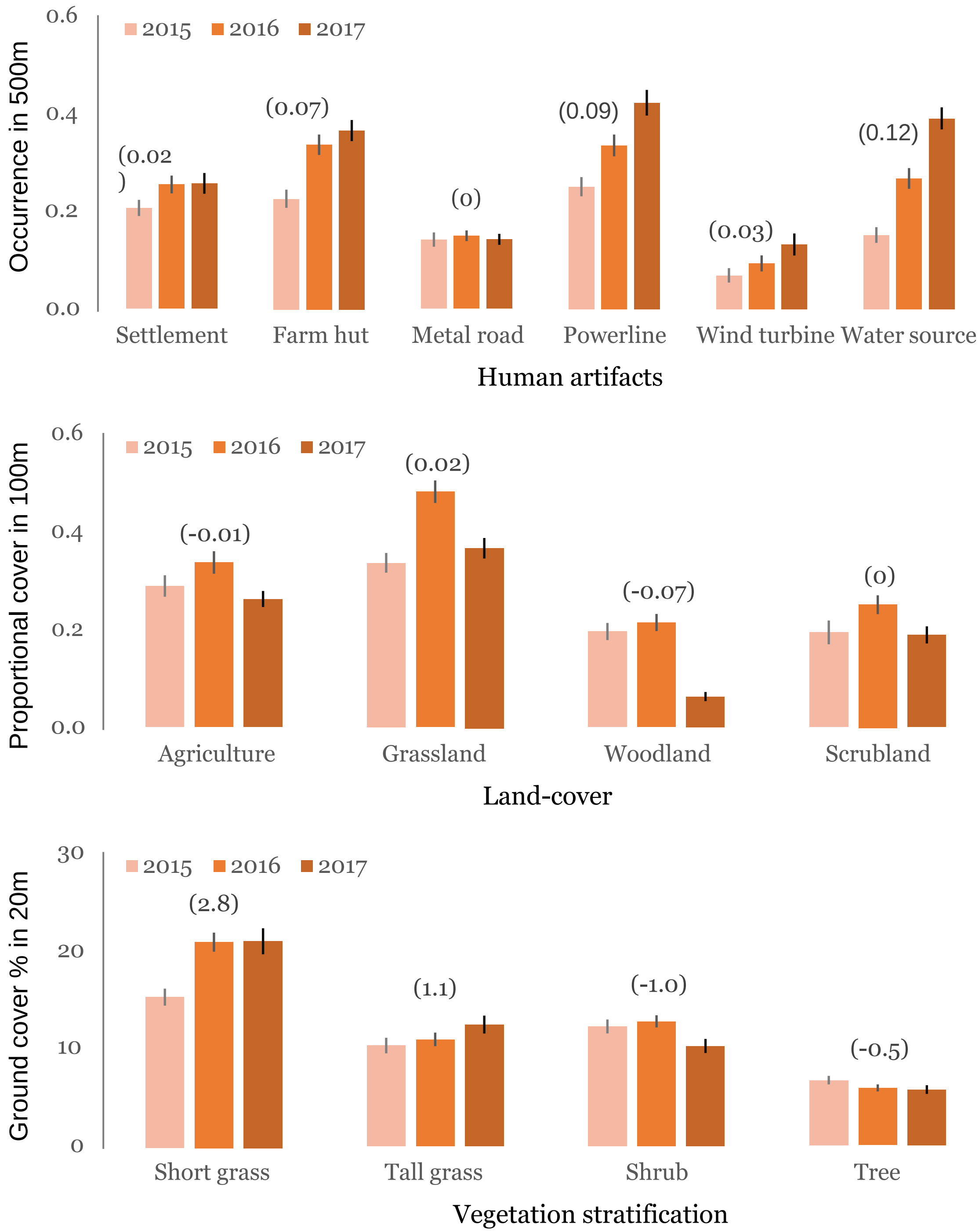


Figure 9 Great Indian Bustard distribution and local extinction in the past decade (based on secondary reports) and from 2014-15 to 2016-17 (based on occupancy surveys) overlaid on the occurrence (2016) and recent trend (2015-17) of power-line expansion across Thar landscape

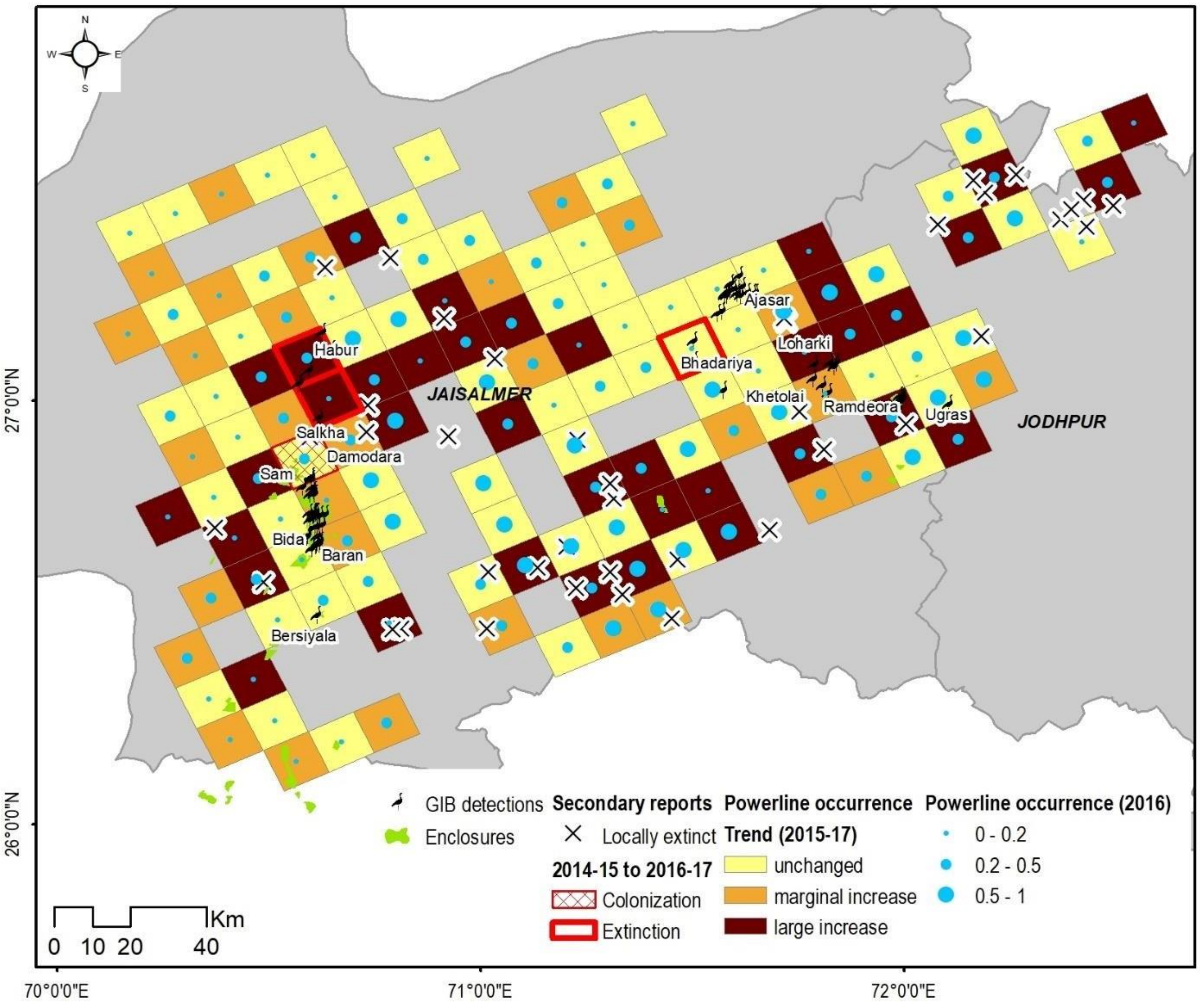
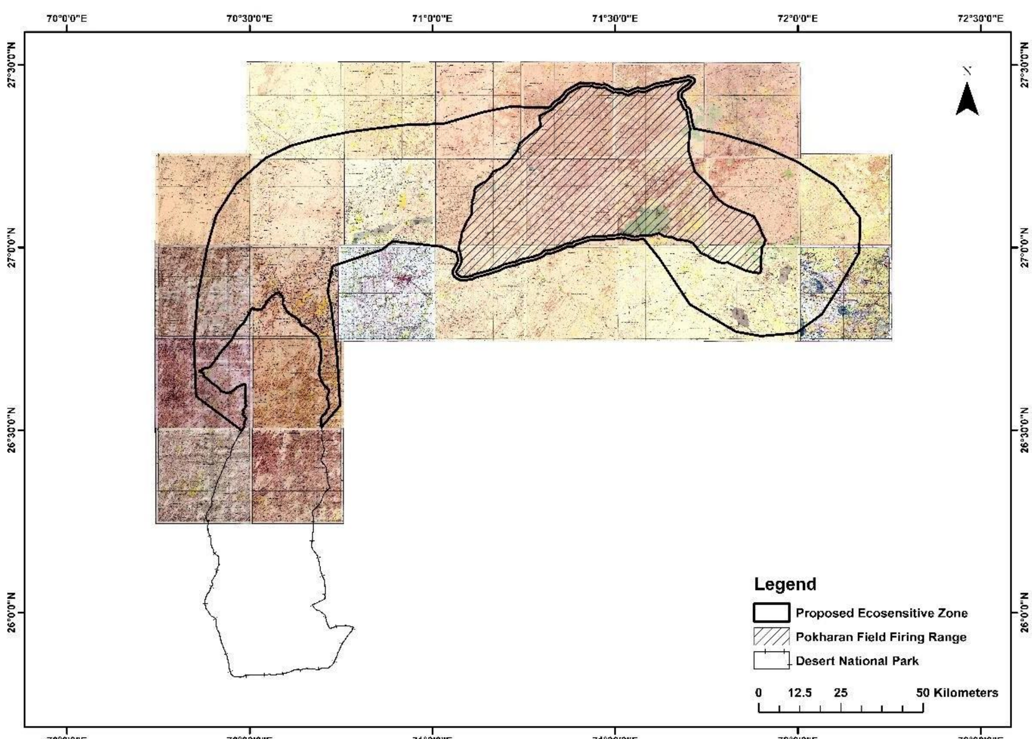


Table 4 Mean (95% CI) of current status and recent trend of putative habitat variables in 144 km² cells where great Indian bustard currently occurs (occupied), occurred 10 years back but not now (extinct) and never occurred (unoccupied) in Thar landscape, based on secondary reports during 2016-17 surveys

	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	

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