Status of Great Indian Bustard and Associated Fauna in Thar

Survey Report 2014 & 2015

Wildlife Institute of India
&
Rajasthan Forest Department

Survey Team

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Executive Summary

Arid ecosystems of India support unique biodiversity and traditional agro-pastoral livelihoods. But, they are highly threatened due to land-use mismanagement and neglect of conservation policies. The Critically Endangered great Indian bustard (GIB) acts as a flagship and indicator of this ecosystem, for which the Government is planning conservation actions that will also benefit the associated wildlife. Persistence of this species critically depends on the Thar landscape, where ~75 % of the global population resides. Yet their status, distribution and ecological context remain poorly understood.

This study assessed the status of GIB, chinkara and fox alongside their habitat and anthropogenic pressures across ~20,000 km^2 of potential bustard landscape in Thar spanning Jaisalmer and Jodhpur districts of Rajasthan. Systematic surveys were conducted in 144 km^2 cells from slow-moving vehicle along $16 \pm 3_{SD}$ km transects to record species' detections, habitat characteristics in sampling plots, and secondary information on species' occurrence. Multiple teams comprising field biologists and Forest Department staff simultaneously and rapidly sampled 108 cells along 1697 km transects in March 2014 and 77 cells along 1246 km transects in March 2015. Species' detection data were analyzed in Occupancy and Distance Sampling framework to estimate proportion of sites used and density/abundance of key species.

Our key findings were that GIB used $18 \pm 6_{SE}$ % of sites, although secondary information obtained from local community using questionnaires indicated usage in 34 % of sites. Bird density was estimated at $0.86 \pm 0.35_{SE}$ /100 km^2, yielding abundance estimates of $133 \pm 55_{SE}$ in the sampled cells (15,552 km^2) and $169 \pm 70_{SE}$ birds in Thar landscape (19,728 km^2 area). During the survey, ~38 (2014) and ~40 (2015) individual birds were detected. Bustard-habitat relationships, assessed using multinomial logistic regression, showed that disturbances and level of protection influenced distribution in this landscape. Chinkara used $92 \pm 3_{SE}$ % of sites at overall density of $375 \pm 41_{SE}$ animals/100 km^2 and abundance of $73{,}976 \pm 8145_{SE}$ in the landscape. Desert and Indian fox used $60 \pm 7_{SE}$ % of sites, at densities of $24.07 \pm 5.02_{SE}$ desert fox/100 km^2 and $1.23 \pm 0.68_{SE}$ Indian fox/100 km^2, and abundances of $4{,}749 \pm 989_{SE}$ desert fox and $243 \pm 135_{SE}$ Indian fox in the landscape. Nineteen percent of sampled cells were found to be of high conservation value, out of which, 75 % cells were outside Protected Area. Although some of them benefit from community or Army protection, majority are threatened by hunting and unplanned landuses.

This study provides robust abundance estimates of key species in Thar. It also provides spatially-explicit information on species' distribution and ecological parameters to guide site-specific management and policy. Thar supports the largest global population of GIB and offers the best hope for its survival. This survey captured snapshots of GIB distribution that needs to be augmented with landscape-scale seasonal use information using satellite telemetry to prioritize areas for conservation investment.

1. Introduction

The great Indian bustard (*Ardeotis nigriceps*) is Critically Endangered (IUCN 2011) with less than 300 birds left. Rajasthan State in India holds the largest population and prime hope for saving the species (Dutta et al. 2011). As the range States across the country are developing species' recovery plans (Dutta et al. 2013), baseline information on current distribution, abundance and habitat relationships are scanty. Such information are essential for conservation planning and subsequently assessing the effectiveness of management actions. Great Indian bustard inhabit open, semiarid 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 can be replicated, incorporate imperfect detection, and allow statistical extrapolation of estimates to non-sampled areas. However, the extreme rarity of bustards makes precise estimation of population abundance difficult and logistically demanding. Through repeated surveys during March 2014 and 2015, 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.

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

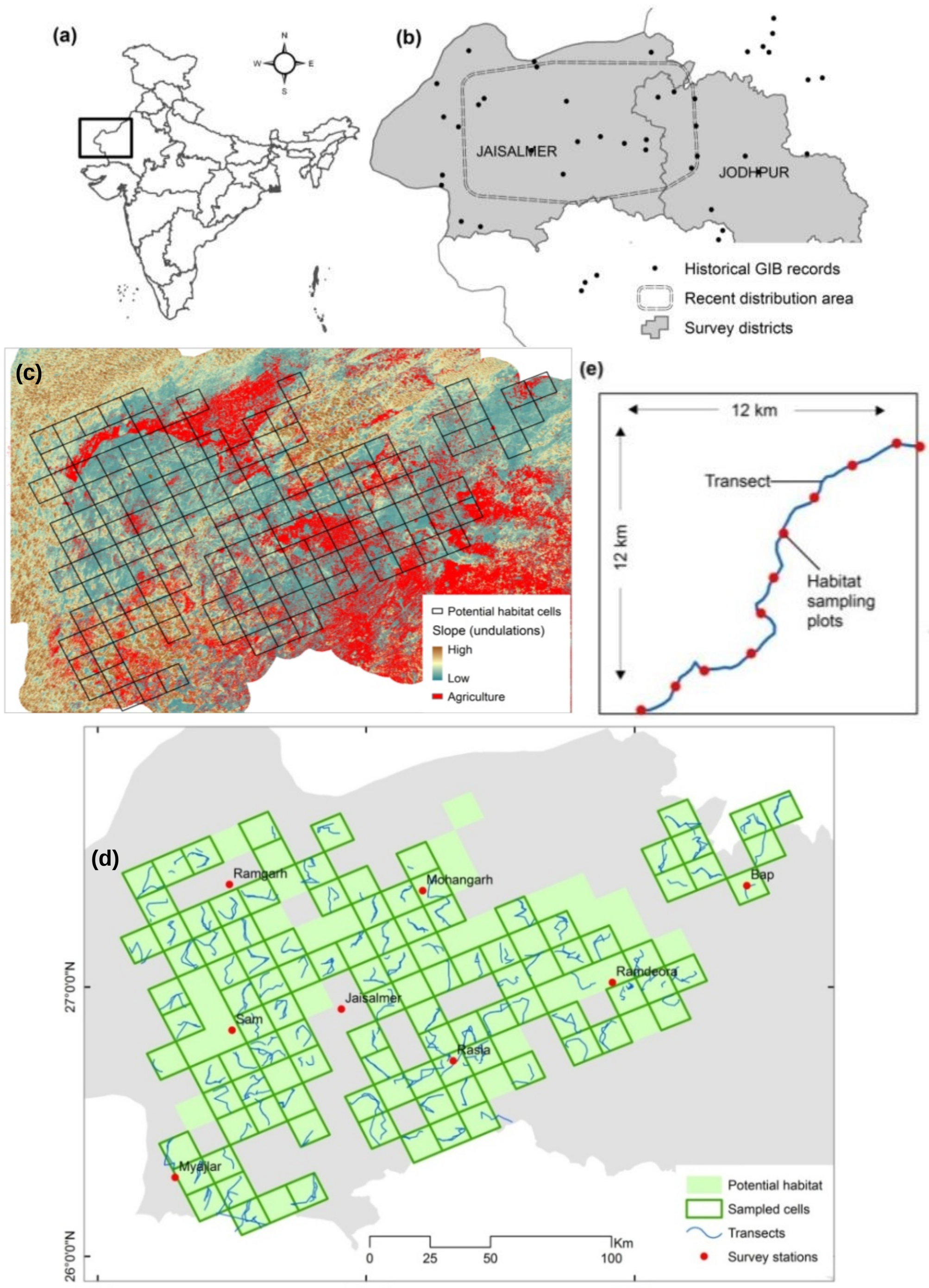
2. Thar landscape

The potential great Indian bustard landscape in Thar was identified in a stepwise manner. Past records (post 1950s) of great Indian bustard in western Rajasthan were collated (Rahmani 1986; Rahmani and Manakadan 1990) and mapped. The broad distribution area was delineated by joining the outermost locations, and 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 20,000 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*, 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 km²) has been declared as Desert National Park (Wildlife Sanctuary), which is not inviolate and includes 37 villages (Rahmani 1989).

Figure 1 Sampling design for great Indian bustard population and habitat assessment in Thar landscape (2014-2015): 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 which were simultaneously surveyed by 18 teams during March 22-26, 2014 and by 17 teams during March 21-25, 2015. This enabled us to cover such large expanse within brief time period in order to minimize bird/animal movements between survey areas. The sampling blocks were named after their respective field-stations, as: a) Ramgarh, b) Mohangarh, c) Bap, d) Ramdeora, e) Rasla, f) Myajlar, and g) Sam-Sudasari. Two-three teams operated for four-five days in each of these blocks. Each team comprised of a researcher/volunteer and two Forest Department guards adept with the locality. Field activities in a sampling block were supervised by a research biologist from the Wildlife Institute of India with many years of field experience on wildlife surveys. Team members were trained through workshops and field exercises on a standardized data collection protocol for two days prior to block surveys. Data collected by different teams were collated after the completion of surveys and analyzed.

3.2. Sampling design

Species and habitat status were assessed using extensive vehicle transects in a systematic sampling design. A grid of 137* cells, each 144 km^2 in size (12 km x 12 km), were overlaid on the potential great Indian bustard habitat (covering 19,728 km^2) and realized on ground by handheld GPS units and Google Earth imageries. Subsequently, 108* cells were randomly selected for sampling in 2014, out of which 77 cells were resampled in 2015. Cells were surveyed along dirt trails of $16.2_{\text{Mean}} \pm 3.4_{\text{SD}}$ km length (single continuous or two broken transects) from a slow moving (10-20 km/hr) vehicle on each occasion. 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 the combination of cell-size and transect length required to cover ≥10 % of cell-area (assuming that species' would be effectively detected within ~250m strips, following Dutta 2012) given our target (systematic coverage of ≥70 % area) and logistic constraints (six days, eight hours/day and 18 teams were feasible).

* Earlier, 25,500 km^2 area was considered potentially suitable and 177 grid-cells were overlaid, out of which, 118 cells were sampled (Dutta et al 2014). Subsequently, as more refined information on habitat and species' distribution became available in 2015, 40 of these cells, inclusive of 10 sampled cells, were considered unsuitable and dropped from sampling/analysis

3.3. Data collection

3.3.1. Species' information

Data on Great Indian Bustard, key associated species (desert fox, Indian fox, chinkara and nilgai *Boselaphus tragocamelus*), 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 recorded. Distances were measured through calibrated visual assessment in broad class-intervals (0-10, 10-25, 25-50, 50-100, 100-150, 150-200, 200-300, 300-400, 400-600 & 600-1000 m) to reduce inconsistency of observation errors between teams. 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). The dominant land-cover type (barren/agriculture/grassland/scrubland/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 (only during 2015) 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 100-m radius (2014) and 500-m radius (2015) 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. Secondary information

Secondary information on bustard and associated species were collected from $3.04_{Mean} \pm 1.81_{SD}$ respondents/cell in 2014 and opportunistically in 2015, preferably from adults and agro-pastoralists with local knowledge (datasheet in appendix 3).

3.4. Data analysis

3.4.1 Population status

Density/abundance and (as a cheaper alternative) occupancy/use are commonly used parameters to assess population status. Species' density was estimated using Distance sampling and analysis in program DISTANCE (Thomas et al. 2010). This technique modeled the declining probability of detecting individual(s) with distance from transect, wherefrom effective detection/strip width ($\overline{ESW}$) and effective sample area ($\overline{ESA}$) were derived. This metric was used to convert encounter rate (count/transect-length averaged across cells) into density estimate ($\overline{D}$) (demonstrated in the footnote, also see Buckland et al. 2001). Subsequently, species' abundances in sampled cells and potential landscape were estimated by multiplying the density estimate with the respective areas. Great Indian bustard sightings on extensive surveys were inadequate for robust estimation of detectability. To circumvent this issue, we had earlier developed detection function using dummy birds in blind tests (Dutta et al. 2014). In 2015, we intensively sampled seven randomly selected cells used by great Indian bustard following similar protocol as our extensive survey. The only difference was that multiple teams simultaneously surveyed different portions of these cells on two occasions. This increased the sightings, allowing direct estimation of detectability from actual bird sightings. For each species, effective strip width was estimated by pooling observations across years since detectability was unlikely to differ annually. We tested for difference in species' encounter rates between years, and since there was no statistical difference (see Results), we obtained pooled density estimate using data from both years. This was also ecologically reasonable since the time-frame was too short for any detectable change in the species' populations. For feral dogs and livestock, mean ± SE of encounter rates across cells were estimated.

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

The proportion of sites used by a species (i.e., its asymptotic occupancy integrated over time, see Efford and Dawson 2012) was estimated using Occupancy analysis in program PRESENCE (Mackenzie et al. 2006). This technique accounts for the probability of missing species present at a site by using detection data from repeated surveys at sites, thereby yielding more accurate estimates of occupancy. We treated the combined length of transects in a cell as a site/plot, and generated detection/non-detection matrix from species' sightings within 2 km transect-segments across two years (spatio-temporal replicates). This was used to estimate asymptotic occupancy following the traditional model of Mackenzie et al (2003) that assumes constant detection probability (across replicates) and occupancy (across sites)*. For spiny-tailed lizard, we used burrow detection in 10 m radius plots to estimate occupancy.

3.4.2. Habitat status and use

Habitat characteristics of a cell were summarized from covariate data collected at $15_{\text{Mean}} \pm 5_{\text{SD}}$ sampling plots along extensive transects in two years. a) For categorical covariates (land-cover and substrate types), frequency of occurrence of each category (in percentage) was estimated. Terrain types were scored as '1' for extreme level of that category (e.g., extremely flat), '0.75' for moderate level (e.g., moderately flat), '0.5' if there were two co-dominant types (e.g., flat-undulating mix), otherwise '0'. These values were averaged across plots to generate an index of prevalence for each terrain type. b) For interval covariates (vegetations structure), mid-values of class-intervals were averaged across plots. c) Vegetation composition was characterized from the frequency of occurrence (%) of dominant plant taxa across plots. c) Disturbance covariates were grouped into: infrastructure intensity – measured as summed occurrence of metal road, power lines and wind turbines; and human incidence – measured as summed occurrence of settlement (weighted twice) and farm hut. 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.

Great Indian bustard occurrence pattern was examined by modeling its presence (sighting or confirmed signage) and secondary report vs. absence (reference category)

* The alternate formulation of Hines et al. (2010) that accounts for spatial correlation of detections was not used since the detections were based on spatial and temporal surveys for estimating "use"

on potential habitat covariates at the cell-level using multinomial logistic regression in program SPSS (Quinn and Keough 2002). Among the covariates collected, the following were selected as potentially important for explaining bustard occurrence based on our ecological understanding: 1) flat or 2) undulating [terrain]; 3) grassland, 4) woodland or 5) agriculture [land-cover]; 6) rock/gravel or 7) sand [substrate]; 8) human incidence in 100m , 9) infrastructure intensity in 100m, and 10) grazing intensity (livestock encounter rate Animal Units/km) [disturbances]; and 11) mean distance to enclosure [protection]. Some of the covariates were inter-correlated (see Results), which could complicate interpretations of regression parameters (Graham 2003). After inspecting the data, Principal Component Analysis (Quinn and Keough 2002) was carried out on terrain, substrate and land-cover covariates in program SPSS that extracted synthetic components to surrogate prominent and independent habitat gradients. A global model incorporating the habitat components, disturbance and protection covariates and its ecologically meaningful subset models were built. These models were compared using Information Theoretic approach (Burnham and Anderson 2002) and goodness-of-fit statistic (R^2) to draw inferences on factors influencing bustard distribution.

3.4.3. Spatially explicit information on ecological parameters

Spatially explicit information on species and habitat status help prioritize conservation areas and target management. Surface maps of habitat covariates were generated by kriging values (Baldwin et al. 2004) from sampled cells in program ArcMap (ESRI 1999-2008). Species' encounter rates were also mapped across cells. Cells were prioritized for conservation management based on the combined population status of great Indian bustard, chinkara and fox. We ranked the status of bustard as: 0 (not detected), 1 (secondary report), or 2 (sighting) and that of chinkara and fox as: 0 (1^{st}–2^{nd} quartiles of encounter rate), 1 (3^{rd} quartile of encounter rate), or 2 (4^{th} quartile of encounter rate). These ranks were weighted by species' endangerment level (3 for bustard, 2 for chinkara and 1 for fox) and summed to generate a conservation priority index. Based on this index, cells were classified as 'low' (1^{st}–2^{nd} quartiles of index), 'medium' (3^{rd} quartile) and 'high' (4^{th} quartile) priority to guide judicious investment of conservation efforts.

4. Results and Findings

4.1. Population status

Total 108 cells covering 15,552 km^2 area was surveyed along 1697 km transect in 2014. Out of these, 77 cells covering 11,088 km^2 area was resurveyed along 1246 km transect in 2015 (figure 1). Data generated from these surveys provided estimates of species' occupancy, density and abundance.

4.1.1. Great Indian Bustard

Surveys conducted during 22–26 March, 2014 and 21-25 March, 2015 recorded minimum 34-43 and 38-42 unique great Indian bustards (encompassing errors due to double counting) respectively, comprising observations along transects and those enroute or while returning from sampling cells. Twelve flocks were detected on extensive transects (2014-2015) at encounter rate of 0.41 ± 0.16_{SE} flocks/100km. There was no statistical difference between the encounter rates of 2014 (0.35, 0-$0.80_{95\%CI}$ flocks/100km) and 2015 (0.50, 0-$1.00_{95\%CI}$ flocks/100km). Supplementing this data with intensive transects in used cells yielded a total of 33 flocks. Flock size estimated from extensive and intensive transects was 1.97 $\pm$ 0.19_{SE} individuals. All detection models tested on distance data pooled from extensive and intensive transects (half-normal, hazard-rate and uniform functions) obtained similar support (ΔAIC<1). Based on the least number of model parameters and the highest goodness-of-fit, we selected the half-normal detection function (χ^2=0.92, df=2, p=0.63). It estimated flock detection probability and effective strip width at 0.48 ± 0.05_{SE} and 476 ± 52_{SE} m, respectively (figure 2). Our detectability experiment based on dummy birds in 2014 returned a similar effective strip width of 423 $\pm$ 120_{SE} m. Incorporation of detection probability in bustard encounter rates on extensive transects returned density estimate of 0.86 ± 0.35_{SE} birds/100km^2 and abundance estimate of 133 ± 55_{SE} in sampled cells (15,552 km^2). Extrapolation of this density to the potential landscape area (19,728 km^2) yielded estimate of 169 ± 70_{SE} birds*. Great Indian bustard was detected in 9 cells or 8.3 % of sites (naïve occupancy). The probability of detecting at least one bustard along 2 km transect-segment was 0.04 ± 0.01. Detection corrected proportion of sites used by great

* This is statistically similar to the earlier estimate (Dutta et al. 2014) but should be treated as more robust since it is based on larger sample size considering similar abundance between years

Indian bustard (asymptotic occupancy) during two years was estimated at 0.18 ± 0.06. Supplementing this with interviews of local people (bird records in last 3 months) and our auxiliary surveys (February-June 2014 & 2015) indicated some level of great Indian bustard usage in 38 (34 %) sampled cells (figure 3).

4.1.2. Chinkara

During extensive surveys of 2014-2015, 887 chinkara herds were detected at encounter rate of $30.17 \pm 2.79_{SE}$ herds/100km and herd size of $2.92 \pm 0.11_{SE}$ individuals. There was no statistical difference between encounter rates of 2014 (30.5, $23.0\text{-}38.0_{95\%CI}$ herds/100km) and 2015 (29.7, $21.8\text{-}37.7_{95\%CI}$ herds/100km). Hazard-rate detection function fitted the distance data best ($\chi^2=7.23$, df=5, p=0.20) that estimated herd detection probability and effective strip width at $0.10 \pm 0.006_{SE}$ and $117 \pm 5_{SE}$ m, respectively (figure 2). Chinkara density was estimated at $375 \pm 41_{SE}$ animals/100km^2, yielding abundance estimates of $58{,}317 \pm 6421_{SE}$ in sampled cells and $73{,}976 \pm 8145_{SE}$ in the landscape. Chinkara was detected in 91 % cells (naïve occupancy) (figure 4). The probability of detecting a chinkara along 2 km transect-segment was $0.32 \pm 0.01_{SE}$. Detection-corrected proportion of sites used by chinkara was estimated at $0.92 \pm 0.03_{SE}$.

4.1.3. Fox

During extensive surveys of 2014-2015, 101 desert fox and 6 Indian fox were detected along transects at encounter rates of $3.42 \pm 0.53_{SE}$ individuals/100km and $0.18 \pm 0.09_{SE}$ individuals/100km, respectively. There was no statistical difference between the encounter rates of 2014 (3.99, $2.62\text{–}5.36_{95\%CI}$ [desert fox] and 0.23, $0\text{-}0.46_{95\%CI}$ [Indian fox]) and 2015 (2.62, $1.14\text{-}4.10_{95\%CI}$ [desert fox] and 0.11, $0\text{-}0.34_{95\%CI}$ [Indian fox]). Both species were observed mostly solitarily (12 % sightings were in pairs), yielding group size estimate of $1.14 \pm 0.04_{SE}$ individuals. Since these species have similar body size and behaviour, a common detection function was built. Hazard-rate detection function fitted the distance data best ($\chi^2=4.13$, df=4, p=0.39) that estimated detection probability and effective strip width at $0.16 \pm 0.02_{SE}$ and $71 \pm 10_{SE}$ m, respectively (figure 2). Species' densities were estimated at $24.07 \pm 5.02_{SE}$ desert fox/100km^2 and $1.23 \pm 0.68_{SE}$ Indian fox/100km^2. Accordingly, their abundances were estimated at 3743 ± 780$_{SE}$ (desert fox) and 192 ± 106$_{SE}$ (Indian fox) in the sampled cells, while 4749 ± 989$_{SE}$ (desert fox) and 243 ± 135$_{SE}$ (Indian fox) in the landscape area. Fox (pooling both species) was detected in 43 % of transects (naïve occupancy) (figure 5). The probability of detecting fox on a 2km transect-segment was 0.09 ± 0.01$_{SE}$. Detection-corrected proportion of sites used was estimated at 0.60 ± 0.07$_{SE}$.

Figure 2. Detection functions relating probability of detecting individual with perpendicular distance from transect for great Indian bustard, chinkara and fox in Thar landscape during 2014-15

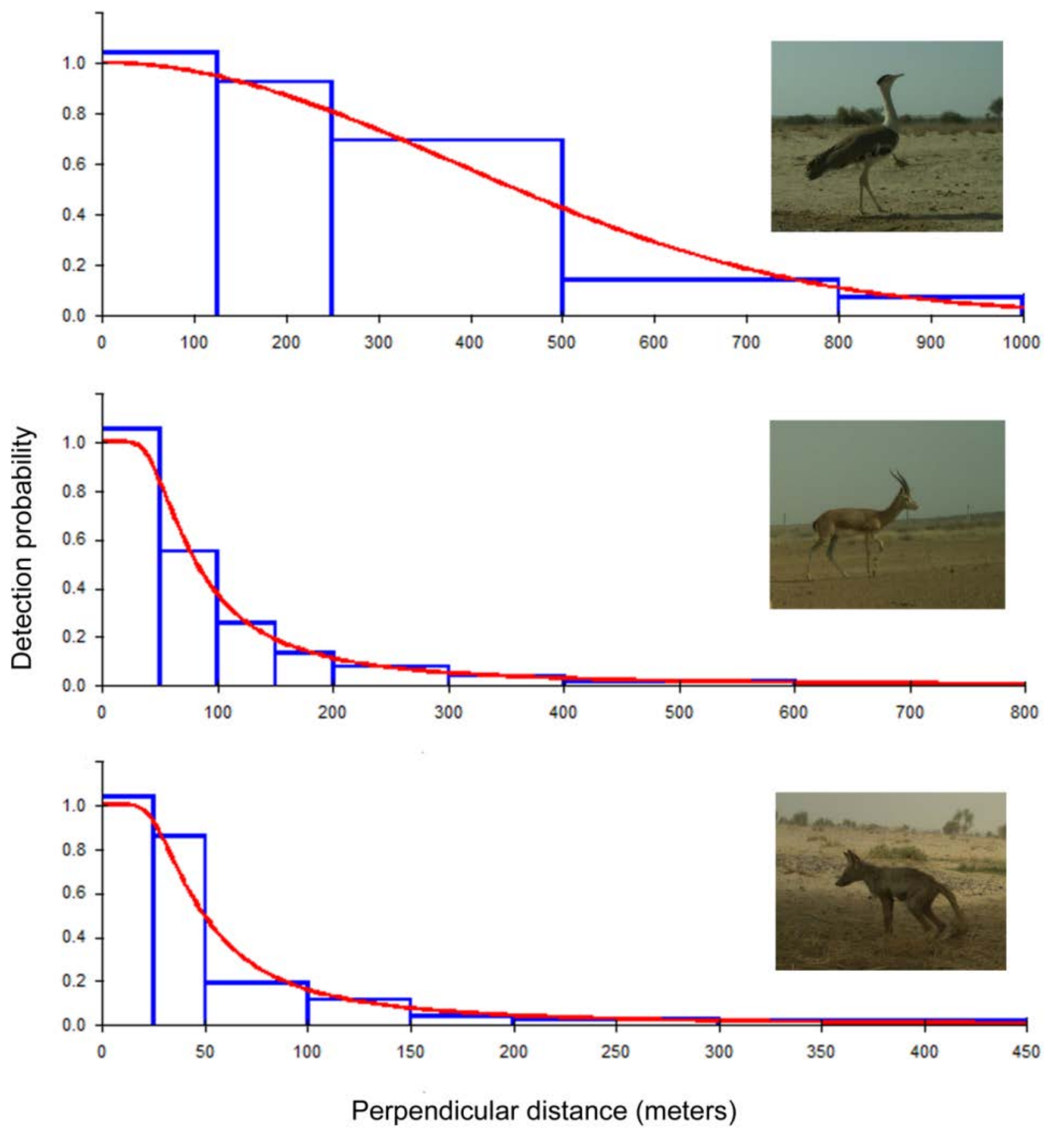


Figure 3. Great Indian bustard occurrence status in 144 km² cells based on surveys (primary data) and reports by local people (secondary data) in Thar landscape (2014-2015)

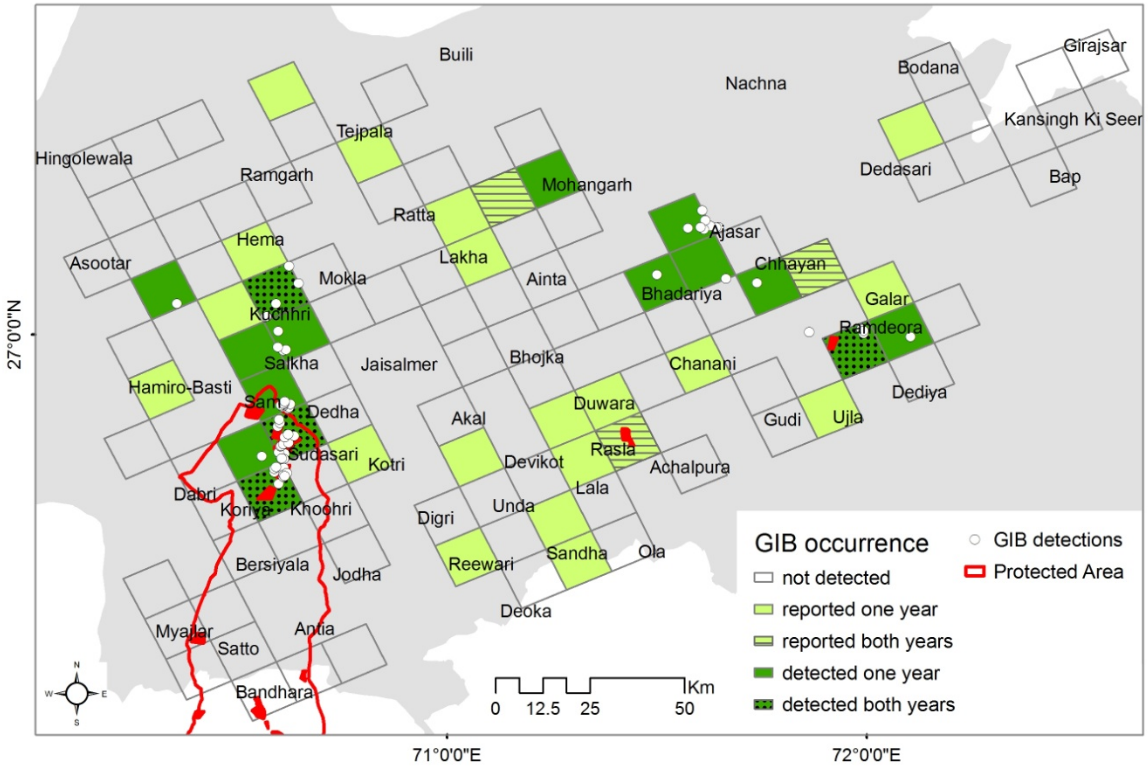


Figure 4. Chinkara encounter rates in 144 km² cells of Thar landscape (2014-2015)

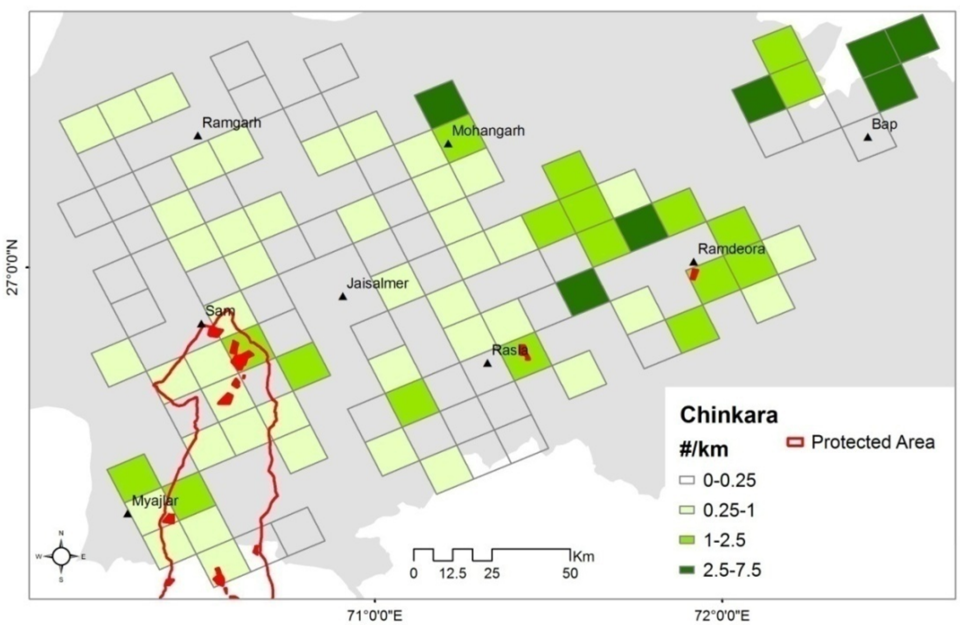
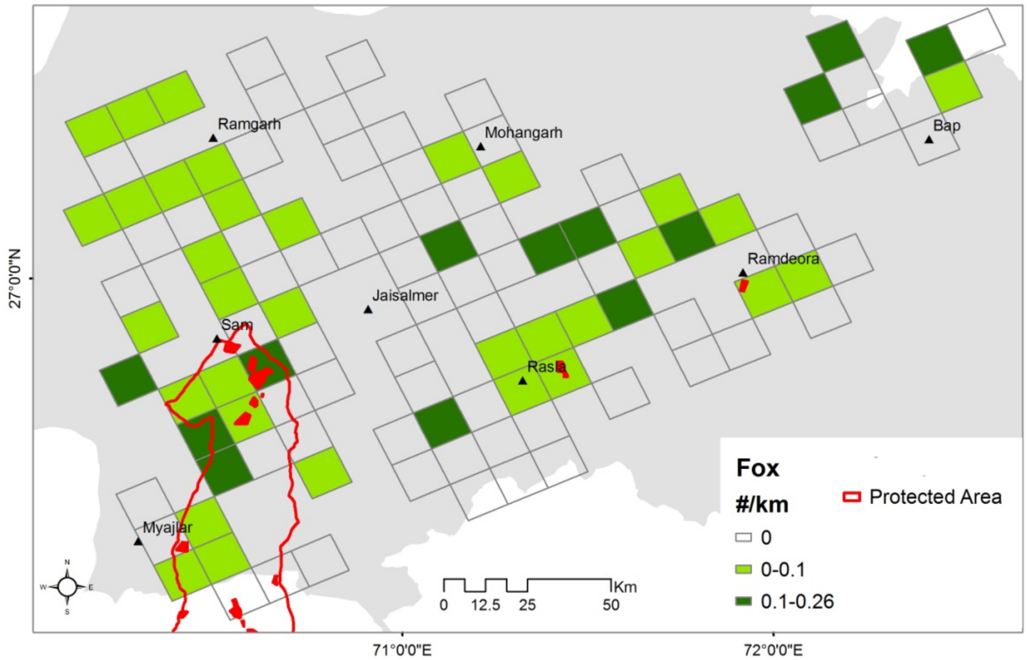


Figure 5. Fox encounter rates in 144 km² cells of Thar landscape (2014-2015)



4.1.3. Other fauna

Our extensive surveys of 2014-2015 also yielded sightings of nilgai (26 groups of 4.79 ± 0.96_{SE} individuals at encounter rate of 3.84 ± 1.25_{SE} individuals/100km) and pig *Sus scrofa* (4 groups of 9.50 ± 3.14_{SE} individuals at encounter rate of 1.15 ± 0.77_{SE} individuals/100km) (figure 5). Spiny-tailed lizard burrows were detected in 7.6 $\pm$ 1.2_{SE} % plots. Sightings of domestic animals included 121 dogs (encounter rate 4.12 ± 0.92_{SE} /100km), 11,753 cattle (371.94 ± 52.08_{SE} /100km) and 42,015 sheep and goat (1300.04 ± 105.94_{SE} /100km). Livestock was converted into Animal Units and their encounter rates were mapped to surrogate grazing intensity for identifying areas of high overlap between wild and domestic species (figure 6).

4.1.4. Conservation Prioritization

Conservation priority index, generated from population status of key species in 144 km² cells, ranged between 0-12. On classifying this range into three ranks (low: 0-3, medium: 3-6, and high: 6-12), 19 % of sampled cells (20) were attributed high priority and 81 % cells (88) were attributed low and medium priority for conservation (figure 7).

Only 25 % (5 cells) of high priority cells had some fraction of area within protective enclosures owned by Forest Department (Sam, Sudasari, Gajaimata, Rasla, and Ramdeora). Whilst unprotected habitats adjoining villages Pithala and Kanoi-Salkha-Habur near Jaislamer, Nathoosar, Chanani, Ugras, Galar, Chhayan, Ajasar-Keroo and Bhadariya near Ramdeora, Mohangarh and Dhaleri also have high conservation value.

Figure 5. Other ungulate (nilgai & pig) occurrence in 144 km² cells of Thar landscape (2014-2015)

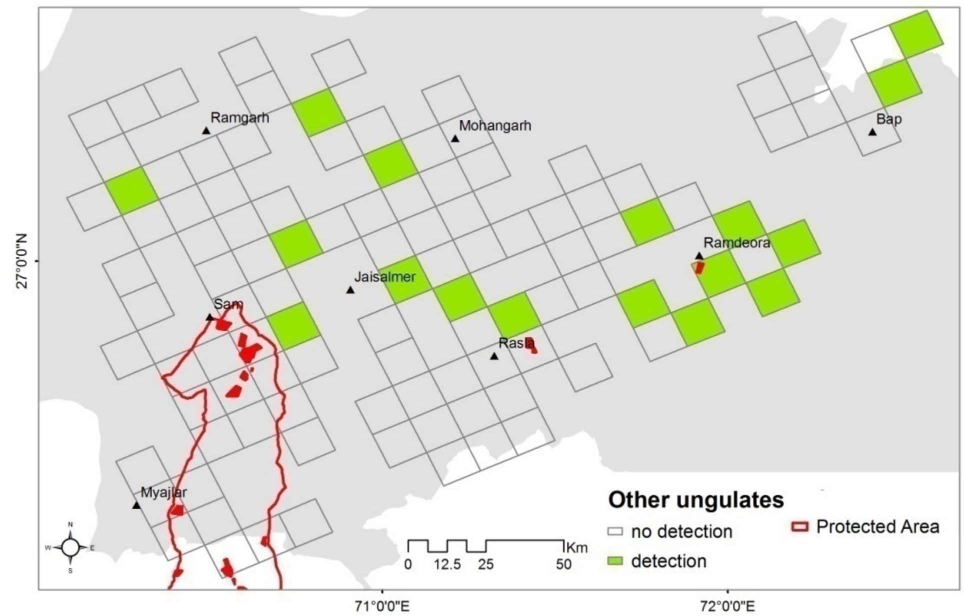


Figure 6. (a) Livestock and (b) dog detections rates in 144 km² cells of Thar landscape (2014-15)

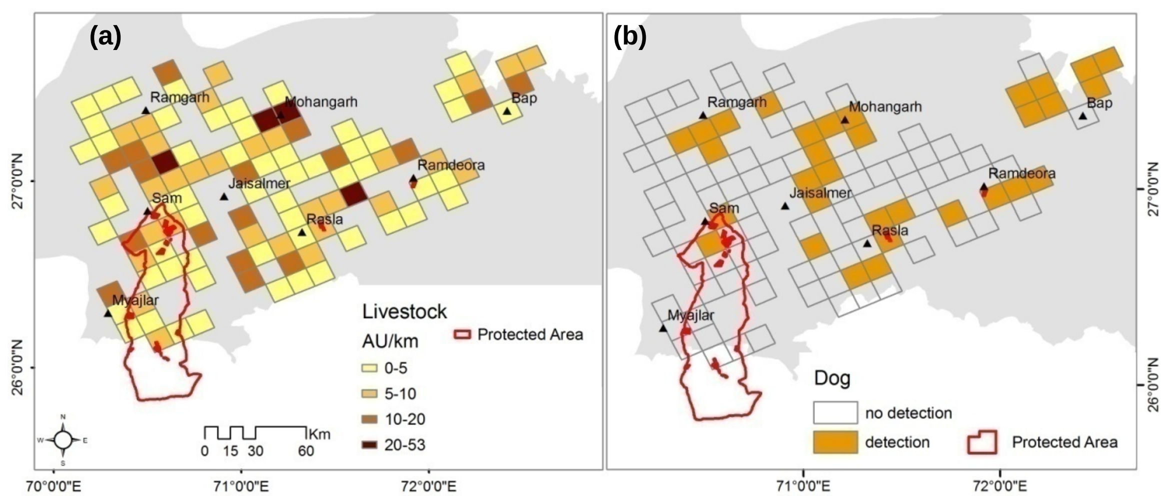
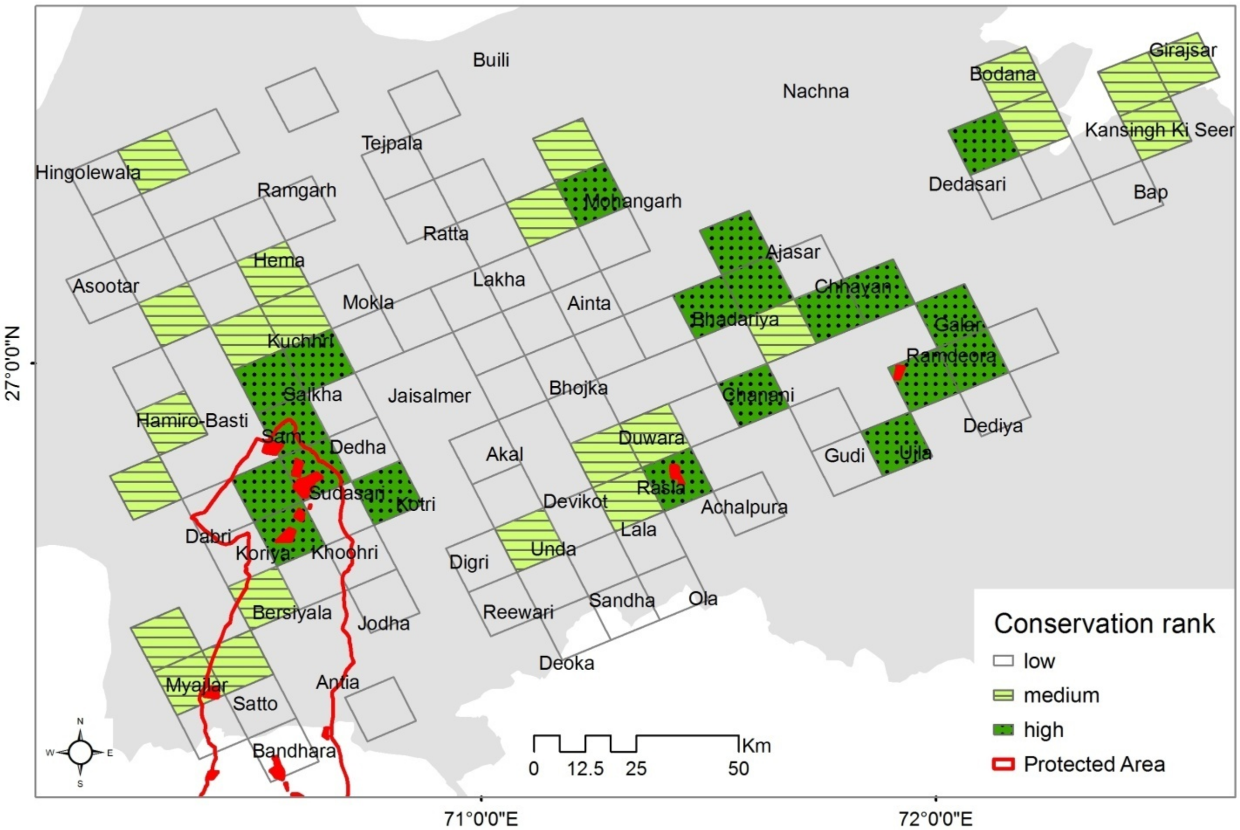


Figure 7. Conservation priority index of 144 km² cells in Thar landscape (2014-15)



4.2. Habitat status and use

Habitat characterization along transects showed that the sampled area was dominated by: a) flat followed by undulating terrain; b) soil followed by sand substrate; c) scrub/wood- land followed by grassland and agriculture land-cover; and d) relatively even mix of short grass, shrubs and tall grass (vegetation structure). The woody vegetation was dominated by *Capparis* > *Calotropis* > *Leptadenia* > *Aerva* ~ *Zizyphus* > *Acacia* ~ *Prosopis cineraria* ~ *Prosopis juliflora* species, while the herbaceous vegetation was dominated by *Lasiurus* ~ *Dactyloctenium* (table 1). Among disturbance covariates, some forms of human presence (settlements or farm-huts) and infrastructure (metal roads, power-lines, and wind-turbines) were found within 500m radius of 52.4 $\pm$ 3.1 % and 49.2 $\pm$ 3.4 % of plots, respectively.

Table 1. Descriptive statistics of habitat covariates in 144 km² cells of Thar landscape (2014-2015)

Factor	Covariate	Measurement	Mean	SE	Median
Terrain	Flat	Prevalence of a category in 100m radius plot, scored as 0 (absent)-1 (dominant) and averaged across plots within cell [index]	0.49	0.02	0.50
	Sloping		0.08	0.01	0.04
	Undulating		0.27	0.02	0.22
Substrate	Rocky/Gravel	Frequency of occurrence of the category in 100m radius plots within cell [proportion]	0.18	0.02	0.13
	Sand		0.33	0.03	0.26
	Soil		0.50	0.02	0.50
Land-cover	Barren	Frequency of occurrence of the category in 100m radius plots within cell (sum > 1 due to co-dominant categories)	0.12	0.01	0.06
	Agriculture		0.28	0.02	0.26
	Grassland		0.33	0.02	0.30
	Woodland		0.19	0.02	0.16
	Scrubland		0.19	0.02	0.13
Vegetation structure	Short grass (<30cm)	Percentage cover of vegetation type in 20m radius plots within cell	15.23	0.86	13.05
	Tall grass (>30cm)		10.16	0.79	7.59
	Shrub (<2m)		12.10	0.70	9.94
	Tree (>2m)		6.57	0.43	5.55
Vegetation composition	*Capparis*	Frequency of occurrence (%) of dominant plant in 100m radius plot within cell [dominance index]	0.43	0.03	0.44
	Calotropis		0.31	0.03	0.25
	Leptadenia		0.22	0.03	0.11
	Aerva		0.17	0.03	0.00
	Lasiurus		0.17	0.03	0.00
	Dactyloctenium		0.16	0.03	0.00
	Zizyphus		0.15	0.02	0.07
	Acacia		0.11	0.02	0.00
	Prosopis cineraria		0.11	0.02	0.00
	Prosopis juliflora		0.10	0.02	0.00
	Zygophyllum		0.08	0.02	0.00
	Salvadora		0.08	0.02	0.00
	Calligonum		0.04	0.01	0.00
Human artifacts	Human incidence	Summed occurrence of settlement (weight 2) and hut (weight 1) in 100m radius [index]	0.46	0.04	0.40
		Summed occurrence of settlement (weight 2) and hut (weight 1) in 500m radius [index]	0.96	0.07	0.83
	Infrastructure intensity	Summed occurrence of power-lines, roads & wind-turbines in 100m radius [index]	0.30	0.03	0.20
		Summed occurrence of power-lines, roads & wind-turbines in 500m radius [index]	0.74	0.06	0.63
	Water	Occurrence of water in 100m radius [proportion]	0.06	0.01	0.00

There was some inter-correlation between the covariates that were considered potentially important for explaining bustard occurrence (table 2). Principal Component Analysis (PCA) on the terrain, substrate and land-cover covariates extracted three components, cumulatively explaining 77 % of information in the data. Of these, two components were considered important for great Indian bustard: one surrogated undulating, sandy (negative value) versus flat (positive value) topography and the other surrogated grassy (negative) versus woody (positive) cover (table 3). There were distinct gradients of these potentially important covariates across the landscape (figure 8).

Table 2. Correlation between select habitat covariates in 144 km² cells of Thar landscape (2014-2015)

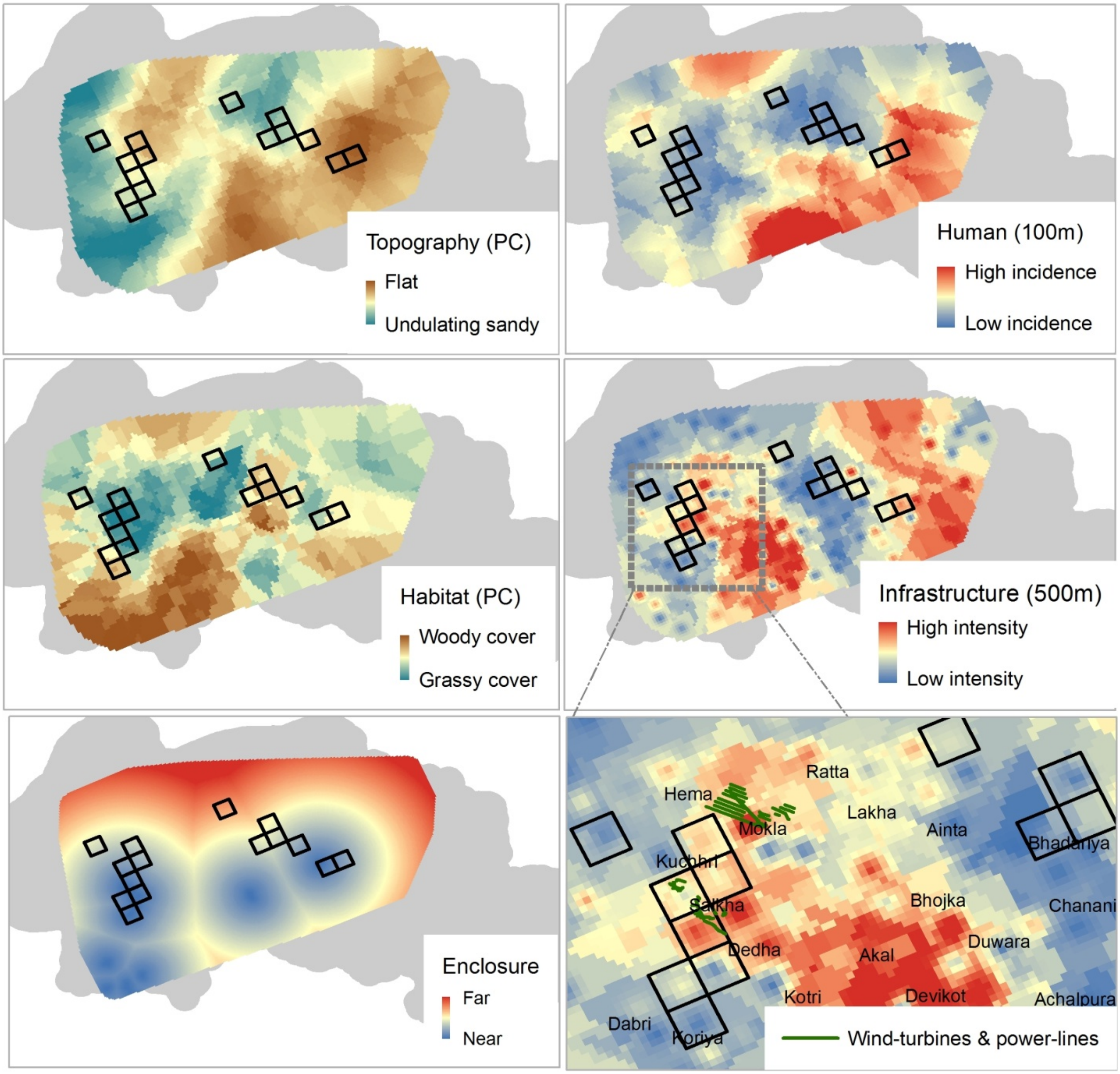
	Flat	Undl	RkGr	Sand	Agri	Grsl	Wood	HumI	InfI	GrzI	EncD
Flat		**-.88**	.04	**-.57**	**.39**	-.08	-.10	**.34**	.00	-.10	-.02
Undulating			-.02	**.55**	**-.38**	-.05	**.19**	**-.28**	-.07	.08	-.01
Rock/Gravel				**-.49**	**-.27**	-.05	.03	-.06	.17	-.06	**-.19**
Sand					**-.24**	.15	.00	**-.25**	**-.25**	-.04	.12
Agriculture						**-.31**	**-.31**	**.46**	.10	.00	**.24**
Grassland							**-.27**	**-.22**	-.11	.04	.17
Woodland								-.04	.18	.03	**-.23**
Human incidence									.14	.04	-.01
Infrastructure intensity										-.02	-.18
Grazing intensity											.11
Distance to enclosure											

Significant correlations ($p<0.05$) indicated in bold; strong correlations ($|r|>0.4$, $p<0.05$) shaded in grey

Table 3. Summary of Principal Component Analysis: covariate loadings, information explained, and ecological interpretation of extracted habitat components in Thar landscape (2014-2015)

Covariates	Principal Component 1	Principal Component 2	Principal Component 3
Flat	0.56		
Undulating	-0.55		
Rocky/ Gravel		0.67	
Sand	-0.47		
Agriculture		-0.41	
Grassland			-0.77
Woodland		0.44	0.43
Information explained (%)	38	21	18
Ecological interpretation	Undulating sand (-) vs. flat topography (+)	Agriculture (-) vs. rocky/gravely woodland (+)	Grass (-) vs. wood (+) cover

Figure 8. Important habitat gradients in Thar landscape (2014-2015), interpolated by kriging from covariates collected and analyzed at 144 km² cells



1. Open squares indicate cells where great Indian bustard was detected during surveys

2. Note the high concentration of infrastructure between western and eastern Thar landscapes that forms a potential barrier to bird movements, increases the chance of bird mortality through collisions with power-lines, and endangers the long-term persistence of great Indian bustard

Among the 15 alternate models postulated to explain great Indian bustard distribution, three models obtained maximum and comparable support from data (ΔAIC < 2, table 4a). These models incorporated disturbances (human incidence, infrastructure intensity and grazing intensity) and protection (distance to enclosure) with or without topography and land-cover. Out of these, the model with least number of parameters was selected for inference. Parameter estimates of this model (*Hum+Inf+Grz+Dst-enc*) indicated that bustard occurrence was determined by protection (declined with distance from enclosure) and disturbance (detections decreased with human incidence and infrastructure intensity but secondary reports were not related to disturbances). There was a positive association between great Indian bustard and grazing intensity, likely due to similar resource requirements (productive grasslands) by both taxa (table 4b).

Table 4. (a) Alternate hypotheses explaining distribution of great Indian bustard in 144 km² cells of Thar landscape, and (b) influence of important covariates on species' occurrence (primary & secondary data) analyzed using multinomial logistic regression (2014-2015)

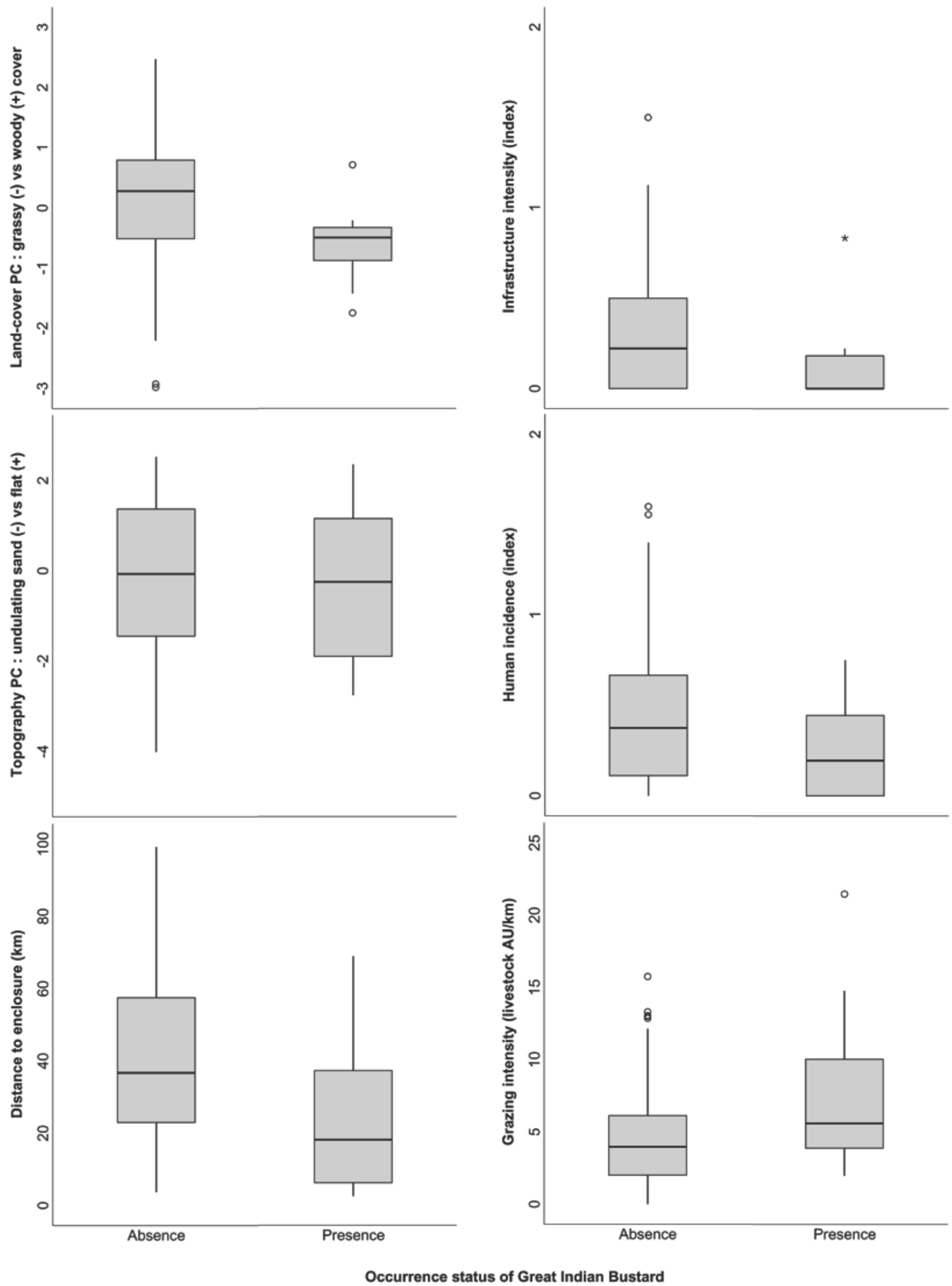
(a) Model	ΔAIC	AIC	Deviance	K	GOF-p	R^2	CC %
PC-top + Hum + Inf + Grz + Dst-enc	**0.00**	**162.51**	**138.51**	**12**	**0.95**	**0.44**	**75**
Hum + Inf + Grz + Dst-enc	**0.97**	**163.48**	**143.48**	**10**	**0.96**	**0.41**	**73**
PC-hab + PC-top + Hum + Inf + Grz +Dst-enc	**1.68**	**164.19**	**136.19**	**14**	**0.57**	**0.46**	**76**
PC-hab + Hum + Inf + Grz +Dst-enc	2.60	165.11	141.11	12	0.64	0.43	73
PC-top + Hum + Inf + Grz	11.50	174.01	154.01	10	0.86	0.33	71
Hum + Inf + Grz	11.69	174.20	158.20	8	0.87	0.30	71
PC-hab + PC-top + Hum + Inf + Grz	13.77	176.28	152.28	12	0.86	0.35	72
PC-hab + Hum + Inf + Grz	13.92	176.43	156.43	10	0.85	0.31	71
PC-hab + PC-top + Dst-enc	23.92	186.43	170.43	8	0.64	0.19	67
PC-hab + Dst-enc	24.52	187.03	175.03	6	0.51	0.14	67
PC-top + Dst-enc	25.70	188.21	176.21	6	0.49	0.13	68
Dst-encl	26.35	188.86	180.86	4	0.35	0.08	68
PC-hab + PC-top	29.68	192.19	180.19	6	0.64	0.10	68
PC-top	30.28	192.79	184.79	4	0.47	0.05	68
PC-hab	30.31	192.82	184.82	4	0.65	0.05	68

(b)	Primary data		Secondary data	
Covariate	$\hat{\beta}$	SE	$\hat{\beta}$	SE
Dst-encl	-0.062	0.022	-0.017	0.012
Hum	-3.223	1.519	0.641	0.598
Infra	-3.969	1.610	-0.444	0.801
Grz	0.218	0.064	0.181	0.057

Covariates
PC-top: undulating-sand (-) vs. flat (+) topography [Principal component]
PC-hab: grassy (-) vs. woody (+) land-cover [Principal component]
Dst-encl: Mean distance to protected enclosures (km)
Hum: Human incidence in 100m radius along transect
Infra: Infrastructure intensity in 100m radius along transect
Grz: Livestock encounter rate in Animal Units/km

Abbreviation: AIC (Akaike Information Criteria); K (parameters); GOF-p (Pearson χ2 p-value as a measure of model goodness-of-fit); R^2 (Nagelkerke's coefficient of determination); CC (Correct classification rate)

Figure 9. Box and whisker plots showing distribution of habitat covariates against occurrence status of great Indian bustard (absence vs. detection) in 144-km^2 cells of Thar landscape (2014-2015)



Occurrence of great Indian bustard and livestock grazing is highly correlated since both prefer similar habitat

5. Discussion

By adopting a standardized, spatially representative sampling and analysis design that accounts for imperfect detectability, we have generated robust population parameter estimates for the critically endangered great Indian bustard and its associated chinkara and desert fox in 20,000 km^2 potential bustard habitat of Thar landscape. These estimates are based on pooled data of March 2014 and 2015 since the time period is too short for any change in population that is also empirically evident from the similarity of encounter rates between years. Therefore, the pooled density/abundance should be considered as more robust than the earlier one (Dutta et al. 2014) because of larger sample size. Since these species are specialized to arid ecosystems, and critically depends on the Thar landscape, our estimates form the crucial baseline information to aide their conservation management.

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. Similarly, our extensive surveys detected 45_{Mean} % of the minimum number of birds present in seven intensively sampled cells (2015) that can be considered as a crude approximation of the proportion of birds in a cell detectable during conventional survey. Moreover, encounter rates of birds on repeated surveys within 18 days varied between 80-173 % among seven cells (2014). These facts emphasize that conventional counts miss substantial proportion of birds that can vary between sites. Our approach of estimating effective detection widths from dummy (2014) and actual birds (2015), that were found to be statistically similar, circumvents this problem and provides a robust framework to assess density/abundance from a sample of sites. Selection of sites following random sampling design allows unbiased extrapolation of this sample statistic into population density/abundance estimate.

The precision of our estimate is relatively poor, as can be expected for a species with extremely small population and patchy distribution across large landscape. Nonetheless, pooling samples from both years provided more precise estimate than the earlier one (Dutta et al. 2014). Precision of abundance estimate can be improved by using individual recognition (possibly by tagging birds and/or through molecular tools) based capture-recapture analysis at small spatial scales. A pilot study on this line is being carried out by the authors in Sam-Sudasari area. For the purpose of monitoring, we recommend replicating our surveys on an annual basis in cells with high conservation value that would allow reliable inferences on population trend. We caution readers against comparing the current abundance estimates (but not density estimates) of associated species to that reported in Dutta et al. (2014), since we have refined the expanse of potential bustard habitat during the latter survey.

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. Rahmani (1986) reported great Indian bustard sightings in/around Bap, Sam-Sudasari, Khuri-Tejsi, Khinya, Rasla and Sankara; whereas, we detected the species in/around Sam-Sudasari, Salkha, Ramdeora-Bhadariya-Ajasar-Loharki. Typical number of birds seen by respondents in their localities has also reduced from earlier times.

Our results on species-habitat relationships 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. The positive relationship between great Indian bustard and grazing intensity was an effect of correlation and not causation, since both taxa prefer similar habitat characteristics; productive grasslands (figure 9). 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. This proposition is supported by observations of great Indian bustards frequently using and breeding in Ramdeora enclosure after anthropogenic disturbances have been excluded from this site through fencing. It was also found that 75 % of priority conservation cells occurred outside of Desert National Park (figure 7). Although some of these areas benefit from protection by Bishnoi community (Bap-Ramdeora area) and inviolate space created for defense activities (Pokhran-Bhadariya-Loharki area), majority are threatened by hunting, development projects (e.g., wind power generation), and over-extraction of resources (e.g., livestock overgrazing). The cells of high conservation value should not have further infrastructural (power-lines, wind-turbines, buildings etc.) or agricultural development that can act as barriers to bird movements between them. The recent (2013) installation of wind-turbines and high tension power-lines between Sam-Sudasiri and Salkha areas is a severe threat to the persistence of great Indian bustard population as they increase the risk of electrocution and fatal collisions of the locally migrating birds. Thar landscape has already lost great Indian bustard from Mokla grasslands following the installation of wind-turbines and high tension power-lines therein in 2011. At least five instances of great Indian bustard mortality due to collision with power-lines have been reported from Kachchh and Solapur districts in the last decade. If the priority conservation cells are to be developed, it should be bustard-friendly such as underground power-lines and rainfed, organic cultivation of food crops.

However, these regulations need to be carefully enforced as the community responses to our questionnaires suggested general lack of support for bustard conservation and the possibility of antagonistic reactions. Effective conservation in Thar would require a multi-pronged approach that involves multiple stakeholders: 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

~7,000 km^2 expanse, comprehensive insights into their ranging patterns, using biotelemetry based research, are required for fine-tuning these conservation actions.

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 in its erstwhile distribution. In order to bring this landscape under the umbrella of Protected Area based conservation, a representative fraction (3162 km^2) was notified as sanctuary (the Desert National Park) in early 1980s. However, the Park authorities have control over only 4 % of this area (in the form of enclosures), leaving the remaining habitat beyond the scope of management as this land is not owned by Forest Department. The role of Forest Department in the rest of the Park has been viewed as anti-development, denying even basic amenities to local communities (73 villages), resulting in strong antagonism and poor conservation support for bustard and associated wildlife. Besides, the Park area encompasses a mere proportion of the priority conservation areas in Thar. Therefore, we strongly recommend rationalizing the Park boundary with the objectives of: a) notifying the northern Sam-Sudasari area (500 km^2) as National Park with appropriate relocation of villages; b) selectively declaring areas in priority conservation cells as Community/Conservation Reserves where human landuses can be regulated (e.g, habitats near Kanoi-Salkha-Habur, Nathoosar, Chanani, Ugras, Galar, Chhayan, Ajasar-Keroo, Bhadariya, Mohangarh and Dhaleri); and c) notifying areas equal to the denotified Park area (2600 km^2) as PA in the relatively less populated Shahgarh Bulge. This process has been initiated and will balance conservation and livelihoods by providing local people with basic amenities, gaining their support for conservation, and deterring commercial misuse of this landmass which is a hot spot for desert biodiversity.

In terms of management activities, we recommend:

a) Consolidating existing enclosures in bustard breeding areas using predator-proof chain-link fences (in Sam, Sudasari, Gajaimata, Rasla and Ramdeora).

b) Removing feral dogs, pigs and other 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.

c) 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.

d) Mitigating the 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 8) 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).

d) 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.

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

f) 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.

The key to conserve this vital yet neglected landscape is a combination of stringent protection measures, scientific habitat management, sensible landuse planning, and provisioning of basic amenities and livelihood options to local people (e.g., regulated ecotourism) in the priority conservation areas.

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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 (100m radius)	Substrate (100m radius)	Land-cover (100m radius)	Vegetation composition (% area in 20m radius)					3 dominant plants (100m radius)	*Sandha* Pr (10m radius)	Human structure (100m radius)
							Short grass/ herb(<30cm)	Tall grass (>30cm)	Shrub (<2m)	Tree (>2m)	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 months?	Q2. When & where was the last that you have seen GIB?	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