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The occupancy of Great Indian Bustard (*Ardeotis nigriceps*) using local people's knowledge in the Deccan Plateau, Karnataka, India

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Abstract. *Kumar PR, Deepak D, Kumara HN, Babu A. 2023. The occupancy of Great Indian Bustard (*Ardeotis nigriceps*) using local people's knowledge in the Deccan Plateau, Karnataka, India. Biodiversitas 24: 1400-1407.* The Great Indian Bustard (*Ardeotis nigriceps*) (GIB) is a critically endangered species that went extinct in most of its geographical range and is facing global extinction risk. The southernmost population of this bird at present is in Siruguppa taluk of Bellary district in Karnataka State, India. Except for a few sight records, data is not available on any aspect of the species in the state. We collected sightings of GIB from the local people for an area of 359 km^2. We modeled the probability of occurrence of GIB for the study site and associated it with the habitat parameters. Keeping the findings of the occupancy, we explored the study site for the GIB. The results showed that tree density and length of the metal road influenced the occupancy positively, while the number of villages and period of land use influenced it negatively. Nearly 30% of the grids were predicted to have high probability of detecting GIB in this landscape. We had 115 detections of GIB and recorded them in 70% of the grid cells where local people reported the sightings of GIBs. The use of local people's knowledge is beneficial and less expensive for the species like GIB for the initial exploration and also to monitor them at a landscape level.

Keywords: *Ardeotis nigriceps*, Bustard, critically endangered, local knowledge, site use prediction

INTRODUCTION

Globally, a major challenge faced by the conservation manager is the conservation of open grassland and dryland habitats and its associated species like Bustards. Most of the Bustard species are threatened, while the Great Indian Bustard (*Ardeotis nigriceps*) (hereafter referred to as GIB) is facing a risk of global extinction (Collar et al. 2017). GIBs were once found in many Indian states, but are now confined to a few small, isolated pockets in five states i.e., Rajasthan, Gujarat, Maharashtra, Andhra Pradesh, and Karnataka. Their population declined drastically and they went locally extinct in 90% of their original range (Dutta et al. 2010). Dharmakumarsinhji (1971) estimated the population of GIBs in India to be 1260 birds in 1969, and Rahmani (2006) estimated them to be 300-350 birds in 2006, which shows a rapid population decline in the country. Currently, the population of GIBs in India stands at ~150 birds (Rahman 2020).

In Karnataka, the GIBs declined in the middle of the last century, and there were no records of their presence in the state between 1940 and 1970, but few sighting records were reported in the state after the 1970s, most of which were from and around the Ranebennur Blackbuck Sanctuary in Haveri district (Kumara and Raj 2007). However, the population of the GIBs in Karnataka was estimated to be 30-40 individuals in 1990 (Rahmani and Manakadan 1990). Except for a few sighting records, many records were of unconfirmed reports based on secondary sources and personal communications (Kumara and Raj 2007). The GIBs were considered locally extinct in the state until the sightings in 2006 from Siruguppa taluk in Bellary district (Ahiraj 2008; Kottur 2016). The population of GIBs in Siruguppa represents the southernmost population of the species in India.

Assessing the population of Bustards is hard to even in small areas as they occur in low-density, are wide-ranging in nature, and have patchy spatial and temporal distribution (Collar et al. 2017). Inadequate knowledge about the species in a landscape is one of the major challenges to the conservation of endangered species (Roman et al. 2009). Nevertheless, secondary information like local people's knowledge of the species becomes one of the important sources of data (Knapp et al. 2013; Echenique-Díaz 2014). All the reports of GIB sightings from Siruguppa in the Bellary district are from agricultural fields (Ahiraj 2008; Kottur 2016). We expected the local people who have spent much of their time in agricultural fields to have sighted the GIBs. Globally, the knowledge of local people about their area, its resource, the past and present abundance, and distribution of the regional wildlife is used to understand the ecology and to determine the conservation status of many endangered species (Griffon and Griffon 2000; Steinmetz 2004; Steinmetz et al. 2006; Brook and McLachlan 2008; Jones et al. 2008; Newton et al. 2008; Silvano and Valbo-Jorgensen 2008; Anadon et al. 2009; Starr et al. 2011; Sato et al. 2018; Filho et al. 2018; Chowdhury et al. 2022). People's knowledge of species has been used as data to understand spatial occupancy and temporal changes in their occupancy in various studies e.g., the spatial distribution of mammals for entire India (Karanth et al. 2009, 2010a, b, 2011), temporal changes in the occupancy of many species for the entire Western Ghats (Pillay et al. 2011). In the current article, to identify the geographical space used by GIBs in the Sirguppa landscape, we opted to use the sightings of GIBs by the local people as data to model the possible site use by the birds.

MATERIALS AND METHODS

Study site

Siruguppa taluk is located in the north-eastern part of the Bellary district in Karnataka, located between 14°51' and 15°50' latitude and between 76°21' and 77°09' longitude (Figure 1). Siruguppa has vast expanses of flat, open areas and agricultural lands with very low tree density. It experiences four seasons (Summer: March to May, Pre-monsoon: June to September, Post-monsoon: October to November, and Winter: December to February) and receives an average annual rainfall of 683 mm, with an average maximum summer temperature of 39.6°C and an average minimum winter temperature of 18.3°C. River Tungabhadra and River Vedavathi are the major water sources for the taluk. The taluk is bordered by the state of Andhra Pradesh in the east (District Census Handbook 2011).

We identified the study site through informal interactions with the local people and the Forest Department personnel on past sightings of GIBs in Siruguppa taluk, that is agricultural fields in the black soil area. The black soil area is spread across the taluk as four different, discontinuous patches of varying sizes i.e., A-253 km^2, B-34.4 km^2, C-53.8 km^2, and D-17.4 km^2 (Figure 1). These patches are arid, discrete, and have dry agricultural crops like Cotton, Jowar, Sunflower, Foxtail millet, and Bengal gram are cultivated. Neem (*Azadirachta indica*), Khejri (*Prosopis cineraria*), Babul (*Acacia nilotica*), and Indian Mulberry (*Morinda tinctoria*) are the common trees present in these patches, with Neem being the most abundant and common tree.

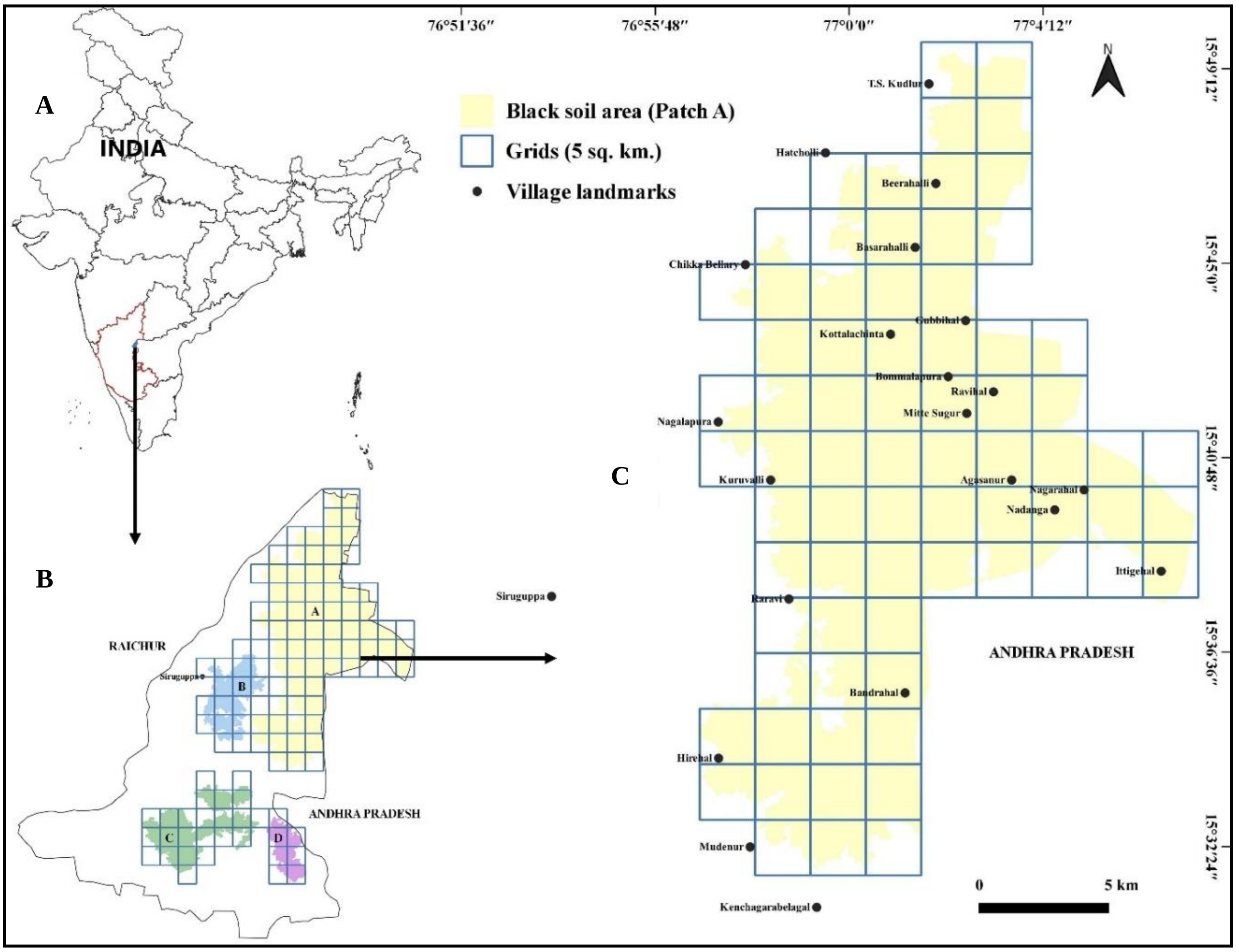

Figure 1. A. Study site in Siruguppa taluk of Bellary district in Karnataka, India; B. The four patches of black soil area overlaid with 5 km^2 grid cells in Siruguppa taluk; C. Patch ‘A’ of the black soil area overlaid with 5 km^2 grid cells and village landmarks

Methods

We selected all four patches of the black soil area to sample for the GIBs. We created 5 km^2 grid cells and overlaid them on the four select sites, resulting in 119 grid cells. In each grid cell, we interviewed local people who have been practicing agriculture for a couple of decades and age above 50 years. People were interviewed when they were in their crop fields in October 2018. For each grid cell, a minimum of five and a maximum of eight people were interviewed.

After we associated the people with their crop field or the specific location, further details on the GIB were asked for and connected to the specific grid cell. People were initially asked for their willingness to respond to the questions, once they accepted to respond, then further questions were posed to them. We asked about the GIB sightings and showed a photo of GIB and similar birds that people can confuse with others e.g., Indian Peafowl (*Pavo cristatus*), different species of Storks and Herons (Woolly-necked Stork *Ciconia episcopus*, Painted Stork *Mycteria leucocephala,* and Grey Heron *Ardea cinerea*), and asked them to point the GIB. People who could differentiate and identify the GIB were only considered as samples. The response of those select people was only considered and recorded as they could differentiate and identify the GIB from other birds, then, if they had sighted a GIB in the recent past, their response was recorded as 'detected', if not it was recorded as 'not detected'. We asked about the location of sightings of the birds.

Keeping the location of sightings, and response on detection by the respondents, the detection matrix for each grid cell was constructed as '1' for detected, '0' for not detected, and '-' indicated the missing observations. Based on the available literature and habitat characteristics of the study site, we considered some of the habitat parameters that are important for the species which included the percent of agricultural land, percent of fallow land, percent of forest land, tree density, percent of the settlement, percent of settlement with buffer (750 m), number of villages, distance to the closest village, length of metal roads, and period of land use (Table 1).

Keeping the reported sightings of GIBs by the local people, we selected Patch 'A' for further exploration of direct sightings of GIBs. A search team of 13 people was formed, they were trained to detect the GIB, photo document it, and record geo-coordinates of its location using the Global Positioning System (GPS). Search plans were developed every day, and each grid cell of Patch 'A' was covered by the team every month. Since the landscape is an open agriculture field, the exploration of each grid cell was made by motorcycle at the speed of 20 km/hour. The geocoordinates and the number of birds with photos were documented for every detection of GIB.

Analysis

There was no positive response of detecting the GIBs from the black soil patches 'B', 'C', and 'D', and the detection history for all the 46 grid cells over these patches (Figure 1) was '0', indicating absence or non-detection, hence they were removed from further modeling for the site occupancy by the species. Therefore, responses from 73 grid cells in patch 'A' were taken for further analysis. Out of 475 interactions, 07 respondents had responded positively, but had wrongly identified the GIB, so we removed those entries from the further analysis. Since all the respondents were farmers, age group above 50 years, and were well aware of GIBs, we have not incorporated any sampling covariates in the model.

Table 1. Quantification, justification, and association (with GIB) of variables selected for analysis

Variables in grid cell (Unit)	Quantification method	Expected response	Justification
Agricultural land (%)	Calculated from the features digitized using Google Earth Pro and QGIS software in each grid cell.	Positive	Grasslands/scrublands are available in the study area as small, isolated patches. So, GIBs spend more time in the agricultural fields. More area of agricultural fields means the increased presence of GIBs.
Fallow land (%)		Positive	GIBs prefer using fallow lands when available. So, increased presence of GIBs in such areas.
Forest land (%)		Positive	Forest lands are currently the biggest patches of grasslands/scrublands available in the study area. GIBs prefer using grasslands/scrublands habitats when available. So, increased presence of GIBs in such areas.
Tree density (count)		Negative	GIBs are birds of open areas and usually avoid wooded areas.
Settlement (%)		Negative	More settlement area means more human movement and disturbance. GIBs tend to avoid areas with high human disturbances. So, GIB presence will be less in such areas.
Settlement & buffer (%)		Negative	
Number of villages (count)		Negative	
Distance to the closest village (km)		Positive	Farther the village, lesser the human movement and disturbance. Such areas are preferred by GIBs.
Length of metal roads (km)		Negative	More metalled roads mean more vehicular movement and disturbance. GIBs tend to avoid such areas.
Period of land use (months)	Based on response from the locals	Negative	GIBs prefer using areas with minimal anthropogenic disturbances. When the number of months of land use is high, there will be continuous disturbance for many months. GIBs tend to avoid such areas.

Initially, variable screening was conducted to remove highly correlated site covariates by conducting Pearson's correlation analysis, i.e., the variables which have a high correlation coefficient i.e., >0.6 values. Only uncorrelated variables (agricultural land, forest land, fallow land. period of land_use, tree density, number of villages, distance to closest village and length of metal roads) were retained and others (settlement and settlement & buffer) were removed from the analysis. Single-season, single-species occupancy model was applied to estimate two model parameters- detection probability (*p*) and proportion of grids occupied by GIBs. We generated a global model by adding all uncorrelated variables into the model. We then used the dredge option to generate all possible competitive models to interpret the habitat use of GIBs in Siruguppa taluk. Model selection, computation of model weights, and averaging of parameters were calculated in the framework of Anderson and Burnham (2004). We also calculated summed computed model weight for each variable to elucidate the relative influence of these variables. Geo-coordinates of all the direct GIB sightings recorded between 2018 and 2022 were overlaid on the data of GIB sightings by the local people.

RESULTS AND DISCUSSION

The descriptive analysis revealed that the Siruguppa landscape is dominated by agriculture fields (79.23) followed by fallow land. Although there exists a small portion of metal roads in grids, number of trees and villages are sparse in this landscape. Farmers cultivate for six to eight months (Table 2)

Out of 73 grid cells, people have seen GIBs in 20 grid cells that yielded naïve detection probability and occupancy values of 0.348 and 0.261 respectively (Figure 2). We constructed several competitive models explaining the possible site use by GIBs in Siruguppa taluk, however, only three models were found with less than 2 Δ QAIC values (Table 3). The most parsimonious model contained two variables *viz*., tree density and the number of villages in a grid cell. Tree density positively influenced the occupancy of GIBs while the number of villages in a grid cell negatively influenced it. We summed the computed model weight for each variable to understand the relative influence of these variables (Table 4). Other than these two variables, the period of land use and the length of the metal roads in a grid cell also influenced the occupancy of GIB. The models identified 14 grid cells having 76-100% probability of GIB presence, 08 grid cells having 51-75% probability, and 10 grid cells with 26-50% probability. The remaining 41 grid cells had <25% probability of having a GIB.

We recorded 115 detections of GIB between 2018 and 2022 in 18 grid cells. GIBs were sighted in 20 grid cells by the local people, of them, we recorded the GIBs in 14 grid cells. That indicates that we recorded the GIBs in about 70% of the grid cells where local people reported the sightings of GIBs (Figure 2).

Table 2. Descriptive statistics of select variables

Covariates	Mean (SD)	Range (Min-Max)
Forest land (%)	0.53 (2.59)	0.00-17.00
Agricultural land (%)	79.23 (8.35)	55.00-93.00
Fallow land (%)	4.73 (3.63)	0.00-15.00
Period of land use (months)	6.19 (0.59)	6.00-8.00
Trees density	0.94 (0.75)	0.14-3.87
Number of villages	0.73 (0.95)	0.00-3.00
Distance to the closest village (km)	1.41 (1.00)	0.01-4.70
Length of metal roads (km)	1.37 (1.43)	0.00-5.09

Table 4. Summed computed model weights and averaged beta coefficients (SE) of parameters of top models (<2 Δ QAICc) used to explain the habitat requirement of Great Indian Bustards in Siruguppa taluk, Karnataka, India

Variables	Summed AICc weights	Beta co-efficient (SE)
Tree density	1.00	2.9278 (1.5880)
No. of villages	1.00	-1.1426 (0.6264)
Period of land use	0.25	-2.5888 (26.3279)
Length of metal roads	0.23	0.5376 (0.4272)

Table 3. Competitive models explaining the factors influencing the detection and occupancy of Great Indian Bustards in Siruguppa taluk, Karnataka, India

Models	K	logLik	QAICc	Δ QAICc	wi
Ψ (Tree density + No. of villages), p (.)	5	-72.48	155.86	0.00	0.53
Ψ (Period of land use + Tree density + No. of villages), p (.)	6	-72.06	157.39	1.53	0.25
Ψ (Length of metal roads + Tree density + No. of villages), p (.)	6	-72.13	157.54	1.68	0.23

Note: K: No. of model parameters; LogLik: Log likelihood; QAICc: Quasi Akaike Information Criterion corrected for small sample size; Δ QAICc: Delta QAICc; *wi*: model weight

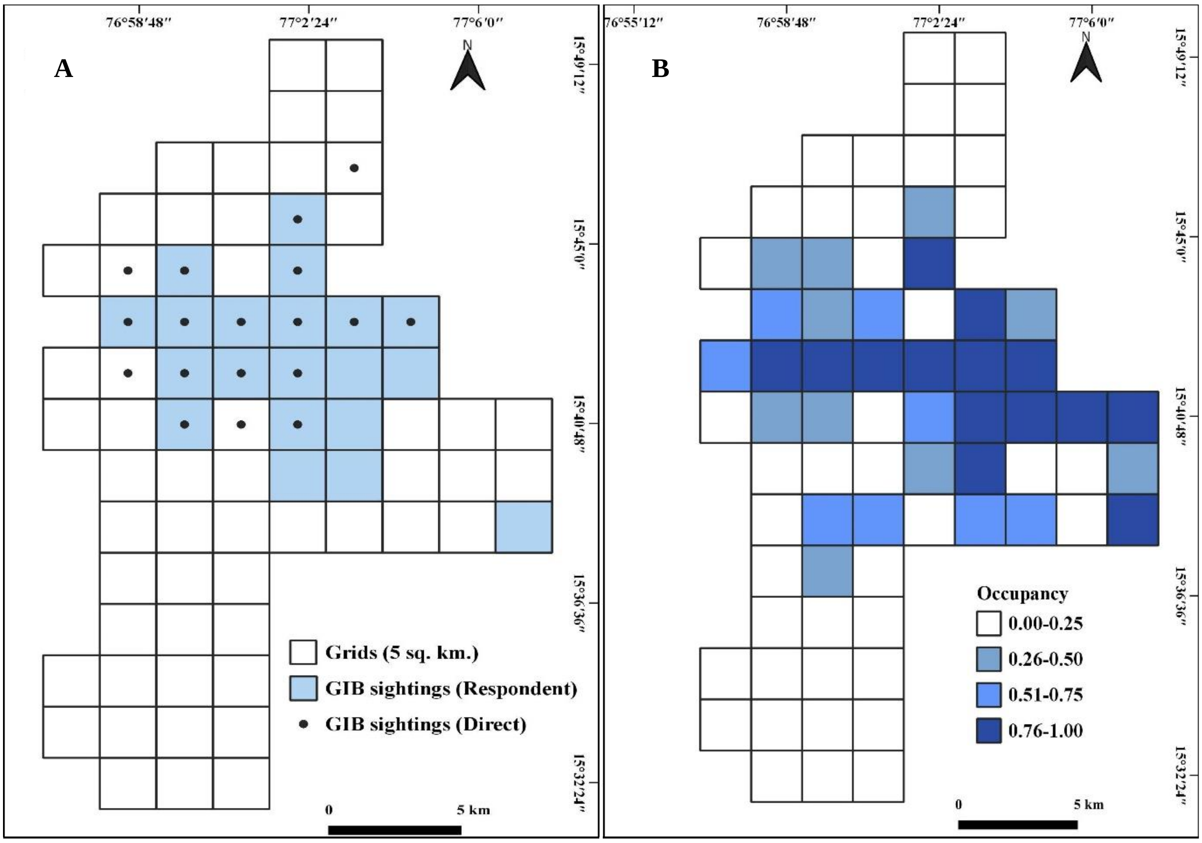

Figure 2. A. Grid cells with GIB sightings as reported by respondents and grid cells where GIBs were sighted from 2018 to 2022 in Siruguppa taluk, Karnataka, India. B. Occupancy of Great Indian Bustards in Patch 'A' of the black soil area in Siruguppa taluk

Figure 3. Great Indian Bustards (*Ardeotis nigriceps*) resting under shade of trees in Siruguppa taluk, Karnataka, India

Discussion

The naïve detection probability and occupancy values of GIB were 0.348 and 0.261 respectively. The occupancy of GIBs in Siruguppa is determined by the relatively higher tree density (3-4 trees/ha), lesser number of settlements, availability of more metal road, and less land use intensity. Further explorations of patch-A resulted in 115 detections of GIB in the 18 grid cells. We recorded the GIBs in 70% of the grid cells where local people reported the sightings of GIBs in the study site.

The tree density of a grid cell showed a positive influence on the occurrence of GIB. The tree density in patch 'A' ranged from a minimum of 0-1 trees/ha to a maximum of 3-4 trees/ha. Habitat characteristics preferred by GIBs are areas with short vegetation mixed with sparse tall vegetation (Ali and Ripley 1969; Manakadan 1986; Rahmani and Manakadan 1986; Rahmani 1989; del Hoyo et al. 1996; Dutta et al. 2010; Bhardwaj et al. 2017). They require spots with shade for roosting (Gupta 1970; Rahmani 1989) (Figure 3). Alonso et al. (2009) reported low tolerance to heat and preferred the areas with a few trees by Great Bustards (*Otis tarda*).

The GIBs avoided the grids with villages, which indicates they avoid areas with high human and domestic animal activities. Wildlife perceives and responds to human disturbance in a similar way they respond to predation risks and the impact of this on the individual or population is believed to be equivalent to that of predation (Frid and Dill 2002). However, in some situations, complete avoidance of human disturbance is not possible, but wildlife responds in many ways to reduce the risk by resorting to selective habitat use and avoidance or spending less time in risky or unfavorable areas (Fortin et al. 2005; Frair et al. 2005; Hebblewhite and Merrill 2009; Dussault et al. 2015). Similarly, Great Bustards were observed to prefer areas with low human densities (Alonso et al. 2009).

The period of land use varies between the grids depending on the crop cultivated (Cotton for about eight months, while Bengal gram for about three months) between the agricultural season from June/July to February/March. Intensive cultivation reduces insect populations in agricultural fields, affecting their abundance and diversity, while fallow lands have higher insect abundance and diversity (Tucker 1992). The GIBs are an omnivorous species that feed on insects, fruits, and crops (Hume and Marshall 1879; Elliot 1880; Dharmakumarsinhji 1957; Ali and Ripley 1969; Rahmani 1989; Bhushan and Rahmani 1992). The negative influence of the land use period indicates that the birds avoid areas that are intensively cultivated and prefer areas that are not cultivated for longer periods. This indicates a preference of the GIB towards fallow lands compared to cultivated agricultural lands. Bustard populations in different parts of the world have shown a decreasing trend following the increased intensity of land use and continuous cultivation (Isakov 1974; Schulz 1985; Goriup 1994; Silva et al. 2007; Ziembicki 2010).

The ecological impact of roads on landscape and wildlife have been recorded to be mostly negative (Forman and Alexander 1998; Forman et al. 2003; Fahrig and Rytwinski 2009). Grid cells that have more metal roads (in length) have shown greater occupancy than grid cells with less or no metal roads. The presence of metal roads increases the accessibility to different areas of a grid cell which implies more coverage of the area, thereby increasing the probability of sighting the birds in that grid cell.

In our study, the report of GIB sightings by local people was found to be 70% valid, which we verified through field surveys. This information helped us in prioritizing areas for monitoring and studying the birds. Without this baseline distribution data obtained from the knowledge of local people in Siruguppa, it would have been difficult to find a bird like the GIB, having few individuals with very low density in such a vast landscape. The use of local people's knowledge is beneficial and less expensive for the species like GIB for the initial exploration and also to monitor them at a landscape level (Anadon et al. 2009).

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