



STATUS AND TREND OF GREAT INDIAN BUSTARD, ASSOCIATED WILDLIFE AND HABITAT IN THAR

**PROJECT
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SUMMARY



The Thar landscape in Jaisalmer district is the last stronghold for the Critically Endangered Great Indian Bustard (GIB) *Ardeotis nigriceps* and supports a unique assemblage of arid-adapted species dependent on Open Natural Ecosystems. This report presents the population status and decadal trend of the GIB, associated wildlife, habitat, and threats, based on landscape-level surveys conducted during October 2024 and April 2025.

Using a standardized vehicle-based distance and occupancy sampling framework consistent with earlier assessments, surveys covered ~14,000 km² across Desert National Park, Pokhran Field Firing Range, and surrounding habitat in Priority GIB Area. A total of 419 transects (4,522 km) with habitat sampling at 2 km intervals, were surveyed systematically in 144 sqkm grid-cells, to ensure adequate and representative spatial and temporal coverage.

The last survey, conducted in 2017-18, estimated a population of 128 ± 19 (SE) GIB and assessed the occupancy and density trends of associated key fauna, habitat and anthropogenic disturbances from 2015 to 2018 (Dutta et al. 2018). The current survey estimated the GIB population (2025) as 130 ± 21 individuals, with an occupancy of about 16% of the surveyed landscape. Trend analysis showed that GIB detections, encounter rate, abundance and occupancy have remained broadly stable since 2017. The species' detections continue to be concentrated in relatively undisturbed, flat grassland-dominated areas without energy infrastructure, particularly in and around enclosures of the northern Desert National Park and Pokhran Range. Native associated species such as chinkara and desert fox also showed stable population trends, while non-native and human-subsidised species, including nilgai, pig, and free-ranging dogs, exhibited increasing occupancy across the landscape.

Habitat assessments revealed that the short grass and sparse shrub cover forming the primary vegetation structure suitable for GIB is widely distributed in the Thar Landscape. The overall land-cover composition has remained relatively stable over the last decade, but there has been a marked increase in anthropogenic features over time. Power lines, agricultural fencing, roads, water sources, and solar plants have expanded substantially, intensifying habitat fragmentation and mortality risks. Although grassland restoration efforts and fenced enclosures have contributed to localized improvements in habitat quality, these gains have been offset by infrastructure expansion at the landscape scale.

Overall, the report highlights that the GIB population remains spatially restricted, underscoring the urgent need for strengthened conservation, threat mitigation, and habitat improvement. The findings emphasize that long-term persistence of the species depends on landscape habitat security alongside conservation breeding and targeted restoration efforts.



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BACKGROUND

The Thar landscape covering Jaisalmer District of Rajasthan represents the last stronghold of the Critically Endangered Great Indian Bustard (*Ardeotis nigriceps*, GIB) with only ~140 individuals surviving globally (Dutta et al. 2017). This arid Open Natural Ecosystem also supports several conservation priority species, including Chinkara (*Gazella bennettii*), Desert Fox (*Vulpes vulpes pusilla*), Indian Fox (*Vulpes bengalensis*), Desert Cat (*Felis lybica*), Spiny-tailed Lizard (*Saara hardwickii*) and threatened raptors. Increasing anthropogenic pressures in the form of habitat modification and infrastructural expansion are impacting this ecosystem. This necessitates regular ecological assessments to track population trends to guide science-based conservation.

The GIB, the State Bird of Rajasthan, is extremely rare, patchily distributed, cryptic, and wide-ranging that makes monitoring challenging. The species typically inhabits flat to slightly undulating terrain with grasslands and sparse fallows, often avoiding intensive agriculture and infrastructure (Dutta et al. 2024). Over the past few decades, its distribution range has contracted substantially, with the Thar region remaining the last viable landscape for population recovery. In response to conservation requirements, structured landscape-level population and habitat surveys were carried out between 2014 and 2018 by Wildlife Institute of India (WII) and Rajasthan Forest Department (RFD), covering over ~19,000 km² of area using vehicle-based distance sampling and occupancy modelling. These surveys estimated a population of 128 ± 19 (SE) individuals in 2017-18 (Dutta et al. 2018). Since 2014, conservation efforts have been ongoing in and around Desert National Park, including habitat restoration through the establishment of fenced grassland reserves and a conservation breeding programme.

Following the protocol standardized in earlier surveys (Dutta et al. 2015), repeat surveys were conducted in October 2024 and April 2025 to capture seasonal variation in population dynamics. The survey covered Desert National Park (DNP), Pokhran Field Firing Range (PFFR), and surrounding habitats in the Priority GIB area (Figure 1). In addition to GIB and associated species, surveys documented fine-scale data on land cover, dominant vegetation, and anthropogenic disturbances. The landscape was stratified into key blocks (Sam, Ramdevra, PFFR, Ramgarh, Rasla, Myajlar, and Mohangarh) in which trained teams conducted vehicle transects within 144km² grids.

This report presents findings from past and recent surveys to provide an updated account of population status, spatial distribution and habitat conditions of the GIB and associated fauna across the Thar landscape. It also evaluates the growing human footprint that fragments habitats and escalate species displacement and mortality risks. These findings aim to inform conservation management under the National Bustard Recovery Program, supporting population recovery through conservation breeding, adaptive habitat management, grassland restoration and threat mitigation.



ABOUT THE LANDSCAPE

The Thar Desert is part of the Desert Biogeographic Zone and is among India's most ecologically distinct and biologically rich arid ecosystems. The region receives mean annual rainfall of 100-400 mm, decreasing from east to west, with high inter-annual variability and recent anomalies marked by increased and stochastic precipitation. Temperatures range from 50°C in summer to 0°C in winter, with high diurnal variation. The landscape features a mosaic of grasslands and croplands over gravel plains, rocky hillocks, sand-soil cover and sand dunes. Vegetation characterised by thorny scrub and open woodland is dominated by native species such as *Prosopis cineraria* and *Salvadora oleoides*, along with non-native *Acacia tortilis* and *Prosopis juliflora*. The shrub layer includes *Capparis decidua*, *Zizyphus mauritiana*, *Leptadenia pyrotechnica* and *Calligonum polygonoides*, and the grass layer largely comprises *Lasiurus scindicus* and *Dactyloctenium aegyptium* (Anoop et al. 2017). These plant communities are crucial for supporting insect populations, ground-nesting birds and native herbivores.

Besides the GIB, Thar supports several other high conservation value species, including Chinkara, Desert fox, Indian fox, Desert cat, and Spiny-tailed lizard. Avian fauna includes resident and migratory species, such as MacQueen's Bustard (*Chlamydotis macqueenii*), Cream-coloured Courser (*Cursorius cursor*), Sandgrouses (*Pterocles* spp.), larks, and a diverse raptor assemblage, including Gyps vultures, eagles and falcons. Many migratory species use the landscape as part of the Central Asian flyway.

Human density is high compared to other deserts (~85 people / km²), with livelihoods largely dependent on pastoralism, tourism and agriculture, including irrigated farming along the Indira Gandhi Canal. Desert National Park Wildlife Sanctuary (area 3,162 km²) is a multiple-use area with 73 resident villages. Despite various anthropogenic pressures, Thar landscape remains one of the relatively less-modified Open Natural Ecosystems in the country and retains large, contiguous habitats of high conservation values.



METHODS

A. Sampling design

The GIB habitat within the Thar landscape (~14,000 km² surveyed), largely covering the Priority GIB Area, was surveyed using a systematic vehicle-based transect design following Dutta et al. (2017). The survey area was stratified into seven blocks: (a) Ramdevra (18 grids), (b) Rasla (14 grids), (c) Pokhran Field Firing Range (PFFR; 16 grids), (d) Mohangarh (10 grids), (e) Ramgarh (19 grids), (f) Sam (22 grids), and (g) Myajlar (16 grids). A total of 115 grids (area of 144 km², 12 x 12 km each) were used as the sampling frame to ensure uniform spatial coverage (Figure 1).

Surveys were conducted during October 2024 (16-30th October 2024) and April 2025 (09-15th April 2025). 20 teams simultaneously surveyed these grids to obtain a temporal snapshot of species distribution and population while minimizing non-random animal movements between survey areas. Each team comprised two to three trained observers, including a primary observer for GIB and associated species, a secondary observer for raptors, and a forest guard from the Rajasthan Forest Department. To maximize detectability, surveys were conducted using four-wheel-drive vehicles driven at 10-20 km/hr speed during morning (06:30-10:30 hrs) and late afternoon hours (16:30-18:30 hrs), the peak activity period. Teams were equipped with binoculars, rangefinders, compasses and handheld mobile GPS. Surveys within each block were coordinated by experienced field biologists from the Bustard Recovery Program team. Intensive pre-survey workshops were conducted to train observers in the standardized survey protocols, equipment use and species identification. The workshop was followed by hands-on field training sessions to ensure methodological consistency across teams.

All observations were recorded digitally using Epicollect5 (v5.0) for standardized data collection. Transect routes were recorded using the Locus mobile application (v4.26), generating .gpx tracks for each trail. Habitat plots were sampled systematically at 2 km intervals along transects, and animal sightings were recorded with perpendicular distance and group size. Areas with dense human settlement were excluded from the sampling frame as these areas are not suitable for GIB.

B. Data collection

1. Species' information

Data on GIB and key associated species (native: chinkara, desert fox, Indian fox, desert cat; non-native: nilgai, pig, free-ranging dogs; resident and migratory raptors) were collected in 2 km segments along transects. For each detection, the following information was recorded: species, number of individuals (group size), sighting distance (radial/perpendicular), transect bearing, animal bearing, and geographic coordinates (degree decimal format). Distances were measured using rangefinders (Bushnell/Nikon make) and bearings using a compass (Suntoo make). Transects were largely linear, and along curvy-linear segments of the transect, the closest approach distances (perpendicular distances) were recorded following Hiby and Krishna (2001).

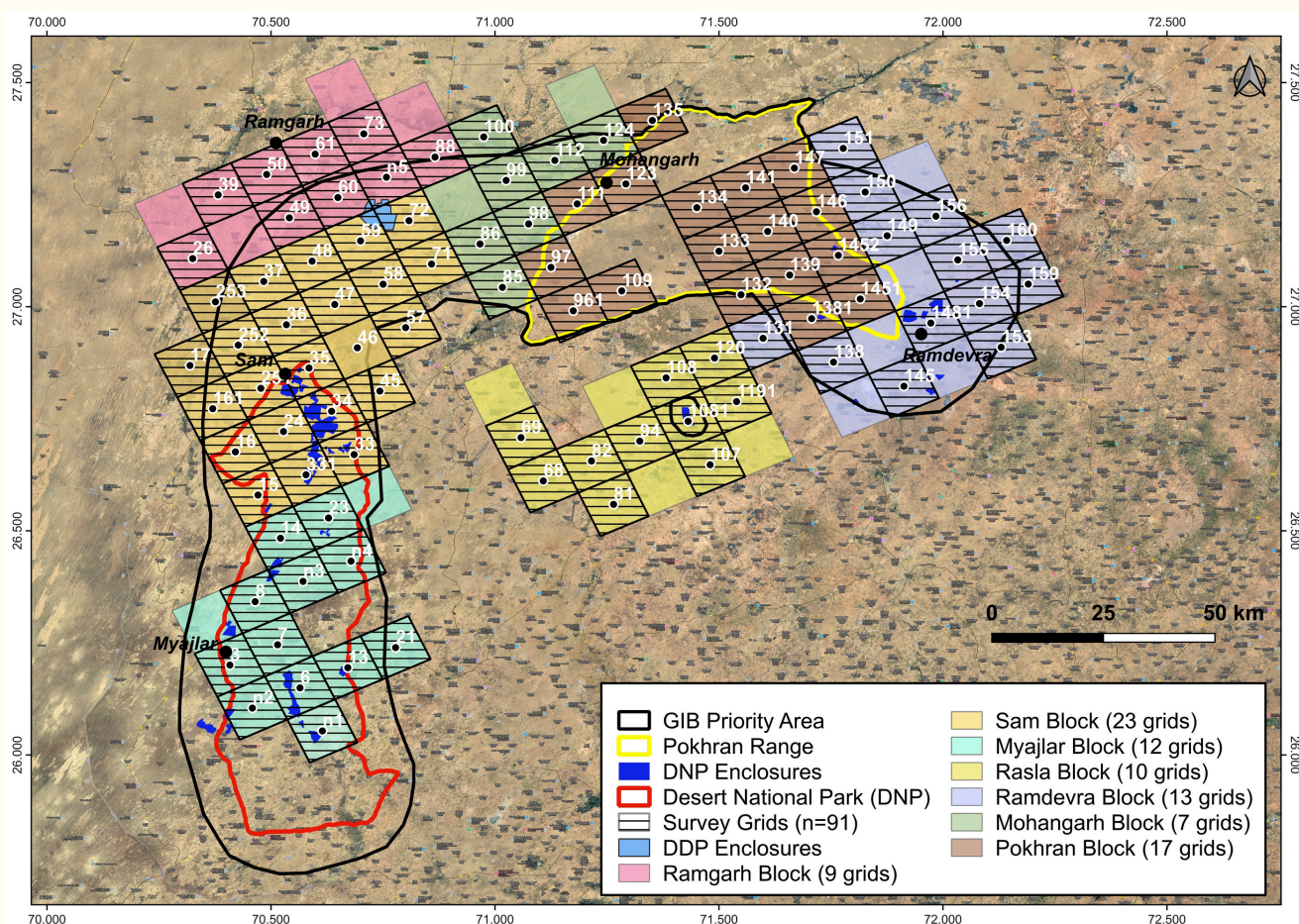


Figure 1. Map showing the survey framework along with the surveyed trails with respect to blocks in Jaisalmer district, Rajasthan, India

2. Habitat variables

Additionally, habitat characteristics were recorded at every 2 km interval along the survey transect, which included:

I. Habitat within a 100 m radius :

- Terrain (flat / slope / undulating)
- Substrate (soil / sand / gravel & rock)
- Land cover (grassland / shrubland / woodland / active or fallow agriculture / barren)

II. Vegetation structure within a 20 m radius - recorded as percentage cover in broad classes (0, 1–10, 11–20, 21–40, 41–60, 61–80, 81–100 %), of:

- Short grass and herbs (< 30 cm height)
- Tall grass (> 30 cm height)
- Shrubs or woody vegetation (< 2 m height)
- Trees or woody vegetation (> 2 m height)
- Crop

III. Vegetation composition (dominant plant species) in 100 m radius - recorded as percentage cover in broad classes (1–10, 11–20, 21–40, 41–60, 61–80, 81–100 %) of:

- a. Names of two dominant upperstorey species (> 2 m height) and their relative cover
- b. Names of three dominant understorey species (< 2 m height) and their relative cover
- c. Crop name

IV. Disturbances - recorded as presence/absence of:

- a. Active disturbances within a 200 m radius (human, vehicle/machinery)
- b. Passive disturbances within a 500 m radius (settlement, farm hut, metal road, wind turbine, solar power plants, water sources, industry/mine)
- c. Power lines within a 500 m radius (further classified as marked high tension, unmarked high tension, and low tension lines)
- d. Agricultural fences within a 500 m radius (further classified as electric, barbed wire, chain-link/weld-mesh and other)

V. Burrowing animals within a 20 m radius -recorded as presence/absence:

- a. Occurrence of spiny-tailed lizard and rodent (Indian desert jird / gerbil) burrows

Additionally, information about the habitat quality of the segments from the GIB perspective (>25% area under contiguous grasslands and less infrastructure) and repeatability of the transects were recorded by observers for future surveys (in the April 2025 survey).



C. Data analysis

1. Population status of GIB and associated species

Population density was estimated using line-transect distance sampling, analysed using the *distance* R package (Marshall et al. 2025). During both landscape surveys, all GIB sightings (excluding juveniles, to ensure comparability with previous estimates) and associated species were recorded along vehicle transects. Perpendicular distances of sightings were used to model detectability as a function of distance from the transect line (Buckland et al. 2001).

For GIB, detection functions were fitted to pooled distance data to account for decreasing detectability with distance from the transect. Half-normal, hazard-rate and uniform key functions with cosine and Hermite adjustment terms were compared. A 5% right truncation was applied to remove extreme distance observations and improve model fit.

Model selection was based on the lowest AICc (Burnham and Anderson 2002), and detection probability was obtained from the top-ranked model. Population density was estimated using a component-wise framework. Encounter rates (individuals km⁻¹) were calculated at cell level and aggregated using geometric mean to reduce the influence of extreme values. Uncertainty in encounter rates was estimated assuming a Poisson distribution by fitting an intercept-only generalised linear model with log-transformed survey effort as an offset. Encounter rates were corrected for detection probability to derive density estimates, and uncertainty was quantified using the delta variance method. Density estimates were extrapolated to the sampled area (13,392 km²) to obtain conservative abundance estimates.

For associated species, population densities were estimated following the conventional distance-sampling framework. Species-specific detection functions were fitted using appropriate key functions and adjustment terms, with truncation applied where required to improve model fit. Model selection was based on AICc, and density estimates were based on encounter rates corrected for detection probability using the least AICc model for each species.

To quantify current distribution patterns of GIB and associated species, occurrence data from both surveys were first analysed using single-season occupancy models (MacKenzie et al. 2006). Detection histories were prepared for each grid cell using detection/non-detection data from 2-km trail segments treated as spatial replicates. Occupancy (ψ) and detection probability (p) were estimated and compared against null models using an information-theoretic approach based on AICc (Burnham and Anderson 2002). All analyses were conducted in the *unmarked* R package (Chandler et al. 2025). These models provide a baseline estimate of the proportion of grid cells occupied by GIB and associated species during 2024-25 (Table 1).

2. Population trends of GIB and associated species

To evaluate recent trends in space use, multi-season (dynamic) occupancy models were fitted for the period 2017 to 2025, as earlier trends have been documented in previous assessments (Dutta et al. 2017). Dynamic occupancy models estimated initial occupancy (ψ), colonization (γ), extinction (ϵ) and detection probability (p), while explicitly accounting for imperfect detection. Detection/non-detection data were structured year-wise, with 2km trail segments treated as spatial replicates. To ensure comparability of occupancy estimates through time, trend analyses were conducted for only those cells that were surveyed in both 2017 and 2025 ($n=79$). A candidate set of models, allowing either constant or time-varying changes in occupancy dynamics, was evaluated using an information-theoretic approach based on AICc, and year-specific occupancy estimates were derived from the best-supported model (Burnham and Anderson 2002) (Table 1). Additionally, encounter rates (count/km) were compared for GIB and associated species between 2017 and 2025 (Table 1).

3. Habitat status

Habitat characteristics were summarised using habitat and vegetation covariates collected, during both 2024-25 surveys at every 2km along the transects within the 144 km² grids. On average, in each grid cell, 16.1 (2.78 SD) plots were sampled. For categorical covariates, incidence was computed as the proportion of plots wherein a category occurred in each cell. Vegetation structure was recorded as percentage cover classes of vegetation in predefined height bins. The midpoint of each cover class was averaged across plots within a cell. Vegetation composition was quantified as the proportions of plots where the dominant species occurred in a cell. Thereafter, for all covariates, including habitat attributes (terrain, substrate, and land cover), vegetation structure (height-based cover classes), vegetation composition (dominant upperstorey and understorey vegetation), disturbances (active and passive), and burrowing species (spiny-tailed lizard and rodents), landscape-level means were estimated across sampled cells, separately for each survey (Table 2).

In addition to current habitat status, temporal trends in habitat condition were assessed by comparing data from 2017 with 2024 and 2025 surveys (Figure 6). These comparisons were used to evaluate changes in the magnitude and spatial prevalence of anthropogenic threats (eg, powerlines, farm huts, roads, settlements, solar plants, water sources, and wind turbines), land-cover classes (agriculture, grassland, scrubland, and woodland), vegetation structure and composition. Comparative trend plots are presented in Figure 7.



RESULTS

A. Efforts

The 2024 survey involved 193 transects of 2061 km length across 87 cells, while the 2025 survey included 226 transects of 2461 km length across 90 cells. Overall, 419 transects covering 4522 km were completed, and habitat sampling was conducted at 2598 points in 93 grid-cells (surveyed at least once).

Each grid cell was surveyed with an effort of 27 ± 4.93 (SD) km, providing substantial coverage of ~35% of the cell area, assuming a visibility range of up to 1 km (with imperfect detection) for large-bodied animals in open landscapes. In each survey, >80% of the cells within the sampling frame were covered (Dutta et al. 2014). The repetition of surveys ensured improved spatial and temporal representativeness, yielding a reliable estimate of GIB population status and enabling seasonal assessment of species distribution and habitat composition.

B. Population status of GIB and associated species

During the 2024-25 surveys, 35 GIB flocks, 1568 chinkara herds and 79 desert foxes were recorded, along with non-native species including nilgai, pigs, and free-ranging dogs.

The GIB occupancy was estimated to be 0.16 (SE 0.06) i.e., 16 ± 6 % area occupied and abundance was estimated as $130 \pm \text{SE } 21$ individuals. The population status of the GIB has remained stable since 2017 (Table 1; Figure 4 & 5).

Density of native mammalian species, namely Chinkara and Desert fox density (#/sqkm) was estimated at 1.42 (0.13) and 0.08 (0.02), respectively. This has also remained stable since 2017. In contrast, non-native species showed expansion, with increased occupancy of nilgai and pigs (Figure 4). Nilgai abundance remained stable, and dogs showed a slight decline in encounter rates since 2017 in the wildlife areas, partly attributable to exclusion of dogs within or in close proximity to human settlements from the survey (Figure 5). GIB detections were largely concentrated in and around northern enclosures of DNP, PFFR and Ramdevra; a pattern also observed for chinkara and desert fox (Figure 3).

Table 1. Population and distribution status of the Great Indian Bustard and associated key and non-native fauna of the Thar landscape during 2024 and 2025.

Parameters	Focal species			Non-native species		
	GIB	Chinkara	Desert fox	Nilgai	Pig	Dog
Observed groups (individuals)	35 (60)	1568 (3179)	79 (85)	171 (426)	34 (118)	222 (335)
Mean group size (SE)	1.65 (0.019)	2.09 (0.06)	1.1 (0.04)	2.74 (0.26)	3.75 (0.07)	1.55 (0.07)
Mean encounter rate (SE)	0.009 (0.001)	0.615 (0.053)	0.018 (0.003)	0.098 (0.016)	0.026 (0.007)	0.086 (0.010)
Best-fit detection model	Uniform cosine	Half normal ~ season	Hazard rate ~ season	Uniform polynomial	Uniform cosine	Hazard rate ~ season
Detection model GOF-CM (p-val)	0.06 (0.81)	0.2 (0.26)	0.11 (0.55)	0.13 (0.44)	0.02 (0.99)	0.04 (0.89)
Group detection probability (SE)	0.55 (0.05)	0.53 (0.013)	0.36 (0.05)	0.68 (0.03)	0.53 (0.04)	0.52 (0.04)
Effective strip width in m (SE)	448 (39)	218 (11)	104 (13)	264 (12)	317 (21)	163 (13)
Density in #/sqkm (SE)	0.01 (0.002)	1.42 (0.13)	0.08 (0.02)	0.18 (0.03)	0.04 (0.01)	0.27 (0.04)
95% CI of density (LCI-UCI)	0.006 - 0.02	1.18 - 1.70	0.06 - 0.13	0.13 - 0.26	0.02 - 0.07	0.20 - 0.35
Abundance (SE)	130 (21)	19017 (1578)	1071 (225)	2411 (410)	NR	3615 (506)
Occupancy (SE)	0.16 (0.06)	0.81 (0.04)	0.59 (0.09)	0.63 (0.09)	0.65 (0.12)	0.63 (0.07)
Species detection probability (SE)	0.08 (0.02)	0.32 (0.01)	0.06 (0.01)	0.09 (0.01)	0.03 (0.01)	0.12 (0.01)
Occupancy trend (2017 to 2025)	Stable	Decreasing	Stable	Increasing	Increasing	Increasing
Population trend (2017 to 2025)	Stable	Stable	Stable	Increasing	Stable	Decreasing

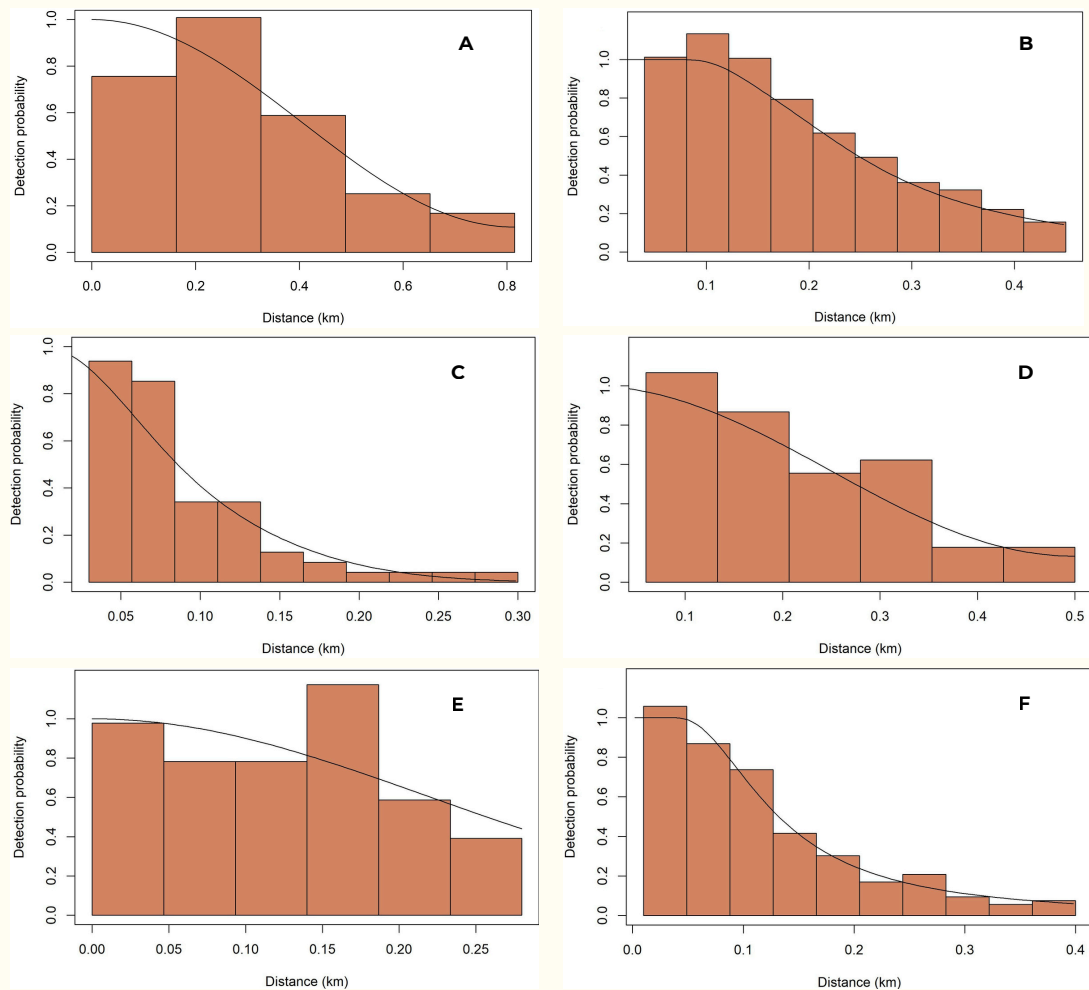
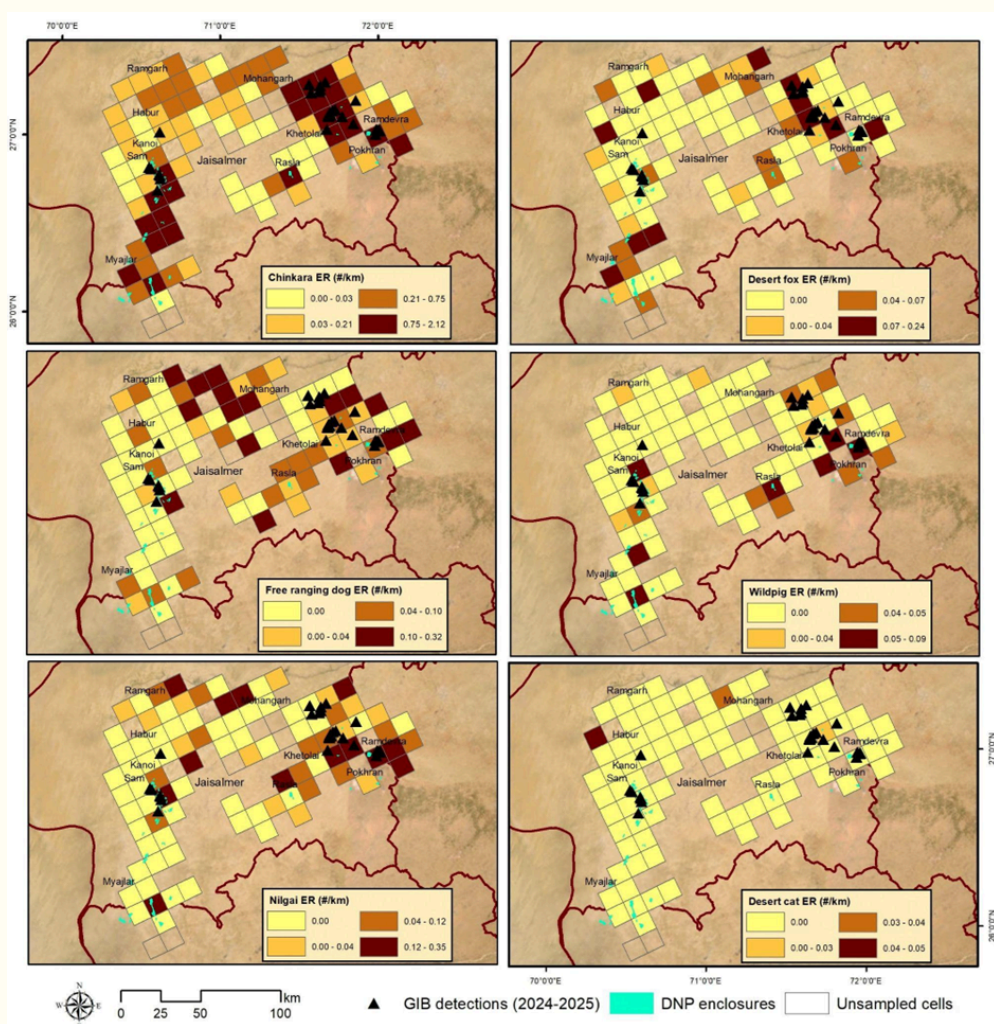


Figure 2. Density detection curves for estimating population as per best fit model (with lowest AIC) for GIB and associated key and non-native fauna in Thar landscape during 2024-25.

- (A) GIB
- (B) Chinkara
- (C) Desert fox
- (D) Nilgai
- (E) Pig
- (F) Free-ranging dog

Figure 3. Spatial distribution of encounter rates for GIB-associated native and non-native species with respect to GIB detections in Thar landscape (2024 and 2025).

- (A) Chinkara
- (B) Desert fox
- (C) Free ranging dogs
- (D) Pig
- (E) Nilgai
- (F) Desert cat



C. Population trends of GIB and associated species

Subsetting the population trend analysis to common grid-cells between 2017 and 2025, a) GIB occupancy and encounter rate remained stable, b) chinkara occupancy declined but encounter rate was stable, c) desert fox occupancy and encounter rate were stable, whereas d) nilgai and pig occupancy increased significantly (Figure 4 & 5). These non-native species, along with free-ranging dogs, displayed persistently high occupancy, indicating presence across the landscape.

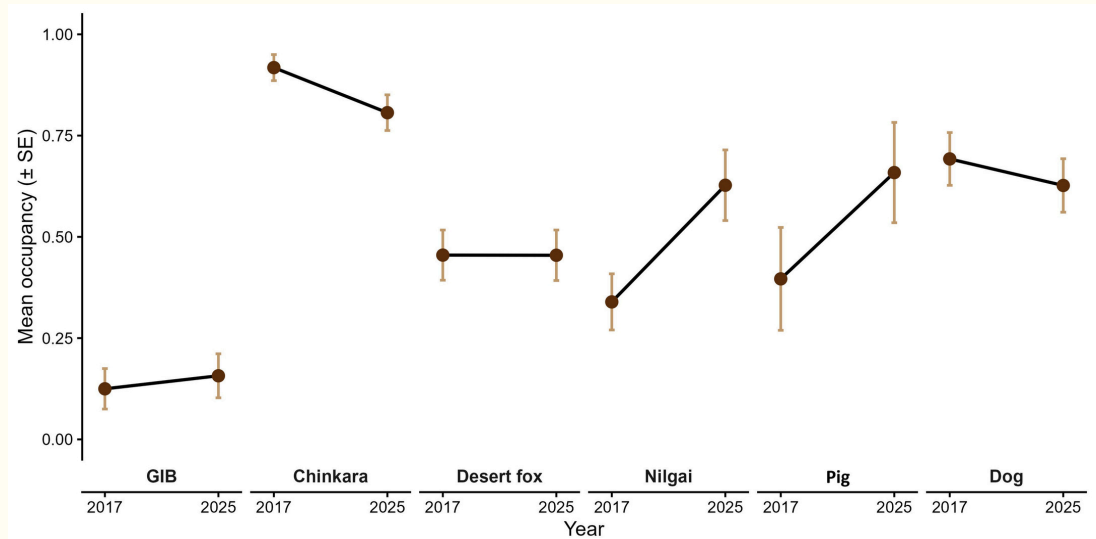


Figure 4. Species' occupancy (mean and SE proportion of sites occupied) trend from 2017 to 2025 in Thar landscape, for native (GIB, chinkara, desert fox) and non-native species (nilgai, pig, dog).

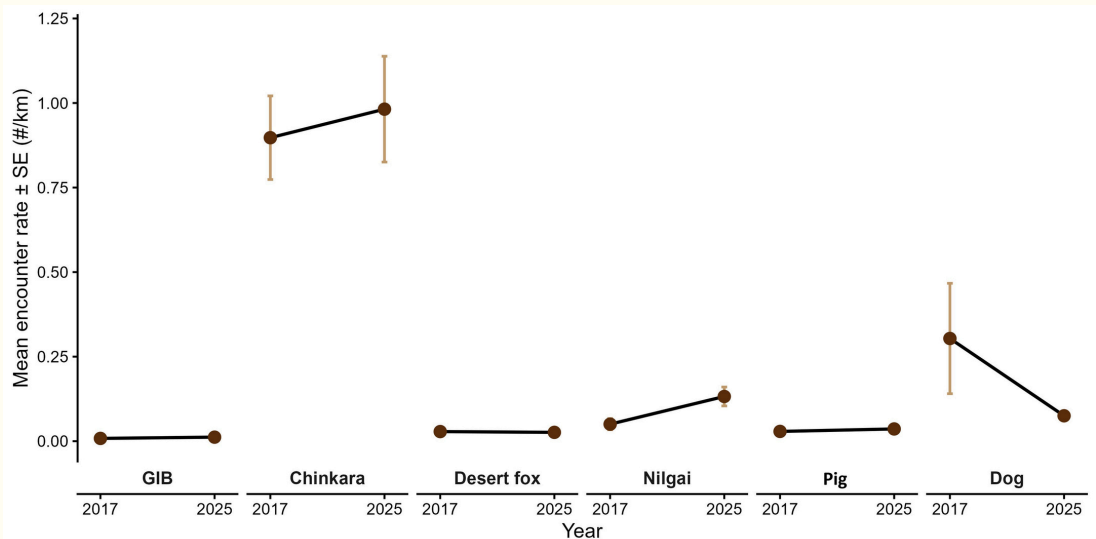


Figure 5. Species' encounter rate trend from 2017 to 2025 in Thar landscape, indicated as mean (SE) count per km, for native (GIB, chinkara, desert fox) and non-native species (nilgai, pig, dog).

D. Habitat status

The surveyed landscape was predominantly flat. Substrate composition was largely dominated by soil, with lower representation of sand and rock or gravel surfaces (Table 2). Land cover was primarily characterised by grassland, followed by scrubland, agriculture, woodland, and barren land (Table 2; Figure 7). Expectedly, active agriculture and crop cover were higher during September 2024 survey compared to April 2025, as cultivation is primarily seasonal and rainfed (Table 2). Vegetation structure was dominated by short grass and herbaceous cover (<30 cm), followed by shrub or low woody vegetation (<2 m) = tall grass or herbaceous cover (>30 cm) > > tree and tall woody vegetation (>2 m) (Table 2; Figure 7).

Among dominant upperstorey vegetation, *Capparis decidua*, *Calotropis procera*, and *Ziziphus* spp. were the most dominant, followed by *Prosopis juliflora* > *Leptadenia pyrotechnica* > *Salvadora oleoides* > *Prosopis cineraria* > *Acacia* spp (Table 2; Figure 6). Dominant understorey vegetation was primarily represented by *Dactyloctenium* spp., followed by *Cassia* spp., *Aerva* spp., *Fagonia* spp., *Aristida* spp., *Indigofera* spp., *Leptadenia* sp., and *Crotalaria* spp. Seasonal variation in understorey composition was evident for some ephemeral species, including *Cassia* spp., *Fagonia* spp., *Crotalaria* spp., and *Indigofera* spp. (Table 2; Figure 6).



Table 2. Descriptive statistics of habitat covariates in 144 km² cells of the Thar landscape (2024 & 2025)

Covariate	Category	Mean occurrence ($\pm$ SE)	
		2024	2025
Active disturbance (200 m radius)	Human	-	0.49 $\pm$ 0.03
	Machinery & Vehicle	-	0.37 $\pm$ 0.02
Passive disturbance (500 m radius)	Farm hut	0.43 $\pm$ 0.02	0.39 $\pm$ 0.02
	Agricultural fence	0.60 $\pm$ 0.03	0.50 $\pm$ 0.03
	Industry / Mine	-	0.01 $\pm$ 0.005
	Power line	0.59 $\pm$ 0.03	0.58 $\pm$ 0.03
	Metal road	0.20 $\pm$ 0.02	0.17 $\pm$ 0.01
	Human settlements	0.15 $\pm$ 0.01	0.16 $\pm$ 0.01
	Solar plants	0.03 $\pm$ 0.01	0.03 $\pm$ 0.01
	Water sources	0.48 $\pm$ 0.03	0.44 $\pm$ 0.02
	Wind turbines	0.09 $\pm$ 0.02	0.10 $\pm$ 0.02
Landcover (100 m radius)	Active agriculture	0.20 $\pm$ 0.01	0.02 $\pm$ 0.01
	Fallow agriculture	0.07 $\pm$ 0.01	0.22 $\pm$ 0.01
	Barren	0.02 $\pm$ 0.01	0.1 $\pm$ 0.01
	Grassland	0.43 $\pm$ 0.02	0.30 $\pm$ 0.02
	Scrubland	0.25 $\pm$ 0.02	0.23 $\pm$ 0.02
	Woodland	0.12 $\pm$ 0.01	0.18 $\pm$ 0.02
Terrain (100 m radius)	Flat	0.79 $\pm$ 0.02	0.76 $\pm$ 0.02
	Slope	0.09 $\pm$ 0.01	0.09 $\pm$ 0.01
	Undulating	0.12 $\pm$ 0.02	0.14 $\pm$ 0.02
Substrate (100 m radius)	Rock / Gravel	0.14 $\pm$ 0.02	0.15 $\pm$ 0.02
	Sand	0.12 $\pm$ 0.01	0.12 $\pm$ 0.01
	Soil	0.11 $\pm$ 0.01	0.12 $\pm$ 0.01
Spiny-tailed lizard (20 m radius)		0.08 $\pm$ 0.01	0.11 $\pm$ 0.01

Covariate	Category	Mean occurrence (± SE)	
		2024	2025
Indian desert gerbil (20 m radius)		0.34 ± 0.03	0.50 ± 0.03
Power line (500 m radius)	Marked high tension	0.08 ± 0.01	0.07 ± 0.01
	Unmarked high tension	0.07 ± 0.01	0.11 ± 0.02
	Low tension	0.52 ± 0.03	0.49 ± 0.03
Agricultural fence (500 m radius)	Barbed wire	0.45 ± 0.03	0.36 ± 0.03
	Chain-link / Weld-mesh	0.25 ± 0.03	0.24 ± 0.02
	Electric	0.20 ± 0.02	0.09 ± 0.02
Vegetation structure (20 m radius)	Short grass / herb (veg < 30 cm) %	27.08 ± 1.05	22.48 ± 1.16
	Tall grass / herb (veg > 30 cm) %	15.52 ± 1.11	9.78 ± 0.83 %
	Shrub / woody (veg < 2 m) %	16.35 ± 1.01	16.29 ± 0.98 %
	Tree / woody (veg > 2 m) %	10.63 ± 0.70	13.31 ± 0.94 %
	Crop %	7.94 ± 0.78	0.75 ± 0.19
Dominant upperstorey vegetation (100 m radius)	<i>Calotropis procera</i>	0.41 ± 0.03	0.42 ± 0.03
	<i>Capparis decidua</i>	0.43 ± 0.03	0.48 ± 0.03
	<i>Prosopis cineraria</i>	0.09 ± 0.01	0.11 ± 0.02
	<i>Acacia sp.</i>	0.01 ± 0.004	0.04 ± 0.01
	<i>Acacia tortilis</i>	0.06 ± 0.01	0.04 ± 0.01
	<i>Leptadenia sp.</i>	0.15 ± 0.02	0.16 ± 0.02
	<i>Prosopis juliflora</i>	0.19 ± 0.02	0.17 ± 0.02
	<i>Salvadora oleoides</i>	0.12 ± 0.02	0.11 ± 0.02
	<i>Ziziphus sp.</i>	0.27 ± 0.03	0.25 ± 0.02
Dominant understorey vegetation (100 m radius)	<i>Dactyloctenium sp.</i>	0.62 ± 0.03	0.61 ± 0.03
	<i>Leptadenia sp.</i>	0.04 ± 0.01	0.27 ± 0.03
	<i>Cassia sp.</i>	0.14 ± 0.02	0.24 ± 0.03

Covariate	Category	Mean occurrence ($\pm$ SE)	
		2024	2025
Dominant understorey vegetation (100 m radius)	<i>Fagonia sp.</i>	0.06 $\pm$ 0.01	0.35 $\pm$ 0.03
	<i>Crotalaria sp.</i>	0.02 $\pm$ 0.01	0.22 $\pm$ 0.02
	<i>Aerva sp.</i>	0.12 $\pm$ 0.02	0.21 $\pm$ 0.02
	<i>Haloxylon sp.</i>	0.04 $\pm$ 0.01	0.10 $\pm$ 0.02
	<i>Aristida sp.</i>	0.24 $\pm$ 0.02	0.10 $\pm$ 0.01
	<i>Lasiurus scindicus</i>	0.02 $\pm$ 0.01	0.08 $\pm$ 0.01
	<i>Indigofera sp.</i>	0.24 $\pm$ 0.02	0.08 $\pm$ 0.01
	<i>Calotropis procera</i>	0.03 $\pm$ 0.01	0.12 $\pm$ 0.02
	<i>Cenchrus sp.</i>	0.12 $\pm$ 0.02	0.06 $\pm$ 0.01
	<i>Tephrosia sp.</i>	0.08 $\pm$ 0.02	0.09 $\pm$ 0.02
	<i>Ziziphus sp.</i>	0.01 $\pm$ 0.003	0.04 $\pm$ 0.01

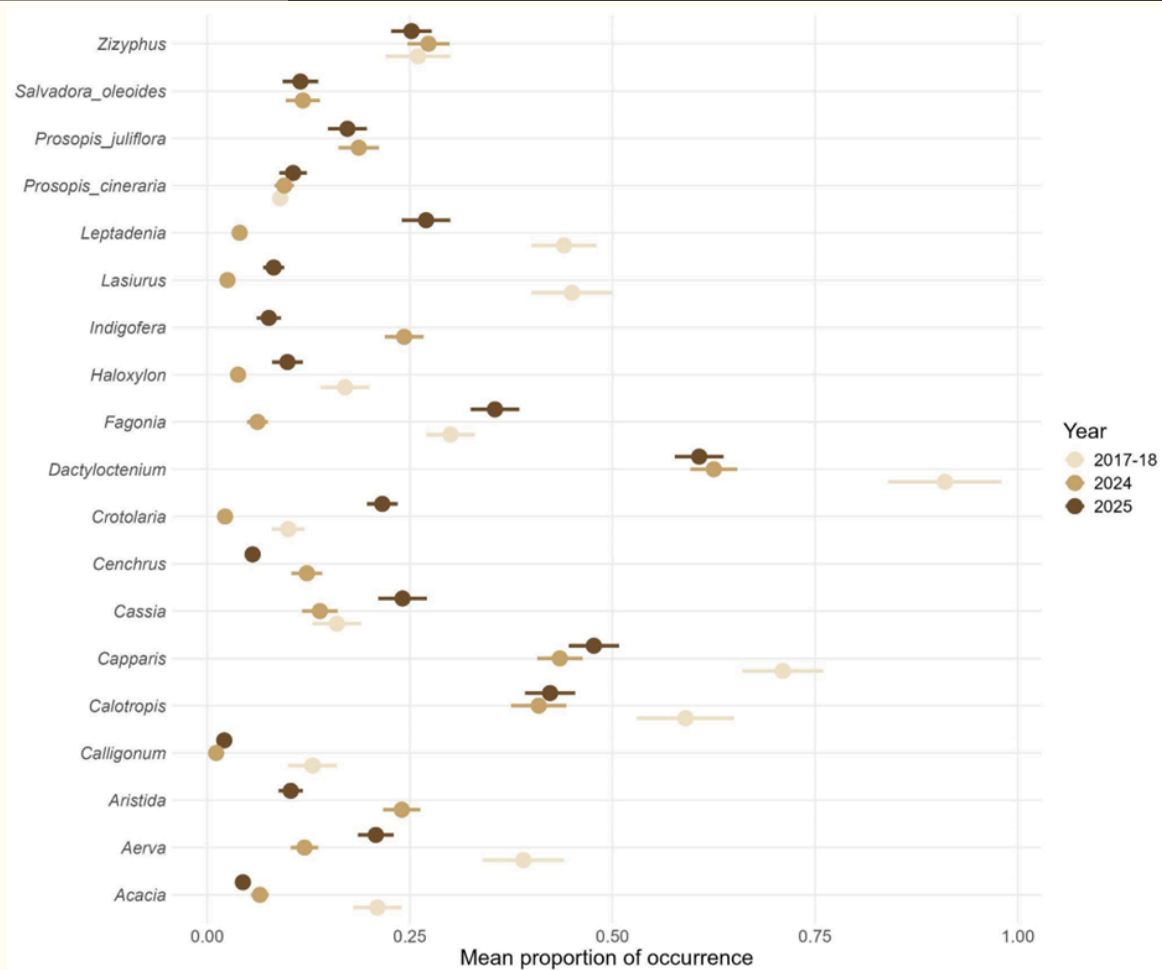


Figure 6. Mean (SE) incidence of dominant vegetation (understorey and upperstorey) in 2017-18 and 2024-2025 surveys (bars not shown for species not found to be dominant during 2017-18)

Anthropogenic features were widespread across the landscape (Table 2). The use of electric fencing was relatively higher during the cropping season (Table 2). However, the continued presence of barbed-wire and chain-link fencing across both surveys suggests permanent installation of such protective structures, even during the non-cropping season. The occurrence of the spiny-tailed lizard was low across the landscape, whereas the Indian desert gerbil showed relatively high presence (Table 2).

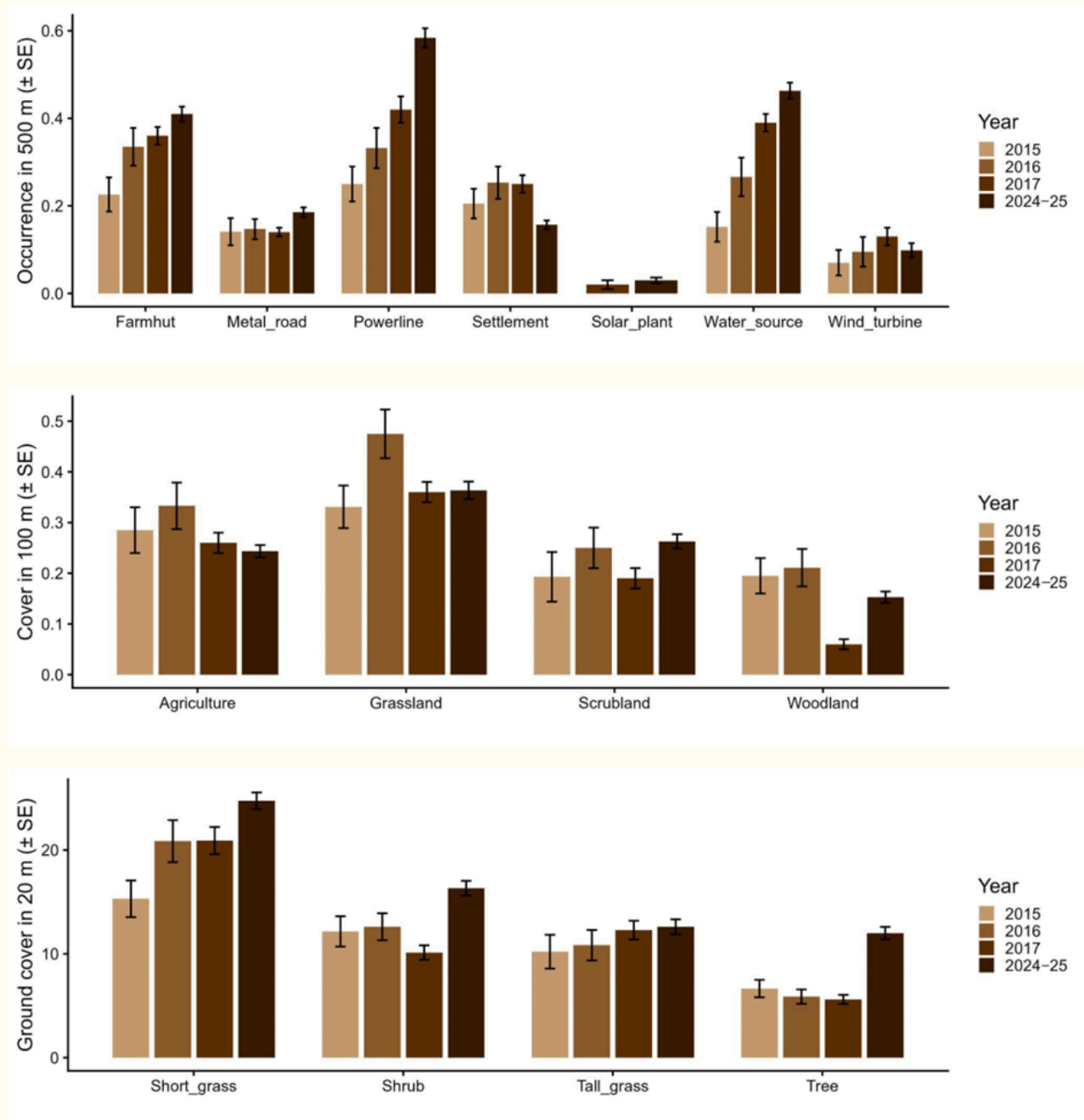


Figure 7. Mean (SE) incidence of human artefacts (top), land-cover (middle) and percentage ground cover of vegetation types across sampling plots in Thar landscape from 2015 to 2024-25

Across the surveyed years (2017-2025), the landscape showed a consistent increase in the occurrence of multiple human artefacts, indicating expansion of human footprint (Figure 7). Increase in water sources indirectly subsidises non-native predators such as pig, nilgai, and free-ranging dogs and facilitates increased livestock presence in grassland areas, impacting native wildlife.

Grassland cover showed moderate increase, likely reflecting targeted conservation interventions such as the establishment of grassland enclosures within DNP and Mokla Conservation Reserve, aimed at enhancing habitat suitability for GIB and associated grassland species. Scrubland cover remained broadly stable. Vegetation structure patterns showed land-cover stability, with total vegetation cover increasing slightly over time and with an observed increase in woodland cover post-2017 (Figure 7).

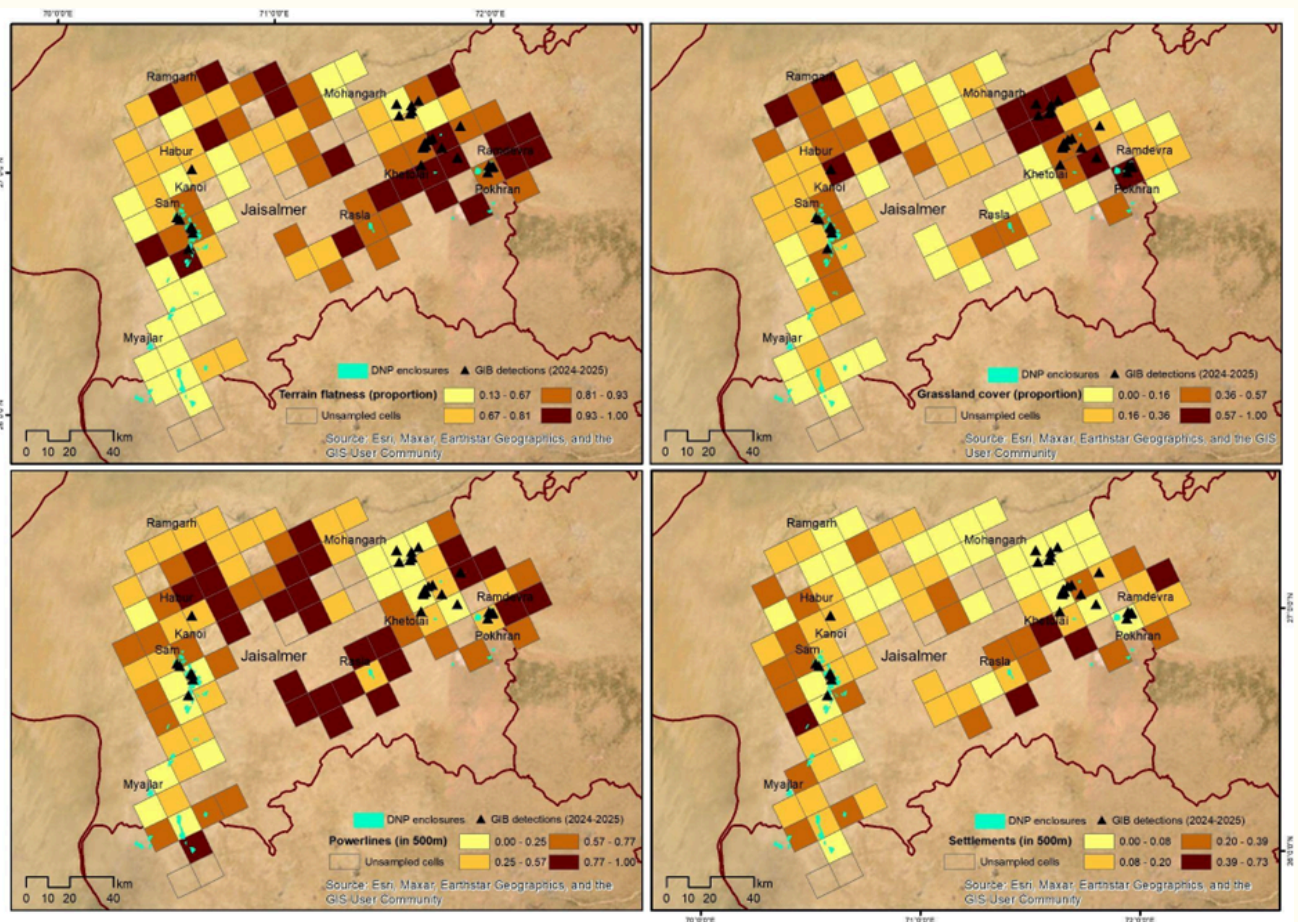


Figure 8. Spatial distribution of key landscape features across Thar landscape (2025): (clockwise) terrain flatness, grassland cover, power lines, and human settlements

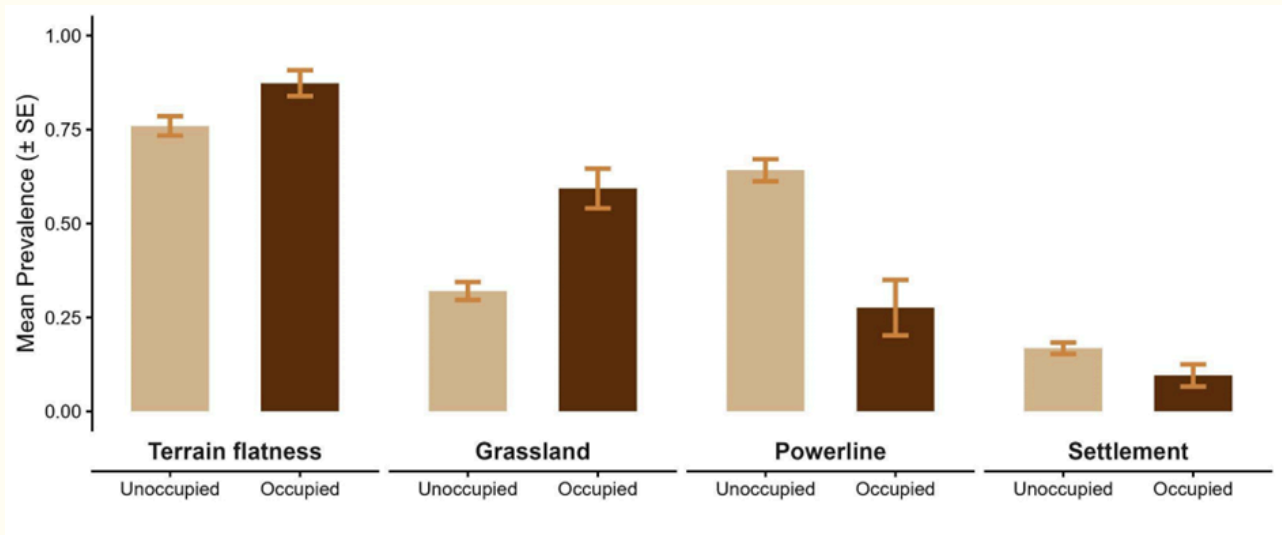


Figure 9. Comparison of habitat features (left to right) - terrain flatness, grassland cover, power lines and settlements between GIB occupied and unoccupied cells in the Thar landscape (2025)

The growing human footprint raises concerns for the conservation of GIB, which is sensitive to anthropogenic disturbances.



E. Status of Raptors

The survey recorded a total of 32 species of raptors, clearly demonstrating the importance of this landscape for raptor conservation. The most commonly recorded species were Common Kestrel and Tawny Eagle, followed by Egyptian Vulture (Figure 10). The survey also recorded rare species such as the Saker Falcon, Merlin, Red-headed Vulture, White-rumped Vulture, Indian Vulture, all of which were found in very low numbers (Figure 10). The postmonsoon period (October 2024) recorded high encounter rates of Harriers (*Circus* spp; 0.35 ± 0.02 / km) indicating the importance of Thar landscape as a major wintering and stopover site for harriers (Figure 10). Encounter rates of the raptor species are shown in Figure 10.

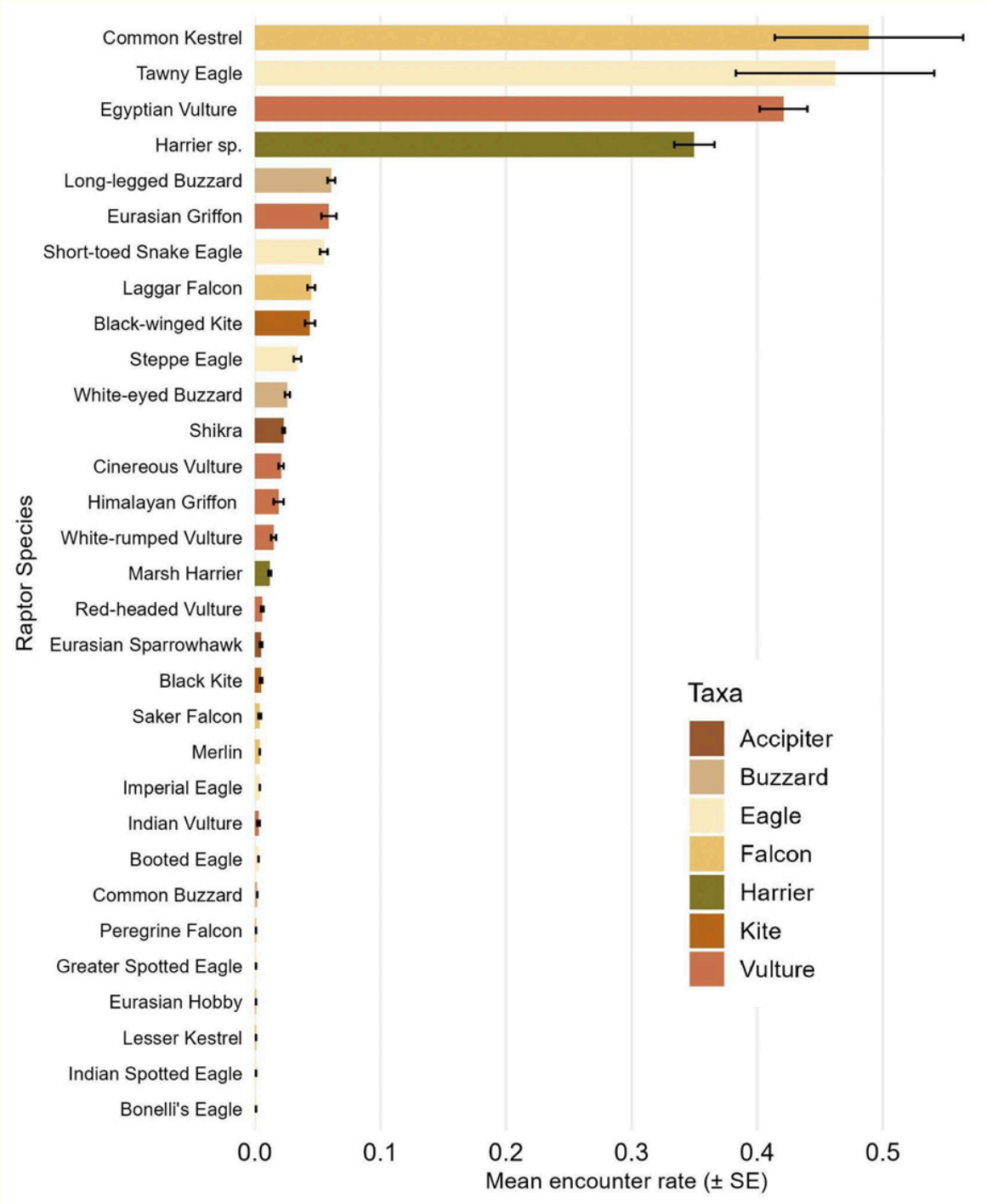


Figure 10. Mean encounter rates of Raptor species in Thar landscape (2024-25)

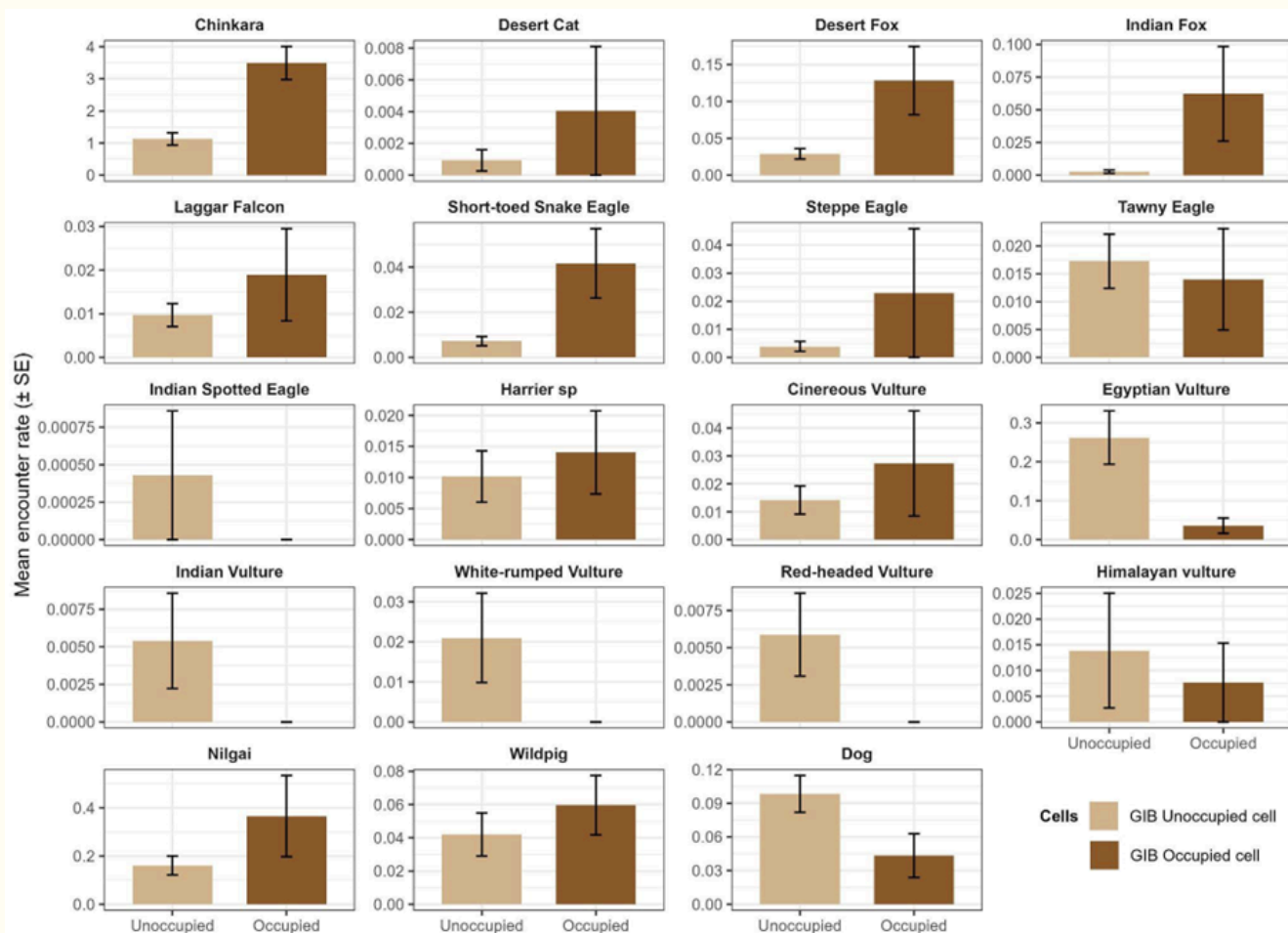


Figure 11. Mean encounter rates of mammals and threatened raptors in GIB occupied and unoccupied cells in Thar landscape during 2024-25



DISCUSSION

The Thar GIB survey is a long-term periodic assessment of the population status of the Great Indian Bustard, associated key fauna, dominant plants, habitat characteristics, and anthropogenic disturbances in the Jaisalmer landscape of the Indian Thar Desert. It is one of the few systematic wildlife monitoring programs running in the country that has generated time-series georeferenced information on the distribution and abundance of key flora and fauna from the largest Open Natural Ecosystem of India. The survey methodology, developed in 2014-15, entailed a balance between scientific rigour and logistic practicability (Dutta et al. 2015). Since a vast landscape has to be covered within a brief duration, and involves large man-power of varying skills - ecologists, frontline staff and volunteers - surveyors are rigorously trained through a field workshop at the start of the annual exercise until their observations are standardized, and the data collection is restricted to minimal essential information on easily identifiable taxa. The exercise was repeated in 2014, 2015, 2016, 2017-2018 and 2024-2025, following the standard methodology. All surveys were conducted in March (except 2018 and 2024), to take advantage of longer day length, relatively mild temperature, and higher species' detectability (short dry grass, minimal haze, and pre-nesting season of GIB). Minor modifications in design have been incorporated over time, such as the addition of raptors and the reduction of the sampling frame in the latest exercise.

The latest survey has covered the Revised GIB Priority Area of Rajasthan, excepting ~2,000 sqkm area in the southern end of Desert National Park, ~1,000 sqkm in restricted parts of Pokhran Firing Range, and additional 1,440 sqkm area around Rasla. To account for the difference in sampling frame, species' trends were compared between the common subset of grid-cells across survey years (2017 and 2025). The Thar landscape is one of India's largest contiguous wilderness with historically low human pressures that has retained substantial populations of many specialised arid-adapted wild species - including the Critically Endangered GIB and threatened raptors of the Central Asian Flyway - and is therefore a priority conservation landscape (Dutta et al. 2024). Additionally, it is one of the most promising areas for renewable energy generation, to meet the national targets of climate change mitigation by substituting fossil fuels. Being one of the marginalized and aspiring districts, it is also prioritized for economic development and livelihood upliftment. The monitoring exercise, helped to understand trends in species' densities, vegetation composition, and anthropogenic disturbances across this globally important landscape.

The conservation flagship of the Thar landscape - GIB - showed a stable population across the last decade, as per our survey findings. Since the species is spatially restricted, the population trend were inferred based on both occupancy and density measures derived from standardized efforts. In-situ conservation efforts included habitat restoration through development of chain-link-fenced grassland enclosures in the species' breeding area, dog neutering programs, predator translocations from GIB breeding enclosures, removal of invasive species (*Prosopis juliflora* and pigs), and development of a few community fodder plots, through combined efforts of Rajasthan State Forest Department, Wildlife Institute of India, and NGOs working in this landscape.

Conservation breeding program has been initiated, under which 44 wild-laid eggs were collected from the Desert National Park and Pokhran Range, resulting in 33 surviving wild founders, along with 35 captive-bred birds that will initiate pilot release of captive-bred chicks. The species' occupancy is restricted to only 16% of the landscape area at any time, despite a larger area with suitable vegetation being available. The occupied sites are largely concentrated in areas with flat grasslands devoid of human settlements and renewable energy infrastructure, in/around Desert National Park and Pokhran Range.

The population of chinkara and desert fox have remained stable, although more robust estimates based on camera traps surveys are required. Whereas, the populations of non-native fauna (nilgai, pig and dogs) are expanding and are now widespread in the landscape.

There was a high congruence between GIB distribution and encounter rates of some other native fauna, such as chinkara, desert fox, Indian fox, laggar falcon, harriers, and short-toed snake eagle that also highlight the benefits to these species under GIB centric conservation of habitat (Figure 11). Also, higher encounters of invasive pigs in GIB occupied areas necessitate egg/chick protection.

Land-cover composition, measured as proportional areas under grassland, scrubland and agriculture, have remained the same in the common sampling frame. The vegetation composition trend shows reduction in *Lasiurus scindicus* and *Dactyloctenium* spp, highly palatable and locally preferred fodder grasses, compared to an increase in weedy species such as *Cassia angustifolia*. An increase in total vegetation cover and of woody species such as *Calotropis procera* was noted, probably correlated with an increasing trend of annual rainfall and availability of surface water. Increase in surface water relaxes hydric constraints earlier limiting the spread of non-native mesic-adapted species, such as nilgai, pig and dogs - that is perhaps the reason behind their increasing distribution across the landscape - and poses new challenges for the native conservation-dependent species such as GIB and chinkara, through competition and/or predation (Dutta et al. 2024).

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