Monitoring threatened birds of the Thar Desert

How does habitat restoration for the Great Indian Bustard impact associated avifauna?

Technical Report 2023-2024

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

INDIAN INSTITUTE OF SCIENCE EDUCATION AND RESEARCH BHOPAL

The Rufford Foundation

How does habitat restoration for the Great Indian Bustard impact associated avifauna of the Thar desert?

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Funded by:

The Rufford Foundation, UK

In collaboration with:

Bustard Recovery Program, Wildlife Institute of India, Dehradun

Acknowledgements

We extend our sincere gratitude to The Rufford Foundation for their funding support, without which this study would not have been possible. PCCF (WL) & CWLW, Rajasthan Forest Department, kindly provided permissions for the banding exercise and we are grateful to him for his support. We are also thankful to the DFO (Wildlife), Jaisalmer Dr. Ashish Vyas, for granting the necessary permissions for our field surveys and to the ground staff of Desert National Park for facilitating our field activities.

The study was hosted by two institutions - Wildlife Institute of India, Dehradun and Indian Institute of Science Education and Research Bhopal (IISER Bhopal), and we thank the administration of both institutes for their cooperation and support. Mr. Harish (IISER Bhopal Biology Department lab manager), Mr. Ankur Saraswat (Grants Officer, IISER Bhopal), Mr. Narendra Singh Chauhan (Finance Officer, WII) were particularly supportive during administrative activities relating to the project. The grant had to be transferred from IISER Bhopal to WII Dehradun in the middle of the tenure and many people in the accounts section of both the institutions helped in the transfer of grant money.

Our appreciation goes to our field assistants, Aradin, Saddam, and Prabhu Singh, for their invaluable support during fieldwork and data collection. Special thanks to Vishnu, Swayam, Sajiri, Ishaan, and Abhiram for their assistance during the surveys and nest search. We would like to acknowledge Aliyar, nature guide DNP for his help with sighting information and their location.

We acknowledge the Bustard Recovery Program team for their collaboration and support. We also thank the Director, Dean and Registrar of the Wildlife Institute of India and the Director and Dean of Academic Affairs at IISER, Bhopal, for their organizational support.

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Executive summary (English) - Varun Kher

Conservation in the Thar Desert centres on the Great Indian Bustard as a flagship species, and this study aimed to comprehensively assess the impact of GIB focused habitat restoration on co-existing threatened species of the Thar Desert. The study employed various methodologies including bird surveys, habitat mapping and advanced analytical methods to assess the impact of habitat restoration on bird populations in the Thar Desert. Some efforts were also made to spread awareness amongst the local stakeholders. Key findings of the study were as follows:

1. We found that occupancy of most raptors was not affected by presence of vegetation recovery enclosures in a grid. The exception to this pattern was the Laggar Falcon *Falco jugger* which had much higher predicted occupancy in areas with enclosures. As for smaller birds, total richness and occupancy of most birds was very similar between restored and unrestored areas. However, there were differences in occupancy of some species. For example, Cream Coloured Courser Cursorius cursor, Laughing Dove *Spilopelia senegalensis* and Eurasian Collared dove *Streptopelia decaocto* had lower occupancy in restored grasslands whereas White-browed Bushchat *Saxicola macrorhynchus*, Tawny Pipit *Anthus campestris* and Long-billed Pipit *Anthus similis* had a higher occupancy.

2. Our preliminary demographic surveys aimed at understanding vital rates of different species in restored and unrestored areas provided us with two learnings – a. Monitoring survival rate and population growth of small birds using banding is not feasible without significantly higher effort. b. Nest monitoring of raptors is feasible and enough nests can be found to compare vital rates between restored and unrestored areas. We found a total of 22 raptor nests, which included threatened species such as White-rumped Vulture *Gyps bengalensis*, Egyptian Vulture *Neophron percnopterus*, Tawny Eagle *Aquila rapax* and Laggar Falcon. These nests are currently being monitored to understand chick survival and the breeding biology of these species.

3. We detected all (except one) of the threatened bird species in the Thar Landscape. Based on the encounter rates, we could get meaningful estimates of occupancy and

habitat responses for the White-browed Bushchat, Laggar Falcon, Egyptian Vulture and Tawny Eagle. The encounter rate for Red-headed Vulture *Sarcogyps calvus*, White-rumped Vulture and Indian Spotted Eagle *Aquila hastata* was too low to infer anything meaningful. We found that Laggar Falcon and the White-browed Bushchat are heavily associated with grassland habitats and are benefiting from GIB conservation activities. Egyptian Vultures, on the other hand, seemed to prefer unrestored cropland habitats and had a marginally lower occupancy and density in restored areas. The Tawny Eagle seemed to be indifferent to the restoration of habitats.

4. Three local youth were employed as field assistants during the project and were trained in bird identification, ecology and survey techniques. Ground staff of the local forest department (who mostly come from the local communities) were informed about the presence of different threatened bird species in their area and flyers were distributed to help them with identification. Our team also facilitated a visit of school children to the Desert National Park in collaboration with the Bustard Recovery Program and the Rajasthan Forest Department. School children were informed about the various birds seen in the region during this visit.

Certain knowledge gaps were identified based on the results of this study and the following activities are suggested for upcoming projects:

- Monitoring of birds in restored areas over the long term to understand the temporal effects of vegetation recovery and protection
- Monitoring of nests identified during this exercise to understand breeding ecology and identify threats and/or demographic bottlenecks.
- Telemetry of a few birds to understand the spatial ecology of threatened species and their interaction with potential threats
- Expansion of restoration programs for mitigating other threats such as invasive species and renewable energy infrastructure, and subsequent monitoring.

1. Introduction

Conservation in India has traditionally revolved around the management of select flagship or umbrella species in protected and semi-protected areas. The rationale here is that the conservation of representative large, charismatic or wide-ranging species passes on direct and indirect benefits of management to associated biodiversity, leading to the conservation of most species in the landscape. Based on this philosophy, wildlife-rich areas in the Thar desert landscape are managed with a focus on the Great Indian Bustard, as a mascot of the desert biodiversity, and acting as an umbrella for their conservation.

Arid and semi-arid ecosystems of India are increasingly under threat from rapid land-use change, driven particularly by the expansion of intensive agriculture and renewable-energy infrastructure over traditional rangelands and agro-pastures. This crisis is exemplified by the decline of the Great Indian Bustard (GIB) - once distributed across India’s dry countryside but now restricted to a few isolated pockets. The sole viable population of the species (c.100 individuals) is found in the Thar desert of western Rajasthan, with an important cluster in Desert National Park WLS (DNP) and surrounding areas.

A major component of GIB conservation in the last few decades has revolved around the restoration of habitats through the construction of habitat regeneration enclosures. Agriculture is not permitted within these enclosures and livestock grazing is highly regulated. This passive restoration facilitates vegetation recovery, and there is growing evidence that such recovered grasslands are extensively used by the GIB, particularly during the breeding season. However, the GIB shares this landscape with many other bird species, some threatened, and the effect of restoration on these co-occurring species is not well understood. Some of these species differ from the GIB in terms of their conservation requirements, and others are potential barometers of the success of GIB-specific conservation measures in areas where the GIB currently does not exist. However, the status, ecology and response of these species to habitat management is poorly known and remains understudied. This project tried to address this gap and develop methods rooted in population and community ecology to holistically assess the effects of GIB-centric ecological restoration on other threatened species of the Thar Desert.

1.1 Ecological History of the Thar Desert

The Thar desert hosts some of India's last remaining patches of extensive grasslands and is an extremely important breeding and wintering area for many threatened bird species. Biogeographically, this arid sandy tract forms the eastern limit of the vast Saharo-Iranian desert and blends into wetter, semiarid conditions to the east. Rainfall is sparse at ~200 mm per year, 90% of which is received during monsoon (June – September), and is intercepted by moderate to severe droughts once in three years (Rao and Roy 2012). However, its paleoclimate was more semiarid and wetter from 2 million years up to 0.25 million years before the present (Dhir et al. 2018). Since then, the climate dried up, characterized by weaker monsoons, extensive sand deposition, and the current arid conditions set in at 4000 years before the present. Sediment core analysis of Lunkaransar and other salt lakes is indicative of such paleoclimatic patterns (Enzel et al. 1999). These changes presumably conferred an advantage to the xeric species over their mesic counterparts.

Aridification also restricted human occupation. While organized human societies harnessed the potential of agriculture and livestock in the Indus plains to the west and east of the Aravalli mountains, the intervening region of Thar remained thinly populated with nomadic hunter-gatherers through early human history (Misra 2001, Madella and Fuller 2006, Dhir et al. 2018). Settlements and agriculture expanded into Thar relatively recently, perhaps around 1000 years ago. Even then, livelihoods depended on pastoralism; the cultivated area was only 15%, and the human population was small, stable and numbered ~6 lakhs in Bikaner in the first half of the 20th century (Dhir et al. 2018). In contrast, the human population exploded by tenfold in the last 60 years, with a recent decadal growth rate of 20-30% (Census data).

The single major change in the environment of the Thar Desert was brought by the Indira Gandhi Canal, which created an agriculturally intensive corridor in the 1980s. Irrigation and mechanized farming facilitated a four-fold increase in cultivated area in Bikaner during the last 50 years, with crop cover increasing from 15% (1960) to 54% (2011) (Dhir et al. 2018). Much of agricultural expansion came at the cost of erstwhile culturable wastelands or areas owned by the Government that were grazed by livestock, and fallow lands or areas not farmed in current year(s). Consequently, the Thar desert with 70% of its area under cultivation has become the most intensively farmed arid region in the world, posing novel challenges for its wildlife and ecological sustainability. These land-use changes have exposed the native wildlife, which remained isolated from humans historically, to a sudden and intense wave of anthropogenic pressures. Only *gauchars* or common village grazing lands, *orans* (sacred groves) or lands spared by local communities for wildlife and grazing, cumulatively known as permanent pastures, and forest department lands remain as a refuge for native wildlife. Moreover, the region has experienced infrastructural developments in the form of industrial growth, rural electrification and expansion of the road network, adding to the anthropogenic pressures. Increased surface water and plantations lining the canal have facilitated mesic species to (re)establish in the region (Rahmani and Soni, 1997). Thus, ecoclimatic trajectories spanning thousands of years are at risk of being reversed within a few decades; the implications of which are yet to be discerned.

1.2 Objectives

Our study evaluated the effectiveness of GIB-centric habitat restoration on associated bird species of the Thar Desert. This was achieved by comparing their population and community-level parameters across restored and unrestored areas in the study site. We paid particular attention to threatened species in the landscape, many of which are highly understudied. Our study provides baseline information on the status and habitat association of many understudied birds in the Thar desert (such as the threatened White-browed Bushchat and Laggar Falcon) and many other species of global conservation interest (such as vultures and Aquila eagles).

Beyond ecological effects, an unintended consequence of flagship-focused conservation is that other associated species are neglected in public discourse. To address this imbalance, we conducted awareness sessions and distributed outreach material to inform the local public (particularly school children, government staff and tourist guides) about the presence and ecological role of threatened species in the landscape.

The specific activities conducted as part of the project were as follows:

1. Comparing bird distribution between restoration areas and outside, across seasons, through:

a. Vehicle surveys for raptors and other large-bodied & wide-ranging birds.
b. Line transect surveys for quantifying diversity of passerine birds

2. Understanding the impacts of GIB-focused restoration on population and distribution parameters of associated bird species, particularly threatened species and establishing a paradigm for monitoring demographics in the future:

a. Capture and banding of small birds to monitor population parameters using mark-recapture techniques.
b. Nest searches for both large and small birds to monitor demographic parameters in enclosures and outside.

3. Ascertaining status of resident threatened species of the Thar desert - White-browed Bushchat, Laggar Falcon, Egyptian Vulture, Red-headed Vulture, White-rumped Vulture, Indian Spotted Eagle, Tawny Eagle:

a. Preliminary status assessment of aforementioned species using data collected from vehicle/ line transects and other ad-libitum surveys.
b. Standardization and refinement of survey methodology for monitoring

4. Acquainting relevant stakeholders with avifauna of the region through in-person meetings and distribution of outreach materials:

a. Meetings with implementation agencies (mainly the forest department) to disseminate information obtained during the study.
b. Distribution of material such as bird photos and pamphlets in schools within the study area

2. Methods

The study had four major methodological components - 1. Mapping and habitat evaluation; 2. Bird surveys; 3. Outreach and Stakeholder engagement; 4. Development and standardization of methods. Each of these is mentioned in detail below.

2.1 Mapping and habitat evaluation

Our primary objective was to compare bird distribution and abundance across restored and unrestored landscapes. To achieve this, it was necessary to map out these areas along with other factors that may influence the said parameters. As some of this information was already available, we retrieved it from relevant sources. The remaining information was collected on the ground through habitat surveys.

2.1.1 Remote sensing of habitat information

GIS layers for restored areas (enclosures) and classified Land use - Land cover (LULC) map of the entire study area were obtained from Wildlife Institute of India's Bustard Recovery Program. Vectors of renewable energy infrastructure were sourced from Open Street Maps (OSM). These layers were ground-truthed and verified during field surveys. The LULC was corrected manually wherever prominent misclassification was identified.

2.1.2 Habitat sampling

In every 1sq.km. cell surveyed for small birds, habitat covariates were measured on four 200m transects that were nested within the bird sampling lines. Basic physiographic parameters such as landcover, terrain and substrate, along with vegetation composition were noted down at every 50m on this transect. Vegetation sampling was conducted separately for the understory and upperstory. For the understory, a 2 x 2m quadrat was laid at every 50m on the vegetation line and a total of 5 such plots were sampled (at 0, 50, 100, 150, and 200m respectively) for every bird transect. The following readings were taken to quantify the understory - Quadrat number, three dominant species for each quadrat, height class, and the percent cover for each species. For the upperstory, a belt transect of 50m width was walked for 200m and all trees (>2m height) were recorded within this area. A subset of this belt with 20m width was used to quantify shrubs (<2m height). For trees, the following data was recorded; height, diameter of the crown, and the canopy start height. For shrubs, the dominant height class and the diameter of the plant were recorded. All the height classes were measured with a stick marked at every 10 cm.

2.2 Bird surveys

The study area was divided into large cells of 36 sq.km. (following Dutta et al., 2018) covering all land-cover features in the landscape. These cells were surveyed for larger birds such as eagles, vultures and falcons, through vehicle transects of appropriate length. As surveying small birds at such large scales was not practical, five representative 1sq.km. cells were randomly selected within the large cells and line transects were walked in each of them to quantify bird population and community parameters. For some large cells, additional 1sq.km. cells were surveyed to ensure coverage of all land-cover types. Details of both raptor and small bird surveys are given below.

2.2.1 Vehicle transects for raptors

Vehicle transects were conducted following Dutta et. al (2018) for the survey of diurnal raptors in the study area. The study area was divided using a 36sq.km. grid and each cell was surveyed at a slow pace, covering an average distance of 10 km (range: 4.4 km to 21.5 km) per cell. The survey trails were repeated twice: the first time in December 2023, covering 33 cells with a total effort of 298.69 km, second time in January-February 2024, covering 32 cells with a total effort of 344.63 km. This resulted in a combined effort of 643.32 km across 34 unique grids.

During the surveys, upon sighting a raptor, the species, number of individuals, location of the sighting (observer's location), and behaviour (perching, flying, or soaring) were recorded. If the raptor was perching, the distance and bearing of the bird were measured following the distance sampling approach (Buckland et al. 2005). Furthermore, active and passive disturbances such as windmills, powerlines, settlements, roads, humans, and dogs were recorded within a 500-meter radius of the bird sighting.

In addition, secondary data collected by collaborators during Great Indian Bustard surveys was used for occupancy analysis. This data was also collected using the same protocol, however, the target of the survey was the Great Indian Bustard. We incorporated this difference in the search frame as a detection covariate during analysis.

Image 1: Team members conducting vehicle surveys in the desert landscape

2.2.2 Line transect surveys for small birds

2.2.2.1 Small Bird surveys

Five 36sq.km. cells were selected for the estimation of small bird populations. Five (±1) representative 1sq.km. cells were randomly selected in a stratified manner. A 2 km transect was laid in each 1sq.km. grid. Each transect was composed of 4 segments of 500m each, arranged in a square fashion for logistical efficiency. Twenty-five such 2km line transects were surveyed twice in a season. Surveys were conducted in summer (May 2023 to June 2023) and winter (December 2023 to February 2024).

Birds were recorded when perched, and the following parameters were noted, using conventional distance sampling protocol (Buckland et al., 2015): species, location, individual count, distance of the bird from the observer, transect bearing, animal bearing and the time of sighting. All transects were walked at an easy uniform speed of 3-4 km/h (15 to 20 minutes per 500m segment).

2.2.2.2. White browed bushchat

For every small bird transect where the White Browed Bushchat was detected, additional surrounding cells were selected for adaptive cluster sampling, as the bushchat populations have been observed to be infrequent but spatially clustered, from previous surveys. Twenty-seven additional 2km transects were surveyed to get an estimate of the population density for the White-browed bushchat. The protocol remained the same except, only the bushchat detections were recorded in this particular survey.

Image 2: A line transect being walked by our field assistant

2.2.3 Nest Search

Ad-libitum nest search was conducted in areas with sightings of resident raptors. Surveys were conducted using camper vehicles with two observers standing in the trolley of the vehicle. To spot nests, large trees were carefully observed for any signs of nesting material or droppings. Additional secondary information was sourced from local naturalists, wildlife enthusiasts and herders. Every nest was observed for the presence of chicks and revisited after a few weeks if no chicks were seen. Some inactive nests were checked physically to check for feathers and to understand nest morphology.

Image 3: Checking of inactive nests

2.2.4 Bird capture and banding

Birds banding was conducted with the primary objective of collecting information on survival and breeding. Specialized mist-nets were erected for capturing birds and each trapped bird was ringed and measured using standardized protocols. The entire procedure of ringing, measurement and sample collection was completed within 15 minutes of capture and the bird was released back at the location where it was caught.

Image 4: Capture of small birds for banding

However, our preliminary efforts showed that capture rates of birds were very low and studying survival demographics and breeding ecology of small birds was not possible without greater funding and human resources. Consequently, the netting efforts were redirected towards species of specific interest, particularly the White-browed Bushchat. One White-browed Bushchat was caught in January 2024 and ringed with a metal + colour ring. The bird was observed post-release to understand its ranging patterns and ecology.

2.3 Analytical methods

2.3.1 Occupancy estimation

To estimate occupancy for each of the target species, data from the raptor surveys mentioned above was clubbed with secondary data from Great Indian Bustard surveys conducted by collaborators at the Wildlife Institute of India's Bustard Recovery Program. Survey covariates used were percentage of grassland cover in the grid, presence of enclosures and an index of renewable energy infrastructure. Nature of data (primary data from raptor survey or secondary data from GIB survey) and survey length was used as a survey/detection covariate. Multiple candidate models were run in a Bayesian single species occupancy framework and compared using BIC values. Models were evaluated through posterior predictive checks using Freeman-Tukey fit statistics. Convergence of the model was confirmed by checking R-hat values for different parameters. Models were compared using wAIC and deviance of k-fold cross-validation, and the ones with lower wAIC and cross-validation deviance were selected. Predicted values were mapped using ArcGIS.

2.3.2 Density estimation

2.3.2.1 Density estimation for raptors

As different raptor species were expected to have different detectability, we grouped certain species together based on morphological characters. A total of eight groups were made for modelling detection function. We constructed two candidate models using the Distance package in the R programming environment - one with raptor groups and one without. The model with groups was selected based on lower AIC values. Species-specific density was calculated by correcting encounter rate values using the grouped detection function.

2.3.2.2 Density estimation of small birds

Similar to raptors, small birds were also classified into groups and two candidate models (with groups and without groups) were run using the Distance package. Land cover was also added as an additional variable and all models were compared using AIC values.

2.3.4 Estimation of community level parameters

A multispecies occupancy model was run on the line transect dataset and community parameters were extracted following Zipkin et al 2023. The land cover of the area (restored vs unrestored) was given as a site covariate and the effect of restoration on community parameters was inferred from the results of the multi-species occupancy model.

2.3.5 Species habitat relationships for key species

Occupancy and relative abundance of few species was computed and the effect of habitat restoration on these parameters was evaluated using standard statistical methods. To understand factors influencing occupancy of species, we used landcover as a site covariate influencing occupancy and evaluated the effects of restoration by comparing posterior distribution for restored and unrestored areas. The occupancy modelling was conducted in a Bayesian multi-species framework. Model was selected on the basis of wAIC and posterior predictive checks were done following Doser et al., 2022.

3. Results and Discussion

3.1 Differences in assemblages between restored and unrestored areas

Predicted species richness in restored and unrestored areas was comparable with a median estimated richness of 15-17 species in all three land-covers (croplands, rangelands and restored grasslands). However, there were species-specific differences in occupancy of some species. For example, Cream Coloured Courser, Laughing Dove and Eurasian Collared dove had lower occupancy in restored grasslands as compared to rangelands whereas White-browed Bushchat, Tawny Pipit and Long-billed Pipit had a higher occupancy. However, as most restored areas were recovered from croplands, we looked at the relative effects of conversion to agriculture and restoration through passive vegetation recovery of birds with respect to a baseline of rangelands. In this comparison, occupancy was higher in restored grasslands for most birds and considerably higher for insectivorous birds. A similar pattern was shown by our previous work in the same area (Kher & Dutta, 2021).

Status of raptors was also evaluated in a similar framework and results of the same are discussed in detail below (see Section 3.3)

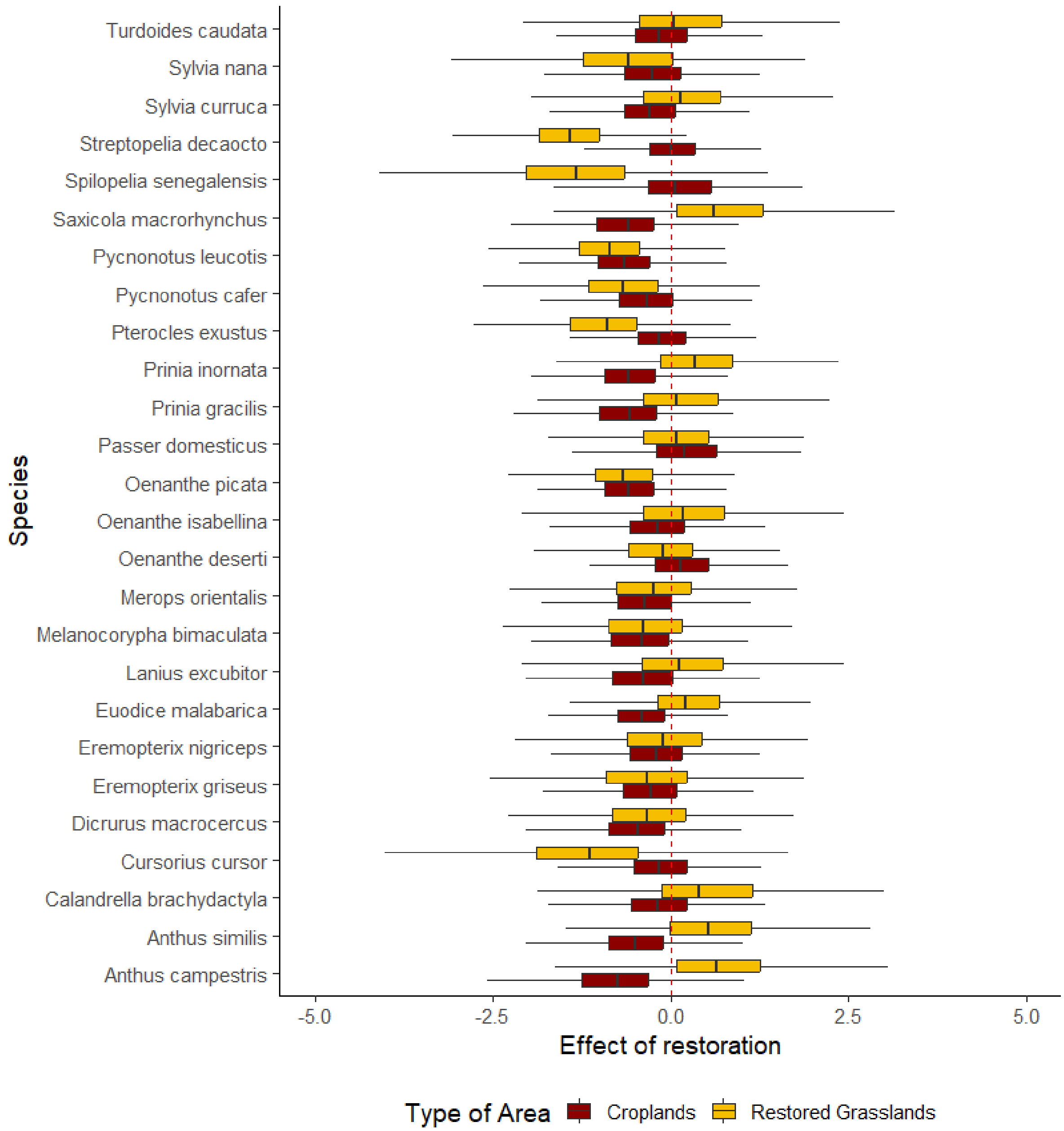


Figure 1: Effect of restoration on bird occupancy with rangelands (red-line) as control.

3.2 Pilot monitoring of demographic vital rates

We intended to band small birds for monitoring demographic parameters using mark-recapture techniques; however, this plan was shelved due to very low capture rates during the initial pilot sampling. Similarly, nest search for small birds was also not successful due to erratic rainfall during the survey year and a consequent low amount of nesting.

Demographic monitoring for raptors was initiated through nest search and subsequent monitoring of hatching success. Active nests of four threatened species were spotted and are currently being monitored to assess nesting success. In addition, multiple inactive nests were observed and recorded. Details of the active raptor nests are given below:

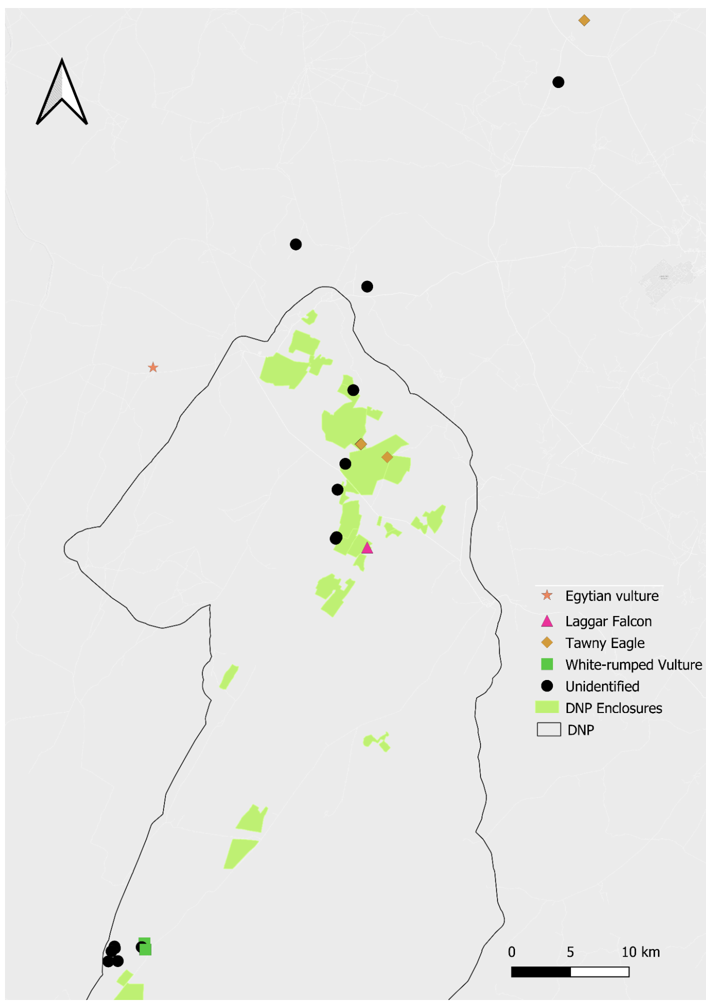


Figure 3: Map of all recorded raptor nests in the surveyed area

1. White-rumped Vulture

   Two active White-rumped Vulture nests were seen in Desert National Park WLS, outside the regenerated areas. Multiple old/inactive nests were seen in the vicinity of the active nest. All the nests were built on Khejri *Prosopis cineraria* at a height of 10+ meters. A total of 6 adults, one sub-adult and two chicks (almost fledged) were observed in and around the colony in late January. Search for more White-rumped vulture nests is currently ongoing.

Image 5: White-rumped Vulture *Gyps bengalensis* with an almost fledged chick

2. Tawny Eagle

   A total of three active Tawny Eagle nests were observed in the study area. Two of these nests were within regenerated areas whereas one was outside the regenerated area. A very young chick was observed in one of the nests in late January. The other two nests had birds incubating during the same period. The nests are being monitored to assess nesting success.

Image 6: A Tawny Eagle *Aquila rapax* nest with a very young chick

3. Egyptian Vulture

During the study two active nests were recorded. One nest of an Egyptian Vulture was observed on a *Procopis cinereria* tree top (Khejri). A fledgling was observed within this nest. Another active nest was observed on the tower of high tension powerline. Egyptian vultures are also known to nest on cliffs, old buildings and towers. Rahmani et al. (2024) also documented a few Egyptian Vulture nests within the DNP.

Image 7 : An almost fledged Egyptian Vulture *Neophron percnopterus* chick

4. Laggar Falcon

Two active nests of Laggar Falcons were observed within the protected enclosure. One nest was found to contain fledglings, while the other was occupied by two adult falcons, with no fledglings observed. Additionally, an inactive nest of possibly Laggar Falcons was observed just outside the protected enclosure. All three nests were observed during the last week of January. These observations do not coincide with published information on Laggar Falcons' nesting timings from Jaisalmer by Mori et al. (2019), where fledglings were observed during the 2nd week of March.

Image 8: Laggar Falcon *Falco jugger* nesting on a tower of a transmission line

3.3 Population status and habitat relationships of threatened species

3.3.1 Vultures

1. Red-headed Vulture

The Red-headed Vulture was detected a total of four times (three times during dedicated raptor surveys and once during the GIB survey) after surveying ~1230 km. The encounter rate for the species was too low for obtaining any meaningful estimates of occupancy and abundance. Given this issue, we additionally deployed camera traps at carcasses and water points. Some preliminary results have been obtained using this method, however, the occupancy of red-headed vultures on carcasses is also very low. Monitoring at water points seems to be the best method for rapid occupancy assessment of this species. We plan to do more focused surveys for this species in the coming year.

Image 9: A Red-headed Vulture *Sarcogyps calvus* at a water-point

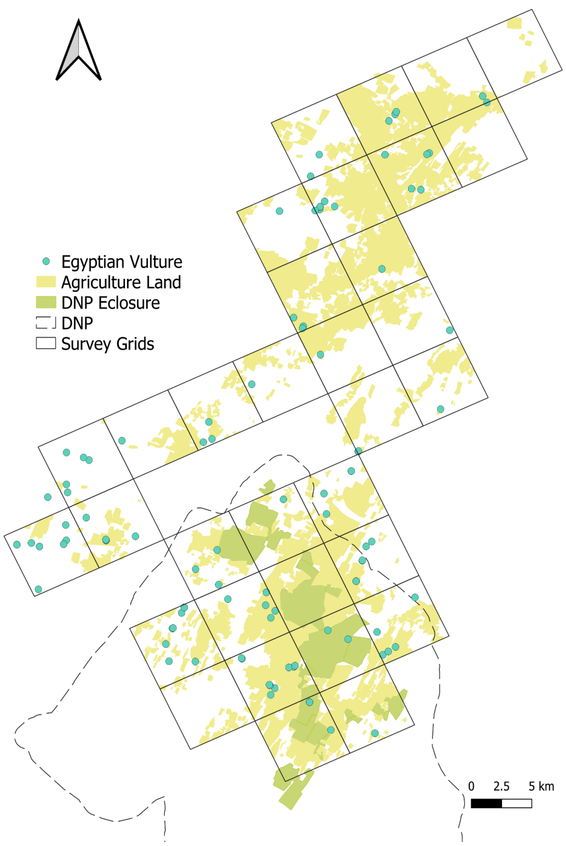
2. White-rumped Vulture

The White-rumped Vulture is another resident raptor species of the Thar Desert. We did not record any individual of the White-rumped Vulture during the vehicle surveys but found individuals and nests otherwise (see the section on demographic monitoring above). The survey results and the pattern of secondary sightings of the species indicate that the species is present in very low occupancy and is restricted to very few areas in the study area. The species was not detected on carcasses and water points either. We have too few detections of the species to make any further inferences. A species-specific survey is required to understand the status of this species in the landscape.

Our nest monitoring results show that the species is a winter breeder in the study area and nests on tall Khejri trees (see section above). Based on the size of the chicks seen, egg laying season seems to be October-November. Both the active nests had one chick each.

Image 10: A nesting White-rumped Vulture *Gyps bengalensis*

3. Egyptian Vulture



The Egyptian Vulture was the most common raptor species encountered during the survey. The estimated occupancy of the species was over 90% and the encounter rate was 43 individuals / 100 km. The estimated density for the species was 1.24. The species was commonly seen around human habitation and was seen to have higher abundance in grids with lower grassland coverage and conversely higher agriculture and human settlements. The abundance of the Egyptian Vulture was lower in areas restored for GIB, whereas renewable energy infrastructure seemed to have no effect on its occupancy or encounter rate. We observed one nest of the species during our nest search. Based on the size of the chick, the species seems to lay eggs around January-February.

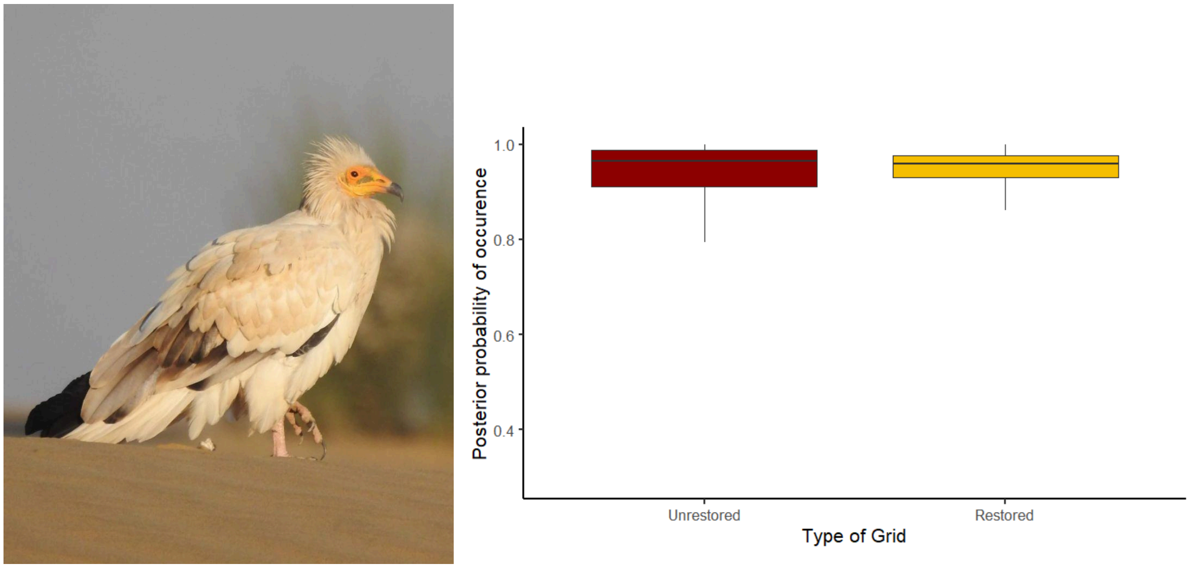
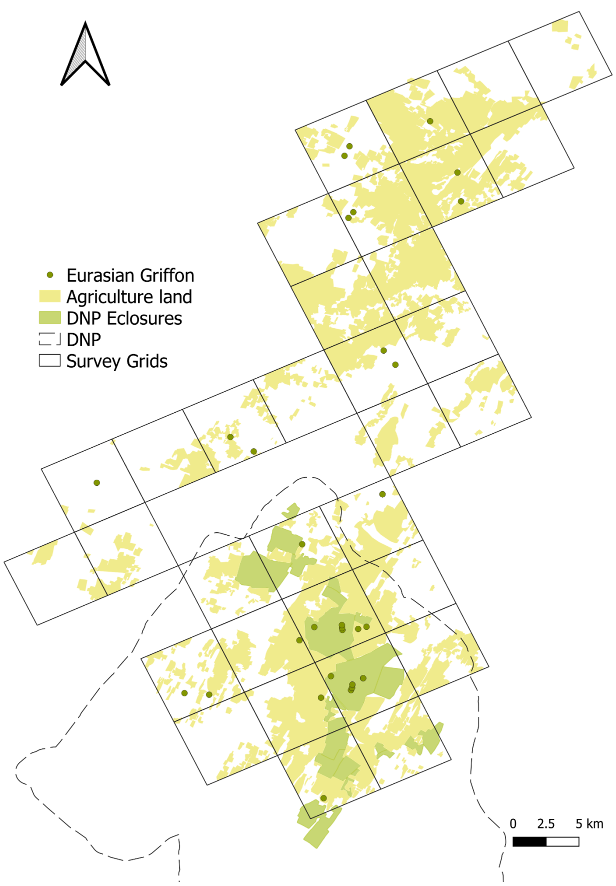


Figure 4: Occupancy of Egyptian Vulture in unrestored and restored areas

4. Griffons - Eurasian Griffon and Himalayan Griffon

The Eurasian Griffon was one of the most abundant raptors in the study area, second only to the ubiquitous Egyptian Vulture. The estimated occupancy of the species was around 75% and the estimated density was 1.5 (Encounter Rate: 20 birds / 100km). The occupancy and encounter rate of griffons was not affected by habitat restoration or the presence of renewable energy infrastructure. Our results suggest that the presence and abundance of Eurasian Griffons are not influenced significantly by GIB-specific conservation actions. However, other studies (Uddin et al., 2021) have shown that Eurasian Griffons commonly die due to collision with powerlines and wind turbines and this may cause longer-term declines in its population. As the species is a winter migrant to the area, these effects cannot be gauged by assessing occupancy



and abundance alone. Moreover, given the widespread abundance of cattle in the area and the large distances that griffons are known to fly in a day, the high occupancy may well be an artifact of the species' ecology.

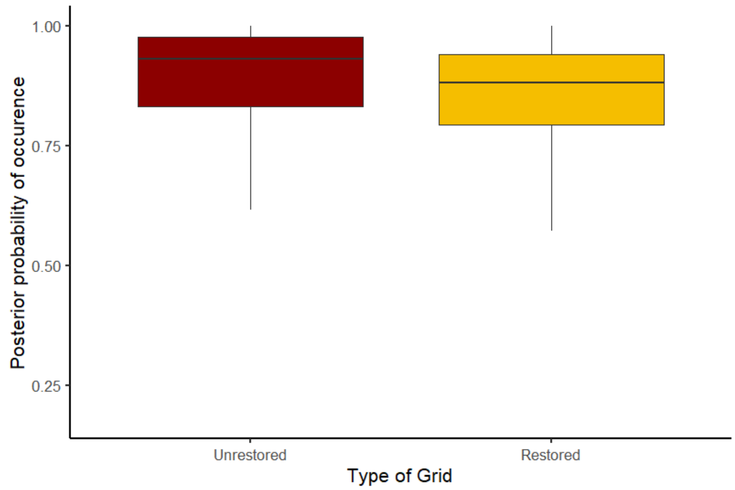
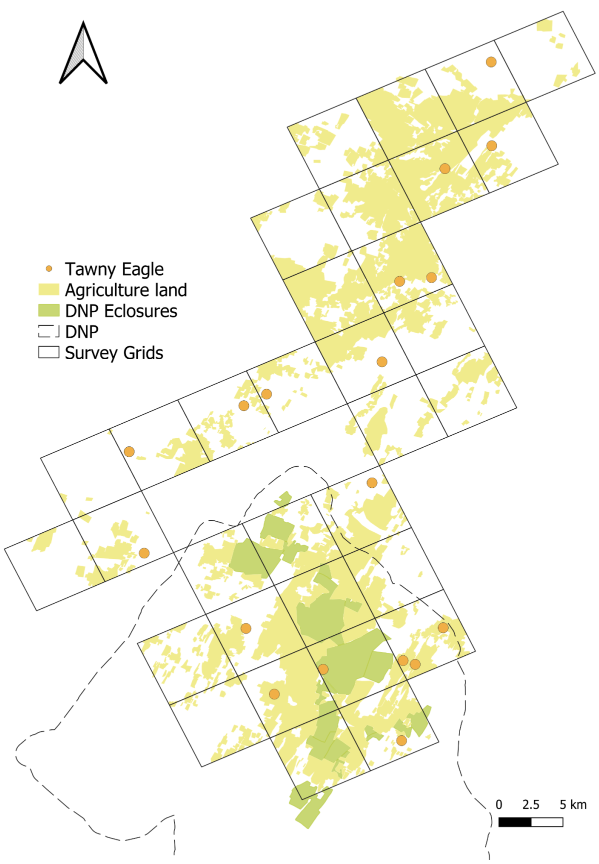


Figure 5: Occupancy of Griffon Vultures in unrestored and restored areas

3.3.2 Eagles and Falcons



1. Tawny Eagle

The Tawny Eagle was observed to be a notable raptor species during the survey. With 19 sightings across 15 unique grids, the species exhibited a naive occupancy of 39 %. The density of the species in the study area is 0.23 individuals / sqkm with the encounter rate of 3 individuals per 100 km. Tawny Eagles are known to breed in the area and 3 nests were also observed (see section on demographic monitoring above).

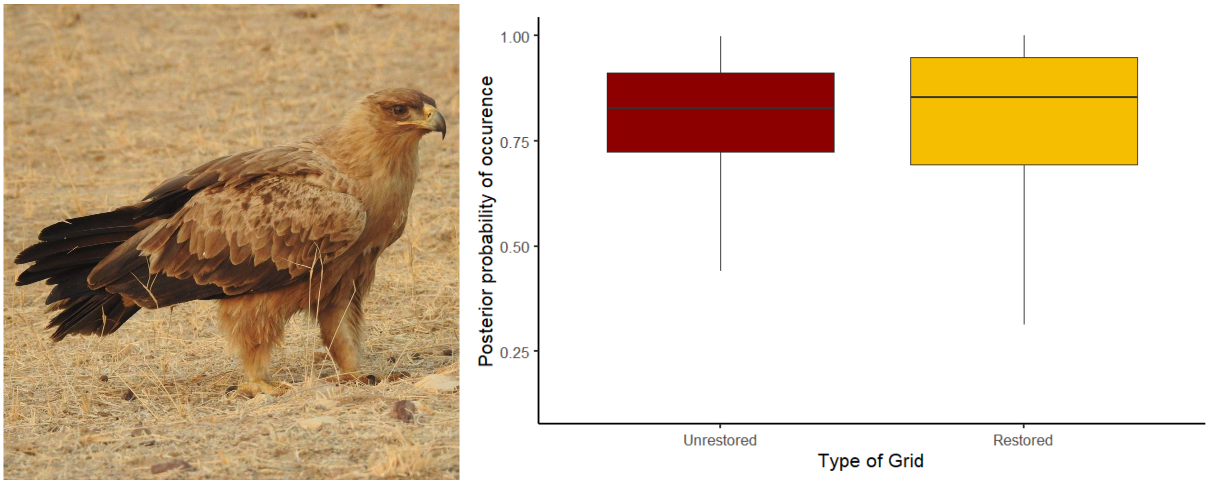
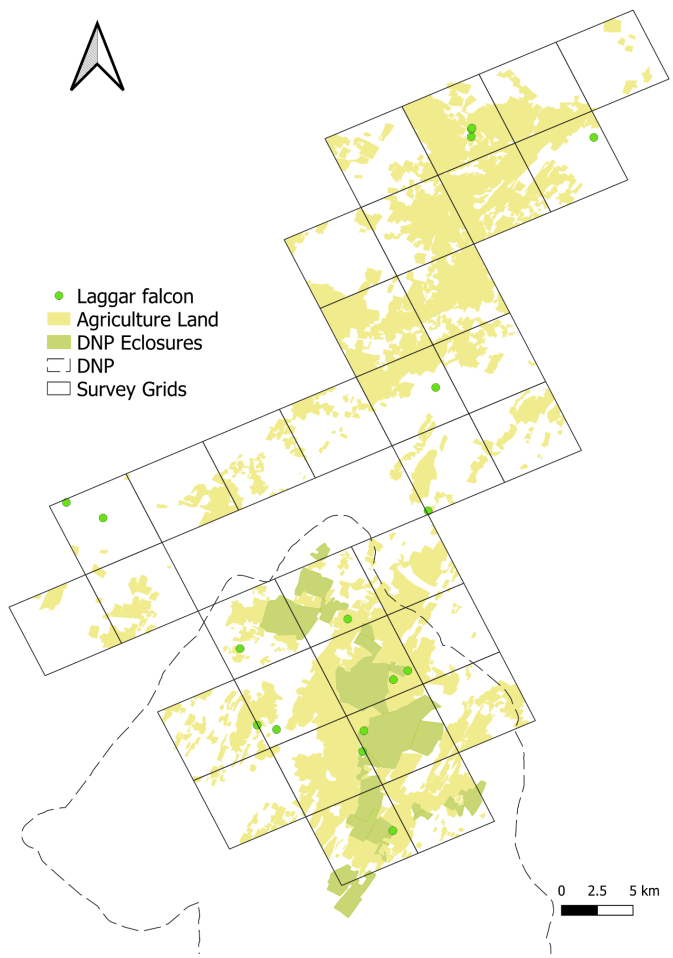


Figure 6: Occupancy of Tawny Eagle in unrestored and restored areas

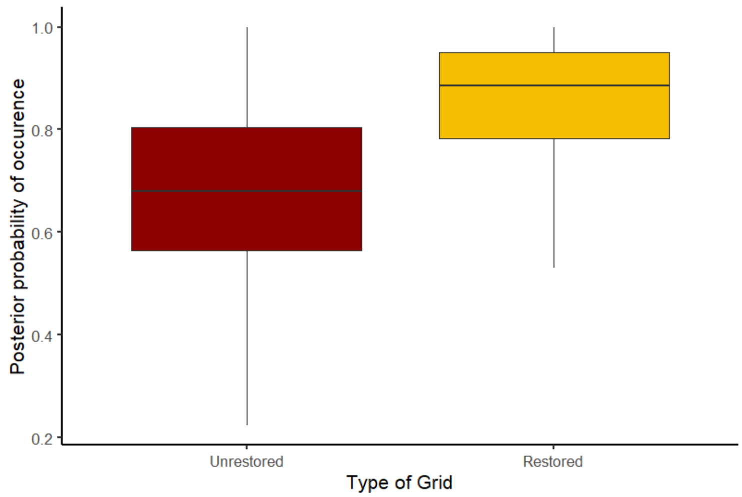
2. Indian Spotted Eagle

With four sightings across four unique grids, Indian Spotted was one of the rarer raptors during the survey. The species exhibited a naive occupancy of 10.5%. The encounter rate for the Indian Spotted Eagle was calculated to be approximately 0.63 individuals per 100 km. Comparatively, the Tawny Eagle had a higher occupancy rate and an encounter rate than Indian Spotted Eagle. This indicates that the Tawny Eagle may be more abundant or have a wider distribution within the surveyed area compared to the Indian Spotted Eagle.



3. Laggar Falcon

The Laggar Falcon emerged as one of the prominent raptor species during the survey. With 19 sightings spread across 14 unique grids, the estimated naive occupancy of Laggar falcons was 36%. The density of the species in the study area is 0.3 individuals / sqkm with the encounter rate of 3 individuals per 100 km. The predicted occurrence probability of Laggar Falcons decreases outside the protected grassland, whereas inside the protected grassland it is almost 90% (see fig). The numbers of Laggar Falcons in the region has gone down considerably in the past few decades (Rahmani et al. 2024). Changing land use can be one of the contributing factors to the decline.



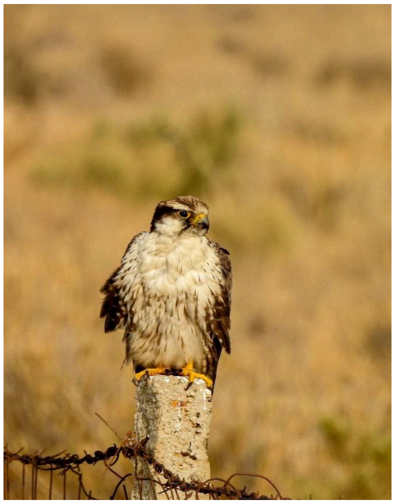


Figure 7: Occupancy of Laggar Falcon in unrestored and restored areas

3.3.3 White-browed Bushchat

A total of 17 White-Browed Bushchats were seen in 90.75 km of transect effort in the winter of 2023-24. The density of White-browed Bushchat was estimated to be 1.92 (0.53 SE) individuals/sq.km. Similarly, the encounter rate was significantly higher in restored grasslands (0.24 / km), followed by rangelands (0.18/km) and croplands (0.12/km). The bird was seen mostly in grassland areas and occupancy in agricultural areas was relatively lower. Birds seen in croplands were also on the boundaries / hedges of agricultural fields. The preferred habitat for the species seems to be open grasslands with a slight shrub understory of less than 1m height. The occupancy of the species was highest in restored grasslands of intermediate age (5-10 yrs) while it was absent in the old-growth grassland enclosed for more than 30 years (perhaps due to the very tall grass height).

Image 10: A White-browed Bushchat captured for banding

In addition to the surveys, one bird was banded/ringed in the RKVY enclosure. The banded bird was observed in the area of capture until the end of March. Our surveys in the summer of 2023 did not yield any White-browed Bushchat sightings in grids where the species was observed during the winter. Similarly, most sightings of the species from citizen science also come from the same November to March window and support the results of our survey. This suggests that the bird is a winter migrant to the area. Monitoring of the ringed individual will help in gaining more clarity on these aspects and will also give information on whether birds return to the same wintering grounds every year or not.

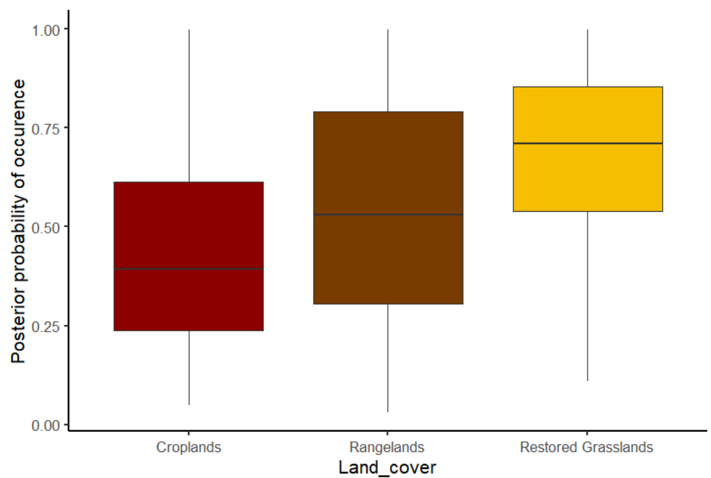


Figure 8: Occupancy of White-browed Bushchat in different land-covers

3.4 Development and standardization of methods

Our study was one of the first few systematic surveys for raptors in the Thar Desert and provides a robust data collection and analysis framework for upcoming projects. We have also refined the methodology for small bird monitoring based on our previous experience in the landscape. Going forward, we recommend one dedicated raptor survey in summer and winter along with additional occupancy surveys (citizen science surveys or ancillary data from other surveys) during each season for robust monitoring of raptor populations. For small birds, we recommend walking line transects in a square design and not repeating a particular transect as the encounter rates saturate within a single transect. We believe line transects are not a good method for group living passerines and these birds can be counted in small segments of the raptor surveys. Such an integrated survey protocol would provide robust results while not requiring too many additional resources. Our methodology has been described in detail above and codes are available on GitHub (Kher, 2024).

4. Conservation implications and way forward

Our study provides ecological baselines for threatened birds in the Thar Desert and also provides preliminary information on other aspects of their ecology such as nesting. In addition, we also report community-level responses of birds to GIB-focused restoration activities. Key conservation-oriented findings from our study are listed below:

1. Certain threatened birds are positively affected by GIB-focused habitat restoration. These birds include the Laggar Falcon and the White-browed Bushchat which had significantly higher occupancy and density in restored areas. These birds are expected to benefit indirectly from GIB conservation activities and are good indicators of potential GIB conservation habitats.
2. However, other threatened birds such as Tawny Eagle, White-rumped Vulture, Egyptian Vulture do not have the same conservation needs as the GIB and need to be managed separately. This is particularly the case with the White-rumped Vulture which was found in areas not suitable for GIB. The Tawny Eagle was seen in GIB areas and even had a marginally higher occupancy and encounter rate in restored areas. However, whether the benefit of restoration is significant for the species is not clear based on the results of our study. The Egyptian Vulture is a synanthropic species in the desert and seems to be benefiting from agricultural expansion in the desert and does not need any targeted conservation action at the moment.
3. Apart from vegetation recovery, GIB conservation aims to mitigate the threat of unplanned renewable energy infrastructure (Dutta et al., 2022, 2023). Our preliminary estimates show that renewable energy is a major problem for a certain species such as the Laggar Falcon and causes additive mortality for other species as well. The same has been reported by other studies in the region (Uddin et al., 2021) and our results provide population-level evidence for the same. The effect of these threats on population parameters of threatened species need to be evaluated in greater detail for better planning of renewable energy infrastructure.
4. Going forward, threats to breeding birds in the desert need to be identified through species-specific studies. Targeted conservation actions need to be planned and implemented for species which do not co-benefit for GIB conservation.

5. Outreach and Stakeholder Engagement

Flyers featuring the Birds of Rajasthan were distributed among frontline forest department staff to assist in the identification and documentation of avifauna in the region. Additionally, a school nature excursion program was conducted for 150 female students from Maharani Ratnavati School, Kanoi, in collaboration with the Bustard Recovery Program and Rajasthan Forest Department in the Sudasari area of the Desert National Park. The primary objective of this initiative was to foster awareness of nature and conservation among the younger generation. Furthermore, efforts were undertaken to engage with local carcass collectors and integrate them into the carcass reporting network, thereby strengthening local information sharing and involving regional stakeholders.


Image 11: Various outreach activities - distribution of flyers, sensitisation of forest department, nature education for students

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Recommended Citation: Kher, V., Pandey, D., Jadhav, M., Dutta, S. & Krishnan, A. (2024) Monitoring threatened birds of the Thar Desert: How does habitat restoration for the Great Indian Bustard impact associated avifauna? Technical Report #TR/2024/08 submitted to the Wildlife Institute of India on 31st March 2024.