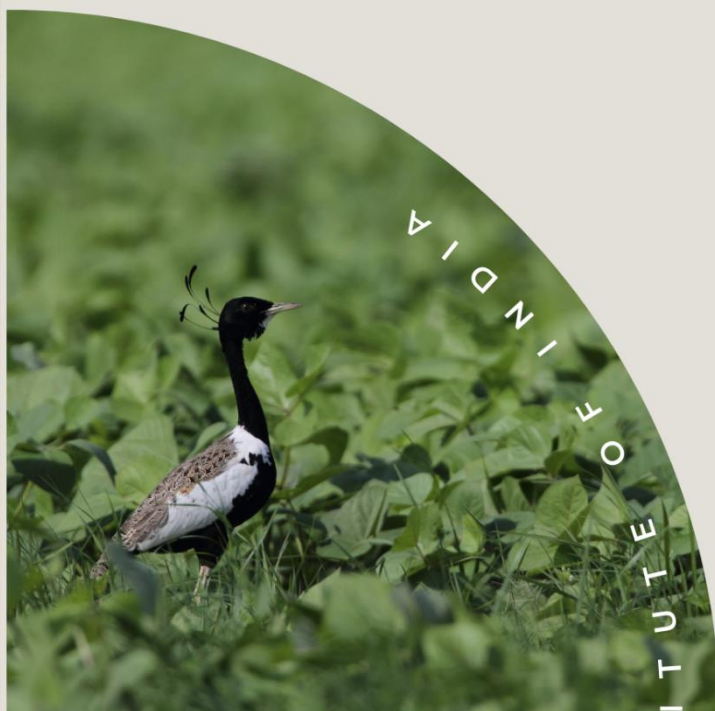


BUSTARD RECOVERY PROGRAM

FINAL REPORT

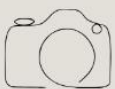
2016-2024



2024

HABITAT IMPROVEMENT AND
CONSERVATION BREEDING OF
GREAT INDIAN BUSTARD

WILDLIFE INSTITUTE OF
INDIA

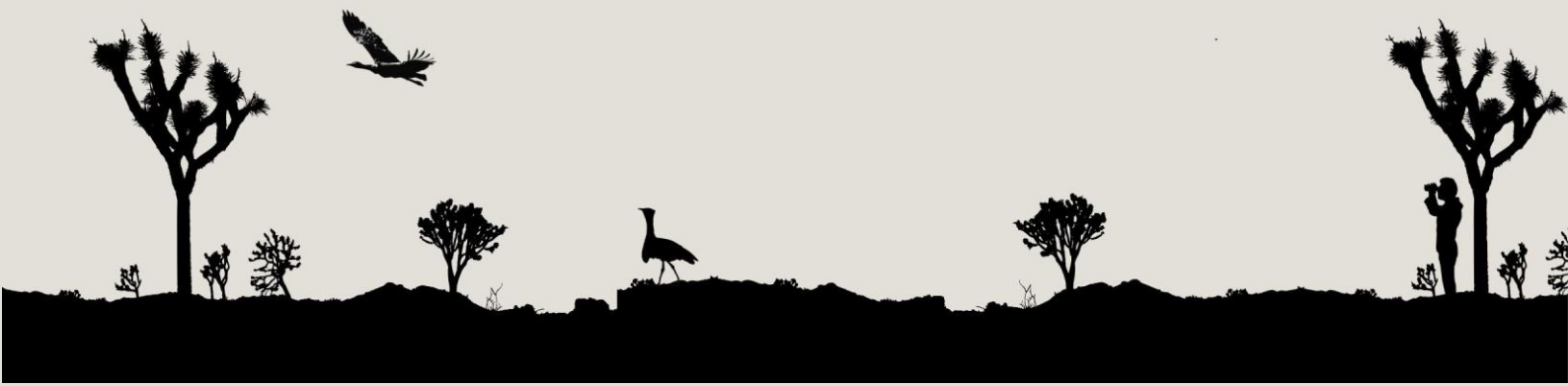


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Bustard Recovery Program Team

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Collaborating agencies:	International Fund for Houbara Conservation / Reneco The Corbett Foundation Bombay Natural History Society Humane Society International Jivdaya Charitable Trust The Grasslands Trust

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Picture Credit: Rajasthan Forest Department

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RATIONALE AND BACKGROUND



The Great Indian Bustard *Ardeotis nigriceps* (hereafter GIB) is one of the rarest birds in the world with ~140 individuals left almost exclusively in India. The species is listed as Critically Endangered (IUCN 2011) and Schedule I (the highest protection status, Wildlife Protection Act, 1972). Their populations have steadily declined by 75% in the last three decades and conservation actions are urgently needed to avoid its extinction.

The GIB inhabits Open Natural Ecosystems or ONEs (savannah, grassland and desert type habitats) of India and until the early 1900s, its population was spread across the country's drier half, covering 11 states from Haryana in the north to Tamil Nadu in the south and Rajasthan in the west to Odisha in the east. Currently, they are restricted to fragmented pockets in five states: Rajasthan, holding the only viable population of ~128 birds in Jaisalmer, Gujarat with ~3 birds in Kachchh, and Maharashtra, Karnataka and Andhra Pradesh having a sub-population of ~10 birds.

Several factors have caused a steady decline in GIB range and numbers. During the British Raj, they were excessively hunted by British officers, Indian Royals and native trappers and their eggs were collected by British naturalists for museum specimens. Such exploitation decimated the bustard population to ~1260 individuals in 1969 (Dharmakumarsinhji 1971). Post-independence, the majority of bustard habitats were lost to agricultural conversion facilitated by irrigation, pesticides, and changes in cropping patterns from food crops to cash crops, which reduced the natural cover and invertebrate prey base. Well-intentioned but ill-informed afforestation practices to increase forest cover across ONEs, which were considered as wastelands since the colonial period, also rendered many bustard habitats unsuitable for the GIB. This exacerbated their decline between 1970-2000 with numbers plummeting to ~600 individuals (Rahmani 2000). More recently, bustard habitats are being used for renewable energy production and are crisscrossed by power lines radiating from wind and solar farms. Having a narrow frontal vision, bustards cannot detect power lines from far away and often fail to manoeuvre around them in the nick of time due to their heavy and fast flights, resulting in fatal collisions. Additionally, by making abundant surface water available in deserts, humans have inadvertently facilitated predators like free-ranging dogs *Canis lupus familiaris* and feral pigs *Sus scrofa cristatus* along with populations of foxes and mongoose to flourish. In a harsh desert environment, where the bird's reproductive output is naturally low, these predators further reduce GIB recruitment by preying on eggs and chicks.

The rapid and continuing decline of GIB has alarmed conservationists since the 1970s. Necessary actions to conserve these birds were discussed in an international symposium organised in 1980 (Goriup and Vardhan 1980). Under the Wildlife Protection Act, many Protected Areas were established for the conservation of three resident bustards – GIB *Ardeotis nigriceps*, lesser florican *Sypheotides indicus* and Bengal Florican *Houbaropsis bengalensis*. However, scientific understanding and management of grasslands were lacking. While the species needed protection, Protected Areas were either too large (>1000 km² area), encompassing public-private mixed ownership lands that were not effectively protected or managed (eg. Nanaj Bustard Sanctuary and Desert National Park (DNP) Wildlife Sanctuary), The National Bustard Recovery Plans prescribed three actions to recover bustard numbers in the wild:

1. safeguarding breeding grounds to improve reproductive success by creating enclosures that are seasonally inviolate from livestock grazing,
2. reduce mortality risks around these enclosures by mitigating infrastructure such as power lines and by intensive patrolling, and
3. involve local communities in conservation by addressing their livelihood concerns.

Ground implementation of these actions commenced in 2013 but continued to be an uphill task because of complex challenges associated with conservation in multi-stakeholder landscapes and the GIB numbers continued to decline.

Besides these in-situ measures, the Plan also recommended a conservation breeding program as an insurance against total extinction and future augmentation of wild populations. Subsequently, a workshop was organised by WII at WWF-India, New Delhi in January 2015 which brought together the country's leading bustard biologists, conservation managers, decision-makers, and international bustard experts, to assess the existing scientific evidence and make an informed decision regarding conservation breeding. The workshop recommended commencing conservation breeding for GIB and through subsequent meetings and discussions, under the leadership of the Additional Director General (Forest) and Inspector General of Forest MoEF&CC, the Wildlife Institute of India was mandated to take up the task of conservation breeding and research to aid habitat management for GIB and lesser florican. The Bustard Recovery Project started in 2016 and was funded from the MoEF&CC's Compensatory Afforestation (CAMPA) funds. Conservation breeding activities began in 2018, when a tripartite Memorandum of Agreement (MoA) was signed between the MoEF&CC, Rajasthan Government and WII and necessary permits were obtained. Further, the WII signed an MoA with the International Fund for Houbara Conservation (IFHC) & Reneco – the leading experts in bustard breeding – for technical collaboration, advice and assistance in the conservation breeding component.

The aim of this Project is to aid in the population recovery of GIB through a holistic approach that integrates conservation breeding and science-informed habitat restoration.





CONSERVATION BREEDING



Great Indian Bustard

Conservation Breeding

The alarming decline of GIB population and inherent time lags of *in-situ* measures necessitates conservation breeding for insurance against total extinction, buying time for habitat restoration, and future augmentation of wild populations. Hence, WII, Rajasthan Forest Department (RFD), MoEF&CC, and the International Fund for Houbara Conservation (IFHC) initiated a scientific conservation breeding program in 2019. The program aims to secure a founder population from wild-laid eggs, breed them in captivity, and release surplus captive-bred birds in future restored habitats, to ensure the long-term survival of this Critically Endangered species.

Sites for establishing the conservation breeding centres were searched and shortlisted based on multiple criteria and after deliberations with experts. These criteria were proximity to source population, availability of Forest department-owned land, disturbances/security, electricity, road, water supply and disease risk. The GIB steering committee along with IFHC representatives selected Sorsan and Ramdevra as the main breeding centre sites while Sam Forest Choki was modified and made immediately operational to save time. Two conservation breeding facilities in Sam and Ramdevra are operational and are run by a technical team engaged by WII and trained in bird husbandry and veterinary care by IFHC experts. These centres house 44 captive-reared GIB sourced from wild- and (subsequently) captive-laid eggs (Table 1). This program has achieved initial success and its continuation is critical for the preservation of GIB, representing a crucial step forward in bustard conservation biology.

1. Conservation breeding centres

The project has established two conservation breeding facilities in Rajasthan, the first smaller facility in Sam (in Desert National Park/DNP) and a larger facility in Ramdevra. The Sam conservation breeding facility was started in 2019 by modifying an existing Forest Department chowki (protection camp). Two existing buildings and two huts were converted into an office, incubation, chick-rearing, live feed and commissary rooms (Image 1). One juvenile cage, two adult cages/tunnels (semicircular aviary supplied by IFHC), soft net quarantine and soft net exercise cage were erected. Recently, a new chick-rearing room was built. Two containers, one used as a biosecurity outpost and the other as a veterinary unit, were added. Predator-proof fencing was installed along the entire boundary wall (Image 1).

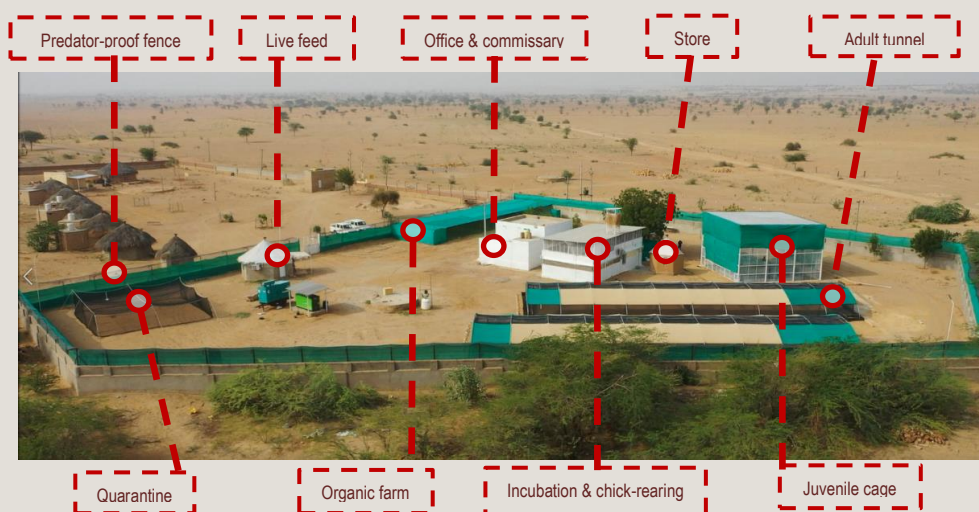


Image 1. Infrastructure of Sam Great Indian Bustard Conservation Breeding Centre

Ramdevra was chosen as the site for the larger GIB breeding centre, for which an area of 1.93 km² was allotted for conservation breeding. Ramdevra CBC construction was majorly done by the Central Public Works Department (CPWD) Jaisalmer and construction began in May 2019 with the majority of work completed by 2022.

This centre includes a) incubation and chick-rearing unit, b) two juvenile indoor-outdoor units, c) four adult cages (shaped like tunnels), d) a veterinary unit, e) a quarantine unit, f) a live feed production unit, g) commissary, h) office, i) staff quarters, and j) organic farm (Image 2). Indoor units will be added to all adult tunnels and two additional adult tunnels will be built. Plans to build a large soft-release aviary using Rajasthan funds are being finalised. The entire centre has been enclosed by predator-proof fencing, with additional predator-proof electric fencing around the juvenile cage and adult tunnels.

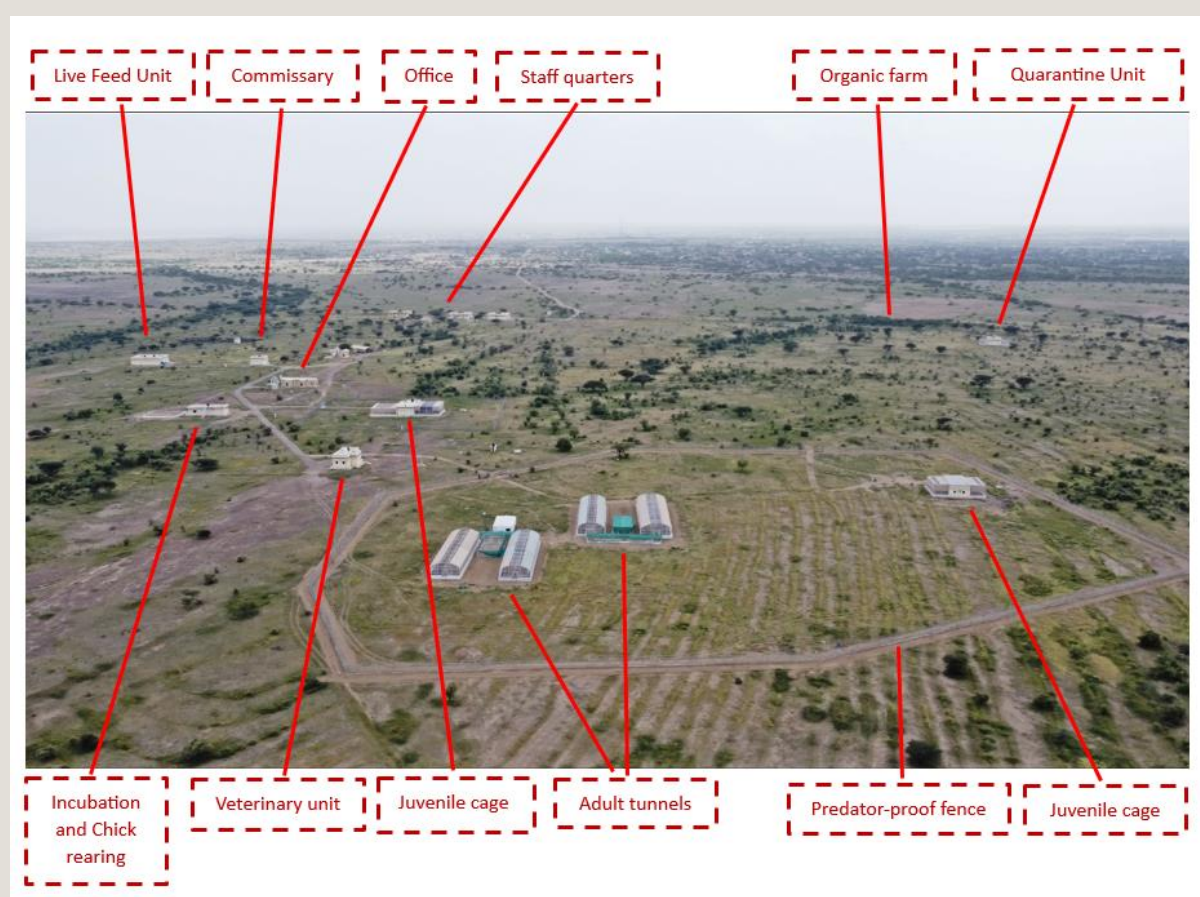


Image 2. Infrastructure at Ramdevra Great Indian Bustard Conservation Breeding Centre

2. Conservation breeding approach

2.1. Nest search, egg collection and artificial incubation

GIB nest search is carried out intensively in all known breeding areas from March to September (the breeding season). Teams routinely survey breeding enclosures from vantages and vehicles with a spotting scope to locate females. Nesting females exhibit characteristic behaviours such as localised radiating movement within a ~300m radius, foraging intensively in short bouts during early mornings or late evenings, and aggressive interactions with conspecifics. Females suspected of nesting are observed remotely from a vantage for a few days, after which a joint visit is made with the Forest Department staff to confirm the nest. Only one-third of detected eggs are collected for conservation breeding and the rest are left in the wild for recruitment.

41 GIB eggs were collected for conservation breeding from the wild (DNP, Ramdevra and surrounding areas) from June 2019 to July 2024. The wild eggs are collected and brought to the Sam CBC in a foam-padded, insulated box (for short distances) or a portable incubator (for long distances) in a slow-moving and soft-suspension vehicle. The external and internal ambient temperatures are monitored during the transport. The temperature inside the vehicle is maintained between 20-25°C and the internal temperature of the box is maintained between 35-37°C. Once the eggs reach the centre, they are cleaned, measured, weighed, and checked for fertility by candling, for a pulse and other signs of embryo development. The temperature and humidity in the incubation room is maintained between 20-25°C and 30-40% RH respectively. All eggs are incubated in Brinsea Ovation/Octagon Incubators at 37.5°C. The humidity is regulated to achieve the target of ~15% weight loss over the incubation period. The eggs are monitored daily to check for signs of fertility and to track the development of the embryo. Once the external pip is seen eggs are transferred to the hatcher, which is maintained at 37°C and 55-65% RH.

Additionally, three successful “jumpstart” attempts have been carried out where eggs from the wild have been artificially incubated and returned to the nest immediately prior to hatching to improve wild hatching rates. Data from tagged birds indicate that females re-lay eggs after losing their initial clutch, laying about 3 eggs in a breeding season, which reduces the impact of egg collection on the wild population.

2.2. Chick-rearing

GIB chicks, after hatching, are kept in the brooder for 24-36 hrs. The brooder allows maintenance of the temperature, required by the newly hatched chick. Chicks are not fed for the first 24 hours to allow yolk-sac absorption. One-day-old chicks are shifted to the chick-rearing room maintained at 27-30°C temperature. They are kept in transparent boxes with rubber mats (as substrate) and heat lamps. The chicks are imprinted on the keepers at an early stage as it is essential for close monitoring of birds in captivity and reduces the stress of husbandry and veterinary practices. Morphometric measurements, weights, photos of plumage, etc are recorded regularly to monitor growth and development. For exercise and muscle development, chicks are taken to the outdoor net cage for a few hours daily. Chicks are gradually shifted from indoors to the second-age (juvenile) cage at around 30 to 35 days (Image 1). After 90-120 days, birds are shifted to the third-age (adult) cages/tunnels.



Image 3. GIB chick in the hatcher immediately after hatching (left) and in the chick-rearing room (right) at the Sam CBC

A total of 21 chicks were transported from Sam to Ramdevra when they were two weeks to three months of age. These birds were trained for transport by performing short mock transport drills before the actual transport. Chicks were transported in foam-padded plastic crates, with a sandy substrate and a modified lid, in a

temperature-controlled vehicle with soft-suspension. Vital parameters of birds were monitored before, during, and after transport by a veterinarian, and the exercise was carried out along with a representative from the Forest Department. Transportation was carried out at night to minimise stress to birds. It takes 4-5 hours to transport birds from the Sam to Ramdevra facility.



Image 4. A sub-adult male eating mealworms at Sam CBC

2.3. Housing

In the adult cages/tunnels, birds are housed in individual soft net compartments. All compartments have *Lasiurus scindicus* sewan grass patches with sandy substrate. During harsh summer, air coolers and water sprinklers are installed near the cages. During the breeding season, adult birds are allowed to move between cages for a few hours during the day so that adult females have access to displaying males (to encourage natural breeding). Adult tunnels in Ramdevra have individual soft net compartments, leading to a common corridor for exercise and short flights. These tunnels have been modified from the initial design borrowed from Houbara Bustard husbandry, such as increased height, based on learnings from Sam Facility. Currently, all outdoor cages in Ramdevra have an attached indoor building/container with smaller interconnected net cages where birds are shifted at night and during inclement weather, to reduce mortality risk, as the frequency of jumps at night in the indoor unit is much less than that observed in outdoor units that are exposed to external stimuli.

2.4. Reproduction

Adult GIB females weigh between 4-5 kg and males between 8-12 kg (Figure 1). Birds reach their maximum weight immediately before the breeding season. Males begin showing signs of breeding display from one year of age, with well-developed courtship display starting at 2-3 years of age (Image 5). Females start showing signs of sexual maturity from three years of age, usually indicated by shorter, less complex displays and laying of eggs. Two females in 2023 and 4 females in 2024 showed signs of breeding and copulated successfully with the male,

laying fertile eggs. The females laid eggs 2-4 days after mating and most eggs were laid right after sunset. To maximise hatching success, eggs were collected and moved to the incubation unit to be artificially incubated. Some copulations were unsuccessful, which could be due to the young age of the birds, resulting in infertile eggs. To circumvent this issue, male birds are also being dummy-trained for semen collection to allow assisted reproduction through artificial insemination of females in the near future.

Currently, four females and one male at the Sam CBC have started successfully breeding, by natural copulation resulting in 13 captive-bred chicks being hatched since March 2023. In addition to that, three females in Sam and one male and female in Ramdevra CBC have started exhibiting signs of sexual maturity, such as displays and laying of infertile eggs, but have not successfully bred yet.



Image 5. A male performing the breeding display at Sam CBC (left); Male and female mating at Sam CBC

2.5. Growth of birds

Adult females weigh 4-5 kg and adult male weights vary between 8-12 kg seasonally (Figure 1). Females start attaining this weight quite early on at around 6-7 months of age whereas males gain this weight close to two years of age.

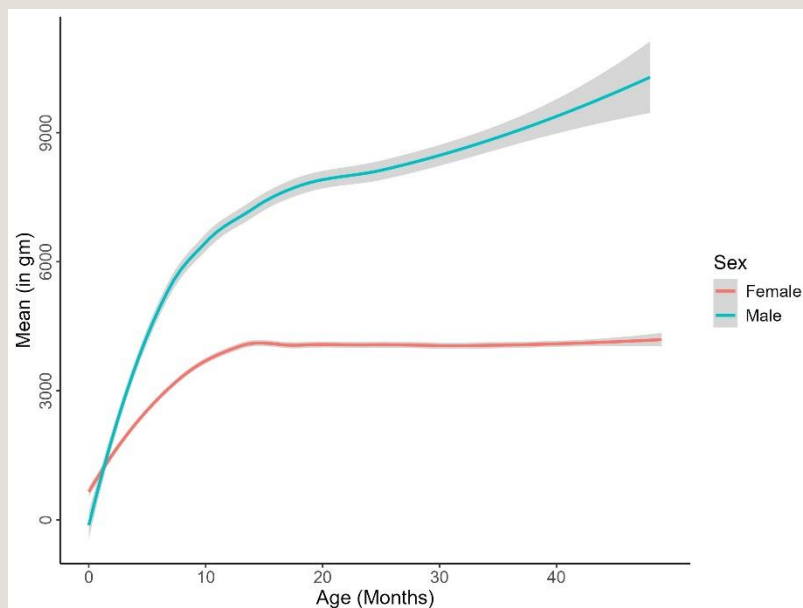


Figure 1. Weight differences in captive male and female Great Indian Bustard

2.6. Veterinary care

All birds are vaccinated for Newcastle disease (ND) and Fowl Pox (pigeon pox/canary pox vaccine). Birds are monitored intensively and any injury or illness is dealt with immediately. Veterinarians along with the keepers check the general health of birds daily, and additionally, birds are physically examined three times a year when blood collection for biochemistry is also done.

2.6.1. Chick stage

- Chicks are initially vaccinated for ND at one month with a booster at two months of age. At three months, they are vaccinated against Fowl Pox with a booster at four months of age.
- Angel wing is common in the first age (one month) and develops around 10 days of age. The wings are bandaged using a vet wrap for one day and the bandage is changed every alternate day till the condition persists. Angel wing generally recovers within a week.
- Rotation of legs is rare and has been observed in a few chicks. Slight rotation when observed has been corrected by providing a harder substrate and through exercise.
- Dehydration was observed in some chicks in the initial days and it is corrected by providing additional water with food or in severe conditions an oral DNS+NS+RL mixture is administered.
- Sometimes chicks are born with genetic deformities like splayed legs or cloacal prolapse. Husbandry measures are modified to take special care of these chicks.
- A mild case of avian pox has been observed in several juvenile birds. Pox lesions are mostly observed on the beak and legs and they gradually dry and fall off. The lesion is cleaned daily with 5% betadine and betadine ointment is applied. Birds are vaccinated against avian pox before shifting them to outdoor juvenile cages.

2.6.2. Adult stage

- All three centres are equipped with X-ray machines, and for cases like fractures, air sac ruptures etc, radiographs are used for diagnostics and providing veterinary care. Additionally, each centre also has an operation theatre with equipment such as gas anaesthesia machines.
- Fractures of wings are the most common injury in captive birds. The fractures are treated and pinning is done when necessary. Some birds with wing fractures cannot fully open their wings making them more prone to future injuries and hence are placed in smaller cages to discourage jumps and flights.
- If birds show any signs of illness such as lethargy, loss of appetite or coughing, samples such as blood, oro-tracheal, cloacal swabs and faeces are collected and sent for testing to labs specialised in avian disease diagnostics. Treatment is then administered accordingly.
- Blood biochemistry is performed routinely to form baseline data for the species and to intervene when necessary. A blood biochemistry analyser is available at the Ramdevra Centre.
- Faecal samples are tested routinely for parasitology. Samples are also checked using a microscope by trained staff at the respective centres.
- One adult GIB male was rescued from the RKVY enclosure of DNP in April 2022 with a leg injury. The bird was given immediate medical care, followed by multiple surgeries where one of his legs was amputated. A prosthetic leg was designed for him, physiotherapy was provided and housed in a special quarantine cage in the Sam forest chowki just outside the CBC where he survived for another 6 months.
- Another GIB male was rescued from Chauhani in October 2023 who had suffered extensive injuries after a collision with an agricultural electric fence. Immediate veterinary care was provided but the bird succumbed to trauma within a few days.
- PME examinations are also carried out for all eggs that fail to hatch, and for birds that die in the centre. These samples are sent to the Indian Veterinary Research Institute and other avian diagnostic labs for histopathology, parasitology and toxicology testing.

2.7. Diet

Bustards are omnivorous species and to fulfil their nutritional requirements, captive birds are given a balanced diet of dry pellets, fruits, vegetables and live feed (Image 3). The pellets are formulated specifically for bustards by IFHC/Reneco and contain 14-24% crude protein. Live feed such as mealworms and crickets are produced in-house. Plants like alfalfa, mustard and pomegranate are organically grown at the centres and seasonal fruits as well as vegetables are provided to the birds. The protein and fibre percentage in the diet changes according to age. In the chick stage, a high protein diet is fed and is reduced gradually by transitioning from 24% to 14 % over the year. Immediately before the breeding season, the total protein content of the diet is increased to meet breeding requirements.

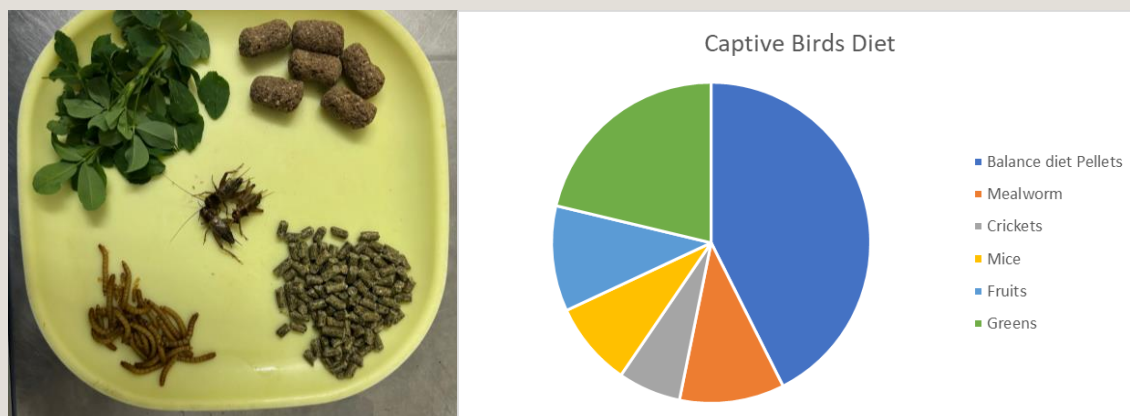


Image 6. Diet of captive Great Indian Bustard (left) and proportion of food items in diet of captive Great Indian Bustard in the Conservation Breeding Centres (right)

2.8. Project staff & training

Currently, the GIB Conservation Breeding Centres are run by a scientist, two full-time and one consultant veterinarian, four biologists, four assistants, seven bird keepers, eight food production staff, and 14 support staff for sanitation, security, maintenance and other miscellaneous work. Additionally, three researchers perform both *ex-situ* and *in-situ* activities, as needed.

2.8.1. Collaboration and training at IFHC, Abu Dhabi

The IFHC runs one of the world's largest species conservation projects, overseeing an international network of specialised houbara bustard breeding centres to support and increase wild populations of African houbara *Chlamydotis undulata* and Asian houbara *Chlamydotis macqueenii* in their natural habitats across the species' ranges. The agency has international reputation and core expertise in houbara bustard captive breeding using Artificial Insemination techniques. Experts from IFHC helped finalise the sites at Sorsan, Ramdevra and Sam. Scientists from IFHC first visited India in October 2018. Dr Loic Lesobre and Mr Thibault Dieuleveut visited the sites at Sorsan, Ramdevra, and DNP in Rajasthan, and shared their knowledge with the Project team. They also met and briefed the CWLW Rajasthan about their mission and collaboration with WII. Subsequently, the Project team travelled to Abu Dhabi at different times, between 2018 to 2023 (six visits) using Rajasthan Government funds. They were trained in incubation, chick-rearing, adult breeding techniques like Artificial Insemination, nutrition, veterinary, and live food production practices by the scientists at the National Avian Research Center (NARC). The Project team learned scientific management on all aspects of breeding for implementing these approaches at the Conservation Breeding Centres and subsequently trained the local Indian staff on these techniques. The IFHC/Reneco have sent subject experts to India to assist in site selection and construction of the Conservation Breeding Centre, egg collection, tagging, incubation, and training staff on husbandry techniques like semen collection of GIB from June 2019 to May 2023. The transfer of technology, expertise and know-how of bustard husbandry from IFHC to WII has played an important role in developing the capacity and skill set of

the project team and continued development of conservation breeding protocols that are required for the establishment of a successful conservation breeding program for GIB and lesser florican in India. The Project team regularly communicates with IFHC/Reneco team for consultation and refining of the conservation breeding approaches.

2.8.2. Training at other facilities

Four project personnel visited the Pinjore Vulture Conservation Breeding Centre and Pheasant Conservation Breeding Centres in Himachal Pradesh for exposure to avian conservation breeding techniques. Four project personnel visited Anand Agriculture University, Anand, Gujarat in February 2023 to train in semen collection and insemination of poultry. It allowed hands-on training in expert techniques that can be applied to GIB artificial breeding efforts.

2.9. Live feed production

During the initial days of the project, invertebrates such as mealworms and crickets were sourced from various suppliers across the country. To reduce the cost of purchasing live feed and the risk of contamination during transportation, and to achieve sustainability, in-house production of live feed for captive birds was started. There are separate units for every type of live feed with dedicated staff and assigned duties. The sanitation process in the live feed unit is followed strictly and all units are cleaned daily. The microenvironment of these rooms, such as temperature and humidity, are logged daily to maintain optimal ambient conditions for the desired production of live food. Weekly production data for each unit is recorded. Production is managed following applied population biology principles, to ensure adequate food for birds and a stable stock.

2.9.1. Cricket production

House crickets (*Acheta domesticus*) are reared in plastic crates with room temperatures maintained at 30-35 °C and relative humidity of 60-90%. Crickets are provided with wheat bran, apple and cabbage/lettuce for food and water is provided in feeders for adults. Cleaning of crates and weighing of crickets in every crate is done weekly. Adult crickets (above six weeks) are provided with organic potting soil in bowls to lay eggs. This soil is decontaminated by washing and treating in a hot air oven before use. The egg bowls are removed after 3-4 days and kept in separate crates where the eggs start hatching after 6-7 days of incubation. Egg bowls are regularly sprayed with water to maintain optimum humidity for incubation. Cricket nymphs are then transferred to separate boxes. Egg trays are kept in every box to provide substrate for the crickets and crates are sprayed with water regularly to maintain humidity. Adult crickets of 9-10 weeks old are fed to birds and others are kept for further production. Currently, an average of 6-10 kg of feeding crickets and 15-20 kg of breeding stock along with cricket nymphs are produced monthly.

2.9.2. Mealworm production

Larvae of the darkling beetle (*Tenebrio molitor*) are reared in shallow plastic crates and given a diet of wheat bran, apples and potatoes. Air conditioners and dehumidifiers help maintain the temperature of the mealworm unit at 25 °C and relative humidity below 40%. The four stages of mealworm (egg, mealworm, pupa and beetle) are kept in separate crates. Beetles mate and lay eggs in the wheat bran which is then kept separately for hatching. Eggs hatch after 7-12 days. The mealworm larvae change into pupae after 10-12 weeks and pupae turn into beetles after 5-7 days. Mealworms of different sizes are separated weekly and wheat bran is changed at the same time. It takes around 7-8 weeks to produce larvae that are fit for feeding birds. An average of 40-50 kg adult mealworms (feeding stock), 150-180 kg of breeding stock, 5-6 kg pupa and 10-15 kg beetles are produced every month at present. Along with mealworms, superworms are also produced in smaller quantities for the occasional nutrient requirements of birds.

3. Outcomes and milestones

Conservation breeding of the Great Indian Bustard was a challenging new endeavour that had never been attempted before. However, with a close collaborative effort and a dedicated team, most targets that were set have been achieved in a timely manner.

- The program has managed to establish a captive population of 44 GIBs, of which 29 are above one year of age (Table 1). Thus, the program has successfully established a part of the founder population, with an aim of securing >15 breeding females and >5 breeding males as founders.
- In the first five years (learning phase), the program has achieved 93% hatchability of fertile eggs, 84% survival of juveniles (0-1 year), and its probability of converting an egg into an adult is >0.60, which is between 0.33-0.48 for other international bustard conservation breeding programs, according to Dolman et al. 2015 (Figure 2).
- Captive breeding has commenced within four years of the program, and since March 2023, five birds (four females and one male) have successfully bred naturally, leading to 13 chicks hatching from captive-laid eggs, a major milestone in the success of GIB conservation breeding efforts.
- Both breeding centres, Sam and Ramdevra, have been made fully functional, with all necessary units and equipment.
- Birds have been successfully transported between centres at the chick-juvenile stages.
- Specific approaches for searching, collecting and transporting wild-laid eggs, artificial hatching, veterinary care and rearing of birds at different ages, natural breeding of GIB, and live feed production, have been developed and are being dynamically refined, by starting from practices in other bustard breeding programs and modifying them for this species through experiential learning.
- Pilot jumpstart has been successfully tried thrice by collecting eggs from the wild and instead keeping a dummy egg for the dam to incubate, reducing the chances of predation of eggs in the wild. The egg is incubated at the centre and replaced just before hatching, after which it is reared by the wild female.
- A team of technicians and local support staff have been trained on specialised husbandry and breeding techniques as well as centre management duties, allowing the Project to become self-sufficient and smooth-running.
- Sensitisation of Forest staff, trainees, dignitaries and other stakeholders on the importance of GIB and conservation breeding activities have been carried out at these Centres.

Table 1. Information on the conservation breeding program of Great Indian Bustard (2019-2024)

Parameter	Number		
Viable eggs collected from wild for conservation breeding (2019-24)	41		
Viable eggs laid in captivity (2023-24)	16		
Chicks hatched from wild- and captive- laid eggs (2019-24)	53		
Current number of birds in the program	44		
Age and sex composition of current stock in two facilities	<i>Facility</i>	<i>Female</i>	<i>Male</i>
> 3 years	Sam	12	1
	Ramdevra	0	0
1 - 3 years	Sam	0	3
	Ramdevra	6	7
0 - 1 year	Sam	8 (unsexed)	
	Ramdevra	7 (unsexed)	

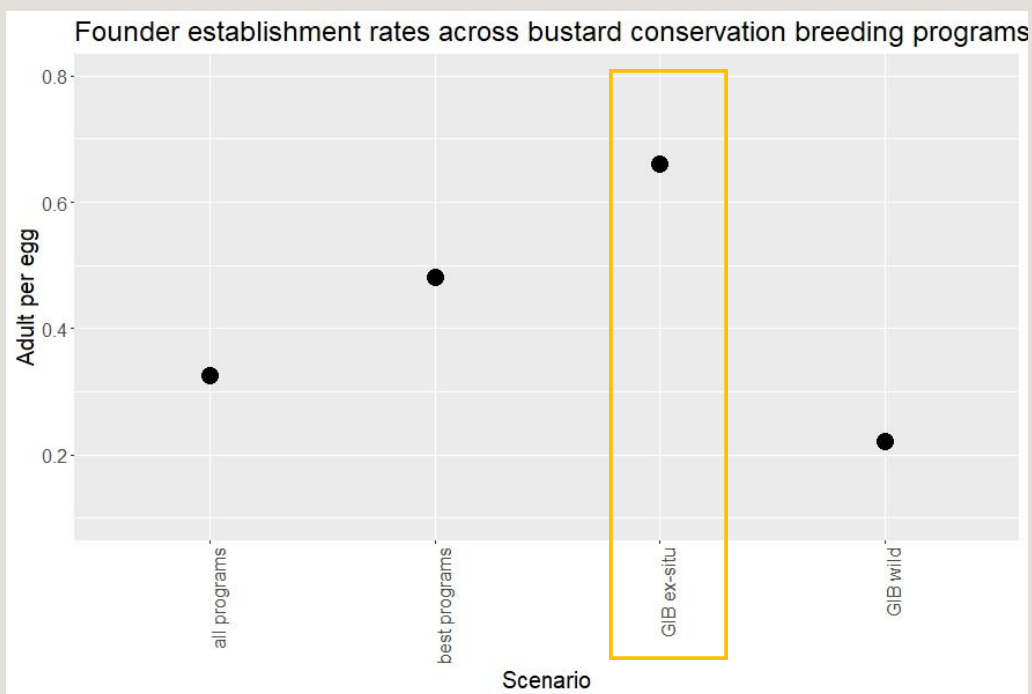


Figure 2. The probability of a collected egg reaching the adult stage for GIB CBC compared to other bustard conservation breeding programs across the world and recruitment in the wild

4. Way forward

4.1. National Conservation Breeding Program

The main aim of this program is to produce GIB chicks in the national conservation breeding centre in Rajasthan and release them in *GIB conservation areas* across their range. The national GIB conservation breeding program in Rajasthan will have the following targets:

- Establishment of founders through the annual collection of at least 3-5 wild eggs till 2026 and 1-2 eggs thereafter, to add to captive genetic diversity
- Production of chicks in captivity through natural breeding (>5 chicks/yr for Yrs 2024-27)
- Development of Artificial Insemination techniques to scale up captive production (10-15 chicks/yr for Yrs 2028-30, 15-20 chicks/yr for 2031-33 and >25 chicks/yr beyond 2033)
- Release training of surplus captive-bred chicks (after retaining adequate chicks for breeding) from 2026 onwards
- Production of surplus captive-bred chicks for pilot release (2-3 birds by 2027-28) and continuous releases after 2029 (cumulatively ~75 chicks between 2029-33 and ~300 chicks if the program is extended during 2034-43)

4.2. Upgrading conservation breeding facility in Ramdevra

- Establishment of more founder cages with indoor units and establishment of breeding units
- Establishment of release aviary for training birds before pilot release

4.3. Release training

Surplus captive-bred chicks will be trained for release initially at the Ramdevra facility. They will be provided with a large space where they can develop the muscle and bone strength required for flights. The birds trained for release will not be imprinted on humans and will learn to forage in the naturalistic aviary and will be exposed to their natural environment stimuli and threats. The trained birds will be pilot-released in Rajasthan first before

being sent to other range states for release. Modifications will be made to the release approach based on learnings from the first few batches.

4.4. Post-release monitoring

The GIBs trained for release will be soft-released in protected areas with additional supplementation of food. They will be tagged/ringed to monitor movement, post-release habitat usage and survival. A ground team will monitor the birds from a distance and note their activity, behaviour and health post-release.

4.5. Release (conservation breeding) facility development in other range states

Release Conservation Breeding facilities are to be established in *GIB conservation areas* of other range states to hold, soft release and monitor captive-bred chicks transported from the Rajasthan facility. Release sites are to be chosen by an Expert Committee based on the status of habitat restoration.

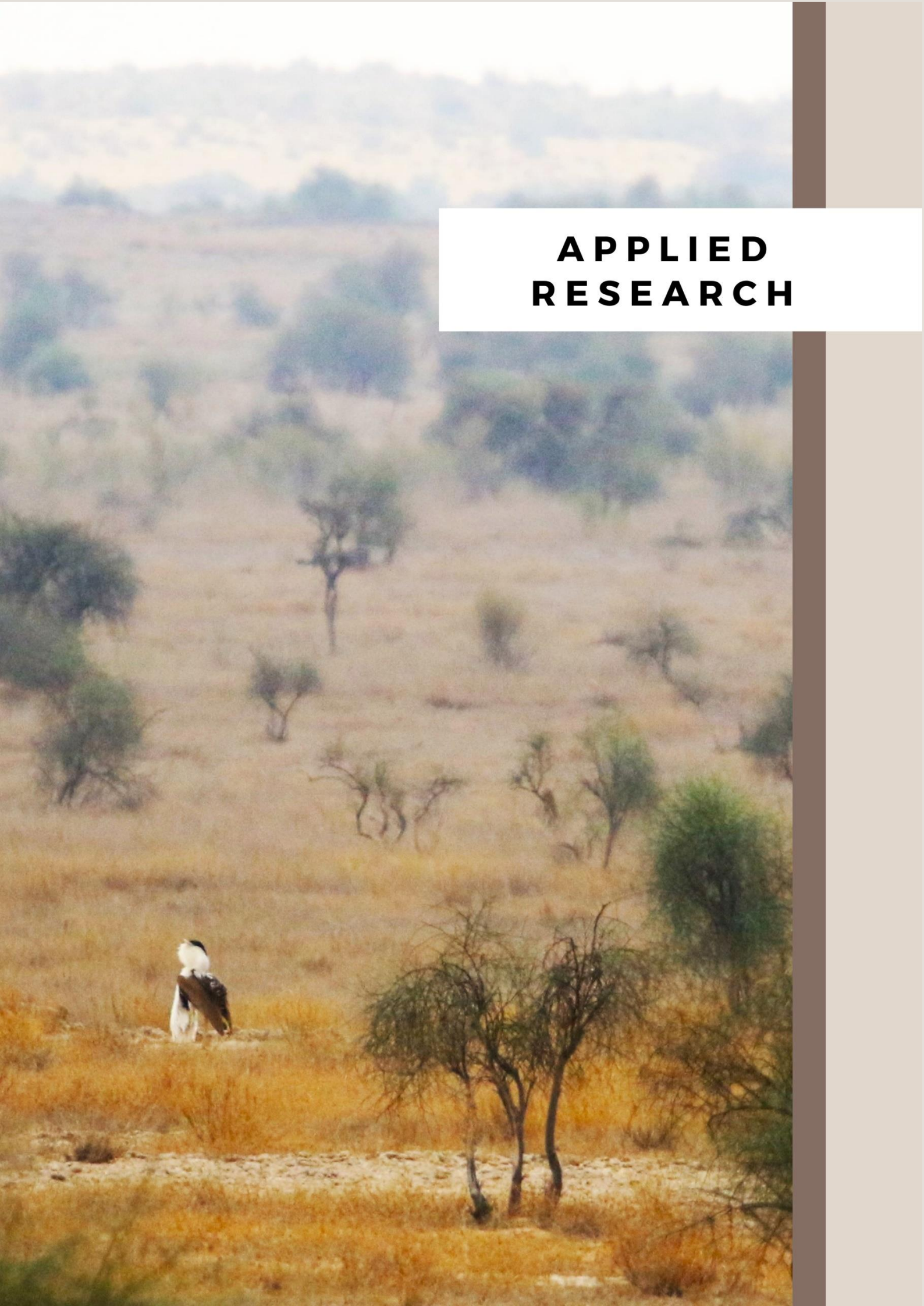
4.6. Transfer of eggs and birds

The feasibility of shifting a few birds from Gujarat and Maharashtra to the national GIB conservation breeding centre in Rajasthan in a planned and phased manner is to be explored, to add to founder genetic diversity. Later, chicks can be transported from Rajasthan centre(s) to GIB conservation areas for release.



Picture Credit: Ratnakar Hiremath



The background image is a blurred photograph of a savanna landscape. In the foreground, a bird with white and dark plumage is perched on a small mound of earth. The middle ground is filled with sparse, dry grass and scattered small trees. The background shows a hazy horizon with more distant trees and hills. A white rectangular box is overlaid on the right side of the image, containing the text "APPLIED RESEARCH".

APPLIED RESEARCH

Applied Research

The Great Indian Bustard is a large terrestrial bird that generally favours flat open landscapes with minimum visual obstruction and fewer disturbances. They use arid–semiarid areas dominated by grasslands with 30–70 cm grass height interspersed with short shrubs and extensive agriculture. Habitats for breeding use are restricted to traditional areas and positively influenced by grassland prevalence, connectivity, and terrain flatness, and negatively influenced by disturbances. On the other hand, non-breeding use is vast and greater in productive and connected agro-grass-scrub patches with short fruiting shrubs. Birds prefer sparse ground cover for roosting, moderately tall and dense vegetation for resting, and agro-grass mix with fruit resources for foraging. Birds show strong fidelity to breeding sites, which occur in grasslands with a mix of sparse cover for displaying males and moderately tall less-grazed cover for nesting females. Here males' mating territories are strategically placed where long-term female usage is high, implying that their destruction can cause serious conservation problems. It is a diurnal gregarious species, usually forming sexually segregated flocks that dissociate during the breeding season. Historically flocks of 20–50 birds have been commonly observed but the current typical flock size is only 2–3 birds (Dutta 2012), probably due to the overall population decline. They are omnivorous with beetles, grasshoppers, fleshy fruits and crops constituting the bulk of their diet. Diet seasonally shifts from predominantly herbivory in winter (71% dry weight of plant matter) to insectivory in summer and monsoon (72% insects) (Rahmani 1989). The species breeds principally between March and September, differing regionally based on rainfall. Breeding males establish territories in an exploded lek mating system (Rahmani 1989) from where they display elaborately by inflating their gular pouch to produce deep resonant calls, cocking their tail, and occasionally engaging in highly ritualized territorial fights with intruding males. Reproduction is slow as the female typically lays a single egg (rarely two) at a time in secluded, open ground and incubation lasts 22–23 days. Disturbance to the nesting site is a major cause of egg and chick mortality. The precocial chick fledges in about 75 days and follows its mother for almost a year. Sexual dimorphism is stark, where males weigh twice as much as females (11–18 kg, Elliott 1880; Vyas et al. 1983) and have prominent secondary sexual characteristics. Insemination of all breeding females by only 1–2 males in Nanaj and Rollapadu (Rahmani 1989; Rahmani and Manakadan 1986) hints at a polygynous mating system, and probable intrasexual selection for more attractive traits (Johnsgard 1994; Zahavi 1975).

The GIB is now largely confined to the Thar Desert landscape in Rajasthan, where habitats are much more extensive than other range states, and its ecological integrity is not yet completely lost. This landscape/population is vital for refining our ecological and conservation knowledge of the GIB, as it is the prime hope for its persistence. Effective conservation of any species needs a research-based understanding of a) current population status and distribution, b) comprehensive understanding of its biology, c) its threats and mitigation measures, c) population genetic structure for conservation management, and d) effectiveness of ongoing conservation measures.

Hence, the Project undertook landscape-level status surveys for GIB, associated key fauna and habitats in Jaisalmer, Rajasthan during 2014–18. To gain a finer understanding of the species' population dynamics, seasonal surveys were carried out in and around Desert National Park. Routine monitoring of nests and chicks were carried out to assess nest success and recruitment rates during the breeding season. For close monitoring of this rare and elusive species, nine females in Jaisalmer and two females in Kachchh were fitted with GPS tags. This allowed us to understand their space use and movement patterns with respect to seasons and landscape characteristics, habitat selection, and find nests for conservation breeding. Impacts of known threats to bustards and associated taxa were assessed, such as bird mortality due to energy infrastructure and predation of wildlife by free-ranging dogs. Vegetation characteristics and arthropod assessments were conducted, to understand how these factors affect GIB ecology and habitat use. Additionally, the effects of grassland restoration on biodiversity recovery were investigated with GIB, insects and spiders as model taxa. Local community perceptions and issues were studied. Genetic analyses of GIB populations across different states were performed to understand their genetic structure. Further, studies on key associated taxa such as bird

communities, spiny-tailed lizards *Saara hardwickii*, chinkara *Gazella bennettii*, and desert foxes *Vulpes vulpes pusilla* were conducted.

The applied research component of the project has provided in-depth insights into the ecology, habitat, and threats of this flagship species and its associates that have fed into conservation plans and technical inputs to State Forest Departments through outreach and pilot *in-situ* action components.

1. Population and habitat monitoring

1.1. Landscape surveys

From 2014 to 2018, WII and RFD conducted joint landscape-scale surveys to understand the population status of the Great Indian Bustard and associated fauna in the western Thar landscape of Rajasthan. The first three surveys were conducted in March 2014, 2015 and 2016, and helped in developing a standardised population monitoring protocol, which was then followed by the project to establish status baselines in March 2017 and 2018.

1.1.1. Survey design and data collection

In 2017-18, an area of 19,728 km² was identified as the Thar GIB landscape, by overlaying historical records of GIB post-1950's in western Rajasthan (Rahmani, 1989, Rahmani and Manakadan, 1986) and excluding non-habitats (extensive sand dunes, built-up and intensive agriculture) (Dutta, 2013).

This area (19,728 km²) was divided into seven sampling blocks (Ramgarh, Mohangarh, Bap, Ramdevra, Rasla, Myajlar, and Sam-Sudasari). These blocks were simultaneously surveyed by 52 teams from March 18-23 in 2017. Each team comprised a WII researcher/volunteer and a forest department staff. Team members were trained on standardised data collection protocols through workshops and practice sessions prior to the survey. The survey area was classified into 137 grids of 144 km² area each (Figure 3), which were surveyed by vehicle transects in a systematic sampling framework. Extensive surveys were conducted in 121 randomly chosen cells with 3,529 km total effort in 2017 (Figure 3). Transects of average 29.2±8.0 SD km length were surveyed along dirt trails by a slow-moving vehicle (10-20 km/hr) in every cell. Surveys were conducted during the peak bird activity period (0600-1000 and 1600-1900) to maximise detections. Cells with GIB detections were surveyed again intensively along multiple transects of 14.6±6.6 SD km mean length each (mean effort 127±13.5 km per cell; total effort of 635 km) (Dutta et al., 2014) (Figure 3). Data was collected on GIB and associated fauna (desert fox, Indian fox, chinkara, nilgai and pig) including the number of individuals, GPS coordinates, perpendicular distances from the transect and biotic disturbances (feral dogs and livestock). Additionally, associated terrain, substrate, land cover, vegetation structure, three dominant plant species at sighting locations and various anthropogenic artefacts were also recorded (Dutta et al., 2014).

1.1.2. Distribution and population estimation

GIB distribution, occupancy, colonisation, and extinction probabilities were estimated using dynamic/multi-season occupancy models that accounts for species non-detections (MacKenzie et al., 2006). A detection/non-detection matrix was prepared from GIB sightings in 2 km transect segments (spatial visits) across sampled years. Year-wise occupancy estimates were derived from the least AICc model.

GIB density was estimated using the Distance sampling framework (Thomas et al., 2010), which models detection probability based on distance from the transect line. This method calculates Effective Strip Width (ESW) to convert encounter rates into density estimates (Buckland et al., 2001).

Intensive surveys in GIB occupied grids supplemented extensive survey data to resolve the bias caused by low and clustered detections of GIB. This combined data was used to model detection function and compute density

at each cell, estimating landscape-scale density as the average of cell-wise densities. Since Pokhran Field Firing Range could not be adequately sampled in 2017, repeat surveys were conducted in & around Desert National Park (4,068 km²) and in and around Pokhran Field Firing Range (5,184 km²) during December 2017-January 2018 and March-April 2018, respectively (Figure 3).

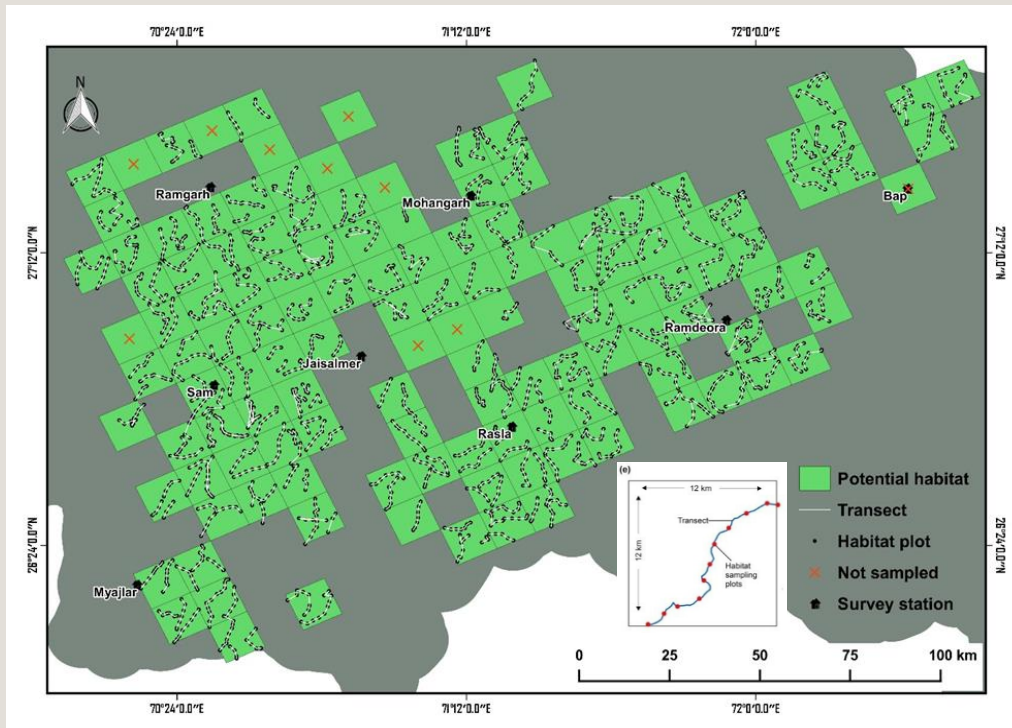


Figure 3. Sampling design for GIB population and habitat assessment in Thar landscape (2014-2016), Rajasthan: distribution of transects in 144 km² cells overlaid on potential habitat and habitat sampling plots at 2 km interval on transect

1.1.3. Distribution and population status of GIB and associated fauna

During the four surveys, 38 (2014), 40 (2015), 37 (2016), and 37 (2017) GIB individuals were detected (Figure 4) and 6.7±2.9% of sites were estimated to be occupied by GIB (Figure 4). The mean flock size was 1.63±0.11 SE. Distance data was fitted best by uniform detection function with cosine adjustment, which calculated ESW at 401±26 SE m (2017) and 447±48 SE (2018). The density of GIB was estimated at 0.48±0.10 SE birds/100 km² for all cells in the 2017 survey and at 1.4±0.2 GIB/100 km² (1.0 - 1.9 at 95% CI) in the subset cells sampled in 2018, yielding abundance of 128±19 SE individuals in Thar landscape during 2017-18.

A total of 1036 chinkara herds (mean herd size 2.49±0.07 SE) and 77 desert foxes were detected during the extensive survey (2017). Chinkara density was best explained by hazard rate with a simple polynomial detection function that estimated ESW of 169±7 SE m, density of 205±14 SE chinkara/100 km², and abundance of 40,442±2810 SE chinkara in the Thar landscape. Desert fox density was estimated to be 15.03±2.39 SE individuals/100 km², yielding an abundance of 2965±471 SE desert fox in the landscape (half-normal cosine detection function; ESW 82±9 SE m).

Additionally, encounter rates of other taxa were computed as 0.22/100 km (±0.08 SE) for Indian fox *Vulpes bengalensis*, 3.93/100 km (±1.11 SE) for Nilgai *Boselaphus tragocamelus*, 1.98/100 km (±26 SE) for pig *Sus scrofa*, 484.49/100 km (±62.84 SE) for cattle and 2065.83/100 km (±138.8 SE) for sheep-goat. 8.2% (±1.5) of surveyed plots were occupied by spiny-tailed lizards.

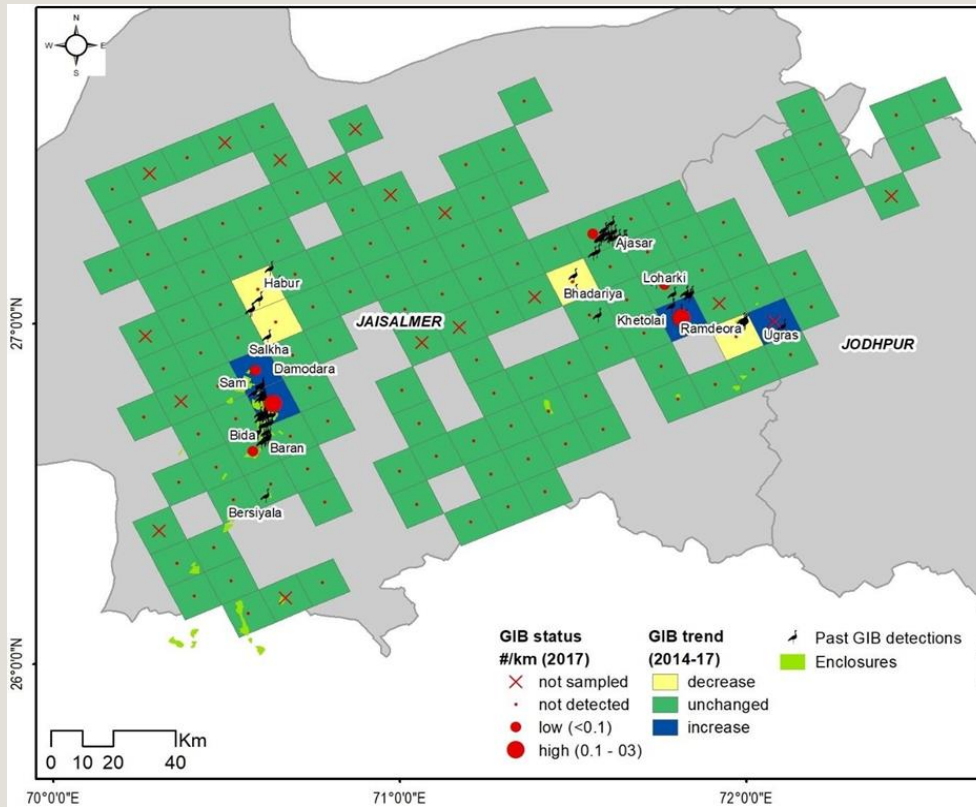
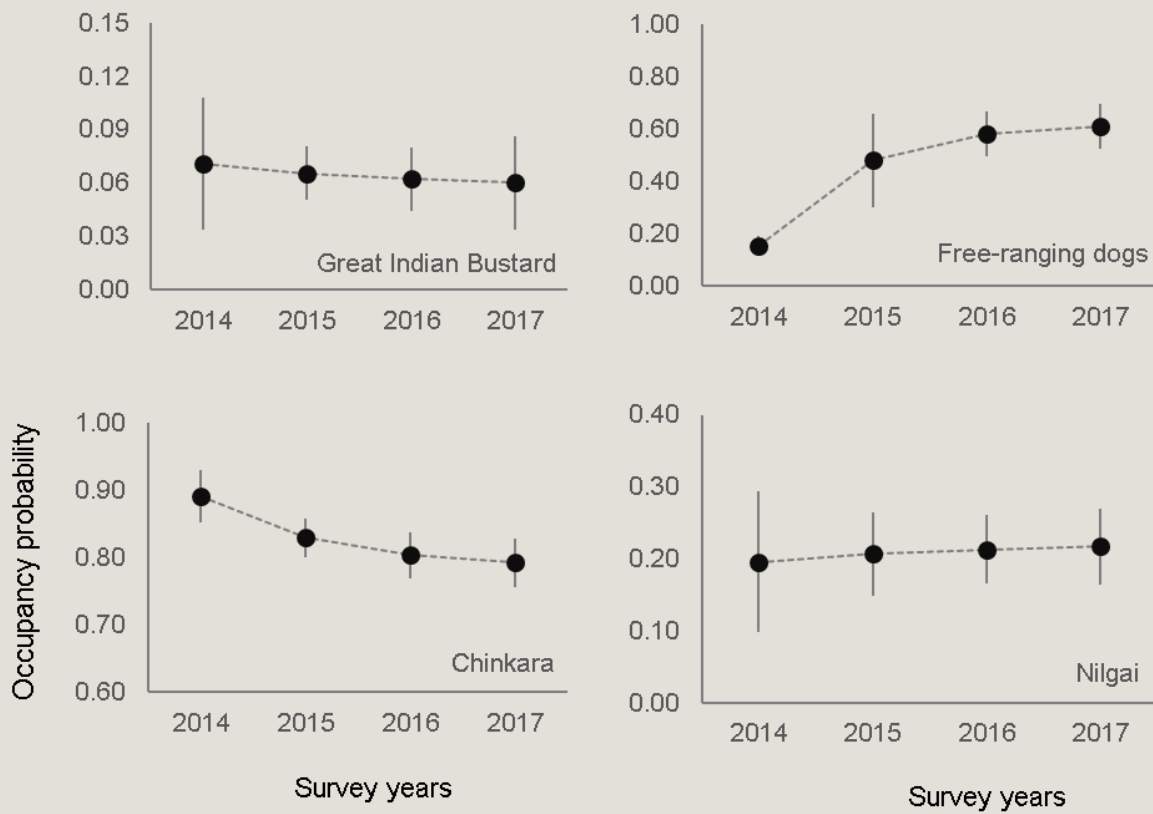


Figure 4. Status (2017) and trend (2014–2017) of Great Indian Bustard in Thar landscape, Rajasthan

Trends of key species over the monitored years (2014-18) suggested a nearly stable population of GIB, an increasing population of dogs, and a declining population of chinkara (Figure 5).



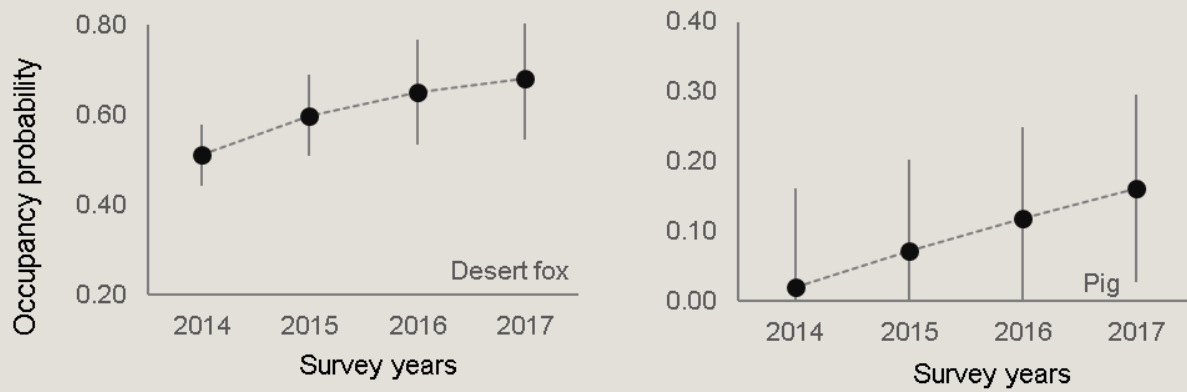


Figure 5. Distribution trend for GIB and associated species across years (2014–17) in Thar landscape, Rajasthan, estimated as mean $\pm$ SE proportion of sites occupied using dynamic occupancy models, for native/‘important’ (left) and non-native/‘problem’ species (right)

1.1.4. Habitat status and trends

The extensive survey (2017) showed that the landscape is dominated by grassland (0.36), agriculture (0.26) and shrub-dominated land (0.19); flat (0.53) and undulated terrain (0.14); soil (0.78) and sand substrate (0.14) (Table 2).

Table 2. Descriptive statistics of habitat covariates in 144 km² cells across the Thar landscape in Rajasthan (2017)

Feature	Units	Habitat covariates	Mean ($\pm$ SE)
Land cover	Proportional cover	Grassland	0.36 (0.02)
		Agriculture	0.26 (0.02)
		Shrubland	0.19 (0.02)
		Barren	0.13 (0.02)
		Woodland	0.06 (0.02)
Terrain	Proportional cover	Flat	0.53 (0.02)
		Undulating	0.14 (0.02)
		Sloping	0.1 (0.01)
Substrate	Proportional cover	Soil	0.78 (0.03)
		Sand	0.11 (0.02)
		Gravel	0.07 (0.02)
		Rocky	0.04 (0.01)
Disturbances	Occurrence probability (500m radius plot)	Power lines	0.42 (0.03)
		Water-body	0.39 (0.02)
		Hut/ <i>dhanis</i>	0.36 (0.02)
		Metal road	0.14 (0.01)
		Wind turbines	0.13 (0.02)
		Solar plant	0.02 (0.01)
Vegetation stratification	Ground cover (%)	Crop	26.02 (2.22)
		Short grass	20.91 (1.31)
		Tall grass	12.28 (0.9)
		Shrub	10.12 (0.7)
		Tree	5.61 (0.44)

Vegetation composition	Grass (dominant score 1-3)	<i>Dactyloctenium sp</i>	0.91 (0.07)
		<i>Lasiurus scindicus</i>	0.45 (0.05)
	Herb (dominant score 1-3)	<i>Fagonia sp</i>	0.3 (0.03)
		<i>Haloxylon sp</i>	0.17 (0.03)
		<i>Senna sp</i>	0.16 (0.03)
	Shrub (dominant score 1-3)	<i>Capparis decidua</i>	0.71 (0.05)
		<i>Calotropis sp</i>	0.59 (0.06)
		<i>Leptadenia pyrotechnica</i>	0.44 (0.04)
	Tree (dominant score 1-3)	<i>Acacia sp</i>	0.21 (0.03)
		<i>Prosopis cineraria</i>	0.09 (0.01)

A strong increase in anthropogenic disturbances was observed over the years, wherein, the proportion of sampling plots with power lines, settlements and wind turbines showed a sharp increasing trend (Figures 6 & 7). There was no major change in land cover composition and vegetation stratification over the survey years.

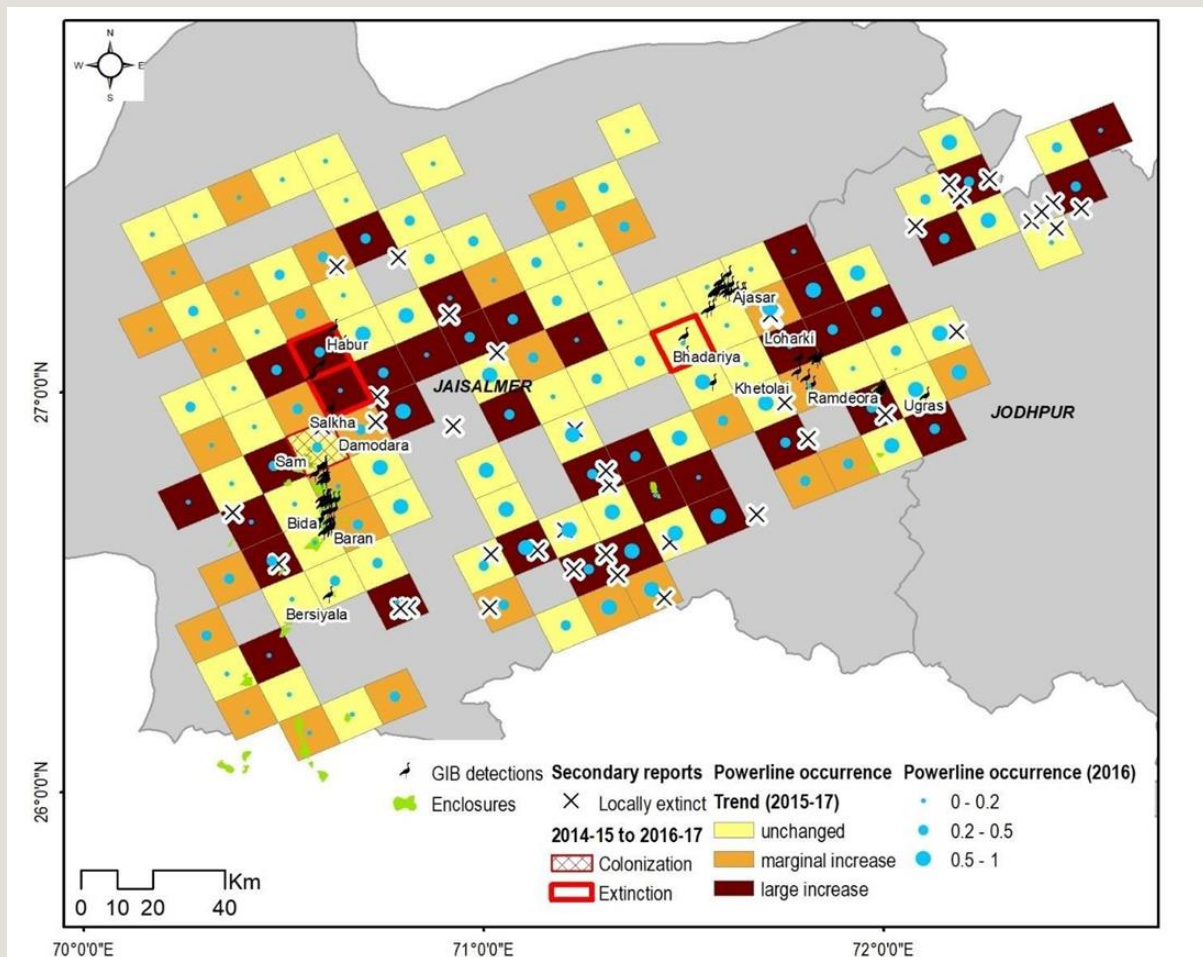


Figure 6. GIB distribution and local extinction in the past decade (based on secondary reports) and from 2014-15 to 2016-17 (based on occupancy surveys) overlaid on the occurrence (2016) and recent trend (2015-17) of power line expansion across Thar landscape in Rajasthan

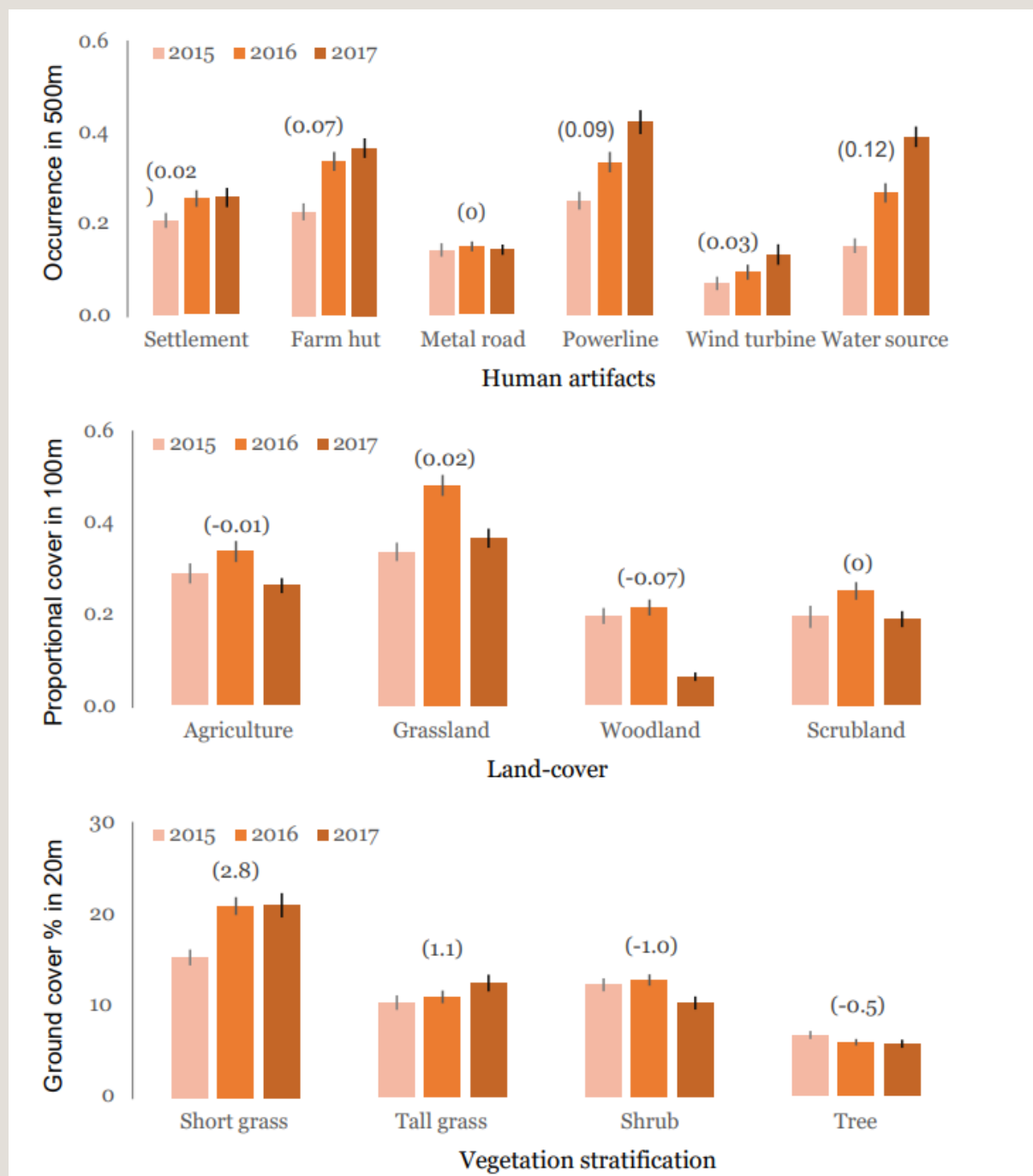


Figure 7. The occurrence probability of human artefacts in sampling plots across the Thar landscape in Rajasthan from 2015 to 2017. Error bars are 1 SE across 144 km² cells, and values in parentheses are regression slopes against years as temporal trends. Also shown are land cover and vegetation structure variables that, expectedly, do not show strong temporal trends

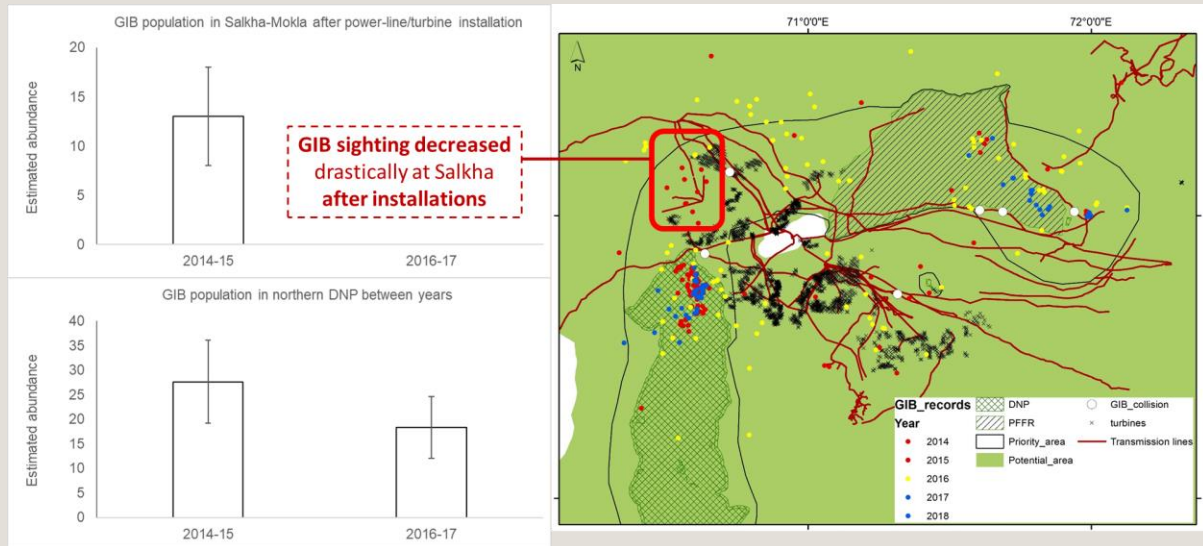


Figure 8. Comparison of GIB abundance in Salkha-Mokla and DNP before and after power line and turbine installations

1.1.5. Conclusion

This study presents the latest estimate of 128 ± 19 SE individuals for the largest and only viable population of the GIB. Even though population trends could not be gauged due to poor estimates in the past, this study highlights the increase of human-induced disturbances in this landscape during the survey years, especially threats like power lines.

1.2. Intensive monitoring of the GIB population

For regular population monitoring of GIB and associated fauna in western Thar, six intensive surveys between 2022 and 2024 were carried out in and around DNP (two surveys each in summer, winter and monsoon) (Table 3). The survey area (1080 km^2) between Mokla in the north and Khuri in the south, which forms the limits of the western Thar (sub)population at present, was divided into 30 grids of 36 km^2 area each (Figure 9). The sampling area was divided into two blocks: protected areas within DNP and non-protected areas outside DNP (with renewable energy infrastructure). The area was systematically sampled following protocols established during the landscape surveys mentioned above and data was analysed for estimating occupancy (single species multiseason) and density (distance sampling) of GIB and associated fauna. Additionally, at every 2 km interval, a rapid habitat assessment was conducted to record features like land cover, vegetation structure and composition, and active and passive disturbances that can potentially influence the distribution of target species, following the approach described in the previous section. In each grid, 2-3 vehicle transects adding up to 10 km were surveyed. In total, 54 transects of 2045 km efforts were sampled.

Table 3. Seasonal landscape survey efforts for assessment of Great Indian Bustard and associated fauna in and around Desert National Park

Season	Number of transects	Survey efforts (km)
Winter (Feb 2024)	55	329
Monsoon (Oct 2023)	55	300
Winter (Feb 2023)	56	358
Summer (Apr 2022)	55	366
Summer (June 2023)	51	342
Monsoon (Sept 2022)	53	349

1.2.1. Distribution and population status

For GIB, the half-normal detection function with sex as a covariate fitted the distance data best (least AICc). This model yielded an ESW of 564.3 ± 74.5 SE m, a GIB density of 3.3 ± 1.1 SE/100 km² and an abundance of $35.3 (\pm 12.07)$ individuals (Table 4). The density of associated species, such as Chinkara (201.89 ± 17.61 SE/100 km²), desert fox (10.95 ± 1.94 SE/100 km²) and nilgai (10.79 ± 2.68 SE/100 km²) were also estimated (Table 4). GIBs were detected in higher numbers in the southern block compared to the northern block, possibly due to less infrastructure and better protection in the southern block.

Table 4. Population status estimates of Great Indian Bustard and key associated fauna in and around Desert National Park (2022-2024)

Species	Detections	Occupancy (SE)	ESW (m) (SE)	Density/100 km ² (SE)	Abundance (SE)
GIB	73	0.17 (0.07)	564.3 (74.5)	3.3 (1.1)	35 (12.1)
Chinkara	2250	0.9 (0.09)	410.3 (9.6)	201.89 (17.61)	2180 (190.1)
Desert Fox	72	0.75 (0.10)	393.2 (34.7)	10.95 (1.94)	118 (20.9)
Indian Fox	11	0.22 (0.10)	-	-	-
Nilgai	148	0.35 (0.09)	535.6 (27.6)	10.79 (2.68)	117 (28.9)

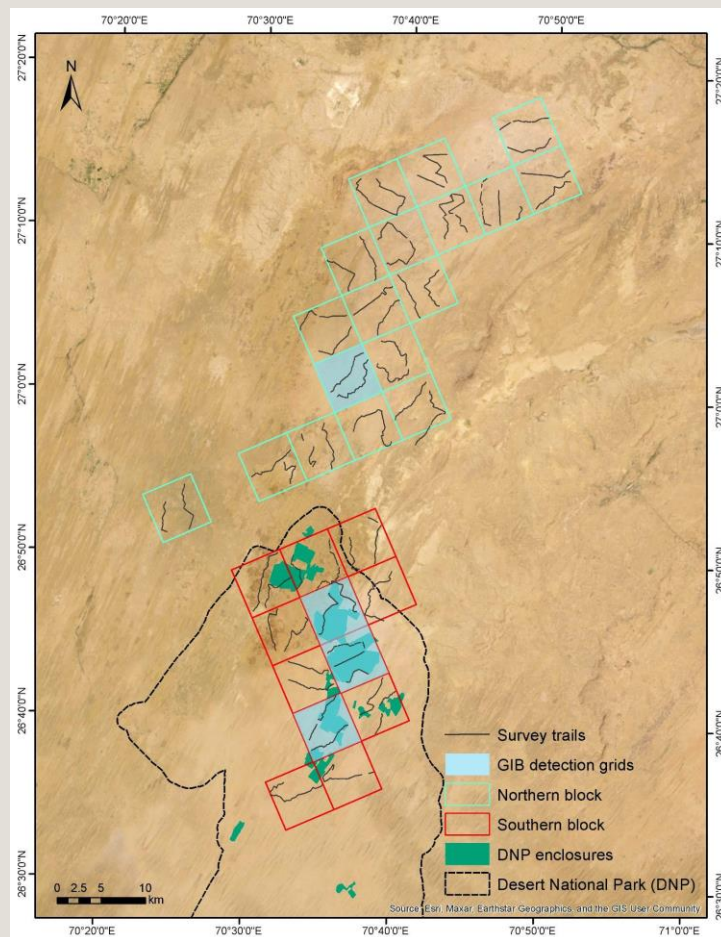


Figure 9. Sampling grids and vehicle transects for GIB population and habitat assessment in intensive monitoring area in and around Desert National Park (2022-2024): distribution of transects in 36 km² cells overlaid along with the cells of GIB detections

1.2.2. Habitat status

Habitat assessment showed that the dominant land cover was grassland followed by fallow agriculture with land cover types and vegetation structures roughly similar between both northern and southern blocks. *Capparis decidua* and *Zizyphus nummularia*, both food sources (fruits) for GIB and other fauna, were among the most dominant trees in both blocks (Table 5). *Calotropis procera*, an invasive species, was found to be the second most dominant upperstorey plant. The four most dominant understorey species were *Dactyloctenium* sp. and *Lasiurus scindicus* (grasses), *Crotalaria burhia* and *Fagonia cretica* (shrubs/ herbs) (Table 5). These four species are characteristic of grasslands and fallow lands, respectively. The occurrence of most active and passive disturbances was also similar between both blocks. However, the intensity of energy infrastructure (wind turbines and power lines) was significantly higher in the northern block (Table 5). Farm huts were higher in the southern block with slightly higher human occurrence, indicating more seasonal human presence in the protected area (Table 5). The results indicate that even though habitat variables are similar between both blocks, the significantly higher incidence of infrastructure and lack of protection in the northern block has led to reduced species densities and displacement of GIB from this area, since much higher GIB density was reported here in 2014-15 than present, as per the joint landscape level surveys conducted by WII and RFD.

Table 5. Descriptive statistics for dominant land cover, anthropogenic disturbances, vegetation structure and composition in the intensive monitoring area, and separately for northern and southern blocks

Feature	Units	Habitat Variable		Mean (SE)		
				Overall	South block (protected)	North block (unprotected)
Land cover	Frequency occurrence in 100m radius of point	Grassland		0.59 (0.06)	0.53 (0.07)	0.65 (0.06)
		Barren		0.12 (0)	0.12 (0.05)	0.13 (0.04)
		Shrubland/Scrubland		0.21 (0.06)	0.28 (0.06)	0.15 (0.05)
		Woodland		0.05 (0.02)	0.03 (0.03)	0.07 (0.02)
		Fallow Agriculture		0.35 (0.04)	0.4 (0.08)	0.31 (0.07)
		Active Agriculture		0.1 (0.01)	0.11 (0.05)	0.09 (0.04)
Disturbance	Occurrence in 500m radius of point	Active Disturbance				
		Human		0.46 (0.03)	0.49 (0.07)	0.42 (0.07)
		Machinery		0.27 (0)	0.27 (0.06)	0.27 (0.06)
		Passive Disturbances				
		Farmhut		0.42 (0.1)	0.52 (0.07)	0.33 (0.05)
		Settlement		0.06 (0.01)	0.06 (0.03)	0.07 (0.03)
		Power line		0.36 (0.21)	0.15 (0.06)	0.58 (0.09)
		Windmill		0.19 (0.16)	0.03 (0.03)	0.36 (0.08)
		Fence		0.37 (0.04)	0.41 (0.09)	0.33 (0.07)
		Road		0.12 (0)	0.12 (0.04)	0.12 (0.03)
Vegetation Structure	Percent cover in 20m radius of point	Vegetation between 0-30cm		32.03 (3.56)	28.47 (3.77)	35.59 (3.51)
		Vegetation between 30-100cm		27.51 (1.81)	29.32 (3.98)	25.69 (3.27)
		Vegetation between 1-2m		9.12 (1.04)	10.16 (1.52)	8.08 (1.1)
		Vegetation>2m		9.51 (0.79)	8.72 (1.43)	10.31 (1.35)
Vegetation Composition	Occurrence in 100m radius of point	Dominant Upperstorey Vegetation (1=most dominant)	<i>Capparis decidua</i>	0.83 (0.03)	0.8 (0.06)	0.85 (0.04)
			<i>Calotropis procera</i>	0.37 (0.05)	0.42 (0.07)	0.33 (0.07)
			<i>Zizyphus nummularia</i>	0.36 (0.06)	0.3 (0.05)	0.42 (0.08)

			<i>Leptadenia pyrotechnica</i>	0.3 (0.05)	0.25 (0.06)	0.34 (0.06)
			<i>Acacia tortilis</i>	0.08 (0.03)	0.05 (0.03)	0.1 (0.05)
		Dominant Understorey Vegetation (1=most dominant)	<i>Dactyloctenium sp</i>	0.83 (0.04)	0.79 (0.05)	0.87 (0.04)
			<i>Crotalaria burhia</i>	0.46 (0.04)	0.41 (0.07)	0.5 (0.07)
			<i>Fagonia cretica</i>	0.34 (0.07)	0.27 (0.08)	0.4 (0.08)
			<i>Lasiurus scindicus</i>	0.26 (0.01)	0.27 (0.06)	0.26 (0.06)
			<i>Aerva sp</i>	0.17 (0.07)	0.24 (0.05)	0.1 (0.04)

1.2.3. Density surface modelling for GIB population estimation

Given the clustered distribution of GIB, Density Surface Modelling (DSM) in Distance sampling framework was additionally used to estimate its spatially explicit density in Western Thar landscape (Hedley and Buckland, 2004; Miller et al. 2013). Pooling data from all six surveys, the number of detections within 2 km transect segments was fitted on a habitat covariate (presence of enclosure) using Generalised Additive Models, after examining the effects of sex and/or season on detection scale parameters. It was postulated that enclosures would positively influence the density of GIB as they indicate protected grasslands with greater insect resources and ground vegetation cover, where bird usage tends to be high. According to the best-fit model (half normal cosine with season covariate), GIB abundance was estimated to be 37.61 (14.11 SE; 37.52% CV; 52.1% deviance explained) using this approach; very similar to the estimate obtained using conventional Distance Sampling.

1.2.4. Mark-resight method for GIB population estimation

Density estimates of GIB obtained from Distance Sampling have low precision and less statistical power to detect changes in density over space and time, because of the rare and patchy distribution of the species. Taking advantage of marked individuals (tagged/ringed), we explored the feasibility of mark-resight approach to estimate the density of female GIB from the ratio of tagged to untagged females in photo captures from camera traps deployed at water guzzlers in summer (June - August 2023), when the usage of water guzzlers by GIB is relatively high and their distribution is concentrated in known areas. 22 guzzlers were selected across eight enclosures within DNP, which included Ganga, RKVY, Sudasari (ACD, B and EF), Gajaimata, New Gajaimata, and PPC Chauhani, from north to south (Figure 10). Camera trap data from July 01 to 15, 2023 was analysed focusing on daylight hours aligning with GIB movements to guzzlers. Photos collected were segregated using a customised deep learning algorithm based on ResNet and Megadetector approaches, combined with manual identification of tagged GIB individuals. The sighting frequency of tagged and untagged female GIB was analysed using the Poisson Mark Resight estimator, suitable for sampling with replacement and individually identifiable marks, in Program MARK (McClintock, 2008). This analysis accounted for individual heterogeneity and the unmarked population size.

Preliminary female GIB abundance in the core usage area of DNP, based on a small pilot sample, was estimated at 17.81 (8.44 SE, 7.38 - 43.02 at 95% CI), with resighting rate of marked females at 6.04 (2.93 SE, 2.45 - 14.87 at 95% CI) and a detection probability of 0.82 (0.18 SE, 0.3 - 0.98 at 95% CI). This estimate is slightly (but not significantly) lower when compared with CDS analysis which yielded female abundance estimates of 22.9 (10.2 SE) individuals. The difference could be because of individuals that were using areas outside the camera trapped and core usage area, and were therefore missed entirely.

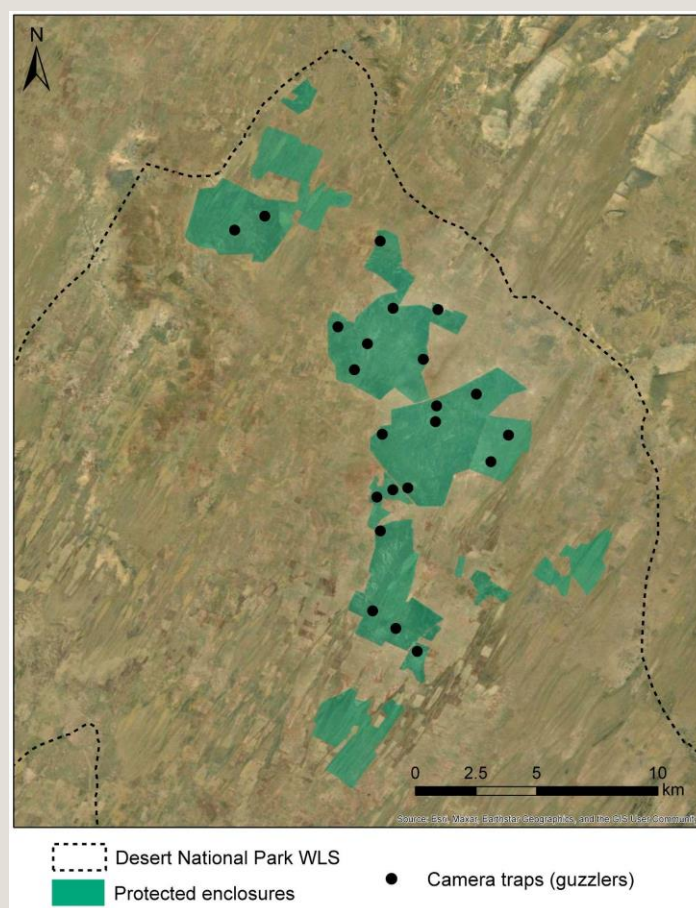


Figure 10. Locations of camera traps at guzzlers in protected enclosures of Desert National Park

2. Telemetry-based understanding of spatial ecology

Two wild female GIB in Kachchh and 10 female GIB in Jaisalmer were tagged with GSM/GPRS PTTs (tags used were Argos PTT 70 g, e-obs telemetry 42 g Bird Solar tags and 50 g Movetech Flyway-50 tag) (Table 6). These tags have an average lifespan of 2-3 years, and on average, the e-obs tags have transmitted for 24.7 months with one tag functioning for 60 months since the time of deployment. At present, there are three functional tags. The Project demonstrated that tagging of birds (males and females) provides highly valuable ecological and conservation information and can be continued in small numbers annually.

Table 6. Summary of tagged Great Indian Bustards

Bird Id	Tag	Population (tagging site)	Tagging date	Tag status
Raheva	Microwave PTT	Kachchh (Naliya)	01-05-2017	Non-functional
Alfin	Microwave	Kachchh (Naliya)	01-05-2017	Non-functional
5949	e-obs	West Thar (DNP KaliMali)	31-03-2019	Functional
5946	e-obs	West Thar (DNP Sudasari)	11-04-2019	Non-functional
5947	e-obs	West Thar (DNP RKVY)	15-04-2020	Removed
5948	e-obs	West Thar (DNP Chauhani)	21-06-2020	Non-functional
865	e-obs	East Thar (Didhoo)	05-07-2020	Non-functional
8649	e-obs	West Thar (DNP Sudasari)	24-04-2021	Functional
8651	e-obs	East Thar (Ramdevra ABC)	29-04-2021	Non-functional
8652	e-obs	West Thar (DNP RKVY)	28-06-2021	Removed
8650	e-obs	West Thar (DNP Sudasari)	12-05-2023	Non-functional
2054	Move tech	West Thar (Salkha)	10-06-2023	Functional



Image 7. Great Indian Bustard tagging team in 2023

2.1. Space use patterns

On average, tagged birds were found to move 5802 (SE 2375) m daily, ranging from 2932 m (5948) to 8585 m (5946) (Table 7; Figure 11). This is an underestimate of the actual distance moved as any movement in between the one-hour recording interval is missed. All birds showed large variation in daily distance moved that indicated non-uniform activity level against time (Figure 11).

Table 7: Daily distance moved by 5 tagged females in the first few months after tagging.

Tag ID	Number of 1hr fixes (used for calculation)	Daily distance moved in m (SE)
865	1409	7684 (6735)
5946	1495	8585 (3583)
5947	1865	4062 (3351)
5948	1129	2932 (3510)
5949	8229	5747 (4276)

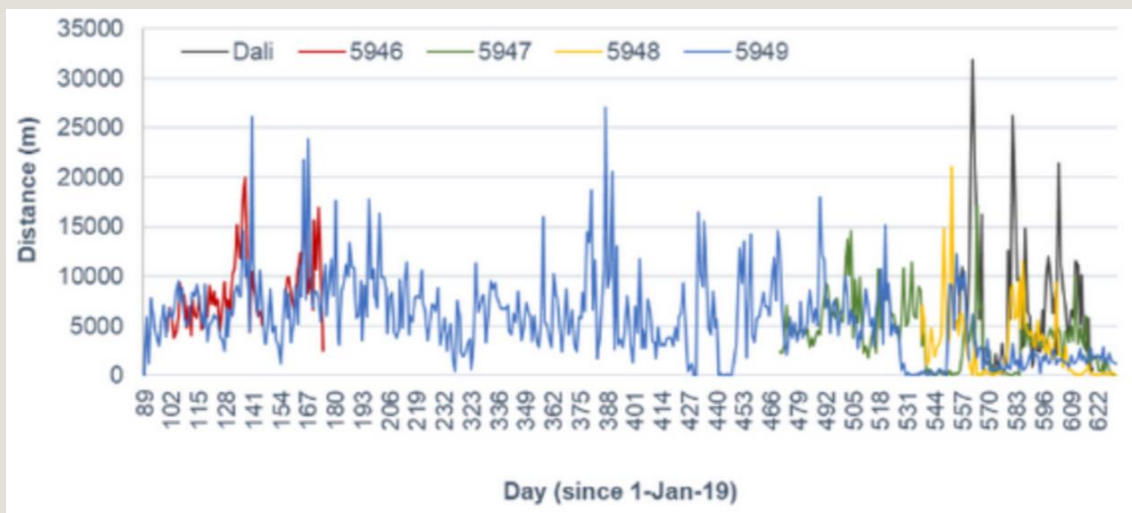


Figure 11: Daily distance moved by female GIB

Telemetry data showed that GIB are wide-ranging but prefer protected areas with less disturbances and old growth grasslands. A 95% Minimum Convex Polygon (MCP) of GPS fixes from eight tagged birds in Thar yielded an average home range estimate of 193 km² area (ranging from 114 - 465 km²) (Figure 13). *Alfin's* (GIB tagged in

Gujarat) home range was estimated at 429 km² with daily movement of 7.2 km (± 4.2 SD; 0.1 - 29.9 km). Home range could not be estimated for the tagged bird *Raheva* as she died due to power line collision within 48 days of tag deployment (Figure 12).

Kernel Density Estimation (KDE) was used to understand the intensity of area utilisation within these MCPs (Figure 13). The KDE maps show that although birds range widely, the maximum usage falls within grassland enclosures (in DNP) or inviolate areas (of Pokhran Field Firing Range).

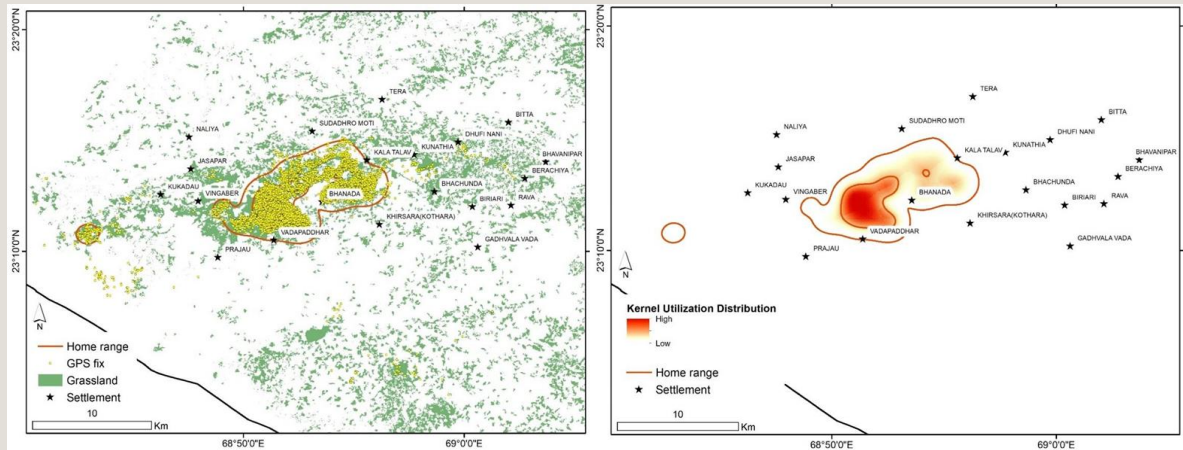


Figure 12. Movement of tagged Great Indian Bustard overlaid on grassland patches (left) and utilisation density for both tagged birds in Kachchh (Gujarat)

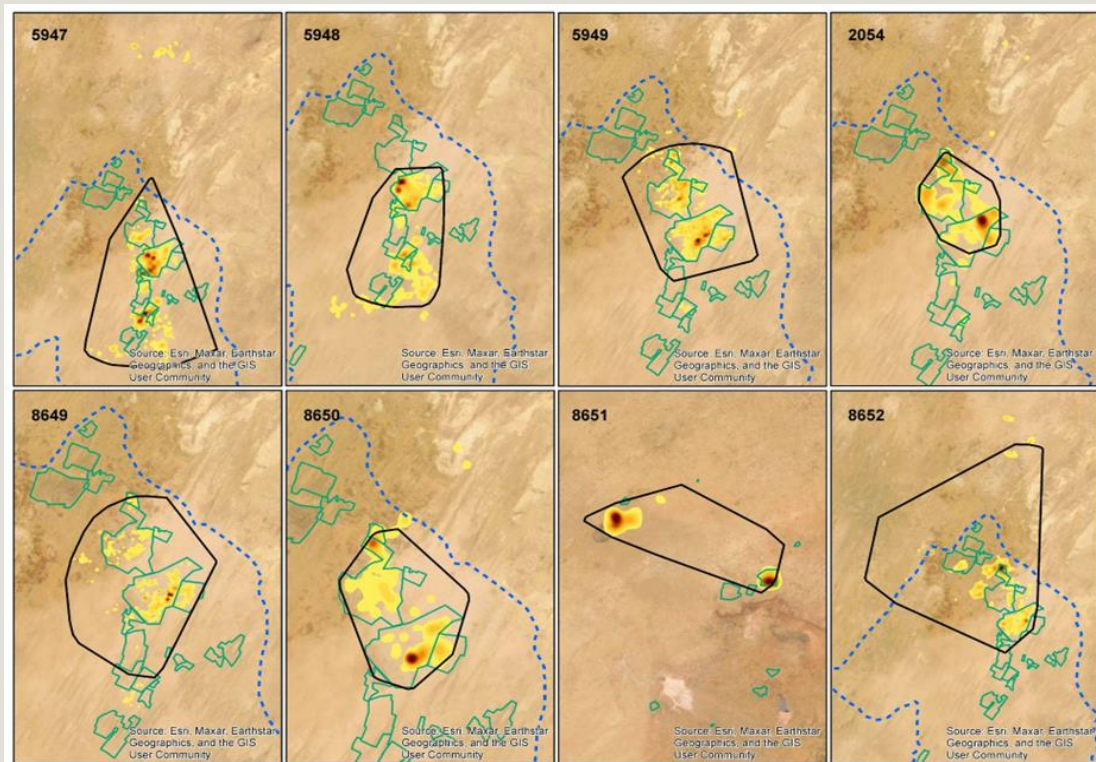


Figure 13. 95% Minimum convex polygons and utilisation density (kernel density) for tagged Great Indian Bustard females showing intensive use of protected grasslands in northern DNP and Ramdevra, Jaisalmer

Space use was also found to vary seasonally, with movement being restricted to certain pockets of old-growth protected grasslands with regulated grazing during the breeding season but ranging more widely across agro-pastoral land uses in the non-breeding season (Figures 13 & 14). The reason behind this is possibly higher

arthropod biomass inside enclosures in monsoon and avoidance of disturbances by GIB during breeding activities (see section 5.2).

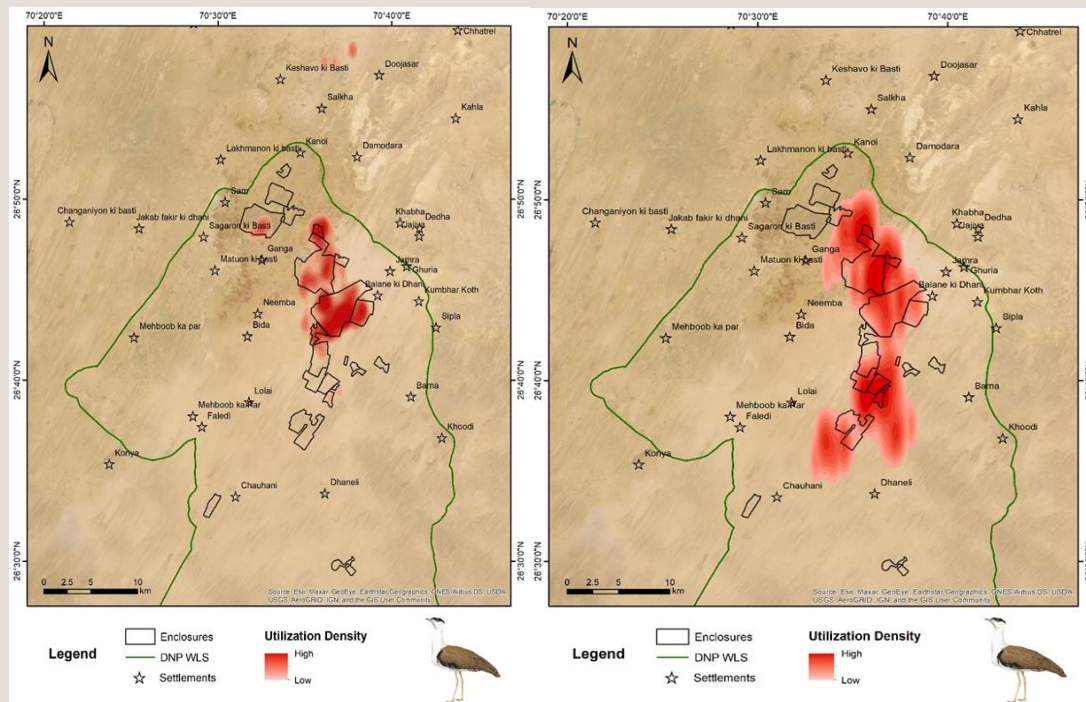


Figure 14. Space utilisation patterns of tagged Great Indian Bustard in breeding season were found to be mostly restricted to protected grassland enclosures (left) than that in the non-breeding season (right)

2.2. Habitat selection and drivers of space use patterns

To understand the selection of land covers by GIB, Ivlev's Electivity Index was computed from the proportion of GPS fixes in various land covers (*use*) vs the proportion of land covers in the MCP area of each individual (availability) (Ivlev 1961). For this purpose, a land use/cover (LULC) map was prepared using Sentinel-2 satellite data with 10m spatial resolution and 95% MCPs were generated using telemetry data of seven birds from 2019-2024. Available grassland and agricultural areas within each MCP were calculated for every tagged female. Ivlev's Index was separately computed for each season since GIB space use varies seasonally.

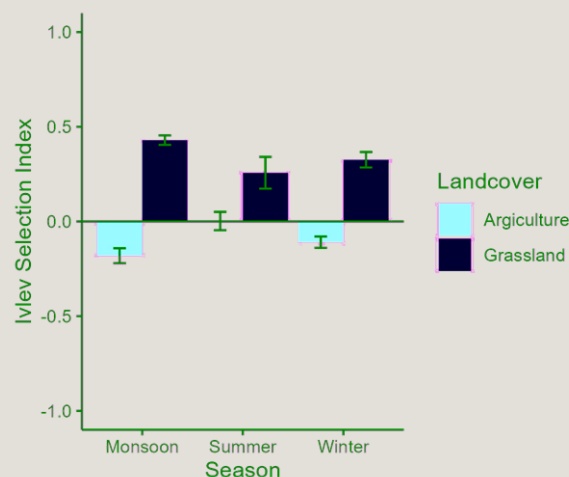


Figure 15. Comparing the Ivlev selection index for GIB in agriculture and grassland land covers

Tagged birds consistently selected grasslands across all seasons, with the highest selection for grasslands during monsoon (Figure 15). They showed a negative selection for agriculture. Ivlev's index offers a basic understanding of GIB land use/cover preferences, but factors like terrain flatness, enclosures, grazing pressure, human disturbances, infrastructure, and resource availability can also impact habitat preference and usage intensity.

To understand which factors influence space-use patterns of GIB, GPS fixes of all tagged females were temporally thinned to one location per hour daily, wherefrom, the pooled number of fixes in 1 km² cells was computed, as an approximate measure of space-use intensity. This metric was log-transformed (continuous response) and binned into use-intensity ranks (discrete response). Habitat variables collected from the field such as the presence of enclosure, land covers, terrain, substrate, and active and passive disturbances at sampling plots (see section 5.1 for methods) were summarised at these 1 km² cells. Thereafter, statistical distributions of these variables against space-use ranks (no - high usage) were explored using box and whisker plots. Additionally, the continuous measure of space-use intensity was modelled against potential habitat covariates using generalised linear models in an Information Theoretic framework, to understand the combination of factors that explain the annual space use of the species. A principal component of the correlated anthropogenic disturbance variables was extracted to explain variance in the data. Habitat variables were examined for correlation and the following potential uncorrelated predictors were selected based on prior ecological knowledge: the presence of enclosure (encl), the proportion of grassland (grsl), the proportion of flat terrain (flat), frequency of power infrastructure, *i.e.*, turbines and/or lines (power), and human disturbance component (pc.dsb) in the cell (Figure 16). Alternative models with combinations of these variables were fitted and the most parsimonious model (based on AICc) was used for inferring factors influencing GIB space use patterns in and around Desert National Park.

Exploratory analysis showed that moderate to high usage of GIB was associated with protected enclosures, flat terrain, absence of power infrastructure, and very low scrubbyness. Although low to moderate usage was associated with partially cultivated areas, high usage of GIB was restricted to areas with >50% grassland cover (Figure 17).

The model with interactive effect of grassland cover and enclosure along with additive effects of power infrastructure and terrain flatness, with or without human disturbance component, found maximum support from data (summed Akaike weight = 1), explaining 46% variance in the data (R²). Model parameter estimates (effect sizes and their significance) showed that GIB usage increased with grassland cover only when they were protected, and was also favoured by flat terrains. Notably, power infrastructure reduced usage drastically, irrespective of habitat availability (Figure 17).

Although these results can be partly influenced by intensive movements of the remaining small numbers of GIB in the most suitable habitats, it underscores the importance of increasing habitat area under protected/restored grasslands that are free from power infrastructure, to support the species' recovery.

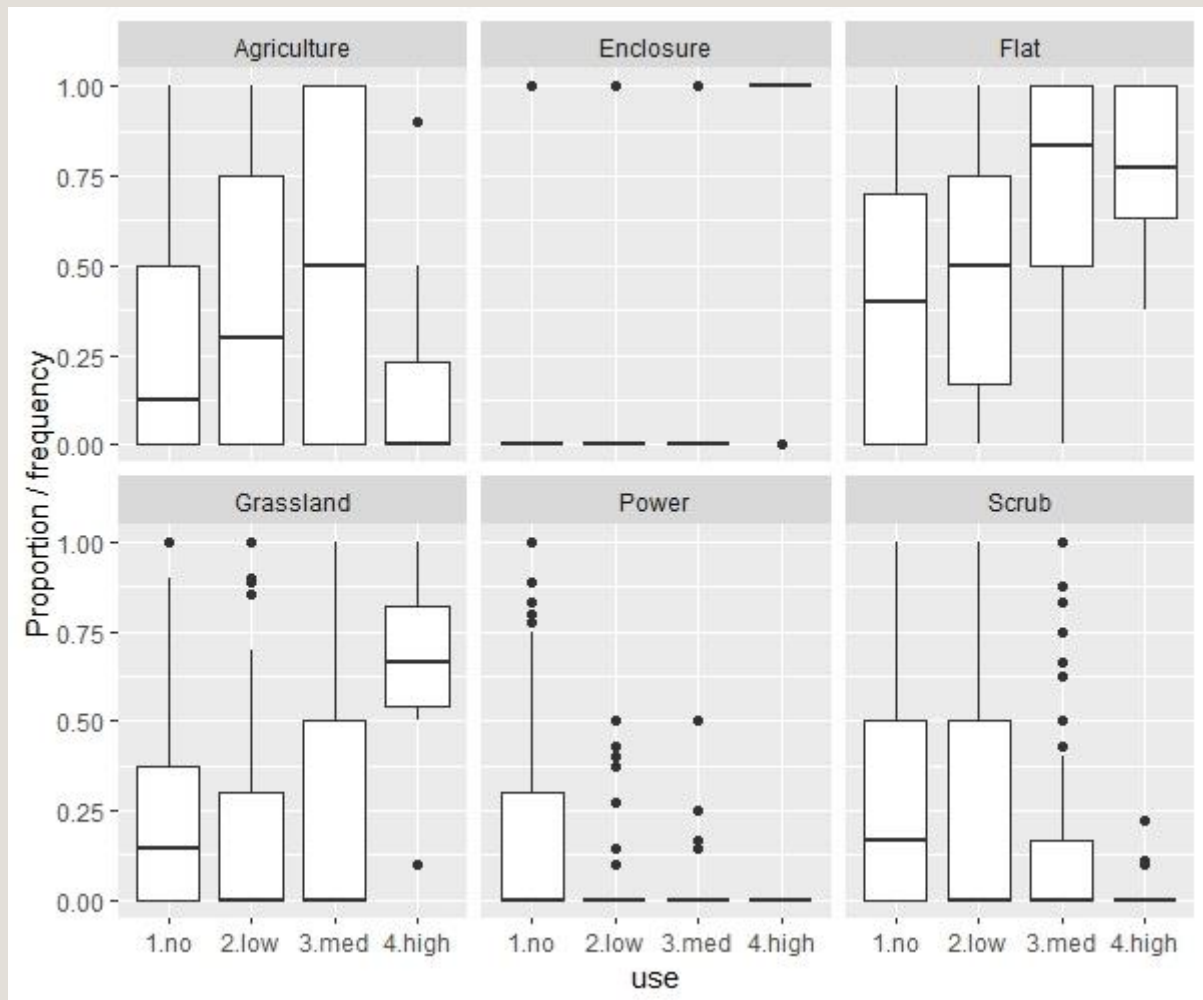


Figure 16. Distributions of frequency (proportion) of agriculture, grassland, scrubland, enclosure, power infrastructure and flat terrain against use-intensity classes of tagged Great Indian Bustards in 1 km² cells of western Thar landscape (2021-24)

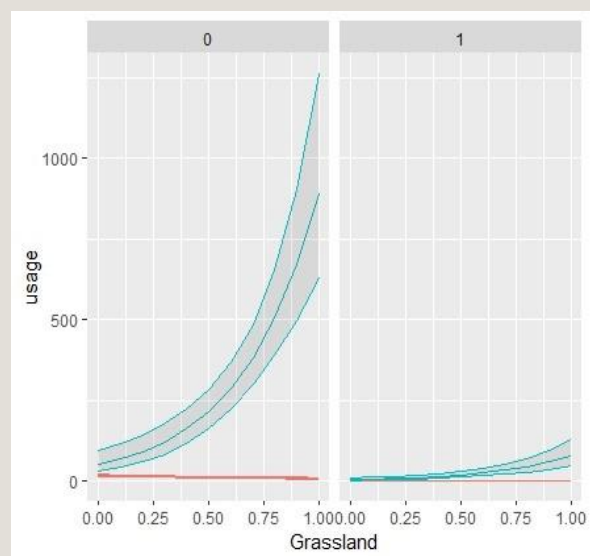


Figure 17. A generalised linear model predicted the use-intensity of tagged GIB against grassland cover in 1 km² cells inside (cyan) and outside (red) enclosures with (right) and without (left) power infrastructure in the western Thar landscape. The shaded area represents 1 SE in generalised prediction.

2.3. Accelerometry

Behavioural monitoring of threatened species, although necessary for ecological understanding and conservation solutions, is challenging for rare and cryptic species such as the GIB, due to low detections and small sample sizes. Remote behaviour recording tools like accelerometers can partly resolve this problem. The accelerometer sensors in e-obs PTTs record the triaxial acceleration of the animal (Figure 18), which, after calibration, can be used to remotely identify target behaviours. A random forest model was trained (accuracy of 92.38%) using 421 time-calibrated video samples from wild and captive birds, to classify accelerometer data into five behavioural classes of interest (Figure 19). This allowed an unbiased and accurate estimation of time activity budgets for five GIB females.

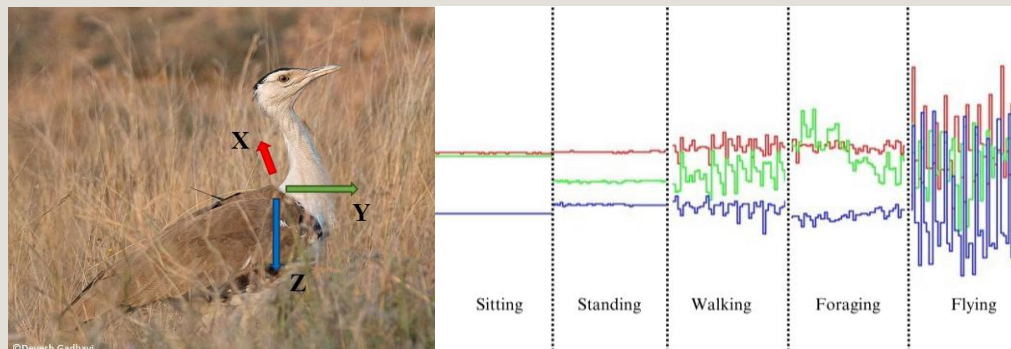
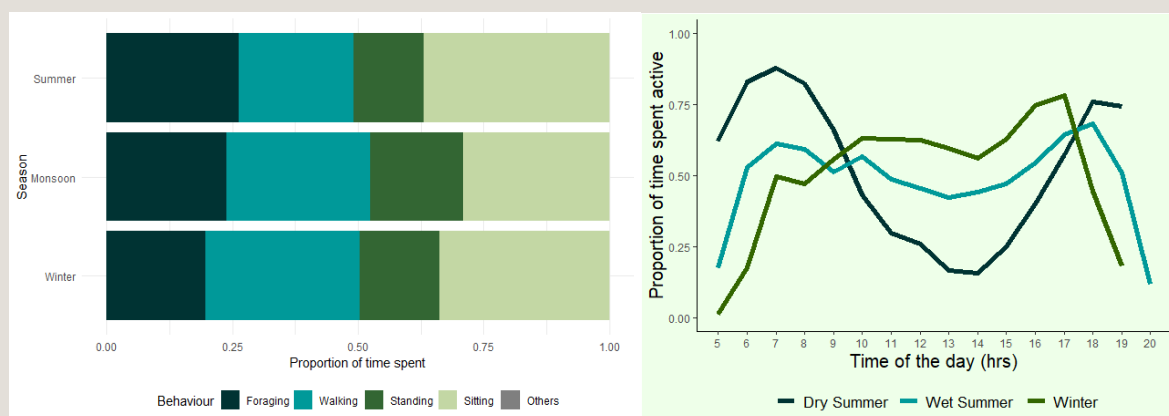


Figure 18. The three-axis along which the accelerometer records acceleration (left) and a visual representation of the accelerometer data (all three axes) and what behaviour that corresponds to.

The results show that, across different seasons, total time allocation between behaviours is similar, but diel activity patterns change, with clear restriction of activity due to heat in summers (Figure 19). Accelerometers also allowed quantification of the frequency of flights, a rarer behaviour for a ground-dwelling bird but of significant importance due to the vulnerability of bustards to power line collisions. It was found that female GIBs take 6.5 flights per day on average and most flights are taken during early morning hours (Figure 19). Accelerometer data for tagged females is collected year-round and with further refinement of the model, it can be used to answer several behavioural questions such as nocturnal activity, and breeding behaviours like incubation and chick rearing.



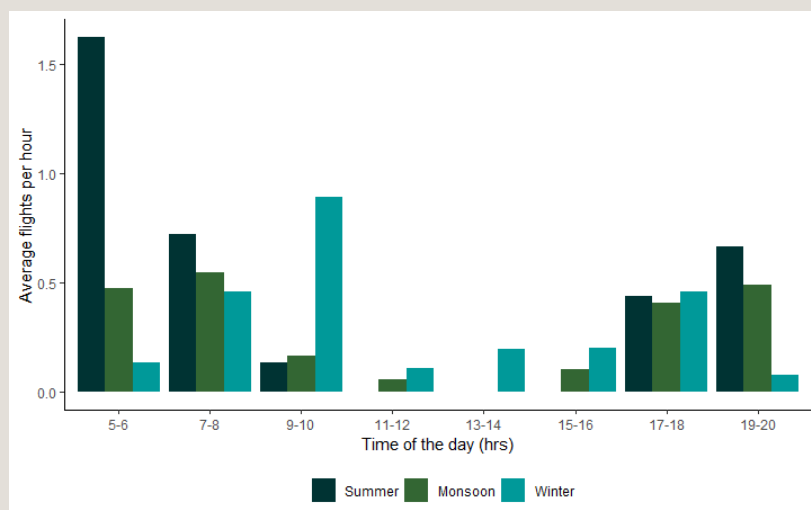


Figure 19. Proportion of time spent by tagged Great Indian Bustard performing a particular behaviour in different seasons (above left), Proportion of time spent active during the day across different seasons (above right) and Average number of flights taken per hour (below)

3. Life history monitoring

The GIB population in Thar is monitored throughout the year to understand their population dynamics, ecology and demographic parameters. The entire landscape is routinely ground surveyed and data on all GIB sightings are collected including information on location, flock size and behaviour. This allows us to closely monitor the GIB population, to understand seasonal patterns of space/habitat use, behaviour and group sizes. Moreover, the population is monitored intensively during the breeding season to estimate annual productivity and includes two main activities, nest monitoring and chick survey. Nest monitoring helps in estimating nest success rates and better understanding the causes of hatching failure in the wild. It also helps in finding eggs to establish the founder conservation breeding stock. Chick surveys, conducted at the end of every breeding season, help in estimating recruitment rates in the wild. Both these activities are critical to monitoring GIB demographics as sensitivity analysis shows that GIB populations are particularly sensitive to adult mortality followed by breeding failure (Dutta et al. 2010).

Nest search has been carried out since 2019 in all known breeding areas in and around DNP, from March to September/October months, using a combination of vantage and vehicular observations. Females found are observed for signs of nesting such as extreme site fidelity, incubating/sitting for long durations, and central place foraging with radiating movements from one spot. Suspected nest sites are monitored from a distance for 2-3 days after which a joint visit of Project and Forest Department staff is undertaken to confirm the nest. For nests that are checked/collected, information such as location, clutch size, fertility, habitat (within 100 m) and insect abundance (within 20m) are collected. Additionally, eggs left in the wild are monitored to determine their fate - hatching failure, predation, or successful hatching. Chick recruitment surveys were conducted from 2021 onwards, between October and December. It covers areas between Salkha to Hatar, the primary breeding ground for the Western Thar GIB (sub)population. Polygons were overlaid on previously recorded breeding and wintering grounds of GIBs and vehicle transects were laid on pre-existing trails in each polygon. Additionally, one or more vantage points at strategic locations were chosen in each polygon to conduct a combination of vehicular and stationary surveys. Information on sightings such as location, flock size, age and sex of chick are recorded. Tagged females also provide the unique opportunity to closely monitor every breeding attempt, from egg laying up to chicks fledging in the next year, giving unbiased estimates for demographic parameters. Nesting events of tagged females can be remotely detected by a characteristic star-like movement pattern radiating from one location in telemetry data (Image 5).

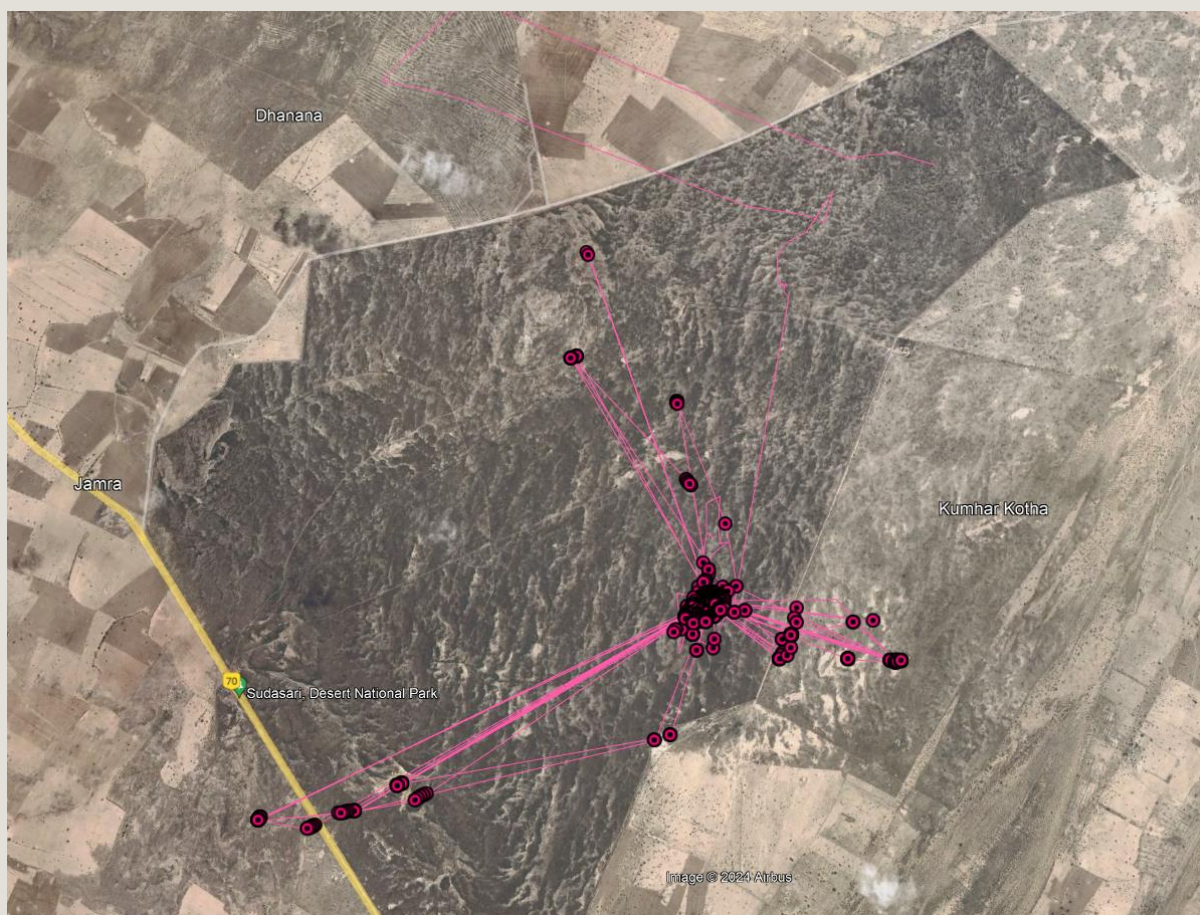


Image 8. Movement pattern of tagged female Great Indian Bustard during nesting

Since 2019, 107 nests and 32 chicks have been detected, of which, the fate of 17 chicks could be monitored (mostly chicks of tagged females). Two main breeding areas have been found in the Western Thar landscape – Sudasari (61% of nests), RKVY and PPC enclosures inside DNP and an unprotected grassland habitat in Salkha. Additionally, birds breed in enclosures around Ramdevra and inside the Pokhran Field Firing Range. The GIB breeding season lasts from March to October with most nests detected in June and July. In years with rainfall >300 mm, the breeding season extends longer, more nests are found, and 10 double clutches have been detected (Image 9), most likely cued by higher resource expectations in the coming months. Females have been found to raise only one chick a year, even when double clutches are laid (Images 9 & 10). Chicks stayed with the mother till she started nesting the next year (for ~9-12 months) and were even seen around incubating females.

Table 8. Summary of key demographic parameter estimates of Great Indian Bustard

Demographic parameter	Estimate (SE)
Hatching rate in the wild	0.36 (0.07)
Number of eggs laid per female	2.87 (0.32)
Chick survivorship up to 3 months	0.61 (0.12)

Demographic monitoring conducted over the last five years (Table 8) provided several key findings of biological and conservation relevance. Firstly, all GIB nests were detected in grasslands, especially protected enclosures that have more grass cover, consequently higher insect abundance, and minimal disturbance. This validates the recommendation of the National Bustard Recovery Plans (Dutta et al. 2013) to establish protected grassland enclosures for improving the species' recruitment. Secondly, egg predation and chick mortality rates (till the first

three months) were found to be 52% and 39%, respectively, in these protected enclosures. Thus, undisturbed grasslands, in the form of protected enclosures, are essential to protect the last few breeding grounds and need to be further safeguarded with active predator management (predator-proof fencing, predator translocations, and “jumpstart” strategy (explained in section 2.1).



Image 9. Double clutch laid by tagged female Great Indian Bustard in 2022, a year with good rainfall



Image 10. Female Great Indian Bustard with male chick of ~3-4 months of age in Desert National Park

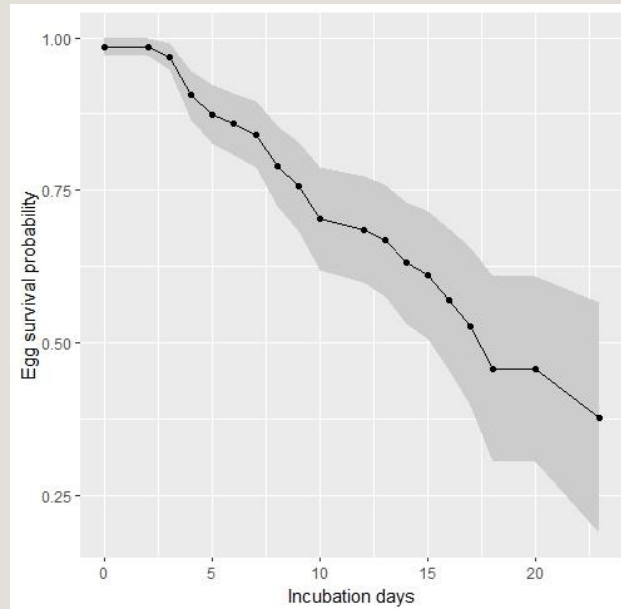


Figure 20. Survival probability of a Great Indian Bustard egg in Thar along incubation time

Thirdly, despite the observed levels of egg and chick mortality, the estimated annual recruitment rate (~0.43 chick/female/year) of GIB was much higher than that of similar bustards (eg, 0.15 chick/female/year in Great Bustard *Otis tarda*, see Morales et al. 2002) (Figure 20). Thus, unlike common belief, slow reproduction *per se* is not the major problem or reason behind the species' decline, as comparable bustard species with even lower recruitment rate do exhibit stable population trends. The relatively higher recruitment rate in GIB is largely contributed by multiple breeding attempts within a season that depends on rainfall quanta (more eggs laid in good rainfall years). The recruitment rate may reduce if the population increases in future, triggering density-dependent factors such as food scarcity. Finally, the high egg re-laying rate of marked females also shows that conservation interventions such as collecting wild eggs for captive breeding had less impact on the wild population than previously anticipated. As our understanding of environmental and intrinsic factors influencing demographic parameters improves, conservation interventions can be further optimised, such as focusing on jumpstart in summer months when hatching failure is particularly high.



Picture Credit: G. S. Bhardwaj

4. Threat assessment

4.1. Power lines – impact and mapping

Globally, power lines are a major conservation problem for many birds, due to electrocution, collision and displacement. Bustards, because of their poor frontal vision, fast flights, and large dimensions, are particularly prone to collisions with lines (Collar et al. 2017, Silva et al. 2022). The rapid expansion of power lines associated with renewable energy infrastructure can pose a threat to such endangered bird species in the Thar landscape that support over 270 bird species, of which, several are threatened. To aid in power line mitigation, WII in collaboration with RFD undertook the following activities.

4.1.1. Impact assessment of power lines on GIB and other birds

4.1.1.1. Carcass and crossing surveys to identify power line-induced bird mortalities

Power line-induced bird mortality was estimated in ~4200 km² area in and around Desert National Park with ~1200 km low-tension (<33 kV) lines and ~500 km high-tension (≥ 33 kV) lines. During 2017, 20 low-tension and 20 high-tension power lines, each 2 km in length, selected randomly, summing to 80 km, were surveyed across multiple seasons. Two observers walked parallelly on either side of the power line and searched for bird carcasses within a 30 m fixed width. Six surveys were conducted between March and December 2017. Carcasses were identified to the species level or their finest discernible taxonomic group. They were also classified into three different size classes - small (<100 g), medium (100 g – 1000 g) and large (>1000 g) (Figure 21). Site-level covariates such as land cover, terrain and substrate were recorded. Power line characteristics including voltage class, the height of the pylon, the number of wires and the range of wire heights of the sampled lines were recorded. To compare bird mortality under power lines to other natural causes, control transects were laid in adjoining habitats without power lines, and surveyed once. Since a majority of carcasses are removed by scavengers (removal bias) or do not get detected in surveys due to vegetation cover (non-detection bias), these potential biases were adjusted for, using standard approaches of monitoring the persistence of freshly deposited carcasses for removal bias and the proportion of available carcasses that were detected in blind surveys for non-detection bias (following Ponce et al, 2010). The carcass encounter rate was then corrected for these biases, to estimate bird mortality rates (Uddin et al. 2021).

A total of 289 carcasses belonging to >40 species were detected. Bird mortality (birds/km/month), adjusted for removal and non-detection biases, was estimated at 3.05 for <33 kV lines and 5.97 for ≥ 33 kV lines. The study estimated that approximately 90,000 bird mortalities occur annually in the 4200 km² area (~20,000 per 1000 km² landscape).

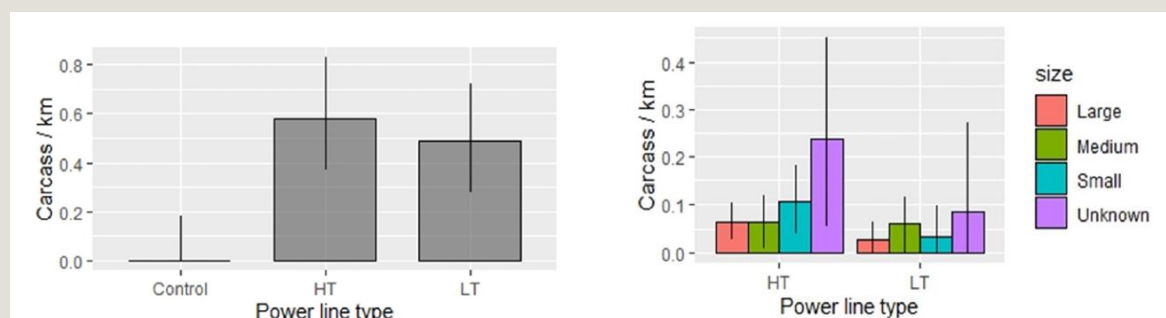


Figure 21. Mean (95% CI) bird carcass encounter rate (km⁻¹) at control transects, ≥ 33 kV (HT) and <33 kV (LT) power lines in baseline survey of January 2017 (left) and mean (95% CI) bird carcass encounter rate (km⁻¹ month⁻¹) against line types based on six monthly carcass surveys (right) in Thar Desert during 2017-18

Bird crossings were observed at five <33 kV and ≥ 33 kV lines once during three seasons (summer, winter and

post-monsoon), to calculate relative vulnerability of different species. Bird movements were recorded by two observers seated in camouflaged hides to avoid disturbances. Bird activity was recorded from sunrise to sunset with a 30-minute break every two hours to prevent fatigue. Data collected included the horizontal distance of sighting as the mid-point between the proximate and distant pylons through which the bird crossed.

A total of 6732 bird crossing observations were recorded, including 14,435 individuals belonging to 64 species and 28 families. Crossings/km/hr were higher at <33 kV (174, 95% CI 116–232) lines than at $\geq$ 33 kV lines (65, 5–125). Crossing rates also differed between seasons with winter months having higher rates than summer. Bias-adjusted crossing rate (individuals/km/month) was greatest for Columbidae (9303 $\pm$ 884 SD) and Alaudidae (7497 $\pm$ 1132 SD) families (Figure 22).

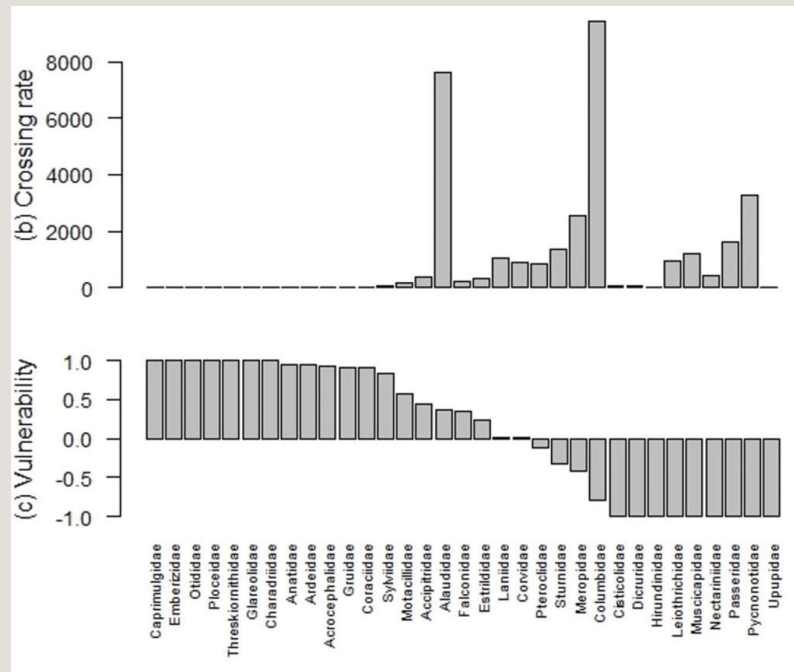


Figure 22. Crossing rate (individuals/km/month) and vulnerability (collision scaled by crossing rates) for various avian taxonomic families in Thar landscape, Rajasthan

4.1.1.2. Carcass surveys in 2023-2024

The first power line impact assessment exercise showed higher mortality under transmission lines than distribution lines and covered ~8% of transmission lines in the western Thar (sub)population. To increase the sampling coverage, for more robust estimates, four surveys were conducted between 2023 and 2024 in the same landscape, wherein, vehicle transects were carried out along the majority of transmission lines (Figure 23) and carcasses were searched within a 30 m width on either side of the power line. Carcasses were identified to the species level or their finest discernible taxonomic group. They were also classified into three different size classes - small (<100 g), medium (100 g – 1000 g) and large (>1000 g). Total survey efforts were 541.1 km spanning four surveys (March 2023, September 2023, January 2024 and June 2024). The carcass encounter rate without bias correction was found to be 0.21 (SE 0.02) in these surveys.

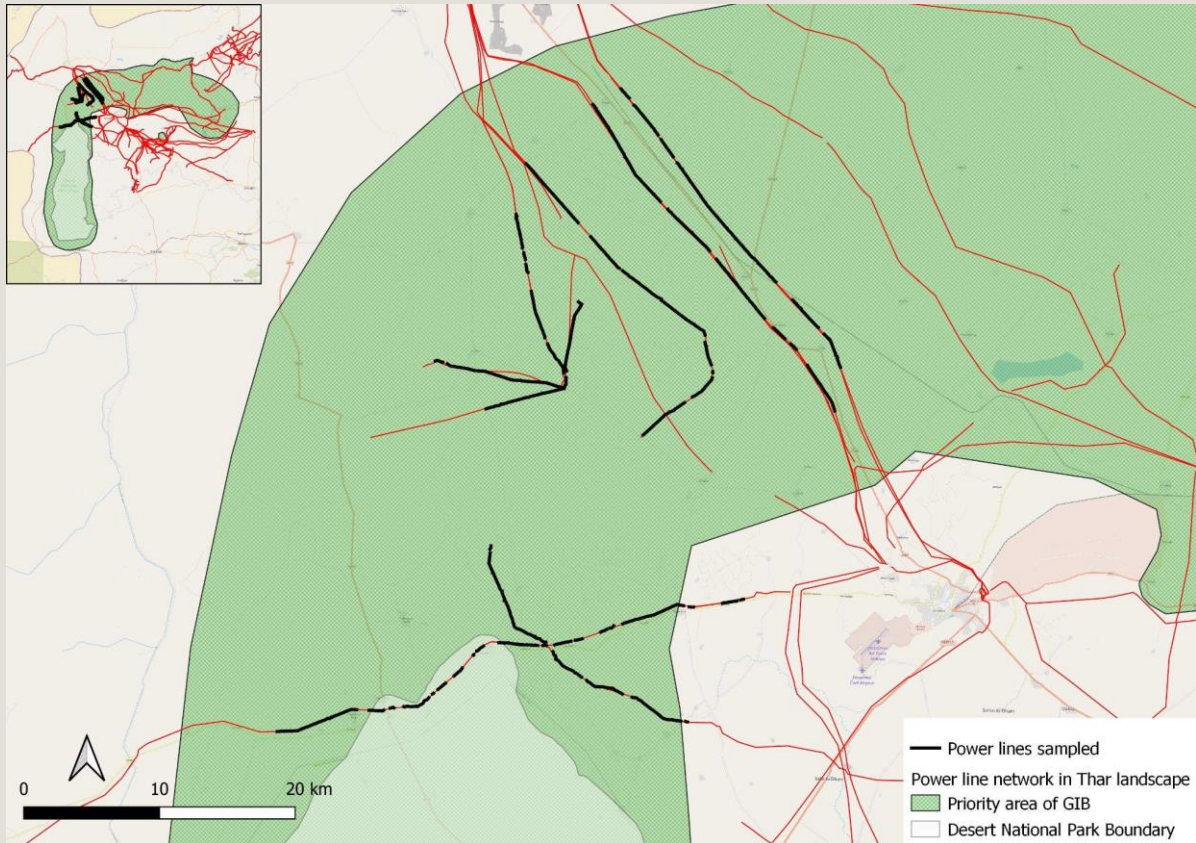


Figure 23. Sampled power lines in the Priority GIB Area in Thar landscape

A total of 115 carcasses were encountered during these surveys, of which, 65 were identified to the species level. The highest encountered species were Egyptian Vulture *Neophron percnopterus* followed by Blue Rock Pigeon *Columba livia*, Eurasian Collared Dove *Streptopelia decaocto* and Steppe Eagle *Aquila nipalensis*. Egyptian vultures accounted for ~22% of the carcasses detected. According to size classes, large-sized birds (>1000 g) accounted for almost 62% of the carcasses detected. Encounter rates of carcasses were estimated for each survey and size class separately. These estimates are yet to be refined using bias correction factors, which account for removal and non-detection biases (as explained above) that may differ from surveys on foot (Uddin et al. 2021). Surveys and analyses are currently ongoing and final results are expected after a year.

4.1.1.3. GIB mortalities under power lines

Between 2014 and 2023, 12 GIB deaths due to power lines have been recorded *ad libitum*; nine of them in Rajasthan, two in Gujarat and one in Maharashtra. Actual deaths are likely as in the absence of extensive surveys, the majority of carcasses go unnoticed across such large landscapes. Power lines accounted for ~60% of all recorded GIB mortalities during this period. According to Population Viability Analysis, a conservative estimate of four deaths annually will cause the GIB metapopulation in the Thar landscape to go extinct within 15-20 years, given its k-selected life-history traits.

4.1.1.4. Power line surveys in Abdasa taluka, Gujarat

Similar to Jaisalmer, carcass surveys were conducted in Kachchh in 2019 to assess the impact of power lines on birds, following the same methodology used by Uddin et al. (2021).

A total of 310 km were surveyed and 169 bird mortalities were encountered between April and May 2019. The mortality rate was estimated at 2.34 birds/km/month. Extrapolated to the existing power line network of the study area (1123 km²), the annual mortality rate was estimated to be 22,000 birds, although this estimate does

not account for expected seasonal variation in bird mortality. The survey was conducted during drought and for a short duration, providing only a snapshot of mortalities in the region. Therefore, more robust estimates need to be obtained in this region spanning multiple seasons/years.

Bird crossing rate was estimated by monitoring bird movement and activity near four randomly selected high-tension and low-tension power lines. Field methods were similar to those used in the Thar landscape, described in section 4.1.1.1. On sighting a bird near the power line, the following variables were recorded - the position of the bird to the wire (above, below, through the line), the vertical distance of the bird from the wire (<1, 1-5, 5-10, 10-20 m and >20m), the horizontal distance of the bird from the observer (measured as the distance class between the proximate and distant pole/pylons through which the bird has crossed), number of wires in the power line, the height of lower and upper wire, and the usage of power line by the bird (perching, crossing, chasing and soaring).

During the study, 3140 individuals of 48 species belonging to 31 families were recorded near power lines. The most abundant species recorded were Indian Robin (20.86%), followed by Eurasian Collared Dove (13.95%), Lark (10.83%), Laughing Dove (9.84%) and Red-vented Bulbul (9.27%) with an average hourly crossing rate of 6.82, 4.56, 3.54, 3.22 and 3.03, respectively. Crossing rate of birds was 6.27 ± 2.3 SE crossings/hr for smaller birds (<100 g) and 4.23 ± 1.11 SE crossings/hr for larger birds (>100 g) (Figure 24). The crossing rate was significantly lower for high-tension power lines (0.45 ± 0.17 SE crossings/hr) than for low-tension power lines (1.60 ± 0.58 SE crossings/hr). The number of birds passing through the wires (1314 individuals) was relatively more than the number of birds crossing above (646 individuals) or below (1174 individuals) the power line.

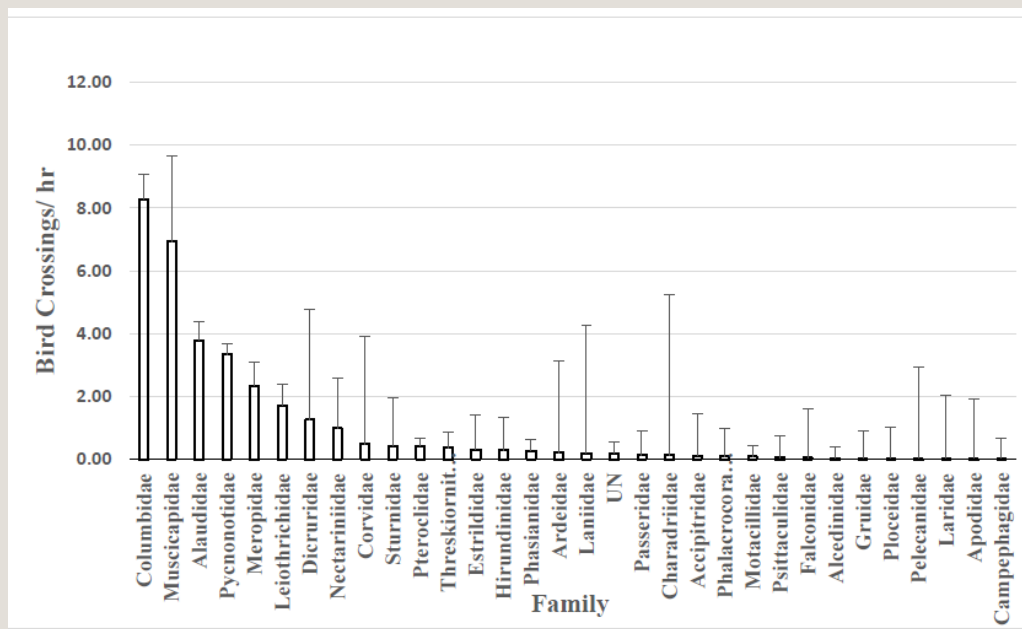


Figure 24. Mean and standard error of crossing rate across various taxonomic families in Kachchh landscape in April 2019

Despite a lower crossing rate at high-tension power lines, their carcass encounter rate was similar to that of low-tension power lines, indicating that more birds die per crossing at high-tension lines.

Given this demonstrated impact of power lines on birds, especially GIB, and subsequent discussions between MoEFCC, RFD, WII, power agencies and regulatory authorities (see section 9), WII was mandated to prioritise areas for mitigating this threat. With this objective, the following activities were undertaken.

4.1.2. Comprehensive mapping of GIB habitats

GIB occurrence and habitat suitability analysis based on long-term surveys and telemetry in Jaisalmer (Rajasthan) and Kachchh (Gujarat) have aided in delineation of priority and potential GIB areas. The priority area and potential area in Rajasthan span $\sim 13,100 \text{ km}^2$ and $\sim 78,500 \text{ km}^2$, respectively, while in Gujarat the priority and potential area span $\sim 500 \text{ km}^2$ and $\sim 2100 \text{ km}^2$, respectively. The priority areas are intensively used by GIB whereas the potential areas have recent historical occurrence and suitable habitats, where the species can be repopulated in future. It was recommended that all power lines in priority areas be undergrounded or rerouted, whereas, power lines in the surrounding potential area may be mitigated using the best mitigation measure on a case-to-case basis, with a general aim of making lines more conspicuous to approaching birds. As many new energy projects are being set up in GIB habitats, the priority area serves as a minimum zone where future projects can be avoided to safeguard the last remaining critical bustard habitats, as vast areas for renewable energy development exist outside these important habitats in Rajasthan and Gujarat. This information was disseminated to MoEFCC, RFD and power agencies from time to time.

4.1.2.1. Validation of priority area using habitat suitability analysis

By combining observational records (post-2000) and locations from the tagged GIBs (2019 - 2021) with eco-geographical covariates, a habitat-suitability surface was generated for the Thar landscape. The GIB, being dependent on large grassland habitat patches, necessitated a detailed spatial analysis using a maximum entropy-based predictive approach (Philips et al., 2006). This method incorporated predictor parameters, such as the proportion of grassland cover, the principal component axis indicating seasonal agricultural cover, distance from large human settlements, and terrain undulations. The areas identified as suitable for GIB were part of the delineated Priority Area. The habitat suitability model was trained and tested on a proportional partition of the total records, ensuring robust and reliable predictions. The model's precision in identifying highly suitable areas for the GIB, especially within the priority GIB area, highlights its potential as a GIB conservation support (Figure 25; Table 9).

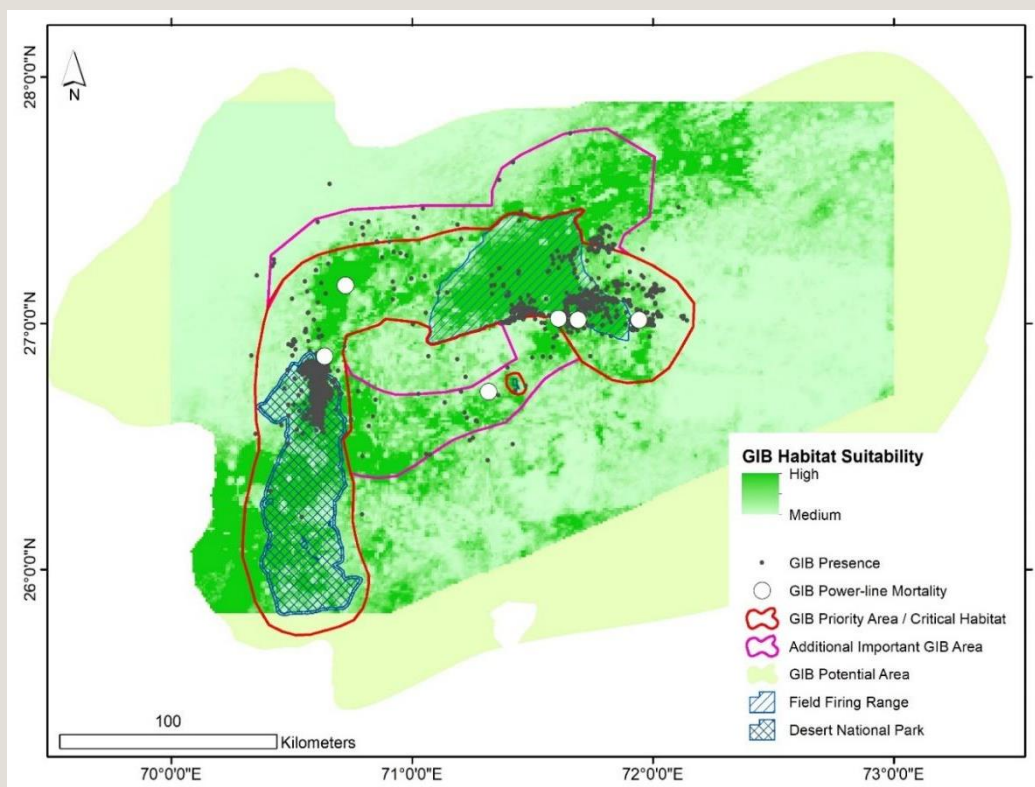


Figure 25. Habitat suitability surface for Great Indian Bustard overlaid with presence records and identified conservation areas in Thar landscape, Rajasthan

Table 9. Great Indian Bustard areas in Rajasthan and Gujarat (as per Hon'ble SC Order)

Area (km ²)	Priority	Potential (including Prioritised)
Rajasthan	13,163 km ² (DNP 3,162 km ² + PFFR 2,807 km ² + non-protected area 7,194 km ²)	78,580 km ²
Gujarat	500 km ²	2,100 km ²
Total	13,663 km ²	80,680 km ²

4.1.3. Mapping of power lines, and wind turbines and priority segments

The task of digitising low and high-tension power lines, wind and solar power projects, roads and settlements was outsourced to M/S. Science Pvt. Ltd and maps were generated. The Project team ground truthed some of the digitised power lines and wind turbines for validation. Power lines and wind turbines with their owner companies, were identified and mapped. Power lines in areas intensively used by GIB or between important habitats were identified as critical segments for mitigation and concerned authorities were sensitised on mitigating this threat.

4.2. Wind turbines

Wind turbines can negatively affect bird populations through collision-induced mortality as birds may collide with turbine blades or be caught in wind vortices. The Thar Desert is a prime hotspot for wind energy development due to its suitable wind conditions, available land, and substantial wind power potential (5050 MW). Consequently, wind energy projects in this region have significantly expanded from 16 MW in 2002 to 2820 MW in 2014.

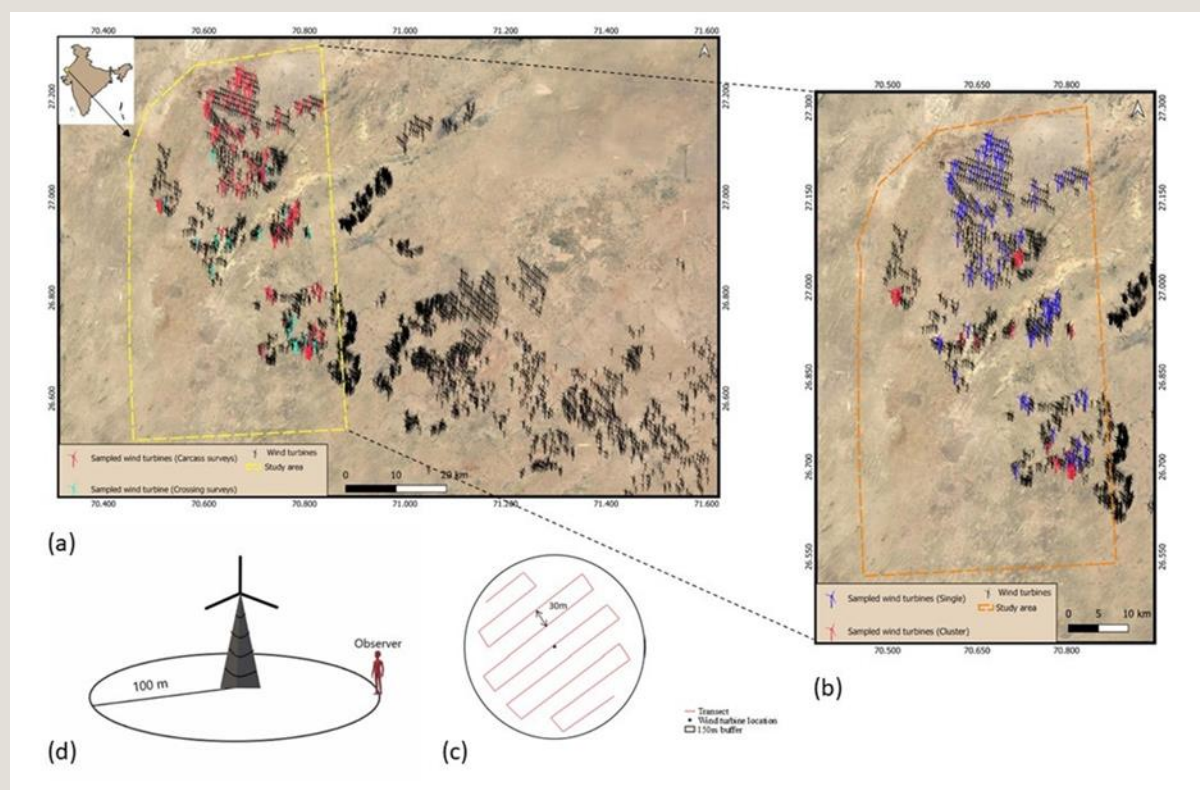


Figure 26. Map of Thar desert showing (a) study area (yellow polygon), (b) population of wind turbines (black), sampled single turbines (blue) and clustered turbines (red), (c) diagrammatic representation of bird carcass survey around sampled turbines, and (d) diagrammatic representation of crossing survey in 2020-21

Among ~900 wind turbines, 90 were randomly sampled to estimate turbine caused bird mortality (Figure 26). Additionally, 16 turbines were surveyed to assess bird usage of turbine areas by estimating bird crossing rates. Vulnerability index was calculated for bird families affected by wind turbines. Collision-to-crossing rates *vis-à-vis* flight patterns of bird families were studied to identify relatively vulnerable taxa.

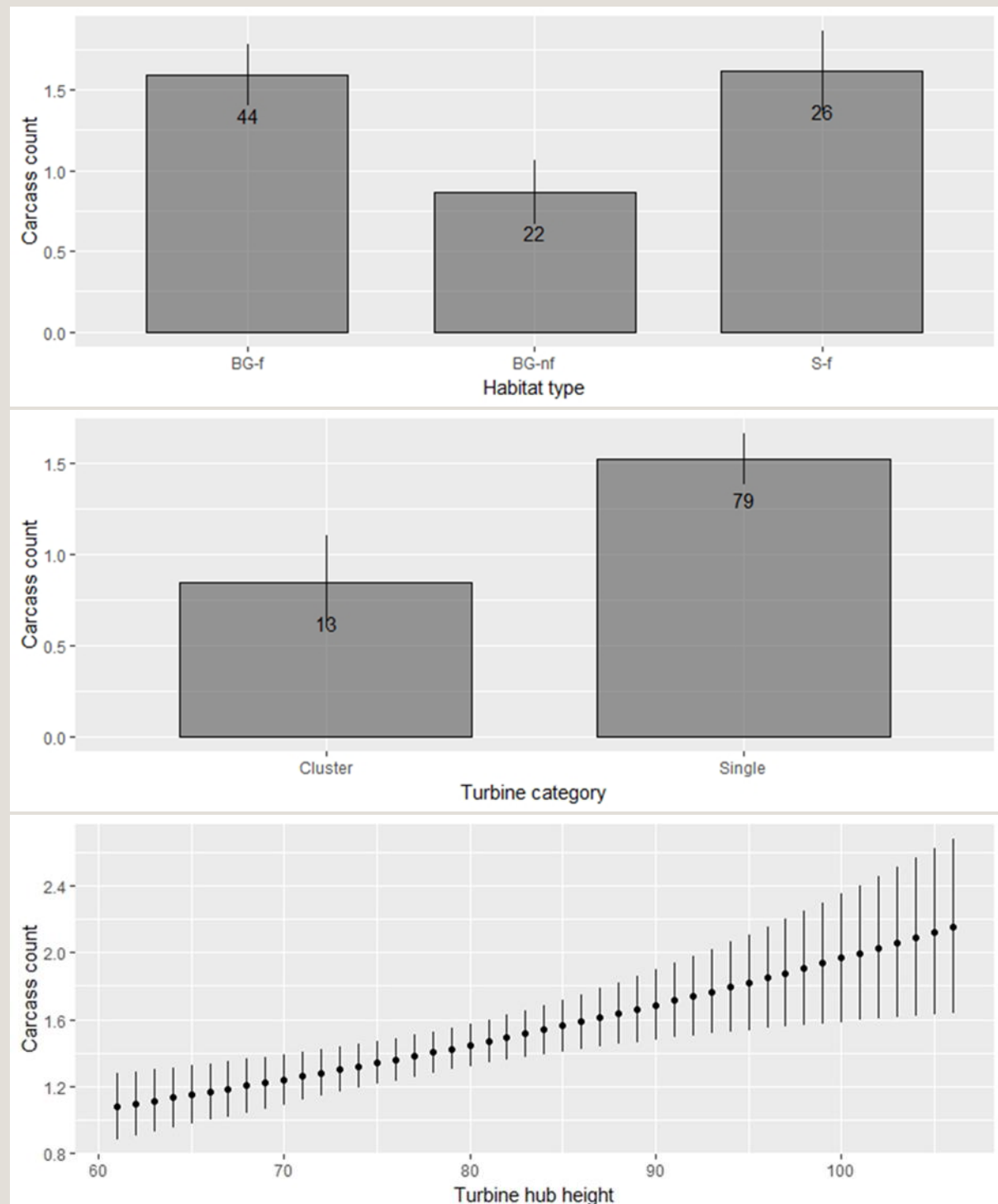


Figure 27. Comparison of model estimated mean (SE) carcass turbine⁻¹ survey⁻¹ against habitats (BG-f: Flat grassland; BG-nf: undulating grassland; S-f: flat scrubland), single vs. clustered turbines and turbine hub height (m) [top to bottom] in Thar desert during 2020–2021

During 630 turbine searches (90 turbines searched seven times), a total of 124 bird carcasses were observed. Among these, 93 carcasses were identified belonging to 19 species across nine families, while 13 carcasses were unidentified raptors, and 18 remained unidentified. Removal and non-detection bias correction factors were estimated similar to the power line surveys. The bias-adjusted mortality rate was estimated to be 1.24 (± 0.18 SE) birds per turbine per month. This yielded an annual mortality estimate of 13,359 (95% CI 11,426 - 15,293) birds and 953 (95% CI 801 - 1,104) raptors for the entire study area with 900 wind turbines.

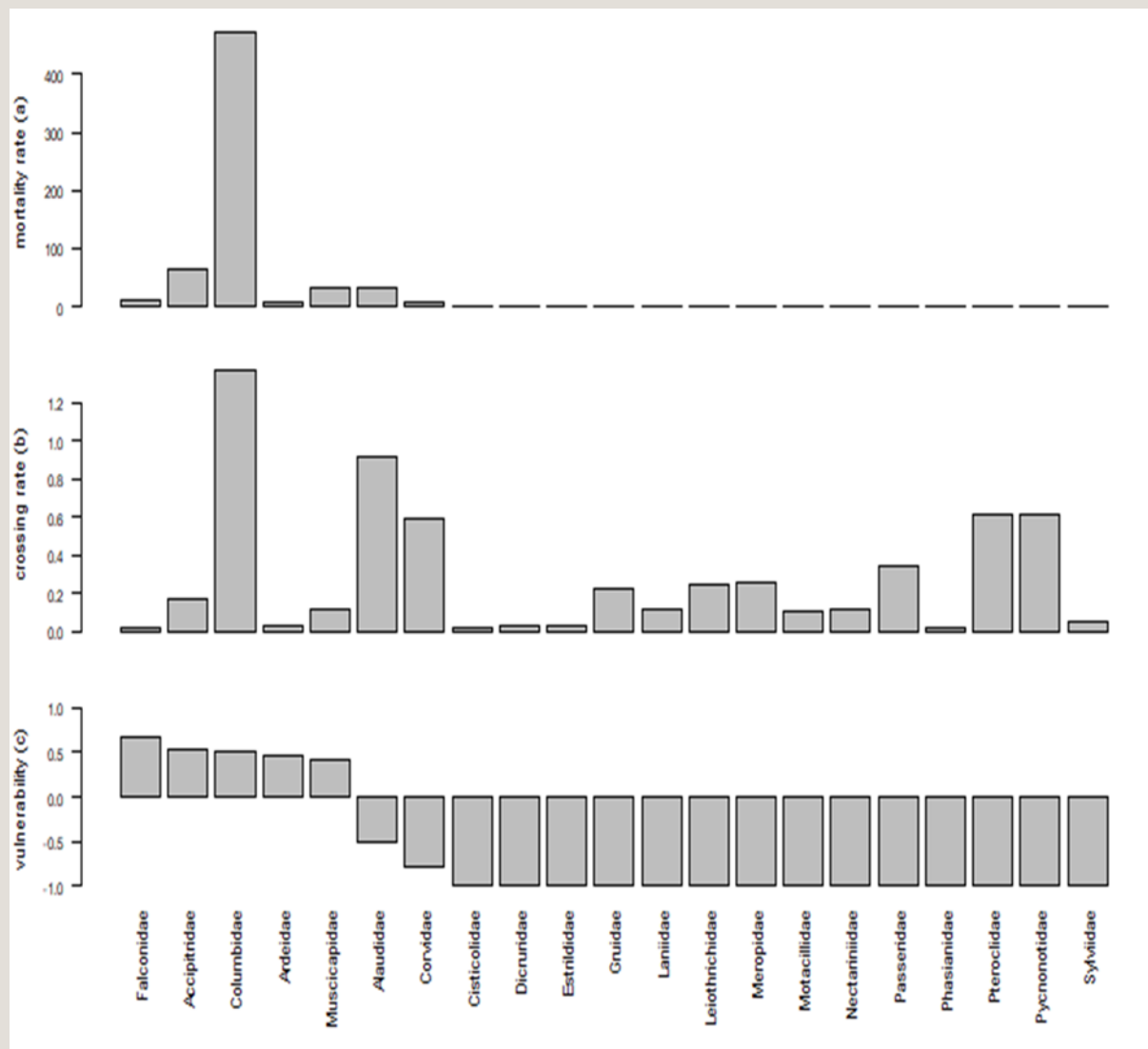


Figure 28. Vulnerability index of bird families (c) computed as the ratio of proportional bias-adjusted mortality (a) and proportional crossings (b) of bird families in Thar desert during 2020–21

Collision rates of birds with wind turbines varied between habitats (Figure 27). Single turbines had higher collision rates compared to clustered turbines, and there was a weak positive correlation between collision rates and hub height (Figure 27). Vulnerability to collisions was highest among families Falconidae, followed by Accipitridae, Columbidae, Ardeidae, and others (Figure 28).

4.3. Impact of free-ranging dogs – ranging patterns, interactions and predation on wildlife

Research shows that rural free-ranging dogs typically stay near settlements but sometimes foray into wild areas, causing negative impacts on wildlife such as mortality, disease transmission, competition, hybridisation, and fear-mediated behavioural changes (Vanak and Gompper, 2010). This study aimed to understand the spatial

ecology, interactions with native fauna, and impact of free-ranging dogs in and around Desert National Park. To understand the ranging patterns of dogs, information was gathered from nine radio-tracked dogs (5 males and 4 females). Additionally, six radio-tracked dogs (4 males and 2 females) were monitored continuously for ~3 days to capture starve-feed cycles, with activity states and interactions of the dogs recorded using a continuous focal observation protocol. The collared dogs were observed for 1815 hours over 35 sessions in 2017, averaging 302.55 (57.09 SE) hours per dog, with sessions lasting ~51.86 (8.34 SE) hours. Additionally, dog space use patterns with respect to covariates such as proximity to settlements and protected grassland enclosures were examined using generalised linear models. Probabilities of negative interactions with species groups (competitors, wild prey, domestic prey) were estimated using intercept-only logistic models.

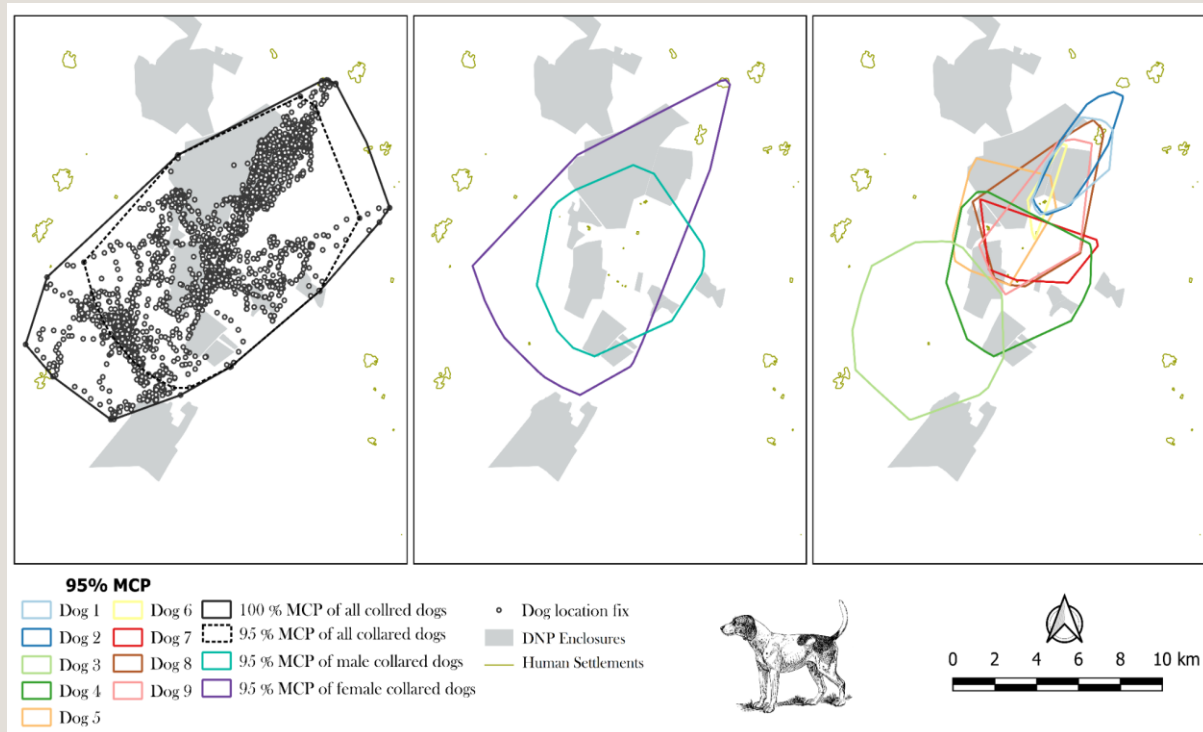


Figure 29. Combined ranging pattern of tagged free-ranging dogs in DNP along with GPS fixes (left), 95% MCPs for male and female tagged free-ranging dogs (middle), 95% of individual tagged free-ranging dogs (right)

The average home range size (95% MCP, $n=9$) was 20.89 ± 1.84 (SE) km^2 , similar between females (21.46 ± 4.13 SE km^2) and males (20.44 ± 3.36 SE km^2). The average 95% and 50% adaptive kernel home range isopleths were 2.84 ± 0.36 (SE) km^2 and 0.16 ± 0.01 (SE) km^2 , respectively (Figure 29). Dog home ranges were clustered around human settlements, with use declining along the distance from settlements and enclosures. Dog space usage was most intensive within 2 km of settlements and enclosures (Figure 30).

A total of 380 neutral and negative interactions were observed. Close proximity between dogs and other animal species escalated into negative interactions in 0.74 (0.09 SE) proportion of events for wild prey, 0.54 (0.07 SE) for competitors, and 0.04 (0.01 SE) for domestic prey (Figure 30). Negative interactions were highest with raptors, wild pigs, and desert foxes - the direct competitors for food (Figure 31).

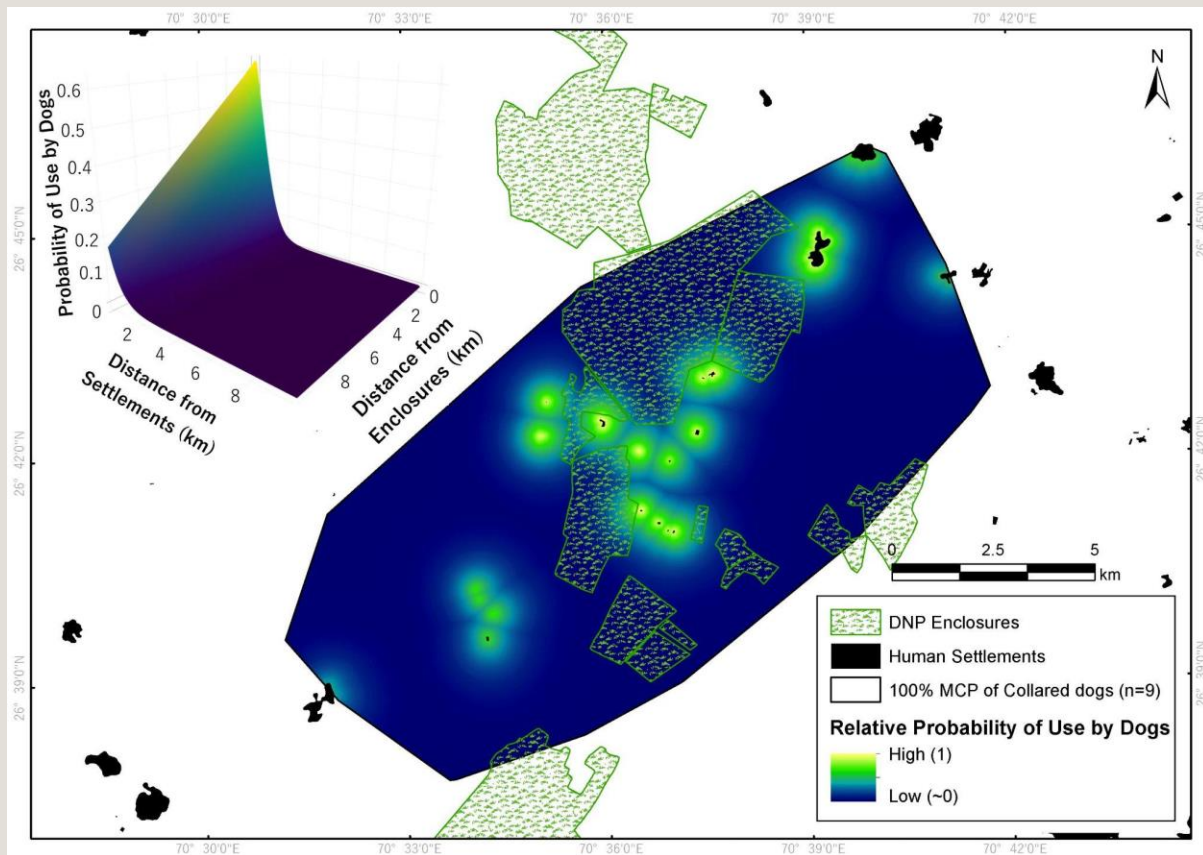


Figure 30. Relative probability of space use by free-ranging dogs in Desert National Park and its association with distance from settlement and protected enclosures

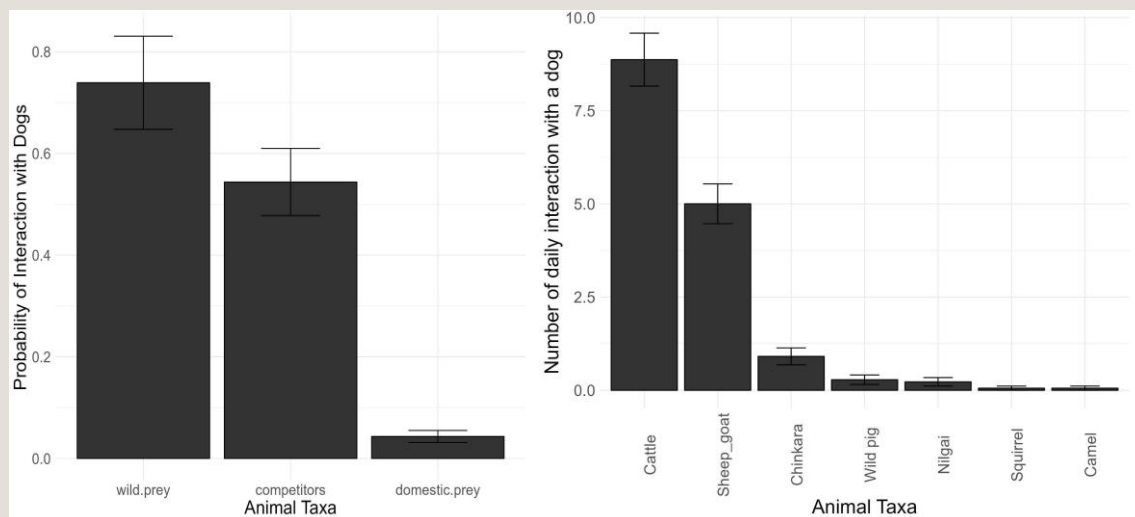


Figure 31. Probability of negative interactions with recipient species group by free-ranging dogs (left) and estimated rate of negative interactions with recipient species group by free-ranging dogs (right)

Among wild prey, Chinkara had the highest negative interaction rate, followed by Wildpig, Nilgai and Great Indian Bustard (0.11 ± 0.1 SE/day/dog; $0 - 0.27$ int./day/dog at 95% CI) (Figure 31). Domestic prey interactions were also very common but mostly neutral. The direct impact of free-ranging dogs on wild animal species was estimated to be around 29.18 ± 11.91 predation attempts per year, although based on a small sample size of 14 unique hunting events. A free-ranging dog in a wildlife habitat might be predating as many as 10 Chinkara per year, as per our preliminary findings, which may have a strong implication on the demographic viability of this sensitive and conservation-dependent species.



Image 11. Dog eating a Nilgai calf in Ramdevra ABC enclosure

4.4. Nest predators

Alongside GIB, the Desert National Park is home to iconic xeric species, such as Desert fox, Desert cat *Felis silvestris ornata*, Chinkara, Spiny-tailed lizard, Houbara, and Cream-coloured courser *Cursorius cursor*. In the recent past, animals such as the Indian Fox, Nilgai, Wild Pigs and free ranging dogs have expanded in this landscape due to changing land use patterns and availability of surface water. The presence of the latter animal species inside fenced grassland enclosures can be detrimental to the conservation of native fauna since many of them predate on eggs and chicks of GIB and associated ground-dwelling birds. This necessitates understanding the population status of predators inside and adjoining enclosures that serve as vital breeding grounds for GIB, as found in section 3. Hence, a camera trap density estimation study was conducted inside nine enclosures of DNP, namely, Sudasari, RKVY, Kanoi, Gajaimata, Chauhani TFC, PPC, Ramdevra, Rasla and Myajlar. Areas outside three enclosures, viz., Rasla, Myajlar and Sudasari, were included to compare with predator populations inside enclosures.

Densities of predators were estimated using Camera Trap Distance Sampling (CTDS) that cuts the sampling period into equally spaced snapshots or 'efforts', computes the species' encounter rate (from number of snapshots where it was detected in the viewframe), and models its detection probability at different distances from the camera, to estimate detection-corrected density (Howe et al. 2017). For this exercise, the target enclosures were gridded into 500 × 500 m cells. Outside areas were also gridded, leaving a buffer of one kilometre from enclosures (Figure 32). Camera traps (Reconyx HC500 Hyperfire Semi-covert Passive Infrared Camera-traps) were systematically deployed within a 50 m radius from the centre of each cell within enclosures. An equal number of cameras were also placed outside the enclosures in three places (Rasla, Myajlar and Sudasari) by selecting grids in a staggered manner ensuring that the entire area around the enclosure is covered (Figure 32).

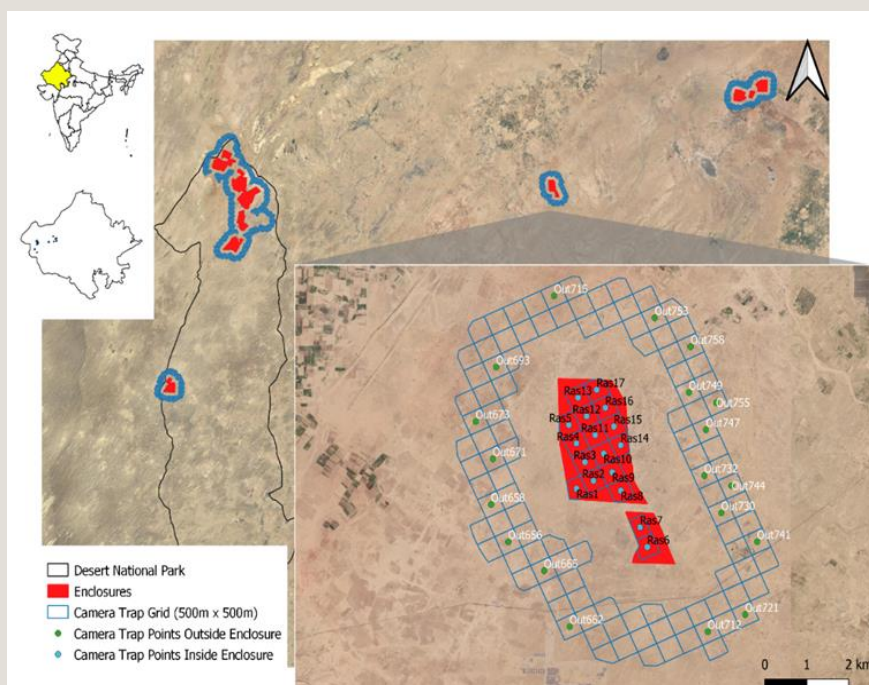
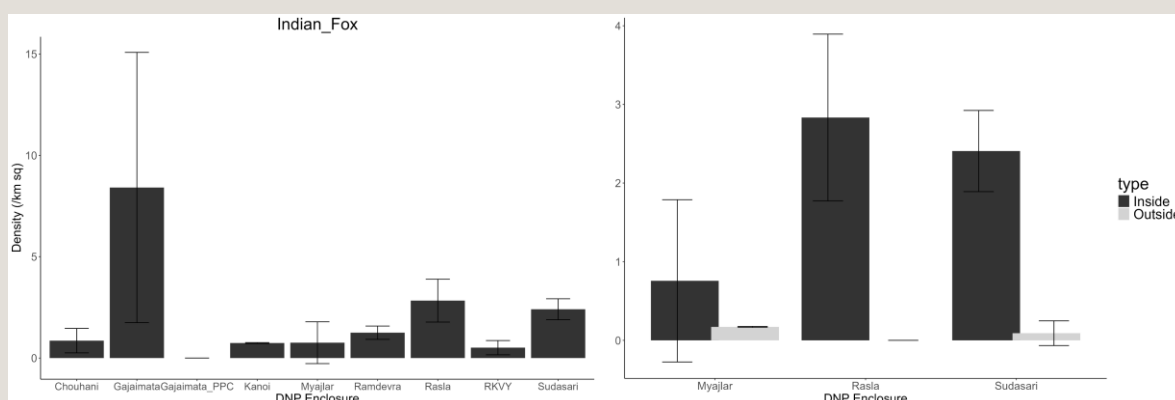


Figure 32. Map showing grids with deployed camera traps for density estimation of nest predators in DNP

Cameras were positioned inside specially designed mounts at 18–23 cm above the ground. Animal detection distance from camera traps was determined using a calibration exercise, wherein a pole of 100 cm height was positioned at intervals of 2, 4, 8..., 20 metres along three radial directions within the camera field of view, and photogrammetry principles were applied. As an alternative approach, which is easy and faster, sticks of various heights and marks were placed at predefined distances from camera traps (2, 4, 8, 12, and 20 m), for direct labelling of distance classes corresponding to animal photo-captures. Camera traps were placed in the field for 30–40 days, with periodic monitoring to assess the cameras' condition and make necessary adjustments. The first exercise was conducted in 2016–2018, during which a total of 307 unique camera trap locations were sampled (Figure 32). Each image obtained was tagged with the name of the species, number of individuals, and distance class using the software ExifPro. A proprietary software 'Animeter' was used to determine the distance class in images where distance classes were not demarcated using sticks. The target species for the study were nest predators such as foxes, desert cat, free-ranging dogs and pigs.

Densities of these animals (per km²) inside enclosures (Chauhani, Gajaimata, Kanoi, Myajlar, Ramdevra, Rasla, RKVY, and Sudasari) and outside three enclosures (Sudasari, Myajlar and Rasla) are shown in Figure 32. Enclosures served as prime habitats and refuges for Indian foxes, a mesic grassland specialist, which occurred at much lower density outside enclosures. Whereas, the densities of the native Desert fox and Desert cat were nearly similar within and outside enclosures (Figure 33).



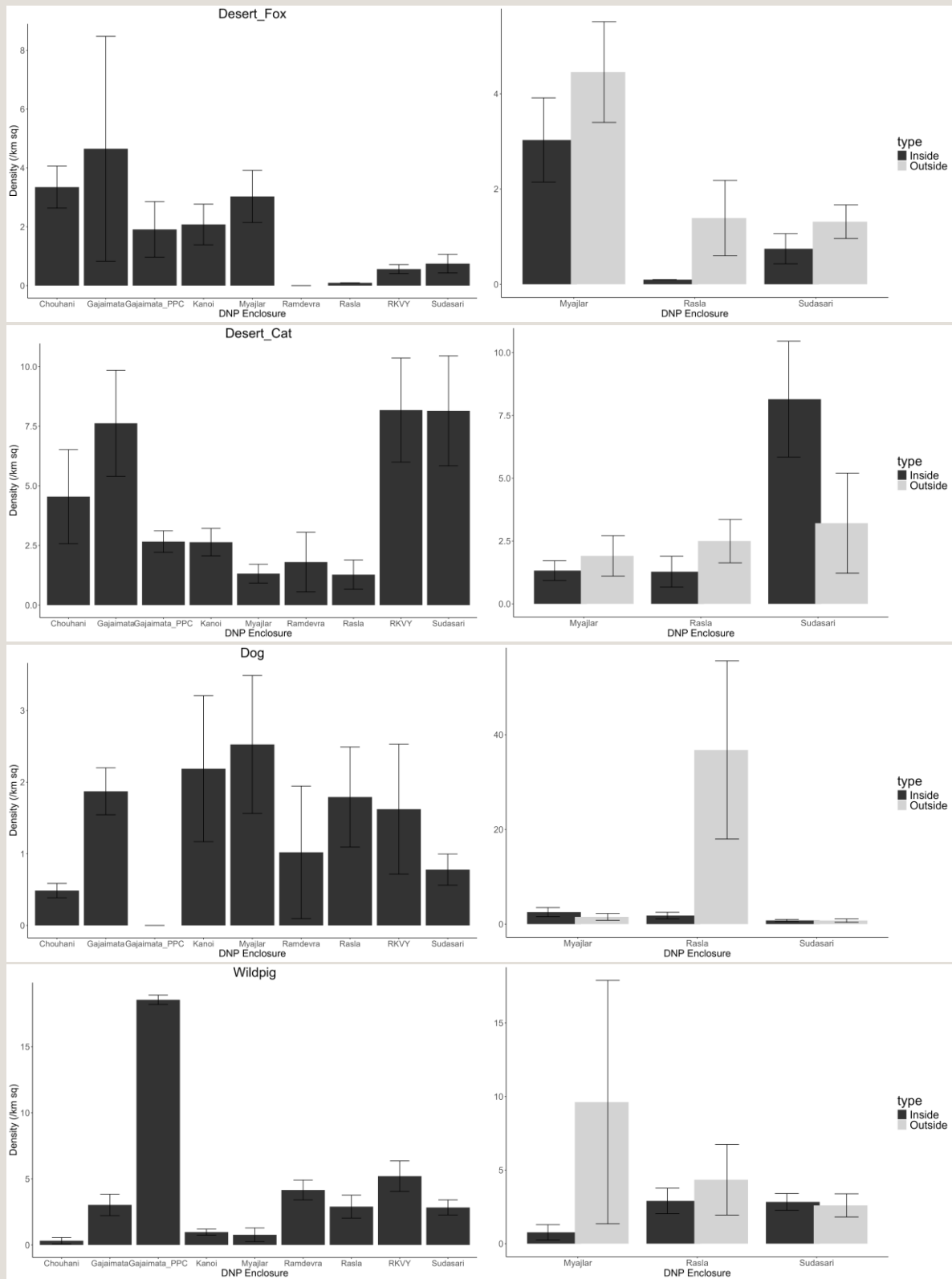


Figure 33. Density estimates of nest predators inside protected enclosures (left) and comparison of densities of nest predators inside and outside protected enclosures of DNP (right) (A - Indian fox, B - Desert fox, C - Desert cat, D - Free-ranging dog, and E - Wild pig)

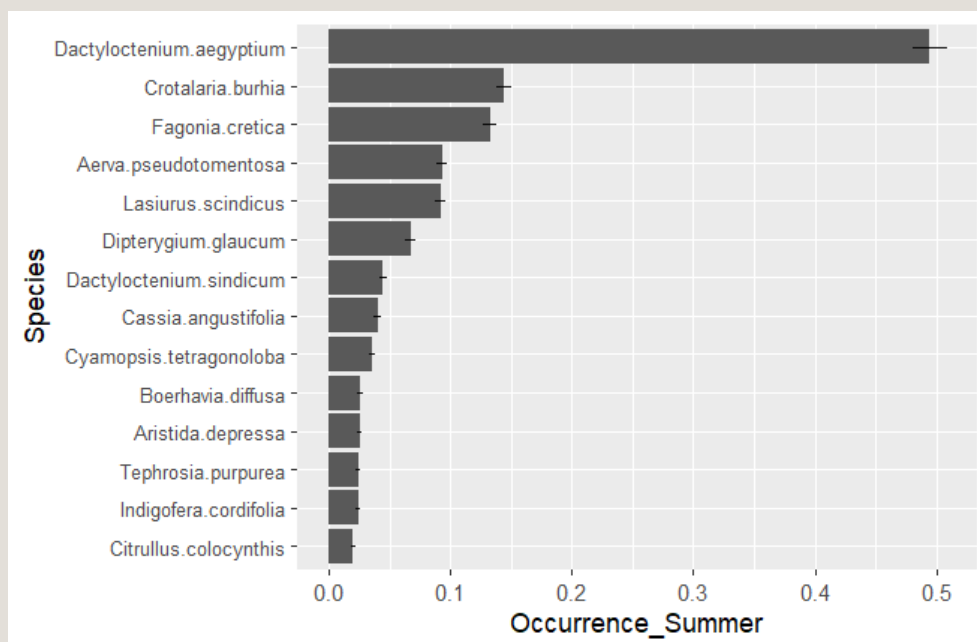
5. Habitat and food assessment

5.1. Vegetation

To understand the seasonal habitat use of GIB with respect to ground vegetation, disturbance and resource availability, habitat assessment was carried out in a 520 km² area, in and around northern part of Desert National Park, that encompassed 95% Minimum Convex Polygon of five tagged birds over three years (2019-2021). This area was divided into 520 cells of 1 km² area each and 311 cells were sampled for vegetation structure and composition, insect abundance, anthropogenic disturbances, grazing pressure and other food resources. In each cell, two 0.25 km² sub-cells were randomly selected for sampling during each season (summer: mid-March to mid-June, monsoon: mid-July to mid-October and winter: mid-November to mid-February).

Ground vegetation composition of the study area is dynamic across seasons (Figure 34). The dominant plants are:

1. *Dactyloctenium aegyptium* > *Crotalaria burhia* > *Fagonia cretica* (>10% frequency occurrence) in summer (Figure 34a),
2. *Dactyloctenium aegyptium* > *Cyamopsis tetragonoloba* > *Indigofera cordifolia* > *Dactyloctenium indicum* > *Cenchrus biflorus* > *Aristida depressa* > *Fagonia cretica* > *Aerva pseudotomentosa* (>10% frequency occurrence) in monsoon (Figure 34b),
3. *Dactyloctenium aegyptium* > *Indigofera cordifolia* > *Crotalaria burhia* > *Fagonia cretica* > *Cenchrus biflorus* > *Aristida depressa* > *Dactyloctenium indicum* > *Aerva pseudotomentosa* > *Lasiurus scindicus* (> 10% frequency occurrence) in winter (Figure 34c).



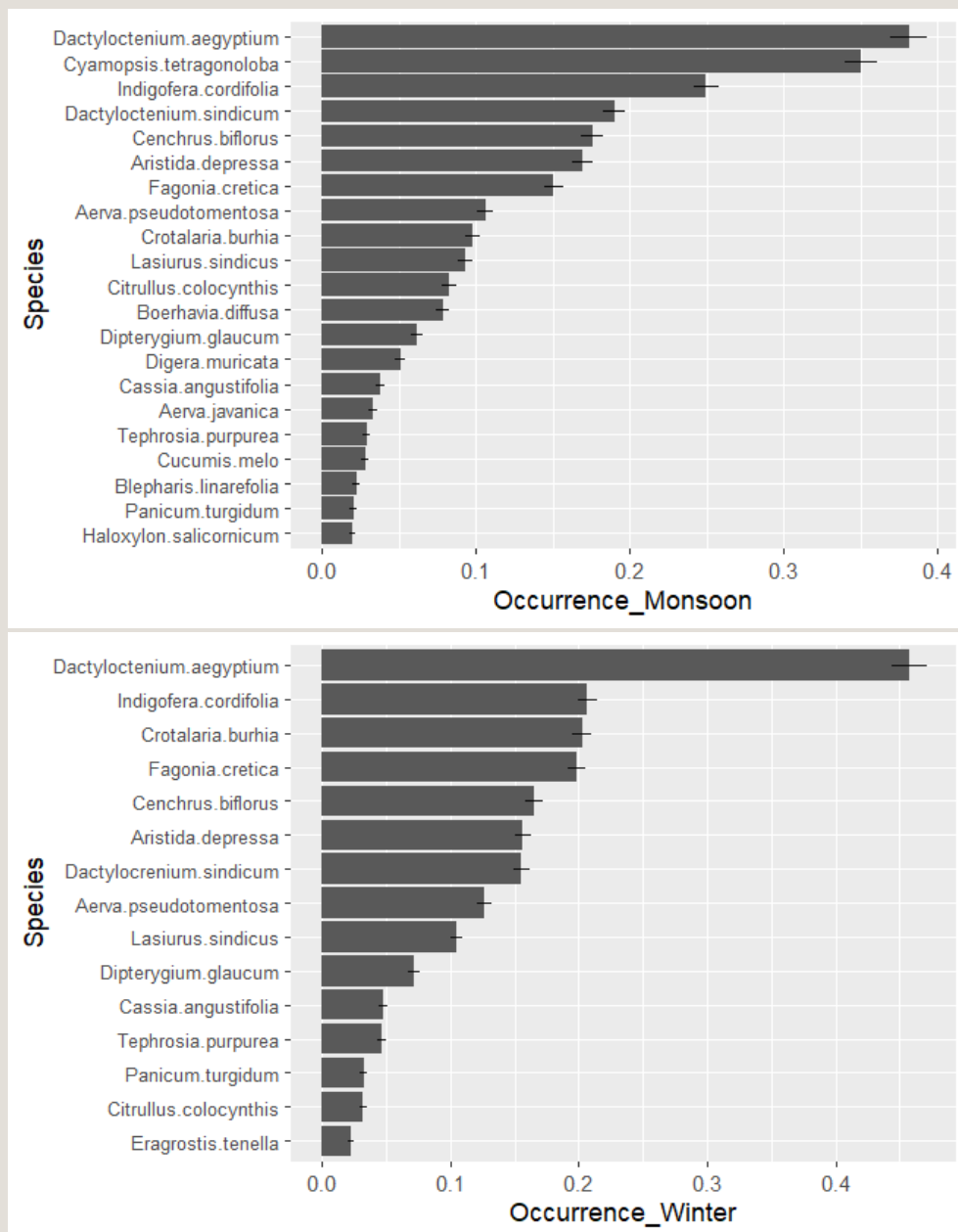


Figure 34. Ground vegetation composition of Great Indian Bustard habitat in/around Desert National Park in a) summer, b) monsoon, and c) winter seasons

5.2. Arthropod assessment

Arthropods are the primary food for GIB, especially during the breeding season (Dutta 2012), and they play a vital role in maintaining natural and managed ecosystems. The global decline in insect populations is a matter of great conservation concern for higher trophic levels that depend on these resources. For the assessment of GIB habitat with respect to food availability, a study on arthropods was carried out in Desert National Park. Sampling points were selected randomly from satellite-telemetry data of the tagged GIB. Transects of 50m were walked, and insects that were flushed within 1 m on either side of the line were noted, which were further identified up to order level and the land cover was noted within a 100 m radius of the sampling points.

A total of 336 transects were sampled. In terms of land cover, the density of total arthropods was highest in shrublands (8.56 ± 0.99 SE individual/100m²) and grasslands (8.22 ± 0.49 SE individual/100m²) and lowest in stabilised dunes (3.5 ± 0.5 SE individual/100m²). Order Orthoptera density was highest in grasslands (5.92 ± 0.45

SE individual/100m²) and lowest in stabilised dunes (0.5±0.5 SE individual/100m²). Order Coleoptera density was highest in shifting dunes (1.2±0.96 SE individual/100m²) and lowest in grasslands (0.14±0.05 SE individual/100m²). Being one of the primary prey of GIB, understanding differences in insect communities across different habitat gradients is essential for managing GIB habitats.

5.3. Effects of habitat restoration

Protected areas represent ~15% of the global terrestrial surface and are generally biodiversity-rich, compared to unprotected areas. Unregulated consumptive human uses of natural resources have resulted in widespread loss and degradation of wildlife habitats, reducing ground vegetation biomass, insect communities, and higher trophic organisms dependent on them. Protection and habitat restoration focusing on flagship species can play an important role in biodiversity conservation. Much of the current conservation practices in the Thar landscape, especially Desert National Park, are focused on GIB conservation. The key habitat protection/restoration measure in Thar, as per the National Bustard Recovery Plan, involves creating and maintaining enclosures where livestock grazing is controlled. This has improved ground vegetation cover and restored grasslands in and around the Park. This measure is likely to have a benevolent effect on arthropod biomass and ultimately benefit bustards. However, its effectiveness is yet untested.

5.3.1. Response of GIB to protected/restored habitats

To examine the response of GIB to habitat protection and restoration, Ivlev's Electivity Index was computed using telemetry data, to compare the preference of protected grassland enclosures of Desert National Park. The proportions of GPS fixes of each tagged bird inside vs outside protected enclosures (use) were compared against the proportion of these areas in the combined 95% MCP of seven tagged birds (availability). The index was computed for each bird and its mean and SE were estimated.

The GIB showed a very strong positive selection (disproportionately greater use) for protected grassland enclosures and no selection (use in proportion to availability) for unprotected areas (Figure 35).

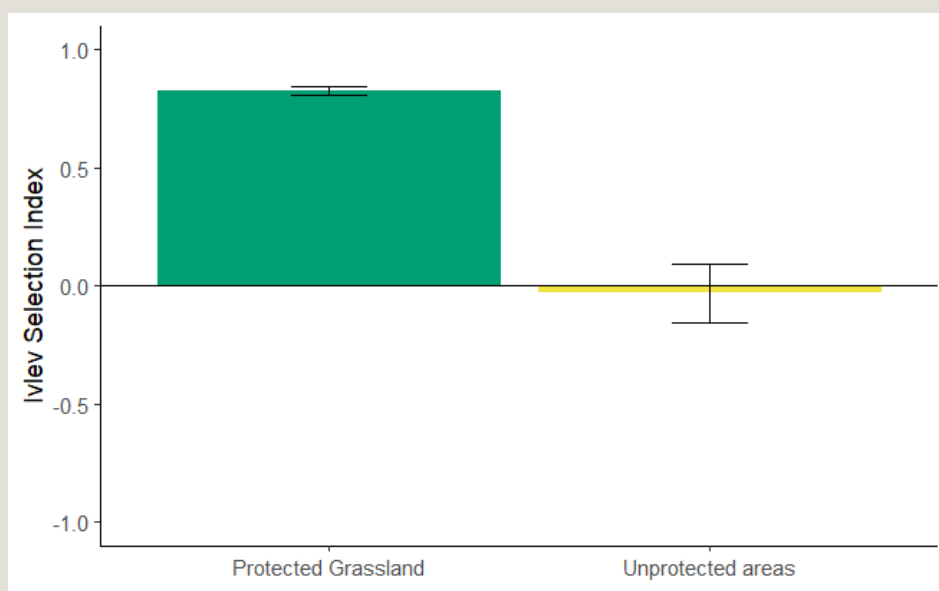


Figure 35. Comparing the Ivlev selection index for tagged Great Indian Bustard (n=7) in protected grassland and unprotected area in and around DNP

5.3.2. Response of insects to protected/restored habitats

To examine the response of insects to habitat protection and restoration, insect sampling was done in grids of 0.25 km², overlaid on the entire study area composed of both protected (enclosures) and unprotected areas (areas outside enclosures) of Desert National Park. Insect density was compared between grids within enclosures and beyond a 2 km buffer of any enclosure boundary. Data was collected for several insect orders like Coleoptera, Diptera, Hymenoptera, Hemiptera, Homoptera, Neuroptera, and Lepidoptera, but the study majorly focused on the Order Orthoptera (mainly grasshoppers). Sampling grids were selected randomly, and a transect was placed in a random direction from the centroid of the grid. To obtain the total count of insects, sweep net sampling was done in 50 x 2 m² transects.

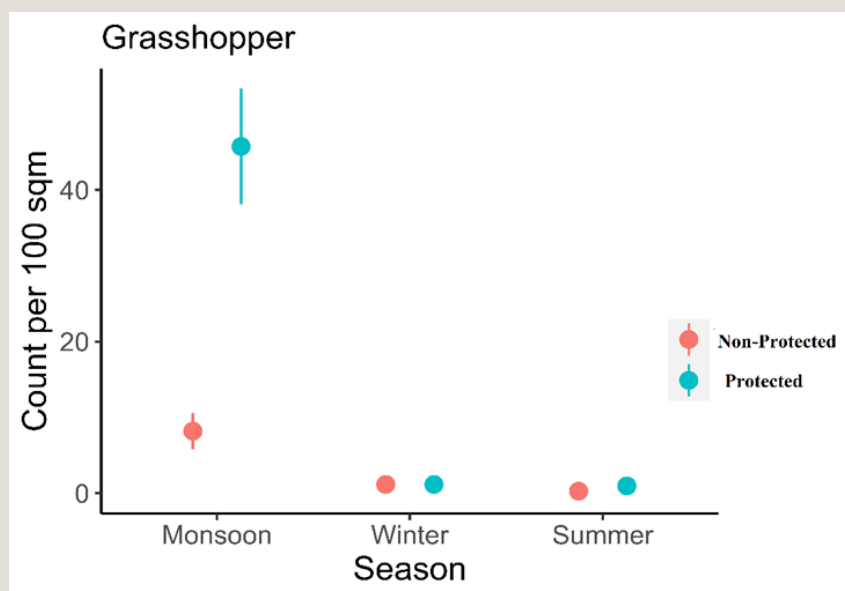


Figure 36. Seasonal density of grasshoppers in protected and non-protected areas of DNP (Note the large difference in count during Monsoon)

Results indicate that grasshopper density is much higher in protected grassland enclosures during monsoon with no significant difference between areas in summer and winter (Figure 36). This shows that in monsoon, an increase in ground vegetation biomass and food abundance in protected grasslands leads to a rapid increase in grasshopper numbers. Outside enclosures, insect densities do not increase to this extent during monsoon. This finding is of significance, as protected grasslands are the primary breeding grounds for GIB, and high insect densities inside the enclosures is perhaps the reason why birds use them intensively for nesting and chick-rearing activities, besides the lack of disturbances in these areas.

5.3.3. Responses of spiders to habitat protection/restoration

The impact of grazing regulation and vegetation recovery on the spider community was also assessed during 2017-2022, since spiders — being predators of other insects — are popular biodiversity indicators. Spider diversity inside and outside protected grassland enclosures were compared. The study was designed using the same methods mentioned above for arthropods.

Spider richness peaked during the monsoon and summer seasons (Figure 37). Species richness was significantly higher inside enclosures, with Sudasari ACD showing the highest diversity, followed by Loharaki and Manihari (Figure 37). Inside enclosures, 28 spider families were recorded as compared to 25 outside, with families like Agelenidae, Scytodidae, and Uloboridae found exclusively within enclosures. Dominant families included Lycosidae, Philodromidae, and Salticidae, while rare families were Cithaeronidae and Sicariidae. On average, sampling plots inside enclosures had twice the spider richness and abundance than plots outside enclosures.

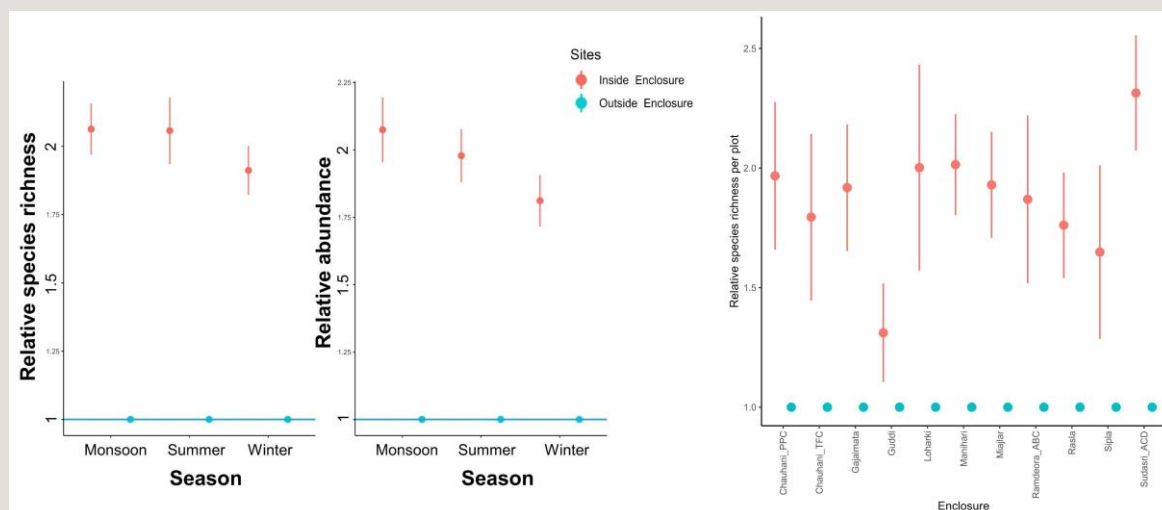


Figure 37. Scaled seasonal species richness and abundance of spiders inside and outside protected enclosures of DNP, with areas outside enclosure as the baseline (left and middle); Comparison of species richness inside and outside protected enclosures of DNP across the study period (right)

The above results highlighted the benevolent effects of protected grassland enclosures on multiple taxa. Habitat restoration by maintaining and expanding such grassland enclosures will foster ecological balance and benefit biodiversity conservation in the Thar landscape.

5.3.4. Potential effect of water availability

The Indian Thar desert has experienced a sharp increase in surface water availability in recent years which was reflected in the trend of water presence in our landscape surveys during 2014-18 (Figure 7). Water is also provisioned by the Forest Department in the form of water guzzlers inside protected enclosures, and by local wildlife enthusiasts in water holes inside *Orans* (sacred pasture lands). This management intervention stems from a noble intention of helping wildlife deal with the harsh dry conditions of the desert. On the other hand, water limits the dispersal of organisms, and determines floral and faunal distributions. Ranges of mesic species, with physiologies adapted to greater water availability, do not extend into arid regions due to scarcity of water. An increase in water availability can dissolve this barrier and facilitate the range expansion of mesic species into previously unoccupied drier ranges. Hence, it is important to examine the effects of water availability on ecological communities and the pros and cons of this management intervention in Jaisalmer.

With this goal, a short study was conducted to compare the relative usage of water guzzlers by major animal species (Chinkara, Desert cat, Desert and Indian foxes, Indian hare *Lepus nigricollis*, GIB, Pig, and Nilgai) in four protected grassland enclosures of Desert National Park (Gajaimata, Sudasari, RKVY and Ramdevra). Camera traps were placed in these enclosures at water guzzlers throughout the year and at systematic plots from winter through summer during 2017-18 (see sections 1.2.4 and 4.4 for field methods). Species identities were labelled in camera trap images using the program ExifPro, and independent snapshots were created by slicing the sampling durations at 30-second intervals. Encounter rates of each species at guzzlers and systematic plots were computed from the frequency of snapshots where the species was photo-captured. Using this information, relative encounter rates of a species out of all species at water guzzlers (metric for relative use) and systematic plots (metric for relative abundance) were estimated. Finally, the ratio of the above two metrics was used to compare water visitation rates among species, after scaling for the difference in their abundances (Figure 38).

Results showed that mesic species such as Nilgai followed by pigs visited water guzzlers far more frequently, relative to their abundance in the area, compared to xeric species such as the Desert hare, Desert cat and Chinkara. Relative water visitation of GIB was three times higher than their relative abundance, probably because of long durations spent by this bird scanning the area around water points before/while drinking,

resulting in many photo-captures of a single drinking event, whereas, drinking bouts of other species were apparently much shorter, and this artefact could not be disentangled in the above analysis.

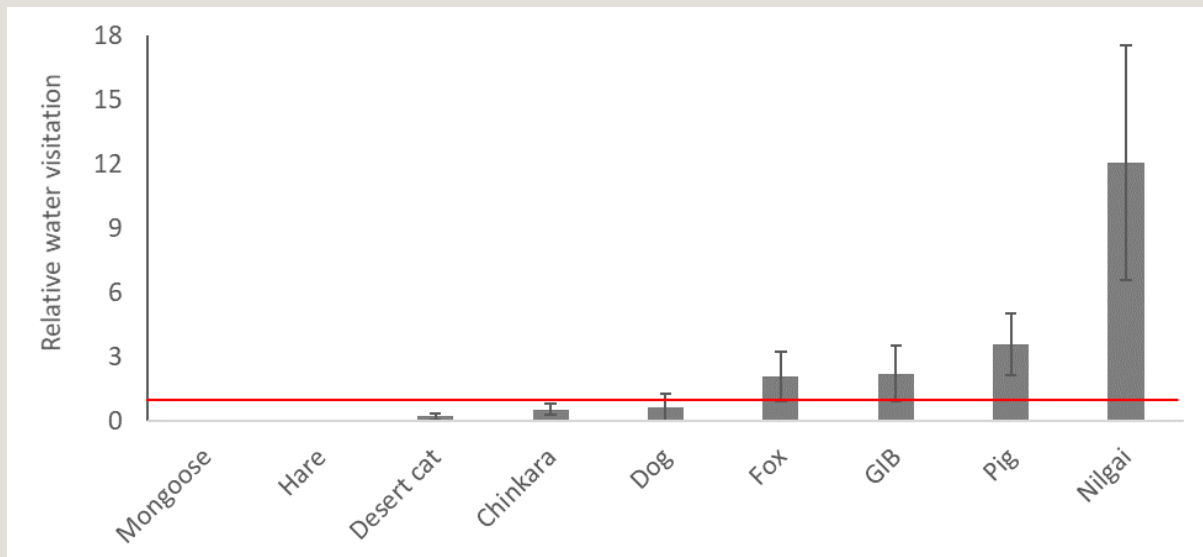


Figure 38. Relative visitation at water guzzlers, scaled to abundance, of various species in protected enclosures of Desert National Park (2017-18). Height of the bar indicates the water visitation rate of a species with respect to its encounter rate in the general area (red line); the horizontal red line showing no difference from the null expectation. Error bars are Standard Errors.

5.3.5. Responses of physical and chemical properties of soil

The Thar Desert has been supporting a large livestock population, involved in extensive grazing across the landscape. In response, the Government of India established DNP in the late 1970s to conserve native fauna and flora, including GIB and associated grassland species. This study aimed to assess the effects of livestock grazing on soil properties by comparing grazing exclusion areas (DNP enclosures, namely, Gajamata, Sudasari, and RKVY) with adjacent grazed areas. Soil samples ($n=200$) were collected systematically from both enclosures and areas outside, focusing on parameters such as pH, electrical conductivity (EC), sodium (Na), potassium (K), bulk density (BD), porosity, moisture content, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), carbon: nitrogen ratio, and basal soil respiration.

The results indicated enclosures have higher bulk density, C:N ratio, electrical conductivity, potassium and TOC, while lower moisture content, soil respiration level, TKN and sodium contents (Figure 39). Lower TKN and soil respiration capacity can be associated with fragmented vegetation and partial dune coverage inside enclosures. Higher potassium in the surrounding areas of sampled enclosures can possibly be due to excessive grazing and subsequent salt accumulation.

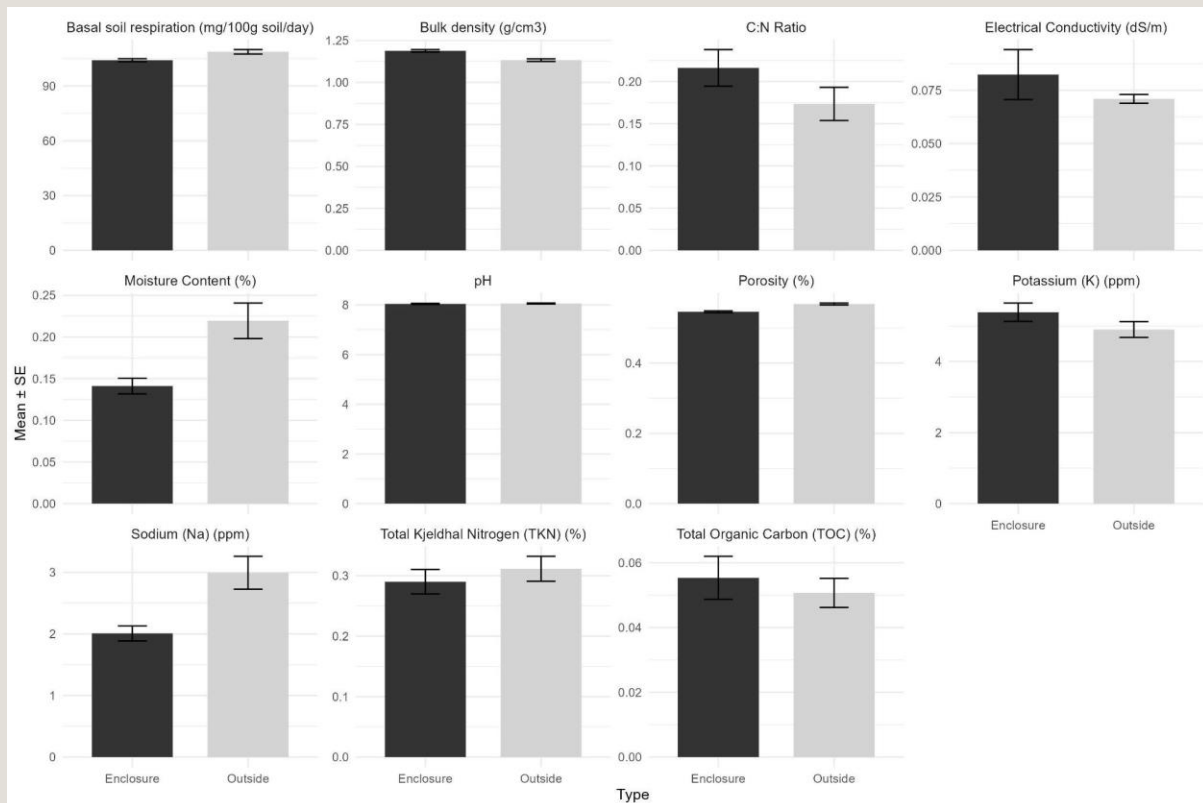


Figure 39. Comparative physical and chemical properties of soil inside and outside DNP enclosures

Study highlighted a significant difference in moisture content and bulk density between enclosures and surrounding areas, suggesting that agro-pastoral practices influence soil properties. However, there were no consistent differences that could definitively attribute changes to these practices. The variations may be due to the differing ages of the enclosures, implying that the effects of grazing exclusion on soil properties evolve over time. Further research is being conducted to better understand these dynamics and guide the management of GIB habitats to restrict detrimental land cover changes.

6. Associated biodiversity studies

6.1. Birds

The Indian Thar desert has lost much of its grasslands over the last few decades, mainly due to land use change from pastoralism to agriculture. Expanding croplands and intensifying grazing pressures are popularly hypothesised to be major drivers of biodiversity loss in the region. This study aimed to investigate the effects of contemporary land use change on bird communities of the Western Thar Desert. For this, we surveyed 58 randomly laid line transects in a c2000 km² study area, to quantify parameters of bird community structure in three predominant land cover types, *viz.*, protected grasslands, rangelands, and fallow croplands. Fieldwork for the study was conducted in the dry season (winter and summer) between December 2018 and April 2019 (Figure 40).

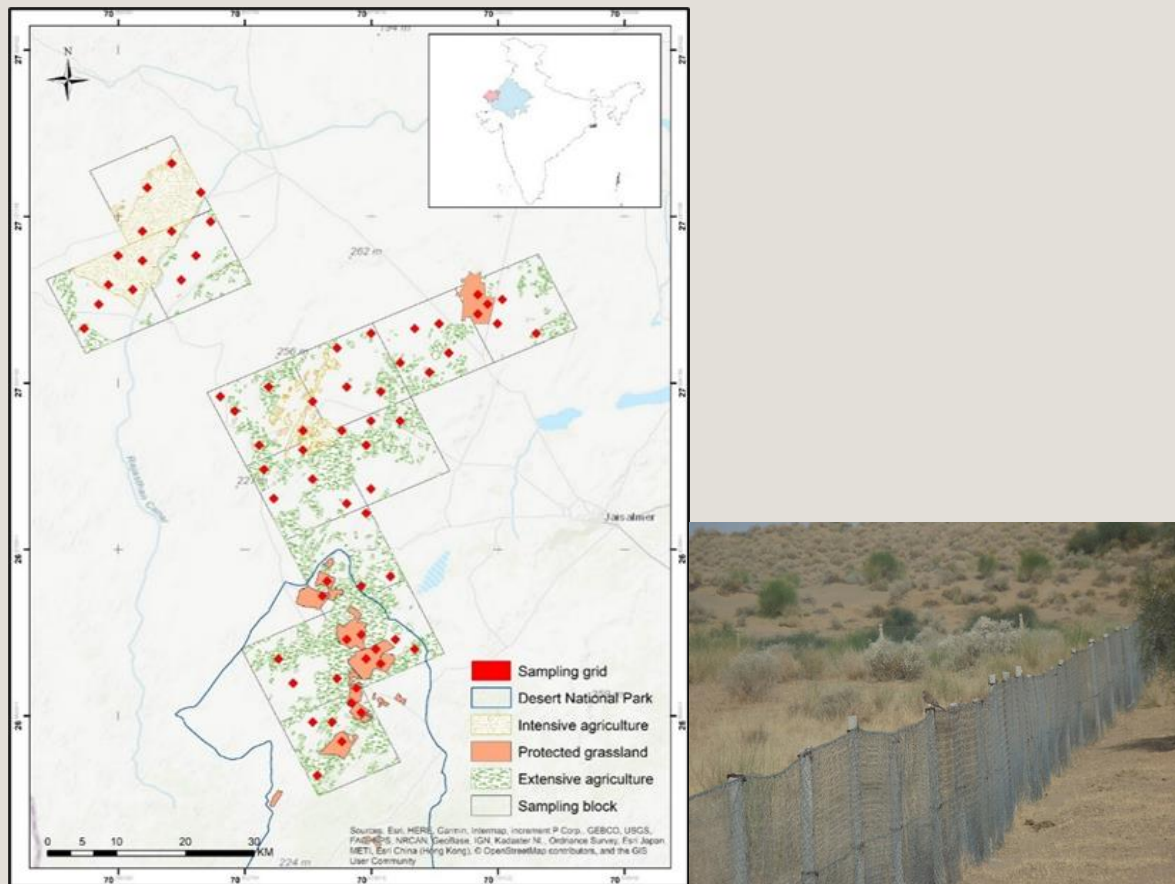


Figure 40. Map of surveyed area with dominant land use types in Jaisalmer district of Western Rajasthan (left), protected grassland and agriculture (right)

We found that during winter, overall bird richness and abundance were highest in protected grasslands followed by fallow croplands and rangelands (Figure 41). Protected grasslands also had a higher abundance of diet and habitat specialists. Compared to protected grasslands, density was lower in fallow croplands and rangelands for 35% and 10% of species, respectively. A majority of the negatively affected species were insectivorous grassland specialists. Contrary to the pattern in winter, overall bird richness, abundance, community composition, and guild structure in summer were similar across the three land use types. Only one of the 17 analysed species had significantly lower density in modified land use types. Overall, protected grasslands were the best habitat for birds and specifically important for diet and habitat specialists, more so during the winter. Rangelands and fallow croplands sustained most generalists at comparable densities but had severe negative impacts on specialist species.

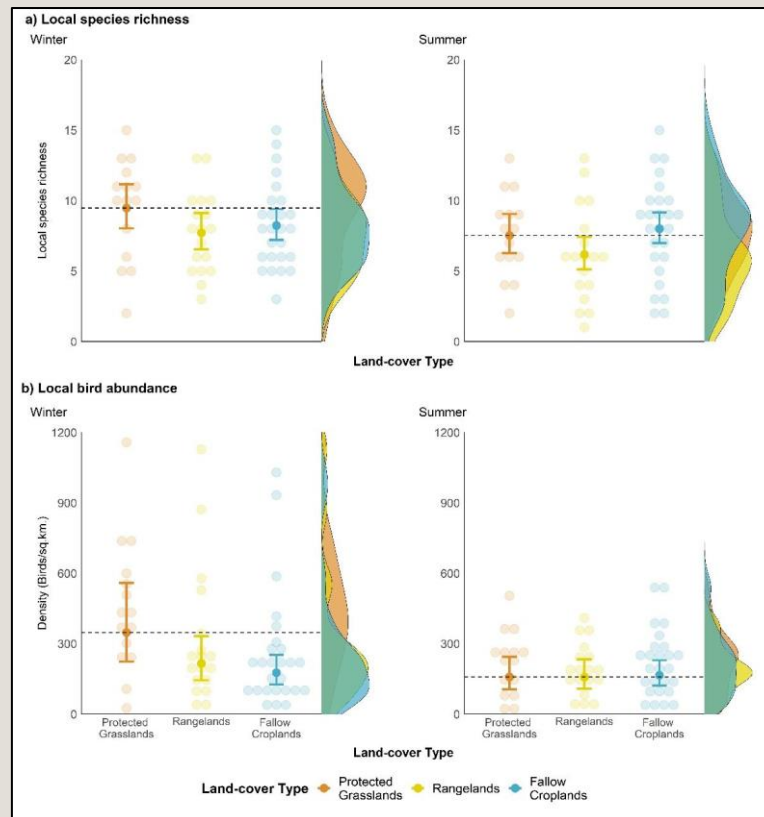


Figure 41. Local species richness and abundance as a function of land use across two seasons: a) Species richness as a function of land use in two seasons. b) Abundance as a function of land use type

Our results point out that low-intensity agro-pastoral land uses can supplement, but not replace, protected areas in the conservation of the Thar desert's avifaunal diversity. This is in consonance with the idea of managing dryland habitats as agro-grassland mosaics with embedded protected areas, in order to reconcile human needs and biodiversity conservation at a landscape scale.

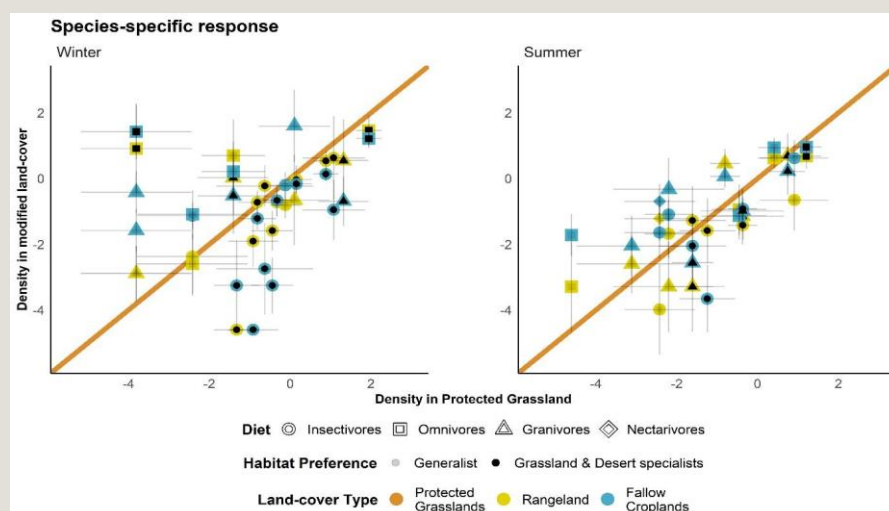


Figure 42. The abundance of species in a modified land use vis-a-vis its abundance in protected grasslands (control)

Simultaneously, we evaluated whether the advent of irrigation and resultant intensification of agriculture has had any effect on the avifauna of the region. To understand this, we conducted line transect surveys in irrigated areas and compared the parameters of bird community structure with those of non-irrigated land covers, viz., protected grasslands and non-irrigated croplands. Transects were walked during the winter and birds were

recorded in a distance sampling framework. We found the following results (Kher and Dutta, 2021) (Figures 42 & 43):

- Bird communities in irrigated areas were significantly different from those in non-irrigated areas. This change was mainly driven by the colonisation of non-native species and the proliferation of native generalists
- Irrigated areas had a lower abundance of native insectivores, but a higher abundance of native omnivores.
- Irrigated areas had multiple non-native species that were absent from non-irrigated land covers. A disproportionate increase in non-native granivores was particularly noteworthy.
- Abundance of arid zone specialists was particularly low in the irrigated areas and they were replaced by native and non-native habitat generalists.

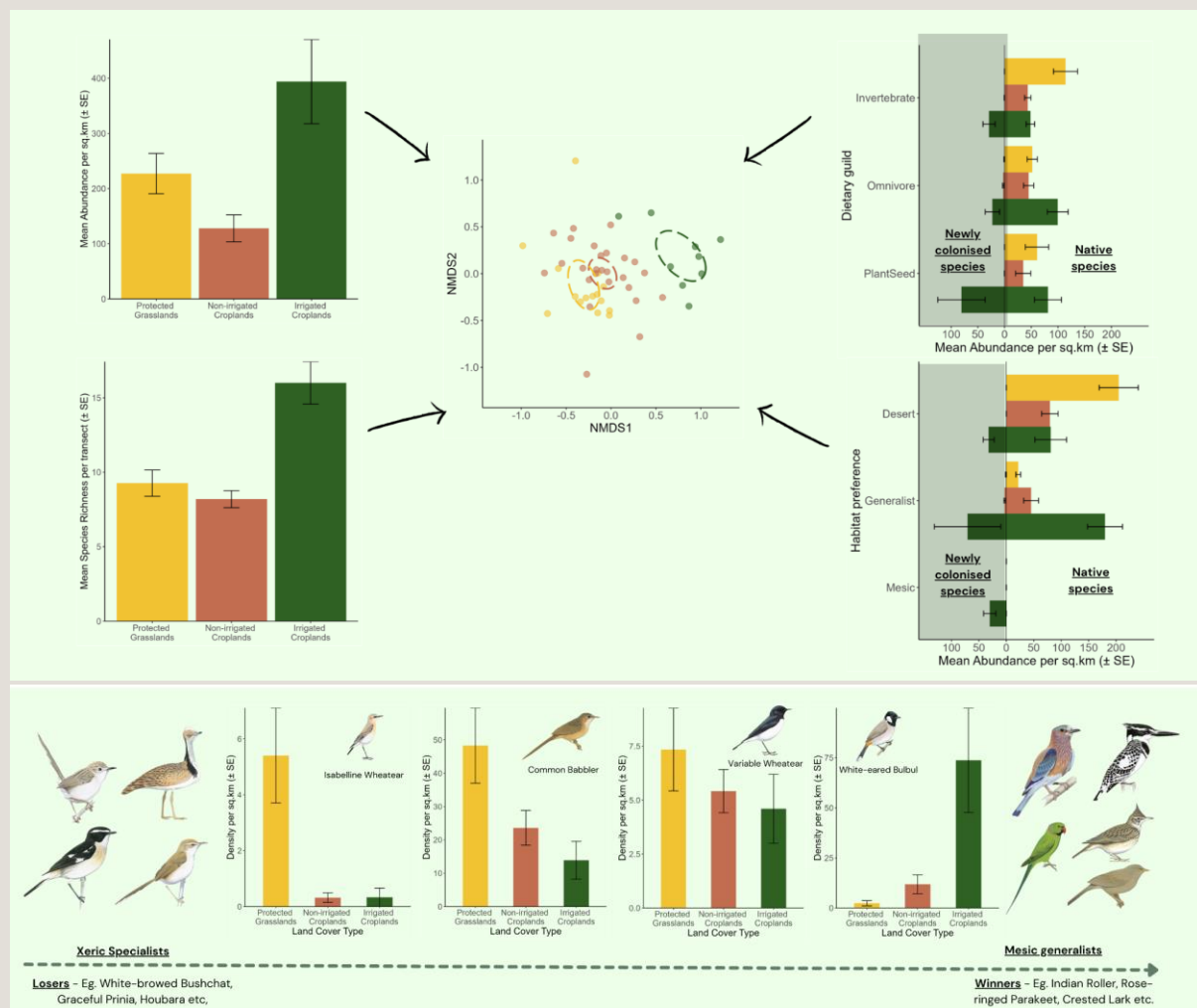


Figure 43. The top panel depicts the change in bird community structure of irrigated areas, mainly due to the presence of non-native species and an increased abundance of native generalists. Note the change in insectivores and grassland specialists due to the advent of irrigation. The lower panel shows the land use responses of select representative species lying on a xeric to mesic axis.

6.2. Thermal ecology of spiny-tailed lizard

Deserts experience extreme environments and can pose further challenges to the fitness of species under climate change scenarios that are worth investigating. Ectotherms, particularly those inhabiting extreme environments like deserts, are highly vulnerable to climate change as rising temperatures constrain their thermal

limits. Hence, a study was carried out focusing on the thermal ecology of the spiny-tailed lizard *Saara hardwickii*, which inhabits the already extreme temperatures of the Thar Desert.

Field data on body temperatures of spiny-tailed lizards and operative temperatures of surrounding environments were collected in natural conditions to evaluate and quantify the degree of thermoregulation observed in lizards, as well as to assess changes in activity patterns over different months. In the laboratory, the preferred operative temperature, thermal thresholds, and locomotor performance of the lizard were measured. The data also helped determine the voluntary thermal maxima, indicating the temperature at which the lizards seek thermal refuge. By combining field and laboratory data, the use of burrows to thermoregulate for lizards was estimated and the impact of climate warming on their locomotor performance and hours of activity under future climatic scenarios were predicted.

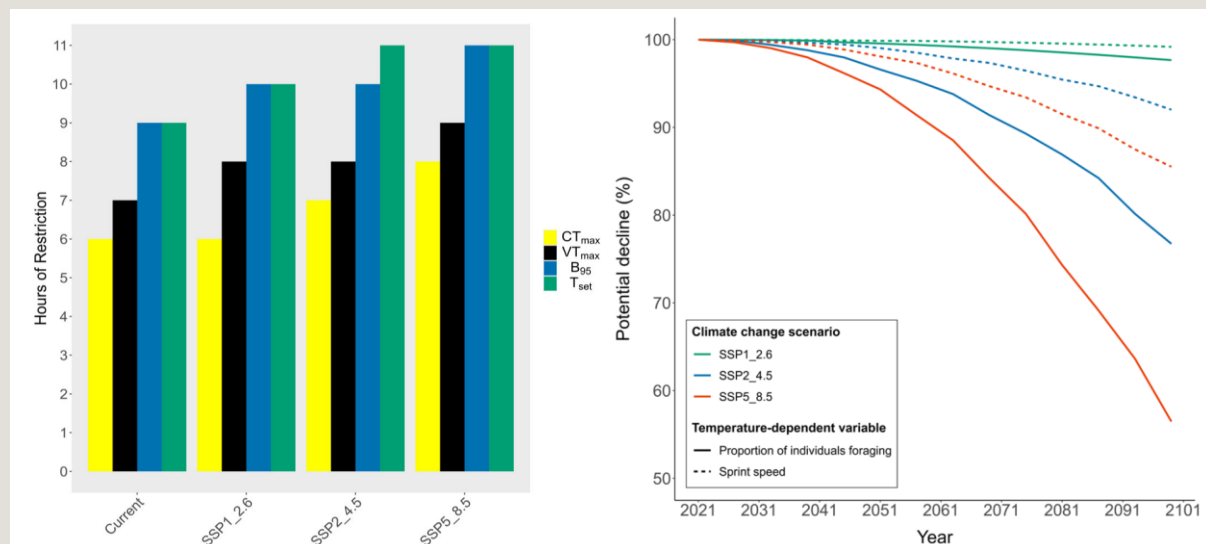


Figure 44. Proportional active-period hours (07:00–20:00) that spiny-tailed lizards are restricted from being in the open forage, calculated as hours in which environmental temperatures exceed CT_{max} (critical thermal maxima), VT_{max} (voluntary thermal maxima), B₉₅ (temperature range T_b at which locomotory performance is greater than or equal to 95% of lizard's maximum speed) and T_{set} (thermal preference range) (left); and potential decline (in %) in sprint speed and proportion of individuals foraging under different climate change scenarios (right)

Burrows provide a significant thermal buffer for spiny-tailed lizards, as temperatures deep within burrows (~1 m) remain within the lizard's preferred temperature, even under the worst-case climate change scenario (Representative Concentration Pathway RCP 8.5) (Figure 44). Currently, these lizards are restricted to their burrows for six hours during their active period. According to the model predictions, by the year 2100, lizards might be confined to their burrows for seven hours in the best-case scenario and for nine hours in the worst-case scenario. Furthermore, the model projected a decrease in locomotor performance by 2.1%, 9.5%, and 28.3% under the best (RCP 2.6), intermediate (RCP 4.5), and worst (RCP 8.5) case climatic change scenarios, respectively, by 2100 (Figure 44) (Tatu et al., 2024). Consequently, the combined effect of reduced active hours and diminished locomotor performance could lead to decreased fitness in spiny-tailed lizards, potentially leading to reduction in population sizes.

6.3. Chinkara

Human activities can alter the spatial distribution and behaviour of sensitive species through a 'landscape of fear' effect. We examined these aspects for the Chinkara *Gazella bennettii*, a historically hunted antelope native to the Thar desert. Chinkara density was estimated across natural and human modified land uses. Additionally,

seasonal activity budget of chinkara, focusing on time allocation to different behaviours, especially vigilance vs foraging trade-offs, was examined. Through this study, we aimed to understand the implications of human-alteration of landscapes on the ecology of this conservation dependent species.

Fieldwork for this study was carried out in Desert National Park and its adjoining non-protected areas between July 2021 and June 2023. Land use types were broadly classified into four classes: grassland, scrubland, agriculture and vegetated dunes. Each land use class comprised four sites covering 10 km² each and a total study area of 160 km² across 16 sites. At each site, species' density was estimated using the Distance Sampling framework along three 2 km line transects that were repeated seasonally.

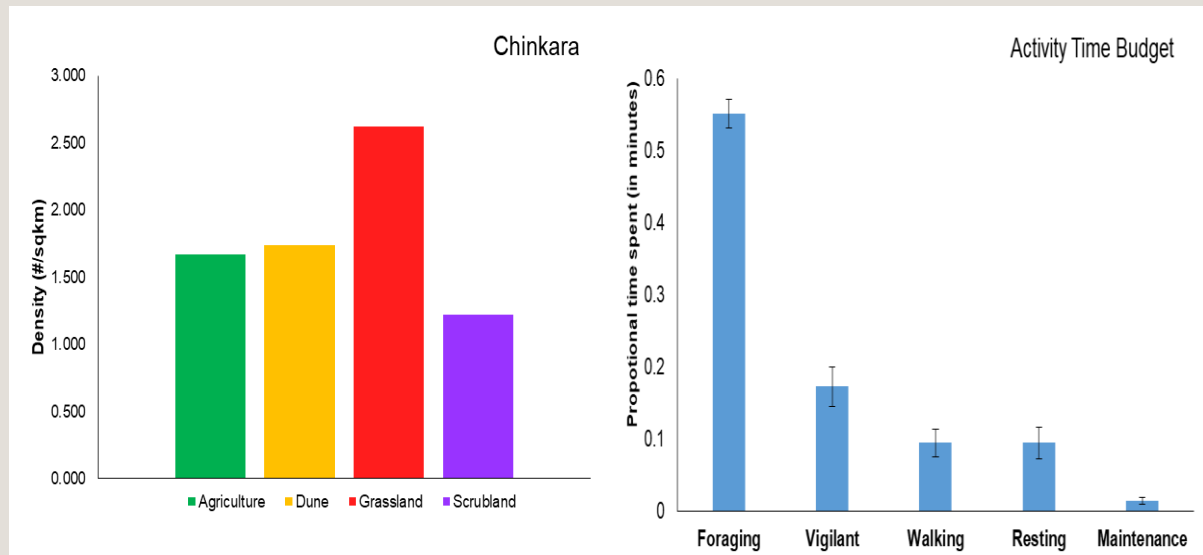


Figure 45. Density estimation of Chinkara across land uses and comparison of time allocation to behaviours (July 2021 – June 2023).

A total of 48 transects were walked twice in each season for two consecutive years (2021 – 2023), resulting in 1152 km walk efforts that yielded a chinkara density of 1.814 (0.15 SE) individuals/km², with the highest density observed in grasslands compared to other land use classes of dune, agriculture and scrubland. General activity budget of Chinkara represents more foraging followed by vigilant, walking, resting and maintenance in all land uses (Figure 45).

Behavioural data was collected using scan sampling method for chinkara herds and focal method for individual chinkara from three fixed observation points within each site. Scan sampling was conducted for one minute at intervals of ten minutes, and focal sampling was conducted in the intervening time between successive scans. Data was collected from dawn to dusk to capture diel activity patterns and response of chinkara to environmental conditions and anthropogenic disturbances. Vigilance and foraging rates of chinkara were studied to understand the landscape of fear effect. Effects of group size and stressors (human, dogs and livestock) along with land use and season on chinkara vigilance and foraging rates were examined using generalised linear models. Results showed that vigilance rate reduces with group size (dilution and detection effects) but is much higher in the presence of humans and dogs, whereas, foraging rate increases with group size (due to reduced investment on vigilance) but reduces in the presence of humans, dogs and livestock (Figure 46).

Thus, the ongoing expansion of human footprint and associated disturbances increases vigilance at the cost of reduced foraging time for this sensitive antelope, consequently reducing its fitness in human-dominated landscapes.

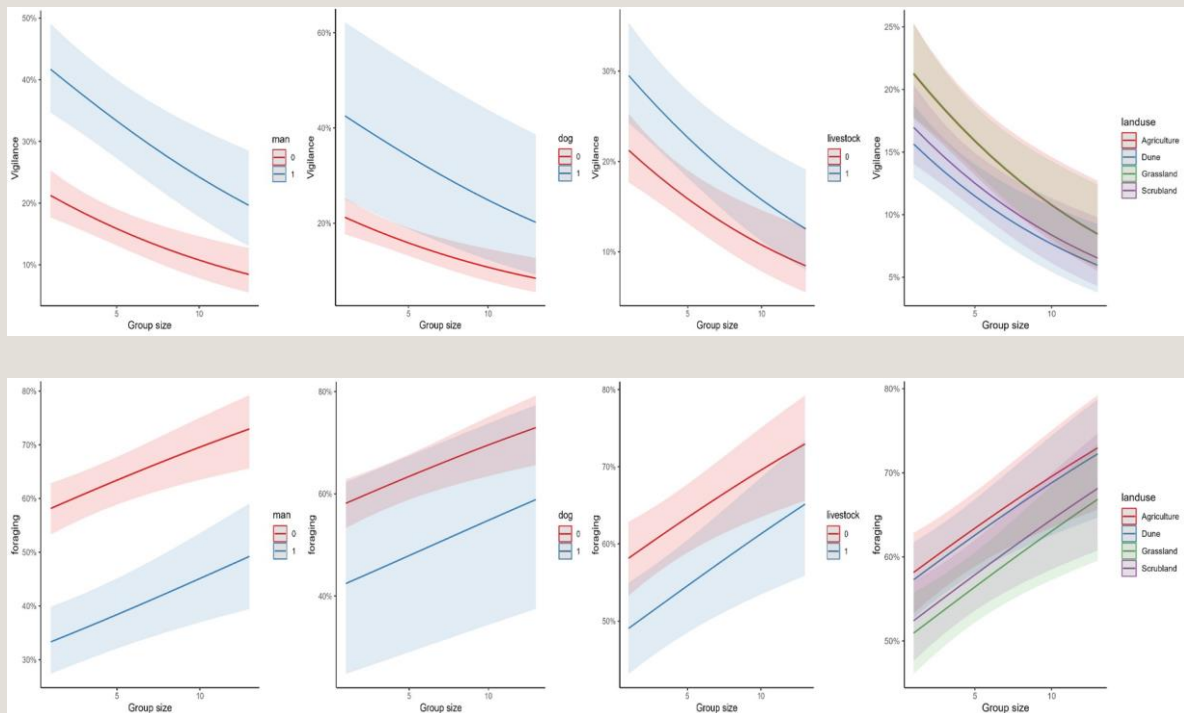


Figure 46. Effects of group size on Chinkara vigilance (top) and foraging rate (bottom) in the presence of disturbance variables: human (a), free-ranging dog (b), livestock (c) and land uses (d)

6.4. Desert fox

How species respond to anthropogenic changes in habitat is highly relevant to conservation biology. The Thar desert has experienced a sixfold increase in agriculture post-Indira Gandhi Canal, potentially impacting arid species such as the desert fox (*Vulpes vulpes pusilla*) (Misher and Vanak, 2021). Protected enclosures within DNP offer a unique setting to study its responses to habitat changes and protection efforts. Hence, a study was carried out to investigate habitat use and den site selection of Desert Fox in and around DNP, specifically assessing how protection measures *vis-a-vis* human modification of landscape influence space use by this species.

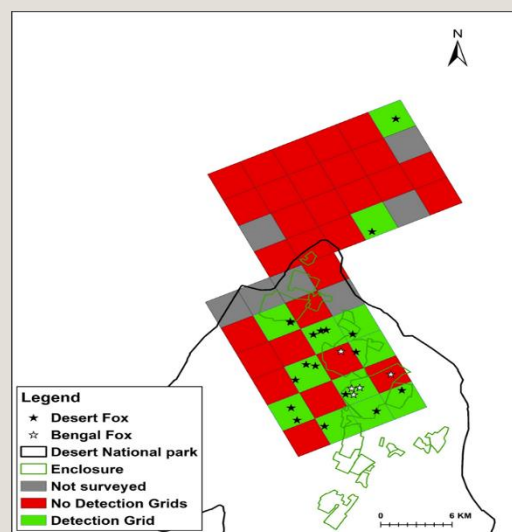


Figure 47. Desert fox occurrence in 9 km² grids inside and outside Desert National Park (2024)

Occupancy surveys were conducted along a 6 km vehicle trail divided into six 1 km segments in 9 km² cells (n = 41) within and outside Desert National Park, during evening hours, documenting habitat variables and fox sightings. Further, an intensive den search within 30 grids of 9 km² area, was carried out that yielded 16 fox dens.

Dens were confirmed via camera trapping. For den site selection, control points were generated and habitat characteristics, such as, the presence of grassland, scrubland, agriculture, soil, sand, gravel, human, dog, livestock, prey (beetle, grasshopper, spiny-tailed lizard, gerbil, fruiting *Capparis* tree), abundance and distance to water source were compared between dens and control sites using generalised linear models.

83% of grids where foxes were detected were inside DNP, many of them in the protected enclosures. Fox occupancy was influenced by protection and other variables (agricultural cover, disturbances, and food abundance) did not influence fox occupancy (Table 10; Figure 47).

The majority of recorded fox dens (68.75%) were located on mounds, with the remaining 31.25% being ground dens. *Capparis decidua* provided the most common plant cover for dens (62.5%), followed by *Haloxylon salicornicum* bushes (37.5%), offering structural stability and escape cover from predators. 68.75% of dens were on soil substrate, while the remaining were on sand, typically under *H. salicornicum* due to its deep, strong roots. On average, fox dens had four openings. The mean distance to enclosures from dens inside DNP was 811 metres. Descriptive statistics and univariate tests demonstrated a significant preference for denning in areas with low livestock (p 0.005) and human presence (p 0.012) (Figure 48). Foxes are sometimes persecuted by herders as they prey on newborn lambs, and lamb carcasses were occasionally found near fox dens during the sampling period.

Table 10. Summary statistics of Desert fox occupancy models in and around Desert National Park

Model	PA	Agri	Dstb	Food	K	AICc	Δ AICc	Ak wt
$\Psi \sim \text{PA}$	2.95 (1.90)				3	148.4	0	0.52
$\Psi \sim \text{PA} + \text{Agri} + \text{Dstb} + \text{Food}$	2.93 (2.02)	5.16 (5.82)	-1.72 (1.85)	0.0004 (0.002)	6	151.1	2.7	0.14
$\Psi \sim \text{Agri}$	14.92 (15.65)				3	151.5	3.1	0.11
$\Psi \sim \text{Dstb}$					3	151.7	3.4	0.1
$\Psi \sim \text{Food}$				0.0022 (0.0017)	3	152.5	4.1	0.07
$\Psi \sim 1$					2	152.5	4.1	0.07

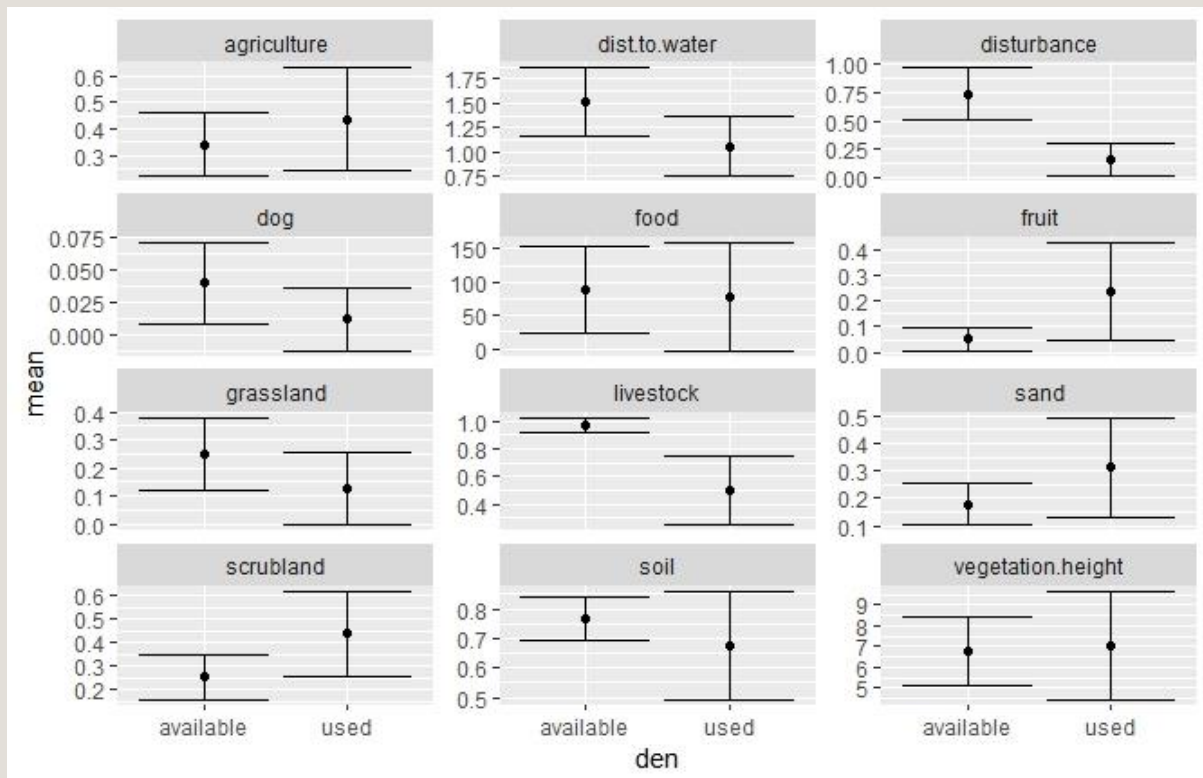


Figure 48. Comparison of mean and 95% CI of potential habitat covariates (proportional cover of agriculture, grassland, scrubland [land covers], sand and soil [burrowing substrate], presence of human disturbance, dog, livestock [disturbances], and vegetation height) between den (used) and control (available) plots for Desert fox in and around Desert National Park (2024)

6.5. Status survey of key wildlife in Bikaner, Rajasthan

The Bikaner district in Rajasthan is known for diverse wildlife and has not previously undergone rigorous wildlife surveys. To address this, the Wildlife Institute of India in collaboration with Rajasthan Forest Department, Government Dungar College, and Maharaja Ganga Singh University, conducted a comprehensive survey. This initiative, prompted by local residents and invited and facilitated by the Hon'ble Member of Parliament through the Ministry of Environment, Forest & Climate Change, was carried out with the help of a group of researchers, forest frontline staff, university students, and wildlife enthusiasts in 2021.

The survey aimed to evaluate the distribution and abundance of key wildlife species, including migratory, arid-adapted, and raptorial birds, and to understand their habitat associations, threats, and community perceptions towards conservation. The Bikaner parliamentary constituency was divided into four sampling blocks and overlaid with a 144 km² grid, covering a total area of 12,816 km² (Figure 49). Extensive surveys were conducted using vehicle transects and point counts.

Key findings from the survey include the detection of 1,880 Chinkara individuals in 684 herds, with an estimated density of 4.27 (± 0.65 SE) individuals/km², and an abundance of 54745 (± 8392 SE) individuals. Desert foxes were observed with a density of 0.58 (± 0.11 SE) foxes/km² and an abundance of 7456 (± 1356 SE) individuals. Desert cats (0.57 $\pm$ 0.2 individuals/100 km), Nilgai (14.39 $\pm$ 2.91 individuals/100 km), free-ranging dogs (26.07 $\pm$ 3.6 individuals/100 km), and Indian Wolves were also recorded.

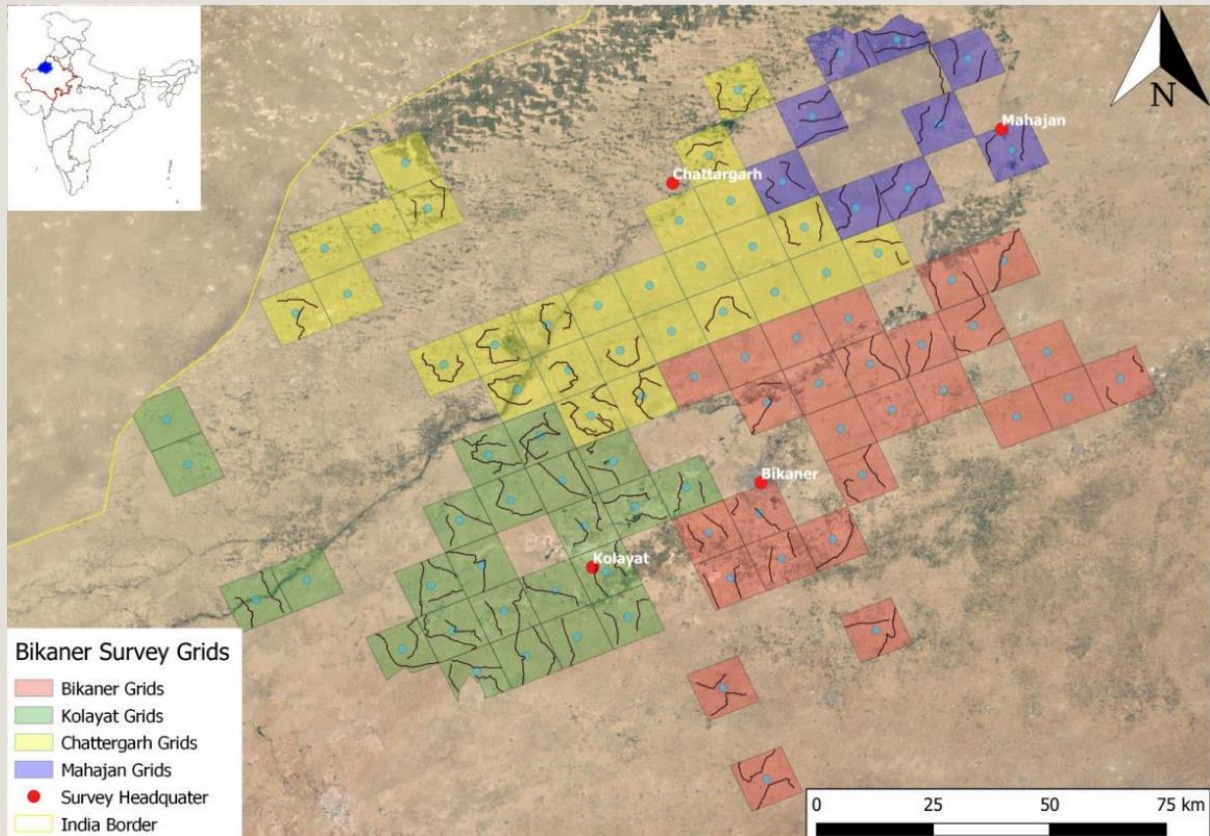


Figure 49. Sampled grids (n = 89) divided into four subdivisions with traversed trails and point counts

Among birds, Demoiselle Cranes *Grus virgo* had an encounter rate of 5.47 ± 3.14 individuals/100 km, and notable raptor species included Griffon Vulture *Gyps sp.* (16.44 ± 6.94 individuals/100 km), Egyptian Vulture (8.73 ± 2.35 individuals/100 km), Common Kestrel *Falco tinnunculus* (7.39 ± 0.88 individuals/100 km), Black-winged Kite *Elanus caeruleus* (5.35 ± 0.89 individuals/100 km), and Long-legged Buzzard *Buteo rufinus* (5.13 ± 0.69 individuals/100 km). Small birds were recorded with a density of 997 ± 58 individuals/km², and hotspot surveys documented 24,674 birds across 95 species, indicating sites such as RD750, RD507, Lunkaransar lake, and Gajner lake as important for bird conservation. Endangered species like the Egyptian Vulture and Steppe Eagle, along with Vulnerable species such as the Common Pochard *Aythya ferina* and River Tern *Aythya ferina*, and Near-Threatened species like the Black-headed Ibis *Threskiornis melanocephalus* and Dalmatian Pelican *Pelecanus crispus*, were also observed.

The habitat was characterised by flat and mildly undulating terrain with dominant scrublands and agricultural areas. Active disturbances from human and livestock activities were noted in 72% of surveyed plots, while passive disturbances were present in 87% of points. Vegetation varied, with dominant species including *Leptadenia pyrotechnica*, *Prosopis cineraria*, and *Aerva sp.* The survey found distinct associations between species and habitat types, with declines in certain wildlife populations attributed to habitat changes and disturbances.

Community feedback revealed a high awareness of conservation areas (85%) but also concerns about encroachment (12%). The rapid land use changes in the region highlight the need for ongoing wildlife assessments.

Based on these findings, it was recommended to include conservation efforts at key sites such as Jorbeer Conservation Reserve and RD750, mitigating threats like power lines and free-ranging dogs, protecting *Orans* from encroachment, developing grasslands for wildlife and regulating livestock use, and promoting ecotourism

at sites like RD750 and Lunkaransar lake. Regular monitoring through similar surveys is crucial for tracking wildlife trends and implementing effective conservation strategies.

7. Community perception

7.1 Social surveys

Social surveys were carried out to understand the socio-economic status, livelihood issues, and conservation perceptions among local people in and around Desert National Park that can inform conservation planning. For this purpose, villages in prime GIB habitats were identified, a village-wise list of household heads was collected from census reports, and 5% of the total households were randomly sampled per village to conduct interviews. All interviews were conducted by the Project team during March - April of 2018 and 2019. In total, 158 households across 24 villages and 11 *dhanis* (settlements) were surveyed (Figure 50). Besides gaining social insights, these interviews also helped in designing the outreach programs to sensitise local people.

A reconnaissance survey was conducted to design a detailed questionnaire that was divided into four major sections:

1. Section I - Socioeconomic Profile
This part of the questionnaire was designed to understand human livelihoods and natural resource dependencies in villages within GIB habitats. It aimed to gather knowledge about current livelihoods and ways of introducing GIB-friendly alternative livelihoods. For pastoralists, information was obtained regarding where grazing resources were available (grasslands, market fodder, harvested crops), quantifying their economy and assessing the potential for community fodder farms. This approach aimed to improve cattle nourishment and foster better relations with the local community, thereby benefiting conservation efforts.
2. Section II - Human-animal conflict
Information on the current status of human-animal conflict, particularly the severity of the problem of free-ranging dogs and pigs so that problem animal population control measures can be implemented to reduce this conflict.
3. Section III – Pastoralism and institutional arrangements
An understanding of conventional pastoral practices and whether they had changed. Specifically, information on reduction in livestock holding, nomadism, or herding were enquired. If pastoralists reported reductions, the causes behind these changes were recorded. Additionally, an assessment was made to determine if pastures with better institutional arrangements or enforcement had experienced less change. This approach aimed to explore the role of institutional arrangements in grassland conservation efforts.
4. Section IV- Veterinary support assessment
Information was gathered on the amount of veterinary support received from the government and whether pastoralists were satisfied with it, aiming to understand differences in livestock health and survival between aided and unaided villages. If differences were noted and attributed to improved veterinary facilities from the government, the inquiry considered whether pastoralists would opt for reducing surplus livestock in exchange for better veterinary services. Moreover, the project aimed to identify potential sites for translocating livestock if the intervention proved successful.
5. Section V - Local communities' attitudes and perceptions towards conservation
Perception studies among communities in areas neighbouring DNP were conducted to assess awareness regarding conservation and existing attitudes toward conservation efforts. The goal was to gain a better understanding of the perceptions of locals toward DNP and to effectively incorporate this information into future management strategies to enhance conservation effectiveness. The focus was to assess the attitudes and perceptions of people toward wildlife, local species conservation, the purpose of protected areas, and role of the Forest Department.

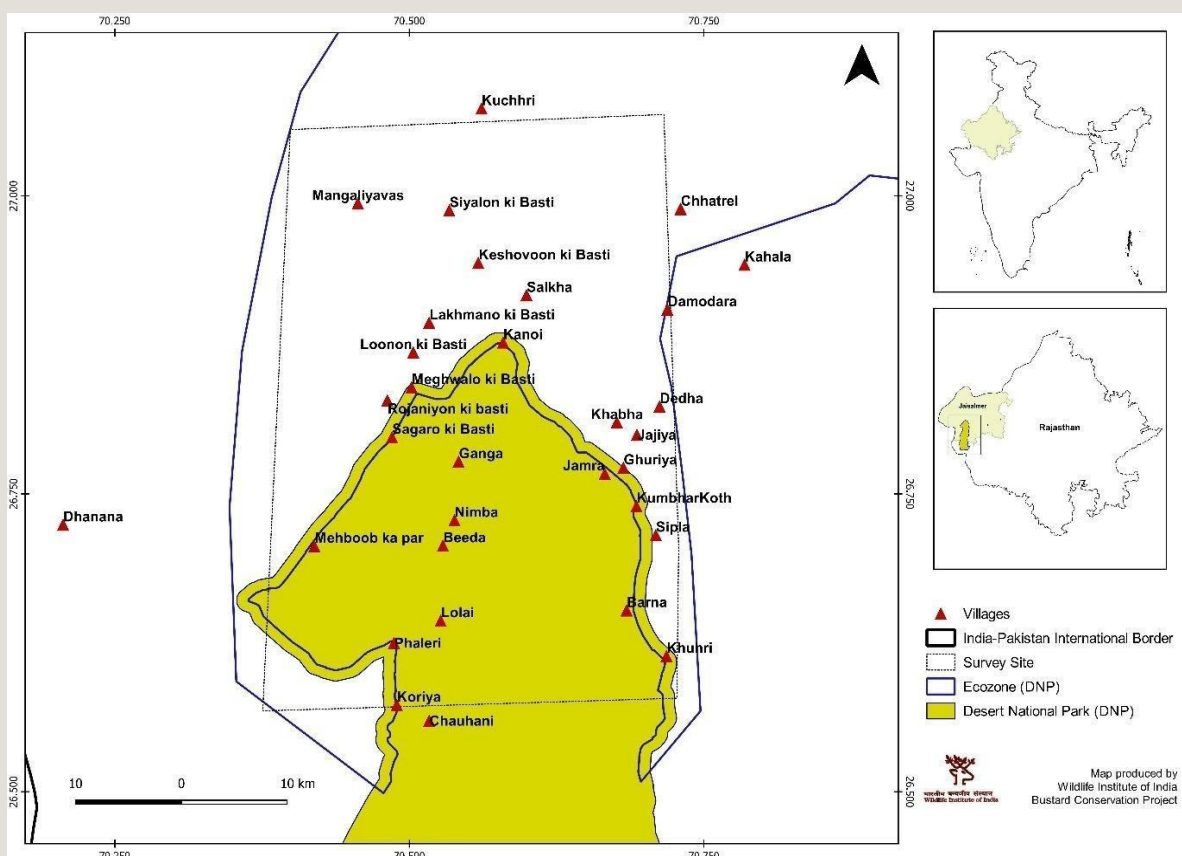


Figure 50. Map showing villages where household surveys were conducted in and around Desert National Park, Jaisalmer

Our focus was a) to examine whether locals are open to alternative income sources and if they have the infrastructure and skills for those livelihoods so that alternate livelihood programmes could be offered to reduce their dependence on grassland resources and also win them over for conservation, b) to understand the spectrum of problems they face in order to neutralise the current park vs people narrative, c) to know grazing pressure on grasslands, and d) to conserve grassland habitats.

Questionnaires (n=158) revealed that local communities depend largely on agriculture > daily wage > pastoral livelihoods, with a few involved in tourism-related and other activities (Figure 51). An average household owned 14.43 (1.26 SE) acres of agricultural land. Among livestock, goats were the most commonly reared animal, followed by sheep, and cattle (Figure 51). Traditionally in a pastoral society, households generate additional revenue by selling milk and dairy products. The desert ecosystem is characterised by low agricultural productivity due to one monsoonal crop, and crop raiding by free-ranging animals was reported.

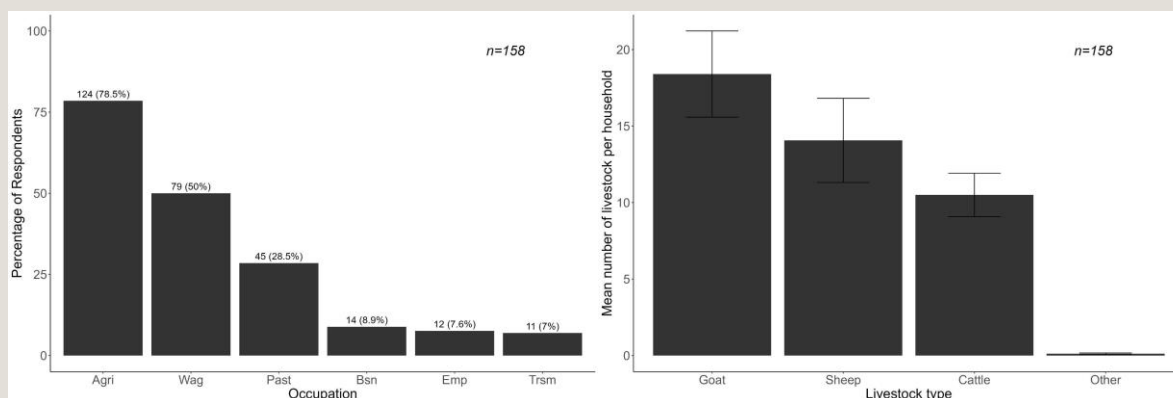


Figure 51. The livelihood of villagers in and around Desert National Park, Jaisalmer (right) (n=185) (Agri - Agriculture, Wag - Daily wager, Past - Animal husbandry, Bsn - Business, Emp - Employed, Trsm - Tourism activities) and the Mean number of livestock holding by villagers in and around Desert National Park (left). Error bars are standard errors

The reduction of grasslands was reported to be a major concern for pastoral livelihoods, as it led to a severe shortage of fodder and compelled communities to seek alternative sources. The fodder requirement (total responses n=156) was met by grazing in open grasslands (72%; n=113), agricultural fields (30%; n=48), and purchasing fodder (16%; n=25) (Figure 52). Livestock travelled an average distance of 5.5 km (0.64 SE) to grazing lands.

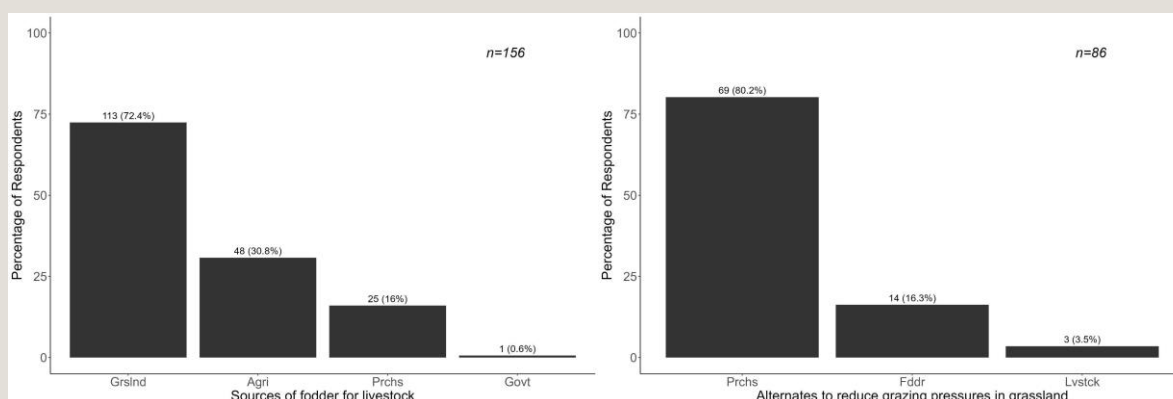


Figure 52. Sources of fodder for livestock (n=156) (GrsInd = Grazing in grassland, Agri = Grazing in harvested agricultural field, Prchs = Purchase from market, Govt = Government subsidised/distributed fodder) (left) and Alternatives suggested by respondents to reduce grazing pressure on village pasture land in and around Desert National Park, Jaisalmer (n=86) (Prchs = Purchase from market, Fddr = Cultivating fodder, Lvstck = Reduce the number of livestock) (right)

89% of respondents (n=141) owned some kind of livestock and reported 1,659 livestock deaths over a period of two years (2017 and 2018). Livestock mortality was primarily attributed to disease, and a few cases of depredation of sheep and goats (10%, 162 cases) (Figure 54). Among these, 29 kills were reportedly caused by free-ranging dogs.

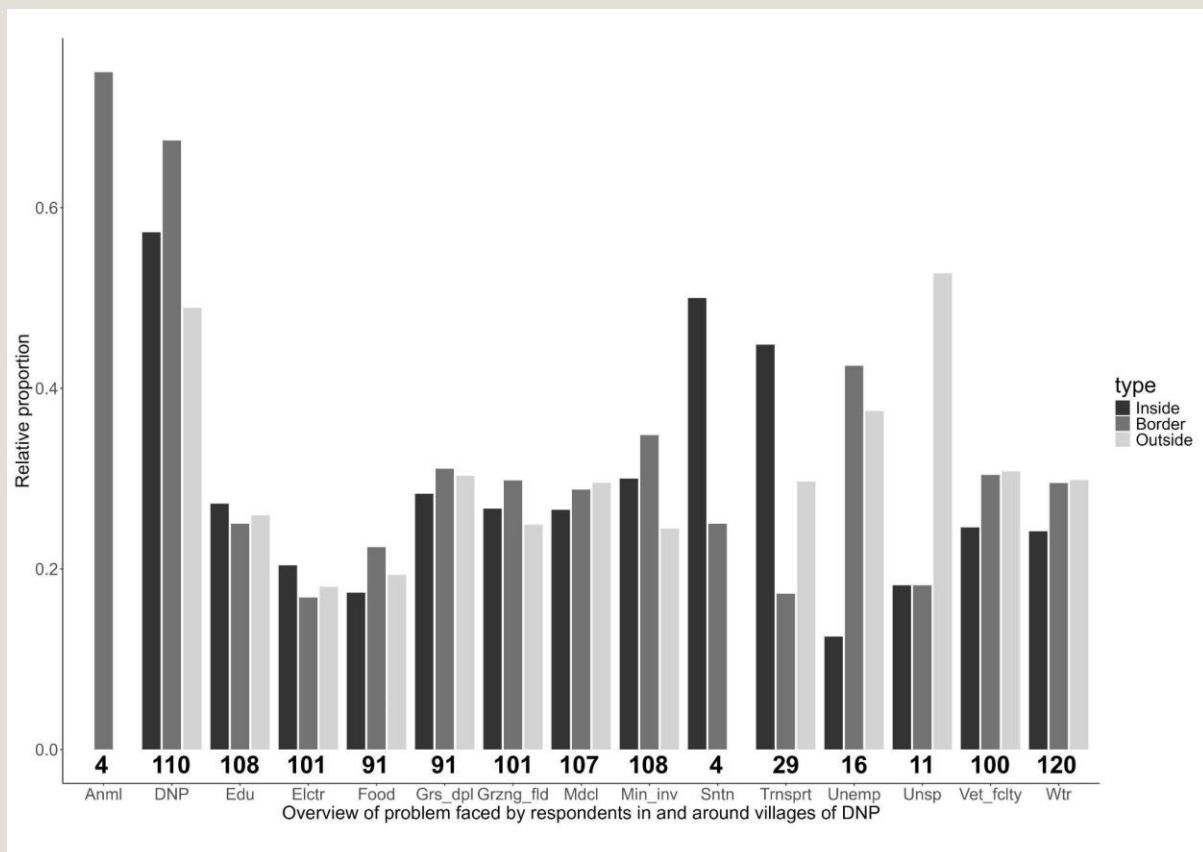


Figure 53. A comparative overview of respondents facing problems, residing inside, outside and border villages/dhanis of Desert National Park (numbers mentioned on the X-axis indicate the number of respondents answered for a particular problem) (Anml = Free-ranging animals, DNP = Restricted access to Desert National Park, Edu = Education, Elctr = Electricity, Food = Food resources, Grs_dpl = Grassland depletion, Grzng_fld = Grazing field, Mdcl = Medical facility, Min_inv = Minimal involvement of government in management, Sntn = Sanitation, Transport = Transportation, Unemp = Unemployment, Unsp = Unspecified, Vet_fclty = Veterinary facility, Wtr = Drinking water)

Respondents living inside and on the fringe of DNP rated issues such as restricted access to DNP, less availability of livestock grazing fields, minimal involvement of authorities in management-related actions, transportation, free-ranging animals and sanitation facilities as major concerns. For residents living outside DNP, the major concerns were grassland depletion outside DNP, medical and veterinary facilities, unemployment and drinking water availability (Figure 53).

According to the survey, 38% (n=60) of respondents reported having direct or indirect benefits from DNP. Locals indicated that tourism has not significantly addressed their daily needs, with only 7% of people relying on tourism activities (Figure 53). Most villagers (118 respondents) believed that the primary causes of grassland degradation were climate change and agricultural expansion, whereas some attributed it counterintuitively to the formation of DNP enclosures (Figure 53).

The majority of villagers (total respondents 97) believed that, over time, wildlife populations in the area had drastically decreased (71%, n=69). They associated this decline with grassland and resource depletion, hunting, development of energy infrastructure, free-ranging dogs, and even the creation of protected enclosures in DNP (Figure 54).

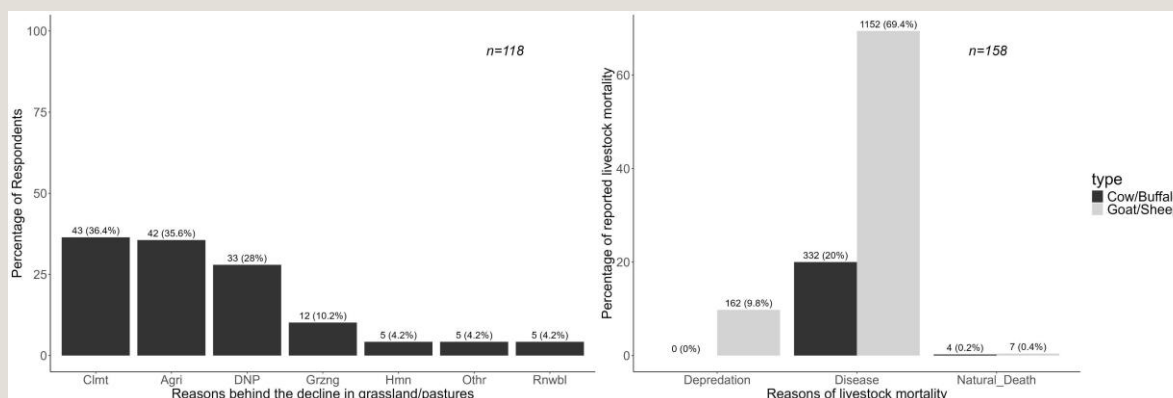


Figure 54. Reasons suggested behind decline in area of grasslands/pastures (n=118) (left) (A – Climate change, B – Agricultural expansion, C – Formation of DNP enclosures, D – Overgrazing, E – Increase in human population, G – Expansion of renewable energy infrastructures, F – Others) and Reasons behind decline in the number of livestock according to respondents in and around Desert National Park, Jaisalmer (n=158) (right)

To address the conservation challenges in and around DNP, it is recommended to develop alternative livelihood programs. These programs can provide locals with the necessary infrastructure and skills to decrease their dependence on grassland resources and encourage support for conservation efforts. Additionally, enhancing grassland management is essential, which involves restoring grasslands, creating community fodder farms, and regulating grazing pressure. Furthermore, strengthening community engagement by increasing local involvement in park management and addressing concerns regarding regulated access and ecotourism-related activities can improve understanding among the surrounding communities.

8. Genetic analysis

Species like the GIB which have highly fragmented and small populations are highly vulnerable to extinction events due to environmental and demographic stochasticity. These populations are also more susceptible to genetic drift leading to a decrease in genetic variation and limited fitness or the fixation of deleterious mutations. Gaining insight into the population genetics of the species such as bottleneck events, population differentiation, dispersal and gene flow between sub-populations can be vital to planning and prioritising scientifically informed conservation action. The only genetic study on GIB (Ishtiaq et al. 2011) identified low genetic variation in mtDNA. It emphasised the importance of using nuclear DNA microsatellite markers to determine the population genetic structure at different spatial scales and sex-specific dispersal patterns in GIB. Furthermore, conservation breeding efforts need to secure a founder population that captures the extant gene pool and carry out strategic breeding of individuals to maintain high effective population sizes and genetic representation of founders in subsequent generations. Maintaining genetic diversity through selective breeding in captivity is a key factor for successful conservation breeding and release programs.

8.1. Genetic structure analysis of GIB populations to aid conservation management

A comprehensive population genetic study of GIBs from their present distribution ranges was conducted to develop genetic datasets consisting of mtDNA and nuclear microsatellites. The data was analysed to identify extant levels of genetic diversity and investigate population differentiation and gene flow across different subpopulations of GIB. This would help evaluate the genetic status of GIB to identify conservation units, if any, to suggest long-term conservation strategies for the species.

Non-invasive samples (faeces, feathers and tissue samples from dead birds) were collected between 2006-2019 from Gujarat, Rajasthan, Maharashtra, Madhya Pradesh and Andhra Pradesh. All the samples were stored either in a sterile ziplock bag filled with silica or preserved in 90% ethanol and later shifted to the laboratory for storage at -20°C until DNA extraction. Total genomic DNA was isolated from faecal samples using Guanidine

isothiocyanate–silica extraction protocol (Boom et al. 1990), tissue samples and moulted feathers using DNeasy blood and tissue kit (Qiagen), and egg membranes using Bush et al. (2005) methodology. Species identities of pellets, egg membranes and feather samples were established by amplifying and sequencing a considerable proportion of either a 399 bps fragment of the cytochrome b gene (LCyt-B4 and LCyt-B6; Broderick et al. 2003) or a 323 bps fragment of control region II (L438 and H772; Wenink et al. 1993) and gene bank comparison.

Eleven polymorphic fluorescently labelled microsatellite loci, namely BUSA2, BUSA10, BUSA22, BUSA112, BUSD110, BUSA18, BUSA205, BUSA210, BUSD117, BUSD12, BUSA204, BUSD118, BUSA29, BUSD119 (Chbel et al. 2002) were amplified by Polymerase chain reaction (PCR) amplification. PCR products were electrophoresed using ABI 3130 Genetic Analyser (Applied Biosystems) with Genescan 500 (-250) LIZ with internal lane size standard and alleles were scored manually using Genemapper software (version 3.7, Applied Biosystems).

Microsatellite genetic variation was characterised for each inferred cluster and all areas combined using summary statistics. The number of alleles (Na), mean number of alleles (MNA), expected (He) and observed (Ho) heterozygosity and allelic richness (AR) for all the microsatellites were estimated using FSTAT ver.2.9.3.2 (Goudet 1995). Information on polymorphic information criteria (PIC) was calculated using CERVUS ver.3.0 (Kalinowski et al. 2007). Significant deviations from Hardy-Weinberg equilibrium at each locus using exact tests (Guo and Thomson 1992) and linkage disequilibrium among all pairs of microsatellite loci were estimated using GENEPOP ver.1.2 (Raymond and Rousset 1995). Bonferroni corrections ($P < 0.05$) were applied for multiple comparisons. ARLEQUIN ver.3.5 (Excoffier and Lischer 2010) was used to calculate Wright's F-statistics and to test the statistical significance between the sampling locations using Weir and Cockerham estimator (Weir and Cockerham 1984) with 10,000 permutations.

Population genetic structure was analysed by computing Wright's F statistics using Arlequin v 3.5 (Excoffier and Lischer, 2010). Alternative genetic differentiation estimators GST (Meirmans and Hedrick, 2011) and DEST (Jost, 2008), which correct for the dependency of FST on the amount of within-population variation were also calculated using GenAlEx v 6.5 (Peakall and Smouse, 2006). Additionally, AMOVA test was carried out to assess genetic variation between sampling sites and when grouped by geographic locations using Arlequin v 3.5 (Excoffier and Lischer, 2010). Multilocus genotypes of GIB individuals were further analysed using the non-spatially explicit Bayesian clustering algorithm, STRUCTURE ver. 2.3.4 (Pritchard et al. 2003) wherein a Bayesian-based Markov chain Monte Carlo (MCMC) approach is used to identify the number of populations (K). STRUCTURE HARVESTER (Earl and vonHoldt 2012) was used to determine the optimal value of K (number of assumed genetic clusters) by calculating the mean likelihood of data (Pritchard et al 2000) and the rate of change in the log probability between successive K values (Delta K) (Evanno et al. 2005). In the multivariate analysis, Discriminant analysis of principal components (DAPC), a non-model-based method was used and Principal Coordinate analysis (PCoA) was carried out using GENALEX ver.6.5 (Peakall and Smouse 2006).

Out of a total of 228 non-invasive samples, amplifiable DNA was extracted from only 112 samples, of which 96 samples were identified as GIB samples based on Cyt B and CR II regions. From the 96 GIB samples, 83 yielded microsatellite data for more than nine loci out of the panel of 11 microsatellites (3 microsatellites were found to be monomorphic and not used for further analysis). These were considered for Identity analysis in CERVUS and gave 73 individuals with 18 recaptures. The total number of individuals used for analysis in this study constitutes ~50% of the extant GIB population based on census data.

Low levels of genetic diversity were observed for both the mtDNA and microsatellite loci for the GIB (results summarised in Table 11). Microsatellite markers used were designed for the Houbara bustard and they were found to be moderately polymorphic (2–5 alleles per locus) with low PID (sib) values (7.0×10^{-3}) but of sufficient power to allow individual identification within the small GIB population. The heterozygosity estimate observed in GIB (0.32) was very low and comparable to other critically endangered and endangered birds. Moreover, the

observed deviations from HWE and significant LD across microsatellite loci often occur due to drift, inbreeding, and null alleles which further contribute to heterozygote deficiency. The population showed evidence of historic bottlenecks as witnessed by the low M ratios (< 0.68). The low genetic diversity was also reflected in the complete lack of population structuring among mtDNA haplotypes (Fig. 2), which were not partitioned according to geography or sampling locality. It appears that GIB populations are still under the phase of genetic impoverishment due to ongoing demographic contraction and loss of rare alleles. A full genome sequence analysis may provide a better understanding of the timing and occurrence of demographic events in the evolutionary history of GIB.

Table 11. Genetic diversity indices of GIB populations based on eight microsatellite and partial mtDNA (CR and Cyt b) sequences (Srinivas et al 2022).

GIB Populations	Microsatellites								Mitochondrial DNA				
	N	MNA	Na	AR	Ho	He	ARA	F_{IS}	N	h	π	Tajima' D value (p-value)	Fu's F value (P-value)
Gujarat	43	3.5	3	1.45	0.32	0.45	21.5	0.29	43	0.468	0.0009	0.050 (0.593)	-0.078 (0.460)
Rajasthan	17	3.75	1	1.59	0.35	0.6	23.75	0.43	17	0.691	0.0013	0.517 (0.731)	-0.943 (0.277)
Maharashtra	6	2.5	–	1.42	0.34	0.49	18.29	0.32	6	0.332	0.0004	-0.933 (0.265)	-0.002 (0.241)
Madhya Pradesh	2	1.75	–	1.45	0.17	0.61	12	0.8	2	–	–	–	–
Andhra Pradesh	5	2	–	1.32	0.34	0.37	8.75	0.11	5	–	–	–	–
Overall Mean (SD)	73	2.7 (0.83)	–	1.44 (0.22)	0.32 (0.08)	0.53 (0.22)	16.82 (11.59)	0.41 (0.25)	73	0.554 (0.050)	0.001 (0.000)	0.501 (0.737)	-1.336 (0.243)

N = Number of samples, MNA=Mean no. of alleles, Na=Number of Private alleles, AR=Allelic richness, Ho=Observed heterozygosity, He= Expected Heterozygosity, ARA=Allelic range, F_{IS} =Wright's fixation index estimate, h= Haplotype diversity and π = Nucleotide diversity, SD=Standard deviation.

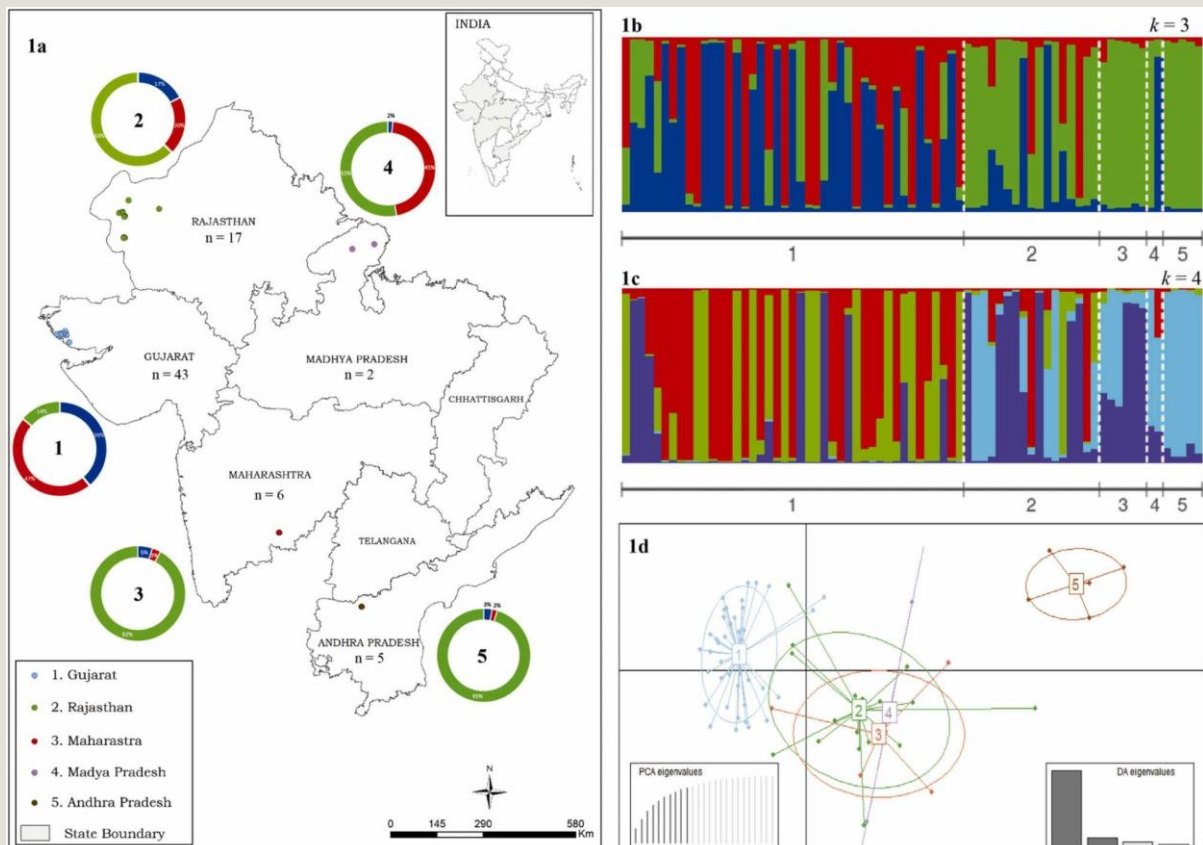


Figure 55. Result of different Bayesian and non-Bayesian clustering analyses to understand the population genetic structure of GIB based on microsatellite loci. a) Map of the study area with geographic locations of GIB

samples, prepared using ArcGIS 10.3. Coloured dots represent samples with microsatellite and mtDNA data and the location from where they were collected. Geographical regions are depicted as States of 1) Gujarat, 2) Rajasthan, 3) Maharashtra, 4) Madhya Pradesh, and 5) Andhra Pradesh shaded in the map inset of India. Doughnut represents the admixture coefficients in each sampling location based on STRUCTURE results at $k = 3$. b) Bar plot of STRUCTURE results for the most likely number of clusters based on ΔK method ($k = 3$, $LOCPRIOR = 1$). c) Bar plots of TESS results for the most likely number of clusters based on DIC criterion ($k = 4$). d) Scatterplot of DAPC with each population indicated by different colour codes (similar to sampling locations) and inertia ellipses shown on the first two axes

Population genetic analysis using three different approaches converged in identifying the same three population genetic units (Figure 55). Gujarat and Andhra Pradesh populations are grouped into two different clusters, the remaining localities of Rajasthan, Madhya Pradesh and Maharashtra were classified to the same genetic cluster. The early divergence of Gujarat from other localities makes ecological sense since the extant GIB population was sampled from the Kachchh region of Gujarat which is separated from other GIB populations by a vast stretch of sea (Gulf of Kachchh) and a large expanse of salt desert (the Rann of Kachchh), likely to be barriers to gene flow. Population divergence in the other localities seems more recent by comparison. The central cluster of Rajasthan, Madhya Pradesh and Maharashtra show features similar to metapopulation source-sink dynamics, as there is evidence of moderate unidirectional migration from Rajasthan to Madhya Pradesh (9.9%) and Maharashtra (4%), but very low migration in the other direction. Gujarat and Andhra Pradesh populations appear totally devoid of migrants and are thus effectively isolated from all other populations in the landscape. Interestingly, the Rajasthan population was found to have allelic representation from almost all extant populations which implies that these entire localities likely formed a single panmictic population maintaining demographic and genetic connectivity until recent times. The spatial autocorrelation suggests that populations > 400 km apart were genetically unrelated. With the source value of Rajasthan population continuously declining (Dutta et al., 2014) the likelihood of Madhya Pradesh or Maharashtra being repopulated naturally by GIB is bleak. The only in-situ population that can potentially recover is that of Rajasthan if threats are mitigated immediately. The role of reintroduction and reinforcement from conservation-bred birds is paramount for the recovery of GIB in much of its former and extant range.

8.2. Conservation genomics

The study of conservation genomics using tools like NextGen sequencing can be used to estimate genetic diversity, mutational load, inbreeding, gene flow and migration patterns, demographic history and effective population size etc. Although the genetic data sets (targeted sequencing and microsatellites) can be used to estimate the above-mentioned parameters, genome-scale data, with an increased density of markers across the genome, can provide more accurate estimations. Therefore, a reference genome of GIB was generated and two more individuals were re-sequenced to help in conservation management of the species.

High-quality genomic DNA (>50KB insert size) was extracted using QIAGEN Genomic-tip 100/G genomic DNA isolation kit (Cat No. 13343). The samples were processed for library preparation followed by sequencing of libraries using PacBio Sequel II and Illumina platforms. Data analysis was finally carried out to create a reference genome for the GIB. The reference genome was further used in combination with two other re-sequenced individuals to gain insights into genetic diversity, inbreeding, demographic history and effective population sizes.

8.2.1. SSRs identification

Mono- to hexa nucleotide Simple Sequence Repeats (SSRs) motifs were identified using two different tools MISA (MISroSATellite identification tool) and PERF. The common SSRs identified from MISA and PERF for each assembly were identified and merged by intersecting with a 90% threshold using Bedtools Intersect. To match the regions containing SSRs and to have concordant flanking regions, 100bp around each SSR was included. This was performed by “slopping” around each SSR using Bedtools.

Table 12. SSR Statistics and comparison of SSRs identified in three individual GIB's (GIB3, Gib 4, and GIB6)

Type of SSRs	GIB4		GIB3		GIB6	
	Number of SSRs	Length of SSRs	Number of SSRs	Length of SSRs	Number of SSRs	Length of SSRs
Mono	127753	1955278	121910	1824949	120782	1812932
Di	8799	138840	8890	133928	8515	128350
Tri	12373	173514	12436	169572	12094	165570
Tetra	22800	302460	23085	296036	22523	289376
Penta	5502	103680	5507	105515	5361	103950
Hexa	217230	2617128	198181	2388000	191494	2306778
Total	394457	5290900	370009	4918000	360769	4806956

8.2.2. PSMC analysis for demographic changes in the past

PSMC (Pairwise Sequential Markovian Coalescent) analysis was conducted using the resequencing data with 40.297 coverage filtering by excluding sex chromosomes and missing sites and setting minimum read depth (-d) and maximum (-D). The recommended (<https://github.com/lh3/psmc>) parameters were used to set -d to a third of the average depth and -D to twice. The upper limit of the number of recent coalescent events joining sequences was set to 5 (by -t option) and the initial h/q value to 1 (by -r option). Other parameters i.e. -p was set to "4+30*2+4+6+10" to infer Ne. To check for variance in Ne, 100 bootstrap replicates were performed (the number of replicates was limited by computational time). A generation time of 3 years and a mutation rate of 1.4×10^{-9} years/site were applied.

Estimates of effective population size are presented on the y-axis as the scaled mutation rate (Figure 56). The bottom x-axis represents per-site pairwise sequence divergence and the top x-axis represents years before present, both on a log scale. Darker lines represent the population size inference, and lighter thinner lines represent 100 bootstraps to quantify the uncertainty of the inference.

The PSMC graph (Godfrey, 2000; Jilong, 2023) of the Great Indian Bustard population indicates fluctuations in effective population size (N_e) over time. During the Last Glacial (LG) period, there was an increase in N_e ranging from 100,000 to 750,000 individuals. This period was characterised by cooler global temperatures, extensive glaciations, and arid conditions in many regions. The Great Indian Bustard population likely expanded during this time, taking advantage of expanding habitats such as grasslands and semi-arid landscapes, which are favourable for their foraging and breeding. However, following this glacial period, there was a population decline during the subsequent warmer phase known as the Last Interglacial (LIG) period. The LIG was marked by higher global temperatures and more humid conditions compared to the LG. These climatic changes likely led to the contraction and fragmentation of suitable habitats for bustards, reducing available resources and causing a decline in population size. The fluctuating N_e observed in the PSMC graph reflects the bustard population's responses to these climatic shifts over these epochs, underscoring their vulnerability to habitat changes influenced by global climate variations.

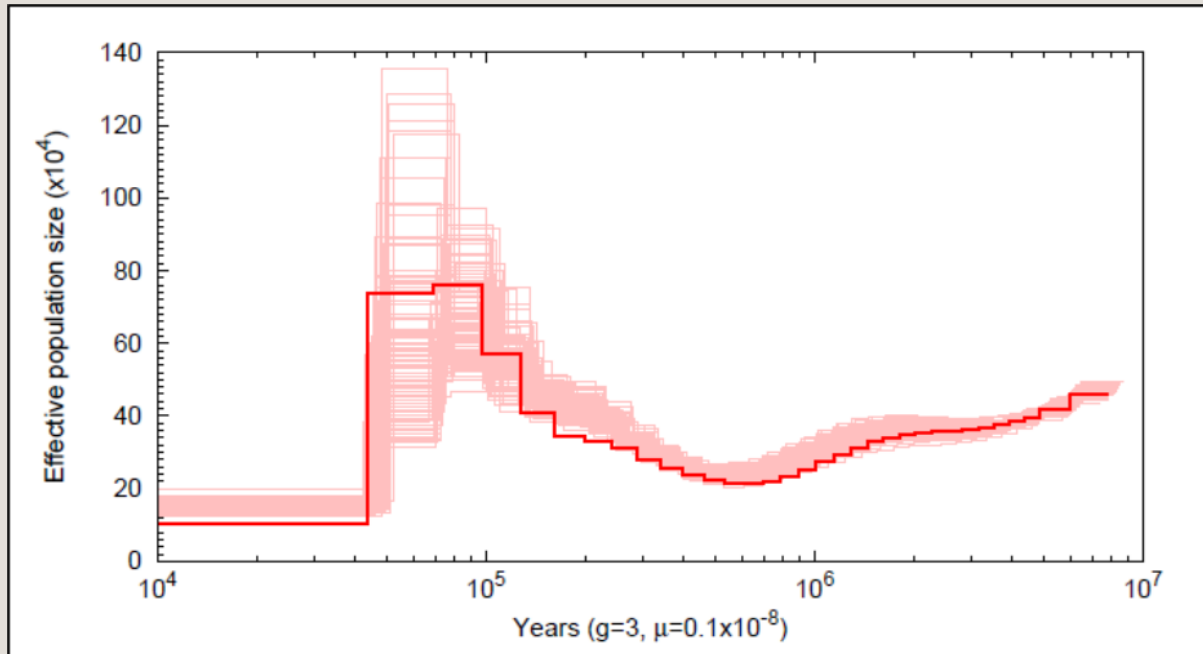


Figure 56. Demographic History Analysis and PSMC Effective Population Size estimates for GIB

8.2.3. Gene gain/loss analysis

OrthoFinder identifies orthogroups and uses them to infer gene trees for all the orthogroups and analyses these gene trees to identify species trees. Orthofinder was used to define gene families across 8 genomes: GIB *Ardeotis nigriceps* (from this study), and wild turkey *Meleagris gallopavo*, mallard *Anas platyrhynchos*, zebra finch *Taeniopygia guttata*, collared flycatcher *Ficedula albicollis*, red junglefowl *Gallus gallus*, (downloaded from Orthovenn2), MacQueens bustard *Chlamydotis macqueenii* and North Island brown kiwi *Apteryx mantelli* species (downloaded from GenBank). Gene gain and loss rates were then estimated within the eight species using a two-lambda model (one lambda value for bustards and the other for the rest of the species), implemented in the package CAFE (computational analysis of gene family evolution; v 4.2.1.).

The number of gene gain ('+'; green colour), gene loss ('-'; red colour) and rapidly evolving gene families (orange colour) are mentioned above the species name (branches) (Figure 57). CAFE was used to estimate death and birth rate (λ) using a two lambda model with $\lambda=0.0026$ for bustards and $\lambda=0.0014$ for the rest of the species.

Gene gain/loss analysis identifies which genes are expanding or contracting in a population, shedding light on evolutionary trends. Mitogenome annotation provides basic gene composition; further analysis is required to understand adaptive selection genes, particularly revealing which adaptive genes the Great Indian Bustard (GIB) may have lost over evolutionary time, and other insights into its genetic adaptations.

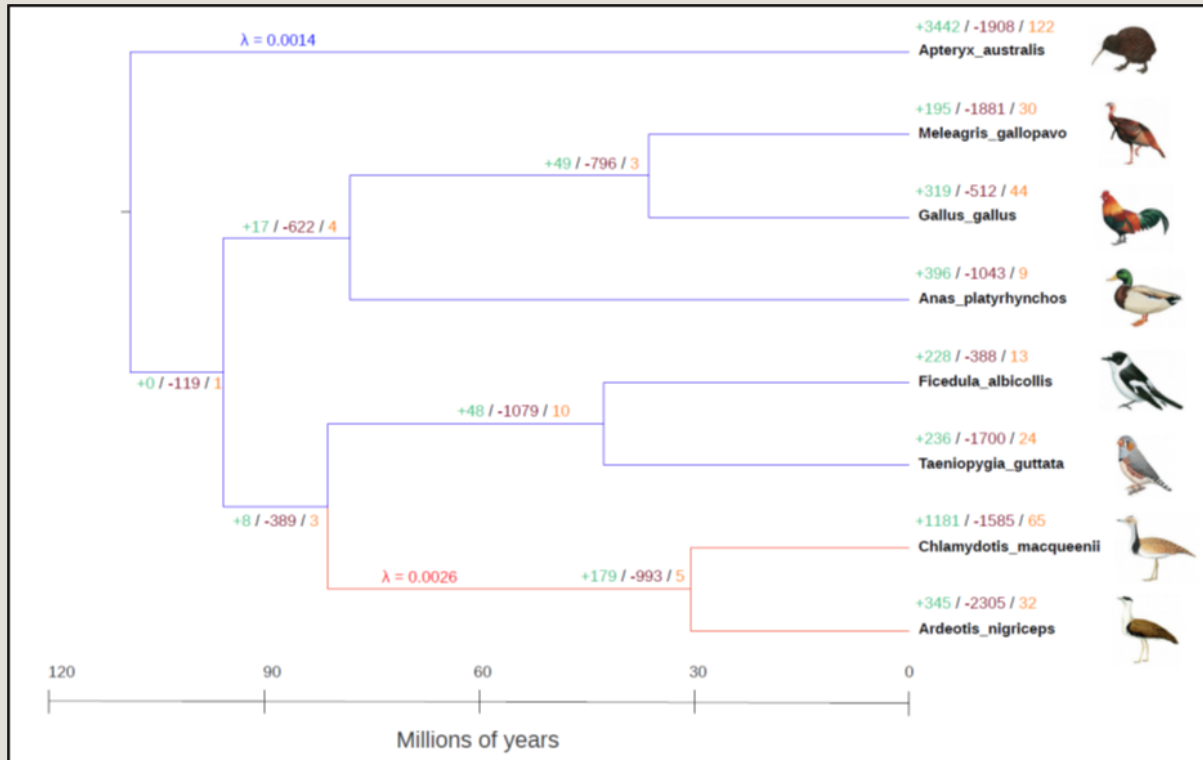


Figure 57. Gene gain and gene loss in the eight bird species

8.2.4. Mitochondria genome assembly and annotation

The assembled genomes of GIB were subjected to blastN against the published bird MT genomes to extract mitochondrial-like contigs. Contigs having more than 90% coverage were selected and subjected to annotation using MITOS2 web server and the circular map of the mitochondrial genome was drawn using OGDRAW online tool. A total of 14 protein-coding genes, 22 tRNAs and 2 rRNAs were identified in GIB.

Visualisation of the mitochondrial genome was done using Organellar Genome DRAW (OGDRAW) with different genes represented with different colour blocks (Figure 58). The colour blocks outside the ring indicate genes that are located on the positive strand, and the colour blocks within the ring indicate genes that are located on the negative strand.

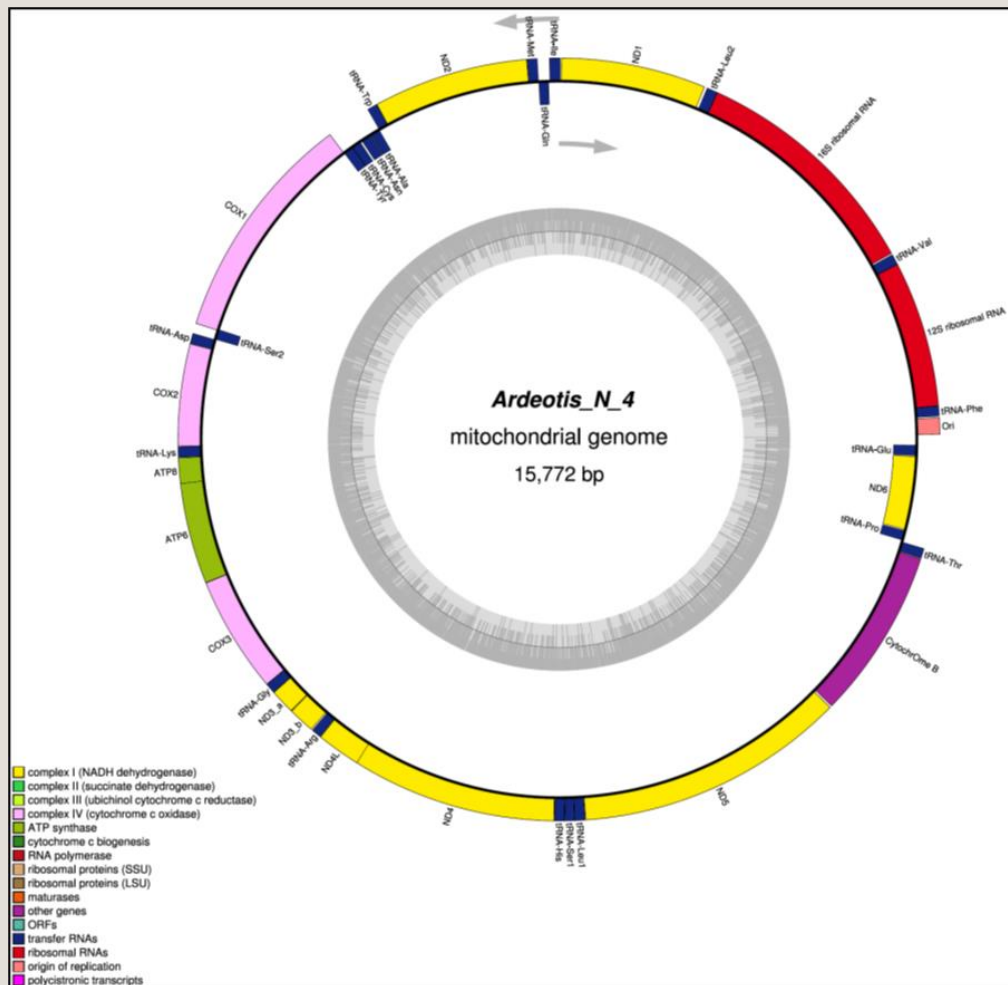


Figure 58. Graphical representation of GIB Mitogenome

8.3. Identification of GIB from tissue and feather samples of carcass

Feather and tissue samples of unidentified carcasses suspected to be GIB have been sent by DFO Jaisalmer to WII for species identification. DNA was extracted using the DNeasy Blood and Tissue kit. Cytochrome B, control region and 16s regions of the MtDNA were amplified using PCR and Sanger sequenced. The sequences were compared with the online repository of sequences available on NCBI and were found to match with GIB, confirming the carcasses belong to GIB.

9. Land use land cover classification

The classification of Land Use Land Cover (LULC) in the Thar Desert undergoes severe seasonal changes and the land cover is crucial to identify suitable habitats for GIB, particularly grassland and savannah areas. The study area of 27488 km² was categorised into land cover types: grassland, grassland-savannah, scrubland, woodland, shrubland, sparse vegetation/open land, agriculture, and settlements.

In the initial phase of the study, a false colour composite (FCC) using Shortwave Infrared (SWIR), Infrared (IR), and Green (G) bands from Landsat 8 OLI data (August 2015) was utilised. Using ground reference points collected during the landscape GIB surveys, land covers were classified into nine categories: sparse, moderate grassland, dense grassland, savannah, tree-dominated woodland, mixed woodland, open scrubland, dense scrubland, and agriculture. These points were evenly split for training and testing purposes.

Further, supervised classification was conducted using these ground points and Google Earth imagery. Multiple iterations were done with classifications of up to 600 classes, but pure habitat (grass and savannah) and non-habitat (scrub/shrub/agriculture/sparse) classes could not be distinctly separated. Consequently, pixels representing agricultural fields and settlements were manually digitised and outsourced with the help of Science Pvt. Ltd. Meanwhile, an unsupervised classification generated 500 classes, which were cross-referenced with Google Earth imagery and categorised into vegetation and non-vegetation layers.

A vegetation-only layer was extracted from the FCC, excluding sand dunes, sparse vegetation, thorny scrub, and woody areas. This layer was converted to a shapefile, resulting in an FCC image focusing on vegetation. The digitised agricultural areas were then removed from this image, yielding a composite with grassland, grass/savannah, shrubland, and scrubland classes. Further supervised classification of four classes was performed by making 500 classes, identifying pure grass/savannah. However, despite these efforts, some areas with significant grassland and savannah were not included in the classified surface. To refine the data, a spectral indices approach was adopted to identify habitat and non-habitat categories for GIB, selecting pixels within a defined range of index values (Figure 59). Unfortunately, even after resampling to a 1 km x 1 km grid unit, some critical habitat areas were still not captured. Spectral indices included MCARI, MSAVI, MSI, NDVI, SARVI, TNDVI, RVI, RDVI, NBR, MTVI and MidIR.

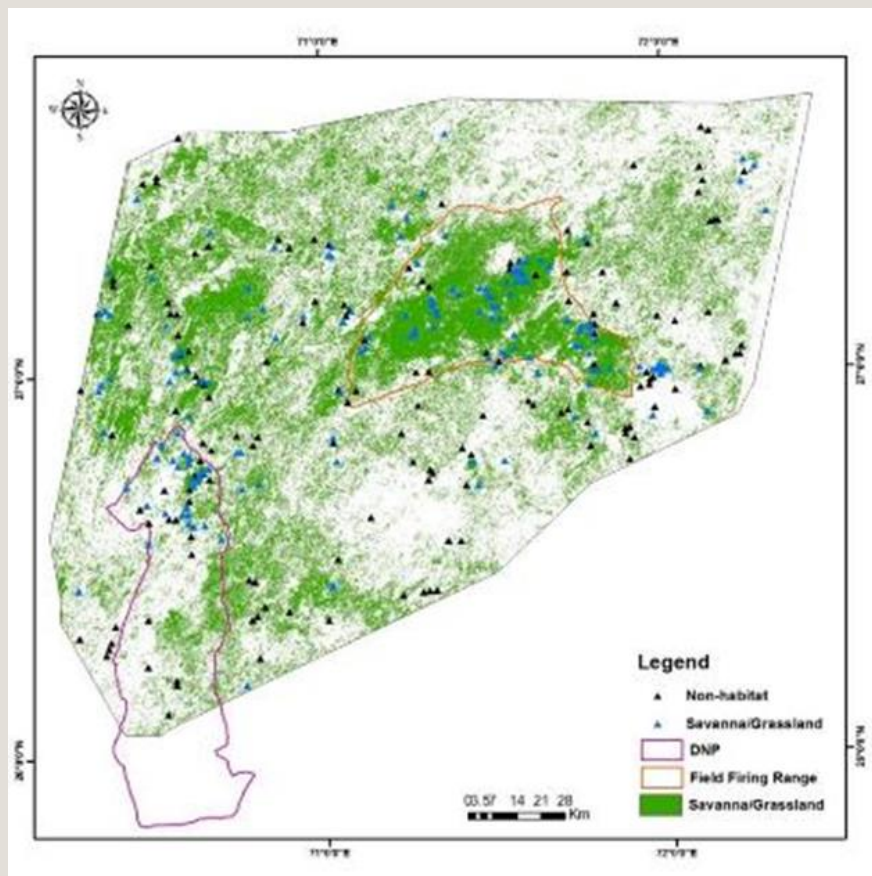


Figure 59. Classified images of habitat (Grassland and Savanna) and non-habitats in Thar landscape

The resulting LULC map will aid in understanding habitat use and distribution of grassland-associated species and monitoring changes in grassland/savannah habitats. A recent 2022 LULC classification update has further refined these classifications, providing more accurate and up-to-date information on habitat conditions. For this, Sentinel -2 satellite imageries were accessed online through the Google Earth engine (from 06-01-2020 to 15-12-2020) (10 m spatial resolution). A set of signatures from ground and Random Forest algorithm were used to classify seven land cover classes, namely, Agriculture, Barren, Grassland, Scrubland, Woodland, Settlement and

Waterbody. Signature features were classified 80 - 20 proportion for training and testing of the classification model, respectively. The output land cover classification model yielded an overall accuracy of 81.67% and kappa 0.74, supporting the high accuracy of classification. In addition, NDBI and NDWI indices were used to enhance the model accuracy. Further, a smaller area from the Thar landscape was considered by integrating more number of ground truthing points, where model accuracy was enhanced and the number of land cover classes were increased to 11, namely, Settlement, Flat scrubland, Flat grassland, Undulating scrubland, Undulating grassland, Woodland, Sand dunes, Barren, Agriculture, and Waterbody (Figure 60). This postprocessing also involved terrain ruggedness factor to identify the pixels as flat or undulated.

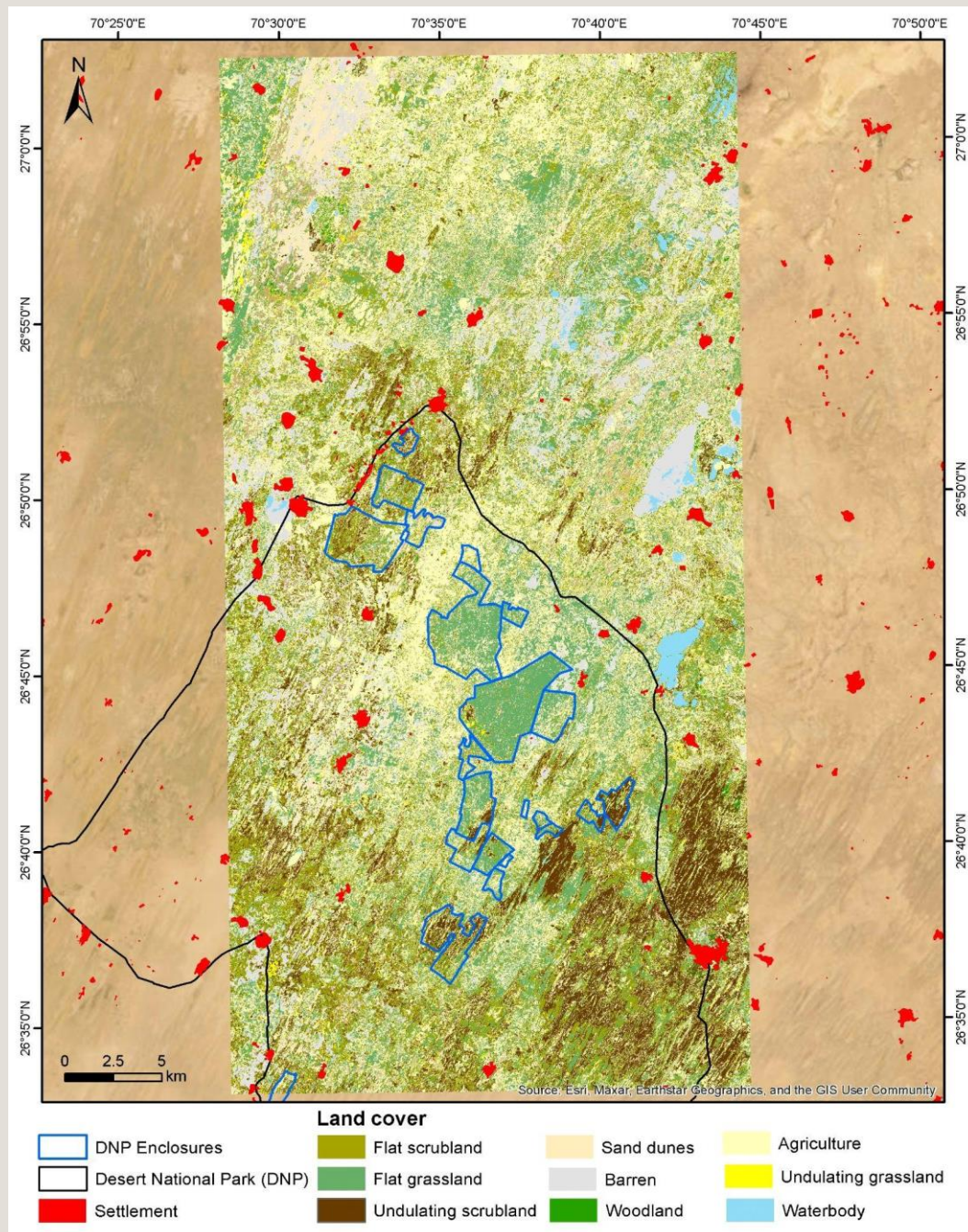


Figure 60. Map of more intensively classified land cover classification in and around DNP

**OUTREACH & ACTIONS
FOR IN-SITU
CONSERVATION**



Outreach & Actions for In-situ Conservation

1. Dissemination of project findings

1.1. Spatial prioritisation – delineation of Priority and Potential Area

The GIB is inherently dependent on large landscapes and uses widely dispersed habitat patches for meeting various biological needs in resource poor environments. Thus, maintaining large areas without critical threats is important for population recovery and long-term conservation of the GIB. Given this requirement, identifying important conservation areas beyond the protected area network and ensuring connectivity holds immense importance. Such an area was previously identified in the DNP Management Plan as the 'GIB arc' and the proposed "Thar Biosphere Reserve" by the Rajasthan Government. In a meeting held on 25.05.2016, and chaired by the Pr. Sec. Energy, Government of Rajasthan, it was decided that laying transmission lines in the GIB Arc may be avoided and the GIB habitat/Arc be properly mapped so that potential interventions and financial implications can be identified. Comprehensive mapping of GIB habitats, power lines, and wind turbines in this area, assessment of the impact of power lines on GIB and other birds, and use of telemetry to study GIB space use were proposed. Subsequently, some of these works were undertaken by WII and a scientifically informed spatial prioritisation map for GIB conservation was prepared jointly by WII and Rajasthan Forest Department. This exercise identified 13,163 km² in Rajasthan (including DNP and PFFR) and 477 km² in Gujarat as Priority GIB Area, based on data from collaborative surveys during 2014-18 (Table 13; Figure 61). Similarly, a Potential GIB Area, covering 78,580 km² in Rajasthan and 2,108 km² in Gujarat, was delineated to include areas for future conservation and as release sites for reintroducing GIB.

Subsequent monitoring and telemetry research (2019-present) refined our understanding on GIB habitat, leading to the identification of Additional Important Areas in Rajasthan. The Priority and Additional Important Areas can hold a viable GIB population and avert extinction if appropriately restored. The rationale and concepts of the Priority and Potential GIB Areas were jointly presented by WII and RFD in a 2021 meeting to formulate an action plan for GIB conservation, as per the Hon'ble NGT Order.

Additionally, based on the telemetry and survey data, collaborative efforts of Wildlife Institute of India, Gujarat Forest Department and The Corbett Foundation aided in declaration of ecosensitive zone in Kachchh.

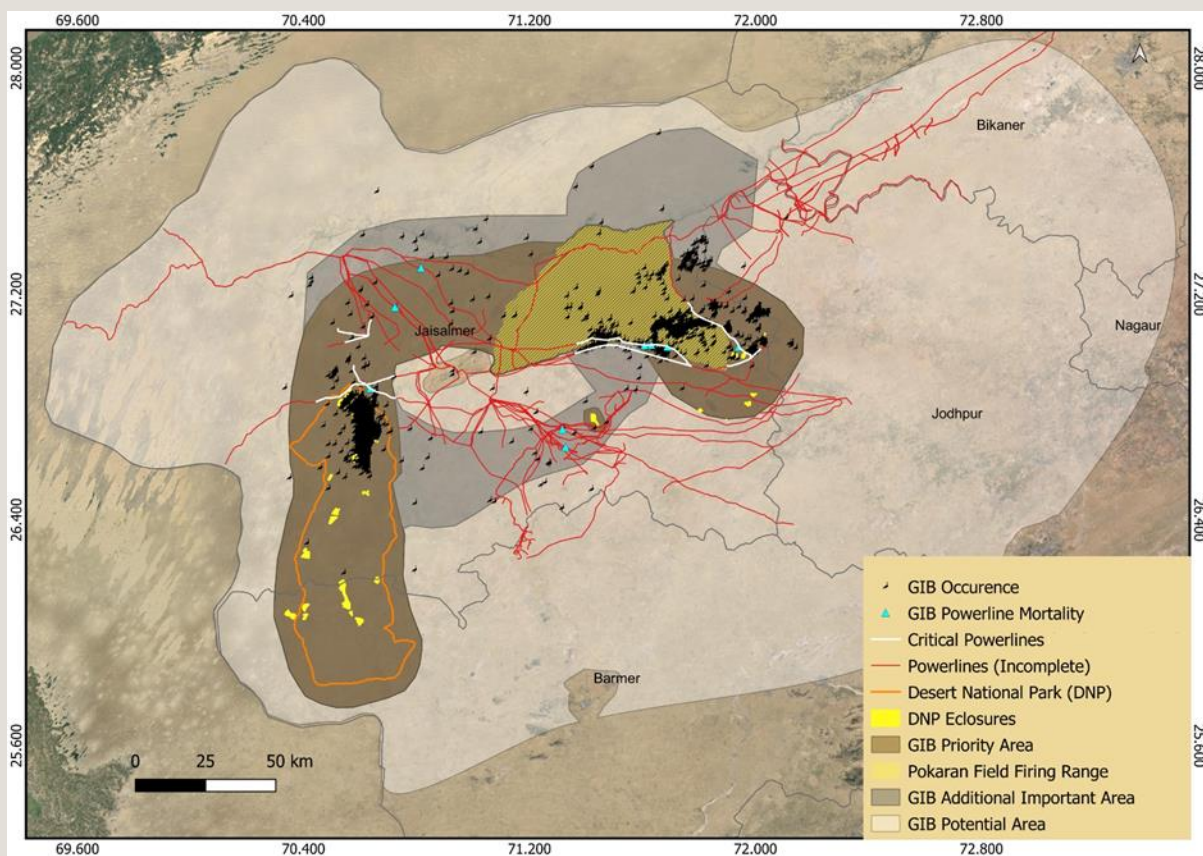


Figure 61. GIB occurrences overlaid with the existing power lines in GIB potential area in Thar desert along with the power line (GIB) mortalities and delineated critical power lines

1.2. Identification of critical power lines for mitigation

Globally and nationally, power lines are the growing cause of mortality for the majority of large bustards. Currently, the Thar desert in Jaisalmer, Rajasthan, holds the single breeding population of GIB of about 128 birds and this region is a recent hotspot for renewable energy development. Conservation agencies recommend immediate threat mitigation to protect these last remaining GIB habitats. WII conducted detailed carcass surveys in 2017-18 and estimated that power lines lead to around 90,000 bird deaths annually in the Thar region (three birds in low-voltage and six birds in high-voltage wire/km/month). These carcass surveys found 289 carcasses of over 40 species, with 12 GIB mortalities recorded since 2014: nine in Rajasthan, two in Gujarat, and one in Maharashtra. These surveys identified power lines as a major contemporary source of mortality for the Great Indian Bustard, and predicted that given its small numbers and slow life-history, even low levels of added human-induced mortality could lead to local extinction of the species.

Based on these results, multiple meetings with concerned stakeholders, and power-agencies were conducted and the feasibility of undergrounding lines up to 66 kV was confirmed. It was understood during these meetings that the desert districts of Rajasthan are an emerging renewable energy hub and mitigation of all power lines (existing and proposed) may not be entirely feasible. It was also understood that development of renewable energy is a major mandate of the government and is part of its commitment to international agencies and multilateral environmental agreements. Given this situation, WII developed a proposal for identifying risky power line segments in the Priority Area and suggested appropriate mitigation measures for each of them. Further, MoEFCC and MNRE directed power-agencies to identify critical power line segments to implement mitigation measures of undergrounding lines up to 66 kV and installing diverters on the remaining lines.

The following practicable solutions for power line mitigation to conserve GIB was proposed - undergrounding 250 km of highest-risk transmission lines in Rajasthan and 280 km in Gujarat, installing BFD on remaining important lines, and realigning a few lines through common power corridors to reduce mortality risks, as specified in the MoM of NGT Case. New power lines should avoid overhead installation where feasible or be rerouted away from Priority Areas in case undergrounding is not feasible. A similar assessment to establish critical conservation areas supporting future releases of captive-bred birds in Maharashtra, Karnataka, and Madhya Pradesh was suggested. These suggestions were reiterated in multiple deliberations that took place between 2019 and 2024.

The following lines were identified for mitigation by the Wildlife Institute of India:

Table 13. Critical power lines identified for mitigation in Rajasthan and Gujarat

State	Mitigation	Power line	Length (km)	Capacity
Rajasthan	Undergrounding	Kanoi – Salkha	21	33 kV
		Sam – Dhanana	45	33 kV
		Tejuva – Kuchri	17	33 kV
		Kuchri horizontal - parallel	21	33 kV
Gujarat	Undergrounding	GETCO line next to breeding site 13 cables	3.19	220 kV
		Bhachunda GIB habitat – Sandhav River line	2.1	Unknown
		Bhanada – Valram Society	6.1	66 kV
		GETCO Substation – Dhanawada - Nanawada	9.81	Unknown
		GETCO Substation – Kothara Mothala Road	9.69	Unknown
		Jakhau – Prajau road substation	10.9	Unknown
		Jakhau – Sindhodi	8.39	Unknown
		Jakhau – Sindhodi	8.53	Unknown
		Jakhau – Sindhodi	8.57	Unknown
		Jakhau - Vanku Road – Prajau Road substation	3.43	Unknown
		Kalatalav Khirsara Road	9.0	Unknown
		Khirsara – Kothara	8.20	Unknown
		Khirsara – Kothara River Wastelands	2.24	Unknown
		Kunathiya GETCO – Bitta & around Adani Solar	6.65	220 kV
		Kunathiya GETCO – Tera	7.32	66 kV
		Kunathiya GETCO towards Rava	3.34	66 kV
		Lala – Jakhau	11.6	Unknown
		Line near Khorsara	2.77	Unknown

State	Mitigation	Power line	Length (km)	Capacity
		Line near Lala village	1.45	Unknown
		Naliya – Kothara Road	6.58	Unknown
		Naliya – Kothara Highway	15.0	Unknown
		Naliya – Kothara Highway Line	15.7	Unknown
		Naliya - Kothara Road – Prajau	9.15	Unknown
		NaliyaKothara Road – Vanku - Lala Road	10.8	66 kV
		Prajau Road	5.57	Unknown
		Prajau – Naliya - Jakhau Road		Unknown
		Prajau Road line passing through Naliya Grasslands	4.43	Unknown
		Prajau Road substation – Naliya Kothara Road substation		Unknown
		Prajau village – Prajau Road	5.82	Unknown
		Part of Bhamedi – Naliya Jakhau Road	8.19	Unknown
		Part of Fulay Vandh – Naliya - Jakhau Highway	8.27	Unknown
		Part of Kothara - Naliya	8.82	Unknown
		Part of Kothara - Naliya line	9.36	Unknown
		Part of Vanku – Fulay Vandh line	1	Unknown
		Khirsara – Highway River Wastelands	1.59	Unknown
		Kunathiya GETCO – Bhanada Village via Agri Farms	12.1	66 KV
Rajasthan	Rerouting or Bird flight diverters	Jaisalmer – Ramgarh - 1	40	132 kV
		Jaisalmer – Ramgarh – 2	40	132 kV
		Askandra (Pokran – Askandra)	30	132 kV
		Askandra (Pokran – Askandra)	20	132 kV
		Amarsagar – Ramgarh	40	220 kV
		Amarsagar – Lilo	8	220 kV
		Amarsagar – Phalodi	54	220 kV
		Amarsagar – Phalodi	71	220 kV
		Ramgarh – Dechu	49	220 kV
		Ramgarh – Dechu	43	220 kV
		Ramgarh – Dechu	50	220 kV
		Akai – Ramgarh	55	400 kV

State	Mitigation	Power line	Length (km)	Capacity
		Tejuva – Kuchadi	138	33 KV
		Kaladongar	70	33 kV
		Mokla – Habur – Sanu	301	33 kV
		Tejuva – Kuchadi	25	132 kV
		Kaladongar	47	132/220 kV
		Mokla – Habur – Sanu	43	132/220 kV
		Chandan Via Bhagu ka Gaon – Mohangarh	70	33 kV
		Amarsagar – Ramgarh	40	220 kV
		Amarsagar – Ludarva	4	33 kV
Gujarat	Rerouting or Bird flight diverters	Kukdau – Vingaber	8.86	Unknown
		Vingaber – Lala	4.84	Unknown
		Agriculture area near highway NH-41	0.53	Unknown
		Agriculture area near highway NH-41	0.86	Unknown
		Khirsara village – Khotara town	3.42	Unknown
		Prajau Substation – Prajau Village on road side	2.81	Unknown
		Part of Bhamedi – Naliya	4.44	Unknown
		Part of Fulay vandh – Naliya - Jakhau Road	10.9	Unknown
		Part of Kothara – Naliya line	9.1	Unknown
		Part of Kothara – Naliya Line	6.90	Unknown
		Part of Vanku – Fulay Vandh	6.25	Unknown

2. Conservation outreach

Community involvement, stakeholder engagement, and capacity-building are necessary for GIB conservation as the species inhabits multiple-use landscapes, largely without effective protection, and will benefit if activities of various stakeholders are sensitive towards its conservation goals. Effective outreach and awareness programs are crucial for sensitising local communities about the importance of protecting GIB. Engaging stakeholders, including government agencies, conservation organisations, and local residents, promotes a collaborative approach for habitat management and threat mitigation. Capacity-building, through training workshops for frontline staff and skill development programs for dependent communities, can bolster conservation efforts.

With these objectives, a series of conservation outreach activities were undertaken by the Project including 1) stakeholder meetings, 2) conservation awareness programs for school children, local people, tourists, and dignitaries, 3) capacity building through training of frontline Forest staff and skill development workshop on nature tourism, 4) dissemination of information on the species and Project in various forms (papers, presentations, video-documentary etc.) and fora, and 5) preparation and dissemination of outreach materials about the species and ecosystem.

2.1. Stakeholder meetings

The Project team organised and attended several meetings and workshops over the last eight years for initiating and implementing activities, sensitising stakeholder agencies, and reviewing the Project progress that are summarised below, highlighting some of the key events.

- *Meetings with Government agencies for collaborative implementation of Project activities*
 - A national launch workshop for the CAMPA funded Endangered Species Recovery Program was organised at WII, Dehradun in 2016, where collaborating agencies were invited and planned activities under the Project were presented for consultation.
 - Three important meetings with Rajasthan Government authorities (Hon. Chief Minister, Hon. Forest Minister, Chief Wildlife Warden and other officers) were held at Jaipur, during 2016-18, for approval and support towards initiating the conservation breeding and research components under the Project.
 - Regular meetings with officers of Rajasthan Forest Department at Jaisalmer (Divisional Office), Jodhpur (Chief Conservator Office) and Jaipur (Chief Wildlife Warden Office), for appraisal on Project updates and consultation on future activities throughout the Project timeline (2016 - 24).
 - Meetings with Gujarat, Karnataka, Maharashtra, and Madhya Pradesh Forest Departments at field sites, where the Project team provided technical inputs on conservation aspects of GIB and lesser florican.
- *Meetings and interactions with the Indian Armed Forces for GIB conservation*
 - A workshop to sensitise Indian Army and Air Force on the importance and their role in GIB conservation was organised in collaboration with BNHS, Rajasthan Forest Department, Indian Army and Air Force in Jodhpur in 2016
 - Multiple follow-up informal meetings between the Project team and Indian Army, Airforce in Jaisalmer and Kachchh, especially the Commanding Officer of Pokhran Field Firing Range, to sensitise them on GIB conservation and gain access to the Range for surveys and monitoring, helped in implementing the last large-scale survey of GIB in Jaisalmer (including Range) in 2017-18
 - Recent meetings and correspondence with the Indian Army to develop a conservation plan for GIB in and around the Pokhran Range
- *Meetings and interactions with power agencies and regulatory bodies regarding the impact of power line on birds, the need and technical aspects of mitigating this threat*

- The Project team participated in following meetings organised by Rajasthan Forest Department and MoEF&CC regarding power line mitigation:
 - Meeting held on 9.12.16 at Rajasthan Renewable Energy Corporation Ltd, Jaipur regarding the assessment of technical feasibility of installing Bird Flight Diverters on existing transmission lines in the GIB Arc where it was decided to undertake a pilot study on installing these devices in Rajasthan
 - The WII's GIB Conservation Project imported and distributed bird flight diverters to power agencies for pilot installation and examination of durability in a meeting held on 31.5.17 at Van Bhawan, Jodhpur
 - Meeting held on 11.1.18 at Van Bhawan, Jodhpur, where WII and RFD jointly sensitised power-agencies on the urgent need of mitigating critical power lines for GIB conservation
 - Meeting held on 20.12.18 under the chairmanship of Pr. Sec. Energy Department, GoR at Jaipur, to highlight the urgent need of power line mitigation for GIB conservation and discuss the financial implications of such mitigation measures. As decided in this meeting, WII developed a technical-and-financial proposal for mitigating risky power line segments in the 'GIB Arc' in consultation with Rajasthan Vidyut Prasaran Nigam Limited (RVPNL) and other power-agencies in Rajasthan.
 - Meetings convened by MoEF&CC under the direction of Hon NGT in case OA No 385 of 2019, where the Project team provided scientific inputs in, *inter alia*: a) VC meeting on 05.05.2020 under the Chairmanship of DG(F) & SS on attended by representatives of MoEFCC(WL), MNRE, MoP, Forest Departments of Rajasthan, Maharashtra, Gujarat and Karnataka, RVPNL, GETCO, PGCIL, NHAI, Sprng Energy, and other renewable energy agencies operating in Rajasthan and Gujarat to discuss plans for conservation of GIB with emphasis on power line mitigation. b) A site visit and meeting in Jaisalmer on 22-23 February 2021, to formulate an action plan for GIB conservation as mandated by MoEF&CC. Critical GIB habitat delineation of priority and additional important areas through joint surveys of WII and RFD and finalised during this site visit by the officials of MoEFCC, RFD, WII and power agencies.
 - Multiple meetings were held with various public and private sector power agencies viz. Rajasthan Vidyuth Prasaran Nigam Limited (RVPNL), Gujarat Energy Transmission Corporation (GETCO), Tata Power, Essel Infra, Arctis Advisers Private Ltd, Sprng energy, Enel Green Power, Sterlite power, General Electric, Sitac Management and Development Private Limited etc. on power line threat mitigation and conservation aspects GIB and lesser florican.
 - Besides the above meetings, the Project team provided regular technical inputs sought by MoEFCC from time to time on litigations pertaining to GIB conservation in Hon'ble National Green Tribunal (OA No 385 of 2019) and Hon'ble Supreme Court (WP 838 of 2019).
- *Consultation meetings with technical partners regarding collaborative activities*
 - Meetings with International Fund for Houbara Conservation (IFHC) and their consultant firm - Reneco - for technical support in GIB conservation breeding at Abu Dhabi in 2018 that resulted in the agreement on knowledge sharing on this activity between the two Institutions
 - Regular physical and videoconference meetings with IFHC/Reneco bustard experts for knowledge sharing and consultation on technical aspects of conservation breeding
 - Meetings with NGO partners (TCF, BNHS, HSI, HYTICOS, TGT, GSS) on collaborative implementation of activities

- *Project review meetings and discussions regarding GIB conservation convened by MoEFCC*
 - Project progress was presented and GIB conservation issues were discussed regularly in meetings convened by MoEFCC in February 2024, October 2022, February 2021, December 2020, November 2020, October 2020, May 2020, January 2019, November 2016 (incomplete list)
 - Deliberations on Project activities, important decisions, and way forward in Steering Committee meetings, chaired by ADG(WL) held in July 2018, July 2019 and August 2022
 - Regular update meetings of Project progress convened by National CAMPA Authority
 - Meeting to discuss the proposal on "Long term project on Great Indian Bustard recovery Programme" seeking funding support from National Authority in November 2023, February 2024, and July 2024
- *Seminars to disseminate knowledge*
 - Workshop on quantitative tools in conservation biology for Project partners (2017)
 - Sexual selection in Great Bustard- by Dr Juan Carlos Alonso (2018)
 - Participation in Bustard conservation conference in Birdlife Flyway Summit at Abu Dhabi to present Project activities and visit to Houbara bustard breeding centre on appraisal on artificial breeding techniques (2018)

2.2. Conservation awareness

2.2.1 Conservation education in schools

Strengthening the connection of local children living in remote areas with their surrounding biodiversity and sensitising them about conservation values, can go a long way in shaping the future of wildlife and their conservation efforts. Hence, the Project carried out nature education programs for school children that are joyful, entertaining, and interactive through games, field visits, and interactions. Various interactive sessions were conducted for school children in the Thar landscape, to improve their understanding of the significance of the desert ecosystem. They got the opportunity to learn about their backyard biodiversity and their role in the ecosystem. During these sessions, children were also awarded with notebooks and bookmarks illustrated with the flora and fauna of the desert.

In the first phase, customised nature education programs were conducted in the Jaisalmer district, covering a) 2279 students in 22 schools across 18 villages in Jaisalmer District from January to April 2019, b) 4197 students from 15 schools across 13 villages in 2022-23, c) 4,475 students from 17 schools across 16 villages in April to September 2023 (Image 12). These programs educated students about GIB, its threats, and conservation issues with the help of documentary films and follow-up interactions.

Subsequently, Phase II of nature education programmes ("make your own bag") was carried out in February 2023 (Image 13). Over 822 students in three schools (2022-2023) and over 400 students (2023-2024) from different villages in Jaisalmer participated in this interactive event. Students block printed bags and t-shirts with images of GIB and chinkara in the traditional Rajasthani style using wooden blocks and coloured dyes.



Image 12. Interactive sessions on the Great Indian Bustard and grassland conservation conducted in schools, Jaisalmer



Image 13. School children engaged in the interactive session of block printing bags in Jaisalmer

2.2.2. Field visit for school students

A nature excursion program for Rajkumari Ratnavati Girl's School was conducted in DNP in association with the Rajasthan Forest Department (Image 14). The students were introduced to the GIB conservation breeding program at Sam. They were also given a demonstration of wildlife research equipment. These visits were expected to inculcate appreciation for nature in students and ultimately instil a sense of connection, responsibility and desire to partake in conservation efforts ongoing in their area.



Image 14. Field visit of school children in GIB habitats in Jaisalmer

2.2.3. Wall-painting/mural

To showcase the activities of GIB conservation to a wider audience, walls in the GIB Conservation Breeding Centre at Sam and a government school in Neemba, both within Desert National Park, were painted by Keerthana, an artist from Kerala. The CBC wall depicted the bond between GIB and their keepers in the conservation breeding program, whereas the school wall depicted iconic flora and fauna of the Thar desert (Image 15).



Image 15. Wall mural in Sam Conservation Breeding Centre (left) and Neemba School (right)

2.2.4. Sensitisation of local people

The project works closely with locals from various villages and field work often requires the team to work in areas abutting their villages or in their fields. Therefore it is crucial to ensure that villagers in and around DNP are sensitised to various project activities. Additionally, it is essential to inculcate positive attitudes towards local wildlife and foster support for ongoing conservation efforts for their successful and long-term implementation. To ensure this, the project has briefed local villagers in multiple informal meetings over the years (Image 16).



Image 16. Informal meetings of Project team and collaborators with local people of Desert National Park

2.2.5. Awareness campaign at Desert festival, Jaisalmer

The Desert Festival in Jaisalmer is an annual mega gathering of local people and tourists that showcases the nature and culture of the Thar desert, providing an unique opportunity to spread information about biodiversity conservation to the public at large. Hence, exhibition stalls were set up with the support of the District Magistrate office and Forest Department in the Desert Festival from 2019 to 2024, reaching out to over 50,000 people, for raising awareness about GIB, its habitats, and ongoing conservation efforts. The Project team engaged with visitors, aided by outreach materials such as a three-dimensional model of GIB and desert habitat, informative posters, brochures and bookmarks on GIB and associated desert fauna, and sought their support in the species' conservation (Image 17).



Image 17. GIB conservation exhibition stall during Annual Desert Festival 2019 -2024, Jaisalmer

2.2.6. Wildlife week and Wildlife Day celebration

Various interactive sessions were conducted in schools around DNP, during the wildlife week of 2023 (Image 18). As part of RFD's Wildlife Week 2023 celebration, students from 12 schools of Jaisalmer visited DNP and were given a demonstration of wildlife research equipment. Similarly, the team held an awareness programme with the Meghwalon ki Basti school's teachers and children as part of the celebration of World Wildlife Day 2024.



Image 18. Wildlife week celebration 2023 in DNP

2.2.7. Sensitisation of delegates at the conservation breeding centres

Many dignitaries were sensitised about the need and efforts towards GIB conservation during their visits to conservation breeding centres in Sam, Ramdevra and Bijainagar in Rajasthan. They were briefed about the natural history of GIB, its threats, ongoing conservation efforts, and necessary urgent actions (Image 19). These dignitaries included Hon. Chief Justice of India, Hon. Union Minister and State Minister of Environment and Forest, District Magistrate, Superintendent of Police Jaisalmer, Indian Army officers, IFS trainees, media executives, Former PCCF and HoFF, Principal Secretary of Department of Tourism, Rajasthan and more (Image 19-22).



Image 19. IFS trainees on a field visit to DNP with project staff (left); Visitors at Ramdevra Conservation Breeding Centre (right)



Image 20. Hon'ble minister Mr Bhupender Yadav, Ministry of Environment, Forest and Climate Change of India, visited GIB conservation breeding centre (Sam) (April 2022)



Image 21. Visit to Sam CBC of Principal Secretary (Sh. Gayatri Rathore) of Department of Tourism, Art and Culture, Rajasthan (Aug 2024) (Left) and Supreme court committee constituting Representatives from MOEFCC, Ministry of Power, Former CWLW, Authorities from Power Agencies of Rajasthan, Officers from Rajasthan FD visited Ramdevra CBC (June 2024) (Right)



Image 22. Sam CBC visit of Former PCCF & HOFF of Rajasthan (Dr Deep Nayaran Pandey) (March 2024) (Left) and Team of Karnataka Forest Department visited Sam and Ramdevra CBC (July 2023) (Right)

2.2.8. Sensitisation workshop on GIB Conservation at New Delhi

A workshop was organised at WWF-India headquarters, New Delhi on 21st February, 2019 to sensitise power agencies and the media on GIB conservation (Image 23). The workshop was attended by ~100 participants including officials from MoEF&CC and State Forest Departments, representatives from power agencies, conservation organisations, legal fraternity and media. The immediate need to mitigate power lines, and the necessity of conservation breeding were highlighted. The objective of this workshop was to create awareness about the plight of the bustard, develop a strategy to communicate with the public and stakeholders, and to communicate to power agencies (governmental and non-governmental) the integral role they serve in saving this iconic species of the Indian grasslands.



Image 23. Stakeholder sensitisation workshop at WWF, New Delhi

2.2.9. Media coverage and popular outreach

Efforts were made to disseminate information regarding the species, its conservation needs and ongoing conservation efforts via popular articles, seminar presentations, and social media posts. The species and Project received a very wide media coverage in the last five years, resulting in positive publicity for the species' conservation. Some key newspaper articles are listed below:

- <https://indianexpress.com/article/explained/great-indian-bustards-recovery-conservation-9430708/>
- <https://timesofindia.indiatimes.com/india/over-rs-33-crore-project-to-save-endangered-great-indian-bustard-environment-ministry/articleshow/70192229.cms>
- <https://economictimes.indiatimes.com/news/politics-and-nation/lease-of-life-saving-the-great-indian-bustard-bird-in-the-rajasthan-desert/articleshow/74260735.cms?from=mdr>
- <https://www.downtoearth.org.in/wildlife-biodiversity/two-female-great-indian-bustards-satellite-tagged-in-rajasthan-64091>
- <https://www.hindustantimes.com/india-news/great-indian-bustard-chick-hatched-in-jaisalmer-breeding-centre-to-boost-declining-population-101680373900870.html>
- <https://timesofindia.indiatimes.com/city/jaipur/second-gib-chick-artificially-hatched-this-yr-in-jaisalmer/articleshow/109208745.cms>
- <https://timesofindia.indiatimes.com/city/jaipur/six-gib-chicks-shifted-from-sudasari-to-new-breeding-centre-in-ramdevra/articleshow/111124071.cms>
- <https://indianexpress.com/article/india/govt-approves-rs-56-crore-for-next-phase-of-conservation-plan-for-great-indian-bustard-9425072/>
- <https://www.deccanherald.com/environment/conservation-and-climate-change-will-the-balancing-act-save-the-giant-flying-bird-2977067>
- <https://www.telegraphindia.com/india/supreme-court-asks-govt-to-come-out-with-comprehensive-plan-to-save-endangered-great-indian-bustard/cid/1994957>

2.3. Capacity building

2.3.1. Skill development workshop on wildlife tourism

The team conducted a two-day skill development training workshop for the frontline staff of Rajasthan State Forest Department, nature guides and wildlife enthusiasts of the area on 27- 28 January 2019 in Jaisalmer (Image 24). During the workshop, subject expert Dr Asad Rahmani introduced the participants to the scope and effects of wildlife tourism, along with field observations and conservation ethics, followed by hands-on instrumentation and field training by our project team. The workshop provided useful job skills to the local youth to work as nature guides. The economy in the Thar Desert functions primarily on tourism in the months between October and January. This activity was an icebreaker to bridge the gap between local communities and the team by assisting youth to get trained in relevant skills and to achieve gainful employment. The event received a huge turnout from the local community, and the participants were also presented with GIB themed mementos to promote the significance of GIB and grassland conservation in the area.



Image 24. Skill development workshop conducted for Rajasthan Forest Department frontline staff, nature guides and enthusiasts in Jaisalmer

2.3.2. Training of frontline staff

Frontline staff of the Forest Department across bustard range states were trained on wildlife population assessment techniques through lectures and hands-on exercise. These training workshops were conducted for:

a) Status assessment of GIB, associated fauna and habitat in Jaisalmer during March 2017 and 2018, wherein 60 volunteers and 68 Forest Department staff were trained in survey methods, instruments such as GPS, Range finder, Suunto compass and navigation using Google maps, sampling protocol for occupancy sampling and line transect-based distance sampling along with data collection and recording techniques prior to the surveys.

b) Status assessment of lesser florican, associated fauna and habitat during July-September of 2017 and 2018 across five states including Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh, wherein 60 volunteers and 120 Forest Department staff were trained on the above aspects in separate workshops at each range state: 1. Gujarat – Department of Marine Science and Department of Zoology, Sir P.P. Institute of Science, M.K. Bhavnagar University and Blackbuck National Park, Velavadar in Bhavnagar on 16-17 July 2017; 2. Madhya Pradesh – Office of the Chief Conservator of Forests, Ujjain and Sailana Wildlife Sanctuary in Ratlam on 24 July 2017; 3. Rajasthan – Department of Environment, MDS University, Ajmer and Shokaliya Conservation Reserve, Nasirabad on 2-3 August 2017; 4. Maharashtra – Vankuti, Divisional Forest Office, Akola on 17 September 2017 (Image 25 & 26).

c) Status assessment of migratory birds and key taxa in Bikaner, wherein ~60 volunteers and ~20 frontline staff were trained on the above species in February 2021.



Image 25. Training workshop of National lesser florican status survey during August 2019 at Bhavnagar, Gujarat and Akola, Maharashtra

Additionally, the following training workshops were carried out:

- Training of DNP field staff in survey techniques was conducted online in November 2020.
- Training of DNP field staff in bird identification was conducted in February 2021.
- Training of forest department staff and volunteers in Bikaner on large-scale surveys and related field techniques.



Image 26. Field training and awareness material distribution for frontline staff

2.4. Meetings and conferences

2.4.1. Thirteenth Conference of Parties of Convention on Migratory Species of Wild Animals (CMS CoP13)



Image 27. CMS CoP13 conference at Gandhinagar, Gujarat

The UN Wildlife Conference dedicated to migratory species in India, held from 15 – 22 February 2020 at Gandhinagar, Gujarat was undertaken to discuss resolutions and decisions to address the conservation needs and threats facing migratory species around the globe. The CoP13 was officially inaugurated by the Prime Minister of India on 17 February 2020. Senior government officials, environment advocates, activists, researchers and biodiversity leaders from 130 countries participated in this conference. During the opening ceremony on Monday, the Government of India also issued a special stamp edition featuring GIB- the mascot of COP13. Ten new species were added to CMS Appendices at COP13. Seven species were added to CITES Appendix I, which provides the strictest protection, namely, GIB, Bengal Florican, Little Bustard, Asian Elephant, Jaguar, Antipodean Albatross and the Oceanic White-tip Shark.

WII participated in three events on 20 February 2020. First event was in partnership with MoEF&CC Species Conservation Initiatives in India with Reference to Asian Elephants, GIB, Gangetic River Dolphins and Tigers. This event was co-chaired by Shri Soumitra Dasgupta, IGF(WL), MoEFCC, Government of India. The second event was on behalf of MoEF&CC with partnership of TCF and WCS on 'The Final Flight: Conserving Eurasia's Iconic Bustard Species.' This event was co-chaired by Dr Borja Heredia, Dr Mimi Kessler (IUCN Bustard Specialist Group), Dr Asad Rahmani, Shri N.K. Vasu, IFS (former), PCCF & HoFF Assam, Shri Devesh Gadhavi and Dr S. Dutta, WII (Image 27). The last event was in partnership with BirdLife International and BNHS on 'Using Sensitivity Mapping to Avoid Conflict between Birds and Renewable Energy Infrastructure in India and Asia.', where findings of the WII study were presented.

2.4.2. G20

The project was represented at the 2nd Environment and Climate Sustainability Working Group meeting- G20 from 27-29 March 2023 in Gandhinagar, Gujarat. An exhibition on the theme- ecosystem restoration through species conservation was set up in which the GIB was showcased to generate awareness about their plight and conservation efforts (Image 28).



Image 28. Environment and climate sustainability working group meeting - G20 at Gandhinagar, Gujarat

2.4.3. Dissemination of Project findings in conferences

Work of the program was presented at the following conservation seminars/meetings:

1. "A Community-based Conservation Approach", conducted by WCS-India at Jodhpur on 8th September 2023 (Image 29).



Image 29. Meeting on community-based conservation approach by WCS-India at Jodhpur, Rajasthan

2. Briefing of delegates about activities conducted under the CAMPA funded GIB project, at a stall set up in the exhibition for Country led Initiatives in the United Nations Forum on Forest conference organised at the Forest Research Institute (FRI), Dehradun.
3. The Project team also participated in the inaugural Indian Conservation Conference (ICCON) on wildlife research, conservation, and management, held in Mysuru, Karnataka, from April 9 to 11, 2023, where they highlighted the conservation efforts to recover GIB population through a stall and poster (Image 30).



Image 30. Dissemination of project activities at Indian Conservation Conference 2023 at Mysuru, Karnataka

Additionally, research outcomes of the program were presented as research talks and posters at various conferences:

1. Kulkarni, A., Kher, V., Dutta, S., Krishnan, A. (2023) Acoustic monitoring of birds in changing land use patterns in semi-arid ecosystems. Talk at the ATBC, Coimbatore July 2023. Bird Monitoring Symposium March 2023.
2. Thakkar, S., Kher, V., Sudame, S., Sandhikar, P., Deshmukh, S., Uddin, M. and Dutta, S. (2023) Automated Passive acoustic monitoring of lesser florican. Talk at the Bird Monitoring Symposium, March 2023.
3. Kher, V., Dutta, S., and Bustard Recovery Program Team (2022) Monitoring ecology of the Great Indian Bustard using telemetry. Oral presentation at the Bird Monitoring Symposium, April 2022.
4. Kher, V. and Dutta, S. (2019) Understanding patterns of bird community structure across different land use types of the Indian Thar Desert. Oral presentation at the National Symposium for Avian Biology, IISER Tirupati, December 2019.
5. Kher, V. and Dutta, S. (2019) Response of bird communities to contemporary land use changes in the Thar Desert of Western India. Oral presentation at the Student Conference on Conservation Science (SCCS), Bengaluru, September 2019. Honors: Best Student Talk
6. Kher, V., and Dutta, S. (2023) Irrigation drives drastic change in bird assemblages of the Thar Desert. Poster presentation at the ATBC conference, Coimbatore, July 2023.
7. Kher, V., Gupta, S., Dutta, S., and Bustard Recovery Program Team (2023) Monitoring Great Indian Bustard behaviour using accelerometry. Poster presentation at the Bird Monitoring Symposium, March 2023.
8. Kulkarni, A., Kher, V., Dutta, S., and Krishnan, A. (2023) Acoustic monitoring of birds in changing land use patterns in semi-arid ecosystems. Annual Biology Meeting, Indian Institute of Science Education and Research, Bhopal.

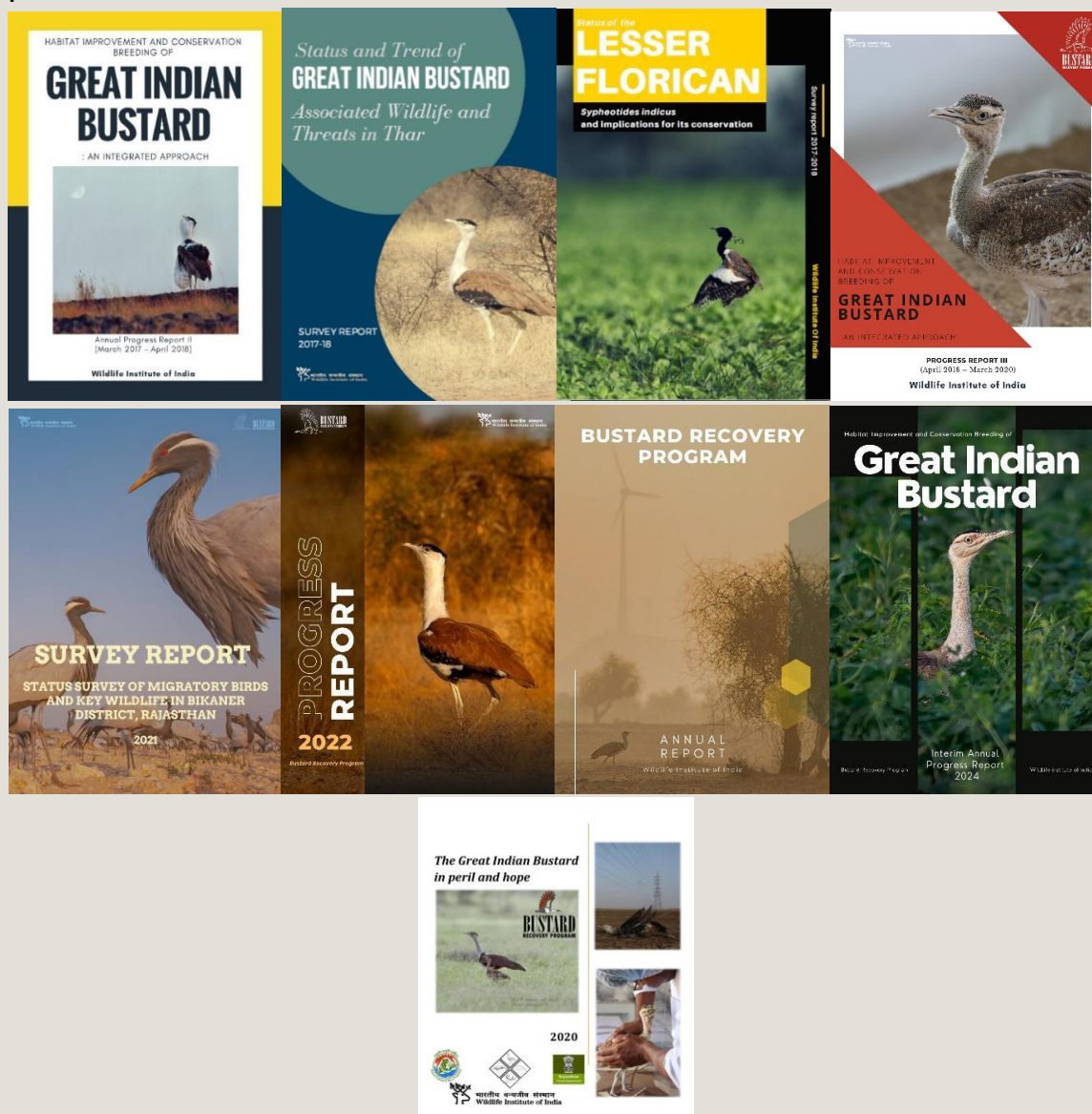
2.5. Publications

2.5.1. Scientific publications and technical reports

1. Dutta, S., Bipin C.M., Anoop, K.R., Uddin. M., Shekhawat, R.S., Jhala, Y.V. 2017. Status and trend of Great Indian Bustard, Associated Wildlife and Threats in Thar. Wildlife Institute of India, Dehradun and Rajasthan Forest Department, Jaipur. Pp 33.
2. Jhala, Y.V., Dutta, S., Habib, B., Narwade, S., Karkaria, T., Bipin, C.M., Awasthi, A., Singh, V., Yellapu, S., Bagaria, P., Uddin, M., Supakar, S., Gupta, T., Pandey, D., Khan, S. 2018. Habitat improvement and conservation breeding of the Great Indian Bustard: An integrated approach. Annual Progress Report II 2018. Wildlife Institute of India, Dehradun. Pp 106.
3. Wildlife Institute of India. 2018. Power Line Mitigation Measures. Second edition (2020). Pp 8.

4. Dutta, S., Narwade, S., Bipin, C.M., Gadhavi, D. Uddin, M., Mhaskar, M., Pandey, D., Mohan, A., Sharma, H., Iyer, S., Tripathi, R., Verma, V., Varma, V., Jangid, A., Chakdar, B., Karulkar, A., Lambture, B., Khongsai, N., Kumar, S., Gore, K., Jhala, D., Vaidya, N., Horne, B., Chittora, A., Annigeri, B.S., Trivedi, M. and Jhala, Y.V. (2018) Status of the lesser florican *Sypheotides indicus* and implications for its conservation. Wildlife Institute of India, Dehradun. Pp 112.
5. Jhala, Y.V., Dutta, S., Rathore, S.S., Narwade, S., Karkaria, T., Bipin, C.M., Awasthi, A., Singh, V., Yellapu, S., Bagaria, P., Sakhlani, P., Uddin, M., Supakar, S., Gupta, T., Pandey, D., Varma, V., Sharma, H., Joshi, H., Paul, I. 2020. Habitat improvement and conservation breeding of the Great Indian Bustard: An integrated approach. Progress Report III 2020. Wildlife Institute of India, Dehradun. Pp 124.
6. Dutta, S., Karkaria, T., Bipin, C.M., Uddin, M., Pandey, D., Awasthi, A., Supakar, S., Gupta, T., Sharma, H., Joshi, H., Varma, V., Nagar, A., Paul, I., Dave, C., Bagaria, P., Yellapu, S., Singh, V., Sakhlani, P., Mohandas, M., Kher, V., Tripathi, R., Jangid, A.K., Mohan, A., Rathore, S.S., Tomar, A., Bhardwaj, G.S., Shekhawat, R.S., Ranjan, P., Anoop, K.R., Chandrawal, K., Borana, V., Lacroix, F., Seabury, J.M., Elhoussaine, E., Dielevent, T., Osman, M.A., Dhakal, D., Boullger, C., Loic, L., Alonso, J.C., Scotland, K., Gadhvi, D., Gore, K., Rahmani, A., Apte, D., Negi, M.S., Mathur, V.B., Garbyal, S.S., Khanduri, S.K., Ranjitsinh, M.K., Jhala, Y.V. 2020. The Great Indian Bustard in peril and hope: Report. Wildlife Institute of India, Dehradun.
7. Jhala, Y.V., Dutta, S., Bhardwaj, G.S., Rathore, S.S., Dave, C., Narwade, S., Karkaria, T., Bipin, C.M., Awasthi, A., Singh, V., Yellapu, S., Bagaria, P., Sakhlani, P., Uddin, M., Supakar, S., Gupta, T., Pandey, D., Varma, V., Paul, I., Sharma, H., Joshi, H. 2020. Conserving Great Indian Bustard landscapes through scientific understanding and participatory planning. Final Report 2020. Pp 66.
8. Dutta, S., Karkaria, T., Bipin, C. M., Uddin, Kher, V., Sharma, H., Joshi, H., Varma, V., Paul, I., Gupta, T., Pandey, D., Supakar, S., Nagar, A., Rathore, S.S., Yellapu, S., Sakhlani, P., Kolipakam, V., Qureshi, Q., Jhala, Y. V. 2022. Bustard Recovery Program: Progress Report. Wildlife Institute of India, Dehradun. Pp 40.
9. Dutta, S., Kher, V., Uddin, M., Supakar, S., Karkaria, T., Gupta, T., Paul, I., Pandey, D., Varma, V., Verma, V., Phasalkar, P., Khanra, A., Jora, V. S., Kataria, P. S., Chhangani, A.K., Bipin, C. M., Jhala, Y. V. 2022. Status survey of migratory birds and key wildlife in Bikaner district, Rajasthan. Wildlife Institute of India, Dehradun. TR No/2021/24. Pp 35.
10. Dutta, S., Karkaria, T., Bipin, C. M., Uddin, Kher, V., Sharma, H., Joshi, H., Paul, I., Gupta, T., Supakar, S., Varma, V., Nagar, A., Bishnoi, V., Pati, A., Gupta, S., Purohit, N. Lawrence, S., Bhattacharya, S., Gujjar, M., Moitra, M., Rathore, S.S., Sakhlani, P., Kolipakam, V., Qureshi, Q. and Jhala, Y. V. (2023) Bustard Recovery Program: Progress Report. Wildlife Institute of India, Dehradun.
11. Dutta, S., Karkaria, T., Bipin, C.M., Uddin, M., Kher, V., Sharma, H., Joshi, H., Bishnoi, V., Sonika, C.K., Paul, I., Gupta, T., Supakar, S., Nagar, A., Pati, A., Gupta, S., Purohit, N., Lawrence, S., Jangid, A.K., Gujjar, M., Moitra, M., Bhattacharya, S., Sawant, M., Krishna, M., Sakhlani, P., Kawlani, L., Kolipakam, V., Qureshi, Q. 2024. Bustard Recovery Program: Annual Progress Report 2023-24. Wildlife Institute of India, Dehradun. Pp 63.

Reports



2.5.2. Power line Mitigation Booklet

A booklet on power line mitigation to conserve bustards was published. Maps with identification of critical power lines for mitigation, information regarding various BFD and installation design were detailed in this quick reference guide. The brochure was widely disseminated to power agencies, State Forest Departments, defence personnel, conservation agencies and the media.



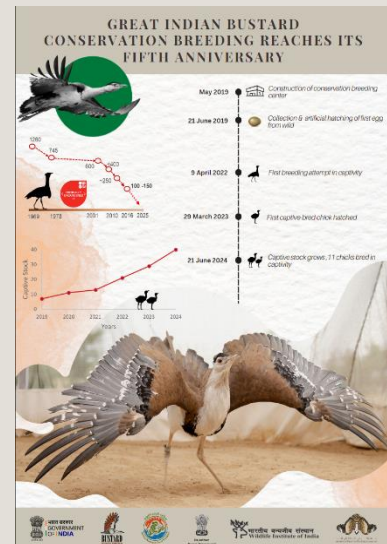
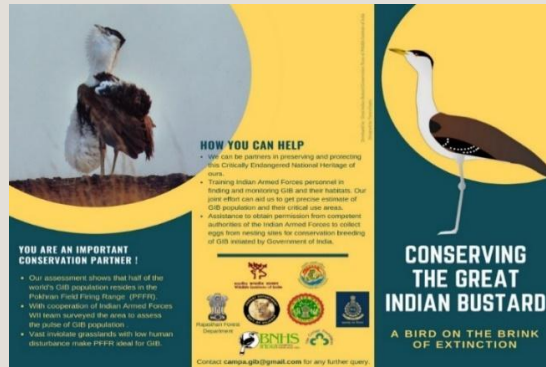
2.5.3. Sensitisation posters and brochures

Standee

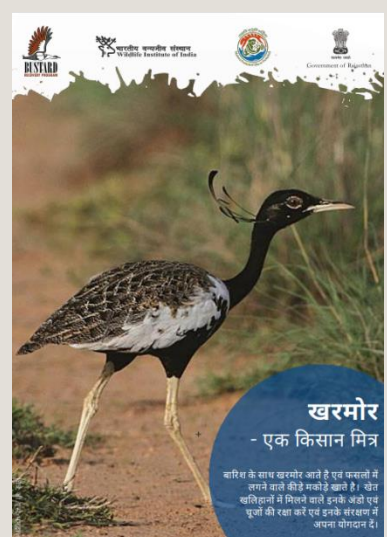


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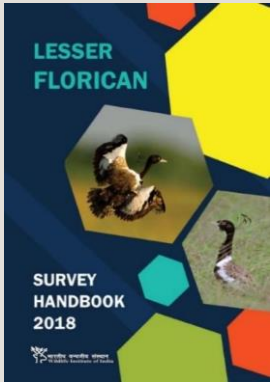
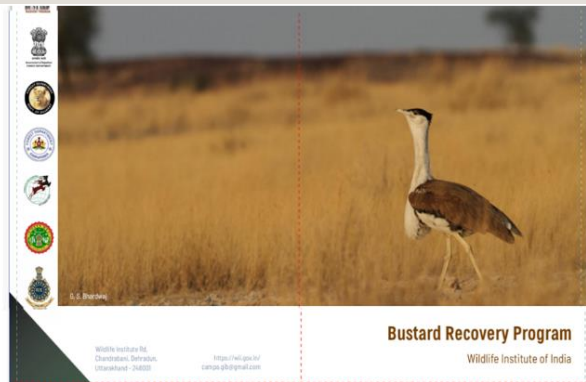


2.5.4. Other outreach materials



Mugs, Stickers and Badges



Survey handbook	Notebook	Folder
		

Bookmarks



T-shirts



Caps



Bags





ACTIONS FOR GIB CONSERVATION



3. Actions for GIB conservation

3.1. Predator removal and translocation

Nest predation impedes rapid recovery of the GIB population in the current scenario of critically low numbers. GIB nests are mere scrapes on the ground that make them vulnerable to predation, and ~50% of GIB nests get predated by predators such as foxes, mongooses, cats, monitor lizards, and pigs. To improve hatching success of GIB in the wild, the Project steering committee decided that these nest/ chick predators should be excluded from important breeding enclosures using predator-proof-fencing and translocations. Additionally, predator density needs to be assessed, and translocated predators need to be tagged/ marked to monitor the effectiveness of management interventions. Permissions were granted to trap, mark and release fox, cat, wild pig, monitor lizard and mongoose.

During 2020-24, predator translocation exercises were undertaken as part of efforts to mitigate predation risks to GIB nests within DNP. Initiated on a pilot basis, the program involved translocating foxes from key GIB breeding enclosures (Sudasari and Chauhani) to other areas not frequented used by GIB. The exercise gained further momentum following a GIB mortality in the Chauhani enclosure in December 2023, attributed to fox predation based on genetic investigations. This led to targeted translocation efforts in Chauhani between December 2023 and January 2024, followed by focused activities in Sudasari ACD (where most of the GIB nests are reported) in May 2024. Details of the translocated predators are provided (Table 14).

Predators were captured using padded foothold traps placed at sites with previously observed predator activity. Traps were monitored every two hours to ensure minimum time in traps and ethical handling. Captured animals were immobilized using a combination of xylazine, ketamine, and medetomidine, with vital parameters monitored throughout the procedure. Vital parameters such as heart rate, respiration, and rectal temperature were monitored continuously during the immobilisation process and a heat source was provided to prevent hypothermia. Few captured animals were tagged with Telonics VHF collars, whereas others were marked with coloured collars for identification. All animals were measured, weighed, and scored for body condition and samples of hair and ectoparasites were collected. All animals were released >35 km of aerial distance from GIB breeding enclosures within 24 hrs of capture.

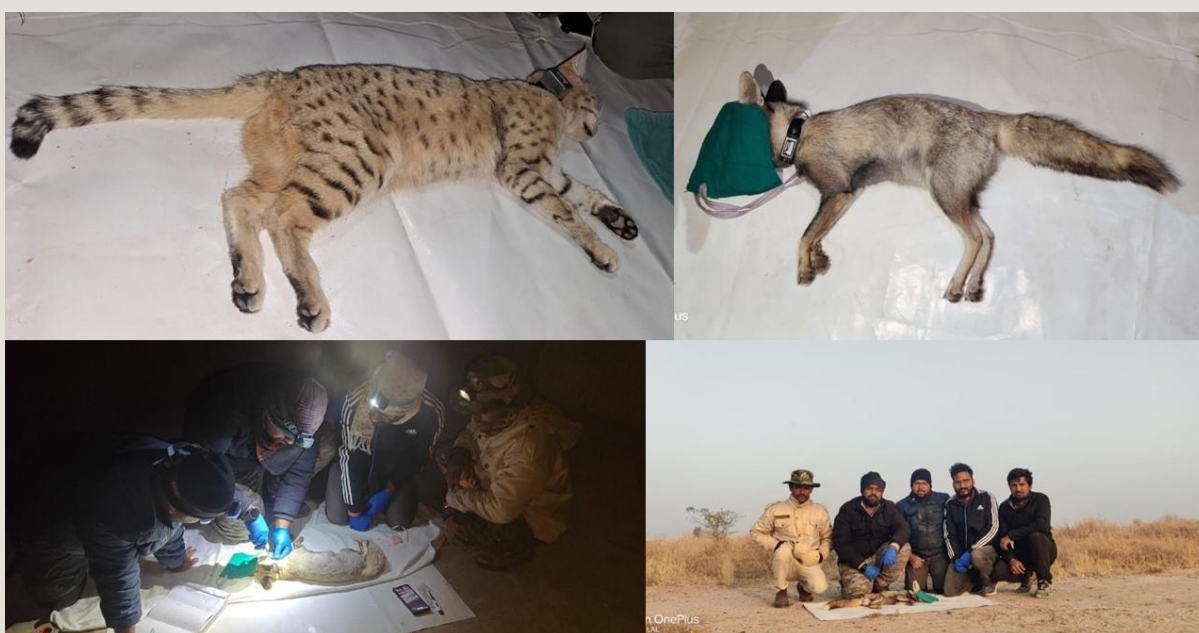


Image 31. Desert Cat with VHF Collar (upper left); Captured Desert fox with VHF Collar (upper right); Collaring of Desert fox (lower left); Predator translocation team with a captured Desert fox (lower right)

Table 14. Details of nest predator translocated from GIB breeding area of DNP during 2020-24

SN	Species	2020-24
1	Desert Cat	4
2	Desert Fox	16
3	Monitor Lizard	4
4	Small Indian Mongoose	11
Grand Total		35

All collared animals were intensively tracked by the team for 2-3 weeks post-release after which the tracking intensity was reduced to once a week. Two foxes and one cat could not be traced post-release, while four foxes trapped in December 2023 returned to the Chauhani enclosure within two months of release. These four foxes were released within 70 km of the site of capture. During the next fox translocation exercise, foxes will be released following a strategic release plan at further distances to understand the minimal distance of release, wherefrom, return rates diminish. Additionally, fences need to be checked by the Forest Department to find areas that foxes and other predators might be crossing through. Some foxes and cats will be collared with GSM/GPRS collars which will allow tracking the animal more precisely post-release. Additionally, a camera trap based predator estimation was conducted in PPC prior to the translocation exercise and the same study will be repeated a few months later to look at the effectiveness of predator removal from these enclosures.

In addition to these native predators, free-ranging dogs in the area were surveyed using vehicles and dogs found were immobilised using dart guns. Captured dogs were placed in trap cages and were translocated by the Project team or Forest Department >50 km away from GIB breeding habitats to areas not used by GIB. Over 289 free-ranging dogs have been translocated from GIB breeding habitats (enclosures) of Sudasari and Pokhran ranges (Table 15).

Table 15. Number of dogs translocated from GIB habitats annually

Year	No. of Dogs Removed
2019	9
2020	15
2021	73
2022	46
2023	124
2024	22
Total	289

3.2. Fence repair

Radio telemetry and ecological monitoring of GIB have shown that fenced enclosures inside DNP are important for breeding. Possible reasons for this are the low disturbance, high arthropod biomass and heterogeneous ground cover in these enclosures. Hence, it is important to minimise livestock grazing during the breeding season in these enclosures, as recommended by the National Bustard Recovery Plan Guidelines (Dutta et al. 2013). Fences were broken by local people to enable livestock to graze inside enclosures, particularly during summer, when fodder is scarce outside enclosures. Thus, it is important to repair and monitor these fences before the

breeding season (monsoon) to ensure there is low grazing pressure on enclosures/ grasslands and so that vegetation and insect populations can recover which will benefit GIB recruitment.

Surveys were carried out to identify these fence breaks in Sudasari, RKVY and PPC enclosures after consultation with RFD. These fence breaks were repaired between July and August 2021, when the recruitment of chicks was high. To ensure fencing is not damaged or broken, at least till the end of the breeding season, adequate monitoring and patrolling are necessary.

3.3. Jumpstart strategy

To improve GIB breeding success, in addition to removal of nest predators from enclosures, a novel “jumpstart” strategy has been pilot-tested to improve wild hatching rates by reducing the time of exposure of wild eggs to the risk of predation. Here eggs are collected from the wild and artificially incubated in the Conservation Breeding Centre while the wild female incubates a dummy egg. The egg is then placed back into the nest immediately prior to hatching. This strategy has been successfully carried out thrice. First in 2022 with a tagged female who successfully raised the male chick to more than 9 months of age and twice in 2024 with untagged females (survival of chicks is currently being monitored) (Image 32).

Considering the initial success of this strategy, the project has proposed to scale up this strategy by replacing wild eggs with surplus about-to-hatch eggs from captive-bred birds to reduce exposure duration and associated predation risk in the wild along with promoting genetic exchange between wild and captive populations. Alternatively, eggs can be hatched in captivity and chicks raised to 3-6 months of age before being released in safe sites with existing flocks. This can especially be attempted for lesser floricans who face even higher egg failure rates due to predation and agricultural activities.



Image 32. Tagged bird 5947 with her jump-start chick

3.4. Measures to reduce adult GIB mortality

3.4.1. Dog sterilisation

Free-ranging dogs are a known threat to wildlife across the globe. Our assessment from 2017 showed that free-ranging dogs in and around DNP are responsible for hunting a significant proportion of the chinkara population annually. To address this issue, spay neutering of dogs in and around DNP in collaboration with Humane Society

International (HSI)-India and RFD (October 2018 – January 2019) was carried out. For the first phase of sterilisation, 23 villages were targeted. A temporary post-op facility was set up in Sam village. The surgeries were performed in a well-equipped mobile operation theatre van. The highest number of dogs captured for sterilisation were from Sam (133), followed by Khuri (117) and Kanoi (95) (Table 16).

Interestingly, the vicinity of these three villages has the maximum tourism activity and therefore food subsidies for dogs. A total of 801 dogs (454 males and 347 females) were spayed/neutered and vaccinated against rabies from 20 villages (Table 16). Post-sterilisation, dogs were monitored in the post-op facility till they recuperated. Operated dogs were marked with an ear notch for future identification and released back to their respective villages (Image 33). To evaluate the coverage and effectiveness of the sterilisation program, we assessed the number and ratio of sterilised to unsterilised dogs using mark-resight based abundance surveys in six major villages (Sam, Kanoi, Salkha, Neemba, Bida, Keshawon ki Basti) and a crude count in all the treatment villages during February- March 2019.

The Project team coordinated the second drive of dog sterilisation exercise in June 2024 targeting 600 free-ranging dogs for spaying/neutering from 9 villages (Ramdevra, Brijpur, Gomat, Viramdevra, Eka, Mawa, Loharki, Chacha, Khetolai and BSF camp in Ramdevra) around Pokhran with technical support of the veterinary organisation ASRA, who were funded by Gramodaya Samajik Sansthan. So far, 352 dogs have been sterilised and vaccinated in this exercise and the program will continue till the target is achieved.

Table 16. Number of free-ranging dogs captured for sterilisation in different villages in/ around DNP during 2018-19

Village	Dogs
Sam	133
Khuri	117
Kanoi	95
Sipla	93
Neemba	66
Kumbhar Kotha	60
Ghuriya	54
Barna	38
Salkha	38
Khaba	32
Bida	21
Jamra	20
Bhilon ki dhani	13
Keshawon ki Basti	13
Meghwalon ki Basti	13
Ganga	6
Raydhan ki Dhani	6
Balanio ki Dhani	4
Singhalon ki Basti	4
Haider ki Dhani	1
Total	827

* 801 out of 827 dogs were vaccinated and sterilised



Image 33. Sterilisation drive for dogs in DNP in collaboration with Humane Society International (HSI), 2018

3.4.2. Bird flight diverter longevity

Installing bird flight diverters (BFD) is one of the most common solutions to reduce collisions with power lines. Overall BFDs are known to reduce collision rates with power lines by 50% (Bernadino et 2019). However, the effectiveness of these diverters varies greatly depending on the make, size, and spacing among other things, and their effectiveness on bustards are known to be much less (Silva et al. 2023).

As mandated by the Hon'ble National Green Tribunal (O.A. 385/2019 dated 23.12.2020), all existing lines in the GIB priority area were to be installed with BFD. In 2021, the Hon'ble Supreme Court (W.P. (C)838 of 2019 dated 19th April 2021) also ordered power line agencies to install diverters on lines until they were being undergrounded. The Project team procured diverters of various makes from international and national agencies (Table 17). These were distributed to various power line agencies including RVPNL, Jodhpur Vidyuth Vitranan Nigam Limited (JDVVNL) and Suzlon. 105 diverters were installed along lines in Khetolai, Mokla, Habur, and Khetolai villages (Image 34). Durability of makes installed varied widely, from 7 to 100% over a period of 2-4 years. Additional 300 diverters of different makes were distributed to various agencies in 2022 for installation.

Table 17. Details of diverters distributed by WII to various power line agencies in GIB priority area in Jaisalmer

SN	Diverter type	Units	Location	Power agency	Installation date	Line capacity	Date last examined	Area	Percent intact
A	FireFly and BirdMark	22	27.05499 70.6035	Suzlon	Feb 2018	33 kV	April 2022	Kuchri	33%
			27.19602 70.57894	Suzlon		220 KV		Habur	
			27.03802 70.57811	Suzlon		220 kV		Habur	
B	Raptor Clamp & Overhead Warning Light	35	27.01168 71.69339	RVPNL	May 2018	220 kV	April 2022	Khetolai	100%
C	Bird Flight LED Diverters	48	27.16142 70.6858	Suzlon	July – 2020	33 kV	April 2022	Mokla	7%

Understanding the effectiveness of diverters requires long-term monitoring. Surveys were conducted along power lines between March 2023 and January 2024 to study the durability and longevity of diverters across multiple lines. To assess the durability of diverters, information on the number of diverters was collected in the first four pylon segments at the start of each line. The surveys found that diverters were placed randomly along most lines and the average reduction in diverter numbers per year was 23%. More surveys will be conducted in the future including crossing surveys to understand the effectiveness of diverters in reducing bird collisions in the Thar landscape.

a) FireFly and BirdMark



c) Bird Flight LED Diverters



b) Raptor Clamp & Overhead Warning Light





Image 34. Pilot installation of bird flight diverter in Mokla and Khetolai for mitigating power lines collision for Bustard conservation





Picture Credit: G. S. Bhardwaj



A blurred photograph of two people in a field. On the left, a person wearing a red headscarf and a blue top is walking. On the right, a person in a white shirt is bent over, possibly working in the field. The foreground is filled with green, leafy plants. The background is out of focus, showing more greenery and a pale sky. A white rectangular box is positioned in the upper right area of the image, containing the text 'LESSER FLORICAN' in bold, black, uppercase letters. The right edge of the image features a vertical color bar with segments of brown, beige, and light tan.

LESSER FLORICAN

Lesser Florican

The lesser florican *Sypheotides indicus* is the smallest of the four bustard species found in India and endemic to this country, distributed across the country's lowland open plains. Historically, its distribution ranged from Gujarat and Rajasthan in west to West Bengal and Odisha in east, and from Saharanpur (Uttar Pradesh) in north to Thiruvananthapuram (Kerala) in south (Baker 1922-1930; BirdLife International 2001; Sankaran 1995). It was also found in the terai region of Nepal, Pakistan and vagrantly in Bangladesh and Myanmar. Though a resident in some areas, elsewhere they are a local migrant, showing irregular movements between breeding and non-breeding areas and their ranging patterns, especially in the non-breeding season, are poorly known (Ali and Ripley 1969). The current breeding distribution is restricted to: 1) Rajasthan, in the districts of Ajmer, Bhilwada, Tonk, Pali and Pratapgarh (Bharadwaj et al. 2011); 2) Gujarat, in the districts of Dahod, Bhavnagar, Amreli, Surendranagar and Kachchh (Bharadwaj et al. 2011); 3) Madhya Pradesh, in the districts of Ratlam (Sailana WLS), Dhar (Sardarpur WLS), Jhabua and Sheopur (Kuno WLS); 4) Maharashtra, in the districts of Yavatmal, Akola (Kasambe and Gahale 2010), Washim (Pandhripande and Patil pers. comm.), Nashik (Raha and Prakash 2001) and Kolhapur (Karkare pers. comm.); and 5) Andhra Pradesh, in the district of Kurnool (Rollapadu WLS and Banganpalli tehsil). Post-breeding, birds migrate to peninsular- (Dharmakumarsinhji 1950) and north- India (Sankaran pers. comm.).

Lesser florican breeds in rain-fed grasslands (0.02-30 km² in area) with ample ground cover (>55% grass and herb cover), moderately tall grasses (~50 cm), and scattered shrubs (BirdLife International 2009; Sankaran 1997; Magrath et al. 1985). Use of croplands for breeding is not common, but has been recorded along with breeding in grasslands within forest plantations. Moderately high grassland biomass, an indicator of low grazing pressure, and remoteness from human settlements (>2.6 km away) are additional important predictors of their occurrence (Dutta and Jhala 2012; Sankaran 1997; Magrath et al. 1985). In agro-grass mosaics, birds tend to clump in the scattered grasslands (Dutta and Jhala 2012), and can breed even in small grassland patches (<1 ha) within agriculture. Hilly terrain, wetland, dense forest, and deserts are avoided. During the non-breeding season, the species sometimes uses lightly wooded areas, grasslands and Zizyphus-dominated scrubland (Sankaran 2000).

Individuals are relatively solitary and extremely elusive, except during the breeding season. The species is omnivorous, feeding on insects such as grasshoppers, beetles, ants and caterpillars, amphibians, and plant parts like seeds, herbs, fruits and plant shoots (Ali et al. 1986; Baker 1922-1930; BirdLife International 2001; Sankaran and Rahmani 1986b). Birds forage in relatively open areas, commonly feeding in short grasses and low crops, and retire into thicker cover during mid-day. The availability of insects is considered an important factor in the reproductive success of female lesser floricans.

The breeding behaviour of lesser florican has been extensively studied in the past (Dharmakumarsinhji 1950; Dharmakumarsinhji 1953; Goriup and Karpowicz 1985; Sankaran 1991a; Sankaran and Manakadan 1990; Sankaran and Rahmani 1986). The species exhibits an exploded lek mating system, where males establish territories of 2-3 ha size, spaced at 200-500 m from each other (Sankaran 1994). Breeding coincides with the timing and intensity of South-West monsoon, beginning from May to August, and continuing till September. During this time, birds immigrate to breeding grounds, where males acquire breeding plumage and establish territories within the first few weeks (Sankaran 1994). They perform an aerial display from specific spots within the territory (Sankaran and Rahmani 1986), where they leap up to two meters in air from the ground, rapidly beating their wings and paddling the legs, after that falling swiftly back to the ground with their wings and legs tucked in. They also emit a frog-like rattle that can be heard from 300 to 400 m distance. Display rates are generally higher during the latter part of the breeding season, early morning and cloudy/rainy weather. It serves the dual function of repelling rival males and advertising to adjacent females. Females visit male arenas exclusively for mating, and nest outside or at the periphery of their territories (Sankaran 1994), raising the offsprings alone. Females prefer tall grass cover for nesting, and lay 4-5 eggs on bare ground (Gadhvi 2003; Sankaran 1994). She incubates these eggs for 21 days and both egg and female are highly vulnerable to predators

and poachers during this time. The newly hatched precocious chicks stay with their mother for roughly 15-30 days. Females and chicks stay in breeding grounds for at least a month longer than males.

In spite of being under Schedule 1 of the Wildlife (Protection) Act, the highest degree of protection, the species have faced catastrophic declines leading to it being listed as Critically Endangered by the IUCN Red List (Birdlife International, 2021). The species is suspected to have declined at an extremely rapid rate over the past three generations (93% over three generations). Although there is uncertainty over the accuracy of the population sizes estimated in each year due to accounting for undetected males, uncertainty over the population sex ratio and level of site fidelity in the species, it is clear that the species is undergoing a catastrophic rate of decline. Their decline was initially attributed to massive hunting for sport. Since the 1960s-70s, the major cause of decline had shifted to habitat loss from land use changes and invasion of non-native woody shrubs like *Prosopis juliflora*. The species' population dynamics most likely depend on rainfall, thus climate change, through the adverse effect of frequent droughts on breeding, can also exert unprecedented effects on birds (BirdLife International 2001). Today, the major threats to the species include habitat loss and mismanagement due to the lack of a holistic grassland conservation policy and scientific management, causing high rates of adult mortality or very low reproductive success (Dutta et al, 2018). A lack of ecological information, particularly for non-breeding habitats, also impedes their conservation.

Subsequently, this species was included as a priority in the Species Recovery Plan by the MOEFCC which recommends: (1) Protection of core areas that make them inviolate of consumptive human use during the breeding months; (2) curtailing the conversion of grasslands to wooded habitats by the plantation of shrub/tree species; (3) declaring unprotected grasslands as conservation/community reserves and integrating livelihood concerns with conservation; (4) population research and monitoring and habitat research using biotelemetry across their range; (5) a liaison committee between government and local communities for joint decision making on the use of private-public mixed ownership lands.

Conservation Breeding

1. Conservation breeding approach

The lesser florican conservation breeding efforts commenced in July 2020 in a temporary rental facility at Bijainagar, Ajmer in Rajasthan. The facility currently houses 10 captive-reared lesser floricans that were secured from 17 eggs, collected from the wild and hatched during years 2020 (2), 2022 (9) and 2023 (6). A substitute long-term facility has been developed in the Arwar Forest Block near Shokaliya and operationalised since July 2024 and construction of a permanent Conservation Breeding Centre at Sorsan has also commenced.

1.1. Collection, transportation and artificial incubation of eggs

All eggs collected from the wild were transported to the facility and artificially hatched following the general protocols described for Great Indian Bustard (section 2.1). Eggs hatched approximately 22 days after laying.





Image 35. Monitoring of lesser florican eggs and chick at LF facility, Bijainagar

1.2. Chick stage

After keeping newly hatched chicks for 24 hours in the brooder, they were shifted to the first age unit - an air-conditioned room - where they were kept in transparent acrylic glass boxes with soft mat padding at the bottom and heat lamps in corners. Chicks were reared on soft balanced diet pellets (SDS), mealworms, crickets, alfalfa and seasonal fruits. In the first age, they were mostly hand-fed by keepers at regular intervals of one hour. Chicks were gradually shifted to an indoor rearing cage with sand and gravel layering for exercise and acclimatisation from 15 days. At 20 days, chicks were introduced to outdoor cage for short periods to encourage play and exercise for skeletal and muscle development. Chicks were weighed daily and measured on alternate days to monitor their health and growth.

1.3. Juvenile stage

Birds were introduced to outdoor metal cages with internal soft net layering (dimensions 3×4×3 m) and were kept in flocks from the age of 30 to 60 days (during September-October). These cages had a gravel substrate with grass, alfalfa and small shrubs for their cover. Birds were fed at regular intervals of 1-2 hours in morning and evening shifts. They were fed with soft and dry balanced diet pellets, mealworms, crickets, alfalfa, pomegranate as well as watermelon and were gradually introduced to dry balanced pellets (produced by IFHC/Reneco for bustards). Chicks were weighed daily and measured twice a week to monitor their growth. Birds gained their adult weight of 450 g (male) and 550 g (female) within the first two months (Figure 62). Keepers continued handling and spending extended time with them to continue habituation to humans. Till the age of 60 days, these birds were kept outdoors during daytime and were shifted indoors during nighttime, till they had acclimatised to the external environment.

1.4. Sub-adult stage

After two months, birds were shifted outdoors completely. Indoor cages, in a portable container, were used in winter (temperature <15°C) for ~3 months and inclement weather conditions, and shifted back to outdoor cages in March when night temperatures reached >17°C. As they are territorial, all birds were kept separately in individual compartments from this age. Birds became independent and started eating by themselves at this age. Weighing was done once a week. Bird weights ranged between 460-480 g for males and 550-580 g for females, with weights varying by 30-40 g between summer and winter (Figure 62). One-year-old males showed partial breeding plumage at the start of breeding season. Birds started avoiding keepers and bird-keeper interactions were minimised after 3-4 months of age.

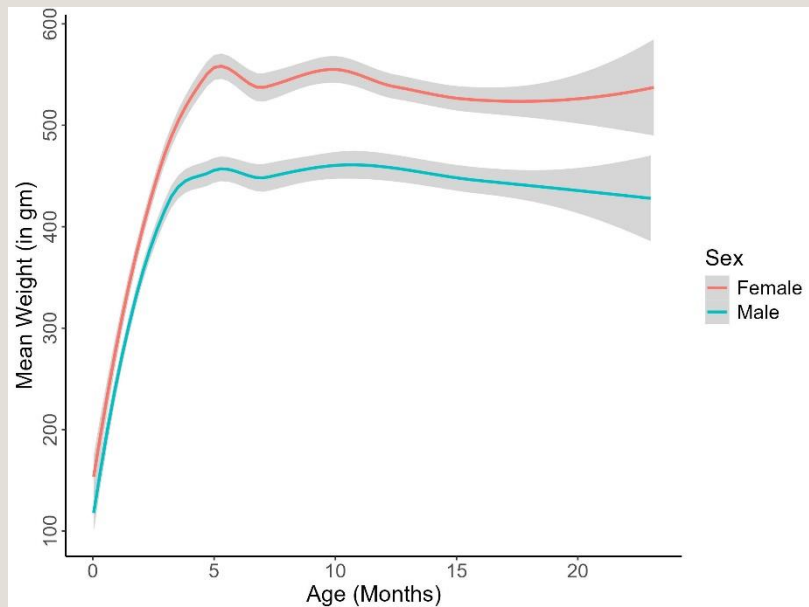


Figure 62. Growth pattern of captive lesser floricans at LF conservation breeding facility in Bijainagar

1.5. Veterinary care

- Birds were vaccinated for Newcastle and Avian Pox.
- Injuries due to jumping in cages are common in the floricans in captivity with a few instances of wing and leg fractures. Radiographs are taken and fractures are corrected with bandaging or using surgical interventions like pinning.
- Physical examination of birds is done routinely and blood parameters are recorded to monitor the health of the individuals. The birds which show any signs or symptoms of illness are monitored closely and treatment is provided including modified diets, medicines and supplements.
- Strict biosecurity protocols are followed to prevent the spread of infectious diseases.

1.6. Centre infrastructure

1.6.1. Bijainagar LF Conservation Breeding Centre

A temporary LF breeding centre was established at a private rental property in Bijainagar, Ajmer in 2020. The facility contains one building within which an incubation, chick-rearing, indoor bird cage, veterinary and live feed unit have been set up. Additionally, one large outdoor cage with two containers have been built to house adult birds. The containers serve as an indoor unit to house birds during inclement weather, especially winters.

1.6.2. Arwar LF Conservation Breeding Centre

To provide a long-term safe space for the captive floricans in Ajmer, the Arwar forest area was jointly selected by the RFD and Project team (Image 36). Two old *chowkis* at the Arwar block were handed over to the Project by RFD and were modified by WII to hold the conservation breeding facilities. One of the *chowkis* was fully repaired and converted into staff accommodation, a store and a live feed rearing room. The second *chowki* was converted into an incubation, chick rearing, veterinary room and office space. A metal cage for outdoor housing of adult LFs was constructed in the facility and internal soft net cages are currently being constructed. All these buildings were interconnected and provided with water, electrical and sewage line connections.



Image 36. Ongoing construction of Arwar LF Conservation Breeding Centre

1.6.3. Sorsan Conservation Breeding Centre

Construction of a permanent facility in Sorsan, as initially planned in the Project, was reinitiated through a joint visit of the Project team, CPWD engineers and Forest Department during May 2023 and a timeline for construction of first phase buildings was mutually decided (Image 37). The first phase of construction would include five buildings, namely, an incubation and chick-rearing unit, a veterinary unit, a bird food production (live feed) unit, an adult indoor/outdoor cage and a security outpost. The CPWD commenced the work on the ground in December 2023 and the work is currently in progress with the foundation for all buildings already constructed.



Image 37. Site for Sorsan Bustard Conservation Breeding Centre

2. Outcomes

- The lesser florican conservation breeding efforts began in July 2020 and the project has successfully established a captive population of 10 individuals (four males and six females) that are currently housed in the Arwar facility.
- Construction of the permanent hatchery facility at Arwar, began in November 2023 after Rajasthan Forest Department had allocated this Forest block for conservation breeding activity. Construction of this facility was completed in June 2024 and had been operationalised since July 2024, and all captive-reared lesser floricans were shifted to this facility.

- The construction of the larger Sorsan facility began in 2023 and significant progress had been made.
- A team of technicians and local staff have been trained in all aspects of lesser florican husbandry and protocols for their rearing have been developed and are being continually adapted based on our learnings.

3. Way forward

3.1. Conservation breeding facilities

The Arwar conservation breeding facility can continue to serve as the egg-collection, hatching and bird-rearing facility for lesser florican in the long-term, given its proximity to breeding areas and allocation of the Forest Block for this purpose. This facility needs to be upgraded in the next phase of the project by adding predator-proof fence, indoor/outdoor bird cage(s), accommodation and other necessary infrastructure/equipment. Construction of a larger conservation breeding facility in Sorsan is in progress. Basic building structures should be completed with water and electricity supply by 2025 and this facility can be made operational soon after. Additional structures such as predator-proof fence, large breeding/rewilding aviary, accommodation, and other necessary infrastructure/equipment have to be added here. Given the large area allocated for this facility, it can serve the purpose of conservation breeding and rewilding for multiple species, subject to expert feasibility assessment.

3.2. Founder establishment and captive breeding

Egg collection of lesser florican to supplement the founder stock with minimal impact to the wild population can be continued till >20 breeding birds (15 females and 5 males) are secured, similar to GIB. Currently, the captive stock is of 10 birds over one year in age and breeding is yet to commence. The species is very shy, sensitive and gets easily stressed in captivity. However, efforts towards conservation breeding are vital since their recruitment and survival in the wild are very poor. Such challenges entail major refinements in captive-rearing and breeding techniques to be developed for this species in the future phase(s) of the project.

3.3. 'Jumpstart' release

Since captive-reared lesser floricans are not easily imprinted on humans, there is a possibility to raise chicks and pilot release them, to assess their survival. Chicks in the wild leave the breeding area when they are three-four months old around October. So, a pilot release of a few chicks that are artificially hatched from wild-laid eggs and initially raised in the conservation breeding facility, can be planned at the same time. Since the bird reaches adult size by this time, the release chicks can be tagged to monitor their post-release survival. If successful, this 'jumpstart' measure can be scaled up. Our observations over the last four years in the prime breeding habitat of Shokaliya suggest very high egg and chick mortality due to predation and farming activities, resulting in very high *in-situ* breeding failure (14 out of 18 predated) of the lesser florican. Their breeding habitats are spread over large unprotected agricultural areas where regulation of farming activities is difficult. Hence, a jumpstart strategy, if successful, can improve the species' *in-situ* recruitment and contribute to its recovery. Birds to be released will have to be tagged and monitored intensively post-release to understand their movements and threats in breeding and non-breeding areas, for effective conservation interventions. Approval on this activity has been sought from MoEFCC and Rajasthan Forest Department.

Applied Research

1. Population and habitat survey of lesser florican

1.1. National lesser florican status assessment

The lesser florican is a Critically Endangered agro-grassland bustard species. Little is known regarding its ecology and population status which impedes conservation efforts. To bridge this gap, national-level status surveys (2017 and 2018) were designed by WII in collaboration with The Corbett Foundation (TCF), BNHS, Hyderabad Tiger Conservation Society (HyTiCoS) and SFD of Range States (Rajasthan, Gujarat, Madhya Pradesh, Maharashtra and Andhra Pradesh).

The lesser florican is cryptic and migratory which makes it unnoticeable for most of the year except during its breeding season where males change their plumage and perform an aerial display to attract mates. Since the breeding season spanning two months is the best opportunity for surveying this species, its breeding range was delineated using species distribution model (MaxEnt) and inputs from local experts (Figure 63) (Philips et al., 2006). The breeding range was divided into eco-geographical regions and landscapes (Ajmer: Shokaliya-Kekri; Rest of Rajasthan: Shahpura, Jalore, and Pratapgarh; Gujarat: Kachchh, and Saurashtra; Madhya Pradesh: Ratlam; Deccan: Akola-Washim in Maharashtra and Kurnool in Andhra Pradesh) (Figure 63).

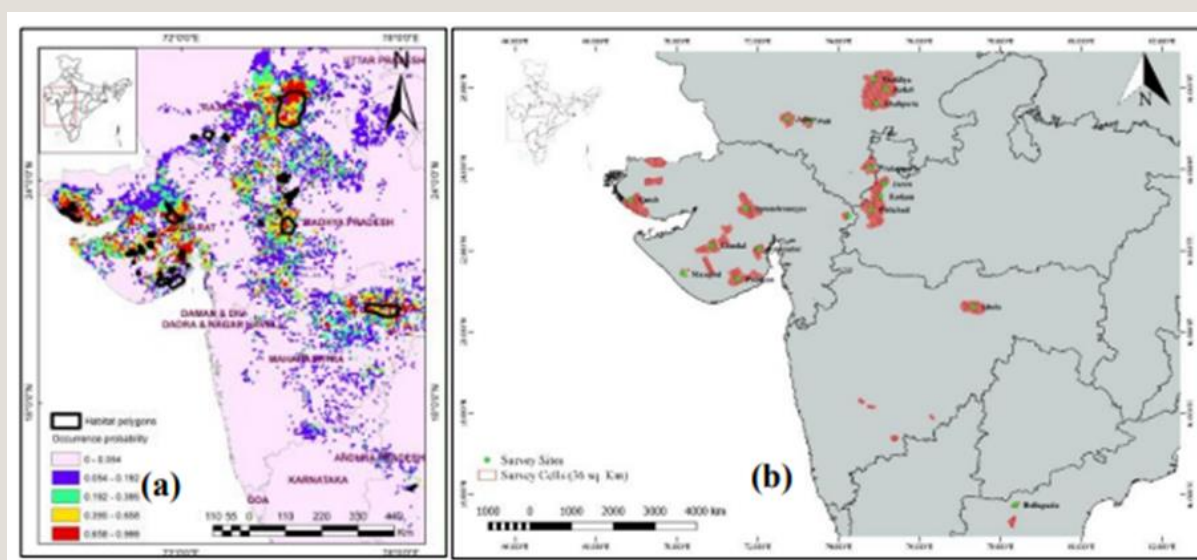
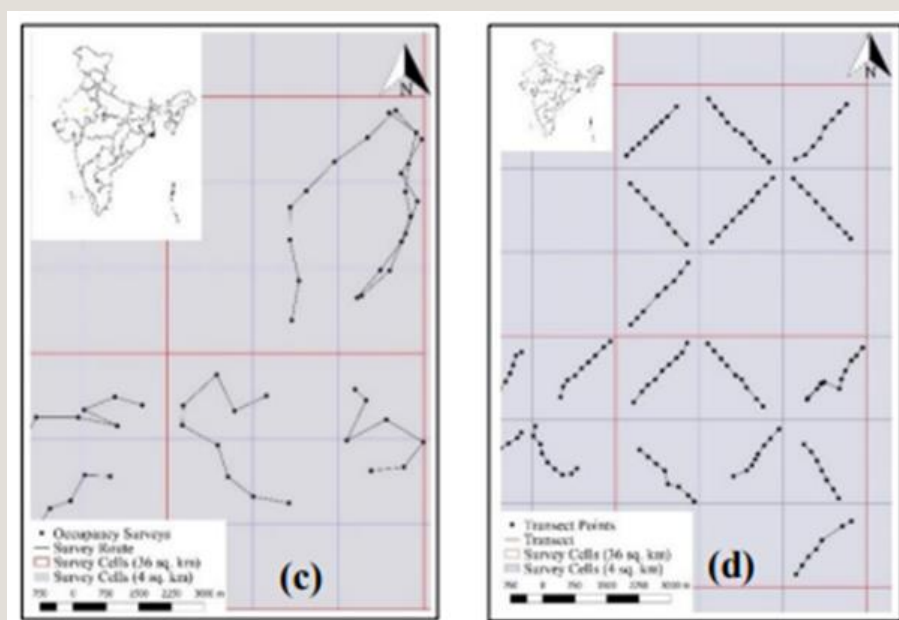


Figure 63. Map showing the occurrence probability of Lesser florican and survey sites in India

Hurdle modelling approach was used to assess the status of the species based on the displaying males, using spatially representative sampling and analytical design, which accounted for imperfect detections. First, the occupancy of the species was estimated in grids of 36 km² using vehicle observation or stop-over points (Figure 64). Sites where the bird was detected were then surveyed for abundance using line transect distance sampling. Habitat parameters such as land cover, vegetation structure and anthropogenic pressures were noted systematically along occupancy and distance surveys. Relationships between the species' occupancy/abundance patterns and habitat covariates were examined. Finally, a conservation priority map was generated using the species' distribution, local densities and threats.



Figures 64. Maps showing the traversed transects to survey lesser florican occurrence within survey cells

The survey was conducted during the breeding season (July- September, 2017 and 2018) with a team of 141 observers/surveyors. Training workshops were conducted at key sites (Bhavnagar, Ajmer, Ujjain and Akola) where observers were trained on standard data collection protocol.

Efforts and findings of 2017 status survey

The first status survey was conducted during the breeding season (July–September, 2017) with a team of 121 observers, who were trained on the standard data collection protocol through state-level workshops at Bhavnagar, Ujjain, Ajmer and Akola. Lesser florican occupancy was assessed at 428 sites (36 km²) spread across ~20,000 km² range, using 5400 stop-overs, and density was assessed in 32 sites (where the species was detected) using 488 km transect walks that yielded 70 sightings (64 males, 6 females) in 218 transects.

Lesser florican occupied $13 \pm 3\text{SE}$ % sites or 1908 km² area, at ecological density of $0.25 \pm 0.06\text{SE}$ territorial males per km² (Table 18). The population size was estimated to be 340 (162–597, 95%CI) territorial males, with a conservative estimate of 264 individuals. Regional assessments indicated that the population was largely restricted to: Velavadar (Bhavnagar, Gujarat) having 96–115 territorial males and Shokaliya-Bhinai (Ajmer, Rajasthan) having 110–136 territorial males (Table 18). The species' response to habitat exhibited regional plasticity, with occupancy favoured by grassland cover in Gujarat, and by agricultural cover in Ajmer (Figure 66). However, density in occupied sites was an increasing function of grassland cover, indicating that males congregated in large contiguous grasslands. Birds were dispersed over a large agricultural expanse at low density in Ajmer (~800 km²) and clustered at high density in a small grassland reserve in Bhavnagar (~100 km²). This inverse density-occupancy relationship perhaps resulted from their flexible social/spatial organisation, implying that a contiguous grassland would achieve the higher conservation outcome. Finally, we prioritised sites and quantified threat levels across landscapes and regions, to guide conservation investments.

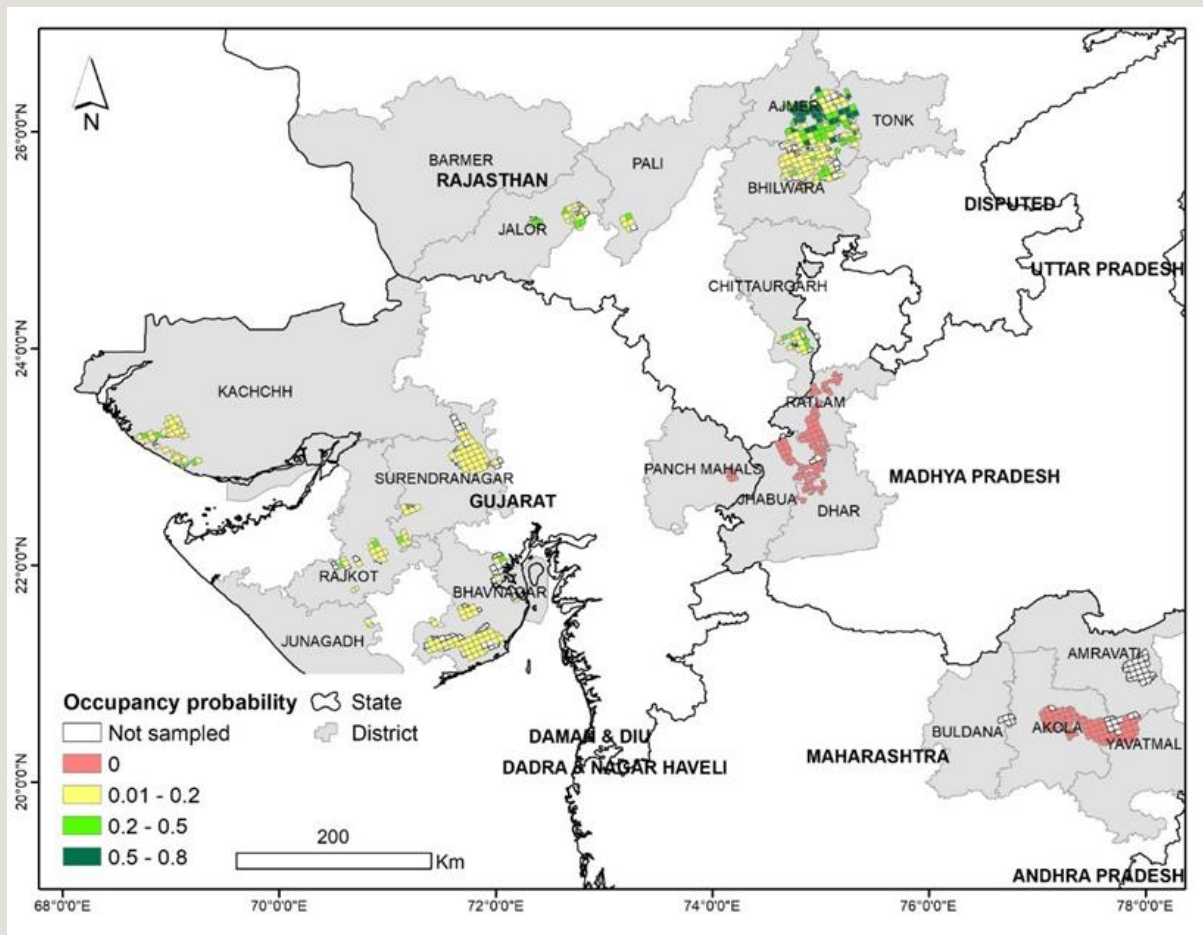


Figure 65. Occupancy probability of lesser florican and conservation importance of sites (36 km² cells) across breeding range during July–September 2017

Table 18. Occupancy sampling and distance sampling results of Lesser florican survey across the landscapes

Area		Occupancy sampling				Density (distance) sampling			
Region	Landscape	Sites	Stopover (surveys)	Detected stopovers	Detected sites	Sites	Transects	Effort (km)	Male sightings
Ajmer	Kekri	37	444	4	2	3	19	39	15
	Shokaliya	51	711	21	17	17	112	244	15
Rajasthan rest	Jalore	20	254	1	1	1	5	9	0
	Pratapgarh	15	140	1	1	1	5	11	2
	Shahpura	48	555	3	3	4	30	72	0
Gujarat	Kachchh	30	407	5	4	4	29	78	1
	Saurashtra	105	1450	14	3	2		35	31
Maharashtra	Akola-Washim	50	649	0	0				
Madhya Pradesh	Ratlam-Sardarpur	72	790	0	0				
Total		428	5400	49	31	32	218	488	64

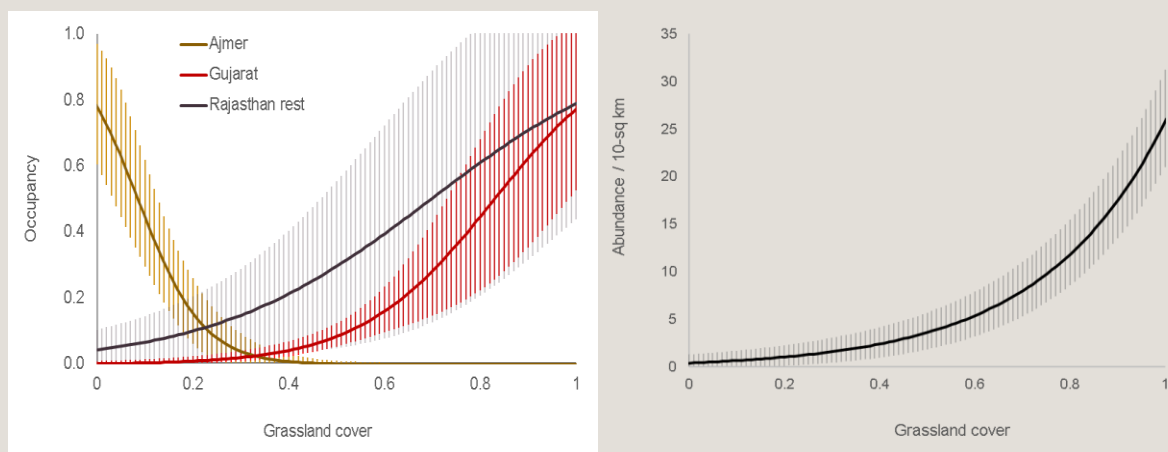


Figure 66. Relationships between occupancy probability and proportional grassland cover across regions (left), and mean abundance /10 km² vs. proportional grassland cover across sites occupied by lesser florican in the breeding range during July–September 2017 (right)

Efforts and findings of 2018 status survey

In 2018, vehicle surveys for estimating occupancy were conducted at 545 sites covering ~31,000 km² area using 8333 stop-over points. Birds were detected in 43 sites in which further walk transects were done to estimate the density. 134 birds (116 males and 18 females) were sighted in the 632 km of walk transects in this survey. Of the total area surveyed, LF occupied only 9.6% (2.3 SE) sites or 2972 km² area, at an ecological density of 0.20 (± 0.07 SE) territorial males/km² (Table 19). The population size was estimated to be 426 (174-805 95% CI) territorial males with a conservative estimate of 220 (± 38 SE) birds in the surveyed region. Thus, the species' abundance estimates were similar between the two-yearly surveys.

Table 19. Estimated occupancy and density of Lesser florican in its ranges states in India

Region	Description of Sites	Occupancy (95% CI)	Density (km ²) (95% CI)
Ajmer	Shokaliya, Bhinai and Malpura	0.35 (0.19-0.55)	0.23 (0.14-0.39)
Deccan	Akola-Washim in Maharashtra and Rollapadu in Kurnool, Andhra Pradesh	0.03 (0-0.18)	0 (0-0)
Gujarat	Kachchh, Surendranagar, Bhavnagar, Rest of Saurashtra and Dahod	0.04 (0.02-0.11)	0.72 (0.31-1.7)
Madhya Pradesh	Ratlam (Sailana), Sardarpur and Petlawad	0.08 (0.03-0.18)	0.06 (0.02-0.24)
Rest of Rajasthan	Shahpura, Jalore, Pali and Pratapgarh	0.04 (0.01-0.16)	0 (0-0)
Global		0.1 (0.05-0.15)	0.2 (0.1-0.39)

Table 20A. Regional habitat characteristics (land use, vegetation structure, crop composition, disturbances), associated species, and sampling details across lesser florican breeding range during July – September 2019 with standard error in brackets

	Attributes	Unit	Akola	Jalore	Kekri	Kachchh	Pratapgarh	Ratlam	Rollapadu	Saurashtra	Sha-pura	Shokaliya	Global
Land uses	Grassland	Proportion cover	0.205 (0.027)	0.172 (0.024)	0.185 (0.024)	0.16 (0.02)	0.21 (0.047)	0.241 (0.017)	0.139 (0.042)	0.19 (0.013)	0.233 (0.019)	0.2 (0.016)	0.2 (0.007)
	Agricultural		0.696 (0.029)	0.43 (0.035)	0.663 (0.028)	0.237 (0.024)	0.74 (0.041)	0.709 (0.019)	0.799 (0.049)	0.55 (0.015)	0.542 (0.025)	0.569 (0.024)	0.585 (0.01)
	Scrubland		0.066 (0.013)	0.166 (0.023)	0.025 (0.005)	0.239 (0.029)	0.026 (0.011)	0.014 (0.003)	0.046 (0.022)	0.151 (0.009)	0.137 (0.018)	0.124 (0.022)	0.105 (0.006)
	Woodland		0.02 (0.005)	0.205 (0.023)	0.121 (0.013)	0.248 (0.028)	0.024 (0.009)	0.03 (0.005)	0.007 (0.007)	0.08 (0.009)	0.075 (0.014)	0.098 (0.013)	0.084 (0.005)
	Barren		0.014 (0.005)	0.028 (0.009)	0.007 (0.004)	0.115 (0.024)	0 (0)	0.006 (0.001)	0.009 (0.007)	0.029 (0.005)	0.013 (0.004)	0.009 (0.002)	0.025 (0.003)
Vegetation structure	Ground vegetation height	metre	0.206 (0.015)	0.319 (0.034)	0.231 (0.013)	0.607 (0.03)	0.29 (0.033)	0.172 (0.009)	0.141 (0.032)	0.223 (0.01)	0.247 (0.019)	0.25 (0.012)	0.255 (0.007)
	Ground vegetation cover	Proportion	0.316 (0.02)	0.448 (0.028)	0.335 (0.025)	0.533 (0.026)	0.331 (0.042)	0.282 (0.014)	0.159 (0.042)	0.379 (0.013)	0.366 (0.02)	0.385 (0.018)	0.357 (0.007)
	Crop height	metre	0.32 (0.017)	0.178 (0.021)	0.473 (0.028)	0.158 (0.026)	0.471 (0.051)	0.406 (0.013)	0.241 (0.035)	0.249 (0.009)	0.549 (0.023)	0.45 (0.022)	0.339 (0.008)
	Crop cover	Proportion	0.488 (0.025)	0.182 (0.022)	0.485 (0.028)	0.207 (0.028)	0.596 (0.056)	0.517 (0.015)	0.241 (0.046)	0.474 (0.014)	0.415 (0.022)	0.535 (0.023)	0.441 (0.009)
Cropping	Sorghum	Frequency occurrence	0.016 (0.006)	0.11 (0.022)	0.583 (0.035)	0.008 (0.003)	0.004 (0.004)	0.004 (0.002)	0 (0)	0.345 (0.02)	0.389 (0.034)	0.655 (0.03)	0.226 (0.012)
	Cotton		0.094 (0.017)	0.04 (0.022)	0.075 (0.014)	0.152 (0.033)	0.012 (0.009)	0.029 (0.005)	0.183 (0.05)	0.591 (0.022)	0.072 (0.013)	0.038 (0.009)	0.203 (0.012)
	Sesame		0 (0)	0.14 (0.031)	0.162 (0.021)	0.026 (0.011)	0.064 (0.027)	0 (0)	0 (0)	0.019 (0.006)	0.252 (0.024)	0.078 (0.017)	0.053 (0.005)
	Soya bean		0.619 (0.045)	0 (0)	0 (0)	0 (0)	0.611 (0.089)	0.589 (0.028)	0 (0)	0 (0)	0.008 (0.006)	0 (0)	0.195 (0.014)
	Maize		0.041 (0.013)	0.016 (0.01)	0.102 (0.023)	0 (0)	0.658 (0.063)	0.478 (0.027)	0.122 (0.039)	0.044 (0.007)	0.27 (0.027)	0.037 (0.01)	0.166 (0.01)
	Green gram		0.066 (0.017)	0.088 (0.021)	0.442 (0.043)	0.006 (0.006)	0.016 (0.007)	0.002 (0.001)	0.002 (0.002)	0.01 (0.003)	0.045 (0.016)	0.466 (0.031)	0.091 (0.008)
	Groundnut		0.002 (0.002)	0.011 (0.007)	0 (0)	0.044 (0.014)	0.015 (0.015)	0.007 (0.002)	0 (0)	0.215 (0.021)	0.001 (0.001)	0.011 (0.004)	0.062 (0.007)
	Pearl millet		0.061 (0.02)	0.045 (0.015)	0 (0)	0.013 (0.005)	0.046 (0.019)	0.004 (0.002)	0.313 (0.059)	0.016 (0.004)	0.018 (0.006)	0.003 (0.002)	0.032 (0.005)
	Other crops		0.024 (0.011)	0.119 (0.023)	0.097 (0.022)	0 (0)	0.022 (0.012)	0.006 (0.003)	0 (0)	0.011 (0.003)	0.033 (0.01)	0.143 (0.025)	0.035 (0.004)

Table 20B. Regional habitat characteristics (land use, vegetation structure, crop composition, disturbances), associated species, and sampling details across lesser florican breeding range during July – September 2019 with standard error in brackets

	Attributes	Unit	Akola	Jalore	Kekri	Kachchh	Pratapgarh	Ratlam	Rollapadu	Saurashtra	Shahpura	Shokaliya	Global
Food	Arthropod	# per metre	0.618 (0.042)	0.802 (0.086)	0.979 (0.073)	0.437 (0.044)	0.774 (0.149)	0.587 (0.025)	0.183 (0.027)	0.292 (0.017)	1.113 (0.065)	0.811 (0.061)	0.586 (0.018)
	Dog	Frequency occurrence	0.287 (0.025)	0.203 (0.041)	0.135 (0.018)	0.155 (0.025)	0.286 (0.064)	0.255 (0.017)	0.086 (0.029)	0.205 (0.013)	0.115 (0.015)	0.169 (0.022)	0.199 (0.007)
Disturbances	Human		0.808 (0.022)	0.636 (0.05)	0.783 (0.029)	0.399 (0.035)	0.909 (0.024)	0.892 (0.011)	0.608 (0.064)	0.803 (0.015)	0.789 (0.02)	0.765 (0.025)	0.763 (0.01)
	Livestock		0.439 (0.034)	0.313 (0.038)	0.347 (0.033)	0.237 (0.027)	0.629 (0.062)	0.57 (0.021)	0.179 (0.053)	0.343 (0.018)	0.438 (0.031)	0.334 (0.026)	0.393 (0.01)
	Pesticide		0.054 (0.011)	0.006 (0.004)	0.037 (0.01)	0.003 (0.002)	0.017 (0.011)	0.03 (0.01)	0.13 (0.043)	0.061 (0.008)	0.004 (0.002)	0.01 (0.004)	0.037 (0.004)
	Machines	Frequency occurrence	0.12 (0.024)	0.169 (0.034)	0.135 (0.026)	0.019 (0.006)	0.085 (0.039)	0.055 (0.012)	0.296 (0.053)	0.138 (0.012)	0.021 (0.007)	0.099 (0.017)	0.102 (0.006)
	Settlements		0.372 (0.036)	0.191 (0.038)	0.176 (0.02)	0.195 (0.035)	0.415 (0.058)	0.443 (0.021)	0.105 (0.03)	0.276 (0.021)	0.186 (0.019)	0.17 (0.025)	0.279 (0.01)
	Power line/turbines		0.824 (0.021)	0.542 (0.052)	0.524 (0.042)	0.454 (0.043)	0.833 (0.062)	0.765 (0.022)	0.488 (0.064)	0.72 (0.023)	0.438 (0.033)	0.5 (0.035)	0.642 (0.012)
	Road		0.435 (0.043)	0.172 (0.029)	0.279 (0.037)	0.14 (0.021)	0.415 (0.062)	0.472 (0.025)	0.433 (0.062)	0.296 (0.017)	0.252 (0.029)	0.274 (0.031)	0.327 (0.011)
	Industries		0.02 (0.007)	0.026 (0.015)	0.021 (0.007)	0.001 (0.001)	0 (0)	0.004 (0.001)	0.027 (0.025)	0.016 (0.005)	0.004 (0.002)	0.01 (0.005)	0.012 (0.002)
	Mines		0.033 (0.01)	0.022 (0.017)	0.027 (0.008)	0 (0)	0 (0)	0.021 (0.005)	0.022 (0.015)	0.012 (0.003)	0.007 (0.003)	0.02 (0.005)	0.016 (0.002)
	Blackbuck	Frequency occurrence	0.072 (0.019)	0 (0)	0 (0)	0.002 (0.002)	0.007 (0.007)	0 (0)	0.064 (0.024)	0.006 (0.004)	0 (0)	0 (0)	0.012 (0.003)
Associated species	Fox		0.003 (0.002)	0 (0)	0.002 (0.002)	0.002 (0.002)	0 (0)	0.001 (0.001)	0.015 (0.01)	0 (0)	0 (0)	0 (0)	0.002 (0.001)
	GIB		0 (0)	0 (0)	0 (0)	0.001 (0.001)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Chinkara		0.009 (0.006)	0.019 (0.008)	0 (0)	0.008 (0.004)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.003 (0.001)
	Nilgai		0.022 (0.008)	0.029 (0.012)	0.038 (0.012)	0.01 (0.004)	0.004 (0.004)	0.013 (0.004)	0.002 (0.002)	0.023 (0.004)	0.008 (0.004)	0.03 (0.007)	0.019 (0.002)
	Wolf		0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Florican past status	Proportion respondents	0.444 (0.069)	0 (0)	1 (0)	0.105 (0.042)	0.167 (0.072)	0.296 (0.039)	0.25 (0.089)	0.107 (0.02)	1 (0)	0.287 (0.05)	0.21 (0.015)
Sampling efforts	Sites		59	24	36	56	16	115	27	147	49	57	586
	Visits		789	351	505	875	222	1825	172	2191	713	794	8437

Conservation recommendations

Based on the survey findings and prior knowledge (Dutta et al. 2013), conservation recommendations for each landscape were developed, to guide species' recovery actions. Given that the lesser florican population might have dwindled by ~80% over the last 3–4 generations, immediate scaling up of efforts for the species' conservation is required. The priority sites for conservation actions are Shokaliya and Saurashtra landscapes >> Kachchh and Kekri landscapes >> Ratlam, Shahpura and Akola landscapes.

Key recommendations for priority sites were to:

1. Provide protection to priority lesser florican sites by creating conservation areas and implementing strict patrolling by Forest Department and local communities,
2. Regulating intensive land uses such as infrastructural, industrial and salt pan developments, and mitigation of existing power infrastructure,
3. Implementing scientific grassland management by consolidating relatively large contiguous grasslands, restricting livestock grazing for monsoon months (June–September), restoring habitats by removing exotic shrub/tree plantations,
4. Incentivising florican-friendly agricultural practices by promoting scattered organic farming and stall-feeding of livestock in monsoon months against compensations,
5. Consolidating networks of local people or ‘florican friends’ who can report and prevent detrimental activities,
6. Reducing nest/chick predation by free-ranging dogs by undertaking a holistic dog population control program in neighbouring villages,
7. Generating scientific information on lesser florican ecology particularly the non-breeding season using satellite telemetry and associated surveys to aid conservation management,
8. Advocacy and outreach programs to generate support among multiple stakeholders for lesser florican conservation, and,
9. Finally, given the potential decline of the species, gaps in our knowledge regarding their key threats, and inherent difficulties in implementing urgent conservation actions in their vast unprotected habitats, a conservation breeding program should be implemented urgently to secure a captive population for insurance and possible reintroduction in future. Given the current numbers, there is still a window of opportunity for recovery of the lesser florican.
10. This status assessment protocol should be implemented periodically with necessary refinements to monitor the pulse of the endangered lesser florican and its dwindling habitats.

2. Telemetry-based understanding of spatial ecology

2.1 Migration pattern

Telemetry of lesser florican was initiated in September 2019, a total of 10 individuals have been tagged over 5 breeding seasons between 2019-23 (Table 21). It includes seven males and three females. Trapping exercise was carried out in Shokaliya-Bhinay landscape of Ajmer during July – September months (breeding season). Males were trapped at display locations and females were trapped around their nesting sites. At the time of trapping, a quick response team was on standby in the vicinity of the trapping location, and captured birds were tagged and released within 20 minutes of trapping. Birds were measured and weighed before release, males weighed between 418 g and 503 g and females weighed between 500 g and 550 g. All tagged males started displaying from their arenas within two days of tagging, some even displayed just after the release within close vicinity of the release site. Two types of transmitters were used, Milsar S-9 GSM solar powered tag and Ornitela OT-E 10 3G. Both the transmitters weighed <3% of the bird’s body weight and transmitted locations via cellular network. The tags were programmed to record GPS coordinates at an interval of 180 minutes and transmit the recorded locations every eight hours effectively giving eight location points daily.



Image 38. Release of a Lesser Florican after deploying radio-telemetry tag in Rajasthan

On average, most tags have transmitted for only a year, despite being some of the best tags available of this weight class. Our preliminary observations show that these birds intensively use areas with dense vegetation during the non-breeding season which does not allow the tag to charge enough and transmit on a regular basis. Further, these birds frequently use remote areas without mobile network coverage which causes delays in the transmission. When tags are non-functional for long durations, due to large data storage and low battery, they can malfunction. However, some tags have recently re-transmitted after months of communication loss, which indicates that these birds with malfunctioned tags may still be alive. And despite the low life of the transmitters, tagged individuals provided valuable insights on the migratory patterns of the species as well as the non-breeding habitat used by males and females.

Four transmitters (two males and two females) worked for two breeding seasons and provided data on bird movement from breeding to non-breeding habitats and the reverse migration from non-breeding to breeding habitats. Tagged floricans were ground-tracked during breeding and non-breeding seasons. Ground tracking was not carried out during 2020-21 due to COVID-19 restrictions. To understand the breeding and non-breeding site selection criteria, the habitat characteristics were quantified (land cover, terrain, vegetation composition, arthropod, disturbances and visibility) at used locations (points within weekly minimum convex polygons of each bird) and control points.

Table 21. Summary of all LF tags deployed in Phase 1

Tag ID	Type	Sex	Nickname	Tagging date	Total distance covered (km)	Current status
3CC06811	Milsar	M	Sufi	17.09.19	568	Non-Functional
C4A5DE11	Milsar	M	Ravi	25.08.20	1030	Non-Functional
C2A5DE11	Milsar	M	Dhantol	31.08.20	428	Non-Functional
C5A5DE11	Milsar	M	Bandu	9.08.21	3398	Non-Functional
49CO6811	Milsar	M	Bhutta	10.08.21	3261	Non-Functional
215636	Ornitela	F	36	24.08.22	8400	Functional
215637	Ornitela	M	37	25.08.22	235	Non-Functional

215638	Ornitela	M	38	24.08.22	268	Non-Functional
C4A5DE11	Milsar	F	Ravina	6.09.22	5744	Functional
216770	Ornitela	F	70	4.08.23	896	Non-Functional

First Record of lesser florican in Desert National Park

A male lesser florican was sighted by the Project team for the first time in Sudasari enclosure of Desert National Park on 2nd July 2024. Following that, up to two breeding males were seen/heard displaying in this enclosure during 11-13 July. This marked the first-ever record of the species in DNP and its westernmost record in India. In 2023, one of our tagged female floricans moved up to Balesar in Jodhpur district of Rajasthan but it is unknown if it bred there.

This species is known to migrate to north-west India in the breeding season with known breeding grounds in southern and western Gujarat, southern Rajasthan and western Madhya Pradesh (Sankaran 1991; 1997). Birds are known to congregate in areas with good quanta and distribution of rainfall that is an important determinant of their breeding success (Sankaran 1994, Dutta et al 2018). DNP received heavy rainfall in the week prior to the first sighting (142 mm). The second factor for breeding habitat selection is availability of undisturbed grasslands with good grass cover and heterogeneous ground vegetation height (Sankaran 1997, Dutta et al 2018). The 15 km² Sudasari enclosure is one of the last few large grassland habitats in Western Thar with minimal grazing and human disturbance and active grassland management in the last few years. These factors might explain the arrival of the bird to this region but it is yet to be determined if environmental conditions are suitable for these birds to continue breeding activity here. However, this shows the importance of good grassland habitats and could serve as potential breeding sites for such vagrant and opportunistic species.

2.2. Movement patterns

Daily movement rate of tagged LFs was assessed through GPS fixes obtained from the transmitter data. The data was subset based on the season, viz. breeding, non-breeding and migration. The males generally restrict themselves to their breeding territories once established and move outside the territory mostly after the breeding season, whereas females move much larger distances to find breeding males until they nest. During the breeding season, females moved larger distances of 2.82 (0.56 SE) km/day in comparison to males that moved 1.07 (0.31 SE) km/day (Figure 67). The non-breeding movement rates were almost similar for both sexes, males and females moved 1.75 (0.66 SE) km/day and 1.79 (0.24 SE) km/day, respectively (Figure 67). During migration, females covered larger distances than males and finished the migration journey sooner than males (Figure 67). On average females moved 26.43 (2.02 SE) km/day while males covered 17.75 (3.07 SE) km/day (Figure 67). During migration, the maximum distances covered in a single day were ~424 km for a female and ~214 km for a male.

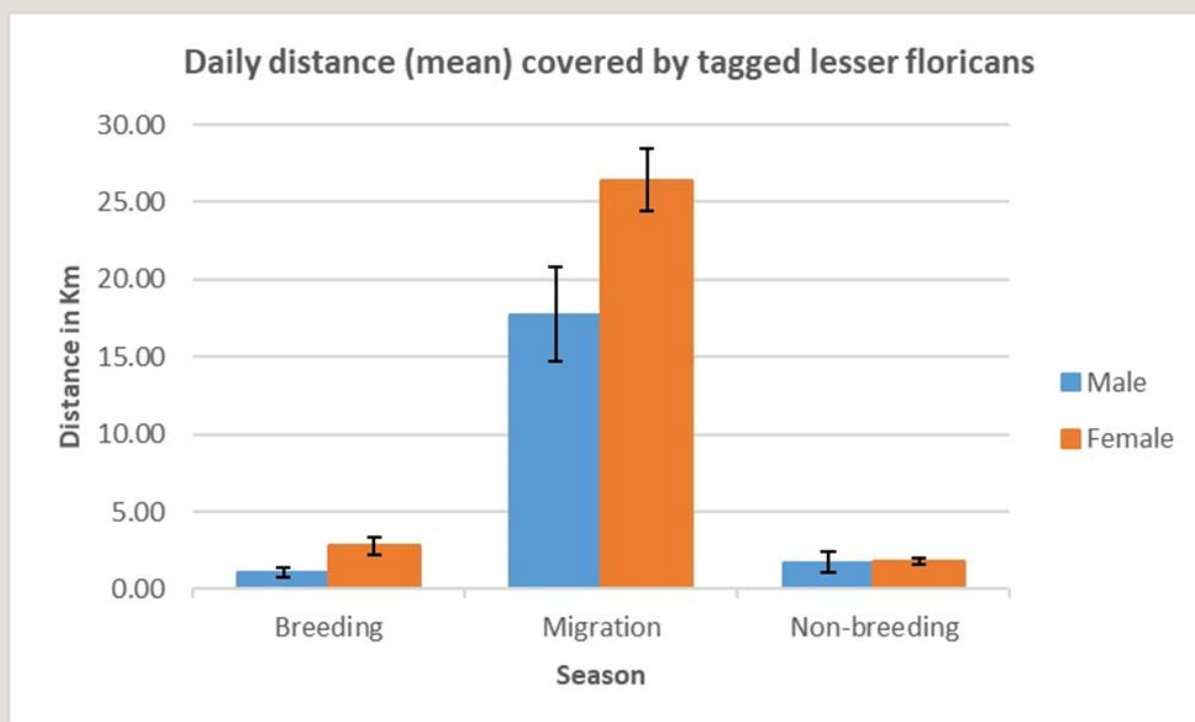


Figure 67. Daily distance moved by tagged lesser floricans with respect to the seasons and sex

Individual summary of tagged lesser floricans (Figure 68)

1. Tag 3CC06811 Sufi: The first tagged male LF initially remained in Kalyanpura, Ajmer, utilising local crop fields. It eventually migrated south-east towards Bijoliya and entered Gandhi Sagar Wildlife Sanctuary, covering 568 km over 88 days, with a maximum daily distance of 101 km.
2. Tag C4A5DE11 Ravi: This male stayed localised in the Dhantol-Bhinai area before migrating into Madhya Pradesh and further into Maharashtra. It travelled 945 km, with evidence suggesting predation or poaching during tracking.
3. Tag C2A5DE11 Dhantol: After remaining near the tagging site, this bird travelled to Ujjain, Madhya Pradesh covering 390 km.
4. Tag C5A5DE11 Bandu: This male exhibited extensive movement, migrating through Rajasthan, Madhya Pradesh, Maharashtra, and Karnataka, covering a total of 3,398 km and establishing a breeding territory upon returning to Rajasthan.
5. Tag 49C06811 Bhutta: After shifting territories, this bird began migration and wintered in Basavana Bagevadi, Karnataka. It travelled a total of 3,261 km, indicating a preference for agricultural areas during winter.
6. Tag 215636 (female): This bird after tagging moved to Pali (Rajasthan), Gujarat and then south to Andhra Pradesh, covering 8,400 km overall.
7. Tag C4A5DE11 (female): This female moved to Bidar, Karnataka, for winter and later to Bihar for breeding, illustrating migratory fidelity and adaptability to agricultural landscapes.
8. Tag 215637 (male): After initial local movements, this male travelled 220 km before succumbing to predation, highlighting the risks faced during migration.
9. Tag 215638 (male): This male displayed locally before travelling to Madhya Pradesh, with the tag currently non-functional, indicating potential issues with tracking technology.
10. Tag 216770 (female): Initially localised, this female moved to Madhya Pradesh and approached Satpura Tiger Reserve but has not transmitted since, suggesting potential habitat challenges.

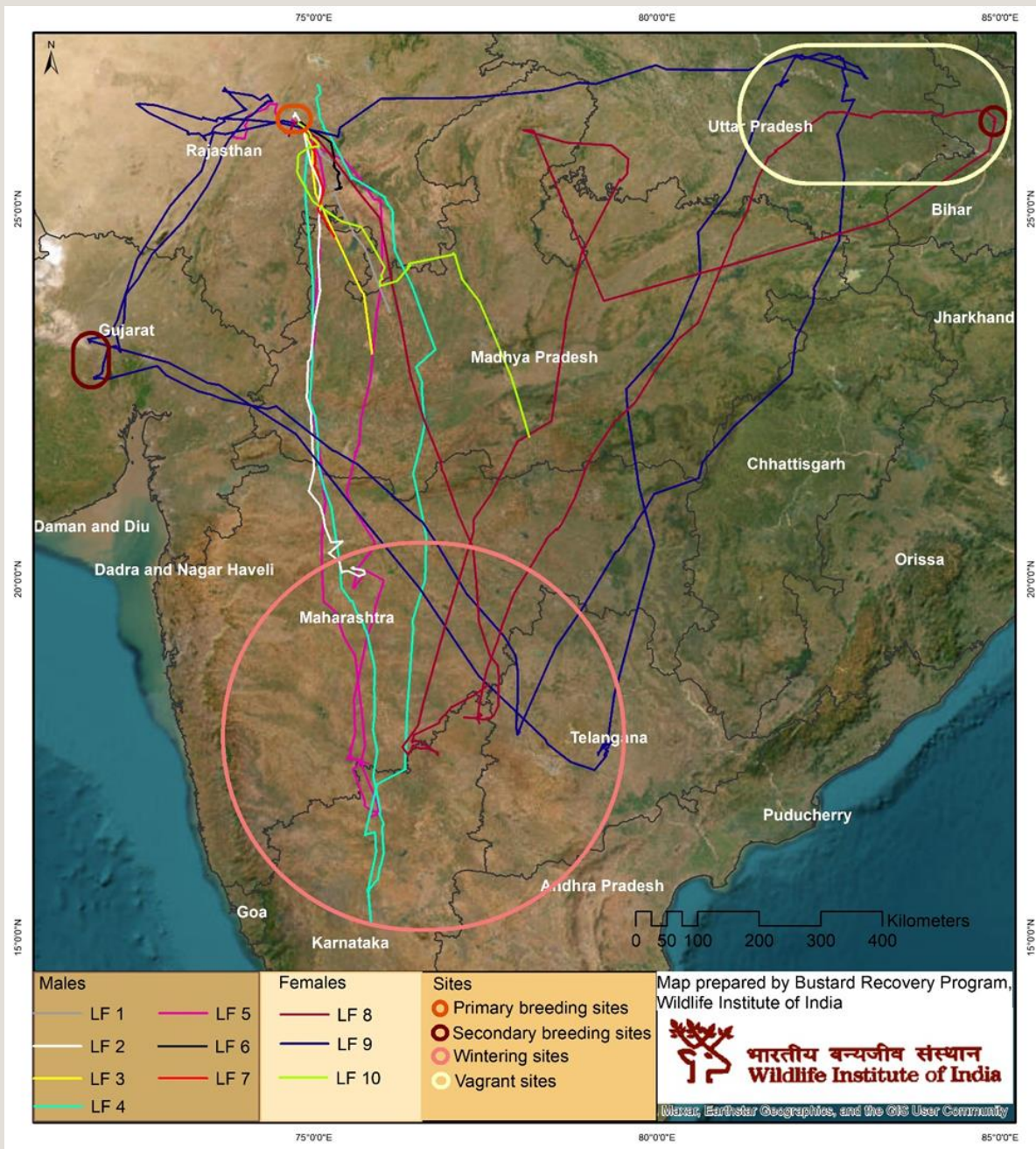


Figure 68. Map showing migration and movement trajectories of tagged lesser floricans during 2019-23

Tagged lesser floricans exhibited adaptability to agricultural landscapes, adjusting movements based on crop harvesting patterns while navigating risks from human interaction, including predation and poaching. Their strong migratory fidelity is evident in significant travel distances and return to breeding territories, highlighting the importance of agricultural areas for wintering (Figure 68). Stable habitat preferences underscore their resilience, though instances of tag malfunction indicate monitoring challenges. Biology and threats of this species are very poorly understood, hence continued telemetry will be critical in developing and implementing effective conservation actions for their future persistence.

3. Pesticide analysis of insect, vegetation and soil samples

Studies have highlighted the detrimental impact of synthetic chemicals and pollutants, particularly pesticides, on wildlife. Rachel Carson's "Silent Spring" (1962) first brought attention to the population decline of songbirds in the United States due to urban use of pesticides. Research has identified insecticides as a considerable factor

in grassland-bird declines, second to habitat loss (Mineau and Whiteside, 2013). In India, lesser floricans occupy a mix of agropastoral lands, which are similarly at risk. The species is known to breed in small grass patches within cultivated areas, which are increasingly being exposed to pesticides in recent years. Pesticide use in these habitats can potentially lead to the mortality of adult birds through consumption of contaminated insects and grains, and may adversely affect hatching success through biomagnification.

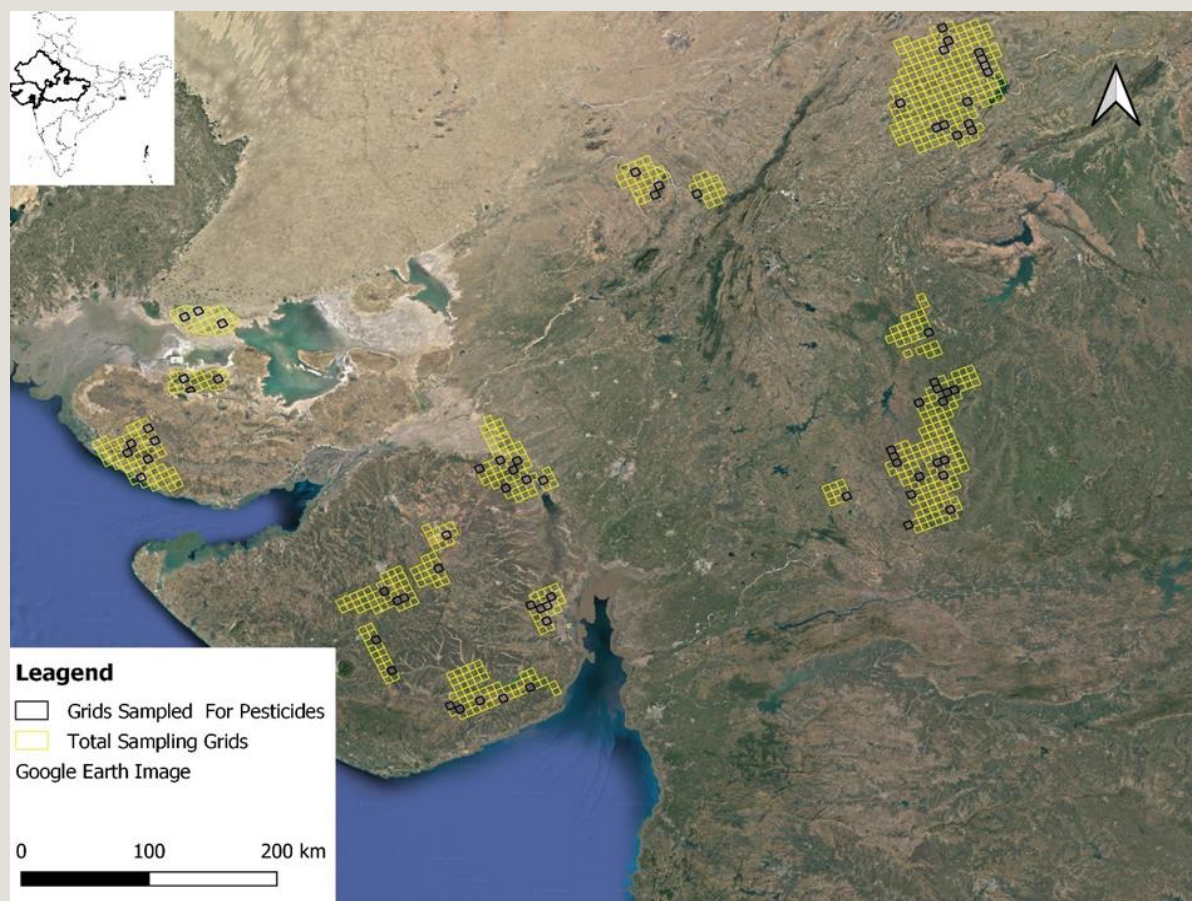


Figure 69. Map of areas sampled (in black outlined dots) for pesticide use in lesser florican habitat (yellow grids) in Rajasthan, Gujarat and Madhya Pradesh

This study focused on the routes of pesticide exposure for birds, including direct ingestion of pesticide-treated seeds or prey, and exposure through skin and respiration. To assess the impact of pesticides on the lesser florican and its habitat, samples of insects, soil, and vegetation were collected from breeding areas across Rajasthan, Gujarat, Madhya Pradesh, and Andhra Pradesh, covering an area of approximately 20,000 km² (Figure 69). The samples were prepared using the QuEChERS AOAC Official 2007.01 method and stored at -20°C.

A total of twenty-three targeted pesticides, primarily organophosphates, were tested for their existing concentration. Organophosphate pesticides, such as monocrotophos, chlorpyrifos, acephate, and profenofos, are known to disrupt the nervous system's functioning in organisms, leading to paralysis or death of the animal. Pyrethroid pesticides, including λ -cyhalothrin, fenvalerate, and cypermethrin, also target the nervous system (Image 39). Imidazolinone herbicides, like imazethapyr, inhibit the acetohydroxy acid synthase enzyme, essential for synthesising the amino acids valine, leucine, and isoleucine. Triazine herbicides, exemplified by atrazine, inhibit photosynthesis, effectively killing the targeted weeds.



Image 39. Different pesticide containers found during the survey: Organophosphate pesticides (A), Pyrethroid (B), Neonicotinoids (C), and Triazine (D)

Table 22. Critical pesticide concentration threshold (LD50 and LC50) of detected pesticides and their derivatives in avian species

Pesticides	Acute Toxicity in Avian Species	Toxicity Level
Atrazine	The LD50 in mallard ducks is greater than 2,000 mg/kg. The NOELs for bobwhite quail and ring-necked pheasants fed atrazine were both greater than 5,000 ppm	Slightly toxic
Chlorpyrifos	Its oral LD50 in pheasants is 8.41 mg/kg, 112 mg/kg in mallard ducks, 21.0 mg/kg in house sparrows, and 32 mg/kg in chickens. The LD50 for a granular product (15G) in bobwhite quail is 108 mg/kg.	Moderately to very highly toxic
Fenvalerate	Acute oral LD50 value for mallard ducks is 9,932 mg/kg. Dietary LC50 values for the technical material, Fenvalerate, are >10,000 ppm in bobwhite quail and 5,500 ppm in mallard ducks.	Moderately toxic
Naled	The LD50 for Naled in ducks is 52 mg/kg, 65 mg/kg in grouse and 37 mg/kg in Canadian geese.	Highly to moderately toxic
Sulprofos	Birds - Acute LD50 -47 (mg kg ⁻¹)	Highly to moderately toxic
Tetrachlorvinphos	Highly toxic to fish and honey bees.	Non-toxic
Fensulfathion	Birds - Acute LD50 - 1.2 (mg kg ⁻¹)	Very highly toxic
Trichloronate	Acute LD50 12.0 mg/kg	Very highly toxic
Ethoprophos	Birds - Acute LD50 - 6.04 (mg kg ⁻¹)	Very highly toxic
Disulfoton	The acute dietary LC50 for Disulfoton in mallard ducks is 692 mg/kg, and 544 mg/kg in quail.	Slightly toxic
Fenchlorphos	Birds - Acute LD50 > 3500(mg kg ⁻¹)	Non-hazardous
Merphos	Highly toxic to fish and moderately to mammals.	Moderately toxic

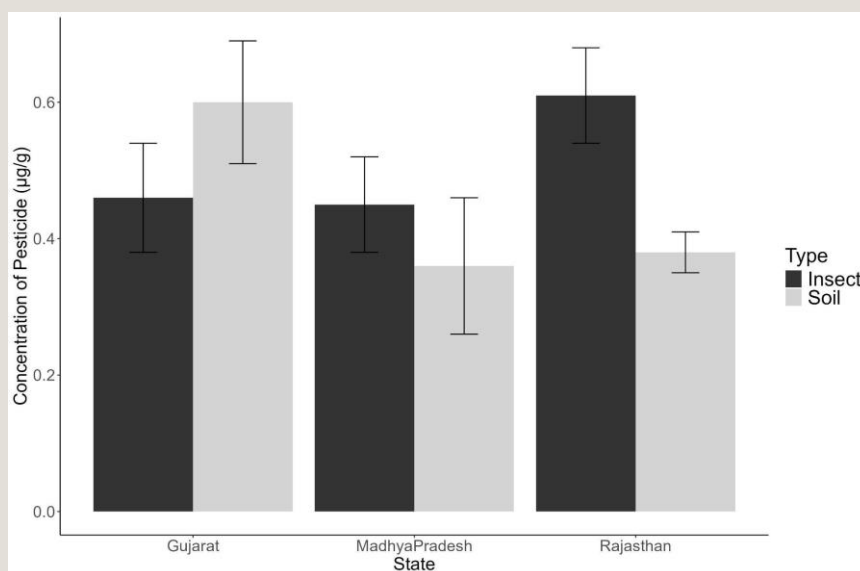


Figure 70. The state-wise average concentration of pesticides analysed in insect and soil samples across three range states of lesser florican



Image 40. Use of agricultural pesticide in Lesser Florican landscape

The pesticide concentrations in insect samples ranged from below detectable limits (BDL) to 4.59 µg/g, with the highest levels recorded in Rajasthan (0.608 µg/g) as compared to Gujarat (0.454 µg/g) and Madhya Pradesh (0.447 µg/g) (Figure 70 & 71). In soil samples, the concentrations ranged from BDL to 2.72 µg/g, with Gujarat showing the highest concentration (0.514 µg/g) (Figures 70 & 71). The high pesticide levels in insects, which are a major food source for birds, pose potential risks to the avian population, particularly in areas with intensive agricultural activity.

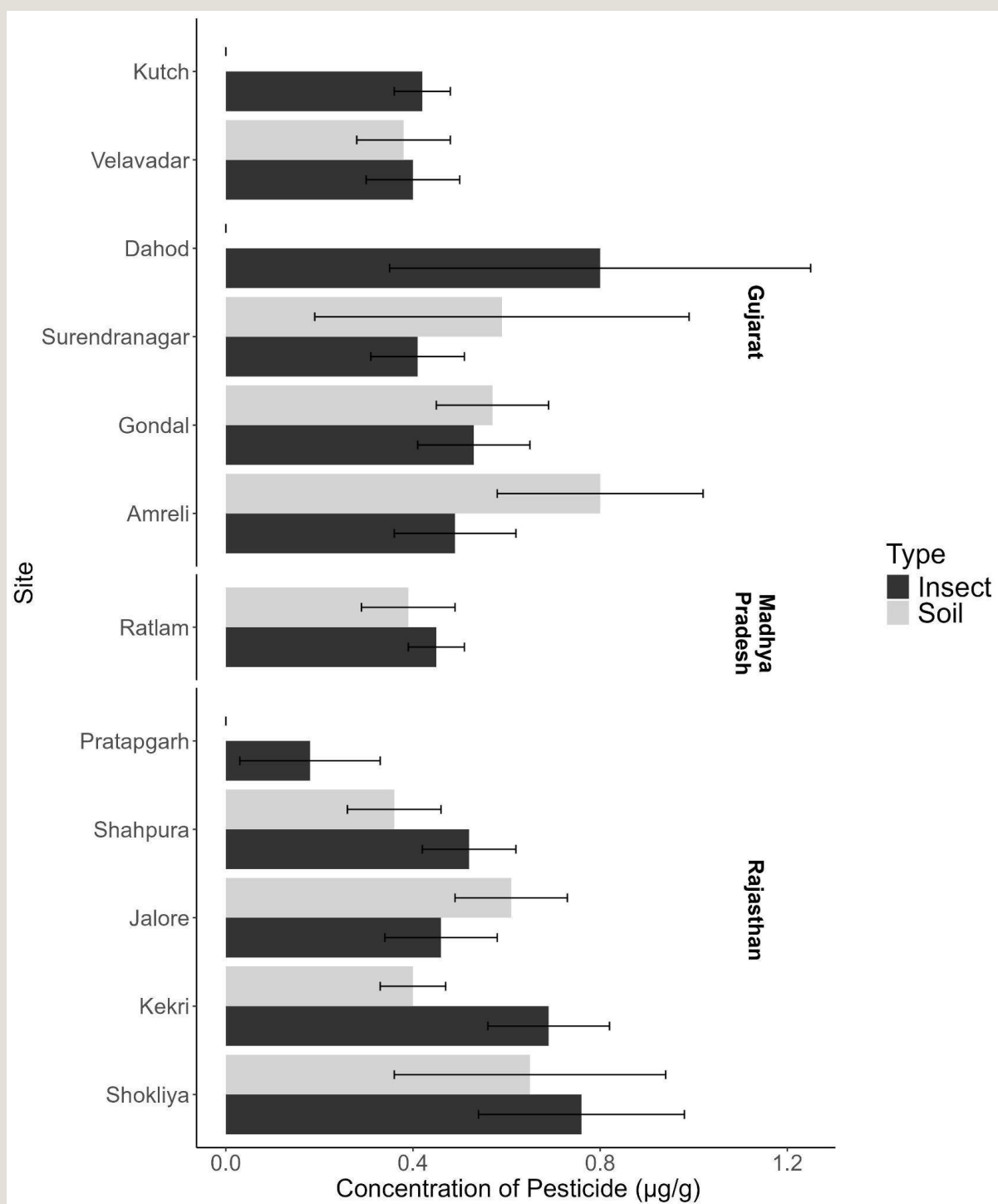


Figure 71. Average concentration of pesticides analysed in insects and soil samples collected from different sites in Gujarat, Madhya Pradesh and Rajasthan

In Rajasthan, the most detected compounds with highest detection frequency were Chlorpyrifos (91.89 %), Fenvalerate (59.46 %) and Sulprofos (51.35 %). The average concentration for different pesticides were found to be 1.54 µg/g (Naled), 1.42 µg/g (Trichloronate) and 1.21 µg/g (Fenvalerate) (Figure 71). Lesser but effective concentrations were recorded for Atrazine (0.33 µg/g), Chlorpyrifos (0.52 µg/g), Disulfoton (0.23 µg/g), Fenchlorphos (0.17 µg/g), Ethoprophos (0.10 µg/g) and Sulprofos (0.05 µg/g). In soil samples, 5 pesticides were detected and the total pesticide concentrations were in the ranges of BDL to 2.72 µg/g.

In Gujarat, pesticide concentrations varied from BDL to 2.50 µg/g. Similar to Rajasthan, the highest mean concentration was observed for Naled (1.51 µg/g), followed by Trichloronate (1.41 µg/g) and Fenvalerate (0.92 µg/g). Small but significant concentrations were found for Chlorpyrifos (0.36 µg/g), Atrazine (0.34 µg/g), Fensulfathion (0.28 µg/g), Fenchlorphos (0.20 µg/g), Tertrachloryinphos (0.15 µg/g), Merphos (0.01 µg/g) and Sulprofos (0.01 µg/g) (Figure 71). Same trend as of insect was observed in the soil samples with the concentration as Naled (1.43 µg/g), Fenvalerate (0.47 µg/g) Chlorpyrifos (0.31 µg/g), Fenchlorphos (0.16 µg/g) and Sulprofos (0.002 µg/g).

In Madhya Pradesh, the analysed concentration ranged from BDL to 1.68 µg/g. Naled (1.60 µg/g), Trichloronate (1.41 µg/g) and Fenvalerate (0.89 µg/g) showed the highest concentration, followed by Atrazine (0.34 µg/g), Chlorpyrifos (0.33 µg/g), Fenchlorphos (0.17 µg/g) and Sulprofos (0.01 µg/g) (Figure 71).

The detected pesticides, such as Chlorpyrifos, Naled, and Fenvalerate, are known to be highly toxic to birds, affecting the nervous system and causing paralysis or even death. However, the detected pesticide concentrations were within the permissible LD50 limits (Table 22). Nonetheless, continuous long-term exposure can threaten bird populations. Pesticides can also deplete the bird's prey base by targeting pests or other non-target organisms, potentially causing a decline in farmland bird populations (Newton, 1995). Further research is needed to understand the spatiotemporal trends and sublethal effects of organophosphate pesticide exposure on Indian bird species.

Outreach and Actions for In-situ Conservation

1. Stakeholder sensitisation

One of the important areas where the lesser florican breeds is Ajmer landscape in Rajasthan and their current breeding habitats are spread among agro-pastoral areas of Ajmer. These areas have shared land ownership by the government and farmers, with most of the breeding happening in private agriculture farms. Therefore, spreading awareness among locals and educating the youth regarding lesser Floricans is crucial. The project has carried out awareness programs on lesser florican conservation in several schools and at the *panchayat* level in the Shokaliya, Madhopura, Bandanwara, Dhantol and Kalyanpura villages of Ajmer where school students and locals were briefed about the species ecology, habitat as well as the research and conservation in the project work being carried out in their area. Farmers were briefed regarding their positive role in florican conservation. With a similar aim, a stall on lesser florican conservation awareness was set up with the Rajasthan Forest Department at the Pushkar fair in 2022. Posters and flyers with information on lesser florican, their nests and chicks, and the role of farmers in saving them were distributed among locals. Awareness programs on the species were also carried out in Bidar, Karnataka. Cumulatively these programs were attended by ~2500 students and ~2000 villagers. Outreach materials (bags, caps, notebooks, bookmarks and badges) were distributed in these schools, villages and at the Pushkar Fair (Image 41).



Image 41. Awareness and sensitisation programs conducted by WII-BRP team

2. LF Community Conservation Areas

In Rajasthan, Shokaliya landscape in Ajmer is a key LF habitat during monsoon (July-October). This area also supported GIB until recently around two decades ago. On 14th October 2020, a meeting was chaired by the Chief Conservator of Forest, Ajmer and included the Bustard Recovery Project team from the WII and BNHS. The meeting focused on establishing a community-based conservation reserve in the LF's distribution area in Ajmer, as directed by the National Green Tribunal (NGT) in response to Original Application No. 135/2017 (CZ) and related cases in the matter of Rajputana Mines Owners and Mineral Merchants Association Vs. State of Rajasthan & Ors. Dated: 3rd March, 2020. The NGT had instructed the Rajasthan State Forest Department to issue a notification for creating a community reserve for the conservation of the GIB and LF within six months.

Using past surveys (2017-18), telemetry data (2019-20), and current ground surveys to identify conservation areas involving local communities, we identified the following areas for recommending as the Conservation Reserve and digitised on Topo/Google Earth map (Figure 72; Table 23).

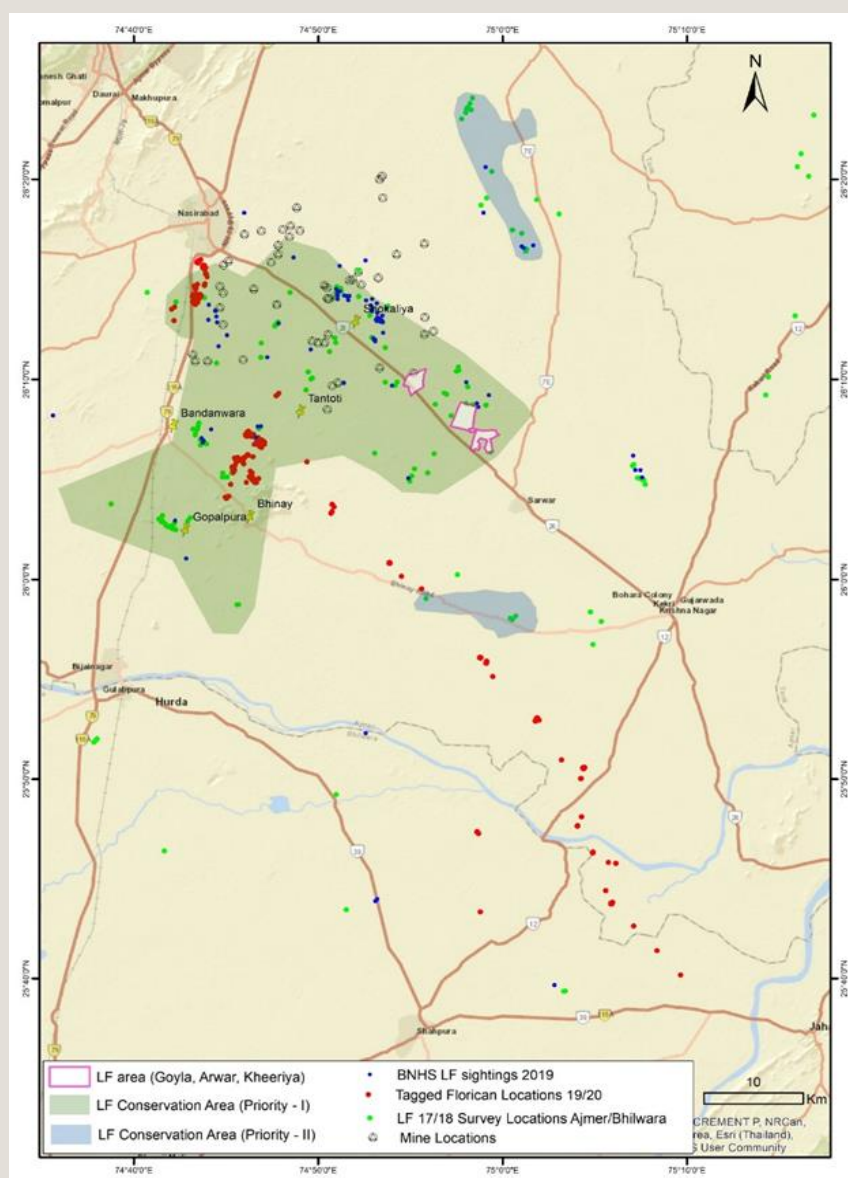


Figure 72. Proposed LF Conservation Areas in Shokaliya landscape, Ajmer, Rajasthan

Table 23. Detailed summary of forest lands recommended for declaration of Community based Conservation Reserve

Proposed site	Area (km ²)	Perimeter (km)	Surrounding villages	Dependent villages
Arwar Forest land	2.71	7.4	Arward, Badla, Ganeshpura	Arwar, Badla, Ganeshpura
Goyal Forest land	3.71	8	Goyla, Shergarh, Aathun, Ganeshpura	Goyla
Kheeriya Forest land	2.41	10.8	Kheeriya, Inderpura, Bherukhera, Aathun Ganeshpura	Kheeriya, Aathun Ganeshpura

The forest lands in the Shokaliya landscape require targeted management to maintain suitable habitats for the lesser florican (Table 23), which include:

1. **Arwar Bid:** Remove *Prosopis juliflora* (Vilayati Babool), which covers 70% of the area, and restore the grassland habitat with native grasses. Enclose the 7.4 km perimeter with chain-link fencing, completing the remaining 5.4 km that is not yet protected.
2. **Goyla Bid:** Remove *P. juliflora* from 60% of the area and restore native grasses. Enclose the entire 8 km perimeter with chain-link fencing.
3. **Kheeriya Bid:** Remove *P. juliflora* from 80% of the area and restore native grasses. Enclose the 10.8 km perimeter with chain-link fencing.

Community consultation is essential for the effective declaration and management of these areas as Conservation Reserves, ensuring species protection and habitat preservation.



Image 42. Compatible livelihood (GSB)

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