Habitat improvement and conservation breeding of Great Indian Bustard: An Integrated Approach

Annual Progress Report I

(April 2016 – March 2017)

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Project title:	Habitat improvement and conservation breeding of the Great Indian Bustard: An Integrated Approach
Project duration:	5 years (2016 – 2021)
Total 5 yr cost:	33.85 crore INR
Year 1 release:	9.95 crore INR
Implementation agencies:	(1) Wildlife Institute of India (2) Rajasthan Forest Department - Dr. G.S. Bhardwaj, Chief Conservator of Forests (Jodhpur) Mr. Anoop K.R., Director, Desert National Park (3) Gujarat Forest Department (4) Maharashtra Forest Department
Collaborating agencies:	(1) Bombay Natural History Society (2) The Corbett Foundation (3) WWF-India
Project team:	Dr. Yadvendradev Jhala, Senior Faculty WII Dr. Bilal Habib, Faculty WII Dr. Sutirtha Dutta, Project Scientist Dr. Chittaranjan Dave, Project Scientist Mr. Bipin C. M., Project Associate Mr. Vineet Singh, CAMPA Project Associate (Toxicology) Mr. Srinivas Yellapu, CAMPA Project Fellow (Genetics) Ms. Priyamvada Bagaria, CAMPA Project Fellow (GIS) Mr. Shaheer Khan, Project Assistant
Project report period:	March 2016 – March 2017

CONTENT

1. Introduction

Great Indian Bustard *Ardeotis nigriceps* (hereafter GIB) is one of the rarest birds in the world. With ~200 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 last 30 years and are facing imminent extinction risk unless serious management interventions are applied (Dutta et al. 2011). Historically, GIB was distributed throughout western half of India, but, currently they are found in five fragmented pockets. According to our recent population assessment (Dutta et al. 2015), the largest population of 169$\pm$70 birds occurs in Thar landscape of Rajasthan (Desert National Park in Jaisalmer alongside Jodhpur). The other populations are <15 birds each, occurring in Gujarat (Lala-Naliya Sanctuary and its neighbourhood in Kachchh), Maharashtra (Bustard Sanctuary in Solapur, alongside Chandrapur and Nagpur), Andhra Pradesh (Rollapadu Sanctuary and its neighbourhood in Kurnool) and Karnataka (Bellary) (Dutta et al. 2011).

The species has declined due to compounding effects of direct and indirect human exploitations on their slow life-history traits. They were subjected to exhaustive hunting and egg collection in the past that reduced their population to ~1260 birds in 1969 (Dharmakumarsinhji 1971). However, their contemporary decline is largely due to prevailing habitat loss as dry grasslands have been marginalized as 'unproductive wastelands' and progressively converted to other land uses since colonial times. Recent developments in irrigation and farming technologies have intensified agriculture in bustard habitats and changed cropping practices from seasonal to year-round, intensive crops. This change has led to food scarcity for bustard, pesticide contamination, and habitat loss. Development activities like infrastructural growth (electricity, road and irrigation networks), industries, power projects, and wind turbines have caused severe habitat degradation and disturbance to birds. Being low and heavy flyers, they face high risk of fatal collisions with power-lines, which are difficult to detect from afar. Populations of free-ranging dogs have increased in bustard habitats, and along with native predators (fox, mongooses, and cats), they have increased predation pressure on nests and chicks and reduced recruitment. Past efforts of banning human activities to create bustard Sanctuaries over large human-use landscapes, without appropriate settlement of land rights, have generated bitterness among local people, lack of conservation support, and backlash. These factors have in turn caused local extinctions from some Sanctuaries. Local people and managers are not sufficiently aware of the conservation benefits of grasslands and the scientific ways to manage them. Whereas, traditional ways to manage these habitats are eroding due to rapid socio-ecological changes driven by State policies (Dutta et al. 2013). Although most remaining breeding habitats are protected to some level, vast movements of bustards expose them to the threats mentioned above in the non-breeding habitats, defeating the purpose of protecting small breeding reserves. Since these large bustard landscapes cannot be freed from human uses, a mixed approach of Protected Area based conservation of breeding habitats and coexistence with compatible human land uses by mitigating survival threats in adjoining landscapes best suits the situation.

Effective conservation of bustard habitats would require information on species' ranging patterns, relative magnitudes and distribution of threats, and ways to reconcile species' ecological needs and livelihood concerns that are poorly known. Furthermore, management authorities in many areas exhibit poor enforcement ability due to inadequate staff and infrastructure, lack of motivation, and inaccessibility. Concerned about the extinction crisis of GIB, Indian conservation circles have proposed strategic recovery plans for the species as a flagship of dry grasslands. The National Guidelines for Bustard Recovery Plans developed by Ministry of Environment, Forests and Climate Change (Dutta et al. 2013) strongly recommend filling research gaps, mitigating threats, improving habitat, improving enforcement capacity, and engaging communities in conservation. However, the implementation of in-situ conservation measures require some gestation time, but, the population size of GIB (with no birds in captivity) is too small to sustain such delays. Thus, a captive population needs to be secured for supplementing wild populations and reintroducing birds into restored habitats in favorable times.

This project aims at integrating all these components into a holistic conservation plan for the priority bustard landscapes of Rajasthan, Gujarat, and Maharashtra. The proposed activities will be undertaken in collaboration with State Governments, local NGOs, and research organizations so as to pool knowledge/expertise and ensure timely and effective implementation. Since both the endangered bustards of dry grasslands – GIB and lesser florican (*Sypheotides indicus*) – share some habitats, these activities will supplement and complement each other's needs. By doing so, habitats that support a plethora of other endangered wildlife, such as the spiny-tailed lizard *Saara hardwickii*, chinkara *Gazella bennettii*, foxes *Vulpes* spp, wolf *Canis lupus* pallipes, caracal *Caracal* caracal and blackbuck *Antilope cervicapra* will be restored.

1.1. Project objectives

The broad goals and objectives of this project are as follows:

1.1.1. Conservation Breeding – Developing and running Conservation Breeding Center to secure captive populations of GIB and (if needed) lesser florican as insurance against extinction and (if possible) subsequent reintroduction/supplementation into restored habitats.

1.1.2. Applied research – Undertaking targeted research for: a) prioritizing conservation areas, b) characterizing threats, c) monitoring populations and habitats to assess the effectiveness of management actions, d) assessing local communities' livelihood concerns and willingness to adopt bustard-friendly land uses, and e) comprehensive understanding of population genetics to inform conservation management.

1.1.3. Capacity-building and awareness – a) Improving protection enforcement through training of Forest staff and implementation of technology aided patrolling , b) sensitizing decision-makers, managers and local communities on bustard conservation, c) raising public awareness and support for bustard conservation through awareness materials, and d) incentivizing local land users to adopt bustard-friendly land uses.

1.1.4. Pilot implementations for surgical habitat management – Demonstrating best practices for habitat improvement through pilot/experimental surgical interventions that will be subsequently replicated by State Forest Departments.

2. Project activities

2.1. Conservation breeding

2.1.1. Selection of conservation breeding site

Based on meetings and discussions with Rajasthan Forest Department officials, the project team identified 14 potential sites for establishing conservation breeding center. These sites were objectively assessed on multiple criteria – including climatic (precipitation, temperature), logistic (uninterrupted water/electricity supply, distance from transportation hubs, accessibility etc.), and ecological (distance from settlements, wild populations, predators and poultry) considerations, and developed in consultation with international experts. These criteria were given weightage on a scale of 1-3 based on their relative importance to ensure successful captive breeding and difficulty of manipulating/managing them. Project team surveyed and scored each site on a 0-2 scale against these criteria, wherein sites with favorable conditions were given higher scores. The total score of each site was obtained by adding weighted scores across multiple criteria. This score was used as an indicator to select five most potential sites for establishing conservation breeding center. Our international consultant/collaborator, Keith Scotland, who is an expert on houbara bustard (*Chlamydotis undulata*) captive breeding, assessed these shortlisted sites based on his experience/understanding. A detailed score-matrix and list of potential sites is provided below (table 1 and 2).

2.1.2. Meetings to operationalise GIB conservation breeding program

To involve appropriate consultation and expert technical support in *in-situ* and *ex-situ* conservation actions for GIB, the Project Investigator corresponded with international bustard scientists and captive breeders such as Dr. Fred Launay, Dr. Yves Hingrat and Dr. Salim Javed from International Fund for Houbara Conservation and Environment Protection Agency, Abu Dhabi, Keith Scotland from Emirates Bird Breeding for Conservation Center, Uzbekistan and Dr. Juan Carlos Alonso from National Museum of Natural Sciences, Spanish Council for Scientific Research. He also visited the Houbara captive breeding facility in Abu Dhabi to gain experience on the various aspects of captive breeding program.

A two-day interaction/meeting was organized between Project team and Dr. Sushil Sood, veterinary officer of Himachal Pradesh Forest Department and expert in Assisted Reproduction of Birds in May 2016, to involve his expertise in developing GIB conservation breeding plan. Dr. Sood presented his work on captive breeding of several birds including the critically endangered Kakapo *Strigops habroptilus*, and shared his inputs on design and execution of GIB captive breeding center. Another interaction/meeting followed by site visit was organized between Project team and Mr. Keith Scotland, houbara bustard breeding expert, in October 2016, to discuss the design, protocol and cost-calculations of GIB conservation breeding center.

Project representatives and Director WII attended meeting with Rajasthan Forest Department in July 2016 to develop a mutually agreed roadmap for in-situ and ex-situ components of GIB conservation program. Project proposal was presented and views/opinions of Forest Department officials were incorporated in the project plan.

As discussed in this meeting, and subsequent to it, the Tripartite Memorandum of Agreement (MoA) between MoEFCC, Rajasthan Government and Wildlife Institute of India were prepared and circulated among concerned agencies to delineate respective roles and responsibilities in implementing *in-situ* and *ex-situ* conservation programs for GIB and lesser florican. The MoA was approved by MoEFCC and was communicated to Rajasthan State for approval and signing.

Subsequently, Project Investigator and Director WII met the Honorable Chief Minister of Rajasthan in November 2016 to appraise her regarding the importance and proposed plan for establishing GIB conservation breeding program. In this meeting it was decided that the decision on establishing the center would be based on a follow-up meeting between Honorable Chief Minister, Rajasthan Forest Department officials, international bustard experts, and the Project team. This meeting will be tentatively scheduled in April-May 2017.

Table 1. Matrix of scores for establishing great Indian bustard conservation breeding center in Rajasthan

Criteria	Influence (0: unfavourable - 2: favorable)	Weight (1-3)
Rainfall	More rainfall essential for center productivity (0: <200mm, 1: 200-400mm, 2: >400mm)	3
Accessibility	Proximity to main cities beneficial for availing expertise & logistic support (0: >200km, 1: 100-200km, 2: <100km)	3
Proximity to wild source	Proximity to egg collection/holding site beneficial as long-distance transportation increases hazard-risks (0: >400km, 1: 200-400km, 2: <200km)	2
Habitat suitability	Grassland/savanna habitat beneficial, else can be restored	1
Topographic suitability	Flat terrain & soil substrate essential as the scope of rectifying these elements is limited (2: flat terrain - well drained sandy loamy soil, 1: gentle rolling - mixed sandy clay soil, 0: undulation / clay soil	3
Land-ownership	Ease of acquisition: Forest (2) > Revenue (1) > Community/Private/PA - (0) ownership	3
Local support	Local Forest Department support beneficial for CB operations	2
Local ecology	Adequate distance from wild GIB, poultry or predator population as well as from human settlements	3
Water facility	24x7 water availability essential (2: existing water line and potable ground water presence, 1: no line but ground water present, 0: no line or ground water)	3
Electricity facility	24x7 electricity availability essential, otherwise solar-power-station can be installed (2: > 1km from 3 phase line, 1: 1-3 km from 3 phase line, 0: <3 km from 3 phase line	1
Transportation facility	Good condition of local roads beneficial as it reduces travel time for CB operations	3
Temperature	Maximum temperature heat index (2: 40-44^{0}C, 1: 44-48^{0}C, 0 > 48^{0}C)	1
Size and shape of the site	Size and shape of the site (2: >200 ha and with compact shape, 1: 100-200 ha or with less compact shape, 0: <100 ha or with fragmented patches)	2
Local community	Community support, 0: antagonist, 1: neutral, 2: supportive	2
TOTAL	Sum-product of criteria ranks & weights	

Table 2. List of potential sites for establishing great Indian bustard conservation breeding center in Rajasthan

S. No	Site	District	S. No	Site	District
01	Tal Chappar	Churu	08	Arwad	Ajmer
02	Bera	Pali	09	Goyla	Ajmer
03	Dhanla	Pali	10	Sorsan	Baran
04	Ghanerao	Pali	11	Mokla	Jaisalmer
05	Guda Endla	Pali	12	Ramdeora	Jaisalmer
06	Kharchee	Pali	13	Rasla	Jaisalmer
07	Sardar Samand	Pali	14	Sudasari	Jaisalmer

2.2. Applied research

2.2.1. Population and habitat surveys

2.2.1.1. Status assessment of GIB, associated fauna and habitat in Thar

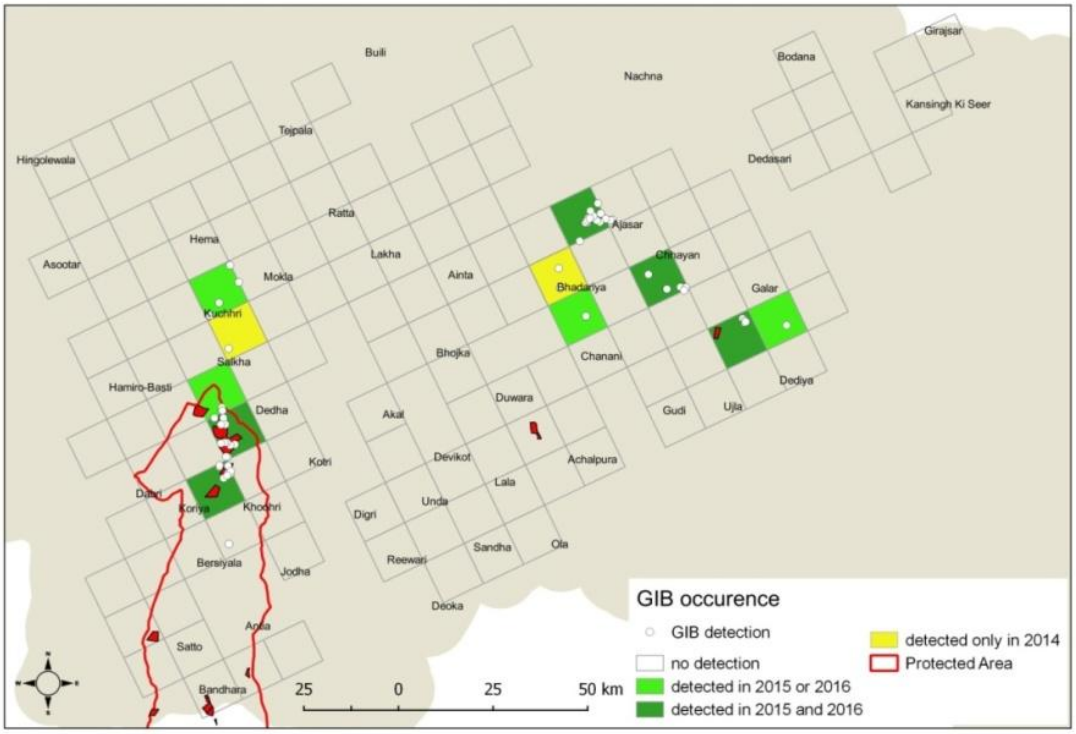
Population and habitat surveys in priority bustard landscapes are essential to assess the status and distribution of GIB, prioritize conservation areas, understand habitat relationships at large, and monitor population recovery. We assessed the status of GIB, and its associated species - chinkara and fox alongside their habitat and anthropogenic pressures across 19,728 km^2 of potential bustard landscape in Thar spanning Jaisalmer, Jodhpur, Barmer and Bikaner districts of Rajasthan. Systematic surveys were conducted in 144 km^2 cells from slow-moving vehicle along $17.9 \pm 3.9_{SD}$ km transects to record species' detections, habitat characteristics in sampling plots, and secondary information on species' occurrences. Multiple teams comprising trained volunteers and Forest Department staff simultaneously and rapidly sampled 120 cells along 2273 km transects in March 2016 (figure 1). Sampling was carried out in two phases: extensive surveys to assess GIB occurrence across the landscape and intensive surveys to estimate their density in used cells. During the survey 37 (2016) individual birds were detected. Sighting data of GIB and other key species' detection data were analyzed in Occupancy and Distance Sampling framework to estimate proportion of sites used and density/abundance. Detection/non-detection data from multiple year surveys (2014-16) showed that GIB used $10.9 \pm 3.4_{SE}$ % sites (naive occupancy 8.4%). Bird density in used sites (cells where at least one bird was detected during 2015-16) was estimated at 6.5 ± 1.4_{SE} /100 km^2. Subsequently, GIB abundance was estimated at 140 ± 50 birds in the landscape (figure 2). Bustard-habitat relationships, assessed using multinomial logistic regression, showed that disturbances and level of protection influenced distribution in this landscape. Great Indian bustard occurrence in the landscape declined with distance from enclosure (regression effect size = -0.06 ± 0.02_{SE}), human presence (-3.22 ± 1.52_{SE}) and infrastructural intensity (-3.97 ± 1.61_{SE}). Chinkara was found in 78% sites and its density at landscape-scale was estimated at 187.5 ± 25.1_{SE} animals/100 km^2, yielding abundance of 37,000 ± 4970_{SE} in the landscape. Desert and Indian fox used 60 ± 7_{SE} % of sites, at densities of 14.35 ± 3.46_{SE} desert fox/100km^2 and 2.28 ± 1.19_{SE} Indian fox/100km^2 at landscape-scale, and abundances of 2830 ± 683_{SE} desert fox and 450 ± 235_{SE} Indian fox in the landscape. Eleven percent of sampled cells were found to be of high conservation value; out of these, 62% cells had no representation of Protected Area. Although some of these 'unprotected' areas benefit from community protection or less disturbed spaces created due to Army presence, others continue to be threatened by hunting and unplanned land-uses.

Our study provides robust abundance estimates of key species in Thar. It provides spatially explicit information on species' distribution and ecological parameters to guide site-specific management and policy. Our questionnaires generated spatial patterns of community composition, livelihoods, livestock holdings and species' occurrence reports that will help in designing community outreach and conservation programs. Thar supports the largest global population of GIB and offers the best hope for its persistence. This survey captured snapshots of GIB distribution that needs to be augmented with satellite telemetry based information on seasonal landscape use to mitigate threats. Based on results and field experiences, we strongly recommend: a) improving great Indian bustard recruitment in existing enclosures using predator-proof-fences and nest-predator removal, b) creating more enclosures or conservation/community reserves in priority conservation cells, c) removal r appropriate mitigation of hostile infrastructure (overhead power-lines and wind-turbines) in priority GIB habitat, d) smart and intensive patrolling to control poaching and generate management information, e) targeted research to understand local ecology of great Indian bustard, characterize threats, and ranging patterns using biotelemetry, f) addressing local livelihood concerns through social research, and g) engaging local communities to monitor and protect wildlife through outreach and incentive programs (see report in appendix 1).

This monitoring exercise has been repeated during March 17-26, 2017, wherein 53 teams of volunteers and Forest guards have surveyed 120 grid-cells with 30 km efforts in each grid-cell (extensive sampling) followed by intensive sampling of 7 grid-cells with 120 km efforts in each grid-cell (intensive sampling) and the data is currently under compilation and analysis.

Figure 1. Field activities (training, surveys and questionnaires) for status assessment of great Indian bustard, associated fauna and habitat in Thar during 2016-17

Figure 2. Great Indian bustard occurrence status in 144 km² cells based on surveys in Thar landscape (2014-2016)



2.2.1.2. Pilot survey in lesser florican breeding sites to develop population and habitat assessment protocols

A pilot survey of lesser florican habitats in Ratlam District, Madhya Pradesh and Ajmer District, Rajasthan was carried out during August- September 2016 for planning landscape level status survey of the lesser florican. Line transect survey was conducted in lesser florican breeding sites to assess the feasibility of the approach for robust population estimation and develop population and habitat assessment protocols. A meeting was held with the Chief Conservator of Forests, Ujjain and Division Forest Officer, Ratlam to discuss issues regarding conservation of lesser florican.

2.2.1.3. Land-cover image classifications of GIB landscapes

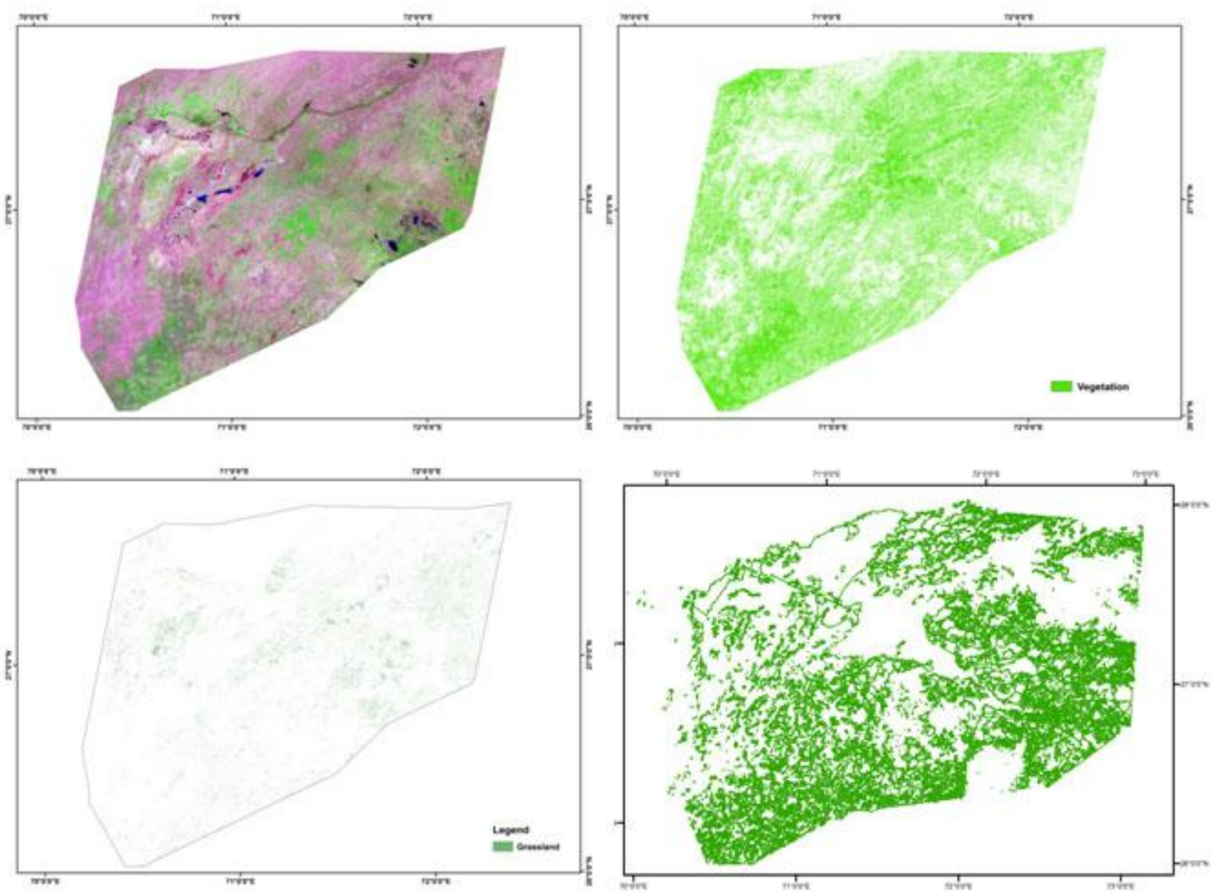
Developing land-use / land-cover (hereafter LULC) map for Thar landscape is essential to identify grassland / savannah areas, the preferred habitat of GIB, and to develop habitat suitability models for species' conservation. The 20,000 km^2 Thar landscape consists of following broad LULC categories:

1) sparse grassland (>20% herbaceous cover and <20% woody cover), 2) dense grassland (>40% herbaceous cover and <20% woody cover), 3) savannah (>40% herbaceous vegetation and 20-40% woody cover), 4) scrubland (20-40% herbaceous cover and 20-60% woody cover), 5) woodland (<20% herbaceous cover and 20-60% tree cover), 6) shrubland (<20% herbaceous cover and 20-60% shrub cover), sparse vegetation / barren land (<20% vegetation cover), 7) agriculture and 8) settlements / built-up areas. Apart from dense grassland and savannah, all other vegetation types have sparse chlorophyll content and are woody in nature, causing pixel mixing with sparsely vegetated areas and open land areas. Thus, the classification had to be carried out using multistep hybrid approach. The following methodology was used:

A false colour composite (FCC) with SWIR, IR and Green bands of Landsat 8 Operational Land Imager data of August 2015 was used as this combination is best suited for desert landscapes (figure 3). Ground reference points from previous Thar surveys were categorised into above mentioned classes. 50% of the points were used for training and remaining 50% were retained for testing the classified image. Using ground reference points and Google Earth™ imagery as reference, the FCC image was subjected to supervised classification. In the initial phase, several trial and error steps were performed during which the supervised classification was attempted with 300, 400, 500, 600 classes and with 10–20 iterations. However, pure classes with only 'habitat' categories (grassland and savannah) or 'non-habitat' categories (scrubland/ shrubland/ woodland/ agriculture/ barren land) could not be achieved. At this stage it was necessary to remove all pixels from the image which were not part of 'habitat' classes in classification. Hence, all agriculture fields and settlements were digitized manually with help of Science Pvt. Ltd. Simultaneously; unsupervised classification of FCC image was carried out to produce 500 classes. Each of these classes was examined and referenced with Google Earth™ imagery closely, and classified into vegetation and non vegetation layers. A vegetation only layer was extracted from FCC that excluded (to an extent) all sand dunes, barren / sparse vegetation, thorny scrub and woody areas. This vegetation only layer was vectorized.

Digitized agricultural areas were clipped from the vegetation vector layer, leaving the following classes - grassland, savannah, shrubland and scrubland. This FCC image with four classes was further classified into 500 classes using supervised classification. Each of these classes was closely examined with reference of Google Earth™ imagery. Pure classes containing only grassland or savannah (GIB habitat) and classes with mostly grassland or savannah and little mixing from other classes were extracted. Finally, we have a layer with all pixels of grassland or savannah with sparse mixing which can be removed with some additional ground truth points (figure 3).

Figure 3. Land-use / land-cover classification of LANDSAT image of Thar landscape, showing (clockwise) False Colour Composite, vegetation only layer, agriculture digitization, and potential grassland/savannah layer



2.2.2. Ecology and ranging patterns

2.2.2.1. Behavioural / ecological study on GIB in Thar

Understanding of GIB phenology and behavioural ecology (habitat use, response to disturbances etc.) are essential for managing breeding habitats. Behavioural observations of GIB were carried out from December 2016 to February 2017. The objectives are to understand their daily activity budget, seasonal landscape use, foraging and breeding behavior and intraspecific interactions in/around Desert National Park (DNP), the most important area for their conservation.

Birds were tracked and located and efforts were made to habituate them to the presence of observers. Most of the observations were recorded in enclosures inside Desert National Park with few observations in agricultural fields. Behavioral observations were recorded using scan and focal sampling methods. Data on daily activity patterns of solitary and flocking individuals were collected. Additionally, human activities such as people and vehicular movement, livestock grazing, tourism activities, presence of predators (dogs, foxes, mongooses, pigs and raptors) in the vicinity as well as weather were recorded. Fecal samples were collected *ad-libitum*.

During December-January, flocks of 9-15 individuals were regularly seen. Courtship behavior by males was first observed after a couple of rain showers in late January for a period of three days. Subsequently, flock sizes reduced to 3-7 individuals. The second display of courtship behavior by males were seen in mid February after rain showers and continued for longer duration (ten days till the end of sampling season). Preliminary observations suggest that the birds are very wary of human activity and their behavior immediately changes when disturbed. Their ongoing activity is disrupted, and they become vigilant or/and hide or/and walk away or/and take flight. Since anthropogenic activities in the area are quiet commonplace with 37 villages and numerous settlements (Dhanis) inside DNP, the study will provide information on GIB behavior in various disturbance regimes and suggest mitigation measures (figure 4).

Figure 4. Great Indian Bustard behavior in Desert National Park during 2016-17 (top row from left) foraging, hiding, (middle row from left) resting, signs at roosting spot, (bottom row from left) vigilant and scanning, displaying, and preening

This research component will quantify the influence of anthropogenic activities such as people and vehicular movement, livestock grazing, tourism activities and landuse types as well as predator presence, on GIB. It will also determine the benefit of enclosures to GIB conservation, and recommend measures to improve the management of enclosures if required, to increase usage by birds. Areas outside enclosures that are frequented and utilized by birds which might require reduction of human activities will be identified.

Breeding sites inside and outside enclosures will be identified so that measures can be implemented to provide adequate protection and make these areas inviolate during breeding season. The dietary requirements and availability will be quantified so as to suggest measures to ensure forage availability inside enclosures during resource lean period. Encounters with nest predators (dogs, pigs, mongooses and foxes) will be quantified so that measures to control predator population can be undertaken.

Our permit to capture and satellite tag four GIB in Desert National Park lapsed in December 2015. We have requested for extension of this permit. However, decision on extension of tagging permit is pending with Rajasthan Forest Department, despite several follow-up communications from WII. Recently, we received permission to tag two GIB in Kachchh, and spade work for this activity will be commenced in April 2017.

2.2.2.2. Habitat assessment of GIB in Maharashtra using biotelemetry

Tagging: Bustard is usually sighted in Bustard Sanctuary Nannaj, Maharashtra, during the breeding period between March-October. A sub-adult male was tagged in April 2015 in Nannaj using noose traps and was fitted with 70 g Solar Argos/GPS PTT (Microwave Telemetry Inc.). The PTT recorded GPS locations daily at 05:00, 07:00, 09:00, 11:00, 17:00, 19:00 and 21:00 hrs and Argos locations on alternate days. The bird was tracked from April 2015 to June 2016, yielding >2000 GPS locations and 670 high quality Argos locations. Since its tracking commenced, several clusters of locations were identified across the landscape that have been used by the tracked individual. After leaving the protected grassland area, all the locations of our tagged individual were found in human dominated landscape and based on these clusters of locations; several new areas used by bustard were found in Maharashtra and Karnataka. On interviewing farmers in these newly found areas, it was understood that they had little knowledge of the bird perhaps because these sites were only used by one tagged individual or were used only recent or sporadically (figure 5). Based on radio-tagging data of 412 days, we estimated the home range of the tagged individual at 14449 km^2 and the daily and total distance moved at $6 \pm 6_{SD}$ km and 2479 km, respectively.

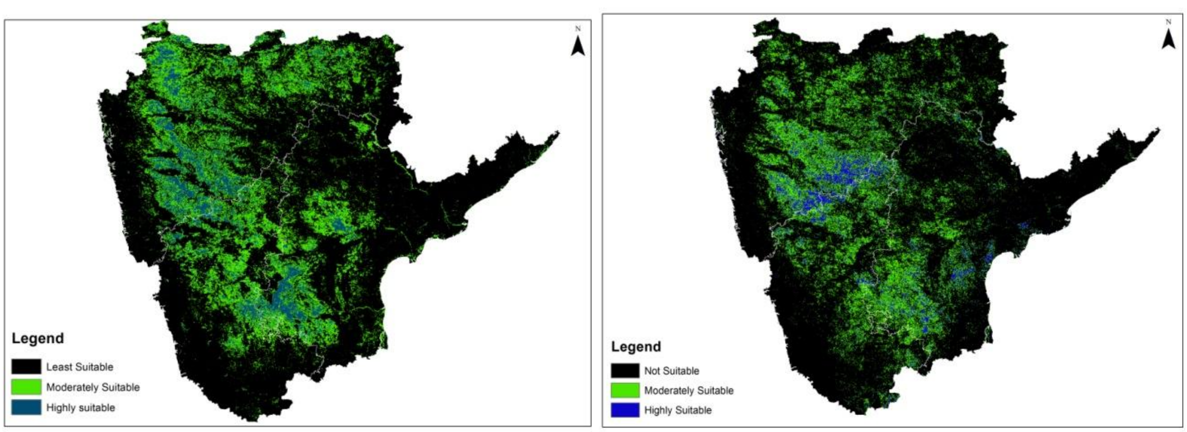
Figure 5. Field activities and outcomes related to tagging and habitat use of Great Indian bustard and questionnaires in Maharashtra.

Probability distribution map of GIB for Deccan: Literature was reviewed to identify previous distribution of GIB between 1900 and 2007 in Maharashtra. Information of their occurrence was collated from published and unpublished data and georeferenced, yielding 100 locations from Maharashtra. This data was supplemented by ~2000 GPS locations from April 2015 to June 2016 that were grouped based on clusters of observations into 96 independent locations. We used these location points to predict distribution map using MaxEnt modeling. For generating distribution map of previous location we used 16 days interval Normalized Difference Vegetation Index (NDVI) map of 1 km resolution of 2001 and for tagged individual locations, we used 16 days interval NDVI layers of 1 km resolution of 2013. Although, NDVI layers used in the analysis for previous location refers to recent years while previous available data comes from as early as 1900, this was likely to affect the result but to compare the results we made sure to use same layers in both maps.

This comparison provided insights into habitat depletion and change in GIB distribution in Deccan landscape. The NDVI data were downloaded from MODIS website (https://modis.gsfc.nasa.gov/data) and all further analysis was done in ArcGIS 10.1 software and MaxEnt software, version 3.3.3 k (https://www.cs.princeton.edu/~schapire/maxent). With the help of these, we predicted species distribution map by using Maximum entropy modeling (Phillips et al. 2006).

We predicted two different time period maximum entropy distribution maps to compare the extent of change in the distributional range of GIB. We predicted distribution map for over 780,000 km^2 area and found a significant change in the areas of least suitable, moderately suitable and highly suitable habitat available for the GIB in Maharashtra, Karnataka and Andhra Pradesh (figure 6). Our result shows some previous available known GIB areas are now converted into unsuitable areas. These drastic conversions are mainly due to habitat change, habitat fragmentation, change in traditional agricultural practices and infrastructure development. The shift towards cash crop production from traditional agricultural pattern is due to low rainfall and poor water source systems. Rapid conversion of grasslands and shrublands into agriculture with excessive use of pesticides, over grazing and human disturbance have contributed to this decline. Although, the distributional range is shrinking rapidly, this landscape still has 36,123 km^2 of suitable habitat which can harbor a reasonably large GIB population; indicating that the species' decline is largely caused by human-induced mortality and habitat loss being the secondary cause. Our result also predicted some new areas which need to be verified and conserved.

Figure 6. Habitat suitability map for great Indian bustard in Deccan Landscape, using previous locations (left) and current tagged individual location (right)



2.2.3. Assessment of threats

2.2.3.1. Population assessment of free-ranging dogs

The GIB landscape in Thar holds a large population of free-ranging dogs that partially depend on village based resources but also depredate wildlife, including GIB nests, thereby being an important threat that needs to be urgently managed. To manage this problem, we assessed population status of free-ranging dogs in/around Desert National Park. A pilot survey was carried out in select settlements during September – October 2016 in collaboration with Humane Society International – India and international consultant Dr. Lex Hiby, wherein a smart-phone application (OSM) based mark-recapture technique was developed to enumerate dogs (figure 7). Subsequently, a comprehensive study was undertaken that included the following activities:

Count surveys: Dogs were counted in 18 settlements, wherein observers walked on predesigned route recording the number of dogs present with consistent effort of ~ 8 km walk in 2 hours per square km of settlement area. Age and sex class of dogs were recorded. This activity generated crude counts of dogs in all settlements dispersed across GIB habitat in/around Desert National Park.

Mark-recapture surveys: A fraction of these settlements – 6 villages (Sam, Salkha, Lakhmano, Kuchhri, Neemba and Beeda) and a tourism area – were targeted for estimation of dog abundance in mark-recapture framework which is robust to imperfect detection. A smart phone with 10x optical zoom lens was used to photo-capture and record sightings of dogs based on distinguishable natural marks (flanks, head, tail). Five sessions were completed for each selected settlement and photographs were compared to find the number of initial marked sample which were included in subsequent samples. Capture recapture data of dogs were used to estimate non-detection corrected abundance in these settlements. Count and mark-recapture abundance estimates in these settlements would yield a correction factor that can be used to estimate dog abundance in all settlements using double sampling approach (figure 8).

Vehicle transects: To assess density and distribution of free-ranging dogs in wildlife habitats, twenty eight ~8 km transect routes were surveyed on slow-moving vehicles.

Corresponding to dog sightings, their distance, angle, and spatial location were recorded. Each transect was surveyed twice; once in winter (January-February 2017) and other in summer (March 2017). Data will be analyzed in Density Surface Modeling framework to generate spatially explicit density of dogs across GIB habitat in Thar.

This activity will generate baseline information on numbers and distribution of dogs in GIB habitat of Thar that will help us in planning sterilization/removal programs and monitor the effectiveness of these programs in reducing the number of dogs within manageable limits.

Figure 7. Smart phone application to photo-capture dogs for population assessment

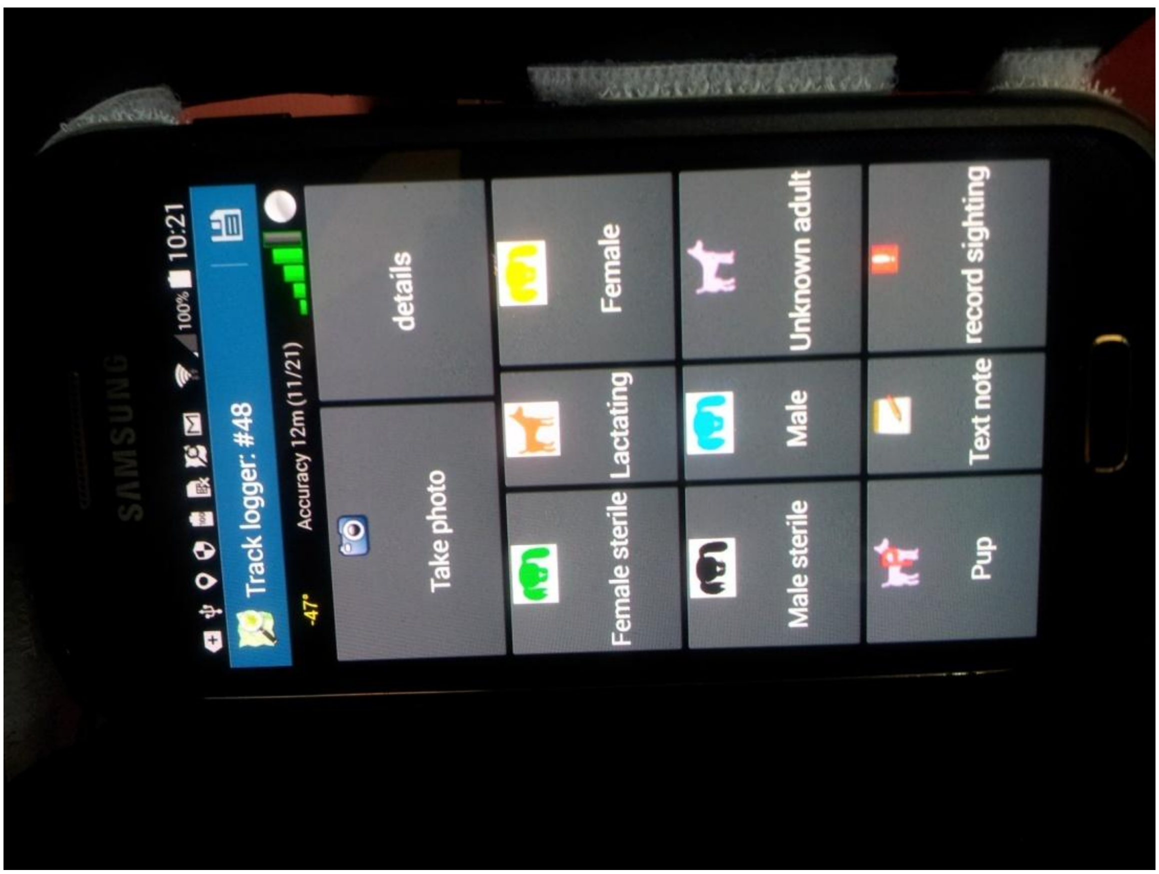
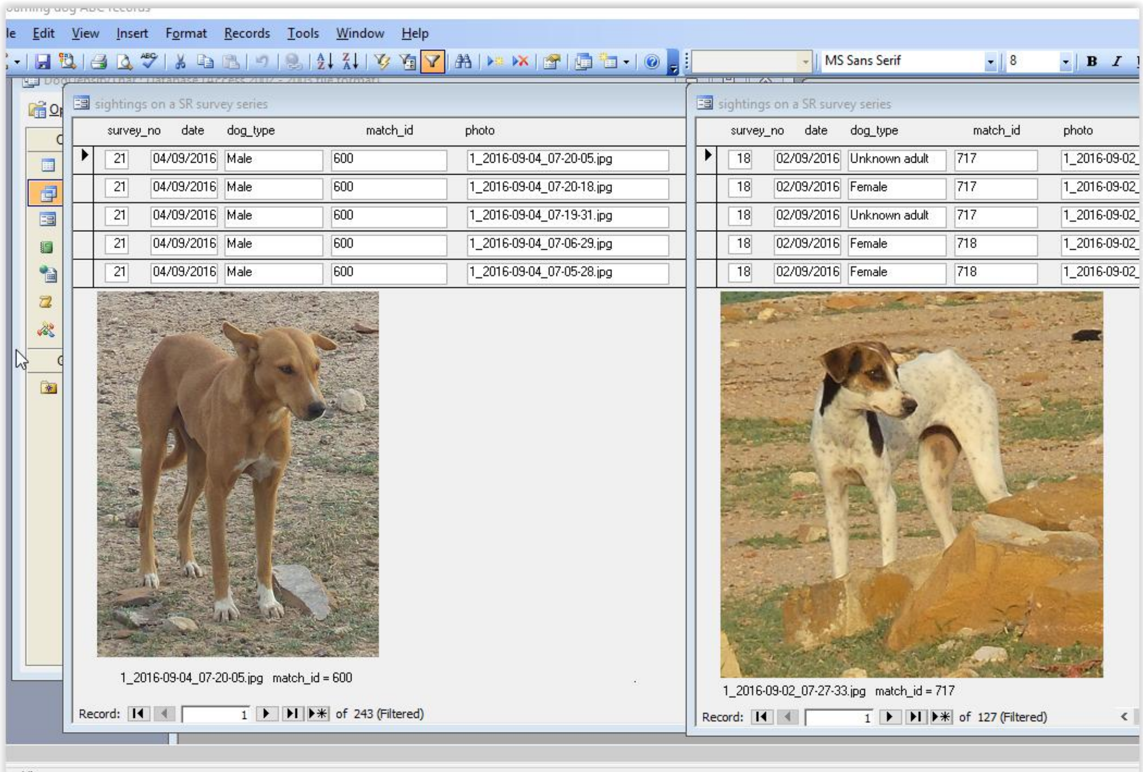


Figure 8. MS Access database to catalog and match dog photographs for mark-recapture based population assessment



2.2.3.2. Impacts of free-ranging dogs on wildlife

To understand the impacts of free-ranging dogs on wildlife, we carried out field activities to determine ranging patterns and resource utilization of dogs using biotelemetry.

Radio tracking: Nine dogs were fitted with radio-collars and tracked daily on vehicle for 1–3 months. GPS locations, time and associated variables (habitat type, activity of animal and associated individuals) were recorded at every 15 minutes. Spatial locations of radio-collared dogs will be analyzed using Minimum Convex Polygons (MCP) and Kernel methods to estimate home range size and habitat use. Time and location data will be analyzed to assess temporal activity pattern, proportion of time and periods spent in settlement vs. wildlife habitats, and time-activity budgets (figure 9).

Behavioural sampling: Each radio tracked dog was observed using focal animal sampling for ~150 hours, including continuous 24 hours monitoring for 4 days, to determine their activity patterns, feeding habits and inter-specific interactions. Data on scavenging, active predation and interactions with conspecifics and potential competitors (fox, cat, raptor etc.) were recorded.

Figure 9. Field activites related to understanding and management of the impact of free-ranging dogs on wildlife in/around Desert National Park

Prey assessment: To assess prey resources in the area used by radio-tracked dogs, the combined MCP with 2 km buffer was converted into ninety four 1 km^2 grid-cells, realized on ground using handheld GPS unit. Each grid-cell was sampled once using 1 km foot transect for potential prey (chinkara and nilgai) in distance sampling framework, and 500 m x 2 m belt for counting the number of spiny tail lizard and rodent burrows. To assess carcass availability, a fixed zig-zag route of 127 km was digitized using Google Earth™ in the same area that was surveyed once every 15 days to record carcasses. Data on condition, distance of carcass from trail, and presence of scavengers around the carcass were collected.

This field activity will yield information on predation rates of wild prey and livestock by dogs.

2.2.3.3. Bird mortality due to power-lines

Expanding networks of power-lines in wildlife habitats are causing fatal collision of birds in general and bustards in particular as the latter have low and heavy flight with small frontal vision because of which they fail to detect these thin structures from afar and collide. As recommended by bustard recovery plans (Dutta et al. 2013), Rajasthan Forest Department and project representatives have engaged with power-line agencies to install bird diverters on power-lines in priority GIB habitats. Simultaneously, to estimate bird collision rates and future effectiveness of mitigation measures (installation of bird diverters or undergrounding of cables), we assessed movement rate of bustard and other birds across power-lines, and their collision rates with power lines.

To quantify bird crossing across power lines, we observed movement of birds at 10 randomly selected 2 km power-line segments which include 5 low tension power lines and 5 high tension power lines in prime GIB habitat. We tried to cover a maximum of 850 m from a point observing bird movements across power lines for 12 hours a day once in winter and other in summer to capture seasonal differences in bird composition. Bird movements across power line, flight height from wires, and use of wires, poles and pylons for perching/roosting were recorded, and segregated into taxa/size groups. Collision events during these observations, if any, were recorded. Movement rates of different taxa will be estimated as number of birds crossing per km power-line and number of birds dying per crossing.

To assess collision rates of birds, forty 2 km power-line segments (20 high-tension and 20 low-tension) were randomly selected in prime GIB habitat and 30-m band on either side of these power-lines were sampled for bird carcasses on a monthly basis from January 2017 onwards. All bird carcasses were removed prior to sampling. As a control, we sampled bird mortality along 20 randomly selected 2 km x 30 m belts without power line in prime GIB habitat to show that mortality under power-lines reflect collision mortality and exceeds natural mortality. Data will be analyzed and number of birds dying from collision per km per month will be estimated to assess taxa/size wise bird mortality due to power-lines (figure 10).

Since, birds found under power-lines do not represent true mortality as a fraction of carcasses can go undetected or decomposed prior to survey, we conducted two experiments to incorporate detection and decomposition rates of carcasses. For carcass decomposition/disappearance experiments we used 28 fresh bird carcasses of various size (50 – 5000 g) and placed them under 10 randomly selected power-line segments and monitored them on days 2, 5, 10, 18, 30 and 60 since placement, and recorded if the carcass persisted or disappeared. For carcass detection experiment, we used 19 fresh country chicken carcasses of different sizes (50 – 5000 g) and placed them at random locations under six randomly selected power-line segments. Three observers surveyed these power-line segments to detect these carcasses in a blind trial. These experiments will yield estimate of size-specific carcass persistence rate and detection rate that will be used to correct the number of birds dying from collision per km per month. Collision vulnerability of various bird taxa/size groups will be assessed by comparing crossing and mortality rates.

Figure 10. Field activities related to assessment of bird mortality caused by power-line collisions in Thar during 2016-17

Monitoring bird crossing rates and their movement across power-lines well help us in understanding the level of problem and, in future, assessing benefits of marking power-lines. Monitoring bird collision rate due to power lines will help in assessing the fatal effect of power line on different species of birds including GIB and help us to know which kind of species are more prone to death due to power lines.

2.2.3.4. Population assessment of nest predator in GIB breeding enclosures

Following recommendations of the national bustard recovery plans (Dutta et al. 2013), Forest Department enclosures in Thar are managed with the objective of improving GIB recruitment. Bustard eggs and chicks are known to suffer from high mortality due to predation and other causes (Morales et al. 2002). To assess abundance of potential nest/chick predators in GIB breeding sites, and subsequently control their populations to improve GIB recruitment, we deployed camera-traps following Random Encounter Model sampling framework (Rowcliffe et al. 2008) from December 2016 onwards. Sites in Thar with GIB breeding records, such as Sudasari, RKVY, Gajaimata and Ganga enclosures were camera-trapped systematically with one camera-trap at the centre of a 500m x 500m grid-cell. We placed Reconyx HC500 Hyperfire Semi-covert passive infrared camera-traps at 0.20–0.25 m height from ground at ~145 unique placement locations, covering a total area of 40 km^2, and operated them for 30-40 days at each location (figure 11). We obtained photo-captures of potential nest predators (fox, mongoose, cats and dogs), bustard, chinkara, nilgai, wildpig, and livestock (figure 12). Photocapture data will be analyzed using Random Encounter Modeling approach that uses independent capture rate and speed to estimate abundance. To enable this, calibration exercises were carried out at the time of camera-trap placement to characterize camera viewing frames that would be used to generate triaxial location, distance from camera, and speed from animal photo-captures.

Figure 11. Camera-trapping to assess great Indian bustard egg/chick predator abundance in Desert National Park enclosures during 2016-17

Figure 12. Species photo-captures in systematically placed camera-traps in Desert National Park enclosures during 2016-17

2.2.4. Conservation genetics

Sample collection and DNA extraction: Non-invasive samples such as molted feathers (n=220), egg membranes (n=14) and fecal pellets (n=290) were collected during field surveys (2010–2016) from five landscapes: Kachchh (Gujarat), Desert National Park (Rajasthan), Nanaj bustard Sanctuary (Maharashtra), Ghatigaon bustard Sanctuary (Madhya Pradesh), and Rollapadu Wildlife Sanctuary (Andhra Pradesh). Samples were collected in zip locks filled with silica and shipped to conservation genetics laboratory at WII for storage at -20^{0}C. DNA was isolated from fecal samples using Guanidine isothiocyanate–silica extraction protocol (Boom et al. 1990), molted feathers using DNeasy blood and tissue kit (Qiagen), and egg membranes using Bush et al. (2005) protocol. All extractions were carried out in a dedicated room and negative controls were used to monitor potential contamination during extractions (figure 13).

Genetic analysis: Species identification was done using conserved primers to amplify mtDNA sequences containing either a 323 bp fragment of control region II (L438 and H772; Wenink et al. 1993) or a 399 bp fragment of the cytochrome b gene (LCyt-B4 and LCyt-B6; Broderick et al. 2003) and compared the sequences using available GenBank sequences. Since misidentification of samples with other birds was possible, a species identification step was carried out before further genetic analysis. The same mtDNA sequences generated were used to identify haplotypes and were compared with the existing (Ishtiaq et. al. 2011). Nuclear microsatellites were also used (n=13) to assess genetic variation and examine patterns of genetic structure across GIB landscapes. Multi tube approach was used to amplify all microsatellites in four panels. Negative controls were included in all PCRs to detect contamination. Few samples were randomly picked and analyzed again to check for any genotyping error. Available programs were used to identify genotyping errors (Pedant v. 1.0 & Microchecker v. 2.2.3), estimate genetic diversity estimates (Fstat v. 2.9.3.2), identify deviations from Hardy Weinberg equilibrium and linkage disequilibrium (Genepop v. 1.2), estimate Wright's F-statistics and exact tests of population differentiation (Arlequin v. 3.5), identify genetic clusters and assignment of individuals to those clusters (Structure v.2.3.3), estimate magnitude and direction of geneflow (Bayeass v.1.3) and number of migrants(Geneclass v. 2.0).

Results: Amplifiable DNA was obtained from 102 samples. Low success rate in DNA amplification could be because high temperature in arid climates increased degradation of genetic material. Comparison of mtDNA sequences with GenBank sequences showed presence of houbara bustard and other bird species in collected samples and only GIB positive samples were further used for genetic analyses. No new haplotype was found apart from the three existing haplotypes (Ishtiaq et al. 2011). Success rate of 13 microsatellites ranged from 60 to 95% and data from 10 microsatellites with maximum success in PCR amplification (n=85 samples) were used for further analysis. Eight microsatellites were polymorphic with number of alleles ranging from 2 to 8 and remaining two microsatellites were found to be monomorphic. Range of allelic dropouts (0-15%) and false alleles (0-10%) confirmed that there was no major genotyping error in the data. Null alleles were found in five microsatellites (Bus A10, Bus A18, Bus D110, Bus D210, Bus A112) at range level but not at landscape level. Low levels of genetic diversity was observed with microsatellite data (mean observed heterozygosity, Ho=0.3145 against expected heterozygosity, He=0.5057) (figure 14). Probability of confusing two individuals as the same individual (PID = $2.1*10^{-05}$) and probability of confusing two siblings as the same individual (PID-sib = $9.8*10^{-3}$) indicated that microsatellites used by us have reasonable power to distinguish individuals from genetic samples.

Genetic structure results supported the presence of two different clusters where Rajasthan population found out to be most diverse population and clubbed with Andhra Pradesh, Maharashtra and Madhya Pradesh populations. Gujarat population emerged as second cluster with some gene flow with Rajasthan population. First generation migrants were detected between Andhra Pradesh, Maharashtra and Madhya Pradesh populations (figure 15).

Figure 13. DNA extraction from non-invasive genetic samples of great Indian bustard in conservation genetics laboratory at Wildlife Institute of India

Figure 14. Allelic patterns across five populations (Pop1=Gujarat, Pop2= Rajasthan, Pop3=Rollapadu, Pop4=Maharashtra, Pop5=Madhya Pradesh, Na- Number of alleles, Ne- Number of effective alleles, I- Shannon index, LComm- Locally common, He- Expected hetrozygosity)

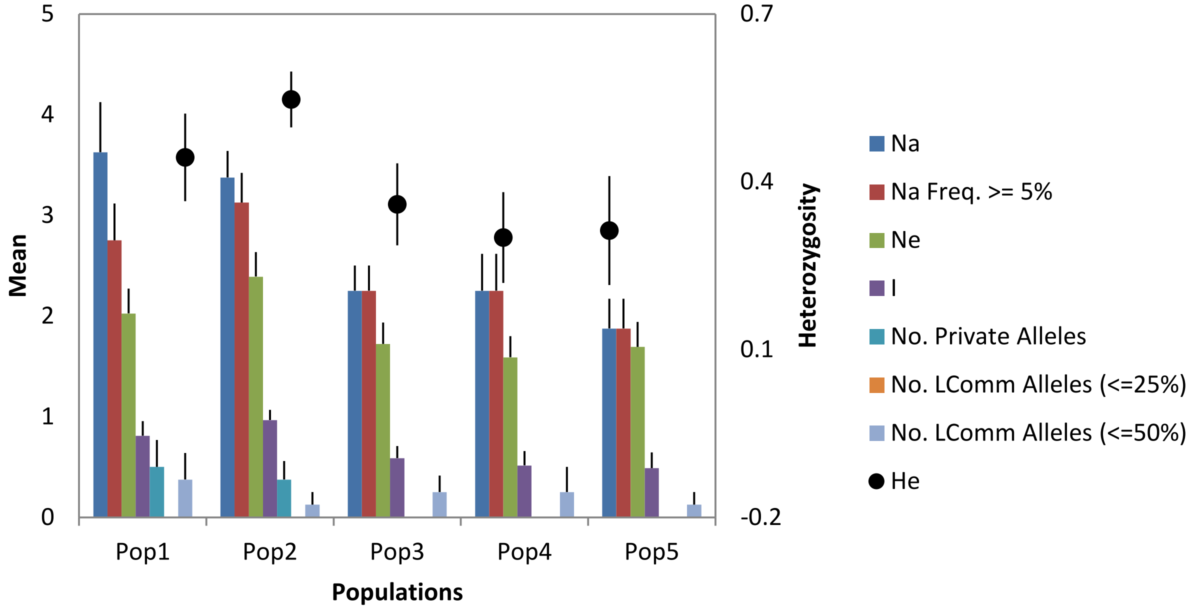
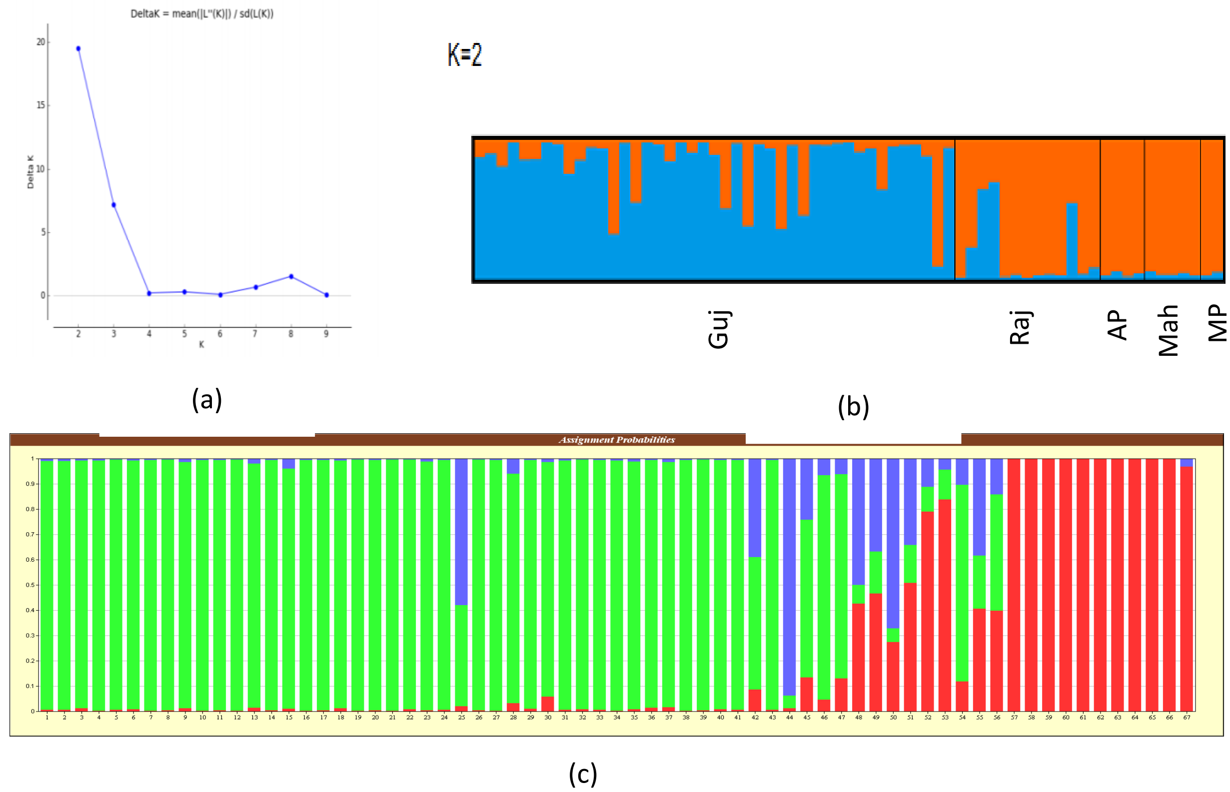


Figure 15. Results of individual clustering analyses. a) Δ*K* was used to identify optimal *K*=2, b) bar plots of results from Structure using k=2 and c) bar plots of results from Tess using k=3. In both b &c, each individual is represented as a vertical line.



2.3. Capacity-building and outreach

2.3.1. Meetings and workshops

Event	Brief description	Timeline
Stakeholder meeting with BNHS at WII	Meeting to discuss GIB conservation actions and priority tasks, and delineate organizational roles and responsibilities to reduce duplication of efforts and optimize use of resources; attended by Director WII and project team	April 2016
Consultation meeting with international bustard expert	Project representatives interacted with visiting international bustard expert, Dr. Juan Carlos Alonso and involved his inputs in refining ongoing *in-situ* conservation actions; the meeting was attended by G.S. Bhardwaj, CCF Jodhpur and Anoop K.R., DCF Jaisalmer	April 2016
CAMPA Endangered Species Recovery Program National	Project proposals were introduced to partner agencies (Rajasthan, Gujarat and Maharashtra State Forest Departments) and concerned stakeholders (representatives of BNHS, TCF and WWF-India); attended	May 2016

Event	Brief description	Timeline
Launch workshop at WII, Dehradun	by Director WII and project team	
Consultative meeting with captive breeding experts	Discussion with Dr. Sushil Sood, Veterinary Officer, Himachal Pradesh and Avian Breeding Expert, on GIB conservation breeding work plan; attended by Project team	May 2016
	Discussion with Keith Scotland, International Houbara Bustard Breeding Expert, on center design, work plan and budgeting for GIB conservation breeding; attended by Project team	October 2016
Awareness program on World Day to Combat Desertification at WII	Project scientist delivered lecture on "deserts and desertification: myths vs. realities" to generate public awareness on desert/grassland conservation and highlight the shortcomings of wasteland policy and the need to bring deserts/grasslands under the fold of environmental governance.	June 2016
Stakeholder meeting with Rajasthan Forest Department at Jaipur	Presentation of project proposal and discussion with concerned officers of Rajasthan Forest Department for developing a mutually agreed roadmap of GIB conservation program; attended by Director WII and project team.	July 2016
Sensitization workshop with Indian Army at Jodhpur	Collaborative workshop between WII, BNHS and Rajasthan Forest Department to sensitize Indian Army on GIB conservation and gain permission to monitor the GIB population in Field Firing Range; attended by project team. Although we received positive feedback from Army on our requests, no formal permission has been received despite repeated correspondences (see report of workshop in appendix 2).	July 2016
Policy meeting	Interaction with Sh. Jairam Ramesh to appraise him on challenges, urgent actions and policy revisions required for GIB conservation; attended by Director WII and Project Investigator and Scientist.	August 2016
Meeting with Chief Minister, Additional Chief Secretary MoE, & PCCF (WL) Rajasthan	Director WII and Project Investigator had a meeting with the Hon. Chief Minister and senior officials of Rajasthan State wherein *in-situ* and *ex-situ* measures for GIB conservation were discussed in detail. The Hon. CM expressed concern and agreed to the measures being taken and the need for establishing the conservation breeding center. However, the Hon. Chief Minister desired to consult with international experts before deciding on the location to set up the conservation breeding center.	October 20, 2016
Review meeting on	Project Investigator and Scientist attended the meeting	November

Event	Brief description	Timeline
GIB (CAMPA) Project called by MoEFCC at New Delhi	with Additional Director General (WL) and Deputy Inspector General (WL), MoEFCC, and PCCF (WL), Rajasthan State wherein Project Investigator made a presentation on the progress of *in-situ* and *ex-situ* project components. He explained the urgent actions required to restore habitats (predator management, power-line mitigation). He appraised the house on the way forward for conservation breeding program, the outcome of Keith Scotland's (international houbara breeding expert) visit and about the meeting with Hon. CM, Rajasthan. He highlighted the need of tagging birds in Rajasthan, for which permission has been granted by MoEFCC but not renewed by Rajasthan Government. It was decided that MoEFCC would process the Memorandum of Agreement for signing by three parties, WII would share the list of 10 possible sites and criteria matrix for setting up GIB conservation breeding center, and Rajasthan Forest Department would take up population control programs for dogs and pigs in GIB habitats.	28, 2016
Consultative meeting with Rajasthan Renewable Energy Corporation at Jaipur	Project scientist attended meeting with Rajasthan Forest Department and power agencies to provide technical inputs on installation of diverters on power lines in priority GIB areas in Thar. Based on this meeting, WII was given the responsibility to procure samples of bird diverters which will be installed on pilot basis by Suzlon for design/installation demonstration.	December 2016
Consultative meeting with Rajasthan Forest Department at Jaipur	Project scientist attended meeting with Rajasthan Forest Department to provide inputs in Desert National Park management plan. Meeting was attended by Chief Wildlife Warden, Chief Conservator of Forests (Jodhpur) and Deputy Conservator of Forests (Jaisalmer) where GIB census methods and priority conservation actions were discussed.	January 2017
Meeting with Minister, Environment and Forests, Rajasthan State	The Project Investigator met with Hon. Minister and gave a presentation regarding measures being taken to conserve the GIB *in-situ* as well as the need to commence *ex-situ* conservation breeding programme. The Minister appreciated the efforts and science behind the initiatives and assured all support for moving ahead.	January 31, 2017
Meeting with PCCF (WL) and Secretary, Forest and Environment, Gujarat State	The Project Investigator gave a presentation to the PCCF (WL) and discussed GIB conservation in Gujarat with the Secretary. The specific *in-situ* measures that are required in Kachchh were communicated and discussed. The possibility of establishing a second *ex-situ* conservation	February 17, 2017

Event	Brief description	Timeline
	breeding center for GIB and lesser florican in Mandvi, Kachchh was also discussed. Copy of the Memorandum of Agreement (MoA) as approved by MoEFCC New Delhi, between Government of Rajasthan, MOEFCC and WII was shared with discussion on a similar MoA being drafted and signed with Gujarat State.	
Presentation on UN World Wildlife Day and meeting with CWLW Gujarat at Gandhinagar	Project Scientist delivered presentation on bustard conservation contexts, challenges and updates to generate awareness among local officers, conservationists and media, and appraised Chief Wildlife Warden Gujarat on urgent in-situ actions such as sensitizing power and revenue departments to implement green development and need of declaring eco-sensitive zone around Naliya.	March 2017
Meeting with partner agencies in Kachchh	Project scientists met representative of The Corbett Foundation for initiating Animal Birth Control and Rabies Vaccination Program to manage dog populations in core GIB habitat; and initiated discussions with Sahjeevan to collaborate on community participation based conservation actions in Kachchh.	March 2017

Figure 16. (Clockwise) Dr. Y.V. Jhala, Faculty WII presenting an overview of CAMPA projects and Mr. S.S. Negi, D G Forests and Special Secretary to MoEF&CC giving opening remarks at the National Launch Workshop of Endangered Species Recovery Projects May 2016. Army officials during the Sensitization workshop at Jodhpur July 2016, and meeting with Rajasthan Forest Department during GIB Census 2017.

2.3.2. Awareness materials

1. Concept note and posters on mitigating power-line operations for GIB conservation to sensitize power agencies (appendix 3)

2. Poster on importance of tagging for GIB conservation – circulated among Army officers in Jodhpur workshop to sensitize Army personnel on the use of biotelemetry in conservation and avoid situations where tagged birds are suspected as spy and shot (appendix 4)

3. GIB Conservation (CAMPA) Project poster to introduce project activities to partner agencies and stakeholders in National Launch Workshop and follow-up stakeholder meetings (appendix 5)

4. Presentation on biodiversity of Rajasthan for India Science Express to sensitize general public on grassland biodiversity and conservation issues

5. Presentation on 'Deserts and desertification – myths vs. realities' to generate public awareness on desert/grassland conservation, shortcomings of wasteland policy, and the need to bring deserts/grasslands under the fold of environmental governance on UN World Day to Combat Desertification at WII, Dehradun

6. Presentation on bustard conservation challenges and updates to generate awareness among local officers, conservationists and media on UN World Wildlife Day at Gandhinagar

2.3.3. Relevant publications

1. Dutta, S. (2016) Bijli, sadak, paani and bustard. *The Indian Express*.

2. Dutta, S., Bipin, C.M., Bhardwaj, G.S., Anoop, K.R. and Jhala, Y.V. (2016) Status of GIB and Associated Fauna in Thar. Wildlife Institute of India and Rajasthan Forest Department, Dehradun, India.

3. Dutta, S. (2017) Greener on neither side: socio-ecological crisis of dry grasslands in India. *Conservation from the Margins* (eds U. Sreenivasan and N. Velho). Orient Blackswan, Hyderabad.

4. Habib, B., Talukdar, G., Kumar, R. S. Nigam, P. Limaye, s., and Vaijayanti, V. (2016): Tracking the Great Indian Bustard in Maharashtra, India. Technical Report 2016. Wildlife Institute of India and Maharashtra Forest Department Pp 20

5. Project Bustard Conservation – Article in Saevus May 2016

6. Hiby, L., Dutta, S., Chaudhari, A., Kartal, T. and Bipin, C.M. (2016) Roaming dogs in settlements to the west of Jaisalmer. Humane Society International and Wildlife Institute of India, Dehradun.
7. Dutta, S. and Jhala, Y.V. (2017) Ark and Park: recovery of critically endangered bustard relies on best in-situ and ex-situ measures. Journal of Applied Ecology, In review.

2.4. Pilot implementations for surgical habitat management

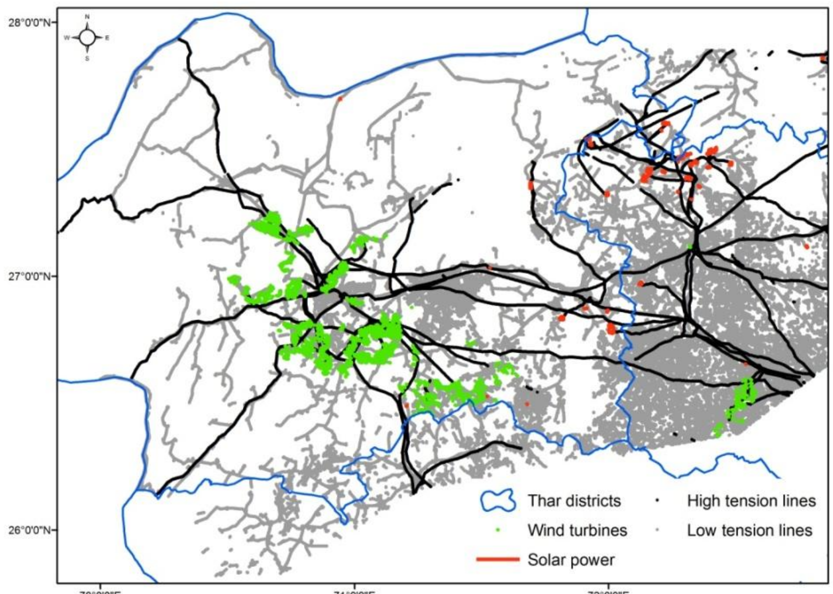
2.4.1. Mapping of power-lines and other infrastructure

Arid grasslands and desert are regarded as 'unproductive wastelands' and targeted for power generation; resulting in rapid increase of wind turbines, solar power projects, and power-lines in GIB habitats. Power-lines pose one of the critical threats to this low flying heavy bird with poor frontal vision. We attempted to map power-lines in GIB habitats so that mitigation measures can be implemented in priority habitats.

The GIB landscape in Thar, extending across 20,000 km^2 area, is too vast to map infrastructure manually. Therefore, low and high tension power-lines, wind and solar power projects, roads, and settlements were digitized from very high resolution satellite imagery available with Google Earth™. This task was outsourced to M/S. Science Pvt. Ltd. and maps have been generated. However, these maps need to be updated by manual digitization of power-lines in areas where many power-lines have come up in the last few years (figure 17).

Abdasa, Kachchh has considerably long coastline favorable for power generation from wind energy. Several hundred wind turbines along with their power transmission lines, power stations, and related infrastructure have come up in this region over last few years. An attempt was made to map the overhead power-lines passing through GIB habitat in Abdasa tehsil, Kachchh. Since most of these power-lines are set up in last couple of years and therefore not available in open sources, the mapping exercise was carried out manually and restricted to ~500 km^2 priority habitat. This area, lying between Naliya – Bhawanipar – Kothara villages, was surveyed on vehicle to identify areas with still intact sizable grassland habitat and high probability of bustard occurrence. Mapping of power-line was carried out using high resolution terrain maps from Google Earth™ and sketch diagrams of power-lines provided by the State owned Electricity Company. All the State roads, village roads and dirt tracks were surveyed to check for power-lines and every power-line was initially drawn on high resolution paper map and later transferred to GIS domain. Additionally, a GPS application in smart phone was used to georeference power-line junctions, road intersections and power stations.

Figure 17. Maps of infrastructure (low-tension power-lines, high-tension power-lines, wind turbines and solar power project) in Thar (top) and high-tension power lines in Kachchh (bottom)



GIB distribution / habitat-suitability model will be superimposed on these infrastructure maps to identify priority areas where further infrastructural development needs to be curtailed and existing infrastructure have to be mitigated to make them bustard-friendly. This includes undergrounding or marking of overhead power-lines with bird diverters that make them visible to bustard and reduce power-line collisions.

2.4.2. Breeding enclosure management

Field officers based at Thar, Mr. Anoop K.R., Director Desert National Park and Dr. G.S. Bhardwaj, Chief Conservator of Forests (Jodhpur) are working in close association with the Project team to implement following management actions recommended by our research in/around Desert National Park (figure 18):

1) Establishing new enclosures in priority conservation areas, such as Gajaimata and Chowani;

2) Consolidating existing enclosures such as Sudasari and Ganga by predator-proof fencing to keep nest predators away and improve GIB recruitment;

3) Removing dogs from enclosures. Additionally, collaborative efforts to control dog populations in settlements within priority GIB habitat by long-term spay neuter programs would be commenced soon in collaboration with implementing agencies such as Humane Society International in Thar and The Corbett Foundation in Kachchh;

4) Managing water guzzlers to remove undesired species such as pigs and nilgai;

5) Organizing sensitization workshops with power corporations and reaching a participatory decision/resolution to avoid new wind-turbines and power-lines in GIB arc and marking existing power-lines with Bird Diverters; and

6) Generating alternative local livelihoods through eco-tourism based activities.

Figure 18. Management actions implemented by Forest Department; showing enclosures, predator-proof-fencing, and predator management.

3. Proposed project activities during 2017–18

Project objective	Activity	Site	Prerequisites / risks
Conservation breeding	Meeting with Hon. Chief Minister Rajasthan involving international bustard experts to discuss the urgent need and modalities of GIB captive breeding program	Rajasthan	Availability of Hon. C.M. Rajasthan, tentatively April last week - May first week 2017
	Signing of Memorandum of Agreement between MoEFCC, Rajasthan Govt and WII (also Gujarat and Maharashtra) to operationalize GIB conservation program		Agreement between Parties
	Finalization of site to establish GIB conservation breeding center		Transfer of land by Rajasthan Forest Department to WII
	Habitat management and construction of buildings to establish GIB conservation breeding center		Construction / management in the acquired land
Applied research – population/habitat surveys	Population and habitat surveys in GIB landscapes and report publication	Rajasthan, Gujarat	Permission to conduct survey in Kachchh
	Pilot population and habitat surveys in select lesser florican breeding sites across range States to develop country-level monitoring program and report publication	Rajasthan, Madhya Pradesh, Gujarat	Permission from respective State Forest Departments
	Intensive surveys to understand GIB phenology and ecological requirements (behavior, events and habitat use) and analysis of existing ecological data	Rajasthan	NA
Applied research – ranging patterns using biotelemetry	Capture, tagging and tracking of GIB to understand their ranging patterns and landscape use	Gujarat, Rajasthan	Renewal of permissions to tag birds in Rajasthan
Applied research – threat assessment	Refining / finalizing infrastructure maps using ground digitization	Rajasthan, Gujarat	NA
	Continuation of camera trap sampling inside breeding enclosures to assess nest predator density and mammalian	Rajasthan	NA

Project objective	Activity	Site	Prerequisites / risks
	diversity. Compilation and analysis of existing camera trapping data		
	Soil samples and GIB food samples collection from priority habitats and laboratory analysis to assess pesticide prevalence	Rajasthan, Gujarat, Maharashtra	NA
Applied research – livelihood concerns	Social surveys and questionnaires to understand livelihood concerns and solutions to reduce public antagonism surrounding GIB conservation	Rajasthan	Recruitment of sociologist and availability of consultant in project
Applied research – conservation genetics	Laboratory analysis of GIB genetic samples using microsatellite markers to estimate abundance. Analysis and publication of GIB population structure data	Rajasthan, Gujarat, Maharashtra	NA
Capacity building and outreach – management enforcement	Training of Forest Department staff on implementation of MSTrIPES using mobile application to improve patrolling and collation of management information	Rajasthan	Agreement between WII and Rajasthan Forest Department
Capacity building and outreach – stakeholder sensitization	Awareness programs with children in priority GIB habitat Sensitization workshop with officers concerned with agriculture / infrastructure development (Revenue Department, Agriculture and Animal Husbandry, Power/energy agencies) in priority GIB habitat	Rajasthan, Gujarat	Liaison and positive response of concerned departments
Capacity building and outreach – publications and awareness	Publication of peer-reviewed papers on 1) the need of *ex-situ* and *in-situ* breeding for GIB conservation, and 2) habitat management for conservation of GIB Publication of reports on population and habitat surveys in GIB landscape Publication of concept notes, posters and presentations on mitigating threats to conserve GIB	NA	NA
Capacity building – recruitment and training of	Recruitment of appropriate personnel to manage different project components, such as Veterinary	NA	MoU between WII and international bustard breeding

Project objective	Activity	Site	Prerequisites / risks
project personnel	officer and Manager of Conservation Breeding Center and hands-on-training of conservation breeding staff at bustard breeding agencies such as EBBCC, Uzbekistan / IFHC, Abu Dhabi		agencies and funding support
Pilot habitat management – power-line mitigation	Procurement / production and distribution of Bird Diverters to concerned officers of Forest Department and power-line agencies for installation on overhead power-lines in priority (mapped) GIB habitat.	Rajasthan, Gujarat	Continued liaison between Rajasthan Forest Department, Rajasthan Renewable Energy Corporation and WII. Building agreement between stakeholder agencies in Kachchh
	Assessment of the effectiveness of Bird Diverters in reducing bird mortality due to power-line collisions		
Pilot habitat management – dog sterilization / removal	Removal of free-ranging dogs from enclosures and sterilization of dogs in settlements in priority (mapped) GIB habitat	Rajasthan, Gujarat	Continued liaison and agreement between WII, Rajasthan Forest Department and implementing agencies – Humane Society International and The Corbett Foundation

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Appendix