भारतीय वन्यजीव संस्थान
Wildlife Institute of India

BUSTARD
RECOVERY PROGRAM

SURVEY REPORT

STATUS SURVEY OF MIGRATORY BIRDS AND KEY WILDLIFE IN BIKANER DISTRICT, RAJASTHAN

2021

Front Cover:
Demoiselle Crane: Dhritiman Mukherjee

STATUS OF WILDLIFE IN BIKANER

Survey Report 2021

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Citation: Dutta, S., Kher, V., Uddin, M., Supakar, S., Karkaria, T., Gupta, T., Paul, I., Varma, V., Pandey, D., Verma, V., Phasalkar, P., Khanra, A., Jora, V. S., Katariya, P. S., Chhangani, A. K., Bipin, C. M., Jhala, Y. V. 2021. Status survey of migratory birds and key wildlife in Bikaner district, Rajasthan. Wildlife Institute of India, Dehradun

STATUS SURVEY OF MIGRATORY BIRDS AND KEY WILDLIFE IN BIKANER DISTRICT, RAJASTHAN

Organised by:

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Funded by:

National CAMPA Authority, MoEF&CC

Acknowledgements

The status survey of wildlife in Bikaner was conducted by the Wildlife Institute of India with the support of Rajasthan Forest Department and Shri Arjun Ram Meghwal, Hon'ble Member of Parliament Bikaner Constituency and Minister of State for Parliamentary Affairs and Culture, Government of India. The Ministry of Environment, Forest and Climate Change (MoEF&CC) provided financial support for this survey under the Endangered Species Recovery Programme (Great Indian Bustard) sanctioned by the National Compensatory Afforestation Fund Management and Planning Advisory Council (CAMPA). We thank the Chief Wildlife Warden of Rajasthan for providing permission to conduct the survey. Offices of the Deputy Conservator of Forest, Assistant Conservator of Forests, Range Forest Officers, Deputy Range Forest Officers, Foresters, and Forest Guards of Bikaner and Chattargarh Forest Divisions are acknowledged for their logistic support and facilitation. We thank the Director, Wildlife Institute of India and Dean, Wildlife Institute of India, for providing academic and institutional support. We would like to express our gratitude to the Vice-Chancellor of Maharaja Ganga Singh University, Bikaner and Principal of Govt. Dungar College, Bikaner, for permission to conduct training workshops and valedictory functions in their respective institutions. We sincerely thank the staff and students of Govt. Dungar College and Maharaja Ganga Singh University for their support and logistic help. We would like to express our gratitude to Major General Gurpreet Singh, 24th Infantry Division and GOC-in-charge, Mahajan Field Firing Range (MFFR), for providing permission and hospitality to survey inside the range. We further thank GOC-in-charge southwest command and the concerned army personnel of MFFR for assisting in the execution of the survey, and Lt Col. Keshvendra Singh for his help. We acknowledge the support of BSF officers for their help in surveying the border areas. We would like to express our gratitude to the management of Gajner Palace for permitting and facilitating the survey of Gajner Lake. The survey wouldn't have been possible without the unconditional support and tireless efforts provided by the Office of Hon'ble Member of Parliament, particularly the support of Mr. Ravi Agrawal and Mr. Ganesh Siyag. Furthermore, we thank Mr. Jitendra Solanki, Mr. Chena Ram (Hanuman Nagar), Mr. Sanjeev Verma (Executive Engineer, Irrigation Department, Chattargarh) for providing organisational support in the execution of the survey. Dr. Dhananjai Mohan, Director WII is specially thanked for reviewing the report.

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EXECUTIVE SUMMARY

Executive summary (English)

The Bikaner district of Rajasthan supports a wide variety of wildlife that has not been rigorously surveyed in the past. Robust status assessments with reproducible methods are vital for monitoring wildlife trends, particularly in regions like Bikaner that are undergoing large-scale land-use changes, which are potentially detrimental to native wildlife. Therefore, a large-scale survey was organised by the Wildlife Institute of India in collaboration with Rajasthan Forest Department, Government Dungar College and Maharaja Ganga Singh University to assess the status of key wildlife in the Bikaner district of Western Rajasthan. Notably, this survey was planned at the request of Bikaner district residents, who conveyed their wish to conduct a wildlife survey to the Hon'ble Member of Parliament, who invited the Wildlife Institute of India through the Ministry of Environment, Forest & Climate Change and to execute the survey. Consequently, the data collection was conducted in a citizen science framework and involved active participation by a diverse group of researchers, frontline staff, University students and wildlife enthusiasts. The survey assessed the distribution and abundance status of key wildlife, particularly migratory, arid-adapted and raptorial species of birds, their habitat associations, potential threats in the landscape, and community perceptions towards conservation.

The Bikaner parliamentary constituency was divided into four sampling blocks (Bikaner, Kolayat, Chattargarh and Mahajan) and overlaid with 144 km^2 (12 x 12 km grid) cells. A total of 89 such cells covering 12,816 km^2 area were extensively surveyed using vehicle transect method. In each cell, dirt-trails or unpaved roads of 16.2 ± 4.1km length were traversed using slow-moving vehicles and animals were recorded during peak activity periods (0700hrs-1300hrs and 1600hrs-1900hrs). Data on iconic native fauna (chinkara, foxes, bustards, cranes and raptors) and key neobiota (dog, pig and nilgai) was collected on these vehicle transects (1442 km total length). Information on small birds, habitat characteristics and anthropogenic disturbances was recorded at regularly placed transect stop-over points (802 points). Major avian congregations or 'hotspots' (carcass dump at Jodbeed, wetlands and lakes at Gajner, Lunkaransar, RD507 and RD750) were surveyed using simultaneous point-counts and line transects. Community perception towards conservation was assessed using structured questionnaires conducted in select households of randomly selected villages. Species' population estimates were obtained using analytical techniques such as distance sampling and simultaneous block counts.

During the survey, 1,880 Chinkara individuals were detected in 684 herds with an encounter rate of 139.78±18.72 individuals per 100km. The estimated density of chinkara in the surveyed area was 4.27±0.65 individuals/km^2, yield abundance of 54,745±8,392 individuals in the surveyed area. Similarly, 112 desert foxes were seen during the survey and the density was estimated to be 0.58±0.11 foxes/km^2, yielding abundance of 7,456±1,356 individuals. Other mammals recorded during the survey were - Desert Cat (0.57±0.2 individuals/100km), Nilgai (14.39±2.91 individuals/100km), free-ranging Domestic Dogs (26.07±3.6 individuals/100km) and Indian Wolf (one sighting).

Among large birds, the encounter rate of the Demoiselle Crane was estimated at 5.47±3.14 individuals/100km. The five most common raptor species (individuals per 100 km) were Griffon Vulture (16.44±6.94), Egyptian Vulture (8.73±2.35), Common Kestrel (7.39±0.88), Black-winged Kite (5.35±0.89) and Long-legged Buzzard (5.13±0.69). Among small birds, 2,859 individuals from 103 species were recorded on point counts. The most abundant species were Common Babbler, Eurasian collared Dove, House Sparrow, White-eared Bulbul, Red-vented Bulbul, Greater short-toed Lark and Variable Wheatear. The total density of small birds, excluding birds in flight and rare species, was estimated at 997±58 individuals/km^2.

A total of 24,674 individual birds belonging to 95 species across 36 families were recorded during hotspot surveys. RD750 had the highest number of individuals and species (15,666 individuals of 76 species), followed by RD507 (6,501 individuals of 34 species), Lunkaransar lake (1,749 individuals of 25 species) and Gajner lake (758 individuals of 38 species). Common Coot, Demoiselle Crane, Common Pochard, Common Teal and Gadwall were the most abundant species that were recorded. Two Endangered (Egyptian Vulture and Steppe Eagle), two Vulnerable (Common Pochard and River Tern), and six Near-Threatened species (Black-headed Ibis, Dalmatian Pelican, Eurasian Curlew, Ferruginous Duck, Northern Lapwing, and Painted Stork) were recorded during the hotspot survey.

The habitat was characterised by flat and mildly undulating terrain, dominated by scrublands followed by agriculture (fallow and cultivated). Active disturbance such as humans or livestock was present in 72% of surveyed plots. Passive disturbance such as fences, electric lines, paved road/ highway etc., was recorded at 87% of the points. In terms of vegetation, the most dominant natural vegetation was Kheemp (*Leptadenia pyrotechnica*) > Khejri (*Prosopis cineraria*) > Bhui (*Aerva sp.*) > Phog (*Calligonum polygonoides*) > Chugh (*Crotalaria burhia*) > Aak (*Calotropis procera*) > Ganthia (*Dactyloctenium scindicum*) > *Prosopis juliflora.*

There was a positive association between the presence of fences and that of cultivation, human, livestock, dog, water-source and power-lines, indicating that fences could be a proxy for other disturbances. We found distinct associations between species and habitat. Plants such as *Leptadenia* and *Calligonum* occurred more in undulating and less disturbed areas. *Aerva* occurred more in sandy, less disturbed areas, whereas *Prosopis juliflora* and *Calotropis procera* occurred more in flat, disturbed areas. Faunal species such as Chinkara decreased in abundance with the proportion of area under cultivation while Nilgai showed an opposite trend. Desert Fox and Desert cat did not show any response to habitat gradients, whereas dogs were more abundant in flat, disturbed areas. Steppe Eagle, Egyptian Vulture and Laggar Falcon decreased in abundance along canal-irrigated areas. Birds such as Eurasian collared dove, Grey Francolin, Indian Robin and Indian Peafowl preferred flat terrain. Presence of disturbances favoured the Common Babbler, Eurasian Collared Dove, Grey Francolin, Red Vented Bulbul and Variable Wheatear, but negatively impacted the Ashy-crowned Sparrow Lark, Greater Short-toed Lark and Yellow-eyed Pigeon.

Questionnaires were conducted with 170 respondents in 61 villages spread over 24 cells. 1.7±1.0% of respondents reported seeing a Great Indian Bustard (*Ardeotis nigriceps)* around their villages in the past 5 years. The reporting frequency of dog, nilgai and fox was higher than that of chinkara, crane and wild pig. More people reported an increasing population trend for neo-colonised species (dogs, nilgai and wild pigs) than for native species (chinkara, fox or crane). On similar lines, more people reported that native biota (particularly chinkara and vultures followed by cranes and peafowls) have reduced in occurrence over the past few years. Habitat loss due to agricultural expansion and associated activities (fencing, pesticide usage, borewell irrigation etc.) was the most widely reported cause for wildlife decline; other causes being poaching, predation by dogs, climate change and powerlines. A high percentage of respondents (85±3%) were aware of a conservation area (managed either traditionally as *Orans* or by the Forest Department) around their village. 12±3 % of respondents complained regarding encroachment of *Orans* around their villages.

Our survey highlights that Bikaner region is undergoing rapid land-use changes due to intensive irrigated agriculture, infrastructure and industries. To understand their ecological impacts, regular assessments of wildlife populations through standard, reproducible methods become important. Based on this survey and consultation with Rajasthan Forest Department and local experts, the following preliminary recommendations are suggested:
a) greater conservation emphasis on sites such as Jorbeed Conservation Reserve, Deshnok *Oran*, Tokla *Oran*, Bhinjranwali and 750RD,

b) mitigation of potential threats such as power-lines, fences and free-ranging dogs,

c) protection of *Orans* from encroachment and development of grasslands for wildlife/livestock use,

d) development of sites such as RD750 and Lunkaransar lake for ecotourism through careful and consultative planning,

e) and replication of this survey for assessing wildlife trends.

Executive summary (Hindi)

बीकानेर जिला राजस्थान राज्य में स्थित थार मरुस्थल का एक भाग है जो विभिन्न प्रजातियों के वन्यजीवों का आश्रय स्थल है, परन्तु दुर्भाग्यवश इस क्षेत्र का वैज्ञानिक पद्धति से अब तक कोई वन्यजीव सर्वेक्षण नहीं किया गया था। इस क्षेत्र की जैव विविधता व वन्य जीवों की स्थिति एवं अनुमानित संख्या की जानकारी का आकलन अत्यंत महत्वपूर्ण हैं। विशेष रूप से बीकानेर जिले के महत्वपूर्ण क्षेत्र,जो बड़े पैमाने पर औद्योगिक एवं भूमि परिवर्तन के दबाव से गुजर रहे हैं, जो संभावित रूप से वहाँ पाए जाने वाले वन्यजीवों के लिए हानिकारक हैं। पश्चिमी राजस्थान के बीकानेर जिले में पाए जाने वाले प्रमुख वन्यजीवों की स्थिति का आकलन करने हेतु राजस्थान वन विभाग, राजकीय डूंगर महाविद्यालय और महाराजा गंगा सिंह विश्वविद्यालय के सहयोग से भारतीय वन्यजीव संस्थान द्वारा बड़े पैमाने पर सर्वेक्षण द्वारा किया गया। विशेष रूप से, इस सर्वेक्षण की योजना बीकानेर जिले के निवासियों के अनुरोध पर बनाई गई थी, वहाँ के निवासियों ने माननीय सांसद को वन्यजीव सर्वेक्षण करने की अपनी इच्छा से अवगत कराया। उन्होंने इस विषय को महत्त्व देते हुए पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय एवं भारतीय वन्यजीव संस्थान को आमंत्रित कर वन्यजीव सर्वेक्षण करने हेतु अनुरोध किया अतः परिणामस्वरूप, इस सर्वे को सिटीजन साइंस अर्थात सामान्य जन व वन्यजीव प्रेमियों के सहयोग से प्राप्त वैज्ञानिक जानकारी द्वारा आयोजित किया गया। यह सर्वेक्षण शोधकर्ताओं, छात्रों और वन्यजीवप्रेमियों की सक्रिय भागीदारी से किया गया। सर्वेक्षण का प्रमुख उद्देश्य वन्यजीवों और विशेष रूप से प्रवासी, शुष्क-अनुकूलित तथा शिकारी पक्षियों की प्रजातियों के वितरण और प्राचुर्यता का अनुमान लगाना था। इस सर्वे का एक उद्देश्य विभिन्न वन्य जीव प्रजातियों के प्राकृतिक आवास की व आवास संबंधित खतरों की जानकारी एवं वहाँ पर उपस्थित समुदाय की संरक्षण के प्रति धारणाओं पर अधिक से अधिक ज्ञान प्राप्त करना था।

इस सर्वेक्षण हेतु बीकानेर क्षेत्र को चार ब्लॉक (बीकानेर, कोलायत, छत्तरगढ़ व महाजन) में विभाजित किया गया और उन्हें पुनः 144 वर्ग किमी (12 X 12 किमी) के ग्रिड में बांटा गया। ऐसे कुल 89 ग्रिड्स (क्षेत्रफल 12,816 वर्ग किमी) का व्यापक सर्वेक्षण किया गया। यह सर्वेक्षण व्हीकल ट्रांसेक्ट पद्धति से किया गया, जिसमे वाहनों की गति निर्धारित (20-30 किमी/घण्टा) रखते हुए औसतन 16.2±4.1 किमी दूरी तय की गयी एवं सर्वेक्षण के दौरान दिखे गए जानवरों की जानकारी नोट की गई। सर्वेक्षण का समय इन जानवरों की गतिविधि के समय के अनुसार तय किया गया था (प्रातः 07:00-अपरान्ह 13:00 एवं अपरान्ह 16:00-सांयकाल 19:00)। इस सर्वे में, बीकानेर क्षेत्र में पाये जाने वाले महत्वपूर्ण वन्यजीव जैसे चिंकारा, गोडावण, कुर्जा और शिकारी पक्षियों के साथ-साथ अन्य जानवर जैसे कुत्ते, सूअर और नीलगाय के बारे में सूचना अर्जित की गई। अतः ट्रांसेक्ट में नियमित दूरी के अंतराल में छोटे पक्षी व उनके आवास व उपस्थित मानव निर्मित संरचनाओ की जानकारी नोट की गई। शिकारी पक्षियों के लिए महत्वपूर्ण व प्रसिद्ध स्थान जोरबीर एवं प्रवासी जलीय पक्षियों के लिए कुछ जरुरी झीले, जैसे RD750 (हनुमान नगर झील), RD507 (संसरदेसर तालाब), गजनेर व लूणकरणसर का सर्वेक्षण पॉइंट काउंट और लाइन ट्रांसेक्ट पद्धतियों से किया गया। डिस्टेंस सैंपलिंग एवं ब्लॉक काउंट जैसी विश्लेषणात्मक तकनीकों का उपयोग करके प्रजातियों की वितरण एवं आबादी का अनुमान लगाया गया। इस सर्वे में सांख्यिकी निष्पक्ष रूप से कुछ गांवों के कुछ घरों में संरचित प्रश्नावली का उपयोग करके संरक्षण के प्रति सामुदायिक धारणा का आकलन किया गया।

सर्वेक्षण के दौरान चिंकारा के 684 झुण्डो में कुल 1,880 चिंकारा देखे गए, और उनके देखे जाने की दर 139.78±18.72 प्रति 100 कि.मी. पाई गयी। सर्वेक्षित आवास में चिंकारा का अनुमानित घनत्व 4.27 ± 0.65 चिंकारा /km^2 है एवं चिंकारा की अनुमानित संख्या 54,745 ± 8,392 पाई गयी। उसी प्रकार से 112 मरुस्थली लोमड़ी देखी गए और उनकी अनुमानित घनत्व 0.58±0.11 लोमड़ी /km^2 पाई गयी तथा सर्वे क्षेत्र में इसकी कुल अनुमानित संख्या 7,456±1,356 है। अन्य जानवर जिनका सर्वेक्षण हुआ, उनमे मरुस्थली बिल्ली (0.57±0.2 बिल्ली/100 किमी), नीलगाय (14.39±2.91 नीलगाय / 100 किमी), घरेलु कुत्ते (26.07±3.6 कुत्ते / 100 किमी) एवं भेड़िये (सर्व मे एक ही भेड़िया देखा गया, अंतः इसके संख्या का अनुमान नहीं लगाया गया) शामिल है।

बड़े पक्षियों में, डेमोइसेल क्रेन का एनकाउंटर दर 5.47 ± 3.14 पक्षी / 100 किमी अनुमानित है। पांच सबसे आम शिकारी पक्षी की प्रजातियां (प्रति 100 किमी पर पक्षी), जैसे ग्रिफॉन गिद्ध (16.44 ± 6.94), इजिप्सियन गिद्ध (8.73 ± 2.35), कॉमन केस्ट्रेल (7.39 ± 0.88), ब्लैक विंग्ड काइट (5.35 ± 0.89) और लॉन्ग लेग्गड़ बजर्ड (5.13 ± 0.69) देखी गयी। छोटे पक्षियों में, 103 प्रजातियों के 2859 पक्षी को पॉइंट काउंट पद्धत्ति से दर्ज किया गया। सबसे प्रचुर प्रजातियां कॉमन बैबलर, यूरेशियन कोलर्ड कबूतर, हाउस स्पैरो, व्हाइट इयर्ड बुलबुल, रेड वेंटेड बुलबुल, ग्रेटर शॉर्ट टोड लार्क और वेरिएबल व्हीटियर है। दुर्लभ प्रजातियों के पक्षियों को छोड़कर छोटे पक्षियों का कुल घनत्व 997 ± 58 पक्षी प्रति वर्ग किमी अनुमानित है।

हॉटस्पॉट सर्वेक्षण के दौरान कुल 24,674 पक्षियों की गणना की गयी, जो कि 95 प्रजातियों, जो 36 कुल के अंतर्गत दर्ज किये गए। RD750 में सबसे अधिक पक्षी और प्रजातियां (76 प्रजातियों के 15,666 पक्षी) देखे गए, इसके बाद RD507 (34 प्रजातियों के 6,501 पक्षी), लुनकरणसर झील (25 प्रजातियों के 1,749 पक्षी) और गजनेर झील (38 प्रजातियों के 758 पक्षी) देखे गए थे। कॉमन कूट, डेमोइसेल क्रेन, कॉमन पोचार्ड, कॉमन टील और गडवाल सबसे अधिक संख्या में दर्ज किए गए। दो संकटग्रस्त (Endangered: इजिप्सियन गिद्ध और स्टेपी ईगल), दो असुरक्षित (Vulnerable: कॉमन पोचार्ड और रिवर टर्न), और छह संकट-निकट प्रजातियां (Near Threatened: ब्लैक हेडेड आइबिस, डालमेंसीएन पेलिकन, यूरेशियन कर्लेव, फेरुगिनस डक, नॉर्दर्न लैपविंग और पेंटेड स्टॉर्क) दर्ज की गई।

सर्वेक्षित क्षेत्र का तलरूप सामान्यतः समतल और मध्यम ऊबड़खाबड़ पाया गया, जिसमें कृषि क्षेत्र (परती और खेती) के बाद झाड़ीदार क्षेत्र का प्रभुत्व है। सर्वेक्षण किए गए भूखंडों के 72% में मानव या पशुधन की उपस्थिति दर्ज की गयी। मानव निर्मित संरचनाये जैसे तारबंदी, बिजली के तार, पक्की सड़क/राजमार्ग आदि की उपस्थिति 87% शोधित बिंदुओं पर देखी गई। वनस्पति के संदर्भ में, सबसे प्रमुख वनस्पति खींप (Leptadenia pyrotechnica) > खेजड़ी (Prosopis cineraria) > भुई (Aerva sp.) > फोग (Calligonum polygonoides) > चघ (Crotalaria burhia) > आक (Calotropis procera) > गांथिया (Dactyloctenium scandium) > विलायती बबूल (Prosopis juliflora) पाई गई।

तारबंदी की उपस्थिति और खेती, मानव, पशुधन, कुत्ते, जल-स्रोत और बिजली के तारों के उपस्थिति के बीच एक पारस्परिक संबंध संगणित किया गया, जो यह दर्शाता है कि तारबंदी की उपस्थिति अन्य भौतिक संकटों के लिए एक प्रतिनिधि कारक हो सकती है। हमने प्रजातियों और आवास के बीच अलग-अलग सहसम्बन्ध पाये। खींप और फोग जैसे पौधे ऊबड़खाबड़ और अबाधित क्षेत्रों में अधिक पाए गये। भुई रेतीले एवं अबाधित क्षेत्रों में अधिक होता है जबकि विलायती बबूल और आक समतल व बाधित क्षेत्रों में अधिक होता है। चिंकारा प्रजाति के लिए खेती क्षेत्र के अनुपात के साथ संख्या में कमी आयी जबकि नीलगाय की विपरीत प्रवृत्ति देखी गयी। कुत्ते समतल और गॉवों के आस पास अधिक देखे अधिक गये। स्टेपी ईगल, इजिप्सियन गिद्ध और लैगर फाल्कन नहर-सिंचित क्षेत्रों में कम पाए गये। यूरेशियन कोलर्ड डव, ग्रे फ्रेंकोलिन, इंडियन रॉबिन और इंडियन पीफॉउल जैसे पक्षी समतल भूभाग अधिक देखे गए हैं। मानव निर्मित संरचनाओ की उपस्थिति ने कॉमन बैबलर, यूरेशियन कोलर्ड डव, ग्रे फ्रेंकोलिन, रेड वेंटेड बुलबुल और वेरिएबल व्हीटियर को बढ़ावा दिया, लेकिन ऐशी क्राउंड स्पैरो लार्क, ग्रेटर शॉर्ट टोड लार्क और येलो आइड पिजन पर नकारात्मक प्रभाव डाला।

24 ग्रिड में फैले 61 गांवों में से 170 उत्तरदाताओं से कुछ प्रश्न किये गये। जिसमे से 1.7±1.0% उत्तरदाताओं ने पिछले 5 वर्षों में अपने गांवों के आसपास गोडावण देखने की सूचना दी। उत्तरदाताओं के अनुसार कुत्ते, नीलगाय और लोमड़ी की दिखने की आवृत्ति चिंकारा, सारस और जंगली सुअर की तुलना में अधिक पायी गयी। तुलनात्मक अधिक लोगो ने नव-उपनिवेशित प्रजातियों (कुत्तों, नीलगाय और जंगली सूअर) की जनसँख्या में बढ़ोतरी देशी प्रजातियों (चिंकारा, लोमड़ी या क्रेन) की तुलना में अधिक बतायी। इसी तरह, अधिक लोगों ने बताया कि पिछले कुछ वर्षों में चिंकारा और गिद्धों के बाद सारस और मोर के दिखने की दर में भी कमी आयी है। कृषि विस्तार और संबंधित गतिविधियों (तारबंदी, कीटनाशक का उपयोग, बोरवेल सिंचाई आदि) के कारण वन्यप्रजातियों के पर्यावास में हानि हुई है एवं इस कारण को वन्य जीवों की संख्या मे कमी का मुख्य बताया गया है। अन्य

कारणों में अवैध शिकार, कुत्तों द्वारा शिकार, जलवायु परिवर्तन और बिजली की तार दर्ज की गयी हैं। तुलनात्मक अधिक उत्तरदाता (85%) अपने गांव के आसपास एक संरक्षण क्षेत्र (पारंपरिक रूप से ओरान या वन विभाग द्वारा प्रबंधित) होने के बारे में अवगत थे। लगभग 12% उत्तरदाताओं ने अपने गांवों के आसपास के संरक्षण क्षेत्रों में अतिक्रमण होने के के बारे में शिकायत की।

इस सर्वे का मुख्य निष्कर्ष यह है कि बीकानेर क्षेत्र में निरंतर भूमि परिवर्तन हो रहा हैं जिसका प्रमुख कारण अत्याधिक सिंचित खेती एवं उद्योगों का विकास हैं, अतः इसका पर्यायवरण पर अत्याधिक प्रभाव पड़ रहा है। यह पारिस्थितिक प्रभाव देखने के लिए नियमित रूप से वन्य जीव गणना करना आवश्यक हैं । वन विभाग एवं स्थानीय विशेषज्ञ के परामर्श व इस सर्वे के आधार पर कुछ महत्वपूर्ण सुझाव दिए गये है, जो निम्न है -

1. जोरबीर संरक्षण रिजर्व, देशनोक ओरण, टोकला ओरण, भिंजरणवाली एवं 750RD जैसे बहुमूल्य छेत्रो में संरक्षक कार्यो को और भी अधिक प्रेरित किया जाना चाइये

जैसे क्षेत्रों पर अधिक संरक्षण की आवश्यकता हैं।

2. पॉवर-लाइनों, तार-बंदी (बाड़) और घरेलु कुत्तों जैसे वन्यजीवों के संभावित खतरों का समाधान खोजनाआवश्यक है।

3. ओरानों का अतिक्रमण से बचाव के लिए घास के मैदानों के विकास की आवश्यकता हैं जिससे वन्य जीवों/पशुधन के उपयोग के लिए चारा भी मिलता रहे।

4. 750 RD और लुनकरणसर झील जैसे स्थलों को इको-पर्यटन(पारिस्थितिक पर्यटन) के लिए सावधानीपूर्वक और परामर्शी योजना के माध्यम से विक्सित किया जाना चाहिए

आवश्यक है। 5. वन्यजीवों की संख्या में बदलाव और किसी भी तरह के खतरों की सालाना जानकारी के लिए इस प्रकार के सर्वे होते रहना चाहिए

INTRODUCTION

1. Introduction

Protected areas are the cornerstone of biodiversity conservation. However, they constitute only 6% of the earth's and 5% of India's geographical areas (Jenkins and Joppa 2009; Ghosh-Harihar et al., 2019). A much larger fraction of biodiversity occurs in unprotected multiple-use landscapes. Protected areas are pivotal to, but cannot displace the need of sustaining ecological functions and flow in the larger landscapes around them. Hence, it is important to also focus on landscapes while developing conservation plans and factoring them into developmental goals (Sayer et al., 2013). This is particularly important for India, given the expansion of its large rural population and developing economy into remote wildlife habitats vis-à-vis its general cultural tolerance towards wildlife and low intensity of land uses – factors that are compatible for species' persistence (Rangarajan, 2005). Fundamental to such planning is the spatial information on biodiversity status – abundance, distribution and habitat relationships of representative species and potential threats. Conservation planning in the Bikaner region of the Thar desert will benefit from such systematically collected information on its biodiversity status.

Birds and large mammals elicit strong admiration and innate connection in the human psyche, thereby being the common focus of ecological assessments and conservation programs. The Indian subcontinent hosts a wide spectrum of birds, including many winter migratory species. About 280 long-distance migrants spend their winter in India's rich and warm tropical habitats that lie immediately south of their Palearctic breeding ranges (SOIB 2020). The country lies along three major bird migratory flyways: Central Asian Flyway (CAF), East Asian Australasian Flyway over parts of eastern India (EAAF), and Asian East African Flyway (EAF). India is a signatory to the Convention of Migratory Species, which prescribes science based conservation measures to ensure the survival of migratory species as well as their habitats to provide sustainable benefits to people. Scientific datasets show that CAF migratory terrestrial birds are declining rapidly and species that breed in grasslands and agricultural areas, including those wintering in the Thar desert, are highly affected by land-use changes (Dasgupta et al., 2017, Kher & Dutta, 2021). Similar to birds, the Indian subcontinent is home to a wide variety of mammalian diversity. The Thar desert is also unique in this regard and hosts many species that are not common elsewhere in the country. However, contemporary landscape level changes like the introduction of the Indira Gandhi Canal and the subsequent expansion of settlements and agriculture have *prima facie* caused a dramatic change in the mammal assemblage of the Thar Desert (Prakash, 1997; Islam & Rahmani, 2011; Dookia et al., 2009). Chinkara, a highly revered antelope in Rajasthan, is speculated to have suffered large scale declines owing to the increased human footprint in the desert over the last few decades (Dookia et al., 2009). On the contrary, other species such as the Nilgai and Wild pig seem to have benefited from the irrigation-driven changes (Dutta et al., 2018). However, these observations are backed by scanty evidence; and require landscape level surveys for greater support.

1.1 Bikaner district from a wildlife context

The Thar desert presents an abruptly changing environment for wildlife from antiquity to Anthropocene. This arid, sandy tract forms the eastern limit of the vast Saharo-Iranian desert and blends into wetter, semiarid conditions to the east. Rainfall is sparse at ~200 mm per year, 90% of which is received during monsoon (June – September), and is intercepted by moderate to severe droughts once in three years (Rao and Roy 2012). However, its paleoclimate was more semiarid and wetter from 2 million years up to 0.25 million years before the present (Dhir et al. 2018). Since then, the climate dried up, characterised by weaker monsoons, extensive sand deposition, and the current arid conditions set in at 4000 years before present. Sediment core analysis of Lunkaransar and other salt lakes indicates such paleoclimatic patterns (Enzel et al. 1999). These changes presumably conferred an advantage to the xeric species over their mesic counterparts. Aridification also restricted human occupation. While organised human societies harnessed the potential of agriculture and livestock in the Indus plains to the west and the east of the Aravalli mountains, the intervening region of Thar remained thinly populated with nomadic hunter-gatherers throughout early human history (Misra 2001, Madella and Fuller 2006, Dhir et al. 2018). Settlements and agriculture expanded into Thar relatively recently, perhaps around 1000 years back. Even then, livelihoods depended on pastoralism; cultivated area was only 15%, and the human population was small, stable and numbered ~6 lakhs in Bikaner in the first half of the 20th century (Dhir et al. 2018). In contrast, the human population exploded by ten folds in the last 60 years, with a recent decadal growth rate of 20-30% (Census data). Perhaps the single major change in regional ecology was brought by the Indira Gandhi Canal, which created an agriculturally intensive corridor in the 1980s. Irrigation and mechanised farming facilitated a four-fold increase of cultivated area in Bikaner during the last 50 years, with crop cover increasing from 15% (1960) to 54% (2011) (Dhir et al. 2018). Much of agricultural expansion came at the cost of erstwhile culturable wastelands or areas owned by the Government that was grazed by livestock, and fallow lands or areas not farmed in current year(s). Consequently, Thar desert, with 70% of its area under cultivation, has become the most intensively farmed arid region, posing novel challenges for its wildlife and ecological sustainability. These land-use changes have exposed the native wildlife, which remained isolated from humans historically, to a sudden and intense wave of anthropogenic pressures. Only *gauchars* or common village grazing lands, *orans* (sacred groves) or lands spared by local communities for wildlife and grazing, cumulatively known as permanent pastures, and forest department lands remain as a refuge for native wildlife. More lately, the region has experienced infrastructural developments in the form of industrial growth, rural electrification and expansion of the road network, adding to the anthropogenic pressures. Increased surface water and plantations lining the canal have facilitated mesic species to (re)establish in the region (Rahmani and Soni, 1997). Thus, ecoclimatic trajectories spanning thousands of years are at risk of being reversed within a few decades, the implications of which are yet to be discerned.

1.2 Objectives

For conservation of migratory birds in India, the National Action Plan proposes measures such as: a) assessing status and distribution of migratory birds in wetlands and terrestrial habitats, b) evaluation of threats and site-specific recommendations to mitigate them, c) involving local communities in conservation activities including citizen science groups, and d) sustainable management of habitats through capacity building and outreach. Similarly, India's National wildlife action plan recommends assessing and evaluating wildlife outside PAs for objective management and targeted species recovery. To further this initiative and develop conservation plans for local wildlife, the Hon'ble Member of Parliament (Bikaner), who is also the Minister of State for Parliamentary Affairs and Culture - GoI, invited the Wildlife Institute of India (WII) through the Ministry of Environment, Forest and Climate Change (MoEFCC) to conduct a status survey on migratory birds and other key wildlife in Bikaner. The WII, in collaboration with Forest Department, local universities, wildlife enthusiasts and citizens, carried out a large-scale wildlife status assessment in the Bikaner district. The focus of this exercise were birds, especially migratory, arid-adapted and raptorial species, and large terrestrial mammals.

Set in this background, the wildlife assessment of Bikaner aims at generating current baselines on key wildlife, their habitats, threats and community perceptions towards conservation so that this information can flow into conservation plans.

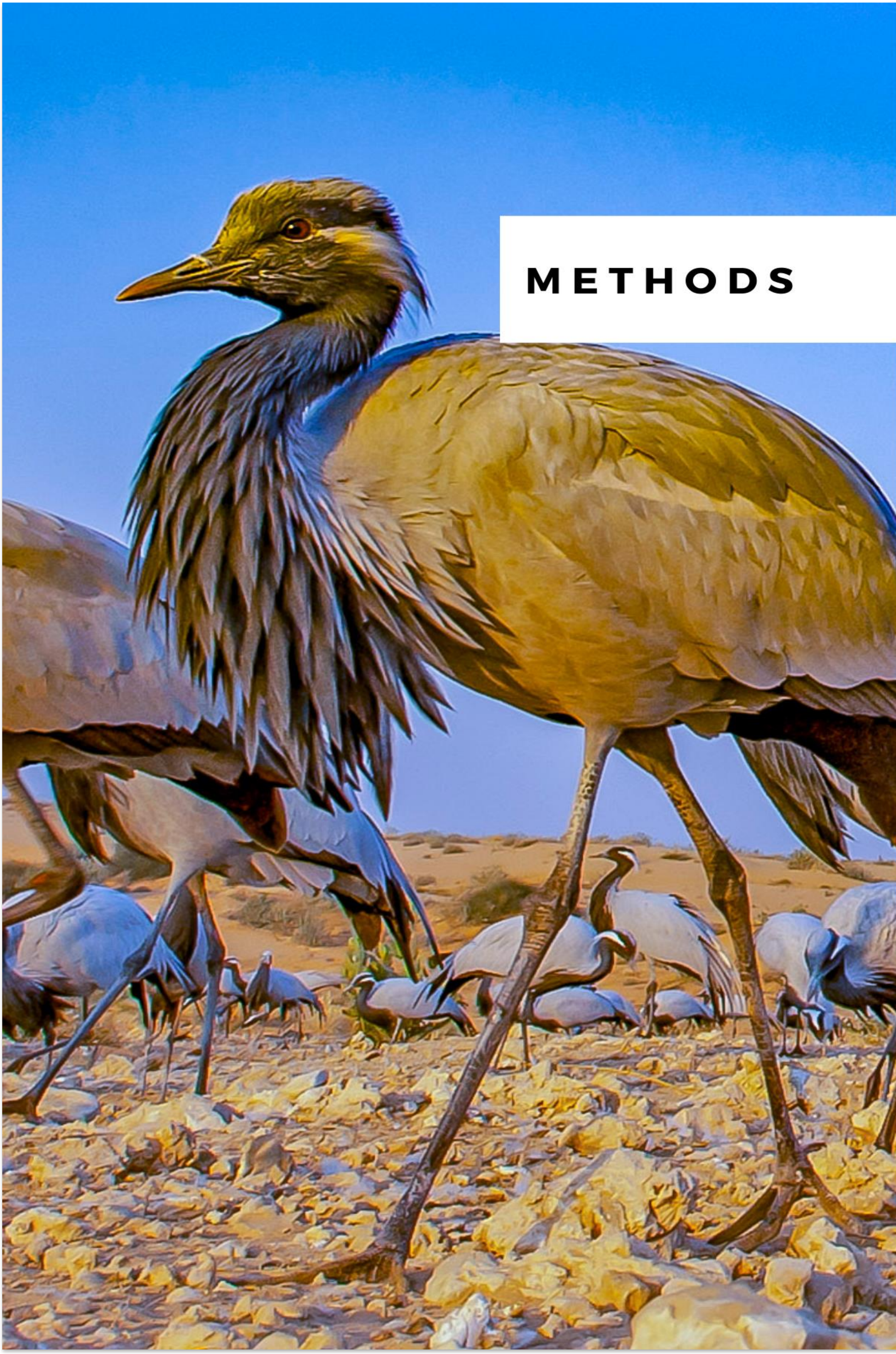
Specifically, we:

1) estimate the occupancy and (relative) abundance of birds, especially migratory, arid-adapted and raptorial species, and that of key mammals representing xeric and mesic adaptations in the general landscape

2) estimate the abundance of the above taxa in select conservation hotspots

3) assess habitat status, potential threats to wildlife, and species-habitat relationships, and

4) assess community perceptions towards wildlife conservation



METHODS

2. Methods

2.1 Organization of survey

The parliamentary constituency of Bikaner was divided into four sampling blocks which were simultaneously surveyed by 10 teams during February 16-28, 2021. This helped us cover a large area within a short period, thus minimising the influence of bird/animal movements on population parameter estimation. The sampling blocks were headquartered at: a) Bikaner, b) Chattargarh, c) Kolayat, and d) Mahajan; and consisted of about 25 grids/cells of 144 km^2 each. Each team consisted of a Wildlife Institute of India researcher, a local volunteer, an experienced birder and Forest Department guard adept with the locality, and one rugged-terrain vehicle with a driver. Field activities in a sampling block were supervised by a research biologist from the Wildlife Institute of India with several years of field experience in conducting wildlife surveys. Team members were trained to follow a standardised data collection protocol through a workshop and rigorous field exercise prior to surveys.

2.2 Sampling design

Our extensive surveys covered 89 cells (12,816 km^2 area) through a transect effort of 1,442 km. These cells were surveyed using a vehicle transect approach. Data generated from this survey provided estimates of species' occupancy, density and abundance. We parallelly collected data on habitat and disturbance at 802 points on the vehicle transect to estimate the effects of natural and anthropogenic factors on animal populations. Additionally, some sites of exceptional biodiversity value were surveyed using an alternate Hotspot survey method.

2.2.1 Vehicle transects

Dirt trails in survey cells were digitised using Google Earth imagery. Cells were surveyed along dirt trails of $16.2 \pm 4.1_{SD}$ km average length (single continuous or two broken transects) from a slow moving (10-20 km/hr) vehicle. Surveys were conducted from morning to noon (0700-1300) and in late afternoon (1600-1900) when bird/animal activity was highest. This sampling scheme was chosen to optimise the combination of cell size, transect length and efforts required to cover ~20% of the cell area (assuming that species would be effectively detected within ~250 m strips, following Dutta 2012). Data collection on vehicle transects has been described below (section 2.3).

2.2.2 Wetland hotspot surveys

Some birds congregate in large numbers at special habitats, such as migratory waterfowl at water bodies and scavenging birds at carcass dumping sites. We selected bird 'hotspots' based on historical literature and eBird records (Interim report, 2020). Since vehicle transects are not feasible to survey these hotspots, we used an alternative approach. At wetlands (750RD/Hanuman Nagar Jheel, 507RD/Sansardesar Lake/Ghegda Jheel, Gajner and Lunkaransar lake), surveys were conducted using simultaneous block count method. Each wetland was divided into 'sectors' that were surveyed from an 'observation point'. A team of surveyors spent a minimum of 10 minutes at an observation point and counted all individuals of each species within the assigned sector. Sectors were surveyed simultaneously to avoid duplication in count at large water bodies. Birds flying/crossing over the sector were not considered. To avoid observer bias, counts were averaged from three independent observations of the number of birds.

2.2.3 Community surveys

Questionnaires for conservation perception of local communities were conducted in 30% of surveyed cells. In these cells, we visited 2-3 villages, and up to three residents per village were opportunistically interviewed (questionnaires in Appendix 1). We collected information on the occurrence of the Great Indian bustard (within the last five years) and associated species (Chinkara, Fox, Nilgai and Crane) from village areas, species with increasing and decreasing population trends, perceived threats to wildlife, and perception on local conservation management.

2.3 Data Collection on vehicle transects

2.3.1 Species' information (key wildlife)

Data on key desert wildlife such as Desert fox, Indian fox, Chinkara, Nilgai, Cranes and raptors, and biotic disturbance (free-ranging dogs) were collected during the vehicle transect survey (data sheet in Appendix 2). For each sighting, the number of individuals, GPS coordinates, distance (using laser rangefinder) and angle (using a compass) were recorded.

2.3.2 Habitat information

Habitat features that could potentially influence species' distribution, such as land-cover, terrain, substrate, vegetation structure, and disturbances were recorded at every 2 km interval along the transect (see data sheet in Appendix 3). The dominant land-cover (barren/ agriculture/ grassland/ shrubland/ woodland), terrain (flat/ sloping/ undulating), and substrate depending on soil characteristics (rock/ gravel/ sand/ soil) were recorded within a 100 m radius of the point. Vegetation structure was recorded as the percentage of ground covered by short grass and herb (<30 cm, >30 cm), shrub (<2 m), tree (>2 m) and crop within 20 m radius of the point. These covariates were recorded in broad class-intervals (0, 1-10, 10-20, 20- 40, 40-60 and 60-100 %) to reduce inconsistency of observation errors between teams. Vegetation composition was recorded as three dominant plant taxa within a 100 m radius of the point. The presence of anthropogenic factors (human/ dog/ livestock/ machinery) was recorded within a 200 m radius of the point. Presence of infrastructure (settlement/ farm-hut/ metal road/ power-line/ wind-turbine/ water-source/ solar-power-plant/ industrial-use/ fence) was recorded within 500 m radius of the point. The presence of the spiny-tailed lizard, based on detection of burrows within a 10 m radius of the point, was also recorded.

2.3.3 Point counts (Birds)

To collect data on general avifauna, we performed a point count of 10 minutes after every 2 km on transects and recorded the number of birds within 200 m of the observation point (Appendix 4). These point counts were conducted in parallel with the habitat surveys and at the same location. For each bird recorded within the 200 m radius, the species' identification and distance from the point were noted. Birds detected using auditory cues were considered, but those flying over the point were not recorded.

2.4 Analytical methods

2.4.1 Habitat assessment

We mapped the proportional occurrence of land-cover, terrain, substrate, active and passive disturbances in sampling plots grouped within 144 km^2 cells and estimated their mean and SE prevalence across cells to describe the current habitat status at the landscape scale. We examined the spatial association between habitat variables using Pearson's correlation analysis. To identify meaningful habitat patterns and reduce data dimensions, we extracted a few latent factors from the proportional occurrence of land-cover, terrain, substrate, active and passive disturbances in sampling plots at 144 km^2 cells, using factor analysis. We mapped these factors to describe prominent habitat gradients across the landscape.

2.4.2 Vegetation assemblage

We estimated the frequency of occurrence of plant species in sampling plots to describe the current status of vegetation and identify dominant species. We attempted to delineate vegetation assemblages from species' co-occurrences (McCune and Grace 2002) but did not find any strong structuring of the vegetation community. Subsequently, we mapped the frequency of occurrence of dominant plants in sampling plots grouped within 144 km^2 cells and modelled them on habitat factors using binomial Generalised Linear Models in Information Theoretic framework to understand plant-habitat associations.

2.4.3 Population status of key taxa

2.4.3.1 Density of Chinkara and Fox using line transect distance sampling

We used Distance sampling (Buckland et al. 2015) based approach to estimate the density of the two common mammal species in the region, viz. Chinkara and Desert Fox. In this framework, detectability is modelled as a function of perpendicular distance from the line. We calculated perpendicular distance from the sighting distance and angle of sightings. We fitted half-normal, uniform and hazard-rate models with appropriate key adjustments after checking the data for evasive movement and peaking at intermediate distances. The least AIC model was used for inference. Goodness of fit for the selected model was assessed using Chi-square and *Cramer-von mises* test score. Encounter rate data collected during vehicle transects was corrected using the detection function to obtain density estimates.

Density estimates were then multiplied with the surveyed area to obtain the conservative abundance estimates for the Bikaner district. We did not project our density estimates beyond our sampled area, and thus our estimates represent the 'minimum population size' for the species in Bikaner district. However, the sampled area covered the majority of the distribution of the species within Bikaner district.

2.4.3.2 Density estimation of small birds using point count distance sampling

We used point count based distance sampling to estimate the density of small birds. We used complete bird lists and species with >5 sightings for this analysis. We modelled species' detection probability as a function of distance from the sampling point. Since detectability will also depend on species' traits, we grouped species into 'low', 'medium' and 'high' detectability categories by classifying the distribution of median detection distances into three roughly equal percentile bins. We fitted half-normal, uniform and hazard-rate models with appropriate key adjustments to the frequency of sightings in increasing distance classes, separately for the three detectability groups. The least AIC model was used for inference. We estimated species' encounter rates as flocks detected per plot, nested within cells, using linear mixed effect intercept only models to accommodate the hierarchical data structure, and mean flock size for each species. Thereafter, we estimated species' densities from their encounter rate, flock size, and detectability and generated bootstrap SEs by sampling from normal distributions of the above parameters.

2.4.3.3 Encounter rate of large birds on line transects

We estimated the encounter rate of large bird species (raptors and cranes) as the means and standard error of individuals detected / km along transects grouped into cells.

2.4.3.4 Bird species richness estimation

Species were first classified into five different groups based on their habitat preferences: a) Grassland and desert specialists, b) Habitat generalists, c) Woodland and Forests, d) Synanthropic, and e) Wetland. In each cell, the total observed number of species belonging to each group was calculated and mapped.

2.4.4 Species habitat relationships

We examined species-habitat relationships using generalised linear models (hereafter, GLM) in the Information Theoretic framework to inform conservation management.

For small birds, we modelled species' distribution (proportion of point-counts in a cell occupied by the species) and relative abundance (logarithm of mean number of individuals detected per point in a cell + 1) on habitat factors and canal length, using binomial and gaussian GLMs, respectively. We drew inferences on habitat responses for each species using untransformed parameter estimates (slopes) of predictors from the full models.

For large birds and mammals, we modelled relative abundance (logarithm of mean number of individuals detected km^{-1} + 1) in a cell on habitat factors using gaussian GLM and inferred habitat responses for each species using model-averaged untransformed parameter estimates (slopes) of predictors.


Pc: sherwin

RESULT

3. Results

3.1 Efforts

We surveyed 89 cells covering 12,816 $km^{2,}$ with 54 observers recording data on 1,442 km vehicle transect and 802 habitat samples and point counts (Figure 1).

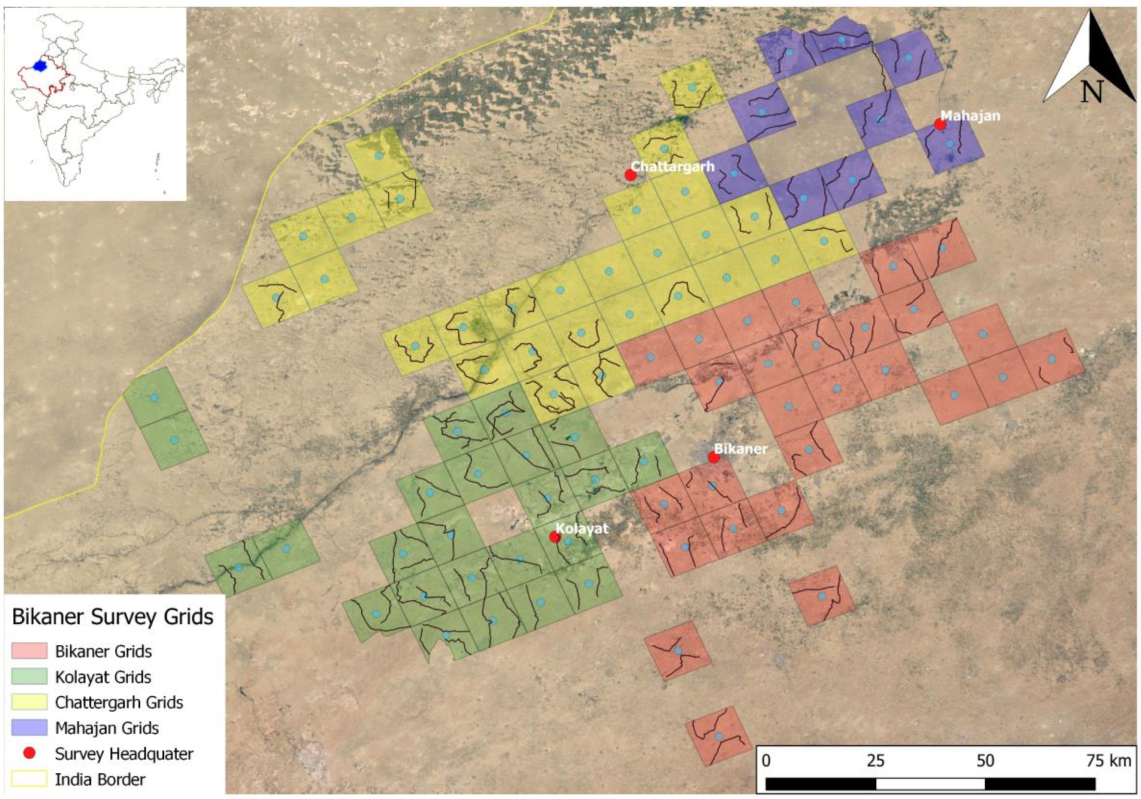


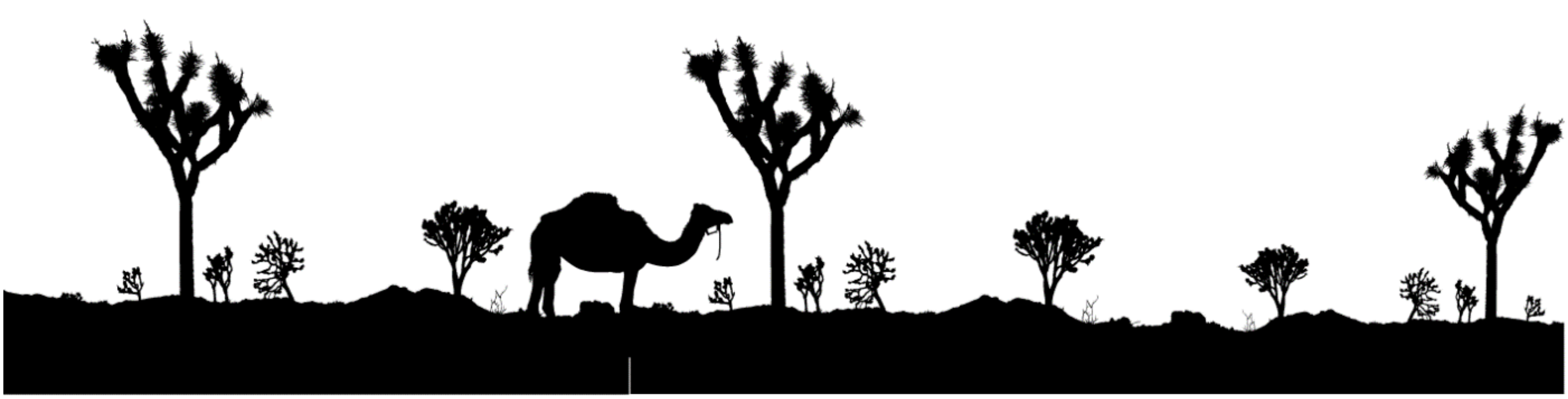
Figure 1. Map of sampled grids (n = 89) divided into subdivisions with trials and point counts displayed.

3.2 Habitat and disturbances

The landscape was characterised by: a) flat followed by undulating terrain (Figure 3); b) soil followed by sand substrate; c) scrubland followed by fallow and cultivated land-cover (figure 2); d) some form of active disturbance (most commonly human and livestock presence) in 72% of plots (Figure 4); and e) some form of passive disturbance (most commonly agricultural fence and power-lines) in 87% of plots (Table 1).

Table 1: Descriptive statistics of habitat variables in Bikaner landscape (2021), measured as the mean and standard error (SE) prevalence of variables within 144 km^2 cells

Feature	**Variable**	**Mean (SE)**
Land-cover	Scrubland	0.6 (0.03)
	Fallow	0.35 (0.03)
	Cultivated	0.17 (0.02)
	Grassland	0.15 (0.02)
Substrate	Soil	0.8 (0.02)
	Sand	0.4 (0.03)
	Gravel	0.01 (0.01)
Terrain	Flat	0.55 (0.03)
	Undulating	0.3 (0.01)
Active disturbance	Human	0.6 (0.03)
	Livestock	0.51 (0.03)
	Dog	0.2 (0.02)
	Machinery	0.12 (0.02)
	No active disturbance	0.28 (0.02)
Infrastructure (Passive disturbance)	Power-line	0.52 (0.03)
	Road	0.23 (0.03)
	Settlement	0.19 (0.02)
	Industrial-uses	0.01 (0)
	Farm hut	0.09 (0.02)
	Fence	0.6 (0.03)
	Water-source	0.48 (0.03)
	No infrastructure	0.13 (0.02)



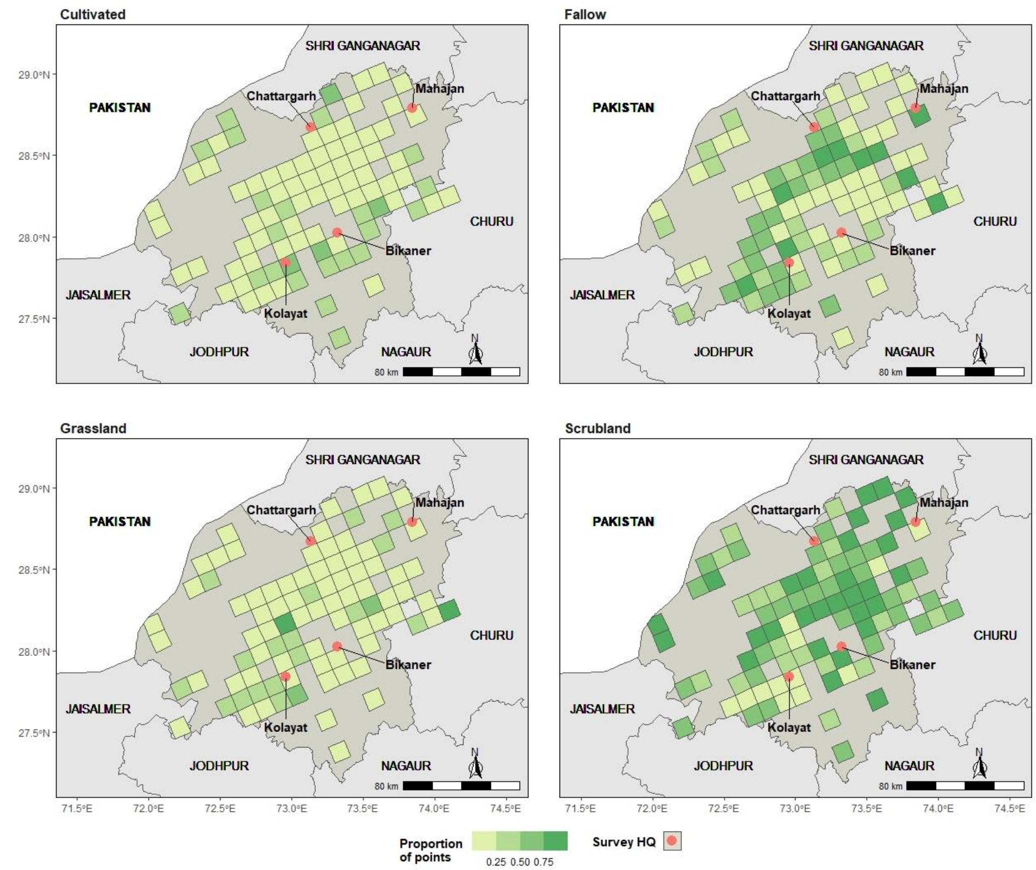


Figure 2. Spatial patterns of land-cover types in Bikaner landscape (2021) measured as the proportion of sampling points having a particular land-cover type within 100 m radius

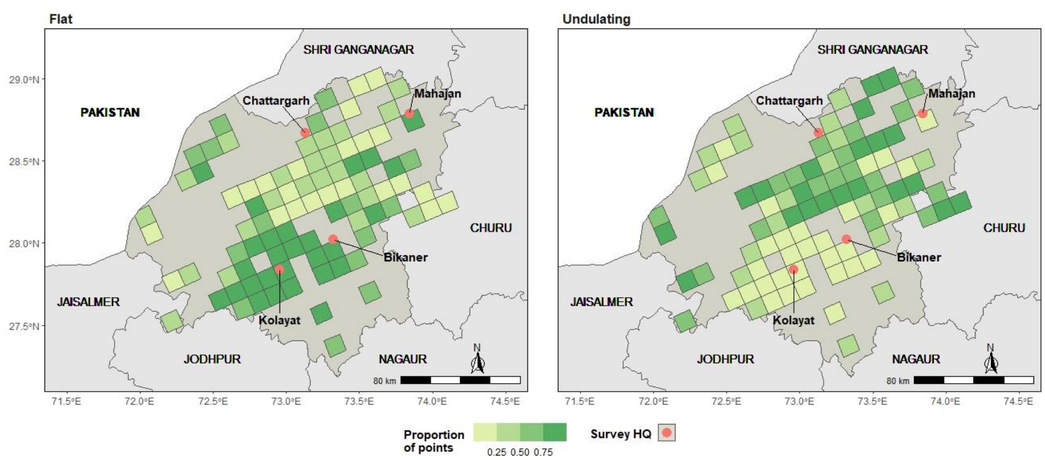


Figure 3. Spatial patterns of terrain in Bikaner landscape (2021) measured as the proportion of sampling points in 144 km^2 cells having a particular terrain type within 100 m radius

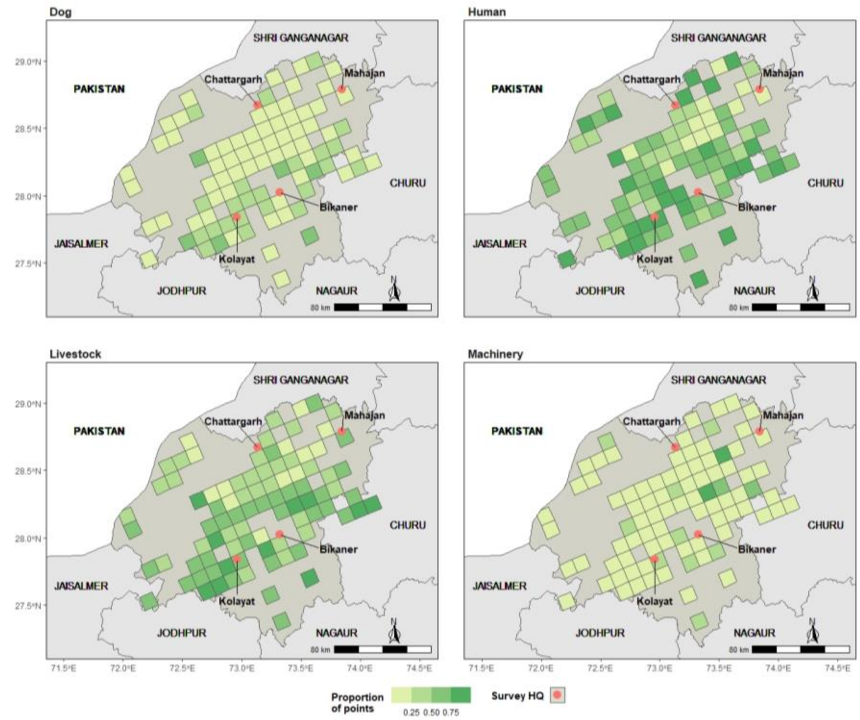


Figure 4. Spatial patterns of active disturbances in Bikaner landscape (2021) measured as the proportion of sampling points in 144 km^2 cells having a particular disturbance within 200 m radius

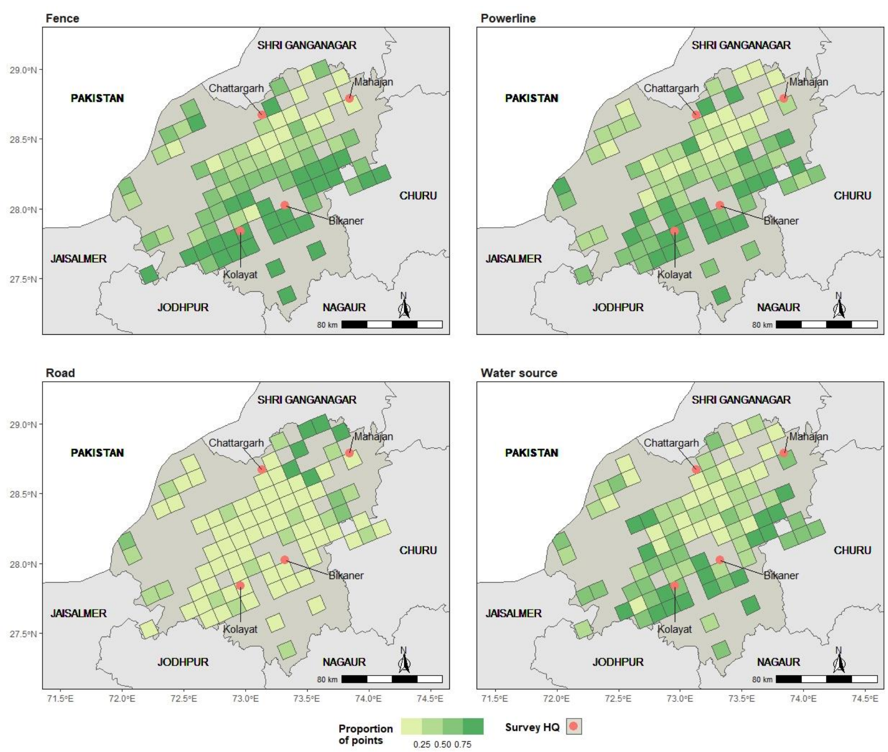


Figure 5. Spatial patterns of passive disturbances in Bikaner landscape (2021) measured as the proportion of sampling points in 144 km^2 cells having a particular infrastructure within 500 m radius

We found two major spatial associations among habitat variables: (1) sandy substrate was positively associated with undulating terrain but negatively associated with flat terrain and soil substrate, (2) presence of agricultural fence was positively associated with cultivation, human, livestock, dog, water-source and power-line presence. Thus, agricultural fences can serve as a single surrogate for disturbances in this landscape (Table 2).

We extracted four latent factors that explained 69% variance in land cover, terrain, substrate, cumulative active and passive disturbances. The first factor represented a gradient of undulating to flat terrain; the second factor represented a gradient of sand to soil substrate; the third factor represented disturbances, and the fourth factor represented the proportion of area cultivated (Table 3). We explored the spatial patterns of these factors (Figure 6) and used them to examine species-habitat relationships.

Table 2. Spatial association of habitat variables characterising land-cover, substrate, terrain, active and passive disturbances in Bikaner (2021), as indicated by strong correlation values (|r| > 0.5)

	HU	LI	MA	DO	SE	IU	PL	RO	FE	WS	FH	FL	SL	UN	SO	SA	GR	GS	CU	FA	SC
Human (HU)									0.6	0.5											
Livestock (LI)									0.54												
Machinery (MA)																					
Dog (DO)									0.53	0.56											
Settlement (SE)																					
Industrial-uses (IU)																					
Power-line (PL)																					
Road (RO)																					
Fence (FE)							0.63			0.63									0.58		
Water-source (WS)							0.58														
Farm-hut (FH)																					
Flat (FL)														-0.9		-0.67					
Sloping (SL)																					
Undulating (UN)																0.61					
Soil (SO)																-0.7					
Sand (SA)																					
Gravel (GR)																					
Grassland (GS)																					
Cultivation (CU)																					
Fallow (FA)																					
Scrubland (SC)																					

Table 3. Interpretation, variance explained and variable loadings of habitat factors extracted from land-cover, terrain, substrate and disturbance data using factor analysis in Bikaner landscape (2021)

Habitat variable	Factor 1	Factor 2	Factor 3	Factor 4
Flat	0.89			
Undulating	-0.92			
Soil		0.96		
Sand		-0.61		
Grassland				
Scrubland				
Cultivation				0.9
Passive disturbances			0.85	
Active disturbances			0.7	
Variance explained	**0.26**	**0.16**	**0.16**	**0.11**

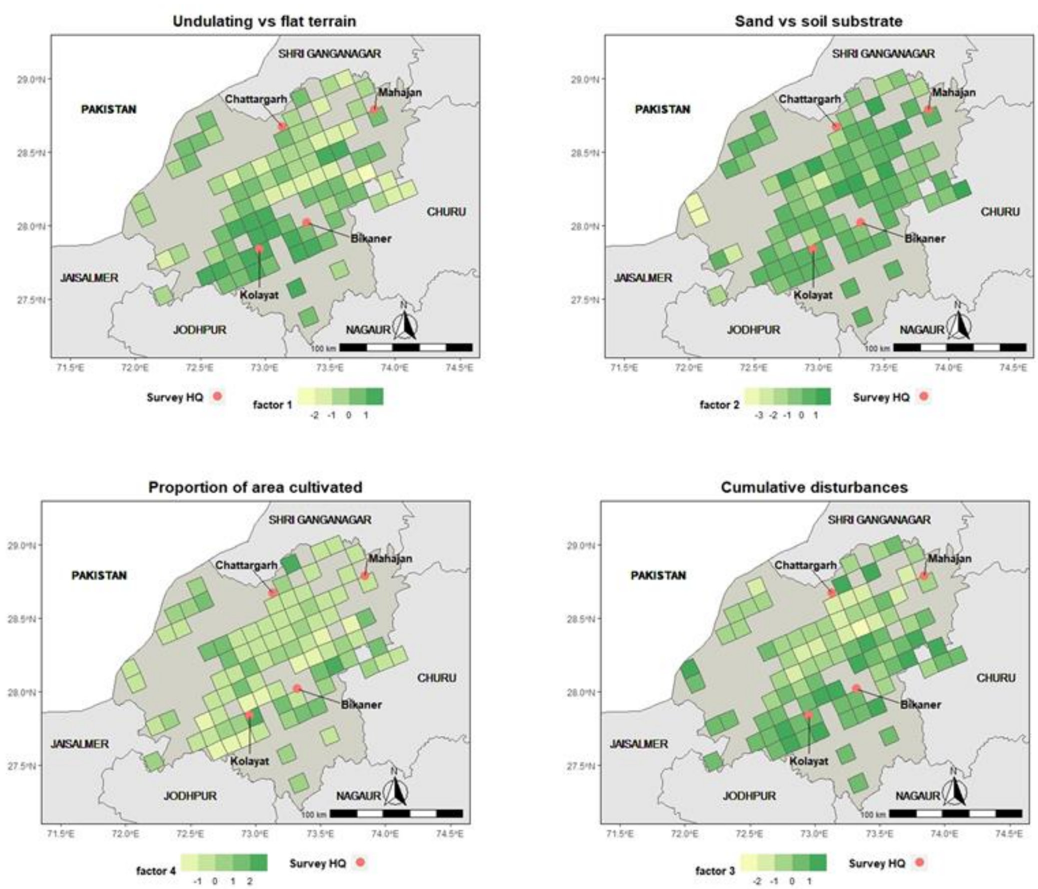


Figure 6. Spatial patterns of habitat factors in Bikaner landscape (2021); (clockwise) factor 1: undulating (yellow) to flat (green) terrain, factor 2: sand (yellow) to soil (green) substrate, factor 3: low (yellow) to high (green) disturbances, and factor 4: low (yellow) to high (green) proportion of area cultivated

3.3 Floristic composition

The natural vegetation of Bikaner was characterised by a few dominant plants such as *Leptadenia pyrotechnica* > *Prosopis cineraria* > *Aerva sp.* > *Calligonum polygonoides* > *Crotalaria burhia* > *Calotropis procera* > *Dactyloctenium scindicum* > *Prosopis juliflora* (occurring in >10% of sampling plots), with another 11 species occurring in <2 % of sampling plots (Figure 7).

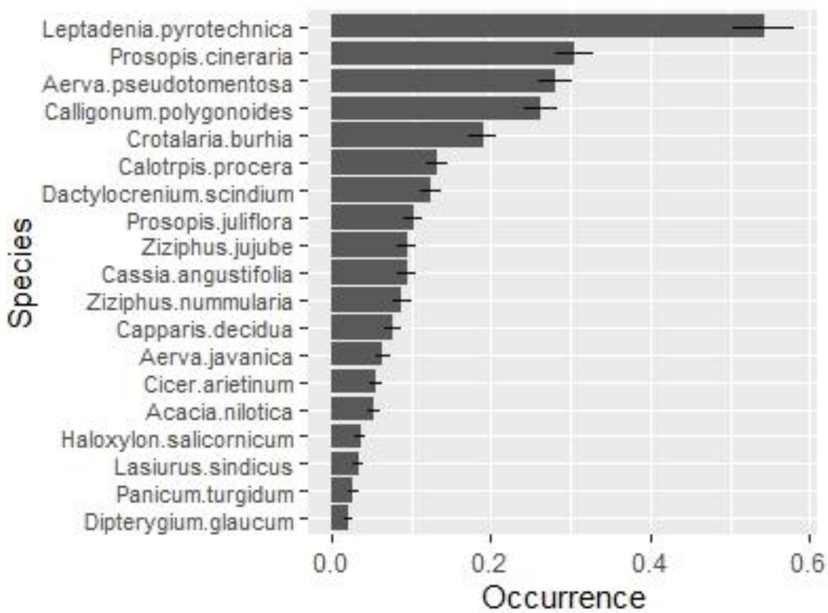


Figure 7. Mean & SE occurrence in sampling plots of plant species in Bikaner landscape (2021)

Dominant plants showed contrasting responses to habitat characteristics and distinct spatial extents of occurrence. *Leptadenia* occurrence was greater in undulating, less disturbed and less cultivated areas distributed across the landscape. *Prosopis cineraria* occurred more in disturbed and cultivated areas located to the south and east. *Aerva* occurrence was greater in sandy, less disturbed areas, in the north and west. *Calligonum* occurred more in undulating, sandy, less disturbed areas located in the north and west. *Crotalaria* and *Dactyloctenium* were associated with less cultivated areas. Whereas the invasive *Prosopis juliflora* and *Calotropis procera* occurrences were greater in flat, more disturbed areas (Table 4 and Figure 8).

Table 4. Plant-habitat relationships in Bikaner landscape (2021): distribution of dominant species (measured as proportion of habitat-plots with the species in a cell) was analysed against habitat factors using binomial generalised linear models and the untransformed mean (SE) parameter estimates for significant effects ($p < 0.1$) are reported. Positive values indicate that the species' occurrence increases with the covariate value and the converse.

Dominant plants	**Factor1**	**Factor2**	**Factor3**	**Factor4**
	Flat (+) vs undulating (-)	Soil (+) vs sand (-)	Disturbances (+)	Cultivation (+)
Leptadenia pyrotechnica	-0.57 (0.08)		-0.35 (0.08)	-0.19 (0.08)
Prosopis cineraria		0.28 (0.08)	0.27 (0.09)	0.23 (0.08)
Aerva sp.		-0.36 (0.08)	-0.42 (0.09)	
Calligonum polygonoides	-0.82 (0.1)	-0.23 (0.08)	-0.46 (0.1)	
Crotalaria burhia		-0.21 (0.08)		-0.3 (0.1)
Dactyloctenium scindium		0.24 (0.12)		-0.8 (0.16)
Calotropis procera	0.52 (0.12)		0.21 (0.12)	
Prosopis juliflora	1.16 (0.19)		0.8 (0.17)	

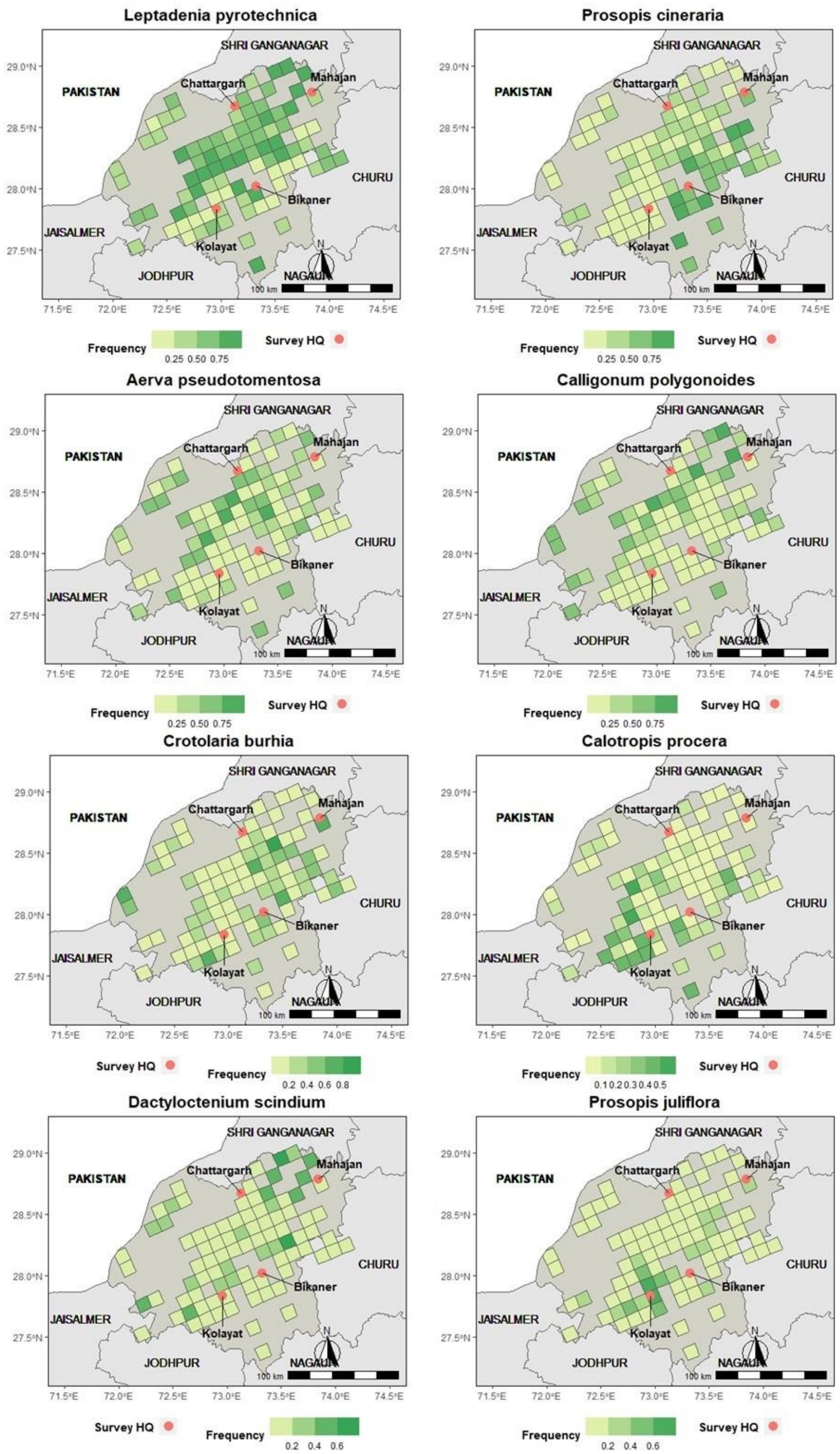


Figure 8. Distribution patterns of plant species represented as low (yellow) to high (green) frequency occurrence in sampling plots in the Bikaner landscape (2021)

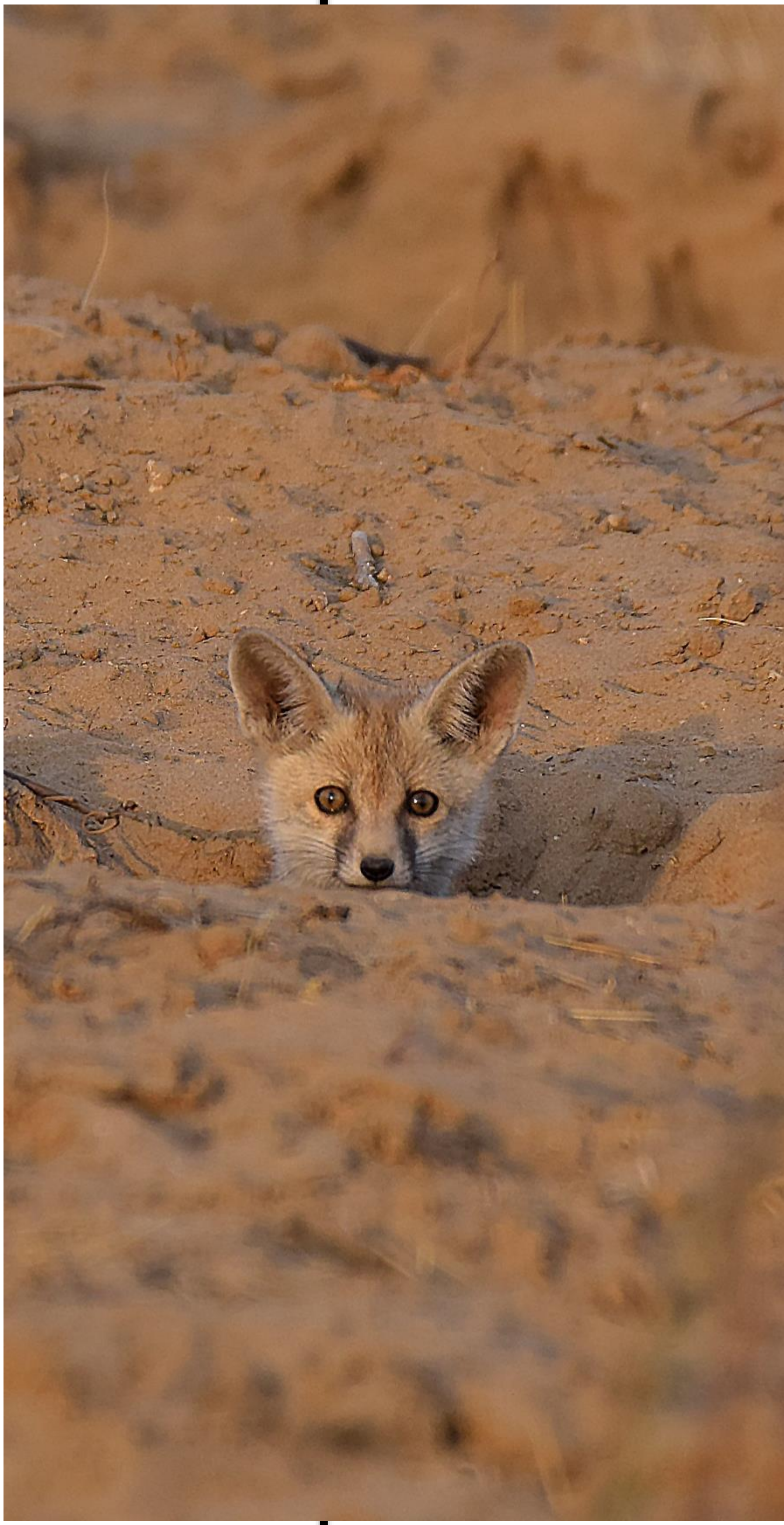
3.4 Wildlife population status

3.4.1 Mammals

Data generated from line transect surveys provided estimates of species' occupancy, density and abundance. Data on habitat and disturbance informed us of their effects on animal populations.

3.4.1.1 Chinkara

Our extensive surveys resulted in the detection of 1,880 Chinkara individuals belonging to 684 herds. The encounter rate of Chinkara herds and individuals was 60.39 ± 6.49 per 100 km and 139.78 ± 18.72 per 100 km, respectively. Distance data of these observations was best explained by a half-normal key function with cosine(2) adjustments ($X2 = 0.05$, $p = 0.82$) . The estimated herd effective strip width was 136.43 ± 7.28 m for a truncation distance of 330 m. The estimated Chinkara density was 4.27 ± 0.65 animals/km^2 with an average group size of 2.75 ± 0.18. This yields a landscape level abundance of 54,745 ± 8,392 individuals.



3.4.1.2 Desert fox

We detected 122 Desert fox individuals during our survey, with an encounter rate of 9.16 ± 1.34 per 100 km. These observations were best explained by a half-normal key function detection model with cosine(2) adjustments ($X2 = 0.02$, $p = 0.88$). The estimated effective strip width was 62.16 ± 6.4 m for a truncation distance of 200 m. The estimated Desert fox density was 0.58 ± 0.11 individuals per km^2 and the average group size was 1.12 ± 0.06. This yields a landscape-level abundance of 7,456 ± 1356 individuals.

3.4.1.3 Other species

Other notable mammals in the Bikaner landscape were the Desert cat (*Felis lybica ornata)*, estimated to be 0.57 + 0.2 individuals per 100 km, Nilgai (*Boselaphus tragocamelus)*, estimated to be 14.39 + 2.91 individuals per 100km, and free-ranging dogs, estimated to be 26.07 + 3.6 individuals per 100 km.

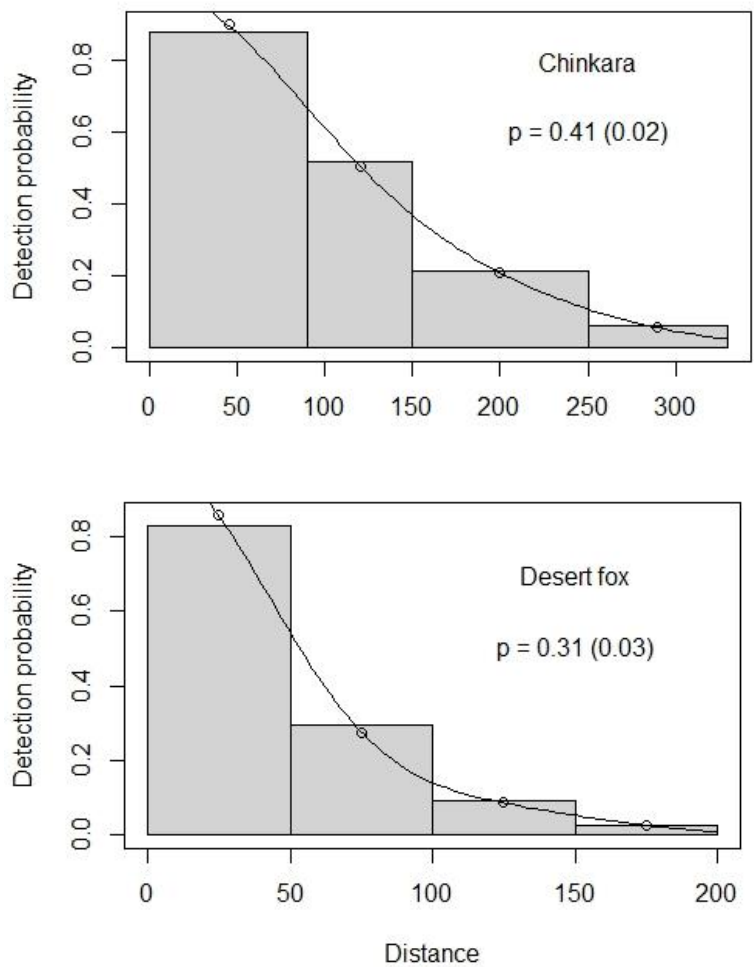
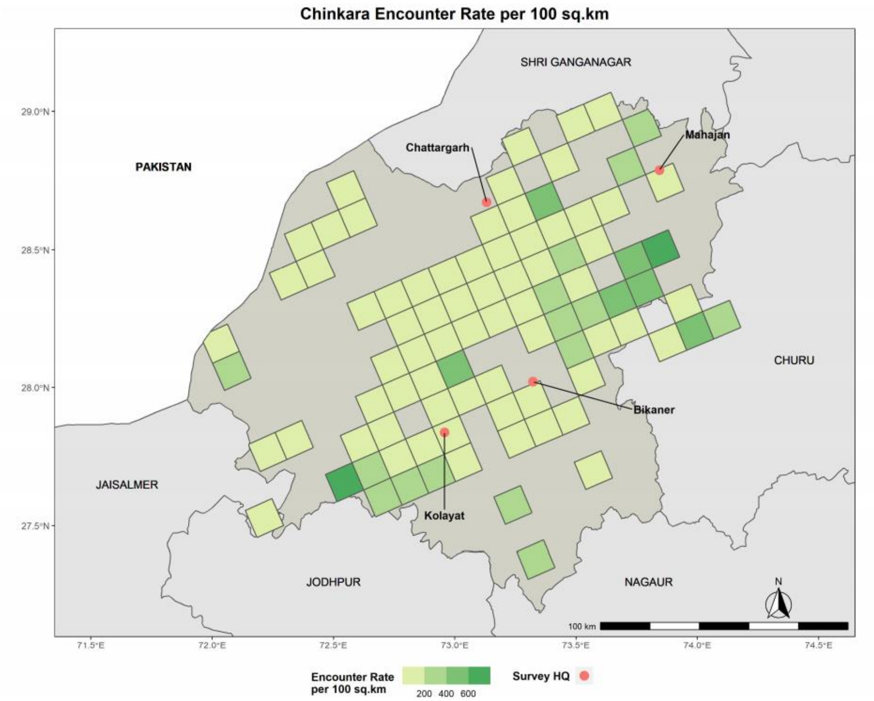


Figure 9. Best fit detection models for Chinkara and Desert fox at line-transects in Bikaner landscape (2021); mean and standard error estimates of species' detection probability also reported



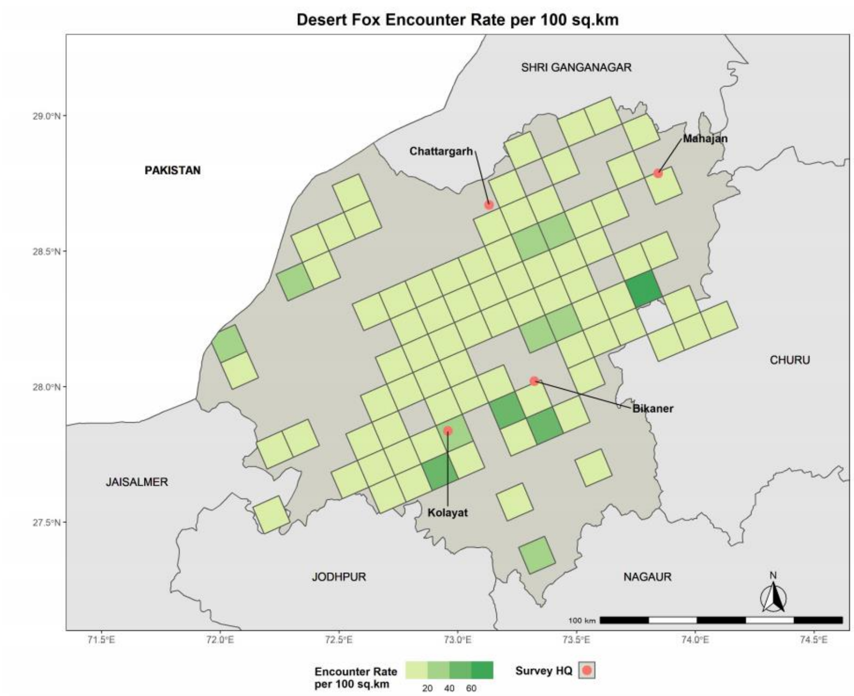


Figure 10. Distribution of Chinkara (top) and Desert fox (bottom) in Bikaner landscape (2021), shown as low (light green) to high (dark green) encounter rates

3.4.2 Large birds

Encounter rate of large birds on line transects showed that Griffon vulture > Egyptian vulture > Common kestrel > Black winged kite > Long-legged buzzard > Steppe eagle > Shikra as the most abundant raptors. The encounter rate of Demoiselle cranes was estimated to be 5.47 (3.14) individuals per 100 km.

Table 5. Mean encounter rate of large birds along with associated standard error. The values are standardised to 100km of vehicle transect effort.

Species	Geometric-mean (SE) individuals / 100 km	Mean (SE) individuals / 100 km
Demoiselle Crane (Grus virgo)	3.47 (1.91)	5.47 (3.14)
Griffon Vulture (Gyps fulvus)	9.95 (3.31)	16.44 (6.94)
Egyptian Vulture (Neophron percnopterus)	7.19 (1.78)	8.73 (2.35)
Cinereous Vulture (Aegypius monachus)	1.24 (0.4)	1.31 (0.42)
Steppe Eagle (Aquila nipalensis)	3.06 (0.55)	3.19 (0.57)
Tawny Eagle (Aquila rapax)	0.6 (0.2)	0.62 (0.21)
Short-toed Snake Eagle (Circaetus gallicus)	0.6 (0.24)	0.62 (0.25)
Eastern Imperial Eagle (Aquila heliaca)	0.31 (0.14)	0.32 (0.14)
Common Kestrel (Falco tinnunculus)	7.08 (0.83)	7.39 (0.88)
Laggar Falcon (Falco jugger)	3.11 (0.67)	3.31 (0.73)
Long-legged Buzzard (Buteo rufinus)	4.94 (0.66)	5.13 (0.69)
White-eyed Buzzard (Butastur teesa)	0.5 (0.23)	0.52 (0.24)
Blackwinged Kite (Elanus caeruleus)	5.04 (0.83)	5.35 (0.89)
Shikra (Accipiter badius)	2.48 (0.55)	2.61 (0.58)
Eurasian Sparrowhawk (Accipiter nisus)	0.54 (0.23)	0.56 (0.25)

3.4.3 Small birds

We recorded 2,859 small birds belonging to 103 species. 640 point counts included all species seen (hereafter ‘complete’), and 162 point-counts included only the focal taxa (francolin, quail, courser, sandgrouse, lark, chat and wheatear). We considered ‘complete lists’ and species with > 5 sightings (n=43 species) while estimating density using distance sampling.

Species were empirically classified into:

a) low-detectability group (n = 23 species) with median sighting distance <60 m and distance data best explained by half-normal cosine detection function;

b) medium-detectability group (n = 18 species) with median sighting distance 60-100 m and distance data best explained by half-normal cosine detection function;

c) high-detectability group (n = 2 species) with median sighting distance >100 m and distance data best explained by a uniform cosine detection function.

Estimated detection probability ranged from 0.05 to 0.44 across groups (Figure 11).

We report landscape level population metrics such as flock encounter rate, flock size and density of these species in Table 7. Species’ rank abundance curves were J-shaped (broken-stick) with a few relatively common species and many relatively rare species (Figure 12). The most abundant species were Common Babbler > Eurasian Collared Dove > House Sparrow > White Eared Bulbul > Red Vented Bulbul > Greater Short Toed Lark > Variable Wheatear.

Total density of small birds was estimated to be 997 (SE 58) individuals / km^2, not including birds in flight and rare species.

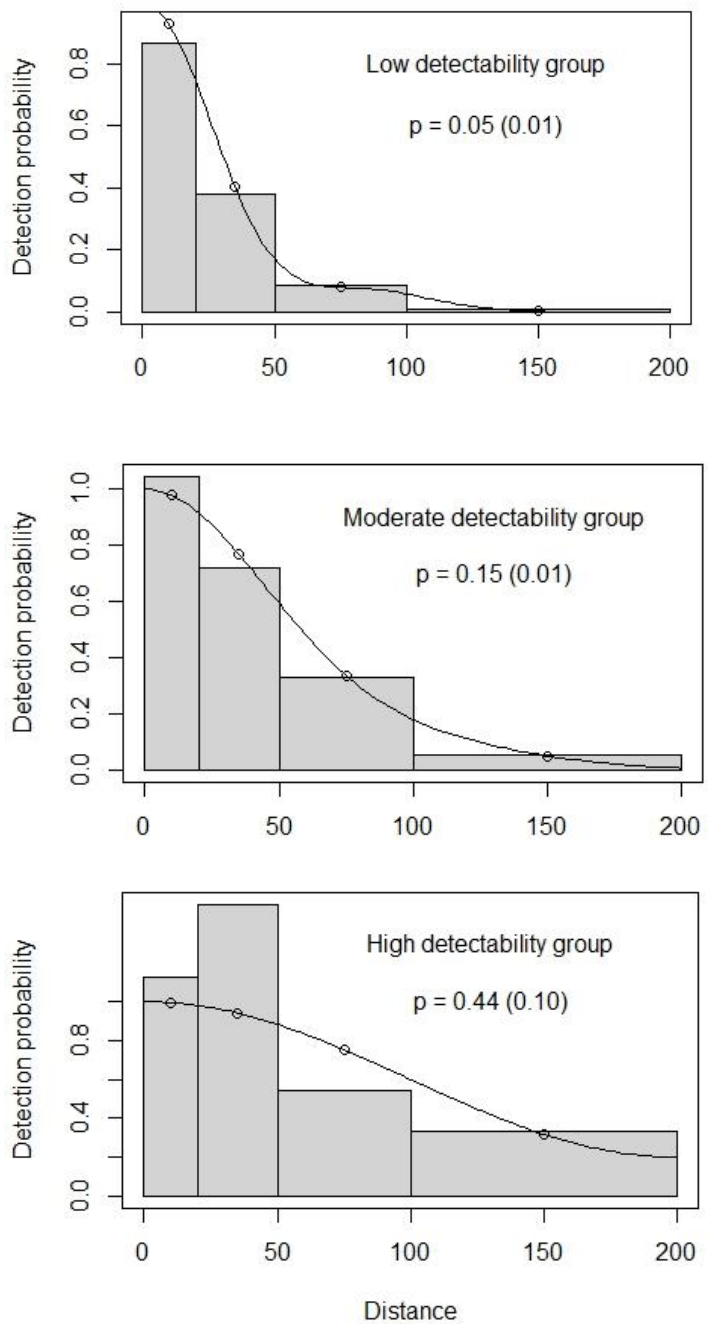


Figure 11. Best fit detection models for low, moderate and high detectability groups of birds at point-counts in Bikaner landscape (2021); estimated mean and standard error proportion of groups detected within 200 m shown for each group

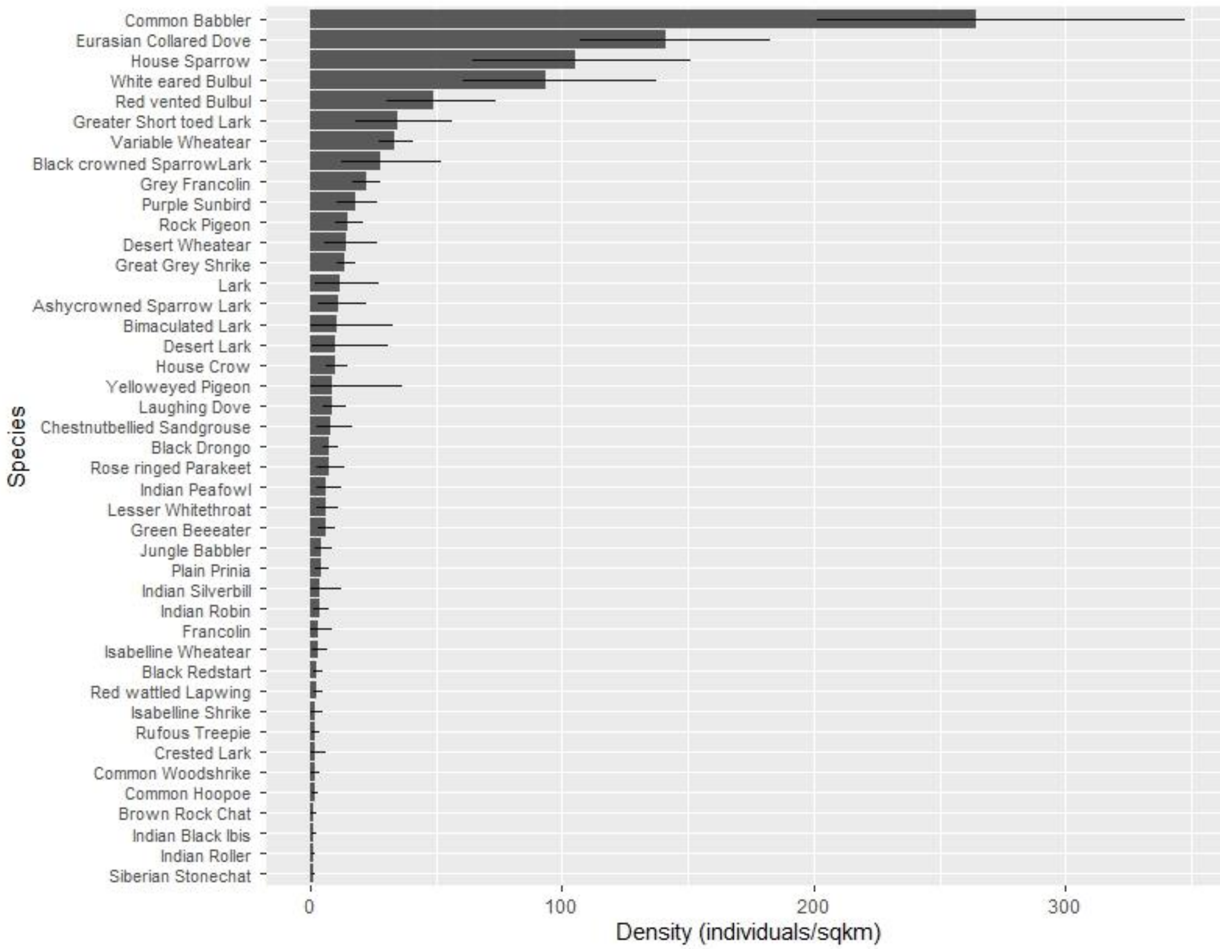


Figure 12. Density (individual / km^2) of small bird species based on point count distance sampling in Bikaner landscape (2021)

Table 6. Population status of bird species estimated as density (individuals per km^2), number of flocks per point (Flock ER), probability of detecting a flock (Det prob) and individuals per flock (Flock size) using point count distance sampling in Bikaner landscape (2021)

Species	Density (95% CI)	Flock ER (95% CI)	Det prob (SE)	Flock size (SE)
Ashycrowned Sparrow Lark (Eremopterix griseus)	10.95 (3.52 - 22.44)	0.02 (0.01 - 0.035)	0.05 (0.01)	3.21 (0.79)
Bimaculated Lark (Melanocorypha bimaculata)	10.41 (0 - 33.27)	0.01 (0 - 0.016)	0.05 (0.01)	8.4 (4.53)
Black crowned SparrowLark (Eremopterix nigriceps)	28.13 (12.6 - 51.64)	0.05 (0.03 - 0.077)	0.05 (0.01)	3.56 (0.73)
Black Drongo (Dicrurus macrocercus)	7.68 (4.73 - 11.2)	0.1 (0.07 - 0.132)	0.15 (0.01)	1.48 (0.17)
Black Redstart (Phoenicurus ochruros)	2.73 (1.1 - 4.87)	0.02 (0.01 - 0.027)	0.05 (0.01)	1.1 (0.1)
Brown Rock Chat (Oenanthe fusca)	1.24 (0.2 - 2.44)	0.01 (0 - 0.015)	0.05 (0.01)	1 (0)
Chestnutbellied Sandgrouse (Pterocles exustus)	8.3 (2.06 - 16.26)	0.01 (0 - 0.022)	0.05 (0.01)	4.12 (0.74)
Common Babbler (Argya caudata)	264.49 (200.14 - 357.21)	0.41 (0.35 - 0.466)	0.05 (0.01)	4.2 (0.28)
Common Hoopoe (Upupa epops)	1.7 (0.39 - 3.2)	0.01 (0 - 0.02)	0.05 (0.01)	1 (0)
Common Woodshrike (Tephrodornis pondicerianus)	1.73 (0.09 - 3.76)	0.01 (0 - 0.016)	0.05 (0.01)	1.4 (0.24)
Crested Lark (Galerida cristata)	1.85 (0 - 6.15)	0.01 (0 - 0.016)	0.15 (0.01)	4.4 (2.91)
Desert Lark (Ammomanes deserti)	10.03 (0.34 - 32.47)	0.01 (0 - 0.02)	0.05 (0.01)	7.2 (3.28)
Desert Wheatear (Oenanthe deserti)	14.26 (5.41 - 26.76)	0.05 (0.03 - 0.078)	0.05 (0.01)	1.71 (0.45)
Eurasian Collared Dove (Streptopelia decaocto)	141.44 (108.15 - 182.07)	0.68 (0.58 - 0.78)	0.15 (0.01)	3.95 (0.36)
Great Grey Shrike (Lanius excubitor)	13.69 (10.34 - 17.62)	0.22 (0.18 - 0.265)	0.15 (0.01)	1.18 (0.08)
Greater Short toed Lark (Calandrella brachydactyla)	34.89 (19.49 - 55.52)	0.06 (0.03 - 0.077)	0.15 (0.01)	11.86 (1.91)
Green Beeeater (Merops orientalis)	5.86 (3.11 - 9.46)	0.05 (0.03 - 0.07)	0.15 (0.01)	2.32 (0.34)
Grey Francolin (Francolinus pondicerianus)	22.34 (16.96 - 28.31)	0.21 (0.17 - 0.251)	0.15 (0.01)	2.02 (0.11)
House Crow (Corvus splendens)	9.81 (5.8 - 15.14)	0.08 (0.06 - 0.11)	0.15 (0.01)	2.25 (0.33)
House Sparrow (Passer domesticus)	105.15 (64.18 - 150.4)	0.19 (0.15 - 0.226)	0.15 (0.01)	10.7 (1.71)
Indian Black Ibis (Pseudibis papillosa)	0.95 (0.33 - 2.2)	0.02 (0.01 - 0.028)	0.44 (0.1)	3.09 (0.62)
Indian Peafowl (Pavo cristatus)	6.39 (2.5 - 11.97)	0.04 (0.02 - 0.063)	0.15 (0.01)	3.04 (0.66)
Indian Robin (Saxicoloides fulicatus)	3.72 (1.31 - 7.47)	0.02 (0.01 - 0.026)	0.05 (0.01)	1.5 (0.31)
Indian Roller (Coracias benghalensis)	0.93 (0.51 - 1.89)	0.04 (0.03 - 0.061)	0.44 (0.1)	1.14 (0.08)
Indian Silverbill (Euodice malabarica)	3.87 (0 - 11.12)	0.01 (0 - 0.016)	0.15 (0.01)	9.2 (5.37)
Isabelline Shrike (Lanius isabellinus)	1.98 (0.07 - 4.71)	0.01 (0 - 0.016)	0.05 (0.01)	1.6 (0.4)
Isabelline Wheatear (Oenanthe isabellina)	2.89 (0.79 - 6.23)	0.01 (0 - 0.025)	0.05 (0.01)	1.33 (0.33)
Jungle Babbler (Turdoides striata)	4.42 (1.62 - 8.46)	0.03 (0.01 - 0.044)	0.15 (0.01)	3.12 (0.57)
Laughing Dove (Streptopelia senegalensis)	8.58 (4.51 - 14.33)	0.04 (0.02 - 0.055)	0.05 (0.01)	1.46 (0.16)
Lesser Whitethroat (Sylvia curruca)	6.22 (2.18 - 11.34)	0.03 (0.01 - 0.056)	0.05 (0.01)	1.18 (0.13)
Plain Prinia (Prinia inornata)	4.14 (2 - 7.02)	0.02 (0.01 - 0.035)	0.05 (0.01)	1.21 (0.11)
Purple Sunbird (Cinnyris asiaticus)	17.68 (10.05 - 27.22)	0.08 (0.05 - 0.115)	0.05 (0.01)	1.39 (0.08)
Red vented Bulbul (Pycnonotus cafer)	49.01 (31.2 - 74.55)	0.14 (0.1 - 0.176)	0.05 (0.01)	2.31 (0.3)
Red wattled Lapwing (Vanellus indicus)	2.6 (1.02 - 4.64)	0.03 (0.01 - 0.046)	0.15 (0.01)	1.76 (0.22)
Rock Pigeon (Columba livia)	14.91 (10.02 - 20.96)	0.11 (0.08 - 0.14)	0.15 (0.01)	2.63 (0.23)
Rose ringed Parakeet (Psittacula krameri)	7.53 (2.56 - 14.03)	0.07 (0.02 - 0.109)	0.15 (0.01)	2.14 (0.39)
Rufous Treepie (Dendrocitta vagabunda)	1.95 (0.59 - 3.72)	0.01 (0 - 0.019)	0.05 (0.01)	1.14 (0.14)
Siberian Stonechat (Saxicola maurus)	0.9 (0.28 - 1.68)	0.01 (0 - 0.024)	0.15 (0.01)	1.22 (0.15)
Variable Wheatear (Oenanthe picata)	33.19 (27.16 - 40.17)	0.5 (0.43 - 0.575)	0.15 (0.01)	1.25 (0.04)
White eared Bulbul (Pycnonotus leucotis)	93.68 (62.59 - 137.26)	0.21 (0.16 - 0.257)	0.05 (0.01)	2.89 (0.33)
Yelloweyed Pigeon (Columba eversmanni)	8.59 (0 - 32.23)	0.01 (0 - 0.02)	0.05 (0.01)	6.17 (4.77)

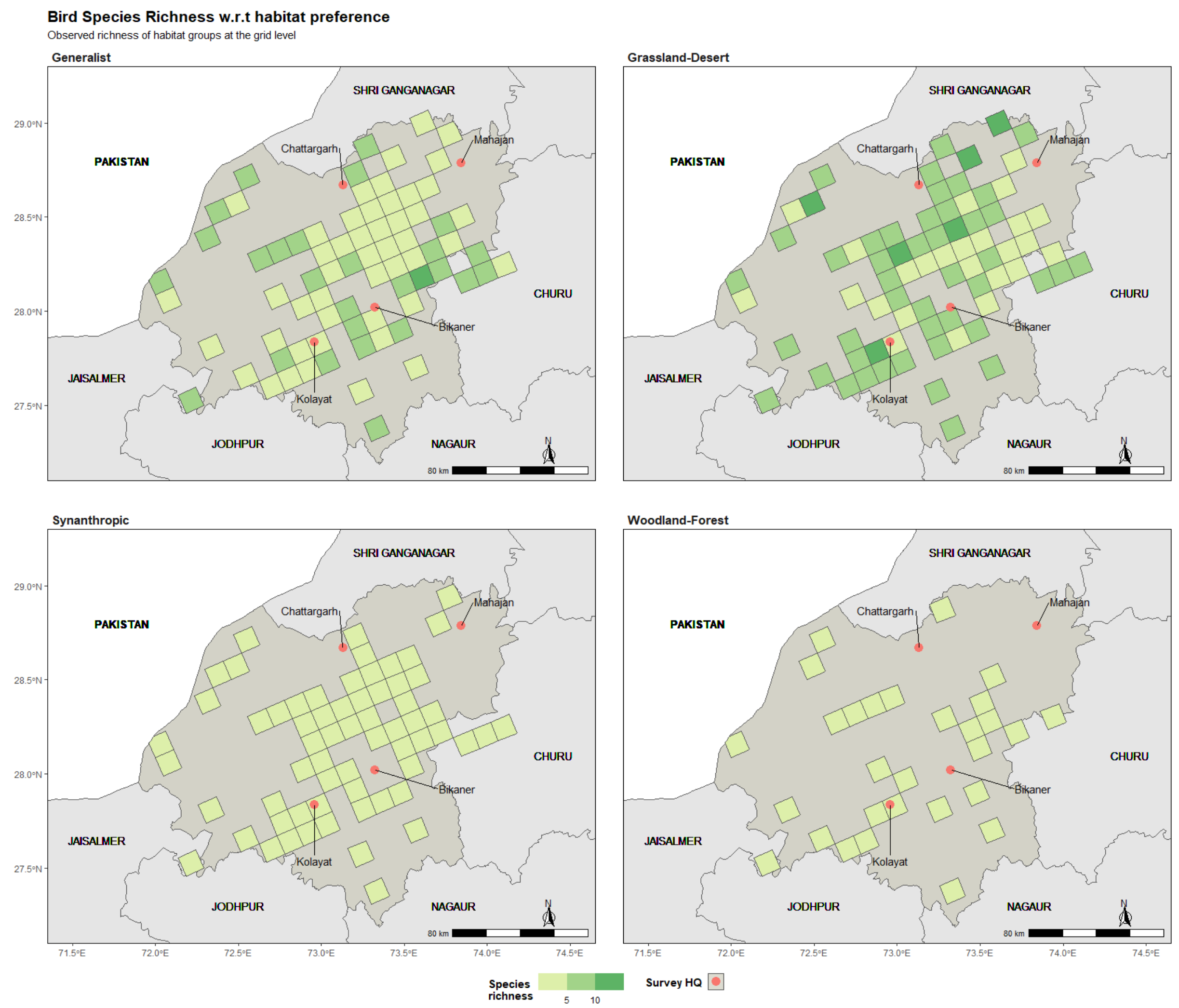


Figure 13. Mean (naive) species richness per point of Generalist (top left), Grassland-Desert specialist (top right), Synanthropic and Woodland-Forest bird species for every 144 km^2 grid in the Bikaner Landscape

3.5 Species-habitat relationships

3.5.1 Mammals

Results of generalised linear models on detection rates of mammals along line transects showed contrasting effects of habitat characteristics on species' abundance at cell-level (Table 7). Chinkara abundance decreased but nilgai abundance increased with the proportion of area under cultivation. Dog abundance was positively associated with flat, disturbed areas. Desert fox and Desert cat abundances did not show any response to these habitat gradients.

Table 7. Habitat relationships of select mammals in Bikaner landscape (2021): species' abundance measured as logarithm of 1 + mean number of individuals detected km^{-1} in a cell analysed against habitat factors using generalised linear models. Model-averaged untransformed mean (SE) parameter estimates of significant effects ($p<0.1$) are reported; positive values indicate that the species' abundance increases with the covariate and the converse.

Species	**Factor 1**	**Factor 3**	**Factor 4**	**Canal**
	Flat (+) vs undulating (-)	Disturbances	Proportion of area cultivated	Canal length
Chinkara (*Gazella bennettii*)			-0.18 (0.06)	
Desert Cat (*Felis lybica ornata*)				
Desert Fox (*Vulpes vulpes pusilla*)				
Dog (*Canis familiaris*)	0.09 (0.02)	0.11 (0.02)		
Nilgai (*Boselaphus tragocamelus*)			0.06 (0.02)	

3.5.2 Large birds

Results of generalised linear models on detection rates of large birds along line transects indicated that Egyptian vulture, Steppe eagle and Laggar falcon abundance decreased in canal-irrigated areas, and Black winged kite abundance increased with disturbances and proportion of area under cultivation (Table 8).

Table 8. Habitat relationships of select large birds in Bikaner landscape (2021): species' abundance measured as logarithm of 1 + mean number of individuals detected km^{-1} in a cell analysed against habitat factors using generalised linear models. Model-averaged untransformed mean (SE) parameter estimates of significant effects (p<0.1) are reported; positive values indicate that the species' abundance increases with the covariate and the converse.

Species	**Factor 1** Flat (+) vs undulating (-)	**Factor 3** Disturbances	**Factor 4** Proportional area cultivated	**Canal** Canal length
Demoiselle Crane (*Grus virgo*)				
Griffon Vulture (*Gyps fulvus*)	-0.08 (0.03)			
Egyptian Vulture (*Neophron percnopterus*)				-0.12 (0.06)
Cinereous Vulture (*Aegypius monachus*)				
Steppe Eagle (*Aquila nipalensis*)				-0.05 (0.02)
Tawny Eagle (*Aquila rapax*)				
Short-toed Snake Eagle (*Circaetus gallicus*)				
Eastern Imperial Eagle (*Aquila heliaca*)				
Long-legged Buzzard (*Buteo rufinus*)				
White-eyed Buzzard (*Butastur teesa*)				
Common Kestrel (*Falco tinnunculus*)				
Laggar falcon (*Falco jugger*)				-0.04 (0.02)
Black-winged kite (*Elanus caeruleus*)		0.02 (0.01)	0.03 (0.01)	
Shikra (*Accipiter badius*)				
Eurasian sparrow hawk (*Accipiter nisus*)				

3.5.3 Small birds

Results of generalised linear models indicated that habitat characteristics influenced population status. Common babbler, Eurasian collared dove, Grey francolin, Indian peafowl, Indian robin, Lesser whitethroat, Red vented bulbul and White eared bulbul selected flat over undulating terrain. Effects of anthropogenic variables differed between species. Distribution and abundance of Black crowned sparrow lark decreased, while that of Black drongo, Common hoopoe, Eurasian collared dove, Grey francolin, Indian black ibis, Jungle babbler, Purple sunbird, Red wattled lapwing and Rose ringed parakeet increased with the proportion of area cultivated. Disturbances adversely affected Ashy crowned sparrow lark, Greater short toed lark, and Yellow eyed pigeon but favoured Common babbler, Eurasian collared dove, Grey francolin, Indian Peafowl, Indian Robin, Red vented bulbul, Rock pigeon and Variable wheatear. Lastly, the canal favoured Indian roller, Rose ringed parakeet and Rufous treepie (Table 9).

Table 9. Bird-habitat relationships in Bikaner landscape (2021): for each species, distribution and abundance were analysed against habitat factors and canal length using generalised linear models and the untransformed mean (SE) parameter estimates for significant effects ($p < 0.1$) are reported. Positive values indicate that the species' distribution and/or abundance increases with the covariate and the converse.

Response	**Distribution (proportion of points occupied)**					**Abundance (Log mean count per point + 1)**				
Predictors	**factor1**	**factor2**	**factor3**	**factor4**	**canal**	**factor1**	**factor2**	**factor3**	**factor4**	**canal**
Species	Flat (+) vs undulating (-)	Soil (+) vs sand (-)	Disturb-ances	Proportion of area cultivated	Canal length	Flat (+) vs undulating (-)	Soil (+) vs sand (-)	Disturb-ances	Proportion of area cultivated	Canal length
Ashy-crowned Sparrow Lark			-0.45 (0.27)					-0.04 (0.02)		
Black-crowned Sparrow Lark		-0.36 (0.15)		-1.11 (0.35)					-0.07 (0.03)	
Black Drongo			0.36 (0.18)	0.51 (0.14)					0.07 (0.02)	
Black Redstart										
Brown Rock Chat										
Chestnut-bellied Sandgrouse										
Common Babbler	0.38 (0.1)		0.17 (0.09)			0.17 (0.06)		0.13 (0.06)		
Common Hoopoe				0.97 (0.46)					0.01 (0)	
Common Woodshrike										
Crested Lark			-3.52 (1.8)	2.09 (1.24)						
Desert Lark						0.05 (0.02)				
Desert Wheatear		-0.43 (0.15)	-0.32 (0.19)							
Eurasian Collared Dove	0.2 (0.09)		0.61 (0.09)	0.24 (0.09)		0.19 (0.07)		0.35 (0.07)	0.16 (0.07)	
Great Grey Shrike										
Greater Short-toed Lark			-0.67 (0.19)					-0.17 (0.07)		
Green Bee-eater										
Grey Francolin	0.35 (0.12)		0.32 (0.12)	0.34 (0.1)	-0.8 (0.42)	0.09 (0.03)		0.08 (0.03)	0.09 (0.03)	-0.25 (0.1)
House Crow				0.26 (0.16)	-1.36 (0.75)					
House Sparrow	0.2 (0.12)	0.2 (0.12)	0.24 (0.12)							
Indian Black Ibis				0.9 (0.32)					0.04 (0.02)	
Indian Peafowl	0.86 (0.37)		0.86 (0.35)			0.06 (0.02)		0.05 (0.03)		
Indian Robin	0.9 (0.5)		0.79 (0.45)			0.02 (0.01)		0.02 (0.01)		
Indian Roller				0.37 (0.17)	1.53 (0.62)		0.01 (0.01)			0.12 (0.03)
Indian Silverbill										
Isabelline Shrike						0.01 (0.01)				0.04 (0.02)
Isabelline Wheatear		-0.66 (0.31)								-0.04 (0.02)
Jungle Babbler				0.74 (0.26)					0.04 (0.02)	
Laughing Dove									0.02 (0.01)	
Lesser Whitethroat	0.65 (0.29)		-0.55 (0.23)		-4.37 (1.97)	0.02 (0.01)				-0.08 (0.04)
Plain Prinia	-0.52 (0.29)					-0.01 (0.01)				
Purple Sunbird			0.37 (0.19)	0.49 (0.14)					0.04 (0.02)	
Red-vented Bulbul	0.35 (0.14)		0.47 (0.15)			0.09 (0.04)		0.08 (0.04)		
Red-wattled Lapwing				0.84 (0.23)					0.05 (0.01)	
Rock Pigeon			0.29 (0.15)					0.07 (0.03)		
Rose-ringed Parakeet				0.65 (0.18)	1.32 (0.63)				0.07 (0.03)	0.22 (0.1)
Rufous Treepie					2.7 (1.33)					0.04 (0.02)
Siberian Stonechat										
Variable Wheatear			0.19 (0.09)					0.06 (0.03)		
White-eared Bulbul	0.44 (0.12)					0.09 (0.05)				0.34 (0.18)
Yellow-eyed Pigeon		-1.17 (0.49)	-1.26 (0.61)				-0.05 (0.02)	-0.03 (0.02)		

3.6 Wetland Hotspot Survey

A total of 24,674 individuals of 95 species across 36 families were counted in four survey sites. A summary of the species' total count is given below (Table 10). Common Coot (13,707), Demoiselle Crane (1,138), Common Pochard (1,690), Common Teal (1,567), and Gadwall (1,134) were the most abundant waterbirds comprising 78% of total birds counted across all survey sites. Two globally Endangered (Egyptian Vulture and Steppe Eagle), two Vulnerable (Common Pochard and River Tern), and six Near-Threatened species (Black headed Ibis, Dalmatian Pelican, Eurasian Curlew, Ferruginous Duck, Northern Lapwing, and Painted Stork) were encountered (Table 10).

3.6.1 Canal escape wetlands at RD 750 and RD 507

Wetlands formed by the escape channels of the Indira Gandhi Canal (namely RD 507 and RD 750) were seen hosting a large number of waterbirds. The escape water of the canal created these connected interdunal lakes of diverse depth profiles. RD 750 is the largest wetland among the four surveyed water bodies, spread over 15 km^2; RD 507 is a smaller wetland spread across 3 km^2 with three connected water bodies.

We recorded 15,691 individuals of 76 bird species in RD 750 that was dominated by Common Coot (8,814 individuals) > Common Pochard (1,645) > Common Teal (1,231) > Gadwall (930) > Northern Pintail (440). Whereas, we recorded 6,501 individuals of 34 species in RD 507, dominated by Common Coot (4,564) > Common Teal (372) > Gadwall (228) > Northern Shoveler (250). Globally Near-Threatened Dalmatian Pelican (55), Northern Lapwing (1), and Painted Stork (8) were also sighted at RD 507.

3.6.2 Gajner Lake

Gajner Lake is a small human-made lake with about 0.20 km^2 of water spread that is a part of the Gajner Wildlife Sanctuary. Historically, it was a hunting ground for the royal family of Bikaner. In total, 758 bird individuals of 38 species were counted in the Gajner wetland. Common Coot (294) > Common Moorhen (101) > Northern Shoveler (80) were among the most common waterbirds here. Two globally Near-Threatened species (Black headed ibis and Ferruginous Duck) and one globally Vulnerable Species (River Tern) were recorded in Gajner Lake.

3.6.3 Lunkaransar Salt Lake

Lunkaransar is a natural salt lake of around 2.5 km^2 area that attracts many winter migratory waterbirds. We counted 1,749 individuals of 25 bird species in Lunkaransar Lake. Large flocks of Demoiselle Crane (946) > Northern Shoveler (436) > Pied Avocet (126) were recorded here.

Table 10. Summary of birds seen at surveyed wetland hotspots in the Bikaner district. The values in the table represent raw counts of birds quantified through the simultaneous block count method.

Order	Family	Species	IUCN status	RD 507	RD 750	Gaj-ner	Lunkar-ansar
Accipitri formes	Accipitridae	Eagle (Unidentified)	NA	0	1	0	0
		Egyptian Vulture (Neophron percnopterus)	EN	0	0	0	6
		Osprey (Pandion haliaetus)	LC	0	3	0	0
		Shikra (Accipiter badius)	LC	0	2	1	0
		Short toed S0ke Eagle (Circaetus gallicus)	LC	0	1	0	0
		Steppe Eagle (Aquila nipalensis)	EN	0	2	0	0
Anseri formes	Anatidae	Bar-headed Goose (Anser indicus)	LC	4	102	0	0
		Common Pochard (Aythya feri0)	VU	28	1645	0	1
		Common Teal (A0s crecca)	LC	372	1231	0	54
		Eurasian Wigeon (Mareca penelope)	LC	53	337	0	5
		Ferruginous Duck (Aythya nyroca)	NT	1	43	4	0
		Gadwall (Mareca strepera)	LC	228	930	0	0
		Garganey (Spatula querquedula)	LC	125	0	0	0
		Greylag Goose (Anser anser)	NA	0	1	0	0
		Indian Spot-billed Duck (A0s poecilorhyncha)	NA	0	3	0	0
		Mallard (A0s platyrhynchos)	LC	60	89	0	0
		Northern Pintail (A0s acuta)	LC	200	440	25	12
		Northern Shoveler (Spatula clypeata)	LC	250	207	80	436
		Redcrested Pochard (Netta rufi0)	LC	192	158	1	0
		Ruddy Shelduck (Tador0 ferruginea)	LC	0	13	0	0
		Tufted Duck (Aythya fuligula)	LC	6	6	0	0
		Duck (unidentified)	NA	0	29	53	0
Charadrii	Charadriidae	Little Ringed Plover (Charadrius dubius)	LC	0	59	6	2

Order	Family	Species	IUCN status	RD 507	RD 750	Gaj-ner	Lunkar-ansar
formes		Northern Lapwing (Vanellus vanellus)	NT	1	0	0	0
		Red wattled Lapwing (Vanellus indicus)	LC	9	26	10	13
		Whitetailed Lapwing (Vanellus leucurus)	LC	3	0	0	2
	Glareolidae	Little Pratincole (Glareola lactea)	LC	1	0	0	1
		Small Pratincole (Glareola lactea)	NA	0	5	0	0
	Laridae	River Tern (Ster0 aurantia)	VU	4	3	4	0
	Recurvirostridae	Black-winged Stilt (Himantopus himantopus)	LC	61	3	14	38
		Pied Avocet (Recurvirostra avosetta)	LC	77	1	0	126
	Scolopacidae	Common Greenshank (Tringa nebularia)	LC	0	3	0	0
		Common Sandpiper (Actitis hypoleucos)	LC	0	39	1	7
		Common Snipe (Galli0go galli0go)	LC	0	0	2	0
		Eurasian Curlew (Numenius arquata)	NT	0	0	0	2
		Ruff (Calidris pug0x)	LC	3	33	0	6
		Spotted Redshank (Tringa erythropus)	LC	0	0	0	7
		Temminck's Stint (Calidris temminckii)	NA	0	2	0	0
Ciconiiformes	**Ciconiidae**	Asian Openbill (Astomus oscitans)	LC	0	9	0	0
		Black Stork (Ciconia nigra)	LC	0	31	0	0
		Painted Stork (Mycteria leucocephala)	NT	8	59	0	2
Columbiformes	**Columbidae**	Eurasian Collared Dove (Streptopelia decaocto)	LC	0	0	3	0
		Rock Pigeon (Columba livia)	LC	0	0	10	0
Coracii formes	**Alcedinidae**	Common Kingfisher (Alcedo atthis)	LC	0	1	0	0
		Pied Kingfisher (Ceryle rudis)	LC	0	2	0	0
		Whitethroated Kingfisher (Halcyon smyrnensis)	LC	0	3	0	0
	Coraciidae	Indian Roller (Coracias benghalensis)	LC	1	4	2	0
	Meropidae	Green Beeeater (Merops orientalis)	LC	0	5	0	0
Falconi formes	**Falconidae**	Falcon (unidentified)	NA	0	1	0	0
Galli formes	**Phasianidae**	Grey Francolin (Francolinus pondicerianus)	LC	0	2	4	0
		Indian Peafowl (Pavo cristatus)	LC	0	0	7	0
Grui formes	**Gruidae**	Demoiselle Crane (Grus virgo)	LC	0	192	0	946
	Rallidae	Common Coot (Fulica atra)	LC	4564	8814	294	35
		Common Moorhen (Gallinula chloropus)	LC	4	23	101	8
		White-breasted Waterhen (Amaurornis phoenicurus)	LC	0	0	3	0
Passeri formes	**Alaudidae**	Crested Lark (Galerida cristata)	LC	0	0	0	2
		Lark (Unidentified)	NA	0	0	4	0
	Corvidae	House Crow (Corvus splendens)	LC	0	2	20	0
		Rufous Treepie (Dendrocitta vagabunda)	LC	0	0	2	0
	Dicruridae	Black Drongo (Dicrurus macrocercus)	Lc	2	6	0	0
	Hirundinidae	Barn Swallow (Hirundo rustica)	NA	0	3	5	0
		Dusky Crag Martin (Ptyonoprogne concolor)	LC	0	20	0	0

Order	Family	Species	IUCN status	RD 507	RD 750	Gaj-ner	Lunkar-ansar
		Swallow (unidentified)	NA	0	3	0	0
	Laniidae	Isabelline Shrike (Lanius isabellinus)	LC	0	1	0	0
	Leiothrichidae	Common Babbler (Argya caudata)	LC	0	15	0	0
	Motacillidae	Citrine Wagtail (Motacilla citreola)	LC	0	4	0	0
		Grey Wagtail (Motacilla cinerea)	LC	0	1	0	3
		Tree Pipit (Anthus trivialis)	LC	0	2	0	0
		Western Yellow Wagtail (Motacilla flava)	LC	0	7	6	0
		White browed Wagtail (Motacilla maderaspatensis)	LC	0	3	0	0
		White Wagtail (Motacilla alba)	LC	1	53	0	0
	Muscicapidae	Black Redstart (Phoenicurus ochruros)	LC	0	1	0	0
		Variable Wheatear (Oe0nthe picata)	LC	0	1	0	0
	Nectariniidae	Purple Sunbird (Cinnyris asiaticus)	LC	0	2	0	0
	Passeridae	House Sparrow (Passer domesticus)	LC	0	0	4	0
	Rhipiduridae	White-browed Fantail (Rhipidura aureola)	LC	0	2	0	0
	Sturnidae	Common Starling (Sturnus vulgaris)	LC	6	0	0	0
Pelecaniformes	**Ardeidae**	Cattle Egret (Bubulcus ibis)	LC	0	6	0	0
		Great Egret (Ardea alba)	NA	1	33	1	0
		Grey Heron (Ardea cinerea)	LC	1	37	6	11
		Indian Pond Heron (Ardeola grayii)	LC	0	3	2	6
		Intermediate Egret (Ardea intermedia)	LC	0	30	3	0
		Little Egret (Egretta garzetta)	LC	0	60	3	0
	Pelecanidae	Dalmatian Pelican (Pelecanus crispus)	NT	55	31	0	0
	Threskiornithidae	Black-headed Ibis (Threskiornis melanocephalus)	NT	0	0	2	0
		Eurasian Spoonbill (Platalea leucorodia)	LC	44	124	1	0
		Indian Black Ibis (Pseudibis papillosa)	NA	0	5	0	0
Podicipediformes	**Podicipedidae**	Great Crested Grebe (Podiceps cristatus)	LC	0	5	0	0
		Little Grebe (Tachybaptus ruficollis)	LC	14	95	11	18
Psittaciformes	**Psittacidae**	Rose ringed Parakeet (Psittacula krameri)	LC	0	0	6	0
Pterocliformes	**Pteroclidae**	Sandgrouse (Unidentified)	NA	0	0	0	0
Strigiformes	**Strigidae**	Indian Eagle Owl (Bubo bengalensis)	LC	0	1	0	0
Suliformes	**Phalacrocoracidae**	Great Cormorant (Phalacrocorax carbo)	LC	93	57	6	0
		Indian Cormorant (Phalacrocorax fuscicollis)	LC	0	8	13	0
		Little Cormorant (Microcarbo niger)	LC	29	56	38	0
Total				6501	15691	758	1749
Grand Total				**24699**			

3.6.4 Jorbeed Conservation Reserve

Jorbeed is a 56 km^2 Conservation Reserve 12 km from Bikaner city. Jorbeed records a high number of diverse raptor species. Lots of them migrate there during winters. We recorded 11 raptor species, out of which 2 are endangered (Table 11).

Table 11. List of raptors sighted at Jorbeed Conservation Reserve

Species	**IUCN status**
Black Kite (*Milvus migrans*)	LC
Cinereous Vulture (*Aegypius monachus*)	NT
Common Kestrel (*Falco tinnunculus*)	LC
Eastern Imperial Eagle (*Aquila heliaca*)	VU
Egyptian Vulture (*Neophron percnopterus*)	EN
Eurasian Griffon (*Gyps fulvus*)	LC
Himalayan Griffon (*Gyps himalayensis*)	NT
Long Legged Buzzard (*Buteo rufinus*)	LC
Steppe Eagle (*Aquila nipalensis*)	EN
Tawny Eagle (*Aquila rapax*)	VU

3.7 Community perceptions

We targeted 170 respondents from 61 villages in 24 cells for questionnaires. Three samples were rejected from analysis as they included contradictory responses. Samples were largely from the central part of the Bikaner landscape. Only 1.7 (SE 1.0) % respondents (n = 4) had seen the Great Indian Bustard around their villages in the last five years.

When asked about the occurrence of focal species around villages, reporting frequencies were highest for Dog, Nilgai and Fox, followed by Chinkara, Crane and Wild pig (Figure 14). Reporting frequencies were positively correlated among species at the village level (Pearson's coefficient, r = 0.4 - 0.9 among species-pairs). Ordination analyses revealed two major patterns of species' reportings. The first gradient (factor 1 explaining 55% variance was positively correlated with reporting frequencies of all species except Wild pig) indicated general wildlife reporting at a village. The second gradient (factor 2 explaining 10% variance was negatively correlated with Chinkara reporting and positively correlated with Nilgai and Wild Pig reporting) indicated villages with greater Nilgai and Wild Pig reporting and less Chinkara reporting (Figure 14).

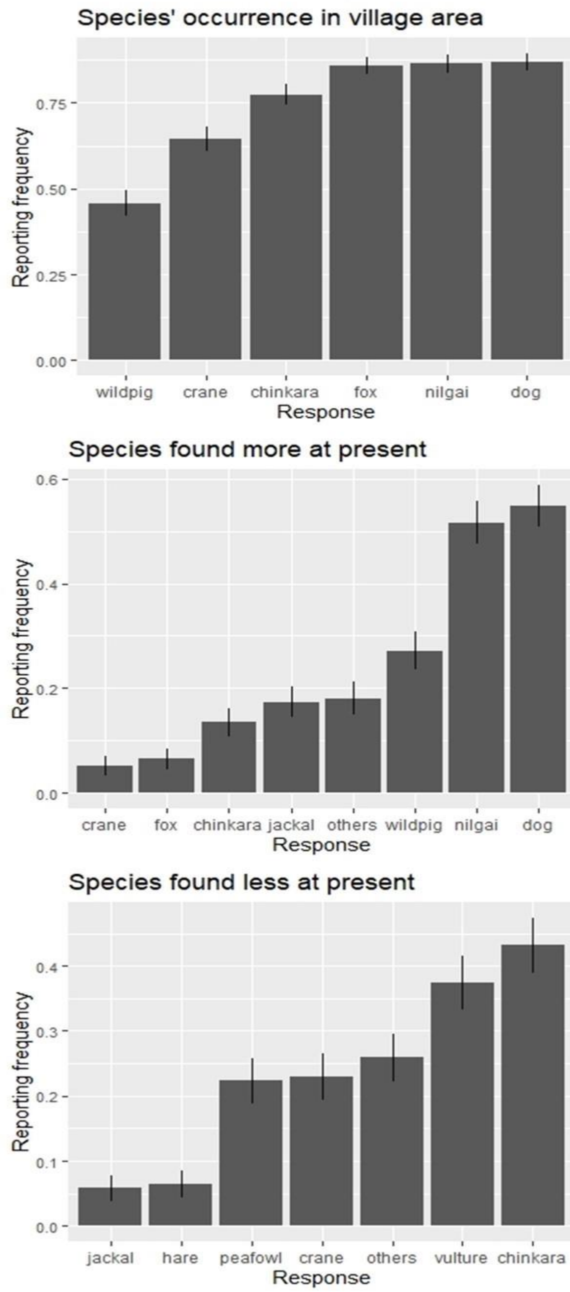


Figure 14. Mean (SE) reporting frequencies of (left) occurrence of focal species, (center) species that currently occur more than earlier, and (right) species that currently occur less than earlier in village areas of Bikaner landscape (2021) based on questionnaires

When asked about species that currently occur more than earlier, reporting frequencies were manifold higher for Dog, Nilgai and Wild pig than for Chinkara, Fox and Crane. Conversely, when asked about species that currently occur less than earlier, reporting frequencies were highest for Chinkara and Vulture, followed by Crane and Peafowl, whereas Dog and Nilgai were not reported (Figure 14).

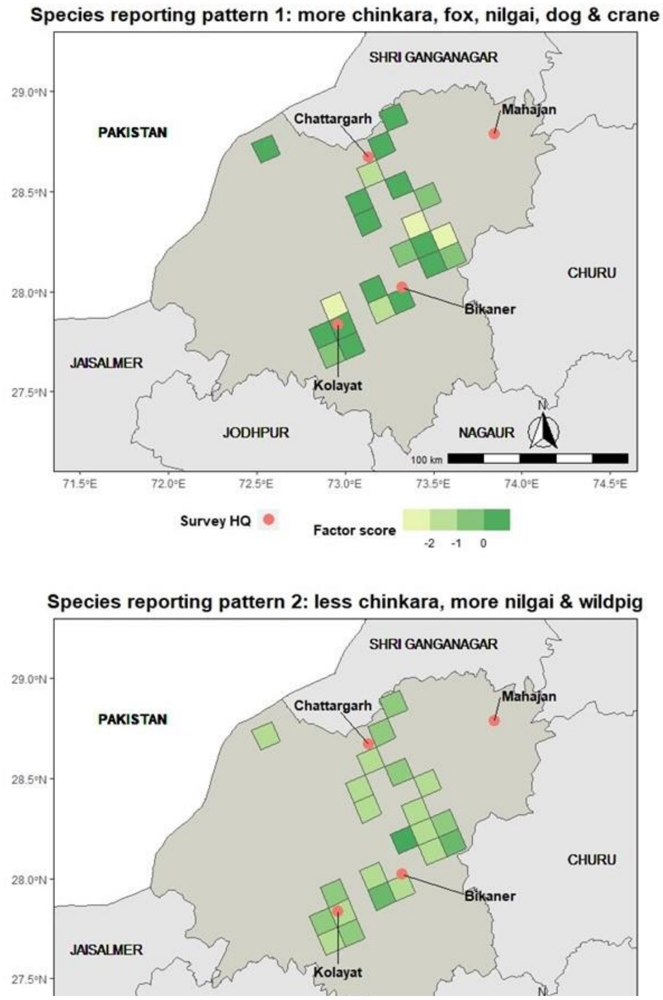


Figure 15. Patterns of species' reporting in Bikaner landscape (2021) based on questionnaires

When asked about causes behind wildlife decline, respondents identified habitat loss due to agricultural expansion and associated borewell irrigation, fencing, pesticide use, and ensuing forage scarcity as important threats alongside poaching, predation by dogs, climate change, and power infrastructure. Among these perceived threats, reporting frequency was highest for habitat loss (Figure 16). Finally, 85 (SE 3) % of respondents were aware of some form of conservation area around their villages, and 42 (SE 5) % of respondents reported that these areas were managed for wildlife protection by the Forest Department or communities (*Orans*), whereas, an equal proportion reported that such areas were not actively managed. Notably, 12 (SE 3) % of respondents complained about recent encroachment of conservation areas adjoining villages.

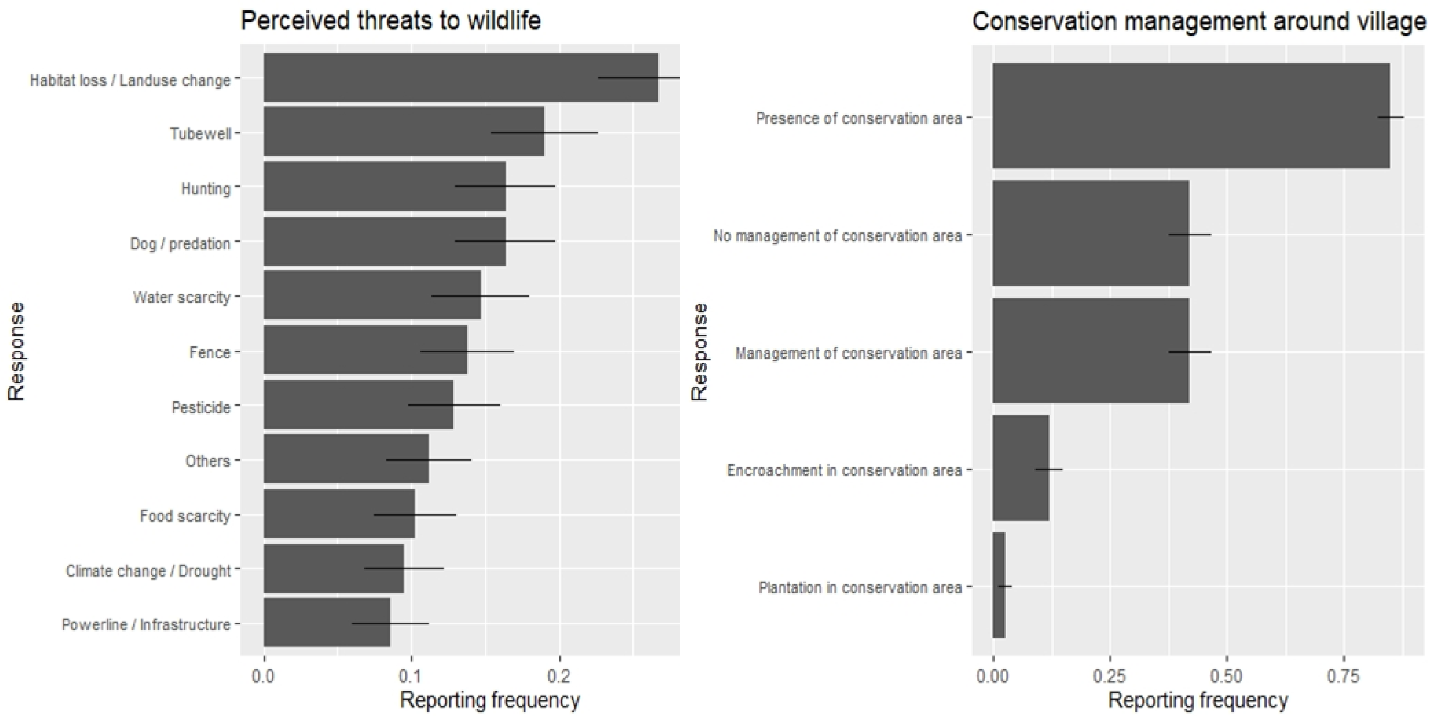


Figure 16. Mean (SE) reporting frequencies of (left) perceived threats to wildlife, and (right) perception related to wildlife conservation management in Bikaner landscape (2021) based on questionnaires

DISCUSSION

4.1 Ecological baselines

Large-scale ecological surveys have rarely been conducted in the Bikaner region. Thus, our study forms a baseline that can facilitate upcoming studies in the region. Such baselines are important for assessing the impacts of environmental changes on native biodiversity, particularly in the current age of land use and climate change. Our survey methodology is reproducible and can be replicated in future. This will provide information on biodiversity and ecological trends and allow a deeper understanding of the effects of large-scale changes in habitat and climate. Through this report, we provide a detailed account of the status of Chinkara and Desert fox in the Bikaner landscape. The chinkara is a revered animal in Rajasthan's culture and is also the state animal of Rajasthan. Yet, few systematic surveys of the species have been conducted. The existing estimates for the Chinkara population in the Bikaner district (Dookia 2009, Kankane 2000) have limited use for temporal comparisons since these surveys have methodological issues such as road-based transects, small sample size, non-representative sampling, and no correction for non-detection. Our estimates will form a robust baseline for comparison across space and time and is comparable with the Thar survey that is regularly conducted in the Jaisalmer district (Dutta et al. 2018). Similarly, the Desert fox, a ubiquitous animal in the desert, is largely under-surveyed and very little information is available about its population status. We present the first landscape wide estimate for the population of Desert fox from the Bikaner landscape.

4.2 Important sightings

1. **Mammals:** One individual of Indian grey wolf was reported from the Chattargarh region during the survey. Wolves have been recorded historically from this landscape (see Jhala and Giles, 1991), but recent records have been sparse.
2. **Birds:** We recorded 10 species of threatened birds. The list includes 7 species of raptors, *i.e.* Indian vulture, Egyptian vulture, Steppe eagle, Eastern imperial eagle, Greater spotted eagle, Indian spotted eagle and Tawny eagle. The rest of the three threatened species were Stoliczka's bushchat, Yellow-eyed pigeon and Common pochard. Egyptian vulture, a resident raptor that breeds in the Bikaner landscape, was recorded in abundance. Similarly, Steppe eagle was encountered commonly with an encounter rate of 3.06 / 100km. However, our generalized linear model showed a decrease in Steppe eagle abundance in canal irrigated areas. Stoliczka's bushchat, a rare and cryptic species, was recorded in Khajuwala and Mahajan Field Firing Range, adding additional distribution records to the range of the understudied bird

(Rahmani, 1996). Northern lapwing, a rare winter migrant to northwestern India, was seen in RD 507 wetland.

4.3 Comparison between Bikaner and Jaisalmer landscapes

Our current survey in Bikaner and the regular surveys in Jaisalmer (Dutta et al. 2018) have allowed us to compare the socio-ecological characteristics of these adjoining districts which are similar in terms of bioclimate but have different trajectories of land-use change.

4.3.1 Habitat

Compared to Jaisalmer, the Bikaner district is more undulating with a predominance of sandy substrate. Consequently, the proportion of shrublands is much higher and the proportion of grasslands much lower in Bikaner as compared to the Jaisalmer district. In terms of human artefacts, the proportion of points with powerlines was seen to be higher in Bikaner (0.52) than in Jaisalmer (0.42).

4.3.2 Mammals

The difference in habitat and perhaps the difference in climatic conditions is reflected in the density of two mammal species which we surveyed rigorously. The density of Desert fox was almost four times higher in Bikaner (0.58 per km^2) as compared to Jaisalmer (0.15); that of Chinkara was twice that of Jaisalmer (2.05) in Bikaner (4.27). The potential reasons for these differences are climate (Bikaner is less arid), habitat (Bikaner is more shrubby), terrain (Bikaner is more undulating) and social outlook towards wild animals.

4.3.3 Small birds

The winter bird assemblage in Bikaner was dominated by common species such as Eurasian collared dove, House sparrow, White-eared bulbul and Red-vented bulbul. It was almost completely devoid of understory insectivores (e.g., Desert wheatear, Isabelline wheatear, Cream-coloured courser). This is in stark contrast to the pattern in Jaisalmer district (Kher and Dutta 2021). The probable reason for this might be the lack of productive grasslands and the general agriculturalization of the landscape that have facilitated these generalist species and negatively affected the specialist species.

4.4 Species habitat associations

Bikaner district presents a variety of habitats that can influence the distribution and ecology of local fauna. Apart from the natural features described in the results section, anthropogenic activities (agriculture and livestock grazing) also vary considerably across the landscape. Our analyses looked at how some of these gradients affect the distribution and abundance of key wildlife species at a landscape scale.

For example, the Chinkara, although present across the region, showed a significant decline in abundance with an increase in irrigation and irrigated agriculture. This validates predictions of other studies (Rahmani and Sankaran, 1991i) from the past, which have listed the development of irrigated agriculture due to the Indira Gandhi Canal as a major threat to the Chinkara population in the Thar desert. On the contrary, Nilgai seemed to increase considerably with the increase in the proportion of irrigated agriculture in the cell. A potential reason for the contrasting patterns might be the availability of surface water, which limits the distribution of Nilgai in the non-irrigated parts of the desert.

Habitat associations of carnivore species in the landscape were markedly different from herbivores. The Desert fox did not show any detectable change in density in response to terrain, substrate, irrigation or proportion of cultivated area in the landscape. This is potentially due to the adaptable nature of the species, which allows it to survive in a variety of habitats, including human-dominated landscapes. However, free-ranging domestic dogs were positively associated with flat terrain and anthropogenic disturbance. Other studies from the Thar desert have shown that free-ranging dogs depend on settlements for subsidies and that their usage is maximum in wildlife areas close to settlements (Mohandas, 2017; Pandey, 2021 unpublished data). Our results are in consonance with this general pattern. We also recorded Desert cats during our surveys but could not discern their habitat relationships due to the small sample size.

For birds, there were three prominent abundance and distribution patterns. Some birds, like the Steppe eagle, Egyptian vulture, Yellow-eyed pigeon, Black-crowned sparrow lark, were significantly less in areas under irrigation and cultivation. These represent the species that are vulnerable to landscape-level land-use change. Raptors were unsurprisingly the worst affected group as they are large ranging and placed higher up on the trophic scale. The second group constituted birds that were favoured by irrigation and irrigated agriculture. Most of these species, such as the Indian Roller, Rufous treepie, Rose-ringed parakeets, were found almost exclusively in irrigated areas; and other studies have shown that their distribution in the area has historically been driven by the Indira Gandhi Canal (Rahmani and Soni 1997). The third group consisted of synanthropic or generalist species that were found in greater numbers in distrubed areas, e.g., Indian peafowl, Black drongo, Eurasian collared dove. Some birds were also associated with terrain: the Indian robin, Indian peafowl, and Common babbler were more widely distributed and abundant in flat terrain.

4.5 Wetlands

Wetlands are important socio-ecological systems and provide ecosystem services to both humans and wildlife. They are particularly important for waterbirds, which depend on them entirely for feeding and breeding. Many of India's wetlands fall on the Central Asian Flyway and are important migratory grounds for Eurasian species. Considering their disproportionate ecological importance, we surveyed one natural and three artificial wetlands. The natural waterbody, Lunkaransar Lake, was an important wintering ground for the Demoiselle cranes, which congregate here in large numbers. The lake also hosts other migratory birds of saline and brackish waters such as Pied Avocet and inland water birds like the Northern shoveler and Great crested grebe. The two artificial water bodies (750 RD and 507 RD), formed by the escape water of the Indira Gandhi Canal, were also found to be rich in migratory avifauna. The 750 RD, which comprises many small and large water bodies, supported a very diverse bird community, probably driven by the higher habitat heterogeneity and, therefore, more foraging niches. A total of 15,666 individuals belonging to 76 bird species were recorded at 750 RD. This included many waterfowls, waders and raptors, most of whom depend entirely on large water bodies.

Some of the species found in these three wetlands are charismatic and sought after by nature enthusiasts and wildlife photographers, thus providing an opportunity for eco-tourism. Eco-tourism could provide an additional livelihood to the people living in the area and help increase environmental awareness. But several factors should be considered before planning an ecotourism site. Tar road network for accessing the site can facilitate tourism, thereby generating more conservation revenue and livelihoods, but can have adverse effects on the wetland bird communities, through the fragmentation of habitats, restriction on bird movements, increased mortality from collisions, and general disturbances, as shown by some studies (Gois et al., 2018). Notably, all three wetlands are currently managed by local communities for fishing and allied activities that are perhaps compatible with wetland conservation, given the high avian diversity and abundance. Thus, any management intervention in the area should be done in consultation and collaboration with the fishers to avoid negative repercussions on their livelihoods that may arise from stringent restrictions. While this ecosystem is very significant for birds and humans and needs to be conserved, the above factors need to be considered when planning management strategies.

4.6 Social perception

Questionnaires revealed a high degree of wildlife awareness among the local people of Bikaner. Responses pertaining to wildlife status, trends and threats were realistic and in line with expert views on this subject. Reporting frequencies of wildlife trends, particularly the increasing occurrences of Dog, Nilgai and Wild pig, and the decreasing occurrence of Chinkara are congruent with scientific observations on the Thar desert ecosystem (Dutta et al., 2018). Such patterns are believed to result from increased water availability due to irrigation and the concomitant spread of agriculture and human footprint that have facilitated species such as free-ranging Dogs and Nilgai. Respondents identified habitat loss due to agricultural expansion and intensification as the most important threat to regional wildlife and pointed out very specific threats such as borewell irrigation, fencing and pesticide use that are prevalent across the Bikaner landscape. Such extensive changes in land use and the emergence of new infrastructure (particularly power lines - Jhala et al. 2020) is a likely reason behind the disappearance of the Great Indian bustard from much of its historical range in Bikaner. Unsurprisingly, only 2% of respondents reported sighting the species in recent times. Large areas of the Bikaner landscape were reserved for pastoral use as *gauchars* and *Orans* that also harboured wildlife. However, as noted by respondents, such areas have been encroached on for cultivation. Strengthening traditional institutions that are compatible with wildlife will be the key to conservation in such vast, unprotected, yet biodiversity rich landscapes.

4.7 Capacity building through citizen science surveys

Awareness about the natural world is essential for both ecological and human well-being; and generally arises from first-hand experience with plants, animals, wildlife and wilderness. At the same time, structured observations by citizens contribute significantly to our understanding of biodiversity and wildlife. Citizen science is thus considered an important part of modern-day ecological research. We conducted the Bikaner Survey 2021 in a citizen science framework considering the huge potential of large-scale surveys in training research personnel and promoting nature awareness. To achieve these dual objectives, we collaborated with local institutions and civil society and conducted the survey through a volunteer driven effort.

Volunteers and interested students were trained through a two-stage workshop. The first stage consisted of a classroom workshop held at Govt. Dungar College, which sensitized the audience about the biodiversity of the Thar landscape and the basics of ecological research. In the second stage, students and volunteers were taken to the Jorbeed Conservation reserve and trained in ecological survey techniques and instrumentation. 52 students/volunteers attended the workshop and were sensitised towards desert biodiversity. Nineteen students/volunteers further joined us for the large scale surveys and got trained in desert ecology, wildlife survey techniques and basics of field biology.

4. Management implications

The Bikaner region is undergoing large-scale land-use changes due to irrigated agriculture, infrastructure and industries. Natural habitats are reducing, and traditionally conserved *Orans* are being encroached on for agriculture, reducing wildlife habitats and pastures for livestock. Borewell irrigation has flourished in the recent past, posing concerns over groundwater sustainability. Yet, some of these developmental activities are necessary for the social and economic development of the local populace. Moreover, the Bikaner region does not have many PAs, which can safeguard some parts of the landscape from ecologically destructive changes. Consequently, a mixed conservation strategy based on land sparing and land sharing principles is advocated to safeguard conservation priorities along with sustainable development - values that are also shared by the local communities who requested this survey via the Hon'ble Member of Parliament. Traditional conservation ethos is strong in the landscape, and we believe that strategic conservation efforts can find ground support in the region. Local residents interviewed during the survey were aware of the resident fauna, general conservation trends and threats and reported many recent instances of agricultural encroachment of conservation areas. We thus recommend that strategic conservation plans be developed for the region by assessing the impacts of the abovementioned threats on key conservation-dependent species and harmonising their mitigation with objectives of human livelihoods and well-being. In this regard, our survey builds up a foundation for more research to build upon. Yet, given the snapshot nature of our survey, we advocate the need for more long-term and focused studies for planning effective conservation measures. Nonetheless, some of the key recommendations based on this survey, and consultation with the State Forest Department and local Universities/Institutions, are as follows:

1. Sites such as Jorbeed Conservation Reserve, Deshnok Oran, Tokla Oran, Bhinjranwali and 750RD require greater conservation emphasis given their wildlife values. The exact conservation actions should be planned through research followed by consultation between local conservation institutions and stakeholders. Agricultural encroachment in *Orans* needs to be reduced by strict enforcement and strengthening local management institutions through consultation with locals.

2. Impacts of potential threats such as power lines, free-ranging dogs and fences need to be mitigated, preferably across the landscape and at least around these key sites. Power lines are a known cause for collision and mortality of birds and bats. Some key sites where power lines need to be mitigated by installing Bird Flight Diverters include areas with high raptor and waterbird populations such as Jorbeed, Deshnok oran, RD507, RD750, Lunkaransar Lake. Whereas the large population of free-ranging dogs are a potential threat to native fauna through the effects of predation, competition and disease risk. Our observations in Jaisalmer also suggest that dogs often corner and predate chinkara at fences; hence, their combined presence can be particularly detrimental.

3. Few grassland areas can be restored across the landscape through fencing, grass plantations and restriction of livestock movement in initial years and rotational grazing in subsequent years to benefit grassland specialists that are currently rare or missing in the region and to simultaneously support livestock production. Similarly, a fodder farm model of grassland management (similar to the *vidi* system in Gujarat) can be adopted in some suitable areas to facilitate both wildlife and domestic livestock.

4. Select wetlands can be promoted for ecotourism to generate conservation revenues and livelihoods, although the exact management actions should be carefully planned through consultation with existing stakeholders and research to avoid any unintended detrimental effect on bird conservation and existing livelihoods.

5. The current survey approach can be reproduced once every 4-5 years by the network of conservation institutions and individuals active in this region, in a citizen science framework, to monitor the wildlife trends and highlight important conservation threats for mitigation. The multiple season species' distribution data generated from these surveys can aid in spatial conservation prioritization, wherein some areas are spared for biodiversity and others shared with agricultural production.

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List of appendices:

1. Data form of questionnaire for assessing community perception towards wildlife
2. Data form for key wildlife sightings in 2-km segments of vehicle trail
3. Data form for habitat characteristics at every 2-km along vehicle trail
4. Data form for bird sampling at point counts
5. Checklist of birds in Bikaner
6. Interim report on the Status of migratory birds and key wildlife in Bikaner, Rajasthan, 2020


Pc: sherwin

APPENDIX

BUSTARD
RECOVERY PROGRAM

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Government of Rajasthan
FOREST DEPARTMENT