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Vertebrate biodiversity in King Khalid Royal Nature Reserve, Central Saudi Arabia, with a new range-expansion of *Trachylepis tessellata*

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Abstract. *Almutairi AA, Albeshr MF, Eid E. 2025. Vertebrate biodiversity in King Khalid Royal Nature Reserve, Central Saudi Arabia, with a new range-expansion of* Trachylepis tessellata*. Biodiversitas 26: 4065-4076.* Arid protected areas in Central Saudi Arabia remain under-surveyed for vertebrate diversity, constraining evidence-based management. King Khalid Royal Nature Reserve (KKRNR), an arid habitat mosaic northeast of Riyadh, Saudi Arabia, lacks contemporary faunal baselines. We conducted the first systematic, year-round assessment of vertebrates in KKRNR to compile a field-verified checklist, highlight notable distributional records, and identify conservation-value habitats. In 2023, we sampled four habitat types (wadis, dunes, plains, plateaus) across 19 fixed sites using complementary methods: diurnal/nocturnal line transects, fixed-radius point counts, visual-encounter surveys, camera trapping (760 trap-days), Sherman live-trapping (665 trap-nights), and verified opportunistic records. We documented 77 species (14 mammals, 43 birds, 20 reptiles), including eight globally threatened taxa and two introduced breeding residents. Birds comprised the largest share (43/77; 56%), consistent with KKRNR's location on the Palearctic–African flyway. Seasonal richness peaked in autumn (57 species) and was lowest in winter (28), with significant seasonal differences (ANOVA $F = 12.84$, $p < 0.001$). Spatial patterns were pronounced: wadis supported the highest diversity (Shannon $H' = 2.73$; evenness $J' = 0.84$), whereas dunes and plateaus were comparatively species-poor, underscoring moisture and structural complexity as key drivers. We confirmed a range extension of the tessellated mabuya (*Trachylepis tessellata*) into the Riyadh region, with seven individuals near cultivated, mesic microhabitats, suggesting broader habitat tolerance or prior under-detection. These results establish a current baseline and pinpoint wadi networks as priority habitats for protection and restoration. Management should safeguard and rehabilitate wadis, regulate grazing/infrastructure on dune and plateau margins, and institute long-term monitoring that couples standardized surveys with passive acoustics and environmental DNA to improve detection of cryptic taxa. The findings align with Saudi Arabia's Vision 2030 objectives for effective protected-area management and biodiversity monitoring in arid ecosystems.

Keywords: Birds, desert fauna, herpetofauna, mammals, protected area

INTRODUCTION

Saudi Arabia, covering approximately 2,149,690 km², roughly 80% of the Arabian Peninsula, is the tenth largest country in the world, comprising 1.64% of global terrestrial area and about 8% of Asia's landmass (Vincent 2008). Geographically, the Kingdom spans latitudes 32°12′N to 16°00′N and is bordered by Jordan, Iraq, and Kuwait to the north; Yemen and Oman to the south; the Red Sea to the west; and the Arabian Gulf and United Arab Emirates to the east. Its terrain is characterized by seven major terrestrial physiographic regions and two distinct marine ecoregions, including the Tihamah coastal plain, Western Highlands, Arabian Hinterland, Cuesta (Sedimentary Najd) region, and extensive aeolian deserts such as An-Nafud, Ad-Dahna, Al-Jafurah, and the Rubʿ al-Khali (Child and Grainger 1990). Other key features include the As-Summan and Widyan plateaus, as well as the coastal zones of the Red Sea and Arabian Gulf (Vincent 2008).

This topographic diversity has given rise to significant biogeographic heterogeneity. Saudi Arabia lies at the intersection of the Afrotropical and Palearctic ecozones, serving as a key biogeographic bridge between Africa and Eurasia (Abuzinada et al. 2004; Al-Midfa et al. 2011). The Kingdom also falls along the Palearctic-African migratory flyway, underscoring its global significance for avian biodiversity (Abuzinada et al. 2004; Czudek 2005). Climatically, the country is largely arid, with extreme temperature variations and low annual rainfall. However, the southwestern highlands receive relatively higher precipitation, fostering localized ecological complexity (Almazroui 2020). These environmental gradients support a wide array of ecosystems that sustain rich biodiversity (Vincent 2008; Anashwan 2017). Nationally, Saudi Arabia is home to 498 bird species, 117 mammals, 128 species and subspecies of reptiles and amphibians, approximately 2,400 flowering plants, 266 coral species, and around 1,230 marine and freshwater fish (Bruckner and Dempsey 2015; Aloufi et al. 2019; Boland et al. 2020; Al Obaid et al. 2023; Al Ahmari et al. 2024; Al Malki et al. 2024; Al Ghamdi et al. 2025). It ranks second in floristic diversity on the Arabian Peninsula, with the highest plant endemism after Yemen (Ghazanfar 2024).

Recognizing this biological wealth, Saudi Arabia has positioned biodiversity conservation as a core pillar of its national development agenda through Vision 2030 (Khayat

et al. 2023). This strategy emphasizes environmental sustainability and the protection of natural ecosystems, supported by the expansion of protected areas, including the royal reserve network (Abuzinada 2003). In line with global commitments under the Convention on Biological Diversity, the Kingdom has pledged to conserve 30% of its terrestrial land area by 2030 (NCW 2022). Despite these advances, persistent knowledge gaps remain in documenting and monitoring vertebrate biodiversity, particularly in central regions. Most faunal surveys have focused on the southwestern and northwestern parts of the country (Aloufi et al. 2023), leaving central reserves like King Khalid Royal Nature Reserve (KKRNR) largely unstudied. Located northeast of Riyadh, KKRNR encompasses a variety of arid habitat types, including wadis, plateaus, sandy plains, and dunes, offering valuable ecological niches for diverse taxa.

Despite Saudi Arabia's expanding protected area network, much of the vertebrate research has focused on the southwestern highlands and western escarpments, including studies in Mahazat as-Sayd (Islam et al. 2014), Harrat al-Harrah (Seddon et al. 1997), and the coastal Eastern Province (Aloufi et al. 2023). Similarly, biodiversity surveys in northern regions such as Turaif (Paray and Al-Sadoon 2018) and northwestern provinces like Tabuk (Ansari et al. 2022) have received increasing attention, particularly in terms of mammalian and avian diversity. However, central desert reserves, such as the KKRNR, remain largely underexplored, especially regarding reptiles and amphibians, taxa that are often overlooked despite their ecological sensitivity to habitat and climate change. Existing faunal inventories rarely integrate seasonal or habitat-specific patterns, resulting in critical data gaps in understanding arid-zone biodiversity (Yoccoz et al. 2001; Hortal et al. 2015; Alsaleem et al. 2024; Alzahrani et al. 2025). Addressing these gaps is essential to Saudi Arabia's Vision 2030, which emphasizes biodiversity conservation, species monitoring, and establishing a robust ecological baseline to guide adaptive protected area management.

This study presents the first systematic faunal assessment of KKRNR, targeting three major vertebrate groups, mammals, reptiles, and birds, across habitats and seasons. It addresses a critical data gap in species distribution and habitat associations within Central Saudi Arabia, contributing essential baseline data for conservation planning under Vision 2030.

MATERIALS AND METHODS

Study area

The King Khalid Royal Nature Reserve (KKRNR) is located northeast of Riyadh in Central Saudi Arabia (approximate centroid: 25.47°N, 47.05°E) and spans an area of ~1,162 km². Established by royal decree in October 2019, it is part of the Kingdom's national efforts under Saudi Vision 2030 and the Saudi Green Initiative to expand terrestrial conservation coverage. The reserve lies within the Afro-Arabian-Sindian desert ecozone and represents a critical arid ecosystem characterized by diverse habitat types (Figure 1). The region exhibits a predominantly arid climate, with summer temperatures exceeding 45°C, winter temperatures ranging from 20°C to 30°C, and highly variable annual rainfall between 50 and 130 mm (Hasanean and Almazroui 2015). Elevation ranges from 600 to 800 meters above sea level, with major features including the Armah mountain range and the Wadi Al-Thumamah system.

KKRNR encompasses four principal habitat types: (i) wadis and depressions representing low-lying seasonal channels with dense vegetation and ephemeral water flow, (ii) sandy plains contain flat, open areas with scattered shrubs and grasses, (iii) elevated plateaus consists of rocky and gravel-covered uplands, and (iv) dune systems composed of loose aeolian sand formations with sparse cover. Key vegetation includes grey-hair acacia (*Vachellia gerrardii*), Common Fleabane (*Pulicaria undulata*), desert broom (*Rhanterium epapposum*), boxthorn (*Lycium shawii*), remith (*Haloxylon salicornicum*), and fire bush (*Calligonum comosum*). Wadis, such as Rawdat Umm Athlah and Wadi Al-Tawqi, function as ecological corridors following seasonal rainfall, enhancing habitat complexity and supporting diverse faunal assemblages.

Procedures

Sampling design

To capture spatial and temporal variation in vertebrate detections, the reserve was stratified into six ecological macro-plots spanning the four main habitat types (wadis, dunes, plains, plateaus). Within these strata, we selected 19 fixed study sites. Surveys ran from January-December 2023, with each site visited four times per season (304 site-visits total). All fieldwork was timed to periods of peak activity: early morning 05:30-11:00 and late afternoon 16:00-19:00 for diurnal taxa, and dusk-midnight 18:30-00:00 for nocturnal taxa. Each visit was conducted by 2-3 trained observers under favorable weather (avoiding extreme heat and high winds).

Line transects

At every site we established two parallel 500-m transects (≥100 m apart) and walked them at constant speed, recording all vertebrates seen or heard within ~200 m on either side. Transects were surveyed during 05:30-08:30 and again 16:00-19:00 on each visit; for nocturnal mammals and reptiles, supplemental passes were made between 18:30-00:00 when conditions allowed. For each detection we noted species, count, perpendicular distance (paced), behavior, and GPS waypoint.

Point count for birds

Five permanent point stations per site were surveyed in the first 3-4 hours after sunrise (within 05:30-09:30 window); each count lasted 10 minutes with a 50-m radius. All visual and aural detections were recorded, and nesting activity was checked during the breeding season (cliffs, trees, anthropogenic structures).

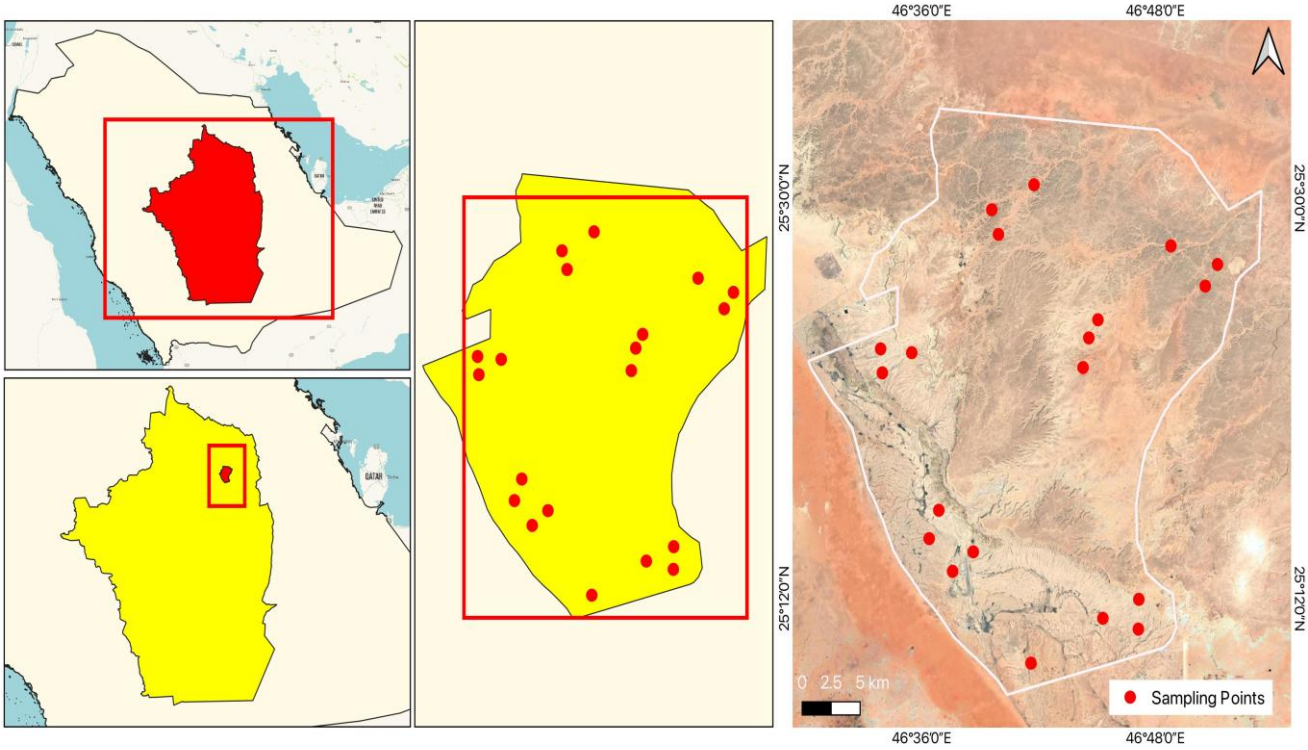

Figure 1. Sampling points in King Khalid Royal Nature Reserve, Saudi Arabia

Camera trapping

At every site we deployed five motion-triggered 1080p camera traps for eight consecutive days (24-h operation), targeting trails, water sources, burrows, and other microhabitats. We used olfactory attractants, where permitted to increase detection probability. All images were time-stamped and georeferenced; effort totaled 760 camera-trap days.

Sherman live traps

Five Sherman live traps (27×7×7 cm) were set at each site at dusk, baited with oats-peanut-butter, and checked at sunrise for seven consecutive nights (665 trap-nights). Captured animals were photographed, identified to species, and released at the capture site. Methods followed Royal Geographical Society field techniques for small mammals.

Active searches

Targeted searches were conducted in rock crevices, vegetated patches, and moist depressions, concentrating on peak thermal periods in spring-summer (typically 16:00-19:00 and, when safe, 18:30-00:00). A local herpetologist accompanied surveys to ensure safe handling/approach and accurate in-field identification.

Species identification

Species were identified using a combination of visual observation, camera-trap imagery, and, for small mammals, live captures (Sherman traps). All identifications were made by trained observers and verified against standard references: birds were identified using Porter and Aspinall (2013) and del Hoyo and Collar (2016); mammals were identified from direct sightings, camera-trap images, and live captures with verification against Harrison and Bates (1991) The Mammals of Arabia, and distributions were validated against the International Union for the Conservation of nature (IUCN) Red List and the regional IUCN assessment of Arabian mammals (2023) (Mallon et al. 2023); reptiles and amphibians were confirmed from active searches and photographs using Arnold's key to Arabian lizards and amphisbaenians and Snakes of Arabia, with taxonomy and status checked against the IUCN Arabian reptiles assessment (Arnold 1986). Where uncertainty remained, photographs were reviewed by a local expert herpetologist.

Statistical analysis

To quantify vertebrate diversity across habitats and seasons, species richness (S), Shannon-Wiener diversity index (H′), and species evenness (J′) were calculated for each site. Differences in richness and diversity between habitats and seasons were tested using one-way Analysis of Variance (ANOVA), followed by Tukey's HSD post hoc tests to detect significant pairwise differences. Confidence intervals (±1 standard error) were computed to evaluate variation in diversity metrics. Prior to analysis, data were tested for normality using the Shapiro-Wilk test and for homogeneity of variances using Levene's test. Data not meeting assumptions were log-transformed. All analyses were performed in R version 4.3.1 (R Core Team 2023). To ensure transparency and reproducibility, a summary of the field sampling design is provided in Table 1. It outlines survey dates, effort, and methods applied for each major

vertebrate group, facilitating assessment of data completeness and temporal coverage.

RESULTS AND DISCUSSION

Mammals

A total of 14 mammalian species representing seven families were recorded in KKRNR. The majority of these species (12 out of 14) are listed as Least Concern (LC) on the IUCN Red List, indicating relatively stable global populations. Two species are classified as Vulnerable (VU) due to ongoing population declines: the sand gazelle (*Gazella marica*), which was recorded in valley, dune, and plain habitats across all seasons, and the Arabian oryx (*Oryx leucoryx*), observed primarily in valleys during spring, summer, and winter (Table 2).

Birds

Table 3 presents 43 bird species recorded during the KKRNR survey. The majority (38 species) are classified as Least Concern (LC) on the IUCN Red List. In comparison, five species, European turtle dove (*Streptopelia turtur*), Eastern imperial eagle (*Aquila heliaca*), steppe eagle (*Aquila nipalensis*), Egyptian vulture (*Neophron percnopterus*), and long-legged buzzard (*Buteo rufinus*), are listed as either Vulnerable (VU) or Endangered (EN). In terms of residency status, 26 species are Breeding Residents (BR), with the remainder consisting of Passage Migrants (PM; 17 species), Winter Visitors (WV; 7 species), and several that exhibit mixed migratory patterns such as BM/PM, PM/WV, or BR/WV/PM, indicating complex movement ecology. In addition, two species, the white-eared bulbul (*Pycnonotus leucotis*) and common myna (*Acridotheres tristis*), are introduced breeding residents. Importantly, eight species recorded during the survey are listed under Appendix II of the Convention on Migratory Species (CMS).

Table 1. Summary of field survey effort by taxonomic group in King Khalid Royal Nature Reserve, Saudi Arabia (January-December 2023)

Taxonomic group	Survey method	Sampling period	Sites visited	Survey frequency	Total effort
Mammals	Line transects, camera traps, Sherman traps	Jan-Dec 2023	19	4 visits/season/site	304 site-visits; 760 trap-days; 665 trap-nights
Birds	Point counts, direct observation	Jan-Dec 2023	19	4 visits/season/site (AM)	304 site-visits; 10 min/point × 5 points/site
Reptiles	Visual encounter surveys (VES)	Mar-Oct 2023 (peak activity)	19	4 visits/season/site (PM)	152 site-visits; ~1.5 hr/search effort/site
All groups	Opportunistic sightings and photos	Jan-Dec 2023	19	Continuous	Integrated into the master checklist

Table 2. Mammalian species recorded during the survey based on season (IUCN red list status: LC: Least Concern, VU: Vulnerable), (Season: S: Spring, Su: Summer, A: Autumn, W: Winter)

Common name (Species)	Red list status	Habitat type				Season
		Valley	Dune	Plain	Plateau	
Family: Erinaceidae						
Desert hedgehog (*Paraechinus aethiopicus*)	LC			X		S, Su, A
Family: Vespertilionidae						
Great pipistrelle (*Pipistrellus kuhlii*)	LC	●				Su
Family: Dipodidae						
Lesser Egyptian jerboa (*Jaculus jaculus*)	LC	●				S, Su, A
Family: Muridae						
Arabian spiny mouse (*Acomys dimidiatus*)	LC				X	Su
Wagner s gerbil (*Dipodillus dasyurus*)	LC	●				S, Su, A
Cheesmans gerbil (*Gerbillus cheesmanii*)	LC	●	X			All
Balochistan gerbil (*Gerbillus nanus*)	LC	●				Su
Asiatic hairy-footed gerbil (*Meriones libycus*)	LC	●	X			S, Su, A
Gentle jird (*Meriones crassus*)	LC	●	X			S
Family: Canidae						
Arabian wolf (*Canis lupus* subsp. *arabs*)	LC	●				All
Red fox (*Vulpes vulpes* subsp. *arabica*)	LC	●			X	All
Family: Felidae						
Wild cat (*Felis silvestris subsp. lybica*)	LC	●			X	S
Family: Bovidae						
Sand gazelle (*Gazella marica*)	VU		X	X		All
Arabian oryx (*Oryx leucoryx*)	VU	●				S, Su, W

Table 3. Bird species recorded during the survey

Common name (Species)	Habitat type				Season	Status in Saudi Arabia	Red list status	CMS status
	Valley	Dune	Plain	Plateau				
Family: Phasianidae								
Sand partridge (*Ammoperdix heyi*)	●				All	BR	LC	NL
Family: Columbidae								
Collared dove (*Streptopelia decaocto*)	●		●	●	A	BR	LC	NL
Common pigeon (*Columba livia*)	●			●	All	BR	LC	NL
Laughing dove (*Spilopelia senegalensis*)	●				A, S	BM/PM	LC	NL
European turtle dove (*Streptopelia turtur*)	●				A	BR	VU	II
Namaqua dove (*Oena capensis*)	●				All	BR	LC	NL
Family: Strigidae								
Desert eagle owl (*Bubo ascalaphus*)	●		●		All	BR	LC	NL
Eurasian scops owl (*Otus scops*)	●				A, S	WV/PM	LC	II
Family: Accipitridae								
Asian imperial eagle (*Aquila heliaca*)	●				All	WV	VU	II
Steppe eagle (*Aquila nipalensis*)	●			●	All	PM/WV	EN	II
Egyptian vulture (*Neophron percnopterus*)	●				All	PM/BR/WV	EN	II
Long-legged buzzard (*Buteo rufinus*)	●				All	PM/WV/BR	VU	II
Family: Meropidae								
Arabian green bee-eater (*Merops cyanophrys*)	●				All	BR	LC	NL
Bee-eater (*Merops apiaster*)	●				A, S	BM/PM	LC	NL
Family: Falconidae								
Common kestrel (*Falco tinnunculus*)	●				All	BR/WV/PM	LC	II
Family: Orilidae								
Eurasian golden oriole (*Oriolus oriolus*)	●				A, S	PM/BR	LC	NL
Family: Laniidae								
Great gray shrike (*Lanius excubitor*)	●				All	BR/WV/PM	LC	II
Lesser gray shrike (*Lanius minor*)	●				A, S	PM	LC	II
Red-backed shrike (*Lanius collurio*)	●				A, S	PM	LC	NL
Family: Corvidae								
Brown-necked raven (*Corvus ruficollis*)	●	●	●	●	All	BR	LC	NL
Family: Alaudidae								
Desert lark (*Ammomanes deserti*)	●		●	●	All	BR	LC	NL
Bar-tailed lark (*Ammomanes cinctura*)	●		●	●	All	BR	LC	NL
Crested lark (*Galerida cristata*)	●		●	●	All	BR	LC	NL
Greater hoopoelark (*Alaemon alaudipes*)	●	●	●	●	All	BR	LC	NL
Temminck's lark (*Eremophila bilopha*)	●	●	●	●	All	BR	LC	NL
Family: Acroceohalida								
Eastern olivaceous warbler (*Iduna pallida*)	●				A, S	BM/PM/MV	LC	NL
Family: Hirundinidae								
Common house martin (*Delichon urbicum*)	●				A, S	PM	LC	NL
Red-rumped swallow (*Cecropis daurica*)	●				A, S	PM/BR	LC	NL
Pale crag martin (*Ptyonoprogne obsoleta*)	●				A, S	BR	LC	NL
Family: Pyconotidae								
White-eared bulbul (*Pycnonotus leucotis*)	●				A, S	BR (Introduced)	LC	NL
Family: Phylloscopidae								
Willow warbler (*Phylloscopus trochilus*)	●				A, S	PM	LC	NL
Family: Sylviidae								
Lesser whitethroat (*Sylvia curruca*)	●				A, S	PM/WV	LC	NL
Common whitethroat (*Sylvia communis*)	●				All	PM	LC	NL
Family: Sturnidae								
Common myna (*Acridotheres tristis*)	●			●	All	BR (Introduced)	LC	NL
Family: Muscicapidae								
Spotted flycatcher (*Muscicapa striata*)	●					PM	LC	NL
White-crowned wheatear (*Oenanthe leucopyga*)	●			●	S, A, W	BR	LC	NL
Mourning wheatear (*Oenanthe lugens*)	●		●	●	S, A, W	BR	LC	NL
Blackstart (*Oenanthe melanura*)	●			●	S, A, W	BR	LC	NL
Northern wheatear (*Oenanthe oenanthe*)	●		●		All	PM	LC	NL
Desert wheatear (*Oenanthe deserti*)	●	●	●	●	All	PM/MV/BR	LC	NL
Family: Hypocoliidae								
Gray hypocolius (*Hypocolius ampelinus*)	●				A, S	WV	LC	NL
Family: Passeridae								
Spanish sparrow (*Passer hispaniolensis*)	●		●	●	A, S	BR/WV	LC	NL
House sparrow (*Passer domesticus*)	●		●	●	All	BR	LC	NL

Note: LC: Least Concern, VU: Vulnerable, EN: Endangered, BR: Breeding Resident, BM: Breeding Migratory, PM: Passage Migrant, WV: Winter Visitor, II: CMS Appendix II, NL: Not Listed), (Season: S: Spring, Su: Summer, A: Autumn, W: Winter

Reptiles

A total of 20 reptile species representing ten families were recorded within King Khalid Royal Nature Reserve, highlighting the herpetofauna diversity of this arid ecosystem (Table 4). Most species (19 out of 20) are classified as Least Concern (LC) on the IUCN Red List, indicating stable populations across their ranges. Notably, the small-scaled Egyptian spiny-tailed lizard (*Uromastyx aegyptia microlepis*) is listed as Vulnerable (VU) due to ongoing threats such as habitat degradation and illegal collection. An important finding was the presence of *Trachylepis tessellata*, a species not previously recorded in Central Saudi Arabia. Seven individuals were observed near the reserve's central macro-plot, all near cultivated areas and residual water sources (Figure 2).

Of the 77 species recorded, eight are listed under global threat categories on the IUCN Red List, including the Vulnerable *G. marica*, *Oryx leucoryx*, *U. a. microlepis*, and the Endangered *A. nipalensis* and *N. percnopterus*. Two introduced species were also recorded: *A. tristis* and *P. leucotis*, both classified as invasive in regional contexts. No regionally endemic species were confirmed, but several taxa (e.g., *Mesalina saudiarabica*, *Pseudotrapelus tuwaiqensis*) are largely restricted to the Arabian Peninsula, highlighting the importance of national conservation priorities. The herpetofauna checklist includes two range-restricted or near-endemic species of significant biogeographic interest. *Mesalina saudiarabica* is a Saudi Arabian endemic, with distribution limited to central and eastern regions of the Kingdom, favoring sandy and gravelly desert habitats (Sindaco and Jeremčenko 2008; Aloufi et al. 2023). Similarly, *P. tuwaiqensis*, recently described and primarily confined to the Tuwaiq escarpment and surrounding central plateau, represents a near-endemic agamid with strong habitat specificity (Aloufi et al. 2019).

Temporal distribution of vertebrate species

Seasonal patterns in vertebrate species richness were evident across KKRNR. A total of 21 species were consistently recorded in all four seasons, reflecting broad ecological adaptability. Species richness peaked in autumn (57), followed by summer (51), spring (49), and winter (28). ANOVA results confirmed significant seasonal differences ($F: 12.84$, $p<0.001$), with autumn showing the highest mean richness (57±2.6 SE), largely driven by migratory bird influx and elevated reptile activity. Winter had the lowest richness, primarily due to reptile inactivity and reduced migrant presence.

Table 4. Reptile species recorded during the survey (LC: Least Concern, VU: Vulnerable); (Season: S: Spring, Su: Summer, A: Autumn, W: Winter)

Common name (Species)	Habitat type				Red list status	Season
	Valley	Dune	Plain	Plateau		
Family: Gekkonidae						
Arabian desert gecko (*Bunopus tuberculatus*)	●				LC	Su, A
Common tuberculate Ground gecko (*Cyrtopodion scabrum*)	●				LC	Su, A
Dune sand gecko (*Stenodactylus doriae*)	●				LC	Su, A
Slevin's short-fingered geckko (*Stenodactylus slevini*)	●	●			LC	Su, A
Family: Phyllodactylidae						
Hasselquist's fan-footed gecko (*Ptyodactylus hasselquistii*)	●			●	LC	Su, A
Family: Agamidae						
Anderson's agama (*Trapelus persicus*)	●				LC	S
Agama (*Pseudotrapelus tuwaiqensis*)		●			LC	S
Egyptian spiny-tailed lizard (*Uromastyx aegyptia microlepis*)	●	●			VU	S, Su, A
Family: Lacertidae						
Bosc's fringe-toed lizard (*Acanthodactylus boskianus*)	●				LC	S, Su, A
Arnold's fringe-fingered lizard (*Acanthodactylus opheodurus*)	●				LC	S, Su, A
Schmidt's fringe-fingered lizard (*Acanthodactylus schmidti*)	●				LC	S, Su, A
Arabian short-nosed desert lizard (*Mesalina saudiarabica*)	●		●		LC	S, Su
Family: Scincidae						
Tessellated mabuya (*Trachylepis tessellata*)			●		LC	A
Family: Varanidae						
Desert monitor (*Varanus griseus*)	●	●			LC	S
Family: Trogonophidae						
Zarudnyi worm lizard (*Diplometopon zarudnyi*)		●			LC	Su, A
Family: Boidae						
Arabian sand boa (*Eryx jayakari*)		●			LC	Su, A
Family: Colubridae						
Diadem snake (*Spalerosophis diadema*)		●			LC	S
Moila snake (*Malpolon moilensis*)	●		●		LC	Su, A
Family: Viperidae						
Arabian horned viper (*Cerastes gasperettii*)	●	●			LC	Su, A
Burton's carpet viper (*Echis coloratus*)	●				LC	S

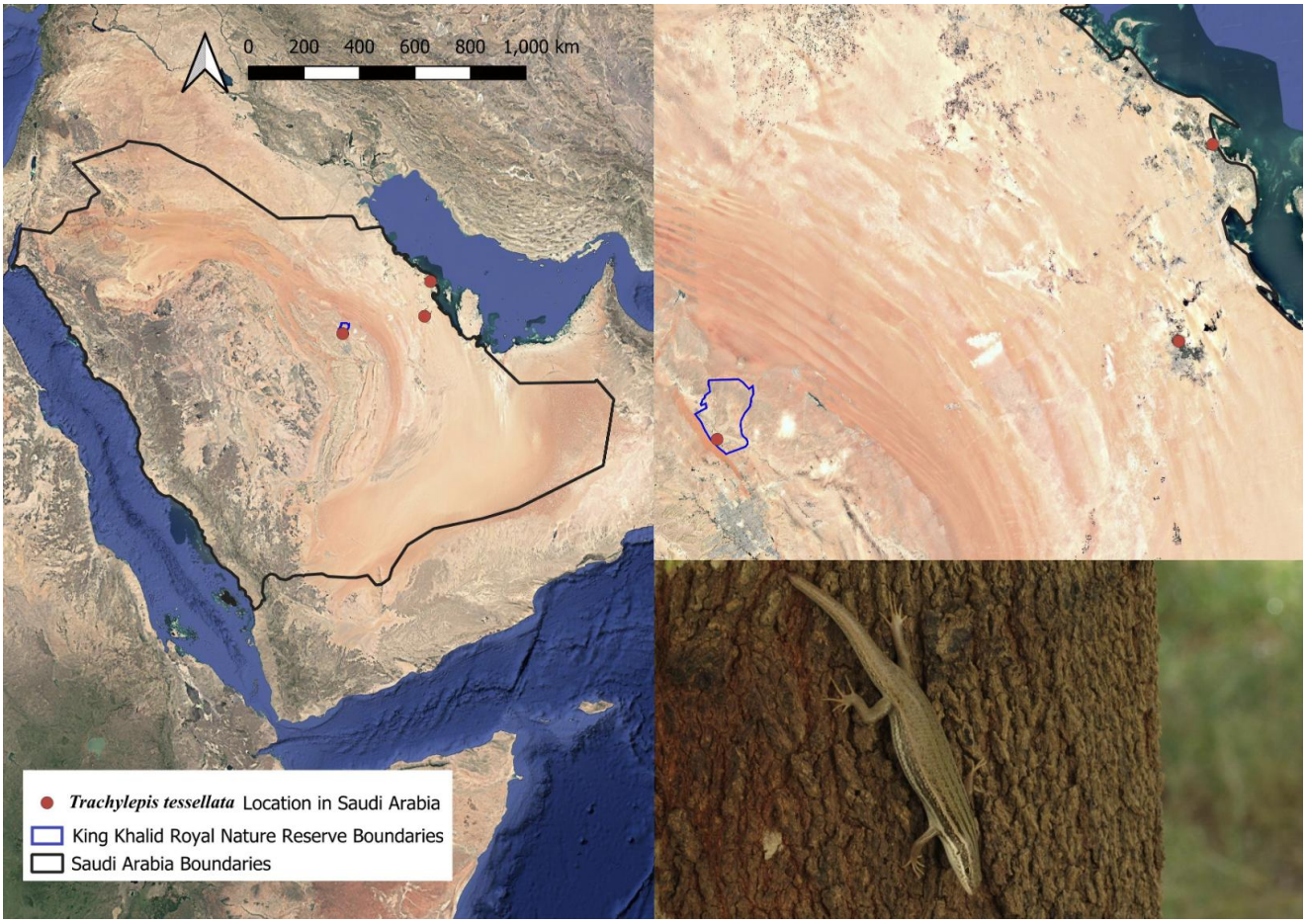

Figure 2. Previously documented distribution of *Trachylepis tessellata* in Saudi Arabia (Aloufi et al. 2023) and the new confirmed record in King Khalid Royal Nature Reserve (KKRNR), Central Saudi Arabia. The figure contains a field photograph of *T. tessellata* (photo by: Abdullah A. Almutairi) taken during the survey in KKRNR

Season-specific observations further revealed nuanced ecological dynamics. Three species, *Lanius minor*, *Delichon urbicum*, and *Cecropis daurica*, were confined to spring and winter, aligning with cool-season migratory patterns. Another three species, *A. heliaca*, *Falco tinnunculus*, and *Ptyonoprogne obsoleta*, occurred in autumn and spring, reflecting raptor migration peaks. Warm-season specialists included *Meriones libycus* and *M. saudiarabica* (spring-summer), and 10 reptile species (e.g., *Cerastes gasperettii*, *Eryx jayakari*, *Acanthodactylus schmidti*) that were exclusive to summer and autumn. Spring alone supported eight unique species, including *Felis lybica* and *S. turtur*, likely reflecting breeding and vegetative recovery. Summer contributed nine unique species, such as *Varanus griseus* and *Pipistrellus kuhlii*. Autumn featured seven exclusive species, including globally important migrants like *N. percnopterus* and *Phylloscopus trochilus*. No species were recorded exclusively in winter, underscoring seasonal climatic constraints.

Spatial distribution of vertebrate species

Vertebrate species richness varied among habitats (one-way ANOVA on Shannon diversity, H′H'H′: F:9.47, F:9.47, p<0.005p<0.005p<0.005). Valleys (wadis) supported the highest mammalian diversity (13 species), including *G. marica*, *F. lybica*, *Canis lupus arabs*, and *Gerbillus cheesmani*. Dunes hosted four specialized mammals, while plains and plateaus supported four and two species, respectively. Bird richness showed a similar pattern, with valleys harboring 43 species, including raptors (*A. nipalensis*, *N. percnopterus*), owls (*Bubo ascalaphus*), and resident larks, whereas plateaus and plains supported 15 and 13 species, and dunes had four species. Reptilian diversity peaked in valleys (14 species; e.g., *A. schmidti*, *U. a. microlepis*); dunes and plains supported five species each, and plateaus hosted one species (*Ptyodactylus hasselquistii*). Quantitative indices were consistent with these patterns: H′H'H′ was highest in wadis (2.73), followed by plains (2.02), plateaus (1.65), and dunes (1.19). Post-hoc Tukey HSD indicated higher H′H'H′ in wadis than in dunes and plateaus (adjusted p<0.05p<0.05p<0.05 for both contrasts). Evenness (J′:0.84, J':0.84, J′:0.84) was also highest in wadis (descriptive). Overall, birds comprised 53% of all records, followed by mammals (25%) and reptiles (22%), underscoring the reserve's importance for avifauna across habitats. Visual summaries showed clear spatial structuring of diversity

(Figure 3). Wadi dominance is consistent with greater structural complexity and moisture retention in these habitats. Photographs of species, including *T. tessellata* and *U. a. microlepis*, are provided in Supplementary Appendix 1.

Discussion

This study presents the first comprehensive assessment of vertebrate diversity in KKRNR, offering a critical ecological baseline for biodiversity monitoring and protected area planning in Central Saudi Arabia. The findings demonstrate that environmental heterogeneity and seasonal climatic variation are key drivers of faunal richness and community composition.

The dominance of birds (56% of all species recorded) reflects both their high ecological mobility and the reserve's location along the Palearctic-African migratory corridor, enabling seasonal influxes of passerines and raptors (Latif 2011). Reptile and mammal richness in KKRNR was closely tied to habitat structure, with wadis offering denser vegetation, moisture retention, and shade, which supported the highest species richness as ecological microrefugia. This is consistent with Boland and Burwell (2022), who found that structurally complex habitats like wadis enhance vertebrate habitat quality in arid ecosystems. These patterns align also with observations from Mahazat as-Sayd and Harrat al-Harrah reserves, where vegetated depressions and permanent water sources have been found to enhance vertebrate occupancy (Seddon et al. 1997; Islam et al. 2014). Human-modified areas near KKRNR's boundaries, including roads and livestock pathways, likely suppressed species presence in adjacent dune and plateau habitats due to noise, vehicle movement, and grazing. Habitat fragmentation and patch connectivity may further influence community composition by limiting dispersal, especially for small mammals and reptiles with low vagility. These findings underscore the importance of conserving heterogeneous habitat mosaics and regulating anthropogenic pressures to maintain vertebrate diversity in Saudi Arabia's central reserves.

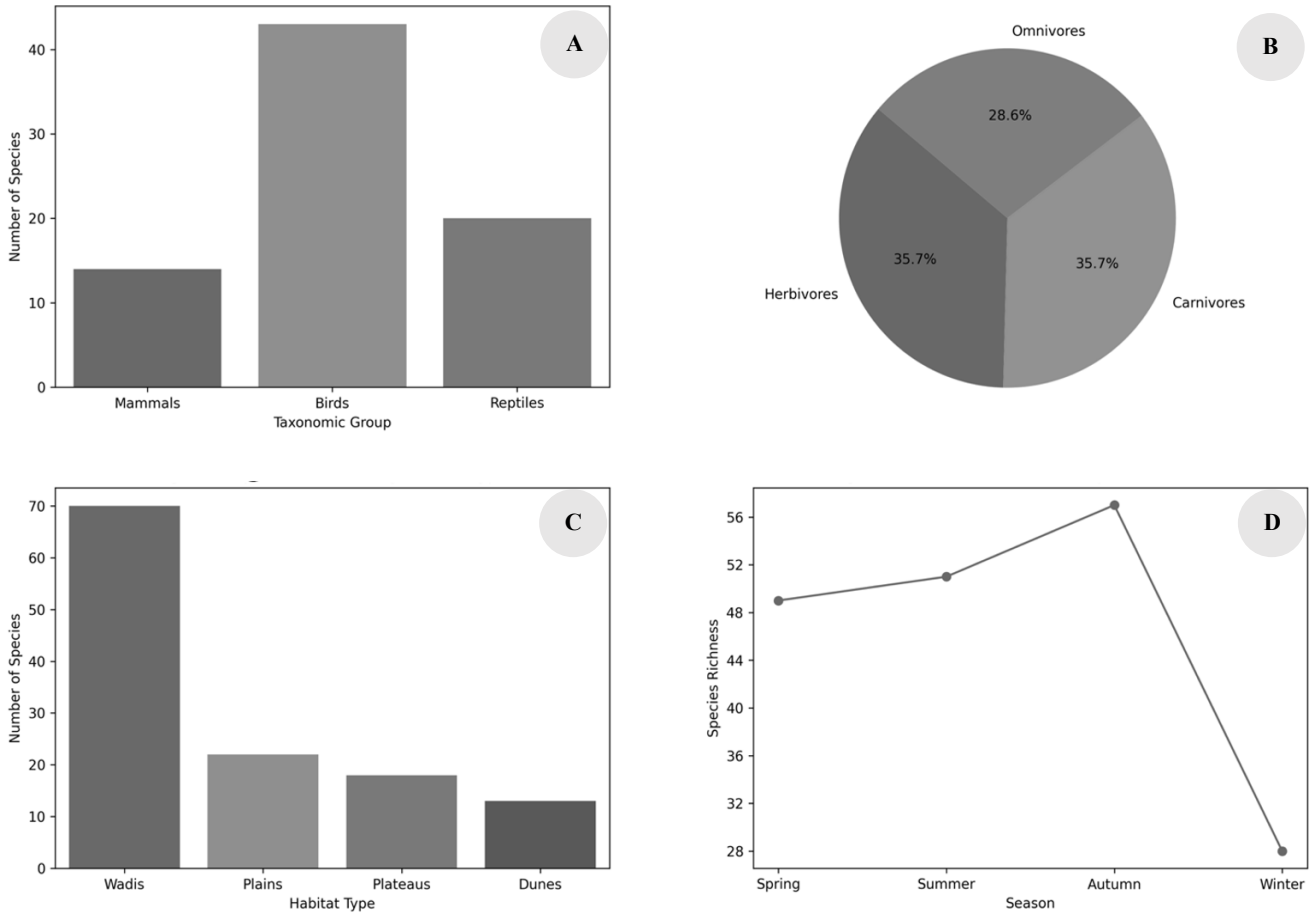

Figure 3. A. Species richness by taxonomic group, B. Mammalian ecological guild composition (no field diet sampling; see Methods, C. Species richness by habitat type, D. Seasonal variation in species richness

In comparison with other protected desert ecosystems in Saudi Arabia, the King Khalid Royal Nature Reserve exhibits both shared and distinctive patterns of vertebrate diversity. For instance, Mahazat as-Sayd supports 16 mammal species, including reintroduced ungulates and resident carnivores (Islam et al. 2014), while Harrat al-Harrah hosts over 20 mammals and 50 bird species in its basaltic lava plains (Seddon et al. 1997). The total of 77 vertebrate species recorded in the King Khalid Royal Nature Reserve, including 14 mammals, 43 birds, and 20 reptiles, is comparable in richness but notable in its inclusion of central desert taxa (e.g., *M. saudiarabica*) not reported from the aforementioned western or northern reserves. Uruq Bani Ma'arid, a southern reserve dominated by Rubʿ al-Khali sand systems, features fewer herpetofaunal records and lower avian diversity due to its hyper-arid environment (Williams et al. 2012). The detection of *T. tessellata* and near-endemic reptiles in the King Khalid Royal Nature Reserve emphasizes the unique biogeographic positioning of the reserve at the intersection of central plateau and escarpment-associated fauna. While some overlap in bird communities reflects regional migratory connectivity, the reptile assemblage of the King Khalid Royal Nature Reserve highlights its distinctiveness and value as a central biodiversity node, underscoring the need for further exploration.

Species richness peaked in autumn, driven largely by migratory bird influx and heightened reptile activity under favorable thermal and moisture conditions, while winter recorded the lowest richness due to climatic constraints on ectothermic taxa. These patterns mirror findings from steppe-desert habitats in northern Saudi Arabia, where bird abundance and diversity similarly fluctuated with season and habitat complexity (van Heezik and Seddon 1999). Unlike reptiles and birds, mammalian species exhibited relatively stable year-round presence, with minor spring peaks likely tied to vegetation growth and breeding cycles (Harding et al. 2007). This temporal variation reinforces the need for year-round monitoring to capture species turnover and detect seasonal specialists. Spatially, wadis supported the highest vertebrate diversity, underpinned by their structural and ecological complexity. These habitats offer not only microclimatic buffering but also harbor seed banks, higher primary productivity, and richer invertebrate prey bases, conditions conducive to sustaining vertebrate populations year-round (Médail and Diadema 2009; Severin et al. 2015). Regional parallels support this observation. In Mahazat as-Sayd Reserve, mammal richness correlates with vegetated depressions (Islam et al. 2014), while Harrat al-Harrah's wadis host a substantial share of the area's avifauna and mammals due to favorable microhabitats (Seddon et al. 1997). These findings affirm the role of structured habitats like wadis as climate refugia and ecological keystones within desert ecosystems. In contrast, species richness was lowest in dunes were high temperatures and sparse vegetation limit faunal assemblages.

The detection of *T. tessellata* in Central Saudi Arabia represents a significant range extension and suggests either broader habitat tolerance or insufficient herpetofauna surveying in inland regions (Sindaco et al. 2012). Previously known from the Red Sea escarpments and Levant, its presence in the King Khalid Royal Nature Reserve indicates that central Arabia may serve as a biogeographic bridge not only for birds but also for reptiles with limited dispersal capacity. Wadis and anthropogenically altered habitats, such as cultivated areas with residual water, may act as stepping-stone environments across the Najd Plateau, traditionally viewed as a dispersal barrier. This underscores the critical role of protected areas in facilitating the detection of cryptic range-expansions and improving species distribution models, as they often serve as initial colonization sites for expanding taxa and refuges that support biodiversity monitoring (Thomas et al. 2012). The species' disjunct distribution likely reflects historical climatic fluctuations: humid Holocene phases may have facilitated eastward expansion through increased vegetation and water availability, while Pleistocene aridification likely fragmented populations and restricted gene flow (Tchernov 1992; Böhme and Corti 1993; Sindaco and Jeremčenko 2008; Arnold 2009). Recent anthropogenic changes may now enable partial connectivity. These findings are consistent with broader Afro-Arabian reptile biogeography, where dry valleys and oases enable dispersal across arid zones (Carranza et al. 2008; Tamar et al. 2016). Phylogeographic studies are needed to resolve colonization pathways and demographic history in the region.

Beyond taxonomic richness, the vertebrate assemblage of the King Khalid Royal Nature Reserve reflects functional diversity, with species occupying key ecological roles in arid ecosystems. Omnivorous and granivorous rodents such as *M. libycus* and *G. cheesmani* contribute to seed dispersal and soil turnover, influencing vegetation dynamics and nutrient cycling (Hirsch et al. 2012). Reptiles such as *U. a. microlepis* act as herbivorous grazers and serve as prey for avian raptors and carnivorous mammals, reinforcing trophic linkages (AlRashidi et al. 2025). The Arabian wolf *C. l. arabs* functions as an apex predator, whereas the African wildcat *F. lybica* is a small-bodied mesopredator that primarily preys on small vertebrates, thereby regulating rodent and bird populations and interacting with higher trophic levels (Bonsen et al. 2024), while raptors including *A. nipalensis* and *B. rufinus* provide top-down control and serve as sensitive bioindicators of ecosystem health due to their susceptibility to environmental contaminants and prey base fluctuations (Sergio et al. 2008). Migratory insectivores and omnivorous birds such as *Lanius excubitor* and *Oenanthe deserti* play roles in pest regulation (Paczuska et al. 2021; Matyukhin et al. 2022), while species like *S. turtur* and *Ammoperdix heyi* support pollination and seed dispersal through their foraging behaviors (Gutiérrez-Galán and Alonso 2016). These trophic roles enhance ecological resilience, and their presence reinforces the importance of the King Khalid Royal Nature Reserve as both a biodiversity reservoir and a functioning arid ecosystem.

While this study employed a multi-method approach to maximize detection, certain taxa, particularly fossorial, cryptic, and strictly nocturnal species, may have been underrepresented due to methodological limitations. The

absence of pitfall trap arrays likely reduced the probability of detecting small, ground-dwelling reptiles and amphibians, while limited auditory surveys at night constrained detection of nocturnally vocal birds and bats. Additionally, acoustic detectors and eDNA tools were not employed, which could have enhanced the detection of elusive taxa such as shrews, small geckos, or insectivorous bats. Future biodiversity assessments in the King Khalid Royal Nature Reserve should incorporate passive acoustic monitoring, pitfall trapping, and environmental DNA sampling to improve detection sensitivity, particularly for secretive or low-abundance species. Addressing these gaps will enhance inventory completeness and inform species-specific conservation planning more effectively.

The King Khalid Royal Nature Reserve's location within the Afro-Arabian-Sindian transition zone and along the Great Rift Valley flyway enhances its international conservation relevance. The occurrence of eight Appendix II species under the Convention on Migratory Species (e.g., *S. turtur*, *F. tinnunculus*) positions the reserve as a priority site for migratory bird conservation under global agreements. However, the area faces mounting anthropogenic pressures, including overgrazing, infrastructure expansion, solid waste accumulation, and localized disturbance from aviation activities. These stressors risk undermining conservation gains unless proactively managed through regulatory enforcement and stakeholder engagement (Haddad et al. 2015; Erbe et al. 2022).

In conclusion, this study presents the first comprehensive inventory of vertebrate species in the King Khalid Royal Nature Reserve, revealing high taxonomic diversity shaped by habitat heterogeneity and seasonal dynamics. The dominance of birds, the range expansion of *T. tessellata*, and the presence of threatened and endemic taxa underscore the King Khalid Royal Nature Reserve's ecological significance and its alignment with Saudi Arabia's Vision 2030 biodiversity goals. Complex habitats such as wadis support rich bird and reptile communities. At the same time, lower diversity in dune and plateau areas may reflect edge effects or localized degradation linked to grazing and infrastructure. These findings underscore the importance of strengthening buffer zones, regulating nearby human activities, and integrating biodiversity monitoring into adaptive management strategies. Persistent knowledge gaps, especially for small mammals and reptiles, warrant targeted surveys and updated distribution records. Incorporating citizen science, local rangers, and community participation, particularly from nomadic herders with traditional ecological knowledge, can enhance data collection and stewardship. Structured outreach, digital tools, and school-based programs can expand monitoring reach. We recommend establishing a long-term biodiversity monitoring framework that combines traditional field methods with emerging tools such as environmental DNA to track trends, assess threats, and guide evidence-based conservation of this vital desert refuge.

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