هيئة تطوير محمية الإمام تركي بن عبدالله الملكية

Imam Turki bin Abdullah Royal Nature Reserve Development Authority

Imam Turki bin Abdullah Royal Reserve Ecological Studies Project

Executive Summary

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Study Methodology and Habitat Classification

Introduction

The habitat mapping activity conducted for the Imam Turki Bin Abdullah Royal Reserve (ITBA) represents a foundational component of its broader ecological assessment and conservation planning. Encompassing approximately 91,500 km²—around 5% of Saudi Arabia's landmass—the reserve is characterized by significant geomorphological and ecological heterogeneity. This study aimed to produce a scientifically robust habitat map that captures the spatial distribution and structure of the reserve's ecosystems. The map provides a critical baseline for biodiversity monitoring, environmental management, and strategic land use planning.

The mapping process was implemented through a phased methodology integrating satellite remote sensing, geospatial analysis, and extensive field validation. It adhered to the International Union for Conservation of Nature (IUCN) classification system, ensuring alignment with international conservation standards.

Geographic and Environmental Context

The ITBA reserve spans five administrative regions—Al-Jouf, the Northern Border, Qassim, Hail, and the Eastern Region—forming a key ecological corridor between the Nafud and Dahna deserts. The terrain exhibits an elevation gradient from 387 to 935 meters above sea level, influencing hydrology, soil characteristics, and microclimatic conditions. The climate is semi-arid, with average annual temperatures ranging between 21°C and 26°C and rainfall between 39 mm and 110 mm. Wind speeds, varying from 15.8 to 38.2 km/h, play a central role in shaping aeolian landforms, particularly sand dunes at higher elevations.

Geologically, the reserve features formations from the Devonian, Jurassic, and Cretaceous periods, in addition to Quaternary aeolian and fluvial deposits. This geological complexity directly impacts soil composition, water retention capacity, and erosion processes, all of which influence vegetation distribution and habitat structure.

General Methodology of Ecological Studies

Al-Hadaf Company selected the sampling sites for the flora and fauna surveys in two phases in coordination with the reserve experts. In the first phase, a map of the basic natural habitats was developed, while In the second phase, random samples representing these natural habitats were selected. This map will be used after the completion of the plant and animal surveys to project the results on the entire reserve to develop the required purpose maps.

The first phase relies on remote sensing techniques and geographic information systems (GIS), especially multispectral satellite images that allow through spectral fingerprints and the use of algorithms to process satellite images in the preparation of the natural habitats map . In addition, data such as topography maps and vegetation indicators were used to assist identifying the habitats of wadis and floodplains. The availability of information and the expertise of the Working Group in the field has also effectively contributed to the integration of this data and the production of an accurate map of the natural habitats in the reserve.

In the second phase, the natural habitats map was used to create a alyaer of squares with a scale of 5000x5000 m2 and selecting random samples representing natural habitats to start the flora and fauna surveys in the reserve.

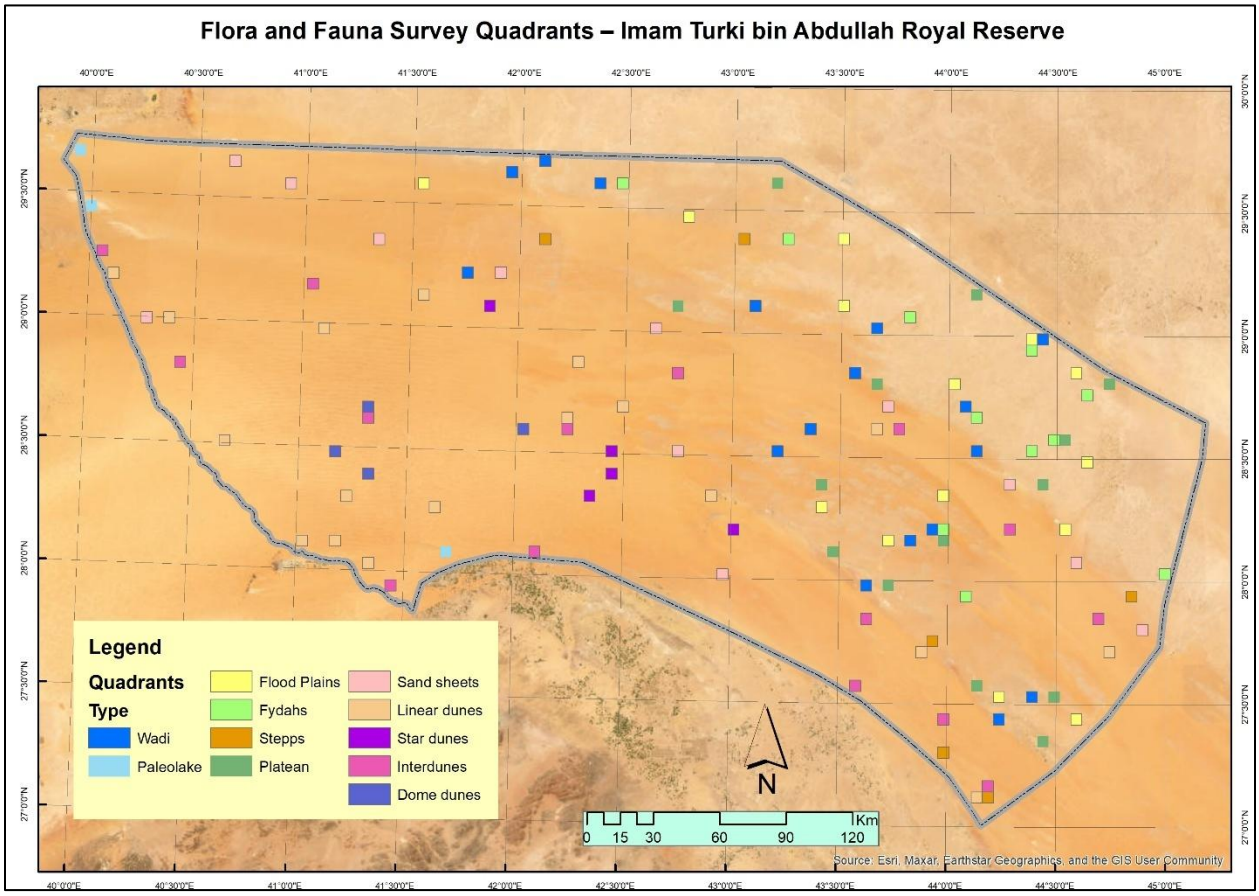
Selection of Sites for Flora and Fauna Surveys

The reserve had been divided into 25 km2 squares using Xtools connected to ArcGIS. An identification number has also been added in a table to be used at the intersection with the map of natural habitats.

Tabulate area analysis tools were used between the map of plots, the map of the natural habitats of the reserve, and the analysis of plots to identify homogeneous habitats, where the largest number of them were found in the following natural habitats: metamorphic dunes, longitudinal dunes and plateaus. While most plots have a great variety of natural habitats. Also, there are some natural habitats, such as Paleolake, that are mainly found in some plots only. In addition,

some natural habitats, such as star dunes were found in very localized areas that represent less than 5% of the plot area.

After several suggestions, Al-Hadaf Company, in cooperation with the experts of the ITBA, reached to an agreement of selecting 119 quadrants representing all natural habitats of the reserve, randomly distributed and covering all the lands of the reserve, and all suggestions and observations of the reserve team were taken into account, noting that the habitats at this stage have been identified based on unsupervised classification relying mostly on remote sensing techniques, to be updated based on the results of field studies and ground truthing.



Methodological Framework

Phase 1: Remote Sensing and Initial Classification

The first phase employed cloud-free, atmospherically corrected multispectral imagery from Sentinel-2 and Landsat 8. Using Google Earth Engine (GEE), initial classifications were performed using unsupervised clustering algorithms (e.g., K-Means, ISODATA, X-Means), allowing for the delineation of spectrally distinct land cover types. Ancillary geospatial datasets, including digital elevation models and landform maps, were incorporated to support ecological interpretation.

An initial habitat classification consisting of 12 habitat types was established based on satellite data and expert consultation. These included dune systems (linear, dome, star), interdunes, sand sheets, paleolakes, plateaus, floodplains, wadis, ElFiyyad depressions, rock outcrops, and steppes.

Phase 2: Field Survey and Supervised Classification

The second phase focused on improving classification accuracy through field data integration. Flora and fauna teams surveyed 1,785 plots within 119 quadrants, each measuring 50 × 50 meters. These ground-truth observations provided training data for supervised classification using machine learning algorithms within GEE, including Random Forest (RF), Support Vector Machine (SVM), and Classification and Regression Trees (CART).

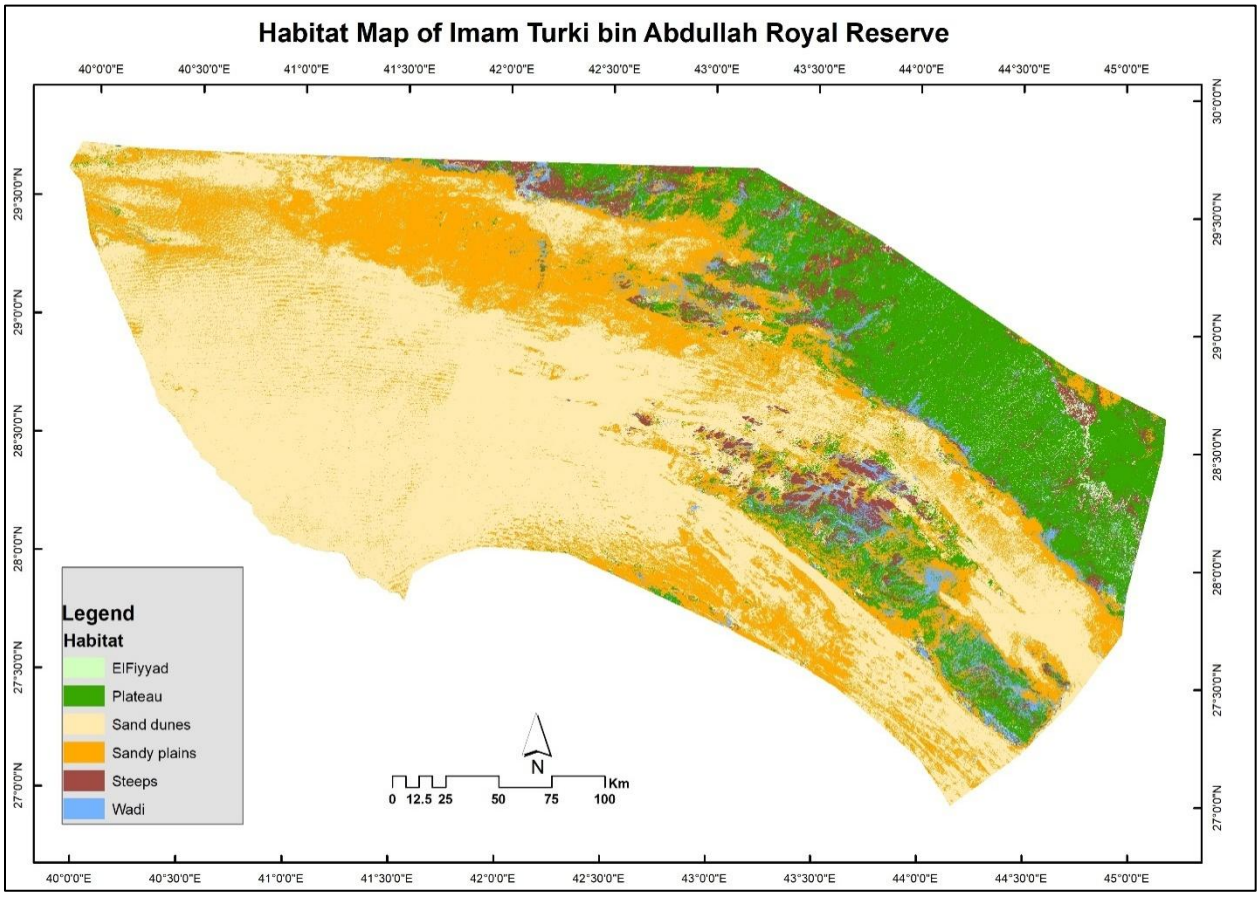
RF emerged as the most accurate model, though initial outputs revealed spectral confusion among sand dune subtypes and errors due to terrain shadows. A post-classification filtering process and topographic validation significantly improved the final output. Following the ecological assessment, the classification system was streamlined into six broader habitat categories more reflective of field observations and ecological relevance.

This restructuring, supported by expert ecological interpretation, addressed the lack of field-distinguishable characteristics among some of the original 12 classes. It also contributed to a substantial increase in classification accuracy—from 65% in Phase 1 to 81% in Phase 2.

Final Habitat Classification and Statistics

The refined classification system was structured according to the IUCN Level 2 typology under the category "8.1 Hot Desert" and comprises the following six classes:

Sand Dunes	Sandy Plains	Wadis	ElFiyyad	Plateaus	Steppes
44442 km2	22869 km2	2827 km2	977 km2	15072 km2	3906 km2



This habitat distribution highlights the dominance of sand dunes, which occupy nearly half of the reserve, followed by sandy plains and plateaus. Wadis, covering 2,826.9 km², represent critical linear features that support ecological corridors and seasonal biodiversity hotspots. ElFiyyad, though smaller in area, are key seasonal depressions of ecological significance. Steppes and rocky plateaus provide transitional zones with unique plant and animal communities.

The habitat map of the Imam Turki Bin Abdullah Royal Reserve reveals a distinct geographic distribution of habitat types closely aligned with topographic variation. Sand dunes are predominantly concentrated in the elevated eastern and southern regions, extending into the central zone—an atypical configuration for desert environments. This pattern suggests that upland wind corridors and exposed sedimentary surfaces have facilitated the accumulation and movement of dunes along ridges and slopes, where aeolian processes remain active even at higher elevations. Surrounding these dune systems, sandy plains are found across moderate elevation zones, forming smoother transitional belts in gently sloping terrain. These zones reflect lower wind intensity and serve as ecological buffers between dynamic dune fields and more stable upland formations. In contrast, plateaus dominate the northeastern highlands, characterized by flat, elevated surfaces and sharp escarpments that shape runoff and enhance habitat stability. Wadis, following steep elevation gradients, form a branching hydrological network that channels seasonal water flows from plateaus to lowland basins—supporting linear vegetation corridors in an otherwise arid landscape. Steppes occupy intermediate elevations, typically situated between plateaus and wadis, where shallow soils and moderate slopes support scattered, drought-adapted vegetation. Meanwhile, ElFiyyad depressions, confined to topographic lows and enclosed basins, act as temporary water catchments, offering essential seasonal habitats despite their limited spatial extent.

Among these diverse systems, the Taysiyah Protected Area, located in the southeastern central part of the reserve, stands out as a core ecological zone due to its exceptional habitat richness and topographic complexity. It spans a mosaic of ecosystems, including 1,526 km² of sand dunes, 1,067 km² of sandy plains, 772 km² of plateaus, 835 km² of steppes, 542 km² of wadis, and 38 km² of ElFiyyad depressions. This composition makes Taysiyah a critical reference area for understanding the reserve's environmental dynamics and a focal point for conservation and ecological monitoring efforts within ITBA.

Habitats Description

The natural habitats within ITBA vary, and each habitats is characterized by its natural landforms and its fauna and flora diversity that also vary according to climatic conditions, water level and altitude.

1. **ElFiyyad**: ElFiyyad is concentrated in the Al-Hujrah area, northeast of Taissiya, and it has important and vital environmental features as it contributes to carbon storage, improving air quality, mitigating the effects of climate change and sand encroachment, in addition to its richness in biodiversity, which includes different types of shrubby and perennial shrub plants such as wild Sidr, Talh and Awsaj, in addition to the biodiversity of animals and birds. ElFiyyad is a fertile habitat for natural rangelands with its high susceptibility to rehabilitation and development programs and the implementation of water harvesting methods, rainfall and afforestation projects.

2. **Plateaus:** The plateaus in the Imam Turki bin Abdullah Royal Reserve are mainly located in the middle of the eastern part of the reserve (Al-Taysiyah area). As the plateau slopes, an increase in vegetation cover is observed due to the growing density of the sand layer, where the tree vegetation cover increases and perennial tree species such as acacia and jujube appear.

3. **Sand Dunes:** Perhaps the most important component of the ecosystem in the Imam Turki bin Abdullah Royal Reserve is the sand dune habitat. Dunes are accumulations of loose sand on the earth's surface in the form of a mound with a crest. Sand dunes are formed as a result of erosion and the interaction of desert rocks with high temperatures and continuous winds, which leads to the disintegration of rocks and their fragmentation into sand grains of varying sizes and shapes. The most famous plants that live in the sand dune habitat are: *Rhanterium epapposum*, *Lycium shawii*, and *Calligonum comosum* L'Hér. some of which have high pastoral value and are relied upon by the local community. Animal species such as reptiles, birds, and mammals live in the sand dune habitat, most notably rodents, due to their special ability to adapt to harsh environmental conditions.

4. **Sandy Plains:** The sandy plains habitat extends across the central and northern parts of the Imam Turki bin Abdullah Royal Reserve.

5. **Steppes:** Steppes are found in many areas of the Imam Turki bin Abdullah Royal Reserve. Many of these plains contain scattered plants such as acacia and jujube trees. Seasonal plants also appear after rainfall, providing suitable food for wild animals. The steppes are an important habitat for a number of wildlife including Gazelles.

6. **Wadis:** Wadis in desert areas form basins that collect water from floods and rain. This results in the permanent growth of a dense vegetation cover, especially in wadis where water flows for long periods. There are many small wadis that form a network that flows into a larger wadi. Wadis vary in length, from short ones that are only a few meters long to long ones that reach hundreds of kilometers. They also vary in width, from narrow wadis that are only a few meters wide to a much wider ones that reach hundreds of meters in width. The Wadi habitat is usually dominated by a group of woody pastoral plants such as acacia, *Ziziphus nummularia*, and *Lycium shawii*. Ground grasses such as the *Stipagrostis drarii* plant also appear in the lowlands.

2. Flora Study

Introduction

The Vegetation and Rangeland Study for Imam Turki Bin Abdullah Royal Reserve (ITBA) provides a comprehensive ecological assessment to guide sustainable land management and restoration efforts. ITBA plays a crucial role in biodiversity conservation, soil stabilization, water regulation, and forage provision, aligning with Saudi Vision 2030 and the global conservation goals. This study utilized field surveys, remote sensing, and GIS analysis to study vegetation composition, habitat distribution, rangeland carrying capacity, and key ecological threats.

A total of 235 plant species from 47 families were identified (90 of them were newly recorded), including 133 annuals and 102 perennials. The study classified vegetation into 16 plant communities and updated the habitat map, delineating 10 land cover types using Sentinel-2 satellite imagery. Local conservation assessments revealed six Extremely Threatened (ET), Moderately Threatened (MT), Least Threatened (LT), Near Threatened (NT), Common (C), and Data Deficient (DD) species. Key threats, including overgrazing, habitat fragmentation, invasive species, and soil degradation, were mapped to identify high-risk areas requiring intervention.

The rangeland carrying capacity was assessed across four seasons, estimating biomass production at 68428.75 tons in winter, 126414.7 tons in spring, 158448.98 tons in summer, and 104467.8 tons in autumn, all biomass production were calculated per habitat and per season for all species. Sustainable stocking rates were calculated for camels, sheep, goats, gazelles, and oryx, providing guidelines for balancing grazing with ecological health. Restoration priorities include stabilizing degraded soils, reintroducing native vegetation, and enhancing community engagement in conservation efforts.

Overview of Findings

Recorded Plants Checklist

A total of 235 plant species from 47 families, the most important of which are Asteraceae, Amaranthaceae, Brassicaceae and Fabaceae were recorded within the study area. These species include 133 annuals and 102 perennial species. Plant life forms include 61 plants Chamaephytes in which buds or bud tops are carried near the ground, 8 Geophytes which is perennials that reproduce from an underground organ such as an bulb or tuber and carry their perennial buds below the soil surface, and 19 Hemicryptophytes which is herbaceous perennials, such as herbs, that produce permanent shoots on the soil surface, 129 Therophytes annual plants that complete their life cycle in a year or less, and 4 parasitic plants that obtain all or part of their nutrition from another plant without contributing to the host's interest. and 14 Phanerophytes which is large shrubs and trees where winter buds are found high above the ground.

Environmental and Economic value of ITBA plants

Regarding their environmental and economic value, 202 species were found to be palatable to all animals, including *Zilla spinosa* (L.) Prantl., and (*Trigonella glabra* thunb), while 7 species were palatable only for camels, including *Teucrium oliverianum* ging. ex Benth., *Vachellia tortilis* (Forssk.) Galasso & Banfi and *Maerua crassifolia* Forssk. Additionally, 26 species were unpalatable, and 6 species were edible like Zilla spinosa *(L.) Prantl.*), and *Ziziphus nummularia* (Burm.f.) Wight & *Arrn.*, and 48 species with medicinal properties, perhaps the most important of which are *Artemisia sieberi* found in the wadis of Al Taysiyah reserve, as well as *Calligonum comosum* L'Hér. and *Scrophularia hypericifolia* wydler found in Nufud and sand dunes. Woody perennials are also widely spread in the wadi habitat , perhaps the most important of which is *Vachellia gerrardi* (Benth.) P.J.H.Hurter), *Ziziphus nummularia* (Burm.f.) Wight & Ring. They are the most important components in the wadi habitats of al Taysiyah, and floodplain regions. This diversity highlights the ecological importance of the rangeland and its potential for sustainable land use and conservation.

The following table shows some examples of plants of economic and medicinal value that have been recorded in the reserve:

Species	Palatable to all animals	palatable only for camels	medicinal Plants	Woody Plant	Foodstuff
Aaronsohnia factorovskyi Warb. & Eig.					
Achillea fragrantissima (Forssk. Schi.- Bip					
Astragalus spinosus (Forssk.) Muschl					
Maerua crassifolia Forssk					
Trigonella glabra Thunb.					
Ziziphus nummularia (Burm.f.) Wight & Arn.					
Zilla spinosa (L.) Prantl.					
Vachellia tortilis (Forssk.) Galasso & Banfi					

The detailed table of species in the main report shows all plants of economic and medicinal value that have been recorded in the reserve.

Newly Recorded Species

During the 2024 flora study, a total of 235 plant species were recorded, compared to a total of 179 species recorded in the 2022 study, and the species that were recorded in the current study include 90 species recorded for the first time in the reserve, noting that the majority of these species were recorded during the spring season.

The distribution of newly recorded species included all different types of habitats in the Imam Turki bin Abdullah Royal Reserve, noting that most of the species were recorded in more than one habitat type. As a summary of the distribution of species to habitats in the reserve from most to least with examples of newly recorded species is as follows: Most of species in the sandy plains habitat where 61 species have been recorded, including *Allium dictyoprasum C.A. Mey*, *Adonis dentata* Del., plateaus 52 species, including *Artemisia sieberi Bioss.*, *Amaranthus graecizans* L., sand dunes 34 species, including *Filago contracta (Boiss.) Chrtek & Holub*, *Horwoodia dicksoniae*

Turril, steppe 20 species of which are *Tamarix tetragyna* Ehrenb., *Trigonella glabra* thunb, and wadis, 13 species have been recorded, including *Hippocrepis areolata* desv., and *Medicago minima* (L.) L., and the least in ElFiyyad, where 4 species have been recorded, including *Erodium laucophyllum* (L,) L'Her and *Horwoodia dicksoniae* Turril.

The following table shows newly recorded plant species in Imam Turki bin Abdullah Royal Reserve.

ID	Family	Taxon	Arabic Name	Habitat	Local Conservation Status
1	Ranunculaceae	Adonis dentata Del.	عين الجمل	Sandy Plain	MT
2	Boraginaceae	Alkanna orientalis (L.) Boiss.	كحلاء	Sandy Plain	LT
3	Amaryllidaceae	Allium dictyoprasum C.A. Mey	ثوم	Sandy Plain	DD
4	Amaryllidaceae	Allium sindjarense Boiss. & Hasskn.	ثوم	Sandy Plain, Sand Dunes, Plateau	LT
5	Brassicaceae	Alyssum homalocarpum (Fisch. & C.A.Mey.) Boiss	لسان	Plateau	ET
6	Amaranthaceae	Amaranthus graecizans L.	قطيفه	Sandy Plain, Sand Dunes, Plateau	LT
7	Amaranthaceae	Amaranthus albus L.	قطيفه بيضاء	Sandy Plain	DD
8	Amaranthaceae	Anabasis ehrenbergii Schweinf. ex Boiss.	شنان	Sandy Plain	DD
9	Phyllanthaceae	Andrachne telephioides L.	بذر الدود	Sandy Plain, Sand Dunes, Plateau	MT
10	Asteraceae	Artemisia sieberi Bioss.	شيح	Plateau	DD
11	Asteraceae	Artemisia scoparia Waldst. & Kit.	شيح مكنسي	Plateau	DD
12	Liliaceae	Asphodelus fistulosus L.	بروق	Sandy Plain, Sand Dunes, Plateau	MT
13	Asteraceae	Asteriscus graveolens (Forssk.) Less.	نقد	Sandy Plain, Sand Dunes, Plateau, Steeps	LT
14	Asteraceae	Asteriscus pygmaeus (DC.) Coss. & Dur.	زياد ريحاوي	Sandy Plain, Sand Dunes, Plateau	MT
15	Fabaceae	Astragalus arpilobus ssp. haurensis (Boiss.) Podlech.	قتاد حواري	Sandy Plain, Sand Dunes, Plateau	NT
16	Fabaceae	Astragalus sieberi DC.	قتاد	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	NT
17	Fabaceae	Astragalus tribuloides var. minutus Boiss	قتاد	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi, Elfiyyad	C
18	Asteraceae	Atractylis mernephthae Aschi. Schweinf.	جلوه	Sandy Plain, Sand Dunes, Plateau	MT
19	Asteraceae	Calendula arvensis L.	بكوريه حقليه	Sandy Plain, Sand Dunes, Plateau, Steeps	LT
20	Capparaceae	Capparis spinosa L.	شفلح	Plateau, Steeps	ET
21	Asteraceae	Centaurea sinaica DC	بركعان	Sandy Plain	DD
22	Colchicaceae	Colchicum ritchii R.Br.	لحلاح	Sandy Plain	DD
23	Convolvulaceae	Convolvulus buschiricus Bornm.	رخام	Sandy Plain	MT

24	Convolvulaceae	Convolvulus excelsus R.R.Mill.	لبلاب	Sandy Plain	DD
25	Convolvulaceae	Convolvulus spicatus Peter ex Hallier	رخامي	Sandy Plain	MT
26	Asteraceae	Crepis aspera L.	حلاوى	Plateau	MT
27	Rubiaceae	Crucianella membranacea Boiss.	صليبيه	Sandy Plain, Sand Dunes, Plateau, Steeps	NT
28	Convolvulaceae	Cuscuta planiflora Ten.	حامول	Sandy Plain	DD
29	Cyperacea	Cyperus macrorrhizus Nees	تنده	Sandy Plain	DD
30	Asparagaceae	Dipcadi erythraeum Webb & Berth.	عنصل	Plateau	DD
31	Apiaceae	Ducrosia anethifolia (DC.) Boiss.	حزا	Sandy Plain, Sand Dunes, Plateau	MT
32	Ephedraceae	Ephedra foliata Boiss. ex C.A. May	علنده	Sandy Plain, Sand Dunes, Plateau	NT
33	Brassicaceae	Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.	تربه	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi, Elfiyyad	C
34	Geraniaceae	Erodium glaucophyllum (L,) L'Her	بختري	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi, Elfiyyad	MT
35	Asteraceae	Filago contracta (Boiss.) Chrtek & Holub	بهرمان	Sandy Plain	DD
36	Caryophyllaceae	Gypsophila viscosa Murray	اسليسله	Sandy Plain, Sand Dunes, Plateau, Steeps	NT
37	Amaranthaceae	Haloxylon persicum Bunge ex Boiss.	غضا	Sandy Plain, Sand Dunes	C
38	Rutaceae	Haplophyllum tuberculatum (Forssk.) A.Juss.	صنان التيس	Plateau	DD
39	Boraginaceae	Heliotropium lasiocarpum Fisch. & C.A.Mey.	رمرام	Steeps	DD
40	Fabaceae	Hippocrepis unisiliquosa L.	حذوه الحصان	Sandy Plain, Sand Dunes, Plateau, Steeps	LT
41	Fabaceae	Hippocrepis areolata Desv.	حذوه الحصان	Sandy Plain	DD
42	Poaceae	Hordeum spontaneum K.Koch	شعير بري	Sandy Plain	DD
43	Brassicaceae	Horwoodia dicksoniae Turril	خزامى	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi, Elfiyyad	NT
44	Solanaceae	Hyoscyamus muticus L.	سكران	Sandy Plain, Sand Dunes, Plateau	MT
45	Solanaceae	Hyoscyamus pusillus L.	سكران	Sandy Plain	DD
46	Asteraceae	Lasiopogon muscoides (Desf.) DC.	قطينه	Sand Dunes	MT
47	Poaceae	Lasiurus scindicus Henr.	ضعه	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	LT
48	Asteraceae	Launaea mucronata (Forssk.) Muschl.	حواء	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	NT
49	Asteraceae	Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze	حوه	Sandy Plain	DD
50	Brassicaceae	Lepidium aucheri Boiss	رشاد	Sandy Plain	DD
51	Plumbaginaceae	Limonium lobatum (L.f.) Chaz.	عويذران	Sandy Plain, Sand Dunes, Plateau	MT
52	Poaceae	Lolium rigidum Gaud.	زوان	Sandy Plain	DD
53	Fabaceae	Medicago minima (L.) L.	نفل	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	NT

54	Fabaceae	Medicago radiata L.	نفل	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	NT
55	Resedaceae	Ochradenus baccatus Del.	قرضي	Plateau	DD
56	Fabaceae	Onobrychis caput-galli (L.) Lam.	عنبريس	Sandy Plain	DD
57	Fabaceae	Onobrychis crista-galli (L.) Lam.	عنبريس	Sandy Plain	DD
58	Orobanchaceae	Orobanche ramosa L.	هالوك	Sandy Plain	DD
59	Caryophyllaceae	Paronychia sinaica Fresen	رجل الحمامه	Plateau	DD
60	Poaceae	Pennisetum divisum (J.F.Gmel.) Henrard	ثيوم سبط	Plateau	DD
61	Arecaceae	Phoenix dactylifera L.	نخيل	Wadi	DD
62	Poaceae	Poa sinaica Steudel.	قبا	Sandy Plain, Sand Dunes, Plateau, Steeps	NT
63	Caryophyllaceae	Polygonum palaestinum Zohary	لويزه	Sandy Plain	DD
64	Caprifoliaceae	Pterocephalus brevis Coult.	عقس	Sandy Plain, Sand Dunes, Plateau	MT
65	Asteraceae	Pulicaria incisa (Lam.) DC.	رعراع	Plateau	DD
66	Asteraceae	Ramaliella musilii (Velen.) Zaika, Sukhor. &	صفيره	Plateau	DD
67	Resedaceae	Reseda muricata C.Presl	ذنبان	Sandy Plain, Sand Dunes, Plateau, Steeps, Wadi	NT
68	Asteraceae	Rhagadiolus stellatus (L.) Gaertn.	ابره العجوز	Sandy Plain	DD
69	Apocynaceae	Rhazya stricta Decne	حرمل	Plateau	DD
70	Amaranthaceae	Salsola imbricata Forssk.	روثا	Plateau	DD
71	Amaranthaceae	Salsola vermiculata L.	حمض	Sandy Plain	DD
72	Amaranthaceae	Salsola tragus L.	حرض	Sand Dunes	DD
73	Salvadoraceae	Salvadora persica L.	اراك	Plateau	DD
74	Brassicaceae	Schimpera arabica Hochst. & Steud	صفراء	Sandy Plain	DD
75	Poaceae	Schismus arabicus Nees	خافور	Plateau	DD
76	Asteraceae	Scorzonera musilii Vel.	ذعلوق الجمل	Plateau	DD
77	Asteraceae	Scorzonera schweinfurthii Boiss.	سلسفي	Sandy Plain	MT
78	Asteraceae	Scorzonera tortuosissima Boiss.	ذعلوق	Sandy Plain	DD
79	Zygophyllaceae	Seetzenia lanata (Willd.) Bullock	حبيان	Plateau	MT
80	Amaranthaceae	Seidlitzia rosmarinus Bunge	عنظوان	Plateau	DD
81	Solanaceae	Solanum elaeagnifolium Cav.	سجوه	Sandy Plain	DD
82	Asteraceae	Sonchus oleraceus L.	جعضيض	Plateau	MT
83	Poaceae	Stipagrostis ciliata (Desf.) de Wint.	صليان	Sandy Plain, Sand Dunes, Plateau, Steeps	NT
84	Amaranthaceae	Suaeda vermiculata Forssk	طحماه	Sandy Plain, Sand Dunes, Plateau, Steeps	NT
85	Tamaricaceae	Tamarix tetragyna Ehrenb.	طرفه	Wadi	DD
86	Amaranthaceae	Traganum nudatum Delile	ضمران	Plateau	DD
87	Fabaceae	Trigonella glabra Thunb.	حلبه	Sandy Plain	DD
88	Fabaceae	Vachellia tortilis (Forssk.) Galasso & Banfi	سمر	Wadi	MT
89	Scrophulariaceae	Verbascum sinaiticum Benth.	بوصير	Plateau	LT
90	Asteraceae	Verbesina encelioides (Cav.) A.Gray	نوار الشمس	Sand Dunes	DD

Herbarium Specimens

One of the most important outcomes of this study was the collection and preservation of plant specimens to create an integrated herbarium for the reserve. In some cases, plant species were classified from the remains of dried fruits, which the study team was unable to find a sample suitable for preservation. In total, 323 specimens representing 178 different plant species were collected and preserved. These samples were sterilized by preservation for 60 days at low temperatures (-20) to ensure that they are free of insects and fungal infection. Appendix 1 shows the list of species preserved in the herbarium collection .

Assessment of Conservation Status

Based on the results of the current study, the plant species recorded in the reserve were classified to determine the conservation status based on a scientific methodology encompassing a quantitative and qualitative analysis of plant data as follows:

First: Criteria shown in the following table have been adopted to classify endangered species Extremely Threatened (ET), Moderately Threatened (MT) and Least Threatened (LT) species.

	Extremely Threatened (ET)	**Moderately Threatened (MT)**	**Least Threatened (LT)**
Extent of Occurrence (EOO)	≤100 km^2	≤5,000 km^2	≤20,000 km^2
Area of Occupancy (AOO)	≤10 km^2	≤500 km^2	≤2,000 km^2
And at least TWO of the THREE following conditions:			
Number of locations	= 1	≤5	≤10
Continuing decline in any of EOO, AOO, habitat quality, number of locations and number of individuals.			
Extreme fluctuations in any of EOO, AOO, number of locations and number of individuals.			

Second: Species that were not classified in the endangered category mentioned above and were among the threatened areas were classified as Near Threatened (NT).

Third: For species that do not fall within the threat zones, they are classified as common (C).

Fourth: Species that do not have sufficient data to conclude a correct scientific conclusion to evaluate them directly or indirectly due to their scarcity for example, have been classified under the category Data Deficient (DD).

Local conservation assessments were conducted for all recorded plant species. The results showed six species as Extremely Threatened (ET), like *Alyssum homalocarpum* (Fisch. & C.A.Mey). Boiss and *Bassia eriophora* (Schrad.) Asch, *Capparis spinosa*, *Carduus pycnocephalus* var. pycnocephalus L., *Convolvulus excelsus* R.R.Mill, *Lolium rigidum* Gaud and *Phalaris minor* Retz, 38 are Moderately Threatened (MT) and 31 are Least Threatened (LT) were recorded. 36 are Near Threatened (NT) with most species recorded in steppe habitats scattered in the northeast and east of the reserve, while some of these species have been recorded in Nafud and Naqd al-Muza'un.

For the Common Species category (C), 44 plant species have been recorded spread across habitats, the majority of which are annual plants spread in wadis, steppes and floods and 80 species are Data Deficient (DD).

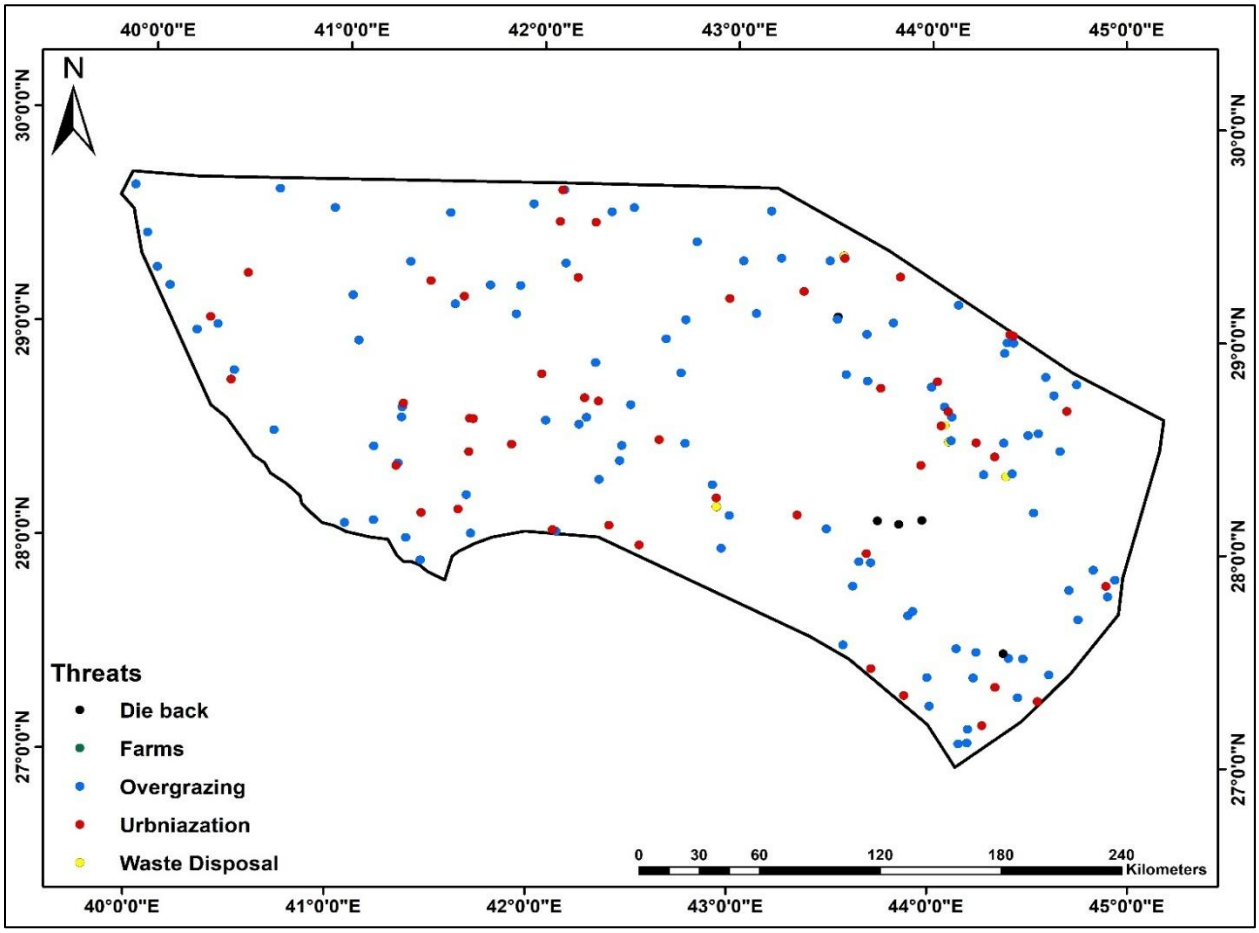
Assessment of Threats to Vegetation Cover

The methodology for assessing habitat quality and determining the degradation index in the Imam Turki bin Abdullah Royal Reserve included a set of field surveys, data collection and spatial analysis. The process is designed to provide a comprehensive understanding of ecosystem conditions and guide restoration efforts by identifying degraded areas and assessing their severity.

Spatial analysis of a set of threats documented in the Imam Turki bin Abdullah Royal Reserve within 238 vegetation plots as shown in the table below was carried out to determine the level of degradation level/threat to different habitats and sites of the reserve. Once field data collection was complete, the threat scores from the survey locations were processed and analyzed using ArcGIS software. The collected scores were interpolated spatially using the Kriging method. To ensure the reliability and consistency of the assessment, quality assurance procedures were implemented throughout the process. Judgment criteria for each parameter were calculated to the specific conditions of ITBA, ensuring that scores accurately reflected the local ecological context. Periodic field checks, conducted during two different seasons, validated the assessment results and captured any temporal variations in habitat conditions. Photos of the sampling reach were used as a reference for cross-verification.

The map below shows the spatial distribution, scope of spread and severity of threats over different habitats. The results of the study showed that overgrazing and urbanization are the most widespread and affect the natural habitats in the reserve and cause loss of vegetation cover, soil compaction and habitat fragmentation.

Threat Type	Root Causes	Severity Level	Main Affected Locations
Dieback	Water scarcity, soil degradation, plant diseases, climate change	5 (High)	Northern and northeastern areas, particularly near Zahwah, Nu'ayjan, Linah, and Al-Jadidah
Farms	Land conversion, overextraction of water, chemical runoff	4 (Moderate)	Concentrated near Zubala, Al-Musandiq, Fayhan, and Al-Jundah
Overgrazing	Unregulated livestock grazing, lack of rotational grazing practices	6 (High)	Widespread across ITBA, particularly near Al-Zubayrah, Qibah, Abu Sur bin Jibrin, Ghunaym, Turbah, and in Skaka which is located northwest from the reserve.
Urbanization	Infrastructure expansion, habitat fragmentation, increased human activity	3 (Moderate)	All major villages and settlements within ITBA, including Al-Qusuriyat, Samudah, Al-Tiraq, Jiblah, Ushayqir, and Al-Hadaqah
Waste Disposal	Improper waste management, illegal dumping, industrial runoff	1 (Low)	Scattered throughout ITBA, with higher concentrations near Al-Muhayrith, Al-Radifah, and Al-Duwai Nagdhah



Threats assessment map within ITBA

The Degradation Risk Map of ITBA, highlights varying levels of ecosystem degradation across the reserve. These levels are categorized into four classes: None, Low (1-2), Medium (3-4), and High (5-6), based on the cumulative impact of identified threats such as urbanization, overgrazing, waste disposal, and natural vegetation dieback. This spatial analysis provides a comprehensive overview of the degradation patterns and helps prioritize areas for restoration.

High-Risk Areas

The high-risk areas, represented in red on the map, indicate zones where multiple threats converge, resulting in significant ecological degradation. These zones are primarily associated with combined impacts from urbanization, overgrazing, and waste disposal, often concentrated near human activities and along the boundaries of the reserve. The high-risk areas require immediate restoration interventions to mitigate further ecological damage and support habitat recovery. High-risk zones are concentrated near Zahwah, Nu'ayjan, Zubala, and Al-Qusuriyat, where multiple threats overlap, requiring urgent restoration efforts.

Medium-Risk Areas

The medium-risk areas, shown in orange, represent zones with moderate levels of degradation. These areas are typically affected by one or two dominant factors, such as overgrazing or vegetation dieback, and may act as transition zones between degraded and healthier ecosystems. Restoration efforts in these areas should focus on addressing specific threats and preventing further degradation.

Low-Risk Areas

The low-risk areas, highlighted in yellow, indicate regions with minimal disturbance. While these areas are relatively intact, they may still be vulnerable to localized threats, such as occasional grazing or waste accumulation. Proactive management in these zones can help maintain their ecological integrity and prevent the onset of further degradation.

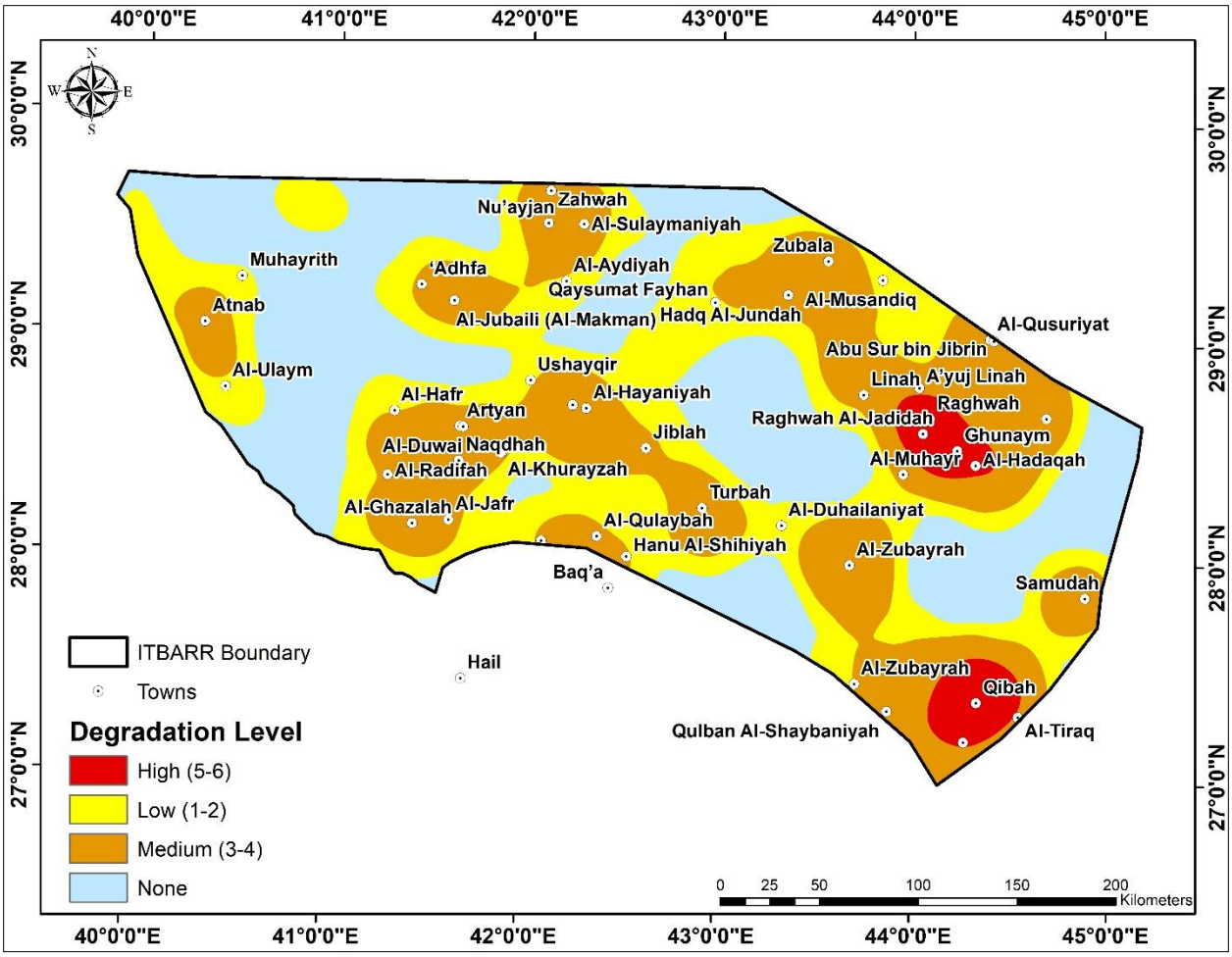
Areas with No Degradation

The areas with no degradation, represented in blue, are largely undisturbed and serve as critical reference sites for restoration planning. These regions can provide baseline data for evaluating

the success of restoration activities and act as seed banks for reintroducing native species into degraded areas.

The degradation risk mapping results underline the need for targeted restoration strategies in high and medium-risk zones, focusing on mitigating the combined impacts of urbanization, overgrazing, and other threats. At the same time, proactive management in low-risk and undisturbed areas will help safeguard ITBA's ecological balance and ensure the sustainability of its natural habitats. This comprehensive analysis serves as a crucial tool for guiding effective restoration and conservation efforts within the reserve.

The overlay of the Degradation Risk Map with the Plant Community Distribution Map, the analysis revealed that certain plant communities within the reserve are more vulnerable to degradation than others. Notably, the *communities of Achillea fragrantissima-Capparis spinosa-Teucrium oliverianum* and *Artemisia monosperma-Haloxylon persicum-Stipagrostis drarii* They are mostly found in areas with high degradation level areas, indicating high susceptibility to environmental stress. These plant populations are commonly found in fragile habitats such as sandy plains and degraded plateaus, where human pressures and environmental constraints converge. In addition, *Lycium shawii-Vachellia gerrardii-Ziziphus nummularia* communities located in eastern wadi systems have also shown signs of weakness, particularly due to overgrazing and hydrological disturbances. These findings underscore the need to prioritize these communities in both active and passive restoration planning to prevent further degradation and support resilience. Ecosystem.



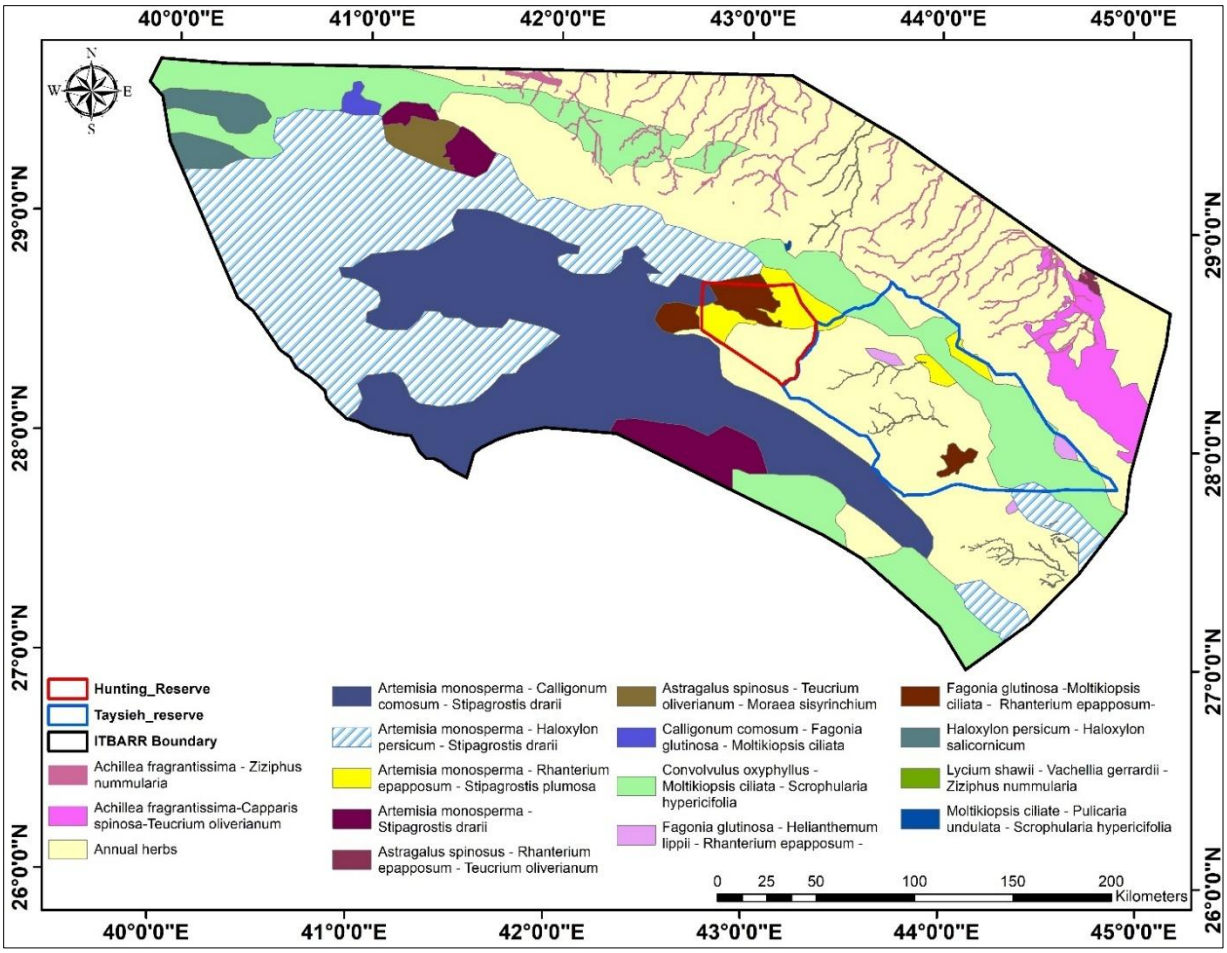
Degradation Risk Level Map

The overlay of the degradation level map with the habitat classification of ITBA reveals significant variations in ecological stress across different habitat types. High degradation levels (scores 5-6) are predominantly found in wadi habitats, sandy plains, and certain sections of sand dunes, indicating that these areas face the most severe environmental pressures. Wadis, known for their vital role in water retention and vegetation support, appear to be particularly impacted, likely due to overgrazing, erosion, and anthropogenic disturbances such as waste disposal and urban expansion. Similarly, the sandy plains and sand dunes, which are naturally prone to shifting and erosion, show widespread moderate to high degradation, suggesting soil instability and vegetation loss. These findings emphasize the urgency of active restoration efforts in these areas, particularly focusing on soil stabilization, reforestation, and controlled grazing strategies.

On the other hand, low degradation levels (scores 1-2) are mainly observed in ElFiyyad, plateau habitats, and certain steppe regions, indicating that these areas have relatively stable ecological conditions. The ElFiyyad habitat, characterized by higher vegetation cover and more favorable soil conditions, can serve as a reference ecosystem for restoration planning in degraded regions. The steppes and sand dunes exhibit a mix of moderate to high degradation levels, suggesting that while some areas remain ecologically resilient, others are facing growing pressures that require targeted conservation actions, such as native species reintroduction and grazing control. This analysis provides a clear prioritization framework for restoration interventions, ensuring that resources and strategies are aligned with the severity of degradation within each habitat type.

Vegetation Map

Based on the habitat map and as a result of using the supervised classification method in interpreting the satellite images, a current vegetation map was produced at a scale of 1:20,000 that contains 16 vegetation types. Each vegetation type has been described in terms of area and percentage of representation at the reserve level. As a result of the field survey, 235 plant species were recorded in different vegetation types. The field data were used to describe each type of vegetation according to the type and distribution of their leading species, percentage of vegetation cover, physiognomic and phytosociological classification and canopy cover. In addition, the DEM map and GIS were used to help determine the vegetation's geographical distribution.



Vegetation map based on satellite image interpretation and extensive field surveys

The following is a simplified description of these communities in terms of scope, composition and predominant vegetation:

1. ***Achillea fragrantissima - Ziziphus nummularia*** **plant community:**

   This vegetation has been identified in the northern and northeastern parts of the reserve and is confined to area where ElFiyyad (floodplains) are present. This community contains three strata which are trees, bushes and herbs. The average vegetation cover ranges from 5% to 25%. The area of the plant community is 78.4 km^2, which constitutes about 1 % of the reserve.

2. ***Achillea fragrantissima-Capparis spinosa-Teucrium oliverianum*** **plant community:**

   This vegetation is distributed in narrow areas northeast of the reserve, adjacent to ElFiyyad (floodplains) areas. No trees grow in this area. This community contains two strata which are

bushes and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 2,109 km2, which constitutes about 2 % of the reserve.

3. **Annual herbs community:**

   This vegetation is widespread over large areas of the plateau, interdune and sand stones, as these areas lack the conditions that support the growth of shrubs, and the presence of plants is limited to annual plant species. The most important plant species that grow in this region are: *Horwoodia dicksoniae, Plantago albicans, Plantago ovata, Plantago ciliata, Schismus barbatus* and *Stipellula capensis*. This community contains only one stratum. The average vegetation cover ranges from 1% to 10%. The area of the plant community is 34,514 km2, which constitutes about 38 % of the reserve.

4. ***Artemisia monosperma - Calligonum comosum - Stipagrostis drarii* plant community:**

   This vegetation extends over large areas of the central and southern regions of the reserve. These plant species grow together in different habitats, with *Artemisia monosperma* being the most abundant in this area. This community contains two strata which are shrubs and herbs. The average vegetation cover ranges from 10% to 40%. The area of the plant community is 16,463km^2, which constitutes about 18 % of the reserve.

5. ***Artemisia monosperma - Haloxylon persicum - Stipagrostis drarii* plant community:**

   This vegetation extends over most of the sand dune areas, where these species grow in varying densities, as *Haloxylon persicum* shrubs play an important role in stabilizing the sand dunes and creating shade for the growth of annual pastoral plants. This community contains two strata which are shrubs and herbs. The average vegetation cover ranges from 10% to 25%. The area of the plant community is 18,991 km^2, which constitutes about 21 % of the reserve.

6. ***Artemisia monosperma - Rhanterium epapposum - Stipagrostis plumosa* plant community:**

   This vegetation found in scattered places in the central and eastern parts of the reserve, and are interspersed with other plant communities such as: "*Convolvulus oxyphyllus - Moltikiopsis ciliata - Scrophularia hypericifolia"* and *"Fagonia glutinosa - Moltikiopsis ciliata - Rhanterium epapposum".* This community contains two strata which are bushes and herbs. The average

vegetation cover ranges from 5% to 10%. The area of the plant community is 1,382 km^2, which constitutes about 2 % of the reserve.

7. ***Artemisia monosperma - Stipagrostis drarii*** **plant community:**

   This vegetation found in scattered places in the southern and northwest parts of the reserve, and are interspersed with other plant communities such as: "*Artemisia monosperma - Calligonum comosum - Stipagrostis drarii"* and *"Artemisia monosperma - Haloxylon persicum - Stipagrostis drarii".* This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 2,054 km^2, which constitutes about 2 % of the reserve.

8. ***Astragalus spinosus - Rhanterium epapposum - Teucrium oliverianum*** **plant community:**

   This vegetation found in the form of islands within areas where annual plants are widespread, due to the availability of soil pockets between the rocks and steppes that work to preserve the seeds of these plant species. This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 1% to 5%. The area of the plant community is 74 km^2, which constitutes less than 1 % of the reserve.

9. ***Astragalus spinosus - Teucrium oliverianum - Moraea sisyrinchium*** **plant community:**

   This cover is located on a small strip in the northwestern part of the reserve. It is characterized by the presence of geophytes (*Moraea sisyrinchium*). This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 1% to 5%. The area of the plant community is 624 km^2, which constitutes less than 1 % of the reserve.

10. ***Calligonum comosum - Fagonia glutinosa - Moltikiopsis ciliata*** **plant community:**

    In this vegetation, some small bushes (i.e. Fagonia glutinosa, Moltikiopsis ciliata) grow in association with the Calligonum shrubs. This community is located in the northern part of the reserve and contains two strata which are shrubs and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 204. km^2, which constitutes less than 1 % of the reserve.

11. *Convolvulus oxyphyllus - Moltikiopsis ciliata - Scrophularia hypericifolia* plant community:

This vegetation is spread over large areas in the east and west of the reserve. It also penetrates the areas where the Achillea plant is widespread within ElFiyyad area north of the reserve. This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 12,358 km^2, which constitutes about 14% of the reserve.

12. *Fagonia glutinosa - Helianthemum lippii - Rhanterium epapposum* plant community:

This vegetation found in the form of islands within areas where annual plants are widespread, due to the availability of soil pockets between the rocks and steppes that work to preserve the seeds of these plant species. This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 1% to 5%. The area of the plant community is 209 km^2, which constitutes less than 1 % of the reserve.

13. *Fagonia glutinosa -Moltikiopsis ciliata - Rhanterium epapposum* plant community:

This vegetation spreads in a narrow place where floodplains prevail in the eastern part of the reserve. This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 1,035 km^2, which constitutes about 1% of the reserve.

14. *Haloxylon persicum - Haloxylon salicornicum* plant community:

This cover is prevalent in the sand dune areas in the far north western part of the reserve. It penetrates the areas where the plant community of "*Convolvulus oxyphyllus - Moltikiopsis ciliata - Scrophularia hypericifolia"* plant is widespread. This community contains two strata which are shrubs and herbs. The average vegetation cover ranges from 5% to 10%. The area of the plant community is 1,231 km^2, which constitutes about 1% of the reserve.

15. *Lycium shawii - Vachellia gerrardii - Ziziphus nummularia* plant community

This vegetation has been identified in some northern and eastern parts of the reserve, and is confined to area where Wadis (Shou`ib) are present. It also extends inside the Taisiya Reserve. Three strata of plants grow inside those Wadis, which are trees, shrubs and herbs.

The average vegetation cover ranges from 10% to 40%. The area of the plant community is 217 km^2, which constitutes less than 1 % of the reserve.

16. *Moltikiopsis ciliate - Pulicaria undulata - Scrophularia hypericifolia* plant community

This vegetation is found in a small area in the central region of the reserve, and is found in a small area surrounded by widespread annual plants. This community contains two strata which are bushes and herbs. The average vegetation cover ranges from 1% to 10%. The area of the plant community is 12.4 km^2, which constitutes less than 1% of the reserve.

The following table shows the distribution of dominant plant communities within the ITBA habitats.

Habitat	Dominant Plant Communities
ElFiyyad	• *Achillea fragrantissima-Capparis spinosa-Teucrium oliverianum* • Annual Herbs
Plateau	• *Achillea fragrantissima - Capparis spinosa - Teucrium oliverianum* and *Fagonia glutinosa - Moltikiopsis ciliata - Rhanterium epapposum*
Sand dunes	• *Convolvulus oxyphyllus - Moltikiopsis ciliata - Scrophularia hypericifolia* • *Artemisia monosperma - Calligonum comosum - Stipagrostis drarii* • *Artemisia monosperma - Haloxylon persicum - Stipagrostis drarii* • *Artemisia monosperma - Rhanterium epapposum - Stipagrostis plumosa*
Sandy plains	• *Convolvulus oxyphyllus - Moltikiopsis ciliata - Scrophularia hypericifolia* • *Artemisia monosperma - Haloxylon persicum - Stipagrostis drarii* • *Calligonum comosum - Fagonia glutinosa - Moltikiopsis ciliata* • *Haloxylon persicum - Haloxylon salicornicum*
Steeps	• *Achillea fragrantissima-Capparis spinosa-Teucrium oliverianum* • Annual herbs
Wadi	• *Lycium shawii - Vachellia gerrardii - Ziziphus nummularia*

Rangeland Carrying Capacity and Stocking Rate (SR)

The spatial analysis of SR distribution per each habitat in ITBA revealed wadi habitats as the most productive grazing areas, followed by ElFiyyad and steppes. Protected areas within ITBA demonstrated improved vegetation conditions, supporting higher SR values. Seasonal variations in SR highlighted spring and summer as peak grazing periods, with the highest potential for

sustainable livestock management. These findings provide essential insights for optimizing grazing strategies and ensuring long-term rangeland sustainability within ITBA.

For example, the total sustainable Stocking rate in the spring season for camels in protected areas (PA) was 3,834 head, while in non-protected areas (NPA) was 3,148, and the SR of goats in protected areas during the spring season was 37,938 and 31,257 in non-protected areas, while the total SR of Arabian oryx in protected areas was 20,346 and 16,762 in non-protected areas in the same season. The table in Appendix 2 shows Detailed data on SR in protected environments of different species and during the four seasons of the year and comparison of load in protected and non-protected areas.

The seasonal biomass production across different habitats within the reserve was calculated through the current study, as shown in the following table:

Habitat	Winter	Spring
	Biomass (ton)/ habitat	Biomass (ton)/ habitat
Wadi	174.689	185.441
ElFiyyad	52.174	81.459
Steeps	219.124	427.647
Plateau	7265.721	12322.075
Sandy plains	14786.890	32861.657
Sand dunes	45930.155	80536.433
Total	**68428.753**	**126414.712**
Habitat	Summer	Autumn
	Biomass (ton))/ habitat	Biomass (ton))/ habitat
Wadi	66.888	14.708
ElFiyyad	38.849	38.421
Steeps	181.443	37.250
Plateau	4827.259	1149.998
Sandy plains	35987.855	23922.890
Sand dunes	117346.694	79304.545
Total	**158448.988**	**104467.812**

More information on this topic are provided in Appendix No. 3

(Analytical report on the status of range lands in ITBA prepared by Dr. Ahmed Al-Gharib - Ali Al-Mubarak - Badran Al-Badrani).

Taysiyah Reserve Stocking Rate Results

The seasonal stocking rates in Taysiyah Reserve show notable variation across the year. Spring records the highest overall sustainable grazing capacity, supporting up to 6,621 sheep, 6,179 goats, and 19,721 gazelles, alongside other species. This peak reflects improved forage availability following winter rainfall. Winter also shows relatively high capacity, particularly for gazelles (15,153) and goats (4,748).

Location	Winter					Spring				
	Camel (head)	Sheep (head)	Goat (head)	Gazelle (head)	Oryx (head)	Camel (head)	Sheep (head)	Goat (head)	Gazelle (head)	Oryx (head)
Sustainable Stocking Rate in Taysiyah Reserve	468	5,138	4,748	15,153	2,543	596	6,621	6,179	19,721	3,310
Full Stocking rate for Taysiyah Reserve	1092	11,988	11,078	35,357	5,933	1,390	15,449	14,417	46,015	7,723
Location	Summer					Autumn				
	Camel (head)	Sheep (head)	Goat (head)	Gazelle (head)	Oryx (head)	Camel (head)	Sheep (head)	Goat (head)	Gazelle (head)	Oryx (head)
Sustainable Stocking Rate in Taysiyah Reserve	204	2,172	2,027	6,471	1,086	134	1,476	1,404	4,469	752
Full Stocking rate for Taysiyah Reserve	476	5,068	4,729	15,099	2,534	312	3,444	3,276	10,427	1,754

(The above rates represent the stocking rates in Taysiyah Reserve for 365 days for any of the species mentioned)

The biomass productivity in Taysiyah Reserve follows a clear seasonal pattern that aligns with rainfall and vegetation growth cycles. The highest biomass yield is recorded during spring, reaching 11,542.64 tons, followed by winter with 9,054.30 tons. These seasons correspond to periods of greater moisture availability, promoting optimal plant growth and forage quality.

Location	Winter	Spring
	Biomass (ton) / Taysiyah area	Biomass (ton) / Taysiyah area
Taysiyah Reserve	9054.299	11542.642
Location	Summer	Autumn
	Biomass (ton) / Taysiyah area	Biomass (ton) / Taysiyah area
Taysiyah Reserve	3951.309	2615.386

Invasive Species

The presence of invasive plant species within ITBA presents a significant ecological challenge, threatening native biodiversity and impacting ongoing restoration efforts. Invasive species can outcompete native flora, alter soil composition, reduce forage quality, and disrupt ecosystem functions. Their spread is often linked to anthropogenic activities, such as overgrazing, agricultural expansion, and habitat disturbances, which create favorable conditions for their establishment and proliferation.

To assess the impact of invasive species within the reserve, a comprehensive field survey was conducted, focusing on identifying their distribution, abundance, and associated environmental conditions. Investigators systematically mapped infested areas, evaluated the potential drivers of spread, and analyzed the ecological impacts of these species on native plant communities.

Through the current study, the presence and spread of invasive species in the reserve have been evaluated, where the presence of three types of invasive plants has been documented:

1. *Calotropis procera* (Ait.) Ait.f. – Found primarily in wadi habitats and floodplains, where it competes with native Acacia trees. (Al-Sodany, Yassin & Al-Juaid, N.S. & Kahil, Anwar. (2016). Ecology of invasive species Calotropis procera (Ait) R.Br. in Saudi Arabia. International Journal of Ecotoxicology and Ecobiology. 1. 127-140).

   Management Recommendations:

   - Mechanical removal and monitoring in targeted areas to prevent further spread.
   - Restoration of native tree species such as *Acacia gerrardii* in infested sites.
   - Community engagement programs to control its spread, particularly in pastoral areas.

2. *Peganum harmala* L. – A species whose spread is strongly linked to overgrazing, colonizing sandy plains and sand dune habitats across the eastern and central parts of ITBA. (Abbott, Laurie B., et al. “Physiology and Recovery of African Rue (Peganum Harmala) Seedlings under Water-Deficit Stress.” Weed Science, vol. 56, no. 1, 2008, pp. 52–57. JSTOR, http://www.jstor.org/stable/25148478 Accessed 4 May 2025.).

Management Recommendations:

- Grazing management strategies, including rotational grazing, to reduce habitat disturbances that promote its spread.
- Mechanical removal in heavily infested areas, followed by native vegetation restoration to outcompete new growth.
- Monitoring and mapping programs to track its expansion and evaluate control efforts.

3. *Solanum elaeagnifolium* Cav. – Associated with agricultural activities, mainly concentrated in the south ern parts of the reserve, particularly in sand dune habitats. (Roberts, Jason & Florentine, Singarayer. (2022). Biology, distribution and management of the globally invasive weed Solanum elaeagnifolium Cav (silverleaf nightshade): A global review of current and future management challenges. Weed Research. 62. 10.1111/wre.12556.).

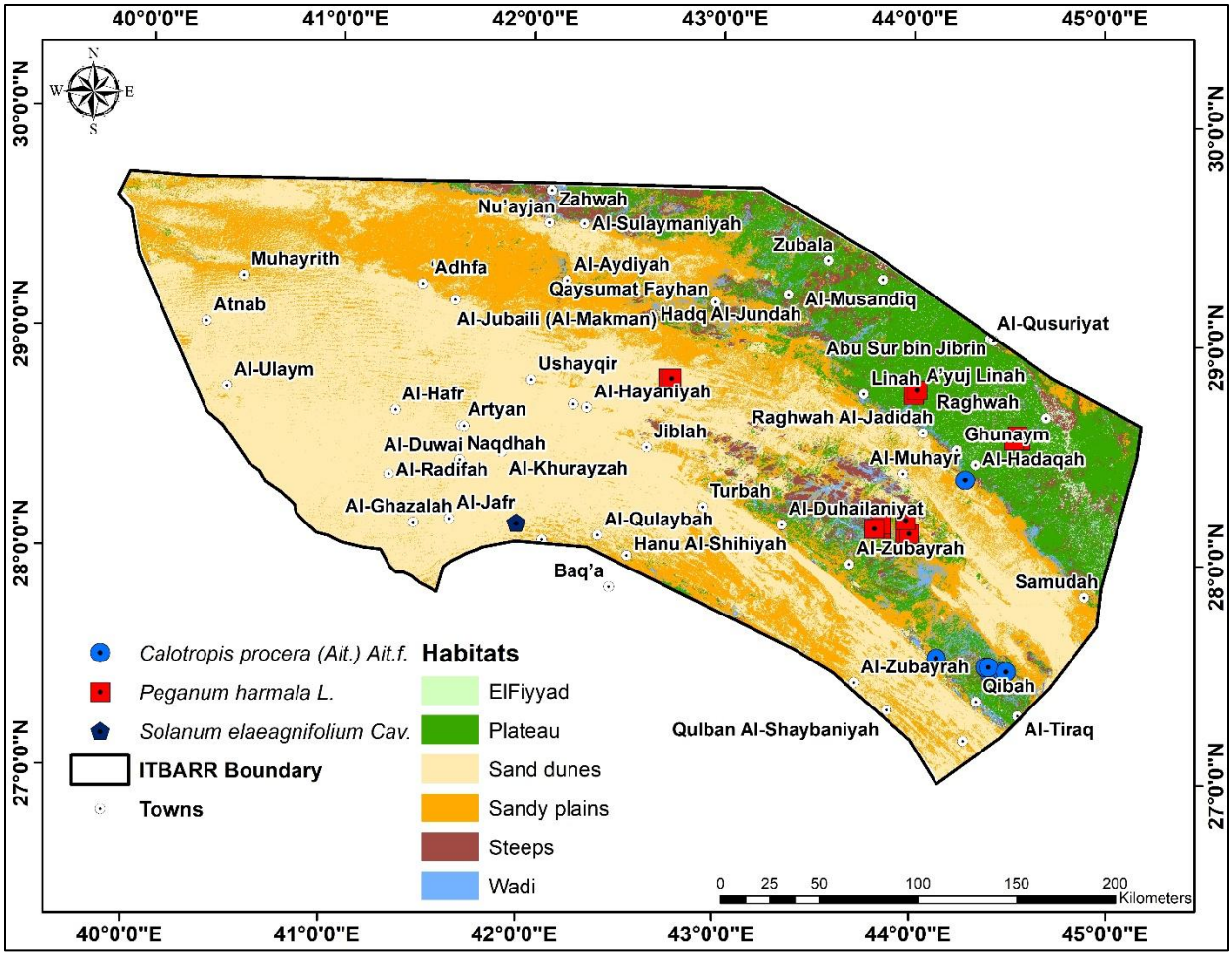
   Management Recommendations:

   - Prevention strategies targeting agricultural areas to reduce further introduction into the reserve.
   - Herbicide application in controlled areas, combined with manual removal of smaller populations.
   - Strengthening biosecurity measures to prevent introduction in new sites.

Calotropis procera (Ait.) Ait.f.

Peganum harmala L.

Solanum elaeagnifolium Cav.



Location map of the invasive species in ITBA.

3. Fauna Study

Executive Summary

Overview of Findings

This Executive Summary presents the key achievements and species detected during the 2024 seasonal fauna baseline assessment surveys of the Imam Turki bin Abdullah Royal Reserve (ITBA). The faunal groups that were surveyed are bats, large mammals, small mammals, reptiles and invertebrates.

The ITBA is located in the north central region of the Kingdom of Saudi Arabia and is comprised of a variety of desert habitats such as dune fields, wadi wadis and rocky plateaus. Sampling was conducted in 119 preselected quadrants that were representative of the 6 main microhabitats within the reserve, to provide a robust baseline assessment across seasonal and spatial scales.

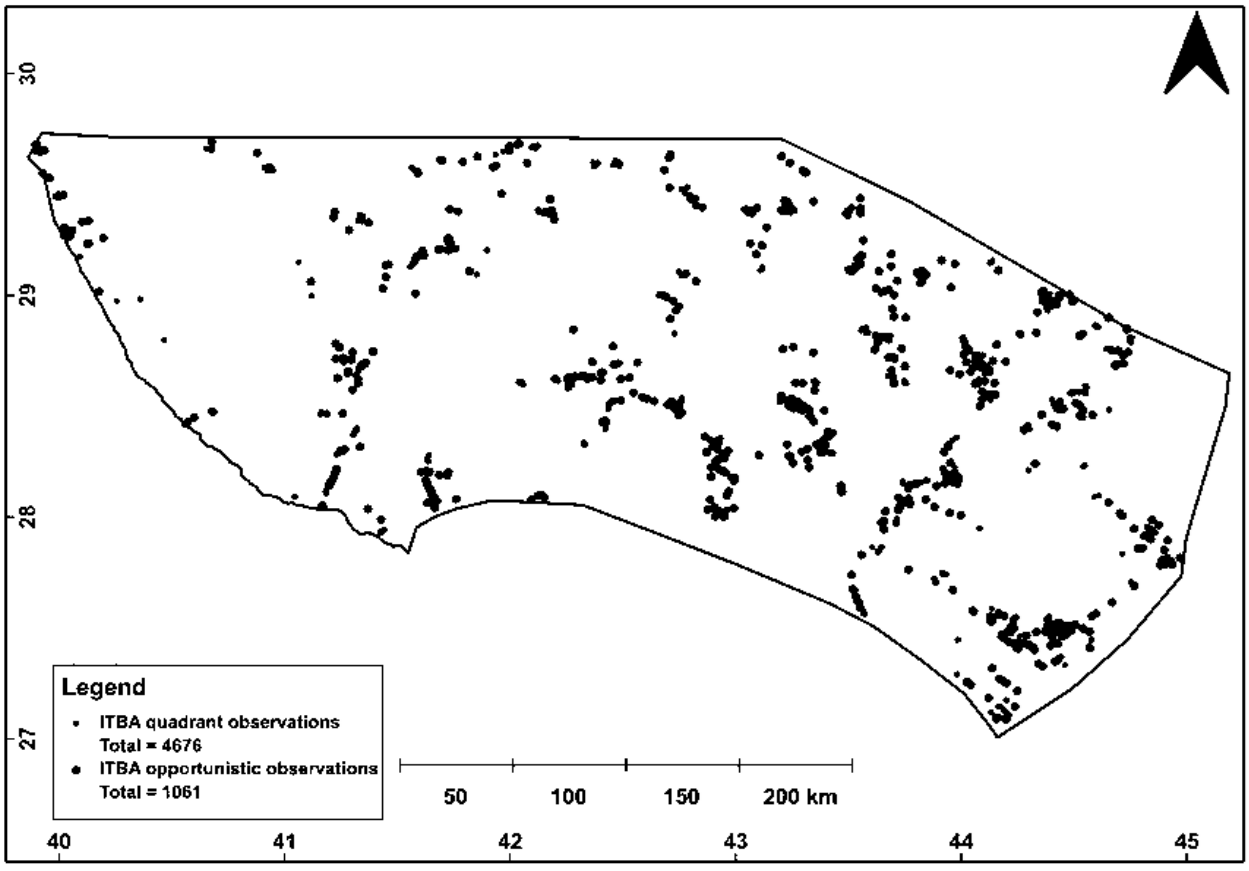
A total of 5,737 fauna observations were logged during the 2024 surveys, where 4,576 were made in sampling quadrats and 1,061 were opportunistic observations outside of quadrants (Figure below). Using habitat suitability and species distribution modelling, the key locations for high biodiversity within the ITBA were identified to assist future management and conservation efforts.

The total number of animal species recorded in the 2024 survey in the Imam Turki bin Abdullah Royal Reserve reached 61 species of vertebrate animals and 23 orders of invertebrates, as one of the main achievements of this great effort in the survey was the identification of 36 species as a new record that was not documented in previous studies conducted in 2022 and 2019, including five species of bats, six species of rodents, six species of carnivores, and 19 species of reptiles, including two species new to science, In addition to 12 orders of invertebrates. Below are details of the different animal species/orders recorded in the Animal Survey 2024 for each animal group..

	ITBA 2024	ITBA 2022	ITBA 2019
Total number of Large Mammal Species	10	4	5
Total number of Small Mammal Species	13	7	Not Specified
Total number of Bat Species	8	1 (Unconfirmed)	0
Total number of Invertebrate Species/Orders	23 Orders	Not clearly quantified	12 Species
Total number of Reptile Species	30	30 (with uncertainties; 21 species plausible)	6

Numbers at a glance for Animal Species in 2024 Survey

5,737 vertebrate fauna observations	**36** vertebrate species **NEW** for the ITBA	**5** bat species **NEW** for the ITBA	**6** rodent species **NEW** for the ITBA
6 mammalian carnivore species **NEW** for the ITBA	**19** reptile species **NEW** for the ITBA	**2** lizard species **NEW TO SCIENCE**	**12** orders of invertebrates **NEW** for the ITBA



A total of 5,737 Fauna sampling observations were made during the 2024 fauna baseline assessment.

Bat Survey

The bats of the ITBA were assessed using multiple methods for the first time between March and October 2024.

Five bat species were acoustically recorded and identified from four families, namely Kuhl's Pipistrelle Bat (*Pipistrellus kuhlii*), Desert Long-eared Bat (*Otonycteris hemprichii*), Trident Leaf-nosed Bat (*Asellia tridens*), Naked- rumped Tomb bat (*Taphazous nudiventris*) and the European Free-tailed Bat (*Tadarida teniotis*).

Acoustic bat activity varied with each season as 13,812 echolocation calls were recorded in the winter/spring survey compared to 3,894 in summer and 7,322 calls recorded in autumn.

Eight roost localities were found, and release calls were obtained for two captured species.

Of the six bats caught, three specimens were taken to assist in unravelling the Pipistrellus species complex, while one individual Desert Long-eared Bat (Otonycteris hemprichii) was caught as a representative specimen.

This survey provided new localities and confirmation of bat roosts within the ITBA, thereby adding to the existing information of species distributional ranges and conservation status of species listed as Data Deficient in the National RedList of bats.

Up to five additional species are predicted to occur within the ITBA, with further monitoring due to assess the seasonal and migratory behaviour of these species.

Numbers at a glance for Bat Survey

5	8	25,028
bat species	roost localities	echolocation calls

Order	Family OR Subfamily	Scientific Name	Local Name	Global IUCN Status	Regional IUCN Status
Chiroptera	Vespertilionidae	*Otonycteris hemprichii*	Desert Long-eared Bat	LC	LC
Chiroptera	Vespertilionidae	*Pipistrellus kuhlii*	Kuhl's Pipistrelle	LC	LC
Chiroptera	Hipposideridae	*Asellia tridens*	Trident Leaf-nosed Bat	LC	LC
Chiroptera	Emballonuridae	*Taphazous nudiventris*	Naked-rumped Tomb Bat	LC	LC
Chiroptera	Molossidae	*Tadarida teniotis*	European Free-tailed Bat	LC	LC
Chiroptera	Miniopteridae	*Miniopterus* sp.	*Miniopterus* sp.	NT	NT

Acoustic monitoring of bats was conducted for the first time in the ITBA with at least five species echolocation calls identified from four families. Kuhl's Pipistrelle Bat (*Pipistrellus kuhlii*) compromised the majority of the total bat echolocation calls followed by the Desert Long-eared Bat (*Otonycteris hemprichii*) with only a few calls recorded of the Trident Leaf- nosed Bat (*Asellia tridens*), the Naked-rumped Tomb bat (*Taphazous nudiventris*) and the European Free- tailed Bat (*Tadarida teniotis*).

Some echolocation calls from a fifth family of a *Miniopterus* species and unidentified vespers were also recorded but require active capture to confirm the identification. The number of sound files from acoustic monitoring totaled up to 56,147 files of which a total of 25,028 contained bat echolocation calls. Acoustic monitoring was conducted at 132 locations throughout ITBA with a sum of 1,558 hours of recordings from sampling nights across all seasons.

For the first time within ITBA, eight bat roost localities and specimen records for *Otonycteris hemprichii* and vesper bat species were confirmed. Preliminary results indicate Kuhl's Pipistrelle Bat (*Pipistrellus kuhlii*) was the most encountered bat species observed during active searching and active trapping but DNA sequencing is required to confirm.

Active trapping was conducted for over 1,223 mistnet hours in 12 different quadrants and an additional seven localities. Active searching to record bat sightings and roosts was performed for over 112 hours in the field in over 50 different quadrants which proved successful during the all-night summer surveys as approximately 65 individual bat sightings were observed.

Large Mammals Survey

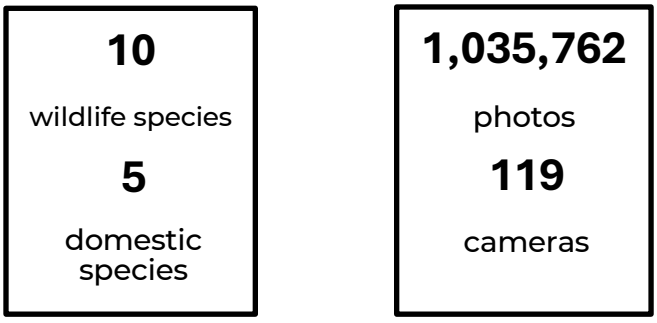
This large mammal survey presents the results of the camera trapping surveys that were conducted in the ITBA to assess mammal diversity and the impact of livestock on the ecosystem. Seasonal surveys were undertaken between March and October 2024: camera deployment, servicing/data collection, and camera retrieval. A total of 119 Browning cameras were strategically placed across diverse habitats within the reserve. Despite the theft of 25 cameras and 10 being vandalised, a total of 93 cameras were recovered. In total, 1,035,762 photos were logged by these cameras.

Data analysis revealed the presence of 10 large wildlife mammal species (nine medium-to- large) and five domestic species. Thousands of images resulted from false triggering by plant movement, wind, and moonlight.

The study used ExifPro and specialised Camera Trap Analysis Packages (CTAP) software for data processing, including generating trap rates, seasonal distribution maps, and 24-hour activity patterns for each large mammal species.

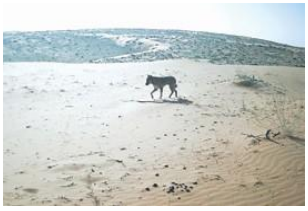
The study highlights specific findings for several key species, including the Arabian Wolf, Arabian Red Fox, Rüppell's Fox, Striped Hyena, Sand Cat, and the Afro-Asiatic Wildcat, providing details on their activity patterns and current conservation status. The report also examines the impact of human activity and livestock, noting that camels were the most frequently encountered.

Numbers at a glance for Large Mammals Survey



Large Mammals

Arabian Wolf
(***Canis lupus arabs***)



Arabian Wolf
(*Canis lupus arabs*)
Camera trap image

Honey Badger
(*Mellivora capensis*)

Striped *Hyena*
(*Hyaena hyaena*)

Striped *Hyena*
(*Hyaena hyaena*)
Camera trap image

Honey Badger
(*Mellivora capensis*)
Camera trap image

Arabian Red Fox
(Vulpes vulpes arabica)

Rüppell's Fox
(*Vulpes rueppellii*)

Arabian Sand Gazelle
(Gazella marica)

Afro-Asiatic Wildcat
(Felis lybica)

Sand Cat
(Felis margarita)

Order	Family OR Subfamily	Scientific Name	Local Name	Global IUCN Status	Regional IUCN Status
Carnivora	Canidae	*Canis lupus arabs*	Arabian Wolf	CR	–
Carnivora	Canidae	*Vulpes rueppellii*	Rüppell's Fox	LC	LC
Carnivora	Canidae	*Vulpes vulpes arabica*	Arabian Red Fox	LC	LC
Carnivora	Felidae	*Felis margarita*	Sand Cat	NT	NT
Carnivora	Felidae	*Felis lybica*	Afro-Asiatic Wildcat	LC	LC
Carnivora	Hyaenidae	*Hyaena hyaena*	Striped Hyena	NT	EN
Carnivora	Mustelidae	*Mellivora capensis*	Honey Badger	LC	NT
Cetartiodactyla	Bovidae-Antilopinae	*Gazella subgutturosa marica*	Arabian Sand Gazelle	VU	VU

Survey effort

The fauna team travelled over 36,000km within the reserve to manage 119 camera traps (placement, servicing, recovery, and data collection). The traps logged 1,035,762 images, all analysed and processed.

First records for the reserve

Striped Hyena (*Hyaena hyaena*): First record, detected in two pictures from one event.
Arabian Wolf (*Canis lupus arabs*): First record, detected in three pictures from two events.
Honey Badger (*Mellivora capensis*): Reconfirmed presence in a new location in eight photographs from one event.

Detection highlights

Arabian Sand Cat (F*elis margarita*): Detected in six photographs from five events.
Rüppell's Fox (*Vulpes rueppellii*): Recorded in 125 photographs from 76 events.
Afro-Asiatic Wildcat (*Felis lybica*): Documented in 70 photographs from 38 events.

Significant results for large mammals

Ten wild terrestrial mammal species recorded, including nine medium-to-large species (≥0.5 kg).
Arabian Red Fox (*Vulpes vulpes arabica*): Highest detection with 604 photographs from 266 events, observed at 21 camera locations, indicating wide distribution.

Species abundance

Arabian Red Fox (*Vulpes vulpes arabica*):
Most recorded carnivore with 604 photos and 266 occurrences, confirming its ecological dominance.

Regional Importance

Findings emphasise the reserve's critical role in supporting regionally endangered species such as the Arabian Wolf (*Canis lupus arabs*) and the Arabian Sand Gazelle (*Gazella subgutturosa marica*).

Small Mammals Survey

This report presents a detailed assessment of the small mammal diversity within the ITBA. Seasonal surveys were conducted to gather data at different times of the year, to account for seasonal variations in species abundance and distribution.

A combination of methods was employed to comprehensively sample small mammal communities in 60 preselected quadrants that were representative of the various habitat types throughout the reserve.

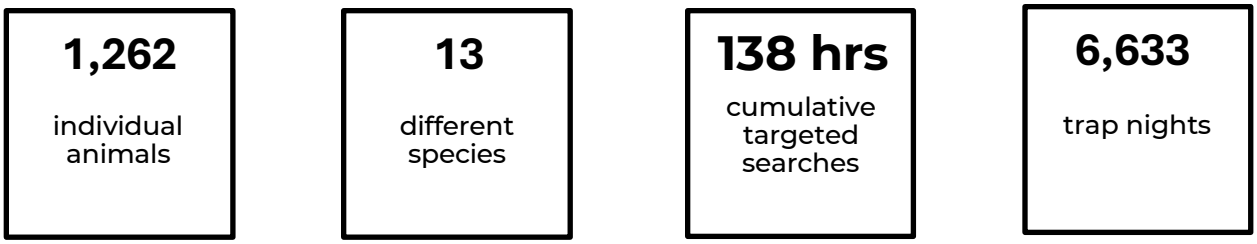
Live traps were strategically deployed for a total of 6,633 trap nights, while targeted searches and transects were carried out for a cumulative total of 138 hours and 20 minutes. These combined efforts resulted in the recording of 1,262 individual animals, representing 13 species.

Among the species identified were Arabian Spiny Mouse (Acomys dimidiatus), Baluchistan Gerbil (Gerbillus nanus), Wagner's Gerbil (Gerbillus dasyurus), Cheesman's Gerbil (Gerbillus cheesmani), Libyan Jird (Meriones libycus), Sundevall's Jird (Meriones crassus), and a single specimen of an invasive House Mouse (Mus musculus), all members of the Muridae family.

Additionally, two species of the Erinaceidae family were recorded: Long-eared Hedgehog (Hemiechinus auritus) and Desert Hedgehog (Paraechinus aethiopicus). Greater Egyptian Jerboa (Jaculus orientalis), Arabian Jerboa (Jaculus loftusi), Lesser Egyptian Jerboa (Jaculus jaculus), and Euphrates Jerboa (Scarturus euphraticus) represented the Dipodidae family, with the latter being the only rodent species of conservation concern in the reserve.

These findings provide valuable insights into the diversity and abundance of small mammal species within the reserve. Species distribution models were also developed to analyse and visualise the spatial distribution of several species, highlighting key habitats and biodiversity hotspots within the reserve. A reference collection of representative specimens were preserved and is stored in the Biobank for future research and use.

Numbers at a glance for Small Mammals Survey



Small Mammals

Long-eared Hedgehog
(*Hemiechinus auritus*)

Desert Hedgehog
(Paraechinus aethiopicus)

Euphrates Jerboa
(Scarturus euphraticus)

Greater Egyptian Jerboa
(Jaculus orientalis)

Arabian Jerboa
(Jaculus loftusi)

Lesser Egyptian Jerboa
(Jaculus jaculus)

House Mouse
(Mus musculus)

Arabian Spiny Mouse
(Acomys dimidiatus)

Baluchistan Gerbil
(Gerbillus nanus)

Wagner’s Gerbil
(Gerbillus dasyurus)

Cheesman's Gerbil
(Gerbillus cheesmani)

Libyan Jird
(Meriones libycus)

Sundevall’s Jird
(Meriones crassus)

Order	Family OR Subfamily	Scientific Name	Local Name	Global IUCN Status	Regional IUCN Status
Eulipotyphla	Erinaceidae	*Hemiechinus auritus*	Long-eared Hedgehog	LC	LC
Eulipotyphla	Erinaceidae	*Paraechinus aethiopicus*	Desert Hedgehog	LC	LC
Rodentia	Dipodidae	*Scarturus euphraticus*	Euphrates Jerboa	LC	NT
Rodentia	Dipodidae	*Jaculus orientalis*	Greater Egyptian Jerboa	LC	LC
Rodentia	Dipodidae	*Jaculus loftusi*	Arabian Jerboa	LC	LC
Rodentia	Dipodidae	*Jaculus jaculus*	Lesser Egyptian Jerboa	LC	LC
Rodentia	Muridae	*Mus musculus*	House Mouse	LC	LC
Rodentia	Muridae	*Acomys dimidiatus*	Arabian Spiny Mouse	LC	LC
Rodentia	Muridae	*Gerbillus nanus*	Baluchistan Gerbil	LC	LC
Rodentia	Muridae	*Gerbillus dasyurus*	Wagner's Gerbil	LC	LC
Rodentia	Muridae	*Gerbillus cheesmani*	Cheesman's Gerbil	LC	LC
Rodentia	Muridae	*Meriones libycus*	Libyan Jird	LC	LC
Rodentia	Muridae	*Meriones crassus*	Sundevall's Jird	LC	LC

The 2024 surveys constitute the most extensive live trapping survey effort for this reserve, with Sherman and cage traps deployed in 60 different quadrants for a total of 6,633 trap nights. These quadrants were selected to adequately represent the 6 microhabitats of the reserve for the most robust representation of the reserve's small mammal species to date. Targeted searches and transects complemented live trapping and proved effective for recording less abundant species and those that might be a bit trap shy.

These efforts resulted in a staggering 1,262 records, representing 13 species, with Long-eared Hedgehog (*Hemiechinus auritus*), Arabian Jerboa (*Jaculus loftusi*), Arabian Spiny Mouse (*Acomys dimidiatus*), Wagner's Gerbil (*Gerbillus dasyurus*), Sundevall's Jird

(*Meriones crassus*), and the invasive House Mouse (*Mus musculus*) all being recorded for the first time within the boundaries of the reserve. With subspecies of *Jaculus jaculus* recently being elevated to species, it was noteworthy to record both the Arabian Jerboa (*J. loftusi*) and the Lesser Egyptian Jerboa (*J. jaculus*) occurring together within the reserve.

The occurrence of four different jerboa species in the reserve is a remarkable scenario. Identifying locations where the Euphrates Jerboa (*Scarturus euphraticus*) could consistently be located was a good sign for a species that is vulnerable to habitat loss, and, with proper management of these areas, this species could persist in the reserve for the long term.

Reptile Survey

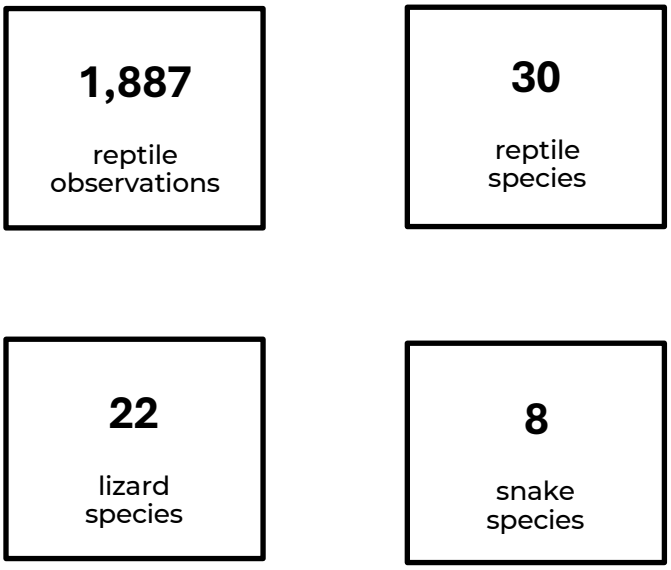
A baseline assessment of the amphibians and reptiles (aka herpetofauna) of the ITBA was conducted in 2024 during surveys spanning winter/spring, summer and autumn seasons.

No species of amphibians were recorded before or during this assessment, presumably because none actually occur here due to the extreme aridity of this region.

Prior to conducting the 2024 field surveys, the only known herpetofauna records from the ITBA study area were 17 reptile observations of 11 reptile species (Šmíd et al. 2021).

The 2024 field surveys contributed a total of 1,887 reptile observations of 30 reptile species, comprising 22 lizard and eight snake species. As a result of the concerted efforts of the 2024 field surveys, the reptile fauna of the ITBA is now one of the most well-studied in all of Saudi Arabia.

Numbers at a glance for Reptile Survey



Reptiles

Arabian Toad-headed Agama (Phrynocephalus arabicus)

North Arabian Plain Agama (Trapelus agnetae)

Horny-scaled Agama (*Trapelus ruderatus*)

Egyptian Spiny-tailed Lizard (Uromastyx aegyptia)

Ananjeva's Fan-footed Gecko (Ptyodactylus ananjevae)

Southern Tuberculated Gecko (Bunopus tuberculatus)

Rough Bent-toed Gecko (Cyrtopodion scabrum)

West Arabian Half-toed Gecko (Hemidactylus granosus)

Dune Sand Gecko (Stenodactylus doriae)

Jordan Sand Gecko (Stenodactylus grandiceps)

Slevin's Sand Gecko (Stenodactylus slevini)

Arabian Web-footed Sand Gecko (Trigonodactylus arabicus)

Bosk's Fringe-toe Lizard (Acanthodactylus boskianus)

Hardy's Fringe-toed Lizard (Acanthodactylus hardyi)

Schmidt's Fringe-toed Lizard (Acanthodactylus schmidti)

Tilbury's Fringe-toed Lizard (Acanthodactylus tilburyi)

Bernoulli's Short-nosed Desert Lizard (Mesalina bernoullii)

Blanford's Short-nosed Desert Lizard (Mesalina brevirostris)

Arabian Sandfish (Scincus mitranus)

Desert Monitor (Varanus griseus)

Order	Family OR Subfamily	Scientific Name	Local Name	Global IUCN Status	Regional IUCN Status
Squamata	Agamidae	*Phrynocephalus arabicus*	Arabian Toad-headed Agama	LC	LC
Squamata	Agamidae	*Trapelus agnetae*	North Arabian Plain Agama	LC	LC
Squamata	Agamidae	*Trapelus ruderatus*	Horny-scaled Agama	LC	LC
Squamata	Agamidae	*Uromastyx aegyptia*	Egyptian Spiny-tailed Lizard	VU	VU
Squamata	Gekkonidae	*Bunopus tuberculatus*	Southern Tuberculated Gecko	LC	LC
Squamata	Gekkonidae	*Cyrtopodion scabrum*	Rough Bent-toed Gecko	LC	LC
Squamata	Gekkonidae	*Hemidactylus granosus*	West Arabian Half-toed Gecko	NE	NE
Squamata	Gekkonidae	*Stenodactylus doriae*	Dune Sand Gecko	LC	LC
Squamata	Gekkonidae	*Stenodactylus grandiceps*	Jordan Sand Gecko	LC	LC
Squamata	Gekkonidae	*Stenodactylus slevini*	Slevin's Sand Gecko	LC	LC
Squamata	Gekkonidae	*Trigonodactylus arabicus*	Arabian Web-footed Sand Gecko	LC	LC
Squamata	Lacertidae	*Acanthodactylus boskianus*	Bosk's Fringe-toed Lizard	LC	LC
Squamata	Lacertidae	*Acanthodactylus hardyi*	Hardy's Fringe-toed Lizard	NE	NE
Squamata	Lacertidae	*Acanthodactylus schmidti*	Schmidt's Fringe-toed Lizard	LC	LC
Squamata	Lacertidae	*Acanthodactylus tilburyi*	Tilbury's Fringe-toed Lizard	LC	LC
Squamata	Lacertidae	*Mesalina bernoullii*	Bernoulli's Short-nosed Desert Lizard	NE	NE
Squamata	Lacertidae	*Mesalina brevirostris*	Blanford's Short-nosed Desert Lizard	LC	LC
Squamata	Lacertidae	*Mesalina guttulata complex*	Small-spotted Desert Lizard	LC	LC
Squamata	Phyllodactylidae	*Ptyodactylus ananjevae*	Ananjeva's Fan-footed Gecko	NE	NE

Squamata	Phyllodactylidae	*Ptyodactylus hasselquistii* complex	Hasselquist's Fan-footed Gecko	LC	LC
Squamata	Scincidae	*Scincus mitranus*	Arabian Sandfish	LC	LC
Squamata	Varanidae	*Varanus griseus*	Desert Monitor	LC	LC
Squamata	Boidae	*Eryx jaculus*	Javelin Sand Boa	LC	LC
Squamata	Boidae	*Eryx jayakari*	Arabian Sand Boa	LC	LC
Squamata	Colubridae	*Lytorhynchus diadema*	Crowned Leaf-nosed Snake	LC	LC
Squamata	Colubridae	*Spalerosophis diadema*	Diadem Snake	LC	LC
Squamata	Psammophiidae	*Malpolon moilensis*	Moila Snake	LC	LC
Squamata	Psammophiidae	*Psammophis schokari*	Schokari Sand Snake	LC	LC
Squamata	Viperidae	*Cerastes gasperettii*	Arabian Horned Viper	LC	LC
Squamata	Viperidae	*Pseudocerastes fieldi*	Field's Horned Viper	LC	LC

Two of the 30 reptile species that were recorded from the ITBA are undescribed lizard taxa that are new to science, i.e. a member of the *Mesalina guttulata* complex and a member of the *Ptyodactylus hasselquistii* complex.

Two lizard and two snake species represent notable range extensions within Saudi Arabia, i.e. Ananjeva's Fan-footed Gecko (*Ptyodactylus ananjevae*), Jordan Sand Gecko (*Stenodactylus grandiceps)*, Javelin Sand Boa (*Eryx jaculus*) and Field's Horned Viper (*Pseudocerastes fieldi*).

Only one reptile species of conservation concern occurs within the ITBA study area, i.e. the Egyptian Spiny-tailed Lizard (*Uromastyx aegyptia*; Vulnerable). It is recommended that a monitoring program for this charismatic lizard be established within the ITBA.

New to Science

Two of the lizard species recorded from the Imam Turki bin Abdullah Royal Reserve are new to science.

Small-spotted Desert Lizard
(*Mesalina guttulata* complex)

Hasselquist's Fan-footed Gecko
(*Ptyodactylus hasselquistii* complex)

Examples of species recorded for the first time in ITBA

Javelin Sand Boa
(Eryx jaculus)

Arabian Sand Boa
(Eryx jayakari)

Crowned Leaf-nose Snake
(*Lytorhynchus diadema*)

Diadem Snake
(*Spalerosophis diadema*)

Hooded Malpolon
(Malpolon moilensis)

Schokari Sand Snake
(Psammophis schokari)

Arabian Horned Viper
(Cerastes gasperettii)

Field's Horned Viper
(Pseudocerastes fieldi)

Invertebrate Survey

Invertebrate diversity at the ITBA was assessed using various methods over seasonal surveys in 2024. Light traps and pitfall traps were deployed in representative quadrants across the reserve to target nocturnal flying and terrestrial inverte- brates, respectively. Invertebrates and collected ectoparasites from trapped rodents during targeted searches and transects were recorded.

A total trapping effort of 154 trap nights and nearly 140 hours of targeted searches and transects across 58 quadrants resulted in the recording of 40,274 invertebrates representing 23 distinct orders.

Notably, large populations of terrestrial beetles, particularly ground beetles (Carabidae) and darkling beetles (Tenebrionidae), were observed throughout the reserve. Particularly at light traps, moths (Lepidoptera) and Wasps (Hymenoptera) were also well-represented. Ectoparasites such as fleas (Siphonaptera), ticks (Ixodidae), and mites (Mesostigmata), were collected from 163 trapped rodents. Fleas and ticks are significant vectors of disease in the local ecosystems, with several zoonotic diseases recorded for the region.

Other medically important invertebrates include Buthidae scorpions and species of the Aranea genera, button spiders (Latrodectus) and long- legged sac spiders (Cheiracanthium), which pose a risk to vulnerable individuals.

While few invertebrate species have been assessed by the IUCN, the conservation status of many species remains unclear, though none appear to be of immediate conservation concern. The analysis of invertebrate abundance and diversity helped identify key biodiversity hotspots within the reserve where targeted conservation efforts could be focused. Invertebrates were also documented during targeted searches and transects, while ectoparasites were collected from trapped rodents.

Numbers at a glance for Invertebrate Survey

Invertebrates

Bigbite Longhorn (*Monocladum aegyptiacum*)

Brush Jewel Beetles (Julodis candida)

Click Beetles (Elateridae)

Robber Flies (Asilidae)

Bee Flies (Bombyliidae)

Brush Jewel Beetles (Julodis candida)

Bagworm Moth (Amicta quadrangularis)

Crimson-speckle Footman (Utetheisa pulchella)

Messor Harvester Ant (Messor arenarius)

Desert Carpenter Ant (Camponotus xerxes)

Dog-toothed Giant Centipede (Scolopendra canidens)

Garden Orbweaver (Argiope sector)

Wolf Spiders (Evippa sp.)

Huntsman Spiders (Sparassidae)

Long-legged Sac Spiders (Cheiracanthium sp.)

Common Romans (Solpugidae)

Hardbacked Ticks (Hyalomma sp.)

Fat-tail Scorpions (Androctonus sp.)

Shield-tailed Scorpion (Apistobuthus

Long-tailed Silverfish (Ctenolepisma longicaudatum)

Order	Family	Scientific Name	Local Name	IUCN Global Status	IUCN Regional Status
Zygentoma	Lepismatidae	*Ctenolepisma longicaudatum*	Long-tailed Silverfish	-	-
Zygentoma	Lepismatidae	*Thermobia domestica*	Firebrat	-	-
Odonata	Aeshnidae	*Anax parthenope*	Lesser Emperor	LC	LC
Blattodea	Hodotermitidae	*Anacanthotermes* sp.	Harvester Termites	LC	LC
Mantodea	Eremiaphilidae	*Eremiaphila brunneri*	Common Ground Mantis	-	-
Mantodea	Empusidae	*Blepharopsis mendica*	Thistle Mantis	LC	LC
Mantodea	Rivetinidae	*Rivetina* sp.	Baetic ground mantis	-	-
Phasmatodea	-	-	Stick Insect	-	-
Embioptera	-	-	Webspinners	-	-
Orthoptera	Gryllidae	*Gryllus bimaculatus*	Common Garden Cricket	-	LC
Orthoptera	Gryllidae	*Acheta domesticus*	European House Cricket	-	LC
Orthoptera	Acrididae	*Sphingonotus rubescens*	Desert Sand Grasshopper	-	LC
Orthoptera	Acrididae	*Heteracris* sp.	Splendid Grasshopper	-	-
Orthoptera	Acrididae	*Oedipoda* sp.	Band-winged Grasshopper	-	-
Dermaptera	-	-	Earwig	-	-
Hemiptera	Reduviidae	*Reduvius* sp.	Assassin Bug	-	-
Hemiptera	Lygaeidae	*Spilostethus pandurus*	Indian Milkweed Bug	-	-
Siphonaptera	-	-	Fleas	-	-
Neuroptera	Myrmeleontidae	*Palpares* sp.	Veld Antlions	-	-
Neuroptera	Myrmeleontidae	*Myrmeleon* sp.	Antlions	-	-
Coleoptera	Carabidae	*Anthia duodecimguttata*	Domino Ground Beetle	-	-
Coleoptera	Carabidae	*Calosoma* sp.	Caterpillar Hunters	-	-

Coleoptera	Tenebrionidae	*Prionotheca coronata*	Urchin Beetle	-	-
Coleoptera	Tenebrionidae	*Blaps polychresta*	Egyptian Beetle	-	-
Coleoptera	Tenebrionidae	*Trachyderma philistina*		-	-
Coleoptera	Tenebrionidae	*Adesmia cancellata*	Pitted Beetle	-	-
Coleoptera	Scarabaeidae	*Oryctes agamemnon*	Rhinoceros Beetle	-	-
Coleoptera	Scarabaeidae	*Scarabaeus* sp.	Dung Beetles	-	-
Coleoptera	Buprestidae	*Julodis candida*	Brush Jewel Beetles	-	-
Coleoptera	Elateridae	-	Click Beetles	-	-
Coleoptera	Cerambycidae	*Monocladum aegyptiacum*	Bigbite Longhorn	-	-
Diptera	Asilidae	-	Robber Flies	-	-
Diptera	Bombyliidae	-	Bee Flies	-	-
Lepidoptera	Erebidae	*Utetheisa pulchella*	Crimson-speckle Footman	-	-
Lepidoptera	Sphingidae	*Hyles livornica*	Striped Hawkmoth	-	-
Lepidoptera	Psychidae	*Amicta quadrangularis*	Bagworm Moth	-	-
Lepidoptera	Nymphalidae	*Danaus chrysippus*	Plain Tiger Butterfly	-	-
Hymenoptera	Apidae	*Apis mellifera*	Western Honeybee	-	-
Hymenoptera	Formicidae	*Messor arenarius*	Messor Harvester Ant	-	-
Hymenoptera	Formicidae	*Camponotus xerxes*	Desert Carpenter Ant	-	-
Scolopendro -morpha	Scolopendridae	*Scolopendra canidens*	Dog-toothed Giant Centipede	-	-
Araneae	Araneidae	*Argiope sector*	Garden Orbweaver	-	-
Araneae	Theridiidae	*Latrodectus* sp.	Black button Spiders	-	-
Araneae	Cheiracanthiidae	*Cheiracanthium* sp.	Long-legged sac Spiders	-	-
Araneae	Sparassidae	-	Huntsman Spiders	-	-
Araneae	Lycosidae	*Evippa* sp.	Wolf Spiders	-	-
Solifugae	Solpugidae	-	Common Romans	-	-
Ixodida	Ixodidae	*Hyalomma* sp.	Hardbacked Ticks	-	-

Order	Family	Scientific Name	Local Name	IUCN Global Status	IUCN Regional Status
Pseudo-scorpiones	-	-	Pseudoscorpions	-	-
Scorpiones	Buthidae	*Apistobuthus pterygocercus*	Shield-tailed Scorpion	-	-
Scorpiones	Buthidae	*Androctonus* sp.	Fat-tail Scorpions	-	-
Notostraca	Triopsidae	*Triops* sp.	Tadpole Shrimps	-	-

This is the most comprehensive invertebrate survey conducted at the ITBA to date. Light and pitfall traps were deployed for 77 trap nights each, covering 49 and 33 quadrants, respectively. In addition, nearly 140 hours of targeted searches and transects were carried out across 58 quadrants, extensively surveying all 6 representative habitats throughout the reserve.

As the first invertebrate survey of this scale, the study recorded 12 new invertebrate orders for the reserve. Notably, it included the detection of rare and difficult-to-detect species such as stick insects (Phasmatodea), webspinners (Embioptera), and pseudoscorpions (Pseudoscorpiones), with the Dog- toothed centipede (*Scolopendra canidens*) being the first species of centipede (Scolopendromorpha) recorded for the reserve. While not new orders, the Striped Hawkmoth (*Hyles livornica*) is a very charismatic and relatively common desert moth species reported for the first time, and Shield-tailed Scorpion (*Apistobuthus pterygocercus*) records were significant, representing new northerly records for the species. This also represents the first ectoparasites collected from such a wide range of small mammal species within the reserve.

This survey offers only a glimpse into the invertebrate diversity within the reserve, with nearly 40,000 specimens deposited in the reserve's Biobank for future studies, allowing for more detailed investigations into specific invertebrate groups.

Key Fauna Biodiversity Areas

A systematic approach was applied to identify Key Fauna Areas (KFAs), which represent the Key Biodiversity Areas for fauna within the Imam Turki bin Abdullah Royal Reserve. Four species distribution models (SDMs) were developed using Maximum Entropy Modelling (MaxEnt) for bats, small mammals, reptiles, and invertebrates. These SDMs predicted habitat suitability based on environmental variables such as elevation, vegetation keys, and anthropogenic factors.

To establish the relationship between Key Fauna Areas and habitat types, the identified KFAs were overlaid with the ITBA habitat classification map. This overlay analysis determined the composition of habitat types within each KFA. The results indicated that Key Fauna Areas are predominantly composed of plateau habitats, with significant proportions of sand dunes, steppes, wadis, and sandy plains. Smaller, but critical habitat types such as floodplains and inter-dunal areas also contributed to the habitat mosaic within KFAs, offering diverse ecological niches.

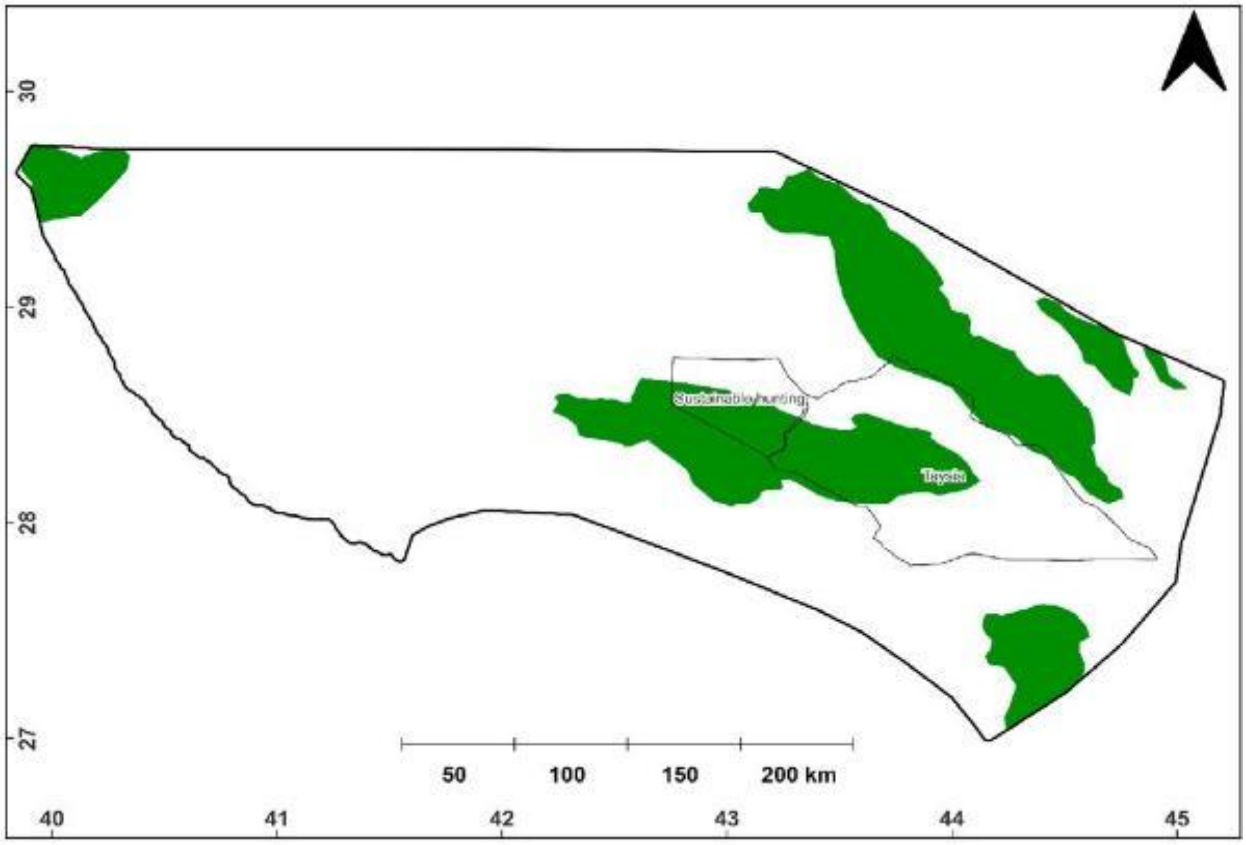
Additionally, separate habitat analyses were conducted for specific taxonomic groups, such as bats, which showed a predominance of plateaus, wadis, and rocky outcrops within the Key Bat Areas. Therefore the linkage between Key Biodiversity Areas and habitat types was explicitly quantified, revealing that the high fauna diversity is largely associated with plateau ecosystems and their associated landforms, while more isolated or fragmented patches of biodiversity are found in sand dune and wadi systems.

The figure below illustrates key fauna biodiversity areas derived from the analysis. These areas are illustrated by the green polygons representing areas of high habitat suitability. The key fauna biodiversity areas are clustered around the central and northeastern parts of ITBA. The Sustainable Hunting area and Taysiyah management zones are situated around areas of potential high biodiversity which make them an important refuge for fauna in the area.

The concentration of green areas in the northeast indicates a potential ecological gradient, where conditions may be more favourable for species in those regions, and this may be due to two management zones. The scattered smaller patches in the western parts of the map might represent isolated habitats that are critical for maintaining connectivity or serving as corridors

for wildlife movement. These patterns underscore the importance of considering habitat connectivity in regional conservation strategies.

The analysis of key fauna biodiversity areas can be a vital tool for conservation planning, providing an effective means to identify priority regions where management resources can be strategically allocated within the ITBA.



The Key Fauna Areas calculated by habitat suitability modelling for ITBA

4. Avifauna Study

Introduction

Between September 2023 and May 2024, a baseline survey to assess the avifauna of Imam Turki bin Abdullah Royal Nature Reserve was completed by ornithologists working under auspices of BirdLife International.

The results of this baseline survey have been fully reported in a thorough and detailed report that includes 18 figures, 33 tables, 76 plates and 12 appendices. It is strongly recommended that that document is consulted fully to attain comprehensive understanding of all survey findings, set in their relevant context and with much additional information.

The present Short Summary Report merely summarises key points and findings but cannot be used nor relied upon in isolation from the full report.

Survey Effort:

Two ornithologists spent a total of 45 days (90 man-days) completing avifaunal surveys at Imam Turki Bin Abdulla Royal Nature Reserve, targeting Autumn migration (Survey 01 – September 2023), Wintering birds (Survey 02 – February 2024) and Breeding birds and Spring migration (Surveys 03 & 04 combined – April and May 2024). Total effort comprised 822 field-hours across Surveys 01–04 as shown in the table below:

Survey #	Start and End Date	Concentrate on	Number of Survey Working Days
01	30 Aug. – 16 Sep. 2023	Autumn migration	15
02	11 – 19 Feb. 2024	Wintering birds	7
03	13 – 30 Apr. 2024	Breeding birds	17
04	1 – 7 May 2024	Spring migration	6

Systematic surveys comprised a combination of Vantage point counts (162), Walked transect surveys (89) and Driven transect surveys (233), with a total of 484 completed (173, Survey 01; 95, Survey 02; 216, Surveys 03 & 04), totalling 297 hrs and distances of 106.5 km (Walked transects) and 1228.8 km (Driven transects). In addition, incidental observations were made daily, and a

number of visits were made to important sites close to but out with the boundaries of the Royal Reserve.

Coverage across the entire reserve was achieved, with 92 (of 119) pre-designated sampling quadrats subjected to systematic surveys. Data recorded included species present and counts, breeding evidence, habitats used and documentation of threats, whilst a literature review investigating recent or ongoing satellite-tracking studies of important species known or suspected to occur in or overfly the reserve was completed.

Main Results

168 species of birds were recorded within the reserve boundaries, of which 162 were recorded during systematic surveys and a further six incidentally. An additional 16 species were recorded out with but very close to reserve boundaries, giving a total of 184 species recorded. Species were categorized as Breeding residents (17.4 %), Winter visitors (7.1 %) or Passage migrants (69.0 %). A small number of species recorded (6.5 %) had an Uncertain (or complex) status.

A total of 42 species recorded were deemed to be breeders or potential breeders. Of these, 18 were confirmed breeders, eight probable breeders and two possible breeders. The remaining 14 were potential breeders, but no evidence for breeding was obtained. Plate 3 depicts Greater Hoopoe-Lark, a common breeding species throughout much of ITBA.

A Greater Hoopoe-Lark *Alaemon alaudipes* carrying food, perching on the dwarf shrub *Scrophularia hypericifolia*. When safe to do so, this bird will return to its nest, which is likely to be in the immediate vicinity. Observation of behaviour such as this allows breeding in the immediate area to be confirmed.

Nine species of global conservation concern (i.e. IUCN Red-Listed as Near Threatened or higher) were recorded. Species involved are: Egyptian Vulture *Neophron percnopterus*, Steppe Eagle *Aquila nipalensis* (both Endangered), Eastern Imperial Eagle *Aquila heliaca*, European Turtle Dove *Streptopelia turtur* (both Endangered) and Curlew Sandpiper *Calidris ferruginea*, Black-winged Pratincole *Glareola nordmanni*, Pallid Harrier *Circus macrourus*, Woodchat Shrike *Lanius senator* and Cinereous Bunting *Emberiza cineracea* (all Near Threatened). Two of the forgoing are illustrated in Plates below.

The globally Endangered Steppe Eagle is the most significant species from a global conservation perspective occurring in ITBA. This bird is a juvenile.

Woodchat Shrike, globally Near Threatened, photographed on migration in ITBA.

Five species recorded are on Appendix I of the Convention on Migratory Species. The species in question are Egyptian Vulture, Steppe Eagle, Eastern Imperial Eagle, Lesser Kestrel *Falco*

naumanni and European Roller *Coracias garrulus*. A further 42 species recorded are on Appendix II of the Convention on Migratory Species.

A total of 24 species recorded are regarded as being of high conservation priority within Saudi Arabia. These species include Arabian Lark *Eremalauda eremodites* (ranked 18th), Cinerous Bunting (ranked 19th) and Egyptian Vulture (ranked 25th). Most species concerned are Passage migrants or Winter visitors although five (including Arabian Lark) are Breeding residents.

Arabian Lark juvenile, photographed on a track within the Taysiyah reserve. This Arabian endemic was found to be a locally common breeder across much of ITBA during the present survey. The neat scaly pattern on the upperside indicates a juvenile, which will have fledged very recently.

The Ecological Importance for the Reserve Birds

Based on population estimates of selected breeding species, it is likely that the reserve is of national importance for Great Grey Shrike *Lanius excubitor*, Greater Hoopoe-Lark *Alaemon alaudipes*, Thick-billed Lark *Ramphocoris clotbey*, Bar-tailed Lark *Ammomanes cinctura*,

Temminck's Lark *Eremophila bilopha*, Arabian Lark and Mediterranean Short-toed Lark *Alaudala rufescens*.

A total of 14 species recorded are regarded as being of regional conservation importance, including two (Black-bellied Sandgrouse *Syrrhaptes orientalis* and Peregrine Falcon *Falco peregrinus*) categorized as Endangered.

The occurrence of eight breeding or potentially breeding species represents an extension of known range within Saudi Arabia. Three species (Chestnut-bellied Sandgrouse *Syrrhaptes exustus*, Black-crowned Sparrow-Lark *Eremopterix nigriceps* and Corn Bunting *Emberiza calandra*) may be regarded as major range extensions.

A total of 12 important bird habitats were identified, and important or indicative species discussed. **Five habitats are exceptionally high value for avian conservation**: Wadi (trees), Fydahs, Wetlands, Agriculture and Parks / Urban areas. Five other habitats (Wadi (dwarf shrubs), Plains (sandy), Plains (gravel), Steppe and Escarpments) have high avian conservation value. Three of these habitats are depicted as Plates 7–9.

All six species for which satellite tracking data was sought were found to at least overfly the Royal Reserve. Four were unrecorded in the present survey, including the globally Critically Endangered Sociable Lapwing *Vanellus gregarius* and globally Endangered Northern Bald Ibis *Geronticus eremita*.

Wadi (trees) with slightly higher edges dominated mature *Vachellia gerrardi* trees. A habitat of exceptionally high value for avian conservation.

A remarkable and ornithologically outstanding wetland. A habitat of exceptionally high value for avian conservation.

Results (Threats):

I. **Illegal killing of birds, mainly by active hunting (with guns) and trapping (by mist nets) is the major threat faced by birds within the Royal Reserve**. This threat is severe throughout the reserve and surrounding areas and is particularly pronounced in or near settlements. Illegal mist-netting is illustrated in Plate 10.

II. Habitats that are particularly targeted by illegal killing include Wadis (trees), fydahs, Wetlands, Parks / Urban and Agriculture.

III. Evidence for illegal killing was noted during each survey, but particularly Surveys 01, 03 and 04, conducted during migration periods. During these, illegal killing was much more widespread and severe during Survey 01 (autumn migration).

IV. **Land degradation by overgrazing is another on-going threat.**

V. High-voltage transmission lines, non-steroidal anti-inflammatory drugs and roadkill by speeding vehicles were identified as potential additional threats.

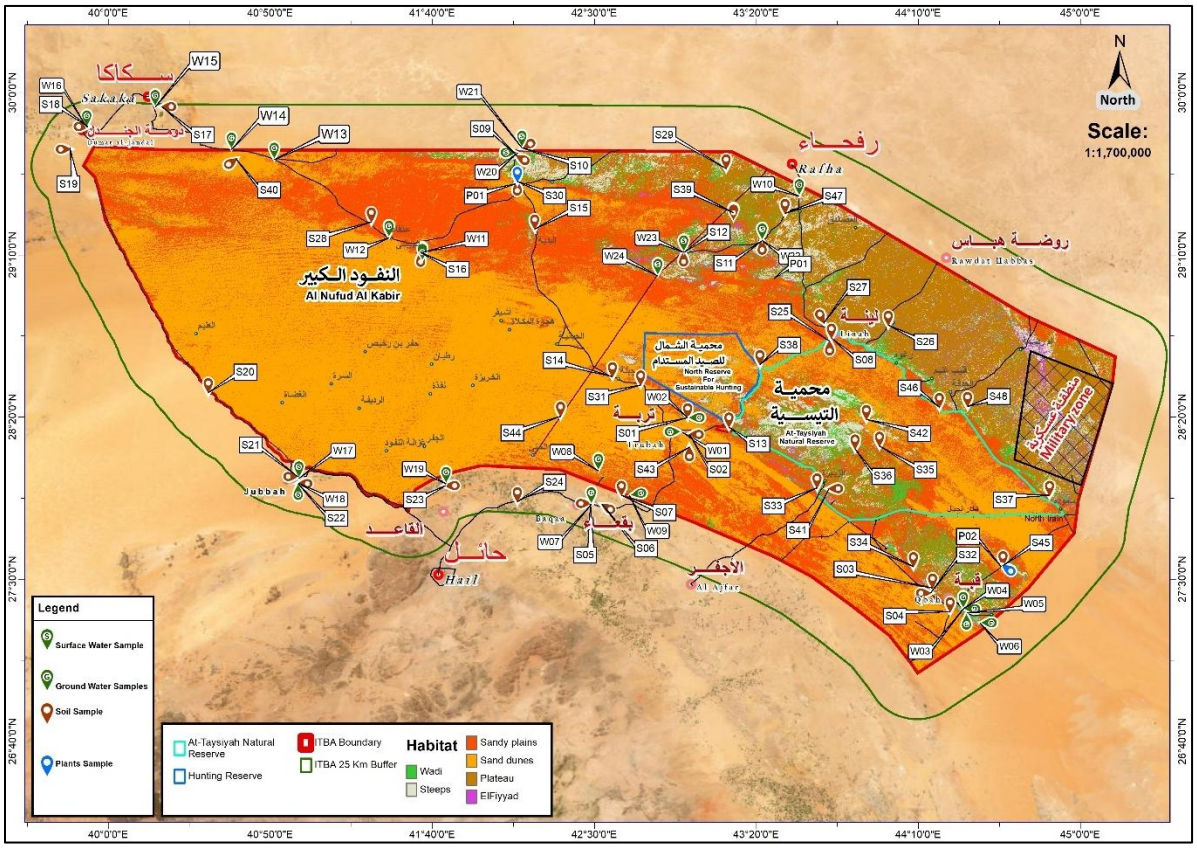
VI. Only one non-native, potentially invasive species (White-cheeked Bulbul *Pycnonotus leucotis*) was recorded.

Mist-netting in a private plantation, photographed during Survey 01, conducted during peak autumn migration and hence peak illegal killing. Multiple birds are visible entangled in this single net; most localities where such mist-netting was observed had numerous such nets.

5. Chemicals Study in the Imam Turki bin Abdullah Royal Reserve

Introduction

Given this rich biodiversity and environmental significance, it is crucial to conduct a comprehensive study to assess the environmental quality of the reserve. This study aims to monitor chemical pollution levels and the key factors affecting the ecosystem, such as heavy metals, organic pollutants, salinity, and nutrients, across different environmental components, including soil, vegetation, water, and wildlife. The goal is to understand the extent of the reserve's exposure to surrounding human activities and to establish appropriate conservation measures for this vital ecosystem. Specific objectives have been identified, including assessing soil and water purity, examining pollutant accumulation in plants and animals and Comparing findings against international environmental standards to ensure that pollutant levels remain within safe limits. This study will provide a scientific foundation for decision-makers to develop sustainable environmental management policies aimed at preserving the reserve's biodiversity in the long term.



Map of Soil, Water, and Plant Sampling Sites

Soil Test Results

The soil samples showed variations in physical and chemical characteristics, but some general patterns were observed.

- pH Levels:
    - ✓ Most soil samples ranged from neutral to mildly alkaline.
    - ✓ Approximately 70% of the samples had a neutral pH (around 7 – 7.5), which is the optimal range for nutrient availability.
    - ✓ Two samples (~4%) were found to be slightly acidic (pH < 6.5), which may limit the availability of certain essential nutrients (such as phosphorus and potassium) and increase the solubility of toxic elements like aluminum and manganese in those areas.
    - ✓ Around 25% of the samples were mildly alkaline (pH > 7.5), potentially leading to reduced availability of micronutrients (such as iron and zinc) for plants.

Overall Interpretation

The pH distribution indicates that most of the reserve's soil is relatively suitable for natural vegetation growth. However, continuous monitoring is needed for highly acidic or alkaline areas to prevent potential negative impacts on plant cover.

Soil Salinity Assessment

Based on Total Dissolved Solids (TDS) values and electrical conductivity measurements, soil salinity levels in the reserve showed significant variation across different samples.

- Low-Salinity Soils:
    - ✓ Some samples were almost non-saline (TDS < 1000 mg/L), making them suitable for most plants without significant restrictions.
- High-Salinity Soils:
    - ✓ A large proportion of samples exhibited elevated salt levels.
    - ✓ A considerable number of samples fell within the highly saline soil category (TDS > 6000 mg/L).
    - ✓ Excessive salinity can hamper plant water absorption, cause osmotic stress, and lead to stunted growth or even the absence of salt-sensitive plant species in these areas.
- Moderate and Medium Salinity Soils:

- ✓ Other samples were classified as moderately saline (TDS 1000–3000 mg/L) and medium saline (TDS 3000–6000 mg/L) but were less prevalent.

Environmental Implications

- Certain areas of the reserve—likely low-lying regions or poorly drained areas—showed salt accumulation in the soil.
- This may be due to natural evaporation processes in the desert environment or the use of saline groundwater for irrigation in adjacent areas.
- Vegetation Response:
  - ✓ Highly saline areas were predominantly covered by salt-tolerant plant species.
  - ✓ Lower-salinity areas had greater plant diversity.

Soil Nutrient Content and Fertility Assessment

The analysis of soil nutrients revealed a general decline in soil fertility across most samples.

- Nitrogen Availability (NH3-N Analysis):
  - ✓ Over two-thirds of the samples (~65%) had very low nitrogen levels (< 0.05 mg/L).
  - ✓ An additional 20% of samples were classified as low nitrogen (0.05–0.1 mg/L).
  - ✓ This indicates that most of the reserve's soil suffers from severe nitrogen deficiency, limiting plant growth.
  - ✓ Only a few samples had moderate to high nitrate levels, with just one sample exceeding 0.2 mg/L, reaching the high range.
- Phosphorus Availability (PO4 Analysis):
  - ✓ The results were similar to nitrogen, showing a clear deficiency in available phosphorus.
  - ✓ Most samples contained phosphorus levels below optimal agricultural thresholds—a common characteristic of desert environments with sandy soils low in organic matter.

Implications for Vegetation and Ecosystem Health

- The soil is generally poor in essential nutrients (nitrogen, phosphorus, and likely organic matter), which are critical for plant growth.
- While this deficiency is not a form of pollution, it reflects natural desert conditions or may result from historical overgrazing and firewood collection.
- Low soil fertility limits plant cover density and productivity, affecting the overall vegetation quality in the reserve.

Potential Management Strategies

To support biodiversity and ecosystem health, the reserve management could consider natural soil fertility improvement approaches, such as:

- ✓ Increasing leguminous plant cover to naturally fix nitrogen in the soil.

Incorporating organic matter into the soil as part of rehabilitation projects to enhance nutrient levels and support plant growth.

Heavy Metal Contamination in Soil

The study focused on measuring heavy metal concentrations in soil to assess whether they exceed natural background levels.

- Most heavy metals (such as manganese, chromium, zinc, and copper) were found to be within the natural range or below pollution thresholds in a significant portion of the samples.
- Based on the Enrichment Factor (EF) calculated for each element:
  - ✓ The vast majority of soil samples were classified as "non-polluted" (EF < 5) for elements like manganese, chromium, and zinc.
  - ✓ This suggests that these elements primarily originate from natural geological sources rather than from human activities.
  - ✓ For example, the average EF for manganese and chromium was below 2, confirming the absence of unnatural enrichment.

Localized Contamination of Toxic Metals

However, some toxic metals showed elevated levels in specific areas, requiring further attention. The most concerning elements included:

- ✓ Cadmium (Cd)
- ✓ Lead (Pb)
- ✓ Arsenic (As)

Cadmium Contamination

- Approximately half of the samples showed an Enrichment Factor (EF) greater than 5 for cadmium.
- Most of these cases fell within the moderate contamination range (EF 5–20).
- However, two samples exceeded EF 20, classifying them as highly contaminated.

Contaminated Sample Locations

- One sample was collected from farmland soil in Jubbah village.
- The other was from a natural habitat on the outskirts of the reserve.

Possible Sources of Cadmium Pollution

- In the farmland, pollution is likely due to agricultural activities, such as:
    - ✓ Heavy use of phosphate fertilizers
    - ✓ Pesticides containing cadmium
- In the natural habitat, contamination may originate from:
    - ✓ Natural geological sources
    - ✓ Airborne cadmium deposits, possibly carried by dust from industrial areas located far away.

Lead Contamination

- Out of 48 soil samples, 46 were within the natural range (non-contaminated).
- One sample showed moderate contamination levels.
- One sample recorded a very high EF value (>40) for lead, indicating severe contamination at that specific site.

Location of Severe Lead Contamination

- The highly contaminated sample was taken from a waste dump site near the Turaif area in Ha'il.

Possible Sources of Lead Pollution

- The extremely high lead concentrations in this soil suggest a direct human-related source, possibly from:
    - ✓ Discarded batteries
    - ✓ Industrial waste containing lead

Arsenic Contamination

- The Enrichment Factor (EF) analysis for arsenic revealed that:
    - ✓ 35% of soil samples fell within the moderate contamination range.
    - ✓ Five samples exhibited high contamination levels (EF 20–40).
    - ✓ Two samples exceeded EF 40, classifying them as severely contaminated with arsenic.

Locations of Severe Arsenic Contamination

- One highly contaminated sample was from the waste dump site (the same location that had lead contamination).
- The other was from a farm near Jubbah village.

Possible Sources of Arsenic Pollution

- Historical pesticide use – In the past, arsenic-based compounds were commonly used for pest control in agriculture.
- Phosphate fertilizers – These may contain arsenic impurities.
- Industrial deposition – Arsenic contamination can result from:
    - ✓ Mining activities
    - ✓ Burning of contaminated waste

Other Heavy Metals

- Copper (Cu):
    - ✓ 11 soil samples (23%) had EF values between 5 and 20, indicating slight to moderate contamination.
    - ✓ This contamination may be linked to intensive use of copper-based fungicides or fertilizers in nearby agricultural areas.
- Nickel (Ni):
    - ✓ Almost all samples showed natural levels of nickel, except for one sample with moderate contamination (from a farm in another village).
    - ✓ This suggests a potential industrial or local geological source for the elevated nickel levels in that specific site.
- Manganese (Mn) and Chromium (Cr):
    - ✓ Both elements remained within natural levels in almost all samples.
    - ✓ EF values were below 5 in all locations, confirming no human-induced enrichment.
- Zinc (Zn):
    - ✓ Although zinc is an essential nutrient for plants, only one case of moderate contamination was recorded (in a sample from a natural habitat).
    - ✓ All other samples showed normal zinc levels.

Overall Soil Contamination Assessment

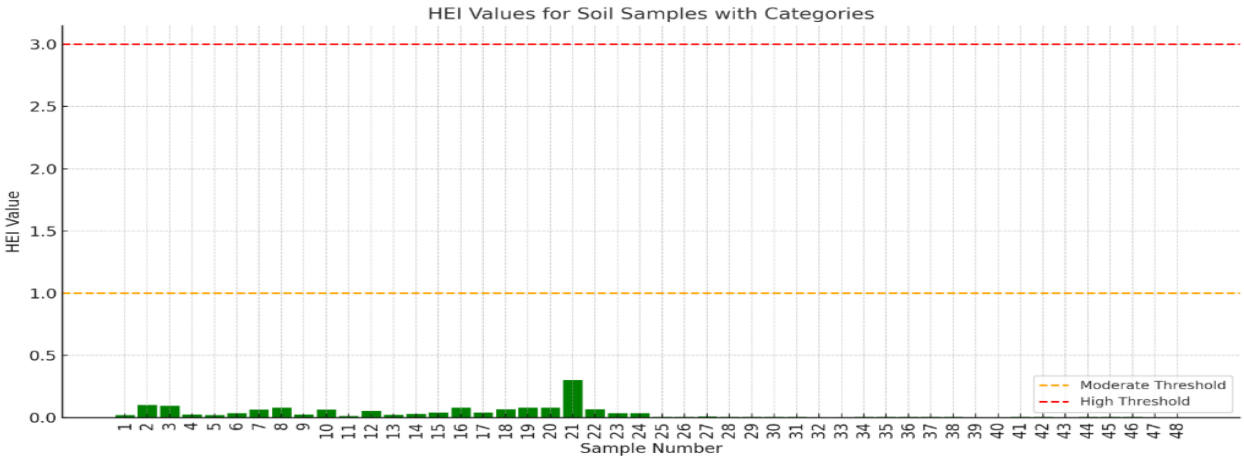
The results indicate that heavy metal contamination in the reserve's soil is generally low, with most areas unaffected by harmful human activities.

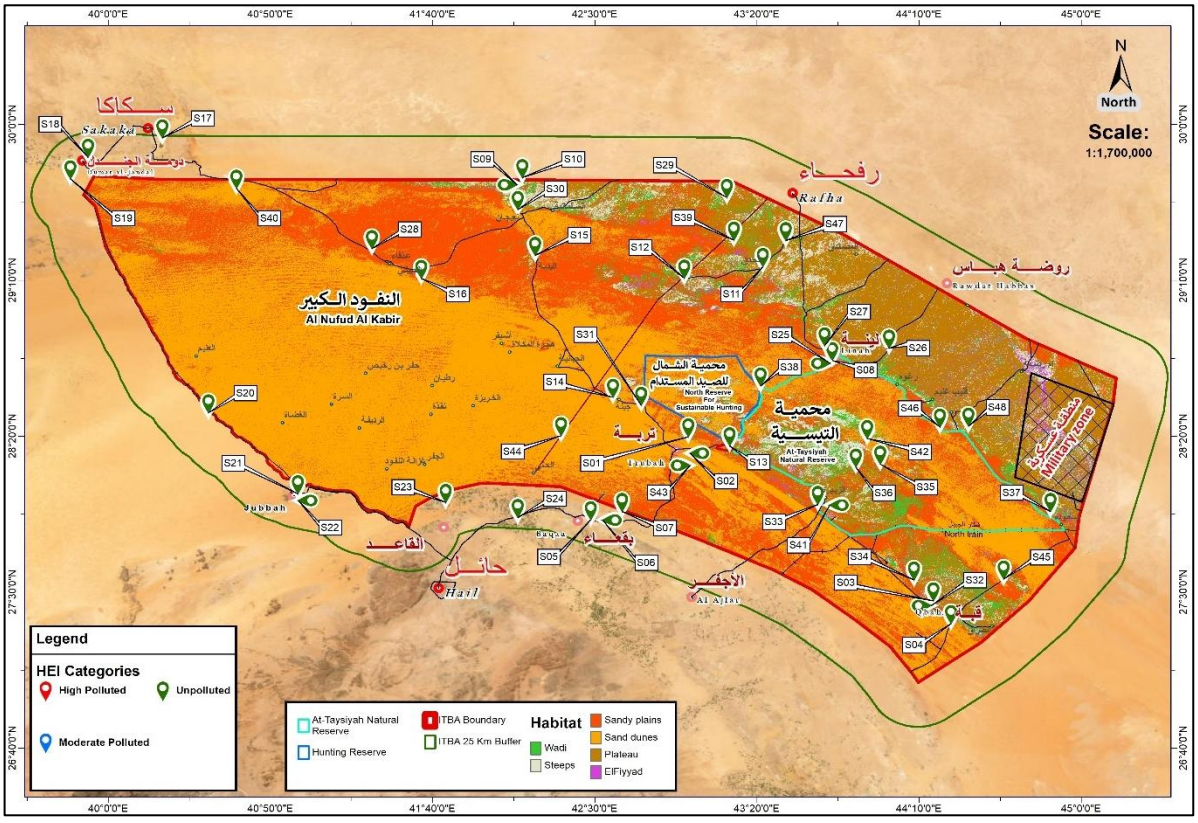
- Localized Contamination Hotspots:
    - ✓ Pollution was concentrated in a few isolated sites, mainly:
      -An external waste dump
      -Some agricultural lands on the reserve's outskirts
    - ✓ These hotspots elevated local concentrations of lead (Pb), cadmium (Cd), and arsenic (As).
    - ✓ However, the deeper core areas of the reserve remain uncontaminated.
- Comparison with International Standards:
    - ✓ When compared to global environmental standards (e.g., agricultural soil guidelines or EPA/WHO residential soil limits), most soil samples fall within safe limits.
    - ✓ Exceptions:
        - A few isolated sites exceeded the permissible levels for cadmium and lead.
        - Lead levels in the waste dump site far exceeded internationally accepted safe limits, highlighting the need for remediation at that location.

Key Takeaway:

- No widespread or generalized contamination was detected in the reserve's soil.
- This is a positive and reassuring finding, indicating that:
    - ✓ The soil remains chemically healthy in most parts of the reserve.
    - ✓ It continues to support natural plant growth and wildlife with minimal risk of heavy metal toxicity.

All 48 samples fell into the low pollution category (HEI < 1).





Map of the geographical distribution of heavy metals valuation results

Plant Test Results

The analysis of plant samples complemented the soil study, providing insight into how contaminants transfer from soil to living organisms.

- Heavy Metal Concentrations in Plant Tissues:
    - ✓ Metal levels were measured in leaves and stems of trees and shrubs from various locations.
    - ✓ Results showed that heavy metal concentrations in plants were generally low and remained within natural background levels for wild vegetation.
- Localized Increases Near Contaminated Areas:
    - ✓ Lead (Pb) and cadmium (Cd) levels were slightly higher in plant leaves near polluted sites compared to those in clean areas.
    - ✓ However, these levels remained below toxic thresholds for plants.
- Limited Metal Accumulation in Plants:
    - ✓ No significant bioaccumulation of heavy metals was observed in plant tissues.
    - ✓ This suggests that:
      Plants in the contaminated areas absorbed only limited amounts of metals from the soil.Many of the studied plant species naturally avoid accumulating heavy metals (a biological defense strategy).
- This is a positive finding, as it indicates that: The plant-based food chain (plants → herbivores) is not carrying high concentrations of heavy metals. The risk of heavy metal transfer to grazing animals remains minimal in the reserve

Pesticide Residue Analysis in Plants: In addition to heavy metals, the study examined pesticide residues in plant samples to assess potential organic contamination affecting plants or their consumers.

- No Detectable Pesticide Contamination:
    - ✓ Laboratory analyses found no significant concentrations of insecticides or herbicides in the plant tissues collected from the reserve.

- ✓ No traces of organochlorine or organophosphate compounds were detected within measurable limits.

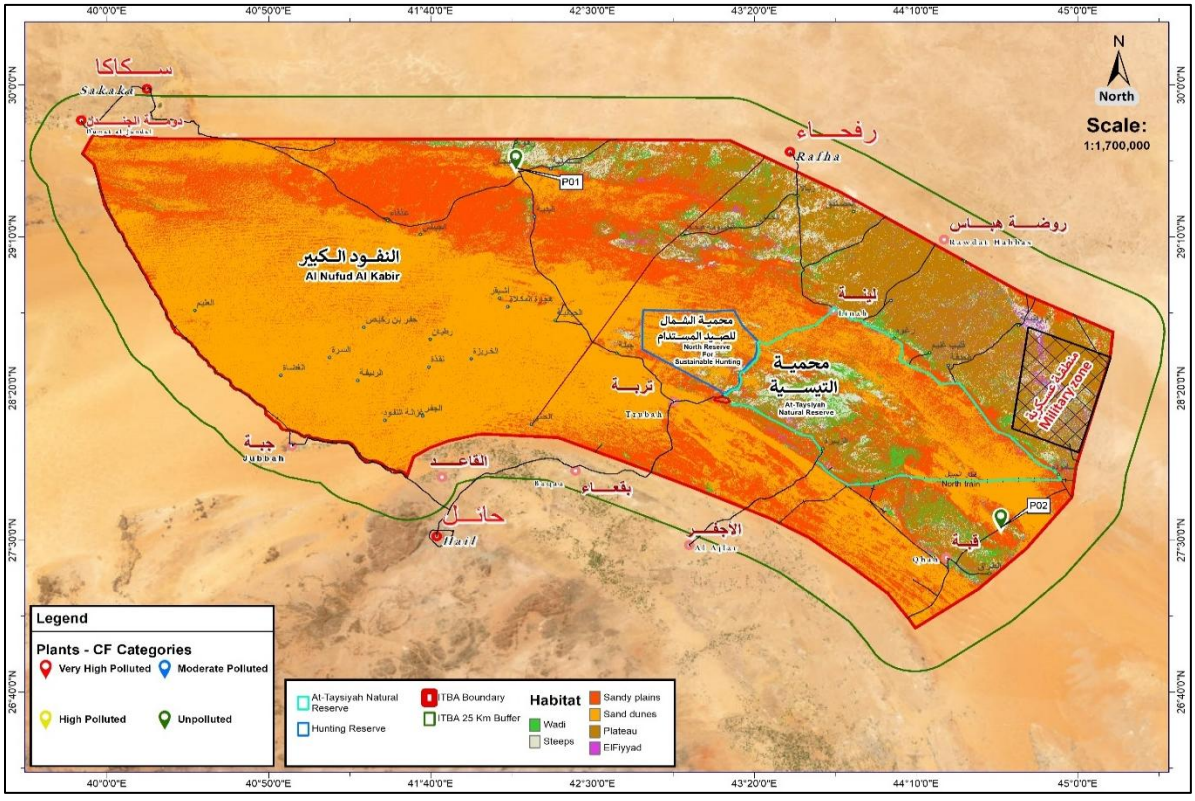
- Possible Reasons for the Absence of Pesticides:

  - ✓ This suggests that no recent intensive pesticide use has occurred within the reserve or from nearby areas.

  - ✓ While trace amounts of older pesticide residues may still exist in the soil, they were too low to be absorbed by plants in detectable amounts.

Vegetation Health and Chemical Pollution: Overall, the reserve's plant cover appears healthy from a chemical pollution perspective: Plants grow naturally across most areas without signs of toxicity or nutrient imbalances due to pollutants.Salinity and nutrient deficiencies in certain areas have affected plant growth and diversity, but not due to heavy metal or pesticide contamination.

Key Implications: This is a crucial finding, as it confirms that plants, the foundation of the food chain, do not store hazardous pollutants that could transfer to herbivorous animals. The absence of significant pesticide residues reinforces the reserve's low chemical pollution status.



Plant Contamination Factor (CF)

Animals Blood Samples Results

The analysis of wild animal blood samples provided a direct biological indicator of environmental quality and ecosystem health.

Key Findings:

- Pollutant levels in animal blood were generally within safe limits, with no signs of acute poisoning detected.
- Heavy metal concentrations (chromium, cadmium, lead) were very low across all samples.

Chromium (Cr): Blood chromium levels ranged between 0.7 to 2.1 ng/g, which is far below known toxic thresholds for this element.

Cadmium (Cd): Cadmium levels in blood ranged from 0.25 to 0.6 ng/g, which is extremely low and does not indicate any serious exposure (toxic effects of cadmium typically occur at significantly higher levels).

Lead (Pb):

- Lead levels in blood were generally low, ranging between 8 to 14 ng/g.
- One wild camel recorded the highest lead concentration (13.8 ng/g).
    - ✓ While higher than other samples, this value is still below the toxic threshold for lead in mammals.
    - ✓ This suggests that the camel may have been exposed to a local lead source (possibly by drinking water or feeding on plants near a contaminated site).
    - ✓ This aligns with soil contamination findings, which identified a high-lead site near a waste dump near Trubah.
- Other animals (gazelles and others) did not show elevated lead or other heavy metals in their blood, indicating no widespread exposure risk.

Implications and Recommendations: Overall, wildlife in the reserve appears to be in good health regarding chemical contamination. The isolated lead exposure case suggests the need for further investigation into localized contamination sources. Continuous monitoring is recommended to detect potential long-term bioaccumulation in certain species.

Cyanide (CN^-) Levels and Overall Wildlife Health Assessment

- Cyanide (CN^-), a key indicator of severe industrial pollution (such as mining activities), was below detection limits in most blood samples or found at very minimal levels (0.01–0.07 ng/g).
- This is a reassuring result, indicating that wildlife has not been exposed to a continuous cyanide source.
- Any trace amounts detected are likely due to natural environmental factors, such as: Burning of plant residue, The presence of certain plants that naturally produce small amounts of cyanide,Not actual industrial contamination

Comparison with Global Animal Health Standards:

- Heavy metal concentrations in animal blood were compared to international veterinary and health organization limits.
- All measured levels were below critical thresholds that could cause toxic effects or health issues.
- No signs of illness were observed in animals during sample collection.
- General health markers (such as hemoglobin levels, liver, and kidney function in selected samples) were within normal ranges.

Wildlife in the reserve does not show significant chemical contamination risks, No major exposure to cyanide or heavy metals was detected. The ecosystem currently supports healthy wildlife without severe pollution-related health threats.

Long-Term Monitoring of Lead and Cadmium Exposure

- The study revealed a noteworthy finding: the presence of trace amounts of lead (Pb) and cadmium (Cd) in animal blood.
- Although these levels are very low, their mere detection indicates continuous low-level environmental exposure to these pollutants.
- Cadmium and lead are not naturally present in living organisms unless the surrounding soil, water, or food sources contain trace amounts of these elements.

Wildlife as Biological Indicators

- Wild animals act as bio-indicators of environmental quality.
- The presence of cadmium and lead in blood, even below toxic thresholds, suggests a need for ongoing monitoring of potential sources to prevent their levels from increasing over time.

Heavy Metal Accumulation Risks

- Lead and cadmium are cumulative toxins, meaning they can gradually accumulate in animal organs (such as the liver and kidneys) over the long term, even if their blood levels remain low initially.

- This reinforces the importance of conducting periodic health screenings to ensure these metals do not build up over time and pose a risk to wildlife.

sample	gender	age	(Cr) (ng/g)	(Pb) (ng/g)	(Cd) (ng/g)	(CN^-) (Blood) (ng/g)
ARABIAN HARE 6527	Male	1	0.86	9.3	0.4	0.01
ARABIAN HARE 6541	Female	1	1.03	11.6	0.35	0.02
GAZELLA MARICA 273	Female	1	1.00	10.9	0.28	0.015
GAZELLA MARICA 029	Male	2	0.74	8.8	0.37	0.022
ORYX 506	Male	1	1.03	10.9	0.39	0.028
HOUBARA (CHLAMYDOTIS UNDULATA) 011	Male	1	0.69	8.03	0.25	0.01
HOUBARA (CHLAMYDOTIS UNDULATA) M22S39125	Male	2	0.73	9.1	0.35	0.03
Sheep 1	Male	3	1.05	11.4	0.38	0.028
Sheep 2	Male	4	0.96	11.4	0.4	0.03
Camel 1	Female	1	2.1	13.8	0.63	0.03
Rodent 1905	Male	1	0.77	8.1	0.32	0.01
Rodent 1917	Male	2	0.93	10.5	0.36	0.022
Rodent 1909	Male	2	0.94	11.8	0.39	0.04
Rodent 1974	Male	3	1.03	11.7	0.31	0.026
Rodent 1968	Male	1	1.08	10.4	0.33	0.017
Rodent 1989	Male	2	1.03	9.9	0.31	0.027
Rodent 1911	Male	1	1.07	10.3	0.32	0.010
Rodent 4274	Male	3	0.90	11.9	0.33	0.021
Rodent 1913	Male	1	1.02	9.7	0.31	0.018
Rodent 1915	Male	1	0.92	11.6	0.38	0.07
Rodent 4282	Male	2	0.91	11.3	0.34	0.010
Rodent 1977	Male	1	1.09	9.8	0.30	0.020
Rodent 1991	Male	3	0.90	10.6	0.36	0.06
Rodent 1986	Male	2	1.01	11.8	0.31	0.019
Rodent 1972	Male	2	1.03	11.4	0.34	0.022

Water Test Results

The analysis of groundwater and surface water samples provided promising results regarding the quality of water resources in the reserve.

1. Water Salinity Levels

- Overall, water quality was high, with no toxic contaminants detected; however, salinity levels varied depending on the water source.
- Groundwater Salinity:
  - ✓ Some groundwater samples were fresh or mildly saline (TDS < 1000 mg/L), making them suitable for drinking and wildlife use.
  - ✓ However, some wells and springs had elevated salinity (TDS ranging 3,000–5,000 mg/L), classifying them as moderately to highly saline.
  - ✓ While such high-salinity water sources may be challenging for certain species, many desert wildlife species are adapted to drinking water with higher salinity.

- Surface Water (Seasonal Ponds):
  - ✓ These had low salinity due to rainwater replenishment.
  - ✓ However, rapid evaporation could increase salt concentrations over time if the water remains stagnant.

- Overall Salinity Conclusion:
  - ✓ Salinity was not a critical issue during the study period.
  - ✓ However, it should be monitored, especially during dry seasons, as salt concentrations may rise further.
  - ✓ Further hydrogeological studies could help explore ways to naturally reduce salinity, such as through rainwater harvesting techniques to support biodiversity.

2. Chemical Contamination in Water

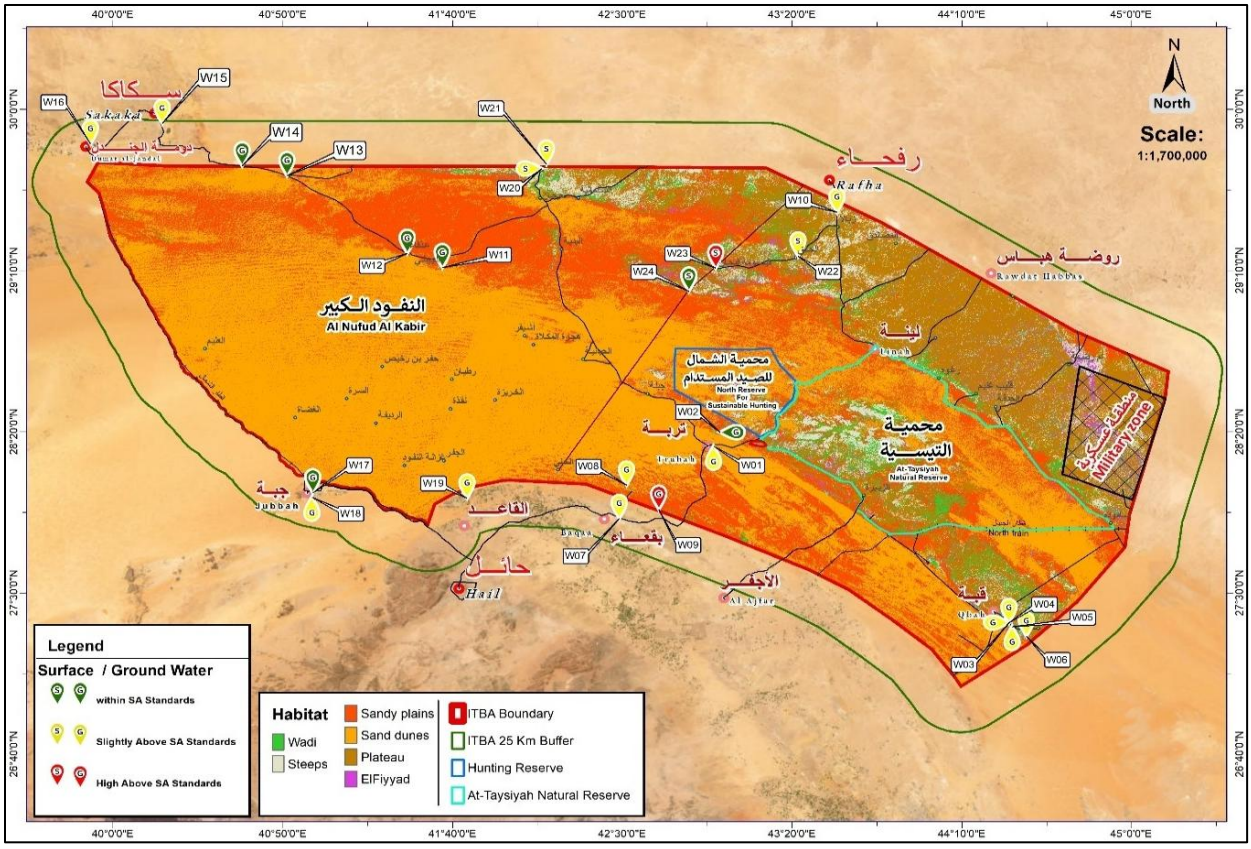
- Water quality results were extremely positive, showing very low heavy metal concentrations, often below detection limits.
- Heavy Metal Pollution Index (HEI):
  - ✓ All water samples were classified as low-pollution and safe (HEI < 1).
  - ✓ This indicates that combined heavy metal concentrations pose no environmental or health risks.

- Specific Heavy Metal Levels:
  - ✓ Lead (Pb): < 5 ppb, far below the WHO drinking water limit (10 ppb).
  - ✓ Cadmium (Cd): Either undetectable or in trace amounts below the WHO limit (3 ppb).
  - ✓ Arsenic (As): Below 10 ppb, within safe limits.
  - ✓ Chromium (Cr): Below 50 ppb, also within safe limits.
- Organic Contamination:
  - ✓ No detectable organic pollutants were found in water samples.
  - ✓ Volatile organic compounds (VOCs) and petroleum residues tested negative, confirming that no industrial pollutants had reached the reserve's water sources.
- pH and Oxygen Levels:
  - ✓ pH values ranged between 7 and 8, indicating neutral to slightly alkaline water, suitable for most biological uses.
  - ✓ Dissolved oxygen levels (where measured) were within normal ranges, meaning no significant organic decomposition or biological oxygen depletion was occurring in surface waters.

3. Conclusion: A Safe Water Environment

The reserve’s water resources are of very high quality, free from toxic contaminants, and provide a safe aquatic environment for wildlife and plants, No significant concern regarding heavy metal or organic pollution was identified.

Salinity is a natural challenge but can be managed, particularly in areas where wildlife relies on highly saline sources, establishing alternative low-salinity water sources could benefit wildlife during dry seasons. The absence of industrial or agricultural pollution suggests that no major contamination is seeping into groundwater or surface water. The positive water quality results align with the low pollution levels found in soil, reinforcing that chemical pollutants have not significantly infiltrated the reserve’s ecosystem.



Geographical distribution map of water salinity results based on the results of groundwater and surface water sample analysis collected from the reserve area and its immediate surroundings - 2024

Based on the above, it can be said that the water resources in the reserve are of very good quality from the perspective of being free of toxic pollutants. They provide a safe aquatic environment for animals and plants and do not pose current concern regarding mineral or organic pollution.

6. Natural Values and Ecosystem Services

Ecosystem Values and Services of Imam Turki bin Abdullah Royal Reserve (ITBA)

The Imam Turki bin Abdullah Royal Reserve (ITBA) is a key contributor to Saudi Arabia's conservation and sustainable development goals, offering a wide range of ecosystem services that support biodiversity, climate regulation, and local economies. These services are classified into Provisioning, Regulating, Supporting, and Cultural services, ensuring the sustainable use of natural resources while maintaining ecological integrity.

A) Provisioning Services (Direct Benefits to Humans)

Provisioning services refer to the tangible resources provided by ITBA that support livelihoods, food security, and economic sustainability.

Sustainable Grazing & Forage Production

- ITBA rangelands provide seasonal grazing opportunities for camels and sheep, directly benefiting local pastoralist communities.
- Regulated grazing permits ensure sustainable livestock management while preventing overgrazing and desertification.

Beekeeping & Honey Production

- ITBA supports sustainable beekeeping due to its floral diversity, particularly Talh (Acacia) and Sidr (Ziziphus) trees, which provide high-quality nectar.
- Honey production enhances pollination, supports biodiversity, and strengthens local economies.

Desert Truffle (Fagaa) Harvesting

- ITBA is home to the desert truffle (Terfeziaceae), locally known as Fagaa, a high-value edible fungus harvested seasonally after rainfall.
- Cultural Importance: Desert truffles hold deep roots in Bedouin traditions, where foraging knowledge has been passed down through generations.
- Economic Significance: Truffles are highly marketable, generating income for local communities through foraging, trade, and eco-tourism experiences.
- Ecological Role: Truffles enhance soil fertility and support native vegetation.

Wildlife Resources & Conservation Breeding

ITBA is a critical reintroduction site for Arabian oryx, sand gazelle, and Arabian wolf, restoring desert ecosystems while contributing to Saudi Arabia's Vision 2030 biodiversity goals.

Medicinal and Traditional Plants

ITBA hosts native plants with medicinal and traditional uses, such as Haloxylon, Calligonum, and Artemisia, supporting pharmaceutical applications and local herbal medicine practices.

B) Regulating Services (Ecosystem Stability & Climate Mitigation)

Regulating services ensure long-term ecological resilience by stabilising the climate, air, soil, and water cycles.

Carbon Sequestration & Climate Regulation

- Vegetation cover acts as a carbon sink, helping mitigate climate change.
- Projected Impact: ITBA is estimated to absorb 228,000 tons of CO_2 by 2030.

Air Quality Improvement & Dust Suppression

- ITBA's vegetation prevents dust storms, improving air quality and reducing respiratory health risks.
- Annual Impact: ITBA prevents 14,000 tons of dust emissions from reaching populated areas.

Soil Erosion Prevention & Land Stabilisation

- Native vegetation and root structures stabilise soils, reducing desertification and wind erosion.
- Projected Benefit: ITBA will prevent 110,000 tons of soil erosion by 2030.

Water Regulation & Groundwater Recharge

Seasonal wadis and desert plants aid in water retention, reducing flash floods and enhancing underground water reserves.

C) Supporting Services (Ecosystem Processes that Enable Other Services)

Supporting services ensure the continuation of ecological functions that sustain ITBA's biodiversity and ecosystems.

Biodiversity Conservation & Habitat Formation

- ITBA provides habitats for 341 documented species, including endemic, threatened, and migratory species.
- ITBA's conservation efforts contribute to Saudi Green Initiative (SGI) targets.

Pollination & Genetic Diversity

ITBA supports wild bee populations, butterflies, and other insect pollinators, enhancing plant reproduction and ecosystem resilience.

Nutrient Cycling & Soil Fertility

Microbial activity, plant decomposition, and seasonal moisture retention contribute to soil enrichment and organic matter recycling.

D) Cultural & Economic Services (Non-Material Benefits to Society)

Cultural services encompass heritage, tourism, recreation, and educational benefits associated with ITBA's landscapes and biodiversity.

Wildlife-Based Tourism

- The reintroduction of flagship species such as Arabian oryx, sand gazelle, and Arabian wolf creates opportunities for wildlife viewing and eco-tourism.
- Sustainable wildlife tourism generates revenue for conservation efforts while creating local employment in eco-tourism services.

Adventure & Desert Exploration Tourism

ITBA's unique landscapes—including sand dunes, rocky plateaus, and ancient wadis—offer activities such as:

Hiking, camping, desert safaris, and guided eco-expeditions.

Controlled eco-tourism zones ensure minimal ecological impact while maximising visitor engagement.

Cultural & Heritage Tourism

- Darb Zubaydah, an ancient trade and pilgrimage route, provides insights into the region's historical significance.
- Engaging local Bedouin communities in storytelling, traditional crafts, falconry demonstrations, and desert survival workshops enhances visitor experiences while preserving intangible cultural heritage.

Desert Truffle & Gastronomic Tourism

- Seasonal desert truffle harvests offer unique agro-tourism experiences, where visitors can:
- Learn about traditional foraging methods.
- Participate in guided truffle hunts.
- Truffle eco-tourism can boost rural economic development while promoting sustainable harvesting practices.

Educational & Scientific Tourism

- ITBA serves as a living laboratory for universities, researchers, and conservationists, supporting:
- Biodiversity monitoring and conservation research.
- Desert ecology studies and climate resilience research.
- Citizen science programmes allow visitors to contribute to wildlife tracking and ecological surveys.

Summary of ITBA's Ecosystem Services

Category	Ecosystem Service	Description & Impact
Provisioning	Grazing	Seasonal forage for livestock; regulated to prevent overgrazing.
	Beekeeping & Honey Production	Supports sustainable honey production through native Talh & Sidr plants.
	Wildlife Conservation	Provides habitats for species reintroduction (Arabian oryx, sand gazelle, Arabian wolf).
	Desert Truffle Harvesting	High-value edible fungi; support Bedouin livelihoods & traditional foraging.
	Traditional Medicinal Plants	Home to native species used in herbal medicine and pharmacology.
Regulating	Carbon Sequestration & Climate Regulation	Estimated 228,000 tons CO_2 absorbed by 2030.
	Air Quality Improvement	Reduces 14,000 tons of dust annually through vegetation cover.
	Soil Erosion Prevention	An estimated 110,000 tons of soil erosion prevented by 2030.
Cultural	Wildlife-Based Ecotourism	Supports sustainable conservation tourism and creates local jobs.
	Desert Exploration & Adventure Tourism	Controlled eco-tourism activities protect fragile desert ecosystems.
	Cultural & Heritage Tourism	Historic sites such as Darb Zubaydah attract cultural tourism.
	Desert Truffle & Gastronomic Tourism	Seasonal truffle hunts connect eco-tourism with local traditions.

The Natural and Cultural Values of the Imam Turki bin Abdullah Royal Reserve[1]

The Imam Turki bin Abdullah Royal Reserve Development Authority has defined the natural and cultural values of the reserve through a holistic and collaborative approach, combining scientific research, stakeholder engagement, and traditional environmental knowledge. This approach included consultations with national environmental bodies such as the National Center for Vegetation Cover Development and Combating Desertification and the National Wildlife Center, as well as contributions from local communities with extensive indiginous knowledge of local cultures and ecological systems. Workshops and meetings with experts and stakeholders were conducted to assess the unique environmental, cultural, social and economic characteristics of the reserve. These engagements contributed to the identification of critical habitats, key species and basic ecosystem services provided by the reserve. Scientific studies, including environmental surveys, socio-economic assessments, and habitat classification efforts, have been adopted as effective tools in determining and assessing the natural values of the reserve. Advanced technologies such as remote sensing, habitat mapping, and biodiversity surveys have also been used to assess the distribution and status of plant and animal species, ensuring a data-driven understanding of the integrity of the ecosystems in the reserve. The reserve's natural values have been categorized according to its environmental, economic and cultural importance, highlighting the reserve's position as a centre of biodiversity, a critical habitat for endangered species, and a valuable resource for local communities. This integrated approach has ensured a comprehensive understanding of the natural values of the reserve, paving the way for the development of sustainable management strategies that align conservation objectives with the local community needs.

Natural values of the Imam Turki bin Abdullah Royal Reserve

Habitat Diversity and Ecological Importance

The Imam Turki bin Abdullah Royal Nature Reserve (ITBA) is a critical conservation site in Saudi Arabia, offering a diverse range of ecological and biological values. The reserve encompasses unique landscapes, including sand dunes, wadis, and steep terrains, which collectively form a dynamic and biologically rich environment. These ecosystems provide essential services such as soil stabilization, water retention, and erosion control while supporting a vast array of plant and animal species. The reserve is a recognized biodiversity hotspot within the Arabian Peninsula, playing a crucial role in sustaining native flora and fauna adapted to arid conditions.

[1] Source Data for this section: The Imam Turki bin Abdullah Royal Reserve Development Authority

The Imam Turki bin Abdullah Royal Reserve shows a unique ecological diversity that reflects the complex interplay between topography, geology, and climatic processes. Sand dunes cover approximately half of the reserve's area and are highly concentrated in the high-altitude eastern and southern regions, where wind plays a key role in its formation and transportation. These dunes are surrounded by sandplains that form transition zones that reduce the impact of wind and maintain the stability of the ecosystem.

The plateaus, which are mainly in the northeast, are characterized by high flat surfaces, and regulate the flow of surface water and promote the stability of the natural habitat. The wadis, which spans 2,827 km², are critical seasonal ecopaths, transporting rainwater from highlands to depressions and supporting plant growth in dry environments.

The steppes occupy areas between plateaus and wadis, characterized by temperate slopes and shallow soils that support plant species capable of adapting to extreme conditions. Despite their limited area, they are of high environmental importance due to their role as catchment areas during wet seasons, making them temporary biotopes that support biodiversity.

The Al-Taisiyah area is one of the most prominent environmental models in the reserve, because of its diversity of natural patterns, as it includes dunes, sandy plains, plateaus, steppes, wadis, and flood areas. Al-Taisiyah includes about 1,526 km² of sand dunes, 1,067 km² of sand plains, 772 km² of plateaus, 835 km² of steppe, 542 km² of wadis and 38 km² of floods. This diversity in Al-Taisiyah represents an important scientific reference for understanding environmental processes and guiding protection efforts and sustainable environmental monitoring in the reserve.

Scenic values

- Mountainous scenes in Taysiyah: Taysiyah is famous for its unique, scenic mountainous scenes that are not found anywhere else. These diverse natural scenes are a source of attraction for visitors and the local community alike, and are considered one of the most prominent landmarks of the reserve.
- Alim Al-Atash Rocks: Prominent rock formations, located on the ancient travel route from Damascus to the Kingdom of Saudi Arabia. In the past, travelers used to climb these rocks in search of water.
- Picturesque desert scenes: The desert scenes extend over wadies and prominent rocks. Many locals head there to camp, relax and enjoy the beauty of the picturesque nature.
- Nafud Desert: It shows uniqueness in the shapes of its dunes, plains, plateaus and sand layers that vary in size and height. Many plants are spread on its surface and between its wadies, such as arta, wormwood and others.

- Al-Hujrah area: It is characterized by gradual terrain that includes hills, wadis and depressions covered with rocky outcrops. In the rainy season, small lakes are formed, adding a picturesque beauty to the area.

Plant Diversity and Plant Communities

The reserve is home to a rich flora diversity, with 235 plant species belonging to 47 families documented, including 133 annual plant and 102 perennial plants. The study classified the protected vegetation into 16 plant communities, updated the habitat map, and identified 10 types of land cover using satellite imagery. Sentinel-2 local conservation assessments revealed six extremely threatened (ET), moderately threatened (MT), least threatened (LT), Near-threatened (NT), common (C), and data deficiency (DD) species. Mapping of key threats, including overgrazing, habitat fragmentation, invasive species, and soil degradation, has been mapped to identify high-risk areas requiring intervention. In terms of their environmental and economic value, 202 species were found to be palatable to animals, including *Zilla spinosa* (L.) Prantl.), while only 7 species were palatable to camels, such as (*Teucrium oliverianum* Ging. ex Benth.), in addition, 26 species were unpalatable, and 6 edible food species such as (*Ziziphus nummularia* (Burm.f.) Wight & *Arrn.*), and 48 species with medicinal properties, perhaps the most important of which are (*Artemisia sieberi*) found in the wadis of Al-Taisiyah, as well as (*Calligonum comosum* L'Hér.) and (*Scrophularia hypericifolia* wydler) found in fountains and sand dunes. Woody perennials are also widely spread in the habitat in wadi habitats, perhaps the most important of which is (*Vachellia gerrardi* (Benth.) P.J.H.Hurter), (*Ziziphus nummularia* (Burm.f.) Wight & Ring.) They are the most important components in the wadi habitat in the region of Al-Taisiyah, Al-Shaaban and the floodplains.

Faunal Diversity and Conservation Value

The reserve supports a great diversity of animal life, including mammals, birds and invertebrates, enhancing its ecological value. The reserve is home to globally threatened species such as the Arabian Oryx (*Oryx leucoryx*) and Arabian sand gazelle (*Gazella marica*), which are classified as endangered species, as well as the steppe eagle (*Aquila nipalensis*). Classified as an endangered species. These species highlight the importance of the reserve in preserving biodiversity and healthy ecosystems. The reserve is also home to various species of small mammals, such as hedgehogs, rodents and bats, which play important roles in ecological food webs.

Data analysis for the 2024 Mammal Survey revealed the presence of 10 species of wild large mammals and five species of domestic mammals, and the Imam Turki bin Abdullah Royal Reserve witnessed the first recording of the striped hyena in the 2024 ecological survey, as well as the Arabian wolf in addition to reconfirming the presence of a badger, and the Arabian sand cat, the Rüppell's fox, and the Afro-Asian wild cat were spotted, reflecting important results for large

mammals in the reserve. 13 mammal species have also been spotted, including the long-eared hedgehog (*Hemiechinus auritus*), the Arabian jerboa (*Jaculus loftusi*), the Arabian spiny mouse (*Acomys dimidiatus*), the Wagner gerboa (*Gerbillus dasyurus*), the sondevial gerbil (*Meriones crassus*) and the invasive domestic mouse (*Mus musculus*), all of which were first recorded within the reserve's boundaries.

The 2024 field surveys contributed to the recording of 30 species of reptiles, including 22 lizards and eight species of snakes. As a result of the concerted efforts of the 2024 field surveys, reptiles in the reserve are now one of the most studied animals across Saudi Arabia. Research efforts and field surveys have resulted in the registration of 40,274 species of invertebrates representing 23 different orders.

Avian Biodiversity and the Importance of ITBA for Migratory Birds

ITBA is a critical protected area for avian biodiversity, offering habitat to a remarkable diversity of bird species. Its strategic location along major migratory flyways makes it an indispensable stopover site for birds migrating between Europe, Asia, and Africa. The reserve provides safe haven and essential resources such as food, water, and shelter across its diverse habitats, which include wadis, wetlands, sand dunes, and agricultural areas.

Recent surveys have documented 184 bird species, with 168 species recorded within the reserve's boundaries. Among these, 17.4% are confirmed breeding residents, 7.1% are winter visitors, and a significant 69.0% are passage migrants. ITBA plays a crucial role in the conservation of globally threatened bird species, with nine species listed on the IUCN Red List, including the endangered Egyptian vulture and the Steppe eagle.

The Natural Value of the Asian Houbara Bustard in ITBA

The Asian Houbara Bustard (*Chlamydotis macqueenii*) is one of the most ecologically and culturally significant species in ITBA. Classified as Vulnerable (VU) by the IUCN, ITBA provides crucial habitat for this elusive bird, offering vast open plains, semi-arid grasslands, and shrub-dominated landscapes essential for its feeding, breeding, and migratory stopovers. Conservation measures within ITBA focus on preserving habitat integrity, monitoring populations through satellite tracking, and implementing anti-poaching initiatives to mitigate threats.

Endemic and Threatened Species

The reserve is an important haven for endemic and threatened plant and animal species, enhancing its role in biodiversity conservation. The reserve is home to two endemic plant species, *Convolvulus excelsus* and *Echinops mandavillei*, which are specially adapted to the arid climate.

The reserve also provides habitat for threatened animal species such as the Arabian Oryx and Arabian Sand Gazelle and during 2024 field surveys in the reserve Nine species of birds have been recorded and are subject to international conservation concern (9 species are on the World IUCN Red List). The species are: the Egyptian eagle (*Neopron percnopterus*), the steppe eagle (*Aquila nipalensis*) (both endangered), the eastern imperial eagle (*Aquila heliaca*), the *Streptopelia turtur* (both endangered), the sand curlew (*Calidirs ferruginea*), the black-winged buzzard (*Glareola nordmanni*), (*Circus macrourus*), (*Lanius senator).*), (*Emberiza cineracea*) (all near threatened). During the 2024 Ecological Survey, two species of lizards is recorded as **new to science** and work is underway to document them in global data lists that will add importance to biodiversity and natural values of ITBA.

Rangelands and Their Importance for Local Communities

The rangelands of ITBA are a vital natural asset, providing essential ecosystem services and supporting local pastoral communities. These vast grazing lands sustain livestock while maintaining ecological balance. The reserve's rangelands are carefully managed to prevent overgrazing and degradation through regulated grazing practices and rotational systems. Sustainable grazing practices within the reserve not only promote biodiversity conservation but also ensure that rangelands continue to provide essential resources for both wildlife and local communities. In assessing the status of rangelands in villages, desertions and cities within the Imam Turki bin Abdullah Royal Reserve, they were classified into four categories according to the percentage of vegetation cover, where the category "severely degraded" (less than 1%) included five rangelands with an area of 2434.15 km² and an average cover of 0.51%, requiring urgent intervention; the category "degraded" (1–5%) included 11 rangelands with an area of 6380.94 km² and an average cover of 2.06%, requiring improved grazing management; and the category "medium" (5-10%) included five rangelands with an area of 922.48%. km² and an average cover of 6.11%, which needs to support natural regeneration; the "good" category (more than 10%) included five rangelands with an area of 1189.66 km² and an average cover of 15.81%, and the reserve works to manage these rangelands and apply sustainable practices in cooperation with the local community.

Cultural and social values

First: The local community

- **Tribes:**

  The Shammar and Harb tribes are among the most prominent tribes in the region from a historical perspective. The Shammar tribe, which was previously known as the Tai tribe, inhabits the western regions of the reserve, while the Harb tribe resides in the east. These tribes are considered an essential part of the social and cultural fabric of the region.

- **Local cuisine:**
  Local resources contribute to strengthening the social economy, such as: fruits and dates that the Hail region is famous for, and olives and olive oil in the Al-Jawf region. Local animals are also used in preparing popular dishes such as Kabsa.

- **Music:**

  The rababa is one of the most common musical instruments throughout the region, and music is famous there in the "Samri" style, which is used to recite charming poems and hymns. There are subtle regional variations in music styles:

  - In the Northern Borders: The art of "Dahha" is performed without rhythm.
  - While in Hail: Two main styles are adopted, derived from the arts of Ardah and Samri.
  - In Al-Jawf: A mixture of styles from the Northern Borders and Hail.

- **Dress:**
  The region is distinguished by its regional dress, where the thobe is the traditional dress of the cities, the furwa used as a winter cover, and the shemagh known as the head scarf, and this dress is common throughout the region.

- **Sports:**
  Falconry and racing are very popular activities in the Northern Borders, where one of the largest falconry festivals in the Arab world is held. The region is also famous for sand riding, safaris and rallies such as the Nissan Hail Rally.

- **General lifestyle:**
  The nomadic lifestyle has been the basis of life in the region throughout history, where the population relied on raising herds and securing their needs by moving in search of rangelands. With the changes in modern economic and urban conditions, the lifestyles of some Bedouin families have shifted to moving short distances in search of new rangelands or clean camping sites. While some still practice nomadic life, such as regular migration in search of winter rangelands, while others reside in villages such as Al-Zubayr and travel to their herds daily. Hail is considered the closest in its lifestyle to "Najd" (the western part of the Kingdom) due to its history as a center for travelers to and from Iraq, Riyadh and Medina.

- **Values:**

  The local community is known for its generosity and hospitality. It is a friendly community by nature and is famous for welcoming visitors and treating everyone with respect. Generosity was and still is part of the daily life of the local community, and the famous poet Hatem Al-Ta'i, who is considered a symbol of generosity, represents these values not only for the local community, but for the entire Arab world.

- **Folklore:**

  represented in cuisine, music, national dress, and sports activities.

Second: Historical and heritage sites

Darb Zubaydah: Darb Zubaydah is a historical road that was used for pilgrimage and trade in the Islamic era. In the Abbasid era, the road became an important link between Baghdad, the Two Holy Mosques, and the rest of the Arabian Peninsula. It connects Kufa and Mecca. This is attributed to Mrs. Zubaydah bint Jaafar bin Abi Jaafar Al-Mansur, the wife of Caliph Harun Al-Rashid, who contributed to the development of the road that immortalizes her memory throughout the ages.

Over the ages, the Abbasid allies paid great attention to developing and expanding the road to make it suitable for travelers and pilgrims. The road was used after the conquest of Iraq and the spread of Islam in the East, so its use became regular, as water.

e Abbasid caliphs took care of this road and provided it with various benefits and facilities, such as building water basins, digging wells, creating ponds, erecting minarets, and more. They also worked to expand the road so that it would be suitable for use by pilgrims, travelers, and their animals. Historical and geographical sources and the remaining monuments mention that the road's path was planned in a distinctive practical and engineering way, as stations, houses, and rest areas were built along it, and its floor was paved with stones in sandy and muddy areas, in addition to providing it with the necessary benefits and facilities such as wells, ponds, and dams. The road was also provided with signs, minarets, torches, and stoves that illustrated its path to serve travelers. Since the beginning of the Abbasid state, Caliph Abu al-Abbas al-Saffah ordered the erection of miles (distance stones) and flags along the road from Kufa to Mecca, in the year 134 AH / 751 AD, and after him, Caliph Abu Jaafar al-Mansur ordered the establishment of forts and water tanks at several points along the road. While Caliph Al-Mahdi ordered the construction of palaces on the road to Mecca, Caliph Harun Al-Rashid ordered the construction of water tanks, the digging of wells, and the establishment of forts along the road, in addition to providing it with public facilities and utilities to serve pilgrims and travelers and their comfort. The caliphs

appointed governors to supervise the road and undertake its maintenance and reconstruction on a regular basis. The number of main stations on this road is twenty-seven stations, and the average distance between each station is about 50 km, and the same number of secondary stations, each of which is called (dinner), which is a rest stop held between every two main stations.

Al-Ashar Pool: Al-Ashar was mentioned by Ibn Khordadbeh under the name Al-Battan, while Ibn Rustah mentioned it under the name Al-Batania. It is located 50 km to the north of the city of Turabah. The Al-Ashar site contains a large number of architectural monuments, the most important of which are:

Ponds and water barriers that extend to long distances to bring rainwater to the western pond located on the western side of the site. To the east of the western pond, there are traces of the remains of another pond with a rectangular floor plan measuring approximately 54m x 30m, with a filter a little further away, with a rectangular floor plan measuring approximately 28m x 16m. The filter basin of this pond was connected to channels and water barriers on the western and southern sides to bring water into it and then into the pond after filtering it. Also among the important archaeological and architectural remains at this site are the remains of the foundations of a fort with a rectangular floor plan, measuring approximately 60m x 56m, its walls were supported by four circular supports, and a group of semi-circular supports on the walls from the outside. Since the building is almost completely covered with sand, it is difficult to identify its internal divisions and function.

Zabala Pools and Wells: One of the major stations on the Darb Zubaydah (the old Hajj Road), dating back to the third century AH/ninth century AD, from the Abbasid era.

Al-Araish Pools: The middle Al-Araish (tanours) contains nine architectural units spread along 400 m north-south, and a width of 250 m east-west. It is a circular pool connected to a basin, a square pool, a dilapidated building north of the circular pool, two wells, and three kilns for making gypsum from limestone.

Al-Bid'a Pool: It is located about 225 km northeast of the city of Hail, and 25 km north of the village of Turabah. Al-Bid'a Station is one of the large stations on the trail; it contains 120 architectural units along 800 x 650 m; and these architectural units include:

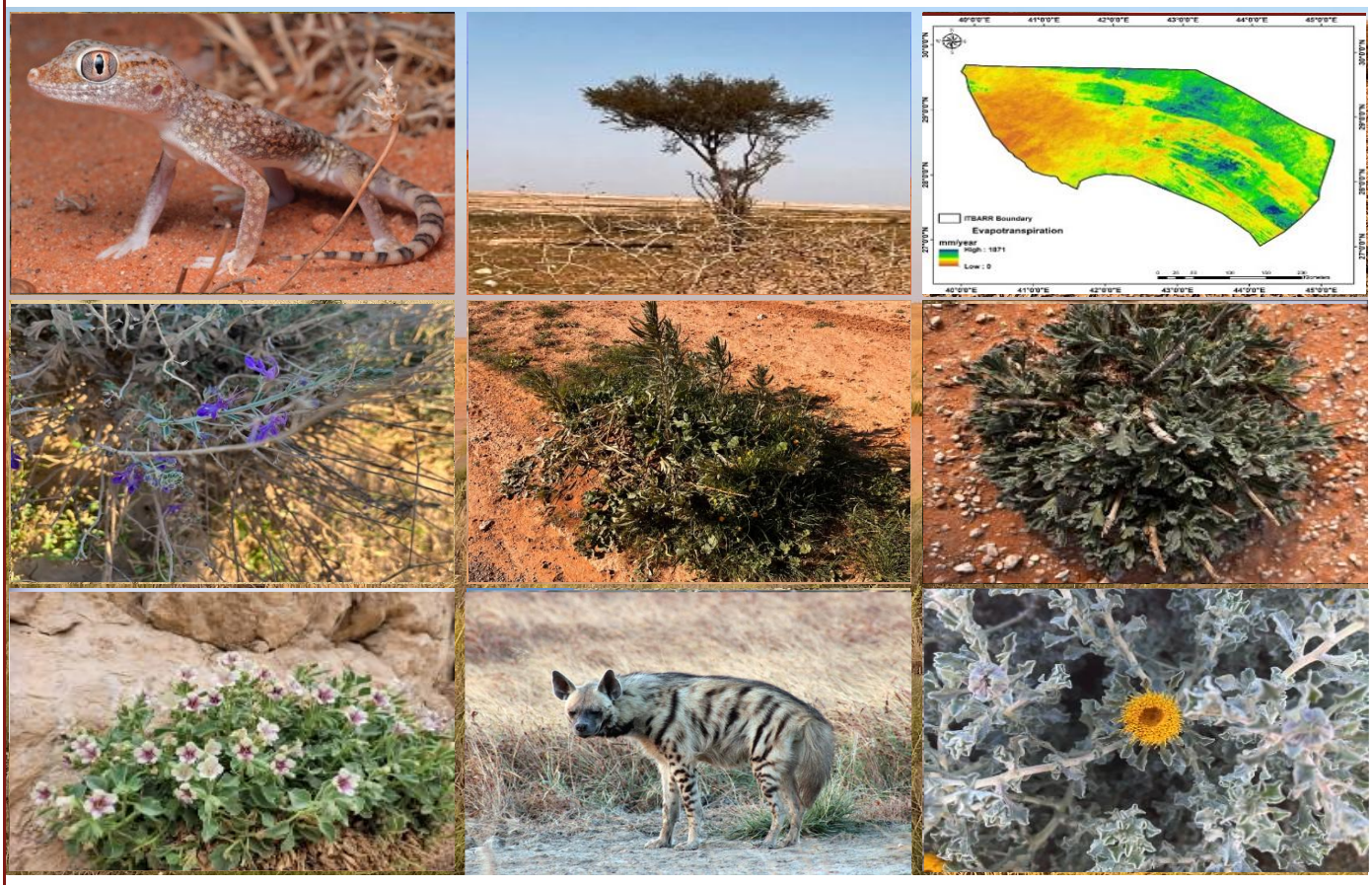
- The rectangular pool: Its dimensions are 38 x 57 m, and a rectangular filter with dimensions of 38 x 16 m is attached to its eastern wall.
- The forts: There are three forts to the north of the pool, which are:
  1. The southern fort: Rectangular in shape with dimensions of 38 x 32 m
  2. The middle fort: Square in shape with a side length of 30 m.
  3. The northern courtyard: completely destroyed and only two parallel walls remain.

To the east lies the well, a circular well covered with stones with a diameter of 11 m. This well is characterized by the presence of an entrance at its bottom with a width of 1 m and a height of 2 m; decorated above it with a semicircular arch. This entrance extends in the form of a vestibule that ends on the ground surface on the western side of the well.

Al-Shihayat Pool: Al-Shihayat Pool is located about 34 km south of Zabala Pool. It is a circular pool with a diameter of about 50 m supported from the inside by cylindrical and rectangular supports. It is considered one of the main stations on the Zubaydah Trail and contains two ponds for water wells and basins. In the higher places there are houses and palaces that have been destroyed over time and only some stones remain and some ponds covered with sand. The famous English traveler "Anne Blunt" visited it in the 18th century AD and praised it and mentioned it in her travel books.

King Abdulaziz Palace in Lina: King Abdulaziz Palace was built in Labna in 1355 AH by order of King Abdulaziz bin Abdulrahman - may God have mercy on him. He ordered its construction to follow up on the affairs of citizens and follow up on the development movement in the northern region. The area of the palace is about 4000 meters. It was built with traditional materials of clay and wood. It includes four circular towers in its corners. It also contains residential rooms for King Abdulaziz and his honorable family, in addition to guest and reception rooms. It also includes a mosque and places designated for horses. King Abdulaziz Palace in Qubbah: King Abdulaziz Palace was built in Qubbah in 1351 AH by order of King Abdulaziz bin Abdulrahman - may God have mercy on him, with the aim of settling the desert and confronting smuggling attempts and fighting outlaws. The palace extends over an area of 15,000 meters, as it was built with traditional materials of clay and wood. The palace contains residential units, watchtowers, a mosque and a prison. The water supply was internal due to the presence of a well in it. Lina Historical Market: Lina Historical Market is located within the Lina Heritage Village area, and is considered one of the oldest and most famous markets in the Northern Borders Commercial Area. It was established about 88 years ago and includes 72 shops in a rectangular shape. They were built of stone and clay and roofed with tree trunks and palm frond mats, over which a layer of clay is poured to prevent leakage.

7. The Ecological Study Plans



Framework for Reintroduction Potential of Native Species at Imam Turki bin Abdullah Royal Reserve

Methodology and Strategies

The project methodology followed a structured process, beginning with an extensive literature review to understand historical species distributions, extinction causes, and conservation translocation strategies. Pre-reintroduction assessments were conducted, including biological and socio-economic feasibility studies, risk assessments for disease transmission, genetic risks, and human-wildlife conflicts. A critical component was the spatial analysis, integrating satellite imagery and ground-truthing data to develop a high-resolution habitat map of ITBA, guiding the selection of suitable reintroduction sites.

Species-specific reintroduction assessments considered ecological needs, genetic viability, disease risks, and socio-political factors. Site selection prioritised areas with low human disturbance, minimal overgrazing, and high habitat suitability, avoiding zones identified through camera trapping and human activity analyses as high-risk conflict areas. The selection of species and introduction sites followed adaptive management principles to allow dynamic responses to environmental variability.

Alignment with Industry Standards

The framework strictly adheres to IUCN Reintroduction Guidelines, ensuring a precautionary approach emphasising:

- Thorough feasibility studies including risk assessment and stakeholder engagement.
- Conservation translocation principles, including assisted colonisation and ecological replacements, were necessary.
- Genetic management through screening, mean kinship strategies, and adaptive monitoring.
- Post-release monitoring protocols employing GPS tracking and phased-release approaches.

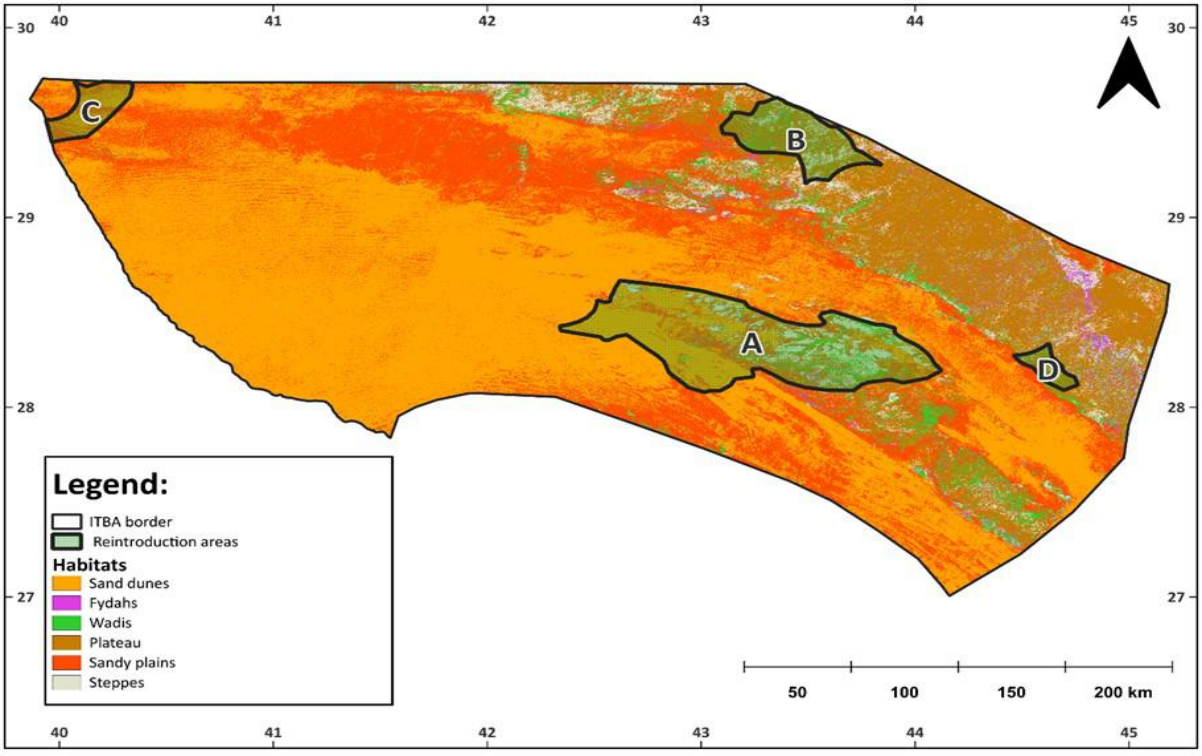
Selection of Reintroduction Areas

Spatial analysis led to the identification of four reintroduction areas within ITBA:

- **Area A (6,059.65 km²):** Dominated by sand dunes and sandy plains, suitable for desert-adapted ungulates and avian species.
- **Area B (1,622.02 km²):** Plateau-dominated, providing stable ground for mountain species.
- **Area C (729.74 km²):** Predominantly sand dunes and sandy plains, favouring desert specialists.
- **Area D (314.77 km²):** Plateau-based with mixed habitats ideal for species requiring rocky environments.

Areas were chosen based on habitat composition, low human-wildlife conflict risk, ecological suitability, and connectivity potential.

The four areas (A - D) as shown below on the habitat map of ITBA.



Species, Suggested Numbers, and Areas of Introduction

Species	Conservation Status	Reintroduction Areas	Suggested Initial Numbers
Arabian Oryx (*Oryx leucoryx*)	Vulnerable	A, C	30-100 (per phase)
Arabian Sand Gazelle (*Gazella marica*)	Vulnerable	A, C	50 (per phase)
Arabian Mountain Gazelle (*Gazella gazella*)	Endangered	B, D	10
Arabian Gazelle (*Gazella arabica*)	Endangered	A, C	10
Onager (*Equus hemionus*)	Near Threatened	A, B, C, D	Deferred
Cape Hare (*Lepus capensis*)	Least Concern	A, B, D	Natural recolonisation
Houbara Bustard (*Chlamydotis undulata*)	Vulnerable	A, B, C	Future Phases
Red-necked Ostrich (*Struthio camelus camelus)*	Extinct	A, C	5
Arabian Partridge (*Alectoris melanocephala)*	Least Concern	A, B, C, D	Future Phases
Stone Curlew (*Burhinus oedicnemus)*	Least Concern	A, B, C, D	Future Phases

Phased reintroductions from 2024 to 2026 focus on Arabian oryx and sand gazelle, with additional introductions of Arabian gazelle and red-necked ostrich. Carnivore species like the Arabian wolf and striped hyena are proposed for later phases (2027–2030), contingent on prey-base establishment.

Summary of the Framework

The ITBA reintroduction framework embodies a science-driven, adaptive management approach anchored in global best practices. Emphasis is placed on habitat suitability, minimisation of human-wildlife conflict, genetic integrity, and disease risk management. Community involvement and economic projections were incorporated to foster local support and promote socio-economic benefits through eco-tourism.

Framework for Mid to Long-Term Ecological Monitoring at Imam Turki bin Abdullah Royal Reserve (ITBA)

Methodological Approach

The monitoring programme is designed to be implemented in phases, beginning with a systematic medium-term phase over two to three years. This initial phase integrates findings from prior ecological studies conducted in 2019, 2022, and 2024, incorporating traditional field surveys, remote sensing applications, camera trapping, genetic sampling, and population modelling techniques. The integration of these varied data streams ensures that species distribution, habitat health, and ecosystem processes are accurately captured.

In the long-term, the programme will transition into a dynamic, scalable framework that includes continuous assessments of biotic and abiotic indicators, as well as ecological process monitoring. This evolutionary approach allows for real-time scenario analysis and adaptive management interventions, essential for responding to emerging environmental threats and shifting climatic conditions.

Key Framework Components

Key Biodiversity Areas (KBAs) and Fauna Monitoring:

The identification and zoning of KBAs are based on robust ecological assessments, highlighting habitats critical for the persistence of key fauna species. The fauna monitoring strategy prioritises large carnivores such as the Arabian wolf (*Canis lupus arabs*), striped hyena (*Hyaena hyaena*), and honey badger (*Mellivora capensis*), employing a multidisciplinary approach combining camera trapping, acoustic monitoring, GPS telemetry, and non-invasive genetic analysis. This approach not only provides critical data on species ecology but also serves as a broader indicator of ecosystem health and habitat connectivity.

Flora and Ecosystem Health Monitoring:

Vegetation dynamics are assessed using remote sensing indices such as NDVI and NDWI, supported by field validation surveys. Particular attention is given to monitoring keystone and endangered plant species, assessing rangeland productivity, and tracking invasive species spread. The monitoring of White Saxaul (*Haloxylon persicum*) stands is prioritised due to its sensitivity to grazing pressure and desertification, providing early warnings of ecosystem degradation.

Environmental Monitoring:

A comprehensive environmental monitoring component addresses pollution risks and large-scale environmental changes. Regular assessments of soil, water, and air quality are conducted, focusing on detecting heavy metals, pesticides, and industrial pollutants. Satellite imagery is used to detect land cover changes, erosion patterns, and desertification trends, facilitating early interventions to mitigate environmental degradation.

Meteorological Monitoring:

Climate variables are monitored through the installation of meteorological stations across eleven distinct microhabitats within ITBA. These stations capture temperature, precipitation, humidity, wind speed, and solar radiation data, critical for understanding local climate dynamics. The on-ground data are calibrated with satellite-derived meteorological products to support climate impact analysis and the development of climate resilience strategies for the reserve.

Resource Use and Impact Monitoring:

Seasonal assessments of livestock grazing impacts, off-road vehicle damage, and other human activities are integrated into the monitoring framework. Sustainable grazing protocols are recommended, incorporating rotational grazing systems and monitoring carrying capacities across different habitats. Off-road vehicle guidelines are proposed, focusing on mitigating soil compaction, vegetation loss, and habitat fragmentation.

Key Recommendations

Centralised Data Management: The establishment of a centralised geospatial database compliant with GEOSA standards is critical for consolidating all environmental, climatic, and socio-economic datasets. The database will facilitate efficient data integration, ensuring that monitoring results are readily accessible for adaptive management and strategic decision-making.

Governance and Stakeholder Engagement: The framework recommends creating a participatory governance structure involving conservation agencies, research institutions, and local communities. This collaborative model will foster transparency, enhance data-sharing mechanisms, and promote collective stewardship of the reserve's natural resources.

Indicator Species Framework: A detailed methodology is proposed for the selection and periodic review of Key Indicator Species (KIS) across multiple taxa, ensuring ecological relevance, sensitivity to environmental changes, and logistical feasibility. Regular evaluations will determine the continued suitability of selected indicator species in reflecting ecosystem health trends.

Adaptive Management Frameworks: The monitoring results will directly feed into adaptive management cycles, supporting real-time adjustments to conservation strategies. This includes refining restoration efforts, adjusting species reintroduction protocols, and developing targeted responses to invasive species outbreaks and climate-induced habitat shifts.

Capacity Building: A phased capacity-building strategy for ITBA staff is outlined, focusing initially on foundational training in biodiversity monitoring, remote sensing, and data management. Subsequent phases include joint fieldwork with contractors, advanced technical training, and eventual independent operation of the monitoring programme by ITBA personnel, ensuring the sustainability of monitoring efforts.

Integration with National and Global Initiatives: The framework is aligned with the Saudi Vision 2030, the Saudi Green Initiative (SGI), and the Sustainable Development Goals (SDGs), ensuring

that conservation activities at ITBA contribute to national biodiversity targets and international environmental commitments.

Additional Highlights

Socio-Economic and Community-Based Monitoring: The framework places importance on socio-economic impact assessments, evaluating how conservation interventions affect local livelihoods, particularly those related to traditional grazing, beekeeping, and desert truffle harvesting. Community-based monitoring programmes are encouraged, integrating citizen science approaches to enhance data collection and foster a conservation ethos among local communities.

Remote Sensing Innovations: Emphasis is placed on the strategic use of satellite imagery, drone-based photogrammetry, and synthetic aperture radar (SAR) for monitoring vegetation health, soil moisture, land use changes, and water resource dynamics. These technologies provide cost-effective, high-resolution data critical for detecting subtle ecological shifts across desert landscapes.

Environmental Risk Management: A systematic approach to environmental risk management is advocated, incorporating early-warning systems for pollution events, development pressure assessments, and monitoring of industrial activities in proximity to the reserve. Buffer zones and strict compliance monitoring are recommended to minimise the risk of adverse environmental impacts.

The Framework for Mid to Long-Term Ecological Monitoring at ITBA represents a scientifically rigorous, operationally feasible, and adaptively managed plan to safeguard the reserve's ecological integrity. By combining traditional ecological methods with cutting-edge remote sensing, participatory governance, and a strong emphasis on capacity building, the framework ensures a sustainable path for biodiversity conservation, climate resilience, and socio-economic development. Through its implementation, ITBA will serve as a national model for integrated, adaptive conservation management in arid environments, contributing meaningfully to Saudi Arabia's environmental goals and global conservation efforts.

Rehabilitation Plan

Methodological Approach

The Imam Turki Bin Abdullah Royal Reserve (ITBA) Rehabilitation Plan is a comprehensive, science-driven strategy aimed at restoring, enhancing, and protecting the reserve's ecological integrity. ITBA plays a critical role in biodiversity conservation, soil stabilization, water regulation, and climate change mitigation, making its restoration a national priority aligned with Saudi Vision 2030 and the Saudi Green Initiative (SGI).

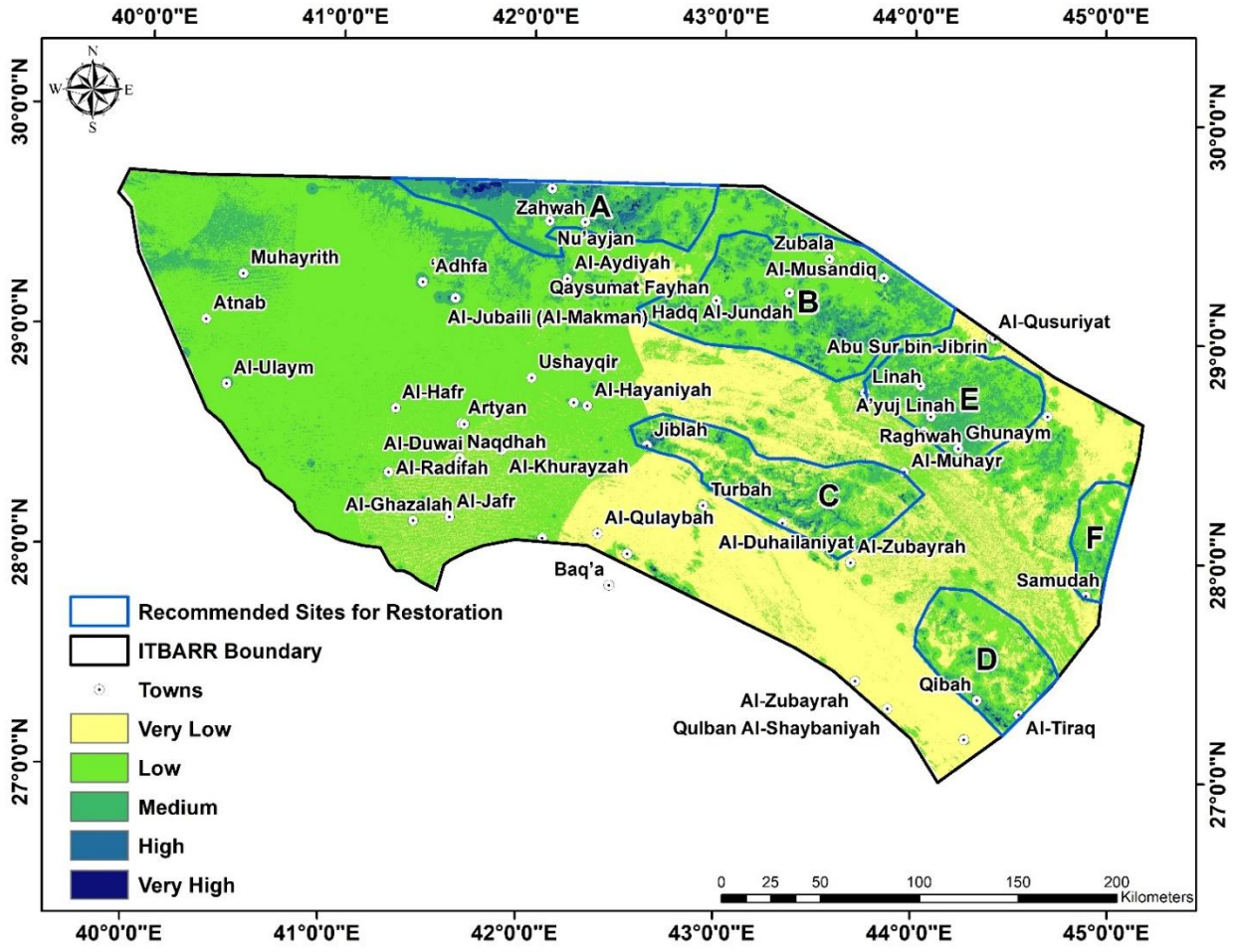
The plan is based on an in-depth ecological assessment, integrating remote sensing, field surveys, GIS mapping, and multi-criteria decision analysis (MCDA) to identify six priority sites for targeted restoration. Restoration efforts focus on key habitats such as sand dunes, wadis, steppes, and floodplains, which support native flora and fauna. A dual approach of active and passive restoration is employed—active interventions include native species planting, soil amendments, and irrigation, while passive strategies focus on grazing control, habitat protection, and invasive species management.

Suitability and Restoration Priorities

The site suitability analysis classified ITBA into six restoration suitability classes: Very High, High, Medium, Low, Very Low, and Restricted. The majority of the reserve falls into the Low (58.14%) and Very Low (27.48%) suitability categories, indicating moderate to significant constraints for restoration due to factors such as soil conditions, aridity, and topographical challenges. Medium suitability areas (12.93%) offer viable locations for targeted restoration with moderate interventions, while High (1.34%) and Very High (0.12%) suitability zones present optimal conditions for ecological recovery with minimal intervention.

Six priority restoration sites were identified, covering key degraded areas and ecological corridors. Sites E and D were designated for active restoration, requiring direct interventions such as planting and soil stabilization, while Sites A, B, C, and F were recommended for passive restoration, supporting natural regeneration through habitat protection and stressor reduction.

This strategic approach ensures that restoration efforts are effectively targeted, addressing degradation while enhancing ecosystem resilience and connectivity within ITBA.



Proposed sites for restoration interventions in ITBA.

- **Site A,** covering 3,790.64 km², is located in the central northern region of the reserve, positioned near Zahwah and Nu'ayjan villages. This site represents an important ecological corridor and holds potential for restoration efforts aimed at improving habitat conditions and promoting ecosystem recovery.
- **Site B,** the largest identified site at 7,019.05 km², is situated east of Site A, extending toward Zubala, Al-Musandiq, and Fayhan villages. This region has been identified as a key

restoration priority due to its degraded state and its strategic location within the broader ecosystem connectivity framework.

- **Site C,** covering 4,447.90 km², is centrally positioned within ITBA, near Jiblah and Turbah villages. This site includes a mix of vegetation types and landforms, making it an ideal location for implementing restoration strategies tailored to its varied ecological conditions.
- **Site D,** with an area of 3,130.78 km², is located in the lower southeastern part of the reserve, close to Qibah village. This area is characterized by higher degradation levels, necessitating focused restoration interventions to mitigate environmental stressors such as soil erosion and habitat fragmentation.
- **Site E,** covering 3,552.84 km², is positioned in the upper northeastern region of the reserve, adjacent to Linah and Al-Muhayr villages. This site plays a crucial role in maintaining habitat connectivity, particularly for native flora and fauna, and is considered an essential target for conservation and habitat enrichment efforts.
- **Site F,** the smallest of the identified sites at 1,148.49 km², is situated on the eastern edges of the reserve, close to Samudah village. This site is particularly important for restoration efforts aimed at stabilizing arid landscapes, ensuring that vegetation recovery aligns with the broader environmental sustainability objectives of ITBA.

Active and Passive Restoration Recommendations

Active restoration efforts in ITBA are focused on Sites D and E, where degradation levels require direct intervention to accelerate ecosystem recovery. A total of 10,434,687 native plants have been proposed for planting across these two sites divided into 2 phases: short-term and long-term, with 7,948,925 plants in Site D and 2,485,762 plants in Site E. The selected species include shrubs, grasses, and trees, strategically chosen to enhance biodiversity, stabilize soil, and improve ecosystem resilience. For wadi areas, a targeted restoration initiative proposes planting 753,720 Acacia trees across 2,740.8 km² to enhance water retention, soil stabilization, and habitat connectivity. The restoration plan prioritizes cluster planting to reflect natural growth patterns and maximize ecological benefits. Passive restoration will be implemented in Sites A, B, C, and F,

where natural regeneration will be supported through grazing control, invasive species management, soil conservation, and community engagement. By integrating both active and passive restoration strategies, ITBA's ecological functions can be restored effectively, ensuring long-term sustainability and habitat resilience.

List of recommended plants for active restoration in site D.

Taxon	Natural Density (Plant/km^2)	Area to be planted (km^2)	Total # of Plants	%	Recommended Spacing (m)
Short-term recommendation – phase 1					
Scrophularia hypericifolia	2296	125.2	287,531	38.1%	3*3
Rhanterium epapposum	470	156.5	73,495	9.7%	3*3
Haloxylon persicum	306	187.8	57,481	7.6%	3*3
Helianthemum lippii	509	219.2	111,440	14.8%	3*3
Vachellia gerrardi	58	344.4	19,974	2.6%	10*10
Ziziphus nummularia	46	281.8	12,891	1.7%	5*5
Haloxylon salicornicum	131	281.8	36,982	4.9%	3*3
Lycium shawii	16	187.8	3,053	0.4%	5*5
Convolvulus oxyphyllus	609	250.5	152,594	20.2%	3*3
Total		**2035**	**755,441**	**100%**	
Long-term recommendation – phase 2					
Artemisia monosperma	10039	250.5	2,514,392	35%	3*3
Stipagrostis drarii	7463	281.8	2,102,851	29%	3*3
Moltikiopsis ciliata	6308	219.2	1,382,427	19%	3*3
Fagonia glutinosa	3467	344.4	1,193,813	17%	3*3
	Total	**1095.9**	**7,193,483**	**100%**	

List of recommended plants for active restoration in site

Taxon	Natural Density (Plant/km2)	Area to be planted (km2)	Total # of Plants	%	Recommended Spacing
Short-term recommendation – phase 1					
Teucrium oliverianum	72	284.2	20,535	6%	3*3
Vachellia gerrardi	55	390.8	21,299	6%	10*10
Ziziphus nummularia	46	355.3	16,254	5%	5*5
Calligonum comosum	255	426.3	108,717	33%	3*3
Haloxylon salicornicum	60	284.2	17,125	5%	3*3
Lycium shawii	16	248.7	4,041	1%	5*5
Convolvulus oxyphyllus	609	213.2	129,874	40%	3*3
Capparis spinosa	31	319.8	9,912	3%	3*3
Total		**2522.5**	**327,757**	**100%**	
Long-term recommendation – phase 2					
Moltikiopsis ciliata		4007	284.2	1,138,756	53%
Achillea fragrantissima		1084	532.9	577,825	27%
Scrophularia hypericifolia		2071	213.2	441,423	20%
Total			**1030.3**	**2,158,004**	**100%**

Propagation Plan

The Propagation Plan for the Imam Turki bin Abdullah Royal Reserve (ITBA) provides a science-based framework for restoring biodiversity through the propagation and reintroduction of native plant species. Addressing key environmental challenges such as habitat degradation, soil erosion, and climate change, the plan aligns with national and international conservation goals to enhance ecosystem resilience. Sites D and E were selected as priority restoration areas based on site suitability and degradation risk analysis. The plan emphasizes propagating species well-adapted to ITBA's arid conditions, with a particular focus on threatened and endangered species. Following global best practices (IUCN, BGCI, FAO), restoration efforts involve seed collection, nursery propagation, and sustainable irrigation, ensuring plant establishment and long-term ecological recovery. Soil conservation measures, including erosion control and hydrological considerations, are integrated to enhance ecosystem stability.

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Seed Collection Procedures

The seed collection procedures for ITBA's Active Restoration Plan are designed to align with international best practices, ensuring ecological sustainability and genetic diversity in restoration efforts. Following the IUCN Guidelines for Reintroductions and the International Principles and

Standards for Native Seeds in Ecological Restoration, the process emphasizes responsible collection methods, minimal disturbance to natural populations, and the conservation of soil seed banks to support passive regeneration. Seeds will be gathered at peak maturity to ensure high viability while leaving enough to sustain natural replenishment. Collection sites will be strategically selected across ITBA's diverse ecological zones to maintain a genetically diverse and adaptable seed pool. Non-invasive techniques, such as hand-picking, will be employed, and collection will be limited to 20% of available seeds from any given population to prevent overharvesting and safeguard natural regeneration.

To ensure traceability and scientific rigor, detailed records will be maintained, documenting species identification, date, location (GPS), habitat type, and seed quantity. Proper storage is critical for seed viability, with short-term storage at 0–5°C and long-term storage at -18°C, in moisture-controlled environments. Additionally, seeds will be sourced from a broad genetic base to enhance adaptability and resilience in restored plant communities, reducing the risk of genetic bottlenecks. By implementing scientifically driven seed collection protocols, ITBA ensures that restoration efforts contribute to ecosystem resilience, biodiversity conservation, and long-term sustainability, supporting both active and passive restoration strategies across the reserve.

Plant Propagation Procedures

The plant propagation procedures for ITBA follow Botanic Gardens Conservation International (BGCI) standards, ensuring optimal conditions for native species propagation to enhance survival and growth in restoration areas. The process begins with species selection and seed collection, where target species are identified based on ecological significance and conservation needs. Seeds are collected from diverse populations to ensure genetic diversity and stored under optimal conditions to maintain viability. Seed treatment and germination involve species-specific pre-treatment techniques such as stratification, scarification, or soaking, with germination trials conducted to determine optimal moisture, light, and temperature conditions. The propagation medium is carefully formulated with organic material and soil to provide adequate drainage, aeration, and moisture retention.

In nursery management, seedlings are cultivated in controlled environments with consistent irrigation, pest management, and shading where necessary. Hardening-off procedures are implemented before transplanting, gradually exposing plants to outdoor conditions to increase resilience. The optimal transplanting period for ITBA is between December and February, allowing seedlings to establish roots during cooler months before the onset of hotter conditions. After planting, a post-planting monitoring program is conducted to track survival rates, assess growth performance, and refine management strategies.

Standard Operating Procedure (SOPs) Native Species Planting

The planting of native species in ITBA follows a structured Standard Operating Procedure (SOP) to enhance survival and growth in the reserve's arid environment. Land preparation and soil amendment are critical first steps to ensure optimal soil conditions, providing essential nutrients, moisture retention, and stability for newly planted species. These best practices provide a scientific and systematic approach to ecological restoration, maximizing plant survival and long-term sustainability.

Irrigation System Recommendations

To enhance water efficiency and support large-scale restoration, ITBA is recommended to implement a centralized irrigation system designed to optimize water use while minimizing labor. The system will consist of water storage tanks, a centrifugal pump and filtration unit, an irrigation network, and pressure-compensating drippers, ensuring precise and controlled water distribution.

The irrigation strategy for native species in ITBA is designed to balance successful plant establishment with sustainable water use in the region's arid environment. This plan integrates insights from literature review, expert judgment, and NCVC standards, ensuring that irrigation schedules align with species-specific requirements and prevailing environmental conditions. Given the variability of field conditions, an adaptive irrigation approach has been adopted, allowing for adjustments based on continuous monitoring of soil moisture levels and plant health. The irrigation schedule follows a phased reduction over three years, In the first year, higher

quantities of water are provided to support the plants' stability and establish their root systems, while gradually reducing irrigation quantities in the following years to enhance the plants' ability to rely on natural water sources (such as rain), which contributes to enhancing the resilience of the ecosystem and ensuring the sustainability of the environmental restoration process in the reserve.

Active Restoration Recommendations

The selection of active restoration sites within ITBA was based on a comprehensive site suitability analysis, integrating ecological conditions and degradation risk assessments. Sites D and E were identified as priority areas for active restoration due to their high restoration potential and significant degradation levels, while Sites A, B, C, and F were designated for passive restoration. These areas offer the best opportunities for ecological recovery, supporting native vegetation regeneration and enhancing habitat connectivity. Site-specific characteristics, such as habitat type, vegetation cover, and ecosystem connectivity, were key factors in determining their restoration suitability. Site D, located in the lower southeastern region, faces significant degradation and requires targeted interventions to mitigate soil erosion and habitat loss. Site E, positioned in the upper northeastern part of the reserve, plays a critical role in maintaining biodiversity and ecosystem stability, making it a focal point for conservation-driven restoration.

Site	Area (km^2)
A	3,790.64
B	7,019.05
C	4,447.90
D	3,130.78
E	3,552.84
F	1,148.49

The selection of plant species for restoration in Sites D and E followed a reference ecosystem approach, ensuring alignment with the existing plant communities. The restoration strategy focuses on species that contribute to ecological stability, enhance biodiversity, and support natural succession. Priority was given to native, drought-tolerant, and endangered species, identified through field surveys and IUCN classifications. This scientific approach enhances the rigor of selection processes and ensures that selected species are able to withstand the dry desert conditions of the reserve, supporting long-term restoration goals and maintaining ecological balance within these biocritical areas.

Mapping of the dominant plant populations at each ecological restoration site was carried out to ensure the selection of appropriate plant species and to enhance the effectiveness of environmental interventions. Site D is characterized by a mixture of annuals, shrubs and trees, and the predominant species include (Artemisia monosperma), (*Stipagrostis drarii*) and (*Haloxylon persicum).*), which play an important role in soil stabilization and resistance to environmental degradation. Site E includes plant species such as *Achillea fragrantissima*, *Capparis spinosa* and *Teucrium oliverianum*), species known for their high potential to enhance biodiversity and stabilize degraded lands. This precise identification of the predominant plant populations at each site helps to guide restoration efforts in a scientific manner that takes into account the specificity of each habitat and enhances the chances of long-term environmental success.

Ecological restoration plans in the reserve include applying an approach that simulates natural plant densities while ensuring that the distribution of selected species is in line with natural spread patterns in the targeted habitats, enhancing the chances of success and environmental stability. In addition to the plant species recommended for use, the plan emphasizes the need to give special priority to threatened plant species. to support conservation objectives and enhance the ecological resilience of the ecosystem in the long term. This approach contributes to the conservation of the genetic diversity of local species, balancing effective interventions and conservation strategies for endangered species, enhancing the reserve's ability to cope with environmental changes and ensure the sustainability of restoration operations.

Passive Restoration Recommendations

Passive restoration efforts in Sites A, B, C, and F will focus on natural regeneration by reducing human-induced pressures and allowing ecosystems to recover without intensive planting interventions. Given the ecological characteristics and existing vegetation structure of these sites, passive restoration presents a cost-effective and sustainable approach that relies on managing disturbances and facilitating ecological succession over time. This approach provides an opportunity to restore habitat stability and stimulate the regeneration of native species without direct artificial intervention, enhancing the sustainability of ecosystems and achieving the environmental objectives of the reserve efficiently and effectively.

Appendixes

Appendix 1: Herbarium specimens table

No	Taxon	Date	Latitude	Longitude
1	*Aaronsohnia factorovskyi Warb. & Eig.*	01/24/24	27.51599	44.41059
2	*Achillea fragrantissima (Forssk.) Schi.- Bip*	03/21/24	28.37942	44.4357
3	*Aizoon canariense L.*	03/30/24	27.32503	44.44826
4	*Alkanna orientalis (L.) Boiss.*	03/20/24	27.51380	44.48901
5	*Allium sindjarense Boiss. & Hasskn.*	03/21/24	28.38308	44.28151
6	*Allium sindjarense Boiss. & Hasskn.*	03/23/24	28.52753	44.12466
7	*Amaranthus viridis L*	07/25/24	28.03046	41.72655
8	*Amaranthus viridis L*	06/04/24	28.25379	42.90967
9	*Amaranthus albus L.*	10/21/24	29.06047	42.81648
10	*Andrachne telephioides L.*	03/21/24	28.56588	44.54798
11	*Andrachne telephioides L.*	01/28/24	28.77043	44.64504
12	*Andrachne telephioides L.*	10/21/24	29.17640	44.12784
13	*Anisosciadium isosciadium Bornm*	03/17/24	28.59503	43.36581
14	*Anisosciadium lanatum Boiss.*	03/18/24	28.18254	43.95960
15	*Anthemis melampodina Del*	03/24/24	28.06539	41.68972
16	*Anthemis melampodina Del*	01/30/24	28.28004	41.24218
17	*Anthemis melampodina Del*	01/28/24	28.86321	44.57693
18	*Anthemis melampodina Del*	01/14/24	28.21821	43.00538
19	*Anthemis melampodina Del*	01/13/24	28.01171	42.95117
20	*Anvillea garcinii (Burm.f.) DC*	03/22/24	29.12593	43.10771
21	*Anvillea garcinii (Burm.f.) DC*	01/17/24	28.25524	43.28804
22	*Arnebia linearifolia A.DC*	01/23/24	27.70820	44.74912
23	*Artemisia monosperma Del.*	01/14/24	28.69211	42.47007
24	*Artemisia sieberi*	07/22/24	28.81739	43.68087
25	*Artemisia sieberi*	07/22/24	28.81739	43.68087
26	*Artemisia scoparia Waldst. & Kit.*	10/19/24	29.62496	42.07869
27	*Artemisia scoparia Waldst. & Kit.*	10/19/24	29.62496	42.07869
28	*Artemisia scoparia Waldst. & Kit.*	10/19/24	29.62496	42.07869
29	*Asphodelus tenuifolius Cav*	01/17/24	28.30861	43.43059
30	*Asphodelus tenuifolius Cav*	01/18/24	28.16207	43.82860
31	*Asteriscus graveolens (Forssk.) Less.*	03/22/24	29.38102	43.05446
32	*Asteriscus graveolens (Forssk.) Less.*	03/17/24	28.59503	43.36581
33	*Asteriscus pygmaeus (DC.) Coss. & Dur.*	01/15/24	29.02893	42.65438
34	*Astragalus kahiricus DC.*	01/15/24	29.02893	42.65438
35	*Astragalus spinosus (Forssk.) Muschl.*	01/15/24	29.02893	42.65438
36	*Astragalus intercedens Sam. ex Rech.f.*	03/17/24	28.64868	43.18965

37	*Astragalus intercedens Sam. ex Rech.f.*	01/29/24	28.39001	44.28552
38	*Astragalus intercedens Sam. ex Rech.f.*	01/29/24	28.39001	44.28552
39	*Astragalus intercedens Sam. ex Rech.f.*	02/07/24	28.70589	43.70089
40	*Atractylis carduus (Forssk.) C. Christ.*	03/27/24	29.34190	41.33540
41	*Atractylis mernephthae Aschi. Schweinf.*	03/23/24	28.52753	44.12466
42	*Atriplex leucoclada Boiss.*	07/25/24	28.16188	41.95267
43	*Bassia muricata (L.) Asch.*	03/24/24	28.06539	41.68972
44	*Blepharis ciliaris (L.) B.L. Burtt.*	01/25/24	27.55372	44.13466
45	*Cakile arabica Velen. & Bornm.*	03/27/24	28.86990	42.28953
46	*Calendula arvensis L.*	10/25/24	27.44548	44.59745
47	*Calendula tripterocarpa Rupr.*	01/16/24	29.02858	43.65208
48	*Calendula tripterocarpa Rupr.*	03/23/24	28.78793	44.02021
49	*Calendula tripterocarpa Rupr.*	01/18/24	28.16207	43.82860
50	*Calligonum comosum L'Her.*	03/24/24	29.11651	43.52707
51	*Calotropis procera (Ait.) Ait.f.*	07/22/24	27.56936	44.60238
52	*Calotropis procera (Ait.) Ait.f.*	10/23/24	27.51599	44.41059
53	*Capparis spinosa L.*	03/18/24	28.18254	43.95960
54	*Carduus pycnocephalus var. pycnocephalus L.*	03/17/24	28.59503	43.36581
55	*Carthamus oxyacantha M. Bieb.*	03/20/24	27.5138	44.48901
56	*Carthamus oxyacantha M. Bieb.*	07/16/24	29.62496	42.07869
57	*Cenchrus echinatus L.*	06/04/24	28.24914	42.91060
58	*Cenchrus echinatus L.*	06/04/24	28.24914	42.91060
59	*Centaurea pseudosinaica Czerp.*	03/24/24	29.11651	43.52707
60	*Centaurea pseudosinaica Czerp.*	03/17/24	28.62935	43.23183
61	*Centaurea pseudosinaica Czerp.*	01/29/24	28.38308	44.28151
62	*Centaurea pseudosinaica Czerp.*	01/15/24	28.83700	42.72801
63	*Centaurea pseudosinaica Czerp.*	03/22/24	29.38102	43.05446
64	*Centropodia forsskalii (Vahl) Cope.*	07/15/27	29.33583	41.33793
65	*Centropodia forsskalii (Vahl) Cope.*	03/24/24	28.06539	41.68972
66	*Chloris virgata Sw.*	07/25/24	28.03046	41.72655
67	*Chloris virgata Sw.*	07/25/24	28.16188	41.95267
68	*Chrozophora tinctoria (L.) Raf.*	07/17/24	29.54424	42.01043
69	*Chrozophora tinctoria (L.) Raf.*	03/21/24	27.96423	43.70696
70	*Chrozophora tinctoria (L.) Raf.*	06/02/24	28.25379	42.90967
71	*Cistanche phelypaea (L.) Cout.*	03/24/24	28.06539	41.68972
72	*Citrullus colocynthis (L.) Schrader*	01/21/24	27.94779	44.07595
73	*Citrullus colocynthis (L.) Schrader*	06/07/24	28.25379	42.90967
74	*Citrullus colocynthis (L.) Schrader*	01/15/24	29.02893	42.65438
75	*Cleome amblyocarpa Barr. & Murb.*	03/20/24	27.70820	44.74912
76	*Cleome amblyocarpa Barr. & Murb.*	06/04/24	28.25379	42.90967
77	*Cleome amblyocarpa Barr. & Murb.*	01/21/24	27.94779	44.07595
78	*Colchicum ritchii R.Br.*	02/08/24	28.72842	43.71357
79	*Colchicum ritchii R.Br.*	02/07/24	28.70589	43.70089

80	*Convolvulus arvensis L*	07/25/24	28.03046	41.72655
81	*Convolvulus arvensis L*	07/25/24	28.03046	41.72655
82	*Convolvulus oxyphyllus Boiss*	01/21/24	27.71656	43.88938
83	*Convolvulus oxyphyllus Boiss*	07/15/27	29.33583	41.33793
84	*Convolvulus oxyphyllus Boiss*	03/17/24	28.62935	43.23183
85	*Convolvulus oxyphyllus Boiss*	01/15/24	28.83700	42.72801
86	*Convolvulus spicatus Peter ex Hallier*	03/20/24	27.70820	44.74912
87	*Convolvulus spicatus Hallier f.*	03/20/24	27.70820	44.74912
88	*Crucianella membranacea Boiss.*	03/24/24	28.06539	41.68972
89	*Cuscuta planiflora Ten.*	03/17/24	28.59503	43.36581
90	*Cutandia memphitica (Sprengel) K. Richter*	03/17/24	29.13263	43.51490
91	*Cutandia memphitica (Sprengel) K. Richter*	01/29/24	28.38308	44.28151
92	*Cymbopogon commutatus (Steud.) Stapf*	01/18/24	28.17058	43.75000
93	*Cynodon dactylon (L.) Pers.*	10/27/24	28.14560	42.54390
94	*Cyperus conglomeratus Rottb.*	01/30/24	28.06539	41.68972
95	*Cyperus conglomeratus Rottb.*	01/14/24	28.69211	42.47007
96	*Cyperus macrorrhizus Nees*	03/27/24	28.86990	42.28953
97	*Deverra triradiata Hochst. ex Boiss.*	07/19/24	27.32503	44.44826
98	*Deverra triradiata Hochst. ex Boiss.*	07/19/24	27.33066	44.43664
99	*Dipcadi erythraeum Webb & Berth.*	03/18/24	28.17841	43.96287
100	*Dipcadi erythraeum Webb & Berth.*	03/18/24	28.17841	43.96287
101	*Diplotaxis acris (Forssk.) Boiss.*	03/17/24	28.51281	43.19883
102	*Diplotaxis acris (Forssk.) Boiss.*	01/25/24	27.55528	44.12454
103	*Diplotaxis acris (Forssk.) Boiss.*	01/24/24	27.32945	44.44335
104	*Ducrosia anethifolia (DC.) Boiss.*	10/22/24	28.51234	44.40677
105	*Echinops mandavillei Kit Tan.*	01/04/24	28.21821	43.00538
106	*Echium rauwolfii Delile*	01/17/24	28.67229	43.62623
107	*Echium rauwolfii Delile*	01/17/24	28.67229	43.62623
108	*Emex spinosa (L.) Campd*	01/15/24	29.02893	42.65438
109	*Emex spinosa (L.) Campd*	01/17/24	28.30861	43.43059
110	*Emex spinosa (L.) Campd*	01/17/24	28.30861	43.43059
111	*Emex spinosa (L.) Campd*	01/24/24	27.32945	44.44335
112	*Emex spinosa (L.) Campd*	01/24/24	27.32945	44.44335
113	*Ephedra alata Decne.*	07/22/24	27.81447	44.92051
114	*Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.*	01/30/24	28.28004	41.24218
115	*Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.*	01/14/24	28.21821	43.00538
116	*Eremobium aegyptiacum (Spreng.) Asch. ex Boiss.*	01/15/24	28.83700	42.72801
117	*Erigeron bonariensis L.*	06/03/24	28.25379	42.90967
118	*Erigeron bonariensis L.*	07/25/24	28.03046	41.72655
119	*Erigeron bonariensis L.*	06/03/24	28.14560	42.5439
120	*Erodium glaucophyllum (L,) L'Her*	03/21/24	28.56588	44.54798
121	*Erodium laciniatum var. laciniatum (Cav.) Willd.*	02/07/24	28.72842	43.71357
122	*Erodium laciniatum (Cav.) Willd.*	01/18/24	28.21470	43.97269

123	*Erodium laciniatum (Cav.) Willd.*	10/22/24	27.14875	44.17334
124	*Erodium touchyanum Delile*	01/29/24	28.64868	43.18965
125	*Erucaria hispanica Druce*	01/23/24	27.70820	44.74912
126	*Erucaria hispanica Druce*	01/14/24	28.69211	42.47007
127	*Erucaria hispanica Druce*	01/17/24	28.28265	43.41361
128	*Erucaria hispanica Druce*	01/19/24	28.63237	43.05858
129	*Euphorbia granulata Forssk*	01/28/24	28.77043	44.64504
130	*Euphorbia nutans Lag*	06/08/24	28.25379	42.90967
131	*Fagonia bruguieri DC.*	01/25/24	27.55528	44.12454
132	*Fagonia bruguieri DC.*	01/16/24	29.022168	43.65343
133	*Fagonia glutinosa Del.*	03/22/24	29.381020	43.05446
134	*Fagonia glutinosa Del.*	10/27/24	28.145600	42.54390
135	*Filago desertorum Pomel*	03/20/24	27.70820	44.74912
136	*Filago desertorum Pomel*	03/17/24	28.10229	43.47120
137	*Filago contracta (Boiss.) Chrtek & Holub*	01/20/24	28.10229	43.47120
138	*Gagea reticulata (Pall.) Schult. & Schult.f.*	01/18/24	28.21470	43.97269
139	*Gastrocotyle hispida (Forssk.) Bunge*	03/21/24	28.06374	44.58679
140	*Gastrocotyle hispida (Forssk.) Bunge*	01/29/24	28.53369	44.40371
141	*Gymnocarpos decander Forssk*	01/17/24	28.30861	43.43059
142	*Gymnocarpos sclerocephalus (Decne.) Dahlgren*	03/20/24	27.51380	44.48901
143	*Gypsophila capillaris (Forssk.) C. Christ.*	01/19/24	28.63237	43.05858
144	*Gypsophila capillaris (Forssk.) C. Christ.*	03/27/24	29.22959	41.75085
145	*Gypsophila capillaris (Forssk.) C. Christ.*	02/08/24	28.72842	43.71357
146	*Haloxylon persicum Bunge ex Boiss.*	03/23/24	28.254350	41.63311
147	*Haloxylon persicum Bunge ex Boiss.*	03/28/24	28.692110	42.47007
148	*Haloxylon salicornicum (Moq.) Bunge*	03/21/24	27.964230	43.70696
149	*Haloxylon salicornicum (Moq.) Bunge*	06/05/24	28.25379	42.90967
151	*Haplophyllum tuberculatum (Forssk.) A.Juss.*	03/21/24	28.565880	44.54798
152	*Haplophyllum tuberculatum (Forssk.) A.Juss.*	10/21/24	29.176400	44.12784
153	*Helianthemum lippii (L.) Doum.- Cours.*	01/17/24	28.67229	43.62623
154	*Heliotropium crispum Desf.*	03/21/24	28.22276	44.52701
155	*Heliotropium digynum Asch. ex C. Chr*	03/28/24	28.69211	42.47007
156	*Heliotropium lasiocarpum Fisch. & C.A.Mey.*	07/17/24	29.62496	42.07869
157	*Herniaria hirsuta L.*	03/21/24	28.56588	44.54798
158	*Hippocrepis multisiliquosa L.*	03/17/24	28.59503	43.36581
159	*Hippocrepis areolata Desv.*	03/17/24	28.62935	43.23183
160	*Hordeum murinum ssp. glaucum L.*	01/24/24	27.51599	44.41059
161	*Hordeum murinum ssp. glaucum L.*	03/20/24	27.51380	44.48901
162	*Hordeum spontaneum K.Koch*	01/17/24	28.30861	43.43059
163	*Horwoodia dicksoniae Turril*	03/22/24	29.12593	43.10771
164	*Horwoodia dicksoniae Turril*	01/15/24	28.83700	42.72801
165	*Hyoscyamus muticus L.*	02/07/24	28.72842	43.71357
166	*Hypecoum pendulum L*	01/24/24	27.51599	44.41059

167	*Hypecoum pendulum L*	01/30/24	28.01204	41.35833
168	*Ifloga spicata (Forssk.) Sch.- Bip.*	01/24/24	27.43165	44.22843
169	*Ifloga spicata (Forssk.) Sch.- Bip.*	01/13/24	28.01171	42.95117
170	*Ifloga spicata (Forssk.) Sch.- Bip.*	01/15/24	29.02893	42.65438
171	*Kickxia aegyptiaca (L.) Na*	03/18/24	28.18254	43.9596
172	*Kickxia aegyptiaca (L.) Na*	07/20/24	28.62150	44.61033
173	*Kickxia aegyptiaca (L.) Na*	07/20/24	28.62150	44.61033
174	*Kickxia aegyptiaca (L.) Na*	01/16/24	29.39374	43.50798
175	*Kickxia aegyptiaca (L.) Na*	10/24/24	27.94779	44.07595
176	*Kickxia aegyptiaca (L.) Na*	10/25/24	27.94779	44.07595
177	*Koelpinia linearis Pall.*	01/25/24	27.44548	44.59745
178	*Lactuca serriola L*	07/25/24	28.03046	41.72655
179	*Lasiurus scindicus Henr.*	07/19/24	27.32945	44.44335
180	*Launaea capitata (Spreng.) Dandy*	01/21/24	27.94779	44.07595
181	*Launaea capitata (Spreng.) Dandy*	03/23/24	28.52753	44.12466
182	*Launaea capitata (Spreng.) Dandy*	01/29/24	28.38308	44.28151
183	*Launaea capitata (Spreng.) Dandy*	01/15/24	29.02893	42.65438
184	*Launaea spinosa (Forssk.) Sch.Bip. ex Kuntze*	03/20/24	27.51380	44.48901
185	*Leontodon laciniatus (Bertol.) Widder*	10/25/24	27.44548	44.59745
186	*Limonium lobatum (L.f.) Chaz.*	03/20/24	27.94557	44.82661
187	*Limonium lobatum (L.f.) Chaz.*	03/20/24	27.94557	44.82661
188	*Lolium rigidum Gaud.*	01/17/24	28.30861	43.43059
189	*Lomelosia olivieri var plmatisecta*	03/17/24	28.59503	43.36581
190	*Lotus halophilus Boiss. & Sprun*	03/17/24	28.62935	43.23183
191	*Lotus halophilus Boiss. & Sprun*	01/17/24	28.67229	43.62623
192	*Lotus halophilus Boiss. & Sprun*	03/17/24	28.62935	43.23183
193	*Lycium shawii Roem. & Schult.*	01/16/24	29.39328	43.50767
194	*Lycium shawii Roem. & Schult.*	10/20/24	29.02679	43.66344
195	*Malva parviflora L.*	01/17/24	28.30861	43.43059
196	*Matricaria aurea (Loefl.) Sch.- Bip.*	03/23/24	29.39374	43.50798
197	*Matricaria aurea (Loefl.) Sch.- Bip.*	01/16/24	29.13263	43.51490
198	*Medicago sativa L.*	07/25/24	28.03046	41.72655
199	*Medicago laciniata (L.) Mill.*	03/20/24	27.51385	44.49468
200	*Medicago polymorpha L.*	03/23/24	28.52753	44.12466
201	*Moltikiopsis ciliata (Forssk.) I.M. Johnston*	01/23/24	27.70820	44.74912
202	*Moltikiopsis ciliata (Forssk.) I.M. Johnston*	01/14/24	28.21821	43.00538
203	*Moltikiopsis ciliata (Forssk.) I.M. Johnston*	01/15/24	28.83700	42.72801
204	*Monsonia nivea (Decne.) Decne. ex Webb.*	03/24/24	28.06539	41.68972
205	*Monsonia nivea (Decne.) Decne. ex Webb.*	03/28/24	28.69211	42.47007
206	*Monsonia nivea (Decne.) Decne. ex Webb.*	03/24/24	29.11651	43.52707
207	*Moraea sisyrinchium (L.) Ker Gawl.*	03/23/24	29.39374	43.50798
208	*Moraea sisyrinchium (L.) Ker Gawl.*	01/29/24	28.38308	44.28151
209	*Moraea sisyrinchium (L.) Ker Gawl.*	01/16/24	29.02216	43.65343

210	*Neurada procumbens L.*	01/14/24	28.69211	42.47007
211	*Notoceras bicorne (Aiton) Amo*	03/17/24	28.10229	43.47120
212	*Notoceras bicorne (Aiton) Amo*	01/24/24	27.32945	44.44335
213	*Onobrychis caput-galli (L.) Lam.*	01/22/24	27.17711	44.20764
214	*Onobrychis crista-galli (L.) Lam.*	06/03/24	28.25379	42.90967
215	*Orobanche ramosa L.*	03/28/24	28.69211	42.47007
216	*Paronychia arabica (L.) DC.*	03/22/24	29.38102	43.05446
217	*Paronychia arabica (L.) DC.*	01/15/24	29.02893	42.65438
218	*Paronychia arabica (L.) DC.*	01/15/24	28.83700	42.72801
219	*Paronychia arabica (L.) DC.*	01/18/24	28.21470	43.97269
220	*Paronychia sinaica Fresen*	10/24/24	27.94779	44.07595
221	*Peganum harmala L.*	03/21/24	28.56588	44.54798
222	*Peganum harmala L.*	07/20/24	28.62150	44.61033
223	*Pennisetum divisum (J.F.Gmel.) Henrard*	10/23/24	27.51599	44.41059
224	*Phragmites australis (Cav.) Trin. ex Steud.*	07/25/24	28.16188	41.95267
225	*Phragmites australis (Cav.) Trin. ex Steud.*	07/25/24	28.16188	41.95267
226	*Plantago ciliata Desf*	03/20/24	27.70820	44.74912
227	*Plantago ciliata Desf*	03/23/24	28.52753	44.12466
228	*Plantago ciliata Desf*	03/17/24	28.59503	43.36581
229	*Plantago ovata Forssk.*	03/22/24	29.38102	43.05446
230	*Plantago albicans L.*	03/22/24	29.38102	43.05446
231	*Plantago albicans L.*	03/17/24	28.59503	43.36581
232	*Plantago albicans L.*	01/29/24	28.38308	44.28151
233	*Poa sinaica Steudel.*	01/15/24	28.83700	42.72801
234	*Polycarpaea repens (Forssk.) Asch. & Schweinf.*	01/23/24	27.70820	44.74912
235	*Polycarpaea repens (Forssk.) Asch. & Schweinf.*	01/29/24	28.38308	44.28151
236	*Polycarpaea repens (Forssk.) Asch. & Schweinf.*	01/13/24	28.01171	42.95117
237	*Polygonum palaestinum Zohary*	10/21/24	29.06047	42.81648
238	*Polygonum palaestinum Zohary*	10/21/24	29.06047	42.81648
239	*Pteranthus dichotomus Forssk.*	03/17/24	28.59503	43.36581
240	*Pulicaria undulata (L.) C.A. May*	01/24/24	27.32945	44.44335
241	*Pulicaria undulata (L.) C.A. May*	03/21/24	28.37942	44.43570
242	*Pulicaria undulata (L.) C.A. May*	01/16/24	29.02216	43.65343
243	*Pulicaria incisa (Lam.) DC.*	10/21/24	29.17640	44.12784
244	*Reseda arabica Boiss.*	03/29/24	28.61432	42.23053
245	*Reseda arabica Boiss.*	03/17/24	28.59503	43.36581
246	*Reseda muricata C.Presl*	01/24/24	27.43165	44.22843
247	*Reseda muricata C.Presl*	03/29/24	28.61432	42.23053
248	*Reseda muricata C.Presl*	03/17/24	28.62935	43.23183
249	*Reseda muricata C.Presl*	01/28/24	28.86321	44.57693
250	*Rhagadiolus stellatus (L.) Gaertn.*	01/25/24	27.45512	44.58154
251	*Rhagadiolus stellatus (L.) Gaertn.*	03/23/24	29.39374	43.50798
252	*Rhanterium epapposum Oliv.*	03/17/24	28.59503	43.36581

253	*Rhanterium epapposum Oliv.*	01/15/24	28.83700	42.72801
254	*Rhazya stricta Decne*	01/16/24	29.022168	43.65343
255	*Rostraria pumila (Desf.) Tzvelev*	03/23/24	29.39374	43.50798
256	*Rumex pictus Forssk.*	03/28/24	28.69211	42.47007
257	*Rumex pictus Forssk.*	02/03/24	28.60444	43.75652
258	*Rumex pictus Forssk.*	01/30/24	28.28004	41.24218
259	*Rumex pictus Forssk.*	01/28/24	28.86321	44.57693
260	*Rumex pictus Forssk.*	01/14/24	28.21821	43.00538
261	*Salsola tragus L.*	07/25/24	28.16188	41.95267
262	*Salvadora persica L.*	07/19/24	27.31414	44.44235
263	*Savignya parviflora (Del.) Webb*	01/21/24	27.94779	44.07595
264	*Savignya parviflora (Del.) Webb*	03/17/24	28.51281	43.19883
265	*Savignya parviflora (Del.) Webb*	02/02/24	29.44054	39.98957
266	*Savignya parviflora (Del.) Webb*	01/17/24	28.30861	43.43059
267	*Savignya parviflora (Del.) Webb*	01/16/24	29.02858	43.65208
268	*Schimpera arabica Hochst. & Steud. ex Steud.*	01/24/24	27.32945	44.44335
269	*Schismus barbatus (L.) Thell*	01/18/24	28.17058	43.75000
270	*Schismus barbatus (L.) Thell*	01/29/24	28.38308	44.28151
271	*Schismus barbatus (L.) Thell*	03/22/24	29.36533	43.04743
272	*Schismus arabicus Nees*	01/18/24	28.16207	43.8286
273	*Scorzonera musilii Vel.*	03/17/24	28.51281	43.19883
274	*Scorzonera tortuosissima Boiss.*	01/18/24	28.21470	43.97269
275	*Scrophularia hypericifolia Wydler*	01/18/24	28.17058	43.75000
276	*Senecio glaucus L.*	01/29/24	28.39001	44.28552
277	*Setaria verticillata (L.) P.Beauv.*	07/25/24	28.16188	41.95267
278	*Silene villosa Forssk.*	01/18/24	28.21470	43.9769
279	*Silene villosa Forssk.*	01/14/24	28.21821	43.00538
280	*Sisymbrium irio L.*	03/22/24	29.13263	43.5149
281	*Solanum elaeagnifolium Cav.*	07/25/24	28.16188	41.95267
282	*Sonchus oleraceus L.*	06/02/24	28.25379	42.90967
283	*Spergula fallax (Lowe) Krause*	03/22/24	29.38102	43.05446
284	*Stipagrostis ciliata (Desf.) de Wint.*	01/15/24	28.83700	42.72801
285	*Stipagrostis ciliata (Desf.) de Wint.*	01/17/24	28.67229	43.62623
286	*Stipagrostis drarii (Tackh. de Wint.*	03/27/24	29.22959	41.75085
287	*Stipagrostis drarii (Tackh. de Wint.*	07/25/24	28.98544	40.37021
288	*Stipagrostis drarii (Tackh. de Wint.*	07/25/24	28.98544	40.37021
289	*Stipagrostis drarii (Tackh. de Wint.*	01/14/24	28.21821	43.00538
290	*Stipagrostis plumosa (L.) Munro ex T. Anders*	01/23/24	27.7082	44.74912
291	*Stipagrostis plumosa (L.) Munro ex T. Anders*	07/15/24	29.33419	41.33275
292	*Stipagrostis plumosa (L.) Munro ex T. Anders*	01/29/24	28.38308	44.28151
293	*Stipagrostis plumosa (L.) Munro ex T. Anders*	01/13/24	28.01171	42.95117
294	*Stipelluta capensis (Thunb.) Röser & Hamasha*	03/22/24	29.38102	43.05446
295	*Stipelluta capensis*	03/17/24	28.51281	43.19883

296	*Tamarix aphylla (L.) Karsten*	07/22/24	27.56936	44.60238
297	*Tamarix aphylla (L.) Karsten*	07/22/24	27.56936	44.60238
298	*Tamarix aphylla (L.) Karsten*	07/22/24	27.56936	44.60238
299	*Tamarix aphylla (L.) Karsten*	10/24/24	28.10229	43.47120
300	*Tamarix tetragyna Ehrenb.*	07/25/24	28.16188	41.95267
301	*Teucrium oliverianum Ging. ex Benth.*	01/24/24	27.43165	44.22843
302	*Teucrium oliverianum Ging. ex Benth.*	03/22/24	29.38102	43.05446
303	*Teucrium oliverianum Ging. ex Benth.*	03/17/24	27.99345	43.62368
304	*Teucrium oliverianum Ging. ex Benth.*	01/16/24	29.022168	43.65343
305	*Teucrium oliverianum Ging. ex Benth.*	01/17/24	28.25524	43.28804
306	*Teucrium polium L.*	03/17/24	28.51281	43.19883
307	*Teucrium polium L.*	01/15/24	29.02893	42.65438
308	*Teucrium polium L.*	01/17/24	28.30861	43.43059
309	*Traganum nudatum Delile*	10/21/24	27.43165	44.22843
310	*Trigonella stellata Forssk.*	03/20/24	27.5138	44.48901
311	*Trigonella stellata Forssk.*	01/15/24	29.02893	42.65438
312	*Vachellia gerrardii (Benth.) P.J.H.Hurte*	07/22/24	27.56936	44.60238
313	*Vachellia gerrardii (Benth.) P.J.H.Hurte*	07/22/24	27.56936	44.60238
314	*Vachellia gerrardii (Benth.) P.J.H.Hurte*	10/20/24	29.39328	43.50767
315	*Vachellia tortilis (Forssk.) Galasso & Banfi*	03/21/24	28.17832	43.92294
316	*Verbesina encelioides (Cav.) A.Gray*	10/19/24	29.25969	41.43487
317	*Verbesina encelioides (Cav.) A.Gray*	10/19/24	29.25969	41.43487
318	*Withania somnifera (L.) Dunal*	07/25/24	28.03046	41.72655
319	*Zilla spinosa (L.) Prantl.*	03/20/24	27.51380	44.48901
320	*Zilla spinosa (L.) Prantl.*	01/18/24	28.17058	43.7500
321	*Ziziphus nummularia (Burm.f.) Wight & Arn.*	01/16/24	29.39328	43.50767
322	*Ziziphus nummularia (Burm.f.) Wight & Arn.*	22/12/24	28.77043	44.64504
323	*Ziziphus nummularia (Burm.f.) Wight & Arn.*	10/20/24	29.02679	43.66344

Appendix 2: Table of Stocking Rate

Habitat	Winter										Spring									
	Camel (head)		Sheep (head)		Goat (head)		Gazelle (head)		Oryx (head)		Camel (head)		Sheep (head)		Goat (head)		Gazelle (head)		Oryx (head)	
	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA
Wadi	5	4	27	19	57	39	81	57	14	10	8	6	55	39	58	40	199	139	32	22
ElFiyyad	2	1	16	15	15	14	48	43	8	7	2	2	25	23	24	21	75	67	13	11
Steeps	6	5	69	56	66	54	204	167	35	29	12	10	138	113	129	105	411	337	69	57
Plateau	190.84	176	2,157	1,992	2,070	1,911	6,427	5,932	1,099	1,015	331	305	3,756	3,468	3,514	3,244	11,205	10,343	1,881	1,736
Sandy plains	400.68	355	4,535	4,022	4,294	3,808	13,510	11,980	2,290	2,031	899	798	10,215	9,059	9,534	8,455	30,458	27,009	5,112	4,534
Sand dunes	1364.72	1072.28	14,941	11,740	14,092	11,072	44,507	34,969	7,549	5,931	2,581	2,028	26,443	20,776	24,680	19,391	78,870	61,969	13,239	10,402
Total	**1,969**	**1,614**	**21,746**	**17,843**	**20,594**	**16,898**	**64,777**	**53,148**	**10,996**	**9,022**	**3,834**	**3,148**	**40,633**	**33,476**	**37,938**	**31,257**	**121,218**	**99,864**	**20,346**	**16,762**

Habitat	Summer										Autumn									
	Camel (head)		Sheep (head)		Goat (head)		Gazelle (head)		Oryx (head)		Camel (head)		Sheep (head)		Goat (head)		Gazelle (head)		Oryx (head)	
	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA	PA	NPA
Wadi	2	1	21	14	19	14	63	43	11	7	1	1	5	3	4	3	14	9	2	2
ElFiyyad	1	1	12	11	11	10	36	32	6	5	1	1	12	11	11	10	36	31	6	5
Steeps	5	4	56	46	52	43	167	137	28	23	1	1	12	9	11	9	35	28	6	5
Plateau	129	119	1,419	1,309	1,324	1,222	4,207	3,883	713	658	31	28	396	365	324	300	1,035	956	174	160
Sandy plains	985	873	11,184	9,918	10,438	9,257	33,314	29,542	5,592	4,959	655	581	7,436	6,595	8,504	7,542	22,151	19,644	3,718	3,298
Sand dunes	3,392	2,666	38,531	30,274	35,962	28,256	114,772	90,178	19,265	15,137	2294.32	1,803	26,048	20,466	24,311	19,102	77,590	60,963	13,024	10,233
Total	**4,514**	**3,664**	**51,222**	**41,573**	**47,807**	**38,801**	**152,558**	**123,816**	**25,615**	**20,789**	**2,983**	**2,414**	**33,908**	**27,450**	**33,166**	**26,965**	**100,860**	**81,632**	**16,930**	**13,703**

الملحق رقم 3: الحمولة الرعوية

تقرير تحليلي عن حالة نطاقات المراعي في محمية الإمام تركي بن عبد الله الملكية

مقدمة

تُعد المراعي في محمية الإمام تركي بن عبد الله الملكية من أهم المكونات البيئية الحيوية التي تلعب دورًا رئيسيًا في استدامة النظم البيئية الصحراوية في المملكة العربية السعودية، حيث وتوفير مصادر غذائية طبيعية للثروة الحيوانية، فضلًا عن دورها في حفظ التنوع الحيوي للنباتات المحلية. بناءً على البيانات المستخلصة من المرئيات الفضائية لربيع 2024م، والتي شملت تحليل 27 نطاقًا من المراعي، تم إجراء تقييم دقيق لحالة الغطاء النباتي وتحديد الأنماط البيئية السائدة، مع اعتماد مقياس عددي لتصنيف درجات التدهور البيئي.

تحليل المساحات ونسبة الغطاء النباتي

تراوحت المساحات الكلية لنطاقات المراعي في محمية الإمام تركي بن عبد الله الملكية بين 78 كم² و1725 كم²، حيث سجل "مرعى الضغط العالي" أعلى مساحة بمقدار 1725.33 كم²، بينما كان "أعويج لينة القديمة" الأصغر بمساحة بلغت 78.16كم². وتبعًا لتحليل مساحة الغطاء النباتي داخل هذه النطاقات، وُجد تفاوت كبير في نسبة الغطاء النباتي، وهو مؤشر بيئي مهم يعكس مدى التدهور أو الاستقرار في كل مرعى.

تشير نتائج تحليل المساحات الكلية للمراعي إلى وجود تباين واسع بين المواقع التي شملتها الدراسة، حيث بلغ عدد المراعي المدروسة (27) مرعى، توزعت على مناطق بيئية مختلفة تتراوح بين السهوب والكثبان الرملية والوديان. وقد تراوحت المساحات الكلية لهذه المراعي بين أعويج لينة القديمة، الذي سُجّل كأصغر مساحة وبلغت مساحته 78.16 كم²، وبين مرعى الضغط العالي، الذي يعد أكبر مرعى من حيث الامتداد الجغرافي، بمساحة بلغت 1725.33كم² .وبلغ متوسط المساحة الكلية للمراعي نحو 274.45كم²، في حين بلغ الوسيط 204.1كم²، مما يشير إلى أن غالبية المراعي تقع ضمن النطاق المتوسط من حيث المساحة، مع وجود بعض المراعي الكبيرة التي ترفع من القيمة المتوسطة الإجمالية.

عند الربط بين المساحة ونسبة الغطاء النباتي، يتبين وجود تباين واضح في الكفاءة البيئية، فبعض المراعي ذات المساحات الكبيرة تُظهر مؤشرات ضعيفة من حيث التغطية النباتية. فعلى سبيل المثال، مرعى الضغط العالي، رغم مساحته الكبيرة، سجل نسبة غطاء نباتي متدنية لم تتجاوز 0.58%، ما يشير إلى وجود خلل في التوازن البيئي لهذا النطاق قد يكون ناتجًا عن الرعي الجائر أو التدهور الطبيعي أو ضعف خصائص التربة في أراضي السهوب الحصوية ذات الغطاء النباتي العشبي. وفي المقابل، تُظهر مراعٍ مثل مرعى الرديفة ومرعى الحيانية، حيث البيئات الرملية، مؤشرات أعلى من حيث التغطية النباتية، حيث بلغت نسبة الغطاء النباتي فيهما 12.7% و11.4% على التوالي، رغم أن مساحتيهما معتدلتان (208.65 كم² و213.62 كم²)، مما يعكس ظروفًا بيئية أكثر ملاءمة، وربما تدخلات إدارية أفضل.

أما مرعى الزبيرة، والذي يُعد من المراعي المتوسطة بمساحة 343.03كم²، فقد سجل نسبة غطاء نباتي منخفضة نسبيًا بلغت 1.5%، بينما سجل مرعى الجفر ومرعى زبالا نسبًا متوسطة من الغطاء النباتي تراوحت بين 4% و6%، ما يعزز الحاجة إلى التدقيق في الفروق المحلية واعداد الحيوانات المسموح في هذه النطاقات.

تؤكد النتائج على أهمية الاعتماد على مؤشرات متعددة الأبعاد عند تقييم كفاءة المراعي، بحيث لا تقتصر على المساحة الجغرافية فحسب، بل تشمل أيضًا التغطية النباتية، ونوع الموائل، والتنوع البيولوجي (اعداد ونوعية الماشية). كما توضح الحاجة إلى تطوير خطط إدارة بيئية مخصصة لكل مرعى، تأخذ في الاعتبار حالته البيئية وقدرته على التعافي، من أجل ضمان الاستخدام المستدام للموارد وتحقيق التوازن بين الإنتاجية البيئية والرعوية.

مقياس تصنيف التدهور البيئي للمراعي

لضمان تصنيف حالة المراعي، تم استخدام مقياس عددي لتصنيف التدهور البيئية للمراعي من خلال تصنيف نسبة الغطاء النباتي إلى أربع فئات، وهي: "شديد التدهور" وتشير إلى نسبة الغطاء النباتي أقل من 1%، و" غطاء نباتي متدهور" ما بين 1 إلى أقل من 5%، و"متوسط" بين 5 إلى أقل من 10%، و"مرتفع" لنسبة تتجاوز نسبة الغطاء النباتي 10%. يُعد هذا التصنيف مرجعًا وفق النتائج الحالية لمؤشرات الغطاء النبت لفصل الربيع 2024، حيث يمكن استخدام هذا المؤشر لتحديد أولويات التدخل الإداري لإعادة تأهيل المراعي.

الفئة الأولى: مراعي شديدة التدهور (الغطاء النباتي 1 % >)

وفق مقياس تصنيف التدهور للمراعي، تم تصنيف خمسة من المراعي تحت فئة "شديد التدهور" وهي: نطاق الحدقة، مرعى الضغط العالي، العليم، مرعى سامودة، ونطاق قبة-الطراق. بلغ إجمالي المساحة لهذه المراعي 2434.15 كم²، بمتوسط نسبة غطاء نباتي لا يتجاوز 0.51 %. تعكس هذه القيم درجة عالية من التدهور البيئي، مما يستدعي تدخلاً عاجلًا يشمل منع الرعي لفترات مؤقتة وإعادة تأهيل النباتات المحلية.

الفئة الثانية: مراعي متدهورة (الغطاء النباتي 1-5 %)

أما فئة "متدهور (1–5%)" فتضم أحد عشر نطاقا رعوياً هي: مرعى الزبيرة، مرعى الوسيط، مرعى أم رضمة، مرعى تربة، مرعى حدق الجندة، مرعى زبالا، مرعى سادة الخر نعيجان، مرعى عذفة، مرعى لينة- أعويج - سنار، مرعى هجرة السلمانية، ومرعى اعويج لينة القديمة. بلغت المساحة الإجمالية لهذه النطاقات 6380.94 كم²، بمتوسط غطاء نباتي بلغ 2.06%. وعلى الرغم من أن الوضع البيئي في هذه الفئة أقل سوءًا من الفئة السابقة، إلا أن هذه المراعي ما زالت متدهورة، وتتطلب تنظيمًا دقيقًا للرعي وتحسينًا في أساليب الإدارة المستدامة.

الفئة الثالثة: مراعي متوسطة (الغطاء النباتي 5-10 %)

أما المراعي المصنفة ضمن فئة "غطاء نباتي متوسط (5–10%)" فتشمل خمسة نطاقات رعوية هي: مرعى رغوة الجديدة، مرعى قيصومة فيحان، مرعى البعيثة، مرعى الأيدية، ومرعى الجبيلي، والتي تغطي مساحة إجمالية تقدر بـ 922.48 كم²، بمتوسط نسبة غطاء نباتي يبلغ 6.11%. تشير هذه النتائج إلى حالة بيئية مستقرة نسبيًا، إلا أنها عرضة للتدهور، ويمكن تعزيزها من خلال دعم عمليات التجديد الطبيعي للنباتات ومراقبة الأنشطة الرعوية.

الفئة الرابعة: مراعي جيدة (الغطاء النباتي 10%>)

وأخيرًا، تضم فئة " المراعي الجيدة ذات الغطاء النباتي المرتفع (10%>) "خمس نطاقات رعوية، وهي: مرعى الحيانية، مرعى جبلة، مرعى الجفر، ومرعى زهوة، ومرعى أشقير ومراعي الرديفة، بإجمالي مساحة 1189.66 كم²، ومتوسط نسبة غطاء نباتي مرتفعة نسبيًا بلغت 15.81%. تعكس هذه النتائج حالة بيئية مستقرة نسبياً، حيث يجب الحفاظ عليها من خلال الممارسات الرعوية المستدامة.

الجدول التالي يوضح الملخص لتصنيف حالة المراعي في المحمية وفق ربيع 2024م.

التصنيف حالة المرعى	عدد النطاقات	أسماء المراعي	إجمالي المساحة (كم²)	متوسط نسبة الغطاء النباتي (%)
مراعي شديدة التدهور (الغطاء النباتي 1 % >)	6	نطاق الحدقة، مرعى الضغط العالي، العليم، مرعى سامودة، ونطاق قبة-الطراق	2434.15	0.51
مراعي متدهورة (الغطاء النباتي 1-5 %)	11	مرعى الزبيرة، مرعى الوسيط، مرعى أم رضمة، مرعى تربة، مرعى حدق الجندة، مرعى زبالا، مرعى سادة الخر نعيجان، مرعى عذفة، مرعى لينة- أعويج - سنار، مرعى	6380.94	2.06

		هجرة السلمانية، ومرعى اعويج لينة القديمة		
مراعي متوسطة (الغطاء النباتي 5-10 %)	5	مرعى رغوة الجديدة، مرعى قيصومة فيحان، مرعى البعيثة، مرعى الأيدية، ومرعى الجبيلي ومرعى الرديفة	922.48	6.11
مراعي جيدة (الغطاء النباتي >10%)	5	: مرعى الحيانية، ، مرعى جبلة، مرعى الجفر، ومرعى زهوة ، ومرعى الشقير ومراعي الرديفة،	1189.66	15.81

تصنيف الموائل البيئية الأساسية في نطاقات المراعي

أظهرت نتائج الدراسة تنوعًا في الموائل البيئية الأساسية التي تغطي نطاقات المراعي، وهو ما يعكس تباين الخصائص الجيومورفولوجية والبيئية بين هذه المواقع. تم تحديد ثلاثة أنواع رئيسة من الموائل البيئية، وهي: السهوب(Steppes) ، والكثبان الرملية(Sand dunes) ، والأودية .(Wadis) تعتبر هذه الموائل عاملًا رئيسيًا في تحديد الغطاء النباتي ونوعية الأنواع النباتية المنتشرة في كل مرعى.

تُعد السهوب من أكثر الموائل شيوعًا، وتوجد في نطاقات مثل مرعى الزبيرة، ومرعى الضغط العالي، وتمتاز بغطاء نباتي منخفض نتيجة قلة الأمطار وطبيعة التربة الحصوية والرملية. أما الموائل الرملية فتتواجد بشكل أساسي في مرعى الرديفة ومرعى الحيانية، وتتميز بوجود أنواع نباتية متأقلمة مع الرمال مثل الأرطى والغضا مما يشكل غطاء نباتي عالي نسبيا مقارنة بالسهوب الخالية من الشجيرات الخشبية. بينما تقتصر الموائل المائية الموسمية كالأودية والسهول الفيضية على عدد محدود من النطاقات مثل مرعى الحدقة، حيث تتجمع مياه الأمطار بشكل مؤقت مما يتيح ظهور نباتات حولية لفترة قصيرة خلال موسم الأمطار.

فريق العمل

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