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Restoring biodiversity in a hyper-arid desert ecosystem in Saudi Arabia

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Abstract

The global biodiversity crisis has manifested itself on the Arabian Peninsula with wildlife population declines and extinctions particularly of the large iconic mammals. Protected areas are increasingly being established to provide refuge, enhance wildlife populations, and reintroduce missing keystone species. Since 2018, eight royal reserves have been established in Saudia Arabia, two in the hyper-arid central region. Understanding current species occurrence, richness, abundance, and diversity is crucial to targeting management and reintroduction efforts. Due to the scarcity of data on wildlife presence and spatial abundance in the region, we utilized camera traps placed on trails, at water stations, and at burrows, as non-intrusive tools for baseline biodiversity assessment in these protected areas. These camera traps revealed the presence of 12 species listed as threatened on the IUCN Red List, underscoring the regional and global importance of these areas. Additionally, these findings contribute valuable information on species distributions in hyper-arid areas for global assessments. The data on the spatial abundance of top predators and meso-predators is crucial for designing feasibility studies for reintroduction programs and can guide spatial management strategies that will enhance biodiversity.

Introduction

Biodiversity has shown an alarming downward trend in the last decades (Díaz et al., 2019). Effective ecological structure and functioning of ecosystems requires the full trophic network of wildlife species to be present. Large predators have cascading trophic effects through predator avoidance by herbivores (Suraci et al., 2016), resulting in spatial variation in vegetation communities in areas these grazers avoid (Boyce, 2018). The presence of large herbivores increases plant diversity through selective browsing (Cook-Patton et al., 2014; Olff & Ritchie, 1998) and the improvement of soil fertility through dung and urine deposits (van der Waal et al., 2011). Birds and small mammals facilitate regeneration through seed dispersal (Kellner et al., 2016). And insects are not only food for many animals, but they are also very important for nutrient recycling. Therefore, an ecosystem with a diverse and abundant wildlife population can enhance the natural regeneration and diversity of the vegetation which in turn supports wildlife communities.

Various species of large mammals used to roam the desert ecosystems of Saudi Arabia, having adapted to the harsh climate conditions. However, most have now disappeared from the wild. These include the

Arabian oryx (*Oryx leucoryx*) which is deemed extinct from the wild since the early 1970s (Henderson, 1974), and the sand gazelle (*Gazella marica*), the mountain gazelle (*Gazella arabica*), and the Arabian grey wolf (*Canis lupus arabs*) are currently only present in small remnant populations in Saudi Arabia (Habibi & Grainger, 1990; Ross et al., 2019, 2020). Overhunting and habitat degradation have resulted in their population decline (Alatawi, 2022) and these species are currently listed on the IUCN Red List as vulnerable to extinction (Mallon et al., 2023). Protected areas are a key component in global biodiversity conservation management and have shown to be effective in conserving terrestrial mammals (Chen et al., 2022). To support the Saudi Vision 2030 and in aligned with international treaties, particularly the Convention of Biological Diversity, the Saudi government has pledged to have 30% of its terrestrial and marine areas protected by 2030. Since 2018, eight royal reserves have been established, covering 13.5% of the total terrestrial land. Two reserves are located in the central hyper-arid desert, the King Khalid Royal Reserve (KKRR) and the Imam Abdulaziz bin Mohammed Royal Reserve (IARR). No studies on the presence and abundance of wildlife have been published for these areas. Monitoring wildlife to assess diversity using camera traps, especially for elusive and nocturnal animals, is now a standard method (Palencia et al., 2021). We used camera traps as point-based sampling units to increase our understanding of wildlife species' occurrence, richness, and relative abundance at two study sites in the recently protected areas.

Methods

The study areas are within KKRR and IARR, approximately 100 km northeast of Riyadh. KKRR is 1,162 km^2 and has four main habitats, the pediplain, plateau, wadi (valley) and catchment. The pediplain is about 250 km^2 and contains numerous catchment areas. It is bordered by the escarpment of the Urumah Mountain plateau to the east and at all other sides by roads and has been fenced for over 40 years allowing the vegetation to regenerate (Al-Harigi et al., 2023). Between 2021 and 2024, 45 Arabian oryx (*Oryx leucoryx*), 120 sand gazelles (*Gazella marica*), 11 Arabian gazelle (*Gazella arabica*), and 15 Asian houbara (*Chlamydotis macqueenii*) have been reintroduced in this pediplain. IARR is 11,300 km^2 and has six main habitats, the pediplain, plateau, wadi, catchment, sand plain, and sand dune. This reserve harbours 13 catchment areas with Rawdhat Khuraym being the largest, with eight main wadis draining into it and a popular destination for people in the winter; Kasr Almuzayri is the second largest catchment. Ten Asian houbara were reintroduced in Rawdhat Khuraym in 2023.

In KKRR, camera traps were positioned at 53 locations, predominantly in the fenced pediplain. In IARR, 11 cameras were placed in Rawdhat Khuraym and 2 in Kasr Almuzayri. To increase the observations of diverse animal assemblages we placed cameras next to water sources (50-60 cm height), burrows (10-15 cm height), and on wildlife trails (50-60 cm height). Photos that were taken two minutes or less apart were combined into a single continuous sequence and reported as a single observation. Species richness was based on the incidence of rare species (Chao et al., 2014; Hsieh et al., 2016). We used Hill numbers to quantify community diversity with q representing species richness (q = 0), Shannon diversity (q = 1), and (1-) Simpson diversity (q = 2). The widely used Relative Abundance Index (RAI), calculated as the ratio of photographic captures to camera trapping effort, provides a baseline species abundance for unmarked populations at each feature type (Rovero and Marshall, 2009; Tanwar et al., 2021).

Results

Species Richness

In total, 59 vertebrate species were observed, 35 birds, 17 mammals (of which 3 were domestic) and 7 reptiles. Of these species, 12 are listed on the IUCN Red List: 2 as Endangered (steppe eagle, Egyptian vulture); 8 as Vulnerable (Eastern imperial eagle, Arabian wolf, sand cat, Egyptian spiny-tailed lizard, and the reintroduced Asian houbara, Arabian gazelle, sand gazelle, and Arabian oryx); and 2 as Near-threatened

(Arabian wildcat, honey badger). Placing cameras at different features resulted in slightly different species assemblages (Fig.1 left panel) with, as can be expected, burrowing animals (*Meriones libycus, Jaculus jaculus, Uromastyx aegyptiae*) being pervasive at burrows; pigeons, domestic cats (*Felix catus*), and raptors (e.g. the steppe eagle, *Aquila nipalensis*, Egyptian vulture, *Neophron percnopterus*) at water sources; and on trails the wolf (*Canis lupus arabs*), Arabian gazelle and oryx were frequently captured. However, overlap in species assemblages was quite large.

Species diversity indices showed similar values for richness among feature types (Fig. 1 right panel), suggesting a similar number of species in each habitat. However, the Shannon and Simpson diversity indices, which account for both species richness and evenness, are lower at wildlife trails. This is likely driven by the occurrence of rare species, such as the rarely observed honey badger, Indian crested porcupine, false cobra, sand skink, and the Arabian babbler. The slightly higher Shannon and Simpson diversity indices at burrows, despite overlapping standard errors with water sources, suggest a more even distribution of species resulting from the frequent observations of burrowing animals.

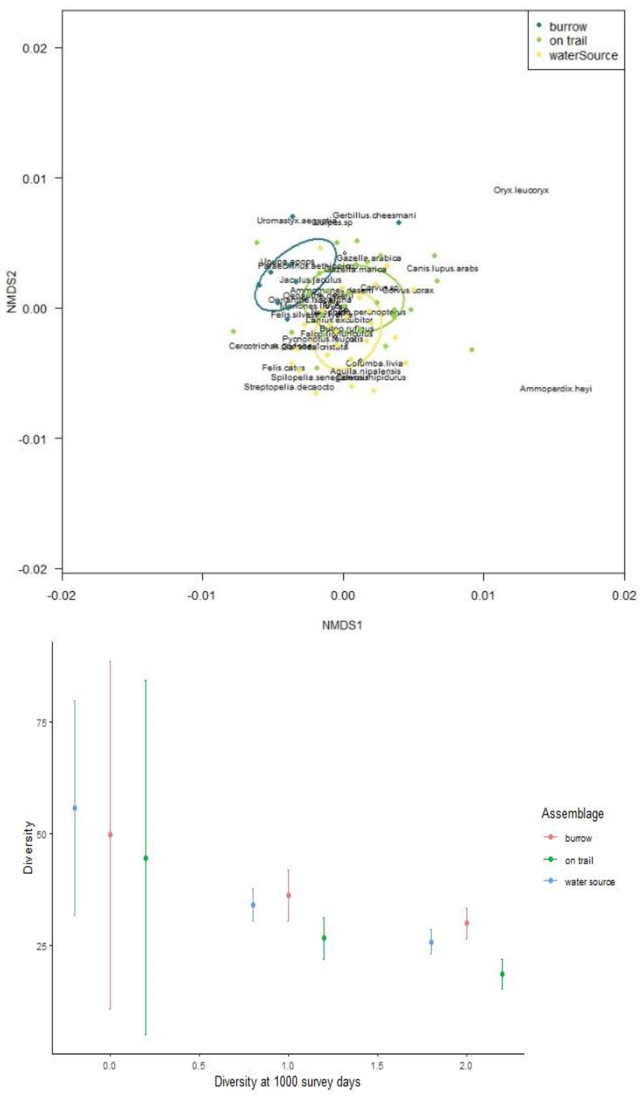

Figure 1. *Left panel*: Non-Metric Multi-Dimensional Scaling (NMDS) plot of species encountered at burrows, water sources or along wildlife trails. *Right panel*: Predicted diversity indices with 0 = species richness, 1 = Shannon diversity, and 2 1-Simpson diversity

Relative Abundance Index (RAI)

Most species had a higher RAI at water sources compared to the other features with only the burrowing species being restricted to observations at burrows (Fig. 2). In KKRR, the reintroduced sand gazelle was the most prominent species at water sources, followed by foxes (*Vulpes*), pigeons, ravens (*Corvus*), and stray dogs (*Canis lupus familiaris*). In IARR, no large herbivores have been reintroduced, and the most abundant species were pigeons, white-eared bulbuls (*Pycnonotus leucotis*), house sparrows (*Passer domesticus*), and feral cats (*Felis catus*) that were all attracted to water sources.

Discussion

Our study demonstrated that the recently established protected areas hold both regional and global significance, as 20% of the observed species are listed as threatened on the IUCN Red List. Providing a refuge for these animals will enhance their survival chances. Water provision also proved crucial for these threatened species, including migrating raptors and native gazelles and oryx. These observations are valuable for biodiversity restoration efforts through reintroduction and wildlife species enhancement programs.

Interestingly, the diversity at water sources, which attracted a high abundance of animals, showed similar species richness with considerable overlap in species assemblages compared to trails and burrows. Only burrowing animals were almost exclusively seen at their burrows, while species mostly associated with urbanized areas (pigeons, sparrows, stray cats, and stray dogs) were predominantly observed at water sources. This was especially notable in Rawdhat Khuraym, which experiences high levels of disturbance in the winter due to thousands of visitors from surrounding areas. Restoring wildlife biodiversity in this area will depend on the restoration of the currently degraded habitat. As a first step the native vegetation, including palatable species for native ungulates and reptiles, will need to be restored and natural regeneration needs to be stimulated. After the successful establishment of these plants for food and shelter, it is expected that wildlife will reoccupy the area from its surrounding and missing keystone species can be reintroduced, increasing the biodiversity.

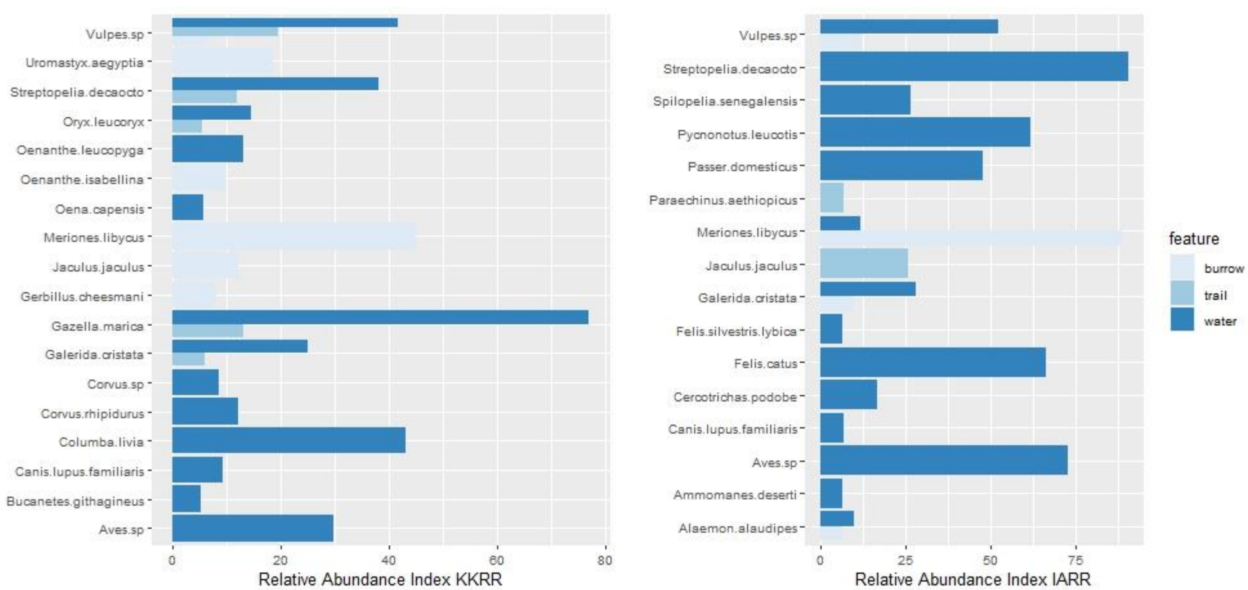

Figure 2. Relative Abundance Index of species frequently encountered (i.e., RAI >5)

For the success of reintroduction programs, it is important to understand the spatial abundance of potential predators near release sites. For example, releasing Asian houbara in areas with low predator abundance (foxes, wild cats, honey badgers) will increase their survival rate, especially after a hard release when they still need to find suitable habitat for shelter. Equally important for species conservation is identifying the locations of stray cats and dogs, as they not only compete for resources with wild cats and wolves but also pose a risk of interbreeding, which can lower genetic integrity. Additionally, dogs can prey on small gazelles or even attack oryx when in packs, and could outcompete the remnant wolves.

Results from our study provide insights into the spatial occupancy of predator and prey animals and highlighted areas of high abundance. Furthermore, they offer crucial information on the spatial abundance of threatened species, which can inform spatial management strategies to effectively protect and conserve these animals.

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