Sustainability and Biodiversity Conservation

The golden jackal in the Jordan River: Ecological insights, coexistence and conservation strategies

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Abstract

This study represents the first comprehensive long-term monitoring program for golden jackal (*Canis aureus syriacus*) in Jordan. The research took place on a private citrus fruit farm in the lower Jordan River region, employing camera traps with a total effort of 2,548 trapping days from June 2020 to February 2022. The findings provide new insights into the species' activity patterns, population estimates, interspecies coexistence, and various ecological aspects. A population of approximately 12 individuals was monitored, with 24% of the recorded photos capturing a mated pair and 8% showing packs of three to six individuals. The jackals exhibited diverse survival strategies, utilizing the Jordan River as a natural barrier for protection and movement and the dense reed vegetation for hiding and shelter. Activity and group formations peaked in October, suggesting that reproductive activities likely commence from August to January. Social behaviors such as grooming, playing, and resting were primarily observed during the autumn and winter seasons, mostly at night, to avoid the high daytime temperatures in the northern Ghor, which can exceed 45 °C in summer. The study recorded no interactions between jackals and feral dogs, suggesting an absence of interspecific hybridization. Additionally, the spatial and temporal coexistence of the golden jackal with other wildlife, including Egyptian mongooses, nutria, and black storks, was noted, possibly due to similar ecological requirements and reduced competition. The study emphasizes the significance of restricted access and protection by the army, which enhances the potential for implementing the Other Effective Conservation Measures (OECMs) approach to conserve species and aid Jordan's efforts in meeting its obligations under the Convention on Biological Diversity. This study significantly contributes to the enhance our understanding of the golden jackals in Jordan.
Keywords: Activity pattern, Camera trap, *Canis aureus*, Jordan, Monitoring

Introduction

The decline of golden jackals (*Canis aureus syriacus*) in Jordan during the 1940s was primarily driven by rapid habitat loss due to agricultural expansion and intensified human encroachment, which led to increased eradication of wildlife and heightened competition from adaptable generalist species such as the red fox that thrived in these altered landscapes (Lewis et al., 1968). However, the population has since recovered, leading to broader distribution, and the species is currently classified as Least Concern in the Red Data Book of Mammals of Jordan (Eid et al., 2020). This recovery is attributed to the jackal's adaptability to diverse habitats, dietary flexibility, positive impacts from protected areas, and restricted border access in northwestern regions. Despite these gains, poisoning, and poaching remain serious threats, with frequent community conflicts documented, including three killings reported by Eid & Handal (2018), highlighting the ongoing need for conservation and community awareness efforts to mitigate human-wildlife conflicts effectively (Eid & Handal, 2018; Eid et al., 2020). The adaptability of golden jackals across various environments, from grasslands to human-dominated landscapes, was documented by various scholars (Šálek et al., 2014; Ranc et al., 2017; Shahnaseri et al., 2019; Torretta et al., 2021). Their resilience is evident near human settlements where abundant resources enhance survival, though this proximity increases vulnerability to human-wildlife conflicts in semi-urban regions (Fenton et al., 2021). Al Atawi et al. (2023) observed jackals inhabiting farmlands with palm trees and diverse crops in Tabuk, Saudi Arabia, while Šálek et al. (2014) found that dense wetland vegetation offers daytime cover, enabling jackals to minimize human interactions. A recent range extension into northwestern Saudi Arabia has been reported (Eid & Smithson, 2024), expanding the species' known southern distribution. Conversely, in Egypt, jackals avoid arid deserts near the Nile, favoring irrigated and inhabited areas (Saleh & Basuony, 2014). In Jordan, jackals are common in oases, swamps, and protected areas with dense vegetation, particularly along army-protected borders, vital for their conservation (Amr, 2012; Eid et al., 2020). In addition, the golden jackals, known for their opportunistic omnivorous diet, thrive on a variety of food sources, including small animals like rodents, hares, and birds, as well as fruits and vegetable matter (Amr, 2012; Penezić & Ćirović, 2015; Lange et al., 2021). Studies across regions reveal dietary adaptability; for instance, in the Serengeti, jackals consume a wide range of prey such as dung beetles, grasshoppers, gerbils, ground birds, eggs, and fallen fruit (Temu et al., 2018; Lange et al., 2021). Regional studies further highlight dietary variation: rodents dominate their diet in Bangladesh (Jaeger et al., 2007), a trend echoed in Bulgaria and Rajasthan, India (Markov & Lanszki, 2012), while Algerian studies indicate mammals, poultry, and insects as significant

food sources depending on location (Alam, 2015; Lange et al., 2021). This adaptability extends to human-altered environments, where jackals often consume human waste, acting as 'cleaners' by reducing discarded animal waste and controlling rodent pests in agricultural zones (Bošković et al., 2013; Ćirović et al., 2016). Such dietary flexibility underlines their resilience and efficient exploitation of diverse habitats, including human-modified landscapes. Golden jackals also exhibit complex social structures, typically forming packs centered around a monogamous pair, their current year's offspring (usually 2–4), and occasionally, older offspring who assist in hunting and delay mating (Lal et al., 2016; Fenton et al., 2021). Research highlights a strong pair bond, often lasting a lifetime, with males supporting females during pregnancy and lactation, aided by older offspring, significantly boosting pup survival rates (Csányi et al., 2023; Böcker et al., 2024). Observations show jackal pairs foraging and resting together, and pack sizes can vary widely, with reports of groups of up to 20 near the Dead Sea (Macdonald, 1979; Lal et al., 2016). In Jordan, a field report recorded a mother and three young in Azraq (Amr, 2012). Territory size varies by habitat quality, spanning 1–12 km² in high-quality areas (Wennink et al., 2019; Lange et al., 2021). Notably, hybridization with domestic dogs has been documented, though the genetic implications for European jackal populations remain unclear (Galov et al., 2015). The survey marks the first extensive monitoring effort for golden jackals in Jordan, offering valuable insights into their activity patterns, social dynamics, breeding behaviors, and interactions with other species. It also examines alternative conservation strategies to enhance species and ecosystem conservation across Jordan.

Material and methods

Study Area

The study was conducted on a 9.9-hectare private farm located in Sheikh Hussein, Northern Ghor, Jordan (UTM UPS: 36 S 742018.23 E; 3597034.04 N), which cultivates citrus varieties supported by irrigation, fertilization, and herbicides. The farm is situated along the banks of the Jordan River within the Saharo–Sindian–Nubo–Sindian subzone, which features riparian vegetation, including *Phragmites communis*, *Typha domingensis*, and *Tamarix* spp., as well as shrubs and herbs such as *Artemisia sieberi*, *Ziziphus spina-christi*, *Fagonia arabica*, and *Malva* spp. This area experiences extreme temperatures ranging from 15 °C to 45 °C with annual rainfall between 50–100 mm (Taifour et al., 2022; Eid & Alayyan, 2024).

Camera-trapping

The survey, conducted from June 1, 2020, to February 28, 2022, deployed four Dark Ops HD MAX Browning camera traps with a trigger speed of 0.6 seconds and a 1-second delay,

operating continuously at fixed locations. Cameras were mounted on iron stakes 40–50 cm above ground level in the riverbed and oriented north-south to minimize false captures during sunrise and sunset. No bait was used to preserve data objectivity and ensure that observed behaviors were natural, providing an accurate picture of jackal activity without artificial attractants. Cameras were checked monthly to ensure reliable operation. The study spanned multiple seasons to observe potential variations in jackal activity linked to breeding and foraging cycles. Data analysis involved documenting the number of individuals in each photograph on an Excel sheet, with columns for species, date, time, individual count, and maturity stage when identifiable. Images capturing irrelevant events, such as plant movements or bird species, were excluded to maintain data accuracy. Initial data organization was performed in Microsoft Excel, with further statistical analysis conducted in "R." A one-way ANOVA assessed annual variations in jackal sightings. At the same time, Chi-Square tests evaluated encounter distributions across time intervals to provide insights into jackal activity patterns. This methodological approach, integrating strategic camera placement with multi-season data collection, establishes foundational insights into golden jackal behavior and habitat use in a managed agricultural landscape. Future improvements, including increased camera density and seasonal adjustments, could enhance understanding of population dynamics.

Results

Photo analysis recorded jackals in 2,528 instances, with 64% featuring single individuals, 24% pairs, and 1% packs, the largest group comprising six jackals. The estimated population density was 1.21 jackals per hectare. Additionally, one individual exhibited unique coloring with an albino head and pale body color (Figure 1). This density aligns with those reported in similar semi-arid and agricultural landscapes (Lange et al., 2021; Al Atawi et al., 2023), indicating that the study area's resources, such as water, dense vegetation, and prey availability, are sufficient to sustain a stable jackal population within a human-dominated setting.

Fig 1. Photos of golden jackals recorded during the survey: (A) Single individual, (B) Pair of jackals with one showing an albino head, and (C) Pack of six individuals.

The data shows two distinct peaks in October 2020 and October 2021, followed by declines, with sharp decreases observed by March 2021 and February 2022, respectively. This pattern suggests periodic increases in jackal activity towards the end of each year, followed by reductions in subsequent months. A one-way ANOVA indicates no significant year-over-year difference in mean population counts (p-value = 0.2205), suggesting a stable population trend (Figure 2). This stability implies resilience in the jackal population despite existing threats in the study area.

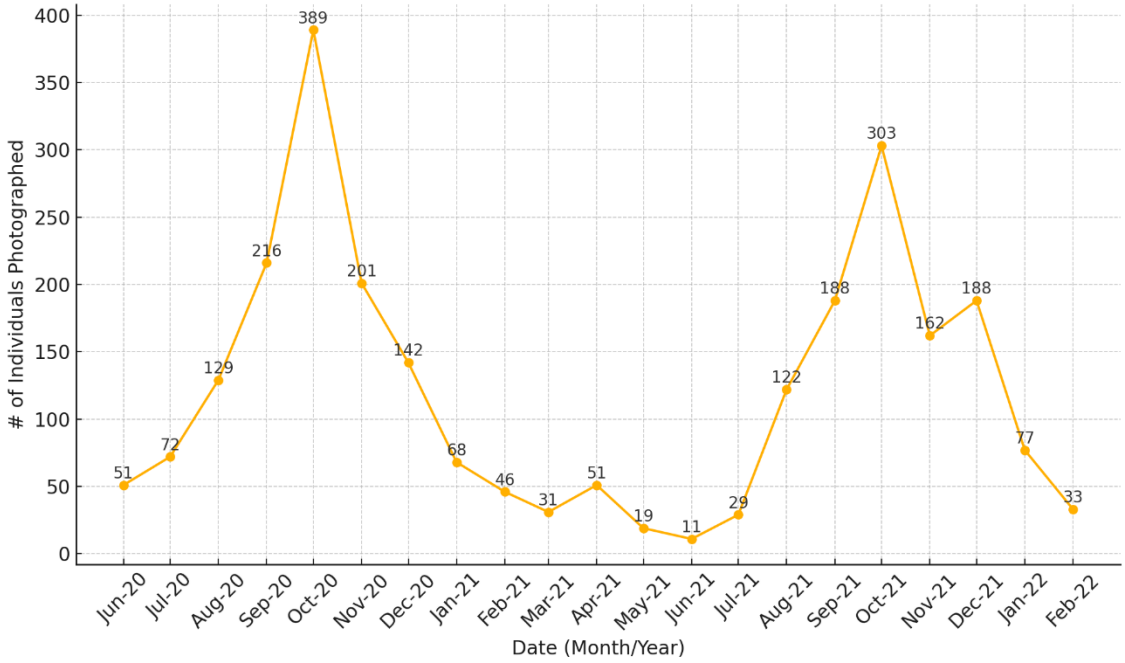

Fig 2. The number of golden Jackal individuals encountered during the study period

The results reveal a distinct pattern of golden jackal encounters across time intervals, with peak sightings occurring between 02:00 and 05:00, especially around 03:00. Fewer encounters were recorded in the late evening and early morning, primarily before midnight and after 05:00. Linear regression analysis of these peak times indicates a slight decrease in encounters as the night progresses, with a slope of -5.00 and an intercept of 118.00. A Chi-Square test for peak encounter times showed no significant deviation from expected values (p-value = 0.8890), indicating no strong preference within the peak period. This early pre-dawn activity aligns with patterns in other mesocarnivores in hot climates, where foraging during cooler hours helps conserve energy and mitigate heat stress, an adaptation beneficial in the extreme summer temperatures of northern Ghor (Mukherjee et al., 2017).

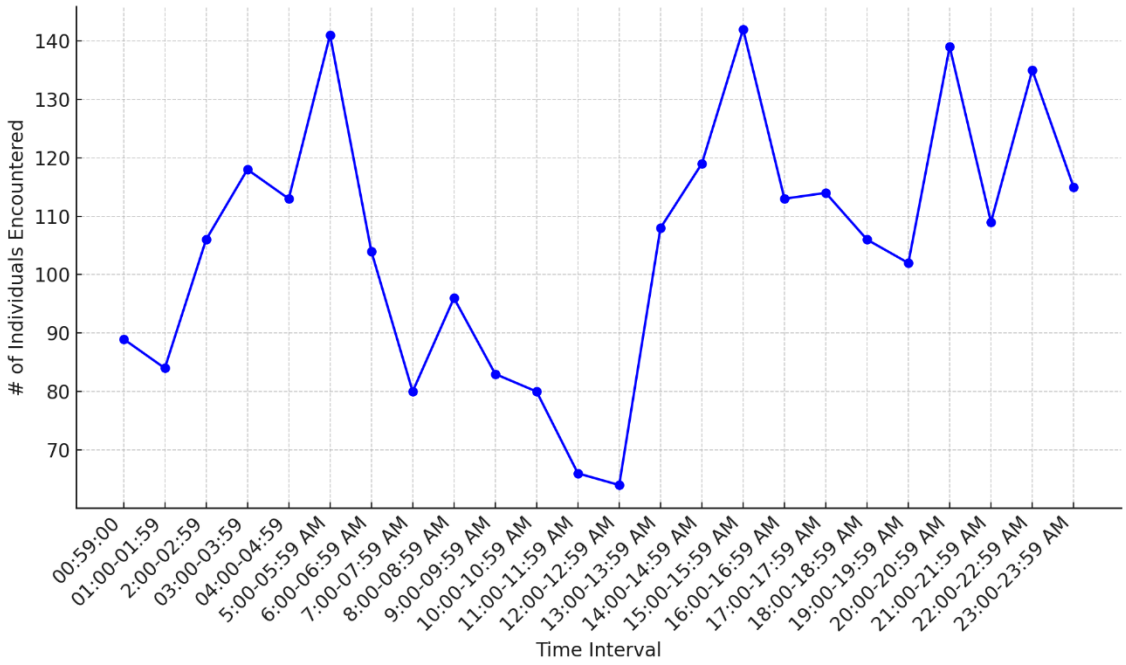

Fig 3. Activity period of the golden Jackal during the study period

The results indicated that feral dogs do not interact with golden jackals, as no photos captured both species. However, several photos showed jackals swimming across the river when disturbed by approaching humans or dogs, as documented in sequential images (Figure 4). Despite the small farm area, the results demonstrated that golden jackals share spatial and temporal coexistence with other species, such as Egyptian mongooses (*Herpestes ichneumon*). These images revealed that jackals would vacate the area, allowing mongooses to forage for food. Golden jackals were also observed in the presence of other species, including nutria (*Myocastor coypus*), black storks (*Ciconia nigra*), and various other bird species (Figure 4).

Fig 4. (A) A golden jackal swimming to the other river bank to avoid feral dogs and/or humans; (B) Coexistence of the golden jackal with other species: B-1: Nutria, B-2: Black stork, and B-3: Egyptian mongooses.

These findings provide an understanding of golden jackal behavior, population density, and ecological interactions within a semi-agricultural landscape, offering insights critical for future conservation strategies.

Discussion

This study marks the first comprehensive monitoring of golden jackals in Jordan, revealing seasonal peaks in activity, particularly in October 2020 and 2021, which suggest cyclical behavior potentially linked to breeding seasons and prey availability. These patterns align with findings from similar semi-arid ecosystems, where cooler months and increased prey abundance drive higher activity and grouping behaviors (Gupta et al., 2016; Acosta-Pankov et al., 2018). Such seasonal fluctuations appear adaptive, maximizing survival and reproductive success in response to environmental cues. The subsequent declines following these peaks may reflect responses to changing conditions. Despite these variations, the one-way ANOVA showed no significant year-over-year difference in mean jackal counts (p-value = 0.2205), indicating population stability. The Chi-Square test confirmed no significant deviation in encounter distribution across time intervals (p-value = 0.8890), with confidence intervals set at 95%, underscoring the consistency of these activity patterns. This stability suggests resilience and adaptability in jackals, while further research could clarify the factors driving seasonal changes and assess their long-term implications for regional populations. The consistent

presence of golden jackals at the study site, whether in packs or individually, is likely due to abundant and reliable food sources, including small mammals, birds, and insects. Studies confirm that jackals primarily prey on small mammals, especially rodents, with fruits as secondary foods in lowland agricultural areas (Stenin et al., 1983; Genov & Vassilev, 1991; Lange et al., 2021). Dense vegetation, such as the riparian flora along the Jordan River, provides effective cover, enabling jackals to avoid predators and human interference (Al-Eisawi, 1996; Damhoureyeh & Al-Khader, 2003; Taifour et al., 2022; Eid et al., 2020; Fenton et al., 2021; Kamler et al., 2021; Selimovic et al., 2021; Eid & Alayyan, 2024). The farm's location near the riverbed facilitates access to natural barriers and supports jackal movement, enhanced by their swimming ability (Fenton et al., 2021). Restricted site access further ensures a safe environment with limited human interaction, mainly with farmers. This food, shelter, and water resource mix likely makes the citrus farm an optimal jackal habitat. Our survey has provided evidence of successful breeding within the golden jackal population, as indicated by photographing two adult individuals and three juveniles in a single frame (Figure 5). This finding is consistent with the typical reproductive output for golden jackals, which usually produce between two and four offspring (Nowak, 1991). Comparable observations of three cubs in the National Park Neusiedler See-Seewinkel/Fertö-Hansäg in Austria (Herzig-Straschil, 2007) serve as a reference for evaluating reproductive success across different regions. The documented successful breeding in Jordan confirms the presence of a breeding population and underscores the ecological significance of the study area as a vital habitat for the golden jackal. The observed reproductive success suggests that the environmental conditions, including food availability and habitat quality, are conducive to the species' continued health and stability in the region.

Fig 5. pair jackals with three juveniles recorded in August

The primary social structure of the golden jackal (*Canis aureus*) is characterized by pair bonding, a behavior well-documented in the literature (Negi, 2014; Yumnam et al., 2015). Our survey observed that 24% of the recorded photos captured a mated pair, reflecting this fundamental social unit. The relatively low frequency of images showing groups of three to six individuals, which accounted for only 8% of the total captures, can be attributed to survey challenges. Specifically, the rapid regeneration and spread of common reed obstructed visibility, resulting in numerous redundant images and likely reducing the chances of documenting larger groups effectively. These findings are consistent with previous studies on golden jackals. For example, research conducted in the Bhal and Kachchh regions of Gujarat, India, reported that 35% of jackal sightings involved pairs, 14% involved groups of three, 20% included more than three individuals, and the remaining were solitary (Jhala & Giles, 1991).

Our survey identified prevalent behaviors among golden jackals, including feeding, grooming, playing, guarding, and group vocalizations (Figure 6), consistent with findings by Mukherjee et al. (2018), who documented similar social interactions. Such insights enhance understanding of the jackal's ecological and social interactions. As opportunistic omnivores, golden jackals significantly impact trophic dynamics, helping control small mammal populations and scavenging, indirectly supporting vegetation health by reducing agricultural pest outbreaks. Studies in human-dominated landscapes emphasize their role in ecosystem services, particularly as 'cleaners' that consume waste and regulate rodent populations (Ćirović et al., 2016). These ecological functions are particularly beneficial in agricultural areas, where jackals contribute to ecosystem balance.

Fig 6. Grooming, playing, and resting were observed during the survey

Our observations reveal that jackals exhibit heightened activity and form groups predominantly in October, overlapping with mating pairs, packs, and juveniles. This pattern suggests that the reproductive period for golden jackals in the lower Jordan River region likely spans from September to January. Social behaviors such as grooming, playing, and resting are most pronounced during this peak period, particularly during nighttime. Previous studies support our findings, with documented breeding seasons varying by region. For instance, Gupta et al. (2016) identified the breeding period in India and Turkmenistan as February to March. Acosta-Pankov et al. (2018) observed breeding from October to December in Tanzania, with pups born between December and March. Our survey data indicate that jackal activity decreases significantly around noon, with activity levels rising steadily as temperatures drop. This behavior aligns with findings by Mukherjee et al. (2017), who reported a reduction in jackal activity during the hotter daytime hours attributed to heat stress in their study area. The climate in northern Ghor, Jordan, characterized by warm winters and extreme summer temperatures exceeding 45 °C (Taifour et al. 2022), likely influences this pattern. Furthermore, our results corroborate previous studies highlighting the association of golden jackals with agricultural landscapes. Al Atawi et al. (2023) reported jackal populations in farmland areas with palm trees and vegetable crops. Similarly, Saleh & Basuony (2014) noted their presence in floodplains and cultivated regions around the Nile in Egypt. Šálek et al. (2014) and Jaeger et al. (2007) also documented jackals adapting to environments with dense human populations and agroecosystems, utilizing these areas for cover and food resources. Overall, the observations from our survey contribute to understanding the seasonal activity patterns and habitat preferences of golden jackals, highlighting their adaptability to both environmental and anthropogenic factors. Our analysis of camera trap images and observations revealed no interactions between golden jackals and feral dogs at the study site. Golden jackals displayed distinct temporal patterns, often retreating across the Jordan River when encountering dogs, suggesting spatial separation and a low risk of interspecific hybridization, which is crucial for maintaining genetic integrity in modified landscapes. These findings support previous research emphasizing the need to prevent hybridization to protect wildlife genetics (Randi & Lucchini, 2002; Randi et al., 2014; Galov et al., 2015). Interspecific hybridization, affecting about 10% of animal species, can lead to genetic admixture and introgression, but its absence here likely minimizes competition and hybridization risks, promoting population stability and genetic preservation (Mallet, 2005; Randi et al., 2014). While the literature on hybridization between golden jackals and other canids is limited, some studies document hybridization events, such as jackal-dog hybridization reported by Galov et al. (2015) and jackal-wolf admixture noted by

Freedman et al. (2014). Studies on African golden jackals (*Canis aureus lupaster*) suggest potential historical hybridization with wolf clades (Gaubert et al., 2012; Ninausz et al., 2014). Claims of jackal-wolf hybrids in Romania (Tóth et al., 2009) and suspected jackal-dog skulls in Hungary (Galov et al., 2015) remain debated, underscoring the need for further genetic research to clarify the occurrence and implications of interspecific hybridization in canid populations. Our study observed spatial and temporal coexistence between golden jackals and species such as Egyptian mongooses (*Herpestes ichneumon*), nutria (*Myocastor coypus*), and birds species such as the black storks (*Ciconia nigra*) in a confined area. Notably, jackals retreated upon mongoose arrival, allowing them to forage freely, suggesting shared habitat use with minimal competition. This coexistence likely results from resource abundance and reduced direct competition, contrasting with Sévêque's (2020) findings that coexistence often depends on temporal separation. Jackals and mongooses displayed overlapping activity patterns rather than time-based partitioning in this case. Similar observations of jackal-mongoose coexistence without significant competition have been documented, indicating that niche differentiation may involve adaptive behaviors other than temporal separation (Osborn & Helmy, 1980; Ragni et al., 1999; Abd Rabou et al., 2021). The observed coexistence in this shared habitat highlights the ecological versatility of golden jackals, facilitating resource sharing through spatial overlap and promoting ecosystem stability. The survey further revealed spatial coexistence with other species, such as the jungle cat (*Felis chaus*), wild boar (*Sus scrofa*), and red fox (*Vulpes vulpes*) (Eid & Alayyan, 2024). Torretta et al. (2021) observed spatial partitioning between golden jackals and red foxes, which likely reduces direct encounters and competition, particularly in risky scenarios such as scavenging large prey carcasses. This spatial separation is indicative of a strategy to minimize interference competition. Historical observations have also documented golden jackals using dens previously occupied by other species, including porcupines (*Hystrix indica*) and even abandoned dens of grey wolves (*Canis lupus*) (Kebede, 2017; Mukherjee et al., 2018). Restricted border areas, particularly along the Jordan River, have facilitated golden jackal population growth by limiting human access and allowing controlled management. Designating the Jordan River as an Other Effective Conservation Measure (OECM) in collaboration with the Jordanian army could enhance Jordan’s commitment to expanding conserved area representation and support the Kunming-Montreal biodiversity targets under the Convention on Biological Diversity (CBD) by protecting diverse species within this critical habitat (Farhadinia et al., 2022).

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