Nesting ecology and territory distribution of Lappet-faced Vulture *Torgos tracheliotos* in Oman

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Summary: Lappet-faced Vulture is classified as globally Endangered, with a small resident population in the Arabian peninsula. Despite longstanding local knowledge of the species' presence in Oman, no formal surveys have been conducted. We studied the nesting distribution, ecology and breeding success of this species in Oman. Between 2021 and 2024, we documented 131 Lappet-faced Vulture nests through information received from local community members and systematic field surveys. Analysis revealed 65 nesting territories. Only 38.2% of surveyed nests were used, with a relatively low breeding success rate of 24.5%. Our findings highlight an urgent need for targeted conservation efforts to protect key vulture habitats and introduce long-term monitoring for their survival in Oman.

INTRODUCTION

Lappet-faced Vulture *Torgos tracheliotos* is classified as globally Endangered (IUCN 2025). The nominate subspecies is widely distributed across Africa, whereas *T. t. negevensis* comprises a relatively small proportion of the global population and occurs in Arabia, including Oman (Mundy *et al* 1992, Newton & Newton 1996, Botha *et al* 2017). The Arabian population is estimated at 600 pairs, although this may be an overestimate (Jennings 2010 as cited in Botha *et al* 2017).

Across their range, Lappet-faced Vultures inhabit dry savannahs, arid plains, desert habitats and open mountain slopes of varying altitude (Mundy *et al* 1992, Shimelis *et al* 2005). They typically feed on the sinews and skin of larger carcasses of both wild and domesticated animals (Mundy *et al* 1992, Shobrak 1996) and build large stick nests in trees, particularly *Vachellia* (formerly *Acacia*) species (Shimelis *et al* 2005, BirdLife International 2021). The nests are often reused, and multiple nests, old and new, may occur in a territory (Shimelis *et al* 2005). Females lay a single egg, incubated for 54–56 days (Newton & Newton 1996, Shimelis *et al* 2005, Chomba *et al* 2013). Fledging occurs at 122–136 days and birds start breeding at six years or older (Newton & Newton 1996, Shimelis *et al* 2005). On average, 0.4 fledglings per pair are produced per year (Mundy *et al* 1992, Shimelis *et al* 2005).

Lappet-faced Vulture is the largest resident bird in Oman. Their earliest local breeding record dates from 1970, through a photograph of a young vulture captured and raised in Jebel Akhdar (Gallagher 1982). A small population was suspected to reside in Oman and was confirmed in February 1982 with the sighting of a nest with an egg in Jebel Akhdar (Gallagher 1982). That nest was deserted by March, possibly due to disturbance from nearby roadworks or heavy rainstorms (Gallagher 1982).

To date, most information about Lappet-faced Vultures in Oman comes from opportunistic reports by locals who have long known of the species' breeding in the Hajar mountains. However, a lack of systematic research has left significant gaps in our understanding the species' distribution, breeding biology and threats. In 2021, a collaborative survey of breeding Lappet-faced Vultures was initiated, the first of its kind in Oman (Environment Society of Oman 2023 unpublished report). The survey aimed to better understand the status and distribution of Lappet-faced Vultures and study their nesting ecology and breeding success in the Hajar mountains. The data aimed to inform effective conservation strategies for the population in Oman.

We report on the results of surveys for Lappet-faced Vultures in the Hajar mountains of northern Oman and Dhofar between 2021 and 2024 and provide recommendations for future research and monitoring to support long-term conservation efforts.

METHODS

The study area covered approximately 35 966 km^2 in the Hajar mountains of northern Oman, and a small area (21 km^2) in Dhofar, south Oman (Figure 1a). Spatial boundaries of the survey area were delineated by generating convex hulls around nest locations using the Minimum Bounding Geometry tool in QGIS (QGIS Development Team 2025). The regions are distinguished by their rugged, rocky terrain with steep cliffs, mountain slopes and dry wadis, which can fill with seasonal rains. Vegetation is sparse, comprised of drought-resistant plants and scattered trees. Goats and sheep are herded regularly and feral donkeys are common.

Nest surveys

Lappet-faced Vulture nesting data were systematically collected between February 2021 and June 2024. Information on the species' breeding was assembled from local communities, Environment Authority rangers and our own field team. Two periods of field surveys were conducted annually, aimed to coincide with presumed egg laying (November–February) and late nesting (April–June) stages. Surveys were conducted by foot, which entailed walking 0.4 to 7.6 km after vehicular access was no longer possible. Binoculars (8x30 and 10x42) were used to search for nests and vultures. GPS coordinates, site elevation, accessibility and nest characteristics were recorded. Nests were classified as i) empty with no evidence of recent use (unused), ii) empty with evidence of recent use but no observations of adult vultures (possibly used), iii) presence of adults but no eggs or chicks (used, presumed unproductive), or iv) the presence of an egg, nestling or fledging (used, productive). Each nest was therefore assigned a value for use (used, unused, or possibly used), breeding season (November–August) and breeding stage (no nesting attempt, productive), and each territory a value for occupancy (occupied, unoccupied).

Survey effort varied across years; in 2021, territories were patrolled and all reported nests were surveyed, while from 2022 onwards, efforts prioritised used and possibly used nests only (Figure 1b).

Nesting territories

Lappet-faced Vultures are territorial when nesting (Bildstein 2022), hence multiple nests in close proximity may be part of the same nesting territory and associated pair. To identify the number of nesting territories, based on the recorded nests, we used the Viewshed tool in QGIS (Čučković 2024). The Viewshed tool uses a digital elevation model to create a viewshed for a series of points and determine if one point is visible from another within a specified range, *ie* whether individual viewsheds for each point overlap (Ross 2024). We used nests as the points and set a visible range of 5.5 km. This distance was based on the mid-point between two simultaneously used nests on flat topography (gravel plains), where a direct line of site between nests was feasible. In the viewshed tool we set 'observer' height to 10 m, to accommodate the maximum height above ground for Lappet-faced Vulture nests in Oman. For the analyses, we assumed that adjacent pairs of nesting Lappet-faced Vultures were unlikely to nest within a direct line of site of each other, *ie* that they would not have overlapping viewsheds, and we tested this by using nests that were classed as used at any point during the study. We found that for each nest used in the same breeding season, no viewsheds overlapped, so our assumption held. We then produced viewsheds for a subset of the recorded nests that had a precise GPS location, and generated an intervisibility network in QGIS that identified all nests that had a direct line of site (<5.5 km) to another nest, and to generate the mean distances between nests and territories. Where identified, this allowed us to assign nests to groups, based on their viewshed overlap, and hence identify nesting territories. We then used the mean coordinate function in QGIS to identify the location of each group of nests comprising a territory and generate a nesting territory map for Lappet-faced Vultures in the surveyed area.

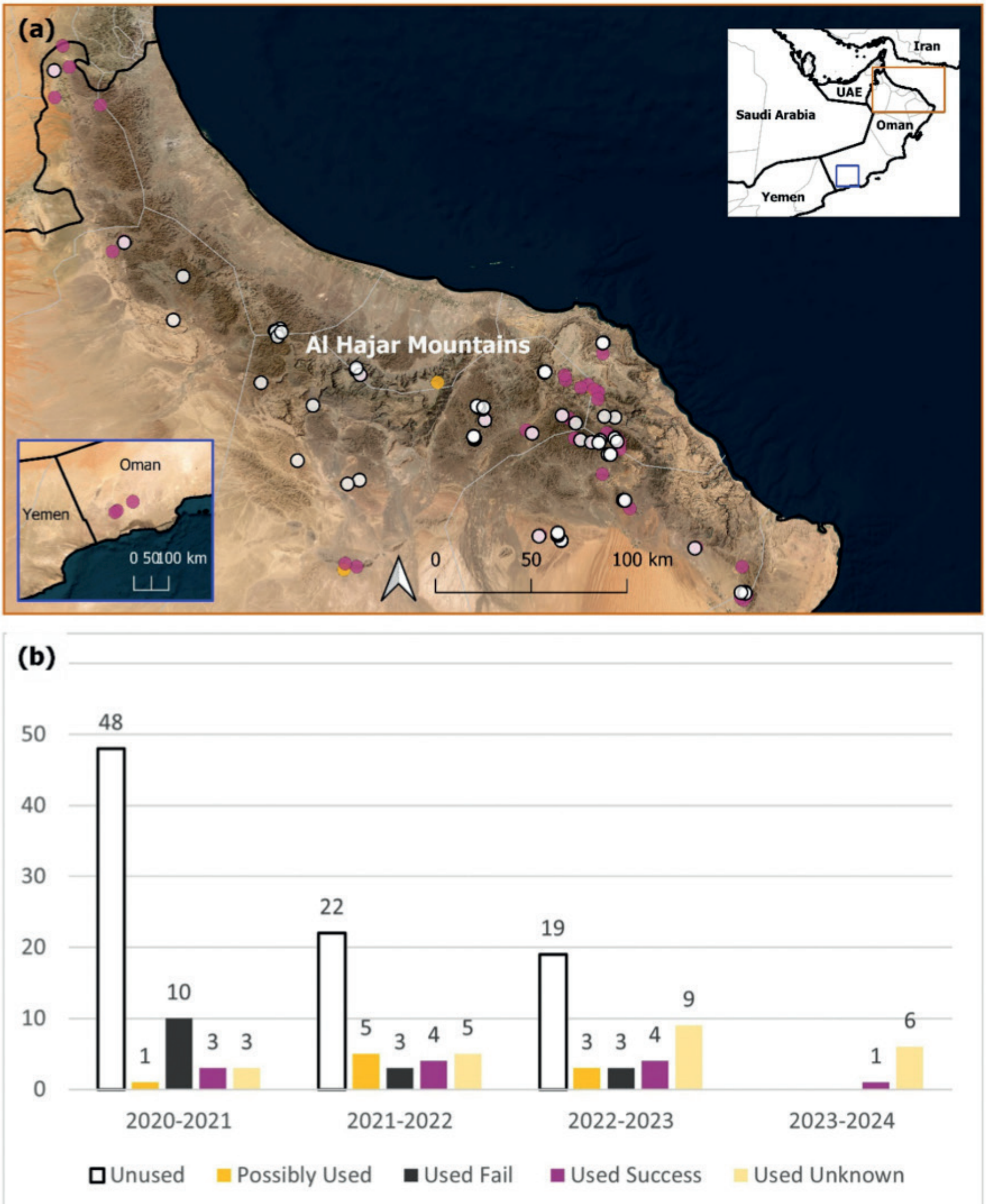

Figure 1. The study system and survey outputs for Lappet-faced Vultures in Oman. (a) Map showing the location of Oman in the Arabian peninsula (inset map, top right) and the study area in the Hajar mountains (orange box) and Dhofar mountains (blue box); pink circles indicate used nests, white circles unused nests and orange circles possibly used nests. Nests found in the Dhofar mountain range are shown in the inset map, bottom left. (b) Frequency histogram showing the number of each nest type recorded during the four breeding seasons in which surveys were conducted. For nest type descriptions and hence classifications, see text.

Breeding success

Nests were presumed successful upon the observation of a fledged chick or a chick older than 100 days. Nest failure was indicated by a broken or missing egg, or a dead or missing chick in the nest. Instances of post-fledging failure were noted. The breeding success was recorded as 'unknown' if the final status of the offspring was not determined (*eg* egg not hatched or chick less than 100 days old at the time of last visit). The combined breeding success for all nesting seasons within the study was derived from Steenhof & Newton (2007), and defined as the proportion of eggs that produce fledglings:

RESULTS

Nest surveys

In total, 131 nests were found. Survey effort varied between breeding seasons (Figure 1b). A higher proportion of unused nests was found in earlier surveys, due to a shift in survey effort from recording all encountered nests to focusing only on used nests in later seasons. Mean elevation of nest locations was 828.4 ±344 m (range: 218–1770 m); n = 99. Nests were built in large trees; the majority (68.7%) in *Vachellia tortilis* ('Samr' in Arabic) and *Maerua crassifolia* (18.3%; 'Sarh' in Arabic). Height was estimated for 74.9% of nest trees (mean = 4.3 ±1.5 m, range: 1–8 m; n = 98). The mean distance between nests was 7.5 km.

Nesting territories

107 nests were selected for viewshed analysis after the removal of data-deficient nests; 36 distinct occupied territories were identified based on used nests (Figure 2a), 31 territories contained a single nest, and five had multiple nests. On average, nesting territories were 8.9 km apart. When considering all nests, 65 nesting territories were identified (Figure 2b), 41 with a single nest and 24 with multiple nests, with an average of 8.4 km between territories.

Breeding success

Of the 131 nests observed, 50 (38.2%) were used. Eight nests (6.1%) were listed as possibly used, and 73 (55.7%) were unused. Of the 50 used nests, 46 were used only once, while four were used twice in different breeding seasons. The locations of nests in the northern Hajar mountains of Oman and Dhofar are shown in Figure 1. Fourteen nests with a single egg each were recorded; 10 failed due to breakage or disappearance, and the status of four was unknown. In total 39 chicks were recorded; 13 (33.3%) fledged, six (15.4%) died pre-fledging and the fledging success of 20 (51.3%) was unknown. Of the six chicks that died, two were of suspected predation. These numbers resulted in a breeding success of 24.5% ([13/(14+39)]*100).

DISCUSSION

Our surveys identified 131 used, possibly used and unused Lappet-faced Vulture nests. Nests were widely distributed across mountain habitats and gravel plains within the study area. Viewshed analysis of 107 nests identified a minimum of 65 nesting territories, with an average inter-territory distance of 8.4 km.

Nesting characteristics and territories

Trees are an important element of the Lappet-faced Vulture's habitat, essential for both roosting and nesting (Shimelis *et al* 2005). Observations from Oman are consistent with those from Saudi Arabia (Gallagher 1982, Newton & Newton 1996, Shobrak 2011, Hashim 2019) and Africa (Chomba *et al* 2013, Botha *et al* 2017), where nests are predominantly found in *Vachellia* and *Maerua* trees of 3.5 to 6.9 m height.

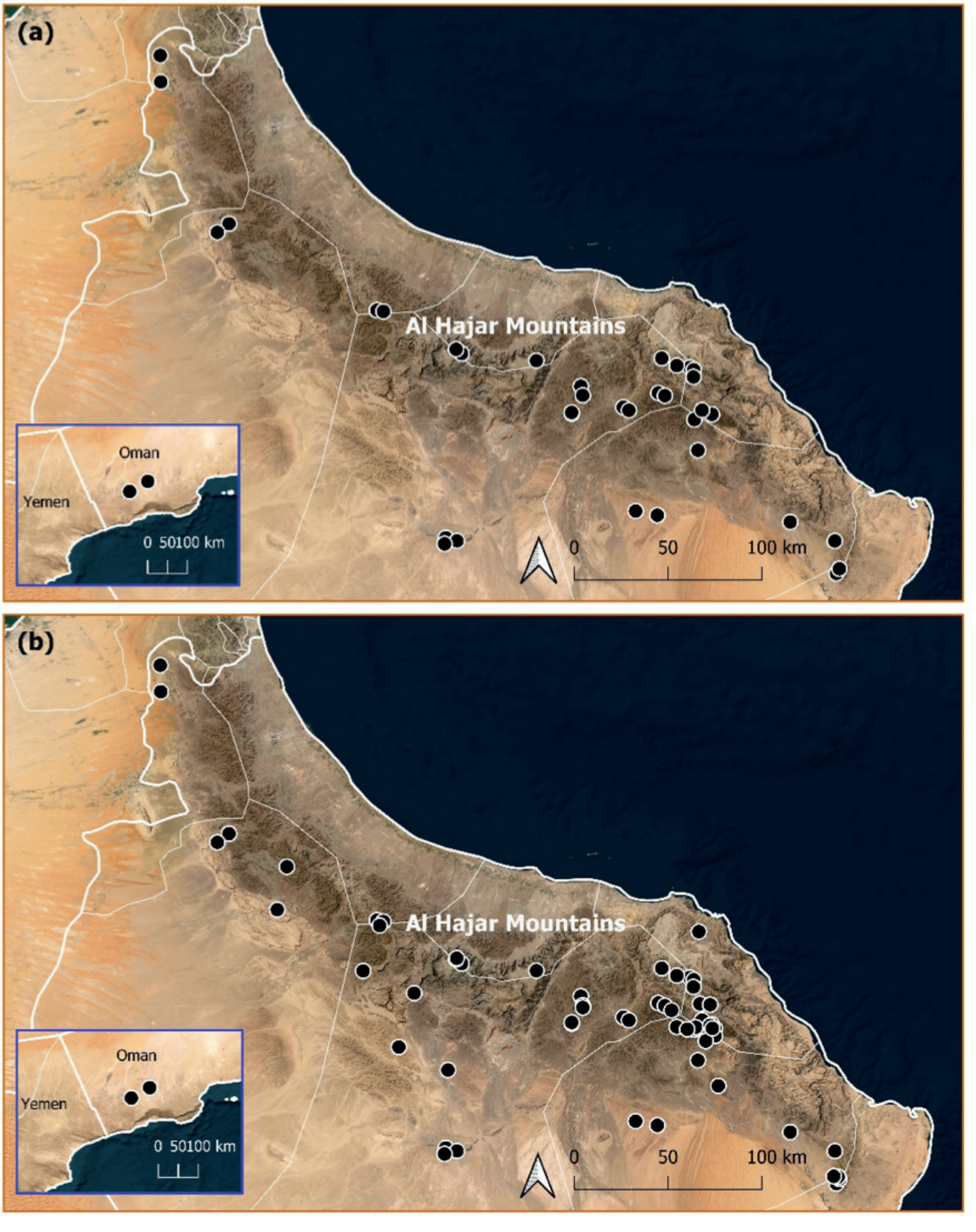

Figure 2. Distribution of identified Lappet-faced Vulture breeding territories in Oman (black circles), derived using viewshed analyses. (a) Locations of 36 territories based on used nests only, (b) Locations of 65 territories based on both used and unused nests. Nests found in the Dhofar mountain range are shown in the inset map.

In our study, four nests were used at least twice, either in consecutive years or at longer intervals of two or three years. While pairs often maintain and repair a single nest for many years, they may alternate between up to three nests (Shimelis *et al* 2005). New nests within 2 km of a previous one are likely to have been built by the same pair (Newton & Newton 1996, Shobrak 2011). Several ecological, environmental and biological factors may influence avian nest re-use patterns, including the availability of suitable nesting sites, past breeding experience, and the effort of building new nests (Tobolka *et al* 2013, Jiménez-Franco *et al* 2014, Jiménez-Franco *et al* 2018). Since nest building can be energetically and temporally costly, re-using nests may be advantageous, allowing pairs to invest in foraging and egg production instead (Jiménez-Franco *et al* 2014). As a result, nest-reuse has been associated with earlier clutch initiation in some species (Jiménez-Franco *et al* 2014). However, older nests are more likely to harbour diseases and ectoparasites, which can weaken nestlings and lead to mortality through blood loss (Wimberger 1984, Jiménez-Franco *et al* 2014). Therefore, birds might reduce parasite contact by changing nest sites (Heeb *et al* 2000).

The mean distance between all nests in Oman is 7.5 km, greater than in Tanzania (4.2 km) and Zimbabwe (3.2 km) (Shimelis *et al* 2005). In Saudi Arabia's fenced Mahazat as-Sayd reserve, nests are typically 3–6 km apart (Newton & Newton 1996, Shobrak, 2011), with a mean distance of 3.11 ±1.61 km between active nests (Shobrak 2011). An observation in Zimbabwe involving 64 nesting sites belonging to 25 pairs showed inter-nest distances of 1.2 km in one year and 2.9 km the next, indicating temporal variation in nest use (Mundy *et al* 1992). In Oman, the greater mean nest distances may reflect a more dispersed and less abundant vulture population.

Breeding success

The breeding success of 24.5% in this study appears to be considerably lower than that reported from other parts of the Arabian peninsula. In the Mahazat as-Sayd reserve, 69% of eggs laid produced fledglings (Newton & Newton 1996), and in four African national parks, breeding success rates ranged from 40% to 50% (Mundy *et al* 1992). Several ecological and anthropogenic factors may contribute to the lower breeding success reported in Oman, such as predation pressure, food availability, habitat degradation and human disturbance, although further research is needed. Survey effort must also be considered; Newton & Newton (1996) surveyed nests up to ten times throughout the breeding season, often until fledging, whereas in our study, due to resource constraints 51.3% of nests were not surveyed frequently enough to determine breeding outputs. Contrary to Newton & Newton (1996) and Shimelis *et al* (2005), most nests in our study were located outside protected areas and fenced reserves. When actively managed, these areas can offer benefits such as improved habitat quality, better food availability, and reduced disturbance (Jha *et al* 2021), which may contribute to higher breeding success.

Although our sample is possibly biased, nests failed at the egg stage at a seemingly high rate (18.9%), although we do not know the causes of these losses. Lappet-faced Vultures rarely abandon incubation unless disturbed by a persistent intruder, leaving eggs vulnerable to predation, breakage by other birds or prolonged sun exposure (Mundy *et al* 1992, Shimelis *et al* 2005). Such abandonment may be the result of adult birds needing to spend more time away from the nests foraging if food is scarce. Other causes of egg loss include structural nest collapse, theft and extreme weather (Shimelis *et al* 2005, Marcelino *et al* 2020). Also, some egg losses may be a result of infertility (Hemmings *et al* 2012).

Breeding phenology

It is believed that Lappet-faced Vultures attempt to breed annually, although factors such as outputs of previous breeding attempts, the post-fledging dependency period, food availability and climate may influence this decision (Mundy *et al* 1992, Chomba *et al* 2013). In our study, Lappet-faced Vulture eggs were observed from December to April, and chicks from January to August. These observations align with findings from Saudi Arabia (Newton & Newton 1996, Hashim 2019). We also found chicks and nest activity in October and December, suggesting later breeding by pairs, re-nesting attempts after earlier failures, or continued use of nests by fledglings during the species' 4- to 5-month post-fledging dependency period (Shobrak 1996). Lappet-faced Vulture fledglings can remain dependent on parental care for a year or more, occasionally limiting pairs to nesting only in alternate years (Chomba *et al* 2013). While beneficial for fledgling survival, extended parental care may impose reproductive costs on breeding pairs, reducing their future fecundity or survival (López-Idiáquez *et al* 2018).

Conservation implications and management requirements

Habitat loss, degradation and fragmentation limit nest site choice and foraging opportunities critical for vulture survival and reproduction, and may influence breeding success, along with nest destruction and human disturbance, to which Lappet-faced Vultures are extremely sensitive (Steyn 1982, Shimelis *et al* 2005, Botha *et al* 2017, CMS 2017). In Saudi Arabia woodcutting, overgrazing and disturbances from livestock seeking shelter have reduced suitable nesting trees for Lappet-faced Vultures (Shobrak 2011, CMS 2017). Although the impacts are unclear, some community members who contributed nest data to this study were herders tending their goats as they grazed in the mountains. In west Africa, habitat loss and degradation are suspected to have contributed to over 98% declines in large vulture populations outside protected areas, where human population growth has been rapid (CMS 2017). Urbanisation in parts of South Africa has limited natural foraging areas for vultures (CMS 2017), emphasizing the importance of preserving vulture habitats. The 2245-km^2 fenced Mahazat as-Sayd reserve in Saudi Arabia demonstrates the benefits of effective habitat protection (Shobrak 2011).

Further understanding the threats to vultures and causes of mortality across all life stages, particularly the post-fledging dependency period, is critical for effective conservation planning. Spatial analyses of nests in relation to human infrastructure and land use, such as roads, residential areas and dumpsites, could identify potential disturbance hotspots and guide management efforts. Identification of individuals is important for understanding nest-reuse and seasonal use.

Recommendations for future work

Our study faced several limitations that hindered comprehensive data collection. A key challenge was the inconsistent survey effort due to limited resources and funding, which restricted data collection opportunities for investigating offspring development and survival. Surveyed locations were occasionally based on historical records and community reports, which, while valuable, were likely not comprehensive. However, these efforts provide a foundation for further improving our understanding of the species in Oman. This is the first systematic survey of the Lappet-faced Vulture in Oman, establishing critical baseline information on the species, its status, nesting ecology and breeding success. It partially fills key knowledge gaps, challenging earlier assumptions that Saudi Arabia hosts the only viable population of Lappet-faced Vultures in the Arabian peninsula (Shobrak 1996, 2011).

Future research should prioritise systematic, spatially expanded surveys and long-term monitoring throughout the breeding season to track breeding success, offspring survival and population trends. Understanding factors influencing Lappet-faced Vulture breeding frequency in Oman remains a key knowledge gap. Although not part of the core surveys, satellite tagging, ringing and camera trapping were conducted opportunistically for additional insights. Satellite tracking data (Finch 2024, McGrady pers obs) of vultures in our study area documented the mortality of three vultures during the first five months after fledging, highlighting the need for further research into the post-fledging dependency period and the high risk of mortality during that time (Shobrak 1996, López-López *et al* 2014). Expanding ringing initiatives would improve individual identification and tracking nest reuse, aiding population estimation. Over time, satellite tracking can lead to a better understanding of the spatial-temporal patterns of juvenile dispersal and support management measures (García-Macía *et al* 2024). Future research could assess links between nest success and tree height and compare breeding success within and beyond protected areas to evaluate current management strategies. Greater community engagement and citizen science could enhance monitoring, raise awareness and foster stewardship to support long-term research and conservation. These steps will help address knowledge gaps and guide long-term conservation efforts for Lappet-faced Vultures in Oman.

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