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Breeding dynamics and threats identified at a small colony of Critically Endangered Rüppell's Vultures *Gyps rueppellii* in a Ugandan Forest Reserve

Ivan Oruka[1]*, Geoffrey M Malinga[1], Stonewall S Kato[1], Darcy Ogada[2] and Derek Pomeroy[3†]

[1] *Department of Environment, Gulu University, Gulu, Uganda*
[2] *The Peregrine Fund, Boise, Idaho, United States of America*
[3] *College of Natural Sciences, Makerere University, Kampala, Uganda*
† *Deceased*
* *Correspondence: orukaivan7@gmail.com*

The Critically Endangered Rüppell's Vulture *Gyps rueppelli* is a resident species in Uganda, with only one known breeding site in Luku Central Forest Reserve, Arua district. The natural resources in this protected forest reserve are under severe threat due to a growing refugee population. Our short-term study documented vulture population size and breeding success at a small colony inside the reserve, and we identified specific threats to vultures and the surrounding habitat. We utilised direct observation and drone photography. The number of Rüppell's Vultures ranged from 18 to 24 individuals. Of the 14 nests located on the cliff face, eight (57%) were successful. Many threats were identified including disturbance to nests from synanthropic species, hunting vultures for belief-based uses, poison use by farmers targeting pest species such as primates and crows, and habitat destruction within the forest reserve. We recommend that the National Forest Authority collaborates closely with the Uganda Wildlife Authority, NGOs and international partners such as the United Nations High Commission for Refugees to urgently engage neighbouring communities to heighten the protection of this site.

Dynamique de la reproduction et menaces identifiées dans une colonie de vautours de Rüppell *Gyps rueppellii*, espèce en danger critique d'extinction, dans une réserve forestière de l'Ouganda

Le Vautour de Rüppell *Gyps rueppelli*, espèce en danger critique d'extinction, est une espèce résidente en Ouganda, avec un seul site de reproduction connu dans le pays, dans la réserve forestière centrale de Luku, district d'Arua. Les ressources naturelles de cette réserve forestière protégée sont menacées par l'augmentation récente de la population de réfugiés. Notre étude à court terme a permis de documenter la taille de la population de vautours, le succès de reproduction dans une colonie à l'intérieur de la réserve, et d'identifier les menaces spécifiques qui pèsent sur les vautours et l'habitat environnant. Nous avons utilisé l'observation directe et la photographie par drone. Le nombre de Vautours de Rüppell a varié entre 18 et 24 individus. Sur les 14 nids situés sur la falaise, huit (57%) ont réussi. Un grand nombre de menaces ont été identifiées, notamment la perturbation des nids par des espèces synanthropiques, la chasse aux vautours pour des raisons de croyances, l'utilisation de poisons par les agriculteurs ciblant des espèces nuisibles telles que les primates et les corbeaux, et la destruction de l'habitat au sein de la réserve forestière. Nous recommandons que la National Forest Authority collabore étroitement avec l'Uganda Wildlife Authority, les ONG et les partenaires internationaux, tel que le Haut-Commissariat des Nations Unies pour les Réfugiés, afin d'engager d'urgence les communautés voisines de façon à renforcer la protection de ce site.

Keywords: breeding success, cliff-nesting raptors, drone monitoring, nest predation, vulture conservation

Introduction

Vultures are birds of prey that primarily feed in groups on carrion and carcasses of livestock or wild animals. Their highly acidic stomachs enable them to consume decaying flesh, neutralising zoonotic diseases and pathogens such as rabies, anthrax, brucellosis, plague, and botulism benefiting humans, livestock, and wildlife (Van Den Heever et al. 2021). Their necrophagy also contributes to nutrient recycling at the top of the food chain (DeVault et al. 2003).

Despite their ecological significance, vulture populations worldwide are declining due to human activities (Ogada et al. 2012b; Safford et al. 2019). In Africa, over 50% of the resident vulture species are listed by the IUCN as either Critically Endangered or Endangered. Among these is the Rüppell's Vulture *Gyps rueppelli*, which now occurs sparsely in north, west and central Africa, while its core populations occur in the savannahs and arid areas of East Africa (Wacher et al. 2013; Ogada et al. 2016; Botha et al. 2021).

Evidence from its East African stronghold indicates that Rüppell's Vulture populations have declined throughout the region. For example, Ogada et al. (2022) reported a 20% decline over the past 40 years in Kenya. In southern

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Tanzania, Bracebridge and Kendall (2019) recorded encounter rates of approximately one Rüppell's Vulture per 100 km annually between 2013 and 2019. Buechley et al. (2022a) highlighted a greater than 70% decline in detections at slaughterhouses in Addis Ababa between 2014 and 2019. Pomeroy et al. (2015) counted only 232 Rüppell's Vultures in Uganda's four major national parks between 2009 and 2013. Worryingly, this decline shows no signs of abating with experts predicting further declines (Ogada et al. 2012a, 2016; Botha et al. 2021; Thompson et al. 2021).

Population declines are variously attributed to several factors, including vultures being inadvertently killed by poisons intended for predators such as lions and hyenas due to escalating human-wildlife conflict (Ogada et al. 2016); electrocution on energy infrastructure (Buechley et al. 2022b) and persecution by humans for illegal trade, including belief-based uses, as well as trapping for human consumption (Buij et al. 2016).

In Western Uganda, the Arua district is a rapidly growing trade hub facilitating regional and international trade with South Sudan and the Democratic Republic of Congo (DRC). The region relies heavily on natural resources, with over 86% of the population depending on them for their livelihoods (Arua District Investment Profile 2017). The district also hosts a significant number of refugees mainly from conflict-affected DRC and South Sudan who contribute to the local economy. Both native and refugee populations have settled along rural infrastructure and social service centres such as schools, churches, and trading hubs, with the majority of settlements located along the road leading to the forest reserve (Arua District Investment Profile 2017).

Monitoring breeding productivity and identifying specific threats to Africa's vultures are objectives outlined in the Multi-species Action Plan to Conserve African-Eurasian Vultures (Botha et al. 2017). Research on the breeding ecology of the Rüppell's Vulture has been limited to southern Kenya (Virani et al. 2012) and Tanzania's Serengeti ecosystem (Houston 1976). This study aimed to establish baseline information on population abundance and breeding success of Rüppell's Vultures at Uganda's only known extant breeding site for this species, and to identify specific threats to this population.

Methods

Study site

Luku Central Forest Reserve (2°53′23.85″ N, 31°05′3.76″ E) is situated in Ngolonyako village, Olevu parish, Ajia subcounty, in the southern part of Arua district, West Nile region, Uganda, approximately 60 km north of Murchison Falls National Park. This protected area features rugged terrain (Figure 1) at altitudes ranging from 800 to 1 060 m, with scattered hills known as tors and inselbergs (Andama et al. 2015). The region experiences two rainy seasons, one from March to April and another from July to November (Andama et al. 2015). The wettest months, August and September, receive over 120 mm of rainfall per month, while the driest months, December to March, see temperatures as high as 30 °C. Sandy loamy ferritic soils, whose structure is highly susceptible to erosion and leaching, dominate the area (Andama et al. 2015). Savannah woodland dominates the vegetation, with key tree species including Shea Nut Butter Tree *Vitellaria paradoxa*, 'Oli' *Vachellia* spp., 'Adu / emeku' *Combretum* spp., and 'Zabibu' *Ficus* spp. Common grasses include Spear Grass *Imperata cylindrica* and Elephant Grass *Pennisetum purpureum* (Andama et al. 2015). The vulture colony is located on steep cliffs facing southeast, 400 m in length and 94 m in height. These cliffs host open ledges marked by whitewash droppings indicative of an active vulture refuge (Virani et al. 2012; Pfeiffer et al. 2017).

Population assessment

We used a longitudinal study design, allowing for repeated observations of the breeding cliff over a nine-month period from September 2023 to May 2024, which coincided with peak rainfall seasons believed to trigger breeding in Rüppell's Vultures (Virani et al. 2012; Houston 1974, 1989).

The cliff was photographed, mapped and divided into different sections following Virani et al. (2012). Absolute counts were employed to determine the population size of the Rüppell's Vultures nesting on the cliff. The cliff face is small and clearly visible, making direct regular counts of all roosting, nesting, and incubating birds very practical, resulting in accurate estimates. This was done from a selected vantage point with the aid of 8 × 42 binoculars and a 50× spotting scope, as well as the naked eye. Counting of the birds was done during two time windows as recommended by Bibby et al. (2000), and commonly used in other studies (e.g. Borello and Borello 2002; Mulu and Subramanian 2013). The first count was done between 06:30–08:30 when both the birds on open ledges and those on concealed ledges prefer to bask in the sun before taking flight. The second count was done in the evening between 16:00–18:30, when bird movement in and out of the colony is reduced, with the majority of birds already roosting at their nest sites. Within each time period, five separate counts, with each lasting no more than 5 minutes, were conducted at 10 minute intervals, as time of the day affected vulture activity and thus the number of vultures counted. We recorded the number of birds seen and their behaviour, such as perching or flying. To avoid duplication, a unidirectional movement for counting was adopted (Sehgal 2020). Following Sutherland et al. (2004), at least one other observer confirmed each count. Adults were identified from the scaled pattern on their wings and yellow or grey bills, whereas juveniles were identified by their black bill and darker reddish-brown back and wings (Lázaro and Elorriaga 2016).

Breeding success

To survey the entire cliff face in detail, we used a white Phantom 4 RTK rotary wing drone equipped with low noise propellers and an on-board high efficiency camera that relayed real time images on a portable screen (Vas et al. 2015). This was deployed three times: early November, early January, and early March, periods coinciding with peak breeding activities (Virani et al. 2012; Houston 1976). The drone was launched at a distance of 250 m from the base of the breeding cliff so as to minimise disturbance to the breeding birds (Brisson-Curadeau et al. 2024). The

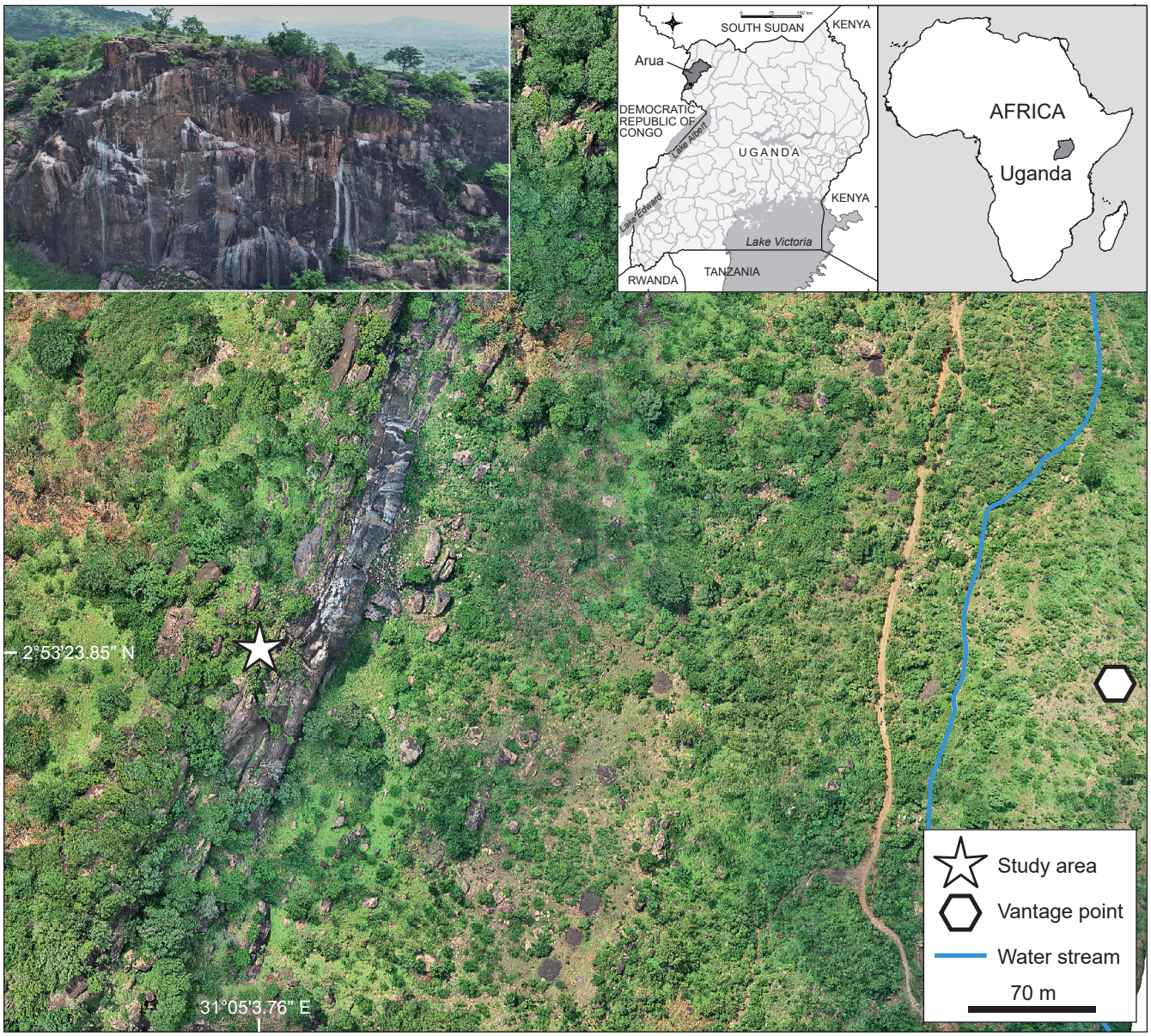


Figure 1: Location of the Rüppell's Vulture *Gyps rueppelli* study area in Uganda, and aerial and side view of the study site

drone ascended above the cliff face prior to approaching it horizontally at an average speed of 7 km hr^{-1}, and was kept stationary at a distance of 35 m from the cliff. While one operator piloted the drone, a second observer monitored the birds closely using binoculars to assess for any signs of disturbance (Vas et al. 2015; Mapes et al. 2020). Each drone flight lasted a maximum of 20 minutes during which photographs of the whole cliff face were taken. Images were arranged in a mosaic using ArcGIS 10.5 to create a single, comprehensive view of the entire cliff face. The resulting image was divided into three sections A, B, and C based on prominent landmarks and the extent of whitewash. A printed copy of this ortho-mosaicked map, showing all potential nesting ledges and nest sites, was labelled with unique alphanumeric codes for each nest site.

Field Global Navigation Satellite System (GNSS) aboard the drone system was used to obtain coordinates that were ground control points. Vulture nesting sites were identified by the presence of nesting material, the observation of a vulture incubating, or the presence of fresh nest material indicating recent use. Roost sites were not marked on the map unless there was a nest (Borello and Borello 2002). Breeding success was determined by counting nests and nest occupancy. A nest was considered active if (1) eggs have been laid or adult(s) were standing on the nest even if no egg or chick was visible; (2) adult(s) were sitting on the nest even if no egg or chick was seen, and breeding was confirmed; and (3) a chick was observed (Xirouchakis and Mylonas 2007; Virani et al. 2012). A nest where eggs had been laid was called an active nest whereas

an occupied nest was one that has building activities but no eggs laid (Wagley et al. 2020). Furthermore, a productive/successful nest is one in which the nestling has fledged and left the nest, whereas a failed nest has no fledging (Xirouchakis 2010). Particular attention was paid to sections of each colony where occupied and hidden nests had previously been marked on the reference photographs. The presence of nestlings hidden from view on deep ledges and in cracks or caves was inferred from repeated observations of adult birds entering these sites. Nest failures were categorised based on the number of days following detection of laying (Xirouchakis 2010) as follows: (1) egg stage (<60 days/ 2 months), (2) hatching stage (between 60 days and 74 days), and (3) chick-rearing stage (>10 weeks until fledging). A spotting scope was used to scan for any signs of a failed nesting attempt, such as dead chicks, or a failed egg.

Threats

Human activities such as logging, settlements, agriculture, cattle grazing, and charcoal production, both from nearby communities and external entities, are known to threaten this forest reserve. We documented threats to the vulture breeding colony and surrounding habitat during fieldwork.

Data analysis

The population size of Rüppell's Vultures was determined through repetitive direct counting at a specified time interval so as to increase the likelihood of counting all birds. Measurements are presented as mean ± standard deviation. Breeding success was calculated as the percentage ratio of productive nests to occupied nests (Wagley et al. 2020).

Results

The number of Rüppell's Vultures observed at the study site ranged from 18 to 24 individuals, with an average of 21 ± 2 individuals (Figure 2). The maximum count was 24 individuals in October 2023, while the lowest was 18 individuals in May 2024. All the birds observed had characteristic scale feathers of mature birds. There was no significant difference between the mean number of birds (21±5) counted during mornings and evenings (20±6) (t = 0.8866, df = 70, p = 0.1891).

Breeding success

A total of 14 nests (Figure 3) were identified and monitored throughout the study period. Twelve were active nests, and two were classified as occupied nests. Overall breeding success was estimated at 57% (8 out of the 14 nests successfully producing fledglings). Among the six unsuccessful nests, 50% (n = 3) failed at the egg stage, one failed during the hatchling stage, and 33% (n = 2) were occupied nests in which breeding was not initiated, suggesting nest abandonment or absconding by the adults. Nesting started in October (Figure 4) when the highest number of occupied nests were found, which later transitioned to active nests, in December. Nest failures took place from December to February.

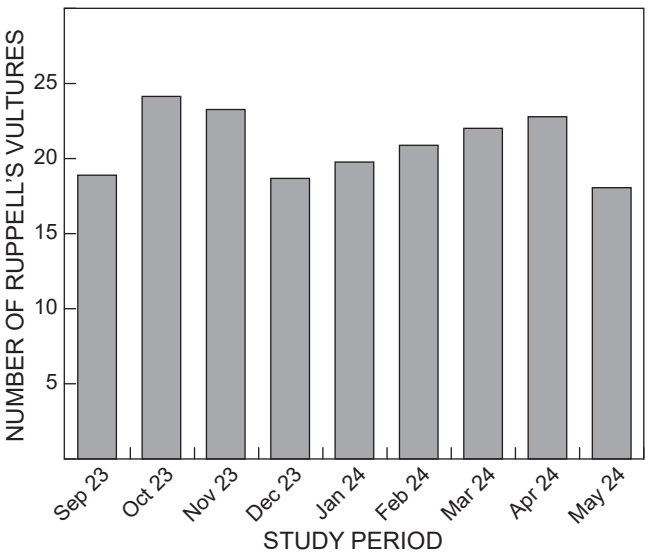


Figure 2: Number of Rüppell's Vultures *Gyps rueppelli* observed at the only known breeding site in Uganda: Luku Central Forest Reserve

Threats

Of the six unsuccessful nests, we could only determine the failure reason for one nest. We observed a group of three Pied Crows *Corvus albus* mobbing a nesting Rüppell's Vulture on two occasions, leading it to abandon the nest with the hatchling unguarded. Subsequent drone monitoring of this nest confirmed it was unsuccessful. Other non-human predators of vulture nests (eggs or chicks) present in the area included Olive Baboons *Papio anubis* and Vervet Monkeys *Chlorocebus pygerythrus* as well as reptiles, such as the Rock Monitor Lizard *Varanus albigularis* (Thompson et al. 2017; Johnson and Murn 2019, 2023).

We confirmed that the harvesting of vultures and their parts for belief-based uses is a booming and lucrative business in neighbouring Democratic Republic of Congo, which has led to an increase in vulture hunting within the study area (Afadriyawo-Forest Guard, pers. comm.). Hunting activities targeting Rock Hyrax *Procavia capensis* brought hunters to the ledges occupied by the vultures for breeding and roosting. In the process, hunters often collected vulture eggs or nestlings presumably for belief-based uses (Arumadri-community leader, pers. comm.)

During our fieldwork, we observed that human presence in the forest reserve and associated disturbance increased in December during the breeding season of Rüppell's Vultures. Trees at the breeding site were cut for timber and charcoal; although not used for nesting, trees are important as roosts and observation points for vultures.

Farming presence is increasing in the area. Besides the already ongoing farming and grazing within the forest reserve, over five livestock farms have appeared around the periphery of the nesting site since 2013. This has led to a significant increase in human-wildlife conflict that indirectly affects the Rüppell's Vulture population. Olive Baboons prey on goats and chicken, and Vervet Monkeys are pests of crops, including cassava and maize. In response, the

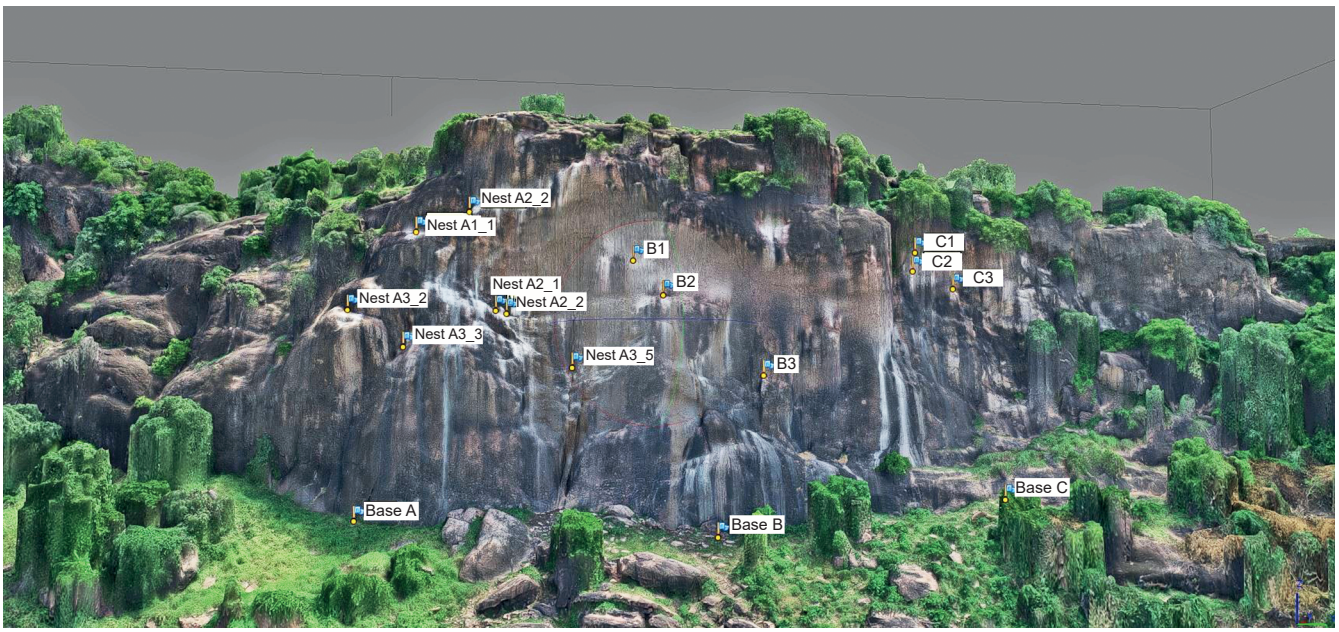


Figure 3: Location of Rüppell's Vultures *Gyps rueppelli* nest sites on the cliff face at the only known breeding site in Uganda: Luku Central Forest Reserve

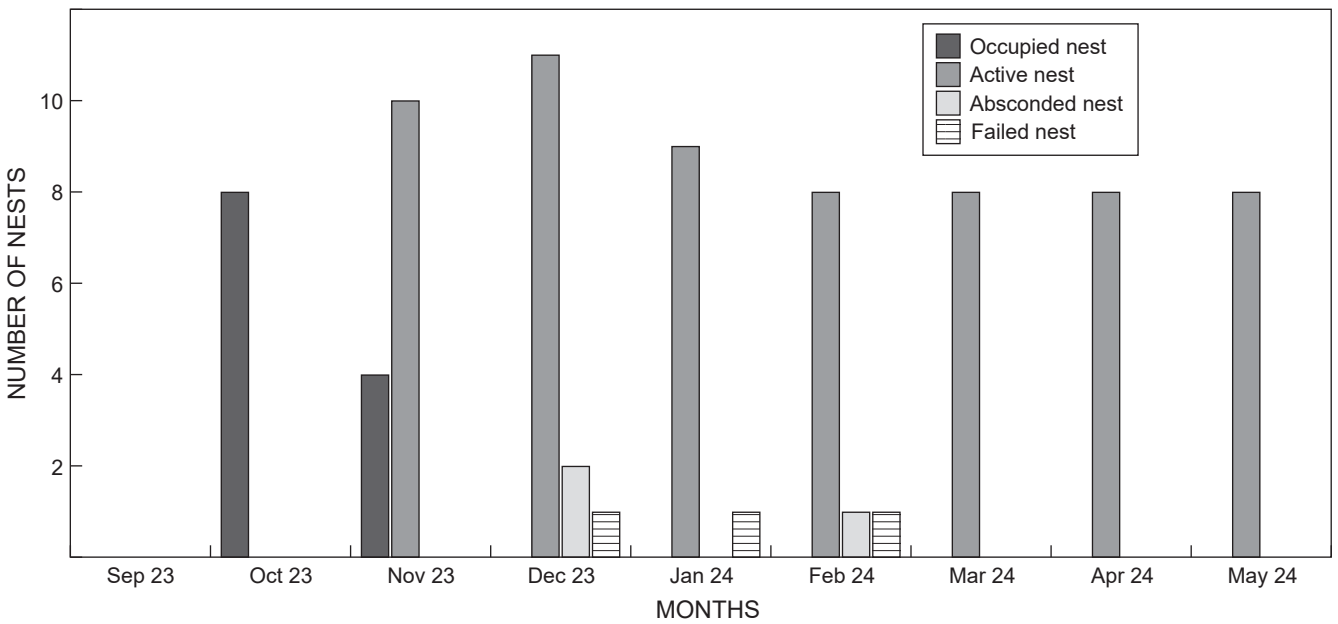


Figure 4: Breeding activity of Rüppell's Vultures *Gyps rueppelli* at the only known breeding site in Uganda: Luku Central Forest Reserve

community uses poison baits of agricultural origin to kill animals, increasing the likelihood of unintended poisoning of Rüppell's Vultures because they might consume the contaminated carcasses.

Discussion

We estimated the total population of Rüppell's Vultures at the only breeding colony in Uganda to range from 18 to 24 individuals, with only 12 breeding pairs. While our study duration was limited, our results suggest that the breeding population of vultures in this forest reserve is small. Considering the number of birds in relation to the size of the nesting site, Ngolonyako is arguably an important focal point and hotspot for breeding Ruppell's Vultures in Uganda. Our field efforts have also led to the discovery of another breeding cliff site in this region, with approximately nine breeding pairs.

The breeding success of Rüppell's Vultures was low (57%) compared to the breeding success of closely related *Gyps* vultures in Europe (74%: Xirouchakis 2010), but it was surprisingly higher than observed in other African and Asian *Gyps* species. Breeding success reported for the Cape Vulture *Gyps coprotheres* was 53% in South Africa (Wolter et al. 2022), and 24% and 44% for two colonies in Botswana (Goikantswemang 2019). In Asia, breeding success for two populations of *Gyps* vultures were reported as 41% (Wagley et al. 2020) and 23% (Baral and Gautam 2007).

Threats to this small, critically endangered population of vultures were substantial and can all be traced to human activities. Even the 'wild' nest predators, e.g., baboons, monkeys and Pied Crows are synanthropic species, which have adapted to live closely with humans and to benefit from human activities and occupation. Therefore, their impacts on this vulture colony can be tied to human presence inside the forest reserve.

Human impacts in the forest reserve are expected to increase significantly with the continued arrival of refugees from the war-plagued, neighbouring Democratic Republic of Congo and South Sudan. Refugees have settled around and within the forest reserve, posing great challenges to conservation efforts. The low agricultural productivity of the area is compounded by climate change, and the increasing refugee pressure is resulting in an unsustainable use of natural resources from the forest.

The use of drone technology during this study was uneventful and did not elicit overt signs of disturbance. The vultures generally remained on or near their nests throughout the surveys, indicating that the drone operations, conducted at a conservative distance and under close behavioural observation, were minimally intrusive.

Recommendations

Based on our findings, we recommend:

1. The National Forest Authority (NFA), the entity responsible for the management of Luku Central Forest Reserve where the colony is located, should work closely with partners such as Uganda Wildlife Authority, Nature Uganda as well as international partners such as the United Nations High Commission for Refugees to engage with the neighbouring communities to heighten the protection of this site. As the only known breeding site for the Critically Endangered Rüppell's Vulture in Uganda, it is crucial to implement regulated access to forest resources and products. Additionally, strengthening law enforcement efforts through increased deployment of rangers will help safeguard the site from encroaching threats.
2. The conservation value of Ngolonyako should be recognised by classifying it as an IBA and/or a KBA. This would raise awareness about the site both at the national and global levels.
3. As a recent signatory to the Raptors MoU under the Convention on Migratory Species (CMS), Uganda should significantly bolster conservation efforts for remaining and highly threatened populations of Rüppell's Vultures.

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Ethical considerations — Prior to the study, permission was sought from Gulu University Research Ethics Committee (GUREC-2024-807). Also, because the nesting sites of the Rüppell's Vultures are on cliffs in Luku Central Forest Reserve, permission was sought from National Forestry Authority (NFA), Uganda Wildlife Authority (UWA), as well as district and the local leadership of the study area. Furthermore, clearance was obtained from Uganda Police Force to use the binoculars and fly the drone on site. To minimise disturbance, vultures were observed from a distance of approximately 300–600 m on the opposite side of the nesting site with 8×42 binoculars. Additionally, a maximum of two observers were always present during data collection. Under no circumstances was contact or handling of birds/eggs made throughout the entire study period.

Disclosure statement — The authors declare no conflict of interest.

ORCIDs

Ivan Oruka: https://orcid.org/0009-0002-5051-2402
Geoffrey M Malinga: https://orcid.org/0000-0002-6551-2897
Stonewall S Kato: https://orcid.org/0000-0002-6073-2890

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