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Abundance, distribution, and conservation status of critically endangered vultures in N'Djamena and environs, Chad, Central Africa

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Vultures provide essential environmental services by eliminating animal carcass remains and preventing the spread of diseases, but unfortunately, many African vulture species have exhibited significant population declines and are now in imminent danger of global extinction. In West Africa, anthropogenic drivers of these declines include poisoning and persecution for a lucrative, burgeoning wildlife trade for belief-based use, in which vultures command some of the highest prices. To date, however, little information has been available to inform vulture conservation in Chad, Central Africa. We assessed the abundance, distribution, and conservation status of critically endangered hooded vultures (*Necrosyrtes monachus*) at 11 slaughterhouses and waste sites in and around N'Djamena, Chad's capital and largest city, and conducted 93 interviews with local residents to evaluate anthropogenic threats, attitudes, and awareness about vultures. Vultures appeared to be absent at more than half (55%) of sites surveyed, and we estimated a total population of ~113 hooded vultures at all remaining sites. Vulture abundance was higher at sites with more vegetation, and lower at sites with higher human population densities. Interview participants reported familiarity with five endangered and critically endangered vulture species, and the majority (89%) recognized that vultures and other birds are protected by law in Chad. However, nearly half (47%) of respondents reported knowledge of recent vulture poisoning incidents, and over a third (37%) indicated that foreign poachers, reportedly from countries including Nigeria, Niger, Benin, and Cameroon, use poison to trap and/or kill vultures in Chad for use in international trade. Illegal wildlife trade in West Africa thus appears to negatively affect vulture populations and environmental health in Central Africa, where international collaboration is urgently needed to protect remaining vulture populations.

KEYWORDS
belief-based use, conservation, critically endangered species, hooded vulture, illegal wildlife trade, *Necrosyrtes monachus*, poaching, slaughterhouses

1 Introduction

As obligate scavengers, vultures provide critical ecosystem services through the rapid removal of animal carcasses, and may thus limit populations of secondary scavengers, such as feral dogs and rats, and in turn reduce the risk of zoonotic disease transmission (Ogada et al., 2011, Ogada et al., 2012; Buechley and Şekercioğlu, 2016). Such ecological services are particularly crucial in regions with limited waste management infrastructure, such as sub-Saharan Africa (Van Den Heever et al., 2021). Without vultures, rotting carcasses and other waste remain in the environment longer, increasing the risk of disease outbreaks and posing particular challenges in communities already facing strained sanitation systems (UNEP-WCMC, 2021).

In recent decades, a range of human activities has resulted in significant global declines of vulture populations (Thiollay, 2007; Ogada et al., 2011, Ogada et al., 2016; Ogada and Buij, 2011; Buechley and Şekercioğlu, 2016; Safford et al., 2019). Drivers of vulture declines include human-driven habitat loss, food shortages associated with wildlife declines, energy infrastructure such as power lines and wind turbines that result in bird electrocutions and collisions, accidental poisoning, and intentional persecution including poisoning, trapping, and shooting (Rondeau and Thiollay, 2004; Thiollay, 2006a, Thiollay, 2006b; Ogada et al., 2011, Ogada et al., 2016; Ogada and Buij, 2011; Gbogbo et al., 2016; Mullié et al., 2017; Deikumah, 2019). Particularly in East and South Africa, vultures may become victims of poisoned carcasses left by herders for large carnivores in retaliation for predation of their livestock, and in other cases, are the victims of deliberate poisoning of carcasses intended to kill them to conceal poaching activities targeting ivory and other illegal wildlife products (Ogada et al., 2015, Ogada et al., 2016; UNEP-WCMC, 2021). In West and Central Africa, by contrast, a major and ongoing driver of vulture population declines is the direct persecution of vultures for illegal wildlife trade for belief-based use, which may be locally known as voodoo, black magic, or "fetish" practices (Cocker, 2000; Nikolaus, 2001; Ogada and Buij, 2011; Saidu and Buij, 2013; Gbogbo et al., 2016; Botha et al., 2017; Deikumah, 2019; Mateo-Tomás and López-Bao, 2020; Chaffra et al., 2025).

A diverse set of acute and interacting threats has driven some vulture species to regional collapse in West Africa (Ogada et al., 2016). At the same time that natural habitat and wildlife populations have sharply declined in West Africa with exponentially rising human populations, vultures are increasingly sought after for ritual use in West African vodun or voodoo and related practices that include animal sacrifice, and promise consumers a wide range of benefits such as protection from evil, business or political success, healing from epilepsy and other ailments, among others (Buij et al., 2016; Ogada et al., 2016; Goded et al., 2023; Chaffra et al., 2025). This demand has fostered a thriving black market where vulture parts are sold for use in charms, fetishes, or ritual treatments, particularly in countries such as Nigeria, Niger, Benin, and Cameroon (Saidu and Buij, 2013; Buij et al., 2016; Gbogbo et al., 2016; Williams et al., 2021; Awoyemi et al., 2023; Agunbiade et al., 2024; Daboné et al., 2024). The trade is not limited to local use, as international networks have linked markets and poachers across borders, with vultures and other wildlife species trafficked for belief-based markets between neighboring countries (Saidu and Buij, 2013; Gbogbo et al., 2016; Daboné et al., 2022; Chaffra et al., 2025; Dognimon et al., 2025). Taken together, these practices represent one of the most pervasive and unsustainable threats to vultures in West and Central Africa that are contending with sharply declining food resources and habitat, accelerating already steep population declines and undermining conservation efforts across the region.

Multiple vulture species in West and Central Africa are classified on the IUCN Red List as critically endangered due to rapid population declines, including the hooded vulture (*Necrosyrtes monachus*), white-backed vulture (*Gyps africanus*), white-headed vulture (*Trigonoceps occipitalis*) and Rüppell's vulture (*Gyps rueppelli*), and the lappet-faced vulture (*Torgos tracheliotos*) is classified as endangered (Thiollay, 2007; Ogada et al., 2016; BirdLife International, 2021a, BirdLife International, 2021b, BirdLife International, 2022, BirdLife International, 2021c, BirdLife International, 2021d). Hooded vultures in particular are heavily persecuted for illegal trade for belief-based use (Nikolaus, 2011; Buij et al., 2016; Gbogbo et al., 2016; Daboné et al., 2023; Goded et al., 2023; Chaffra et al., 2025), likely because they are the most accessible vulture species to people due to their history of presence in human-dominated areas. As a human commensal species (Fawthrop et al., 2025), the hooded vulture is often associated with urban areas around slaughterhouses, markets, and waste sites where it feeds on human-produced refuse (Mundy et al., 1992; Thiollay, 2006a; Henriques et al., 2018), although it also occurs in natural environments, such as national parks (Thiollay, 2006b; Dowsett-Lemaire and Dowsett, 2019).

As natural areas in West and Central Africa are increasingly degraded or converted for human use, urban environments may continue to provide food for vultures (Van Den Heever et al., 2021; Copsey, 2022). Urban centers offer concentrated and predictable food sources, and recent research confirms that vulture populations may thrive in landscapes characterized by high human densities due to consistently available resources such as livestock carcasses and waste disposal sites (Henriques et al., 2018; Van Den Heever et al., 2021; Copsey, 2022; Asso et al., 2024). Despite these benefits, urban areas may expose vultures to threats such as poisoning, habitat disturbance, and collisions with power infrastructure (Ogada et al., 2016; Henriques et al., 2018; Copsey, 2022). In this context, understanding local knowledge and perceptions can provide crucial information for effective conservation, especially in regions where traditional beliefs and direct interactions with wildlife influence human attitudes (Daboné et al., 2022; Manqele et al., 2023; Asso et al., 2024; Hounnouvi et al., 2025).

Chad, Central Africa, is considered a potential stronghold for critically endangered and endangered vultures, including the hooded vulture, white-backed vulture, white-headed vulture, Rüppell's vulture and lappet-faced vulture (Chandra, 2024), but the conservation status of these species in the country remains poorly documented. A study conducted around Chad's Manda National Park revealed that many local residents were familiar with vulture species, including the hooded vulture, white-backed vulture, and Rüppell's vulture (Piebeng et al., 2023). However,

though respondents identified major threats such as habitat loss, food scarcity, and poaching for belief-based use as key contributors to vulture declines, the study revealed a lack of understanding of the ecological importance or conservation status of the affected vultures (Piebeng et al., 2023). Given that many African vultures are approaching global extinction, this situation highlights the importance both of understanding local knowledge and attitudes and of raising environmental awareness as part of vulture conservation efforts.

To date, however, basic information on vulture abundance and distribution in Chad has remained scarce, leaving critical gaps in our understanding of the status of these species in this part of their range. In this study, we assessed vulture abundance and distribution in N'Djamena, Chad's capital, and four surrounding towns, using direct counts at 10 slaughterhouses and one landfill site that took place between August 2024 and January 2025. In addition, we interviewed local residents, slaughterhouse staff, and other people in the vicinity of survey sites using a questionnaire to evaluate respondents' perceptions and understanding of vultures' conservation status and the threats they face. Finally, we analyzed both vulture survey and local interview data to contribute to understanding vulture conservation status in the study area, and to make recommendations for improving vulture conservation and future research directions.

2 Materials and methods

2.1 Study sites

The study was carried out in N'Djamena, the administrative capital of the Republic of Chad, and four surrounding towns. N'Djamena is located in the central-western part of the country, at the confluence of the Chari and Logone Rivers, on the right bank of the Chari (12.11023°N, 15.04997°E). All slaughterhouses located in N'Djamena were included in the study, along with four additional slaughterhouses from nearby towns (Table 1, Figure 1).

TABLE 1 Study site details.

Name, city	Description	Number of employees	Number of slaughtered animals per day	Number of visits
Farcha refrigerated slaughterhouse, N'Djamena	Located on the banks of the Chari River, the largest and first state-run slaughterhouse in N'Djamena; managed by a private company, Laham Tchad SAS, in a partnership between the Chadian state and the Arise Group.	105	100–250 cattle, and 50–150 goats and sheep	2
Gassi slaughterhouse, N'Djamena	Located between the small Gassi market and the Chari River, created in 2015 by a group of young butchers called the Azarack Group from the Walia slaughterhouse; now partly state-run, partly private.	122	10–35 cattle, and 20–50 goats and sheep	2
Walia slaughterhouse, N'Djamena	Located on the banks of the Chari River; a partnership between the Chadian state and an association of young butchers.	134	15–40 cattle and camels, and 30–65 goats and sheep	2
Dinguesso slaughterhouse, N'Djamena	Located to the northeast of the city of N'Djamena; managed by a private company in cooperation with the state; the second largest slaughterhouse in N'Djamena.	220	up to 110 cattle, camels and dromedaries, and 150 goats and sheep	5
Lamadji slaughterhouse, N'Djamena	Located to the east, in a remote area of N'Djamena; a private enterprise in collaboration with the state.	156	20–50 cattle, and 50–100 goats and sheep	5
Gueli slaughterhouse, N'Djamena	Located between the border of Chad and Cameroon, on the banks of the Chari River.	70	7–25 cattle, and 15–35 goats and sheep	2
Mandelia slaughterhouse, Mandelia	Located in a remote area of Mandalia; managed in collaboration with the state.	97	20–35 cattle, and 35–60 goats and sheep	3
Dourbali slaughterhouse, Dourbali	Located at the entrance of the city of Dourbali; managed in cooperation with the state.	132	>100 cattle, horses, camels and dromedaries, and >70 goats and sheep	2
Kournari slaughterhouse, Kournari	Located in a remote area from the city center; a small slaughterhouse initiated by locals in agreement with the government.	33	5–10 cattle, and up to 20–35 goats and sheep	2
Koundoul slaughterhouse, Koundoul	Located in the middle of the city; a small private slaughterhouse that partially supplies the city of Koundoul.	17	15–30 goats and sheep and 10 oxen	2
Guinabord dumpsite, N'Djamena	Rather than a slaughterhouse, a chicken carcass dumpsite crossed by a vast valley depression located next to the Farcha district of N'Djamena, with significant vegetation.			1

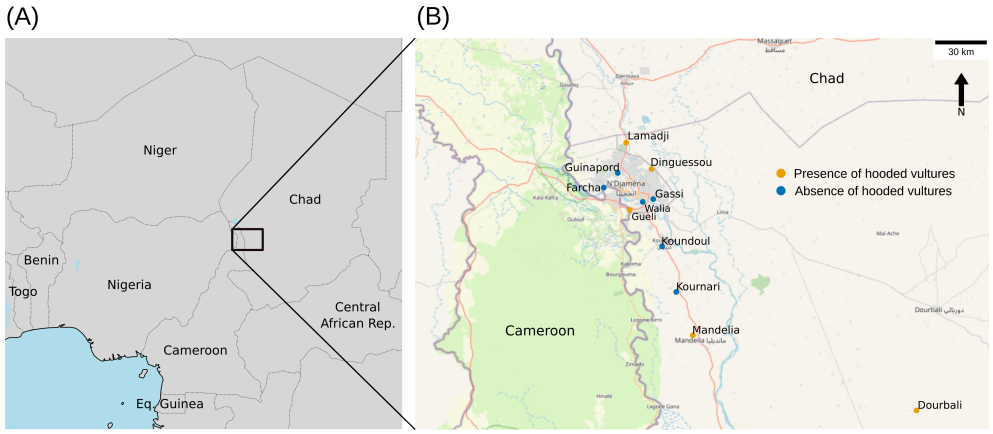

FIGURE 1
Geographic and administrative location of the surveyed sites. **(A)** shows West and Central Africa with a box over the study area in southwestern Chad near Cameroon and **(B)** zooms into this area, mapping presence (orange) and absence (blue) of hooded vultures in the surveyed sites in and outside N'Djamena.

2.2 Vulture survey

We carried out vulture counts from August 2024 to January 2025, during the dry season, which corresponds to the breeding season for vultures. A total of 11 sites were visited: eight were visited earlier in the season in August and September 2024, while three later in the season, between October 2024 and January 2025, for logistic reasons. Our objective was to identify as many sites used by vultures as possible, to inform future monitoring. As such, sites were visited first to assess the presence or absence of vultures, and sites where vulture presence was confirmed received follow up visits for initial monitoring. At a given site, a fixed-point count was used to quantify the vulture number and carried out during the daytime, typically between 10:00 am and 12:00 pm. Vultures feeding on the ground, perched on trees and flying over the slaughterhouse were counted. The maximum number of vultures was recorded at any given time.

2.3 Questionnaire

During visits to the sites, interviews were opportunistically conducted with local staff and residents, including butchers, slaughterhouse managers and workers, herders, farmers, traditional healers, and others, using a semi-structured anonymous questionnaire (Table 2; Supplementary Material). Five officials from the Ministry of Livestock and two from the Ministry of Environment, Fisheries, and Sustainable Development, N'Djamena, also granted us interviews at their offices (Table 2). The purpose of the questionnaire was to collect (1) information about the vulture species most likely to be encountered at the site by showing respondents illustrations of these species presented in the French version of *Birds of Western Africa* (Borrow and Demey, 2021); (2) information about the level of local knowledge about vultures; (3) respondents' perceptions about the main threats faced by vultures; and (4) respondents' perceptions about existing protection measures for vultures. We recorded age, gender, and occupation of respondents.

2.4 Statistical analyses

We estimated site-level abundance using a single-season N-mixture model, with Poisson mixture, using the "pcount" function implemented in the "unmarked" R package (Fiske and Chandler, 2011). We included the following site covariates to explain variation in the estimated abundance: 1) topographic roughness and flow direction, both derived from a digital elevation data model (retrieved from https://www.worldclim.org/); 2) Normalized Difference Vegetation Index (NDVI) calculated from Moderate Resolution Imaging Spectroradiometer (MODIS) data using the google earth engine; and 3) human population density, calculated from GPWv4 using the google earth engine (Center For International Earth Science Information Network-CIESIN-Columbia University, 2016). Topographic roughness is characterized by the unevenness of surface elevation values. Flow direction is defined as the direction water would flow across a surface, based on elevation data. Topographic roughness and flow direction both characterize terrain structure and drainage orientation, which we expected *a priori* to influence space use and carrion discovery by large soaring scavengers.

NDVI (hereafter, "vegetation greenness") is a quantitative assessment of the health and density of vegetation, with higher values indicating denser vegetation and lower values indicating bare land or water. NDVI was used as a proxy for landscape productivity (Pettorelli et al., 2011), and human population density as a proxy for anthropogenic pressure and carcass management practices. All continuous covariates were z-standardized (mean = 0, SD = 1) prior to analysis to improve numerical stability. Detection was modeled as constant across visits because replication was limited and visit-level covariates were sparse/irregular; missing visits were coded as "NA" and contributed no likelihood. Given the small sample size and uneven replication, an N-mixture framework (that separates detection from abundance) was chosen with a heuristic goal, i.e. to identify the most plausibly variables related to vulture abundance and to inform conservation management, rather than to deliver precise population estimates.

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TABLE 2 Dates, location and numbers of interviewed people. interviewees were butchers, local residents, slaughterhouse customers, slaughterhouse managers, herders, farmers, traditional healers and officials from the Ministry of Livestock and Animal Production and the Ministry of Environment, Fisheries, and Sustainable Development.

Site	Date	Number of interviewees	Occupation
Lamadji slaughterhouse, N'Djamena	28/08/2024	2	Butchers, local residents, slaughterhouse customers, slaughterhouse managers, herders, farmers
	24/10/2024	5	
Farcha refrigerated slaughterhouse, N'Djamena	21/08/2024	5	
Gueli slaughterhouse, N'Djamena	09/08/2024	3	
Dinguesso slaughterhouse, N'Djamena	06/09/2024	5	
	08/11/2024	9	
	05/12/2024	13	
Walia slaughterhouse, N'Djamena	14/08/2024	3	
Dourbali slaughterhouse, Dourbali	06/01/2025	4	
	19/01/2025	9	
Mandelia slaughterhouse, Mandelia	15/11/2024	6	
	05/01/2025	9	
Koundoul slaughterhouse, Koundoul	09/09/2024	4	
Kournari slaughterhouse, Kournari	18/10/2024	3	
Livestock Management Department, Ministry of Livestock and Animal Production, N'Djamena	03/08/2024	2	Officials
Livestock Inspection Department, Ministry of Livestock and Animal Production, N'Djamena	14/08/2024	3	
Wildlife and Protected Areas Department, Ministry of Environment, Fisheries, and Sustainable Development, N'Djamena	05/09/2024	2	
Atrone and Ngonne-mba neighborhoods, N'Djamena	25/09/2024	2	Traditional healers
Ngazal neighborhood, Kournari	25/09/2024	1	
Djoumanga neighborhood, Mandelia	25/09/2024	1	
Bakara neighborhood, N'Djamena	29/12/2024	1	
Bornos neighborhood, Dourbali	29/12/2024	1	

3 Results

3.1 Vulture occurrence and abundance

The hooded vulture was the only critically endangered vulture species we observed at sites visited in N'Djamena and its environs; no evidence of other critically endangered or endangered vultures, including the white-backed vulture, white-headed vulture, Rüppell's vulture and lappet-faced vulture, was found in the study area. Of the 11 sites visited, six (55%) did not appear to host any vultures at the time of our visits; the remaining five sites varied in the number of individuals they host from two to 33 individuals. We estimated a total vulture population in the study area of ~113 individual birds, with estimated abundance at individual sites where vultures were detected ranging from 1 to 49 birds (Figure 2). We modeled vulture counts at the 11 sites using a Poisson-mixture N-mixture model. Baseline expected abundance (λ) at mean covariate values was 2.8 birds per site (SE on log scale = 0.397); Figure 2. Our model showed a strong positive association between hooded vulture abundance and both NDVI (β=0.421 ± 0.156, p=0.007) and flow direction (β=0.574 ± 0.171, p<0.001). In contrast, human population density showed a negative association (β=−1.387 ± 0.441, p=0.0016). Roughness had a negative but non-significant effect (β=−0.426 ± 0.324, p=0.189). Detection probability per visit was $e^{0.452}$≈0.39, reflecting moderate detectability.

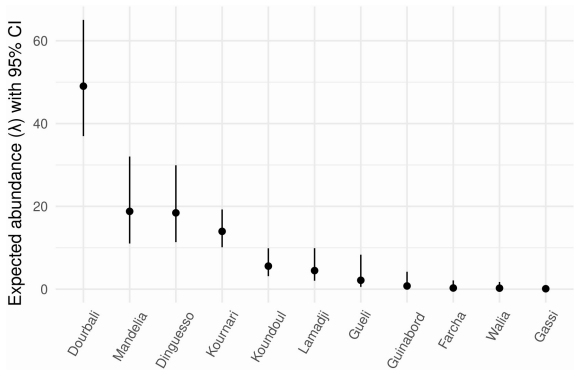

FIGURE 2
Estimated abundance of hooded vultures by site using an N-mixture model.

FIGURE 3
Hooded vultures observed **(A, B)** and Djekillamber Djekadjim collecting data **(C, D)** at slaughterhouses in Chad; photos by Abiola Sylvestre Chaffra.

3.2 Questionnaire

We interviewed 93 people in the study area about their knowledge, attitudes, and beliefs about vultures (Figure 3). The majority of respondents were males (86%) between 20 and 45 years old (88%). Of these, 44% were butchers, 17% farmers, 8% livestock breeders, 6% traditional healers, 3% wood harvesters, and 22% other professions. Respondents reported familiarity with species including hooded vultures (55%) and four additional species: the white-headed vulture (25%), lappet-faced vulture (15%), Rüppell's vulture (4%), and white-backed vulture (1%). Most respondents (89%) were aware that vultures are protected by law, and the vast majority (97%) expressed a belief in the importance of protecting vultures. Most (70%) also affirmed the usefulness of vultures, agreeing that vultures are beneficial to people.

Almost half (48%) of the respondents considered food scarcity as the key threat to vulture population, and almost half (44%) also considered habitat loss from deforestation and urban expansion to be the major cause of vulture population declines. Additionally, nearly half (47%) of respondents were aware of poisoning incidents in their vicinity, and 15% were aware of poisoning events occurring at their respective slaughterhouse. Strikingly, however, fewer than 1% of respondents considered poisoning among the key threats to vultures, and only 5% of respondents perceived that vulture populations have decreased in recent years. Few respondents considered either poaching for belief-based use (2%) or improved slaughterhouse sanitation (4%) as key threats to vultures. Most (96%) respondents were unaware of any specific group of people involved in the hunting, consumption, belief-based use, or commercialization of vultures in the area. However, over a third (37%) of interview respondents stated that foreigners from countries including Nigeria, Niger, Benin, and Cameroon trap and kill vultures, including at slaughterhouses in Farcha, Dourbali, Gueli, and Mandalia, reportedly with the complicity of certain butchers. This information was confirmed by five officials from the Ministry of Livestock and two from the Department of Wildlife and Protected Areas, Ministry of Environment, Fisheries, and Sustainable Development, who granted us interviews in their respective offices on 3 separate occasions during the study period (Table 2).

4 Discussion

This is the first study to assess the presence and estimate hooded vulture abundance at urban slaughterhouses in Chad and the second to collect information on local people's attitudes and perceptions towards vultures in the country. We estimated a total vulture population of ~113 during the study period in N'Djamena and the four surrounding towns in the study area. Surprisingly, as hooded vultures have a long history as human commensal species in this region of Africa, hooded vultures appeared to be absent at most slaughterhouses and the waste site surveyed, despite an abundance of food. Vulture presence was confirmed in fewer than half (45%; 5 out of 11) of surveyed sites in N'Djamena and its environs. Few data are currently available to explain the absence of vultures from over half (55%) of the surveyed sites, but we can hypothesize that at least

in some cases, this might be a result of persecution for illegal wildlife trade, a phenomenon reported by over a third (37%) of interview respondents that has been known to drive the disappearances of hooded vultures in West Africa (Gbogbo et al., 2016; Williams et al., 2021).

Vulture abundance in N'Djamena and its environs increased in greener sites along the flow direction gradient. Higher vulture abundance at greener sites might indicate the presence of large trees close to the slaughterhouses, which provide roosting and nesting sites (Daboné et al., 2019). Given that habitat loss is one of the major causes of species extinction (White et al., 1997), the presence of suitable vegetation is fundamental to support vulture populations. For example, in Senegal, seven species of vultures have been identified in the vicinity of the Great Green Wall project, where reforestation has been underway to restore ecosystems degraded by anthropogenic activities and climate change in the Sahel, and which appears to be the only area in the country where more than two vulture species may be observed (Diop et al., 2024). By contrast, raptor surveys in Burkina Faso, Mali and Niger revealed 98% declines of large vultures outside protected areas, as well as population collapses of hooded vultures in human-dominated environments, while hooded vulture populations remained stable in national parks (Thiollay, 2006b).

Vulture abundance declined in more densely human-populated sites in N'Djamena and its environs. We expected human population density to be correlated with a higher availability of carcasses at slaughterhouses, where higher levels of waste typically attract higher numbers of hooded vultures (Agunbiade et al., 2025). Surprisingly, however, vulture abundance did not appear to be directly correlated with food availability, as sites where we did not detect vultures included the slaughterhouse ranked first for number of slaughtered animals per day (Farcha refrigerated slaughterhouse). On the other hand, the highest number of vultures was recorded at a slaughterhouse that was ranked second in terms of the number of slaughtered animals per day (Dourbali slaughterhouse). Lower abundance of hooded vultures at more densely human-populated sites in and around N'Djamena may thus reflect levels of disturbance and/or persecution affecting vultures (Saidu and Buij, 2013; Buij et al., 2016; Daboné et al., 2019).

Many recent hooded vultures declines and disappearances in many regions of West Africa appear to be largely driven by their direct persecution for use in wildlife trade (Gbogbo et al., 2016; Dowsett-Lemaire and Dowsett, 2019; Goded et al., 2023). For example, a study in Nigeria reported that slaughterhouse workers had witnessed large numbers of hooded vultures—once frequent visitors to their facilities—being killed or injured for use in traditional medicine, ultimately leading to the birds' complete disappearance (Williams et al., 2021). Similarly, a study in Ghana demonstrated precipitous declines and disappearances of hooded vultures from areas of the capital city, Accra, as a direct consequence of persecution for illegal trade (Gbogbo et al., 2016), reportedly for export to Nigeria. Hooded vultures have also been extirpated at multiple sites in Togo, such as at the slaughterhouse in Badou, where they were previously reported in numbers of 60 or more (Cheke and Walsh, 1996), reportedly because poachers used fishhooks embedded in bait meat to trap and remove them all for illegal trade. Traders selling vultures for belief-based use at voodoo markets in Benin (Chaffra et al., 2025) reported sourcing vultures from at least 10 foreign countries, including Chad.

Our questionnaire revealed that respondents were familiar with multiple vulture species: hooded vulture, white-headed vulture, lappet-faced vulture, Rüppell's vulture and white-backed vulture, in common with a previous study carried out with residents around Chad's Manda National Park (Piebeng et al., 2023). Most respondents of the present study were aware of the legal protections for vultures and the need to safeguard these species due to their ecological importance, recognizing their usefulness to humans. They also identified major threats such as food scarcity and habitat loss as key contributors to vulture decline, consistent with previous studies (Daboné et al., 2022, Daboné et al., 2024). Improved sanitation linked to the construction or renovation of large, modern and closed slaughterhouses may lead to lower food availability for vultures and therefore displacement and decline of urban vulture populations. For instance, in Accra, Ghana, improved waste management practices, the renovation of slaughterhouses and the closure of landfill sites have reduced available feeding sites for vultures (Gbogbo et al., 2016). Unfortunately, we have no information at present on any changes in the waste management practices in Chad at the surveyed slaughterhouses.

Although nearly half (47%) of residents were aware of recent vulture poisoning incidents in their vicinity, only 3% of respondents identified illegal poaching and poisoning for belief-based use as a key threat to vultures. The culture of using wildlife in ritual animal sacrifice that is prevalent in voodoo and other animist practices in West Africa appears to be largely absent in Chad, a distinction that might contribute to the apparent discrepancy between local knowledge of vulture poisoning events and perception of persecution for belief-based use as a major threat to vultures. Unlike West African countries such as Nigeria and Benin, where there is high demand for vultures in trade for belief-based use (Atuo et al., 2015; Dowsett-Lemaire and Dowsett, 2019; Williams et al., 2021; Chaffra et al., 2025), there do not appear to be any published data on belief-based uses of birds in Chad (Williams et al., 2014). However, 34 interview respondents reported that foreigners from neighboring countries such as Nigeria, Niger, Benin, and Cameroon visit Chad to use poisoned bait for capturing vultures in N'Djamena and its environs.

Reports of cross-border trafficking activity in N'Djamena underscores the transnational nature of the illegal vulture trade and highlights how Chad's vulture populations may be threatened by demand from regional black markets in addition to local pressures. The fact that foreign poachers specifically target slaughterhouses in Chad, as reported by 34 people interviewed in this study, suggests that sites in N'Djamena are recognized as reliable sources of vultures, making them critical nodes in international wildlife trafficking networks. This external pressure compounds any local threats and demonstrates the urgent need for coordinated regional enforcement efforts to disrupt international wildlife crime. These findings underscore the urgent need for further research into these activities, as well as to conduct campaigns to raise awareness about the need to protect vultures from persecution for wildlife trade.

Though all respondents were able to identify at least one vulture species and acknowledged the need for their legal protection, half of the respondents did not answer the question on the usefulness of vultures, suggesting a disconnection between recognizing vulture species and understanding their ecological importance. This gap highlights the need for awareness campaigns that emphasize the role vultures play in public health and environmental services. Community-based education could help inform local residents, reduce persecution, and support the enforcement of protective legislation (Daboné et al., 2024). In urban contexts like N'Djamena, where modern influences coexist with deeply rooted African traditions, conservation strategies must engage with both to be effective. Understanding how residents perceive the presence of vultures around urban slaughterhouses, waste sites, and neighborhoods can inform future outreach efforts that may contribute to improving coexistence with vultures and reducing illegal trade pressures. Such efforts could be paired with environmental protection and restoration activities that might contribute to the urban greenness we found to be positively correlated with vulture abundance.

This study provides only a first step towards understanding critically endangered vulture abundance, distribution and conservation status in N'Djamena and environs, and we recommend ongoing monitoring and future research. Specifically, we recommend conducting additional vulture surveys both in N'Djamena and elsewhere in Chad and other understudied regions of Africa (Buechley et al., 2019) with a particular emphasis on identifying both anthropogenic threats as well as areas where vultures may thrive, such as in protected areas or areas where nature restoration efforts are underway (Thiollay, 2006b; Goded et al., 2023; Diop et al., 2024). We also recommend further and deeper investigations of wildlife trade markets and networks for which vultures are persecuted across borders, both within Africa and around the world (Su et al., 2024; Chaffra et al., 2025), in order to more effectively engage and enforce legal, policy, and international trade agreements to protect vultures (CITES (Convention on International Trade in Endangered Species), 2025; CMS Raptors, 2025). Protecting vulture populations in Chad, and throughout West and Central Africa, demands urgent, informed, and coordinated action.

5 Conclusions

The decline of vulture populations across West and Central Africa is not only a conservation crisis but also an emerging public health and environmental issue, due to the valuable ecosystem services vultures provide. Our findings highlight the position of N'Djamena, Chad within the broader context of regional vulture conservation challenges in West and Central Africa. N'Djamena serves as both a potential refuge for declining populations and a point of vulnerability where multiple threats converge, such as natural habitat loss, food scarcity, and international wildlife trafficking. The persistence of even small vulture numbers in some urban sites suggests that with appropriate management and protection measures, urban areas can play a crucial role in species conservation. However, reports by interviewees suggest that the illegal wildlife trade for belief-based use in West Africa may negatively affect vulture populations and environmental health in Central Africa, and that international conservation collaboration is urgently needed to protect remaining vulture populations.

Increasing public awareness, especially through education initiatives that emphasize the ecological role of vultures, may help build local support for their protection, together with protecting and restoring natural habitat features in urban areas such as green spaces and mature trees that provide refuge and roosting areas for urban vultures and other wildlife. At the same time, stronger enforcement and monitoring of illegal trade are needed to disrupt black market networks, particularly as there is mounting evidence that those involved in the illegal but lucrative vulture trade for belief-based use may source vultures across great distances. Addressing the African vulture conservation crisis thus requires an integrated approach that incorporates wildlife ecology, human dimensions, law enforcement, public health considerations, cultural knowledge, and international collaboration.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Ethics statement

All research was conducted in accordance with local legislation and institutional requirements. Vulture surveys consisted of observations only, with no animal handling. Authorization for access to slaughterhouses was sought and obtained by DD from Dr Abakar Goukounigalma; access was facilitated by Lafoi Bassa, Mahamat Yacoub, Christophe Cheflengar and Ramadji. DD and ASC also sought and obtained approval from the Government of Chad's Ministry of the Environment, Fisheries, and Sustainable Development (permit number 110/MEPDD/SG/DGRFFP/DFAP/2025) from Wildlife and Protected Areas Director Mr. Etienne Bemadjim Ngakoutou. Permission to conduct this study and interview local residents was sought and obtained by DD from relevant local authorities and administrators as well as residents themselves. Prior informed consent was sought and obtained by DD from all respondents participating in interviews, whose personal identities were not recorded nor attached to any interview data recorded in order to protect respondents' privacy. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article.

Author contributions

DD: Conceptualization, Methodology, Data curation, Supervision, Investigation, Resources, Project administration, Writing – original draft. ID: Investigation, Validation, Methodology, Supervision, Software, Formal analysis, Writing – original draft, Visualization,

Data curation, Writing – review & editing. AC: Supervision, Methodology, Investigation, Project administration, Writing – original draft. EE: Investigation, Project administration, Writing – original draft. DG: Validation, Writing – original draft, Writing – review & editing, Investigation. AS: Investigation, Writing – review & editing, Formal analysis, Supervision, Methodology, Data curation. NA: Methodology, Funding acquisition, Project administration, Writing – review & editing, Resources, Writing – original draft, Conceptualization, Data curation, Supervision, Investigation.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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