Understanding Vulture Movement in Tanzania

A PROPOSAL SUBMITTED TO

TANZANIA WILDLIFE RESEARCH INSTITUTE

(TAWIRI) and

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY (COSTECH)

BY

Drs Corinne Kendall and Claire Bracebridge

North Carolina Zoo, 2024

Contents

Summary

This proposal describes a North Carolina Zoo (NC Zoo) long-term research and monitoring project working in close partnership with TANAPA, TAWA, Wildlife Conservation Society (WCS), Frankfurt Zoological Society and Lion Landscapes.

The objective of this study is continue to use systematic monitoring of vulture populations via road surveys for abundance estimates, and via movement studies, to provide important information about foraging ecology and mortality factors, rates, and hotspots. We use this information to establish population ranges and core foraging areas, understand habitat use, discover important breeding sites, and determine principal mortality causes and rates. In addition, telemetry data has valuable real-time monitoring uses to inform on-going protection efforts in protected areas. With our partners, these data can help us to address the threats of poisoning and poaching and to target human-carnivore conflict mitigation efforts. Information can also be useful for finding disease outbreaks and disposing of carcasses during disease outbreaks to reduce spread. These are all critical for tracking the continued declines in vultures whilst also assessing the impact of intervention developed by the first vulture action plan of Tanzania aimed to stabilize and reverse the population declines.

These data will continue to contribute to the landscape-level vulture monitoring program, and will guide and assist conservation measures by TANAPA, TAWIRI and other NGOs.

The following research activities are proposed:

a) Continue monitoring population status and trends of vultures in Tanzania via established standardised road transects in Ruaha, Katavi and Nyerere National Parks, and use this information to inform conservation strategies.
b) Continue to expand the movement study by attaching satellite units to White-backed, Ruppell's, White-headed, Lappet-faced, and Hooded vultures in both current study landscape to further enhance understanding of population ranges, habitat use, diet selection, and determine principle mortality causes and rates, as well as to inform roadside survey efforts into new areas.
c) Use vulture movement to discover and identify carcass taxa to study foraging ecology.
d) Use mortality events that occur among tagged vultures to track trends in cause of mortality, identify emerging poisoning hotspots, and general extent of poisoning and other mortality factors. Use this information to guide intervention strategies for improved vulture conservation.
e) Investigate types of poison used from tagged bird mortality or other poisoning events in the landscape to determine the extent of the poisoning threat.

f) Lead testing of vultures and other scavenging raptors to assess exposure from hunting and other possible sources.
g) Establish ground and aerial nest monitoring to monitor occupancy and fledgling success, for both tree nesting and cliff nesting vultures in key selected areas.
h) Provide training to rangers and key community stakeholders in proper protocols for collecting samples and data as well as proper clean-up at a poisoning event.
i) Provide awareness raising to selected communities in a poisoning hotspot area near Lukwati-Piti GRs on the risk of use of pesticides to human, domestic animal and wildlife health and evaluate if this creates attitudinal and behavioural change around wildlife poisoning.
j) Provide training to tour guides in vulture identification to improve nest sightings and counts of vultures at carcasses.
k) Provide a suite of awareness raising activities to key stakeholders to increase their understanding of the importance of vultures for ecosystem integrity.
l) Assess vulture genetics and blood parasites.
m) Evaluate the role of ecosystem services of vultures by investigating how vulture activity at carcasses affects arthropod and microbe communities. This is a MSc student project.
n) Work with TAWIRI and MNRT to implement the national vulture action plan for Tanzania, which was co-developed by TAWIRI and North Carolina Zoo in 2023.

Introduction

Vultures are currently the fastest declining group of birds globally, with vultures threatened across all of Africa (Ogada et al., 2016) (Table 1). This has resulted in the development of the Convention on Migratory Species' (CMS) Multi-Species Action Plan for African-Eurasian Vultures (Botha et al., 2017), used as a framework for conservation practitioners and to coordinate transboundary collaborations necessary for these wide-ranging species. Other than records on distribution collected for the Tanzania Bird Atlas, there was little information on vultures in Tanzania until we started our study in 2013. Tanzania was also identified as an area likely to be important for vultures but in need of further study during a Pan-African Vulture Summit in 2012.

A recent global review highlighted that the greatest threats to vultures are poisoning, particularly from pesticides (such as organophosphates and carbamates) and trauma from collisions with infrastructure such as powerlines and associated electrocution, as well as from windfarms (Ives et al., 2022). In East Africa, declines have been severe (Ogada and Keesing, 2010; Virani et al., 2011; Ogada et al., 2022) with poisoning having the greatest impact rather than trauma, although the latter remains a looming threat with increased infrastructure development. Poisoned carrion is the primary cause (Kendall and Virani, 2012) with carbofuran pesticides widely used for this purpose, and efforts to ban these pesticides have been largely unsuccessful (Otieno et al., 2010). Other studies have shown that few poisoned carcasses are needed to result in precipitous declines. In Asia, only 1% of consumed carcasses resulted in the death of 98% of the vulture *Gyps* species (Green et al., 2004), whilst Murn and Botha (2018) estimated that vulture extinction in South Africa could occur in 50 years with just 1 elephant poisoning every 2 years. There is little doubt we are reaching a tipping point where only significant conservation efforts will change the trajectory of African vultures' population declines.

In East Africa, retaliatory poisoning against lions, hyenas and other carnivores for livestock predation has been the main driver of poisoning events. Whilst lacing livestock carcasses with pesticides aims to eliminate carnivores, most often large numbers of vultures are killed as well as, or instead of, the original target species. This is despite pastoralists generally having a positive attitude towards vultures (Didarali et al., 2022). Additionally, sentinel poisoning by ivory poachers has also become a more prevalent threat to Africa's declining vulture populations (Ogada et al., 2016). Because vultures can act as an early warning system to rangers for large poached carcasses, poachers intentionally poison elephant carcasses to reduce vulture populations and, in some cases, also collect vulture parts (Mateo-Tomás & López-Bao, 2020). In Tanzania, we have also recorded sentinel poisoning events linked to bushmeat poaching using large snare lines. In some cases, vulture parts were collected opportunistically. The use of vulture parts in muthi and bushmeat trade is well known in West Africa and South Africa. Two thousand Hooded vultures were poisoned for this reason in 2019 / 2020 in Guinéa-Bissau (Henriques et al., 2020), but in East Africa, the extent to which harvesting is occurring and if parts are used locally or are part of international trade is less clear. In August 2022, 150 vultures were killed in two poisoning incidents in Kruger National Park, South Africa and near Chobe, Botswana. Poachers not only removed heads and feet, but also internal organs, which was previously unknown and adds to the concern that there is a shift in the trend of vulture harvesting.

Table 1 Main scavenging vulture species found in NC Zoo focal areas in Tanzania

Species	IUCN 2015
Hooded vulture *Necrosyrtes monachus*	Critically Endangered
Lappet-faced vulture *Torgos tracheliotos*	Endangered
Ruppell's vulture *Gyps rueppellii*	Critically Endangered
White-backed vulture *Gyps africanus*	Critically Endangered
White-headed vulture *Trigonoceps occipitalis*	Critically Endangered

Statement of the Problem and Justification

Vultures in Africa are in severe decline. Given their important ecological and conservation significance, such as rapid waste disposal, disease removal, nutrient cycling, carbon emission reduction and carnivore population mediation, the costs of losing vultures could have disastrous consequences to ecosystems, wildlife and humans. This is shown in India where 99% declines of three vultures species resulted in 500,000 human deaths from the contamination of water and the environment without the vultures rapid cleaning up of carcasses. The costs to control this environmental and health catastrophe are billions of US dollars.

Our long-term monitoring data in southern Tanzania have shown that instead of a 5% natural adult mortality rate, vultures in Tanzania have a 25% mortality rate (or 75% survival). Generally, vulture populations are only stable or growing with 90% or greater survival. The declines in Tanzania are therefore not sustainable. The main threat is poisoning, linked to livestock-carnivore conflict, where vultures are not deliberately targeted but are unintended victims of their own efficient scavenging abilities. This is particularly a problem in southern Tanzania, where there is increasing pressure on protected area boundaries from (agro-)pastoralists. It is also a dynamic threat. Vultures are also targeted by poachers to avoid detection by rangers and for an increasing demand of vulture body parts in belief-based use. Northern Tanzania seems to be a particular hotspot for belief-based poisoning. It is critical to continue to monitor the poisoning threat and spatio-temporal shifts, as well as to track the trends in the population status as conversation efforts are ramped up through the implementation of the vulture action plan. Vulture conservation needs overlap heavily with those of other species, particularly carnivores and elephants. Data collected on vultures can provide a landscape level view of ecosystem health, potentially highlighting broader issues that may be missed when working on a site-by-site basis. Vulture research is thus of great value to the protected areas in Tanzania.

Literature Review

Vultures are important providers of ecosystem services such as disease control and, due to their wide-ranging behaviors, are key indicators of ecosystem health at a landscape scale (Sekercioglu et al. 2004; Markandya et al. 2008; Ogada et al. 2012). Scavengers play a critical role in decomposition and disease control, and loss of vultures can have huge effects on the environment and in some cases, lead to major economic losses as well. Loss of vultures in India is estimated to have caused nearly $34 billion in damages (Markandya et al. 2008). In India, vulture declines lead to an increase in feral dog populations which precipitated rabies outbreaks in dogs and humans. In addition to healthcare costs, loss of vultures in Africa could have important implications for the tourism industry given the likely rise in rotting carcasses that would arise from their demise becoming an unpleasant nuisance to tourists. Without vultures' efficiency at carcass consumption (as compared to mammalian scavengers), there may be risk of either persistence or increase of harmful diseases within the ecosystem (Van Den Heever et al., 2021).

Vultures are the only obligate scavenging vertebrates (DeVault et al. 2003). Because of their unique ecology, vultures must travel large distances in search of carrion, a disparate and ephemeral food source. Studies of vulture movement have demonstrated that vultures can range over areas of hundreds of square kilometers (Phipps et al. 2013; Kendall et al. 2014). Studies of vulture movement are thus critical to understanding their ecological needs and for protecting these species.

Given large range sizes and dependence on high wildlife density, vultures indicate ecosystem health at the landscape scale (Sekercioglu et al., 2004; Markandya et al., 2008; Ogada et al., 2012). Vultures can also be important indicators of poaching activity as they are attracted to large carcasses, such as those of poached elephant and rhino, in large numbers. In addition, because vulture populations are likely to be more sensitive to poisoning than lions, they may prove to be important indicators of conservation success when it comes to mitigating human-predator conflicts. In particular, White-backed vultures act as an umbrella species for other scavengers (Thompson et al., 2021), as their wide-ranging and gregarious feeding makes them most at risk from poisoning events. Continued vulture monitoring and subsequent conservation efforts is not only critical for vultures but can benefit a range of other highly threatened species e.g., elephants and lions.

Objectives and Significance of the Research

Satellite telemetry is an important tool for vulture conservation that can be used to inform survey efforts, establish relevant population ranges or neighborhoods, discover important breeding sites, and determine principle mortality causes and rates. Studies of White-backed vulture movement in South Africa (Phipps et al. 2013) and Kenya (Kendall and Virani 2012) have provided important insights into ranging behaviors and highlighted threats.

Based on surveys from Kenya and South Africa, it is known that vultures can range over 100,000 km^2 in a single year, an area much larger than the national parks in Tanzania. Because vultures range widely, it is impossible to survey an entire population. However without knowing where vultures are concentrated at different times of year, findings from surveys can be difficult to interpret. In Kenya, vulture movement studies have helped to inform survey efforts. By studying the movement of Lappet-faced, Ruppell's, and White-backed vultures, Kendall et al. (2014) were able to determine that vulture populations concentrate in Masai Mara National Reserve and northern Serengeti National Park during the dry season. This same population spreads out to a much larger range using much of Kenya with some birds traveling as far north as Boma-Jongeli in Sudan and Ethiopia and others as far south as Ruaha National Park during other times of the year. As a result of these findings, it has become clear that surveys in Masai Mara National Reserve during the dry season can be used to monitor most of Kenya's vulture population. In particular, changes in abundance seen in this area and during this period are indicative of the conservation status of Kenya's entire White-backed vulture population.

In addition, findings from studying vulture movement are important for establishing the causes and rates of vulture mortality. During a study of vulture movement in Kenya in 2010, it was possible to establish that poisoning incidents could be causing annual mortality of some vulture species of up to 33%. After a decade of conducting monitoring work with vultures in southern Tanzania, our data has culminated in a publication this year (Kendall et al. 2023, Conservation Biology https://doi.org/10.1111/cobi.14146) that shows vulture declines of 25% annual mortality for White-backed vultures in southern Tanzania. Natural annual mortality should be only 5%, as these long-lived animals have very few natural threats. This is not a sustainable rate of declines.

This understanding of the high rate of mortality being experienced by vultures allows for careful pinpointing of where poisoning is occurring, allowing local law enforcement to follow up on poisoning incidents.

Understanding the population range of vultures in Southern Tanzania is critical for their conservation in the long term. Recent continent-wide estimates for White-headed vultures, combined with our data, highlighted southern Tanzania as containing one of the largest remaining populations of this species (Murn et al., 2016). Findings from continent-wide movement studies also suggest that vultures in southern Tanzania may have smaller home range sizes, with greater overlap with large, protected areas, making them easier to conserve, as compared to other sites in south-eastern Africa (Kane et al., 2022). Given the challenges of reducing poisoning across the typically large range for vulture species, this may make southern Tanzania a critical area for long-term vulture survival.

Systematic monitoring of vulture populations via road surveys for abundance estimates, and via movement studies, provides important information about foraging ecology and mortality factors, rates, and hotspots. We use this information to establish population ranges and core foraging areas, understand habitat use, discover important breeding sites, and determine principal mortality causes and rates. In addition, telemetry data has valuable real-time monitoring uses to inform on-going law enforcement efforts. With our partners, these data can help us to address the threats of poisoning and poaching and to target human-carnivore conflict mitigation efforts. Information can also be useful for finding disease outbreaks and disposing of carcasses during disease outbreaks to reduce spread.

Methodologies

Overview of data collection methods / tools:

a) Standardised and seasonal roadside surveys for counts of vultures to calculate abundance and encounter rates; data collected on handheld device using Cybertracker.
b) Solar-powered satellite units to track movement of the birds; daily downloads of 26 points per day.
c) Aerial and ground truthing movement data in order to understand more about foraging ecology and better use the telemetry data for carcass detection.
d) Repeated nest site visits over breeding season to establish nest activity and status – bird's eye view of tree nest using extendable pole and GroPro camera.
e) Blood and feather sample collection during trapping for tagged birds for lead testing using LeadCare Analyzer, genetic sampling, and assessment of blood parasites.
f) Repeat household interviews in targeted community area that has human-wildlife conflict and assess whether a training on Hazards of Pesticide use to human health, environmental and wildlife has resulted in attitudinal and behaviour change.
g) Arthropod and microbe samples collected from natural and/or experimental carcasses with and without vulture / scavenger activity in both wet and dry season. Live samples of immature insects present will be collected and reared for identification (Amendt et al. 2007).

Monitoring population abundance using road surveys

We use dry season roadside counts to monitor vulture populations. This monitoring, with baselines set from 2013 at the beginning of our research, gives us information about the trends of vulture populations across both long-term and relatively short-term time intervals. Short-term population trends can also be used to assess and adapt conservation interventions. For instance, whilst southern Tanzania is undoubtedly a stronghold for African vultures, analysis of survey trends provides sobering evidence that some species are in decline (Kendall et al., 2023).

Vulture and scavenging raptor (Bateleur and Tawny eagle) abundance is measured using roadside transect counts. Roadside surveys are used as a standardized monitoring tool to track trends in vulture abundance over time, as absolute counts are extremely challenging for mobile, wide-ranging, social, non-colonial breeding or non-migratory species. Flying and perched birds are counted along either side of the road. Transects are treated as lines and the distances measured with the vehicle odometer averaging 30 km/hour. Transects are chosen to represent a large diversity of habitats and maximize coverage across the protected areas, as well as along roads that are likely to be useable during both the wet and dry seasons. Between 200-300 km of transects is aimed for in each protected areas. Data are collected in CyberTracker on tablets. From these data we can calculate encounter rates (number of individuals per species per 100 km) which allows us to track trends in populations over time in each surveyed area. We will conduct transect surveys in Ruaha, Katavi and Nyerere National Parks.

Satellite Telemetry Study

We started studying vulture movement in 2015 in Tanzania in partnership with WCS, and continue to expand the project each year, in terms of numbers of satellite units deployed and location of unit deployment. We have tagged over 80 birds. We target White-backed vultures, as their wide-ranging and social feeding makes them most at risk from poisoning events and allows them to act as an umbrella species for other scavengers (Thompson et al., 2021). However, where opportunities allow we will tag other species and in the past we have tagged White-headed and Hooded vultures too. Movement studies help us to understand vultures' ecological needs as well as identifying core areas of threat. In real-time, our telemetry study provides us with information on vulture mortality and poisoning events, disease outbreaks, and allows the location of carcasses of large mammals to be confirmed. Our data also provide a useful monitoring and evaluation tool for partners addressing human-carnivore conflict, such as Lion Landscapes. More effective and rapid detection of poisoning and poaching events as well as highlighting hotspots are key steps in reducing these illegal activities and vultures provide unique insight into the environment in real-time.

Vultures are trapped using nooses, set up as lines, along carcasses (Watson and Watson, 1985). Noose on noose lines are made of coated wire cord or monofilament, and the noose line is made of parachute cord. Nooses are 10-15 cm in diameter, and the lines are staked into the ground using tent pegs for added stability. Noose lines consist of approximately 6-8 nooses. Once a bird is captured, processing took approximately 15 minutes per bird; birds' eyes are covered to reduce stress and the handler restrained both feet and head. Blood is taken for sexing and lead sampling, weight is measure and photos are taken of the head and wing for aging.

We use Solar-powered satellite units (55g Spoortracker units), and attach them to the bird using the pelvic harness method using Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania, U.S.A.) with bungee cord inside for additional flexibility. The pelvic harness loops over the legs and sits over the pelvic bone which is a prominent notch on a vulture. The unit is positioned on the lower back.

Units are set to take GPS waypoints every half an hour from 7 AM to 6 PM and at midnight each day for a total of 26 points per day, transmiting data daily. The transmitters provide information on velocity, altitude, and location (GPS coordinates) and have an internal activity sensor that detects movement. A mortality event can be identified based on transmitter metrics (lack of movement, limited activity based on sensor, and/or changes in battery life, which can occur if bird dies on its back), follow up is made as rapidly as logistically possible to determine cause of death.

Disease dynamics

Vultures are well known for providing ecosystem services, such as consuming a carcass more quickly than mammalian scavengers, thereby also preventing the development of fly larvae at a carcass, and overall, potentially reducing the spread of disease. However there has been very little systematic and experimental research to quantify this dynamic. We will work with a Tanzanian MSc student (yet to be selected) to investigate the interaction between vultures, disease and flies at a decaying carcass. If this research confirms the vultures' key role in disease control then their declines in the ecosystem could have real and catastrophic impacts on humans as well, and it highlights more strongly the need for concerted and coordinated efforts for their conservation for a multitude of reasons.

Arthropod samples (comprising largely of Diptera and Coleoptera) will be collected from experimentally placed carcasses (primarily goats) and opportunistically from existing carcasses. Experimental carcasses will include some placed in exclosure plots to prevent use by vultures and/or scavenging mammals. Natural carcasses may be comprised of various species of ungulates, based on availability at the time of collection. Field collection methods as outlined by Amendt et al. (2007) will be employed. In order to envisage an accurate estimate of the population composition and species abundances for the area, sampling of insects associated with decomposing vertebrate remains will be done at least twice per year. More specifically, carcasses will be placed in the field once during the dry season and again during the wet season with insects present on the remains over the course of carrion decomposition being sampled. Sample sizes will be variable depending on size of carrion and degree of decomposition and scavenging by vultures with an initial target of 10 carcasses – 5 with and 5 without vulture scavenging activity. Live samples of the immature insects present will be collected and reared, while further samples will be killed *in situ* and preserved in ethanol for analysis (Amendt et al. 2007). All collected samples will be identified to species level, using taxonomic keys available for the region.

Community baseline mapping and interviews to develop trainings

As human-wildlife conflicts (HWC) are known to precipitate the use of poison in retaliatory killings, and as households on the peripheries of communities typically experience more severe HWC than those in village interiors, it is critical that these outlying households are adequately sampled in the baseline. Data will be collected in Kobo on a handheld device by a team of enumerators and will gather information on basic background data in 2 target villages on the edge of Lukwati-Piti Game reserves where we have seen tagged vulture mortalities. Information will be collected on the following key topics (community demographics, homestead locations, boma prevalent and attributes, seasonal movement), which will inform the development of baseline survey interviews aimed to track changes in the community-level conditions, particularly with regard to 1) knowledge and attitudes towards vultures; 2) knowledge and attitudes surrounding the dangers posed by poisons; and 3) perceptions of both the acceptability of poisoning events and the people who use poison. A community training on hazards of pesticide use and dangers to human and wildlife health will be developed and conducted to address the use of pesticide use in human-wildlife conflict. Pre- and post-evaluation of the trainings will also be conducted to measure attitidunal and behaviour change.

Expected Outputs

This project is part of a larger conservation effort being undertaken by the North Carolina Zoo in partnership with Wildlife Conservation Society, Frankfurt Zoological Society, Lion Landscapes, TAWA, TANAPA and TAWIRI, the needs of which is now clearly outlined in the new vulture action plan for Tanzania. This study aims to improve conservation in the protected areas through careful monitoring of key species such as vultures, building capacity of rangers to deal with poisoning events efficiently and safely. Results from this study will establish the population status across time, as well as the range and seasonal movement behavior of vultures in Tanzania, which will be critical for creating meaningful monitoring efforts. Findings from our previous movement studies have proven critical to establishing the mortality causes and rates of vultures, key to identify threat hotspots in Tanzania (Kendall et al. 2023) and have underpinned the development of the vulture action plan for Tanzania.

Capacity building rangers and training communities in use of pesticides for wildlife poisoning will also increase awareness of the plight of vultures. Current local attitudes towards mammalian scavengers tend to be increasingly negative, but people are not aware of the impact poisoning to kill mammals has on the vulture populations. By talking with local people outside the park and with tourist lodge employees and park rangers in the park, we increase the public's knowledge of both the threats facing these species and of the species critical role in the ecosystem, which will be better understood as a result of this study.

Bibliographies/References

Amendt J, Campobasso CP, Gaudry E, Reiter C, LeBlanc HN & Hall MJR. (2007). Best practice in forensic entomology – standards and guidelines. *Int J Legal Med* 121: 90-104.

Botha, A. J., Andevski, J., Bowden, C. G. R., Gudka, M., Safford, R. J., Tavares, J. and Williams, N. P. (2017). Multi-species Action Plan to Conserve African-Eurasian Vultures. CMS Raptors MOU Technical Publication No. 5. CMS Technical Series No. 35. Coordinating Unit of the CMS Raptors MOU, Abu Dhabi, United Arab Emirates.

DeVault, T. L., O. E. Rhodes, and J. A. Shivik. (2003). Scavenging by vertebrates: behavioral, ecological, and evolutionary perspectives on an important energy transfer pathway in terrestrial ecosystems. Oikos 102:225-234.

Didarali, Z., Kuiper, T., Brink, C. W., Buij, R., Virani, M. Z., Reson, E. O., and Santangeli, A. (2022). Awareness of environmental legislation as a deterrent for wildlife crime: A case with Masaai pastoralists, poison use and the Kenya Wildlife Act. *Ambio:* 1-11.

Green R.E., Newton, I., Shultz, S., Cunningham, A.A., Gilbert, M., Pain, D.J. and Prakash, V. (2004). Diclofenac poisoning as a cause of vulture population declines across the Indian subcontinent. *Journal of Applied Ecology*, 41:793-800.

Henriques, M., Buij, R., Monteiro, H., Sá, J., Wambar, F., Tavares, J.P., Botha, A., Citegetse, G., Lecoq, M., Catry, P. and Ogada, D. (2020). Deliberate poisoning of Africa's vultures. *Science,* 370 (6514): 304. DOI: 10.1126/science.abd1862.

Ives, A. M., Brenn-White, M., Buckley, J. Y., Kendall, C. J., Wilton, S., and Deem, S. L. (2022). A Global Review of Causes of Morbidity and Mortality in Free-Living Vultures. *EcoHealth*, 1-15.

Kane, A., Monadjem, A., Bildstein, K., Botha, A., Bracebridge, C., Buechlet, E.R., Buij, R., Davies, J.P., Diekmann, M., Downs, C., Farwig, N., Galligan, T., Kaltenecker, G., Kelly, C., Kemp, R., Kolberg, H., MacKenzie, M., Mendelsohn, J., Mgumba, M., Nathan, R., Nicholas, A., Ogada, D., Pffeifer, M.B., Phipps, L.W., Pretorius, M., Rösner, S., Schabo, D.G., Spiegel, O., Thompson, L.J., Venter, J.A., Virani, M., Wolter, K and Kendall, C. (2022). Understanding continent-wide variation in vulture ranging behavior to assess feasibility of Vulture Safe Zones in Africa: challenges and possibilities. *Biological Conservation.*

Kendall, C., and M. Virani. (2012). Assessing mortality of african vultures using wing tags and GSM-GPS transmitters. Journal of Raptor Research 46:135-140.

Kendall, C. J., M. Z. Virani, J. G. C. Hopcraft, K. L. Bildstein, and D. I. Rubenstein. (2014). African Vultures Don't Follow Migratory Herds: Scavenger Habitat Use Is Not Mediated by Prey Abundance. PLoS ONE 9:e83470.

Kendall, C. J., Bracebridge, C., Lynch, E. C., Mgumba, M., Monadjem, A., Nicholas, A., & Kane, A. (2023). Value of combining transect counts and telemetry data to determine short-term population trends in a globally threatened species. *Conservation Biology*, e14146.

Markandya, A., T. Taylor, A. Longo, M. N. Murty, S. Murty, and K. Dhavala. (2008). Counting the cost of vulture decline - An appraisal of the human health and other benefits of vultures in India. Ecological Economics 67:194-204.

Mateo-Tomás, P., & López-Bao, J. V. (2020). Poisoning poached megafauna can boost trade in African vultures. *Biological Conservation*, *24:* 108389.

Murn, C., Mundy, P., Virani, M.Z., Borello, W.D., Holloway, G.J. and Thiollay, J. (2016). Using Africa's protected area network to estimate the global population of a threatened and declining species: a case study of the Critically Endangered White-headed Vulture Trigonoceps occipitalis. *Ecology and Evolution* 6 (4):1092-1103. doi: 10.1002/ece3.1931.

Murn, C. and Botha, A. (2018). A clear and present danger: impacts of poisoning on a vulture population and the effect of poison response activities. *Oryx*, *52*(3): 552-558.

Ogada, D. L., and F. Keesing. (2010). Decline of Raptors over a Three-Year Period in Laikipia, Central Kenya. Journal of Raptor Research 44:129-135.

Ogada, D. L., M. E. Torchin, M. F. Kinnaird, and V. O. Ezenwa. (2012). Effects of Vulture Declines on Facultative Scavengers and Potential Implications for Mammalian Disease Transmission. Conservation Biology.

Ogada, D., Shaw, P., Beyers, R. L., Buij, R., Murn, C., Thiollay, J. M. and Krüger, S. C. (2016). Another continental vulture crisis: Africa's vultures collapsing toward extinction. *Conservation Letters*, *9*(2): 89-97.

Ogada, D., Virani, M.Z., Thiollay, J.M., Kendall, C.J., Thomsett, S., Odino, M., Kapila, S., Patel, T., Wairasho, P., Dunn, L. and Shaw, P. (2022). Evidence of widespread declines in Kenya's raptor populations over a 40-year period. *Biological Conservation*, 266: 109361.

Otieno, P. O., J. O. Lalah, M. Virani, I. O. Jondiko, and K. Schramm. (2010). Carbofuran and its toxic metabolites provide forensic evidence for Furadan exposure in vultures (*Gyps africanus*) in Kenya. Bulletin of Environmental Contamination and Toxicology 84:536-544.

Phipps, W. L., S. G. Willis, K. Wolter, and V. Naidoo. (2013). Foraging Ranges of Immature African White-backed Vultures (*Gyps africanus*) and Their Use of Protected Areas in Southern Africa. PlosOne 8.

Sekercioglu, C. H., G. C. Daily, and P. Ehrlich. (2004). Ecosystem consequences of bird declines. Proceedings of the National Academy of Sciences 101:18042-18047.

Thompson L.J., Krüger, S.C., Coverdale, B.M., Shaffer, L.J., Ottinger, M.A., Davies, J.P., Daboné, C., Kibuule, M., Cherkaoui, S.I., Garbett, R.A., Phipps, W.L., Buechley, E.R., Godino Ruiz, A., Lecoq, M., Carneiro, C., Harrell, R.M., Gore, M.L. and Bowerman, W.W. (2021).

Assessing African Vultures as Biomonitors and Umbrella Species. *Frontiers in Conservation Science*, 2: 729025. doi: 10.3389/fcosc.2021.729025.

Van Den Heever, L., Thompson, L.J., Bowerman, W.W., Smit-Robinson, H., Shaffer, L.J., Harrell, R.M. and Ottinger, M.A. (2021). Reviewing the role of vultures at the human-wildlife livestock disease interface: an African perspective. *Journal of Raptor Research*, 55(3): 311-327.

Virani, M. Z., C. Kendall, P. Njoroge, and S. Thomsett. (2011). Major declines in the abundance of vultures and other scavenging raptors in and around the Masai Mara ecosystem, Kenya. Biological Conservation 144:746-752.

Watson, R. T., and C. R. B. Watson. (1985). A trap to capture Bateleur eagles and other scavenging birds. South African Journal of Wildlife Research 15:63-66