Southern Tanzania
Vulture Monitoring and Conservation

Annual Report
2021

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Executive Summary

Vultures are currently the fastest declining group of birds globally, with most now listed as critically endangered or endangered. As wide-ranging species operating at a landscape scale, with a vital role in the ecosystem, vultures can act as early warning systems for other conservation issues, especially linked to poisoning and poaching.

Prior to the start of our work in 2013, little was known about vulture populations in southern Tanzania. Based on the information we have on the population status and threats to vultures over the last 9 years from tagged individuals and roadside surveys, we are sadly seeing declines in vultures in southern Tanzania, like so many other parts of Africa. Our priority is to work with partners to reduce poisoning and other threats. Effective vulture conservation can inform conservation efforts for a range of species. In particular, vultures and carnivores suffer from the similar threat of poisoning and addressing this human-carnivore conflict will help to protect both suites of species.

In 2021, we continued population monitoring and conservation activities. We conducted wet and dry season transect surveys across three national parks (Ruaha, Katavi and Nyerere), tagged 11 White-backed vultures, retrieved 3 units, discovered to 2 retaliatory poisoning events, conducted 2 response to poisoning trainings with wildlife rangers, and supported a PhD and 2 MSc students.

Monitoring population abundance

We use wet and dry season roadside counts to monitor vulture populations. We have collected 9 years of data for Ruaha and Katavi National Park (NP) and 4 years of data for Selous Game Reserve / Nyerere National Park. While we lack historical data, this monitoring gives us information about the trends of vulture populations in southern Tanzania. Whilst southern Tanzania is undoubtedly a stronghold for African vultures, analysis of survey trends provides sobering evidence that some species are now in decline, though they had maintained relative stability up from 2013 - 2018. Below are some of the key findings from our work:

- For Ruaha NP, populations were mostly stable from 2013-2017, with declines appearing from 2018 onwards.
- Katavi NP remains relatively stable for most species.
- Nyerere NP has had high poisoning rates and concerning declines since surveys began in 2018, with initially high counts consistently reduced over this short-time period especially for White-backed vultures.
- Species declines were detected in White-backed and White-headed vultures as well as Tawny eagles. Overall abundance of White-backed vultures was higher in Katavi / Nyerere NPs than Ruaha NP.
- Slight species increases were detected in Hooded vultures in Katavi NP, Lappet-faced vultures in Ruaha NP, and Bateleur eagle in Ruaha and Nyerere NPs.

Satellite telemetry

We began tagging vultures in 2015, with a total of 62 vultures tagged in southern Tanzania. At the end of 2021, we had 23 active units on 22 White-backed vultures and 1 White-headed vulture. We target White-backed vultures, as their wide-ranging and gregarious 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). 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. Below are some of the key outcomes from our work in 2021:

- Monitored data from up to 30 tagged vultures in any one month from 2 species (29 White-backed and one White-headed vulture).
- Our long-term data set grows with (for active units): 2 birds with over 5 years of data, 1 bird with 4 years, 5 birds with between 2.0-2.5 years, 5 birds with around 1.5 years and 9 birds with <6 months of data.
- A total of 560,715 km was flown by all tagged birds in 2021, with 337,347 km travelled by 20 Ruaha-Katavi tagged birds, and 223,365 km by 10 Selous-Nyerere tagged birds.
- In Ruaha-Katavi, movement patterns by birds tagged across three different locations suggest potential subpopulations dynamics within the main Ruaha-Katavi population.
- Two confirmed mortalities and 1 presumed mortality were recorded in 2021. Both confirmed mortalities were due to retaliatory poisoning (i.e. carnivore-livestock conflict), with some missing heads suggesting harvesting vulture parts was a secondary motivation. In addition, 5 units fell off and were retrieved for future redeployment.
- A survival analysis of the 62 tagged birds showed between a 20-36% average annual mortality across all years of study. This is in stark contrast to an expected background adult mortality rate which should be no more than 5% and corroborates the declines we are seeing in the survey data, primarily caused by poisoning.
- Of poisoning discovered to date, most poisoning is occurring on the edges of protected areas or around the buffer zones. Most casualties were vultures (97% of all recorded dead animals), of which 87% were White-backed vultures. Thirty-one percent of vultures had their head removed.
- One PhD student working with NCZ continued analysis of the movement data and will begin to publish findings in 2022 aimed at comparing key feeding areas with potential exposure to poisoned carcasses to provide a poisoning risk assessment across southern Tanzania to assist in conservation management decisions.

Capacity building

- A total of 88 rangers were trained in response to poisoning events. In northern Tanzania, 39 participants were trained from Maswa Game Reserve, Wildlife Conservation Limited, and Makao Wildlife Management Area and 49 TANAPA rangers were trained from Nyerere National Park in southern Tanzania.

- Support continued for a MSc student at SUA (a collaboration between NCZ and the Grumeti Fund), with on the ground nest surveys commencing in Grumeti and Ikorongo Game Reserve and Ikona Wildlife Management Area during the 2021 vulture breeding season.
- MSc student at University of Glasgow completed analysis of vulture behavioral data from Mara-Serengeti ecosystem on the effects of human disturbance and competition on feeding ecology of vultures.

Communications

- Monthly summaries on tagged birds were shared with all key local partners.
- Coordination of the African Vulture SAFE program within Association of Zoo and Aquariums continued.
- The program's work outputs were shared at the Tanzania Wildlife research Institute's (TAWIRI) conference, at the Association of Zoos and Aquarium's annual conference, and at the Society of Conservation Biology's International Congress for Conservation Biology.

Plans for 2022

- Continued use of telemetry study for anti-poaching support in partnership with Wildlife Conservation Society and wildlife authorities (Tanzanian National Parks Authority (TANAPA) and Tanzanian Wildlife Management Authority (TAWA).
- Continued support and supervision to two students (PhD and MSc), with addition of at least 1 Masters student.
- Provide response to poisoning training to at least 50 rangers.
- Continue working on the possibility of integrating vulture nest recognition via machine learning processes into WCS Aviation program's aircraft imaging database.
- Together with key Tanzanian wildlife institutes, initiate development of a Tanzania National Action Plan for Vultures.

Vulture Status and Threats

Vultures are currently the fastest declining group of birds globally and recent work suggests that vultures are threatened across all of Africa (Ogada et al., 2016). This resulted in the development of the CMS's Multi-Species Action Plan for African-Eurasian Vultures in 2017 to use as a framework for conservation practitioners, particularly as transboundary collaborations are necessary for these wide-ranging species.

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 (2017) estimated that vulture extinction in South Africa could occur in 50 years with just one elephant poisoning every 2 years. There is little doubt we are reaching a tipping point where only 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). We have also recorded sentinel poisoning events linked to bushmeat poaching using large snare lines. In some cases, vulture parts are collected opportunistically. The use of vulture parts in muthi and bushmeat trade is well known in western 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, it is less clear the extent to which harvesting is occurring and if parts are used locally or are part of international trade.

Importance of vultures in ecosystem health and conservation

Scavengers play a critical role in decomposition and disease control (Sekercioglu, 2006, Sekercioglu et al., 2004, Plaza et al., 2020), 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), partially due to an increase in feral dog populations following vulture declines that precipitated rabies outbreaks in dogs and humans. In addition, 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 also important indicators of ecosystem health. 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. Vulture conservation thus has significant ecological and economic ramifications, which merits their study.

Southern Tanzania Vulture Program

Our work has corroborated prior assumptions, such as those outlined in the CMS Multi-Species Action Plan for African-Eurasian Vultures 2017, that Tanzania is a critical country for African vulture conservation. Recent continent-wide estimates for White-headed vultures, combined with our data, highlight 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 particularly small home range sizes, contained primarily within large, protected areas, making them easier to conserve (Kane et al., in review). Given the challenges of reducing poisoning across the typically wide range for vulture species, like the White-backed vulture, this may make southern Tanzania one of the best hopes for long-term vulture survival. The importance of African vultures has also been recognized by the Association of Zoos and Aquariums with African vultures becoming a SAFE (Saving Animals from Extinction) program species group in February 2018, under the leadership of North Carolina Zoo.

North Carolina Zoo (NCZ) works across southern Tanzania in two important vulture landscapes encompassing over 150,000km^2, some of the last remaining strongholds for this avian scavenger guild. Four of the vulture species found in southern Tanzania are now critically endangered, and one endangered (Table 1). Monitoring and understanding the needs and behavior of this population of vultures will be vital for the future of African vultures and needs to be conducted over the long-term. In Asia, rapid declines went unnoticed largely due to the lack of consistent monitoring.

Since 2013, NCZ has worked in the Ruaha-Katavi landscape, partnering with the Wildlife Conservation Society (WCS) and the Tanzania National Parks (TANAPA), and in 2018, initiated further conservation activities in the Selous-Nyerere ecosystem, partnering with the Tanzania Wildlife Authority (TAWA), TANAPA and Frankfurt Zoological Society (FZS). Systematic monitoring of vulture populations is conducted via road surveys for abundance estimates, and via movement studies, which have provided important information about foraging ecology and mortality factors, rates, and hotspots. In addition, vulture movement studies offer insights for the conservation of other species, particularly in relation to the threats of poaching and poisoning. Information from vultures can thus help to target the threats to carnivores and other large mammals as well. In 2020, we started to establish connections with organizations in northern Tanzania in response to the regular movement of the tagged White-backed vultures from Selous-Nyerere, necessitating broadening the network of partnerships for effective conservation. In 2021, we expanded this to transboundary partnerships in Kenya.

Table 1 Scavenging vulture species found in southern 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

Program Goal

The goal of the Southern Tanzania Vulture Program is to conserve southern Tanzania's vulture populations by reducing poisoning and improving our understanding of the population status and threats to vultures to improve conservation efforts. In addition, as a landscape species, vulture conservation can help to inform and improve conservation outcomes for other species as well, including carnivores and other large mammals.

Program Objectives

1. Conduct standardized roadside surveys in Ruaha, Katavi, and Nyerere (formerly Selous Game Reserve) National Parks to monitor vulture populations and track changes in vulture abundance over time.
2. Use satellite telemetry to study vulture movement and 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 anti-poaching efforts, and to identify poisoning events. 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 mortalities and disposing of carcasses during disease outbreaks.
3. Train rangers and other partners in appropriate rapid response to poisoning events (knowledge of proper protocols for collection of samples and disposal of carcasses at poisoning events) to deter perpetrators, reduce additional poisoning, and to encourage associated prosecution processes being convened, drawing on data collected at the scene to guide follow up investigations. Where possible, prepare trainees in proper care of live, poisoned birds for appropriate rehabilitation.
4. Monitor lead levels from tagged vultures to assess the risk of lead exposure and poisoning in southern Tanzania's vulture populations and look for seasonal variation in lead levels that may relate to legal and illegal hunting.
5. Monitor breeding populations and measure occupancy over time using data from roadside surveys, satellite units, tour guide sightings and aerial nest surveys within main protected areas of southern Tanzania and Grumeti.
6. Continue to build partnerships with key stakeholders e.g. protected area authorities and other NGOs particularly working in anti-poaching, carnivore and other large mammal conservation, to allow closer knowledge sharing and collaboration in understanding threats and developing coordinated conservation strategies.

Study Area

The research and monitoring focuses on two main landscapes in southern Tanzania (Figure 1) – the Ruaha-Katavi landscape, a vast area of 100,000km^2, with Ruaha and Katavi National Parks (NP) connected by a network of Game Reserves (GR), Game Controlled Areas (GCA) and Open Areas (OA).

Approximately 200 km east from Ruaha National Park, is the greater Selous ecosystem, consisting of over 50,000km^2 encompassing Selous GR / Nyerere and Mikumi NPs.

For vultures, connectivity between the Ruaha-Katavi and Selous landscapes is blocked by the Eastern Arc Mountain ranges (Udzungwa and Rubeho mountains), resulting in two separate southern Tanzanian vulture populations. These overlap with critical stronghold populations and corridors of elephants, lions and wild dogs in Ruaha-Rungwa and greater Selous.

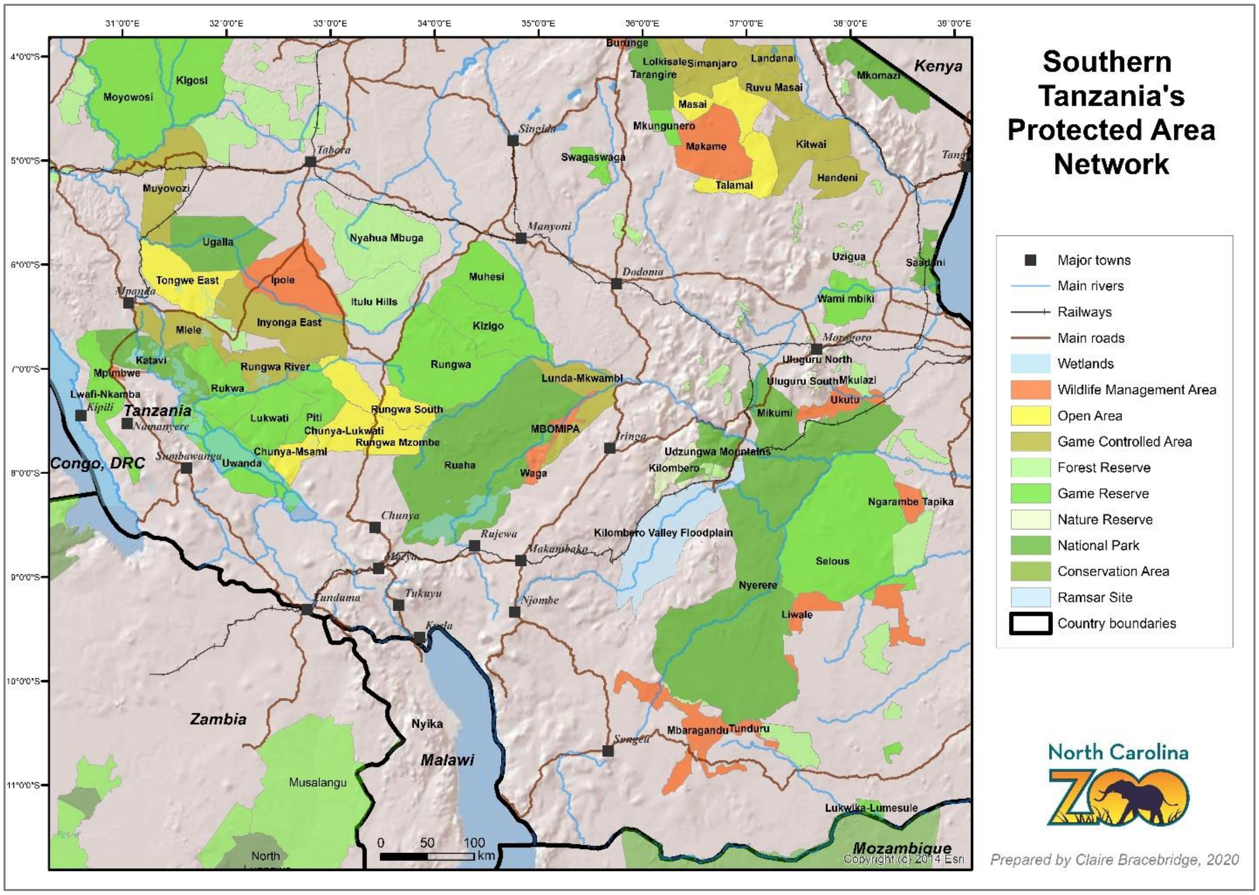


Figure 1 Map of the southern Tanzanian landscape, showing the main protected areas, including Ruaha, Katavi, Mikumi and Nyerere National Parks, the Rungwa-Kizigo-Muhesi, Lukwati-Piti, Rukwa-Lwafi and and Selous Game Reserves.

Vulture Abundance Surveys

Vulture and scavenging raptor (Bateleur and Tawny eagle) abundance was 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 impossible for mobile, wide-ranging, social, non-colonial breeding or non-migratory species. Flying and perched birds were counted along either side of the road. Transects were treated as lines and the distances measured with the vehicle odometer. Transects were driven along main roads and other paths, traveling at 15-50 km/hour, averaging 40 km/hour. Data were collected in CyberTracker on tablets. Transects were 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. From these data we can calculate encounter rates (number of individuals per species per 100km) which allows us to track trends in populations over time.

With 9 years of data from 2013 to 2021 for Ruaha and Katavi National Parks (NP) and 4 years of data (2018-2021) for Nyerere NP, a population trend analysis was conducted with the data. It must be noted that as we do not have historical data, the first year of our monitoring acts as our baseline data – this means that population trend changes are relatively recent (<10 years data), but any trajectories are likely to reflect a longer pattern of population change. It is also important to understand short-term population trends to assess and adapt conservation interventions.

A summary of the analysis will be presented here, as a paper with full details will be submitted for peer-reviewed publication in early 2022. We ran a hierarchical generalized linear model with a negative binomial error structure. The resulting model was fitted within a Bayesian framework and used total count per transect as the dependent variable, included date, national park, season, and carcass presence (seen during transect) as predictive factors, whilst transect ID was included as a random factor and transect length as an offset.

Survey Results

Wet and dry season survey transects were conducted across all three national parks in 2021 (Table 2) with a total of 1327.6 km driven along 9 standardized transects. Wet season total distances were between 15-30 km shorter than the dry season equivalent due to poor road conditions towards the end of the transects. Table 3 presents the encounter rates (number of individuals per species per 100 km) across all three sites between 2013 and2021, including average encounter rates across all years.

Table 2 Summary of the vulture monitoring surveys conducted in three national parks in 2021

Location	Season	Month conducted	# transects	Total distance (km)
Ruaha	Wet	January	3	215.9
Katavi	Wet	February	3	193.5
Nyerere	Wet	March	3	217.9
Ruaha	Dry	August	3	246.8
Nyerere	Dry	September	3	235.1
Katavi	Dry	September	3	218.4

Population declines

Based on model outputs, Ruaha NP had generally stable populations from 2013 to 2017, with significant declines appearing from 2018 onwards. For Selous-Nyerere, we have seen concerning declines since surveys began in 2018. It appears to have a high poisoning rate, particularly linked to bushmeat poaching using long snare lines.

Declines were detected for three species: White-backed and White-headed vultures and the Tawny eagle. Southern Tanzania is one of the most important areas for White-headed vultures in Africa, which are territorial and live in low densities, so declines of this species are of great concern.

As an example of the worrying declining trend in White-backed vulture's populations, the encounter rates have steadily reduced across time in Nyerere. In 2018, the White-backed vulture encounter rate was over 80 individuals per 100 km, dropping to an average of around 50 individuals in 2019 and 33 in 2021 (Figure 2). These data are corroborated with high mortality rates in the White-backed vultures tagged in Selous-Nyerere, particularly in 2018 and 2019.

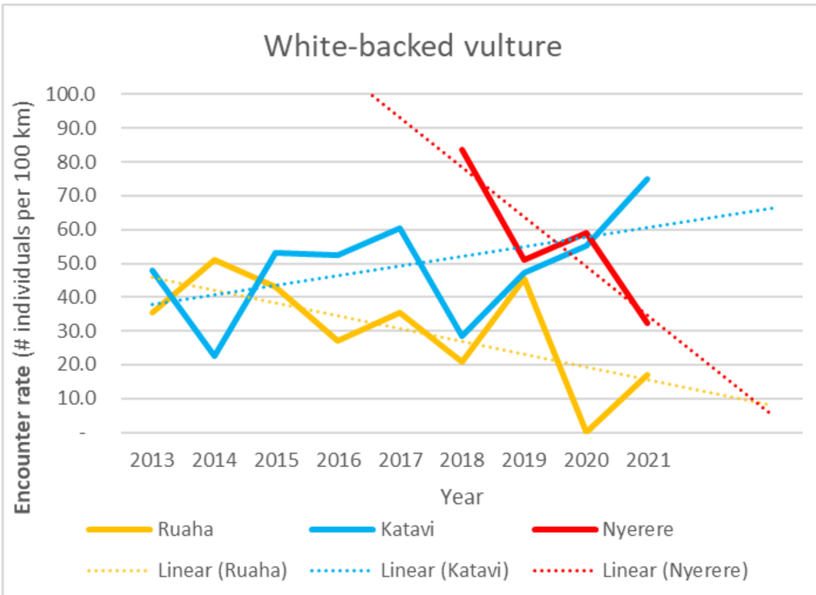
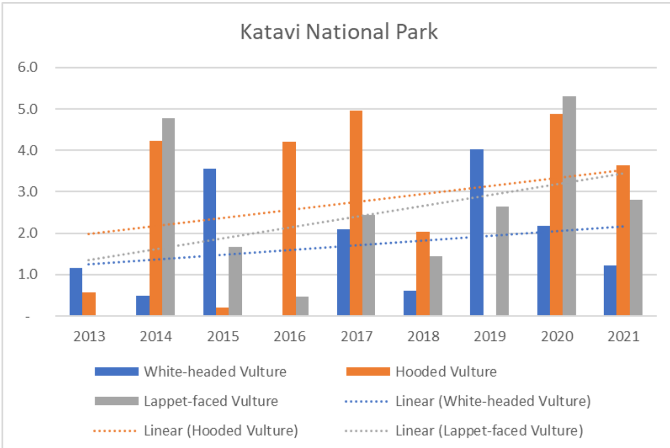
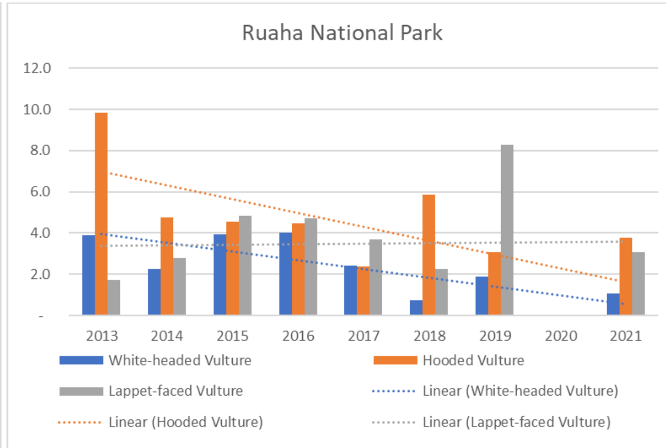


Figure 2 Encounter rates for White-backed vultures across three national parks in southern Tanzania from 2013 to 2021, with a concerning decline in Nyerere NP.

Geographical and seasonal variation

Katavi NP appears relatively stable for most species across time, whilst trends are more variable in Ruaha and Nyerere NPs (Figure 3 and Table 3). Overall abundance of White-backed vultures was higher in Katavi (average encounter rate [ER] was 50.8 birds per 100 km) and Nyerere (average ER 56.1) NPs than Ruaha NP (average ER 32.2) (Figure 2 and Table 3), whilst Tawny eagle abundance was higher in Ruaha NP than Katavi and Nyerere NPs. Abundance differences may be related to food availability and habitat. This also potentially explains some seasonal variation in abundance for species which tend to be more territorial. More Lappet-faced and White-headed vultures and Bateleur eagles were recorded in the wet season, in contrast to fewer Hooded vultures in wet season. On a positive note, we detected increases in Hooded vultures in Katavi NP, Lappet-faced vultures in Ruaha and Katavi NPs, and Bateleur in Ruaha and Nyerere NPs (see Figure 3).





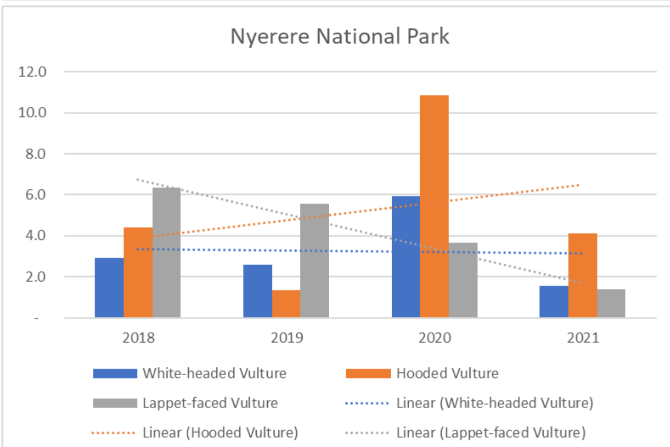


Figure 3 Encounter rates across time for White-headed, Hooded and Lappet-faced vultures in Katavi, Ruaha and Nyerere National Parks, with dashed linear trend lines.

Note that trends in White-backed vultures' abundance are provided in Figure 2. Ruppell's vulture was not included in our analysis due to low observation rates; southern Tanzania is the species southern range limit, and they are far more abundant in northern Tanzania.

Presence of carcasses

A challenge of the roadside count methodology is that vultures aggregate at carcasses, which can lead to higher counts when carcasses are present. Adding carcass presence to the model helped to mitigate this effect in assessing overall population trends. Unsurprisingly, carcass presence during the survey had greatest effect on White-backed, Hooded and Lappet-faced vultures, all of which are primarily scavenging, in contrast to the Bateleur and Tawny eagles, and the White-headed vulture, that have a more mixed diet from hunting and scavenging.

Summary

In 2017, we presented the first five years of monitoring surveys (for Ruaha and Katavi NPs), and concluded southern Tanzania had significant and generally **stable** populations of vultures. Our analysis now shows that the situation has changed with a worrying series of declines across sites and species – this is corroborated by our telemetry study. In particular, we are seeing significant declines for White-backed and White-headed vultures, with Ruaha and Nyerere NPs of most concern in overall declines for several species.

Table 3 Encounter rates (number of individuals per species per 100 km) for three monitoring locations in southern Tanzania

RUAHA	2013 Dry	2014 Dry	2015 Dry	2015 Wet	2016 Dry	2016 Wet	2017 Dry	2017 Wet	2018 Dry	2018 Wet	2019 Wet	2021 Wet	2021 Dry	Average
African White-backed Vulture	35.4	50.9	33.9	52.0	13.6	40.8	31.6	39.4	14.1	27.4	45.5	18.2	16.2	32.2
Bateleur	14.3	18.9	14.6	18.6	17.0	20.6	19.3	21.0	9.5	10.5	28.6	23.1	15.2	17.8
Tawny Eagle	5.2	3.7	6.0	1.0	4.8	3.9	2.7	4.8	2.6	1.2	5.6	2.3	3.3	3.6
White-headed Vulture	3.9	2.3	3.9	4.0	2.8	5.2	2.9	1.9	-	1.5	1.9	1.0	1.1	2.5
Hooded Vulture	9.8	4.8	5.5	3.5	4.7	4.3	3.3	1.5	7.9	3.9	3.1	5.6	2.0	4.6
Lappet-faced Vulture	1.7	2.8	5.6	4.0	1.3	8.1	3.3	4.1	1.9	2.7	8.3	4.6	1.6	3.8
Ruppell's Vulture	-	-	-	-	-	-	-	-	-	0.8	1.1	-	-	0.1

KATAVI	2013 Dry	2014 Dry	2015 Dry	2015 Wet	2016 Dry	2017 Dry	2017 Wet	2018 Dry	2018 Wet	2019 Wet	2020 Wet	2021 Wet	2021 Dry	Average
African White-backed Vulture	47.9	22.7	52.4	54.2	52.3	38.7	82.2	26.5	30.4	47.4	55.1	123.3	26.7	50.8
Bateleur	21.0	7.4	10.5	12.6	14.4	8.3	10.0	11.9	16.3	16.8	11.9	14.0	24.8	13.8
Tawny Eagle	1.2	-	-	-	4.0	1.4	1.0	0.4	2.8	1.8	0.8	-	0.5	1.1
White-headed Vulture	1.2	0.5	-	7.1	-	1.0	3.2	0.4	0.8	4.0	2.2	2.0	0.40	1.8
Hooded Vulture	0.6	4.2	0.4	-	4.2	6.9	3.0	2.0	2.0	-	4.9	6.4	0.9	2.7
Lappet-faced Vulture	-	4.8	0.9	2.5	0.5	1.9	2.9	1.9	1.0	2.6	5.3	5.1	0.5	2.3
Ruppell's Vulture	-	-	-	-	-	-	-	0.4	-	-	-	1.8	-	0.2

SELOUS / NYERERE	2018 Dry	2018 Wet	2019 Dry	2019 Wet	2020 Wet	2021 Wet	2021 Dry	Average
African White-backed Vulture	85.3	81.9	41.9	60.3	58.9	24.3	40.0	56.1
Bateleur	24.6	27.7	8.6	16.4	21.3	7.2	13.2	17.0
Tawny Eagle	-	2.7	-	-	-	-	0.8	0.5
White-headed Vulture	4.6	1.2	2.2	3.0	5.9	-	3.1	2.9
Hooded Vulture	7.6	1.2	1.3	1.4	10.9	5.8	2.5	4.4
Lappet-faced Vulture	9.4	3.3	4.4	6.7	3.6	0.5	2.3	4.3
Ruppell's Vulture	1.4	0.7	-	-	1.4	-	-	0.5

Satellite Telemetry Study

We started the movement study in 2015, and continue to expand the project each year, in terms of numbers of satellite units deployed and location of unit deployment. To date in Tanzania, we have tagged 62 vultures in total from three species (58 White-backed vultures, 2 Hooded vultures and 2 White-headed vultures).

In 2021, we were able to monitor movement data from up to 30 tagged vultures in any one month (29 White-backed and 1 White-headed vulture), trapped from Ruaha, Katavi and Nyerere National Parks, Rukwa and Lukwati-Piti Game Reserves. Birds trapped in the Game Reserves have provided valuable additional information about vulture movement and other activities in the central game reserve complex of the Ruaha-Katavi landscape.

The movement study provides critical real-time information about illegal activities and disease outbreaks. Tagged vultures have become an effective tool for finding large carcasses and extensive snare lines as well as poisoning events. This allows data from our work to contribute to anti-poaching efforts supported by partners Wildlife Conservation Society, Frankfurt Zoological Society, Tanzanian National Parks, and Tanzanian Wildlife Management Authority. Because vultures range across a wider area than carnivores, 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.

Methods

Vultures were trapped using nooses, set up as lines, along carcasses (Watson and Watson, 1985). Noose on noose lines were made of coated wire cord or monofilament, and the noose line was made of parachute cord. Nooses were 10-15 cm in diameter. Noose on noose lines were staked into the ground using tent pegs for added stability. Grass or carrion was used to help hold the nooses upright to increase the chance of a capture. Noose lines consisted of approximately 6-8 nooses. Once a bird was captured, processing took approximately 20 minutes per bird; birds' eyes were covered to reduce stress and the handler restrained both feet and head.

Solar-powered ARGOS/GPS PTT tags (Microwave Telemetry, Inc., Columbia, Maryland, U.S.A.) units (70g for White-backed vultures and 45g for Hooded vultures) were attached as backpacks using Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania, U.S.A.). Units are set to take GPS waypoints every hour from 6 AM to 7 PM and at midnight each day for a total of 15 points per day, and to transmit data every day via ARGOS satellites. The transmitters provided information on velocity, altitude, and location (GPS coordinates) and have an internal activity sensor that detects movement. When a mortality event was 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 was made as rapidly as was logistically possible to determine cause of death.

Photo 1 Vulture trapping in the Ruaha-Katavi landscape, targeting the critically endangered White-backed vulture.

Top left, Dr Claire Bracebridge, NCZ, with a tagged White-backed vulture prior to deployment; top right, researcher Leons Mlawila holds an adult White-backed vulture whilst Msafiri Mgumba, WCS, attaches a satellite unit. Bottom right, release of tagged bird by Dr Jessica Manzak; bottom right, a female Spotted hyena visiting the trapsite, attracted by the bait. Photos @ Claire Bracebridge, NCZ.

Results

In 2021, we successfully deployed a total of 11 satellite units on White-backed vultures, including 3 new units and 8 redeployments (Table 4). At the end of 2021, we had 23 active units in Tanzania. The longevity of our dataset is significant with 2 birds with more than 5 years of data, 1 bird with 4 years of data, 5 birds with between 2.0-2.5 years, 5 birds with around 1.5 years and 9 birds with <6 months of data. Real-time data from these tagged individuals is shared with our partners across the project sites to assist in monitoring and anti-poaching efforts.

Table 4 Information on satellite unit tagged vultures across 2021

Category	Subcategory	Ruaha-Katavi	Greater Selous	Total
Current # tagged birds (Dec 2021)	WBV	15	7	22
	WHV	1	0	1
	Subtotal	***16***	***7***	***23***
Mortality	Confirmed poisoning	2	0	2
	Presumed mortality; no unit retrieved, no bird	1	0	1
	Subtotal	***3***	***0***	***3***
Unit issues	Unit transmission stopped, unknown if bird death	0	1	1
	Unit comes off	2	3	5
	Subtotal	***2***	***4***	***6***
Known nests	WBV	4	5	9
	WHV	1	0	1
	Subtotal	***5***	***5***	***10***

** WBV – White-backed vulture; WHV – White-headed vulture.*

Range, habitat, and connectivity

A total of 560,715 km was flown by all tagged birds in 2021, with 337,347 km travelled by 20 Ruaha-Katavi tagged birds and 223,365 km by 10 Selous-Nyerere tagged birds. On average, Ruaha-Katavi birds travelled 16,867 km per year contrasting to the greater average distances of Selous-Nyerere birds at 22,337 km.

The Selous-Nyerere tagged birds regularly flew to northern Tanzania, and this likely accounts for the greater average annual distances flown when compared to the Ruaha-Katavi birds. Movement north was more frequent during the wet season via the two corridor routes connecting Nyerere and Mikumi to the important Wami Mbiki Game reserve, and then via a distinct narrow corridor using the flat plains of the Masaai steppe between the mountains (Figure 4). The birds tended to forage within the Tarangire-Simanjiro ecosystem, but did not travel into Serengeti in 2021, suggesting the Serengeti-Mara population is largely distinct from the two southern Tanzanian populations. One bird travelled into Tsavo in Kenya in January, whilst one bird, tagged in Lukwati-Piti GR in Ruaha-Katavi, travelled to Uganda at the end of May and spent one month in Lake Mburo NP before returning via Burigi-Biharamulo NP and the Moyowosi-Kigosi ecosystem. This bird also tended to spend time in the northern part of Ruaha-Katavi in Ugalla GR and Ipole WMA.

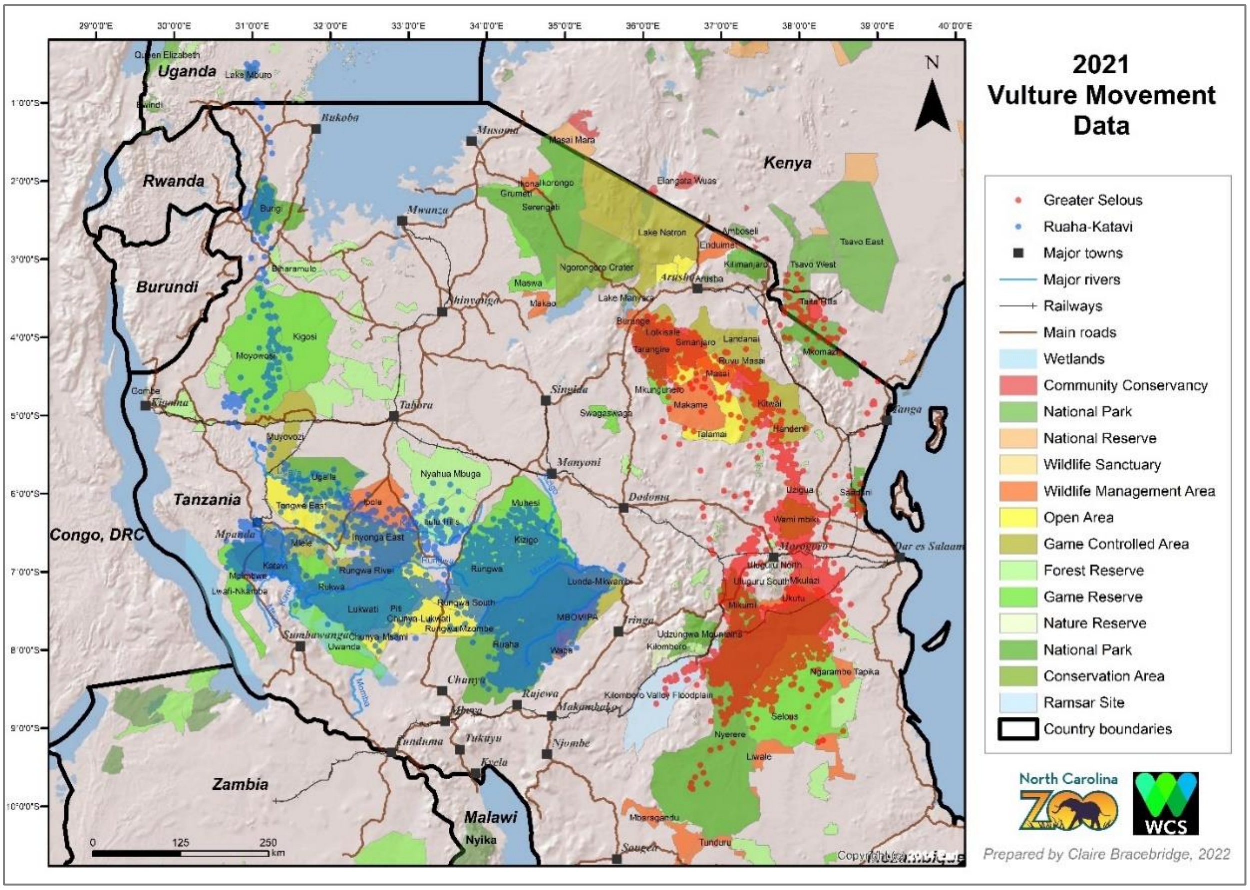


Figure 4 Movement data from January to December 2021 for a total of 20 tagged vultures in the Ruaha-Katavi landscape (blue circles) and 10 tagged in Selous-Nyerere in southern Tanzania (red circles).

In Ruaha-Katavi, movement patterns from the birds tagged in different locations across the landscape suggests there may be a subpopulation structure of White-backed vultures within the landscape. Ruaha tagged birds (n=21, Figure 5) tended to stay within the northern half of Ruaha NP, whilst birds tagged in Lukwati-Piti GR (n = 9, Figure 6) utilized more of the centre of the landscape, as well as some parts of the eastern Ruaha-Rungwa ecosystem. Birds tagged far west in Katavi NP and western Rukwa GR (n =11, Figure 7) predominantly focused ranging in these areas and to a far lesser extent the central and eastern parts of the landscape. Most common overlap of the subpopulation ranging was the use of Ruaha, particularly along the Great Ruaha River, where high aggregations of wildlife are found. This has implications when assessing variations in poisoning risk and dynamics of source-sink populations.

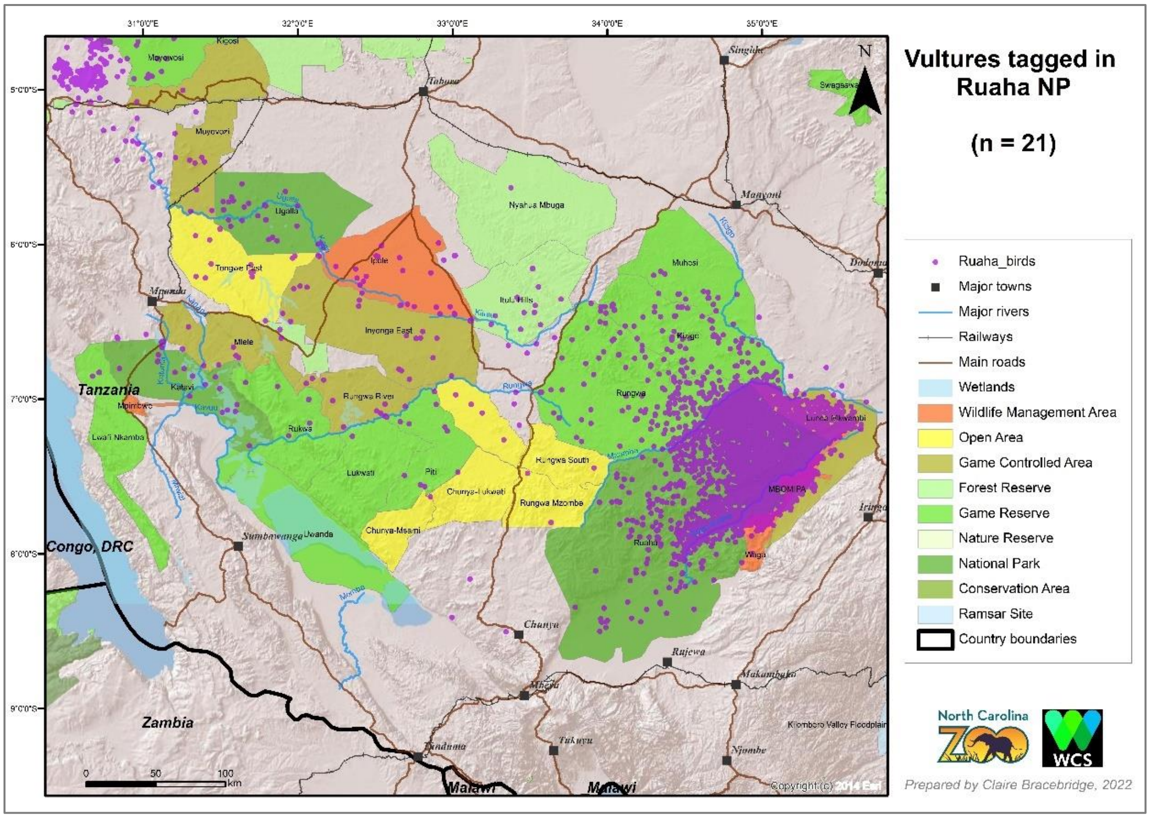


Figure 5 Ranging patterns of 21 vultures tagged in Ruaha National Park between 2015 and 2021.

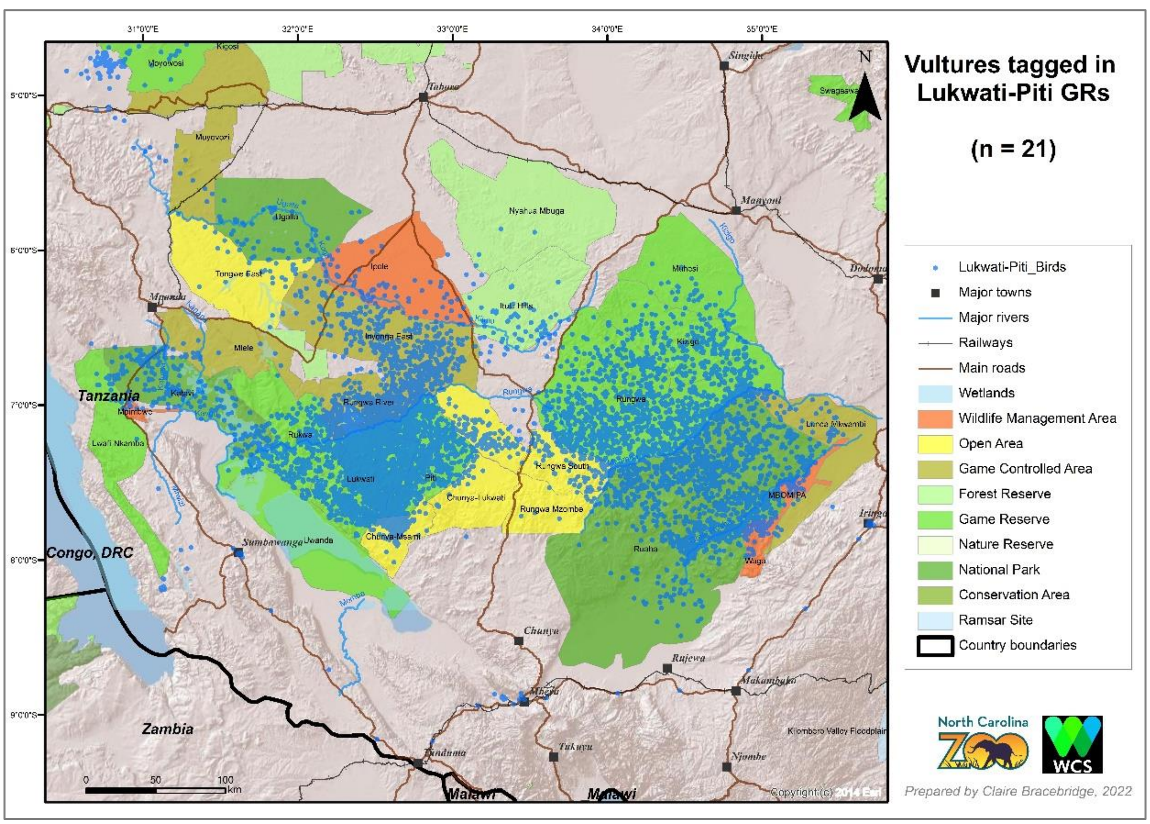


Figure 6 Ranging patterns of vultures tagged in Lukwati-Piti GR between 2018 and 2021.

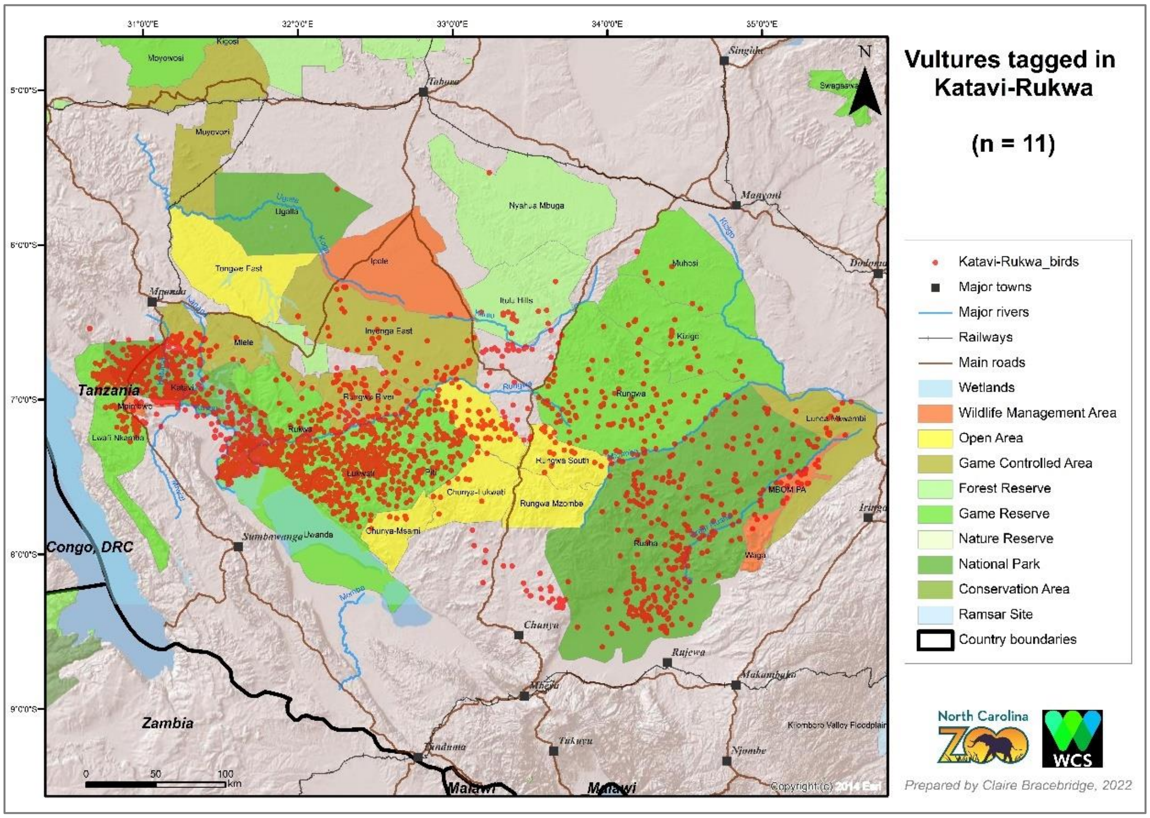


Figure 7 Ranging patterns of vultures tagged in Katavi NP and Rukwa GR during 2018 and 2021.

Breeding

We confirmed a record number of breeding records this year. One of the two remaining White-backed vultures tagged from 2016 was recorded breeding for the fourth year throughout this period, using the same breeding site. The other bird tagged in 2016 was an immature individual, and this year, movement patterns clearly indicated breeding behavior. For both birds, palm trees were used beside the river in Ruaha NP. We also confirmed breeding of the White-headed vulture in Katavi NP. This is the third breeding record since it was tagged in 2018, although only two have been confirmed by visual observation. A fourth bird was thought to be breeding in Lukwati-Piti GR based on movement data, but we were not able to verify, whilst a White-backed vulture only tagged in August 2021 indicated it was visiting a nest on a near daily basis during August and September. Frequency of visits reduced in October consistent with the normal fledging period for grown chicks.

In Nyerere NP, 50% of our tagged birds (5 out of 10) were recorded breeding – a significant record. From aerial checks, we were able to see 4 of the nests, but could not confirm the fifth. Birds here preferred the use of tall trees, such as *Sterculia appendiculata* and *Adansonia digitata*. In contrast, we only had one bird in 2020 whose movement patterns indicated breeding behavior (although this was not verified).

Poisoning detection

Information from tagged vultures used to detect carcasses has provided vital information about other wildlife species of concern. Bird mortalities alert to poisoning events when carcasses are laced with pesticides. We have discovered retaliatory, sentinel and belief-based driven poisonings across southern Tanzania. Working with our partners, such as WCS and wildlife authorities, we have been able to contribute to law enforcement efforts.

Tagged bird mortality

2021 mortality

In 2021, we had 2 confirmed mortalities in the buffer zones around Ruaha NP. Both were due to retaliatory poisoning i.e., livestock-carnivore conflict. In the one instance, 4 White-backed vultures were found dead, and 2 heads were missing. This suggested harvesting vulture parts was a secondary motivation and most likely for local, not commercial, use. Unfortunately, the satellite unit was destroyed. In the second poisoning, the bird died just 2 weeks after the unit had been deployed on it. The bird, along with 2 other vultures, died from secondary poisoning after feeding on a poisoned hyena, likely the intended target of the poisoning. Another presumed death was recorded, despite no unit or bird being located. This was because the last known point before unit transmission stopped was at a poacher's camp used for drying buffalo bushmeat. We assume the bird was killed and unit destroyed by the poachers. Mortalities were lower than 2020 where there were 3 confirmed mortalities, one of which was a large-scale retaliatory poisoning event, and 2 presumed mortalities, likely linked to human activity. Because many poisoning events in these ecosystems appear to be smaller in extent, tagged vultures are unlikely to be detecting all poisoning events in the landscape.

Five units fell off, either from the weak point at the knot or wearing through the straps at the point of entry to the unit as intended. Units were retrieved and will be redeployed. Units were on the bird for between 688 – 1,752 days before falling off, an average of 1,000 days or 2.75 years.

Transmission stopped for 1 bird. This is less likely to be a death, as unit battery and downloading was sporadic prior to transmission halting. The unit was either sitting on the bird poorly i.e. it was getting loose, or there is a problem with the unit itself. The tag was deployed in September 2020.

Overall mortality (2015-2021)

Of the 62 vultures tagged in southern Tanzania since 2015, we have recorded 18 confirmed mortalities – an overall mortality rate of 29% (Figure 8). Of these, 6 were confirmed to be the direct result of poisoning events, all of which were on the edges or the buffer zones around the national parks (Figure 6, red circles, and triangles). Four incidents were retaliatory poisoning and 2 were sentinel poisoning. There were another 8 presumed deaths, where the bird was not located, but circumstantial evidence suggested that human activity was linked to the mortality alert of the unit and the disappearance of the bird e.g., the last known location at a poaching camp. From the known 6 poisoning events, a total of 204 birds were killed, of which 197 were vultures (97% of all birds) in contrast to just 5 hyenas. Of the vultures killed, 117 or 87% were White-backed vultures. A total of 61 heads (31%) were missing from the birds, in what appeared to be a secondary motivation for harvesting the body parts. At least one of the poisoning events, with 43 heads taken from approximately 100 vultures, suggested commercial trade of vulture parts, whilst all other incidents had a few heads taken most likely to be used locally.

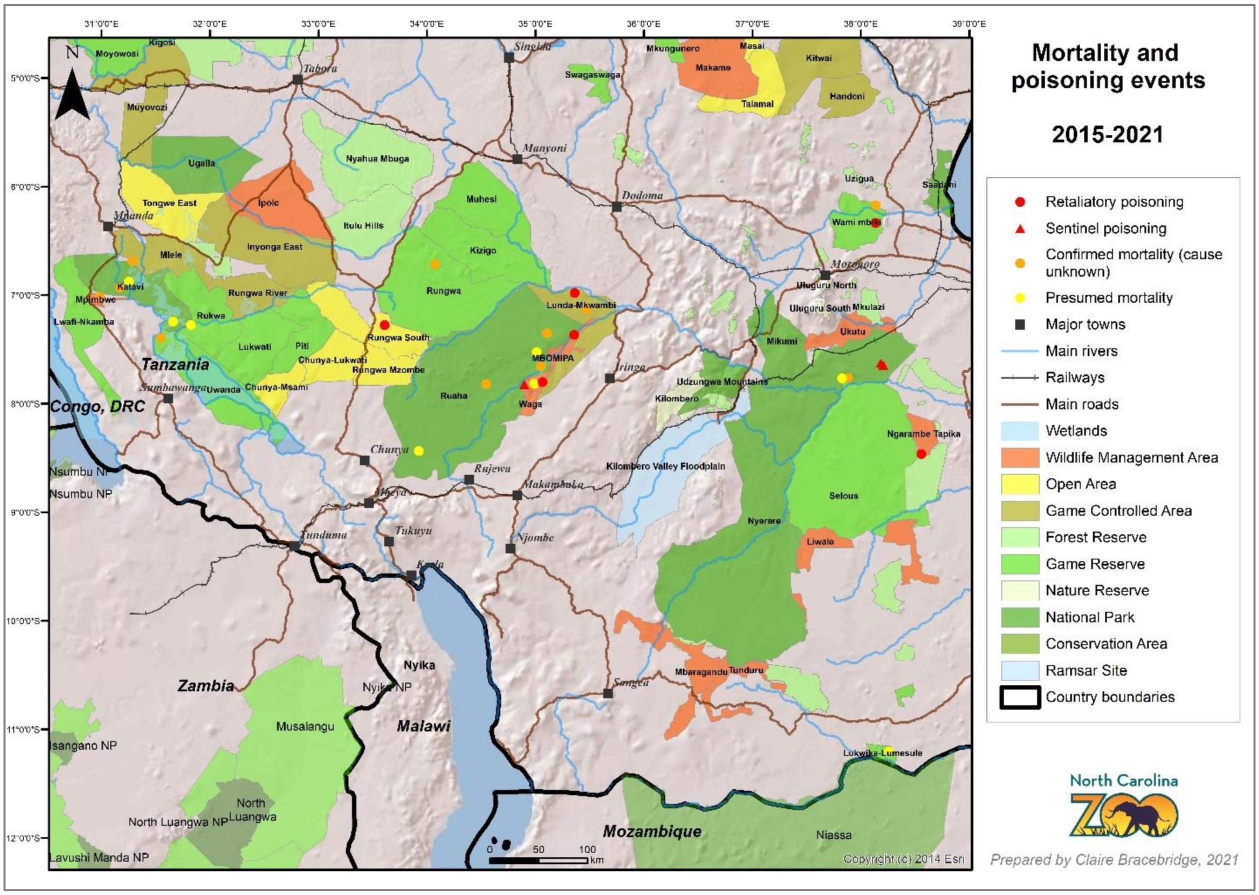


Figure 8 Mortality events (n = 26) from a total of 62 vultures, tagged across southern Tanzania between 2015-2021.

A survival analysis of the tagged bird data showed that approximately 75% of tagged birds survived one full year after tagging. However, in contrast to an expected annual adult mortality rate of 5% (i.e., death from natural causes), we found there was between 20-36% average annual mortality. Mortality across years was variable and may be impacted by resource availability and seasonality, with both wildlife (ungulate and carnivore) and livestock movement patterns shifting in response to potentially overlapping resources and increasing the risk for human-wildlife conflict and retaliatory poisoning. It is clear that these high mortality rates are not sustainable, and the vulture's trajectory continues towards extinction if solutions are not found to reduce poisoning.

Two key analyses by PhD student Natasha Peters (based at University of York, with advisory support from NCZ's Dr Corinne Kendall) have used the tagged vulture movement data to understand and predict poisoning risk within the landscape to inform conservation management decisions. From her foraging analysis based on Hidden Markov models, Natasha was able to identify several behavioral states i.e., feeding, foraging, resting, and travelling within tagged vulture movements. From this, she could explore how feeding habitat use varied in relation to other behaviors. Vulture overall ranging and feeding ranging behavior across the landscape are not uniformly distributed. The analysis highlighted the importance of assessing feeding behavior rather than ranging behavior to identify areas of high risk for poisoning, which is only of concern in areas where vultures are feeding. In a second set of analyses, Natasha used mark-recapture analysis to assess how carcass detection by vultures varied spatially. Based on information from the tagged bird mortality and other poisoning incidents reported to the African Wildlife Poisoning Database (https://www.africanwildlifepoisoning.org/), poisoning threat was overlayed with exposure to carcasses to identify areas which represented high risk of poisoning. These high-risk areas tended to be in the buffer zones around main protected areas. More details will be available once the manuscripts have been published.

Nest surveys in Grumeti

It is challenging to obtain meaningful information on nesting densities within the vast southern Tanzania landscapes due to high tree cover, large areas of the study, use of palm trees for nests which makes nests difficult to detect and limited aerial surveys. For this reason, we have focused our efforts on roadside surveys which allow us to get comparable estimates of population numbers over time for several tree-nesting vulture species at once. However, in northern Tanzania, the Grumeti Fund support management within 12,000 km^2 of protected area buffering the northern edge of the Serengeti, consisting of Grumeti and Ikorongo GRs and Ikona WMA. Nesting opportunities for White-backed vultures, who prefer tall trees, is limited to discrete riparian strips along key river networks. This effectively imitates the behavior of cliff-nesting vultures, such as Ruppell's vultures, where colonies of cliff nests enable accurate information about population trends and density because the breeding behaviors are concentrated in a small, consistently used area. Additionally, the Grumeti Fund has conducted aerial surveys of riparian habitat between 2013 and 2021, and results from these indicate declines in the number of active White-backed vulture nests over time. This provides an important opportunity to try to understand for a tree-nesting species what is driving these declines – is it changes in food availability, habitat factors (reduced tree availability), or other underlying mortality causes, such as poisoning? To assess this, NCZ and Grumeti Fund are collaborating to fund and support a Tanzanian Masters student at Sokoine University of Agriculture. For the 2021 breeding season, two ground nest surveys were conducted during the breeding season (March to September), which will provide insight into breeding success, in addition to the 2021 riparian aerial census. A trend analysis of the aerial census and initial analysis of ground survey results will be conducted in early 2022, whilst a second season of nest surveys will be conducted from April 2022.

Capacity building

The telemetry study, in particular the death of tagged vultures, has highlighted the threat of poisoning to these birds (and other scavenging species). In general, the problems of poisoning, the impact to vulture population numbers and the overall importance of vultures to ecosystem health and services is little known or appreciated by those working within the protected area networks. Therefore, our project focuses on ranger training to provide awareness raising and capacity building on practical steps in dealing with a poisoning incident in a systematic way, as well as providing general education about vultures. We conducted two ‘response to poisoning’ trainings in 2021, one in Maswa Game Reserve with a total of 39 participants, a mixture of rangers from Maswa Game Reserve, Wildlife Conservation Limited and Makao Wildlife Management Area, which was organized and part-funded by Mwiba Ranch. In addition, we trained 49 Nyerere National Park rangers, organized, and funded by FZS. Together with the 50 TAWA rangers trained for Selous GR in September 2019, there are now 99 wildlife staff trained for the Selous-Nyerere ecosystem, bringing the overall total rangers and local NGO partners trained by NCZ to 237.

Table 5 Participants during two ‘response to poisoning’ trainings conducted by NCZ during 2021

Area	Protected area	# participants	# male	# female	% females
Northern Tanzania	Maswa Game Reserve	19	12	7	37
Northern Tanzania	Wildlife Conservation Limited	10	10	0	-
Northern Tanzania	Makao Wildlife Management Area	10	6	4	40
Southern Tanzania	Nyerere National Park	49	46	3	6
Total participants		**88**	**74**	**14**	**16**

The training consisted of the following:

1) importance of vultures (status and threats),

2) their biology, and

3) what to do in the event of a poisoning event, including

   a) area search protocol,

   b) filling in a poisoning incident form (data collection / evidence),

   c) how to deal with sick but live birds,

   d) how to take samples from carcasses to test for the type of poison used (especially if a vet is not present to do this), and finally,

   e) safe disposal of the carcasses to prevent secondary poisoning occurring.

Training focused on practical group work based on poisoning event ‘scenarios’. These became progressively more complex to assist in discussion of what might occur and how to deal with such situations in the field. Scenarios initially comprised of indoor group work switching to outdoors, implementing search protocols to find ‘carcasses’. After the training each participant was given a manual covering all the above topics, whilst poison sample kits were distributed to patrol teams. Pre- and post-training evaluation tests showed improvement in vulture identification skills and a sound theoretical knowledge of what to do during a poisoning event, as well as confidence in implementing the training and appreciation of the acquired new knowledge and skills. For Nyerere rangers, average test results went from 20.2% to 68.5% and from 23.9% to 71.5% for the rangers from northern Tanzania.

Photo 2 Response to poisoning training

Top: Group work, filling in the data form for evidence collection. Middle: Dealing with a poisoning event practical - searching for carcasses. Bottom: Post-training group photos with training certificate. Photos @ Claire Bracebridge and Jessica Manzak, NCZ.

Communications

Monthly summaries of our movement data are shared with our key local partners in both project sites as well as to the Tanzania Wildlife Research Institute and the Tanzania Commission for Science and Technology, who authorize the research to be conducted in Tanzania.

We also disseminated our work via newsletters to specialist groups, such as the Raptor Taxon Advisory Group and the IUCN Vulture Specialist Group, and wrote popular articles for various social media outlets, including the North Carolina Zoo blog series (https://www.nczoo.org/blog/capacity-building-tanzania-training-rangers-how-deal-poisoning-incident) and Facebook posts (https://www.facebook.com/nczoo/videos/542388676971741/). We have several co-authored papers in progress based on our vulture monitoring and research work in Tanzania (see below).

	Title / Author	Journal	Status
1	Chapter: Ecology and Conservation of African White-backed Vultures (Gyps africanus) Corinne J. Kendall, Claire E. Bracebridge https://doi.org/10.1016/B978-0-12-821139-7.00160-4	Book: Reference Module in Earth Systems and Environmental Sciences	Published
2	Understanding continent-wide variation in vulture ranging behavior to assess feasibility of Vulture Safe Zones in Africa: challenges and possibilities Adam Kane, Ara Monadjem, Keith Bildstein, André Botha, Claire Bracebridge, Evan R. Buechley, Ralph Buij, John P. Davies, Maria Diekmann, Colleen Downs, Nina Farwig, Toby Galligan, Gregory Kaltenecker, Chris Kelly, Ryno Kemp, Holger Kolberg, Monique MacKenzie, John Mendelsohn, Msafiri Mgumba, Ran Nathan, Aaron Nicholas, Darcy Ogada, Morgan B. Pfeiffer, W. Louis Phipps, Matt Pretorius, Sascha Rösner, Dana G. Schabo, Orr Spiegel, Lindy J. Thompson, Jan A. Venter, Munir Virani, Kerri Wolter, Corinne Kendall	Biological Conservation	In review
3	A Novel Approach to Modelling Animal Tracking Data: Defining Behavioural States to Understand Space Use for Conservation Natasha Peters, Colin M. Beale, Claire Bracebridge, Corinne J. Kendall, Msafiri Mgumba	Journal of Biogeography	In revision
4	Incorporating spatial distribution into risk assessment for a wide-ranging scavenger Natasha Peters, Corinne J. Kendall, Jacob Davies, Claire Bracebridge, Msafiri P. Mgumba, Aaron Nicholas, Colin M. Beale	Conservation biology	In prep.
5	Comparison of transects and telemetry to determine short-term population trends in a highly threatened species	Conservation Biology	In prep.

	Corinne J. Kendall, Claire Bracebridge, Adam Kane, Emily Lynch, Msafiri Mgumba, Ara Monadjem, Aaron Nicholas	
6	How Do Human Disturbance and Competition Affect the Feeding Ecology of Scavenging Raptors? Behavioral ecology and sociobiology Mika Takahashi, Grant Hopcraft, Jana Jeglinski, Corinne J. Kendall	In prep.

Findings from our work were presented at the Tanzania Wildlife research Institute's (TAWIRI) conference, at the Association of Zoos and Aquarium's annual conference, and at the Society of Conservation Biology's International Congress for Conservation Biology (ICCB) in December 2021. At the ICCB, NCZ chaired a symposium called "The Problem of Poisoning: Understanding and addressing an overlooked threat to African Wildlife", with panelists representing some of the main vulture conservation and research activities in southern and eastern Africa. This functioned as a forerunner to the Pan-African Ornithological Congress workshop, which will be held in November (postponed since November 2020 due to Covid-19) and will bring together practitioners from multiple countries to develop best practices for response to poisoning training. This workshop will be coordinated by NCZ, as chair of the African Vulture SAFE program.

Project Development

We continued to strengthen partnerships with Birdlife International and the Peregrine Fund for cross-border vulture conservation and research in the Mara-Serengeti, with initial discussions about the concept of Vulture Safe Zones for this ecosystem. In southern Tanzania, we started to formalize work with Lion Landscapes (formerly Ruaha Carnivore Project) to support their community-based project expansion to north-eastern Nyerere National Park / Selous Game Reserve – an area of high poisoning risk.

As part of our broader goal to conserve wildlife using vultures as ecosystem indicators and informants within the large, protected landscapes in Africa, we expanded our partnership and work beyond the borders of Tanzania. In September 2021, we collaborated with Panthera to establish our vulture research and monitoring activities (transect surveys, telemetry work and response to poisoning training) in Kafue National Park, Zambia. The 2017 Multi-species action plan for Eurasian-African vultures highlighted the lack of information on vulture status in Zambia. Efforts have been made to survey vultures in large, protected areas including South Luangwa and Lower Zambezi National Parks, but not Kafue. This work continues an existing NCZ-Panthera partnership which has been focused on SMART (Spatial Monitoring and Reporting Tool). Using the established SMART system combined with data provided by tagged vultures will greatly improve patrol efforts. To further streamline the accessibility, efficiency, and response time, we are working with Movebank (an online platform for storing movement data hosted by the Max Planck Institute of Animal Behavior) to automate the NCZ custom-developed tool which analyzes the vulture movement data to detect carcasses. In 2022, this will be integrated into the EarthRanger software used by park authorities for real-time monitoring.

Conclusions and Future Work

Analysis of our monitoring data between 2013 and 2021 have produced results that unequivocally highlight worrying declines seen in most vulture species, but particularly the White-backed vulture. As a landscape species, with a vital role in the ecosystem, vultures can act as early warning systems for other conservation issues, especially linked to poisoning and poaching. White-backed vultures are most at risk from poisoning events due to their wide-ranging behavior and gregarious feeding habits. As such, they can act as an umbrella species for other vultures (Thompson et al., 2021) as well as carnivores and elephants and thus their declines are worrying in relation to the entire ecosystem.

Our efforts in 2022 will focus on conservation interventions. Overarching other activities will be developing a National Action Plan for vultures. A comprehensive guideline is needed to recognize and address the threats facing vultures of Tanzania to enhance the long-term conservation of these highly threatened species. Other work will include:

- Continue monitoring tagged vultures and responding to any mortality alerts
- Conduct response to poisoning training with wildlife authorities and communities
- Continue important partnerships via the telemetry study for anti-poaching support together with WCS, FZS, and wildlife authorities (TANAPA and TAWA)
- Develop and support the Lion Landscapes community program around Nyerere-Selous ecosystem
- Work with WCS to explore the possibility of integrating vulture nest recognition via machine learning into the work supported by their aviation program
- Provide continued support and supervision to at least two (PhD and MSc) students.

Acknowledgements

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Partnerships

Donors

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