Unearthing poison use and consequent anecdotal vulture mortalities in Namibia's commercial farmland – implications for conservation

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Type of article: Research article
Short running title: Anthropogenic vulture mortality in Namibia

Abstract

Across Africa, the illegal use of poison is triggering a continent-wide scavenger crisis, with vultures suffering the most severe negative consequences. Vultures may die as indirect victims of the conflict between livestock farmers and predators, or they may be directly targeted by poachers with the aim to reduce the role of vultures as sentinels that alert authorities of poaching events. In this study, we provide novel information on vulture mortalities across the commercial farmlands of Namibia. We show that estimated mortalities of vultures due to anthropogenic causes amount to over 800 individuals over the period 2000-2015, which underscores the magnitude of the problem. The highest numbers of vulture deaths were reported from the southern half of the country, with the exception of the areas just south of Etosha national park, and poisoning was the number one cause of reported deaths. Aldicarb or carbofuran were the most commonly used poisons, but strychnine is still used by about one farmer out of ten. Poison is typically used by means of distributing poisoned baits on the landscape. Furthermore, willingness to use poison in the future was highest for farmers who own large properties with high livestock numbers, particularly sheep and goats, farmers who purportedly suffered high livestock losses to predators and who have a negative perception towards predators. We discuss the implications of these results and the possible urgent actions that should be implemented in order to address this devastating practice before it will impact vulture populations to irreversible levels.

Introduction

The human appropriation over natural resources has been intensifying during the past decades as a result of the growing needs of modern societies (Vitousek et al. 1997). This appropriation has taken place in different ways, typically causing, among others, loss and degradation of habitats and species overexploitation (Pimm et al. 2014). Farming is among the land uses with the highest footprint on Earth's ecosystems, and livestock farming is among the most important livelihoods in rural Africa (Robinson et al. 2014).

In recent decades, human-wildlife conflict has been escalating across Africa (Lindsey et al. 2013). When predators kill livestock, individual farmers often react by applying a range of measures, typically involving an attempt to eliminate the predator. In their attempt to eliminate predators, farmers often revert to using poison (Ogada 2014, Santangeli et al. 2016). Poison is typically strewn over the carcass of the killed livestock or placed in the environment using small contaminated baits. The use of poison to eliminate predators is an illegal practice in most countries of the world (Ogada 2014) and may affect not only the primary target animal, but the whole scavenger community, including vultures, with possible cascading effects through the ecosystem (Buechley and Şekercioğlu 2016, Ogada et al. 2016a).

In Africa, unintentional and sometimes secondary poisoning of vultures is widespread and has escalated to a level such that it is considered the major threat to the persistence of most vulture species across the continent (Ogada et al. 2016b). Along with unintentional poisoning, African vultures are also affected by rapidly increasing intentional poisoning perpetrated by poachers intending to eliminate vultures, as they act as sentinels that can lead authorities to poaching events (Ogada et al. 2016a). Other threats include collision with and electrocution on energy infrastructure, as well as direct taking for traditional medicinal practices, disturbance at breeding sites, and possibly to a lesser extent drowning in water tanks and other threats (Ogada et al. 2016b).

Vultures provide key services to the ecosystem, including preventing the spread of diseases, such as anthrax and rabies, by cleaning the environment of decomposing organic material (Buechley and Şekercioğlu 2016). In doing so, they have also been found to reduce the carbon emissions from livestock farming (Morales-Reyes et al. 2015). Vultures are also charismatic species that can play a role in the ecotourism business. For these reasons, there is a strong and increasing interest in pushing vulture conservation to the top of the agenda of African governments, conservation organizations and scientists (http://web.unep.org/unea/table-resolutions-adopted-unea-2). In this light, science can play a key role in providing the evidence base for implementing effective actions.

In order to design and implement effective conservation actions, it is important that the underlying conservation issue is thoroughly understood and characterized. A recent study shed light on the factors underlying poison use by commercial farmers in Namibia, and quantified its prevalence and distribution (Santangeli et al. 2016). Here we build and expand on that study. Our general aim is to unravel poison use and consequent vulture mortalities on Namibia's commercial farmland with data from the recent past, but also with an eye to the future. Specifically, we first quantify reported numbers of vulture mortalities on commercial farmlands of Namibia. We then quantify the causes of death and their distribution across the country. Further, we provide information on the type and manner in which poisons are used by commercial farmers. Finally, we quantify the factors affecting the intention of farmers to use poison in the near future.

Methods

Questionnaire design

We administered a questionnaire to commercial farmers across Namibia between September and November 2015. The questionnaire included a series of relevant questions aimed to characterize and quantify the past, present and future intention to use poison by farmers in Namibia (see below and Santangeli et al. 2016 for details about the protocol for data collection). Overall, a total of 412 questionnaires were filled by farmers across Namibia's commercial livestock farmland (see Santangeli et al. 2016).

AS or VA administered the questionnaires in person. Questionnaires were administered in English, each lasted about 10 minutes, and respondents could fill them by themselves or with guidance (e.g. AS or VA read the questions and marked answers given by respondents). Most respondents from all ethnic groups could speak English to a very good level, thus the use of English did not introduce any bias in the representation of the ethnic groups. We approached commercial farmers in Namibia by driving along roads and stopping at farms (n = 32 questionnaires), and by spending a few days in agricultural retail chain stores (n = 380), which are scattered across the country and regularly visited by farmers.

The survey included a first set of 12 questions on factors believed to be important in explaining why farmers use poison. The questions asked about the total number of livestock owned (here after *Total stock N.*), number of small stock owned (*N. small stock*), *farm size*, the percentage of overall livestock lost in the past year *(% stock lost*), the *cause of loss* (whether it was mainly predators or other causes), the *age* of respondent, the percentage of income generated from livestock farming (*% income from farming*), the frequency with which they see vultures on the farm (*frequency vulture sighting*), their *relationship to predators* (on a five point Likert scale from strongly disagree to strongly agree), *to game*, *to farmworkers*, and their *perception towards vultures*. In addition, we calculated a posteriori, the distance of the farm to the closest national park (*Distance to National Park*). More details about these questions are available in (Santangeli et al. 2016).

We then asked the following sensitive question to each respondent: "Would you use poison to kill a predator, if you had lost livestock to predators?". Because this is a sensitive question, asking it directly to a farmer may generate biased results, i.e. the prevalence of the behavior may be underestimated as respondents may not always tell the truth. We thus employed a technique, called the randomized response technique (RRT) as a method to obtain accurate estimates of the prevalence of the studied sensitive behavior (Nuno and St John

2015). The RRT uses a randomizing device (see details of the application of the technique in Santangeli et al. 2016) to introduce a chance component when answering a sensitive question, thereby ensuring respondents protection (Nuno and St John 2015). We chose an RRT design that allows for the highest statistical efficiency: the “forced response” randomized response technique (Lensvelt-Mulders et al. 2005, Nuno and St John 2015). The choice was driven by the suitability of the technique for use across a range of respondents with different education levels. Furthermore, it allows modeling the link between the prevalence of the sensitive behavior and predictors possibly associated with that behavior (Nuno and St John 2015).

After asking the sensitive question with the appropriate technique (as detailed above), we asked a series of specific questions. Specifically, we asked whether the farmer has seen / found any dead vultures on the farm in past years. If dead vultures were found, we asked how many were found, when that occurred and what the cause of death was. As for the determination of the cause of death, this was based on farmers own assessment grounded on past experience. If a farmer admitted to using poison, we asked what type of poison was used, how it was administered and whether the carcass of the dead predator was removed after using poison.

Statistical analyses

We first derived descriptive statistics to address the first three aims of the study (i.e. to quantify vulture mortalities, to determine the cause of death and distribution, and to assess the type and manner of poison use). We also created maps showing the number of vulture mortalities and the causes of these mortalities using ArcGIS 10.1 (ESRI). We then modeled the relationship between intention to use poison and the 13 socio-environmental predictors using Generalized Linear Modelling (GLM). The error structure was assumed to be binomial with a link function appropriate for randomized responses (van den Hout et al. 2007). This consists of a modified logit link function that incorporates known probabilities of the forced RRT responses (van den Hout et al. 2007). We then applied the same protocol for multi-model averaging and inference as done by Santangeli et al. (2016). That is, we ran all model combinations using the 13 predictors and derived the predictor coefficients by calculating the average of all the regression coefficients within the 95% confidence set, weighted by their BIC (Bayesian information criterion) weights (Santangeli et al. 2016). The relative importance of individual predictors was then derived using the ratio of absolute values of the t statistics for unstandardized predictors (Cade 2015). The GLM was fitted using the RRreg (Heck and Moshagen 2016) package in R 3.3.0 (R Core Team 2016).

Not all the questionnaires were fully completed, and not all of the questions were relevant to the full set of respondents (e.g. poison type was only relevant to those who admitted to have used poison). Because of this, the sample size for the various questions linked to the aims differs.

Results

A total of 412 commercial farmers were interviewed between September and November 2015 as part of a study aimed at quantifying current poison use and the factors affecting this behavior (Santangeli et al. 2016). Out of the total farmers interviewed, 375 (approximately 11% of all commercial farmers estimated at3500 in the country) replied to at least one of the additional questions regarding the occurrence of dead vultures on their farm, the cause of death, and more specific questions related to the poisoning method and type of poison.

Number, distribution and cause of vulture mortality

Of the 375 farmers who provided information on dead vultures, 84 reported to have found dead vultures over the past years. An overall estimated number of vultures found dead totaled 804 individuals over the period 2000 - 2015. Vulture mortalities appear to concentrate in particular regions of Namibia (Figure 1), specifically in the southern half of the country and in the area just south of the Etosha National Park (in the north).

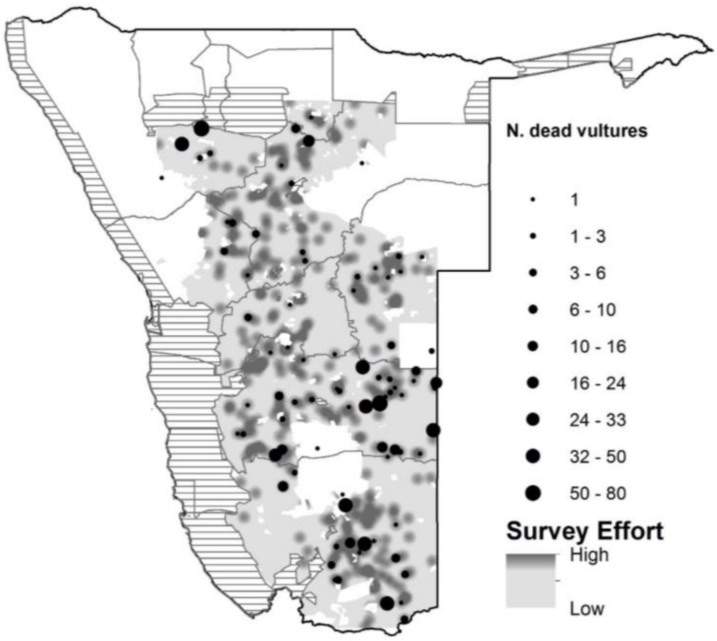

Figure 1. *Number of estimated vulture mortalities (from any cause; black dots of increasing size) for the period 2000 – 2015 as derived from causalities reported by 375 farmers who answered questionnaires. The grey shaded area represents commercial farmland, with increasing color darkness depicting how well the area was surveyed (the darker the color, the greater the number of farmers interviewed in that area). Polygons with horizontal lines represent national parks, and continuous grey lines represent regional boundaries. The accuracy of the point locations has purposely been decreased and slightly randomized to prevent identification of individual farms.*

A total of 83 out of the 84 farmers who reported having found dead vultures during 2000 - 2015 also provided information on the cause of death, which was thus available for 801 incidences. Poisoning was by far the main cause of vulture deaths according to farmers responses (Figure 2). When established (actual) poisoning deaths are coupled with probable incidences, the overall contribution of poisoning amounts to 74% of all vulture mortalities reported. Incidences of drowning, mainly at reservoirs and tanks providing water for livestock was also relatively high (Figure 2). Collision and electrocution on energy grid infrastructures as well as other causes of mortality represent a minority of reported incidences. The occurrence of vulture mortality from different causes over the period 2000 – 2015 seems to be rather homogeneous across Namibia's commercial farmland (Figure 3). However, drowning seems to be most prevalent in the southern and eastern part of the country as compared to the north, and it seems to be spatially associated with poisoning incidences.

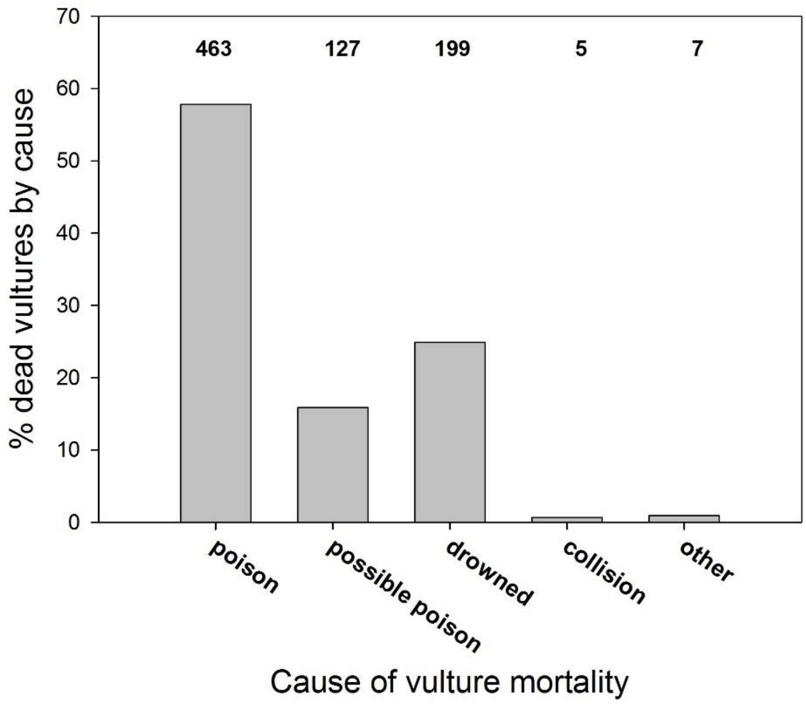

Figure 2. *Prevalence of the different reported causes of vulture mortality on Namibia's commercial farmland over the period 2000 – 2015. Numbers on top of the bars depict the total number of incidences reported for each specific cause of death. Other causes (N = 7) include, e.g. shot by farmer, electrocuted, unknown cause.*

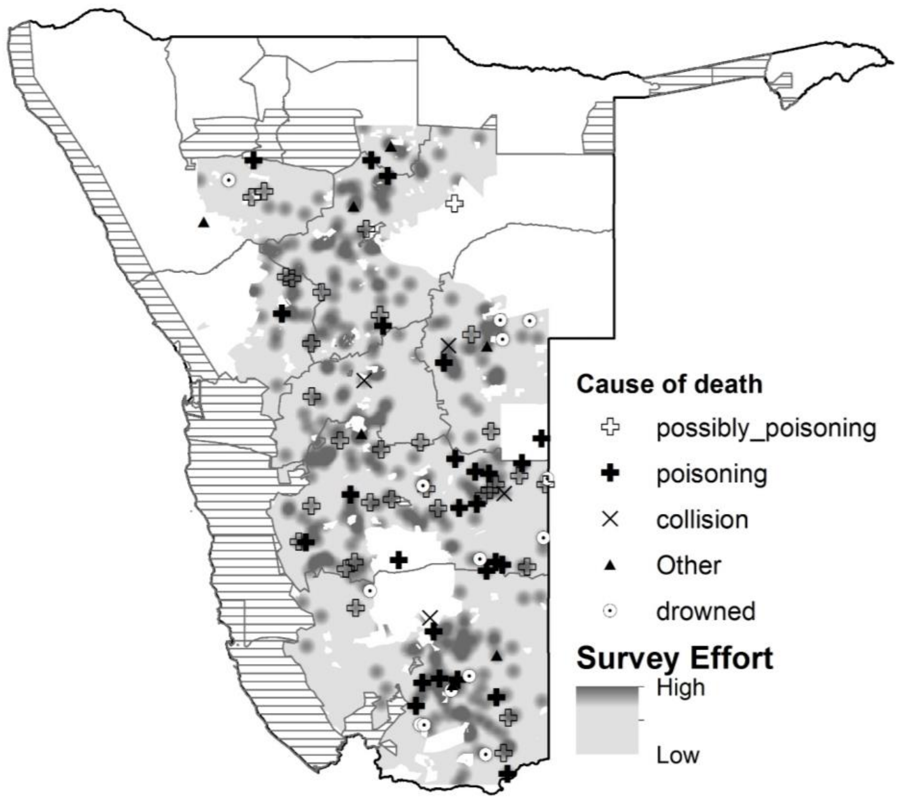

Figure 3. *Distribution of the causes of vulture deaths as reported by 375 farmers who answered questionnaires. Other causes (N = 7) include, e.g. shot by farmer, electrocuted, unknown cause. The grey shaded area represents commercial farmland, with increasing darkness color depicting how thoroughly the area has been surveyed (the darker the color, the greater the number of farmers interviewed in that area). Polygons with horizontal lines represent national parks, while continuous grey lines represent regional boundaries. The accuracy of the point locations has been purposely decreased and slightly randomized to prevent identification of individual farms.*

Type and method of poison use

Of all the farmers interviewed that admitted to having used poison, 58 farmers reported the type of poison used and 60 indicated how they administered it. Overall, aldicarb or carbofuran were by far the most commonly used poisons, followed by strychnine (Figure 4a). The vast majority of farmers (over 80%) used poison by placing poisoned baits on the farm (Figure 4b), whereas some (13%) contaminate a whole carcass with poison. Few use a combination of a whole carcass and baits, and only one farmer reported the use of poison collars placed on sheep. Moreover, among the farmers (N = 51) who also indicated whether they retrieve the carcass of the poisoned predator, 39 of them (76.5%) stated that they also search and collect the poisoned predator afterwards.

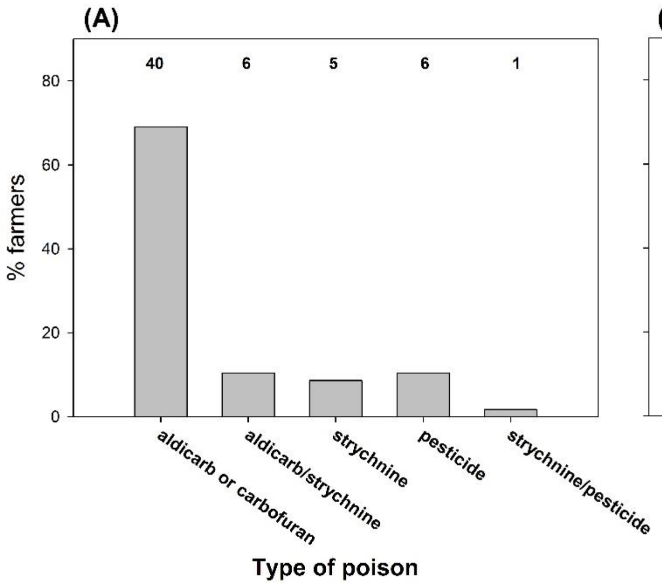

Figure 4. *Percentage of use of (A) different poison types by farmers who admitted to having used poison, and (B) the way in which poison is administered in order to control predators by commercial farmers in Namibia. Numbers on top of the bars depict the total number of incidences reported for each specific cause of death. The values are based on responses directly obtained by the farmers regarding what poisons they used and how.*

Factors underlying farmers' intention to use poison

We modeled the intention of farmers to use poison in the near future using a set of 13 socio-ecological factors (see Table 1 and Figure 5). Among all factors, the total livestock number, the number of small stock as well as farmers' attitude towards predators were the strongest predictors of intention to use poison (Figure 5). Specifically, intention to use poison in the future is highest for farmers owing large numbers of livestock, and also large numbers of small stock, and also for farmers with a negative perception towards predators (Table 1). Other factors, such as the size of the farm and percentage of stock lost, among others, had lower importance in predicting the intention by farmers to use poison (Figure 5).

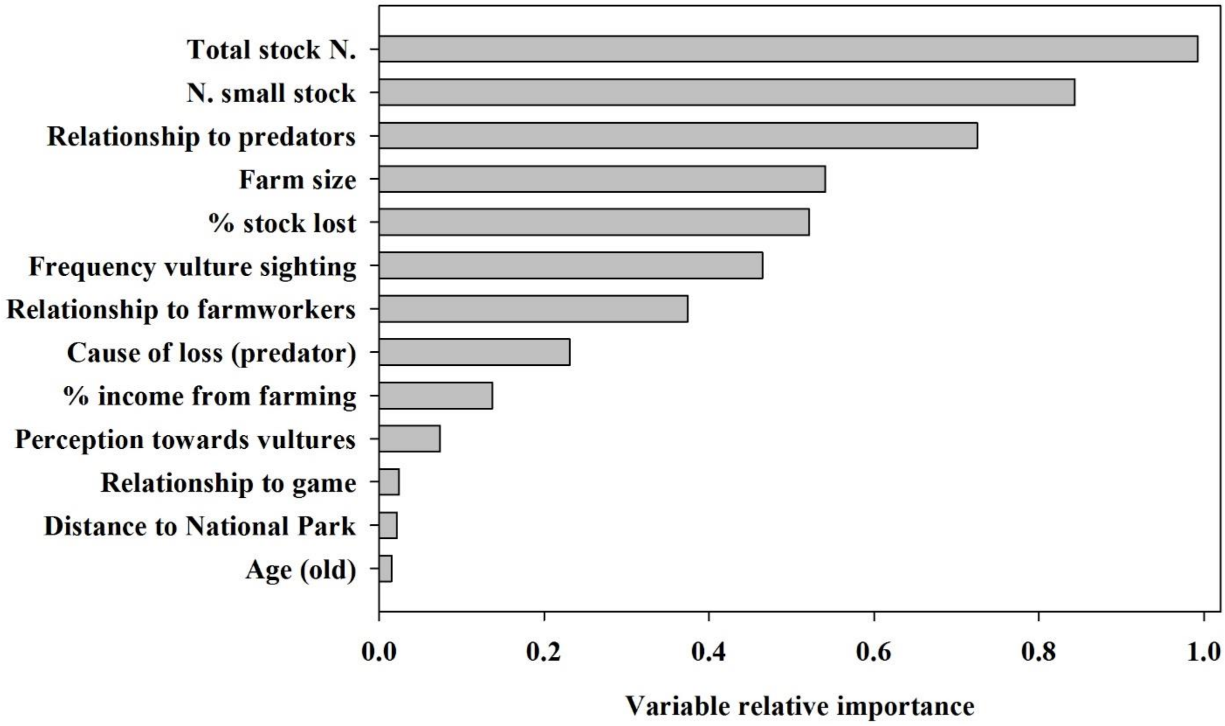

Figure 5. *Relative importance of each of the 13 socio-ecological variables as they related to the intention to use poison by commercial farmers in Namibia (see also Table 1 for the direction and strength of the effect of each variable). Variable importance was calculated as the ratio of the t statistics included within individual candidate models. Values were then averaged across the 95% confidence set weighted by model weights.*

Table 1. Relationship between intention to use poison by commercial farmers in Namibia and 13 socio-ecological factors.

Variable	**Coefficient**	**SE**	**Lower.CI**	**Upper.CI**
(Intercept)	-3,47	1,61	-6,63	-0,30
Total stock N.	0,48	0,18	0,12	0,83
N. small stock	0,12	0,07	-0,01	0,25
Relationship to predators	-0,32	0,16	-0,62	-0,01
Farm size	0,25	0,21	-0,16	0,65
% stock lost	0,07	0,05	-0,02	0,16
Frequency vulture sighting	0,18	0,13	-0,08	0,43
Relationship to farmworkers	-0,26	0,18	-0,61	0,08
Cause of loss (predator)	0,32	0,33	-0,33	0,98
% income from farming	0,00	0,01	-0,01	0,02
Perception towards vultures	0,14	0,22	-0,29	0,58
Relationship to game	-0,07	0,25	-0,56	0,42
Distance to National Park	0,00	0,00	-0,01	0,01
Age (old)	-0,05	0,33	-0,70	0,60

Coefficients, standard errors and 95% upper and lower confidence intervals are derived from a model-averaging procedure using the 95% confidence set of models built using the 13 variables and ranked with BIC (Bayesian Information Criterion). All variables were continuous except cause of loss (whether stock loss was related to predator or other cause; using other cause as the reference category); Age (young ≤ 45 vs old ≥ 46; using young as the reference category).

Discussion

We present the reported vulture mortalities occurring over a 16-year period on the commercial farmland of Namibia. We show that estimated mortalities of vultures due to anthropogenic causes amount to over 800 individuals over the study period, which underscores the magnitude of the problem. The highest numbers of vulture deaths were reported from the southern half of the country, with the exception of the areas just south of Etosha national park, and poisoning was the number one cause of reported deaths. Aldicarb or carbofuran, which are two common carbamate pesticides, were the most commonly used poisons, but strychnine is still used by about one farmer out of ten. For the majority of cases, poison is used by means of distributing poisoned baits across the landscape. Furthermore, willingness to use poison in the future was highest for farmers who own large properties with high livestock numbers, particularly sheep and goats, and farmers who suffered high livestock losses to predators, and who have a negative perception towards predators.

Our results clearly show that illegal and irresponsible poison use is claiming the life of many vultures across Namibia. The spatial occurrence of the incidences presented here strongly correlates with areas where poison use is most prevalent across commercial farmlands (Santangeli et al. 2016). The numbers of dead vultures reported here may not be very accurate and are an underestimate of the real values, because we did not address all farmers and because many incidences may go undetected or are detected but never reported. In this light, the figure of over 800 vulture mortalities reported in the past 16 years is alarming. Most likely these incidences involved the two most common vulture species in Namibia, the White-backed vulture (*Gyps africanus*) and the Lappet-faced vulture (*Torgos tracheliotos*), which have national populations of approximately 10 000 individuals and 500 pairs, respectively (Simmons et al. 2015). The above assertion is also confirmed by several descriptions by the farmers that most likely can be ascribed to one of the two abovementioned species. Such a high level of potential mortality could be particularly detrimental to these long-lived species, especially if mortality affects adult birds (Carrete et al. 2009, Santangeli et al. 2014).

Interestingly, we also report a high percentage of vulture deaths due to drowning. We speculate that while drowning was the ultimate cause of vulture death, poisoning might have been the primary reason behind most of the reported drowning incidences. For example, after consuming poison, vultures typically search for water, and when they finally approach water reservoirs to drink, they may be already debilitated to a level that they can no longer lift themselves from the water and drown (E.J. Komen, personal observation; Mundy PJ et al. 1992, Anderson 2000). The above mentioned connection may also explain the spatial correlation shown in figure 3, where drowning often occurs close to poisoning incidences. The above connections may suggest that poisoning could represent an even greater threat, not only to vultures but to the whole farmland system. Poisoned vultures that die in water reservoirs for livestock may contaminate the water, with spillover impacts on the whole system, including the livestock that farmers tried to protect by using poison. There have been reported cases of livestock, as well as guard dogs, being poisoned inadvertently by irresponsible farmers aiming to eliminate predators (anecdotal information from farmers in Namibia). These cases, as well as the quantitative information provided here, suggest that using poison may backfire and produce the opposite result of what it was intended to produce.

We however caution that vulture mortality as determined by each cause (e.g. poisoning, drowning, electrocution) may introduce some bias and uncertainty. This is because the cause of death was assessed by the farmers and based on own experience and not determined by toxicological analyses (see e.g. Botha et al. 2015). Moreover, detectability of vulture mortalities may also bias the results. For example, dead vultures may be more likely to be detected at a water reservoir that is regularly visited by farm workers as compared to a vulture killed along a power line. This may cause an over-representation of the poisoning and drowning cases as compared, for example, to collision and electrocution cases.

We show that aldicarb or carbofuran are widely and illegally used as poisons by farmers. Aldicarb is among the most widely used pesticides globally and in southern Africa, and it is often used to control stray dogs, for example in East Africa (Ogada 2014). Aldicarb can be obtained commercially and it is known to be highly toxic to vultures (Botha et al. 2015). Conversely, the sale and import of strychnine was banned in Namibia in 2003. However, legislation regulating its use was never amended, which may explain the low percentage of farmers that continue to report using strychnine, possibly from stocks that they attained before 2003.

Most farmers use poison by means of placing small contaminated baits in their farms. While this practice may be less catastrophic for vultures than lacing a whole carcass with poison, it still has high potential for killing vultures owing to their extraordinary ability to scan the landscape for dead matter (Ogada 2014). This may also be further exacerbated by the presence of other species, such as Bateleur eagles (*Terathopius ecaudatus*) that efficiently detect and scavenge on small animals, and their presence on the ground may also attract vultures (Ogada 2014). Moreover, although a small contaminated bait may go undetected to a vulture's eyes, the poisoned predator may be more visible. This may cause secondary poisoning of vultures that gathered to feed on the poisoned predator carcass. To this end, several farmers reported that they use poison in a somewhat "responsible" way, by placing it in the evening, often under a bush or other vegetative cover, and they would remove the remaining poison as well as any dead animal the following morning. This information was gathered in a non-systematic way, therefore it may only count as anecdotal. Yet, we believe that this method of using poison may not often be effective, because the victim may die relatively far from the poisoning spot. Removing the leftover poison as well as the victim may be particularly challenging, if not impossible, on large farms. Rather alarmingly, large farms, as well as those with high stock numbers, appear to be those where farmers are most willing to use poison in the near future according to our models. These are the farms where conservation efforts should be concentrated, particularly those within the distribution range of vultures, such as the White-backed and Lappet-faced vultures.

Sustainable livestock management practices, such as better herding methods using guard dogs, among other animals, and the use of corrals and calving camps, should be promoted among the community of farmers. Compensation schemes for livestock losses due to predators should also be made more efficient and reliable for farmers. At the same time, authorities should do more to effectively enforce the legislation and discourage any off-label and illegal use of pesticides, as well as amending the outdated legislation on use of strychnine (Ogada 2014). The practice of applying poison in the environment not only has devastating consequences on predators and the whole ecosystem, including scavengers, but poses also serious risks to the health of humans who live and depend on the products of the land that they irresponsibly contaminate.

Ultimately, the vulture mortalities reported here represent an unknown fraction of the overall numbers, especially when deliberate poisoning perpetrated by poachers is considered (Ogada et al. 2016a). This practice can kill hundreds of vultures in a single occasion and has escalated in recent years in southern Africa (Ogada et al. 2016a, Murn and Botha 2017). While effective poison intervention responses by trained field staff may reduce collateral damage, it will not be able to prevent actual poisoning incidences (Murn and Botha 2017). As vulture populations are collapsing across large tracts of Africa (Ogada et al. 2016b), there is an urgent need for actions. We believe that the findings of this study will help conservationists and authorities in effectively designing and implementing appropriate actions in order to address the problem of illegal poison use before it’s too late (Buechley and Şekercioğlu 2016).

Akcnowledgements:

AS is grateful to the Kone foundation and the Mohamed bin Zayed Species Conservation Fund (Project number: 142510056) for financially supporting this study. We are also grateful to the farmers for providing information, to Marco Girardello for help with the statistics and to Niki Rust for help in designing the questionnaire. Darcy Ogada and two anonymous referees are also acknowledged for their constructive comments that helped improve this manuscript.

Reference list:

Anderson, M. D. 2000. Mass mortalities. Why do vultures drown in farm reservoirs? African Wildlife 54:22-23.

Botha, C. J., H. Coetser, L. Labuschagne, and A. Basson. 2015. Confirmed organophosphorus and carbamate pesticide poisonings in South African wildlife (2009–2014). Journal of the South African Veterinary Association 86:1 - 4.

Buechley, E. R., and Ç. H. Şekercioğlu. 2016. The avian scavenger crisis: Looming extinctions, trophic cascades, and loss of critical ecosystem functions. Biological Conservation 198:220-228.

Cade, B. S. 2015. Model averaging and muddled multimodel inferences. Ecology 96:2370-2382.

Carrete, M., J. A. Sánchez-Zapata, J. R. Benítez, M. Lobón, and J. A. Donázar. 2009. Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. Biological Conservation 142:2954-2961.

Heck, D. W., and M. Moshagen. 2016. RRreg: Correlation and Regression Analyses for Randomized Response Data.

Lensvelt-Mulders, G., J. J. Hox, and P. G. M. Van der Heijden. 2005. How to improve the efficiency of randomised response designs. Quality & Quantity 39:253-265.

Lindsey, P. A., C. P. Havemann, R. Lines, L. Palazy, A. E. Price, T. A. Retief, T. Rhebergen, and C. Van der Waal. 2013. Determinants of Persistence and Tolerance of Carnivores on Namibian Ranches: Implications for Conservation on Southern African Private Lands. Plos One 8.

Morales-Reyes, Z., J. M. Pérez-García, M. Moleón, F. Botella, M. Carrete, C. Lazcano, R. Moreno-Opo, A. Margalida, J. A. Donázar, and J. A. Sánchez-Zapata. 2015. Supplanting ecosystem services provided by scavengers raises greenhouse gas emissions. Scientific Reports 5:7811.

Mundy PJ, Butchart D, Ledger J, and Piper S. 1992. The vultures of Africa. Academic Press, London.

Murn, C., and A. Botha. 2017. A clear and present danger: impacts of poisoning on a vulture population and the effect of poison response activities. Oryx *in press*:1-7.

Nuno, A., and F. A. V. St John. 2015. How to ask sensitive questions in conservation: A review of specialized questioning techniques. Biological Conservation 189:5-15.

Ogada, D., A. Botha, and P. Shaw. 2016a. Ivory poachers and poison: drivers of Africa's declining vulture populations. Oryx 50:593-596.

Ogada, D., P. Shaw, R. L. Beyers, R. Buij, C. Murn, J. M. Thiollay, C. M. Beale, R. M. Holdo, D. Pomeroy, N. Baker, S. C. Krüger, A. Botha, M. Z. Virani, A. Monadjem, and A. R. E. Sinclair. 2016b. Another Continental Vulture Crisis: Africa's Vultures Collapsing toward Extinction. Conservation Letters 9:89-97.

Ogada, D. L. 2014. The power of poison: pesticide poisoning of Africa's wildlife. Annals of the New York Academy of Sciences 1322:1-20.

Pimm, S. L., C. N. Jenkins, R. Abell, T. M. Brooks, J. L. Gittleman, L. N. Joppa, P. H. Raven, C. M. Roberts, and J. O. Sexton. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science 344:987-+.

Robinson, T. P., G. R. W. Wint, G. Conchedda, T. P. Van Boeckel, V. Ercoli, E. Palamara, G. Cinardi, L. D'Aietti, S. I. Hay, and M. Gilbert. 2014. Mapping the Global Distribution of Livestock. Plos One 9:e96084.

Santangeli, A., V. Arkumarev, N. Rust, and M. Girardello. 2016. Understanding, quantifying and mapping the use of poison by commercial farmers in Namibia – Implications for scavengers' conservation and ecosystem health. Biological Conservation 204, Part B:205-211.

Santangeli, A., E. Di Minin, and B. Arroyo. 2014. Bridging the research implementation gap – Identifying cost-effective protection measures for Montagu's harrier nests in Spanish farmlands. Biological Conservation 177:126-133.

Simmons, R. E., C. J. Brown, and J. Kemper. 2015. Birds to watch in Namibia: red, rare and endemic species. Ministry of Environment and Tourism and Namibia Nature Foundation, Windhoek, Namibia.

van den Hout, A., P. G. M. van der Heijden, and R. Gilchrist. 2007. The logistic regression model with response variables subject to randomized response. Computational Statistics & Data Analysis 51:6060-6069.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. Science 277:494-499.