

## A STRATEGY FOR CONSERVING OLD WORLD VULTURE POPULATIONS IN THE FRAMEWORK OF ONE HEALTH

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**ABSTRACT.**—One Health brings the powerful interrelationship between human and wildlife health together with ecosystem health. The initial concept of One Health was formulated decades ago and focused on disease transfer from wildlife to human populations. More recently, the concept has been used to associate resilience to disease with the health of the ecosystem and resilience to environmental stressors. The need for a One Health approach is particularly evident in the plight of Old World vultures, which are facing a conservation crisis due to drastic reductions in populations across their entire range. Moreover, vulture conservation exemplifies many contemporary tenets of One Health; vultures are critical to a sustainable and resilient ecosystem, which in turn is essential for the socio-ecological health of human communities. In this review, we examine the complex factors contributing to the demise of Old World vulture populations, using the lens of One Health to conceptualize the primary drivers impacting the health and sustainability of these populations. The One Health concept provides the basis for the development of a framework that incorporates a multidimensional approach and includes human health, wildlife health, environmental and disease-related stressors, disease incidences, societal pressures, and environmental contaminants. Integrating societal needs with management aimed at maintaining healthy vulture populations is key for successfully using a One Health framework to optimize the health of human and wildlife populations and ensure ecosystem health.

**KEY WORDS:** *Africa; climate change; ecosystem health; environmental contaminants; global health; human health; obligate scavenger; Old World vulture; sustainability.*

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ESTRATEGIA PARA CONSERVAR LAS POBLACIONES DE BUITRES DEL VIEJO MUNDO UTILIZANDO EL ENFOQUE DE UNA SALUD

**RESUMEN.**—El enfoque “Una Salud” promueve una poderosa interrelación entre la salud de los humanos y de la fauna salvaje asociados a la salud de los ecosistemas. El concepto inicial de Una Salud fue formulado décadas atrás y se enfocaba en la transferencia de enfermedades de la fauna salvaje a las poblaciones humanas. Más recientemente, el concepto ha sido usado para asociar la resiliencia a las enfermedades con la salud de los ecosistemas y la resiliencia a factores de estrés ambiental. La necesidad de utilizar el enfoque de Una Salud es particularmente evidente ante la difícil situación de los buitres del Viejo Mundo, los cuales se

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enfrentan a una situación de crisis de conservación debido a la reducción drástica en sus poblaciones a lo largo de toda su área de distribución. Además, la conservación de los buitres ejemplifica mucho de los principios contemporáneos de Una Salud; los buitres son críticos para un ecosistema sostenible y resiliente, lo que a su vez es esencial para la salud socio-ecológica de las comunidades humanas. En esta revisión, examinamos los factores complejos que contribuyen al descenso de las poblaciones de buitres del Viejo Mundo, usando el enfoque de Una Salud para conceptualizar los factores principales que impactan en la salud y la sostenibilidad de estas poblaciones. El concepto de Una Salud proporciona las bases para el desarrollo de un marco de referencia que incorpora un enfoque multidimensional, incluyendo la salud humana y de la vida silvestre, factores estresantes ambientales y de enfermedades, incidencia de enfermedades, presiones sociales y químicos ambientales. Integrar las necesidades de la sociedad con la gestión destinada a mantener poblaciones saludables de buitres es clave para usar exitosamente el marco de referencia de Una Salud y así optimizar la salud de las poblaciones humanas y de la fauna salvaje asegurando la salud del ecosistema.

[Traducción del equipo editorial]

#### INTRODUCTION

Populations of eight Old World vulture species have declined dramatically, especially throughout Africa (Ogada et al. 2012a, 2012b, 2016; Krüger et al. 2014, Buechley and Şekercioğlu 2016). African and Eurasian (Old World) vultures have been considered in the traditional context of One Health in relation to their role in the possible mitigation of disease transmission due to their feeding strategy as obligate scavengers that remove carcasses (Houston and Cooper 1975, Ogada et al. 2012b, Carlson et al. 2018, Kock et al. 2019). The plight of Old World vultures is compounded by their life histories; like most long-lived birds, these vultures mature slowly and produce few young annually, resulting in dramatic demographic impacts from the loss of breeding adults (Ottinger 2010). As discussed in detail below, there are many other challenges faced by Old World vultures including the loss of suitable habitat for foraging and breeding due to agricultural expansion, deliberate or secondary poisoning, human disturbance, reduced food or carcass availability (Margalida and Colomer 2012), and wildlife trafficking for belief-based practices (Bamford et al. 2009, Margalida and Colomer 2012, Buij et al. 2016). One Health can provide a conceptual framework to visualize and integrate multiple and sometimes opposing pressures on wildlife and human communities, which may conflict with the protection of the fitness and biodiversity of wildlife populations and overall ecosystem health.

#### RELEVANCE OF ONE HEALTH TO CONSERVATION OF VULTURE POPULATIONS

Despite advances in approaching conservation using a One Health strategy, no such strategy exists for Old World vulture conservation. Here we

describe how One Health can provide a framework for developing targeted and sustainable interventions to conserve Old World vulture populations. It is important to identify and rank the threats to vulture populations to develop a structured conservation approach. This has been done in the Multi-species Action Plan to conserve African-Eurasian vultures (MsAP; Botha et al. 2017) and has been included in site-specific national action plans for vultures, such as that adopted by Zimbabwe (Santangeli et al. 2019, Zimbabwe Parks and Wildlife Management Authority and BirdLife Zimbabwe 2019). Using a One Health framework provides the opportunity to align the needs of vultures and human communities, especially where they overlap, such as in areas encompassing vulture core ranges as well as regions of human expansion (Henriques et al. 2018).

The continuing decrease in resources contributes to the decline of Old World vulture populations; these include loss of prey diversity, reduced carcass or carrion availability, and loss of suitable breeding habitat due in part to human disturbance, which can affect nesting success (Buechley and Şekercioğlu 2016, Ogada et al. 2016, Daboné et al. 2019). Vultures are also vulnerable to secondary poisoning from the deliberate misuse of agricultural chemicals in poisoned carcasses deployed by farmers in retaliation for predation on livestock (Ogada et al. 2016). In addition, some poachers use poison to obtain birds to sell for cultural belief-based use, which may adversely impact vulture populations and humans through exposure to poisons (Buij et al. 2016, Daboné et al. 2019, Mashele et al. 2021). Consequently, exposure risk of vultures to poisons is significant (Monadjem et al. 2018, Margalida et al. 2019). Regional and national policies related to

agrochemical usage are inconsistent and poorly implemented. This is compounded by the fact that vultures move across jurisdictional boundaries.

As obligate scavengers, Old World vultures provide critical ecosystem services by removing carcasses of dead animals, a service that may be crucial for the mitigation of disease (Houston and Cooper 1975, Ogada et al. 2012b, Carlson et al. 2018, Kock et al. 2019, van den Heever et al. 2021). Although more data are needed to fully assess the impacts of declining Old World vulture populations on the incidence and spread of disease (International Union for Conservation of Nature [IUCN] Vulture Specialist Group 2020), it is critical to address these losses due to the importance of vultures in performing ecosystem services.

A One Health framework directs attention to the interdependence among human health, vulture health, and ecosystem health, and illustrates how this complex interrelationship is critical for health and ecosystem sustainability. Developing an inclusive One Health framework for survival of vulture populations requires a multidimensional approach that integrates metrics of health; stressors; disease incidence in vultures and other wildlife, livestock, and humans; societal pressures, habitat fragmentation and loss; and other environmental factors. More specific measures of health for people, wildlife, and vultures should include overall physical health, immune, metabolic, and endocrine function, and nutrition/food availability. One Health can provide a structured and interdisciplinary approach with the capability to express quantitative outcomes such as disease risk, economic savings, health improvement potential, and policy change impacts (Falzon et al. 2018, Mackenzie and Jeggo 2019).

In this review, we consider the origins and evolution of the One Health approach, discuss the considerations that should be addressed for the development of an effective One Health framework for sustaining Old World vulture populations, and suggest some next steps. We also discuss community education programs, which are valuable in changing local and regional practices. Such programs have been critical in reducing practices that pose risks to both humans and wildlife, and coordinating and promoting sound interventions for human-wildlife conflict by using a multi-faceted approach (Gebreyes et al. 2014, Allen-Scott et al. 2015, Lerner and Berg 2015, Errecaborde et al. 2017, 2019, Pelican et al. 2019). Each of the contributing factors (shown in Fig. 1) will be considered in more detail below from

the perspective of conserving Old World vulture populations. Implementing a One Health approach that clearly delineates the relationship between the health of human communities and sustainable vulture populations is important for optimizing the health of humans, vultures, and the ecosystem.

#### ORIGINS AND EVOLUTION OF THE ONE HEALTH CONCEPT

A criticism of the initial concept of One Health, codified three decades ago, was the primary focus on disease transmission (Evans and Leighton 2014, Capua and Cattoli 2018, Rabinowitz et al. 2018). This led to a broadened concept of One Health articulated at a “One World, One Health” conference (see Manhattan principles, [www.oneworldonehealth.org](http://www.oneworldonehealth.org)) held in 2004, which included recommendations aimed at community health and sustainable maintenance of wildlife populations (Osofsky et al. 2005, Zinsstag et al. 2011, Lerner and Berg 2017, Rabinowitz et al. 2018). Although disease transmission among wildlife, domestic animals, and humans remains a central element of One Health, physiology/medicine, economics, anthropology, toxicology, and education are now incorporated into the conceptual framework (Schwind et al. 2014, Bonilla-Aldana et al. 2020). Humans and wildlife must contend with the effects of global changes in climate and land use, which have resulted in the loss of wildlife habitat and increased disease transmission between wildlife and livestock. Environmental pollutants, including both those in current use and persistent chemicals such as DDT and its metabolites, impact wildlife and humans alike (Köhler and Triebkorn 2013, Alarcón and Lambertucci 2018a, 2018b, Richards et al. 2018). This broad and complicated array of interactive factors influences the health of humans, wildlife, and the ecosystem. Recognition of these complex interrelationships has led to a considerably broadened scope of the One Health concept (Zinsstag et al. 2005, 2018, Mi et al. 2016, Sleeman et al. 2017, Destoumleux-Garzon et al. 2018, Vesterinen et al. 2019), which brings together the relationships among the health of humans, domestic species, wildlife species, and the ecosystem. The One Health concept can facilitate decision-making and resource allocation based on scientific evidence, eventually leading to programmatic and policy-making initiatives that optimize human-wildlife-ecosystem health.

More recently, focus has been directed toward the emergence of novel diseases and the necessity for human and animal surveillance by the international

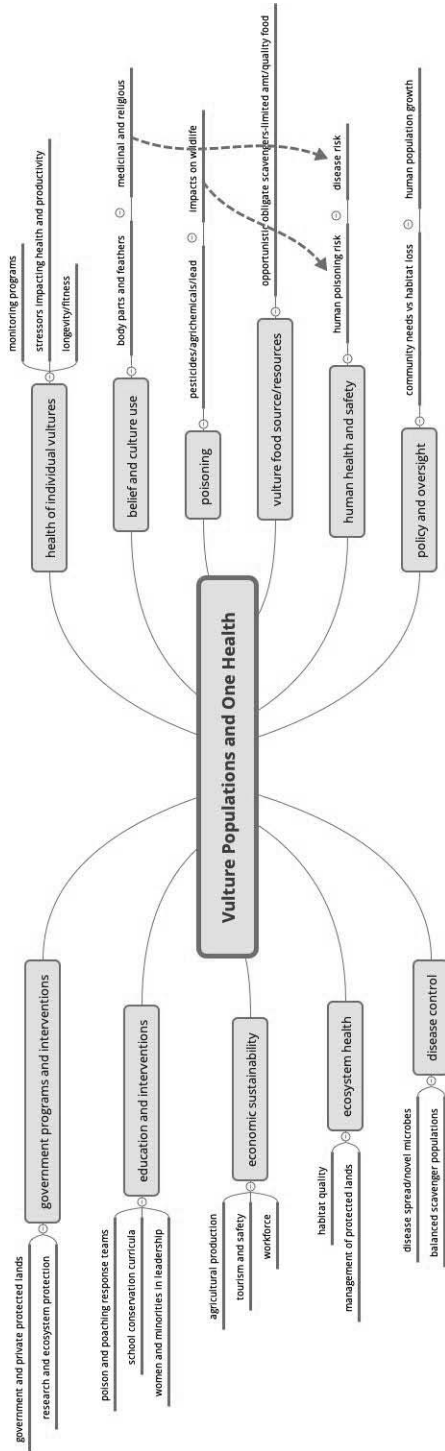


Figure 1. Factors and drivers contributing to the sustainability of Old World vulture populations; blue boxes represent Primary Factors and horizontal blue lines represent Key Drivers that influence the Primary Factors (see text for more details). These factors and drivers are pertinent to both human and vulture health.

scientific community and governmental organizations (Cunningham et al. 2017a, 2017b). Interest in this topic has surged due to global recognition of the threat posed by the spillover of pathogens from wildlife into humans. The One Health approach has evolved from a primary focus on disease transmission to the development of a framework that considers multiple factors and potential implementation strategies (Allen-Scott 2015, Nyatanyi et al. 2016, Pieracci et al. 2016, Cunningham et al. 2017b, Acharya et al. 2019). Specific training and resources have been developed, such as the One Health Training Modules Curricula in East and Central Africa (Amuguni et al. 2019), capacity-building programs through networks in Africa, such as Afrique One, One Health Central and Eastern Africa (Rwego et al. 2016), and One Health Systems Mapping and Analysis Resource Toolkit (OH-SMART; Vesterinen et al. 2019). These efforts represent coordinated approaches to develop, customize, and implement effective protection of human–domestic species–wildlife health and safeguard ecosystem health using a One Health strategy.

For new practitioners, a One Health approach can be difficult to grasp in terms of its development, strategy, and use for integrating human communities and wildlife sustainability. The complexity of the contributing factors has been captured in recommendations from the One World–One Health conference in 2004 entitled “One World One Health’s Manhattan Principles” (<http://www.oneworldonehealth.org/>) and in the image “The One Health Umbrella” developed by One Health Sweden and the One Health Initiative (Gibbs 2014, Lerner and Berg 2015). Both recognize that One Health addresses both human health and wildlife health in conjunction with ecosystem health. Partnerships between academia, nonprofit organizations, governmental agencies, and consortia are critical to build the capacity to take on these complex challenges (Allen-Scott et al. 2015, Rabinowitz et al. 2018, Vesterinen et al. 2019). There are also ongoing alliances focused on organizing data for sharing across disciplines (Gebreyes et al. 2014, Davis et al. 2017, Errecaborde et al. 2017, 2019, Pelican et al. 2019, Vesterinen et al. 2019). An integrative One Health strategy that considers the key role of vultures in community and ecosystem health can help optimize community health and will contribute to achieving the United Nations, Department of Economic and Social Affairs-Sustainable Development Goals: #3 “Ensure healthy lives and

promote well-being for all at all ages” and #17 “Strengthen the means of implementation and revitalize the global partnership for sustainable development” (<https://sdgs.un.org/goals/goal3>; <https://sdgs.un.org/goals/goal17>). Hereafter we discuss the considerations that must be incorporated in the development of an effective One Health framework for sustaining Old World vulture populations.

#### A ONE HEALTH FRAMEWORK FOR SUSTAINING VULTURE POPULATIONS

The rapid demise of Old World vulture populations presents a dire need for an integrative cross-national approach offered by One Health to address the complexities underpinning these precipitous population declines (Safford et al. 2019). It is critical to develop interdisciplinary teams that consider the Primary Factors that impact Old World vultures, both for individuals and the populations (Fig. 1). The Primary Factors span policy, conservation, and human communities and are moderated by secondary and tertiary factors (termed Key Drivers), which should be considered in the development of an inclusive One Health approach to sustaining Old World vulture populations. As shown in Figure 1 and discussed in more detail within this review, the characteristics and requirements of Old World vulture populations include life history, resource needs, and multiple other contributing factors that must be integrated into a One Health conceptual framework. Collaborations are important for positioning the scientific/conservation community to develop global and consistent evidence-based interventions accompanied by metrics to assess the effectiveness of these interventions, as highlighted in the United Nations Goals mentioned above. For example, the impact of environmental and disease stressors on vultures can be assessed using key health measures, such as markers of immune, metabolic, and reproductive endocrine function (Ottinger et al. 2019). Publicly available datasets with metadata including environmental contaminants, poisoning incidences, community proximity to breeding sites and resources, climate conditions, and drought conditions also exist (e.g., the African Wildlife Poisoning Database; <https://africanwildlifepoisoning.org/>). These databases are critical to link the respective levels of stress at an individual level (and ultimately at the population level) to physiological indicators of health such as immune, metabolic, and reproductive endocrine functions. It is important to

have pertinent metadata that accompanies monitoring data for the Old World vulture populations to understand the specific environmental conditions experienced by monitored populations; such understanding will provide insight into the critical factors impacting Old World vulture populations and provide baseline information necessary for establishing optimal conditions for vulture population viability. As discussed below, the strong interrelationships among these factors influences the lifetime health and productivity of individuals and ultimately drives changes in population dynamics.

**Primary Factors Contributing to the Decline of Old World Vulture Populations.** The Primary Factors that have contributed to the demise of Old World vultures include specific challenges such as poisoning by farmers and for trade as well as a vast array of other issues including habitat loss, energy infrastructure (power lines and wind farms), food resource availability, and drowning (Ogada et al. 2012a, 2012b, 2016, Margalida et al. 2019, Daboné et al. 2019, Gore et al. 2020). As mentioned above, a host of Primary Factors impact vulture populations (Fig. 1). The health of individual vultures is impacted by environmental stressors that translate into physiological responses, as shown in the sequential effects of environmental factors (Fig. 2). Further, diminished numbers of Old World vultures also contribute to the downward spiral of population viability because individuals rely on cues from other vultures to find food and feeding events at carcasses usually involve a large assemblage of vultures (Mundy et al. 1992). The health of each vulture determines its fitness, productivity, and longevity, and ultimately contributes to the sustainability of entire Old World vulture populations.

**Primary Factors Reflect Key Drivers.** Considering how Key Drivers influence the Primary Factors is fundamental to understanding the web of impacts on Old World vulture populations (Fig. 1). For example, ecosystem health, which directly influences Old World vultures, is in turn affected by a suite of Key Drivers such as habitat quality and effective management of protected federal and private lands. Additional subfactors (Key Drivers) modulate these Primary Factors; for example, disease control is affected by disease spread, novel microbes, and balanced scavenger populations. There are also interactions between the Key Drivers. Human health and safety are influenced by poisoning risk and disease risk associated with cultural belief-based uses of vulture body parts.

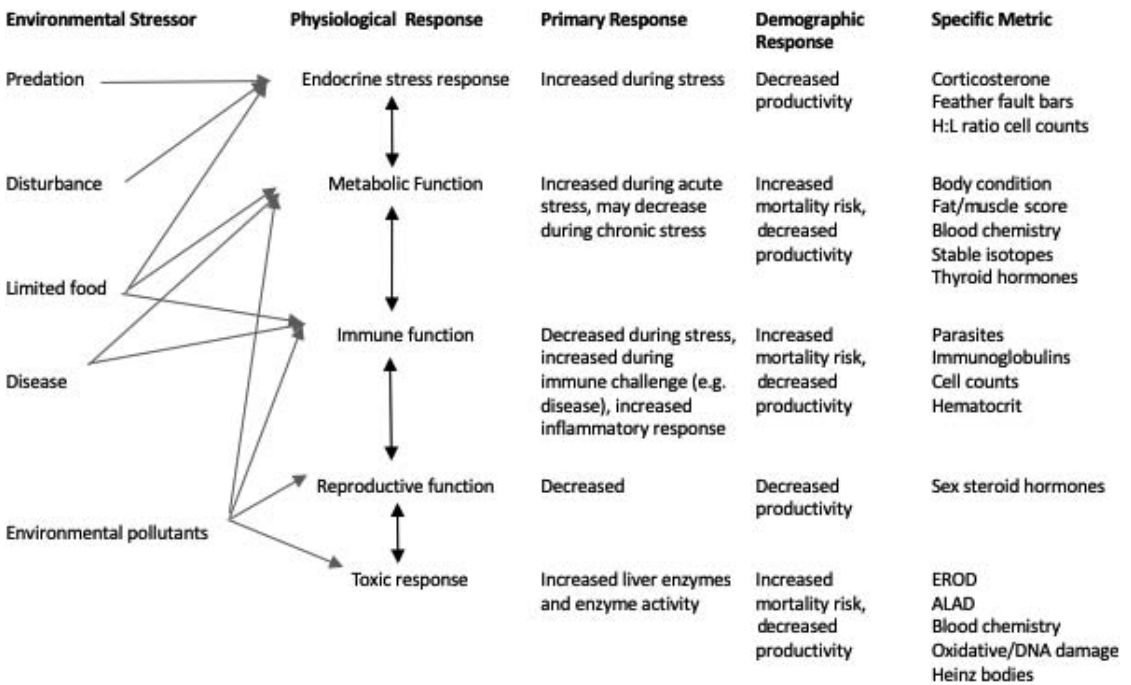


Figure 2. The physiological responses of individual birds to environmental stressors, the primary and demographic responses associated with that physiological response, and the specific metrics that can be used to measure that physiological response (modified from Ottinger et al. 2019). All physiological responses have the potential to interact with one another as represented by the double-headed arrows.

Developing a targeted One Health framework for vulture conservation requires an understanding of (1) available pertinent data, (2) points of potential effective intervention, and (3) potential causal links between Key Drivers and Primary Factors. There are critical data gaps (Fig. 3) that must be addressed. For example, knowledge about the movements of vultures and their breeding/foraging areas in conjunction with the locations of human settlements, land use, poverty/unemployment levels, and levels of belief-based use would be valuable in identifying areas of high risk for human-wildlife conflict (e.g., Santangeli et al. 2018). Additionally, areas with significant overlap between vultures and humans are likely to have higher vulture mortalities (from poisoning and other threats) and potentially higher risk of transmission for some diseases and lower risk for others (due to the removal of carcasses by vultures; IUCN Vulture Specialist Group 2020). Addressing these gaps in a targeted manner will provide critical data and a focused approach to implementing effective interventions.

**Integrating Societal Traditions and Community Needs.** Societal traditions and community needs present the greatest challenges in, and opportunities for, changing the current course of loss of Old World vultures. Expanding human populations require increased land for food production, thereby raising the likelihood of human-wildlife conflict as well as reducing habitat for wildlife (Gore et al. 2020). Many community factors impact both human and wildlife health; investigating these factors (along with with potential interventions to mitigate these factors and projected outcomes of interventions) improves our understanding of interactive, synergistic, or additive effects (Fig. 4). Developing a suite of interventions is critical to focus implementation strategies and direct the efforts of a community into effective programs. These interventions improve ecosystem health, sustaining populations of wildlife in general, and of Old World vultures in particular. Integrating societal and community needs with maintenance of healthy vulture populations is key in successfully using a One Health framework as a

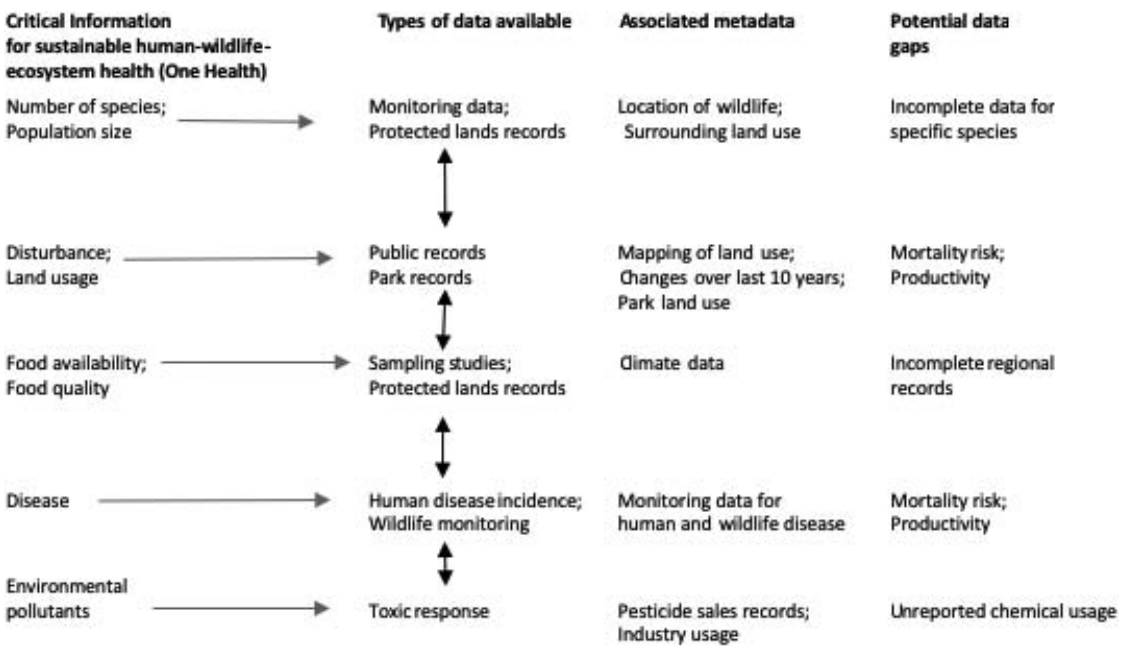


Figure 3. Critical information needed to evaluate the status and assess the fitness and sustainability of vulture populations. Double-headed arrows indicate interactive relationships between types of data.

roadmap for safeguarding human and wildlife populations and ecosystem health.

**Understanding the Impacts of Disease and Environmental Stressors on Population Status.** Understanding the relationships among disease, environmental stressors, and population status requires historical information to provide a context for current risks to Old World vulture populations. There is a need for cross-sectional and longitudinal epidemiological and disease ecology studies to effectively link the impacts of Old World vulture population declines to ecosystem health and human health outcomes (IUCN Vulture Specialist Group 2020). Monitoring programs are critical to provide a historical comparison as well as a current assessment of population status, based on number, age distribution, health, and overall fitness; this includes monitoring the range and movements of individuals (Alarcón and Lambertucci 2018a, 2018b). Monitoring programs that are repeated annually at designated sites are valuable for providing long-term information on the status of Old World vulture populations, particularly when combined with metadata that reflect changing environmental conditions and stressors.

**A Coordinated Global Response.** A coordinated global response is critical to successfully mitigating the precipitous loss of Old World vultures. As mentioned earlier, the Vulture MsAP (Botha et al. 2017) is now being used by various countries to formalize their own nation-specific versions of this plan, focusing on the threats to vultures that are most prevalent locally. Zimbabwe has already published their own Zimbabwe Vulture Action Plan (Zimbabwe Parks and Wildlife Management Authority and BirdLife Zimbabwe 2019) and similar documents are being drafted in South Africa, Nigeria, Morocco, and Rwanda. This kind of national response still needs multilateral coordination, because vultures' home ranges span international borders. It also requires the involvement of numerous stakeholders including government agencies, educators, nongovernmental conservation organizations, local communities, and the general public. Implementation of a One Health approach by managers, policy makers, and agency leaders will require education and coordination. Lessons learned from the Asian vulture crisis in the 1990s (Ogada et al. 2016), lead poisoning incidents in California Condors (Church et al. 2006, Finkelstein



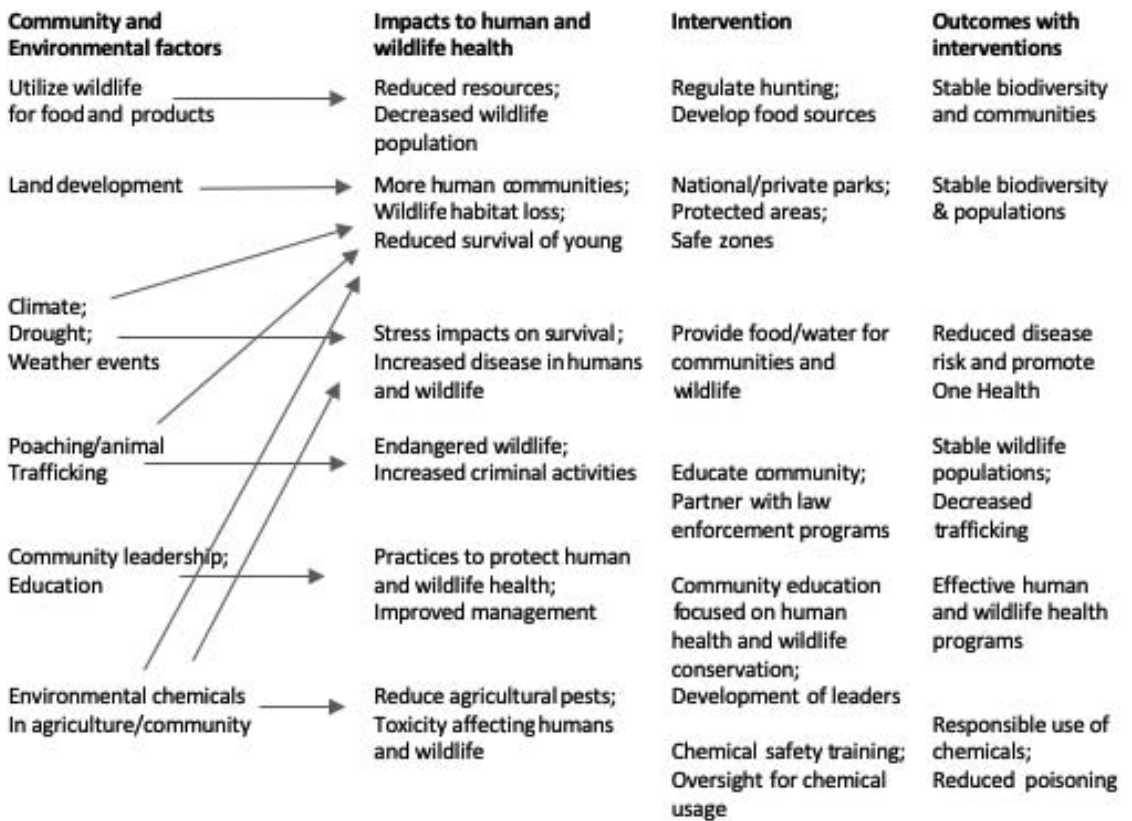


Figure 4. The interrelationship of community-associated impacts to human and wildlife health, with potential interventions leading to predicted outcomes.

et al. 2012, 2014), and the efforts to mitigate lead poisoning from ammunition (Lambertucci et al. 2011, Berny et al. 2015, Mateo-Tomás et al. 2016) provide valuable insights for developing a One Health strategy for Old World vultures and raptors.

**Monitoring Programs for Vulture Populations.** Monitoring programs for vulture populations may include monitoring of home ranges and nesting sites, productivity, fitness of adults and young, and environmental characteristics such as habitat, land use, food availability, disease incidence, chemical exposures, poisoning events, and climate and weather (Santangeli et al. 2018). Associated metadata on environmental and climate conditions are important for interpreting both short- and long-term impacts, including the effects of environmental contaminants (Bohannon et al. 2018, Plaza et al. 2019). Long-term monitoring of Old World vulture populations provides valuable information for elucidating population trends (e.g., a 35-yr study of

Cape Vultures; Benson and McClure 2019). Collaboration and integration of information from multiple studies or datasets are critical. For example, information from long-term monitoring of population numbers and reproductive success should be integrated with data on lead levels, health metrics of stress, immune function, genomics, and parameters of population dynamics including survival. Further, associated metadata is extremely valuable for linking population status to land use and habitat availability, climate and annual weather cycles, resource availability, disease incidence, environmental contaminant levels, and incidences of poisoning.

Some infrastructure for such data sharing and collaboration is already in place. The African Raptor DataBank (ARDB) was a data collection, sharing, and analysis platform designed by HabitatInfo to ascertain the conservation status of Africa’s raptors. Researchers across Africa used a mobile application to collect and share data via the ARDB. Researchers

also mobilized historical data sets to compare with current data. The ARDB was integral to the development of the MsAP (Botha et al. 2017) and the uplisting of several species of Old World vultures on the IUCN's Red List in 2012. The Peregrine Fund has since expanded the ARDB globally and added functionality to create the Global Raptor Impact Network (GRIN; [www.globalraptors.org](http://www.globalraptors.org)). Using the GRIN mobile application and website, researchers can share vulture data (e.g., population levels, mortality events, and reproduction) with scientists who are collecting other types of data from around the world.

#### **Education and Science Communication Programs.**

Education and science communication programs are essential to inform the public and provide sound scientific information to policy makers. This goes beyond just providing the One Health framework as a means to conceptualize the scope and components impacting the overall challenge of sustaining Old World vultures. It is essential to empower citizens and decision-makers to support the conservation of vultures and at the same time to understand how this will enhance their own health and the well-being of their community (Lerner and Berg 2015). This involves academic institutions, governments, nongovernment agencies, nonprofit organizations and community consortia (including traditional and community leaders), and collaborations. Conservation success in Africa will depend on these collaborations and partnerships to understand and effectively address the plight of Old World vultures.

#### **NEXT STEPS AND CONCLUSIONS**

A One Health strategy for Old World vulture conservation will require developing a framework based on factors identified here as well as other emerging factors, such as novel diseases. It is important to use available data, including associated metadata. There are excellent documents that already provide many pieces of a One Health strategy designed specifically for Old World vultures. As outlined below, there are steps that can be taken now to develop and implement a One Health framework. It is critical to have a clear research strategy that ties vulture population dynamics, disease, and human health together as central components in this framework, alongside the policy and conservation ecology strategies in the action plan outlined below.

The advantage of using the One Health framework to address the challenges of sustaining vulture populations is the ability to incorporate an interdisciplinary approach that recognizes the true interrelationship of human-vulture-ecosystem health. As described above, there are multiple factors and drivers that impact vulture populations and often these interact either additively or synergistically to increase stress on individuals and on the population.

We recommend the following steps as a general roadmap for developing a One Health framework. (1) Identify the Primary Factors impacting the sustainability of vulture populations (e.g., Fig. 1). The interdependence of human, wildlife, and ecosystem health is an important consideration for identifying factors. (2) Define the complexities driving the pressures on vultures; for example, Figure 2 captures stressors that diminish the fitness of vultures and the ecosystems on which they depend. (3) Ascertain the availability of tools for field-relevant measures and identify the key stressors and metrics for assessing the impacts of these stressors, such as those associated with community impacts (Fig. 4), and determine the availability of historical and current relevant data and data gaps (Fig. 3). Use collaborative approaches such as GRIN (<http://www.globalraptors.org/grin/indexAlt.asp>), which aids researchers in collecting their own data and also allows them to contribute to larger efforts to conserve vultures. (4) Provide community education on the interrelationship of human-wildlife-ecosystem health with a focus on societal and community needs. (5) Translate Primary Factors and Key Drivers to a One Health framework, develop decision-making tools that focus on meaningful individual and population metrics, and relate/link these metrics to next steps in implementing effective restoration and remediation projects. Define key metrics for human health and ecosystem health and promote them as goals for policy makers and the public. (6) Establish multi-lateral agreements (e.g., the Convention of Migratory Species [CMS]) that bring global communities and countries together. Integrate societal/community needs with the conservation of healthy vulture populations. As an example, indicators focused on One Health and vulture conservation could be proposed and submitted as resolutions to the CMS, such as the Vulture MsAP (Botha et al. 2017). Coordinate policies across regional and national borders and mobilize funding to allow rapid implementation.

In summary, Old World vultures are critical to the health of humans, wildlife, and the ecosystem. Furthermore, the One Health concept can provide a novel application for conserving avian scavengers. The One Health integrated approach will provide a strategic framework for sustaining Old World vulture populations. The current rate of decline of many vulture populations underscores the urgency of conservation action. We recommend prompt development of a comprehensive One Health approach to protecting Old World vulture populations.

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