



## Research article

# Vulture poisoning in Sub-Saharan Africa and its implications for conservation planning: A systematic review

Vincent Raphael Nyirenda<sup>a,\*</sup>, Bimo Abraham Nkhata<sup>b</sup>, Darius Phiri<sup>c</sup>, Wilfred Nyirenda<sup>d</sup>, Daniel Nyamphande Phiri<sup>e</sup>, Mary Malasa<sup>e</sup>, Matthew Smith Becker<sup>f</sup>, Enala Mwase Tembo<sup>g</sup>, Moses Amos Nyirenda<sup>h</sup>, Twakundine Simpamba<sup>i</sup>, Jacob Mwitwa<sup>j</sup>, Chansa Chomba<sup>k</sup>

<sup>a</sup> Department of Zoology and Aquatic Sciences, School of Natural Resources, The Copperbelt University, Jambo Drive, Riverside, P.O. Box 21692, Kitwe, Zambia

<sup>b</sup> University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa

<sup>c</sup> Plant and Environmental Sciences, School of Natural Resources, The Copperbelt University, Jambo Drive, Riverside, P.O. Box 21692, Kitwe, Zambia

<sup>d</sup> Department of Clinical Sciences, School of Medicine, The Copperbelt University, P.O. Box 21692, Ndola, Zambia

<sup>e</sup> BirdWatch Zambia, 25 Joseph Mwilwa Road, Rhodes Park, P.O. Box 33944, Lusaka, Zambia

<sup>f</sup> Zambia Carnivore Program, P.O. Box 80, Mfuwe, Zambia

<sup>g</sup> Department of Paraclinical Studies, School of Veterinary Medicine, University of Zambia, P.O. Box 32379, Lusaka, Zambia

<sup>h</sup> Worldwide Fund for Nature Conservation, Los Angeles Boulevard, P.O. Box 50551 RW, Long acres, Lusaka, Zambia

<sup>i</sup> Department of National Parks and Wildlife, Private Bag 1, Chilanga, Zambia

<sup>j</sup> Kapasa Makasa University, P.O. Box 480195, Chinsali, Zambia

<sup>k</sup> Department of Natural Resources and Environmental Sciences, School of Agriculture and Natural Resources, Mulungushi University, P.O. Box 80415, Kabwe, Zambia

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## ABSTRACT

The Old World Vultures (OWV), constituting 16 species primarily in Africa, Europe and Asia, are currently being driven to extinction mostly by anthropogenic activities, especially poisoning. The vulture losses from poisoning caused by human-related activities are *en masse* at a single mortality event-level and occur in complex social-ecological systems. There has been a growing body of knowledge on wildlife poisoning over the years. However, no review has been done to consolidate vulture poisoning studies in sub-Saharan Africa (SSA), with a social lens of conservation planning. Here we present a review of the vulture poisoning research by re-contextualizing the problem of vulture poisoning across SSA. We employed stepwise Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method to search for literature on vulture poisoning. The search yielded 211 studies which were trimmed to 55 after applying sets of eligibility criteria. Literature shows that efforts aimed at successful vulture conservation planning will require an understanding of the relational aspects of stakeholder social capital (assets) that are critical to the implementation of species recovery strategies. Strengthening relational social capital through multi-scale stakeholder evidence-based awareness creation and participation is necessary for

\* Corresponding author.

*E-mail addresses:* [vincent.nyirenda@cbu.ac.zm](mailto:vincent.nyirenda@cbu.ac.zm) (V.R. Nyirenda), [nkhataba@ufs.ac.za](mailto:nkhataba@ufs.ac.za) (B.A. Nkhata), [dariusphiri@rocketmail.com](mailto:dariusphiri@rocketmail.com) (D. Phiri), [wilfrednyirenda02@gmail.com](mailto:wilfrednyirenda02@gmail.com) (W. Nyirenda), [daniel.phiri@birdwatchzambia.org](mailto:daniel.phiri@birdwatchzambia.org) (D.N. Phiri), [mary.malasa@birdwatchzambia.org](mailto:mary.malasa@birdwatchzambia.org) (M. Malasa), [matt@zambiacarnivores.org](mailto:matt@zambiacarnivores.org) (M.S. Becker), [emwase@gmail.com](mailto:emwase@gmail.com) (E.M. Tembo), [mnyirenda@wwfzam.org](mailto:mnyirenda@wwfzam.org) (M.A. Nyirenda), [stwakundine@yahoo.co.uk](mailto:stwakundine@yahoo.co.uk) (T. Simpamba), [jacob.mwitwa@gmail.com](mailto:jacob.mwitwa@gmail.com) (J. Mwitwa), [chansachomba@rocketmail.com](mailto:chansachomba@rocketmail.com) (C. Chomba).

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addressing the African Vulture Crisis (AVC). Applying stakeholder social capital approaches to different vulture conservation scenarios at local, regional and international scales can enhance successful implementation of conservation strategies for the persistence of vultures in complex socio-ecological systems in African landscapes. Existing literature also showed the importance of stakeholder social capital as a countermeasure against vulture losses.

## 1. Introduction

The African Vulture Crisis (AVC) is a growing concern arising from rapidly declining vulture populations in Sub-Saharan Africa (SSA) [1]. The SSA is considered a major vulture conservation but poison use hotspot [2,3], requiring urgent interventions to save vultures from extinction [4]. Vulture population decline is associated with composite environmental stressors, such as human and ecological factors, undercutting conservation efforts. As such, the human-vulture mutualism is disappearing [5]. The [6,7] postulate that limited food supply due to habitat fragmentation and degradation from land use changes constrains the growth of vulture populations. On the other hand, use of natural plant- and animal-based toxins has a long history, but recently synthetic chemicals are commonly used to kill wildlife [8,9].

Poisoning through agricultural chemicals, heavy metals, and veterinary pharmaceuticals from public provenance is reported to affect the health of vultures at sub-lethal levels, and high levels of toxicity result in high levels of vulture mortalities. For instance, poisoning incidences in respect to lead ammunition [10], cyanide [11,12], and myriad types of agricultural chemicals/pesticides [13–15] have been widely reported. Although electrocutions and collisions of vultures have also been growing concerns around vulture mortalities [14], poisoning remains the top cause among several stressors of the plummeting vulture populations in SSA, accounting for 62 % of vulture deaths [16].

Vulture poisoning constitutes an impactful negative interaction between humans and vultures, resulting in a primary threat to vultures as it causes greatest mortalities [17]. Several African societies hold cultural norms and practices associated with fetish, clairvoyant abilities or faith-based (e.g., intellectual capacity, good luck) traditional medicine extracted from vulture body parts [18–21]. The threat to humans and terrestrial carnivores could be through the herbivore carcasses laced with poisons, for instance Refs. [20,22,23], but also exposure to chemical contaminated run-off into rivers and wetlands [12]. Ironically, poisoning also directly threaten human health as poisoned vultures are supplied to unsuspecting consumers as a source of food or for other consumptive purposes [9,21].

Though researchers have in the past collaborated to produce appellation of vultures as providers of critical ecosystem services [24], there is a need for more quantification of their contribution to humans for better awareness and human-vulture co-existence [25]. There are several co-benefits regarding humans and vultures [24]. While contemporary conservation efforts are critical to the vultures [2], African vultures, renowned for clean ups of the carcasses (i.e., an important sanitary ecosystem service for public and animal health) by feeding on the carrions of livestock, wildlife and other organisms [17,25], play an important role in disease transmission control to humans and among carnivorous scavengers [26,27]. Vultures also contribute to ecotourism-based incomes that are important to increasing community appreciation of vulture [28,29].

As vultures are obligate carnivorous scavengers, with high risk of exposure to poisoned food sources, they are deliberately targeted by humans [30], against the backdrop of the use of poisons in wildlife hunting being illegal in more than 83 % of African countries [9]. A single poisoning event can decimate vultures, making poisoning one of the major vulture-related environmental threats [31–33]. A vulture poisoning event can either be intentional (primary) or unintentional (secondary). The vulture poisoning is usually secondary [3,15]. For instance, intentional poisoning may involve sentinel vultures that are killed by poachers to elude arrests from law enforcement officers [22,33,34], or vultures executed by local community members seeking vulture body parts for traditional use [16, 21,35]. On the other hand, pastoralists and commercial farmers may unintentionally kill vultures when they use meat baits to poison predators in an effort to protect their livestock [3,15].

Vulture killings through poisoning are under-reported by conservation stakeholders [9], partly because of limited surveillances by law enforcement agencies due to low investment levels in biodiversity conservation [36,37]. The other reasons for under-reporting include the secretive nature of illicit activities regarding vultures [35,38,39], absence of stringent laws [12], and stakeholder resistance to cooperate in conservation programs [40]. The poisons are cheap, easy to acquire and use, and can kill the victims silently, non-selectively and in large numbers [3,9].

Much of wildlife poisoning incidences are undetected by the authorities, signaling huge magnitude of this wildlife crime in the ecosystems [39], and occur in area-specific locations, particularly those areas with high human-wildlife interactions [38]. Therefore, the actual numbers and proportion of the vulture populations attributed to poison mortalities in SSA is unknown [41], compromising stakeholder awareness of the magnitude of the challenge regarding vulture conservation strategies.

In the recent years, though, there are estimates, especially in some countries, such as South Africa, Botswana and Zambia reporting poisoning incidences fairly well on cloud platform (<https://awpd.cloud/>) and African Wildlife Poisoning Database (AWPD) Website (<https://www.africanwildlifepoisoning.org>). Though vulture species are rapidly driven toward extinction in the SSA [2,16,42], despite the existence of biodiversity laws in many African vulture range countries [9], the AWPD is an attempt to understand the magnitude of poisoning.

We contend that solutions to AVC involve social capital and could be linked to several relevant theories that would leverage stakeholders' affirmative and collective actions toward vulture conservation. Relational social capital refers to social assets, their

complex mechanisms and intensity of interactions between actors to achieve a shared goal, such as vulture conservation [43,44]. Such relationships could be anchored on absorptive capabilities of information sharing/transfer, innovations and implementation of novel solutions in resource management, and involve social capital aspects, such as trust, cooperation, networking/connectedness, commitment, reputation and reciprocity among allied individuals and institutions [45].

However, these socio-psychological elements create uneasy choices for the stakeholders between valuing nature (e.g., vultures) and elevated anthropogenic uses of resources [46], spanning across eco-centrism and anthropocentrism. Yet, the socio-psychological elements can play a critical role in reducing or preventing biodiversity loss, while safeguarding human-wellbeing [47]. Through active stakeholders' participation in resource management [48], strong social capital can stabilize or help resolve conservation conflicts in SSA [49].

## 2. The theories

In this study, we utilize two theories around social capital perspectives of vulture research: (1) theory of planned behavior, and (2) theory of change. The theory of planned behavior stipulates that shared beliefs, cultural norms and values influence intentions and social behavior of stakeholders [50], which could also theoretically and plausibly explain vulture poisoning in the SSA. The theory of change suggests that a goal would be better achieved via a well-defined and implemented pathway as a learning approach [51] and helps decompose complexities in social-ecological systems (SESs) [52]. Therefore, embracing positive intentions and social changes by stakeholders may help to enable better implementation of vulture conservation strategies, considering the goal (i.e., prevention of vulture species extinction), outcomes, outputs, activities and resources.

Against the background of the two theories employed in this study, we utilize the Pulse-Press Dynamics (PPD) framework [53] to explore the role of social capital in complex socio-ecological systems inhabited by African vultures. The PPD framework proposes pulse-press events as dynamic interrelationships between the social and biophysical domains [54], regarding vulture population stability and recovery. We use the framework to categorize events into two sets: events with discrete and acute effects and events with diffuse and sustained effects. In this sense, pulse events ensue precipitously, whereas press events occur gradually and persistently.

Using the PPD framework, we conceptualize and analyze the important cyclic relationships between AVC and social capital, including the social change implications among stakeholders. The most important pulse associated with vulture conservation in the SSA is the vulture poisoning [16], whereas the major press is AVC [1]. In the African landscapes, social capital approaches can play a critical role in realizing favorable conservation outcomes of reducing or reversing the AVC.

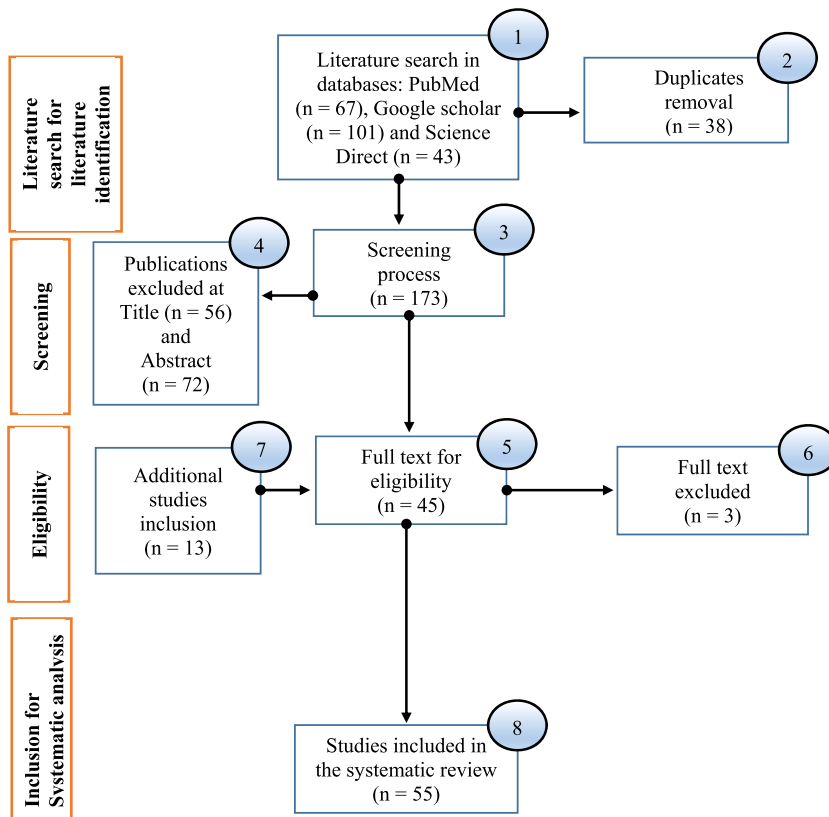


Fig. 1. Literature search schematic flowchart on the social capital regarding African vulture crisis in Sub-Saharan Africa.

**Table 1**

Exemplar disparities between the existing strategies and recommended actions associated with vulture conservation, based on vulture research literature.

Components	Existing strategies	Recommended interventions	Proposed anti-poisoning protocol	Country/Region coverage	References
<ul style="list-style-type: none"> <li>• Legal and policies</li> </ul>	<ul style="list-style-type: none"> <li>• Weak legislation and implementation;</li> <li>• Pesticide regulations are inadequate, with low enforcement of existing legislation;</li> <li>• Limited legislation awareness.</li> </ul>	<ul style="list-style-type: none"> <li>• Implementation of new and more stringent legislation that supports prosecution of suspects with intention to use cyanide or other poisons in wildlife crime;</li> <li>• National governments should urgently enact and enforce legislation to strictly regulate the sale and use of pesticides and poisons;</li> <li>• Banning pesticides, improving pesticide regulations and controlling distribution, better enforcement and stiffer penalties for offenders, increasing international support and awareness, and developing regional pesticide centers;</li> <li>• Continued focused education of public (e.g., commercial farmers, traditional medicine healers), local community awareness campaigns/ environmental outreach;</li> <li>• Implement effective compensation schemes to pastoralists/commercial farmers as reparations for livestock loss; sanitary regulations at abattoirs and dumpsites, and in carcass removal strategies;</li> <li>• Legal framework at regional/local scales;</li> <li>• Inclusion of vulture-safe designs in future constructions of powerlines and poles and the conservation of big trees in construction planning;</li> </ul>	<ul style="list-style-type: none"> <li>• Decontamination by use of Calcium hydro-chlorite of small contaminated water sources;</li> <li>• “Lagooning” (dilution, evaporation and exposure to UV light) of large water sources; or simply drained, flushed and refilled with fresh water or exclude animals from accessing the contaminated water through patrols and providing new water sources;</li> <li>• Originally applied in food chemistry, a simple-relatively cheap-easy protocol Picrate Test can be used to test and identify presence of cyanide;</li> <li>• Training adequate personnel in forensic field protocols.</li> </ul>	Ghana, Kenya, South Africa, Zimbabwe, Africa	Allan (1989); Nwokoro et al. (2009); Virani et al. (2011); McKean et al. (2013); Ogada et al., 2014, 2015a; Santangeli et al. (2016); Garbett et al. (2017); Henriques et al. (2018); Kankam and Abukari (2020); Thompson and Blackmore (2020); Brink et al. (2021); Mashele et al. (2021); Didarali et al. (2022); Hoare et al. (2022).
<ul style="list-style-type: none"> <li>• Intelligence</li> </ul>	<ul style="list-style-type: none"> <li>• Weak intelligence networks</li> </ul>	<ul style="list-style-type: none"> <li>• Strong intelligence network</li> </ul>	–	South Africa	McKean et al. (2013)
<ul style="list-style-type: none"> <li>• Translocations and restocking</li> </ul>	<ul style="list-style-type: none"> <li>• Translocations and restocking</li> </ul>	<ul style="list-style-type: none"> <li>• Continued education of the public;</li> <li>• Identification of potential areas for assisted re-establishment;</li> <li>• Further research on toxicological aspects of wildlife.</li> </ul>	–	South Africa, Nigeria, Ethiopia, Kenya, Tanzania, Botswana, Africa	Basson (1978); Murn et al., 2016; Ash and Patterson (2022)
<ul style="list-style-type: none"> <li>• Data collection and management</li> </ul>	<ul style="list-style-type: none"> <li>• Surveillance and monitoring of poison hotspots</li> </ul>	<ul style="list-style-type: none"> <li>• Reporting, and veterinary treatment;</li> <li>• Studying the poison rates;</li> <li>• Vulture population monitoring;</li> <li>• Developing and using Databases on poisoning incidences;</li> </ul>	<ul style="list-style-type: none"> <li>• Broad-based participation;</li> <li>• Transboundary coordination through use of African Wildlife Poison Database;</li> <li>• Implementation of international conservation science and policy</li> </ul>	South Africa, Nigeria, Ethiopia, Kenya, Tanzania, Botswana, Africa	Groom et al. (2013); Santangeli et al. (2016); Murn et al. (2016); Henriques et al. (2018); Monadjem et al. (2018); Mateo-Tamás and Lopez-Bao (2020); Plaza and

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Table 1 (continued)

Components	Existing strategies	Recommended interventions	Proposed anti-poisoning protocol	Country/Region coverage	References
		<ul style="list-style-type: none"> <li>• Basic protocol for land owners and game rangers in the sampling methods of poisoned species as well as a protocol for the best practice to dispose of a poisoned carcass to avoid further contamination;</li> <li>• Mapping priority conservation areas;</li> <li>• Local and large-scale prioritization and conservation planning</li> </ul>			Lambertucci (2019); Santangeli et al., 2019, 2020; Ash and Patterson (2022)
<ul style="list-style-type: none"> <li>• Social-ecological systems</li> </ul>	<ul style="list-style-type: none"> <li>• Fragmented human, wildlife and ecosystem health frameworks in many SSA countries</li> </ul>	<ul style="list-style-type: none"> <li>• One Health framework – a concept of collaborative implementation of interventions by stakeholders</li> </ul>	<ul style="list-style-type: none"> <li>• Creation of community-oriented information sharing and capacity building collaborations/partnerships/alliances among the stakeholders, such as researchers, conservation organizations, private actors, governmental agencies, and consortia;</li> <li>• Develop and implement National Vulture Action Plan, including monitoring, education and coordination programs at different scales.</li> </ul>	Africa	Phipps et al. (2013); Ottinger et al. (2021); Krüger et al. (2022)
<ul style="list-style-type: none"> <li>• Site management</li> </ul>	–	<ul style="list-style-type: none"> <li>• Site decontamination: e.g., removal of contaminated gut piles from the field and burning/incineration;</li> <li>• Supplementary feeding sites management;</li> <li>• Research focusing on finding lead contaminants sources;</li> <li>• Replacing lead bullets with non-lead alternatives;</li> <li>• Removing the bullet and tract of carcasses placed out for feeding;</li> <li>• Enforcing non-hunting in the areas where birds breed.</li> </ul>	–	South Africa	Masterson (2015); Naidoo et al. (2017); van den Heever et al. (2019); Hoare et al. (2022).
<ul style="list-style-type: none"> <li>• Combined approaches</li> </ul>	<ul style="list-style-type: none"> <li>• Based on large scale and severity of the vulture poisoning, a Multi-species Action Plan to conserve African-Eurasian Vultures (Vulture MsAP) was developed under Convention on the Conservation of Migratory Species of Wild Animals (CMS) in 2017. Ongoing efforts: integrated anti-poisoning campaigns in Africa, combining some or all of rapid response, law enforcement and mitigating human-wildlife conflict, while</li> </ul>	<ul style="list-style-type: none"> <li>• Based on lessons drawn from Asia, statutory ban alone is inadequate;</li> <li>• A combination of creation of statutory ban with other measures, such as creation of vulture safe zones, targeted persuasion, and education of public to allow recovery and reintroduction of captive-bred birds.</li> </ul>	<ul style="list-style-type: none"> <li>• Multi-stakeholder coordination at local and international levels.</li> </ul>	Africa	Buij et al., 2016; Henriques et al. (2018); Margalida et al. (2019); Plaza et al. (2019); Safford et al. (2019).

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**Table 1** (continued)

Components	Existing strategies	Recommended interventions	Proposed anti-poisoning protocol	Country/Region coverage	References
	linking the plight of vultures to that of carnivores and elephants to form stronger conservation coalitions; reintroduction or restocking with captive-bred vultures, linked to reduction of the threat from veterinary NSAIDs. Zimbabwe and South Africa have national vulture and/or raptor action plans.				

In response to the clarion call for urgent action to conserve African vultures [55], this review aims at exploring the stakeholder social capital that could leverage conservation efforts contributing toward tackling AVC, based on the reported evidence and insights from existing literature. In particular, we review the relevant publications, perceptions on vulture conservation, and conservation strategies/actions related to vulture poisoning. We ask the following questions: (1) what has been the nature of relational social capital among stakeholders in bridling the vulture decline in SSA? and (2) how could relational social capital be important to the implementation of AVC counter strategies?

### 3. Materials and methods

#### 3.1. Study registration

The Copperbelt University exempted this study from registration as review, but provided ethical oversight. We collated information from the existing literature regarding vulture poisoning across SSA.

#### 3.2. Search strategy

We conducted a systematic literature review in October 2022 using the stepwise Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method [56,57], [Fig. 1], with particular attention to conservation and environmental management records [58]. The PRISMA method proves effective in conceptualizing a review, designing, data identification, data searching and extraction, data eligibility and inclusion/exclusion, and reporting the results [57,59], [Fig. 1]. To ensure a comprehensive review of the evolution of social capital regarding the AVC, the search was not limited by time period up to October 1, 2022. Each author took part in the independent searches, which were later confirmed by other team reviewers, and collective reviews of the publications. This approach covered the effect measures by eliminating differences in publication acquisition between reviewers, and reduced risk ratio to bare minimum, while increasing the levels of sensitivity and confidence around the collected data [57].

The search for essential literature was conducted in PubMed, Google Scholar and Science Direct databases. The search terms used for the literature identification regarding vulture poisoning were: (ALL = (pesticide\*) OR ALL = (lead\*) OR ALL = (cyanide\*) OR ALL = (perception\*) OR ALL = (scavenger\*) OR ALL = (toxic\*) OR ALL = (Africa vulture crisis\*)) AND (ALL = (vulture\*) OR ALL = (poison\*) OR ALL = (sub-Saharan Africa \*) OR ALL = (exposure\*) OR ALL = (bird\*)). Missing data were assumed unavailable to reviewers.

#### 3.3. Data screening

In the publication review process, the extracted literature were screened for their suitability for inclusion. Initial assessment involved the relevance of the title and abstract.

#### 3.4. Eligibility criteria

To determine the eligibility of the literature for further consideration, each publication had to meet *a priori* set criteria and explicitly convey aspects of social capital (e.g., stakeholder trust, cooperation, commitment, and networking) for the analysis (Fig. 1; Table A1). Only original research/peer reviewed publications written in English were reviewed. Eligible studies in the reference lists of identified publications were also searched and examined for inclusion. By carefully searching the reference lists of identified publications from the initial search, 13 more studies were determined eligible for inclusion for detailed examination (Fig. 1). The additional inclusion was made if the publication: (1) contained evidence of vulture poisoning in SSA; (2) was not already identified from the initial search; (3) was a peer reviewed publication (e.g., journal article), available and accessed in full English text, and depict social capital in vulture

research and conservation in SSA; and (4) examined AVC counter strategies. The peer referential snowball approach stipulated by Ref. [60] was applied by each author, and counter-checked by the rest of the authors, to include publications omitted primarily because they did not contain specific indexing keywords we initially sought for in the initial search.

Literature failing to comply with the criteria were excluded from further analysis. Such literature were those solely focusing on outside Africa; the grey literature, dissertations/theses, conference proceedings, purely biological or ecological and inaccessible full articles (Fig. 1). We searched for duplicates, and only retained copies for further detailed reviews.

### 3.5. Inclusion for systematic analysis, and search validation

Based on the aforementioned review processes, the final identified publications were reviewed in details, while the resultant review repository is given in Table A1. Following the step-by-step independent searches, screening, iteratively reading of identified publications by authors (Fig. 1), data were extracted by authors through consultative discussions involving entire research team. Quality assurance of the search was done using the PRISMA 2020 checklist.

### 3.6. Data extraction and reporting

The collectively extracted data were populated into Garrard's table [60,61], reporting the search characteristics of the review that formed grouped evidence-based items for the synthesis (Table A1). The reported items were: year of study, lead author, affiliation of the lead author, country of origin, study country/region, number of institutions involved, number of authors, whether vultures and/or other wildlife studied, species, year of case, intended or unintended poisoning, purpose, whether in protected area or non-protected area, percentage of people practicing the poisoning, type of poison, source of poisons, method of poisoning, number of killed wildlife/vulture at event of poisoning, action taken, action recommended, and references. These items were identified as attributes associated with the purpose of this review.

### 3.7. Analysis of the African vulture crisis from the social capital perspective

The AVC reflects the negative human-vulture interactions, co-occurring in a complex SES with linkages and interdependences, requiring self-organization of resource users and conservation actors to reverse the trend [62]. While thriving to achieve sustainable development goals (SDGs) [14], integrating stakeholder social capital can inform sustainable mitigation pathways and solutions to the crisis. This study's focus is on relational stakeholder social capital that foster successful implementation of strategies and their resilience.

Resilient SESs are important for sustainable natural resource management that would ensure species are fully protected from extirpation or extinction, altogether [63,64]. The concept of social capital implies stakeholder relationships regarding SESs within vulture conservation that require self-adjusting/re-organizing with the rightful human dimensional interventions [47], which would then translate into recovery of vulture population.

In this study, we use thematic analysis [65] to represent and highlight various social capital thematic groups that decipher important social capital elements associated with AVC in the SSA (Table A1). The distribution of collaborative research authorship is one element we consider as a proxy to a suite of social capital, such as trust, cooperation, networking/connectedness, commitment, reputation, and reciprocity among researchers and institutions. The formal processes and frameworks associated with collaborative research among the alliances epitomize several social capital attributes, *inter alia* mutual trust, cooperation, professional social networking/connectedness in the co-creation of knowledge on vultures.

To compare and test statistical proportional differences between categories, we applied *prop.test* function in R statistical software [66]. The vulture range countries and regions in this study were adapted from Ref. [2]. The people with field experience and relevant background formed the research team, collected and analyzed data for this study [cf., 2].

## 4. Results

### 4.1. Search outputs

The search yielded a total of 211 studies at the beginning of this review exercise and this number was trimmed to 55 after a thorough literature review process and application of set eligibility criteria. Fig. 1 shows the literature review process of studies on vulture poisoning in SSA.

### 4.2. Stakeholder perceptions of the plight of vultures

Following an unequivocal confirmation and publicizing of the decline of African vultures [16], the agenda around the plight of the vulture is centered on the need to take urgent action to save vultures from extirpation and extinction (Table 1). However, there seem to be inconsistencies between the existing strategies and the recommended best practices in many of the wildlife poisoning hotspots (Table 1), which could be partly attributed to waning social capital [3]. The stakeholders' perceptions and attitudes toward wildlife, such as vultures, could be affected by the strength of wildlife institutions and rules that govern species and ecosystem conservation [67] as well as the existing knowledge gaps on the conservation status of vultures [68].

Ultimately, the call for stakeholders' prioritization of remedial actions in the vulture hotspots [2] underpins the general perception by the stakeholders for an urgent need to protect African vultures from anthropogenic effects. In this case, several researchers and institutions have participated in the development of conservation response frameworks, for instance Ref. [20] and African vulture case studies [37], while engaging and lobbying governments and other stakeholders into collaborative action (Table 1), with a view of halting the decline of the African vultures.

Such perceptions are compromised where the intrinsic value of vultures is discounted by stakeholders, such as traditional healers and vulture parts traders in lieu of bequest values [21,30]. Commercial farmers and pastoralists may also have their livestock production threatened by predation [3,15], thereby reducing their tolerance against wildlife [69]. Thus, positive perceptions require affirmative stakeholder social change, with emphatic effort on vulture conservation through such strategies as highlighted in Table 1.

4.3. Collaborative research authorship on vulture studies

There was uneven distribution of vulture studies by country and region across SSA, even in high priority vulture conservation areas [2], with Kenya and South Africa receiving the most collaborative research (Figs. 2 and 3). At least 12 studies covered entire particular region/SSA. The number of publications covering West Africa were significantly higher than those of other SSA regions (Fig. 3). The Central African region had the least number of publications partly because some parts are in none-vulture range, whereas East and Southern Africa had insignificantly different coverage (Fig. 3).

Except for the Central African region, there has been an increase in collaborative research (Fig. 4). Preponderance of publications (94.5 %, n = 52) embedded collaborative research (i.e., produced by more than one researcher or institution) involving universities, research institutes, conservation non-governmental organizations (NGOs), and state wildlife agencies. Details of the mean number of studies, authors and their respective institutions are given in Table 2. Universities constituted the majority (55.84 %, n = 287) of primary author affiliations, followed by research institutes (25.10 %, n = 129), conservation organizations (18.29 %, n = 94) and national parks and wildlife agencies (0.78 %, n = 4), with inter-institutional research collaborations that incorporated various fields (Table A1).

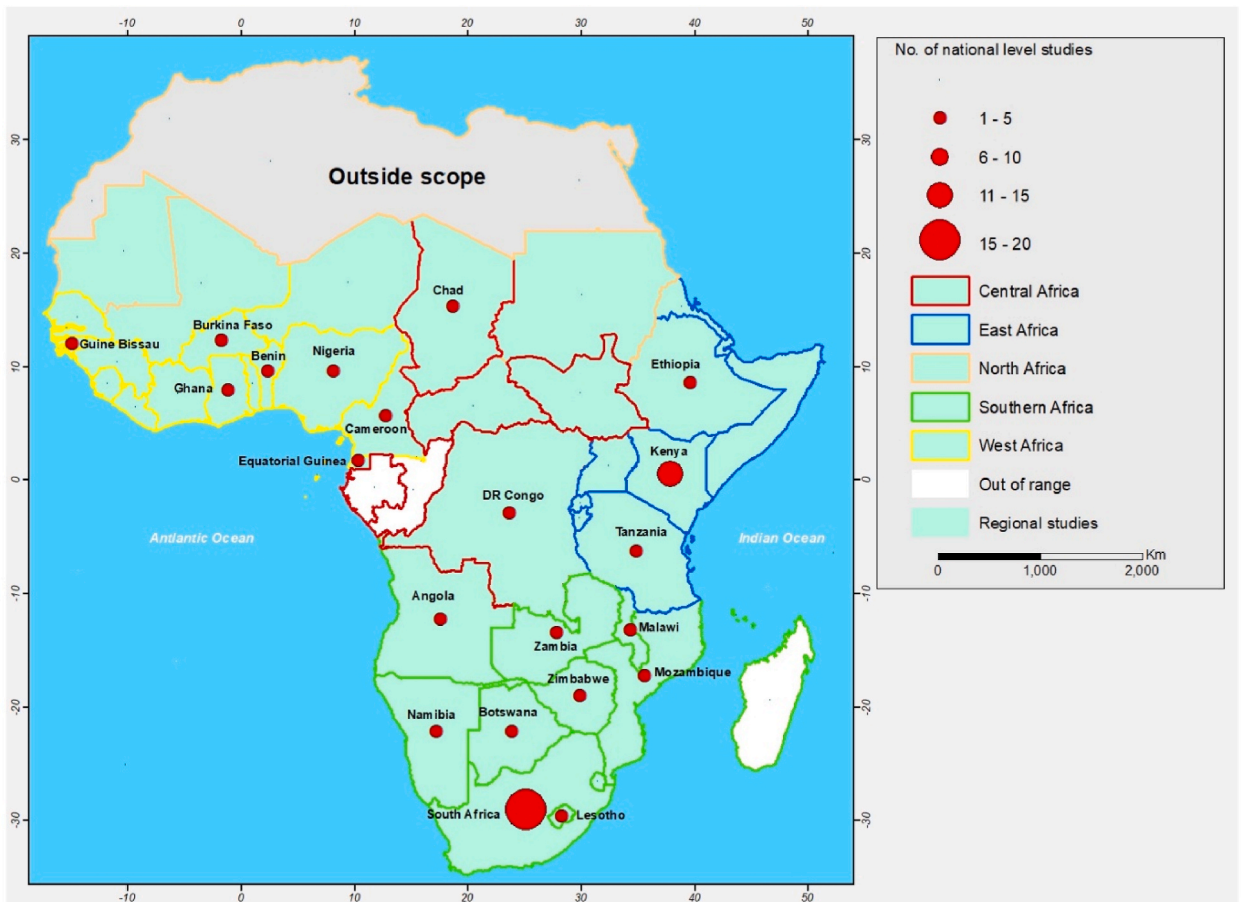
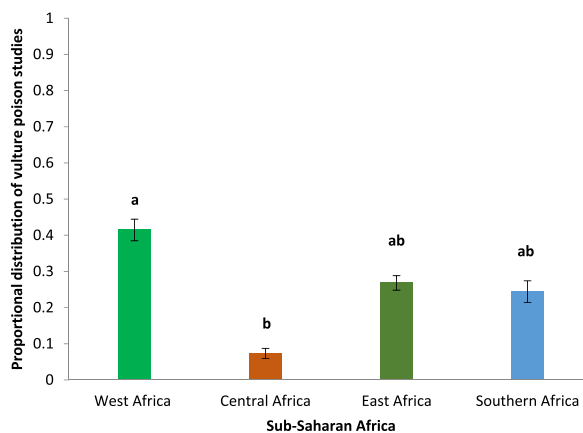
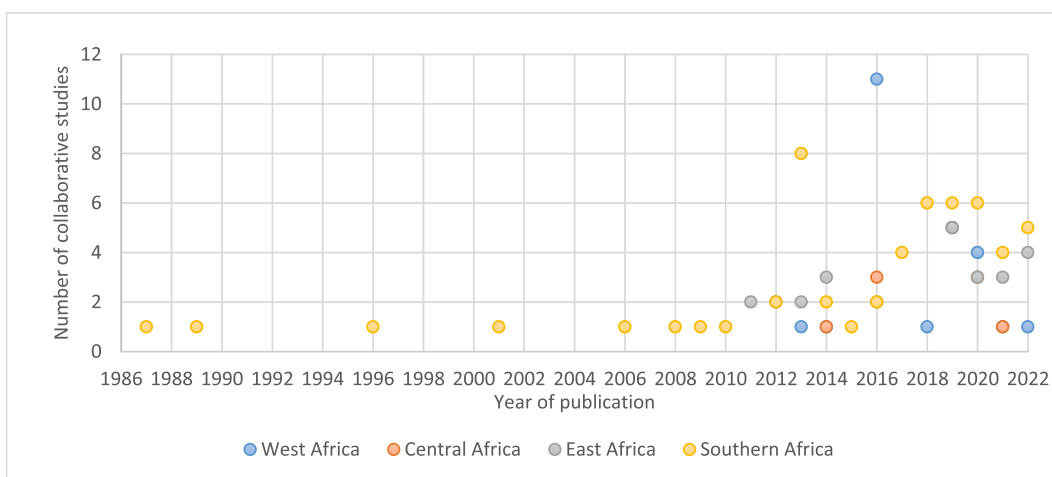


Fig. 2. Spatial distribution of vulture poisoning studies covering social capital aspects in Sub-Saharan Africa. The map shows regional distribution in green, while country specific studies are represented by graduated symbols.





**Fig. 3.** Proportional distribution of poisoning studies by region in Sub-Saharan Africa. The letters above the error bars are indicative of the level of statistical significance of proportions of vulture poison studies between regions.



**Fig. 4.** Trends in collaborative research indicative of growth in social capital among researchers and research institutions in SSA between 1987 and 2022.

**Table 2**

Summarized presentation of collaborative research on vulture, with explicit social capital elements in sub-Saharan Africa, 1987–2022 (in parentheses are value ranges).

Regions	No. of countries	Mean number of studies per county (±SE)	Mean number of author per county (±SE)	Mean number of institutions per county (±SE)
West Africa	17	12.47 ± 0.17 (12–14)	84 ± 0.70 (82–90)	93.00 ± 0.73 (93–102)
Central Africa	3	12.67 ± 0.33 (12–13)	85.33 ± 1.67 (82–87)	96.33 ± 1.67 (93–98)
East Africa	11	13.36 ± 1.00 (12–23)	87.18 ± 3.43 (82–119)	98.09 ± 3.71 (93–134)
Southern Africa	10	16.00 ± 1.96 (12–33)	104.20 ± 11.18 (82–201)	112.20 ± 10.34 (93–203)
<b>Total</b>	<b>41</b>	-	-	-

4.4. Performance of existing strategies and recommended actions

Over several decades, researchers have reported a myriad of strategies to avert the declining vulture populations from principal effects of poisoning in different locations of SSA (Table A1). Many researchers have advocated for a ban of sales and use of poisons, accompanied with stiffer penalties to the culprits, especially to be implemented with international support, for instance Refs. [9,16,23,70]. In some cases, treatment of livestock with alternative veterinary chemicals, such as non-steroidal anti-inflammatory drug (NSAID) meloxicam deemed less detrimental to vultures than other chemicals has been proposed [71]. However, many of the suggested

solutions have not yet shown positive effects on the African vulture populations, which has led to some researchers suggesting a combination of measures, for instance Refs. [13,55,72].

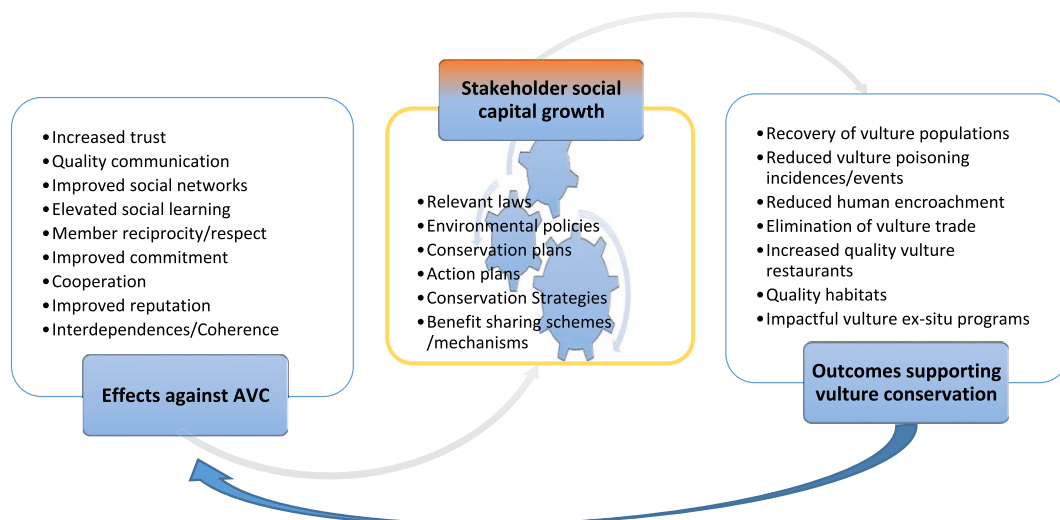
Much of biodiversity, including vultures, in the SSA is understudied [73], and vulture poisoning is not an exception [74]. The slow traction of many proposed actions could partially be due to low reproductive rates of vultures in response to dynamic environmental conditions [35,75], and questionable efficacy of the interventions as they are rarely evaluated [76]. The evaluations are important for reviewing the relevance and content of legislation regarding vulture conservation [77]. The [78] have proposed several relevant interventions (e.g., Increasing the effort and risks of crime; Reducing rewards, provocation and excuses; Increasing incentives for compliance with rule of law and rules of use) for vulture conservation. Although there exist several interventions, little successes are realized due to gaps between the strategies in place and the perceived ideal (recommended) actions in the SSA (Table A1).

Clearly, the resolution of colossal implementation gaps is constrained by environmental, socio-economical, as well as legal and technical factors, such as inadequate and in some cases lack of skilled personnel and other resources, such as funding to support the required levels of law enforcement accompanied by stringent laws in support of vulture conservation, forensic field protocols and successful prosecution [12]. Consequently, the recommended actions do not meet the corresponding levels of support from the stakeholders.

To improve conservation outcomes, there is a need to build a critical mass of stakeholders having high social capital with multiple assets, such as trust, collaboration/networking, and proactive participation in various vulture conservation initiatives. There are several relevant stakeholders and institutions, such as toxicological laboratories: crime laboratories, medical examiners, governmental health laboratories; ecotourism: tour operators, tour guides, local communities; conservation practitioners: conservation NGOs; University and research institutes: academics, researchers, ecologists; government agencies: wildlife, agriculture, education, community development, water, and environmental agencies to undertake the recommended actions (Table 1).

As exemplar for a functional social capital [3], suggest establishment of trusted and legit organizational bodies, such as farmer association to serve commercial farmers to deal with poison use and secure their support into alternative and more effective livestock protection measures. Quality information communication and exchanges among the partners, particularly use of deterrent informer networks [12] and functional databases, such as African Wildlife Poison Database [20], can prove to be effective measures to support control of use of lethal poisons against vultures. Such interventions to be effective, they consistently require coherent multi-scale alliances among stakeholders.

The favorable stakeholders' attitude positively shapes the trajectory of performance of the vulture conservation, and brings about affirmative stakeholder social change for sustaining vulture populations [79]. Social capital can leverage paucity of forensic field protocols, and essential storage and testing facilities [9]. The concept of One Health [1,80], which suggests collaborative stakeholder implementation of the interventions to leverage each other's weaknesses and strengths along the fund mobilization and community education [2], can be a critical element towards vulture conservation. Galvanizing the stakeholders into effectively participating is an important process of collective action for vulture conservation (Table 1). To actualize the collective action, there should be some effects under enabling conditions, such as policies, laws, conservation plans and strategies that should proffer positive outcomes (Fig. 5; Table A1).



**Fig. 5.** Conceptualized effects, stakeholder social capital growth factors and outcomes associated with vulture conservation in the Sub-Saharan Africa.

## 5. Discussion

### 5.1. Social capital growth regarding vulture conservation

Given that stakeholder social capital growth (e.g., trust, cooperation, networking/connectedness, commitment, reputation, reciprocity) is an important aspect of vulture conservation, the anti-African vulture crisis strategies should be centered on it. For sustainable conservation solutions, multi-stakeholder decision-making processes are emphasized [81]. The collaborative research can leverage local efforts to generate evidence-based data for decision-making at multiple scales [82], particularly where there are challenges and barriers to evidence use, such as inadequate research funding and toxicological laboratory facilities.

Besides, though information gaps have been reported in this study, social capital can lead to positive pathway (Fig. 4) as it can be self-reinforcing and regulating. Mechanisms on how to deal with evidence use in crisis zones exist, for instance Ref. [83], and can be adapted to vulture incidents to leverage the effort by champions and facilitators of vulture conservation. An example of functional collaboration would be where international partners assist countries to develop and implement national action plans to conserve vultures and avoid their looming extinction [30]. Furthermore, [12] suggest use of intelligence networks to gather wildlife crime information leading to successful arrests and prosecution of suspects. Such interventions call for philanthropy groups to constantly catalyze the vulture research and conservation. The role of such vertical integrations with the local institutions are important to wildlife conservation as they can reduce the opportunity cost and leverage local institutional efforts [36].

Though there are numerous advantages of growing stakeholder social capital, limitations can have “slow down” effects on vulture conservation. The secretive and illegal nature of vulture use [35], already highlighted, can hamstring the growth of relational social capital by reducing trust, cooperation, commitment and reciprocity among stakeholders in active information exchange and participation in vulture conservation. Essentially, this could be as a result of defiance against local wildlife authorities by the perpetrators of the act of vulture poisoning and other wildlife crimes, such as poaching [84].

Willingness of stakeholders to collaborate in the fight against wildlife poisoning may be an excellent ingredient to sustainable vulture conservation. While national wildlife poisoning response protocols are important to addressing vulture decline, they should go beyond securing successful prosecution of perpetrators. These protocols should incorporate strong evidence-based awareness creation as pre-emptive measure to influence lasting positive stakeholder social change and halt occurrence of wildlife poisoning before it happens. The overall framework for the social capital growth should consider the theory of change, associated with programmatic/project-based anti-vulture poisoning strategies.

### 5.2. Potential for social capital growth in support of vulture conservation

With the rightful base or benchmarks, the theory of change should be employed using available resources against set targets and timelines to achieve the goals and objectives of reducing or halting vulture decline, without harming the long-term sustainability of the ecosystem. High granularity (details) in the laws, policies, strategies, plans and schemes (Fig. 5) may improve the conformity and achievement of the goal by the stakeholders. Previously, conservation scientists co-produced information that was never put in action, but nowadays useful guidance to creating actionable science aimed at addressing conservation challenges, such as African vulture crisis, exists, for instance Ref. [85].

Theoretically, the potential of relational social capital contribution goes beyond the binary outcomes of vulture survival or mortality. It encourages persistent participation of multiple stakeholders to co-benefit the humans and vultures, while supporting conservation to allow for tolerance or adaptation of vultures to changing environments. The rapid vulture poisoning responses in the immediate/short phase, the long-term but more sustainable manner should include stakeholder environmental education and awareness to support permanent positive stakeholder social behavioral change, and preventing the poisoning taking place in the first place [84]. Given that there is a wide array of stakeholders and institutions involved in the development, deployment and implementation of vulture conservation strategies, it requires a novel environmental stewardship culture that promotes more integration among stakeholders and disciplines [86].

### 5.3. Future response strategies and implications for vulture conservation

A combination of several strategies for policy, practice and future research could be useful in addressing the AVC. The future strategies to AVC should consider stakeholders' needs and aspirations [87], to increase traction of the interventions by stakeholders through creation of direct incentives, such as income generation [28,29,88]. To guarantee successful conservation outcomes, there is a need to implement combined strategies by multiple stakeholders through collaborations. Ban of pesticides is important, but not a “cure-all solution” [23], so a combined suite of solutions is needed to reduce the prevalence and effects of vulture poisoning in SSA. On the other hand, proper use of pesticides remains an important aspect of food security [89]. As vultures are scroungers/obligate scavengers over spatially wide areas [7,14,90,91], landscape-based management of vultures involving multiple research and conservation stakeholders is recommended.

The prowess of the implementation of interventions will depend on the social capital of the stakeholders. The social capital could help increase human emotions, identities, attitudes and values [47], among co-created implementation collaborators [92]. More in-depth vulture studies across SESs in all the four African regions (i.e., west, central, east and southern) are urgently needed to guide essential broad-based collective actions [93]. Achieving environmental sustainability within a SES has become a challenge to stakeholders due to sheer magnitude of environmental degradation [94], such as one reflected by AVC.

#### 5.4. Review limitations

Although this review compressively highlights evidence, and implements processes suggested by Ref. [57], there are inherent limitations in the study. The limitations of the evidence included in this review are: (1) absence of formal social capital analysis, (2) possible missing data, (3) varying objectives of the source literature, and (4) non-testing of influence of use of technology by stakeholders in dealing with wildlife poisoning.

In-depth analysis on individual social assets, such as trust, cooperation, commitment, networking/connectedness, reputation, and reciprocity was not conducted. Such social assets may variedly affect the vulture conservation. Non-reported data in the existing literature was pragmatically difficult to source, which could affect the quality of our analysis. The varying objectives in literature could form premise for generation of different recommendations referred to in this study. Furthermore, whereas external factors, such as use of technology in conservation, and social infrastructure to assess effects of institutional dynamics on vulture populations, could be important elements about stakeholder social behavior change, none of these have been tested in this study as they were outside its scope.

The limitations of the review processes used in this study are: (1) the non-registration of this review under the established review protocol, (2) inability to validate the review, (3) inclusion/exclusion of literature based on language, and (4) difficult in tracking social behavioral change in vulture conservation literature.

This review was not registered as suggested by Ref. [57], due to technicalities, though all other review requirements were met. This review process did not incorporate SSA-wide validation of literature used with field surveys, key informant interviews or workshops to further confirm stakeholder contemporary thinking and social changes regarding vulture conservation practice. Given that the literature search and selection criteria considered only materials published in English (i.e., inclusion/exclusion criteria), some insightful contributions in none-English speaking countries may have been missed out. There is a need for more long-term focused studies towards collation of stakeholder social behavior change regarding vulture conservation across SSA landscape, extending to systems analysis of social capital. Such an analysis will provide more insights on how various social elements interact and work together to influence the outcomes on the vulture conservation implementation.

#### 6. Conclusions

This review demonstrates the importance of considering integration of stakeholder social capital in the development and implementation of vulture conservation strategies in the SSA. The human dimension is a critical ingredient to vulture conservation, but largely a neglected nuance. The social capital perspective underscores a need for multiple participation in first growing social capital components, such as trust, cooperation and vertical/horizontal networking. It calls for holistic and coherent approaches *inter alia* political will, stakeholder willingness to cooperate, increased investments to vulture conservation using vultures as umbrella species, and social learning for enhanced governance. As vulture sub-Saharan range countries' governments consider meeting biodiversity conservation commitments, we encourage them to closely collaborate with multiple stakeholders, such as universities, biodiversity researchers, conservation NGOs, conservation practitioners, local communities, farmers, traders, traditional players (e.g., healers), and pharmaceuticals in successfully scaling-up working vulture strategy implementation for positive conservation outcomes. The human-nature centered/oriented interventions through social capital growth would increase the chances of reduced vulture poisoning-linked infractions, while increasing human-vulture co-existence. The approaches suggested here can also be applied to other wildlife species, ecosystems and landscapes. Further research may focus on the cost-effectiveness and resilience of the social capital in vulture conservation.

#### Conflicts of interest

The authors declare that they have no conflict of interest.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Ethics approval

Review and/or approval by an ethics committee was not needed for this study because it does not directly involve interactions with animals and people.

Informed consent was not required for this study because it used secondary data that were already synthesized into publication, without traceable participating people.

#### Funding

No funding was received from a funder.

#### Data availability statement

Has data associated with your study been deposited into a publicly available repository?

No.

Has data associated with your study been deposited into a publicly available repository?

Data included in article/supplementary material/referenced in article.

While the data is not deposited into a publicly available repository, all data generated or analyzed during this study are included in this published article (Table A1).

### CRedit authorship contribution statement

**Vincent Raphael Nyirenda:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Bimo Abraham Nkhata:** Writing – review & editing, Validation, Investigation. **Darius Phiri:** Writing – review & editing, Visualization, Validation, Investigation. **Wilfred Nyirenda:** Writing – review & editing, Validation, Methodology, Investigation, Conceptualization. **Daniel Nyamphande Phiri:** Writing – review & editing, Validation, Investigation. **Mary Malasa:** Writing – review & editing, Validation, Investigation. **Matthew Smith Becker:** Writing – review & editing, Validation. **Enala Mwase Tembo:** Writing – review & editing, Validation, Investigation. **Moses Amos Nyirenda:** Writing – review & editing, Validation, Investigation. **Twakundine Simpamba:** Writing – review & editing, Validation, Investigation. **Jacob Mwitwa:** Writing – review & editing, Validation, Investigation, Funding acquisition. **Chansa Chomba:** Writing – review & editing, Validation, Investigation, Conceptualization.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2024.e25126>.

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