Full Length Article

Total economic Vulture: The value of ecosystem services provided by vultures in Southern Africa

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ABSTRACT

Africa is home to eleven species of vultures, seven of which face the risk of extinction and are listed as Vulnerable, Endangered or Critically endangered on the IUCN Red List. The major threats are poisoning, belief-based use, electrocutions and collisions. The loss of vultures in Asia provided a window into a catastrophic scenario without vultures and the impact of the loss of the ecosystem services they provide. In the African context, there is a knowledge gap on the importance of vultures to humans and the impact that a loss of vultures would have. This paper attempts to fill this gap with an economic valuation of the ecosystem services provided by vultures in Southern Africa, with a focus on Botswana, Zambia and Zimbabwe. The ecosystem services addressed in the assessment include provisioning, regulating and cultural services. Data were collected through four surveys targeting different beneficiary groups: 1. local communities in the Kavango Zambezi Transfrontier Conservation Area; 2. the general public within each country; 3. the international public; and 4. rangers and park managers. A mix of valuation methods were used including discrete choice experiments, contingent valuation, avoided damage costs, replacement costs, and net factor income. The total economic value of ecosystem services in the three countries is estimated to be just over USD 250 million per year. This is largely attributed to existence and bequest values and the sanitation and pest control service provided by vultures. Although vultures are arguably not as charismatic as other species of interest in the continent, their conservation is highly important to the welfare and health of people in Southern Africa.

1. Introduction

Vultures are facing many threats and declining populations worldwide (Ogada et al., 2012; Safford et al., 2019), with 7 of 11 species in sub-Saharan Africa listed as either Vulnerable, Endangered or Critically Endangered and 9 of 11 species facing decreasing populations (IUCN, 2023). Fig. 1 represents the location of vulture hotspots in Africa (Buij et al., 2024). The main threats to African vulture populations include poisoning, belief-based use, electrocutions and collisions, and direct persecution (Botha et al., 2024). The population decline is of great concern as vultures provide a number of ecosystem services that are of substantial benefit to people (Ogada et al., 2012; Carucci et al., 2022;

Santangeli et al., 2024) including provisioning services (e.g., vulture parts that are used in traditional medicines), regulating services (e.g., disposal of carrion and waste) and cultural services (e.g., aesthetic enjoyment, inspiration for art, nature tourism, existence and bequest values). Information on the contribution of vultures to human wellbeing can be useful to inform decision-making regarding their use and conservation (Wenny et al., 2011). In particular, economic values can be used to highlight the economic importance of vultures to policy makers and the public, to design policy instruments and conservation financing mechanisms, in appraisal of conservation plans, and to set compensation for damage to vulture populations that reflects full economic loss (Pearce and Turner, 1990).

Carucci et al. (2022) conducted a recent systematic review of the literature on ecosystem services and disservices associated with vultures. They identify major knowledge gaps on the understanding of ecosystem services and disservices related to vultures and conclude that there is an urgent need to quantify the net contribution of vultures to people. The loss of vultures in Asia provided a window into a catastrophic scenario without vultures and the impact of the loss of the ecosystem services they provide (Markandya et al., 2008; Frank and Sudarshan, 2023; Ishwar and Das, 2024). In the African context, there is a knowledge gap on the importance of vultures to humans and the impact that a loss of vultures would have. The research presented in this paper attempts to fill part of this knowledge gap by estimating the economic value of ecosystem services provided by vultures in three countries in Southern Africa (Botswana, Zambia and Zimbabwe) and assessing the benefits of policy action and the costs of policy inaction.

The structure of the remainder of the paper is as follows: Section 2 provides a review of the literature on vulture ecosystem services and their values; Section 3 describes the methods that are applied to quantify and value vulture ecosystem services in Southern Africa; Section 4

reports the estimated values for each ecosystem service and the results of a scenario analysis that explores how these values might change over time under alternative conservation futures; finally, Section 5 provides conclusions and identifies avenues for future research.

2. Literature review

The literature review presented in this section serves two purposes: firstly, to identify the key ecosystem services provided by vultures; and secondly to collect existing estimates of their economic value that can potentially be used as a basis for estimating values for Southern Africa.

2.1. Ecosystem services provided by vultures

The literature review builds on existing reviews and involved a search of literature databases to provide an overview of studies on the economic value of ecosystem services derived from vultures. The review includes peer reviewed journal articles, working papers and research reports, academic dissertations and theses, NGO publications, and
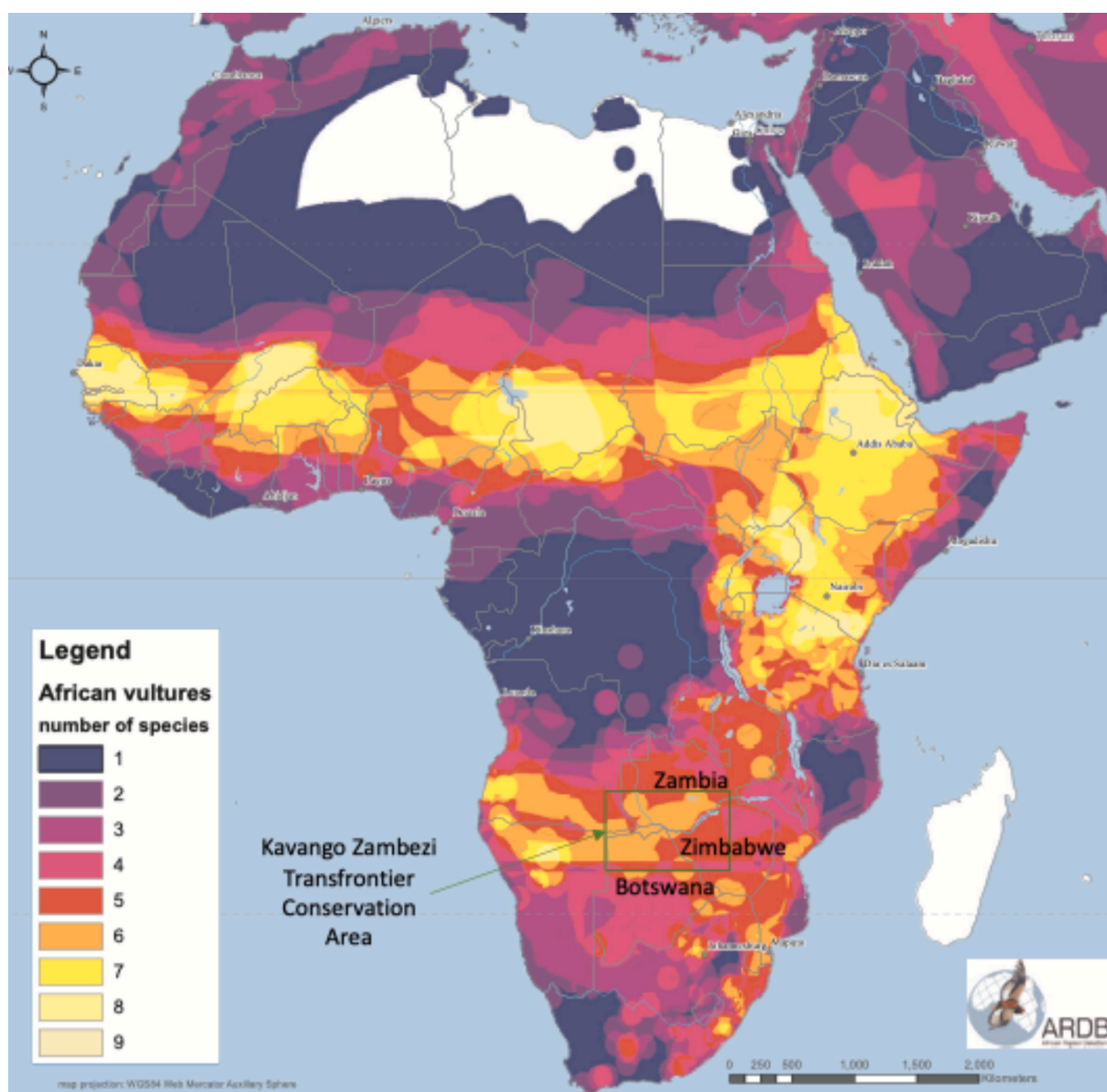

Fig. 1. Vulture species richness. .
Source: African Raptor Databank (Buij et al., 2024)

government reports. The literature search was conducted using a variety of sources to ensure a comprehensive collection of studies was obtained. Conventional online literature tools and libraries such as Google Scholar, Scopus, ResearchGate, Mendeley, and institutional libraries were utilized to gather relevant published literature. Reports and studies that cited a large number of sources were used as a source of references, which helped to identify additional relevant literature. Combinations of search terms were used to encompass a literature that uses a diverse terminology. The results of the literature review are summarised in Table 1, which lists ecosystem services provided by vultures, provides a brief description of the service, and cites relevant publications.

We note here that there is high correspondence in the benefits derived from the regulating services "waste disposal" and "sanitation and pest control services". They are treated as separate services to make the distinction between the benefit of reduced human disposal of animal carcasses and the benefit of positive effects on human and animal health. Van den Heever et al (2021) describe two impact pathways through which the removal of carcasses from the environment by vultures can have positive health outcomes: 1. by directly preventing the development and spread of pathogenic microbes in carcasses; 2. by limiting the numbers and composition of mammalian scavengers that spread diseases to human and animal populations, including livestock.

2.2. Literature on economic valuation of vulture ecosystem services

In addition to identifying key ecosystem services provided by vultures, the literature review was used to obtain relevant existing vulture valuation studies, the results of which may potentially be transferred or scaled up to the Southern African context. The collected valuation studies may also provide guidance and recommendations for future valuations of vultures.

From the literature review, we identified ten studies that estimate the economic value of vulture ecosystem services. These studies are summarised in Table 2. The geographic coverage of these studies is broad, including locations in Europe, Asia, North and South America. Notably, there are currently no valuation studies for vultures in Africa.

Regarding the ecosystem services that have been valued in the literature, three studies estimate values for waste disposal (Margalida and Colomer, 2012; Ishwar et al., 2016; Grilli et al., 2019), three for ecotourism (Becker et al., 2005; García-Jiménez et al., 2021; Becker et al., 2010), three for existence values (Becker et al., 2010; Baral et al., 2007; Zambrano-Monserrate, 2020), and two for the control of pests (and in consequence the control of diseases spread by feral dogs – Markandya et al., 2008; Berlinguer et al., 2021). There are currently no valuation studies for provisioning services supplied by vultures.

The application of valuation methods corresponds closely to the ecosystem services that are valued. All three valuations of waste disposal use the replacement cost method, with the underlying assumption that carrion disposed of by vultures would need to be replaced by human-made processing, such as collection, burial or incineration.

The first study that examines the role of vultures in controlling pests (Markandya et al., 2008), estimates the value of changes in the prevalence of human health endpoints (morbidity and mortality) due to changes in the abundance of feral dogs that spread rabies using a combination of the costs of treatment and the value of a statistical life (VOSL). In this approach, the biophysical quantification of changes in pest populations in response to changes in vulture populations (controlling for other factors), and the associated changes in prevalence of disease (again controlling for other factors) presents a greater challenge that the monetary valuation of health endpoints, for which country specific data are generally available. The second study to estimate the value of this service (Berlinguer et al., 2021) applies the replacement cost method in a similar approach to the valuations of the waste disposal service.

Ecotourism associated with vultures has been valued using several methods, including the travel cost method, gross expenditure and time

Table 1
Ecosystem services provided by vultures (adapted from Fitzpatrick et al., 2018; Carucci et al. 2022; Sebele 2022).

	Ecosystem service	Description of vulture ecosystem service	Reference
Provisioning services	Food from wild animals	Vultures used or traded for consumption	Saidu and Buij, 2013
	Materials from wild animals	Vulture parts used in traditional practices (medicine, healing, prophecy)	Craig et al., 2018; Mdhlano et al., 2018; Mashele et al., 2021
Regulating services	Waste disposal	Disposal of dead livestock and organic waste produced by humans	Gangoso et al., 2012; Buechley et al., 2022
	Sanitation service through disposal of carrion and waste	Reduced accumulation of toxins from breeding micro-organisms in carrion. In addition, pathogens are destroyed in the digestive tract of vultures.	Margalida, A., and Colomer, 2012; Ishwar et al., 2016; Donázar et al., 2016; Grilli et al., 2019; Houston and Cooper 1975; van den Heever et al. 2021; Jalihal et al., 2022; Frank and Sudarshan, 2023
	Controlling pests and invasive species	Presence of vultures reduces number of other scavengers (e.g. feral dogs, jackals, rats and hyenas) at carcasses that can be harmful to human and livestock health through disease transfer. This can also result in a reduction in human-wildlife conflict. Also reduction in invertebrate pest species that hatch their eggs in rotting meat.	Markandya et al., 2008; Ogada et al., 2012; 2012b; Berlinguer et al., 2021; van den Heever et al. 2021; Buechley and Şekercioğlu, 2016; 2022; Brink, 2022; Frank and Sudarshan, 2023
	Maintenance of soil quality	Soil microbial communities associated with vultures exhibit greater phylogenetic clustering in bacterial communities.	Ganz et al., 2012
	Global climate regulation	Vultures consume dead animals that would otherwise decompose and release greenhouse gases to the atmosphere	Plaza and Lambertucci, 2022
Cultural services	Cultural significance	Role in mythology. Seeing vultures in flight is uplifting for many people. Inspiration for art, music and creativity. Part of traditional stories and expressions.	Craig et al., 2018; Jacques-Coper et al. 2019; Aguilera-Alcala et al. 2020; Daboné et al., 2022
	Nature based tourism	Viewing and photographing vultures is among the reasons for visiting nature reserves.	Becker et al., 2005; 2010; García-Jiménez et al., 2021
	Sentinel role for identifying the	The presence of vultures can help livestock farmers/	Safford et al. (2019)

Table 1 (*continued*)

Ecosystem service	Description of vulture ecosystem service	Reference
location of dead animals	park rangers to locate dead livestock/poaching sites	
Existence and bequest values*	People place value on the continued existence of vultures irrespective of any current or future use; or to ensure their existence for future generations	Baral et al., 2007; Zambrano-Monserrate, 2020;

* Existence and bequest values are not present in all classifications of ecosystem services but often represent a significant component of the total economic value of ecosystems and species and have been included in more recent classifications such as CICES 5.1, codes 3.2.2.1 and 3.2.2.2 (Haines-Young and Potschin-Young, 2018), and the System of Environmental Economic Accounting Ecosystem Accounts classification, code 4.1 (United Nations et al., 2021).

Table 2
Economic valuations of ecosystem services provided by vultures.

Ecosystem Service	Species	Valuation Method	Location	Reference
Waste disposal	European vultures	Replacement cost	Europe	Margalida and Colomer, 2012
Waste disposal	Griffon vulture	Replacement cost	India	Ishwar et al., 2016
Waste disposal	Turkey Vultures	Replacement cost	North and South America	Grilli et al., 2019
Control of pests	Vultures	Treatment costs; Value of statistical life	India	Markandya et al., 2008
Control of pests	Griffon vulture	Replacement cost	Sardinia	Berlinguer et al., 2021
Ecotourism	Avian scavengers	Market price; Opportunity cost	Spain	García-Jiménez et al., 2021
Ecotourism; Existence value	Griffon vulture	Travel cost; Contingent valuation	Israel	Becker et al., 2010
Existence value	White-rumped vulture	Contingent valuation	Nepal	Baral et al., 2007
Existence value	Andean Condor	Contingent valuation	Ecuador	Zambrano-Monserrate, 2020

opportunity per trip, and the contingent valuation method (Becker et al., 2005; 2010; García-Jiménez et al., 2021). These methods measure different concepts of value derived from tourist activities. The travel cost and contingent valuation applications produce estimates of consumer surplus to tourists; whereas gross expenditure and time opportunity cost produce an estimate of exchange value. The latter approach is likely to substantially over-estimate the value of vulture viewing since it attributes the entire cost of a trip to this single motivation.

The values that people place on the continued existence of vultures have been estimated using the contingent valuation method. This approach enables the measurement of public willingness to pay (WTP) for a specified change in vulture population or conservation programme. It is notable that currently there are no valuations of existence values for vultures using discrete choice experiments, although this may simply be because they are not considered charismatic and do not attract public sympathy. This stated preference method has largely superseded the contingent valuation method over the past decade and enables the estimation of WTP for changes in defined attributes of conservation (e.

g., population trends, population size, species diversity, species extinctions) and subsequently the valuation of alternative conservation programmes/outcomes defined in terms of these attributes (Hanley et al., 2001). As such, the present study is the first to apply the discrete choice experiment (DCE) method to the valuation of vulture ecosystem services.

3. Conceptual and methodological framework

This section provides a description of the conceptual framework, the valuation methods applied to value each ecosystem service, the data collection methods, and the scenario analysis.

3.1. Conceptual framework

The conceptual framework for identifying and valuing the benefits that people derive from vultures combines the Ecosystem Services (ES) approach (MA, 2005; Haines-Young and Potschin, 2010) and the Total Economic Value (TEV) framework (Pearce and Turner, 1990; Pascual et al., 2012; IPBES, 2022). Ecosystem services are defined as the benefits that ecosystems provide for people (MA, 2005). In Fig. 2 we adapt the ecosystem services cascade (Haines-Young and Potschin, 2010) to represent the linkages between vulture populations, functions, services, values and beneficiaries. This formulation helps to define separate services and avoid potential double counting in the computation of total economic value. This is of particular concern regarding the services derived from the consumption of carcasses by vultures and our reasoning for identifying distinct services is as follows: 1. The consumption of carcasses (of both livestock and wild animals) and other waste by vultures can be considered as an ecosystem function; 2. This ecosystem function cascades into multiple ecosystem services; 3. One service is the disposal of livestock carcasses that would otherwise need to be disposed of by farmers, who are the beneficiaries of this service; 4. A second service is sanitation and pest control that reduces the prevalence of diseases. People that would otherwise contract and suffer from disease are the beneficiaries of this service. Since this service is derived from the consumption of both domesticated and wild animal carcasses and other types of waste, it is of broader scope than the disposal of livestock carcasses only; 5. A third service is the sentinel role that facilitates the location of missing livestock and poaching sites, for which the beneficiaries are livestock farmers and managers of protected areas; 6. A fourth service is vulture related tourism, in the case that tourists view feeding vultures, for which the beneficiaries are the tourists and tour operators.

The focus of this study is on the positive contributions that vultures make to human wellbeing and we estimate values for provisioning, regulating and cultural services provided by vultures. We acknowledge, however, that vultures may also provide disservices, which can be defined as the negative contributions from an ecosystem to human wellbeing, irrespective of the role of human agency in the underlying processes (Campagne et al., 2018; Lliso et al., 2022). In the case of vultures, disservices may include the predation of or harm to livestock, collisions with aircraft, and negative symbolism (Carucci et al., 2022). Given limited resources of the study and the primary demand for information to support conservation advocacy, it was decided not estimate the value of vulture disservices. We do, however, provide some results on perceptions of vultures obtained through public surveys.

In valuing ecosystem services, it is important to define the scope of the service provision, or change in service provision, that is being valued in order to relate the estimated value to a specific quantity of service (Kahneman and Knetsch, 1992; Botzen and van Beukering, 2018). In this study, the geographic scope of the valuation is vulture populations in Southern Africa and the scale of ecosystem service provision is the total flow of benefits received in one year. In the application of the discrete choice experiment, however, the scale of the good that is valued is systematically varied in terms of trends in vulture populations and
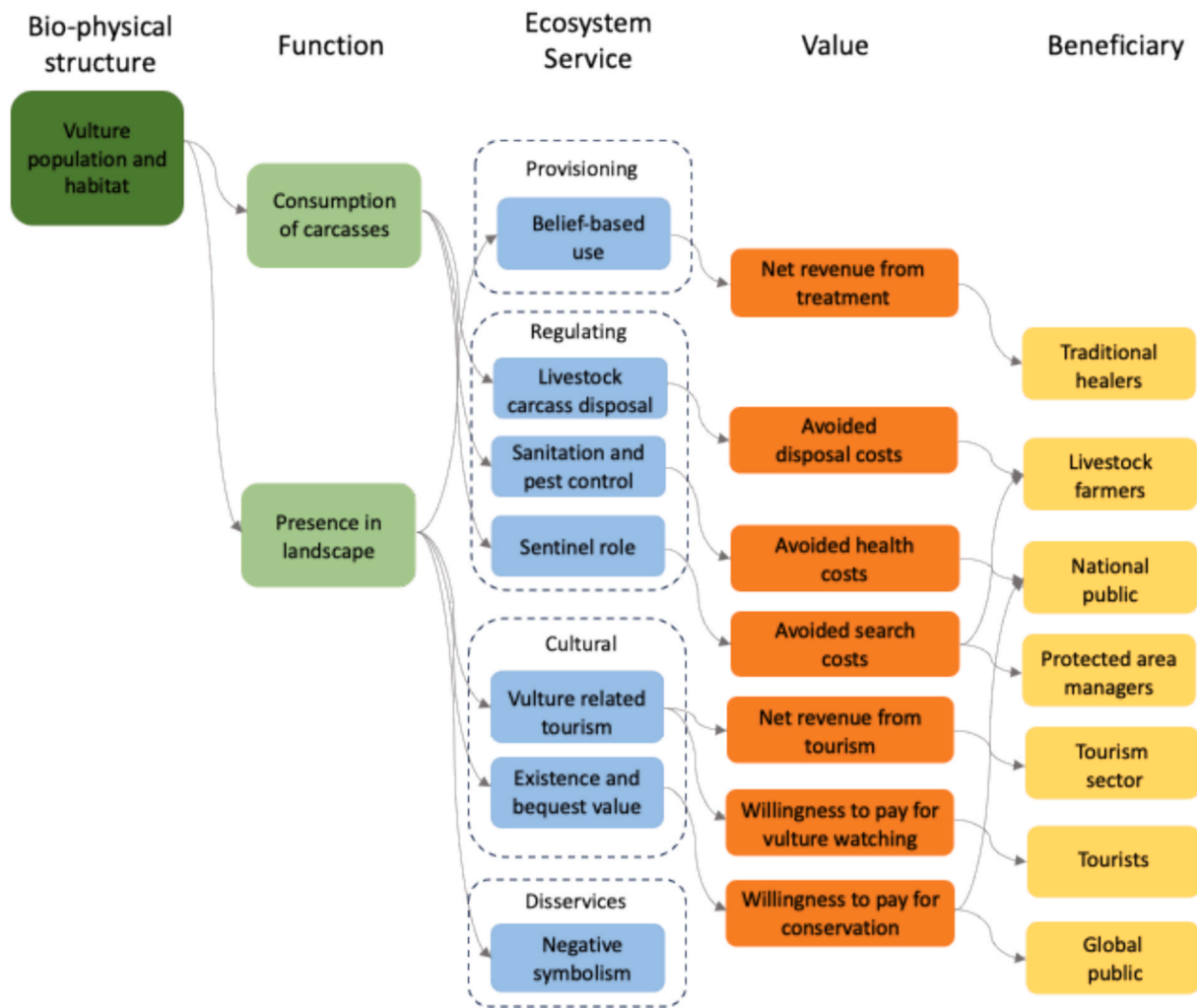
Fig. 2. Ecosystem services cascade for vultures (adapted from Haines-Young and Potschin, 2010).

number of species conserved in order to estimate marginal values for these environmental attributes.

3.2. Valuation methods

Given the very limited number of existing primary valuation studies for vulture ecosystem services (and none for Africa) summarised in Table 2, it was concluded that there is very limited scope for applying value transfer methods and that the study should therefore apply mainly primary valuation methods.[1]

An important issue in designing the valuation methods is the challenge of measuring vulture specific values within bundled goods and services (e.g., non-use values for vultures within broader landscape conservation; vulture ecotourism activities within holidays that involve multiple activities). The valuation methods have been developed to estimate values that are separably attributable to vultures. In addition, the valuation methods are designed and applied to estimate values for each ecosystem service separately so as to avoid double counting values in the summation of Total Economic Value. The selected valuation method(s) for each ecosystem service are outlined in Table 3. Full details of the applied methods can be found in Brander et al. (2025).

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[1] Value transfer involves the use of results from existing primary valuation studies to estimate the value of ecosystem services at other locations or contexts (Brander, 2013).

3.3. Data collection

The data collection for the study comprises of four surveys targeting different beneficiary groups: 1. Households in local communities in the vicinity of vulture habitats; 2. Households representing the general public in Botswana, Zambia and Zimbabwe; 3. Households in countries outside of the study area; 4. Rangers and park managers. Each of these surveys are outlined below.

The *local community survey* contains questions on the use, perception and traditional beliefs related to vultures and stated preference questions to quantify willingness to pay (contribute time) for vulture conservation. The full survey instrument is provided in the Supplementary Information. The survey was implemented through face-to-face interviews by BirdLife representatives in Botswana, Zambia and Zimbabwe during February-April 2024. The target sample size for each country is 200 respondents to enable statistically significant WTP estimates from the discrete choice experiment. A convenience sampling approach was used to enable the achievement of the target sample size in the limited time available for the survey. Target communities (4–6 in each country) were identified based on current BirdLife activities, representing different regions of each country, including locations in the Kavango-Zambezi Transfrontier Conservation Area (KAZA). Respondents within each target community were selected through simple intercept approaches (e.g. at convenient locations such as at home, markets, transport hubs). Survey enumerators used a web-based form (using a phone or tablet) in order to avoid the need for data entry. The

Table 3
Key vulture ecosystem services and selected valuation methods.

	Ecosystem service	Valuation Method
Provisioning services	Materials from vultures used in traditional medicines	Net factor income. Estimate producer surplus as gross revenue (market price equivalent * quantity traded/consumed) minus the costs of production. Data collected through household survey of local communities
Regulating services	Waste disposal	Replacement cost. Estimate the avoided costs of waste disposal attributable to the presence of vultures: 1. Estimate quantities of livestock carcasses consumed by vultures; 2. Identify use of alternative human processes for disposal of carcasses (in order to show effective demand for carcass disposal); 3. Estimate cost of human processes for disposal of carcasses. Data collected through household surveys of local communities.
	Control of disease through disposal of carrion and waste (sanitation and control of pest species)	Avoided damage cost. Estimate the avoided cost to human health from pathogens in carrion and waste attributable to the presence of vultures: 1. Obtain data on human populations living in vulture ranges; 2. Estimate reduction in human mortalities attributable to the sanitation service provided by vultures; 3. Estimate the reduced cost of human mortality in terms of the value of a statistical life. Data collected from national censuses and secondary sources.
Cultural services	Cultural significance	Contingent valuation and Discrete choice experiment. Two stated preference methods, administered through household surveys, are used to jointly estimate the value of cultural significance and existence/bequest values. Follow-up questions on the motivations underlying willingness to pay for vulture conservation used to disaggregate values across ecosystem services. Three separate beneficiary groups are targeted: 1. Local communities living in the vicinity of vulture habitats; 2. General public in Botswana, Zambia and Zimbabwe; 3. General public internationally (primarily in Europe due to availability of mailing lists). The geographic scope of the conservation good is defined as Southern Africa and the outcome of conservation is defined as "conserving vulture populations and maintaining the diversity of species". The payment vehicle for the local community survey is the number of days volunteered per month for vulture conservation*; and for the general and international public survey, a voluntary money contribution per month to a fund for vulture conservation administered by an environmental NGO. A payment card elicitation format is used for the contingent valuation question.

Table 3 (*continued*)

Ecosystem service	Valuation Method
	The discrete choice experiment includes three attributes: 1. vulture population trends (declining, stable, increasing); 2. species diversity (number of vulture species becoming extinction in the study area); 3. Days/money donated to vulture conservation. The CV and DCE questions and example choice card from the local community survey are included in the Supplementary Information.
Nature based tourism	Net factor income. Estimate producer surplus derived from vulture related tourism: 1. Estimate the number of tourists that visit areas with vultures (from tourist operators); 2. Estimate mean tourist expenditure for whole trip (from tourist survey); 3. Estimate net revenue as expenditure*profit factor (from tourist operators); 4. Attribute share of producer surplus to vultures using information on relative importance of vultures in motivation for tourist trip (from tourist survey).
Sentinel role for identifying the location of dead animals	Replacement cost. Estimate the avoided costs of locating dead animals attributable to the presence of vultures: 1. Quantify use of vultures for locating dead livestock and wild animals of interest such as elephants and rhinos; 2. Identify use of alternative human processes for identifying dead animals (in order to show effective demand for this service); 3. Estimate cost of human processes for locating dead animals in terms of time and resources. Data to be collected through household surveys of local communities and consultation/survey of rangers.
Existence and bequest values	Contingent valuation; Discrete choice experiment. See description of methods for cultural significance.

* The payment vehicle used in the local community stated preference questions was volunteered time for conservation activities instead of money, since households are likely to be cash-constrained and have limited past experience of donating money. Using time as a payment vehicle has been shown to enable the expression of preferences for conservation by households in developing country contexts (Hagedoorn et al., 2020).

survey questionnaire was developed and distributed in English. Care was taken to avoid using technical terms and jargon. Survey enumerators translated the questions into the relevant local language for respondents during the interview. The survey questionnaire was tested on a small sample of respondents in each country to check the timing, clarity of the questions and response options, and the statistical design of the DCE.

The *general public survey* contained questions on the perception of vultures and stated preference questions to quantify willingness to pay for vulture conservation. The survey was implemented as an online questionnaire distributed through available networks and mailing lists in Botswana, Zambia and Zimbabwe. A link to the online questionnaire was distributed to respondents with the request to share it further with their social networks in order for the sample to "snowball". This

sampling approach is likely to be biased towards respondents with higher interest in environmental conservation and we explore this in the collected sample. The minimum target sample size is 200 per country to enable statistically significant WTP estimates from the discrete choice experiment and larger sample would allow sub-sample effects to be analysed. The questionnaire was developed and administered in English. The length of the questionnaire was limited so that it could be completed in 5–10 min, in order to enable a higher response rate and sample size. The questionnaire for the general public survey was tested on a small sample of respondents in each country to check the timing, clarity of the questions and response options, and the statistical design of the DCE.

The *international survey* is similar in content, format, length and timing as the general public survey. It was distributed through available global networks and mailing lists. The purpose of this survey was to elicit existence and bequest values for vultures in Southern Africa for international beneficiaries. The questionnaire for the international survey was tested on a small sample of respondents to check the timing, clarity of the questions and response options, and the statistical design of the DCE.

The *ranger and park manager survey* contained questions on the use of vultures for identifying the location of carcasses, either identified as natural mortalities or poaching activities, and the time and cost savings attributed to the sentinel service. This survey was distributed as an on-line questionnaire to rangers and park managers in the three study countries.

3.4. Scenario analysis

A scenario analysis is used to explore the potential welfare gains or losses of alternative vulture conservation interventions to people living in the Botswana, Zambia and Zimbabwe. We define a baseline scenario and two conservation scenarios "Policy Inaction" and "Policy Action". The baseline scenario describes the current case in which no vulture extinctions have occurred but populations in the region are declining. The "Policy Inaction" scenario describes a situation with no additional conservation intervention or regulatory enforcement. Vulture populations continue to decline and two species become extinct in the region. The "Policy Action" scenario describes a future in which conservation interventions are successful, resulting in increasing vulture populations and no species extinctions. The scenarios are summarised in Table 4. These scenarios are explorative "what if" storylines developed with the intention to explore alternative plausible scenarios for vulture population trends and extinctions that could result from policy inaction or policy action. They are not based on predictive modelling of vulture populations and extinctions. It is important to note that the term "Policy Action" implies not only the development of vulture conservation policy, but also subsequent implementation, enforcement and sufficient compliance to improve the survival of vulture species and populations. The time horizon for the scenario analysis is 5–10 years to reflect a time frame over which population trends can be reversed and/or extinctions of vulture species may occur. To estimate the welfare consequences of each scenario, we make use of the results of the discrete choice experiment to estimate changes in the values held by local communities and the general public. The focus of this analysis is on the potential benefits of conservation, or losses due to inaction, and we do not estimate the costs of conservation implementation or conduct a cost-benefit analysis.

Table 4
Scenario descriptions.

Scenario	Local extinction of vulture species	Trend in vulture populations
Current	No extinctions	Declining populations
Policy Inaction	Two species become extinct in the region	Declining populations
Policy Action	No extinctions	Increasing populations

Applying the same approach as for the aggregation of existence and bequest values, we estimate the WTP per local community and general public household for each country. For the Policy Inaction scenario, we multiply the estimated WTP to avoid the loss of a vulture species by two (the number of vulture species that are lost under this scenario). For the Policy Action scenario, we used the estimated WTP to obtain a change from declining to increasing vulture populations. These household-level WTP amounts were then multiplied by the estimated number of households that are willing to contribute time/donate money in each country, to estimate the total welfare effects of each scenario nationally.

4. Results

The estimated values for each ecosystem service derived from vultures for Botswana, Zambia and Zimbabwe are reported in Table 5. The sections below address each ecosystem service in turn and further details on the data, computations and results are provided in Supplementary Information.

4.1. Provisioning services valuation

Respondents to the local community survey identified a number of uses of vulture parts. Firstly, it is noteworthy that the use of vultures for food was not identified by respondents and in consequence, a value for this use is not estimated.

A moderate proportion of respondents (22 %) indicated that vulture parts are used in traditional medicine in their community, although a higher proportion stated that this isn't the case (32 %) or didn't know (45 %). The proportions of respondents that indicate that they visit traditional healers that use vulture parts in their remedies is low (5.3 %), which may partially reflect an unwillingness to share this information or a lack of knowledge of the variety of medicines or ingredients used in medicines by the traditional healers. In either case, we consider this an under-estimate of the actual proportion of households that visit traditional healers and the extent to which vulture parts are used based on the results of previously conducted market surveys (BirdLife International, 2022). This is because visits to traditional healers are often done discreetly (Madigele and Tabalaka, 2023) and many won't admit to conducting them (Manyonganise, 2024). Respondents that indicated that they do visit such traditional healers were asked to give the cost of treatment when vulture parts are used. Responses varied substantially across respondents within the range USD 15–85 and the mean cost of a treatment when vulture parts are used is 57.33 USD/visit.

We used this information to estimate the net annual value of the use of vulture parts in traditional medicine by extrapolating the extent of use and cost per visit across local community populations living within vulture ranges in each country. We use the rural population as a proxy of the relevant local community population given that vultures are present in most rural areas. We further assume that each household that indicated that they visit traditional healers using vulture parts, makes one visit per year (Stekelenburg et al., 2005). In recognition that this is a sensitive topic, the local community survey questionnaire did not ask for detailed information on frequency of visits. We consider the assumption of one visit per year to be conservative (WHO, 2019). The gross revenue

Table 5
Total economic value of vultures in Botswana, Zambia and Zimbabwe (USD/year; millions).

	Botswana	Zambia	Zimbabwe	All
Materials (for belief based use)	0.12	4.16	3.14	7.42
Carcass disposal	0.06	0.55	1.17	1.77
Sentinel	0.54	9.13	1.76	11.44
Sanitation	11.36	42.87	39.19	93.42
Existence and bequest	5.95	35.84	95.64	137.43
Tourism	0.12	0.06	0.16	0.34
Total Economic Value	18.16	92.61	141.07	251.83

is computed as the number of visits multiplied by the average price of a treatment when vulture parts are used; and the net value is computed by subtracting the costs of other inputs to the service, which is assumed to be 50 % of gross revenue based on the relatively simple supply chain from harvest to treatment (Mander et al., 2007). We estimate that approximately 250,000 households in the three target countries visit traditional healers that use vulture parts in medication; and that the net value of vulture parts as input to traditional medicine is over USD 7 million per year (see Table S1 in Supplementary Information for details).

4.2. Carcass disposal

The service of livestock carcass disposal by vultures is estimated as the value of time saved by not having to incinerate or bury deceased livestock. Information on the quantities of livestock kept by households living in vulture ranges, livestock mortality rates, means of carcass disposal (including disposal by vultures), time required for alternative disposal methods, and value of time is obtained from the local community survey (see Table S2 in Supplementary Information for details).

We find that a high proportion of households that participated in the local community survey keep livestock (cows, goats, sheep) ranging from 44 % in Zimbabwe to 72 % in Zambia. The average number of livestock kept per household also varies across the countries from 22 in Zimbabwe to 53 in Botswana. The most common methods for disposing of livestock carcasses reported by respondents are to burn, bury or eat the carcass, which is corroborated by results reported in the literature (e. g., Sitali et al., 2018; FAO, 2021). A small proportion of respondents, however, dispose of carcasses by leaving them for vultures (approximately 9 % of households that keep livestock "mostly" or "often" use vultures for carcass disposal). The value of this service is estimated as the time saved from not having to burn or bury the carcass. For respondents that do leave carcasses to be consumed by vultures, this is on average 2.3 h per household per year. Other avoided costs, such as transportation or fuel wood for burning, are not included in the value estimate. The value of time is derived from information on household monthly income, converted to an hourly rate assuming 22 working days per month and 8 working hours per day. The estimated value of this service is low and mainly reflects that relatively few households rely on vultures to dispose of their livestock carcasses.

4.3. Sentinel role

The value of the sentinel role of vultures is estimated for two beneficiary groups: 1. Local communities that use vultures to locate the carcasses of missing livestock; 2. Protected Area managers and rangers that use vultures to locate the carcasses of dead/poached animals. In both cases, the service is valued as the avoided costs of searching for animal carcasses.

For the local communities, information on the quantities of livestock kept by households living in vulture ranges, the use of vultures to locate carcasses, time spent searching for missing livestock, and the value of time is obtained from the local community survey (see Table S3 in Supplementary Information for details).

We find that a high proportion of households that keep livestock use vultures to help locate the carcasses of missing animals. This ranges from 52 % of households in Zimbabwe to 84 % of households in Zambia. The average time spent searching for missing livestock is lower when using vultures, with an overall mean of approximately 2.5 days (without the use of vultures), which falls to 1.7 days (with the use of vultures). For households that keep livestock, this translates into an annual time saving of just over 1 day per year. The time saving per household is higher in Botswana and Zambia (1.53 and 1.46 days per year respectively) than in Zimbabwe (0.53 days per year) because both the number of livestock kept and the use of vultures to find missing livestock is higher. In aggregate, the value of this time saving to households in Botswana, Zambia and Zimbabwe that keep livestock is estimated to be just over

USD 11 million per year.

Regarding the sentinel role of vultures in protected area management, vultures are used to identify locations of dead animals and poaching activities. Where there is an incursion or a dead animal which has clearly been poached, more rangers are brought in to comb the area for more carcasses or the trail of the poacher. The costs related to this include the rangers' time and expenditures on vehicles, fuel, food and communication. The use of vultures in early detection means rate of deployment per size of area for anti-poaching is reduced, hence reducing the cost of employing more rangers.

For the valuation of the sentinel roles of vultures to protected area management, information on the use of vultures to locate carcasses, and time and expenditure savings is obtained from the ranger and park manager survey (see Table S4 in Supplementary Information for details).

Of the 12 protected areas represented in the survey responses, 11 use vultures to help to locate animal carcasses. The effectiveness of using vultures to locate animal carcasses is considered to be effective or very effective by 18 % and 23 % of respondents respectively, although 50 % of respondents indicated that they don't know the effectiveness of this approach. The average reported time saving from using vultures to locate animal carcasses is 54 h per month, which we monetise using a mean wage rate of 10 USD/hour; and the average reported expenditure saving per protected area is 510 USD/month. Aggregating these cost savings in terms of time and expenditure across the number protected areas with vultures (42) gives a value of this service of approximately USD 291,000 per year for the three countries jointly.

We note that the estimated value of the sentinel role of vultures in terms of avoided costs does not capture the full benefits of early detection of poaching activities. Early detection of a poisoned carcass also means further mortalities of vultures and other carnivores can be stopped by securing and disposing of the carcass. In the case where elephants are drinking or licking a poisoned source, then the area can be secured to prevent further losses of these animals as well.

4.4. Sanitation and pest control

The service that vultures provide to protect human health through sanitation (removal of carcasses and waste that host pathogens causing human illness) and pest control (reduction in populations of mammalian scavengers such as rats and stray dogs that spread diseases to humans) is valued as the avoided damage to human health attributable to the presence of vultures.

Detailed data and quantified relationships for estimating the avoided health damages attributable to the role of vultures in Africa is largely unavailable (van den Heever et al., 2021). This includes data on vulture populations, quantities of carcasses and waste consumed, and the consequent reduction in exposure to pathogens and the prevalence of diseases. To provide a first estimate of the value of this ecosystem service for the countries addressed by this report, we make use of quantified relationships from the literature. We caution, however, that these quantities are unlikely to reflect the biophysical and socio-economic context of this study, particularly in terms of the level of dependence on vultures to remove carcasses and waste.

Information on increased human mortality due to a large-scale decline in vulture populations is taken from a study for India, which provides a central estimate of a 4.2 % increase in mortality per year (Frank and Sudarshan, 2023). We apply this rate to the background mortality rate in each country and the human populations living in vulture ranges to estimate the number of additional deaths that would occur each year in the absence of vultures (see Table S5 in Supplementary Information for details). The value of these avoided deaths is estimated using the Human Capital Approach (HCA), which assigns the value of foregone income due to pre-mature mortality (Hanly et al., 2022). We compute the HCA value of a mortality in each country as the difference in years between the average age of respondents to the local community survey and a retirement age of 65, multiplied by per capita

GDP for each country.

The results show that the value of this service is substantial, with an annual value for the region of over USD 90 million. Using the value of a statistical life (VSL) as an alternative approach to valuing human mortality (we use a VSL of USD 580,633 obtained from a recent international review of VSL studies, Keller et al., 2021) results in a value for this service that is an order of magnitude higher and exceeds USD 1.3 billion per year.

It should be noted that this estimation of the value of sanitation and pest control service provided by vultures focuses on human health and does not include the value of reduced disease in livestock and wild animals or of the health of the broader ecosystem. Taking a broader One Health perspective of the integrated health of people, animals and ecosystems was not feasible within the present study given existing limitations on the quantification of functional relationships between vulture populations and the health of other animals and the ecosystems in which they live. This is considered as a potentially important avenue for future research.

4.5. Existence and bequest value

The existence and bequest values that are placed on vultures in Botswana, Zambia and Zimbabwe are estimated separately for three groups of beneficiaries: local community households living in vulture ranges, the general public in the three countries, and the international public. We describe the results for each beneficiary group separately and summarise them jointly at the end of the section.

Among local community households, a relatively high proportion state that they are willing to contribute time to support vulture conservation. This ranges from approximately 62 % of households in Zambia to 82 % in Botswana. The most frequently provided reason for not being willing to contribute is that the respondent does not have spare time. The most frequently cited reason for being willing to contribute time are that vultures play an important role in the environment by disposing of animal carcasses (i.e., reflecting recognition of the sanitation and pest control service valued in the preceding section), which is in line with the findings of Manqele et al. (2023) in a case study of perceptions in three protected areas in KwaZulu Natal. The second most frequently selected reasons are that it is important to conserve all animal species (i.e., existence value) and that it is important to conserve vultures for future generations (i.e., bequest value). The importance of vultures to the respondents' culture is the least frequently selected motivation for being willing to contribute time to vulture conservation.

On average, local community households are willing to contribute a maximum of 1.6 days per month for vulture conservation. We convert from volunteered time to money using information on mean household income from the local community survey; and then extrapolate to the number of households living in vulture ranges in each country, controlling for the proportion that are not willing to contribute time (see Table S6 in Supplementary Information for details) and the weighted importance of non-use motivations for the respondents that are willing to contribute. The estimated existence and bequest value to local communities across the three countries is substantial at over USD 94 million per year. The value of this service is notably higher in Zimbabwe due to the higher proportion of households that are willing to contribute time and the stronger motivation attributed to non-use values.

Among general public respondents, a relatively high proportion state that they are willing to contribute money to support vulture conservation. This ranges from approximately 71 % of households in Botswana to 81 % in Zimbabwe. The most frequently provided reason for not being willing to contribute is that the respondent already participates in conservation activities. The most frequently cited reasons for being willing to contribute money are that it is important to conserve all animal species (i.e., existence value) and that vultures play an important role in the environment by disposing of animal carcasses (i.e., reflecting recognition of the sanitation and pest control service valued in the preceding section). The importance of vultures to the respondents' culture is again the least frequently selected motivation for being willing to contribute to vulture conservation.

On average, general public households are willing to contribute a maximum of just over USD 6 per month for vulture conservation. We extrapolate these values to the number of households in each country living in urban areas, controlling for the proportion that are not willing to contribute money (see Table S7 in Supplementary Information for details) and the weighted importance of non-use motivations. The estimated existence and bequest value to the general public across the three countries is substantial at over USD 43 million per year. The value of this service is again notably higher in Zimbabwe due to the higher proportion of households that are willing to contribute money and the stronger motivation attributed to non-use values.

The international survey received 293 responses from 23 countries and 5 continents. The majority (78 %) of respondents, however, are from Europe. We therefore limit the extrapolation of non-use values to the European population. Among respondents to the international public survey a relatively low proportion state that they are willing to contribute money to support vulture conservation (41 %). The reasons for not being willing to contribute are that the respondent does not have any spare money and already contributes to or participates in conservation activities. The main reasons for being willing to contribute money are that it is important to conserve all animal species (i.e., existence value) – 52 %; and that vultures play an important role in the environment by disposing of animal carcasses (i.e., reflecting recognition of the sanitation and pest control service) – 35 %. The motivation to conserve vultures for future generations (bequest value) is relatively unimportant – 7 % of respondents.

From the contingent valuation question, we find that on average, the international public are willing to contribute a maximum of almost USD 9 per household per month for vulture conservation. We extrapolate these values to the number of households in Europe controlling for the proportion that are not willing to contribute money (see Table S8 in Supplementary Information for details) and the weighted importance of non-use motivations. The estimated existence and bequest value to the international public in Europe is substantial at over USD 5 billion per year and largely determined by the large population size over which the aggregation is made. We note that this estimate is characterised by high uncertainty given the small sample size and unrepresentative sample. Although the mean income and age of respondents approximately corresponds to the European average, it is likely that the sample is biased towards people with high interest in environmental conservation.

4.6. Tourism

The distribution of a survey to international tourists through safari tour operators proved not to be possible and secondary data on safari tourism could not be accessed. We therefore focus on the value of vultures to domestic safari tourism, for which we obtained information through the general public survey. Future research could potentially examine the value of vultures to international tourism.

The proportion of respondents to the general public survey that have been on safari is surprisingly high, ranging from 84 % in Zambia to 100 % in Botswana (see Table S9 in Supplementary Information for details). These high proportions suggest a biased sample, possibly due to the distribution of the survey via email and social media mostly reaching people in urban areas with higher incomes. It may also be explained by the increased in local tourism, which has been promoted in recent years (Botswana Tourism Organisation, 2020; NewsDay Zimbabwe, 2023; Travel + Leisure, 2024). We make the conservative assumption, however, that each urban household only makes one safari tour and then estimate the total number of safari visits per year. Prices of safari tours were obtained from tour operators and multiplied by the estimated number of visits per year to estimate gross revenues. We approximate the producer surplus generated by tour operators assuming that costs are

50 % of revenues based on information from the prior studies and valuation guidance material (UNEP-Nairobi Convention/WIOMSA, 2022) and then attribute a proportion of this to vultures (3 %) based on the relative importance of vultures to the safari experience reported by respondents to the general public survey. The value of vultures to domestic safari tourism is estimated to be almost USD 345,000 per year. Although this is not a high value, it is noteworthy that respondents considered seeing vultures as important or very important to the overall safari experience.

4.7. Vulture disservices

Although it falls outside of the scope of the study to estimate the economic value of disservices provided by vulture, we summarise here results from the local community, general public and international survey on negative perceptions of vultures. In the local community survey, respondents were asked to indicate their agreement or disagreement with the statement "sometimes vultures kill livestock", to which 9 % agreed, 68 % disagreed, and 23 % didn't know. The response to an equivalent question in the interational survey was that 23 % agreed and 77 % disagreed; showing that generally people do not believe that vultures predate on livestock and that the misconception that they do increases in populations with less familarity of vultures. Regarding the symbolism of vultures, respondents to the local community and general public surveys were also asked to briefly summarise traditional stories about vultures. The majority of responses are positive including the belief that vultures bring good luck. The few cases of negative symbolism relate to belief that the presence of vulture nests reduces rainfall.

4.8. Total economic value

The results of the valuation are summarised in Table 5 and Fig. 3. This summary focuses on the values of ecosystem services received by domestic beneficiaries. We therefore omit values accruing to international beneficiaries in terms of existence and bequest value, which would otherwise dominate the result, and international tourism, which we were unable to estimate. All three countries receive substantial value from vulture ecosystem services. Jointly across the three countries, the total economic value is estimated to be just over USD 250 million per year. This is largely attributed to existence and bequest values and the sanitation and pest control service provided by vultures.

To provide a first estimate of the value of vulture ecosystem services in the South African Development Community (SADC), with 12 countries that are home to vultures, we make a simple extrapolation of the estimated values across rural (local community) and urban (general public) human populations. The mean annual value per local community household is estimated to be USD 47; whereas the mean annual value per general public household is USD 9. This difference in values is due to the broader range of ecosystem services assessed for local community households and in particular the inclusion and high value of the sanitation and pest control service. The estimated values for SADC countries are provided in Table 6, and show that the total annual value of vulture ecosystem services in the region is just under USD 1.8 billion.

4.9. Scenario analysis

As a further guide for decision-making, this section analyses the economic welfare impacts of alternative vulture conservation scenarios. The changes in domestic non-use value of vultures under "Policy Inaction" and "Policy Action" scenarios are estimated to show the welfare cost of taking no action versus the potential welfare gain of taking action to conserve vultures (see Table 4 for scenario descriptions). The monetary values of welfare changes are estimated using the results of the discrete choice experiments for the local community and general public in each country. In the case of "Policy Inaction", the estimated annual

Table 6
Total economic value of vultures in the South African Development Community (USD/year; millions).

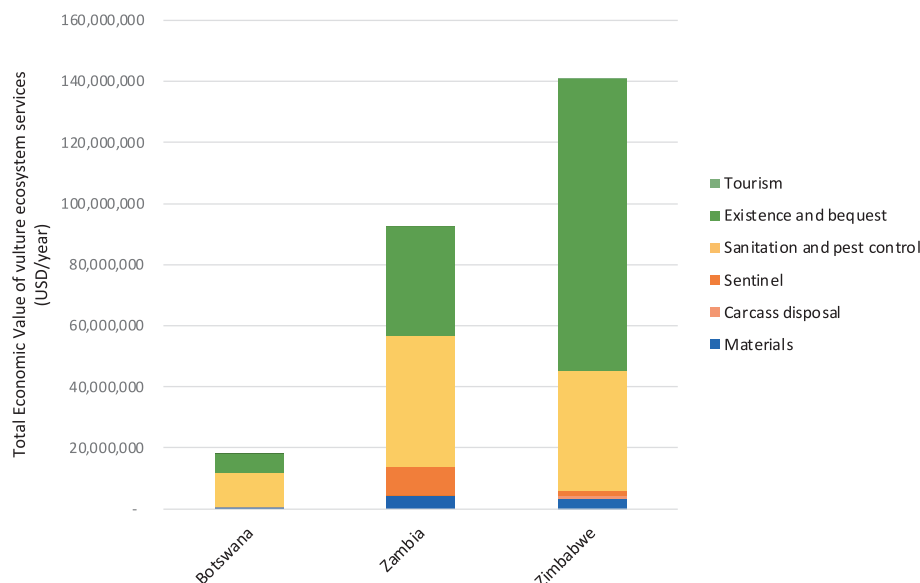| Country	Local community	General public	Total
Botswana	13.37	4.79	18.16
Zambia	81.96	10.65	92.61
Zimbabwe	113.06	28.00	141.07
Angola	73.58	67.22	140.80
Democratic Republic of Congo	340.96	161.01	501.97
Lesotho	10.46	3.27	13.73
Malawi	108.41	25.91	134.32
Mozambique	132.01	50.09	182.10
Namibia	7.66	4.40	12.06
South Africa	122.85	113.31	236.16
Swaziland	5.47	1.75	7.22
Tanzania	268.64	98.29	366.93
SADC	1,204.44	583.83	1,788.27

Fig. 3. Total economic value of vultures in Botswana, Zambia and Zimbabwe.

mean household willingness to pay to avoid declining vulture populations (USD 2.8 and USD 4.4 for local community and general public households respectively) and two extinctions (USD 4 and USD 2.4 for local community and general public households respectively) is multiplied by the numbers of households in each community that are willing to contribute to vulture conservation.[2] In the case of "Policy Action", the estimated mean household willingness to pay for increasing vulture populations (USD 6 and USD 3 for local community and general public households respectively) is multiplied by the numbers of households in each community that are willing to contribute to vulture conservation.

The results are presented in Table 7 and show large welfare losses from allowing vultures to become locally extinct due to policy inaction; and welfare gains from taking policy action to enable vulture populations to increase.

The welfare loss, as a consequence of not acting on vulture conservation, equates to almost USD 47 million per year, whereas the welfare gain from taking policy action to conserve, manage and protect vultures is almost USD 30 million per year. As such, the economic benefits of investing in the conservation of vulture populations is considerable, but letting them decline or go extinct will result in a large economic welfare cost. Combined, this provides a strong rationale for governments and other institutions to fund vulture conservation programs.

5. Conclusions

5.1. Summary of findings

Vulture species face loss of habitat, declining populations and, in some cases, extinction. Population trends vary among species, ranges and populations but, in general, vultures face high threats and continue to experience population declines. Understanding the associated loss in ecosystem services and human welfare can potentially motivate action and increased financing to protect and restore vulture populations. This study provides first estimates of the economic values of ecosystem services provided by vultures in Botswana, Zambia and Zimbabwe.

The total economic value of vulture ecosystem services to these three countries is estimated to be just over USD 250 million per year. This is largely attributed to existence and bequest values and the sanitation and pest control service provided by vultures.

Focusing on existence and bequest values, the results of an explorative scenario analysis revealed the large welfare losses people may experience from allowing vulture populations to continue to decline and two species to become extinct due to policy inaction (USD 47 million per year). The welfare gains from taking policy action to enable vulture populations to increase are also substantial (USD 30 million per year). As such, the economic benefits of investing in vulture conservation are large, but letting vulture species go extinct would result in huge economic cost. Combined, this provides a strong rationale for governments to explore publicly-funded vulture conservation programs.

Table 7
Annual welfare changes due to policy inaction and action for vulture conservation (USD/year; millions).

	Botswana	Zambia	Zimbabwe	All
Policy inaction	−3.95	−18.80	−24.00	−46.74
Policy action	2.06	12.68	15.24	29.98

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[2] The estimated WTP to avoid the local extinction of a vulture species is linear (i.e., WTP to avoid two extinctions is double the WTP to avoid one extinction). We test the linearity of the species extinction attribute in the estimated utility function using polynomial and dummy coded specifications and find that the linear specification is supported.

We extrapolated the mean values per rural and urban household for Botswana, Zambia and Zimbabwe across the South African Development Community. This yielded an estimate of the total economic value of vulture ecosystem services in the region of just under USD 1.8 billion per year. This estimate is characterised by high uncertainty, but nevertheless conveys the economic importance of vultures in the region.

5.2. Comparison to results in the literature

The estimated values of vulture ecosystem services for Southern Africa is broadly consistent with values for other locations reported in the literature, although direct comparisons are limited by differences in the scope of valued services. In general, the previous studies also find high existence values, with Becker et al. (2010) reporting willingness-to-pay values up to USD 93,000 for conservation of griffon vultures in Israeli reserves, and Baral et al. (2007) and Zambrano-Monserrate (2020) reporting high WTP for vulture conservation in Nepal and Ecuador, respectively. The sanitation and pest control service provided by vultures has also received high valuations. For example, Markandya et al. (2008) estimate the annual health costs in India due to vulture population decline and associated increase in feral dog population during the period 1992–2006 to be in the range USD 830–911 k. Estimates in the literature on the value of vultures for waste disposal are arguably higher than we find for Southern Africa, with Ishwar et al. (2016) estimating the lifetime scavenging value of a single griffon vulture in India to be in the range USD 3,350–4,450 depending on location. Grilli et al. (2019) valued the organic material removal by turkey vultures at over USD 500,000 annually in the Americas, with global extrapolations reaching up to USD 700 million.

It is also worth noting that previous studies on other scavenger species provide comparable results. For instance, coyotes, which are facultative scavengers, have been the focus of valuation studies reporting estimates around USD 18–20 per individual (Martínez-Espiñeira, 2007). Similarly, the existence value of bald eagles, which also scavenge opportunistically, were valued at USD 19 per person (Stevens et al., 1991). Several valuation estimates also exist for golden eagles, with household WTP in the UK ranging from USD 28–61, depending on whether the valuation was for maintaining current populations or increasing them by 20 % (Hanley et al., 2010). These studies demonstrate that scavenger species can hold considerable non-use value, particularly in terms of existence or symbolic conservation value, even if their ecological role as scavengers is not explicitly acknowledged.

5.3. Caveats and directions for future research

The analysis and results described in this report are constrained by several limitations and uncertainties. These are identified below and intended to support future research.

The study made use of a number of surveys targeting different beneficiary groups to collect information on their knowledge and use of vultures and preferences for conservation. Such surveys were considered the only feasible means of obtaining information on which to base the valuation analysis. We recognise, however, that the sample sizes are generally low and the representativeness of the populations of beneficiaries is imperfect. This has implications for the level of certainty and potential biases in the results. Future research could expand the scope of the surveys conducted for this study and attempt to reach a more representative sample.

The valuation of the sanitation and pest control service is limited in several respects. Firstly, the analysis assesses only human health and it was not possible to estimate values for the control of disease among livestock and other animals. This could be an important avenue for future research and would require quantification of the effect of changing vulture populations on the prevalence of diseases in other animals, including diseases that are transmitted by mammalian scavengers. Such research could apply the One Health perspective of the

integrated health of people, animals and ecosystems. Secondly, the valuation of sanitation and pest control to human health makes use of information on the quantification of human health implications of vulture loss in India, which is unlikely to match the African context. Future research could try to address this limitation by compiling sufficient data for Africa to quantify the linkages between vultures and health.

The valuation of existence and bequest values for vultures using stated preference methods faces a gamut of limitations and potential biases. Potential future refinements might include the use of alternative payment vehicles to avoid hypothetical bias associated with voluntary donations; using quantitative measures of change in vulture populations; specifying attributes for specific vulture species; and testing for the influence of the survey mode on respondent choice and uncertainty.

This study is focused on the positive contributions to human welfare provided by vultures and does not attempt to estimate the value of vulture disservices. Some of the survey results do, however, provide insights into public perceptions of vultures, which are found to be predominantly positive rather than negative. Future research could potentially explore this further to understand what drives negative perceptions of some species and quantify the value of disservices.

The economic appraisal of vulture conservation measures would require a direct comparison of both the costs and benefits of alternative options. Such a cost-benefit analysis would require quantified measurement of the effectiveness of various conservation actions and their respective costs, including both implementation costs and the opportunity costs of restricted activities. At a national level, evaluating the extent to which the benefits of vulture conservation outweigh the costs (which could include many different actions addressing the threats facing vultures) and the relative cost-effectiveness of specific measures requires further research.

Estimating a ballpark figure for the financial costs of vulture conservation is inherently challenging due to the complexity and diversity of required interventions which involve various players including governments, NGOs, academic institutions and local communities. In Southern Africa, key conservation actions include anti-poaching operations, habitat protection, the establishment and maintenance of Vulture Safe Zones, education and awareness campaigns, mitigation of dangerous electricity transmission infrastructure and ongoing research and monitoring.

Among these, anti-poaching efforts are particularly costly, especially given the vast landscapes that need to be patrolled. Vultures often forage and breed in areas that overlap with elephant habitats—regions that are already under intense anti-poaching surveillance due to the targeting these high value species. These anti-poaching activities have significant costs, whilst not aimed at vulture conservation per se, the success of antipoaching contributes to a positive outcome for vultures. The most relevant approach to economic appraisal of conservation activities may therefore be a more wholistic evaluation of the ecosystem, or at least multiple species, in which the benefits provided by vultures plays its part.

CRediT authorship contribution statement

Luke Brander: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lovelater Sebele:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Fadzai Matsvimbo:** Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Victoria Guisado Goñi:** Methodology, Investigation. **Florian Eppink:** Methodology, Formal analysis.

Declaration of competing interest

The authors declare the following financial interests/personal

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2025.101775.

Data availability

Data will be made available on request.

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