LIFE AEGYPIUS RETURN

REPORT

Deliverable 6.1. Quantification and valuation of ecosystem services provided by vultures in Portugal.

July 2025

LIFE AEGYPIUS RETURN

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Almost four decades after becoming extinct in Portugal as a breeding species, the Cinereous Vulture (*Aegypius monachus*) returned to colonize the country in 2010, as some birds coming from Spain nested in the Tejo International Natural Park. Thanks to the conservation efforts carried out in both countries by NGOs and government entities, the number of breeding pairs has been steadily increasing. However, the Portuguese population is still too fragile, and its future remains uncertain. The LIFE Aegypius Return project will ensure the definitive return of the species.

https://4vultures.org/life-aegypius-return/

Coordinating beneficiary

VCF VULTURE CONSERVATION FOUNDATION

Associated beneficiaries

Palombar Associação de Conservação da Natureza e do Património Rural

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spea Sociedade Portuguesa para o Estudo das Aves

LPN liga para a protecção da natureza

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LPN - Liga para a Protecção da Natureza

Palombar - Conservação da Natureza e do Património Rural

SPEA - Sociedade Portuguesa para o Estudo das Aves

VCF - Vulture Conservation Foundation

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ABSTRACT / RESUMO / RESUMEN

1. ABSTRACT / RESUMO / RESUMEN

Abstract (EN)

This report provides a first quantification and valuation of selected ecosystem services provided by the populations of Cinereous (*Aegypius monachus*), Griffon (*Gyps fulvus*) and Egyptian (*Neophron percnopterus*) vultures in Portugal, which are recovering following implementation of conservation measures in the last decade, through a number of projects, including the LIFE Aegypius Return project (2022-2027).

The vulture populations in Portugal interact with the local environment and human activities contributing to the provision of ecosystem services and human wellbeing. The regulating and cultural services provided by vultures in Portugal include:

- The consumption of livestock carcasses, which has value in terms of the avoided disposal costs (e.g., collection and transportation to incineration plants). The beneficiaries of this service are livestock farmers and the State, which would otherwise incur these costs.
- The avoided greenhouse gas (GHG) emissions from transporting and incinerating carcasses. This is a global benefit, in terms of reduced climate change damages worldwide
- The sanitation service whereby the consumption of carcasses helps reducing the accumulation and transmission of toxins and pathogens to other animals including humans. The beneficiaries of this service are livestock farmers and the Portuguese general public.
- Nature based tourism (ecotourism) in the form of vulture watching, which has value in terms of revenue to the tourism sector and the enjoyment attained by tourists.
- The value that the Portuguese public place on the continued existence of vultures in Portugal irrespective of any current or future use.

The current populations of Cinereous, Griffon and Egyptian vultures in Portugal are estimated to be approximately 600, 4.500 and 300 individuals, respectively. These population estimates include breeding pairs nesting in Portugal, breeding pairs nesting in Spain that also forage in Portugal, and non-breeders from both countries.

The value of ecosystem services provided by the three vulture species in 2023 is estimated to be 313.000 EUR in avoided carcass disposal costs, 163.000 EUR in avoided GHG emissions, and potentially 192.000 EUR for vulture related ecotourism (corresponding to a total estimated value of over 668.000 EUR).

Focusing on Cinereous Vultures, we use a scenario analysis to estimate the benefits of conservation in terms of the increased value of regulating services over the period 2023-2048. Under the *conservation* scenario (i.e., population benefitting from conservation actions), the population of Cinereous Vultures in Portugal is projected to increase to approximately 1500 individuals in 2048 (reaching the carrying capacity projected for the study area); whereas under the *without conservation* scenario, the population is projected to decline to approximately 100 vultures (reverting to the numbers before directed conservation efforts started). We estimate that the aggregated benefits of conservation actions over this 26-year period would be over 1,6 million EUR (970.000 EUR for avoided carcass disposal costs and 695.000 EUR for avoided climate change damages).

Assuming a continued increase in the Cinereous Vulture population in Portugal due to conservation efforts, alongside stable populations of Griffon and Egyptian Vultures in both Portugal and Spain, we estimate the aggregated and cumulative value of avoided carcass disposal and greenhouse gas (GHG) emissions costs for the three species could reach approximately 2.435.000 EUR by the end of the project (2027), 4.974.000 EUR by the after-LIFE period (2032), and 13.670.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048). Adding the potential contribution of vultures to ecotourism, assuming a steady annual demand, the estimated total value of these three ecosystem services rises to 3.396.000 EUR by the end of the project (2027), 6.896.000 EUR by the after-LIFE period (2032), and 18.665.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048).

These value estimates provide a first indication of the importance of vultures in Portugal to human activities and wellbeing. It should be noted, however, that this analysis encompasses only a subset of the ecosystem services provided by vultures. Potential avenues for further research include the estimation of existence values held by the Portuguese public for increased vulture populations and the estimation of the return on investment in conservation activities.

Resumo (PT)

O presente relatório apresenta a primeira quantificação e valoração de um conjunto selecionado de serviços dos ecossistemas prestados pelas populações de abutre-preto (*Aegypius monachus*), grifo (*Gyps fulvus*) e britango (*Neophron percnopterus*) em Portugal. Estas populações encontram-se em recuperação na sequência da implementação de medidas de conservação ao longo da última década, através de vários projetos, incluindo o projeto LIFE Aegypius Return (2022-2027).

As populações de abutres em Portugal interagem com o ambiente e com as atividades humanas, contribuindo para a prestação de serviços dos ecossistemas e para o bem-estar humano. Entre os serviços de regulação e culturais prestados pelos abutres em Portugal, destacam-se:

- O consumo de carcaças de gado, que tem valor em termos dos custos evitados com o seu encaminhamento para eliminação (por exemplo, recolha e transporte para unidades de incineração). Os beneficiários deste serviço são os produtores pecuários e o Estado, que, de outra forma, suportariam esses custos.
- As emissões de gases com efeito de estufa (GEE) evitadas, associadas ao transporte e incineração de carcaças. Este é um benefício global, na medida em que contribui para a redução dos danos provocados pelas alterações climáticas a nível mundial.
- O serviço de saneamento, em que o consumo de carcaças contribui para reduzir a acumulação e transmissão de toxinas e agentes patogénicos a outros animais, incluindo seres humanos. Os beneficiários deste serviço são os produtores pecuários e o público em geral em Portugal.
- O turismo de natureza (ecoturismo) sob a forma de observação de abutres, que tem valor tanto em termos de receitas para o setor do turismo como do usufruto por parte dos visitantes.
- O valor que a população portuguesa atribui à continuidade da existência de abutres em Portugal, independentemente da sua utilização atual ou futura.

As populações atuais de abutre-preto, grifo e britango em Portugal estão estimadas em cerca de 600, 4.500 e 300 indivíduos, respetivamente. Estas estimativas incluem casais reprodutores com ninhos em Portugal, casais reprodutores com ninhos em Espanha que também se alimentam em território português, e indivíduos não-reprodutores de ambos os países.

O valor dos serviços dos ecossistemas prestados pelas três espécies de abutres, em 2023, estima-se em 313.000 EUR em custos evitados com a eliminação de carcaças, 163.000 EUR em emissões de GEE evitadas e, potencialmente, 192.000 EUR relacionados com o ecoturismo (correspondendo a um valor total estimado superior a 668.000 EUR).

Em relação ao abutre-preto, foi utilizada uma análise de cenários para estimar os benefícios da conservação em termos do aumento do valor dos serviços de regulação no período de 2023 a 2048. No cenário com conservação (ou seja, com a população de abutre-preto a beneficiar de ações de conservação), projeta-se que a população de abutre-preto em Portugal aumente para cerca de 1.500 indivíduos em 2048 (atingindo a capacidade de carga estimada para a área de estudo); enquanto no cenário sem conservação se projeta que a população decline para cerca de 100 indivíduos (regressando aos números anteriores ao início dos esforços de conservação). Estima-se que os benefícios agregados das ações de conservação ao longo deste período de 26 anos possam ultrapassar os 1,6 milhões de euros (970.000 EUR em custos evitados com a eliminação de carcaças e 695.000 EUR em danos climáticos evitados).

Assumindo um aumento contínuo da população de abutre-preto em Portugal devido aos esforços de conservação, bem como a estabilidade das populações de grifo e britango em Portugal e em Espanha, estima-se que o valor agregado e cumulativo dos custos evitados com a eliminação de carcaças e com as emissões de GEE para as três espécies possa atingir aproximadamente 2.435.000 EUR até ao final do projeto (2027), 4.974.000 EUR até ao período pós-LIFE (2032) e 13.670.000 EUR quando for atingida a capacidade de carga para o abutre-preto (2048). Acrescentando a potencial contribuição dos abutres para o ecoturismo, assumindo uma procura anual constante e semelhante à atual, o valor total estimado destes três serviços dos ecossistemas aumenta para 3.396.000 EUR até ao final do projeto (2027), 6.896.000 EUR até ao período pós-LIFE (2032) e 18.665.000 EUR quando for atingida a capacidade de carga para o abutre-preto (2048).

Estas estimativas de valor constituem uma primeira indicação da importância dos abutres em Portugal para as atividades humanas e para o bem-estar. Contudo, importa salientar que esta análise abrange apenas um subconjunto dos serviços dos ecossistemas prestados pelos abutres. Possíveis caminhos para investigação futura incluem a estimativa do valor de existência atribuído pela população portuguesa ao aumento das populações de abutres, bem como a avaliação do retorno do investimento em atividades de conservação.

Resumen (ES)

Este informe presenta la primera cuantificación y valoración de una selección de servicios ecosistémicos proporcionados por las poblaciones de buitre negro (*Aegypius monachus*), buitre leonado (*Gyps fulvus*) y alimoche (*Neophron percnopterus*) en Portugal, las cuales están en proceso de recuperación tras la implementación de medidas de conservación durante la última década, a través de diversos proyectos, incluido el proyecto LIFE Aegypius Return (2022-2027).

Las poblaciones de buitres en Portugal interactúan con el entorno local y con las actividades humanas, contribuyendo a la provisión de servicios ecosistémicos y al bienestar humano. Entre los servicios de regulación y culturales proporcionados por los buitres en Portugal, se incluyen:

- El consumo de cadáveres de ganado, que tiene valor en términos de los costes evitados de su eliminación (por ejemplo, recogida y transporte a plantas de incineración). Los beneficiarios de este servicio son los ganaderos y el Estado, que, de otro modo, asumirían estos costes.

- Las emisiones de gases de efecto invernadero (GEI) evitadas gracias a la reducción del transporte e incineración de cadáveres. Este es un beneficio global, ya que contribuye a mitigar los daños del cambio climático a nivel mundial.

- El servicio de saneamiento, mediante el cual el consumo de cadáveres ayuda a reducir la acumulación y transmisión de toxinas y patógenos a otros animales, incluidos los seres humanos. Los beneficiarios de este servicio son los ganaderos y la población portuguesa en general.

- El turismo de naturaleza (ecoturismo), en forma de observación de buitres, que genera valor tanto en términos de ingresos para el sector turístico como de disfrute para los visitantes.

- El valor que la sociedad portuguesa otorga a la mera existencia de los buitres en Portugal, independientemente de su uso presente o futuro.

Las poblaciones actuales de buitre negro, buitre leonado y alimoche en Portugal se estiman en aproximadamente 600, 4.500 y 300 individuos, respectivamente. Estas estimaciones incluyen parejas reproductoras nidificantes en Portugal, parejas nidificantes en España que también se alimentan en territorio portugués, y ejemplares no reproductores de ambos países.

El valor de los servicios ecosistémicos proporcionados por las tres especies de buitres en 2023 se estima en 313.000 EUR en costes evitados de eliminación de cadáveres, 163.000 EUR en emisiones de GEI evitadas y, potencialmente, 192.000 EUR relacionados con el ecoturismo asociado a los buitres (lo que representa un valor total estimado superior a 668.000 EUR).

Centrando el análisis en el buitre negro, se ha empleado un análisis de escenarios para estimar los beneficios de la conservación en términos del aumento del valor de los servicios de regulación en el período 2023-2048. En el escenario con conservación (es decir, con una población de buitre negro beneficiada por acciones de conservación), se proyecta que la población de buitre negro en Portugal aumente hasta aproximadamente 1.500 individuos en 2048 (alcanzando la capacidad de carga proyectada para el área de estudio); mientras que en el escenario sin conservación, se proyecta un descenso hasta unos 100 individuos (revirtiendo a las cifras anteriores al inicio de los esfuerzos de conservación dirigidos). Se estima que los beneficios acumulados de las acciones de conservación durante este período de 26 años

superarían los 1,6 millones de euros (970.000 EUR en costes evitados de eliminación de cadáveres y 695.000 EUR en daños climáticos evitados).

Asumiendo un aumento continuo de la población de buitre negro en Portugal gracias a los esfuerzos de conservación, junto con poblaciones estables de buitre leonado y alimoche tanto en Portugal como en España, estimamos que el valor agregado y acumulado del ahorro en costes de eliminación de carroñas y de emisiones GEI para las tres especies podría alcanzar aproximadamente 2.435.000 EUR para el final del proyecto (2027), 4.974.000 EUR para el periodo posterior al LIFE (2032), y 13.670.000 EUR al alcanzar la capacidad de carga del buitre negro (2048). Sumando la posible contribución de los buitres al ecoturismo, asumiendo una demanda anual constante, el valor total estimado de estos tres servicios ecosistémicos asciende a 3.396.000 EUR para el final del proyecto (2027), 6.896.000 EUR para el periodo posterior al LIFE (2032), y 18.665.000 EUR al alcanzar la capacidad de carga del buitre negro (2048).

Estas estimaciones de valor constituyen una primera indicación de la importancia de los buitres en Portugal para las actividades humanas y el bienestar. No obstante, cabe señalar que este análisis abarca solo un subconjunto de los servicios ecosistémicos proporcionados por los buitres. Entre las posibles líneas de investigación futura se incluyen la estimación del valor de existencia que la sociedad portuguesa asigna al aumento de las poblaciones de buitres y la evaluación del retorno de la inversión en actividades de conservación.

REPORT

2. INTRODUCTION

Vultures in Portugal provide a number of ecosystem services that benefit people, including the consumption of livestock carcasses, which reduces the direct financial costs and the greenhouse gas emissions associated with carcass disposal, and the contribution to ecotourism in the form of vulture watching. This report provides a quantification and valuation of these ecosystem services provided by the populations of Cinereous (*Aegypius monachus*), Griffon (*Gyps fulvus*) and Egyptian (*Neophron percnopterus*) vultures in Portugal, which are recovering following implementation of conservation measures – including those undertaken by the LIFE Aegypius Return project.

2.1. Ecosystem Services

The concept of ecosystem services provides a useful framework to identify the importance of the natural environment, including wild animal species, to humans. The Millennium Ecosystem Assessment (MA, 2005) defines ecosystem services as benefits that ecosystems provide for people while The Economics of Ecosystems and Biodiversity (TEEB, 2010) describes these services as the direct and indirect contributions of ecosystems to human well-being. Put most simply, Ecosystem Services are the variety of benefits that people obtain from the environment.

Ecosystems contribute to human wellbeing in a wide variety of ways and the processes by which ecosystems provide benefits to people has been described as an "ecosystem services cascade" in which bio-physical structures and processes ("ecosystem functions") can deliver inputs (ecosystem services) to the production of goods and services that contribute to the wellbeing of people (Fig. 1).

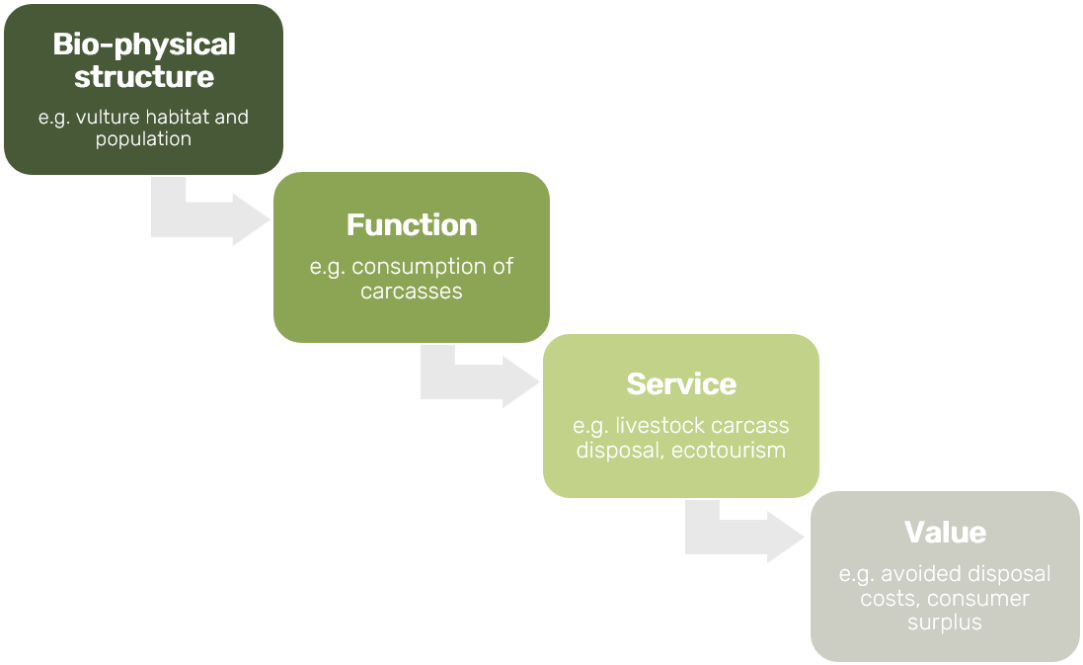

Fig. 1. Ecosystem services "cascade". Adapted from Haines-Young and Potschin (2010).

The Millennium Ecosystem Assessment (MA, 2005) classification of ecosystem services introduced the following four categories of services:

- Provisioning services are the "products obtained from ecosystems". Examples include food, timber and fuel.
- Regulating services are the "benefits obtained from the regulation of ecosystem processes". Examples include water flow regulation, carbon sequestration and protection from storms.
- Cultural services are the "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences".
- Supporting services "are necessary for the production of all other ecosystem services". Examples include nutrient cycling, soil formation and primary production.

The inclusion of supporting services in the classification can potentially lead to the double counting of values, since the ecosystem contribution is counted as both an intermediate and final service, and more recent classification systems have therefore omitted such "intermediate services" (e.g. Common International Classification of Ecosystem services – CICES; and the SEEA Ecosystem Accounting reference list).

2.2. Total Economic Value

The concept of Total Economic Value (TEV) is used to describe the comprehensive set of utilitarian values derived from an ecosystem or natural resource (Pearce and Turner, 1990). The concept is useful for identifying the different types of value that may be derived from an ecosystem or species population. TEV comprises of "use values" and "non-use values". Use values are the benefits that are derived from some physical use of the resource. "Direct use values" may derive from on-site extraction of resources (e.g., meat) or non-consumptive activities (e.g., nature based tourism). "Indirect use values" are derived from off-site services or other processes that are impacted by the resource (e.g., disposal of carcasses; control of disease). "Option value" is the value that people place on maintaining the option to use a resource in the future (e.g., the option to develop ecotourism). "Non-use values" are derived from the knowledge that an ecosystem or species population is maintained without regard to any current or future personal use. "Non-use values" may be related to altruism (maintaining a species population for use by others), bequest (for future generations) and existence (preservation unrelated to any use) motivations. The constituent values of TEV are represented in Fig. 2. It should be noted that the "total" in Total Economic Value refers to the *inclusion of all components* of value rather than the sum of all value derived from a resource.

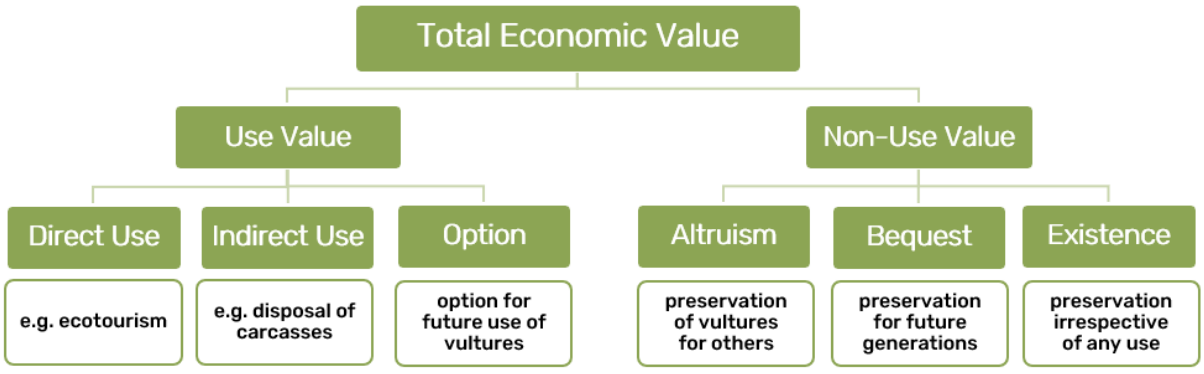

Fig. 2. Components of Total Economic Value derived from vultures.

The classification of different types of economic value within the concept of TEV is complementary to the classification of ecosystem services. Fig. 3 sets out the correspondence between categories of ecosystem service and components of TEV.

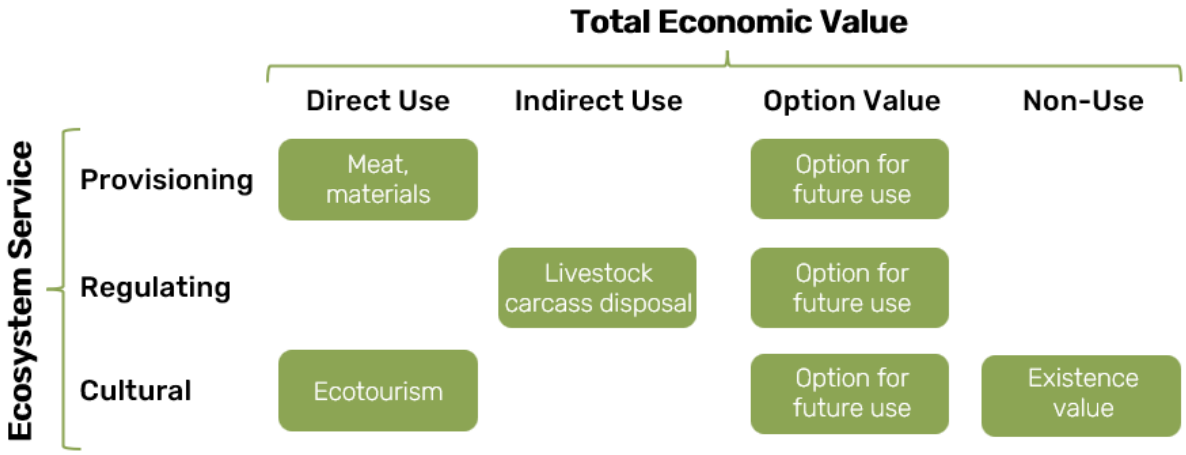

Fig. 3. Correspondence between ecosystem services and components of TEV with examples related to vultures.

2.3. Scenario Analysis

Understanding how ecosystem services may evolve under different future conditions is essential for supporting informed decision-making in conservation and natural resource management. Given that ecological and social changes can unfold along divergent political, economic, and environmental pathways, scenario analysis is a valuable tool for anticipating potential outcomes and guiding strategic action.

A scenario analysis is used to explore how ecosystem services might change in the future and how these changes can influence human well-being. A scenario is a description of the future that might potentially arise under certain assumptions and conditions.

The scenario analysis developed in this study is explorative and asks the questions "what if vulture conservation efforts were not undertaken?" and "what if vulture conservation efforts are continued?" The intention is to explore plausible scenarios for vulture population trends that could result from policy action vs. inaction. 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 populations. The difference between the "with" and "without" conservation scenarios are the additional ecosystem services provided by larger populations of vultures, which can be interpreted as the benefit of conservation action.

2.4. The Cinereous Vulture and LIFE Aegypius Return

The Cinereous Vulture is an endangered species with conservation status of Endangered (EN) in Portugal (Almeida et al., 2022) and Near Threatened (NT) in Spain (SEO/BirdLife, 2021). Globally, it is classified as Near Threatened (NT) (BirdLife International, 2021). It is protected by the Habitats Directive (Annex I), as a priority conservation species in Europe, by the Bern Convention (Annex II), by the Bonn Convention (Annex II) and by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES - Annex II-A).

As a scavenger bird, it plays a fundamental ecological role by feeding on carcasses and minimising the spread of disease.

Formerly widespread in Iberia, the Cinereous Vulture became increasingly scarce in the region over the 20th century mostly due to habitat loss, wildlife poisoning and direct persecution. In the 1970s the breeding population went extinct in Portugal, and only around 200 pairs remained in Spain. Following the implementation of legal protection and targeted conservation measures, the species started recovering in Spain and naturally recolonised Portugal with the first breeding pair detected in 2010 in the Tejo Internacional Natural Park. Since then, more pairs began settling across different regions of Portugal and five colonies are currently known (the fifth discovered in June 2024).

The recovery process has been steady, although slow and limited, and the need of urgent action to ensure the definitive return of the species to Portugal and Western Spain led to the approval of the LIFE Aegypius Return project.

The main objectives of the project included increasing the breeding population in Portugal to at least 80 pairs in five colonies (which already happened), improving the breeding success, encouraging the connectivity between colonies and downgrade the national conservation status from Critically Endangered to Endangered (which already occurred in 2023 with the update of the Portuguese Red List of Breeding Birds; Almeida et al., 2022).

The LIFE Aegypius Return project aims to consolidate and expand the Cinereous Vulture population in Portugal and Western Spain. Until 2027, concrete conservation actions within the project include the reduction of disturbance around the nests, fire prevention, the installation and reparation of nesting platforms, the improvement of food availability, anti-poisoning fights, and population reinforcement via soft release strategies. Furthermore, a thorough collaboration and capacitation plan will be put in place, promoting joint work with all relevant stakeholders – e.g., hunters, farmers, national authorities, conservationists – to improve ecological conditions for the species and to detect and fight relevant threats, such as illegal poisoning, disturbance, electrocution, collision, among others.

These actions are expected to also benefit other species, such as the Griffon Vulture and the Egyptian Vulture, which also occur in the area.

The success of LIFE Aegypius Return depends on the strong collaboration between project partners and stakeholders, but lasting outcomes will also hinge on public perception of vultures. This report provides data that complements the intrinsic and ecological value of vultures, serving as a crucial basis to guide communication and environmental strategies for their conservation.

2.5. Objectives

The overall objective of this study is to assess the contribution of Cinereous, Griffon and Egyptian vultures in the study area to ecosystem services. The specific objectives are to:

1. Develop a conceptual model of how the vulture population interacts with the local environment and human activities to contribute to the provision of ecosystem services and human wellbeing.

2. Quantify in biophysical and monetary terms the following ecosystem services provided by Cinereous, Griffon and Egyptian vultures in the study area:
    a. Livestock carcass consumption and its potential to reduce costs to farmers and public authorities associated with carcass removal and transportation;
    b. Climate regulation by reducing greenhouse gas emissions associated with collection and transportation of carcasses;
    c. Ecotourism revenue associated with vulture populations.

3. Quantify the change in ecosystem service values associated with the growth of the Cinereous Vulture population due to conservation investment during the period 2023-2048.

3. STUDY AREA AND VULTURE POPULATIONS

3.1. Study area

The area of intervention of the LIFE Aegypius Return project runs along the border between Portugal and Spain, comprising 10 Special Protection Areas (SPAs) in both countries (seven in Portugal, three in Spain):

PTZPE0038 Douro Internacional e Vale do Águeda
PTZPE0037 Rios Sabor e Maçãs
PTZPE0039 Vale do Côa
PTZPE0007 Serra da Malcata
PTZPE0042 Tejo Internacional, Erges e Pônsul
PTZPE0045 Mourão/Moura/Barrancos
PTZPE0047 Vale do Guadiana
ES0000202 Campo de Azaba
ES0000370 Sierra de Gata y Vale de Pilas
ES0000434 Canchos de Ramiro y Ladronera

These SPAs are home to Cinereous Vulture colonies or, being in their area of regular occurrence, have habitat considered suitable for the expansion and recolonisation of the species (Fig. 4).

The analysis presented in this report focuses on the Portuguese part of the project area due to limited availability of data for the Spanish territory regarding costs of carcass disposal and food availability (Santos et al., 2024).

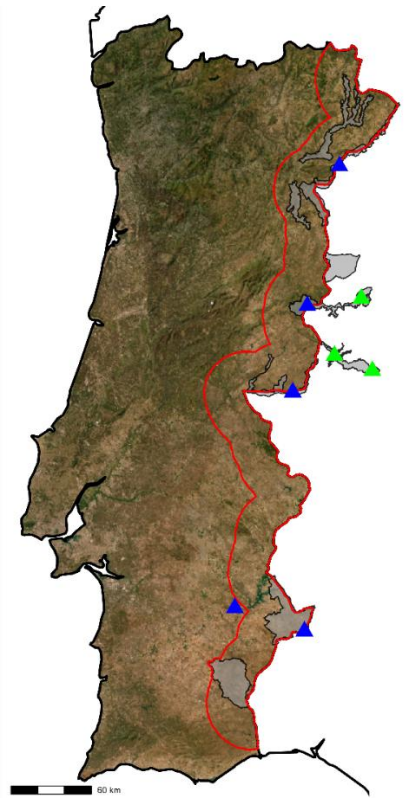

Fig. 4. Study area (red): corresponds to a strip of territory covering 40 kilometres to the west of the north-south border of Portugal and Spain, plus the boundaries of the 10 Special Protection Areas in which the LIFE Aegypius Return project is working (grey polygons). Blue triangles mark all the Cinereous Vultures breeding colonies in Portugal. Green triangles mark the Cinereous Vultures breeding colonies in the project's target Special Protection Areas (SPA) in Spain.

3.2. Vulture populations

Current populations

Estimates for the populations of Cinereous, Griffon and Egyptian vultures in Portugal were obtained from Santos et al (2024). These population estimates include breeding pairs nesting in Portugal, breeding pairs nesting in Spain that also forage in Portugal, and non-breeding birds (i.e., immature birds) from both countries. Projected distributions of each species in the study area were produced using the location of nests or colonies and the respective number of breeding birds (see methods in Santos et al., 2024).

For the Cinereous vulture colonies surveyed by the LIFE project, data from the most recent survey, conducted in 2024, were used, while for other colonies in Spain, data from the 2017 census were used (Del Moral, 2017). For the Griffon and Egyptian vultures, data from the census in 2018 conducted in both countries were used (Alonso et al., 2022; Del Moral e Molina, 2018a; Del Moral e Molina, 2018b).

To account for the presence of non-breeding birds, it was considered that non-breeding Cinereous Vultures represent 24% of the population, non-breeding Griffon Vultures represent 30% of the population, and non-breeding Egyptian Vultures represent 7% of the population (López & Meroño, 2019).

The estimates of current population for each species in Portugal and the considered regions of Spain are: 585 Cinereous Vultures; 4494 Griffon Vultures; 273 Egyptian Vultures.

Forecasting vulture populations

Predicting how vulture populations may change in the future entails uncertainty but provides a basis to conduct the exploratory scenario analysis and estimate the benefits of conservation action. We forecast how vulture populations may change under a scenario 'with conservation' and under a scenario 'without conservation'.

The number of Cinereous Vulture breeding pairs in Portugal at the time of the LIFE project submission and start in 2022 was estimated to be 40. Following the start of the LIFE Aegypius Return project, more resources could be allocated for a thorough survey and 78 breeding pairs were found in Portugal in 2023. This increase is believed to reflect both actual population growth and the improved survey effort conducted in 2023. The most recent survey, conducted in 2024, detected 108 breeding pairs in Portugal.

Given the steady increase in the Cinereous Vulture breeding population in Portugal, it was assumed that this growth would follow the positive trends observed in neighbouring colonies in Spain. Therefore, the growth rate of colonies in Castile and León (Junta de Castilla y León, 2024) was used to project the future number of breeding pairs in Portugal (see details of Methods in Appendix 2). Based on these projections, the number of breeding pairs in Portugal is expected to rise to 164 by the end of the LIFE project (2027) and continue increasing to approximately 256 pairs by 2032 (the end of the after-LIFE period). These figures remain below the estimated carrying capacity of the study area, which is projected to be 545 breeding pairs by 2048, assuming the growth rate follows the considered linear trajectory. We highlight that this estimated carrying capacity is primarily driven by management limitations related to the provisioning of supplementary food to vulture populations in a regulatory manner, rather than by ecological constraints (see details of methods in Appendix 2).

Regarding the Cinereous Vultures breeding in Spain, it was assumed the population numbers will remain stable for the period 2024-2048. Although very conservative (as Spanish breeding areas will likely register some growth due to positive impact from ongoing conservation action in both countries), there is no data available for a robust population forecast, making the stable population the most appropriate assumption.

Therefore, the population values used for the quantification and valuation of ecosystem services (see below) in the period 2024-2048 were the sum of the population forecast in Portugal in each year and the stable population of birds from Spain that forage in Portugal.

It was considered unlikely that the population in Portugal would disappear completely without conservation action given that there are legal protections that, indirectly, should secure some individuals (e.g., anti-poisoning and veterinary regulation). Therefore, it was considered that 'without conservation' efforts the Cinereous Vulture population would have remained stable at 40 breeding pairs (105 individuals). The estimated total populations of Cinereous Vultures in Portugal over the period 2024-2048, with and without conservation action, are represented in Fig. 5.

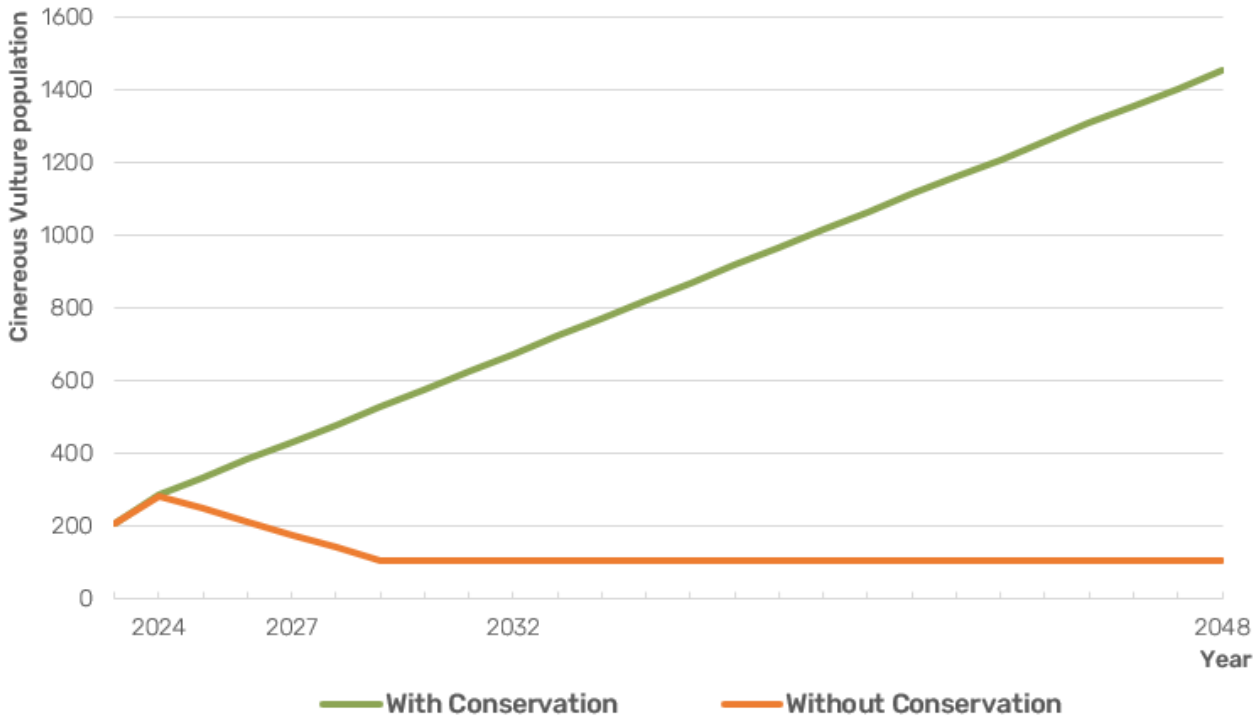

Fig. 5. Estimated population (number of individuals) of Cinereous Vultures in Portugal, with and without conservation efforts (2023-2048). The years indicated refer to key milestones of the LIFE Aegypius Return project: implementation of the LIFE Aegypius Return project (2023-2027), after-LIFE period (2027-2032), and carrying capacity reached in 2048. The population figures represent total number of individuals, including breeding pairs in Portugal, birds breeding in Spain that forage in Portugal, and non-breeding individuals. It was considered that non-breeding birds represent 24% of the population (López & Meroño, 2019).

4. CONCEPTUAL MODEL FOR VULTURE VALUATION IN PORTUGAL

This conceptual model aims at identifying and quantifying the benefits that people derive from vultures and makes use of both the Ecosystem Services (ES) approach (MA, 2005; TEEB, 2010; Maes et al., 2012) and the Total Economic Value (TEV) framework (Pearce and Turner, 1990). This conceptual framework is in line with the guidance for assessing ecosystems and their services in LIFE projects (LIFE, 2021).

To develop a conceptual model for the valuation of vultures in Portugal (see Fig. 6), we build on the ecosystem services cascade (Fig. 1; Haines-Young and Potschin, 2010) and total economic valuation frameworks (Fig. 2; Pearce and Turner, 1990). Futhermore, a literature review was used to obtain information on the ecosystem services provided by vultures (see Appendix 1).

In the Portuguese context, vultures provide both regulating and cultural services. Provisioning services are not relevant in this context because vulture parts are not used or consumed in Portugal (for examples elsewhere see Daboné et al., 2022). Regulating services include the consumption of livestock carcasses, which has value both in terms of the avoided disposal costs and the avoided greenhouse gas emissions from transporting and incinerating carcasses.

The avoided disposal costs are a potential benefit to livestock farmers and the State, which would otherwise incur these costs. The avoided costs of greenhouse gas emissions are a global benefit, in terms of reduced climate change damages worldwide. A second regulating service that is potentially relevant in the Portuguese context is the sanitation service whereby the consumption of carcasses helps reducing the accumulation and transmission of toxins and pathogens to other animals including humans. This service, however, is not assessed in the present study (indicated by the lighter shading in Fig. 6).

Regarding cultural services, vultures provide a service to nature-based tourism, which has value in terms of revenue to the tourism sector (and the general economy) and the enjoyment attained by tourists. A second relevant cultural service is the value that the Portuguese public place on the continued existence of vultures in Portugal irrespective of any current or future use. Such non-use values have been shown to be substantial for vulture populations in other countries (e.g., Brander et al., 2024) and are likely to also be relevant in the Portuguese context.

The conceptual framework identifies the different groups of beneficiaries that obtain value from vultures in Portugal. These include livestock farmers, the Portuguese general public, the global public, the tourism sector and tourists.

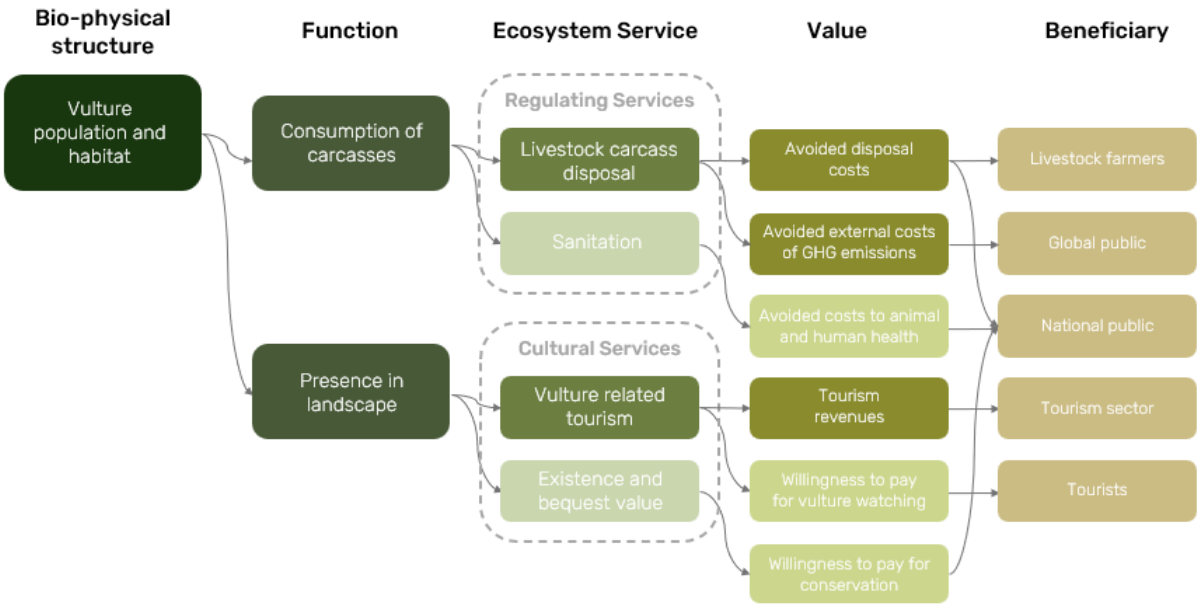

Fig. 6. Conceptual framework linking the Cinerous, Griffon and Egyptian vultures in Portugal with ecosystem services, their values and beneficiaries. Lighter shaded ecosystem services and values indicate that these are potentially relevant in the Portuguese context, but were not included in the assessment presented in this report.

5. QUANTIFICATION AND VALUATION OF ECOSYSTEM SERVICES

5.1. Reduced financial cost of livestock carcass disposal

In Portugal, livestock carcasses in most regions are processed through the System for the Collection of Dead Animals on Farms (SIRCA - *Sistema de Recolha de Cadáveres de Animais Mortos na Exploração*, in Portuguese). Where SIRCA operates, farmers can request the collection of animal carcasses from their properties, which are then transported to authorised disposal sites including incineration plants and some landfills. The system is designed to facilitate the safe and environmentally responsible disposal of dead livestock, helping prevent the spread of disease and toxins in compliance with Europan health regulations.

The role of vultures in consuming livestock carcasses is estimated using information on the size of vulture populations, daily food requirements, the proportion of livestock in vultures' diet, and the proportion of a carcass that is soft tissue consumed by vultures. The value of this ecosystem service is estimated as the avoided costs of carcass collection and disposal using information on the total annual costs and quantities from the SIRCA system.

1. The annual consumption of livestock carcasses by vultures is computed by multiplying the vulture population by the daily food requirement of an adult vulture (Cinereous 0,58 kg/day; Griffon 0,52 kg/day; Egyptian 0,2 kg/day; Lopez and Meroño, 2019; Santos et al., 2024) by 365 days (200 days in the case of Egyptian Vultures, which are migratory and spend part of the year in Africa) and by the proportion of diet derived from livestock (68,3%; Arrondo et al., 2023).[1]
2. The live weight of livestock carcasses consumed by vultures is computed by multiplying the quantity estimated in step 1 by the inverse proportion of soft tissue in a carcass (73%; Jarvis et al., 1974). This provides an estimate of the weight of livestock carcasses that would otherwise need to be collected and disposed of.
3. The avoided cost of carcass collection and disposal per kg is computed by dividing the SIRCA budget for 2025 (15 million EUR[2]) by the total weight of collected carcasses (44,23 million kg/year), which was estimated from the reported number of carcasses collected per year (221.169 carcasses per year; 5-year average for the period 2018-2022) multiplied by the mean live weight of a carcass (200 kg; Lopez and Meroño, 2019), computed as a weighted average of cattle, sheep and goats. This provides a disposal cost per kg of 0,34 EUR/kg.[3]
4. The estimated weight of livestock carcasses that are consumed by vultures (step 2) is multiplied by the cost of collection and disposal (step 3) to estimate the annual avoided costs attributable to this ecosystem service.

[1] We note that the proportion of vulture diet derived from livestock as opposed to wild animals is highly spatially variable and likely to be lower in remote areas (Arrondo et al., 2023).

[2] Resolution of the Council of Ministers No. 172/2024, of 29 November

[3] This estimated cost for carcass disposal is somewhat lower than the costs estimated for Sardinia by Santangeli et al. (2024) but those include the cost of transportation to mainland Italy by truck and ferry.

The estimated quantities and values of livestock carcass disposal by Cinereous, Griffon and Egyptian Vultures in 2023 are provided in Table 1. The total quantity of livestock carcasses consumed by vultures in Portugal is estimated to be over 900 tonnes, which is equivalent to approximately 2% of the quantity collected annually by SIRCA. The annual avoided disposal costs are estimated to be over 313.000 EUR (Table 1). The differences across vulture species are driven by their respective population sizes and food requirements.

Table 1. Avoided quantities and costs of carcass collection and disposal by the Cinereous, Griffon and Egyptian vultures in Portugal, in 2023 (calculated using 2024 price level; present values using a discount rate of 1.67%).

	Cinereous	Griffon	Egyptian	Total
Live weight of carcasses (kg)	115.471	798.045	10.217	923.733
Avoided disposal costs (EUR)	39.157	270.623	3.465	313.244

5.2. Scenario analysis

A scenario analysis is developed to explore how Cinereous Vulture populations and ecosystem services might change over time with conservation relative to a baseline case in which no active conservation is undertaken. Specifically, we make use of the results of the literature review (Appendix 1) and study area data to estimate changes in ecosystem services and values relative to the baseline 'without conservation' case. The time horizon for the scenario analysis is 2024-2048, which includes key milestones for the conservation of the Cinereous Vulture in Portugal – i.e., current situation (2024), end of the LIFE Aegypius Return project (2027), the after-LIFE period (2032), and the carrying capacity (forecasted to 2048) – and reflects a medium-term perspective on the species, over which conservation measures can influence vulture populations.

For Cinereous Vultures we then estimate the quantities and values of livestock carcass disposal for the period 2023-2048 under with- and without conservation scenarios. The results are summarised in Table 2 and represented in Fig. 7. All values are reported at the 2024 price level in present values (i.e., values that occur in future years are discounted to present values to enable comparison across temporally distributed impacts by reflecting society's preferences for current vs. future consumption and the opportunity cost of capital using a discount rate of 1.67%, Florio and Sirtori, 2013).[4] With conservation, the annual value of this service is projected to increase to over 81.000 EUR in 2048 as the Cinereous Vulture population increases.

[4] The flow of ecosystem service values has a temporal distribution, and it is important to account for this distribution over time because people tend to place higher importance on values received in the present compared to values received in the future. The practice of accounting for this time preference is called discounting and involves putting a lower weight on values that occur in the future. The conventional way to deal with temporally distributed values is to apply a discount rate to future values so that they can be compared as "present values".

The difference between the "with" and "without" conservation scenarios can be interpreted as the benefit of conservation action. This benefit reaches almost 60.000 EUR per year in 2048. The aggregate value of this benefit for the period 2023-2048 is approximately 971.000 EUR.

Table 2. Forecasted avoided quantities and costs of carcass collection and disposal in Portugal by the Cinereous Vultures in Portugal 'with conservation' at key milestones for the conservation of the species in the country (calculated using 2024 price level; present values using a discount rate of 1.67%).

Year	2024 (current)	2027 (end of LIFE project)	2032 (after-LIFE)	2048 (carrying capacity)
Cinereous Vulture Population (No. individuals)	664	810	1.053	1.832
Live weight of carcasses (kg)	131.065	159.883	207.849	361.613
Avoided disposal costs (EUR)	43.715	50.742	60.722	81.051

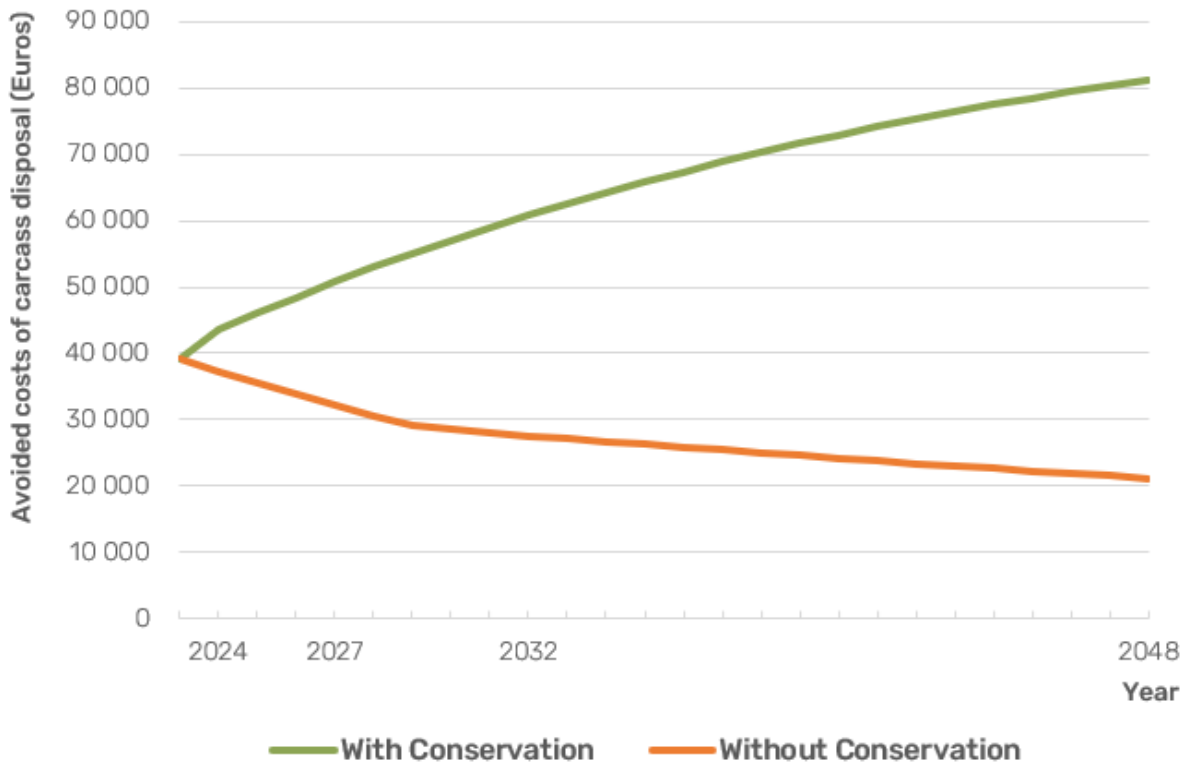

Fig. 7. Avoided costs of carcass collection and disposal by the Cinereous Vulture in Portugal at different moments (key LIFE Aegypius Return milestones), with and without conservation efforts (2024 price level; present values using a discount rate of 1.67%).

Assuming that (i) under a 'with conservation' scenario in Portugal, the Cinereous Vulture population will grow as explained in the *3.2. Vulture populations* section, and (ii) the Griffon and Egyptian vulture populations in Portugal and Spain will remain stable, the aggregated and cumulative contribution of the three species in avoided costs of carcass collection and disposal at key milestones for the LIFE Aegypius Return project would potentially be of 1.600.000 EUR by the end of the project (2027), 3.250.000 EUR by the after-LIFE period (2032), and 8.805.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048).

5.3. Reduced greenhouse gas emissions

The reduced emission of greenhouse gases (GHG) attributable to the role of vultures in consuming livestock carcasses is estimated using information on the quantity of livestock carcasses that would otherwise need to be collected and disposed of (see quantification in preceding section) and the emissions associated with transportation of carcasses. The value of this ecosystem service is measured as the avoided damage costs of climate change using estimates of the social cost of carbon (SCC). The SCC is the monetary value of damages caused by emitting one additional tonne of CO_2 in a given year —the monetized impacts of climate change including changes in agricultural productivity, human health, property damages from increased flood risk, and changes in energy system costs— and therefore also represents the value of damages avoided for a small reduction in emissions. The SCC is widely used to inform climate policy and cost–benefit analyses (Nordhaus, 2017).

1. The estimated weight of livestock carcasses that are consumed by vultures and would otherwise need to be collected and disposed of by farmers is described in the preceding section (steps 1 and 2).
2. The quantity of GHG emissions per tonne of collected livestock carcass is obtained from a study for Spain (Morales-Reyes et al., 2017). Dividing the estimates provided in that study for the annual quantity of GHG emissions associated with carcass collection and disposal (43.344 tonnes CO_2-equivalent) by the annual quantity of carcasses collected (33.474 tonnes) gives a rate of emissions of 1.29 tonnes CO_2-equivalent per tonne of carcasses.[5]
3. The quantity of avoided GHG emissions per year is estimated by multiplying the quantity of livestock carcasses consumed by vultures (step 1) by the rate of GHG emissions (step 2).
4. The avoided climate change damage costs attributable to the reduced GHG emissions is computed by multiplying the quantity of reduced emissions (step 3) by the social cost of carbon (SCC). The estimated SCC for emissions in each year 2020-2030 provided by the US EPA (2023) were converted from 2020 to 2024 price level using GDP deflator data from the World Bank (2024) and from USD to EUR using a market exchange rate of 0.95 (Oanda, 2024). The SCC values used in this study are provided in Appendix 3 (Table A3: 1). The SCC increases over time to reflect the increasing marginal damage cost of CO_2 emissions as the concentration of CO_2 in the atmosphere increases (i.e., the amount of damage caused by each additional tonne CO_2 will be higher in the future). For example, the estimated SCC published by the US EPA and other US agencies for appraisal of

[5] This rate of emissions is slightly higher than the rate estimated for carcass disposal on Sardinia by Santangeli et al. (2024).

emissions reductions in 2024 is equivalent to 149 EUR/t CO_2 and rises to 168 EUR/t CO_2 for emissions in 2030 (US EPA, 2023).

The estimated quantities and values of avoided greenhouse gas emissions attributable to Cinereous, Griffon and Egyptian vultures in 2023 are provided in Table 3. The total quantity of avoided GHG emissions attributable to vultures in Portugal is estimated to be almost 1.200 tCO_2, with a value in terms of avoided climate change damage costs of over 160.000 EUR.

Table 3. Avoided quantities and costs of GHG emissions by Cinereous, Griffon and Egyptian vultures in Portugal in 2023 (2024 price level; present values using a discount rate of 1.67%).

	Cinereous	Griffon	Egyptian	Total
Avoided GHG emissions (tCO_2)	150	1.033	13	1.196
Avoided GHG emissions (EUR)	20.352	140.654	1.801	162.806

For Cinereous Vultures we then estimate the quantities and values of avoided GHG emissions for the period 2023-2048 under "with" and "without" conservation scenarios. The results are summarised in Table 4 and represented in Fig. 8. All values are reported at the 2024 price level in present values (using a discount rate of 1.67%, Florio and Sirtori, 2013). With conservation, the annual value of this service is projected to increase to over 68.000 EUR in 2048 as the vulture population increases.

The difference between the "with" and "without" conservation scenarios can be interpreted as the benefit of conservation action. This benefit reaches just over 50.000 EUR per year in 2048 (from 346 tCO_2 avoided emissions). The potential aggregate value of this benefit for the period 2023-2048 is almost 700.000 EUR (from 4.847 tCO_2 avoided emissions).

Table 4. Avoided quantities and costs of GHG emissions by the Cinereous Vulture in Portugal per year, with conservation (2024 price level; present values using a discount rate of 1.67%).

Year	2024	2027	2032	2048
Cinereous Vulture Population (No. individuals)	664	810	1.053	1.832
Avoided GHG emissions (tCO_2)	170	207	269	468
Avoided damage costs (EUR)	23.109	28.852	38.034	68.049

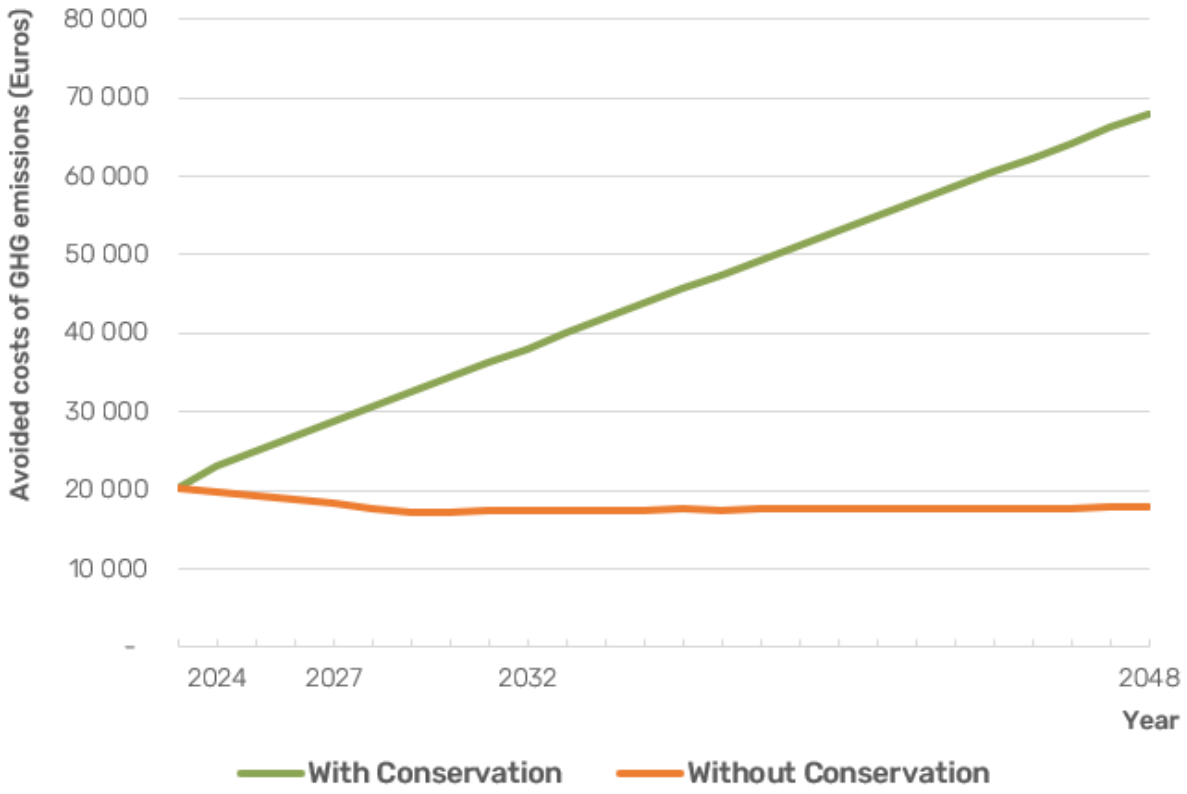

Fig. 8. Avoided costs of GHG emissions by Cinereous Vultures in Portugal per year with and without conservation efforts (2024 price level; present values using a discount rate of 1.67%).

Assuming that (i) under a 'with conservation' scenario in Portugal, the Cinereous Vulture population will grow as explained in the *3.2. Vulture populations* section, (ii) the Griffon and Egyptian vultures populations in Portugal and Spain will remain stable, the aggregated and cumulative contribution of the three species in avoided costs of carcass collection and disposal at key milestones for the LIFE Aegypius Return project would potentially be of 837.000 EUR by the end of the project (2027), 1.721.000 EUR by the after-LIFE period (2032), and 4.864.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048).

5.4. Ecotourism

Ecotourism is travel to natural areas that conserves the environment and improves the well-being of local people. In many cases, ecotourism generates financial and public support for conservation activities (Buckley et al., 2016). In the context of this study, the presence of vultures in the landscape has the potential to attract bird watchers and generate revenues in the local economy for tours and other tourism services.

Data on the number of nature-related tourism visits in the study area and the role of vultures in motivating visits is not available. In order to provide a first estimate of the potential value of vulture watching activities in Portugal, we make use of statistics on visitors to the study area, membership rates of bird conservation organisations in visitors' countries of origin, the price of birdwatching tours, and the average amount a tourist spends per day provided by Turismo de Portugal. We further describe two case studies that illustrate this ecosystem service: one involving a tourism operator based in the Côa Valley and Douro Internacional

Nature Park (Wildlife Portugal; Box 1), and the other focused on guided boat tours for vulture and bird-of-prey observation in the Douro Internacional region of the Douro River (Box 2).

1. The number of tourist visitors in 2023 to the 14 municipalities within the study area were obtained from Turismo de Portugal (see Table 7).
2. The proportion of visitors that are potentially interested in bird watching was estimated using the rates of membership of national bird conservation organisations, which was available for the UK, Germany, the Netherlands, Sweden, Italy and Spain (CBI, 2021). We computed the average rate of membership across these six countries (0,52%). We consider this to be a highly conservative estimate of potential interest in vulture viewing.[6]
3. The number of visitors that are potentially interested in bird watching is computed by multiplying the number of visitors to a municipality (step 1) by the bird conservation organisation membership rate (step 2), following Phipps and Vogiatzakis (2020).
4. The potential direct expenditure on vulture watching tours is computed by multiplying the estimated number of bird watchers by the mean cost of a bird watching half-day tour (65 EUR; Alves, 2020).
5. The potential indirect expenditure on other tourist services while participating in a vulture watching tour (e.g., accommodation, food etc.), is computed by multiplying the estimated number of bird watchers by the mean daily tourist expenditure in Portugal (59,4 EUR per day; Instituto Nacional de Estatística, 2024).

The results of this first estimation of potential vulture ecotourism value are provided in Table5. The total number of visitors to the study area is fairly high at almost 300.000 in 2023 but we apply a very conservative assumption regarding the number of these visitors that would be interested in vulture watching (1.545 per year). The estimated potential expenditure on vulture watching tours is over 100.000 EUR per year and the estimated indirect expenditure on other tourist services is about 92.000 EUR per year (total combined value over 192.000 EUR).

Assuming a scenario of steadiness in ecotourism demand, the estimated cumulative potential vulture ecotourism value at key milestones for the LIFE Aegypius Return project would potentially be of 961.000 EUR by the end of the project (2027), 1.921.000 EUR by the after-LIFE period (2032), and 4.996.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048).

[6] The results of a survey of visitors to Sardinia by Santangeli et al (2024), suggest that 73% of respondents are willing to pay for vulture watching.

Table 5. Number of visitors, estimated number of bird watchers, potential expenditure on vulture watching tours, and estimated indirect expenditure of bird watchers in tourist services in the 14 municipalities within the study area in 2024.

Municipality	Total number of visitors	Visitors interested in bird watching	Expenditure on vulture tours (EUR)	Indirect expenditure (EUR)
Almeida	11.500	60	3.881	3.546
Castelo Branco	69.302	360	23.386	21.371
Castelo De Vide	16.210	84	5.470	4.999
Figueira De Castelo Rodrigo	7.096	37	2.395	2.188
Freixo De Espada a Cinta	13.298	69	4.487	4.101
Idanha-A-Nova	23.730	123	8.008	7.318
Marvão	24.607	128	8.304	7.588
Mértola	31.870	165	10.755	9.828
Miranda Do Douro	22.198	115	7.491	6.845
Mogadouro	5.183	27	1.749	1.598
Moura	20.661	107	6.972	6.371
Mourão	9.481	49	3.199	2.924
Penamacor	12.096	63	4.082	3.730
Portalegre	30.286	157	10.220	9.340
Total	297518	1.545	100.399	91.749

Box 1

Birdwatching tours in the Côa Valley and Douro Internacional Nature Park operated by Wildlife Portugal

As an example of bird watching ecotourism in the study area, we describe the case of a tourism operator (**Wildlife Portugal**; Fernando Romão, pers. com.) that provides guided birdwatching tours in the Côa Valley and Douro Internacional Nature Park. The number of tourists that joined birdwatching tours operated by Wildlife Portugal during the period 2016-2024 is represented in

Fig. 9. The number of annual visits is highly variable and, unsurprisingly, fell to low levels during the COVID-19 pandemic. Variation in visitor numbers is affected by multiple factors including the occurrence of forest fires. Tours include birdwatching as part of a visit to nature areas and vultures are considered to be the species of greatest interest. The people that joined these tours comprise of both domestic (Portuguese) and international tourists. International tourists are mainly from other European countries but also include visitors from Australia, Canada, New Zealand and the United States. The cost of a birdwatching tour is 100-200 EUR per group of up to four people.

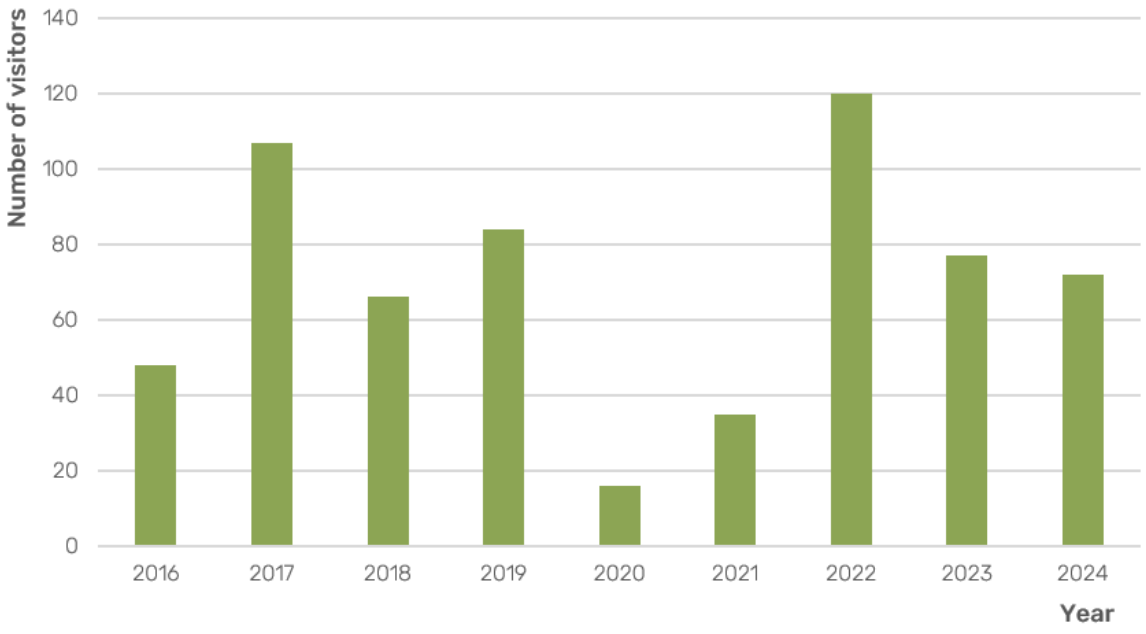

Fig. 9. Number of visitors joining birdwatching tours operated by Wildlife Portugal in the Côa Valley and Douro Internacional Nature Park (2016-2024).

Box 2

Guided boat tours for vulture and bird-of-prey observation in the Douro Internacional region of the Douro River

A second example of bird watching ecotourism is the guided boat tours for vulture and bird-of-prey observation in the Douro International River region. We describe the case of two tourism operators.

Naturisnor operates river tours on the stretch of the Douro River between the Bemposta Dam and the Picote Dam, providing visitors a unique experience of contact with nature and the region's biodiversity. Birdwatching, including various species of vultures, is often one of the highlights of their tours. Naturisnor runs approximately 160 cruises per year with an average of 14 passengers per trip. The price of a cruise is 25 EUR per person. The tourists that join these cruises are predominantly Portuguese and Spanish, with some visitors from other countries, including France and Germany. The cruise is led by specialized guides who provide interpretation of the landscape and local biodiversity.

The International Biological Station mainly operates in the Douro River Basin, where it receives around 80.000 visitors per year. They operate two cruises: the Sanabria Environmental Cruise with a capacity of 80 passengers and the Miranda Environmental Cruise with a capacity of 116 passengers. The nationality of the visitors is typically 80% Spanish, 15% Portuguese, and 5% from other nationalities. Prices range between 18 and 22 EUR per person. All trips are guided by nature guides who interpret the various Portuguese-Spanish environmental restoration projects, as well as the fauna, flora, geology, and ethnographic resources of the park, where birds are a key element. According to visitor motivation surveys conducted for their tour booking, Nature Tourism emerged as the primary reason for visits, cited by 87,1% of respondents. Nature Tourism-related expenditure in the local economy is estimated to be distributed as follows: 50,2% on restaurants, 28% on accommodation, and 21,8% on retail and other services.

6. DISCUSSION AND CONCLUSIONS

In this section we provide a brief summary of the findings and identify potential avenues for further research into vulture ecosystem services and their values in the study area.

6.1. Summary of findings

The analysis presented in this report focuses on three ecosystem services provided by vultures in Portugal, namely the avoided costs of livestock carcass disposal, reduced greenhouse gas emissions associated with carcass transportation, and the contribution to ecotourism by attracting visitors that want to view vultures in the wild.

The current populations of Cinereous, Griffon and Egyptian vultures in Portugal are estimated to be 585, 4.494 and 273 individuals respectively. The values of the ecosystem services provided by these vulture species in 2023 are estimated to be 313.000 EUR in avoided carcass disposal costs, 163.000 EUR in avoided GHG emissions, and potentially 192.000 EUR for ecotourism (corresponding to a total estimated value of 668.000 EUR).

As the population of Cinereous Vultures in Portugal increases over time due to ongoing conservation efforts, the value of the ecosystem services that they provide will also increase. For the period 2023-2048, we estimate the benefits of conservation (i.e., the increased value of ecosystem services relative to a without conservation scenario). With a focus only on regulating services, we estimate that the aggregated benefits of conservation over the 26-year period are approximately 970.000 EUR for avoided carcass disposal costs and 695.000 EUR for avoided climate change damages (corresponding to a total estimated value of over 1.665.000 EUR).

Assuming a continued increase in the Cinereous Vulture population in Portugal due to conservation efforts, alongside stable populations of Griffon and Egyptian vultures in both Portugal and Spain, we estimate the aggregated and cumulative value of avoided carcass disposal and greenhouse gas (GHG) emissions costs for the three species to reach approximately 2.435.000 EUR by the end of the project (2027), 4.974.000 EUR by the after-LIFE period (2032), and 13.670.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048). Adding the potential contribution of vultures to ecotourism, assuming a steady annual demand, the estimated total value of these three ecosystem services rises to 3.396.000 EUR by the end of the project (2027), 6.896.000 EUR by the after-LIFE period (2032), and 18.665.000 EUR when reaching carrying capacity for the Cinereous Vulture (2048).

6.2. Avenues for future research to quantify ecosystem services provided by vultures

The assessment presented in this report has a number of limitations that could be potentially be addressed in future research including:

- There are several uncertainties regarding the data and parameters used in the analysis. To the largest extent possible, we have used information pertaining directly to the study area but several uncertainties remain. Projections of future vulture populations with- and without conservation are inherently uncertain and potentially influenced by multiple factors. The estimates used in this report are based on the best currently available information and could be revised as updated observations and projections become available. It would also be possible to develop additional scenarios to explore alternative population trends and their associated ecosystem service values.
- Due to the lack of available data on the numbers of ecotourism visits in the study area and the importance of vultures to the ecotourism experience, we provide only a first estimate of the potential value of vulture based ecotourism. To do so, we make a very conservative assumption regarding the proportion of current visitors that might be interested in viewing vultures. We also do not estimate how the value of this ecosystem service might develop over time as the vulture population (and interest in ecotourism experiences) increases. Future research could therefore aim to provide greater understanding of the role of vultures for ecotourism through surveys of visitors. Such surveys could try to quantify the proportion of visitors that would be interested in viewing vultures in Portugal, their willingness to pay per visit, and how this might change with increasing vulture populations.
- The assessment addresses a sub-set of three ecosystem services provided by vultures in Portugal. Other services are relevant in the Portuguese context (Fig. 6) and potentially of high importance. Future research could therefore attempt to quantify and value these ecosystem services. In particular, the non-use (existence and bequest) values that people in Portugal and Spain place on increased vulture populations could be assessed using stated preference methods. This would involve conducting a survey of the general public to ask questions on willingness to pay for increasing the population and distribution of vultures.
- The assessment provides a partial estimate of the benefits of vulture conservation. The analysis could be expanded to provide a more comprehensive estimate of conservation benefits and potentially extend to a Cost-Benefit Analysis to evaluate the return on conservation investments. This would provide conservation partners and donors with information on the extent to which investments deliver positive returns.

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APPENDICES

Appendix 1.

Literature review on ecosystem services provided by vultures

A literature review is used to obtain information on the ecosystem services provided by vultures. It builds on existing reviews and involves a search of literature databases to provide an overview of the literature on ecosystem services derived from vultures and the economic value of these services. The review includes peer reviewed journal articles, working papers and research reports, academic dissertations and theses, NGO publications, and 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 capture the diverse terminology used in the field.

The results of the literature review are summarised in Table A1: 1, which lists ecosystem services provided by vultures, provides a brief description of the service, and cites relevant publications.

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

From the literature review, we identified 12 studies that estimate the economic value of vulture ecosystem services. These studies are summarised in Table A1: 2. The geographic coverage of these studies is broad, including locations in Europe, Asia, North and South America, and Southern Africa.

Regarding the ecosystem services that have been valued in the literature, six studies estimate values for carcass and waste disposal (Margalida and Colomer, 2012; Ishwar et al., 2016; Grilli et al., 2019; Phipps and Vogiatzakis, 2020; Brander et al., 2024; Santangeli et al., 2024), four for ecotourism (Becker et al., 2005; García-Jiménez et al., 2021; Becker et al., 2010; Brander et al., 2024), four for existence values (Becker et al., 2010; Baral et al., 2007; Zambrano-Monserrate, 2020; Brander et al., 2024), 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). The single valuation study for provisioning services supplied by vultures estimates the value of vulture parts used in belief-based use in Southern Africa (Brander et al., 2024).

The application of valuation methods corresponds closely to the ecosystem services that are valued. The valuation of waste disposal used the replacement cost method, with the underlying assumption that livestock carcasses disposed of by vultures would need to be replaced by human-made processing, such as collection, burial or incineration. This valuation method can provide lower bound estimates of the value of an ecosystem service, but only if the following conditions are met: (1) the human-made disposal process provides the same level of service as the ecosystem being replaced; (2) the human-made process should be the least-cost alternative; and (3) there should be substantial evidence that the service delivered by the infrastructure would be demanded by society if it were provided at cost (Shabman and Batie, 1978). In practice, most applications of the replacement cost method do not meet these conditions and tend to greatly over-estimate the value of ecosystem services (Barbier, 2016). This is because the cost of infrastructure is not a good proxy of the benefits that it delivers (benefits can be lower than costs if the infrastructure is redundant); and the selected replacement infrastructures/processes used in many

studies are not the least-cost alternative. The replacement cost method is widely used due to its relative convenience (costs of human-made infrastructure are widely available) (World Bank, 2016) but when used inappropriately, delivers misinformation on the value of ecosystem services.

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 opportunity per trip, and the contingent valuation method. 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, irrespective of any current or future use, have been estimated using stated preference methods (contingent valuation and choice experiments). The contingent valuation method involves the measurement of willingness to pay (WTP) for a specified change in vulture population or conservation programme through a public survey. To date there is only one application of the discrete choice experiment method to estimate existence values for vultures (Brander et al., 2024). 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.

Table A1: 1. Ecosystem services provided by vultures (adapted from Fitzpatrick et al., 2018; Carucci et al. 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; Phipps and Vogiatzakis, 2020; 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; Donazar et al., 2016; Grilli et al., 2019; Houston 1975; van den Heever et al. 2021; Jalihal et al., 2022; Frank and Sudarshan, 2024
	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., 2012a; 2012b; Berlinguer et al., 2021; van den Heever et al. 2021; Buechley et al., 2016; 2022; Brink, 2022; Frank and Sudarshan, 2024
	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 livestock carcasses that would otherwise require collection, transportation and disposal.	Morales-Reyes et al., 2017; Phipps and Vogiatzakis, 2020; Plaza and Lambertucci, 2022; Santangeli et al., 2024.
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 tourism visits.	Becker et al., 2005; 2010; Phipps and Vogiatzakis, 2020; García-Jiménez et al., 2021; Brander et al., 2024
	Sentinel role for identifying the location of dead animals	The presence of vultures can help livestock farmers and wildlife managers to locate dead livestock/poaching sites	Safford et al., 2019; Brander et al., 2024
	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;

Table A1: 2. Economic valuations of ecosystem services provided by vultures.

Ecosystem Service	Species	Valuation Method	Location	Reference
Materials from vultures used in traditional medicines	Vultures	Net factor income	Botswana, Zambia, Zimbabwe	Brander et al., 2024
Waste disposal	European vultures	Replacement cost	Europe	Margalida and Colomer, 2012
	Griffon vulture	Replacement cost	India	Ishwar et al., 2016
	Turkey Vultures	Replacement cost	North and South America	Grilli et al., 2019
	Vultures	Replacement cost	Botswana, Zambia, Zimbabwe	Brander et al., 2024
	Griffon vultures	Replacement cost	Sardinia, Italy	Santangeli et al., 2024
Control of disease	Vultures	Avoided damage costs to human heath	Botswana, Zambia, Zimbabwe	Brander et al., 2024
Control of pests and disease	Vultures	Treatment costs; Value of statistical life	India	Markandya et al., 2008
Control of pests	Griffon vulture	Replacement cost	Sardinia	Berlinguer et al., 2021
Sentinel role for identifying the location of dead animals	Vultures	Replacement cost	Botswana, Zambia, Zimbabwe	Brander et al., 2024
Ecotourism	Avian scavengers	Market price; Opportunity cost	Spain	García-Jiménez et al., 2021

	Griffon vulture	Gross revenue	Cyprus	Phipps and Vogiatzakis, 2020
	Vultures	Net factor income	Botswana, Zambia, Zimbabwe	Brander et al., 2024
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
	Andean Condor	Contingent valuation	Ecuador	Zambrano-Monserrate, 2020
	Vultures	Contingent valuation; Choice experiment	Botswana, Zimbabwe	Brander et al., 2024

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Appendix 2.

Detailed methods on Cinereous Vulture population forecast (2024-2048)

To forecast the future number of Cinereous Vulture breeding pairs in Portugal, we estimated the growth rate of breeding colonies in Castile and León (Guadarrama, Gredos Macizo Oriental, Gredos Macizo Central, Sierra de Ávila, Sierra de Francia, and Sierra de Gata). A linear regression was conducted to analyze the relationship between year (2000–2023) and the number of breeding pairs in Castile and León (Junta de Castilla y León, 2024). The model explained 92,5% of the variance in population size (R2=0,93), indicating a strong fit. The slope (β=18,50) was statistically significant (t= 9,31, p < 0,001), indicating an annual increase of approximately 18,5 breeding pairs (Fig. A2: 1); i.e., the model assumes that the population increases by a constant absolute amount each year). We adjusted the intercept for Portugal using the 108 breeding pairs censused in 2024 and projected the population until it reaches the estimated carrying capacity (Table A2: 1).

To estimate the carrying capacity of the study area, we assumed that everything else remaining stable, the Cinereous Vulture population size is limited by the capacity to provide supplementary food in a regulatory manner. Therefore, the carrying capacity is driven by management constraints rather than ecological factors. This approach was adopted for simplicity and because the available data did not permit more refined estimates that could account for other potential limiting factors. In this context, we assumed a scenario where: (1) non-natural mortality of Cinereous Vultures is negligible due to continued conservation action; (2) available habitat is not a limiting factor for population growth, given the relatively low density of breeding pairs in Portuguese colonies compared to Spanish ones, and the presence of potentially favourable, yet unused, nesting habitat ;Terraube et al., 2024); (3) populations of Griffon and Egyptian vultures will remain stable and hence should already be foraging at sufficient levels (see 3.2. Vulture populations), and (4) food reinforcement levels in each Special Protection Area of the study area follow the recommendations developed within the LIFE Aegypius Return project (Santos et al., 2024). Under these assumptions, food availability supplied in a regulatory manner under conservation efforts is thus the sole limiting factor for the Cinereous Vulture population growth in the study area. This means that current food gaps identified for the study area in Portugal (Santos et al., 2024) are suppressed by the food resources available nearby in Spain and, to a certain extent, by animal by-products made available in an unregulated manner in Portugal. Although it is not possible to confirm or estimate this hypothetical quantity (Santos et al., 2024), these by-products will in many cases be regulated under the implementation of new supplementary feeding sites, which is already underway within the project.

To calculate the available food, we summed up the recommended food reinforcement values for each Special Protection Area in the project area with the food resources currently available in vulture supplementary feeding stations (totaling 302.411 kg/year; Santos et al., 2024). Assuming each Cinereous Vulture requires 0,578 kg of food per day, the carrying capacity was estimated to be 1.434 individuals, including 344 non-breeding individuals (24%) and 545 breeding pairs. This population was projected to be attained by 2048 (Table A2: 1).

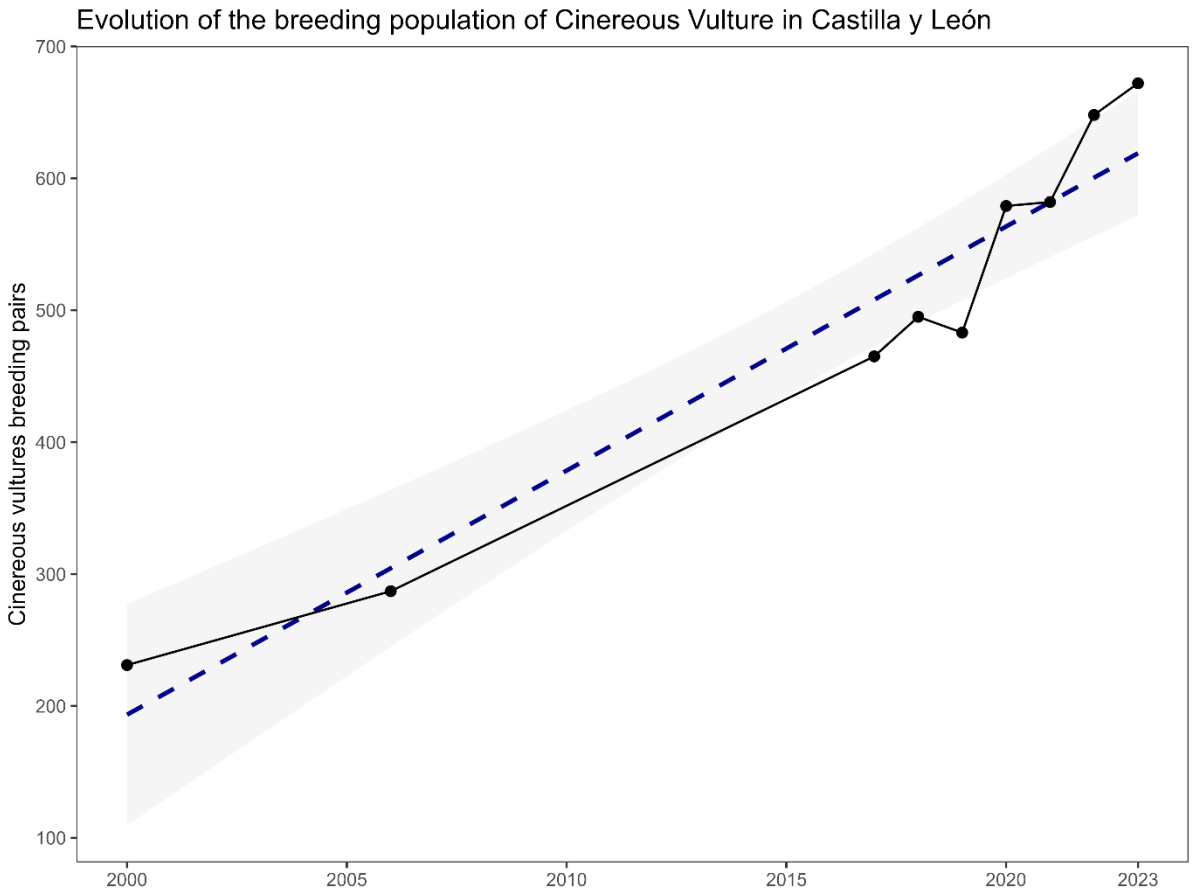

Fig. A2: 1. Evolution of the breeding population of Cinereous Vulture in Castilla y León, with a linear regression (dashed line) showing the population growth trend observed in 2000 – 2023, and the shaded area indicating the standard error of the regression. Data points represent the observed number of breeding pairs for the years with available data (i.e., 2000, 2006, 2017, 2018, 2019, 2020, 2021, 2022, 2023).

Table A2: 1. Observed or predicted number of Cinereous Vultures breeding pairs in Portugal, by year and key milestones of the LIFE Aegypius Return project.

Year	Number of breeding pairs	Type	LIFE Aegypius Return Milestone
2023	78	Observed	
2024	108	Observed	Reference
2025	126	Predicted	
2026	145	Predicted	
2027	164	Predicted	End of project
2028	182	Predicted	
2029	200	Predicted	
2030	219	Predicted	
2031	238	Predicted	
2032	256	Predicted	After LIFE
2033	274	Predicted	
2034	293	Predicted	
2035	312	Predicted	
2036	330	Predicted	
2037	348	Predicted	
2038	367	Predicted	
2039	386	Predicted	
2040	404	Predicted	
2041	422	Predicted	
2042	441	Predicted	
2043	460	Predicted	
2044	478	Predicted	
2045	496	Predicted	
2046	515	Predicted	
2047	534	Predicted	
2048	552	Predicted	Carrying capacity

REFERENCES in Appendix 2

Junta de Castilla y León. 2024. Seguimiento del estado de conservación de la población reproductora de buitre negro (*Aegypius monachus*) en Castilla y León. Año 2023. Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio. Valladolid. https://medioambiente.jcyl.es/web/es/buitre-negro.html

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Appendix 3.

Social Cost of Carbon

The table below presents the Social Cost of Carbon considered in the present study, adapted from US EPA (2023).

Table A3: 1. Social Cost of Carbon (SCC) 2020-2050. (EUR at 2024 price level; initial discount rate 2.5%). Adapted from US EPA (2023).

Year	SCC (EUR/tCO_2) 2024 price level
2020	136
2021	138
2022	142
2023	145
2024	149
2025	151
2026	155
2027	158
2028	162
2029	164
2030	168
2031	171
2032	175
2033	178
2034	180
2035	184
2036	187
2037	191
2038	194
2039	198
2040	201
2041	205
2042	208
2043	212
2044	216
2045	220

2046	223
2047	227
2048	232
2049	235
2050	238

REFERENCES in Appendix 3

US EPA. 2023. Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. https://www.epa.gov/environmental-economics/scghg