



**FEASIBILITY STUDY FOR
THE REINTRODUCTION
OF THE CINEREOUS VULTURE
(*Aegypius monachus*)
AND THE BEARDED VULTURE
(*Gypaetus barbatus*)
IN THE CENTRAL APENNINES**

**Rewilding
Apennines**

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CENTRAL APENNINES

ITALY

info@rewilding-apennines.com
www.rewilding-apennines.com



Purpose and context

This feasibility study was sponsored by Rewilding Europe and realised by their Italian partner organisation Rewilding Apennines in collaboration with some of the major vulture experts in Italy and Europe.

This work was carried out 14 years after a similar study by Genero and collaborators, who assessed the suitability of the central Apennines for griffon and bearded vultures, and can be considered as an update including a focus on the cinereous vulture.

It provides a comprehensive assessment of the suitability of this region for two of the largest European vultures, paving the way for further monitoring and research activities and while providing suggestions for a vulture-smart land management, particularly regarding the mitigation of threats to these valuable birds.

Finalità e contesto

Questo studio di fattibilità è stato finanziato da Rewilding Europe e realizzato dal suo partner italiano Rewilding Apennines, in collaborazione con alcuni tra i principali esperti di avvoltoi in Italia e in Europa.

Il lavoro è stato condotto a 14 anni di distanza da un precedente studio di Genero e collaboratori, che aveva valutato l'idoneità dell'Appennino centrale per il grifone e il gipeto, e può essere considerato un aggiornamento di quell'analisi, con un'attenzione specifica rivolta anche all'avvoltoio monaco.

Lo studio fornisce una valutazione complessiva dell'idoneità di questa regione per due delle più grandi specie di avvoltoi europei, ponendo le basi per future attività di monitoraggio e ricerca e offrendo al contempo indicazioni per una gestione del territorio "vulture-smart", in particolare per quanto riguarda la mitigazione delle minacce a carico di queste specie di grande valore conservazionistico.



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Authors

Enrico Bassi¹, Nicolò Borgianni², Luca Chiaverini², Mario Cipollone², Fabrizio Cordischi², Pietrantonio Costrini², Fulvio Genero³, Jenny Anne Glikman⁴, Bérénice Guinel², Marleen Huyghe⁵, Sarah Le Berre²⁻⁶, Raphaël Néouze⁷, Emma Néouze⁷, Giulia Pace², Mario Posillico⁸, Jan-Niklas Trei²⁻⁹

¹ Centro Italiano Studi Ornitologici, Dipartimento Scienze Agrarie e Forestali Università di Palermo, Palermo Italy.

² Rewilding Apennines ETS, Gioia dei Marsi, Italy.

³ Riserva Naturale Regionale del Lago di Cornino, Forgaria del Friuli, Italy.

⁴ Instituto de Estudios Sociales Avanzados - IESA-CSIC, Córdoba, Spain.

⁵ Planckendael Zoo, Mechelen, Belgium.

⁶ TUD, Dresden University of Technology, Tharandt, Germany.

⁷ LPO Birdlife France, Rochefort Cedex, France.

⁸ ARDEA APS, Napoli, Italy.

⁹ FVA-BW Forest Research Institute of Baden-Württemberg, Freiburg, Germany.

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Foreword

The area of the central Apennines is one of the rewilding landscapes – areas where ecological processes are restored – part of the Rewilding Europe foundation network. After World War II, the European continent experienced a period in which nature reclaimed many of the vast spaces that unsustainable human activities had taken away from it. Passive rewilding has witnessed the return of woodlands and wildlife in many places, where the transition from a rural society, based on agriculture and pastoralism, to an urban one, based on industry and services, decreed the failure of an economic model that was more tied to the direct exploitation of land resources.

In Italy, the decline of wildlife worsened between the second half of the 19th century and the first half of the 20th, due to a boom of the human population and the consequent overexploitation of natural resources. This prompted the creation of the first national parks because people were becoming aware of the irreversible loss of the national wildlife heritage.

The following post-war economic boom revealed the dangers that the current development model represented for the Italian ecosystems in terms of pollution, land consumption and land transformation.

At that time, awareness started growing around the environmental damage caused by human activities, and ecology emerged as a discipline capable of mitigating the harmful effects of progress on nature. In the following years the value of ecosystem services, the benefits nature provides to human societies, became widely recognized.

Prefazione

L'Appennino centrale è uno dei paesaggi di rewilding, ovvero ripristino dei processi ecologici, che fanno parte della rete della fondazione Rewilding Europe. Nel secondo dopoguerra, il continente europeo ha vissuto un periodo in cui la natura si è riappropriata di molti degli ampi spazi che attività umane spesso insostenibili le avevano sottratto. Così il rewilding passivo ha visto il ritorno del bosco e degli animali selvatici un po' ovunque, laddove la transizione da una società rurale, basata su agricoltura e pastorizia, a una urbana, fondata su industria e servizi, ha decretato il fallimento di un modello economico più legato allo sfruttamento diretto delle risorse del territorio.

Il declino della fauna italiana si è accentuato tra la seconda metà dell'800 e i primi decenni del '900, a causa dell'esplosione demografica e del conseguente sovrasfruttamento delle risorse naturali, inducendo alla creazione dei primi parchi nazionali proprio perché si stava acquisendo coscienza dell'inesorabile depauperamento del patrimonio faunistico nazionale. Il periodo del boom economico, successivo al secondo conflitto mondiale, ha mostrato i pericoli che anche questo modello di sviluppo rappresentava in termini di inquinamento, consumo e trasformazione del suolo per gli ecosistemi del nostro Paese, uno dei più ricchi di biodiversità d'Europa. In quel periodo si è iniziato a prendere coscienza dei danni ambientali provocati dalle attività umane e l'ecologia si è affermata come disciplina in grado di mitigare gli effetti deleteri del progresso sulla natura, riconoscendo negli anni a seguire i servizi ecosistemici forniti alle società umane dall'ambiente naturale.

The protection of habitats and species that reflect the health of ecosystems became part of the European Commission's strategy for the protection of biodiversity through the enactment of the two key directives (Habitats Directive and Birds Directives) and the establishment of the Natura 2000 Network. This is the world's largest system of protected areas, which mirrors a new vision of development that was, and still is, based on the protection of the continent's natural capital.

In this specific historical context, some species once considered harmful to humans, particularly carnivores, whose extermination was even encouraged in the past, have been protected because of their recognized ecological function of keeping ecosystems in balance. By controlling prey populations, these predators generate cascade effects across the trophic levels of an ecosystem.

Vultures have long been denigrated and therefore persecuted in most European countries due to their reputation as scavengers and birds of ill omen because they were associated with death or because they were mistakenly considered vermin. This vision of these has then changed, although at a later stage than the one regarding large carnivores. There has been growing awareness of their unique role as scavengers, capable of preventing or slowing the transmission of pathogens, a function that neither other animals nor humans are able to perform with the same effectiveness.

Beginning in the late 1970s, the first efforts to reintroduce the bearded vulture to the Alps began. In the 1990s the National Forest Service then carried out the first griffon vulture reintroductions in the central Apennines, which resulted in the return of

La protezione degli habitat e delle specie indicatrici del loro stato di salute è diventata parte della strategia della Commissione Europea per la tutela della biodiversità attraverso l'emanazione delle due direttive fondamentali (Habitat e Uccelli) e l'istituzione della Rete Natura 2000, il più vasto sistema di aree protette del mondo, per una nuova visione di sviluppo che si fondava, e tuttora si fonda, sulla protezione del capitale naturale del continente.

In questo specifico contesto storico, alcuni animali un tempo considerati antagonisti dell'uomo, in particolare i carnivori, il cui sterminio era addirittura incentivato nel passato, sono stati protetti in virtù della funzione ecologica loro riconosciuta di mantenere in equilibrio gli ecosistemi, controllando il numero delle prede e generando in questo modo effetti che si propagano verso il basso attraverso i livelli trofici di un ecosistema.

Denigrati per la loro reputazione di spazzini e uccelli del malaugurio poiché associati alla morte o perché erroneamente considerati nocivi e per questo perseguitati nella maggior parte dei paesi europei, gli avvoltoi sono stati rivalutati, anche se più tardi rispetto ai grandi carnivori terrestri. Si è infatti sviluppata una maggiore consapevolezza del loro ruolo unico come consumatori di carogne, capaci di bloccare o rallentare la trasmissione di patogeni, un compito che né altri animali né l'uomo sono in grado di svolgere con la stessa efficacia.

A partire dalla fine degli anni '70 del 1900 sono iniziati i primi sforzi di reintroduzione del gipeto sulle Alpi. Negli anni '90, invece, il Corpo Forestale dello Stato ha effettuato la reintroduzione del grifone in Appennino, determinando il ritorno di questo maestoso

this majestic bird. Thirty years later, this species reached a population of about 350 individuals in Abruzzi and Latium regions.

However, the scavenger community, which in Europe is made of griffon vultures, cinereous vultures, Egyptian vultures and bearded vultures, in Italy is still incomplete and poorly represented. The griffon vulture population has not yet reached numbers that can be considered completely safe from the risk of local extinction, while the Egyptian vulture population is strongly threatened. The bearded vulture has recolonised much of the Alpine arc, but has been absent from the Apennines as a breeding species for around 500 years.

Apart from the occasional appearance of dispersing individuals from the nearest European populations, the cinereous vulture has not bred in the Apennines for around 500 years.

Rewilding Apennines, the Italian NGO partner of the Rewilding Europe network, is committed since 2013 to the restoration of ecological processes through environmental restoration and reintroduction of keystone species, those species that have a significant impact on their habitat, such as vultures. In this context, for Rewilding Apennines considering to facilitate the return of the cinereous and bearded vultures to the skies of the central Apennines was a natural step, not only for a romantic or aesthetic vision, but above all because of their functional importance.

This feasibility study has the purpose of comprehensively analyzing what caused the disappearance of these two vulture species from the Italian territory and whether there are currently the environmental and social conditions for their return to the Apennines, a landscape

uccello che, a trent'anni di distanza, conta tra l'Abruzzo e il Lazio una popolazione di circa 350 individui.

Tuttavia, la comunità di necrofagi obbligati, composta in Europa da grifone, avvoltoio monaco, capovaccaio e gipeto, in Italia è ancora incompleta e poco rappresentata. Le popolazioni di grifone non hanno ancora raggiunto numeri tali da poter essere considerate completamente al sicuro dal rischio di estinzione locale, mentre quella del capovaccaio risulta fortemente minacciata. Solo il gipeto ha ricolonizzato gran parte dell'arco alpino, ma è assente dall'Appennino come nidificante da circa 500 anni.

A parte qualche sporadica apparizione di individui in dispersione dalle popolazioni europee più vicine, l'avvoltoio monaco non nidifica in Appennino da circa 500 anni.

Per Rewilding Apennines, un ente del terzo settore e partner italiano della fondazione Rewilding Europe, impegnato dal 2013 nel ripristino dei processi ecologici attraverso la riqualificazione ambientale e la reintroduzione di specie chiave di volta, ovvero in grado di avere un impatto significativo sul proprio habitat, come appunto gli avvoltoi, è stato naturale ragionare sul ritorno di questi due enormi avvoltoi nei cieli dell'Appennino centrale, non solo per una visione romantica o estetica, ma soprattutto funzionale.

Questo studio di fattibilità ha proprio la finalità di analizzare in maniera esauriente quali siano state le cause della scomparsa dell'avvoltoio monaco e del gipeto dal territorio italiano e se ci sono attualmente le condizioni ambientali e sociali affinché questi uccelli possano tornare in Appennino, un paesaggio che è comunque caratterizzato dalla presenza di infrastrutture umane diffuse.

characterized by the presence of widespread human infrastructures.

The hope of people who practice rewilding in Italy is that you appreciate the contents of this feasibility study and the effort involved in carrying it out in almost two years of research and analysis, involving the cooperation of some of the top vulture experts at the national and European level. We also hope that the return of the cinereous vulture and the bearded vulture will be supported by people who more and more recognize the value of nature conservation and biodiversity.

Annette Mertens

Rewilding Europe's Head of Landscapes

L'augurio di chi pratica il rewilding in Italia è ovviamente che apprezziate i contenuti dello studio di fattibilità e lo sforzo che ha comportato realizzarlo in quasi due anni di ricerche e analisi, alle quali hanno collaborato alcuni tra i massimi esperti di avvoltoi al livello nazionale ed europeo, e che il ritorno dell'avvoltoio monaco e del gipeto si realizzi con l'impegno di quanti, speriamo sempre più numerosi, riconoscono il valore della salvaguardia della natura e della biodiversità.



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Chapter 1

Motivation, purpose of the project, and study objectives

Mario Cipollone and Fabrizio Cordischi



1. Introduction

Rewilding Apennines ETS (RA)¹ aims to restore the ecological processes of the central Apennines for the benefit of nature and people, highlighting the exceptional biological and landscape richness of the region to counteract depopulation and create a network of businesses connected to a more intact post-agricultural landscape. The organisation was reshuffled in 2019 from a homonymous NGO founded in 2013, and is closely linked to the Rewilding Europe Foundation² based in the Netherlands. Rewilding Europe works to restore wild nature and ecosystem services in eleven European landscapes, one of which is central Italy.

RA currently consists of a Board of Directors with four members and an executive team with diverse and complementary skills and roles, totalling 14 units which are distributed in the areas of research, nature conservation, communication, and business development. 35% of the staff are women.

Over the last ten years, RA has worked closely with Salviamo L'Orso³ and other local NGOs, such as LIPU, WWF, ARDEA, Stazione Ornitologica Abruzzese and ALTURA, some national and regional protected areas, in particular the Abruzzo, Lazio and Molise National Park, the Gran Sasso and Monti della Laga National Park, the Sirente Velino Regional Park and the Monte Genzana Alto Gizio Nature Reserve and the Carabinieri Forestali⁴. This collaboration aims to improve the protection of habitats and wildlife in the ecological corridors connecting the main protected areas of the region.

RA is committed to biodiversity enhancement through environmental restoration actions and conservation of keystone species such as the **Eurasian griffon vulture** (*Gyps fulvus*), which is the only vulture species steadily flying in the central Apennines skies thanks to reintroductions operated in 1990s by the Italian Forest Service (Corpo Forestale dello Stato, merged into Carabinieri in 2017 and hence renamed Carabinieri Forestali), the Apennines brown bear (*Ursus arctos marsicanus*), a subspecies of the critically endangered European brown bear, the Italian wolf (*Canis lupus italicus*) and the native white-clawed crayfish (*Austropotamobius italicus meridionalis*).

Concerning nature restoration and rewilding, the association has, to date, removed 180,000 metres of barbed wire which also pose a threat to large birds, secured 25 wells and ponds in mountain areas from the risk of falling and drowning for wildlife (including 5 Apennine bears in 2010-2018, raptors and other bird species), and worked intensively on the implementation and dissemination of best practices of coexistence between humans and large carnivores. The latter is made possible through several granted projects, including the latest LIFENAT/NL/001107 project "Bear-Smart Corridors"⁵, co-financed for 75% by the European Commission, with the main goal of improving conditions for coexistence between humans and bears in expansion areas and ecological corridors.

¹ <https://rewilding-apennines.com/>

² <https://rewildingeurope.com/>

³ <https://www.salviamolorso.it/>

⁴ <https://www.carabinieri.it/chi-siamo/oggi/organizzazione/tutela-forestale-ambientale-e-agroalimentare>

⁵ <https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE20-NAT-NL-001107/enhancing-the-viability-of-brown-bears-in-central-italy-and-greece-through-the-development-of-coexistence-corridors>

The organisation's operational area covers 525,000 hectares across the regions of Abruzzo, Lazio, and Molise, in collaboration with local authorities. However, the team dedicated to vulture monitoring - consisting of a vulture expert, a field operation manager, a wildlife officer, an ornithologist, and supported by ten volunteers on average - operates even on a larger scale, following the movements of these long-ranging birds.

Since June 2021, an agreement between RA and the Carabinieri Forestali Raggruppamento Biodiversità⁶, has enabled this NGO and the Reparto Carabinieri Biodiversità Castel di Sangro⁷ to equip 67 griffon vultures with GPS transmitters to detect and mitigate poisoning events, monitor reproduction, monitor feeding events by surveying GPS clusters, monitor the impact of wind farms as well as build feeding stations and other research and management actions. This agreement allows for better monitoring of the griffon vulture population in the central Apennines.

The main results of this partnership are summarised below for the years 2021-2023:

- **1,717 field surveys** (Figure 1) were carried out (of which 200 by volunteers) to identify the species of the carcass consumed by the griffon vultures and assess threats, including the presence of poison.
- As a result of more deployed GPS tags and increased sampling efforts, **56 griffon vulture carcasses were found**. In two cases it was possible to initiate investigations, which in one instance led to a fine for the probable perpetrator for reasons not related to poisoning, and in the other case led to the identification of the perpetrator. From 2021 to 2023, **77 potentially poisoned carcasses (55 griffons and 22 of other species) were removed** (Figure 2).
- Between January 2022 and June 2024, 161 surveys were carried out at two wind farms near griffon vulture breeding colonies. During the surveys, carcasses and/or remains of birds were searched for under each of the 76 turbines yielding a total of 16 carcasses: eight **griffon vultures** (Figure 3), 2 hooded crows (*Corvus cornix*), 1 pallid swift (*Apus pallidus*), 1 northern wheatear (*Oenanthe oenanthe*), 5 common ravens (*Corvus corax*), 1 buzzard (*Buteo buteo*), 1 kestrel (*Falco tinnunculus*), and 2 bats (unidentified species). With the data collected, 2 meetings were also held with the management companies of one of the wind farms and with Sirente Velino Regional Park, to raise awareness and seek a solution to mitigate the threat that wind turbines pose to wildlife.
- Six **griffon vultures were recovered**, in 3 cases by observing anomalies in the GPS track and in three cases the vultures were found near a driveway. One of the individuals died the day after recovery due to poison ingestion, while the **other five were fed and kept under control for several days and then successfully released** (Figures 4, 5).
- **A feeding station was built for vultures in Massa d'Albe, within Monte Velino Reserve**(Figure 7).
- Between November 2021 and December 2023 RA have organised or co-organised **73 events**: 42 simultaneous counts at the nesting sites (Figure 6), 4 simultaneous summer counts in the central Apennine area (where both counts involved Carabinieri Forestali and also involved many protected areas administrations), 14 griffon vulture capture events with Reparto Carabinieri

⁶ <https://rgpbio.it/evento/il-ritorno-del-grifone-sullappennino-centrale/>

⁷ <https://rgpbio.it/reparto/castel-di-sangro/>

Biodiversità Castel di Sangro and L'Aquila and many volunteering ringers, 13 dissemination events with local stakeholders (Figure 8), involving approximately **1,580 people**.

- In November 2023, a workshop was organised **on the legal basis for the creation and management of further Poison Detection Dog units** (Figure 9).
- The presence in the central Apennines of the first **griffon vulture from Greece** was reported by one of the camera traps which were used to monitor the use of carrions by wildlife.
- The presence of griffon vultures from France, Spain and Croatia was also confirmed. During monitoring activities, a **cinereous vulture** (*Aegypius monachus*) was directly observed while feeding with griffon vultures at the feeding station in Riserva Naturale Orientata Monte Velino (Figure 10). **Egyptian vultures** (*Neophron percnopterus*) were also observed flying across the central Apennines landscape.

The direct observations of these vulture species have reinforced the objective to **restore a community of scavenging birds in the region**, in line with the 2019-2023 and 2024-2030 strategic plans of RA. In fact, one of the principles inspiring the action of RA is the restoration of trophic networks. In most environments in Italy, the apex of the trophic pyramid, which is occupied by obligate scavengers, is missing or incomplete (A. Andreotti, personal communication).

2. Motivations

The **bearded vulture** (*Gypaetus barbatus*) is Near Threatened (NT) in Europe⁸ as fewer than 465 breeding pairs have been estimated⁹. However, the Italian IUCN Red List of breeding birds considers this species as Critically Endangered (CR)¹⁰. It is listed on Annex I of the EU Wild Birds Directive¹¹ and Appendix II of the Bern Convention and Bonn Convention as strictly protected fauna species¹².

Efforts to reintroduce the bearded vulture began in the late 1970s with the Alpine Reintroduction Project. Within just 40 years, the population of bearded vultures in the Alps has firmly been reestablished, making it one of the world's most successful wildlife comeback stories. Following the success of this project efforts began in Spain to bring the bearded vulture back with the Andalucia Reintroduction Projects in 1996 followed by the Valencia Reintroduction Project in 2018.

Whilst the bearded vulture today occupies a small percentage of its former range, parts of the Pyrenees, Sierra Nevada and Alpine mountain ranges as well as small, remnant populations on the islands of Corsica and Crete, the population in western Europe is increasing¹³.

The **cinereous vulture** or Eurasian black vulture is a Near Threatened species globally¹⁴, though with a decreasing population trend. In Europe, however, its status of conservation is ranked as Least Concern (LC) with 2,739 – 2,749 breeding pairs. From a historic viewpoint, the cinereous vulture in Europe has been steadily recovering since the 1980s and a 2018 survey showed an increasing trend in the number of breeding pairs. This trend can be explained through the measures taken to protect wildlife from poisoning which resulted in a rapid recovery of the species in the Spanish population. In France, efforts to reintroduce cinereous vultures began in the 1990s and has seen the species return to the south-west part of the country. In 2018, the Eastern population was strengthened with the Vultures Back to LIFE project, which saw the first releases of the Bulgarian reintroduction project¹⁵. The Italian Red List reports this vulture as Regional Extinct (RE), with the last extant individual disappearing from Sardinia in the '60s-'70s of the last century.

The cinereous vulture is listed on Annex I of the EU Wild Birds Directive and Appendix II of the Bern Convention and Bonn Convention as a strictly protected species.

⁸<https://www.birdlife.org/wp-content/uploads/2022/05/BirdLife-European-Red-List-of-Birds-2021.pdf.pdf>

⁹<https://4vultures.org/wp-content/uploads/2022/09/Report-Vulture-Population-Estimates-Europe-VCF-September-2022.pdf>

¹⁰ <https://www.iucn.it/pdf/Lista-Rossa-Uccelli-Nidificanti-2021.pdf>

¹¹ <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:en:PDF>

¹² <https://rm.coe.int/168078e2ff>

¹³ <https://4vultures.org/vultures/bearded-vulture/>

¹⁴ <https://www.iucnredlist.org/species/22695231/154915043>

¹⁵ <https://4vultures.org/vultures/cinereous-vulture/>

Both bearded and cinereous vultures are also protected under Annex II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)¹⁶, which aims to ensure that international trade of wild animals and plants does not threaten the survival of the species.

The reintroduction of the cinereous vulture and bearded vulture in the central Apennines takes inspiration from the previous successful reintroduction programmes in other European countries or areas with similar environmental characteristics. It also aims at significantly improving the conservation status of both species in the Old Continent, restoring the trophic web in Italy, recognising the precious ecosystem services provided by scavenging birds. These ecosystem services include reducing the time a carcass remains in the environment, boosting the cycle of nutrients, slowing down or stopping the transmission of pathogens, competing with facultative scavengers such as dogs, foxes and wolves balancing their populations, contributing to reduce CO₂ emissions and reducing the cost for carcass incineration¹⁷.

Currently, this role of cleaners in central Italy is often played by facultative scavengers, which are less effective than vultures. Therefore, risks of transmission of pathogens increases as well as the populations of facultative scavengers, including feral dogs, which often cause conflicts with rural economies.

Conflicts with large carnivores may generate retaliatory killings through poisoning, which is currently recognised as the main threat for the griffon vulture population in the central Apennines. Restocking of griffons and reintroductions of cinereous and bearded vultures could draw the attention of the public opinion and institutions on the conservation challenges these scavenging birds are facing, attracting adequate funding to ensure means to mitigate anthropogenic threats and create the proper conditions for them to thrive in the area.

¹⁶ <https://cites.org/eng>

¹⁷ <https://4vultures.org/blog/ecosystem-service-provision-what-do-vultures-do-for-us-and-the-environment/>



Figure 1. Volunteers while checking clusters identified through GPS tags deployed on griffon vultures.



Figure 2. The carcasses of 2 wolves and 4 griffon vultures poisoned in Cocullo municipality on May 2023 deployed into the bags just before their delivery to the laboratory for necropsy.



Figure 3. One of the griffon vultures hit by a wind turbine in 2023 and the field crew in charge of monitoring collisions.



Figures 4-5. A rescued griffon vulture in the LIPU's Trasimeno rescue centre, ringed and equipped with GPS and then released.



Figure 6. Volunteers during simultaneous counting of griffon vultures at nesting cliffs.



Figure 7. Vulture feeding station in Massa d'Albe.



Figure 6. Volunteers during simultaneous counting of griffon vultures at nesting cliffs.



Figure 7. Vulture feeding station in Massa d'Albe.



Figure 10. Cinereous vulture photographed at the Carabinieri Forestali feeding station in 2022, Riserva Naturale Orientata Monte Velino. Picture courtesy of Reparto Carabinieri Biodiversità Castel di Sangro.

3. The restoration of a vulture community - feasibility studies

The following three studies were sponsored by Rewilding Apennines in the last years to assess how sound the objective to restore a community of scavenging birds was:

- Preliminary assessment on the restoration of a vulture community in the central Apennines (Izzo et al. 2020¹⁸).
- Extension of a preliminary assessment on the restoration of a vulture community in the RA project area focusing on the existing population of griffon vulture (Balestrieri and Posillico 2021¹⁹).
- A roadmap to apply European regulations for the alternative management of carcasses in the Apennine griffon vulture range: preserving vultures and facilitating disposal by farmers through ecosystem services provided by scavengers (Posillico and Balestrieri, 2022²⁰).

The previous works paved the way to this feasibility study for the reintroduction of the cinereous and bearded vultures for which a group of experts was purposefully created during the event “Workshop on the Supplementary feedings for vultures”, which was held in Alghero (Sardinia) in October 2022.

The group of experts in charge of planning the reintroduction through a feasibility study is composed of Mario Posillico (external consultant, ARDEA APS, scientific coordinator of the study), Fulvio Genero (external consultant, Scientific Director of the Cornino Lake Regional Nature Reserve), Enrico Bassi (external consultant, through the Centro Italiano Studi Ornitologici, a non-profit scientific association), Marleen Huyghe (Former Studbookkeeper for the cinereous vulture at Planckendael zoo in Belgium), Raphaël Néouze (external consultant from LPO Birdlife France) and Emma Néouze, from LPO Birdlife France, who have kindly joined the initiative on a voluntary basis. RA contributes to the feasibility study with their expertise: Mario Cipollone (Team Leader and responsible for the overall organisation), Fabrizio Cordischi (Field Operation Manager), Nicolò Borgianni (Vulture Field Officer), Luca Chiaverini (GIS Analyst), Pietrantonio Costrini (Wildlife Field Officer, expert of legislation about feeding stations and other health and safety issues), Bérénice Guinel (Wildlife Officer with high skills in economic and human dimension aspects), Jan-Niklas Trei (GIS Analyst and Research Coordinator), Giulia Pace (Admin & Finance Officer and ornithologist), Sarah Le Berre (volunteer, GIS analyst), Jenny Anne Glikman (human dimension specialists).

The contents of this feasibility study were agreed upon and selected by the board of experts, mainly based on IUCN guidelines and international/national relevant regulation as well as on a deep knowledge of local/national issues related to wildlife and environmental conservation and management.

¹⁸https://www.researchgate.net/publication/352192334_Preliminary_assessment_on_the_restoration_of_a_vulture_community_in_the_central_Apennines_Italy

¹⁹https://www.researchgate.net/publication/372860852_Extension_of_a_preliminary_assessment_on_the_restoration_of_a_vulture_community_in_the_Rewilding_Apennines_project_area_focusing_on_the_existing_population_of_Griffon_vulture_Gyps_fulvus

²⁰https://www.researchgate.net/publication/373041325_A_roadmap_to_apply_European_regulations_for_the_alternative_management_of_carcasses_in_the_Apennines_Griffon_vulture_range_preserving_vultures_and_facilitating_disposal_by_farmers_through_ecosystem_services

4. Conclusion

Since 2021, RA has created a team of specialists in vulture conservation, thanks to a strong collaboration with Raggruppamento Carabinieri Biodiversità and Reparto Carabinieri Biodiversità Castel di Sangro (formerly *Corpo Forestale dello Stato*, National Forest Service), who reintroduced the griffon vultures in 1990s, and a growing support from a guild of international donors. The activities that this NGO has carried out enabled a tangible improvement in the conservation of vultures in central Italy, bringing to light challenges - such as the necessity to mitigate the main threats to these scavenging birds - and opportunities. This feasibility study is part of a series of similar preparatory studies aiming to restore a community of scavenging birds in the Italian central Apennines.

Chapter 2

Legal framework for translocations

Mario Posillico



1. Introduction

Translocations, in their widest meaning, are an increasingly common approach to restore or preserve both plants and animals. Translocation-related literature is full of examples on how to carry them out. However, scientific approach and technical solutions are not the only issues concerned when intentionally moving wildlife somewhere else. Fundamental legal aspects – often involving non trivial scientific and technical issues - are also involved. These could change according to country-specific laws, and international agreements.

Below, a synthesis on national and international regulations concerning translocation is given, as well as practical suggestions about how to carry out the process. Currently, there are some uncertainties and some shortcomings. Uncertainties are related to the need for vulture translocation, and especially for cinereous and bearded vulture, to be subject to an environmental impact assessment (EIA) *sensu lato* (and then to the specific procedure required by Italian regulations: *Valutazione di Incidenza Ambientale, Valutazione Ambientale Strategica, Valutazione di Incidenza Ambientale*). Many consider the reintroduction of these species as an action directly related to biodiversity and habitat preservation (ex Art. 6 of the Habitat directive) and therefore not subject to an EIA, although their occurrence as breeders in the area concerned by this document probably dates to more than 5 centuries ago. However, others claim for possible impact on other fully protected raptors, both endangered or almost vanished like the Lanner falcon (*Falco biarmicus feldeggii*), or with a ‘least concern’ conservation status, like the golden eagle.

Shortcomings are related to some sort of legislative vacuum, which emerged when, after the amendment of art. 12 of presidential decree n. 357/97 (and presidential decree n.120/2003), any reference to birds in Annex I of Birds directive disappeared in the new law. Subsequently, a fundamental reference for bird translocation had been missed: both in terms of the need for a specific authorisation *per se*, and in terms of scientific-technical documents for translocation planning and implementation. All this is treated in more detail later in this report, and possible solutions are reported. This report has benefitted from suggestions and ideas exchanged with many people with an extensive background in bird translocations and their legal aspects. Particularly, Alessandro Andreotti, Dionigi Secci and Luigi Logiudice contributed decisively to the clarification of some technical and legal aspects.

2. National regulations

National regulations behind reintroduction and restocking have been recently reissued, and are covered by presidential decree (DPR) N. 102, July 5th 2019²¹, that has been completed, concerning some practical aspects, by ministerial decree (DM) April 2nd 2020²². This last decree is an update of the former guidelines

²¹ *DECRETO DEL PRESIDENTE DELLA REPUBBLICA 5 luglio 2019, n. 102. Regolamento recante ulteriori modifiche dell'articolo 12 del decreto del Presidente della Repubblica 8 settembre 1997, n. 357, concernente attuazione della direttiva 92/43/CEE relativa alla conservazione degli habitat naturali e seminaturali, nonché della flora e della fauna selvatiche (19G00108). (Gazzetta Ufficiale n.208 del 5-9-2019).*

²² *MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE. DECRETO 2 aprile 2020. Criteri per la reintroduzione e il ripopolamento delle specie autoctone di cui all'allegato D del decreto del Presidente della*

from the Ministry of Environment-ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) (Anonymous 2007), that has now received full legal value. Appendix 1 of DM 02/04/2020 lists the topics that a complete feasibility study must cover, also considering IUCN/SSC guidelines (IUCN 2013).

Although presidential decree 102/2019 – differing from the previous decrees on the same subject - literally applies only to the species listed in the habitat directive, the related ministerial decree 04/02/2020 also quotes in its preamble the Birds Directive. So, presently, there is some questioning about the applicability of the ministerial decree to the translocation of autochthonous birds. Despite such a conspicuous legislative vacuum, defining whose origins are beyond the aims of such a chapter, it is warmly suggested to carry out a technical investigation according to the criteria established for the other animal classes, e.g., by following ISPRA guidelines (Anonymous 2007) and further regulations (as mentioned above). Although not mandatory, this would fully demonstrate the ability of the proponent to deal at the required professional level with this specific topic.

According to DM April 2nd 2020, the main criteria for reintroduction/restocking of autochthonous species, are the following (article 2):

1. *a feasibility study (with reference to DPR 357/1997) should be prepared according to the criteria mentioned in the annex 1 of DM April 2nd 2020;*
2. *the feasibility study considers the technical directions published by SNPA National System for Environment Protection²³ and, when existing, the national action plans and guidelines, or the international guidelines for a given taxon;*
3. *to restore locally extinct species, priority should be given to in situ conservation interventions of residual populations of that species, even by favouring their natural expansion;*
4. *the feasibility study is evaluated by the regional administration, or by the national protected areas involved, with the support of ISPRA (national environmental protection and research agency) or of the regional/provincial agency if relevant. The evaluation must consider: the opportunity of the intervention, its feasibility, its success probability, and its contribution to the improvement of the species' conservation status; moreover, possible environmental, sanitary socio-economical risks and impacts in the area where individuals are taken where they will be released must be evaluated, as well as the actions to stem the possible risks;*
5. *approved interventions, in conformity with article 22, letter a) of directive 92/43/CEE are to be considered as connected and necessary to maintain, in a satisfactory conservation condition, habitats and species indicated in DPR n. 357/1997.*

As from above, the authorities **responsible for issuing the necessary authorizations for translocations** are the **national protected areas** when the project should be carried out in protected areas of national relevance, or the **regional administrations** (in the remaining areas). Before being released, the authorisation from regional administrations must also foresee (article 2, subsection 2 DPR 102/2019) an adequate consultation of the interested communities; while management authorities of national protected areas should communicate their will to proceed with translocations to the regional

Repubblica 8 settembre 1997, n. 357, e per l'immissione di specie e di popolazioni non autoctone (20A02112). (Gazzetta Ufficiale n.98 del 14-4-2020).

²³ <https://www.isprambiente.gov.it/it/sistema-nazionale-protezione-ambiente>

administrations. We underline that some years ago both the Monti Sibillini and the Gran Sasso and Monti della Laga National Parks, in a joint effort, promoted a feasibility study for the translocation of both bearded and griffon vultures in those areas (Genero et al. 2010). This testifies the positive attitude towards a translocation initiative from those parks. Although, compared to 2010, the presence of the Griffon vulture is now steady year-round in several areas of the Gran Sasso-Laga National Park (yet they do not breed there), and in the Sibillini Mountains vultures occur only seasonally (spring and summer).

Importing birds intended for reintroduction into the wild, requires authorization pursuant to art. 20 of Law n.157/1992 from the Ministry of Agriculture, also based on an assessment by ISPRA. Such a procedure was developed to import game for hunting purposes, but it could be applied in general to all wildlife covered by L. 157/92 (i.e. birds and mammals), although interpretation of this rule seems largely subjective, even according to the exact meaning of ‘importation’, which in the European Union, in such a specific case, could be more conveniently and accurately intended as a simple movement of animals.

As to the central Apennines, there are some national/regional parks (and many state/regional reserves and regional parks) within 5 regions (Umbria, Marche, Latium, Abruzzi, Molise) that could potentially be involved in the authorisation process, from north to south (figures 1 and 3):

- Monti Sibillini National Park (in Marche and Umbria regions),
- Gran Sasso and Monti della Laga National Park (Marche, Latium and Abruzzi regions),
- Sirente Velino Regional Park (Abruzzi),
- Maiella National Park (Abruzzi),
- Abruzzo, Lazio e Molise National Park (across those three regions).

Depending on the actual involvement of such administrative units, an analysis of their legislation would be carried out if relevant, once the logistical and geographical aspects of the translocation are defined.

In Italy there is no national strategy for the conservation of vultures. Only for the Egyptian vulture an action plan has been issued (Andreotti & Leonardi 2009). At an international level, Italy signed the agreement upon the vulture Multi species Action Plan (Botha et al. 2017) issued by the Convention on Migratory Species (CMS). Although signing this agreement should ideally foresee planning and implementation of conservation strategies for vultures, or, at least, some idealistically coordinated actions, this does not seem to be the case. Thus, when actions are implemented, they are mostly addressing - at best – conservation problems specific to some areas or species, with no general strategy and aims.

Whether conservation translocations of vultures in this context should be subject to an impact assessment in Natura 2000 areas is a controversial issue. According to the habitats directive (92/43/EEC) article 6, *“any plan or project not directly connected with or necessary to the management of the site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subject to appropriate assessment of its implications for the site in view of the site’s conservation objectives”*. According to some, the incidence or impact assessment should not be carried out as these initiatives are functional to the restoration of biocenoses – provided they do not represent introductions – and, therefore, cannot exert a negative effect on the environment within Natura 2000 network. However, there is no univocal orientation. We suggest it would be deontologically honest and more

appropriate including assessments on possible negative impacts on other environmental components in the feasibility plan (e.g., the type of interactions between bearded vultures and golden eagles, competition for nesting sites on breeding cliffs between vultures and other rock nesting raptors of concern) to streamline the authorization process, rather than directly activating environmental assessment procedures. A thorough literature review of both direct and indirect interactions between released vultures and existing wildlife could be easily accomplished. It should be anyway regarded that in well-structured ecosystems, with a high degree of naturalness, at a population level no significant and negative interactions or competition between vultures and other wildlife are reported.

3. International regulations

All vulture species involved are included in convention for the international trade of endangered species (CITES) appendices, and their transportation to release sites will require formal CITES authorisation, which should be issued by the national competent authority, upon the opinion of the CITES scientific commission at the “Ministry of the Environment”.

Furthermore, while transferring wildlife among countries, even within the EU, other regulations should be considered and their instructions applied, which cannot be described here. An outstanding case is represented, for example, by the Decision 2003/623/CE for the implementation of an integrated veterinary information system (Traces), allowing monitoring of the movements of animals and their byproducts as well as of many other products.

4. Procedures

Schematically the following table lists the necessary authorizations/opinions and the legislation that requires them (Table 1). The authorization/opinion request should be issued and concurrently signed by all those figures (public bodies, NGOs, etc.) involved in the translocation project. Supposedly, if all the figures are committed to the project by a formal agreement which is legally valid, and just a single participant is formally responsible for the action which now deals with carrying out all the formal acts related to the release of authorizations and opinions, the documents could be signed only by this last participant.

As a final remark, once the translocation enters its operational phase, it is recommended that any possible changes in the regulations governing the various aspects related to wildlife transportation between countries be evaluated along with the relevant authorities.

Table 1. Main authorizations/opinions needed for translocation of the griffon vulture, cinereous vulture and bearded vulture (from EU countries and Italy) in the central Apennines, upon submission of a feasibility study.

SEND TO	FOR	REFERENCE TO	DOCUMENTS TO FORWARD
Ministero dell’Agricoltura, della Sovranità Alimentare e delle Foreste	Import permit	Art. 20, L.157/1992	Feasibility study
Ministero degli Affari Esteri e della Cooperazione Internazionale – Direzione Centrale per la Politica Commerciale Internazionale – Ufficio XI-CITES.	Import permit	CITES convention (various documents and EU regulations)	Forms available on the Ministry webpage, and a synthesis of the feasibility study to explain scientific purposes, on the behalf of the opinion of the CITES scientific committee within MASE.
Administrative regions	Translocation permit	According to the different contents of regional acts	Feasibility study
ISPRA	Opinion	All regulations above, but for CITES, DPR 120/2003, DPR 102/2019	Feasibility study

5. References

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Chapter 3

Engagement of agencies and analysis of funding opportunities

Mario Cipollone and Giulia Pace



Since the beginning of the initiative, RA has sought the collaboration of local agencies and institutions to foster the feasibility study for the reintroduction of the cinereous and bearded vultures and pave the way to possible reintroduction projects. The need for such an engagement urged RA to receive permits for both field and social surveys within protected areas.

Preliminary meetings showed overall availability to collaborate from these authorities:

- Carabinieri Forestali,
- Regione Lazio,
- Abruzzo, Lazio and Molise National Park,
- Sirente Velino Regional Park,
- Montagne della Duchessa Regional Reserve
- Monte Genzana Alto Gizio Regional Nature Reserve
- Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA), agency for environmental protection and research of the Italian Ministry of the Environment
- Azienda Sanitaria Locale (Health Authority at a sub-regional level) ASL 1 Avezzano Sulmona L'Aquila.

The availability of the authorities above was confirmed in an online meeting on October 12, 2023. The attendees verbally confirmed their interest in the initiative and a possible partnership in developing a LIFE proposal for the reintroduction of the cinereous vulture in central Italy. However, concern on the high number of poisoning events which occurred in the area in 2023 and the potential food conditioning of large carnivores, such as bears and wolves, to feeding stations was expressed.

International partners, such as Rewilding Velebit and Rewilding Romania, are also interested in replicating similar initiatives in their countries.

Preliminary conversations with the Vulture Conservation Foundation were encouraging in terms of both environmental suitability, especially for the cinereous vultures, and availability of birds in the next 3-5 years.

ISPRA representatives showed great interest in the initiative. Considering their crucial role as advisor for the Italian Ministry of the Environment in the final evaluation of the feasibility study, their current position is encouraging.

If, on the one hand, institutional consensus about the reintroduction of these species was tangible, on the other hand, the number of animals being killed every year, mostly because of negative interactions with humans, raises great concern. The need for strengthening coexistence with large carnivores (the wolf in particular), raising awareness in the public opinion about crimes against wildlife and re-engaging police authorities in their contrast, is particularly urgent.

Thus, RA recognizes that large amounts of funds are necessary to support and make a vulture reintroduction and conservation in the central Apennines feasible. So far, the organisation has demonstrated a great capacity to attract funding to carry out their rewilding goals. The availability of a financial basis from Rewilding Europe complemented with grants from other foundations, such as

Fondation Ensemble, and The European Outdoor Conservation, has enabled RA to deliver what was expected according to Rewilding Apennines and Rewilding Europe's strategy²⁴.

In 2021-23, RA allocated **€ 252,400 in total** with a mean of **€ 84,000 per year** to vulture conservation initiatives (see Figure 1) with a peak in 2022 due to large expenditure for the purchase of most of the organisation's 63 GPS transmitters. This amount would have been doubled or tripled if it included the money allocated to human-large carnivore coexistence, which is proven to have a positive impact in terms of improving monitoring and reducing threats for vultures. In the next few years, the organisation is aiming to raise annual funds for vultures through several financial tools such as private donations and grants, LIFE proposals.

Some potential donors have already been identified:

- **European Wildlife Comeback Fund²⁵ (EWCF)**: this group of donors is part of Rewilding Europe and supports reintroduction initiatives that have already received permits from competent authorities, with a grant between € 50-100,000 in total. This fund should support the building of an acclimatisation aviary which would facilitate the transportation and transition phase of the griffon vultures before they are released into the central Apennine landscape.
- **European Outdoor Conservation Association (EOCA)**: This organisation is supporting conservation and rewilding initiatives with grants of € 40-60,000. As they have a strong orientation towards the involvement of outdoor enthusiasts, their grant could be allocated to the construction of artificial nests with expert climbers and monitoring activities.
- **Local private businesses**: Thanks to their dedicated enterprise team, RA will involve local businesses which may contribute to fund the initiative, understanding its high potential in terms of communication, branding (if linked to local products, such as a wine label), and publicity.

Since the initiative is strictly dependent on the involvement of national and local authorities, the main funding instrument that RA has identified is the **LIFE programme**, especially the "Nature and Biodiversity" sub-programme, which contributes to conservation actions up to 75%.

In view of developing a proposal for the reintroduction of the cinereous vulture, a strong partnership is needed. The authorities listed at the beginning of this chapter are the best candidates to build a partnership with.

A LIFE grant would be the best option to finance all aspects of a reintroduction programme, including further surveys to investigate the best locations for bird release, etc.

Moreover, RA can rely upon a solid volunteering programme²⁶ operating since 2019. In the last three years, RA's volunteer staff - which is composed of trained volunteers and university interns - have contributed in-kind to the results summarised in Chapter 1 with a working effort, reported in Table 1, which has been estimated at **€ 466,670 in total** from a EU's benchmark²⁷. This estimated amount is the 131 € of daily cost for a volunteer in Italy, multiplied by the number of volunteers and days they dedicate

²⁴ <https://rewilding-europe.com/news/rewilding-europe-launches-ambitious-new-strategy-for-2030/>

²⁵ <https://rewilding-europe.com/european-wildlife-comeback-fund/>

²⁶ <https://rewilding-apennines.com/volunteering-programme/>

²⁷ https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/common/guidance/unit-cost-decision-volunteers_en.pdf

on average (1,5 days a week each) to vulture conservation during their mean 3-month volunteer experience for RA. It is worth noticing that RA allocates on average 150 days a year to vulture monitoring and conservation activities (i.e., check of GPS clusters, observations at roosts and breeding sites, counts, transects under windmills and powerlines, communication actions), which is about 50% of RA's volunteers' activities, with the supervision of three staff members. In 2021-2023, vulture conservation works absorbed on average 16% of RA's annual budget (see Figure 2).

RA's volunteering programme is very popular amongst national and European universities. The rising profile of this NGO is attracting more interest from the youth. In 2022 Rewilding Europe created the European Young Rewilders²⁸ initiative, bringing more volunteers and interns towards RA. Therefore, in the next few years, the growth of volunteers' participation in vulture conservation actions is very likely.

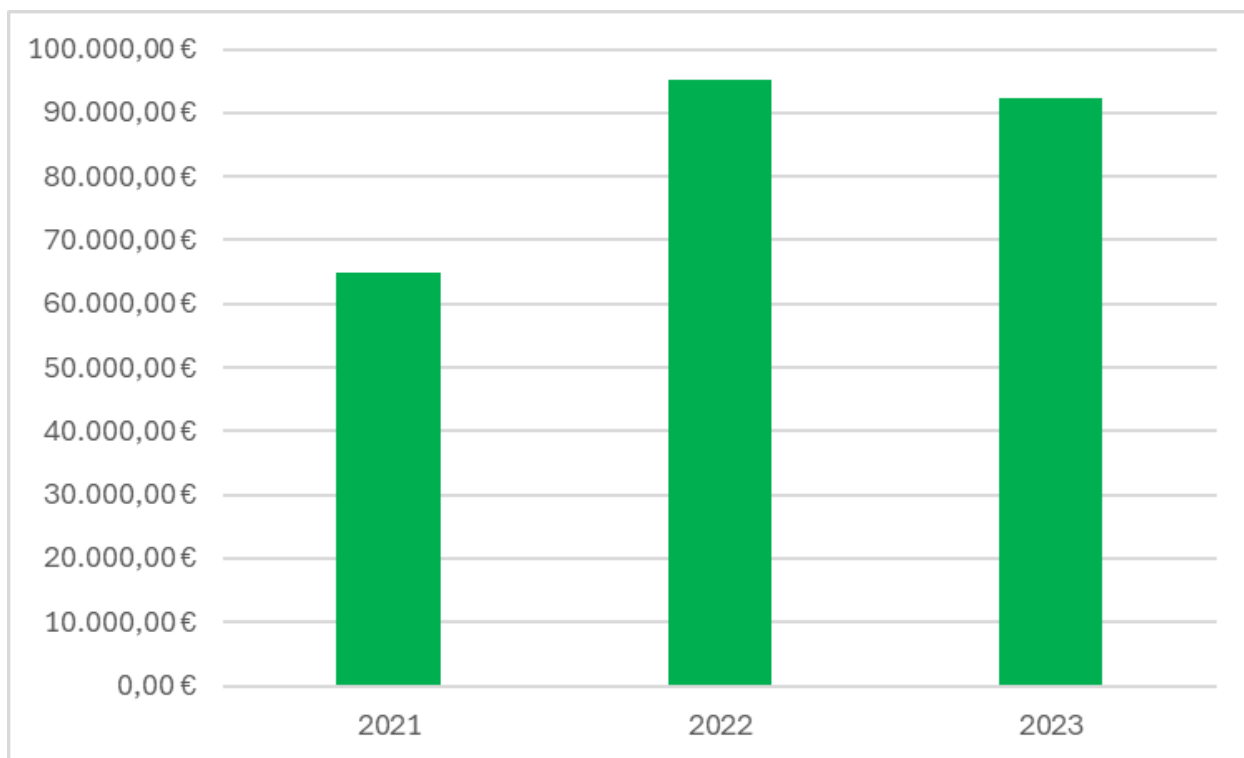
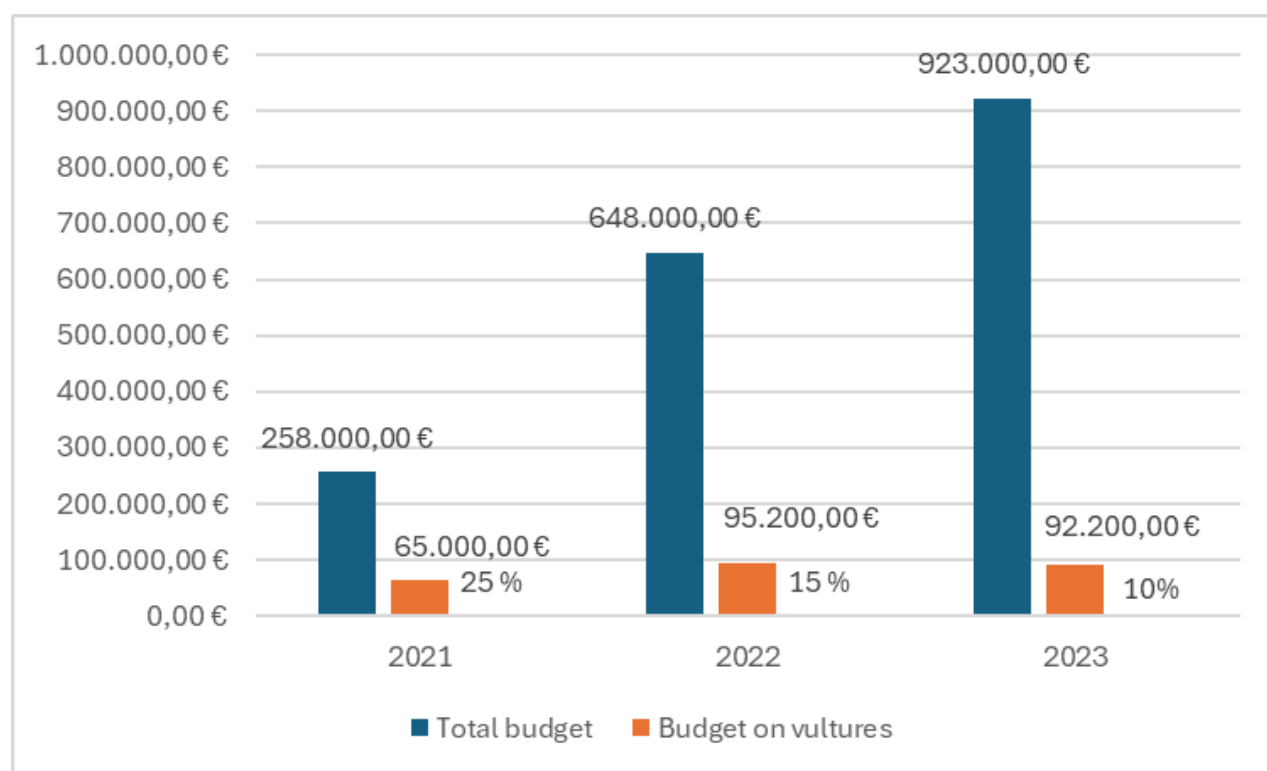


Figure 1. Rewilding Apennines' monetary contribution to vulture conservation.

²⁸ <https://europeanyoungrewilders.com/>

Table 1. Calculation of the in-kind values.

Year	Volunteers	In-kind daily cost (€)	Days	Total
2021	62	131	12	97,464 €
2022	73	131	18	172,134 €
2023	84	131	18	198,072 €

**Figure 2.** Rewilding Apennines' yearly expenditures on vultures.

In conclusion, both Rewilding Europe and Rewilding Apennines consider vultures high-priority species due to their irreplaceable ecological role as obligate scavengers. Therefore, field work has been balanced by a similar fundraising effort which has produced **€ 252,400 funds** spent on vulture conservation in 2021-2023, supported by **€ 466,670 in kind contribution** from a well-structured volunteer programme. In the coming years, Rewilding Apennines aims to intensify fundraising to fulfil their vision to restore a community of scavenging birds in the central Apennines.

Chapter 4

Analysis, evaluation, and application of IUCN translocation criteria

Mario Posillico



1. Introduction

According to extant regulations in Italy, there is no formal need to follow specific guidelines nor authorization procedures for the translocation of bird species, but for those intended as game. This singular condition likely represents an involuntary misinterpretation of previous regulations (see Chapter 2 for further details). Regardless, there are some obvious, practical and ethical reasons why a decision has been made in this study to pursue a logical and organised approach for translocation planning and implementation. The first step of planning the reintroduction should be carried out within an international cooperation context, which gives concrete guidelines and is used to follow a biologically sound approach, both at a national and international level. In this sense, IUCN translocation criteria provide a wealth of useful procedures. Further on, an extended network of Natura 2000 sites covers most of the predictable translocation area along - and widely overlapping - with many and often large, protected areas (e.g. National and Regional parks, reserves). For the project to be convincing and properly conveyed, it would be significant that the approach with Natura 2000 sites and Protected Areas management boards be realised according to a rationale which follows the logical approach that represents a legal and technical standard for other species (e.g., mammals). Possibly, the reintroduction could be subject to an impact assessment evaluation (*sensu lato*). In this case, a transparent and reasonable approach, while planning and implementing the reintroduction, could be more easily understood and possibly accepted by the relevant stakeholders. Finally, the translocation will be eventually realised in an area where a not negligible human density with competing interests exists. Thus, once again, a clear and overt logical approach recognised and endorsed at a national and international level, is more likely to produce the desired outcome.

2. IUCN translocation criteria

The IUCN guidelines (IUCN/SSC 2013), as well as those conveyed at a national level by the *Istituto Superiore per la Ricerca e la Protezione Ambientale* (ISPRA, Higher Institute for Environmental Research and Protection) (Anonymous 2007), will be used as a paradigm for reintroduction planning and hopefully implementation. IUCN translocation criteria, and ISPRA guidelines, will not be trivially described here, but a focus on relevant aspects will be reported with reference to the area and the species involved. As the proper terminology and its explicit meaning would promote and support a clear understanding of the arguments, a synthesis of relevant terms is given in Annex I. An emphasis is put here in the arguments closely linked with the structure of the feasibility study which was agreed upon by Rewilding Apennines and the consultant board, following the suggestions delivered by the Vulture Conservation Foundation. Regardless, further important topics, though related to aspects which will be endorsed only after the formal acceptance of the feasibility study and its founding, will be pointed out here as they make up a prerequisite for the translocation.

To comply with the IUCN guidelines for translocations, the feasibility study, considering the characteristics of the area where the vultures should be released, will deal with a series of aspects. These aspects have also been introduced in a former study, where a preliminary assessment for the restoration of a vulture community was carried out (Izzo et al. 2020). In this chapter, a synthesis of IUCN guidelines is provided in

a tabular form, and the chapters dealing with IUCN provisions are indicated. There are some specific guidelines which this feasibility study is not aiming at. Although these have not been dealt with in detail, preliminary information on the procedures and contact with relevant agencies, institutions and stakeholders have been collected and considered while writing the feasibility study. The table does not represent all of IUCN criteria, nor a thorough examination of them, but only points out those most relevant for the area and species concerned and for the aims of this feasibility study. For full explanation and future applications, IUCN/SSC (2013) should be checked. Accordingly, some arguments mentioned in the IUCN guidelines represent topics which are beyond the aims of this feasibility study and will be dealt with in a future releasing plan. Others, although interesting, have not been covered by this study.

Table 1. A synthesis of IUCN translocation criteria applied to the translocation of cinereous and bearded vultures as well as to the reinforcement of griffon vulture in the central Apennines. The list does not represent all of IUCN criteria, nor an in-depth examination, but only an indication about those most relevant for the area and species concerned and for the aims of this feasibility study. For full explanation, reference and applications, IUCN/SSC (2013) should be checked.

IUCN translocation criteria
<p>Section 3</p> <p>Deciding when translocation is an acceptable option</p> <ul style="list-style-type: none"> ● Provide evidence that threats causing previous extinction have been correctly identified, removed, or sufficiently reduced. ● Identify potential benefits and potential negative impacts, covering ecological, social and economic aspects.
<p>Section 4</p> <p>4.1 Translocation planning: goals, objectives, actions</p> <ul style="list-style-type: none"> ● Goals: a statement of the intended result of the translocation: describe the intended conservation benefit, and express it in terms of (<i>e.g.</i>) the desired size and number of populations that will achieve the required conservation benefit (locally or globally), within a certain time frame. ● Objectives: detail how the goals will be realised; ensure they address all identified or presumed current threats to the species (partly beyond the aims of this feasibility study). ● Actions: precise statements of what should be done to meet the objectives; Actions are the elements against which translocation progress will be monitored and assessed (partly beyond the aims of this feasibility study) <p>4.2 Monitoring programme design (<i>beyond the aims of the feasibility study</i>)</p> <ul style="list-style-type: none"> ● What evidence will measure progress towards meeting translocation objectives? ● What data should be collected, to provide this evidence, and what methods should be used? ● Who will collect the data, analyse it and ensure safe keeping? ● Who will be responsible for disseminating monitoring information to relevant parties? <p>4.3 Exit strategy (<i>beyond the aims of this feasibility study</i>)</p> <ul style="list-style-type: none"> ● An exit strategy should be an integral part of any translocation plan. Having a strategy in place allows an orderly and justifiable exit.

Section 5

5.1. Biological feasibility

5.1.1 Basic biological knowledge

- Collect knowledge on biotic and abiotic habitat needs, interspecific relationships and critical dependencies, and basic biology. Information should be used to confirm or adjust management.

5.1.2 & 5.1.3 Habitat & Climate

- Analyse habitat suitability and availability with respect to the needs of candidate species for all life stages and phenology.
- The climate at the destination site should be suitable for the foreseeable future (**Not covered**).

5.1.4 Founders

(not covered in detail; beyond the aims of this feasibility study)

- Founders should show characteristics (genetics, morphology, physiology, behaviour) that are assessed as appropriate for translocation.
- The potential negative effects of removing individuals from wild or captive populations should be assessed.
- Captive individuals should be from populations with appropriate demographic, genetic, welfare and health management, and behaviour.
- Founder selection should aim to provide adequate genetic diversity.

5.1.5 Animal welfare

(not covered, but mandatory for ethical and legal reasons)

- Conservation translocations should adhere to internationally accepted standards for welfare, and should comply with the legislation and regulations in both the source and release areas.

5.1.6 Diseases and parasites

(not covered, but mandatory for legal reasons)

- Management of disease and known pathogen transfer is important, to maximise the health of translocated organisms and to minimise the risk of introducing a new pathogen to the destination area.
- Quarantine before release is a basic precaution for most translocations; its use should be assessed on a case-by-case basis as it may cause unacceptable stress; conversely, stress may usefully bring out latent infections.

Section 5

5.2 Social feasibility

- Any conservation translocation proposal should be developed within national and regional conservation infrastructures, recognizing the mandate of existing agencies, legal and policy frameworks, national biodiversity action plans or existing species recovery plans
- Human communities will have legitimate interests in any translocation. Community attitudes can be extreme and internally contradictory. Consequently, translocation planning should accommodate and deal with all social aspects, as this is the basis for developing public relations activities to orient the public in favour of a translocation.
- Mechanisms for communication, engagement and problem-solving especially between the key individuals most likely to be affected by the translocation and project managers should be established well in advance.
- If extinction in the proposed destination area occurred long ago, local communities may have no connection to species unknown to them, and hence oppose their release. In such cases, special effort to counter such attitudes should be made well in advance of any release.
- Successful translocations may yield economic opportunities, such as through ecotourism, but negative economic impacts may also occur; the design and implementation stages should acknowledge the potential for negative impacts and where possible, sustainable economic opportunities should be established for local communities, especially where they are challenged economically.
- A successful translocation can contribute to a general ethical obligation to conserve species and

ecosystems; but the conservation gain from the translocation should be balanced against the obligation to avoid collateral harm to other species, ecosystems or human interests; this is especially important in the case of a conservation introduction (but also for translocations of long-time (i.e. centuries) missing species.

Section 5

5.3 Regulatory compliance

- A conservation translocation may need to meet regulatory requirements at any or all international, national, etc. levels.

Section 5

5.4 Resources availability

(Not fully applicable)

- Effective translocation management will be truly multi-disciplinary, with strong emphasis on incorporating social skill sets as well as biological/technical expertise
- Under normal circumstances, a translocation should not proceed without assurance of funding for all essential activities over an adequate period.

Section 6

6 Risk assessment

(Beyond the aims of this feasibility study)

- Any translocation bears risks that it will not achieve its objectives or will cause unintended damage. Consequently, the full array of possible hazards both during a translocation and after release of organisms should be assessed in advance
- The probability of a risk to occur will generally increase according to the duration of any extinction period, the extent of ecological change during any extinction period, the potential negative impacts on human interests, the probability of unacceptable ecological impacts (and others)
- The total risk landscape will be determined by:
 - the number of risks and the uncertainty over their occurrence, as well as uncertainty over the severity of their impacts,
 - ignorance of other possible risks factors
 - the cumulative effects of all occurring risks and their interactions
- The main categories of risk around a translocation are:
 - ecological risk: a translocated species may have major impacts at its destination on other species, on ecosystem functions; its own performance may not be the same as at its origin; evidence shows that risks are greater for a translocation outside a species' indigenous range, and adverse impacts may not appear for many years.
 - disease risk: no translocated organisms are entirely free of infection with microorganisms or parasites, with consequent risk of their spread; disease risk assessment should start at the planning stage, with its depth in proportion to the estimated likelihood of occurrence and severity of impact of any prospective pathogen and should be reviewed periodically through implementation.
 - socio-economic risks: these include the risk of direct, harmful impacts on people and their livelihoods and, hence, adverse public attitudes.
 - financial risks: there should be awareness of the possible need for funding to discontinue the translocation.

Section 7

Release and implementation

(Beyond the aims of this feasibility study)

7.1 Selecting release sites and areas

7.2 Release strategy

Section 8

Monitoring and continuing management

(Beyond the aims of this study)

8.1 Monitoring

- The monitoring programme measures the performance of released organisms against objectives, to assess impacts, and provide the basis for adaptive management or exit strategy. Adequate resources for monitoring should be part of financial feasibility and commitment.
- Monitoring should identify new threats to the translocated population which were not part of translocation design.
- The intensity and duration of monitoring of translocated populations should be appropriate to each situation.

Some post release monitoring elements are:

- **Demographic monitoring.** Key aspects for any translocation should include monitoring of demographic performance or spread;
- **Behavioural monitoring.** Monitoring the behaviour of translocated individuals can be a valuable, early indicator of translocation progress; but its value depends on the availability of comparative data.
- **Ecological monitoring.** Where a translocation is designed to create or restore an ecological function, progress towards such objectives should be assessed;
- **Genetic monitoring.** Where genetic issues are identified as being critical to the success of a translocation, monitoring can be used to assess genetic diversity in establishing populations or the effects of reinforcement or other management.
- **Health and mortality monitoring.** This assesses the extent that an established population is experiencing disease, or adverse welfare conditions or mortality, as a basis for identifying underlying causes.
- **Social, cultural and economic monitoring.** Participation in monitoring may be a practical means of engaging the interest and support of local communities, and can be used to assess attitudes towards the translocation, and any benefits and costs, direct and indirect, arising.

8.2 Continuing management

- Some translocations require management over many years; monitoring results provide the basis and the justification for either continuing or changing management regimes or change in translocation objectives or time schedules.
- Learning from translocation outcomes can be improved through adaptive management approaches, whereby alternative models are defined in advance and are tested through monitoring.

Section 9

Dissemination and information

(Beyond the aims of the feasibility project)

- Regular reporting and dissemination of information should start early, from the intention to translocate and continue throughout the process.
- It serves many purposes:
- To create awareness and support for the translocation in key affected parties.
- To meet any statutory requirements.
- To contribute to the body of information on, and understanding of, translocations.
- Collaborative efforts to develop translocation science are helped when reports are published in peer-reviewed journals (as an objective indicator of high quality), and include well-documented but unsuccessful translocations or methods as well as successful ones.

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GLOSSARY	
Translocation	Human-mediated movement of living organisms from one area, with release in another
Conservation translocation	The intentional movement and release of a living organism where the primary objective is a conservation benefit (not at an individual level).
Population restoration	Any conservation translocation within indigenous range of the involved taxa. Population restoration acts through reintroduction and reinforcement.
Reinforcement (synonymous: re-stocking, supplementation, augmentation)	The intentional movement and release of an organism into an existing population of conspecifics. It is usually aimed at enhancing population viability (genetically, demographically, etc.).
Reintroduction	The intentional movement and release of an organism inside its indigenous range , from which it has disappeared. Reintroduction aims to re-establish a viable population of the focal taxa within its indigenous range.
Conservation introduction	The intentional movement and release of an organism outside its indigenous range . Two types of conservation introduction are recognised, assisted colonisation and ecological replacement.
Assisted colonisation (synonymous: benign introduction, assisted migration, managed relocation)	The intentional movement and release of an organism outside its indigenous range to avoid extinction of populations of the focal species. The term includes a wide spectrum of operations, from those involving the movement of organisms into areas that are both far from current range and separated by non-habitat areas, to those involving small range extensions into contiguous areas
Ecological replacement (synonymous: taxon substitution, ecological substitutes/proxies/surrogates, subspecific substitution, analogue species)	The intentional movement and release of an organism outside its indigenous range to perform a specific ecological function. This is used to re-establish an ecological function lost through extinction, and will often involve the most suitable existing sub-species, or a close relative of the extinct species.

Chapter 5

Past distribution of vultures, causes of extinction and rarefaction

Fulvio Genero



Vultures (Accipitridae, subfamilies Gypaetinae and Aegyptiinae) have been present in peninsular Italy from the Bronze age (various references in Soppelsa & Tancredi 2023) and even earlier, from the late Pleistocene (Iurino et al. 2014). Nevertheless, the knowledge and evidence regarding the presence of vultures in the Apennines in more recent historical times, *i.e.*, later than XIII-XIV centuries, are relatively scarce and poorly documented, and sometimes the authors disagree in their conclusions. For this reason, in addition to the sparse information about the cinereous vulture (*Aegyptius monachus*) and the bearded vulture (*Gypaetus barbatus*), it is important to report the knowledge related to the griffon vulture (*Gyps fulvus*), which, analogous with present times, should have been more widely distributed, even in the past. This approach is also justified by the fact that the names used through the centuries for the different species, often do not allow for their clear identification. Furthermore, it would be useful to better define the historical distribution of the griffon vulture considering potential restocking or reintroduction in other areas in the Apennines.

In Italy, surveys and scientific research carried out in the previous centuries showed evidence or reported cinereous vultures nesting in Sardinia and Sicily, and bearded vulture nesting in Sardinia, Sicily, and the Alps. The available information is incomplete, and in a favourable historical context characterised by widespread traditional farming and numerous mountain areas with high suitability for these species, it could be argued that - notwithstanding the likely intensive use of natural resources by humans - the concerned species may have had a wider distribution.

Italy is also located in the centre of the Mediterranean and, previously, higher amounts of individuals from the much larger surrounding population of these species presumably occurred more often than nowadays. Under these conditions, it is clear to see that vultures can easily colonise new areas, or exploit temporary trophic resources during seasonal displacements. It is therefore reasonable to hypothesise a much wider historical distribution than the current one, taking the faunistic, environmental, and biogeographic considerations into account.

Furthermore, it is not easy to understand which species the historical information refers to, considering the basic information and the limited knowledge at that time about bird taxonomy and identification. Toponyms sometimes explicitly refer to the presence of vultures, or to words that could be associated to what we now call vultures (though they could be eventually associated to other features) such as Volturara Appula (Foggia province), Monte Vulture (Potenza province), Volturara Irpina (Avellino province) etc. A passage from Aldrovandi's work²⁹ reports: "*Francesco Patrizi once wrote to me that on the Apennines, near Monte Averna in Etruria, where there is the illustrious Salviati gentlemen's forest, is located a vulture nest*". In the Marche region, the presence of vultures was described for the first time in 1563 by Costanzo Felici from Piobbico. In a letter to Ulisse Aldrovandi dated July 21, 1563, Costanzo Felici mentions a "voltore", commonly called *viultur*, present in the mountains of the Marche. In this case, it could be the

²⁹ Ornithologiae hoc est de avibus historiae libri XII, Bononiae, Giovan Battista Bellagamba, 1599

Ornithologiae tomus alter cum indice copiosissimo variarum linguarum, Bononiae, Giovan Battista Bellagamba, 1600
Ornithologiae tomus tertius, ac postremus. Cum indice copiosissimo variarum linguarum, Bononiae, Giovan Battista Bellagamba, 1603

Eurasian cinereous vulture, as he reports “it also nests on the tops of trees.”. In the commentary on Costanzo Felici's letters, Pandolfi & Zanazzo (1993) reported that in Felici's *Voltore*, both the Eurasian cinereous vulture and the griffon vulture seem to be recognizable since they are identified as nesting both in trees, typical of the cinereous vulture, and rocky cliffs, typical of the griffon vulture. Perhaps in the area, they did not distinguish between the two species, which they referred to with the single name of *Voltore*. In particular, the area of Monte Nerone (Pesaro e Urbino), a limestone massif near Monte Catria and the Furlo Gorge, is mentioned. The bearded vulture was called ‘bone bearded’ and “*It is of greater body than the eagle, mostly black feathered. It willingly follows the eagle to serve itself with the remains of this bird's food and throws away the bones, which it takes and sometimes, if they are too big and cannot be used, it lifts them up by talons and lets them fall on rocks and breaks them, then eats them...?*” (Costanzo Felici, letter 19, July 21, 1563, in Pandolfi & Zanazzo, 1993).

The griffon vulture is described, again by Felici, as follows: “*Behind this (the Egyptian vulture) the vulture is born in the lofty cliffs and precipices...*”. Also interesting is the report of the griffon vulture nesting together with the golden eagle (*Aquila chrysaetos*) by Avicenna (1644) in the province of Ancona, an area of the mountains of the Cingoli municipality: in the rocky cliffs of Monte Acuto and Monte Sant'Angelo (Cingoli municipal library - Paolo Appignanesi) (Naturalistic environmental itinerary Terra Flora and Fauna, VOL. II., Soc. Coop. Colli Esini, S. Vicino pp.51). It can be hypothesised that in the limestone Apennines (at least in the Pesaro area in northern Marche region, but probably also in other areas), all four species of vultures could have coexisted, albeit already rare, unlike in the central-southern Apennines, where they have long been extinct (except for the Egyptian vulture (*Neophron percnopterus*), which is still present with a few pairs). It seems that, even at that time, vultures were rare, considering that Giuseppe Altobello in his “*Essay on Italian Ornithology - the raptors of 1920*”, reports only one historical account related to the bearded vulture in Abruzzi. Frugis (1988), in his commentary on the famous work “*De Arte Venandi cum Avibus*” written in the 13th century by Emperor Fredericus II (1194-1250), writes: “*It is not easy to recognize, not even in the illuminated illustrations, which species (of vultures) are being referred to on some occasions, and it is curious that in this first part of the treatise there is no definite mention of the Griffon vulture, which should have been present even in southern Italy at that time, and certainly in the Middle East.*”. He continues about the cinereous vulture: “*(...) it is somewhat surprising the abundance of illustrations of the cinereous vulture... which, judging from the numerous illustrations of the Codex, must have been numerous in southern Italy*”. In any case, a more careful reading of Fredericus II *De Arte Venandi cum Avibus*, and specifically *De Arte* l 41 as outlined by Soppelsa & Tancredi 2023, could be interpreted as clearly referring to the griffon vulture, based on the behavioural interpretation of the following: “*Et si unus de ipsis subito descenderit ad cadaver [...] congregant se multi, ubi erit corpus (if one of them descends on a carrion [...]) many gather in the place where the body is found*”.

Moreover, there is no conclusive evidence in the last centuries of the presence of the cinereous vulture and the bearded vulture, which could plausibly have been present in the peninsular reliefs, but for the area of the Gran Sasso Park e Monti della Laga National Park, where historical references to the presence of this latter species are certain, though breeding was not reported with certainty. In fact, referring to the literature cited by Manzi (2003) regarding its historical presence on the Gran Sasso, we find that Salvadori

(1872)³⁰ reports: “I remember having heard from the distinguished geologist Count Alessandro Spada, that he had seen the head of an individual killed on the Gran Sasso d'Italia at Monte Corno”. Furthermore, Lionardo (Leonardo) Dorotea (1797-1865) from Villetta Barrea (L'Aquila province) in the upper Sangro river basin, about the chamois' (*Rupicapra pyrenaica ornata*) predators, writes: “...the chamois could fear nothing from voracious animals and little from man, if the bearded falcon, the Ossifrage of the Latins, did not hunt them down...” (Dorotea 1842). Other publications, such as Francesco De Marchi, 1573, “Chronicle of the first ascent to the peak of Gran Sasso” in L'Aquila Section of Italian Alpine Club (CAI) 1973, page 15, refer to the presence of the bearded vulture in the area. The common names used in the past, such as bearded eagle, bearded falcon or, in general, eagle, have certainly created some confusion about their exact interpretation. However, direct observation of a head and the definition “*Ossifrage of the Latins*” should leave few doubts about its occurrence, though it was not possible to determine if it was resident and, possibly, breeding.

Regarding subsequent epochs, there are some mentions of the griffon vulture. According to Geroudet (1984), the griffon vulture was once present in Calabria, southern Italy. Lopez (1892) describes it as accidental in the mountains of the province of Teramo. De Leone (1908) writes: “I have never seen them in Abruzzi, I don't know if anyone else has.”. On the other hand, it is possible that the presence of certain species, even of considerable size, could go unnoticed and quickly disappear from the memory of the local population or scientific community. This situation also occurred with the bearded vulture in various Alpine regions despite its relatively recent extinction between the end of the 19th and the beginning of the 20th century. Similarly, the recent disappearance of the common raven (*Corvus corax*) in the central-northern Apennines has left very little evidence, even though it is still present in the memory of some old shepherds and hunters. Likewise, for the Abruzzo chamois mentioned by many authors since 1500, no remains of stuffed animals or trophies have ever come from Gran Sasso, but for a recent finding from Sibillini Mountains (Fioravanti et al. 2019).

Chiavetta (1981) considers the limestone massifs, typical of the central-southern Apennines, among the Italian areas (in addition to Sardinia and Sicily) that are best suited for the reproduction of the griffon vulture. Ultimately, the nesting of the griffon vulture in the Italian peninsula is conceivable based on ecological and faunistic considerations, even though it certainly concerns distant epochs and can be excluded from the late 18th century onwards (Genero, 1992). Recent objective evidence provides further interesting data. De Curtis (1997), during the study of osteological material from raptor's preys in the Marche Apennines, identified, in an ancient golden eagle nest (Gola della Rossa, Ancona province) in the Regional Park Gola della Rossa and Frasassi, 23 bone fragments attributed to an adult griffon vulture. Bones were likely dating back to the end of the XIX and early XX century, though the author concluded that there was no evidence to support the hypothesis of a breeding site.

For the Sibillini Mountains, the presence of the griffon vulture is described in the following texts:

a) the first edition of Guerrin Meschino, dating back to 1473 (although the citation concerns a popular edition published in Florence in 1889) and titled Guerrino detto il Meschino, “History of the great deeds and victories against the Turks during the reign of Charlemagne Emperor King of France”. In the fifth part, which deals with the legends of the Sibillini Mountains, we read: “*He, who had climbed the said Mountain, told of having heard many winds blow originating from the mountain and that all around*

³⁰ https://books.google.it/books/about/Uccelli.html?id=MDYwwQEACAAJ&redir_esc=y

there are very great and fierce griffon vultures. Below the Mountain lies the city of Norcia, and Guerrino headed towards it." (La Storia tra storie e leggende. I Monti Sibillini nelle fonti storiche e letterarie. Maroni publisher, Luigi Paolucci, 1990, p. 212);

b) "Mountaineering excursion to Monte Vettore by the Marchigiana and Umbra sections, August 1876 for Girolamo Orsi, President of the CAI Marchigiana section, Turin 1878". On page 30 referring to the Sibillini Mountains he wrote: "*It is not new that among the rugged mountains and the ancient woods there is some wolf wandering, but it is more frequent that the eagle and the griffon vulture nest in those rocks, among which the alpine choughs, pyrrhocorax alpinus nest, taking the place of our house sparrow the fringilla nivalis.*";

c) "Historical memories of Amandola. Statutes of Amandola (15th century)". In paragraph 52, some names of places are mentioned near Monte Birro (Monte Berro) including the *Avultore* hill (Maroni publisher, Pietro Ferranti, 1985, p. 115). Amongst the places named, in the Monti Gemelli, the Hermitage of Sant'Angelo in Volturino stands out.

As for the cinereous vulture, starting from the XIX century its presence is unclear in the central-southern Apennines. A few authors give brief and unconfirmed information on its occurrence such as Zuccagni-Orlandini 1844 (p. 102) in Terra di Lavoro (northernmost Campania, southern Latium and westernmost Molise regions). And some question its presence such as Costa (1857; p. 7), who wrote about an individual caught on mount Tifata (Caserta province) and brought to Naples, and about another one killed near Reggio Calabria (stating that it originated from Sicily). Savi (1873) and Doderlein (1869), agreed upon the presence of the cinereous vulture in Sardinia, but their opinion about its occurrence in Sicily diverged, as reviewed in Soppelsa & Tancredi (2023). Interestingly, Salvadori (1872) reported that in May 1863 two cinereous vultures were seen at Ripatransone (Ascoli Piceno province, Marche region) and one individual was shot and donated to him, then kept in his private collection. Similarly, he reported the occurrence of a griffon vulture caught in Bevagna (Perugia province, Umbria region), though the date was not reported (likely between the first and second half of the XIX century), as well as another griffon vulture at Marradi (Firenze province, Tuscany region), caught in 1859 and kept in his private collection.

More recently, from 2015 to 2022, 4 different cinereous vultures crossed the Apennines. In 2015, 2021 and 2022 three tagged individuals (two of which had a GPS device) crossed the Apennines. Two other vultures (in 2021 and 2022) also entered the feeding station managed by the Carabinieri Forestali in Monte Velino reserve. There were several observations of cinereous vultures (likely the same individual) in southern-central Abruzzi and Latium Apennines in 2022, which allowed us to estimate that this individual was present for about two months in that area.

Although it cannot be considered as a conclusive information about vultures' presence in the XIX century in the Apennines, Zimmermann Ludwig Richard, lieutenant of the "brigand" Luigi Alonzi, known as Chiavone, who operated in the mountains overlooking the city of Sora in the service of the Bourbon dynasty, testified the presence of vultures in the Ernici Mountains. It was most likely griffon vultures but it remains unconfirmed as can be read in these words: "It was about ten o'clock: beyond the pass between Madonna di Rosa and Monte delle Scalelle, our outpost no. 2 had just clashed with a Piedmontese patrol, and the sound of gunfire had flushed out five or six vultures perched on the corpse of the spy (note: a traitor shot a few days earlier), not far from there. Rising with sharp and wild shrieks and tracing wide

circles above us, they seemed ready to resume the interrupted meal at any moment or to secure a new one that the men down there shooting at each other would provide... Closer, ever closer, the vultures now traced their circles around the peak of Madonna di Rosa and, in the end, swooped down quickly to quickly finish the interrupted feast." (*Erinnerungen eines ehemaligen Briganten-Chefs* - Berlin 1868).

Causes and period of extinction. Based on available data, it can be hypothesised that environmental and ecological conditions allowed the presence of the griffon vulture, the cinereous vulture, and the bearded vulture in the central Apennines in the past. The findings related to such species are scarce and discontinuous especially from the XVIII century onward. Furthermore, surveys aimed at exploring the Italian fauna report different, even contradictory, conclusions. There was a relative agreement and proof of their occurrence and even breeding in Sardinia, Sicily, some areas in the Alps and to a certain extent the very southern Apennines (Izzo et al. 2020). Only in the case of the bearded vulture do reports suggest a feeble probability that its occurrence in the central Apennines could be related to breeding individuals in the XIX century, and thus likely present before.

The causes that could have led to their disappearance are consistent with those reported in much of Europe, though in different periods. The research from Soppelsa & Tancredi (2023) highlights how vultures (cinereous and griffon vulture) became rare and eventually disappeared at the end of Angevin wars (ca. 90 years of conflicts between XIII and XIV centuries) in most of the peninsular portion of the Kingdom of Sicily, as their plumage represented the main source of feathers to fletch bolts, especially crossbow quarrels, and were exploited to a great extent. Generally, it is believed that the most important factors determining their decline and disappearance were the human impact on the territory, the spread of firearms and poisoned baits, and the decline and evolution of pastoralism. Climate change, *i.e.*, the possible consequences of the little Ice Age (from about mid XIV to mid XIX centuries) remain largely unexplored as a direct and indirect cause of rarefaction and even extinction of such vultures in the central Apennines.

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Chapter 6

Main threats to vultures

Mario Posillico, Enrico Bassi, Nicolò Borgianni
and Fulvio Genero



All over the world, and for both the New- and Old-world vultures, anthropogenic activities represent the most frequent threats and causes of deaths (*e.g.*, Ogada et al. 2016; Botha et al. 2017; Estrada Pacheco et al. 2020; Serratos et al. 2024). This paradigm has been recently confirmed by a focus on causes of mortality through the Eurasian-African flyways for tracked raptors, cranes, and storks. Electrocutation (40.5%), illegal killing (21.7%), and poisoning (16.3%) represented the most frequent causes of casualties (Serratos et al. 2024). Combined, the energy infrastructure-related mortality (electrocutation, power line and wind-farm collision) were 49% of all human-induced mortality. This last study, considering data from 2003 to 2021, also underscores that human drivers of bird mortality in the African-Eurasian flyway have not declined over the last 15 years, and that stronger conservation actions to address these threats need to be enforced to reduce their impacts.

A general overview of threats and mortality causes affecting the Old-world vultures have been reported in the Vulture Multi-Species Action Plan by Botha et al. (2017) and in the mid-term update of the implementation of those conservation actions (Botha et al. 2024). A summary of the threats facing the species in this study and for the griffon vulture is shown in table 1. The threats are classified by Botha et al. (2017) on a global scale according to their guessed or estimated severity. Providing a full detail of such threats at a global scale goes beyond this feasibility study. Therefore, a synthesis of the local and available evidence and information at a scale coherent with the spatial extent of this study is provided.

From 1994 to 2020 in the central Apennines, considering casualties where the cause of death has been ascertained, anthropogenic mortality is responsible for 67% of griffon vulture mortality (the only breeding vulture in the area) (Posillico et al. 2023), while for 30% of the vultures delivered to labs for necropsy, causes could not be determined. Indirect or secondary poisoning represents overall the most frequent cause of death (53%), although other causes are not negligible (Monti et al. 2022; Posillico et al. 2023). Tackling retaliation poisoning, the most likely source of poisoning affecting vultures, is a complex and multifaceted issue with many related social and cultural aspects, where strict law enforcement and crime prosecution plays a fundamental role. From 2020 to 2023, an analysis of wildlife poisoning has been carried out for most of the north-central to southern Italy for presumed or confirmed poisoning cases, thanks to the data contribution of Ministero della Salute, Istituto Zooprofilattico Sperimentale del Lazio e della Toscana “M. Aleandri”³². An evaluation of the risk of poisoning has been worked out to both individuate the environmental correlates associated to confirmed poisoning cases, and to possibly predict poisoning hotspots.

Furthermore, Bassi et al. (2021) and data in Chapter 12, showed that lead ingestion from spent hunting ammunition in 70 raptors specimens (16 golden eagle, GE, and 54 griffon vultures, GV) is responsible for a significant occurrence of lead exposure in the Apennines. This is found at both sub-clinical (37.2% GE and 37.5% GV) and clinical levels (10% GE and 12.5% GV) in the griffon vulture and the golden eagle respectively. Consequently, the foreseen red and roe deer hunting in the Abruzzi region, the stronghold of griffon vultures, is raising further concerns about an increase in the occurrence of lead intoxication for those and other facultative scavengers. The results of lead intoxication monitoring and the perspectives for an increase in the hunting quota of wild ungulate species in the central Apennines both entail that the

³² Portale Nazionale degli Avvelenamenti Dolosi degli Animali <https://avvelenamenti.izslt.it/>

need for a more restrictive and effective regulation licensing on the use of lead-free ammunition and the opportunity of a well-organised monitoring of lead concentration in concerned wildlife, is significant. Moreover, the empirical evidence of a sustained poaching aimed at the red deer in some areas already alerts for a possible source of lead poisoning, although for the moment at a local scale.

In addition to a more reinforced and extended ban of lead ammunition (especially for wild boar hunting where the current lead ban is only partially regulated), the role of surveillance is crucial to check the effective compliance with regulations. We suggest that, to be useful, controls by adequately prepared officials should check at least 5-10% of the overall number of annual regional culling.

In the feasibility study, the main risk factors have been carefully examined in relation to the daily movements of 53 griffon vultures equipped with a GPS in and outside the hunting period of 2023, and to the main hunted species in central Apennines. After a deep analysis of the current hunting modalities, especially for ungulates and other smaller game species described within the Hunting Plan Abruzzo Region, a series of practical measures have been compiled for the progressive and definitive mitigation of the Lead issue, also following the rectrices of ECHA European Chemical Agency recommendations.

Power lines at different voltages represent an important mortality factor for many bird species and vultures because they can provoke electrocution, electro collision, collision and electrifying events throughout the year.

Electrocution can alter the population dynamics of the most affected species like some diurnal and nocturnal birds of prey. Tucker and Heath (1994) showed that at least 7% of the threatened species in Europe suffer significant losses due to interaction with electrical conductors either through collision or electrocution. Even in the case of the griffon vultures, electrocution represents an additional mortality factor. In the study area, 6 griffon vultures died due to electrocution in the province of L'Aquila, between 2000 and 2018 (1 every approximately 3.1 years). From a preliminary analysis, the impact caused by this kind of mortality factor seems to represent a further additive source of mortality, though less harmful than others, such as impact with wind turbines and lead exposure. These considerations must be taken with caution as previous data about griffon vultures died by electrocution has been reported opportunistically.

Furthermore, the impact of power lines on birds, being very widespread and estimated for Italy at between 2.1 and 20.5 dead birds per km of line/year (Rubolini et al. 2005), is almost always largely underestimated due to a high removal rate by scavengers. The feasibility plan outlines the need to proceed with the identification of the danger of existing power lines in relation to the habitats and sensitive areas for the target species (e.g. breeding, release and feeding sites), as a measure to plan and apply the first mitigation measures ever implemented until now. The involvement of the main power suppliers, Terna and e-distribuzione companies, will be crucial in the signature of an official agreement to find solutions for the mitigation of the most dangerous power lines.

Table 1. A synthesis of the threats for griffon vulture (*Gyps fulvus*), bearded vulture (*Gypaetus barbatus*) and cinereous vulture (*Aegypius monachus*) ranked according to their known or perceived severity on a global scale (after Botha et al. 2017). Ranking could change according to local conditions. An asterisk and bold character marks threats

known to affect the central Apennines griffon vulture population, thus likely of concern for other reintroduced vultures.

<i>Species</i>	Threats (global scale)		
	<i>Major</i>	<i>Secondary</i>	<i>Potential</i>
<i>Gypaetus barbatus</i>	<ul style="list-style-type: none"> ◆ Unintentional (<u>poisoned baits</u>) poisoning ◆ Collision with energy infrastructure (<u>powerlines and cableways</u>) ◆ Unintentional (<u>lead</u>) poisoning 	<ul style="list-style-type: none"> ◆ Direct persecution ◆ Declining food availability ◆ Human disturbance ◆ Habitat loss and degradation 	<ul style="list-style-type: none"> ◆ Unintentional (<u>NSAIDs</u>) poisoning ◆ Collision with energy infrastructure (wind farms) ◆ Genetic bottlenecks ◆ Climate change
<i>Aegypius monachus</i>	<ul style="list-style-type: none"> ◆ Unintentional poisoning (poison baits) ◆ Electrocutation on or collision with energy infrastructure. ◆ Decline of food availability (wild and domestic ungulate populations) 	<ul style="list-style-type: none"> ◆ Habitat degradation ◆ Human disturbance ◆ Direct persecution ◆ Unintentional poisoning (NSAIDs) ◆ Climate change ◆ Intentional poisoning (belief-based use) 	
<i>Gyps fulvus</i>	<ul style="list-style-type: none"> ◆ Unintentional poisoning (poisoned baits) * ◆ Electrocutation on energy infrastructure * ◆ Collision with energy infrastructures (wind farms * and even powerwires) ◆ Decline of food availability (domestic ungulate populations) 	<ul style="list-style-type: none"> ◆ Decline of food availability (domestic ungulate populations) ◆ Unintentional poisoning (NSAIDs) * ◆ Unintentional poisoning (lead) * ◆ Human persecution (excluding poison) ◆ Habitat degradation ◆ Human disturbance * 	

In the central-southern Apennines, Monti et al. (2023) and a joint effort between Rewilding Apennines and Raggruppamento Carabinieri Biodiversità (unpublished reports), have outlined for GPS-tagged griffon vultures, that 10% to 17% of GPS-tagged vultures have died by collision with wind turbines. Among them, 8 pieces of evidence of griffon vulture collision with wind turbines have been ascertained in 2022 and 2023, at the Collarmente (mostly) and Cocullo wind farms (both municipalities in L'Aquila province), during a specific monitoring programme. Overall, these figures represent an amount of mortality causes that is not a priori negligible. This is - unfortunately - not a novelty for the griffon vulture, whose sensitivity to the collision with wind turbines has been well outlined by Lucas et al. (2012), among many other authors. Thus, there is the need to apply appropriate conservation actions for existing wind energy infrastructures, e.g., implementing mitigation measures (e.g., Ferrer et al. 2022; McClure et al. 2022; Tomé et al. 2017). Moreover, to act proactively for conservation, governmental agencies should act with full rigour while locating areas and sites to set new wind energy infrastructures. Indeed, land-use planning based on sound evidence would hopefully allow a wide-extent energy development planning which should better tackle the conflict between biodiversity-sensitive species conservation and energetical needs, especially within participatory and adaptive processes (Gauld et al., 2022; Oppel et al., 2021). It is foreseen that energy from renewable sources will contribute to 90% of total produced energy by 2050 (International Energy Agency 2021). This implies a tenfold increase of energy produced by onshore wind plants within that year (International Energy Agency 2021; International Renewable Energy Agency 2019), with an approximate

5-fold proportional increase of the energy distribution network. This suggests a dramatic increase in raptors' mortality by collision with energy infrastructures (cables, wind turbines) with significant consequences on EU targets on biodiversity conservation. Following Smeraldo et al. (2020), the effects of wind turbines on the habitat of griffon vulture were predicted in this study, by overlapping information on wind facilities and suitability to wind farm placements with a stochastic model predicting the probability of occurrence of the griffon vulture, with main reference to habitat predictors associated to movements of griffon vultures outside their core range. This will provide, at a biologically-meaningful scale and grain, a tool to identify critical areas (*i.e.*, marked by a high potential collision risk) where both the likelihood of vultures to occur and the suitability for the placement of wind farms is high. Embedding this outcome in a landscape scale planning effort for renewable energies and biodiversity conservation, should minimise (though not eliminate) the risk of collision for griffon vultures. This does not imply that all raptors or soaring species would equally benefit from the output of this modelling approach, though the griffon vulture is by far the most affected.

Finally, the use and misuse of non-steroidal anti-inflammatory drugs for livestock medication has been subject to a very limited monitoring in the griffon vulture in the central Apennines, although it was a widespread plague for vultures in the Indian subcontinent (Green et al. 2004) and could also represent a powerful threat in Spain (Green et al. 2016). To date, in the central Apennines, only one individual in 2020 was positive for diclofenac (7% of 13 birds tested for NSAIDs), although the concentration in muscle tissues was by far lower than the estimated lethal dose (Posillico et al. 2023). Differently from the use of lead hunting ammunition, there are only feeble provisions, if any, at EU or national level, regarding cautious and safe NSAIDs administration to livestock in key areas for vultures and raptors. Considering the lethal effect that NSAIDs ingestion from carcasses could exert on raptors, the absence or poorly specified provision is a largely unsatisfactory prevention measure. Accordingly, in addition to developing pressures on stakeholders for the use of well-known alternative safe drugs, a strong need exists to establish a thorough monitoring of NSAIDs concentration in potentially susceptible species and to ascertain its actual use in livestock farming, also considering that NSAIDs could be also administered illegally and imported illegally, like other veterinary drugs.

Within the relevant chapters of this study, some aspects about distribution, biology, ecology, and conservation status of the concerned vulture species have been described in detail. Further information on these species and on other aspects of their natural history could be accessed at the following web sources:

<https://birdsoftheworld.org/bow/home>

<https://www.iucnredlist.org/>

<https://datazone.birdlife.org/species/search>

A swift and readily accessible fact-sheet for the cinereous vulture and the bearded vulture (compiled by FG) is given in the Annex I of this chapter as a readily accessible reference. Information there is mostly or completely referred to:

<https://cites.org/sites/default/files/eng/com/ac/31/Inf/E-AC31-Inf-03.pdf>

<https://vultureslife.fwff.org/en/target-species/cinereous-vulture/>

<https://vultureslife.fwff.org/en/target-species/bearded-vulture/>

and, for European vultures, to:

https://www.researchgate.net/publication/363693622_Report-Vulture-Population-Estimates-Europe-VCF-September-2022-2

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Annex 1 - Species description



1. Cinereous vulture (or Eurasian black vulture) (*Aegypius monachus* Linnaeus, 1766)

Red List Category: Near Threatened (since 2004); **Extinct in the Wild** (as breeder; Italian red list, 2021 assessment)

Population size: 16,800–22,800 mature individuals³³⁶

Population trend: Stable to slightly increasing

Range: Europe, Asia

Distribution: This species breeds in Spain, Greece, Turkey, Armenia, Azerbaijan, Georgia, Ukraine, Russia, Uzbekistan, Kazakhstan, Tajikistan, Turkmenistan, Kyrgyzstan, Iran, Afghanistan, northern Pakistan, Mongolia and mainland China, with a reintroduced population in France and Bulgaria. The wintering range includes additional countries to the south of the breeding range.

Population size and trend: The most recent global population estimate for cinereous vulture is 16,800–22,800 mature individuals. This consists of about 2,750 pairs in Europe and Turkey. (Terraube et al., 2022) with increasing to steady population size in Europe, while the trend across Turkey and Asia in general is believed to moderately decline.

Movements: The species is a partial migrant; while it is sedentary in some areas, many individuals winter south of the breeding range, and there is also a good deal of nomadism. Long movements are known for birds in Asia. In Europe, the adults are mostly sedentary, while the juvenile birds disperse over larger areas. In Spain, the movements of the juveniles are mostly limited to the western part of the Iberian Peninsula and in the surroundings of the breeding colonies. Reports of cinereous vultures as regular winter visitors to Africa (Egypt and Sudan) appear to be unfounded, at least at the present time, although very small numbers have been recorded in Egypt.



2. Bearded vulture (or Lammergeier) (*Gypaetus barbatus* Linnaeus, 1758)

Red List Category: Near Threatened (2014); previously Least Concern; **Critical Risk** (Italian red list, 2021 assessment).

Population size: 1,675–6,700 mature individuals

Population trend: Decreasing

Range: Africa, Europe, Asia

Distribution: In Europe, the distribution is patchy, following a widespread decline over the last two centuries principally because of direct or indirect human causes; it has disappeared from almost all mountain ranges across Europe. The population in the Balkans was the last to become extinct, as late as in the beginning of this century, and the species remained only in the Pyrenees, Corsica and Crete. Since the mid-1980s the species has been reintroduced to several European mountain ranges, initially in the Alps, and more recently in Andalusia, Grands Causses and Picos de Europa. In Asia, the main and substantial populations occur along the full length of the Himalayas, extending from central China westwards through all the montane states of northern India, and Nepal, Pakistan, Afghanistan into central Asia as well as Mongolia. Middle Eastern populations extend from south-west Iran into much of Turkey,

with more isolated populations in Yemen and south-west Saudi Arabia. Bearded vultures occur in Ethiopia, Kenya and Tanzania in East Africa, Lesotho and South Africa in southern Africa, and Morocco. They could conceivably survive in Algeria and Mauritania (Botha et al. 2017; Terraube *et al.* 2022).

Italy (Bassi 2022). Historically present in the Alps, Apennines and the main islands. In the Alps the species vanished in the early years of the XX century. In Sardinia it went extinct around 1968-69.

Population size and trend: The current European population estimate is 590–749 pairs, which equates to 1,200–1,600 mature individuals. Population trends in Europe vary regionally and locally. Even though the population in western Europe is increasing, the last two island populations, Crete and Corsica, are stable and near extinction respectively. There is a lack of information for the species in Turkey and the Caucasus. The species has been successfully reintroduced in the Alps (Austria, France, Italy and Switzerland) and Andalusia, Spain. In Europe, the species occurs in Spain (163 breeding pairs), France (76), Swiss (25), Italy (16), Greece (10), Austria (9), Andorra (1) (Terraube et al. 2022). Asian populations are regarded as being relatively large and stable but with signs of significant, more localised declines. The higher Himalayan populations together with those in south-east Kazakhstan and Armenia are all regarded as more stable. In Africa, the largest known populations are found in Ethiopia, where there are an estimated few hundred pairs, but this population has not been fully assessed. There is also a small population of less than 10 pairs in Kenya and northern Tanzania. The geographically isolated population in Lesotho and South Africa is currently estimated at 200–250 individuals and has declined by more than 80% over the last three generations. In North Africa, there are an estimated 1–2 breeding pairs in Morocco, but no current information from elsewhere.

Italy (Bassi, 2022). Widely translocated in the whole Alps from the second half of XX century, the Italian population increased from 3 occupied territories in 2002 to 17 territories in 2021, when fledging occurred in at least 13 nests.

Movements: It is resident but has vast home ranges; juveniles will wander even more widely than adults. The home range of adult birds depends on their territorial status. Territorial individuals exploit home ranges of about 50-200 km², while non-territorial birds use areas of around 10,000 km² (Margarida *et al.* 2020). Although younger birds can exploit large areas moving across much of Europe before becoming territorial, the species shows philopatric behaviour, which has a negative effect in the expansion of occupied territories. Irregular movements for this species have also been recorded in Europe with recent records for this species from Denmark, the Netherlands and the United Kingdom. The species occupies remote mountainous areas, with precipitous terrain, usually above 1,000 m; and in Europe and Asia in particular areas where large predators such as wolves, snow leopard and golden eagles are present, and there are herds of mammals such as mountain goats, ibex, and sheep. In Africa, it is also restricted to higher altitudes such as the Ethiopian highlands and the Ukuhlamba-Drakensberg, but in southern Africa it is almost entirely dependent on livestock carcasses due to the almost complete absence of wild ungulates over much of its range. Usually, they are limited to alpine habitat, with vegetation being the distribution limiting factor.

3. References for annex 1

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Chapter 7

Project area and geographical context

Luca Chiaverini and Nicolò Borgianni



The area the feasibility study refers to is extended from ca. 41° to 43° N, latitude, and 12° to 14.5°E, longitude, and has been identified based on the distribution of GPS fixes from 2021 to 2023, excluding those referred to sallies or dispersal/erratism, based on a visual classification (Figure 1). A minimum convex polygon has then been drawn around those fixes to highlight the municipalities occurring inside it, and the continuous area described in this way has been selected. We aimed at selecting municipalities because they represented the smallest administrative and spatial unit for which the data related to husbandry and livestock are available in the existing databases. The study area comprises the combined surface of 628 municipalities, extending over a surface of 25,059 km², and it is predominantly located in the central Apennines, with small portions extending across the southern Apennines. The area comprises 6 Italian regions (Umbria, Marche, Latium, Abruzzi, Molise and Campania) and 19 provinces (Perugia, Terni, Ancona, Macerata, Ascoli Piceno, Fermo, Viterbo, Rieti, Roma, Latina, Frosinone, L'Aquila, Teramo, Pescara, Chieti, Isernia, Campobasso, Caserta and Benevento).

The project area includes 78 protected areas (both regional and national parks and reserves). Among the biggest, the study area includes (North to South) Monti Sibillini National Park, Gran Sasso and Monti della Laga National Park, Sirente Velino Regional Park, Maiella National Park, Monti Simbruini Regional Park, Monti Lucretili Regional Park, Abruzzo, Lazio and Molise National Park and Matese Regional Park, which marks the southern border of the area in Campania region. The combined amount of protected area comprises: 4,822.94 km². Additionally, the area includes 297 Natura 2000 areas which partially overlap with the aforementioned protected areas. The Natura 2000 sites cover 10,696.85 km², representing approximately 42% of the study area. These significant proportions underscore the ecological importance of the region.

Following the Köppen-Geier climate classification, most of the study area falls within the temperate climatic zone. The areas of Latium and Campania that are closest to the Tyrrhenian coasts are characterised by typical Mediterranean climate, with warm to very hot and dry summers, and mild to cool winters. The central part, where the altitude becomes higher, has a more oceanic climate, with cool summers and mild winters, and no dry seasons. However, the highest areas of the Apennines and the internal plateaus, mostly occurring near the aforementioned national and regional parks, experience

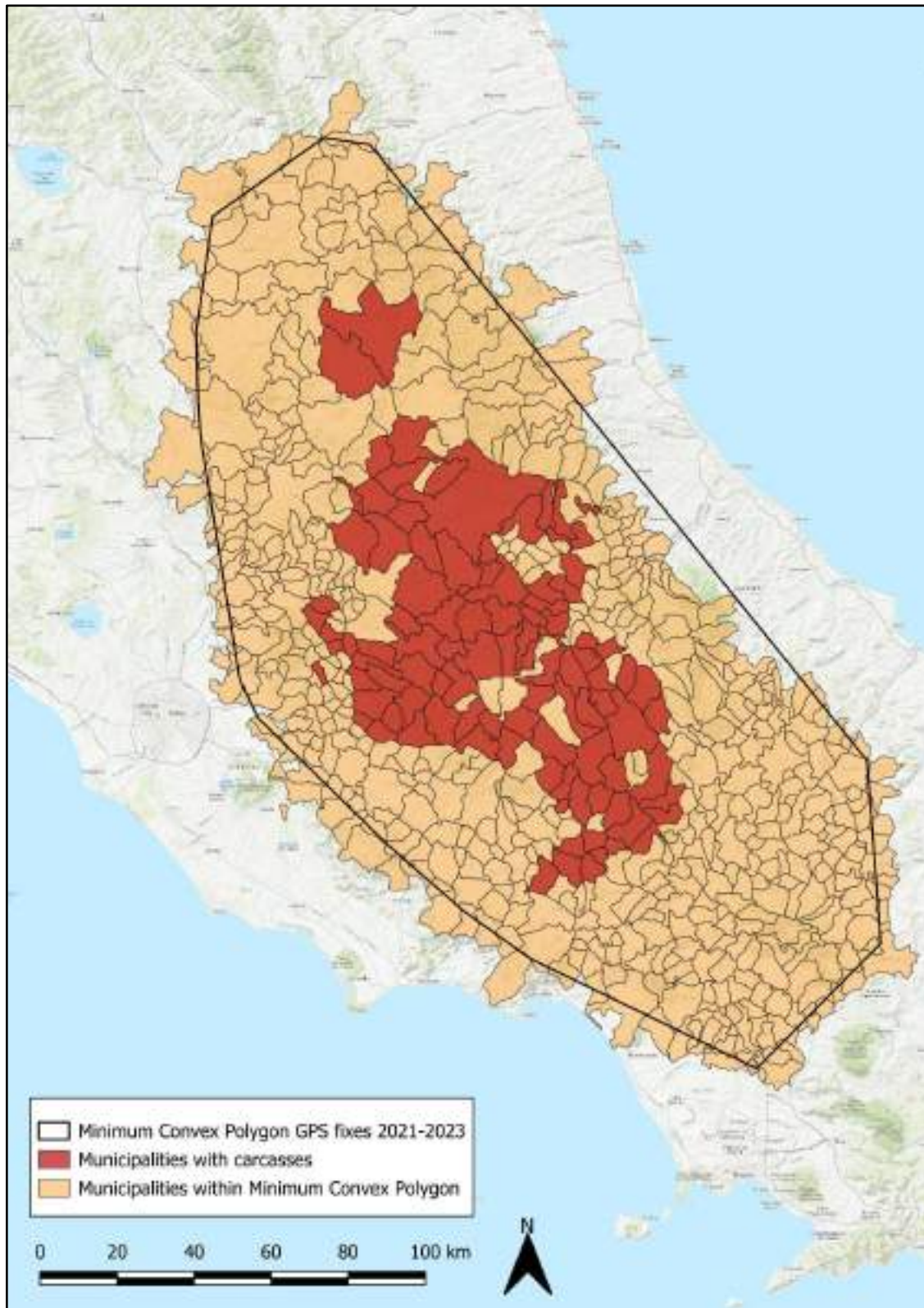


Figure 1. Map of the study area. The area highlights the municipalities selected based on a Minimum Convex Polygon (MCP) derived from Griffon vultures GPS locations (2021–2023). Peripheral municipalities with negligible vulture presence were excluded to maintain the functional consistency of the study area.

much colder climates, classified as continental climate, and characterised by long and cold winters and short, warm to cool summers. Precipitations of the continental climate area are variable, but the project area generally has a humid continental climate.

The highest mean annual temperatures are around 15°C, and they are registered in the lower altitude areas of Campania and Latium, while the lowest mean annual temperature, as expected, occurs in the highest peaks of the Apennines. The areas with the highest annual precipitation occur mostly in the lowlands of Latium, and especially in the province of Frosinone, with precipitation peaking more than 1,000 mm/year. On the contrary, the driest areas occur in Molise, and especially in the areas closest to the Adriatic sea, in the province of Campobasso, and in the province of Terni, in Umbria, with maximums of around 600 mm/year.

Regarding its geography, the study area is mostly located in the central Apennines, with a small portion of the southern Apennines. The highest peaks of the area include Corno Grande (Gran Sasso massif, 2,912 m a.s.l.), Monte Amaro (Maiella massif, 2,793 m a.s.l.), Monte Velino (2,486 m a.s.l.) and Monte Vettore (2,476 m a.s.l.). The area is characterised by steep slopes on the eastern fringes of the Apennines towards the Adriatic coast, while the western slopes are shallower and forming foothills towards the west. The mean elevation in the study area is 821 m, with the lowest elevation at sea level where the study area encounters the Tyrrhenian coasts between Latium and Campania.

The central Apennines are a rugged terrain with mountain chains interrupted by valleys and plains that hold the majority of the bigger cities. Examples are the Valle Peligna, Valle Aterno/Pescara, Valle del Sangro, Vallerlonga and the Fucino basin, which is the largest plain in the central Apennines and once contained Italy's 3rd largest lake (Lago Fucino). The biggest rivers in the area are the Pescara, Sangro and Aterno rivers in the eastern part, flowing towards the Adriatic coast and the Nera and Aniene the major rivers in the Western part, flowing towards the Tyrrhenian sea. The small portion of the southern Apennines, south of Sangro valley are defined by smaller mountain chains with the Matese mountains marking the southern border of the study area. The major river in this area is the Liri.

According to the land cover classification by the European Space Agency, the majority of the study area is covered by forests, whose surfaces extend over 60% of the study area. Following, grassland extends over 23% of the study area, cropland accounts for 9%, shrubland over 4% and urban areas over 3%. Other land cover classes are, in proportion, much less represented in the study area.

The climatic and topographic diversity of the central Apennines is characterised by a diversity of habitats and vegetation types whose description goes far beyond the aims of this feasibility study. The following notes should be only considered as general indication with respect to the vegetation landscape, which is also characterised by diverse and various kinds of agriculture, from intensive cropland to organic farming. Lower elevations are characterised by the predominance of mixed sclerophyllous evergreen oak forests, such as *Quercus ilex* and *Q. suber*, as well as deciduous, often oak-dominated forests, where most common tree species are as *Quercus pubescens*, *Fraxinus ornus*, *Ostrya carpinifolia* and *Celtis australis*. At medium elevations, mixed deciduous forests of *Quercus cerris*, *Q. pubescens*, *Q. frainetto*, *Castanea sativa* and *Ostrya carpinifolia* are mostly common. Higher elevations are characterised by a variety of mixed deciduous forests, of which beech (*Fagus sylvatica*) represents the most common species dominating the tree canopy. Among other common species we find maples (e.g., *Acer pseudoplatanus*, *A. platanoides* and

A. obtusatum), *Sorbus aria*, *S. aucuparia*, *S. torminalis*, *Ulmus glabra*, *Tilia platyphyllos*, *Populus tremula*, *Ilex aquifolium* and *Taxus baccata*. The mountain summits are mostly characterised by herbaceous vegetation, shrubs and alpine meadows, and not rarely characterised by extended rocky outcrops, cliffs and gorges. Shrubs include *Juniperus communis* subsp. *nana*, *Atadinus alpinus*, *Sorbus chamaemespilus*, *Arctostaphylos uva-ursi*, *Vaccinium vitis-idaea* and relict *Pinus mugo*, while in the alpine meadows common species are *Brachipodium* sp. pl., *Festuca* sp. pl., *Gentiana lutea*, *G. dinarica*, *G. nivalis*, *Androsace alpina*, *Polygala chamaebuxus*, *Saxifraga oppositifolia*, *Ranunculus seguieri* and *Carlina acaulis*. Herbaceous vegetation (generically grassland), covers a large part of the landscape, both as primary and secondary vegetation and habitats.

Chapter 8

Expert-opinion suitability assessment: field surveys in the central Apennines

Enrico Bassi, Nicolò Borgianni, Mario Cipollone,
Fabrizio Cordischi, Fulvio Genero, Marleen Huyghe,
Emma Néouze, Raphaël Néouze, Giulia Pace,
and Mario Posillico



1. Introduction

In addition to the planned habitat assessment in terms of stochastic habitat modelling ((chapters 9, 10 and 13), we carried out two field surveys with researchers who had renown specific expertise on both concerned species and successful vulture translocation projects. The aim of the surveys was to evaluate the presence and availability of specific resources, *e.g.*, suitable nesting trees, which cannot be identified by habitat modelling through available digital layers. Furthermore, field surveys also aimed at assessing the overall suitability of an area, through an expert-based comparison between some central Apennines sites and other areas, well known by the involved researchers, where successful reintroductions have been carried out. We felt that it was useful to evaluate areas based on direct surveys in addition to other approaches even as a complimentary approach.

The first surveys were carried out in June 2023. Besides consultants directly involved in writing the feasibility study with specific expertise on some vulture species (Fulvio Genero, Enrico Bassi, Mario Posillico), Marleen Huyghe (former Studbookkeeper for the cinereous vulture at Planckendael zoo in Belgium) and Raphaël Néouze (external consultant from LPO Birdlife France) participated in the surveys along with a large base of Rewilding Apennines' personnel (Mario Cipollone, Fabrizio Cordischi, Giulia Pace, Nicolò Borgiaanni) and Annalisa Brucoli within ARDEA (Associazione per la Ricerca, la Divulgazione e l'Educazione Ambientale). From October 28th to November 4th 2023, a further survey was carried out by Emma and Raphaël Néouze who assessed some areas, especially in the Abruzzo, Lazio and Molise National Park, that were not previously evaluated due to meteorological constraints earlier in June. The surveys were organised with the intention of not only visiting the areas and getting more confident with their environmental characteristics, but also to meet and discuss the translocation project with local stakeholders, which at this stage were mainly represented by managers of protected areas (parks, reserves and Natura2000 sites).

The main topics to be assessed in the field and advice from local stakeholders or local experts were acquired and discussed during the inspection of each site. Later on, we discussed our notes on the field surveys through briefings (figure 1) and drafted our reports on the same day with all participants. Rewilding Apennines compiled the drafts, which were distributed to the people involved, and comments were discussed and integrated into the report. A synthesis of the reports is given below and the location of the surveyed site is shown on map 1.



Figure 1. Rewilding Apennines Team Leader presenting the field trip to the vulture experts.

2. June 2023 survey

Day 1 (June 12th)

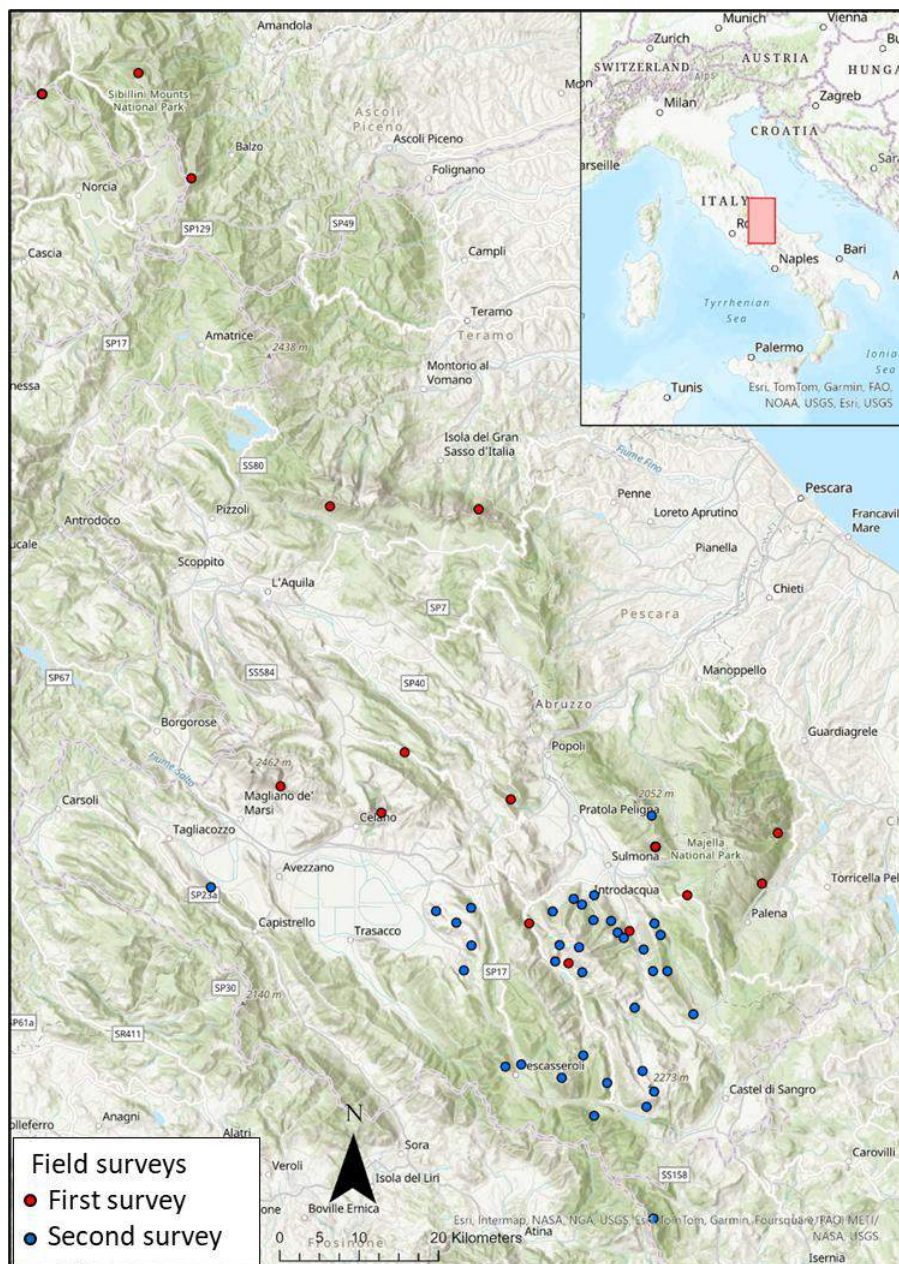
Concerned protected areas: *Gole del Sagittario* Regional Reserve and *Gole di San Venanzio* Regional Reserve

Assessed sites

1- Castrovalva (observation point in front of the eagle's nest, figure 2). According to an overall assessment, the valley is very suitable for the cinereous vulture due to the presence of many evergreen trees on steep walls. These vultures usually nest on the upper third of the cliff. Four or five locations on the visible portion of the cliffs would be ideal for nests. Winter temperatures that rarely drop below 0 during the night, according to Sefora Inzaghi - manager of Gole del Sagittario Regional Reserve, are an advantage. The Reserve covers about 500 hectares. Intense rains in May (like – exceptionally - in 2023), can lead to poor reproductive years, though continuous rain in that area is very uncommon in Spring.

2- Frattura (Figure 3). There are interesting cavities as hacking sites for both the cinereous and the bearded vultures (at least 2 cavities), but it is necessary to determine their accessibility. The aerology (wind conditions) of the area also needs to be verified. The valley is considered interesting (adjacent to the Abruzzo, Lazio and Molise National Park and bordering Monte Genzana-Alto Gizio Regional Reserve), however, it is less favourable for nesting due to some disturbance from grazing livestock and especially human activities. The situation on the opposite side of the valley might be better as to disturbance. Regarding the localization of an eventual acclimatisation aviary, there was one near Frattura, which was used during the second phase of the reintroduction of griffon vultures (2000-2002) and was surrounded by a fence, enclosing a few hectares buffer. Eventually, the aviary should be rebuilt from scratch and the

surrounding fence should be fixed. A good approach for the cinereous vultures might involve both methodologies (hacking and soft release of immatures). It should also be considered that it will be necessary to build a feeding station near the aviary. The area is outside the boundaries of PNALM, but is within its external buffer and partly encompasses two Natura 2000 sites.



Map 1. Location of the surveyed sites during the first (June 2023) and second (October-November 2023) field surveys. Mt. Prena and Mt. Corvo areas were not directly assessed and are not shown in the map. For Taranta Peligna Valley and Taranta Peligna Cliffs a single landmark is represented on the map because of their nearness.

SITE (Lat., Long.)	PROS	CONS	OVERALL SUITABILITY	
			Cinereous vulture	Bearded vulture
CASTROVALVA (41.979738, 13.806735)	<ul style="list-style-type: none"> • Good availability of nesting trees (<i>Pinus nigra</i>) • Very steep rocky cliffs 	<ul style="list-style-type: none"> • Medium voltage power line owned by E-Distribuzione, on a small tunnel in front of the village. • Proximity to Cocullo (windmills and past poisoning area). • Small-sized reserve (politically not strong). 	X	

3- Gole di San Venanzio. The area extends for about 100 hectares. The area could be considered as suitable for the cinereous vulture but not for the bearded vulture. There is a golden eagle pair regularly breeding in the gorges.

SITE (Lat., Long.)	PROS	CONS	OVERALL SUITABILITY	
			Cinereous vulture	Bearded vulture
FRATTURA/MONTE GENZANA (41.935397, 13.867355)	<ul style="list-style-type: none"> • Griffon vultures have already been released in the area • The area is open habitat and easy to monitor • Near protected area (buffer zone of PNALM) 	<ul style="list-style-type: none"> • Few trees • Anthropogenic disturbance 	X	
GOLE DI SAN VENANZIO (42.119915, 13.776088)	<ul style="list-style-type: none"> • Wild canyon • No powerline, but at the very bottom, no wind turbines • Good nesting trees • The area is well connected to the Sirente Velino Regional Park 	<ul style="list-style-type: none"> • No good release sites • Small protected area 	X	



Figure 2. Gole del Sagittario Regional Nature Reserve.

Figure 3. The group in front of the Frattura cliffs.

Day 2 (June 13th)

Concerned protected areas: Sirente Velino Regional Park and Monte Velino State Reserve.

Assessed sites

4- AIELLI-CELANO GORGE. The habitat is suitable for the cinereous vulture, but less if compared to the Gole del Sagittario. There are fewer evergreen trees on the cliffs and griffon vultures (with a breeding colony) are present, albeit quite far from the trees indicated for the cinereous vulture's nesting (Figure 4). Tourism could be a potential source of disturbance, though the access to the bottom of the gorges is often forbidden due to rockfall.

In conclusion, it might be a suitable location for the release of the cinereous vulture, but not for reproduction. Indeed, the site is not fit for the presence of multiple pairs.

The biologist of the Sirente Velino Regional Park, Paola Morini, who joined the morning survey, confirms her availability for the feasibility study and the reintroduction project. This regional park, covering approximately 540 km², would be a strategic area due to the abundance of grazing livestock and wild ungulates. Additionally, it holds significance as the first release site for griffon vultures in the 1990s. Acclimatisation aviaries are still present near the Costa Grande location, in the Monte Velino State Reserve managed by Carabinieri Forestali and, nearby, RA has restored a feeding station for vultures.

5- Mt. SIRENTE NORTH FACE. The observation of the cliff (> 3 km long) was carried out from Prati del Sirente. The slope is suitable for the bearded vulture. The elevation is comparable to that where they nest in the Alps (average nest height 2,200 m a.s.l.) with suitable cliffs, significant karst features, and cavities (also suitable for release by hacking). However, the nests to be identified for hacking should be at a certain height from the bottom of the cliff/slope and at a certain distance from the forest to prevent the chicks from ending up among the trees after fledging. Regarding trophic resources, there are a few chamois (about 70, but growing population) on Mt. Sirente slopes, while deer, wild boar and livestock are abundant. There are also open areas and breaking-bone sites. Tourism could be a potential issue, especially from ski mountaineers, although Bassi states that winter sports in the Alps are much more practised and do not pose an excessive problem if they remain within legal limits. The area also appears suitable for nest monitoring, and there seem to be no dangerous infrastructures in the vicinity (cableways, ski lifts, power lines etc.).

6- MAJELAMA VALLEY. It is close to a feeding station which Rewilding Apennines has recently restored as well as Forestry Carabinieri's aviaries, it could be suitable for releasing cinereous vultures (Figure 5). Unfortunately, adverse weather conditions have not allowed for more in-depth observations or comments. There are few, if any, pine trees to support cinereous vulture nesting, though nesting platforms could be built on other tree species.

SITE (Lat., Long.)	PROS	CONS	OVERALL SUITABILITY	
			Cinereous vulture	Bearded vulture
AIELLI-CELANO GORGE (42.102851, 13.579142)	<ul style="list-style-type: none"> ● Low-human presence ● Good release location ● Protected and surveilled area ● Proximity to a feeding station. 	<ul style="list-style-type: none"> ● High density of griffon vultures (probable food competition) ● No farming supportive policies ● Poisoning events 	X	
MT. SIRENTE NORTH FACE (42.171654, 13.613086)	<ul style="list-style-type: none"> ● Protected area ● Good presence of livestock and deer ● Limestone cliffs ● Presence of breaking-bone sites and cavities for release accessible by humans ● Monitoring ● Availability of carrion bones Massa d'Albe ● No power lines ● No infrastructures (except for Ovindoli) 	<ul style="list-style-type: none"> ● Chamois ● Tourist disturbance 		X
MAJELAMA VALLEY (42.130392, 13.424988)	<ul style="list-style-type: none"> ● Close to Costa Grande feeding station and griffon vultures acclimatisation aviaries ● Rich in wild ungulates and livestock ● No infrastructures ● Protected area 	<ul style="list-style-type: none"> ● No pine trees 	X	



Figure 4. Aielli-Celano Gorge.



Figure 5. Looking towards Majelama valley.

Day 3 (June 14th)

Concerned protected areas: Gran Sasso and Monti della Laga National Park

Assessed sites

7- MALECOSTE. According to park unpublished reports, approximately 1,500 chamois, 3,000 wild boars, and no fewer than 500 deer are present in the whole Gran Sasso and Monti della Laga National Park (Carlo Artese personal communication). The wall is potentially suitable for the bearded vulture, but clouds greatly hinder visibility. The altitude reaches 2,400 metres a.s.l. In front of Malecoste, on the opposite side of the valley, there is a lower and rounder relief with trees that could be suitable for cinereous vulture nesting. In the whole area there are many, even though fragmented, conifer reforestations.

8- MT. CAMICIA NORTH FACE. Suitable habitat for the bearded vulture but not for the cinereous vulture. There are areas of light rock on the cliff classifying it as a drier zone, which is more suitable than dark areas that are usually wet for most of the year. Regrettably, heavy rainfall prevented further assessments along the rich huge rock wall complexes which characterise the north face of the whole Gran Sasso massif. Monte Corvo and Monte Prena (Gran Sasso massif) have also been judged as suitable for the bearded vulture, according to the feasibility study by Genero et al. (2010)³³. Thus, based on this study, they have been added in the relevant table below. The third day of the survey was affected by adverse weather conditions (rain and fog on the mountain summits and slopes) and therefore its outcome should be considered a partial one.

³³ Genero F., Allavena S., Angelini J., Ceccolini G. and G. Gaibani. 2010. Analisi di fattibilità per la reintroduzione del Gipeto (*Gypaetus barbatus*) e il ripopolamento del Grifone (*Gyps fulvus*) nell'Appennino centrale. Parco Nazionale del Gran Sasso e Monti della Laga – Parco Nazionale dei Monti Sibillini. Versione 1.0. 109 pp.

SITE (Lat., Long.)	PROS	CONS	OVERALL SUITABILITY	
			Cinereous vulture	Bearded vulture
MALECOSTE (42.448322, 13.492630)	<ul style="list-style-type: none"> Abundant presence of griffon vultures, especially in the summer. Active surveillance. Presence of wild ungulates and livestock animals. Locations in Gravona and Pizzo Cefalone are probably suitable but not evaluable due to adverse weather conditions. Only the lower and side area is suitable for the cinereous vulture. 	<ul style="list-style-type: none"> Campo Imperatore ski facilities 	X	X
MT. CAMICIA NORTH FACE (42.447810, 13.720776)	<ul style="list-style-type: none"> White cliffs with ledges. Protected area. No power lines (to be verified more thoroughly). 			X
MONTE CORVO (western summit: 42.47932, 13.49331)	Not assessed during the survey, though positively evaluated for the bearded vulture by Genero et al. (2010)		NA	X
MONTE PRENA (summit: 42.44238, 13.68321)			NA	X

Day 4 (June 15th)

Concerned protected areas: Monti Sibillini National Park

GENERAL INFORMATION. Monti Sibillini National Park covers approximately 70,000 hectares. The southern chamois was reintroduced to Monte Bove in 2008 (10 km from Monte Vettore). In his aforementioned study, Genero et al (2010) suggested Monte Bove and Monte Vettore for the release of bearded vultures. In both Monte Bove and Monte Vettore there are two golden eagle pairs territories (Jacopo Angelini, personal communication). A fruitful meeting with the national park scientific staff (Alessandro Rossetti and Paolo Salvi) occurred before the surveys of June 15th (Figure 6).

Assessed sites

9- MT. BOVE NORTH FACE. Extensive cliffs, suitable for the bearded vulture, but too high in elevation for the cinereous vulture. Some downhill ski facilities could bear disturbance to the area. An unimproved road along with downhill ski facilities could favour accessibility to the area for hacking operations. A medium voltage powerline is present though it should not bear a high risk due to its positioning. Very wide and extended high elevation mountain habitat. There is a golden eagles pair, whose nest is said to have been there for more than 400-500 years. A nucleus of Southern chamois occurs in the Mt. Bove area.

10- MT. VETTORE SOUTHEAST FACE. The cliff could be suitable for the bearded vulture but considered too high in elevation for the cinereous vulture. Among the pros, what stands out is the lack of power lines and low human presence (very few equipped climbing areas subject to strict regulation, few trails mostly along the valley ridge, and almost no overflights with light aircraft such as gliders and paragliders), as well as the

presence of a good and growing chamois population as trophic resource. Additionally, suitable cavities for the introduction of the bearded vulture through hacking (accessible to humans and of suitable size) have been identified.

11- UPPER VALNERINA GORGES. It is an extended stretch of cliffs on both sides of the valley. The paved road at the bottom and some powerlines (medium-voltage) could represent a threat due to disturbance and electrocution. Woodland is quite abundant, mainly broadleaved, although suitable nesting-trees for the Cinereous vulture are likely quite rare. The area better fits the needs of the griffon vulture.



Figure 6. Meeting with national park scientific staff (Paolo Salvi and Alessandro Rossetti).

Overall, the most potentially suitable areas for the bearded vulture reintroduction are:

- Monte Bove, particularly the north-east slopes (figure 7)
- Monte Vettore: southern face
- Monte Argentella
- Pizzo del Diavolo (2,400 m).



Figure 7. Monte Bove north face, in the Monti Sibillini National Park.

SITE (Lat., Long.)	PROS	CONS	OVERALL SUITABILITY	
			Cinereous vulture	Bearded vulture
MT. BOVE NORTH FACE (42.934542, 13.184693)	<ul style="list-style-type: none"> ● Good availability of open habitat for bearded vultures and cinereous vultures. 	<ul style="list-style-type: none"> ● Ski lifts ● Medium voltage power line (but not very dangerous) 	X	X
MT. VETTORE SOUTH-EAST FACE (42.816868, 13.270382)	<ul style="list-style-type: none"> ● No powerline ● No ski area ● Good exposure ● No helicopters allowed ● Presence of deer, horses, and cows ● Possible release sites in the Ambro gorges (Infernaccio) and near M.te Bove 	<ul style="list-style-type: none"> ● Only 50 chamois (natural recolonization) ● Sheep only from May to October ● Paragliding allowed in the plain of Castelluccio 		X
UPPER VALNERINA VALLEY GORGES (42.918950, 13.051041) (more suitable for Griffon vulture)	<ul style="list-style-type: none"> ● Long stretch of cliffs ● Tree vegetation 	<ul style="list-style-type: none"> ● Medium voltage powerline in some sectors of the gorges ● Paved road at valley bottom ● Sensitive to some disturbance 	X	

Day 5 (June 16th)

Concerned protected areas: Maiella National Park and Monte Genzana-Alto Gizio Regional Reserve

Assessed sites

12- PETTORANO SUL GIZIO (Monte Genzana Regional Nature Reserve)

- Positive aspects identified for the cinereous vulture include the presence of large conifers, very positive relationship with the management board of the reserve, the presence of the RA team on-site, and the fact that the area is not very crowded with tourists.
- The area around Pettorano sul Gizio could be ideal to start company-owned feeding stations given the positive relationships with breeders.
- Negative points include the relative proximity to the Cocullo wind farm and some of the potential nesting areas near the village (figure 8). There is a power line running in the lower part of the eastern slopes of the reserve, which could pose some danger.



Figure 8. Assessors at Pettorano Sul Gizio Regional Reserve. In the background some conifer reforestations.

13- PACENTRO SLOPES

- Suitable for the cinereous vulture.

There is an old chamois enclosure that could be suitable for acclimatisation aviaries and, consequently, for the release of cinereous vultures. It is located within the Maiella National Park, a protected area of 75,000 hectares, with a chamois population of about 1,500 individuals and abundant red deer and wild boar.

14- CAMPO DI GIOVE CLIFFS

CINEREOUS VULTURE

- Cliffs and vegetation are suboptimal, with high altitude at the upper limit but still suitable.
- Anthropogenic disturbance due to a cableway (used less in winter, more in summer).

BEARDED VULTURE

- Suitable cavities and cliffs are present, with a large scree, an excellent bone-breaking site.
- Somewhat low in altitude, with a low risk of avalanches.
- Not an ideal release area (too many trees, difficult to monitor, disturbance from hikers).

15a- TARANTA PELIGNA (cliffs)

- Potentially good for griffon vultures, although they do not frequent the area.
- Presence of a power line.

15b- TARANTA PELIGNA VALLEY

CINEREOUS VULTURE: conditions are good. The presence of the lift system to the Cavallone caves, which operates in summer, could be a disturbance. A breeding golden eagle pair is steadily present. The area has not been thoroughly assessed due to logistical constraints.

BEARDED VULTURE AND GRIFFON VULTURE: Excellent for both species, with good places for hacking (bearded vulture) and suitable roosting and nesting sites for the griffon vulture.

Other general information:

- There is a road, but it is not busy (except in the summer).
- Power line with helicord (less problematic).
- Presence of a cable way in the lower half of the valley (con).
- The area seems to have good aerology and thermals, there is a breeding golden eagle pair.
- Presence of at least one scree, useful for bone breaking.

16- FARA SAN MARTINO GORGE

Considerations are quite like those of the previous valley. The area has been screened at a distance due to logistical constraints.

SITE (Lat., Long.)	PROS	CONS	Overall suitability	
			Cinereous vulture	Bearded vulture
PETTORANO SUL GIZIO (41.972641, 13.959349)	<ul style="list-style-type: none"> ● Large pines ● Protected area ● Area monitored by RA ● No disturbance ● Easy to monitor and excellent relations with the Nature Reserve ● No infrastructures ● Possible release sites (Valle Marsolina) 	<ul style="list-style-type: none"> ● Cocullo power plant ● Medium and high voltage powerline (to check) ● No rangers (but Carabinieri Forestali) 	X	
CAMPO DI GIOVE (42.013963, 14.046486)	<ul style="list-style-type: none"> ● Protected area ● Chamois population in the park: 1,500 ● Possible feeding site in Pacentro ● Good cliffs (no cavities) ● Scree for bone-breaking ● Trophic resources 	<ul style="list-style-type: none"> ● Ski slopes ● Anthropoc disturbance 		X

TARANTA PELIGNA (cliffs) (for griffon vulture)	<ul style="list-style-type: none"> Favourable aspect of the cliffs 	<ul style="list-style-type: none"> Medium voltage powerline Sport climbing Limited grazing Potential human disturbance 		
TARANTA PELIGNA VALLEY (42.028155, 14.160202)	<ul style="list-style-type: none"> Protected area Extensive rocky complexes Holm oaks and pines (<i>Pinus sp.</i>) suitable for the cinereous vulture Road closed to traffic for hacking Good cavities Bone-breaking site Roosting site Wealthy chamois population 	<ul style="list-style-type: none"> Few livestock Cable line along the road Cableway Few griffon vultures Doubtful release site for cinereous 	X	X
FARA SAN MARTINO GORGE (42.085683, 14.183539)	<ul style="list-style-type: none"> Very good for bearded and griffon vultures (observed from a distance) 	<ul style="list-style-type: none"> Few livestock Rarely occurring griffon vultures Few suitable trees for cinereous vulture 	X	X

3. October-November 2023 survey

The second survey was carried out from October 28th to November 4th 2023 by Emma and Raphaël Néouze. The purpose was to continue checking suitability in further areas, especially in the southern griffon vulture range within which the Abruzzo, Lazio and Molise National Park is located.

In addition to the previous evaluation approach, suitability here was also ranked on a 6 level scale, from 0/5 (not suitable) to 5/5 very suitable:

Habitat suitability rating scale:

0/5 – No interest

1/5 – Very little possibility

2/5 – Possible site







3/5 – Very probable site

4/5 – Suitable site

5/5 – Very suitable site

The outcome of the survey, with respect to the investigated sites, was reported in the following maps according to the legend below.

Legend:

-  Area not checked but planned for suitability study
-  Area of interest as potentially suitable habitat for cinereous vultures
-  Area with suitable habitat for cinereous vultures
-  Area with a potentially suitable habitat for bearded vultures
-  Site that could be studied further as a potential release site for cinereous vultures
-  Site that could be studied further as a potential release site for bearded vultures

1) Petrella Liri (Cappadocia municipality)**Figure 9.** Map of Petrella Liri area.

This area is hosting a fair part of the breeding colony of griffon vultures. The only very few patches of suitable pine tree cover are situated along the cliffs and close to the villages and human infrastructures. Another potential nesting site in a patch of pine trees is situated close to the village of Tagliacozzo. These elements together with the strong presence of griffon vultures make it a low rated area for the reproduction of cinereous vulture and bearded vulture.

Threats: human presence is important with all the indirect threats implicated.

Interests: the project for a communal natural recycling station nearby (village of Verrecchie, Cappadocia municipality) represents a strong interest together with the presence of positive local inhabitants and elected representatives.

Other elements: deciduous trees cover most of this area which makes it unsuitable for reproduction as well as for the availability of small wildlife carcasses.

Habitat suitability rating: 1/5

2) Abruzzo, Lazio and Molise National Park



Figure 10. Map of the central-northern Abruzzo, Lazio and Molise National Park.

2.1.) Valle Macrana

This small valley is pretty interesting as it is quiet, fairly rocky and steep with a few pine trees. The rocky small cliffs are certainly too small for the bearded vulture but they could be used by cinereous vultures.

Threats: the presence of a Golden Eagle pair will represent a difficulty for cinereous vultures and bearded vultures to settle there.

Interests: food availability and little human disturbances.

Other elements: close to Rewilding Apennines' head office.

Habitat suitability rating: 2/5

2.2.) Area around Gioia dei Marsi

This area was not in the list suggested by the staff from Rewilding Apennines. However, it represents a fairly interesting one, as it does not present any paths or real interest for trekking and there are some patches of suitable habitats worth of consideration for the cinereous vulture. Hunting poses a threat, but it could be reasonably managed, modulating hunting activity in accordance with relevant stakeholders. Above all, this area is situated next to the village of Gioia dei Marsi where Rewilding Apennines has its head office and a house to host volunteers. Together, these elements make this area an interesting option to establish a release site for cinereous vulture. It would be easy to reach and it would be easy to monitor from the village or the surrounding hills. This sector has another advantage as it is situated in the main range of the griffon vulture's movements but also quite far from the griffon vulture's reproducing colonies which could make the food management easier as well as put less pressure on the young cinereous vultures. A disadvantage for this area is that it is not within the Abruzzo, Lazio and Molise National Park or in any protected area.

Threats: some power lines in the surroundings, hunting at season

Interests: close to the office/house of Rewilding Apennines

Habitat suitability rating: 3/5

2.3.) Area around Pescasseroli



Figure 11. Map of the area around Pescasseroli.

Because it is close to the sector of Camosciara, a few patches of pine trees could be of interest for cinereous vultures in this area which was not in the list of suggested sites.

Threats: the human presence is important with all the indirect threats implicated.

Interests: in the range of the Abruzzo, Lazio and Molise National Park.

Habitat suitability rating: 2/5

2.4.) La Camosciara

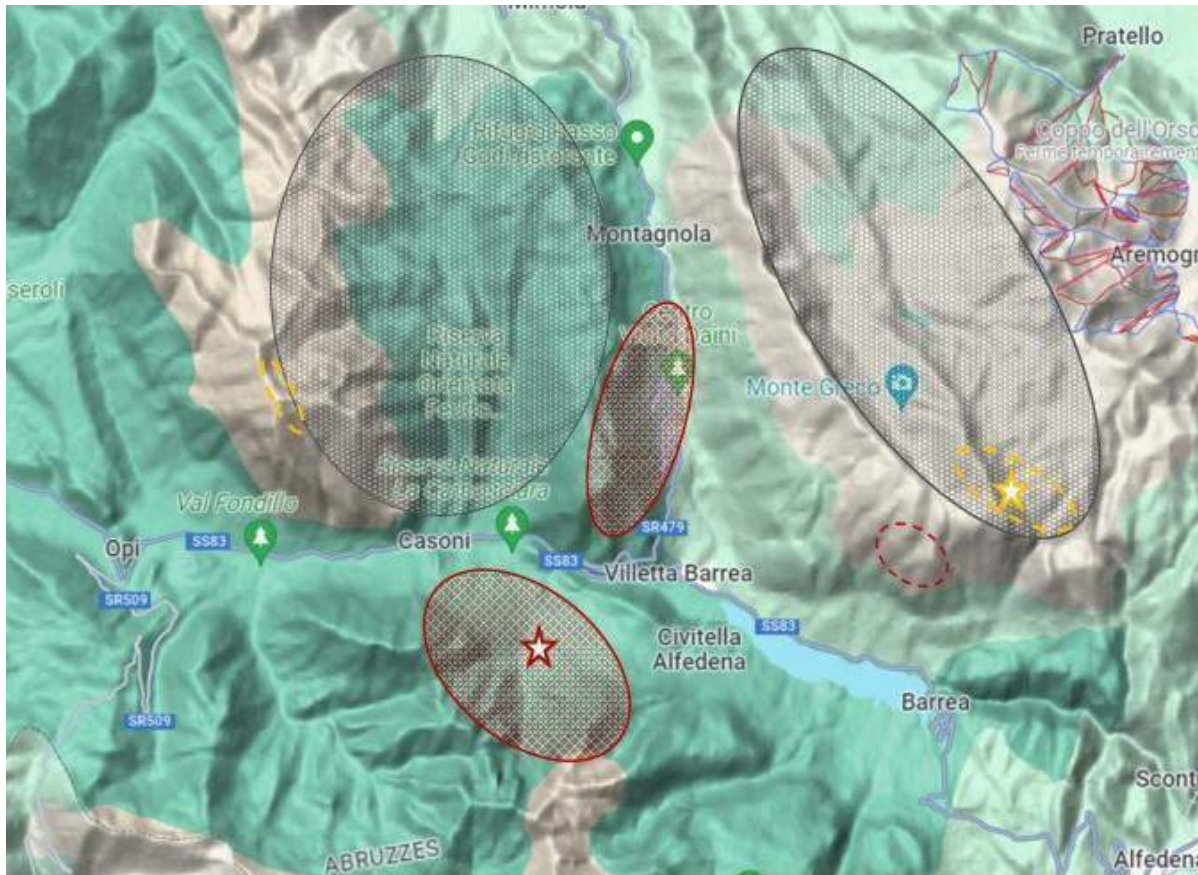


Figure 12. Map of the area around La Camosciara.

This sector is probably the most suitable for the reproduction of the cinereous vulture in the Abruzzo, Lazio and Molise National Park and even in the whole Apennine region. It is a particularly well protected area (Integral Biosphere reserve) with no human disturbance. It presents some rocky steep slopes covered by sparse old pine trees that look like platforms. There is some livestock breeding all around the area and the Abruzzo, Lazio and Molise National Park owns some farm buildings that could be the base camp for the monitoring team of a release site in this sector. It is also an interesting territory for bearded vulture reproduction. This southern part of the Abruzzo, Lazio and Molise National Park is on the edge of the main range of griffon vulture movements. This could be an advantage to help settle the two species and to run release sites.

Threats: relatively few threats in the very nearest environment. There are a few power lines close by and the presence of the golden eagles needs to be checked.

Interests: very well protected area (as it is within the Abruzzo, Lazio and Molise National Park) and the elevation and vegetation are ideal for cinereous vulture.

Other elements: this place could also be used for release as it is easy to access and to manage for the people from the Park and partners.

Habitat suitability rating: 5/5

2.5.) Monte Marsicano

The Monte Marsicano in itself does not hold a very interesting potential. Despite its nice dry and steep slopes, it is covered by deciduous trees and it is probably the best habitat for cinereous vultures. Some interesting cliffs and rocks in its south-western part could be of interest for some bearded vultures but this is not guaranteed. A fairly big population of southern chamois is present both on Mt. Marsicano and, in front of it, on Mt. Amaro.

On the East of the Monte Marsicano, the area of the Riserva Naturale Orientata Feudo e Colle di Licco, is not accessible as it is an integral reserve. The highest parts of this reserve are covered by deciduous trees with few conifer reforestations, though mainly located along the valley bottom and very sparsely through slopes. This area could present a good potential like the nearby Camosciara.

Threats: some power lines in the lower parts

Interests: easy to monitor from surrounding heights

Other elements: well protected area in the Abruzzo, Lazio and Molise National Park

Habitat suitability rating: 1/5

2.6.) Monte Mattone - Slopes above Villetta Barrea

There is a very interesting sector facing the Camosciara and above the village of Villetta Barrea. It is covered by old pine trees and the upper part is suitable for cinereous vultures. Its closeness to La Camosciara makes this whole sector interesting for the settlement of a nucleus of breeding cinereous vultures' pairs.

Threats: some power lines and the numerous trekking paths that could cause disturbance

Interests: not very easy to monitor from the road in the Valley

Habitat suitability rating: 4/5

2.7.) Foce di Barrea

This little valley downstream from the Lago di Barrea is not suitable for vultures as the cliffs are not high enough and the valley is really narrow. A golden eagle pair breeds regularly in the gorges.

Other elements: very difficult to access for monitoring

Habitat suitability rating: 1/5

2.8.) Southern slopes of Monte Greco

Even if Foce di Barrea seems unsuitable, the southern slopes of Monte Greco facing the village of Barrea are interesting. These slopes are accessible through a path of very rocky cliffs that lead to large accessible caves. Some higher parts could be exploited for monitoring and, therefore, this area could be used as a release site for bearded vultures. The whole sector of the Monte Greco could also be explored to check the presence of cliffs and rocky habitats that could suit the bearded vulture.

On the lower parts of these slopes toward the lake, a few patches of pine trees could be suitable for the cinereous vultures.

Habitat suitability rating: 3/5

3) Slopes close to Pescocostanzo (partly within Maiella national park)



Figure 13. Map of the area of Pescocostanzo.

As it is close to the sector of Pettorano sul Gizio, a few patches of pine trees are of interest for cinereous vultures in this area within the Maiella National Park, which was not in the list of suggested sites.

Threats: the human presence is important with all the indirect threats implicated.

Interests: easy to monitor if some cinereous vultures use these places.

Habitat suitability rating: 1/5

4) Valley from the road between Alfedena and Pizzone



Figure 14. Map of the area between Alfedena and Pizzone.

This sector, mostly included within the Abruzzo, Lazio and Molise national park and in its outer buffer area, facing the road that winds between Alfedena and Pizzone could be interesting if pine trees or evergreen trees were present. It is steep, rocky and apparently quiet, however, it is not certain that it would attract a pair of cinereous vultures.

Nevertheless, the very large and seemingly wild sector in the South-west direction from Pizzone could be investigated. The Monte Cavallo or La Meta and their rocky parts could be interesting regarding bearded vultures and the lower slopes could suit cinereous vultures.

Other elements: this sector is quite far from the offices of Rewilding Apennines and the partners, though it is very well patrolled by Abruzzo Lazio and Molise park rangers as well as Carabinieri Forestali.

Habitat suitability rating: 1/5

5) Monte Genzana Alto Gizio Regional Nature Reserve



Figure 15. Map of the Monte Genzana Alto Gizio Regional Nature Reserve.

This area is globally very interesting for the cinereous vultures. In the higher altitude it is covered with beech tree forest so it is not suitable. However, in some lower parts of the valleys, the steep rocky slopes covered with pine trees are highly suitable habitats, especially as they are orientated southward and therefore dry and covered by old pine trees. The valley above the village of Introdacqua is particularly interesting and suitable.

In this sector, it could be very interesting to settle a release site for cinereous vulture. This has to be assessed furthermore but it is a very convenient option because of the implication of the local elected representatives and the presence of the very favourable reserve managers.

Threats: the human presence is important with all the indirect threats implicated.

Interests: within an area where they are very dedicated and proactive local people and staff of the reserve.

Other elements: close to the office of Rewilding Apennines.

Habitat suitability rating: 4/5

5.1.) Valle Marsolina

This little valley is really pretty and quiet. It presents some patches of pine trees but the slope and height of the relief may not be sufficient for this area to be a suitable habitat for cinereous vultures.

Threats: people hiking on the paths.

Interests: within an area where there are dedicated and proactive Reserve and local people and staff of the reserve.

Other elements: close to the office of Rewilding Apennines.

Habitat suitability rating: 2/5

5.2.) Vallone Margherita

This is an interesting little valley. It is very suitable with its old pine trees and steep rocky slopes. It is in the heart of the Rewilding Apennines range.

Interests: within an area where they are very dedicated and proactive local people and staff of the reserve.

Other elements: close to the office of Rewilding Apennines.

Habitat suitability rating: 4/5

5.3.) West orientated slopes between Pettorano sul Gizio and Maiella National Park

Because it is close to the sector of Pettorano sul Gizio, a few patches of pine trees could be of interest for cinereous vultures in this area which was not in the list of the suggested sites.

Interests: Easy to monitor if some cinereous vultures use these places.

Habitat suitability rating: 1/5

5.4.) Slopes around Frattura, Villalago and Scanno

Once again, a few patches of pine trees could be of interest for cinereous vultures in this area.

Interests: easy to monitor if some cinereous vultures use these places.

Habitat suitability rating: 1/5

6) Surroundings of Sulmona



Figure 16. Map of the area around Sulmona.

The rocky slopes at the North-Eastern side of the city of Sulmona could be very interesting despite the irregular presence of pine trees. The area is included within Maiella National Park.

Also, the area between the villages of Cocullo and Pratola Peligna presents a few interesting patches of habitat. However, it would not be helpful that some cinereous vultures choose this area because of the presence of wind farms.

Threats: the human presence is important with all the indirect threats implicated.

Other elements: close to the office of Rewilding Apennines

Habitat suitability rating: 1/5

4. Conclusions

Based on the assessments made by the Rewilding Apennines team and the indications and suitability characteristics provided by the experts, 20 general areas were selected and surveyed and within those areas some sites were analysed and assessed.

The surveys found 14 sites to be suitable for the cinereous vulture and 10 for the bearded vulture. Of these, 5 were found to be suitable for both species. Many areas suitable for griffon vulture restocking were located in Maiella national park (pending some aerology consideration) as well as in Monti Sibillini national park: in peripheral areas of the griffon vulture core range, it would be preferable to proceed with griffon vulture restocking in order to reintroduce, later, the cinereous vulture.

Though the surveys could not check all the potential sites in the central Apennines, a satisfactory number of sites were positively evaluated for both the cinereous and the bearded vulture. Thus, we would expect that many more could be found. Breeding sites (*e.g.*, suitable nesting trees and suitable cliffs with

appropriate caves and ledges) were clearly recognised and should not be considered as a limiting factor. The most prominent issues at the sites are the proximity to wind farms and power lines, as well as the use of poison to kill animals deemed harmful, a crime that inevitably affects scavenger species. However, as for the LIFE BalkanDetox project, given appropriate actions are properly endorsed and threats effectively tackled, translocations have the potential to succeed.

Chapter 9

Habitat suitability modelling for the cinereous vulture and the bearded vulture in the central Apennines

Jan-Niklas Trei, Sarah Le Berre and Luca Chiaverini



1. Introduction

Habitat suitability modelling has been a central part of feasibility studies for the last decade as part of the guidelines provided by the IUCN (IUCN, 2013). The presence and availability of sufficient suitable habitat for the species which are the target of a reintroduction is critical to the success of the project (Osborne & Sedon 2012).

Species Distribution Modelling (SDM) has been widely used in recent years to understand important environmental factors for concerned species and assess or predict habitat suitability (Villero et al. 2017). Maximum entropy modelling (MaxEnt) (Phillips 2006) is among the most widely used algorithms for SDM with 714 research articles having MaxEnt in their topic according to Web of Science when accessed on April 19th, 2024. MaxEnt is particularly well adapted to datasets missing absence values, such as the ones often obtained from citizen science projects (Tye et al. 2016) and, despite being in use for nearly two decades, it still compares to more recent and complex SDM techniques (Ahmadi et al. 2023).

MaxEnt is a presence-based modelling approach based on the Maximum-Entropy principle (Phillips et al. 2006). Its general purpose is the modelling of geographical species distribution (both plant or animals, Phillips et al. 2006) and it has been used successfully to model habitat suitability of various species including raptors (Zhang et al. 2019, Dobrev & Popgeorgiev 2021). The Maximum entropy method is a general machine learning technique (Phillips et al. 2006). It assigns a probability of the species distribution to each pixel of the study site. The habitat suitability value therefore ranges from 0 (low) to 1 (high) (Phillips et al. 2006).

In this chapter, through MaxEnt, we will assess the habitat suitability for the two target species of this feasibility study, the cinereous vulture (*Aegypius monachus*) and the bearded vulture (*Gypaetus barbatus*), within the study area (Chapter 7).

2. Materials and methods

The study area encompasses an area slightly wider than the central Apennines in southern-central Italy, whose general description is given in Chapter 7. The study area represents most of the steady range of the griffon vulture (*Gyps fulvus*) in the central Apennines.

Presence points used to train MaxEnt for the cinereous vulture were recovered from GBIF.org (2024), while presence points for the bearded vulture were generously provided by the authors of Subedi et al. (2022). They were consequently filtered to keep only precise occurrences (georeferencing accuracy < 500 m) within the resident, reintroduced or breeding ranges, as classified by the IUCN Red List of Species for both vultures (BirdLife International 2021). To account for bias in data collection and over sampling of some areas, occurrences were filtered randomly using the R (R Core Team 2024) package spThin (Aiello-Lammens *et al.* 2015) with buffers of 10 km, 25 km, 50 km and 100 km. Each of these datasets were tested in MaxEnt and only the results from the best performing ones (10 km for both species) will be presented here. Model performance was evaluated based on AUC scores of the models. The two final datasets obtained had 533 occurrences for the cinereous vulture and 1239 for the bearded vulture.

The environmental variables used to train the model are the same ones as used in Subedi et al. 2022. They consist of a combination of climatic and topographical variables derived from the bioclimatic variables of the WorldClim database (<https://worldclim.org>, Hijmans et al. 2005): annual precipitation (“Bio12”), precipitation of driest month (“Bio14”), precipitation seasonality (“Bio15”), precipitation of coldest quarter (“Bio19”), mean diurnal temperature range (“Bio2”), temperature seasonality (“Bio4”), maximum temperature of the warmest month (“Bio5”), terrain slope and ruggedness. The resolution for the predictor layers is set at 2.5’ (4.5 km).

For the bearded vulture, 958 presence records were used to train the model, while for the Cinereous vulture 258 were used, which corresponds to ca. 75% of available presence points each. Apart from the number of presence points of each species, the same settings were used to set up the MaxEnt models. All variables were treated as continuous. The regularisation values are as follows: linear/quadratic/product: 0.050, categorical: 0.250, threshold: 1.000, hinge: 0.500, corresponding to used feature types: hinge, product, linear and quadratic. Additionally, response curves were created and a jackknife test applied to evaluate variable importance and individual training gain.

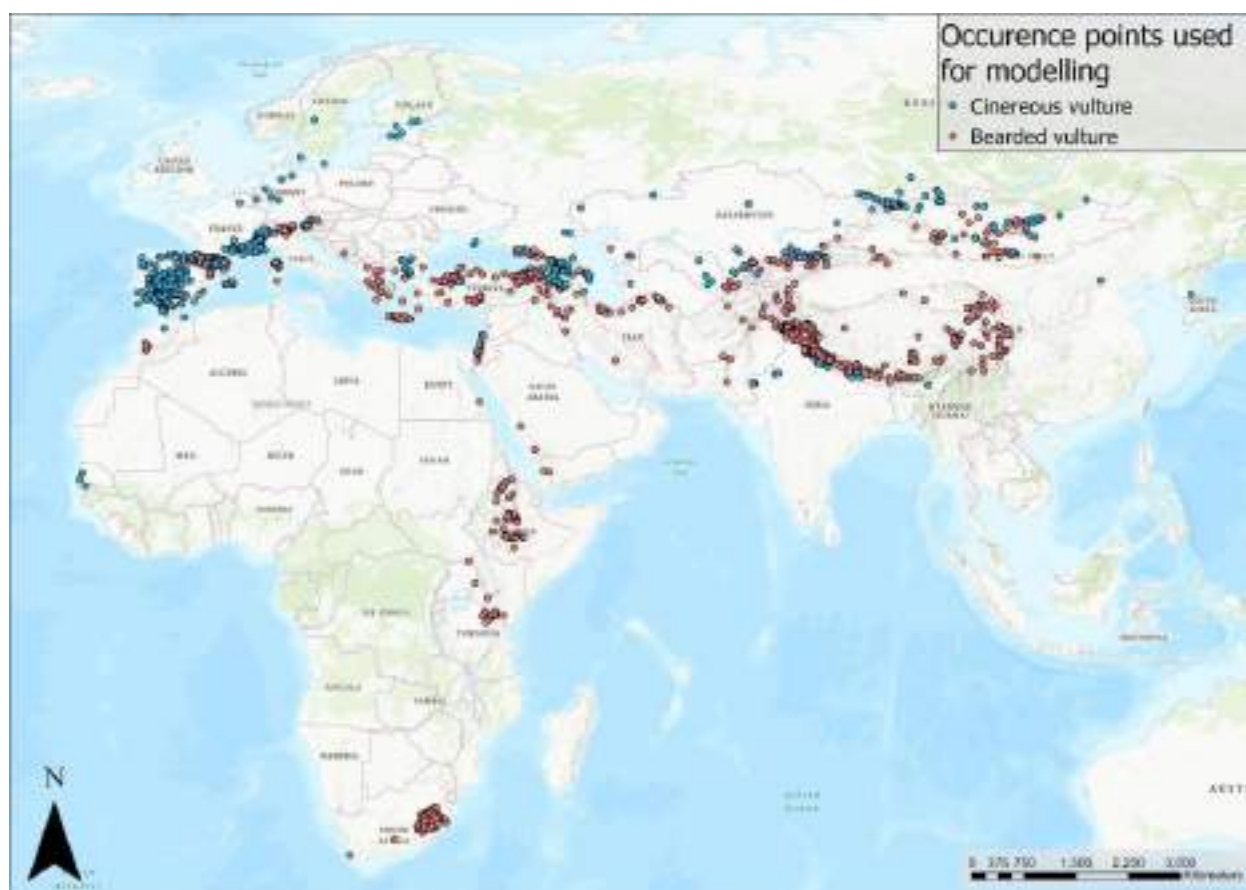


Figure 1. Species occurrence locations used in the models, thinned to 10 km minimum distance between each location (for each species respectively). The habitat suitability models for both species were run using the MaxEnt v. 3.4.4 software (Phillips et al. 2024) and the model was trained across the above defined ranges. The same extent is also used by the software to create the necessary pseudo-absences (10.000 random points). The predicted habitat suitability was subsequently projected for the whole area of Italy. Models were evaluated based on their Area Under Receiver Operating Characteristic Curve (AUC) scores and omission rate of the training data vs. the model prediction

(Phillips & Dudik 2008). Additionally, MaxEnt provides two measures for evaluating the importance of used variables, permutation importance and percent contribution of each variable to the final model (Phillips 2006).

3. Results

Cinereous vulture

The AUC for the cinereous vulture habitat suitability model was 0.931, indicating good model performance. The environmental variables with the highest contribution in the model were temperature seasonality (33.7%), precipitation of coldest quarter (26.1%), precipitation of the driest month (19.0%) and maximum temperature of the warmest month (8.4%). The two topographic variables only showed little contribution and importance in the model, with respective contributions of 2.7% and 0.9% for slope and ruggedness (see Appendix 1 for details).

According to our model, cinereous vultures habitat suitability increases with reduced temperature seasonality, high precipitation during winter, between 20 to 70 mm of precipitation during the driest month and maximum temperatures of the hottest month between 17 and 40°C. (Figure 2 – see Appendix 2 for more details).

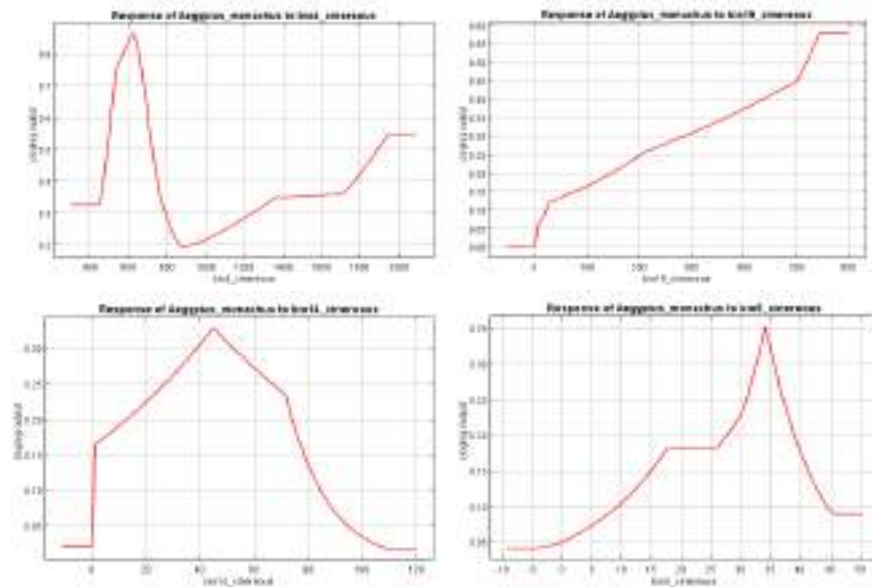


Figure 2. Response of vulture suitability to the four most important predictor variables for the Cinereous vulture (decreasing importance from top left to bottom right)

The final projection for the central Apennines (Figure 4) shows an abundance of highly suitable habitat in the Apennines, with 93% of the area above 0.8. The highest mountainous peaks show the lowest habitat suitability, while the rest of the area shows an overall very high suitability. The protected areas of the

study area mostly fall within areas with the highest predicted suitability scores, with an average score of ca. 0.9. Protected areas with a high coverage of mountainous areas display lower scores (e.g. Maiella NP - 0.81), while the flatter protected areas achieved very high scores (Simbruini Natural Regional Park, MAB Reserve).

Bearded vulture

The AUC for the bearded vulture habitat suitability model was 0.833, indicating good model performance. The environmental variables with the highest contribution in the model were precipitation of driest month (49.1%), annual precipitation (14.3%), temperature seasonality (12.1%) and maximum temperature of the warmest month (8.6%). The permutation tests showed temperature seasonality was the most important variable. Ruggedness has a higher contribution to the model than for the cinereous vulture with 5.6%, while slope still had a low contribution (see Appendix 3 for details).

According to our model, suitable bearded vultures' habitat is characterised by less than 60 mm of precipitation during the driest month and less than 2000 mm annually, low temperature seasonality and maximum temperature of the warmest month below 30°C (Figure 3 – see Appendix 4 for details).

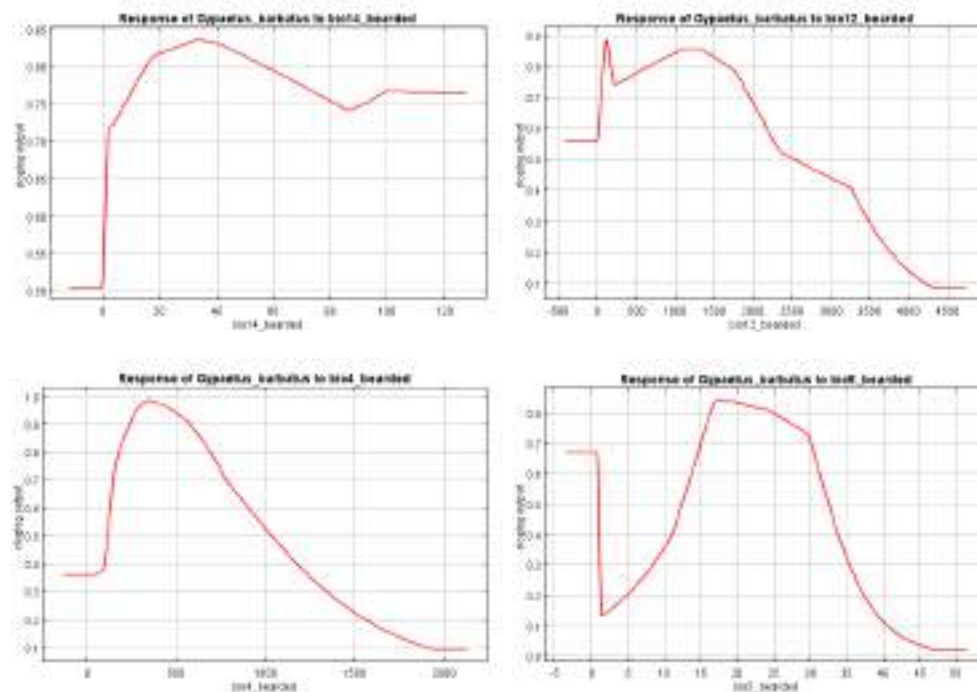


Figure 3. Response of vulture suitability to the four most important predictor variables for the Bearded vulture (decreasing importance from top left to bottom right)

The final projection for the central Apennines (Figure 4) shows an abundance of highly suitable habitat in the Apennines, with 86.0% of the area above 0.8. The protected areas cover the patches of most suitable

habitats, while the lower plains have lower, even though still high, habitat suitability. Predicted habitat suitability within the protected areas incorporated in the study area is especially high, with the average score of ca. 0.94 for the bearded vulture across all protected areas. None of the protected areas display a suitability value below 0.9.

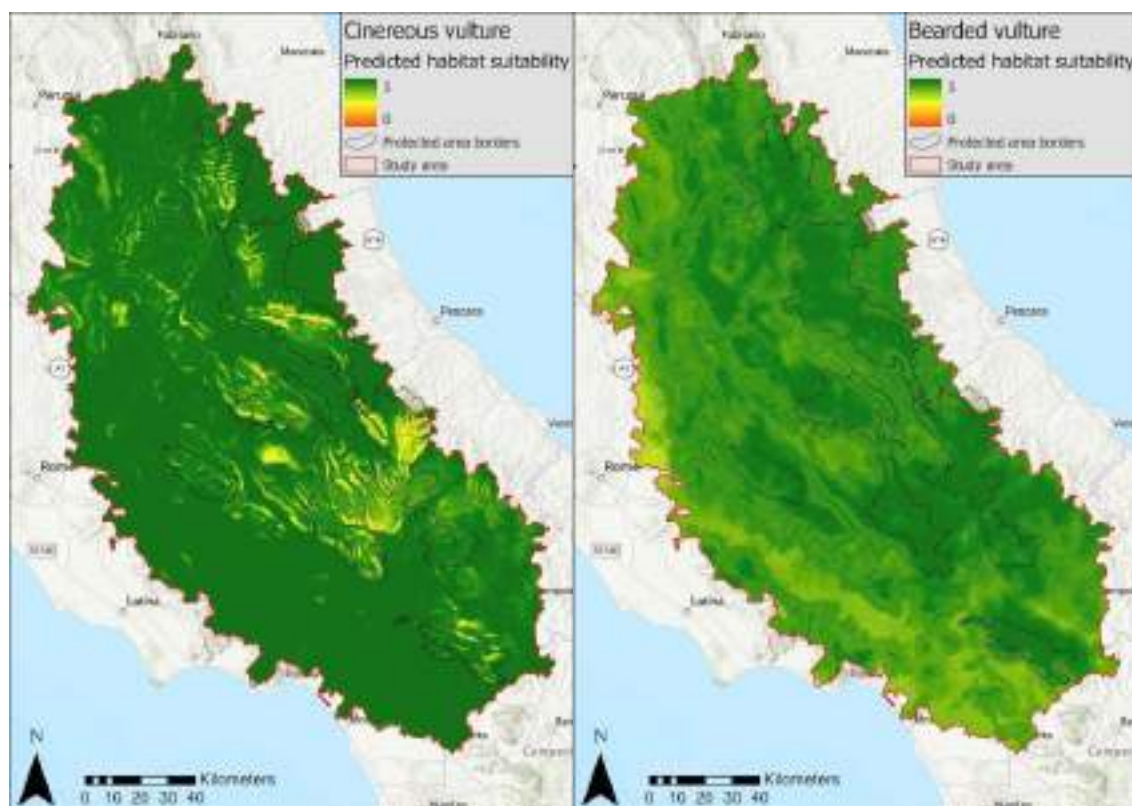


Figure 4. Probabilistic surfaces of the habitat suitability for cinereous vulture (left) and bearded vulture (right) in the study area, produced by implementing MaxEnt algorithm.

4. Discussion

Summing up the results, the habitat suitability prediction of our cinereous vulture model indicates that the majority of the study area is deemed as suitable, with roughly 93% of the area showing a suitability score above 0.8. Adding to this, also the AUC score of 0.931 underlines a robust model performance. The modelled cinereous vulture habitat suitability seems to strongly rely on areas with low temperature seasonality, higher precipitation in winter, between 40-80 mm of precipitation during the driest month and maximum temperatures between 17 and 34 degrees in summer. The results of this analysis align well with the analysis done by Gavashelishvili et al. (2012), whose results indicate that higher temperature seasonality and very high temperatures during summer force the vultures to leave an area. Additionally, the described preferences regarding precipitation are similar to the modelling results of Jha & Jha (2024). On the other hand, slope and ruggedness did not play an important role in the model, underlined by the model prediction shown in Appendix, where steeper slopes are associated as less suitable for the cinereous vulture. This is additionally highlighted by the Maiella massif, Sirente and Velino mountain

peaks as well as the Gran Sasso Mountain range having lower predicted suitability than their surroundings. However, increasing ruggedness predicts higher habitat suitability. Similar studies suggest that the cinereous vulture prefers steep slopes and old-growth forests as nesting habitat (Gavashelishvili et al. 2006; Lourenço et al. 2013, Guerrero-Casado et al. 2013; García-Barón et al. 2018), the lack of importance of the slope and ruggedness predictors and preference of lower values respectively (Appendix) could thus be explained by the occurrence points not being divided into nesting locations and foraging locations, due to the random occurrence point selection. Indeed, D'Elia et al. (2015) suggested modelling separately nesting, roosting, foraging to account for most relevant vulture's ecology and ranging behaviour, which is unfeasible for the dataset available for our modelling exercise, which anyway should have captured most of or the full environmental niche of the two species.

Similarly to the cinereous vulture, the most important predictor variables for the bearded vulture habitat suitability were climatic. However, the response of the bearded vulture suitability to the used predictors was quite different. In this case, habitat suitability mostly depends on low precipitation during the driest month, a preferred yearly precipitation below 2000 mm, followed by low temperature seasonality and maximum temperatures of the warmest month below 30°C. Indicating a preference for dry and relatively colder areas than the cinereous vulture in the study area. Contrasting to the cinereous vulture model, higher bearded vulture habitat suitability aligns with higher elevations, although ruggedness and slope were not very important in the model itself, implying that climatic variables associated with elevation have a higher importance than slope and ruggedness alone. Overall, variable performance highly overlapped with the results of Subedi et al. (2022) and other habitat suitability studies on bearded vultures (Hirzel et al., 2004; Yousefi et al., 2023), except that the preference for low precipitation during the hottest months was stronger. For the bearded vulture, the combined predicted habitat suitability is predicted to be very good with 86% of the study area having suitability values above 0.8. Again, it has to be highlighted that for this analysis, occurrence points were selected randomly.

The results of statistical modelling approaches and predictions always have to be treated carefully, while they have proven to be a very helpful tool for conservation planning and reintroduction of species (Larson et al., 2004; Rondinini et al., 2005), they remain an entirely theoretical assumption. Thus, the results of this initial habitat suitability analysis should be considered together with the other components of this feasibility study, especially compared to results of the risk analysis (Chapters 10 to 13) and of the field surveys which provided an expert-opinion assessment of suitability in several sites in the central Apennines. Indeed, the outcome of field surveys depict habitat suitability at a different scale and aim at evaluating different resources (Chapter 8). Additionally, the current state of the extant griffon vulture population in the central Apennines must be considered and can provide valuable information regarding the challenges that vulture populations in the area facing, such as illegal killings, poisoning incidents and collisions with wind turbines (Monti et al., 2022; Posillico et al., 2023; Rewilding Apennines unpublished data). In Appendix 5, the predicted habitat suitability can be found for the full range of Italy.

Due to following the approach of Subedi et al. (2022), the used predictors are entirely focused on climate and geomorphology, for a more holistic suitability prediction, also other predictors that include land-use, food availability and human disturbances should be considered. Thus, the variables can be tailored to better fit the biology of both species, as has been done in various other studies (Lourenço et al. 2013;

Guerrero-Casado et al. 2013; García-Barón et al. 2018). Additionally, care should be taken when selecting variables to be included in the same model, to avoid autocorrelation and added bias.

For comparative purposes, the results of the same habitat suitability models, using the same predictors but using a different algorithm (GLMs - generalised linear models) are attached, providing relatively similar, yet more conservative results in terms of predicted suitable area as the ones described for the MaxEnt models (Appendix 6). The results are again emphasising the importance of interpreting the results with caution.

5. Conclusion

The initial habitat suitability analysis shows promising first results for our study area and the reintroduction of bearded and cinereous vulture respectively. Good model performance and mostly plausible response of habitat suitability to our predictor variables indicate a good predictive power of our results. Caution is however advised for interpretation; the results should be viewed in light of the other chapters of this feasibility study and future refinements of the predictor variables are advised.

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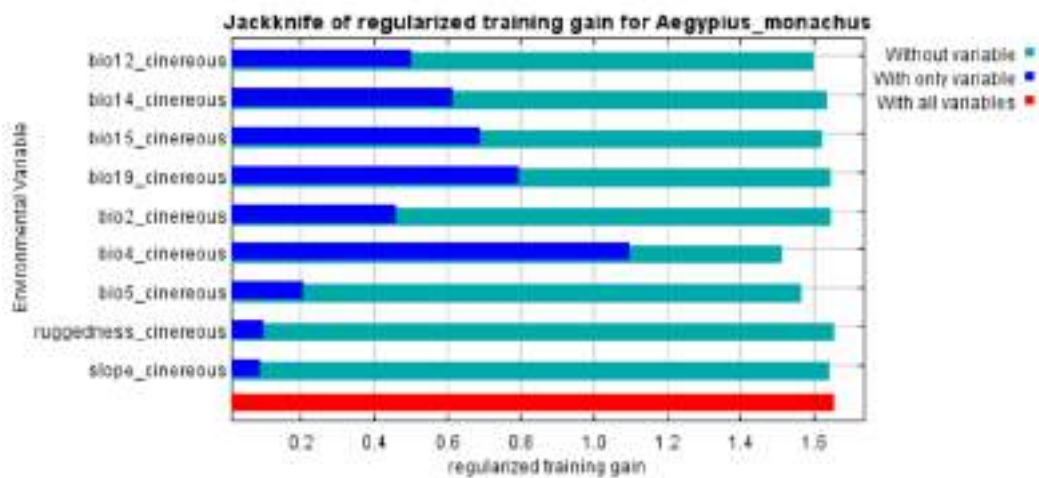
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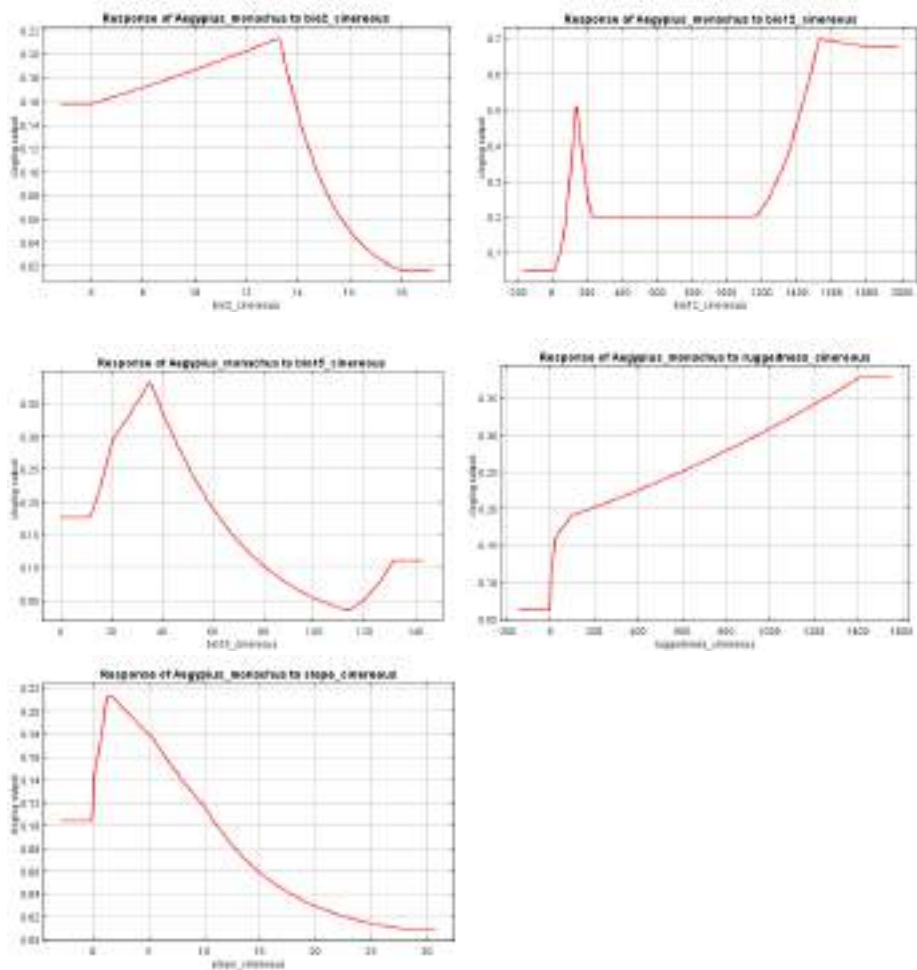
7. Annex

Appendix 1 – Variable contribution to the cinereous vulture model

Variable	Percent contribution	Permutation importance
bio4_cinereous	33.7	10.6
bio19_cinereous	26.1	26.1
bio14_cinereous	19	10.7
bio5_cinereous	8.4	9.8
bio12_cinereous	4.5	12.9
bio15_cinereous	3.1	20.5
slope_cinereous	2.7	3.7
bio2_cinereous	1.7	3.5
ruggedness_cinereous	0.9	2.1

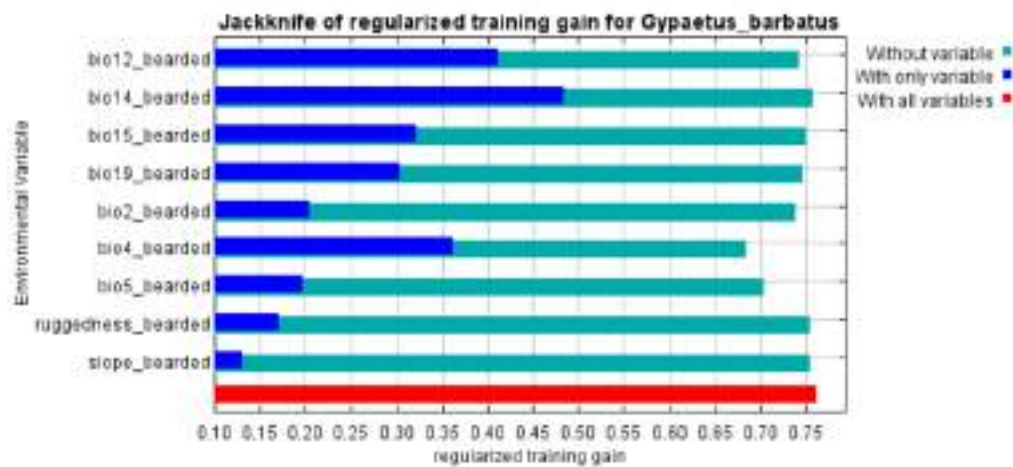


Appendix 2 – Response curves for the remaining environmental variables in the cinereous vulture model

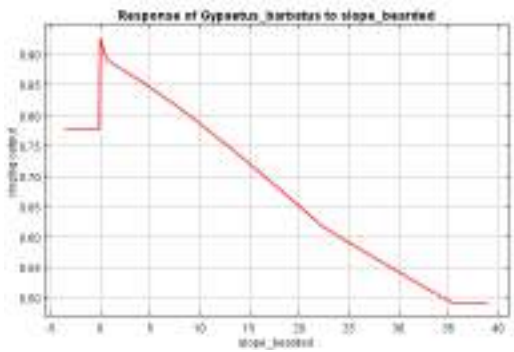
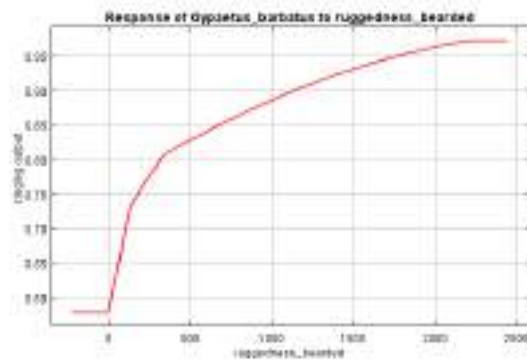
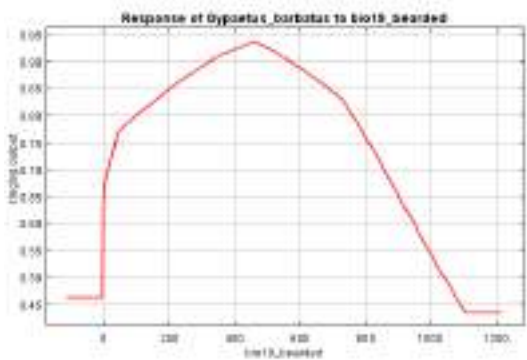
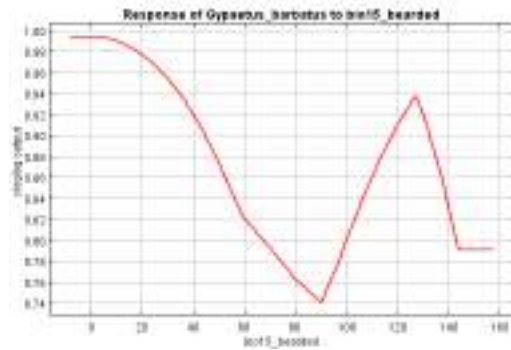
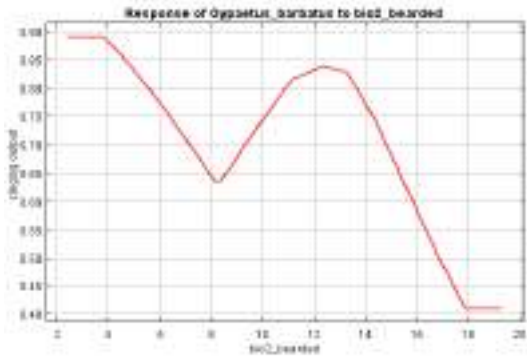


Appendix 3 – Variable contribution for the bearded vulture model

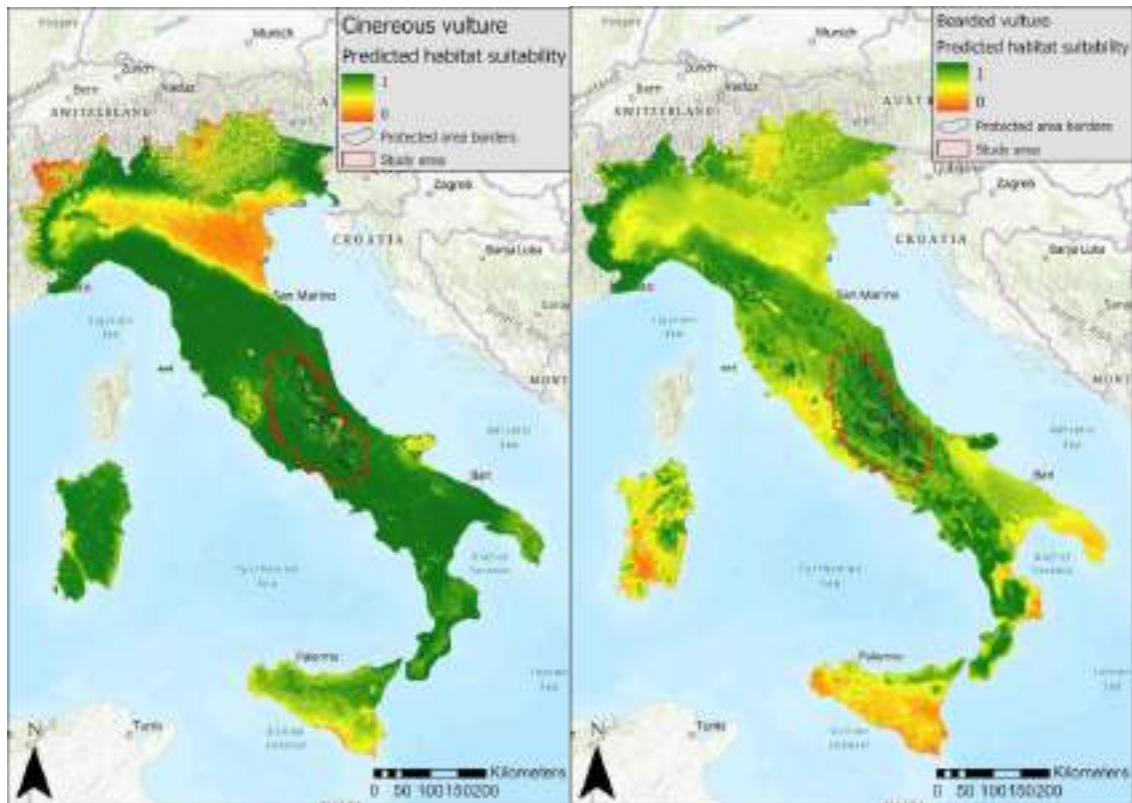
Variable	Percent contribution	Permutation importance
bio14_bearded	49.1	4
bio12_bearded	14.3	7.5
bio4_bearded	12.1	36.2
bio5_bearded	8.6	27.9
bio15_bearded	6.1	6.5
ruggedness_bearded	5.9	5.3
bio2_bearded	1.4	5.5
slope_bearded	1.3	2.9
bio19_bearded	1.2	4.1



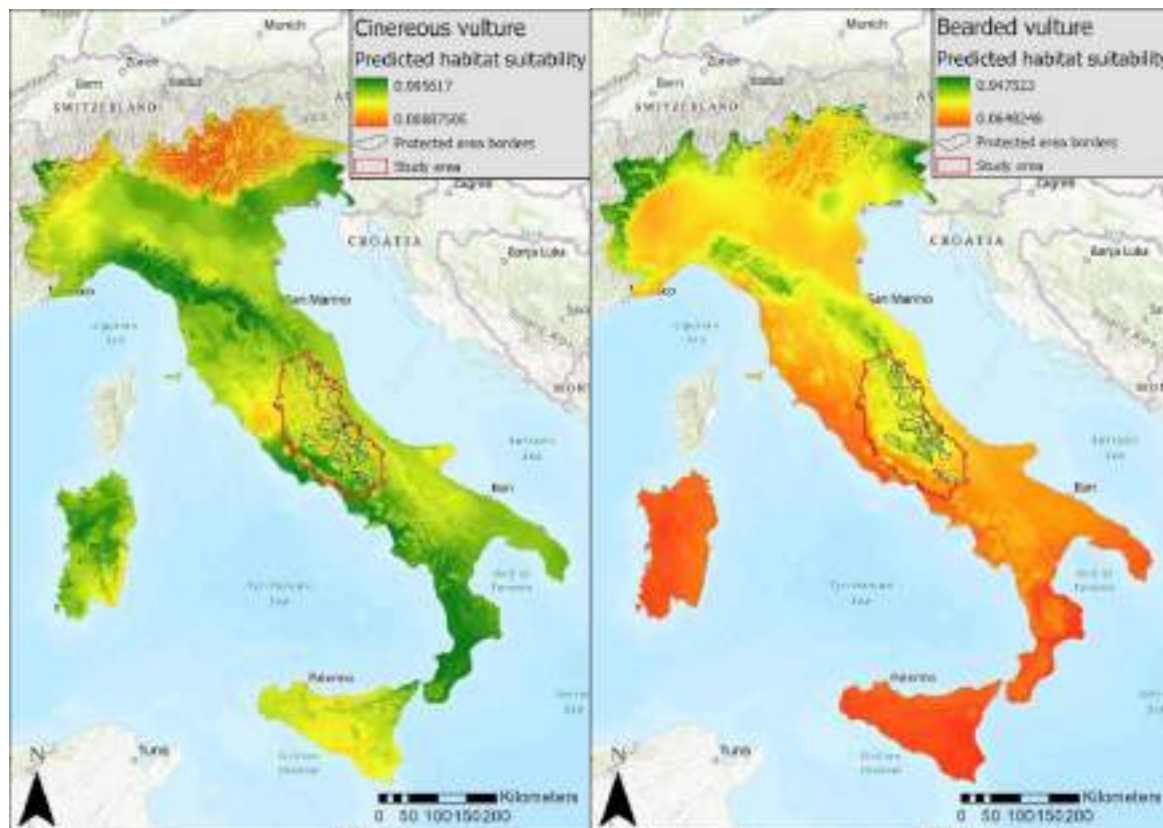
Appendix 4 – Response curves for the remaining environmental variables in the bearded vulture model



Appendix 5 – MaxEnt model predictions for the entire national territory



Appendix 6 - GLM model predictions for the entire national territory



Chapter 10

Poisoning risk factors and spatial prediction of poisoning risk

Luca Chiaverini



Highlights

- Two models of the probability of occurrence of poisoning events have been produced within the study area, using 1) all the certain cases of poisoning events (n= 846) and 2) the cases of poisoning events 500 m from urban areas (n= 136).
- The first model highlighted urban areas and main roads as the main predictor of probability of poisoning. Clearly this model is highly biased towards urban areas and, although it provides interesting insights, it will be of very little use to predict the risk for vultures and other wildlife either in rural or remote areas.
- The second model, worryingly, predicts several wild areas at high risk of poisoning events. The presence of unpaved roads is among the first and strongest drivers of a high probability for poisoning events to occur. Other strong predictors are tree cover (negatively related, therefore meaning that the probability is higher where there is little forest cover, such as in pastures and open meadows) and human population abundance (also in this case negatively related, but this result is likely associated to the exclusion of poisoning events occurring close to urban areas).
- The results show extensive areas within the Sirente Velino Regional Park to have high probability for poisoning events to occur, as well as within the Gran Sasso and Monti della Laga National Park and within the Monti Sibillini National Park.
- The results are worrying, since the areas showing the highest probability of poisoning events to occur are also among the most suitable for the presence and the reintroduction of vulture species, and are home of other endangered wildlife. The results suggest that, in order to ensure the survival of vulture populations, as well as that of other wildlife, it is urgent to tackle the risk of illegal poisoning, to avoid jeopardising the viability of the vulture population already occurring in the area, and the success of future reintroduction programs.

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1. Introduction

Illegal human activities affecting natural resources or resulting from human-wildlife conflicts represent a major threat for the sustainability of ecosystems and for the conservation of wildlife (Gavin et al., 2010). Therefore, for the correct evaluation and implementation of conservation plans, it is vital to include not only the evaluation of the factors driving the subsistence of the environment or of the wildlife population, but also the factors risking jeopardising these conservation efforts (Bunnefeld et al., 2011).

Among the most impactful threats deriving from human illegal activities, poisoning has been used for centuries to control wildlife species representing a threat or a competitor for humans and livestock (Woodroffe et al., 2005). Even though in the past this way of controlling wildlife populations was legal, it has now been heavily restricted in several countries worldwide, and legal poisoning compounds are currently restricted to pesticides, including insecticides and rodenticides (Berny et al., 2010). However, the use of pesticides still represents a major source of unintentional poisoning of non-target species (Berny et al., 2010). In addition to the unintentional mortality, these compounds are sometimes used illegally to deliberately poison wildlife. Illegal and purposeful wildlife poisoning is sometimes perpetrated also with banned compounds, including strychnine and endrin (Martínez-Haro et al., 2008).

Poisoning is therefore a significant threat to wildlife populations worldwide with devastating effects on various species. In fact, although deliberate illegal poisoning is majorly used as a form of retaliatory killing mainly targeted at controlling predator populations (Kissui, 2008), the use of poisoning compounds that are likely left in the environment often reaches other not-target species. Usually, deliberate poisoning consists in placing poisoned baits, such as meat and carcasses, in the environment. It is therefore an indiscriminate way to control wildlife, which often reaches far beyond the target species.

Among the species that are more likely to be negatively affected by poisoning, surely vultures, being scavengers, and often gregarious, with a crucial ecological role of consuming carrions and cleaning up the environment from carcasses, are positioned them at a perilous position in the trophic chains in relation to poisoning events (Ogada et al., 2016). The impact of poisoning of vulture populations can be catastrophic. Vultures are slow breeders (Blanco et al., 1997), and even a few deaths can have a significant impact on their population numbers.

Additionally, the loss of vultures can have far-reaching consequences in the environments, as they play a crucial role in controlling disease spread by consuming carrions that could, otherwise, harbour pathogens. Loss of vultures has, consequently, also economic implications as they provide valuable ecosystem services by disposing of carrions and reducing the spread of diseases.

It is therefore crucial to reduce the rates of loss of these species due to illegal poisoning, with strategies ranging from legal prosecution of the poisoners to educational activities among the public to increase the awareness on the fundamental roles that vultures play in the environments and to promote a change of attitude against illegal poisoning. However, since the resources to adequately implement actions against illegal poisoning are limited, it is fundamental to identify the areas where poisoning events are more likely to occur, to prioritise and, consequently, optimise, these actions.

Species distribution models are a powerful tool to derive spatially explicit predictions of habitat suitability for species, by statistically relating species occurrence data at known locations with the environmental features of those locations (Elith & Leathwick, 2009). Similarly, not only species occurrence can be modelled with these techniques, but also the probability of occurrence of other events, such as poisoning events. Moreover, several statistical approaches have been developed to produce species distribution models, with regression methods being among the most used ones and having been proved to provide more supported results than other techniques (Chiaverini et al., 2023).

In this chapter we will then produce a spatially explicit model of the probability of poisoning events to occur in the study area. The results will help prioritise the areas to monitor for reducing the poisoning risk, by either patrolling the areas or implementing educational programs with the local stakeholders to raise awareness on this risk for vultures and for other wildlife.

2. Materials and methods

2.1. Poisoning events

To evaluate the risk of illegal poisoning, we gathered data from the *Portale Nazionale degli Avvelenamenti Dolosi degli Animali* (<https://avvelenamenti.izslt.it/>) of the Istituto Zooprofilattico Sperimentale (IZS) del Lazio e della Toscana “M. Aleandri”. Specifically, we required data of poisoning events that occurred between 2019 and January 2024 in the Italian regions of Tuscany, Marche, Umbria, Abruzzi, Latium, Molise, Puglia, Campania, Basilicata and Calabria, across the whole central and southern Apennines, and further.

We applied a first geographic filter to select only those poisoning occurrences internal to our study area. In addition, some of the poisoning events in the dataset had clearly wrong coordinates (e.g., occurred outside of Italy), and limiting the events solely to those within the study area allowed us also to filter out the misplaced ones. Additionally, the poisoning events in the database also included records whose positivity to poisoning compounds could not be confirmed. Therefore, a second filter was applied to select only the cases whose samples were unambiguously positive to poisoning compounds, and the cases in which baits had been found, since we could generally be sure about the malicious intention when finding baits, even though they did not show poisoning compounds. In Figure 1 we summarised the flowchart applied to select the poisoning events used to model the poisoning risk.

With the dataset obtained in such a way, we produced a first model of the risk of occurrence of poisoning events. However, we also noticed that several events occurred near urban areas. Since we were also strongly interested in modelling the probability of poisoning events in the wild, we further filtered the data to exclude the events occurring 500 m from urban areas, where the urban areas have been selected from the land cover layer that we used for the analyses (Zanaga et al., 2021). For this study, the land cover layer defined as urban areas include all the pixels containing human settlements, including cities, industrial areas, small villages and isolated habitations, when these are big enough to occupy a pixel of the land cover layer that, in the case of the layer that we used, was 10 m x 10 m. We decided to exclude the poisoning events occurring within and close to urban areas to use only the events that were more likely to affect wild species, assuming that, although not impossible, it is more difficult for wild species to access urban areas. The limit of 500 m was decided to create a buffer zone around urban areas that wild species would still consider as anthropic, and therefore would try to avoid. We realise that, by excluding urban areas, we have considered in the same way big cities and small villages, where the chances of wild species to approach human settlements are very different. However, the need of excluding points occurring within urban areas, and the difficulty of automatically separating pixels of urban areas belonging to big cities from pixels of urban areas of small villages, forced us to opt for a harsh criteria, and therefore we excluded the poisoning events occurring within and close to any urban area.

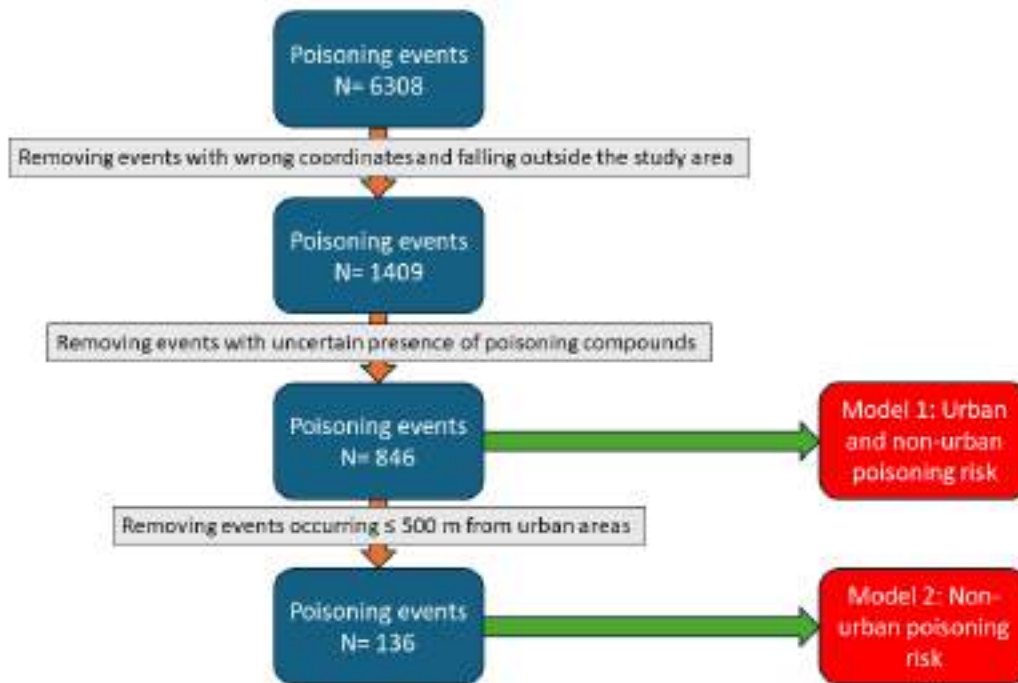


Figure 1. Flowchart applied to select the poisoning events used to model the risk of poisoning.

2.2. Environmental variables

To model the probability of poisoning events to occur we used environmental variables that could best describe the composition of the natural, topographic and anthropic features of the study area. Specifically, from the ESA World Cover land-use map (Zanaga et al., 2021) we selected bare land, cropland, grassland, shrubland, tree cover and urban areas. We then selected elevation, ruggedness and slope to describe the topography of the study area. As a proxy of the permeability of the environment to human disturbance, we used paths, paved roads and unpaved roads. Additionally, we also included the human population. Finally, from Chapter 15 of this study, focused on evaluating the carrying capacity of the study area, we also used abundance of livestock and, specifically, abundance of cattle, equids and sheep (Table 1). All of the aforementioned variables have been evaluated by computing their focal mean statistics, which calculates and assigns, for each pixel of the layer, the mean of all the pixels occurring within a circular moving window. Several moving windows radii have been tested to choose the most representative spatial scale, following a multi-scale model optimization framework (see below). Therefore, for continuous variables such as elevation, ruggedness, slope and human population, calculating the mean of the pixel values within a moving window meant obtaining an average of their values over a certain surface. For binary variables, such as bare land, cropland, grassland, shrubland, tree cover, urban, paths, paved roads and unpaved roads, averaging their values within the moving window produced the density, or the percentage of coverage, of those variables over a certain surface. Unlike the other variables, the data on the number of cows, horses and sheep was available only at municipality level. Therefore, we could not have a pixel-level precise indication of the number of domestic animals in the study area, but we had to limit the information to the entire extent of the municipalities (see Chapter 15). This has clearly limited

the precision of the information of the effect of domestic animals on the occurrence of poisoning events. However, we believe this information to be vital for a precise representation of the factors affecting the likelihood of poisoning events to happen, and we nevertheless decided to use the data, although available only at the municipality level.

3.3. Modelling framework

We produced the models of probability for poisoning events to occur by implementing a multi-scale model optimization, since this approach, based on evaluating the variables at multiple spatial scales and selecting the most representative one, better reflects the ecological processes that drive habitat selection by species (Levin, 1992), and it has been proved to produce better and more reliable models (Timm et al., 2016).

Table 1. Variables selected to model the probability of occurrence of poisoning events.

Variables	Source
Bare land	Zanaga et al. (2021)
Cropland	Zanaga et al. (2021)
Grassland	Zanaga et al. (2021)
Shrubland	Zanaga et al. (2021)
Tree cover	Zanaga et al. (2021)
Urban	Zanaga et al. (2021)
Elevation	European Space Agency & Sinergise (2021)
Ruggedness	Derived from European Space Agency & Sinergise (2021)
Slope	Derived from European Space Agency & Sinergise (2021)
Paths	OpenStreetMap (2015)
Paved roads	OpenStreetMap (2015)
Unpaved roads	OpenStreetMap (2015)
Human population abundance	Meta and Center for Int. Earth Science Information Network et al. (2022)
Cows	Chapter 15
Horses	Chapter 15
Sheep	Chapter 15

Therefore, we first calculated focal mean for all the variables at six spatial scales: 100 m, 500 m, 1000 m, 2000 m, 4000 m and 8000 m, and we then performed a binomial Generalised Linear Model (GLM) independently at each spatial scale. We then compared the results of the linear model for each scale, independently for each variable, and selected as most representative the scale of the most parsimonious model based on its Akaike's Information Criterion (AIC). However, for the model produced by excluding the poisoning events within 500 m from urban areas, to avoid circularity in the modelling framework, we decided to exclude urban areas from the variables.

We then checked for multicollinearity by calculating Pearson's correlation index between each pair of scale-optimised variables. When a dyad of variables was found to be highly correlated ($|r| \geq 0.7$; Appendices 1 and 2), we removed the variables whose univariate GLM showed the greatest AIC.

We then carried out an all-subset logistic regression analysis and ran GLMs with every combination of the uncorrelated, scale-optimised variables. We ranked the candidate models based on their AIC and retained only those with $\Delta AIC \leq 2$ to represent competing models. We calculated the coefficients of each variable by averaging the coefficients from the suit of competing models, according to the respective model weight.

Using these coefficients, we produced a spatially explicit predictive map of the probability of poisoning events to occur in the study area. We performed this modelling framework twice, using the entire dataset of the certain cases of poisoning events, and the dataset filtered by removing cases occurring 500 m from urban areas.

Additionally, to evaluate the explanatory performance of the final models, we trained the model with 80% of the dataset produced in the aforementioned ways, and kept the remaining 20% for model validation. Specifically, we calculated Area Under the Receiver Operating Characteristic Curve (AUC), a widely used validation metric, ranging from 0 to 1 where, generally, models with $AUC \leq 0.5$ are considered unsatisfactory as producing predictions not better than a random choice, model with AUC between 0.5 and 0.7 are considered poorly informative, models with AUC between 0.7 and 0.8 are considered good, models with AUC between 0.8 and 0.9 are considered very good, and models with AUC between 0.9 and 1 are considered excellent.

3. Results

3.1. Poisoning events

The original dataset gathered from the *Portale Nazionale degli Avvelenamenti Dolosi degli Animali* of the Istituto Zooprofilattico Sperimentale del Lazio e della Toscana “M. Aleandri” was composed of a grand total of 6,308 reports, of which 128 (2.0%) from 2019, 1,515 (24.0%) from 2020, 1,670 (26.5%) from 2021, 1,365 (21.6%) from 2022, 1,613 (25.6%) from 2023 and 17 (0.3%) from January 2024 (Figure 2).

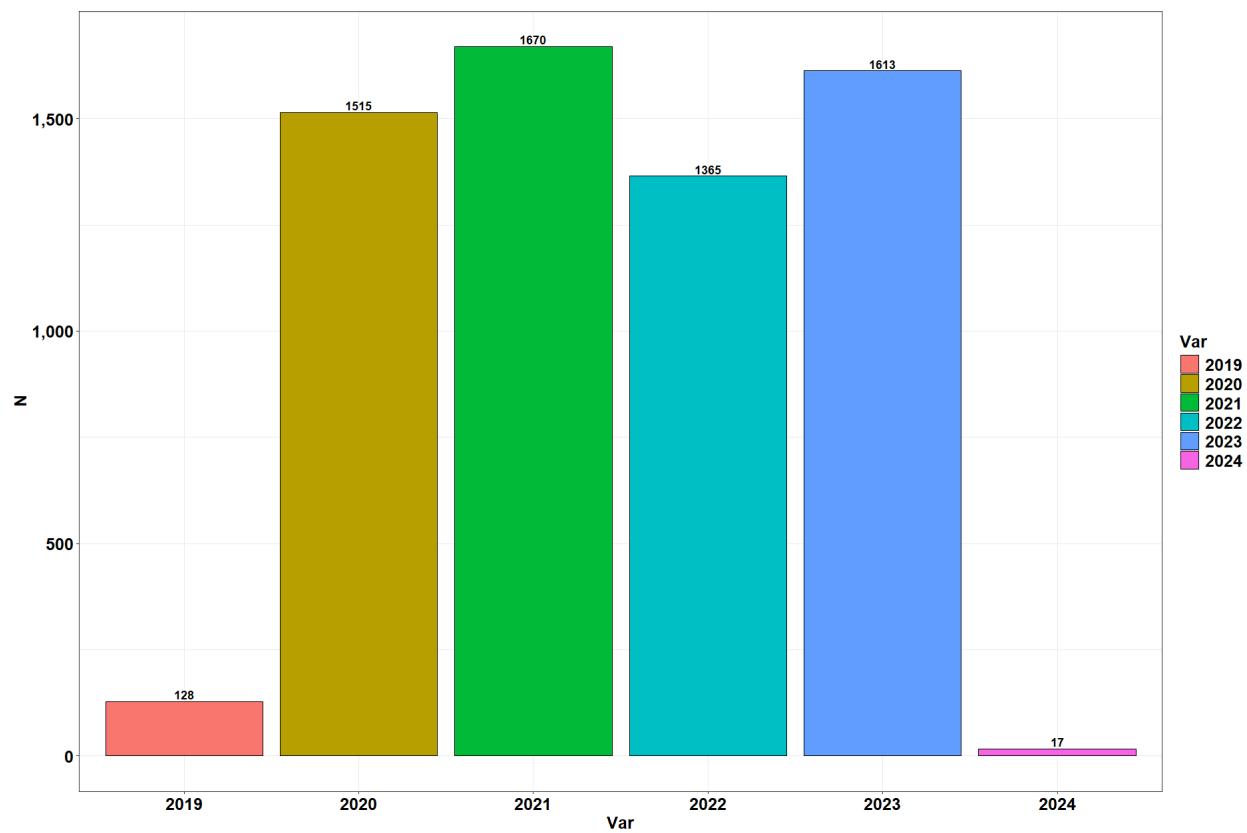


Figure 2. Distribution of poisoning events during the years.

Additionally, cases of poisoning were reported more frequently during autumn and winter months, with a peak in March, while during summer months the frequency of poisoning cases was lower (Figure 3).

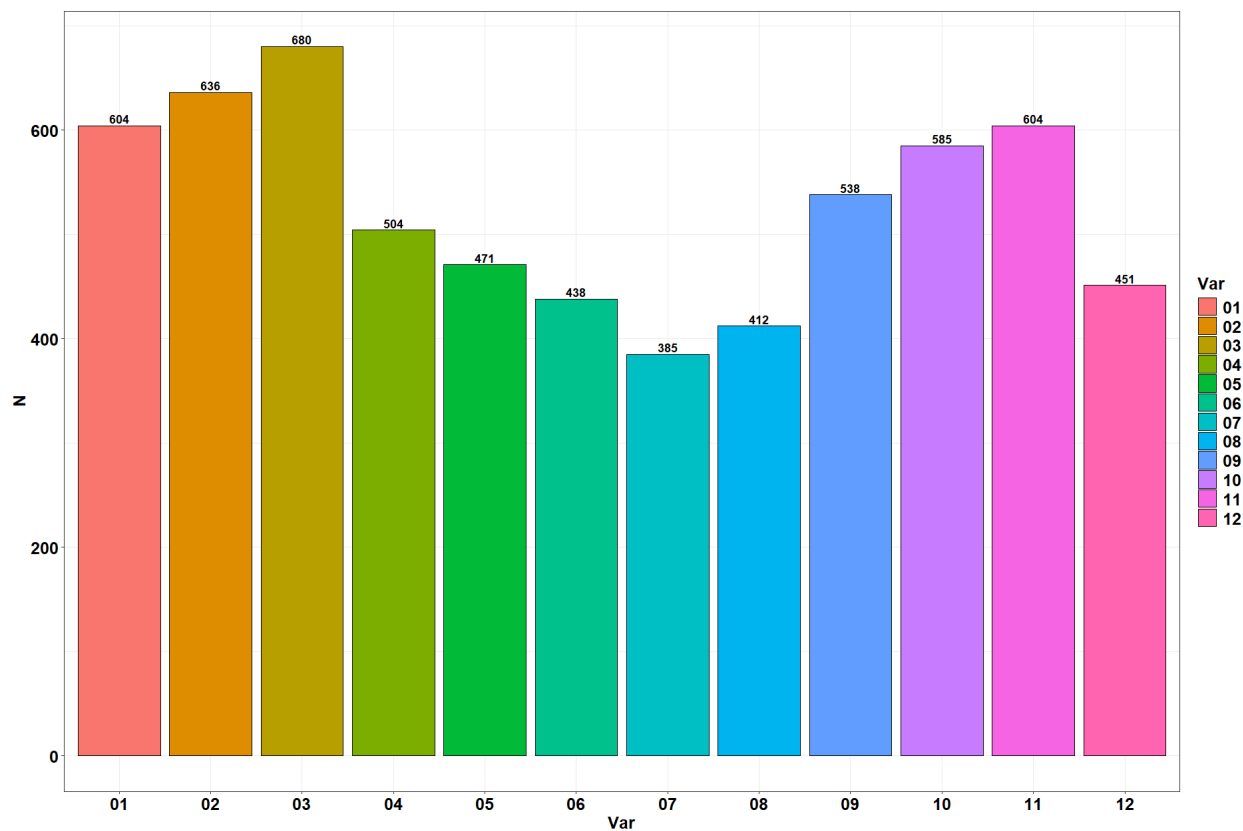


Figure 3. Monthly distribution of poisoning events.

Geographically, the poisoning events showed a strong bias towards the regions of Latium and Tuscany with respectively, 1,247 (19.8%) and 1,198 (19.0%) cases of poisoning, followed by Umbria (820 cases, 13.0%), Abruzzi (764 cases, 12.1%), Campania (729 cases, 11.6%), Marche (528 cases, 8.4%), Puglia (492 cases, 7.8%) Calabria (258 cases, 4.1%), Basilicata (156 cases, 2.5%) and Molise (116 cases, 1.8%; Figure 4).

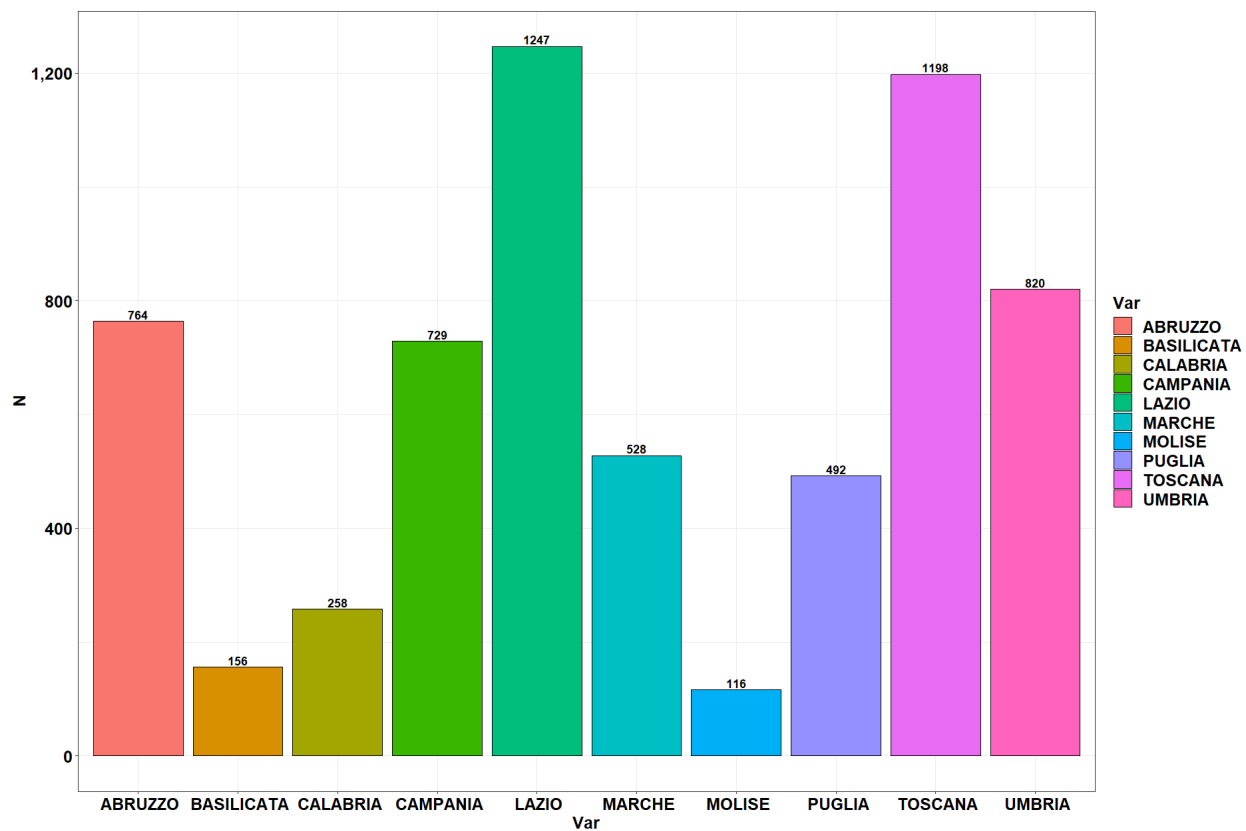


Figure 4. Geographic distribution of poisoning events in the regions we obtained the data from.

However, dividing the number of poisoning events by the extent of each region, therefore calculating the density or the frequency of poisoning events, the situation becomes very different, with Umbria showing the highest density of poisoning events, followed by Latium, Abruzzo, Campania and Marche, Tuscany, Molise, Puglia, Calabria and Basilicata (Figure 5).

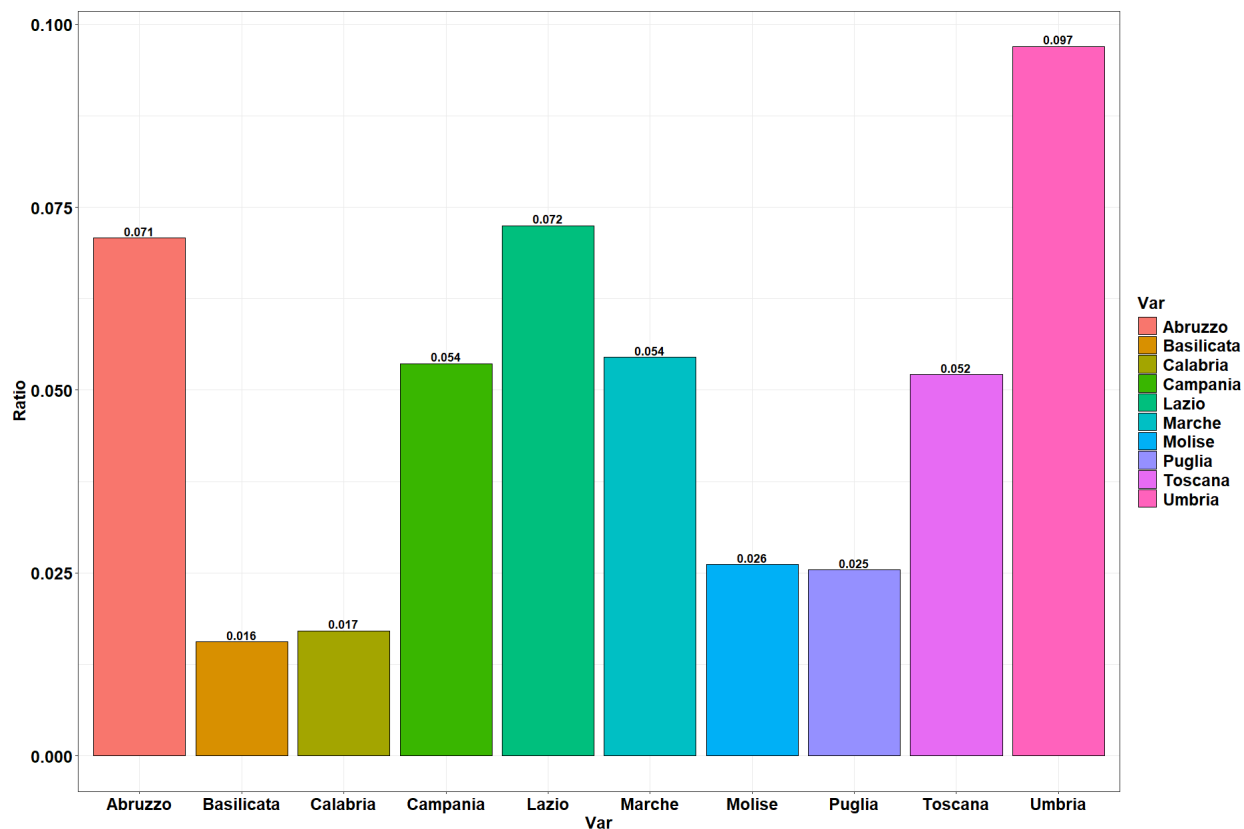


Figure 5. Spatial density of poisoning events in the regions we obtained the data from, calculated by dividing the number of poisoning events per region, by the extent of the region.

However, the grand total of the poisoning events included cases in which the positivity of the sample to poisoning compounds was not confirmed. Specifically, for 4,107 samples, representing 65.1% of the total initial dataset, it had not been possible to confirm the positivity to any poisoning compounds. These cases were therefore excluded, retaining along with the positive cases, only those in which baits had been found, since we could be confident about the deliberate intention of harming wildlife. Additionally, several cases occurred outside the study area. Since some of the variables we decided to use to model the risk of poisoning were obtained only for the study area, such as the abundance of livestock, described in Chapter 15 of this study focused on the evaluation of the carrying capacity, we had to limit the poisoning cases only to those occurring within the study area.

Therefore, from the initial grand total of 6,308 points, we selected 1,409 cases occurring within the study area and, from these, we selected only those in which the presence of poisoning compounds was confirmed by the analyses carried out by the relevant public laboratory, limiting the dataset used to model the probability of occurrence of poisoning events to 846 cases (Figure 6).

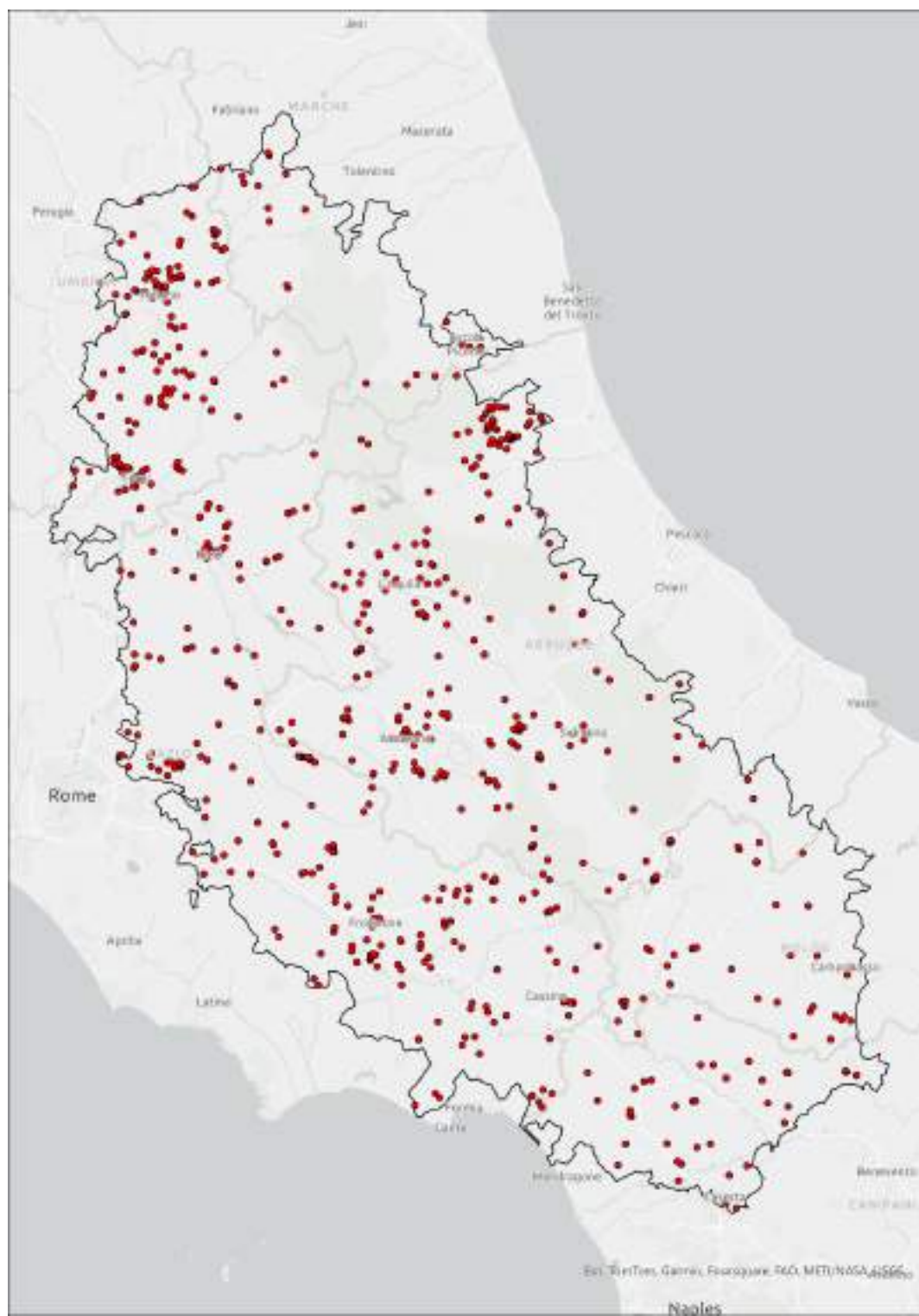


Figure 6. Study area with the 846 cases of poisoning events, used to model the risk of poisoning.

The vast majority of these poisoning instances were represented by baits (n= 430, 50.8%), followed by carcasses of dogs (*Canis lupus familiaris*, n= 253, 29.9%), domestic cats (*Felis catus*, n= 104, 12.3%), foxes (*Vulpes vulpes*, n= 22, 2.6%), wolves (*Canis lupus*, n= 18, 2.1%), griffon vultures (*Gyps fulvus*, n= 8, 0.9%) and common ravens (*Corvus corax*, n= 3, 0.4%). Among the other poisoned species, data also included bee, domestic goat, deer (*Cervus elaphus*), wild cat (*Felis silvestris*), pine marten (*Martes martes*), house sparrow (*Passer sp.*), grey squirrel (*Sciurus carolinensis*) and collared dove (*Streptopelia decaocto*), all found in only one case (Figure 7).

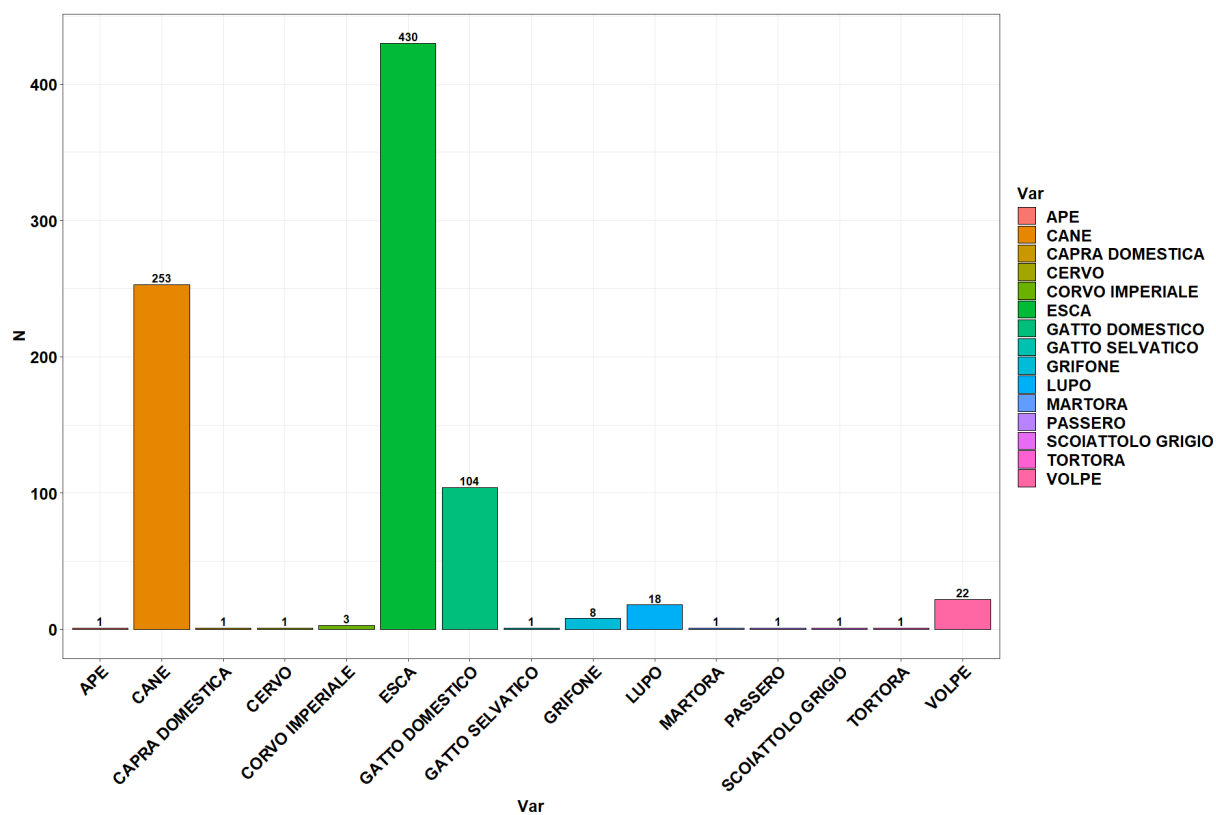


Figure 7. Number of poisoned carcasses and baits.

We performed a first model of the risk of poisoning using this dataset. However, we also realised that several poisoning occurrences were associated with urban environments. Even though we thought it was relevant to model the probability of occurrence of poisoning events in these circumstances, we were also aware that the possible poisoning of wildlife is very unlikely to occur too close to urban areas. Therefore, we further subset the dataset, excluding the cases that occurred within 500 m from urban areas. This second dataset was composed of 136 points of confirmed poisoning events (Figure 8).

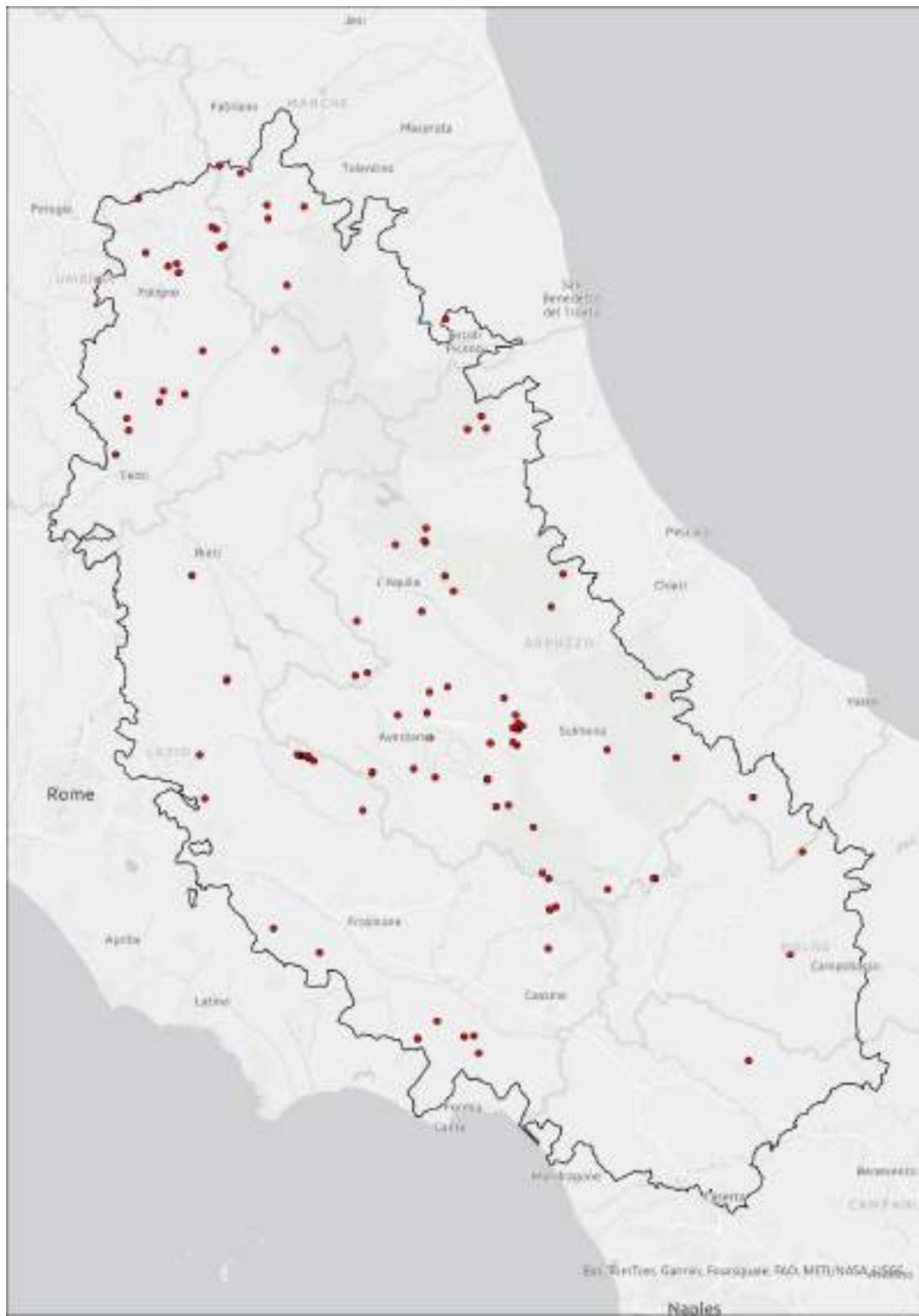


Figure 8. Study area with the 136 cases of poisoning events occurring 500 m away from urban areas, used to model the risk of poisoning.

Interestingly, evaluating the temporal patterns of the poisoning event occurring further away from urban areas, we noticed a more balanced frequency of events throughout the year, although with much lower peaks during summer months (Figure 9).

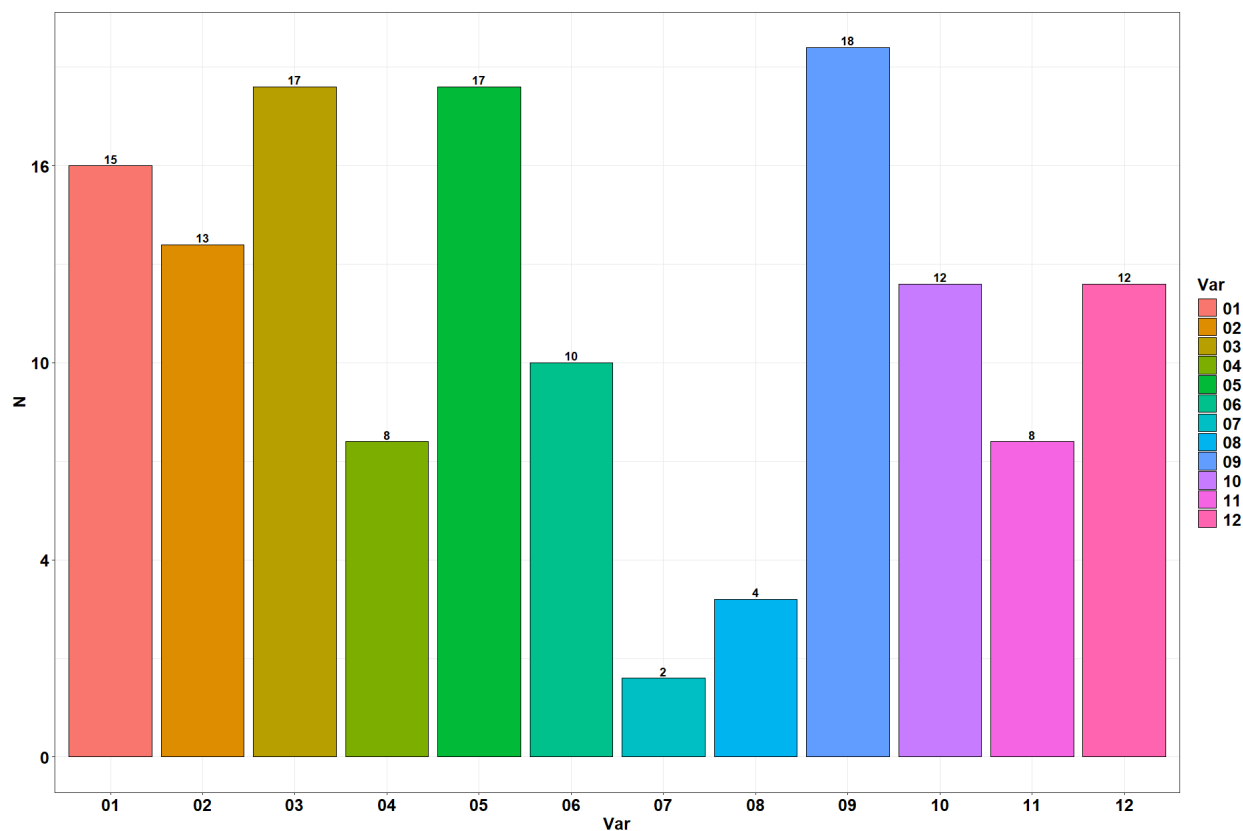


Figure 9. Temporal distribution of poisoning events occurring 500 m from urban areas during the months.

The geographic distribution of these events revealed a different pattern, with more than half of the events occurring in Abruzzi (72 cases, 52.9%), followed by Latium (28 cases, 20.6%), Umbria (22 cases, 16.2%), Marche (8 cases, 5.9%), Molise (4 cases, 2.9%) and Campania (2 cases, 1.5%; Figure 10). However, it has to be noted that the regions with the highest cases of poisoning events were also those with the broadest extents included in the study area.

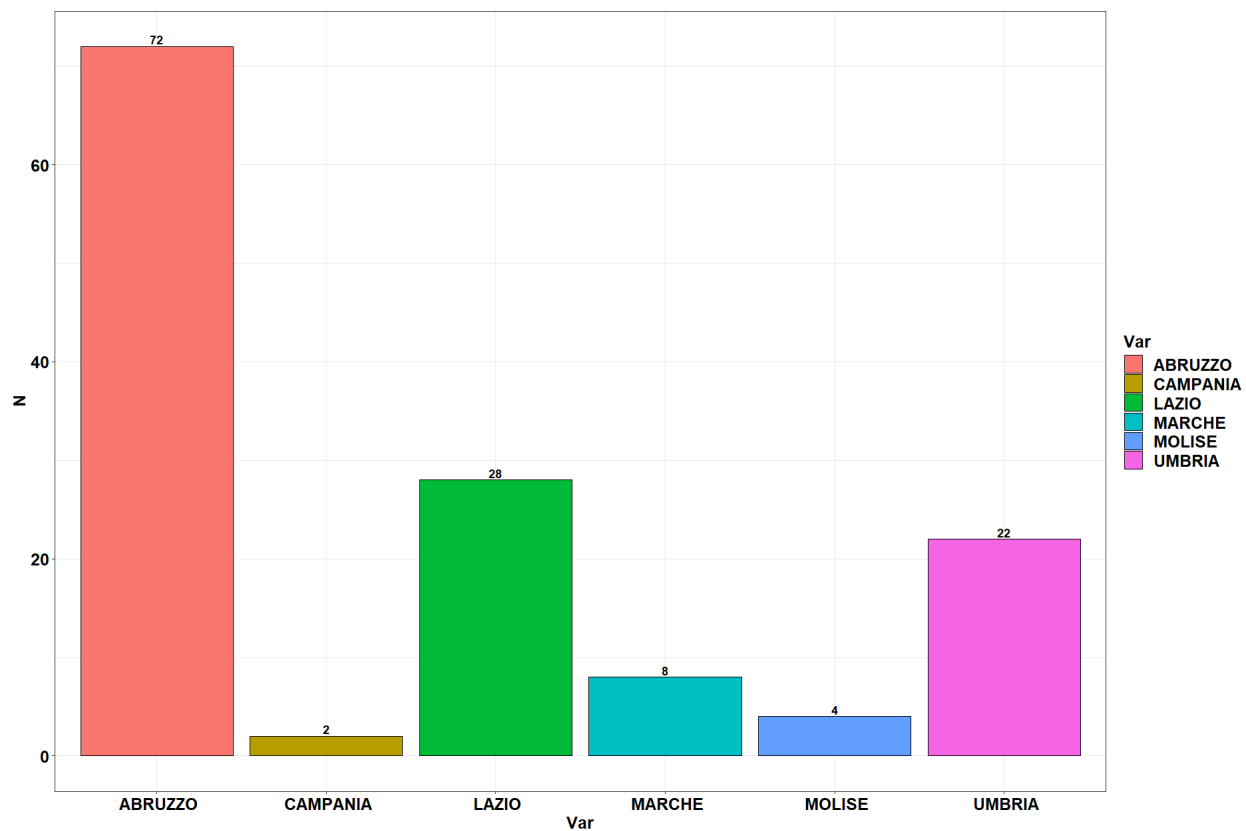


Figure 10. Geographic distribution of poisoning events occurring 500 m from urban areas in the regions we obtained the data from.

However, dividing the number of poisoning events occurring 500 m from urban areas by the extent of the respective region included within the study area, to have a more representative information of the frequency of the events, we see that Abruzzi is still the region with the highest frequency of these poisoning events, followed by Umbria, Marche, Latium, Molise and Campania (Figure 11).

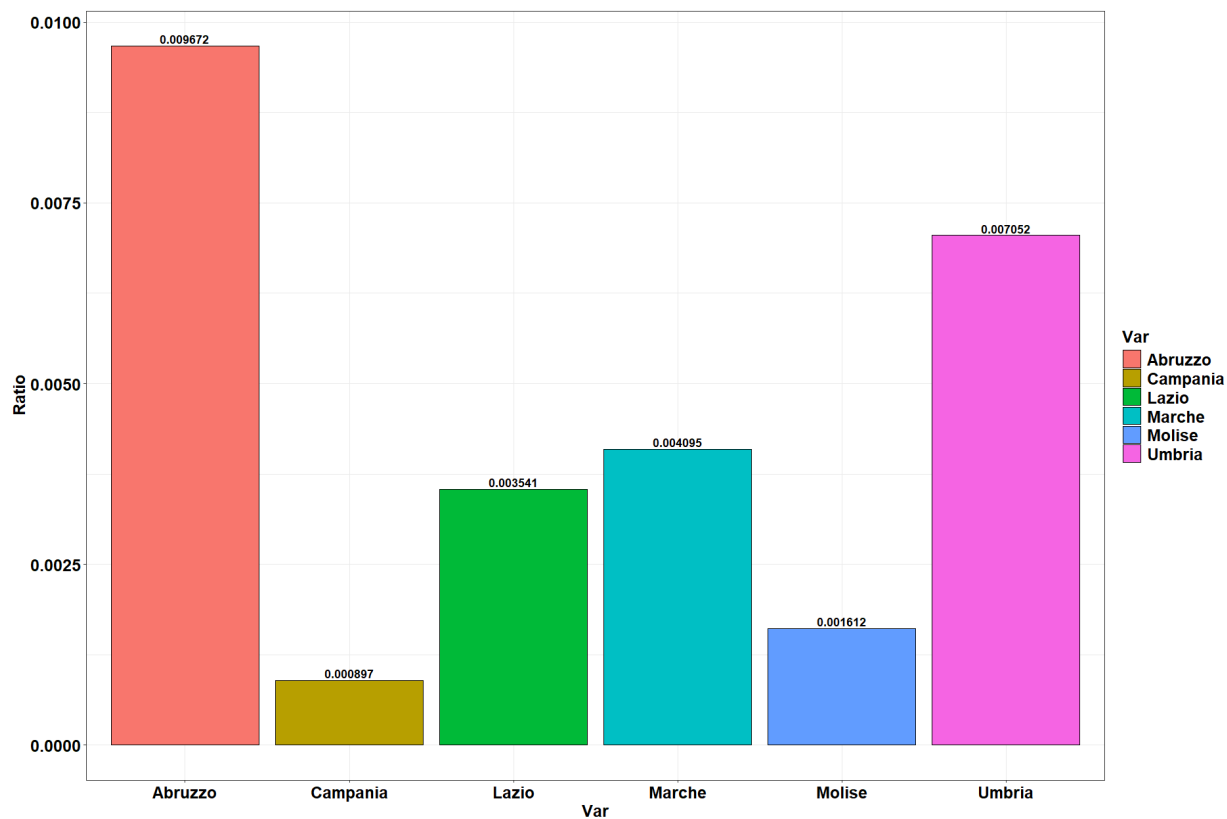


Figure 11. Spatial density of poisoning events occurring 500 m from urban areas in the regions included within the study area, calculated by dividing the number of poisoning events per region, by the extent of the region.

3.2. Model of risk of poisoning – all cases of poisoning

The first model of risk of poisoning, produced also with the cases occurring in proximity to urban areas, showed interesting results (Figure 12, Table 2, Appendix 3). The most striking result was, as expected, that paved roads, followed by urban areas showed the strongest positive coefficients, indicating that several poisoning cases were indeed associated with urban environments. Other variables strongly and positively associated with the risk of poisoning events to occur were grassland, human population and tree cover. On the other side, slope was negatively associated with the probability of poisoning events to occur, meaning that the risk of poisoning is lower where the terrain is more impervious, and higher where the terrain is flatter and more easily accessible.

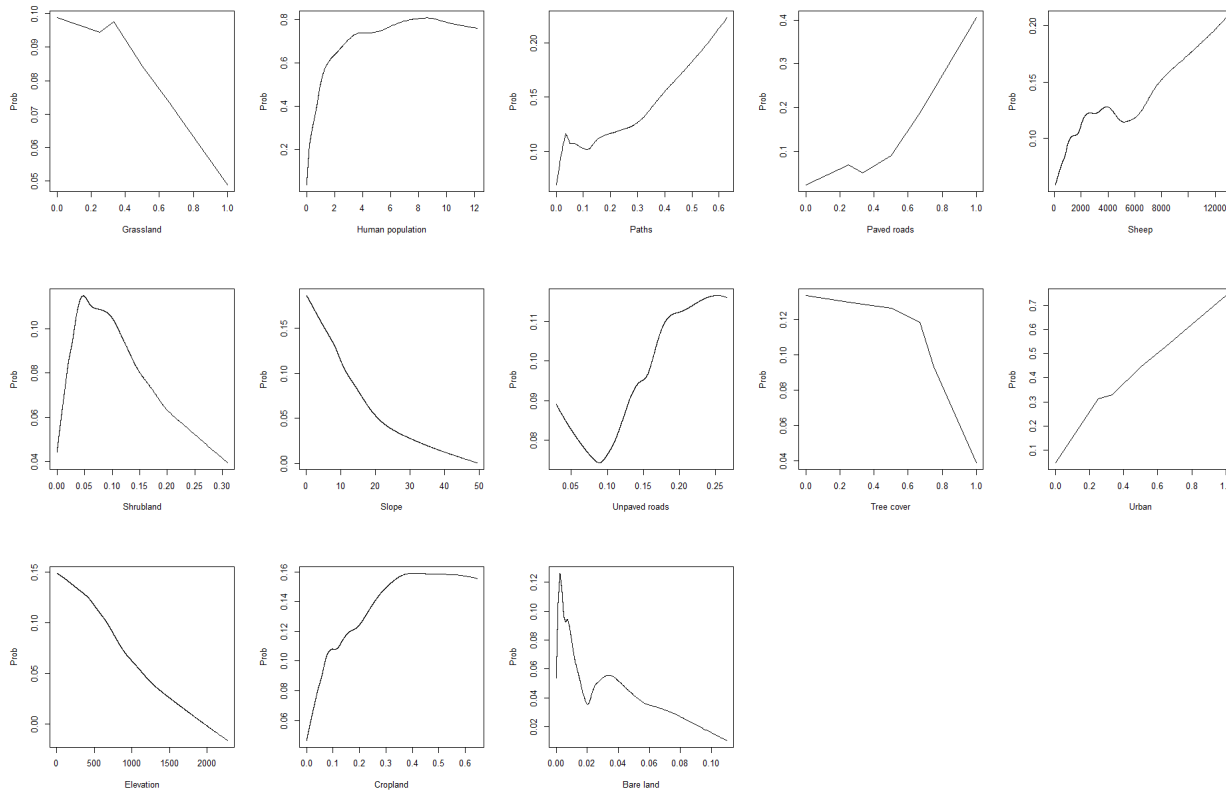


Figure 12. Spline curves of the variables used to model the poisoning risk for the whole dataset.

Table 2. Variables used to model the urban and non-urban poisoning risk, showing the most representative spatial scale for each variable, their standardised coefficient and the p-value.

Variable	Scale (m)	Coefficient	p-value
Intercept	NA	-3.07	<0.001
Grassland	100	0.25	<0.01
Human population abundance	100	0.26	<0.001
Paths	500	0.18	<0.001
Paved roads	100	0.93	<0.001
Sheep	8000	0.14	<0.01
Shrubland	4000	-0.04	0.48
Slope	100	-0.18	<0.05
Unpaved roads	8000	0.10	<0.05
Tree cover	100	0.28	<0.01
Urban	100	0.40	<0.001
Elevation	500	0.02	0.70
Cropland	8000	0.02	0.69
Bare land	8000	-0.002	0.92

Using these coefficients, we produced a spatially explicit probability map of the risk of poisoning (Figure 13). The map shows, as expected from the coefficients, that the risk of poisoning is highest along the main

paved roads and in urban areas. The model validation showed AUC= 0.88, revealing a very good ability of the model to predict poisoning events.

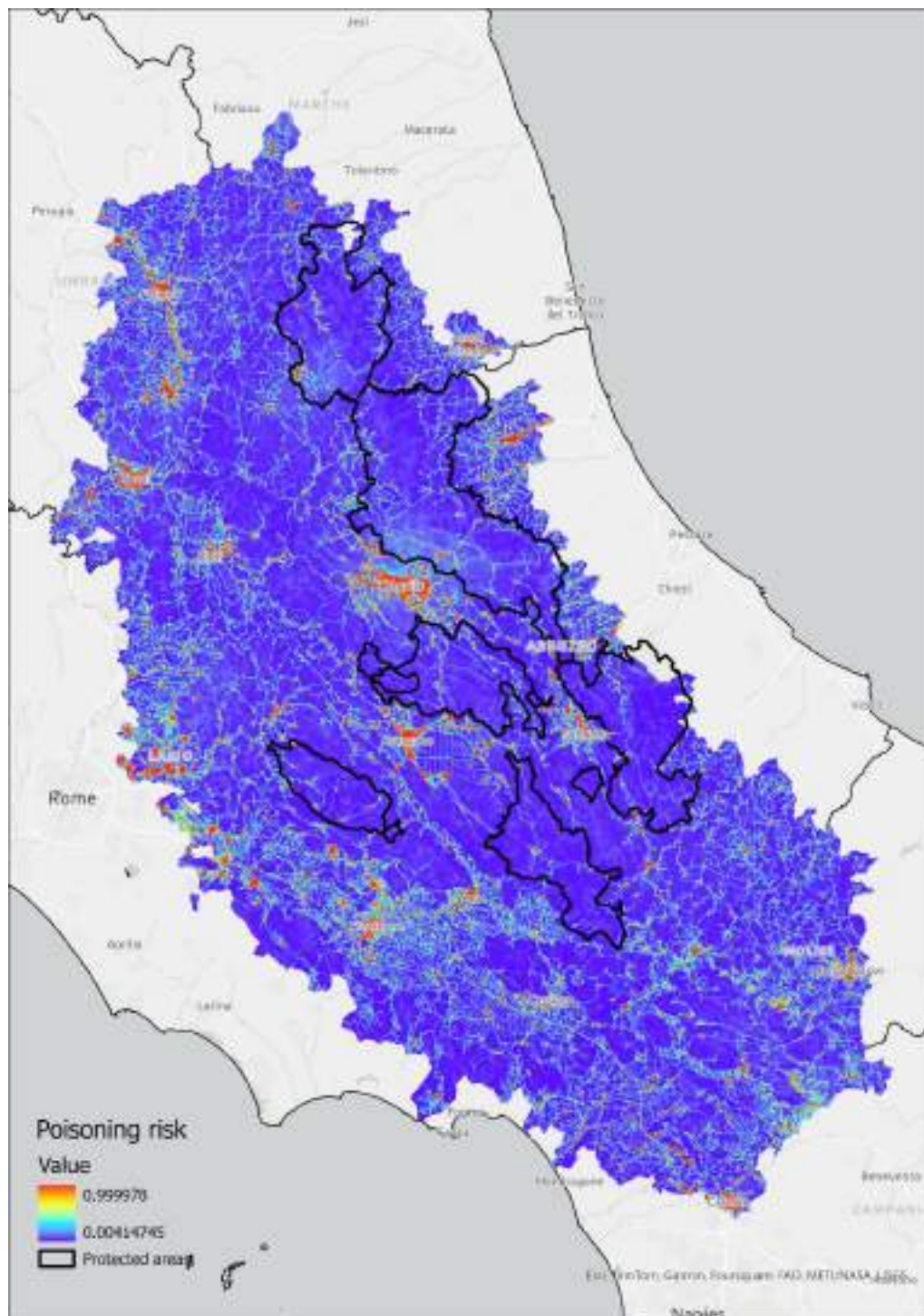


Figure 13. Predictive map of the urban and non-urban poisoning risk.

3.3. Model of risk of poisoning – cases of poisoning 500 m from urban areas

The second model, produced with poisoning events occurring ≥ 500 m from urban areas, showed very different results from the first model (Figure 14, Table 3, Appendix 4). The coefficients of the variables revealed that, in this case, the risk of poisoning outside urban areas was most strongly associated with the presence of unpaved roads, followed by the presence of paths. The variables showing the strongest negative coefficients were human population, although this is very likely an artefact of having removed points occurring close to urban areas, tree cover and cropland.

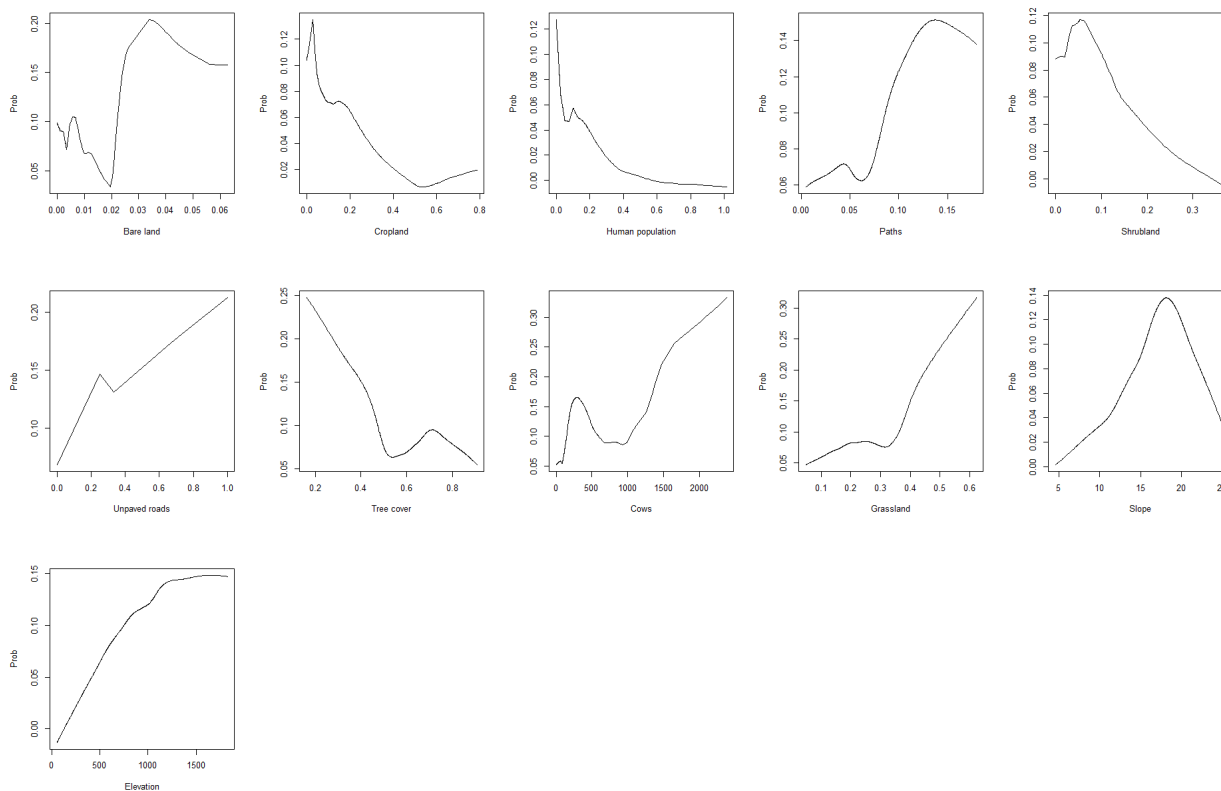


Figure 14. Spline curves of the variables used to model the non-urban probability of poisoning risk.

Using these coefficients, we produced a spatially explicit prediction of the risk of poisoning further away from urban areas (Figure 15). The map is very different from the previous one and shows extensive areas with high risk in proximity of the Sirente Velino Regional Park, of the Gran Sasso e Monti della Laga National Park and of the Monti Sibillini National Park.

The model validation showed $AUC = 0.73$, lower than the AUC value of the first model, but still revealing a good predictive ability of this model.

Table 3. Variables used to model the non-urban poisoning risk, showing the most representative spatial scale for each variable, their standardised coefficient and the p-value.

Variable	Scale (m)	Coefficient	p-value
Intercept	NA	-2.75	<0.001
Bare land	8000	-0.19	0.11
Cropland	2000	-0.53	<0.05
Human population abundance	1000	-0.85	<0.05
Paths	8000	0.34	<0.05
Shrubland	500	-0.14	0.37
Unpaved roads	100	0.43	<0.001
Tree cover	8000	-0.84	<0.05
Cows	8000	0.04	0.57
Grassland	8000	-0.24	0.47
Slope	8000	0.16	0.50
Elevation	4000	0.12	0.55

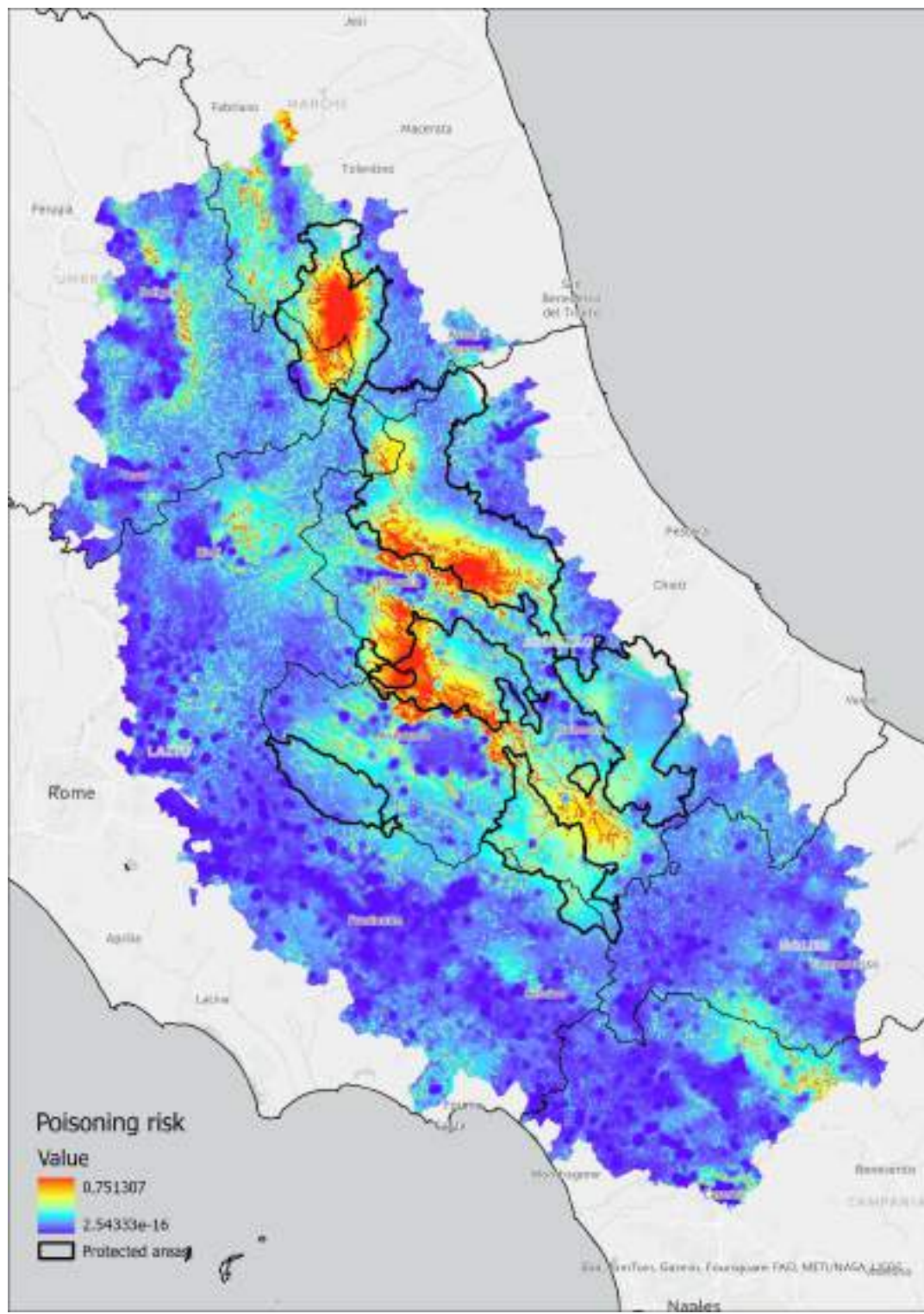


Figure 15. Predictive map of the non-urban poisoning risk.

4. Discussion

The results of this chapter provide potentially useful information on the risk of illegal poisoning in the study area that, however, have to be taken with a pinch of salt. The model of the risk that accounts for all the cases of illegal poisoning events, including those that occurred within urban areas, is strongly biased towards anthropic features, including both paved roads and urban areas. Although it would have been expected that poisoning risk is higher in proximity of human enterprises, this model shows very little beyond the anthropic facilities. Therefore, we thought that excluding the cases within urban areas could have provided a better understanding of the probability of poisoning in wild areas. By doing so, we have excluded all the poisoning cases occurring within a buffer of 500 m from the pixels that the Zanaga et al. (2021) classified as urban, including small settlements that are remote accommodations. However, proximity of small villages and rural houses can still be an important source of risk of poisoning, also for vultures, especially in the cases when domestic or confident wild animals could get poisoned, but then dying in wilder places, where vultures can feed on their carrions. This has not been accounted for in the model, due to the objectivity of telling “small rural houses” and “villages” from “bigger settlements” and “towns”. We have in this way kept a more conservative approach, that might have underestimated the risk of poisoning, especially close to what was classified as urban areas.

The model produced by excluding the cases of poisoning events occurring 500 m from urban areas provided much more interesting insights than the first model. The most striking result is the strong association between poisoning events and unpaved roads, demonstrating how the accessibility of natural wild areas to humans and, especially, to vehicles, is a critical risk for wildlife, since carcasses can be easily transported, and baits deployed. However, a limitation of the use of unpaved roads to model the risk of poisoning, is that we have considered the entire length of the unpaved roads, while it is much more likely that carcasses for poisoning are carried only for the first few kilometres along unpaved roads. The model could be refined in the future by using the unpaved road variables, but calculating the distance from their access points. In this way we would provide a more precise description of the behaviour that potential poisoners might adopt.

Finally, in these models we have used only the number of livestock as a proxy for trophic availability for vultures, and we have not accounted for wild species, especially ungulates, which are also known to be an important element in the diet of vultures. Unfortunately, spatially explicit information on the distribution and abundance of wildlife species was not available, and we have then been unable to use it as a variable. However, it is known from previous observations in the study area that domestic animals compose most of the diet of vultures. Therefore, we believe that by not including wild species we have only minorly underestimated the trophic availability for vultures. Moreover, as many poisoning cases in rural or remote areas represent retaliation for wildlife predation on livestock, we could reasonably assume that livestock density and distribution is definitely more representative than wild ungulates, as far as cases of voluntary wildlife poisoning are concerned.

Except for its limitations, the model can still be of help for preventing poisoning cases by highlighting the areas with the highest risk for poisoning events to occur, and by describing the features that are major drivers of the risk of poisoning. Beyond the aforementioned presence of unpaved roads, paths were strongly associated with cases of poisoning, supporting that accessibility to wild areas represents a risk.

Interestingly, tree cover was strongly negatively associated with the risk of poisoning. This is likely due to two main reasons. First, there could be a spatial bias of where poisoning events have been registered, and it is probable the finding carcasses and baits in more densely forested areas is more difficult, and then the majority of poisoning events were reported in open areas. Additionally, since often the carcasses that are poisoned to harm wildlife are those of domestic animals, it is more likely that they are poisoned right in the areas where they graze, which are mountain meadows and open areas.

5. Conclusion

In this chapter we have produced two models of the risk of poisoning events to occur. The model produced with data collected also within urban areas strongly suffered from a geographic bias towards anthropic features, such as paved roads and urban areas. However, the model produced by excluding these events provided interesting insights into the main drivers of poisoning events. Accessibility to wild areas, either by vehicles or on foot is by far the most important factor predicting poisoning cases. Therefore, it might be desirable that access to unpaved roads be restricted or, at least, controlled, to reduce the cases of illegal poisoning.

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7. Annexes

Annex 1 - Correlation table showing the Pearson's correlation index between each dyad of scale-optimised variables evaluated for the model of the urban and non-urban poisoning risk. In bold are the correlation with $|r| \geq 0.7$. Legend of the variables' names is provided at the bottom of the table.

Var*	H	SL	C	BL	UR	GL	S	P	CL	TC	E	R	SO	HP	U	PR
H	1.00	-0.04	0.85	0.14	0.14	0.12	0.80	0.08	-0.14	-0.06	0.27	0.06	0.07	-0.03	0.00	-0.03
SL	-0.04	1.00	-0.05	-0.12	0.03	-0.07	-0.04	-0.09	0.06	-0.08	-0.38	-0.11	-0.10	0.07	0.08	0.11
C	0.85	-0.05	1.00	0.20	0.10	0.17	0.79	0.08	-0.14	-0.11	0.31	0.04	0.05	-0.03	0.01	-0.03
BL	0.14	-0.12	0.20	1.00	-0.18	0.18	0.15	0.11	-0.13	-0.11	0.33	0.16	0.15	-0.02	-0.04	-0.09
UR	0.14	0.03	0.10	-0.18	1.00	-0.01	0.24	0.02	0.08	0.00	0.00	0.00	0.01	0.01	0.01	0.00
GL	0.12	-0.07	0.17	0.18	-0.01	1.00	0.11	0.02	-0.10	-0.66	0.31	-0.10	-0.09	-0.11	-0.13	-0.07
S	0.80	-0.04	0.79	0.15	0.24	0.11	1.00	0.08	0.00	-0.11	0.14	0.00	0.00	0.02	0.05	0.02
P	0.08	-0.09	0.08	0.11	0.02	0.02	0.08	1.00	-0.16	0.06	0.28	0.22	0.22	0.16	0.10	-0.05
CL	-0.14	0.06	-0.14	-0.13	0.08	-0.10	0.00	-0.16	1.00	-0.30	-0.50	-0.42	-0.43	0.11	0.16	0.21
TC	-0.06	-0.08	-0.11	-0.11	0.00	-0.66	-0.11	0.06	-0.30	1.00	0.04	0.40	0.41	-0.16	-0.29	-0.21
E	0.27	-0.4	0.31	0.33	0.00	0.31	0.14	0.28	-0.5	0.04	1.00	0.46	0.47	-0.2	-0.2	-0.4
R	0.06	-0.1	0.04	0.16	0.00	-0.1	0.00	0.22	-0.4	0.40	0.46	1.00	0.98	-0.2	-0.2	-0.3
SO	0.07	-0.1	0.05	0.15	0.01	-0.1	0.00	0.22	-0.4	0.41	0.47	0.98	1.00	-0.2	-0.3	-0.4
HP	-0.03	0.07	-0.0	-0.0	0.01	-0.1	0.02	0.16	0.11	-0.16	-0.17	-0.15	-0.17	1.00	0.62	0.38
U	0.00	0.08	0.01	-0.04	0.01	-0.13	0.05	0.10	0.16	-0.29	-0.22	-0.24	-0.26	0.62	1.00	0.52
PR	-0.03	0.11	-0.03	-0.09	0.00	-0.07	0.02	-0.05	0.21	-0.21	-0.37	-0.34	-0.36	0.38	0.52	1.00

*H= horses 8000, SL= shrubland 4000, C= cows 8000, BL= bare land 8000, UR= unpaved roads 8000, GL= grassland 100, S= sheep 8000, P= paths 500, CL= cropland 8000, TC= tree cover100, E= elevation 500, R= ruggedness 100, SO= slope 100, HP= human population abundance 100, U= urban 100, PR= paved roads 100.

Annex 2 - Correlation table showing the Pearson's correlation index between each dyad of scale-optimised variables evaluated for the model of the non-urban poisoning risk. In bold are the correlation with $|r| \geq 0.7$. Legend of the variables' names is provided at the bottom of the table.

Var*	BL	SL	TC	R	S	P	SO	CL	H	C	UR	HP	PR	E	GL
BL	1.00	-0.06	-0.24	0.25	0.14	0.23	0.23	-0.08	0.14	0.22	-0.03	-0.04	-0.19	0.33	0.36
SL	-0.06	1.00	-0.11	-0.13	0.01	-0.12	-0.13	-0.02	0.02	-0.02	0.03	0.04	0.20	-0.25	-0.05
TC	-0.24	-0.11	1.00	0.48	-0.26	0.27	0.48	-0.47	-0.17	-0.32	-0.05	-0.05	-0.24	0.00	-0.66
R	0.25	-0.13	0.48	1.00	0.04	0.61	1.00	-0.60	0.12	0.10	0.02	-0.25	-0.68	0.69	0.15
S	0.14	0.01	-0.26	0.04	1.00	0.16	0.04	0.01	0.80	0.77	0.04	-0.01	-0.03	0.16	0.29
P	0.23	-0.12	0.27	0.61	0.16	1.00	0.59	-0.33	0.19	0.19	0.05	-0.07	-0.40	0.48	0.04
SO	0.23	-0.13	0.48	1.00	0.04	0.59	1.00	-0.60	0.12	0.10	0.02	-0.26	-0.68	0.69	0.17
CL	-0.08	-0.02	-0.47	-0.60	0.01	-0.33	-0.60	1.00	-0.07	-0.09	-0.01	0.09	0.42	-0.43	-0.14
H	0.14	0.02	-0.17	0.12	0.80	0.19	0.12	-0.07	1.00	0.81	0.04	-0.01	-0.10	0.25	0.28
C	0.22	-0.02	-0.32	0.10	0.77	0.19	0.10	-0.09	0.81	1.00	0.05	-0.04	-0.15	0.34	0.49
UR	-0.03	0.03	-0.05	0.02	0.04	0.05	0.02	-0.01	0.04	0.05	1.00	-0.05	-0.05	0.04	0.04
HP	-0.04	0.04	-0.05	-0.25	-0.01	-0.07	-0.26	0.09	-0.01	-0.04	-0.05	1.00	0.42	-0.30	-0.16
PR	-0.19	0.20	-0.24	-0.68	-0.03	-0.40	-0.68	0.42	-0.10	-0.15	-0.05	0.42	1.00	-0.78	-0.29
E	0.33	-0.25	0.00	0.69	0.16	0.48	0.69	-0.43	0.25	0.34	0.04	-0.30	-0.78	1.00	0.60
GL	0.36	-0.05	-0.66	0.15	0.29	0.04	0.17	-0.14	0.28	0.49	0.04	-0.16	-0.29	0.60	1.00

*BL= bare land 8000, SL= shrubland 500, TC= tree cover 8000, R= ruggedness 8000, S= sheep 4000, P= paths 8000, SO= slope 8000, CL= cropland 2000, H= horses 4000, C= cows 8000, UR= unpaved roads 100, HP= human population abundance 1000, PR= paved roads 4000, E= elevation 4000, GL= grassland 8000.

Annex 3. Variables used to model the urban and non-urban poisoning risk, showing the most representative spatial scale for each variable, their standardised coefficient, the standard error, the adjusted standard error, the z-value and the p-value.

Variable	Scale (m)	Coefficient	Standard Error	Adjusted SE	z-value	p-value
Intercept	NA	-3.07	0.067	0.067	45.481	<0.001
Grassland	100	0.25	0.088	0.088	2.837	<0.01
Human population abundance	100	0.26	0.053	0.053	4.835	<0.001
Paths	500	0.18	0.051	0.051	3.561	<0.001
Paved roads	100	0.93	0.052	0.052	17.742	<0.001
Sheep	8000	0.14	0.043	0.043	3.153	<0.01
Shrubland	4000	-0.04	0.054	0.054	0.710	0.48
Slope	100	-0.18	0.073	0.073	2.497	<0.05
Unpaved roads	8000	0.10	0.049	0.049	2.034	<0.05
Tree cover	100	0.28	0.098	0.098	2.854	<0.01
Urban	100	0.40	0.054	0.054	7.475	<0.001
Elevation	500	0.02	0.053	0.053	0.391	0.7
Cropland	8000	0.02	0.039	0.039	0.400	0.69
Bare land	8000	0.00	0.023	0.023	0.103	0.92

Annex 4. Variables used to model the non-urban poisoning risk, showing the most representative spatial scale for each variable, their standardised coefficient, the standard error, the adjusted standard error, the z-value and the p-value.

Variable	Scale (m)	Coefficient	Standard Error	Adjusted SE	z-value	p-value
Intercept	NA	-2.75	0.153	0.153	17.986	<0.001
Bare land	8000	-0.19	0.121	0.121	1.599	0.11
Cropland	2000	-0.53	0.219	0.219	2.423	<0.05
Human population abundance	1000	-0.85	0.390	0.390	2.171	<0.05
Paths	8000	0.34	0.146	0.146	2.330	<0.05
Shrubland	500	-0.14	0.152	0.152	0.900	0.37
Unpaved roads	100	0.43	0.084	0.084	5.085	<0.001
Tree cover	8000	-0.84	0.352	0.352	2.385	<0.05
Cows	8000	0.04	0.076	0.076	0.566	0.57
Grassland	8000	-0.24	0.332	0.332	0.728	0.47
Slope	8000	0.16	0.235	0.235	0.673	0.5
Elevation	4000	0.12	0.200	0.200	0.597	0.55

Chapter 11

The impact of power lines

Enrico Bassi



1. Introduction - Impact of power lines and aerial cables on birds

Power lines have a direct impact on the survival of birds. The presence of electrical lines of high, medium and low voltage causes the death of numerous individuals due to the collision with aerial cables but also by electrocution, a phenomenon that usually occurs on the top of the pylons of the medium voltage (MV) lines (Ferrer et al. 1991; Ferrer 2012; Marchesi et al. 2001; Penteriani 1998; Rubolini et al. 2001). The risk of collision, to which all bird species are potentially exposed, is related to flight modes, to factors that intervene in modifying these modes, and to the types of environments power lines cross. Electrocution on the pylons of low and medium voltage lines mostly affect medium-large sized birds (diurnal raptors, owls, corvids, storks, etc.) which, by placing themselves in the presence of live electrical conduction elements not far apart from each other, can trigger electrocution. Tucker & Heath (1994) highlighted that at least 7% of threatened species at European level suffer significant losses due to interaction with electrical conductors either through collision or electrocution.

Even for large vultures, power lines potentially constitute an important additional mortality factor which adds to the already considerable losses of natural and anthropic origin. This threat is particularly dangerous as the power lines are to be considered permanent infrastructures capable of generating a permanent impact. Furthermore, mortality is largely underestimated in any environmental context due to a high rate of removal of carcasses by carnivores and scavengers.

Power lines also represent, as mentioned, an ecological barrier capable of negatively influencing the movements of birds. The impact of these lines is obviously proportional to the number of birds that frequent the area as well as to the presence of attractive habitats for the birds themselves (trophic sources, roosting places, wetlands).

Mortality data for Abruzzo and the central Apennines

Very few references are available for Abruzzi and most refer to the eagle owl (*Bubo bubo*), for which electrocution and collision with power lines could be considered the main factors responsible for the decline of the Abruzzi Apennines population (Penteriani & Pinchera 1992). In Abruzzi, the eagle owl occurred at very low densities in three mountain areas of the Apennines, below the minimum density necessary for the long term survival of a population. This situation, since the area examined was very large, was believed to be representative of the central Apennines, from 1960 to 1989 (Penteriani & Pinchera 1990). Recent studies (Pellegrini M. *in verbis*) state that the species is recovering compared to the strong decline recorded in the 70s and 80s due to unknown causes.

As regards to the target species of this study, in the defined area, 6 griffon vultures died due to electrocution in the province of L'Aquila, between 2000 and 2018 (1 every approximately 3.1 years) (Table 1) (Posillico et al. 2023). From a rough analysis because of limited samples available, the impact caused by power lines undoubtedly appears to be a further source of mortality even if it seems less impactful than other threats such as poisoning, impact with wind turbines and lead exposure. These results must be considered with extreme caution because all age classes were involved: 2 adults, 2 subadults, 1 immature, 1 juvenile and 1 unknown. Four out of 6 vultures were marked individuals.

Indeed, the impact of power lines on birds is widespread and estimated at between 2.1 and 20.5 dead birds per km of line/year in Italy (Rubolini *et al.* 2005). This is likely underestimated due to the high rate of removal by carnivores, scavengers and general consumers.

Date of presumed death	Recovery date	Municipality	Age	Marked
4/13/2018	4/14/2018	Tagliacozzo	Adult	Yes
n.a.	04/09/2008	Cappadocia	n.a.	No
n.a.	03/23/2007	Magliano de' Marsi	Juvenile	No
n.a.	05/06/2000	Cappadocia	Subadult	Yes
22/2/2004	02/23/2004	Cappadocia	Subadult	Yes
24/12/2005	01/18/2006	Magliano de' Marsi	Adult	Yes

Table 1. Summary of the 6 recoveries of griffon vultures dead from electrocution and unspecified under power lines. N.a.: not available. Source: Reparto Carabinieri Biodiversità Castel di Sangro (AQ)- Vulture Conservation Foundation, vulture mortality database.

Since electrocution in the griffon vulture generally occurs at MV power lines, and more rarely in HV/AAT lines, we proceeded with the mapping of the recovery points in relation to the sections of the power lines available so far (OpenStreetMap). These sections in public databases (open source) are rather complete as regards to the large electrical infrastructures of the HV/AAT lines owned exclusively by TERNA S.p.A., but very incomplete for the others which could belong to various private companies (such as e-distribuzione S.p.A.) and local ones. In fact, from the comparison of the mapped recovery points, their overlap with the available sections of the power lines was verified and it was deduced that in five cases electrocution happened in areas where the MV sections are not available from the maps, with the exception of Tagliacozzo point (Figure 1) which falls near a 60,000 V HV power line.

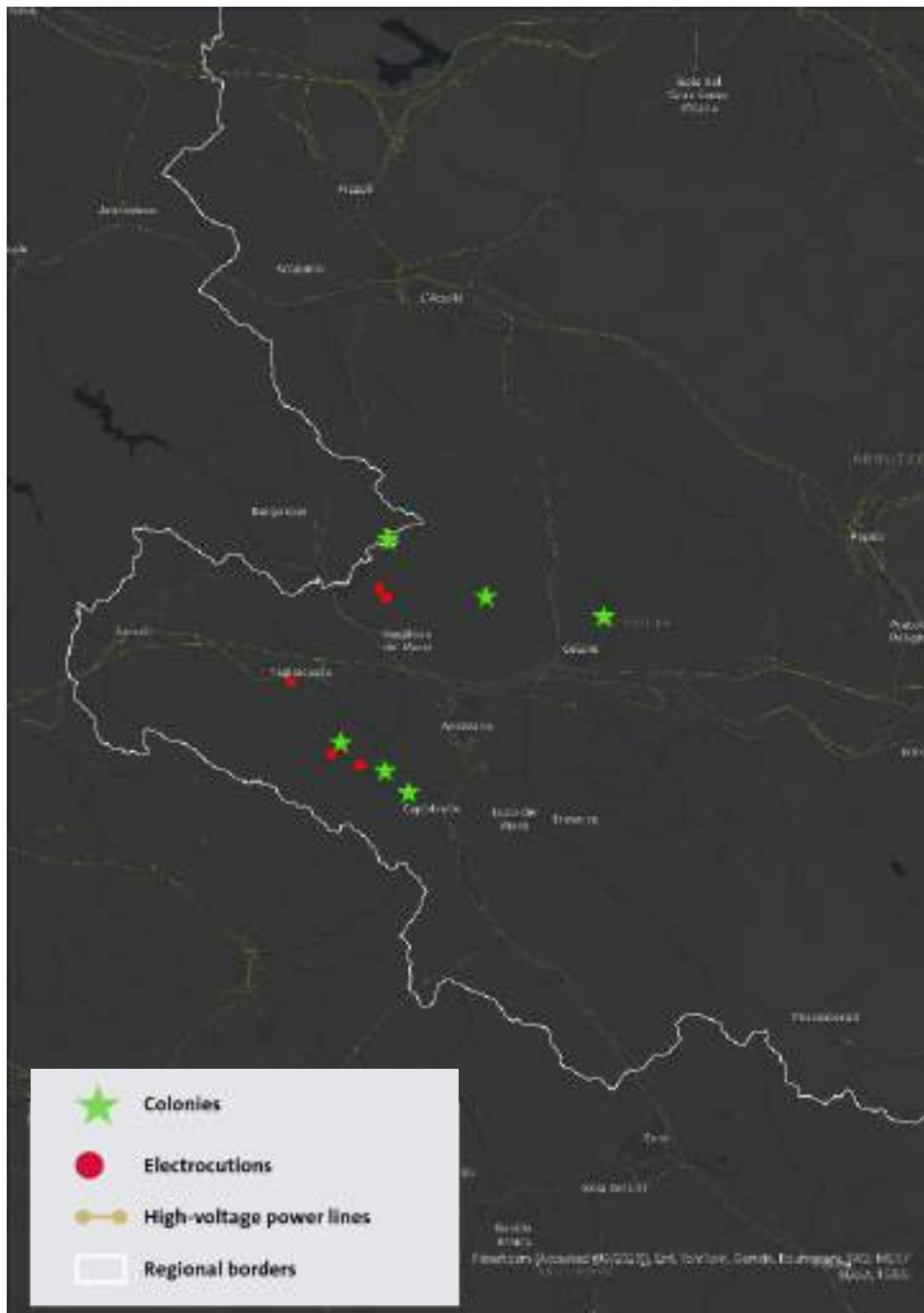


Figure 1. Tracks of the High Voltage HV/AAT power lines (in light yellow) available for the central Apennines provided by OpenStreetMap. Data precision (error in metres: 0.4). Specification date: 8/12/2010. The recovery points are all very close to the 6 known breeding colonies (green stars). Two of the three recovery points in the Municipality of Cappadocia concern exactly the same power line and are therefore overlapped.

2. Classification of the danger of power lines and aerial cables in relation to the target species

As part of future initiatives of restocking the griffon vulture population and reintroducing the cinereous vulture and the bearded vulture, it will be necessary to carry out a preliminary action (maximum duration 2 years) to evaluate and classify the danger of the power lines and of the suspended cables in relation to the target species. This should be done in analogy with what was recently carried out as part of the LIFE Gestire 2020 project in Lombardy in northern Italy (Bassi 2018).

It will be necessary to interact with the companies and managers of ski lifts operating in the central Apennines to recover the cartographic material on GIS support as well as recover the data available from ornithologists, regional stakeholders, responsible for local wildlife recovery centres and regional veterinary authority, as well as the Provincial Police and Carabinieri Forestali which are responsible for the recovery of dead and wounded wildlife. In addition to the mortality of the target species, the mortality relating to other more common sentinel species such as corvids, small and medium-sized birds of prey, etc., should be included in the data to be processed. Finally, the output must be related to the sites of confirmed and potential presence of the target species (nesting sites, feeding areas, release areas and acclimatisation aviaries, main trajectories, time spent-cumulative/geographical sector, orography, artificial feeding sites, etc.).

3. Aims of the assessment

The main aim of this preliminary action will be to collect qualitative and quantitative information in the most uniform way to offer an overall framework for evaluating the risk from power lines. This will be useful to discriminate the degree of danger of aerial cables and electric pylons.

This classification and hierarchization, based on standard criteria that can be replicated at other territorial scales, constitutes the basis for making the most effective and parsimonious choices aimed at mitigating the power lines. It also constitutes a future planning tool to guide the managers involved in actions for habitat conservation and restoration.

To summarise, the aims of the assessment are the following:

- definition of a study area and risk analysis of the sections of all the overhead lines;
- mapping of the nesting sites of the priority target species (griffon vulture) and areas of potential presence (cinereous vulture and bearded vulture);
- identification of the main critical issues in relation to the different ecological needs and behavioural habits of the target species and on the basis of the geographical location of the sections of line (intersection of aerial infrastructures with lakes, rivers, secondary valleys, passes and gorges);

- increase the ecological connectivity of the airspace at the bottom of the valley which constitutes a preferential migration corridor for birds and a very important resting and feeding area, eliminating or minimising the risk of electrocution;
- research and identification of the most effective mitigation measures for the different types of overhead cables present in the study area;
- securing the power lines and MV supports through the installation of insulating sheaths and visual bird diverters (indicators), research into the most appropriate types and testing of innovative devices for total and long-lasting isolation of the electrical disconnectors;
- decrease in mortality cases from electrocution and collision of griffon vultures and other more widespread species indicating the phenomenon;
- approval of an official Agreement that commits the companies that own the electricity lines (e-distribuzione, other operators and TERNA) to implement mitigation measures in the event that cases of electrocution/collision occur and during ordinary/extraordinary maintenance work of the power lines defined as very high and high risk as well as implementing mitigation measures for a few km of dangerous lines near the sites considered to be at highest risk by the proposed classification;
- broaden awareness at all levels such as electricity sector operators, planners, ornithologists, managers of protected areas, citizens and schools.

4. The problem of collision and electrocution

As mentioned, in birds, mortality caused by power lines (collision and electrocution) is an "artificial interaction" factor representing an additive mortality source, with a proportionally greater danger in relation to the location of power lines and bird's behaviour. The risk of collision is related to flight modes and the factors that intervene to modify these modes. In the study area the main risks related to power lines are:

- 1) direct collision when visibility or manoeuvrability is scarce, due to meteorological conditions (rain, fog, clouds and strong winds), the scarce visibility during some of the hours when activity and movements take place, the poor visibility of suspended elements of the electricity grid (*e.g.*, electric cables close to areas with wooded vegetation, wetland, etc.) or even for their "strategic" position (*e.g.*, power lines close to rocky cliffs suitable for nesting, etc.). All three types of power lines (High, Medium and Low Voltage) and the suspended cables of ski lifts and cableways present this kind of risk.
- 2) Electrocution: pylons and power line supports are often used as perches, exposing birds to variable risk of electrocution.

Most medium and low voltage lines are at risk of electrocution as they often have a reduced distance between the electrical conductors and the support points used by birds (metal tops of

supports, metal side arms, live insulators, etc.). Overhead line supports are lethal when birds simultaneously touch elements carrying different voltages or if they come into contact simultaneously with current-carrying elements and earthed elements. In fact, the majority of accidents occur on disconnectors, on supports with rigid insulators and conductors above the bracket, in the case of dangerously constructed pole switches and in the case of terminal supports (with or without switches).

5. Mitigation solutions

Securing the lines is a practice already adopted in many instances in European areas, especially within parks and nature reserves. In Italy there are some examples of collaboration between protected area management bodies and managers of power companies which have led to the adoption of rigorous protection measures (raised perches on pylons, spirals and visual indicators to reduce the risk of impact with cables, burial of some sections of line). Examples of these collaborations are found in the Po Delta Regional Park, in Valtellina and Valchiavenna (province of Sondrio), on Lake Iseo (Bergamo and Brescia provinces), in the Stelvio National Park (central Alps, Sondrio province), in the Comunità Montana of Mount Amiata and in the Burano WWF Oasis, Tuscany, in the Pollino National Park (Basilicata and Calabria) and in the Murgia Materana (Basilicata).

5.1. Insulating sheaths on MV power lines pylons at risk of electrocution

To reduce the phenomenon of electrocution on the poles supporting medium voltage power lines, it is necessary to apply special insulating sheaths in silicone and flexible TPE and/or EPDM on the live conductors which would thus be insulated within 1m from each support. The material used has a dielectric strength greater than at least 10 Kv per mm of thickness. These solutions, approved by e-distribuzione, are easy to install and can be applied on dead and live packages, on jumpers in branch poles and on conductors in correspondence with rigid insulators. To be able to apply the sheaths it is necessary to temporarily interrupt the electricity line service. In addition to the rubber and/or silicone profile, the affixing of other insulating material (self-bonding tape) on the live conductors and terminals within 1m of each electrical support considered at risk will be guaranteed. To obtain adequate insulation towards the ground, it is necessary to apply two strata of tape (back and forth) with an overlap of 50% pulled until obtaining a width equal to 75% of the initial width. To reduce costs, operations could take place as much as possible during the scheduled maintenance activity of the power lines.

5.2. Bird diverters (flappers, buoys or spirals) on HV and MV lines at risk of collision

In the territory considered there are some stretches of MV lines that are particularly lethal for a wide range of species. It is therefore proposed to make the suspended cables visible by installing visual warning systems, such as spirals, buoys or coloured spheres. The positioning of coloured spheres is normally used to make the lines visible to devices flying over at low height, but is essentially used for high voltage lines. These simple measures, by highlighting the course of the power line, divert the flight paths of the birds, avoiding impact. Concerning the choice of colours: red is perceived more in good lighting conditions, white in poor lighting conditions; the combination of both colours is therefore desirable.

Since the insulating sheaths and spirals are particularly evident even to the human eye, it is believed that their installation will also be particularly useful for raising awareness among the local people who usually are completely unaware of this problem.

Illustrative documentation

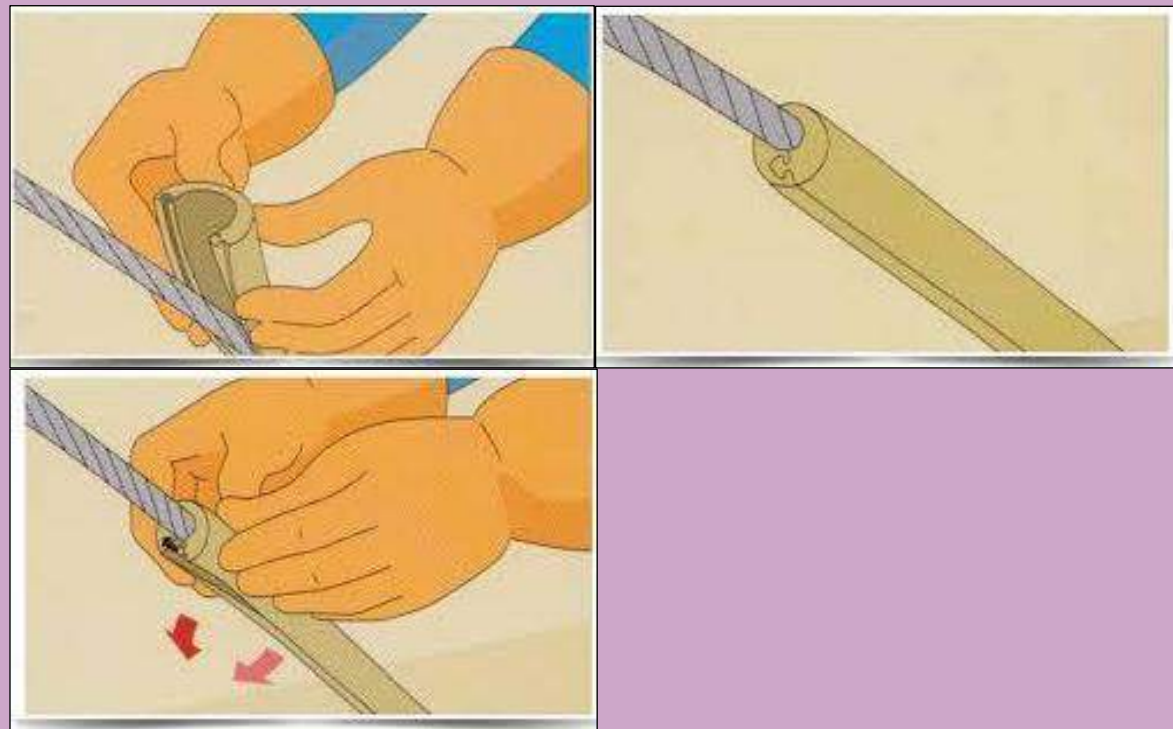


Figure 2. Insulating sheath in silicone and flexible TPE, already applied on ENEL (former public electric power distributor and producer) MV lines in the provinces of Ancona, Grosseto and Bergamo, correctly applied definitively eliminates the risk of electrocution, which is detrimental to medium and large-sized birds (from improlax.it).



Figure 3. As an alternative to the insulating sheath, the rubber profile EPDM can be applied on MV lines as already done in Valtellina (province of Sondrio). Photo E. Bassi.

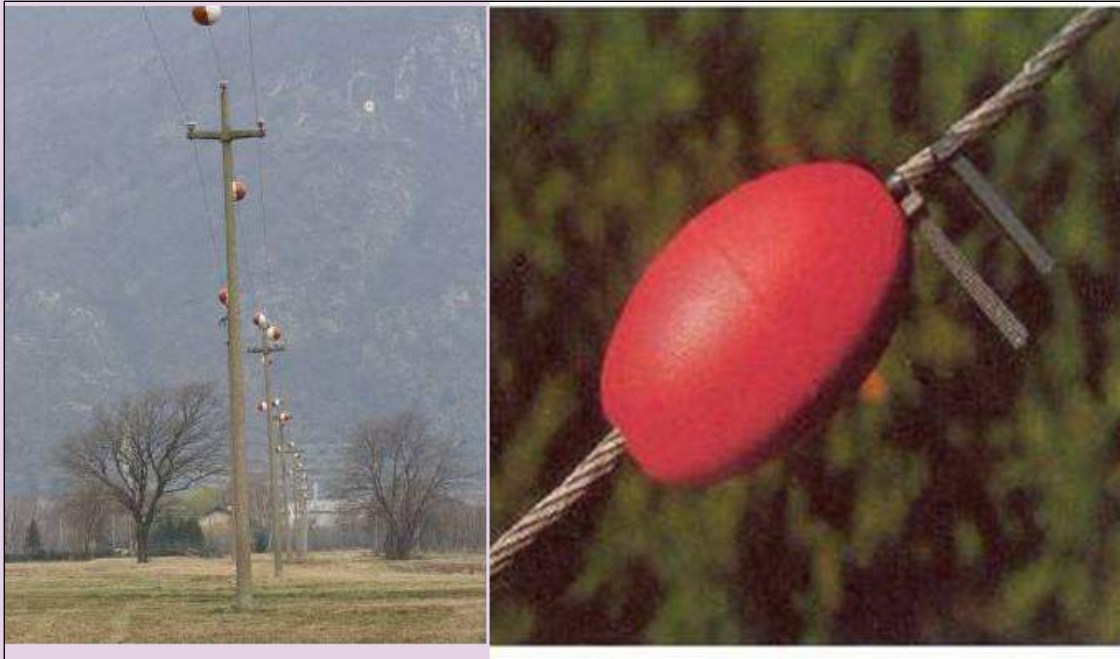


Figure 4. Application of anti-collision warning devices for birds (polyurethane buoys) in Verbano Cusio Ossola. Photo R. Bionda and ENEL.

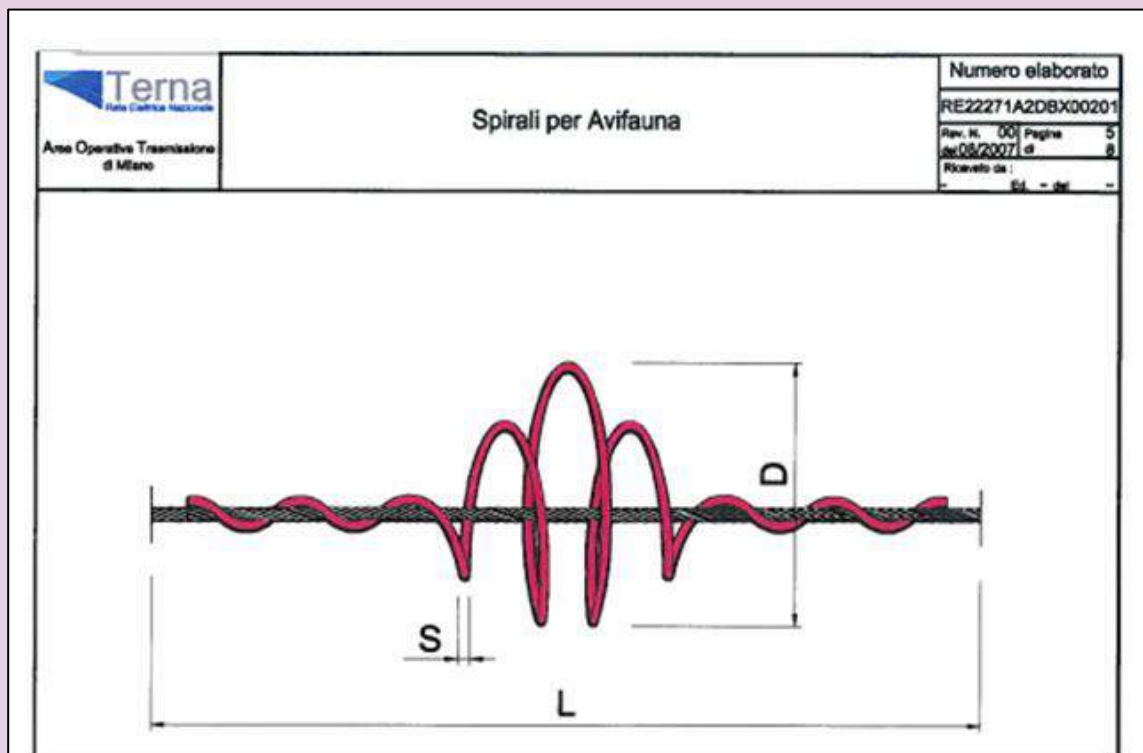


Figure 5. Cables at high risk of collision are also marked with plastic spirals which, under the effect of the wind, produce a noise that can be heard by birds which then change their flight route. From Terna.

6. Hierarchization of intervention priorities

General principle

Evaluate the activation of *ad hoc projects* which aim to mitigate specific threats and specific situations, with importance to feasibility and economic sustainability, and foresight and replicability over time. A more careful management of ordinary maintenance interventions to ensure the safety of a greater number of power lines and to save precious economic resources would also be important.

This should allow greater guarantees of survival for an increased number of individuals and breeding pairs. The common thread of this inclusive choice is unique: there are lines that are more dangerous than others, regardless of their ownership, and therefore action should be taken in a pragmatic and transversal manner with all operators in the area of intervention. This could also constitute a strong sign of encouragement so that these interventions become increasingly routine, a sign of a new sensibility that must be encouraged within companies dealing with electric power distribution and production.

Similar analyses should, therefore, be replicated to locate the riskier sections, allowing substantial economic savings for their future mitigation as it is an action that can be replicated in the medium to long term by all managing bodies of parks, reserves and Natura 2000 Network sites managers.

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Chapter 12

Risk of lead intoxication in relation to current hunting methods

Enrico Bassi



1. Introduction

A vast literature has been collected about the serious and persistent forms of contamination of ecosystems, food networks and animal species, especially birds, linked to the use of lead in hunting activities.

In humans, lead exposure is particularly dangerous and is associated with neurodevelopmental effects, impaired renal function and fertility, hypertension, adverse pregnancy outcomes, and death. For this reason, the European Chemical Agency's (ECHA) Risk Assessment Committee (RAC) adopted an opinion on 9 March 2018 in accordance with Article 70 of Regulation (EC) No. 1907/2006 in relation to the file pursuant to Annex XV. In its opinion, the RAC agreed with the Agency's conclusions that the ingestion of fired lead ammunition by waterfowl causes toxicological effects including death. With regard to human health, the RAC concluded that lead is highly toxic and that no threshold has been set for neurodevelopmental effects in children or blood pressure or renal effects in adults, so any exposure to lead constitutes a risk. The RAC therefore concluded that the proposed restriction constitutes an appropriate measure at the European Union level to address the identified risks. The RAC was strongly in favour of a shorter period than the three years proposed by the Agency.

In Italy, the quantity of lead spread through hunting is very significant, especially in points strategically frequented by birds (wetlands and mountain passes), and is estimated between 17,000 and 25,000 tons (each fired cartridge of calibre 12 spreads throughout the environment 32 grams of lead, Gariboldi et al. 2004). Other authors report values between 40 and 60 tons with an annual average of 1,300-2,000 g/hunter (Andreotti & Borghesi 2012). The produced pollution tends to be concentrated mainly around fixed hunting huts. Applying a calculation only to animals killed from sheds in the province of Brescia, for example, it turns out that on average, at least 5-6 kg of pellets are dumped in the land surrounding each hunting hut (Andreotti et al. 2010). Similar concentrations are also found at fixed hunting posts in wet areas (barrels) for hunting waterfowl, as well as at shooting ranges.

The risk of lead poisoning which causes the pathology called "saturnism" is also particularly related to the current ungulate hunting methods, and other terrestrial species, as well as to the culling programme for invasive and alien species. Numerous scavengers, in fact, can suffer from saturnism due to the ingestion of lead pellets and splinters of lead bullets used while hunting ungulates occurring in the meat, viscera abandoned on the ground or in carcasses of animals shot but not retrieved. In Italy, threatened birds are obligate necrophagous species (bearded vulture *Gypaetus barbatus*, cinereous vulture *Aegypius monachus*, griffon vulture *Gyps fulvus*, Egyptian vulture *Neophron percnopterus*), facultative necrophagous species (golden eagle *Aquila chrysaetos*, black kite *Milvus migrans*, red kite *Milvus milvus*, marsh harrier *Circus aeruginosus*, hen harrier *C. cyaneus*, buzzard *Buteo buteo*, raven *Corvus corax*, eagle owl *Bubo bubo*, and tawny owl *Strix aluco*) and ornithophagous species (peregrine falcon *Falco peregrinus*, goshawk *Accipiter gentilis*, and sparrowhawk *Accipiter nisus*).

The European Chemical Agency has carried out an in-depth technical investigation on the subject of lead in hunting ammunition on behalf of the European Commission, evaluating the huge scientific literature available and examining in depth all aspects relating to the introduction of a possible ban on lead from

hunting ammunition. At the end of this investigation which involved various stakeholders, experts and ammunition manufacturers, ECHA produced a comprehensive technical dossier in which the harmful effects of lead on wildlife, environment and human health were illustrated, providing technical solutions to overcome such problems. ECHA lists the main negative effects due to the use of lead in hunting ammunition on the territory of the European Union in the following points:

- emission of lead contained in bullets: 122 tons/year
- emission of lead contained in cartridges: 14,000 tons/year
- number of birds poisoned in a lethal form by primary ingestion: 1.3 million/year (data referring to the poisoning of birds that ingest hunting pellets dispersed on the ground outside of wetlands. In the wetlands of the European Union, it is estimated that at least another 700,000 waterfowl die every year)
- number of birds poisoned in sub-lethal form by primary ingestion: 135 million/year
- number of birds poisoned in sub-lethal form by secondary ingestion: 14 million/year
- number of children who suffer a loss of IQ >0.06 points: 70,000/year
- number of children who suffer a loss of IQ >1 point: 4,400/year.

To overcome these problems, ECHA has proposed a ban on the use of lead, which makes the use of alternative ammunition mandatory. This solution, according to ECHA's opinion, would entail an economic burden for European hunters of between 0 and 1.3% of the cost of purchasing lead ammunition. The timing indicated by ECHA for the introduction of the ban provides for 18 months for bullets used for shooting with rifles and 5 years for cartridges used for shotguns.

2. Waterfowl threatened by lead poisoning in Italy

Priority target species pursuant to Dir. 2009/147/EC: ducks, geese, other waterbird species and birds of prey potentially linked to wetland. Birds take in lead released into the environment in different ways depending on their feeding habits: by directly ingesting lead pellets found in the ground or at the bottom of water bodies (primary intake) and through the consumption of species hit by ammunition (secondary intake - embedded pellets and bullet fragments). Pellets that do not reach the target also accumulate at the bottom of water bodies. Here, they can locally reach very high quantities, thus they are likely ingested by waterbirds due to their habit of swallowing pebbles (grit) to help crush food in the stomach. It has been shown that 4-10 lead pellets are sufficient to cause the progressive deterioration and death of mute swans and geese in 36-72 days (in ducks 2-6 pellets are sufficient).

Recently, the EC approved Commission Regulation (EU) 2021/57 of 25 January 2021 amending Annex XVII of Regulation (EC) No. 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) with regard to lead

ammunition used in or near wetlands (<https://eur-lex.europa.eu/eli/reg/2021/57/oj>). The Regulation established that, from 16 February 2023, in wetlands or no further than 100 metres from them it is prohibited to carry out the following activities: a) firing ammunition containing a concentration of lead (expressed as metal) equal to or greater than 1% in weight; b) carry such ammunition when on shooting activities in wet areas, going to carry out shooting activities in wet areas or returning after carrying out such activity. For the purposes of the first subparagraph: (a) 'no further than 100 metres' means within 100 metres of any external boundary of a wetland.

In Italy, however, the full enforcement of the notice contained in Regulation (EU) 2021/57 of the Commission of 25 January 2021 (effective from 16 February 2023) is yet to be implemented, since its application has recently been limited by the Italian Government with the enactment of Law no. 136 of 9 October 2023, which amended the National Hunting Law 157/92 regarding the use and transport of lead ammunition in or near wetland. This law is valid from 10.10.2023 but Italy has been officially called by the European Commission to comply with Regulation 2021/57 by launching an infringement procedure.

3. Raptors threatened by lead poisoning in Italy

Directive 2009/147/EC identified the following birds as a priority target: bearded vulture, griffon vulture, cinereous vulture, Egyptian vulture, short-toed eagle *Circaetus gallicus*, golden eagle, red kite, black kite, marsh harrier, hen harrier, Montagu's harrier *Circus pygargus*, pallid harrier *C. macrourus*, and peregrine falcon. Due to their peculiar top position in ecosystems, birds of prey are more exposed to the risk of direct and secondary lead poisoning through bioaccumulation, which occurs when they feed on dead or debilitated subjects because of lead poisoning or being wounded with firearms. Findings carcasses containing fragments of fragmented bullets (*e.g.*, ungulates) and of small-medium sized animals containing pellets (thrushes, doves, ravens, grouses, pheasants, hares, etc.), live prey with embedded pellets and viscera contaminated by lead splinters left on the ground after killing ungulate species are particularly dangerous for raptors. As regards lead pellets, Andreotti & Borghesi (2013) have shown that even the shot used to hit starlings *Sturnus vulgaris* and other songbirds can shatter into splinters, making the spread of the harmful metal in the body of the shot animal even more pervasive.

This broad case study, as it can be imagined, concerns all the environments in the central Apennines even if, locally, the type of risk can vary depending on the geographical area, the type of hunting and control practised and the phenology of these raptor species. For example, when hunting small birds in migratory transit, the probability that a bird of prey feeds on unrecovered birds hit by pellets is certainly higher in areas with high hunting density. In these contexts, in addition to the priority species, buzzards, sparrowhawks and goshawks also expose themselves to the risk of intoxication, as demonstrated by an enormous amount of publications (Thomas 1980; Storch 1994; Pain 1990; Kenntner et al. 2003; Grainger Hunt et al. 2006, Brant et al. 2003). On the contrary, in lowland contexts where shooting activity for the control of invasive species is particularly spread (*e.g.* aiming at starlings, pigeons *Columba* sp., corvids and coypu *Myocastor coypus*), many scavengers are particularly at risk of exposure to lead poisoning. Andreotti et al. (2018) have documented the death due to acute lead poisoning of a female peregrine

falcon in Bologna which had numerous pellets in the digestive tract and remains of *Columba livia* var. *domestica* and *Sturnus vulgaris* feathers.

4. The risk of lead poisoning in relation to the target species of the feasibility study

To frame the problem in relation to the target species such as the griffon vulture and the golden eagle (already occurring in the study area), the cinereous vulture (for which the occurrence of dispersal/erratic birds is documented) and the bearded vulture (which has never been documented in this century in the central Apennines), we referred to a recent study carried out in 4 south-central European countries (Italy, France, Austria and Switzerland). The study launched by Ente Regionale Servizi Agricoltura Foreste Lombardia (ERSAF)-Stelvio National Park and province of Sondrio, in collaboration with the Experimental Zooprophyllactic Institute of Lombardy and Emilia-Romagna - Sondrio and Bologna section - and the network of International Bearded vulture Monitoring (IBM), analysed lead contamination in large raptors (Bassi et al. 2021). Between 2005 and 2019, 595 tissue samples were collected and analysed from 252 carcasses of the above-mentioned 4 species. Lead concentrations in target internal organs showed a similar pattern across species, with long and short bones showing the highest median values (5.56 and 6.8 mg/kg wet weight, respectively), the brain the lowest (0.12) and the liver and kidney an intermediate concentration (0.47 and 0.284). Overall, 111 individuals (44%) showed lead concentrations above background thresholds in at least one tissue (*i.e.*, >2 mg/kg ww in soft tissue, >8.33 in bone) and 66 (26%) had values indicative of clinical poisoning (> 6 mg/kg ww in the liver, > 4 in the kidney, > 16.6 in the bone). Tissue lead concentrations and incidence of clinical and subclinical poisoning were higher in golden eagles and griffon vultures. Worth to be mentioned are the cases of a 14-day-old embryo extracted from a golden eagle egg with 1.16 mg/kg in the femur and two 30-day-old golden eagle chicks with subchronic contamination, collected in the Adamello Regional Park within province of Brescia and in province of Sondrio, both in northern Italy.

Overall results are worrying since 3 of the 4 most sampled species (golden eagle, bearded vulture and griffon vulture) show particularly high lead values and prevalence. In the Alps, acute and chronic saturnism was detected in 22% of bearded vultures (5 out of 23 individuals), in 55% of golden eagles (44 out of 80), in 50% of griffon vultures (23 out of 46) and in cinereous vulture median bone lead concentrations indicative of chronic exposure (18,326 mg/kg, n = 6) exceed the value from environmental contamination although no acute cases have been recorded (Bassi *et al.* 2021). Particularly worrying values were also collected for the Apennines and will be described in detail below.

5. Golden eagle and griffon vulture in the central and northern Apennines

The data obtained from the research reported above, still in progress, outline a very critical trend for these two species considered respectively facultative and obligatory scavengers. The golden eagle is an excellent “sentinel” species, an indicator of lead contamination of hunting origin detrimental to vultures, due to its trophic ecology and its wide distribution in the Apennines. It demonstrates how widespread the problem is and at the same time not yet addressed with the attention it deserves from the relevant Public Administrations. In fact, in particular, in the north-central Apennines, 50% of 16 golden eagles analysed to evaluate the accumulation of lead in the tissues, showed acute/chronic exposure values (2 cases, 12.5%) and subacute/subchronic (6 cases, 37.5%). In eight cases the levels found were compatible with the environmental background level but the analyses were incomplete in 7 out of 8 cases (Table 1).

The examined golden eagles came mainly from Emilia-Romagna (5 cases) and the central Apennines, from the Marche, Umbria, Abruzzi and Latium regions (8 cases) while 76% of the griffon vultures were recovered in Abruzzi and 16.6% in Latium (table 1). The remaining 4 griffons were recovered in Liguria, Tuscany, Umbria and Puglia.

Table 1. Origin of the birds of prey recovered in the central-northern Apennines analysed to evaluate the accumulation of lead in the tissues Data: ERSAF- Stelvio National Park, province of Sondrio, Reparto Carabinieri Biodiversità Castel di Sangro (AQ) and Enrico Bassi.

Regions	Golden eagle	Griffon vulture
Emilia-Romagna	5	0
Liguria	0	1
Tuscany	3	1
Marche	3	0
Umbria	2	1
Abruzzi	1	41
Latium	2	9
Apulia	0	1
Total	16	54

As mentioned, the griffon vulture due to its feeding and behavioural habits, is also an excellent indicator for assessing the exposure to lead from hunting, and for this reason it was the most widely sampled species at the Apennines level compared to the golden eagle (54 vs 16), also thanks to the pluriannual collaboration established with the Reparto Carabinieri Biodiversità Castel di Sangro, which has been monitoring the population for 3 decades in collaboration with Rewilding Apennines (Table 2).

Table 2. Summary of ecotoxicological monitoring of lead levels in the tissues of golden eagles and griffon vultures in the central-northern Apennines. ERSAF- Stelvio National Park, province of Sondrio, Reparto Carabinieri Biodiversità Castel di Sangro (AQ) and Enrico Bassi.

Lead exposure level	<i>Golden eagle</i>	<i>% Golden eagle</i>	<i>Griffon vulture</i>	<i>% Griffon vulture</i>	<i>% total</i>
chronic/acute	2	12.5	5	9.2	10
subchronic/subacute	6	37.5	20	37.1	37.2
background but incomplete analyses	7	43.7	22	40.7	41.4
Background	1	6.3	7	13	11.4
Total	16	100	54	100	70

In the north-central Apennines, combining both species, 47.2% of all individuals in whom at least one tissue had been analysed, were exposed to lead of hunting origin (33 out of 70). However, by reducing the sample only to carcasses that had complete analyses available and to subjects captured alive whose blood lead levels were analysed, the percentage of subjects exposed to lead increased to 67% (16 out of 24) (Table 2). These values must be considered particularly serious if we consider that in the area, in the period 1994-2021, 9 “artificial feeding stations” for large and medium-sized scavengers (kites) were alternatively activated of which, at the moment, only 3 are still operating (Figure 1). One of those which are still active, was built specifically to support the griffon vulture populations in the central Apennines (Massa d'Albe).

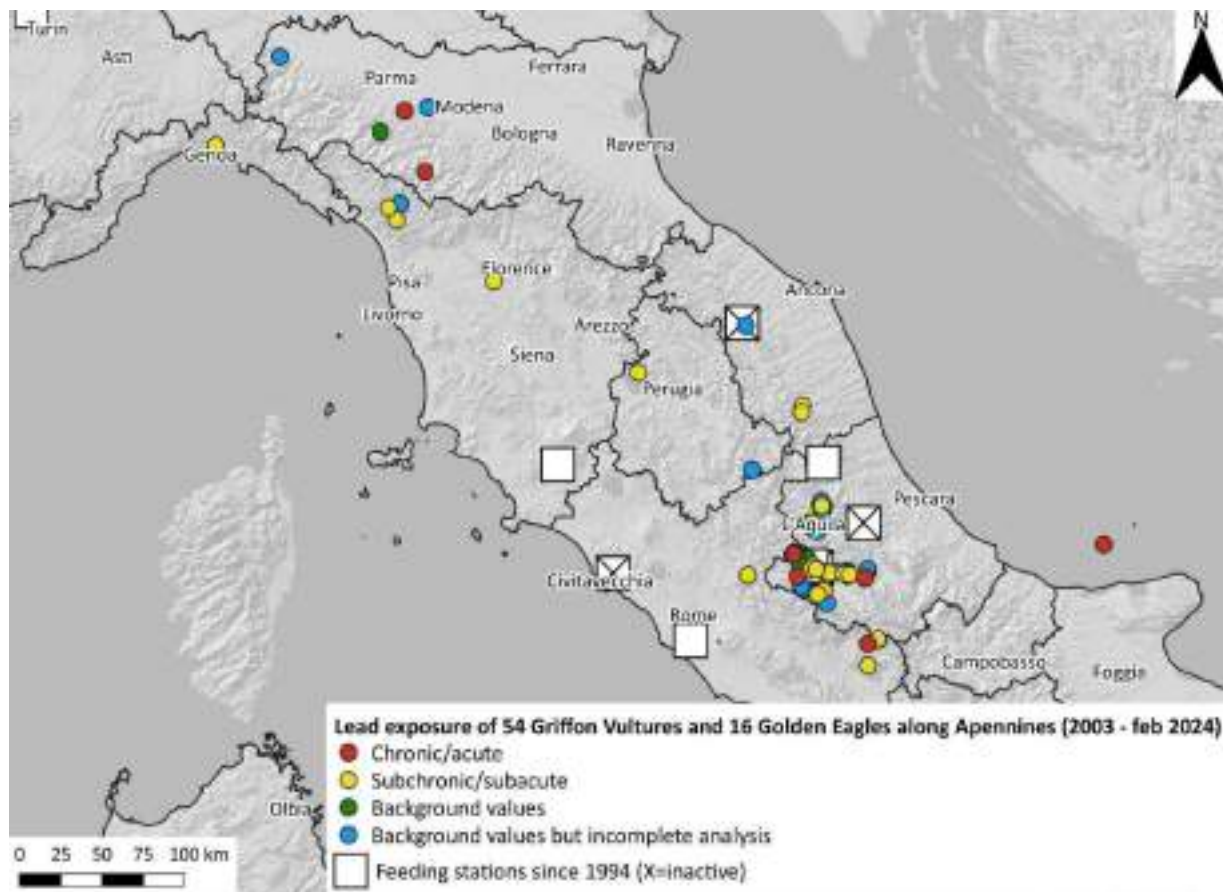


Figure 1. Distribution of griffon vulture and golden eagle individuals from the central-northern Apennines subjected to analyses on lead concentrations in their tissues (skeleton, liver, kidney, brain, gonads, blood and clot). ERSAF-Stelvio National Park, province of Sondrio, Reparto Carabinieri Biodiversità Castel di Sangro (AQ) and Enrico Bassi.

The situation remains almost unchanged if the northern Apennines are excluded from the analyses (Figure 2). In fact, considering only data from the central Apennines (Abruzzi, Marche, Umbria, Latium and the exception of the case from Isola di Capraia in Apulia) 45% (27 out of 60) of all individuals with at least one tissue analysed were intoxicated or exposed to lead, while the individuals with complete analyses resulted intoxicated/exposed to lead in 67% of cases (14 out of 21).

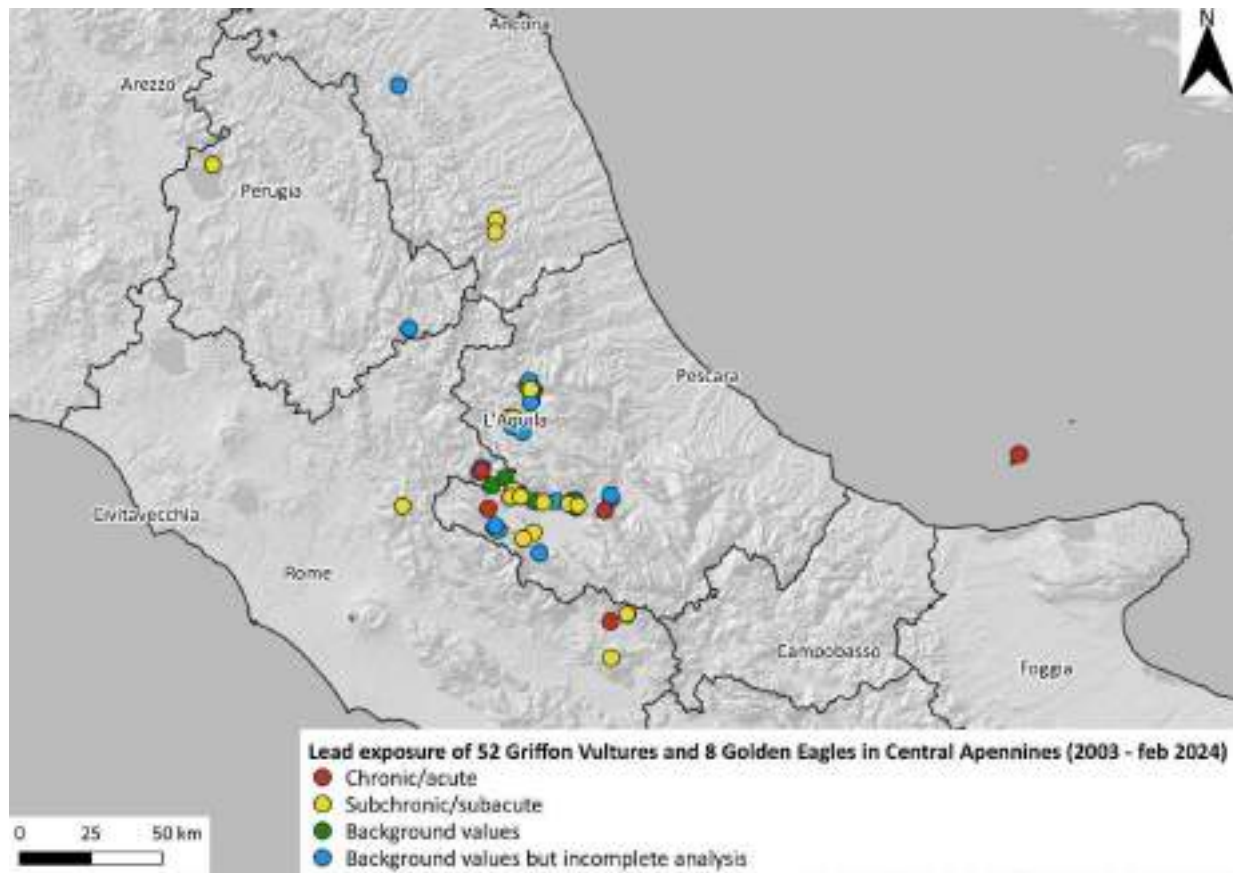


Figure 2. Distribution of griffon vulture and golden eagle individuals from the central-northern Apennines subjected to specialist analyses on the concentrations of lead of hunting origin in their tissues (skeleton, liver, kidney, brain, gonads, blood and clot). ERSAF- Stelvio National Park, province of Sondrio, Reparto Carabinieri Biodiversità Castel di Sangro (AQ) and Enrico Bassi.

The following table (Table 3) shows for each analysed individual the lead levels in the study area, collected from 2003 to 2024, as part of the ecotoxicological research coordinated at a European level by Enrico Bassi.

Table 3 (following pages). Lead levels of hunting origin (mg/kg, wet weight) found in golden eagle (GE) and griffon vulture (GV) tissues recovered in the north-central Apennines. In red the acute/chronic (clinical) cases, in yellow the subacute/subchronic ones, in blue those considered not exposed to lead but with incomplete analyses and in green the individuals exhaustively analysed which revealed an exposure compatible with environmental background. Bold character, after Franson & Pain (2011), highlights a lead concentration higher than the background. ERSAF- Stelvio National Park, province of Sondrio, Reparto Carabinieri Biodiversità Castel di Sangro (AQ) and Enrico Bassi.

Species	Municipality	Date	Bone	Liver Kidney	Brain	Blood- Clot	Death causes post Lead analysis
GV	Cappadocia (AQ)	01/06/2003	1.87				Poisoning
GV	Capistrello (AQ)	17/01/2011	6.57	0.294			Poisoning. lead subchronic exposure
GV	Borgorose (RI)	30/03/2011	23.6				Chronic lead exposure (clinical)
GE	Reggio Emilia (RE)	01/05/2011	3.46				Unknown
GV	Celano (AQ)	16/05/2011	4.78				Poisoning
GE	Genga (AN)	04/24/2012	1.42	0.054			Intraspecific aggression
GE	M. Pania Secca (LU)	07/28/2012	8.62				Poaching. lead subchronic exposure
GE	Pianello Val Tidone (PC)	05/01/2013	0.391				Unknown
GE	Filicaia (LU)	11/02/2013		0.093			Poaching
GV	Collarmele (AQ)	03/19/2014	1.33				Collision with wind turbines
GE	Costa Grande (AQ)	01/12/2014	0.279	<0.005			Weakness
GV	Borgorose (RI)	06/03/2015	6.337	0.288			Poisoning
GV	Ginestra Fiorentina (FI)	03/22/2017				0.129	Lead subclinical exposure
GV	La Stanga (AQ)	04/14/2017	5.165				Weakness
GV	Civitella Roveto (AQ)	06/06/2017	5.42				Unknown
GV	Laghi di Camarda (AQ)	07/30/2017	2.133				Intraspecific aggression
GV	Magliano de Marsi (AQ)	28/10/2017	5.735	0.157	0.022	0.098	Poisoning
GV	Cerchio (AQ)	14/11/2017	1.67	0.214	0.041		Collision with wind turbines
GV	Massa d'Albe (AQ)	04/13/2018	3				Unknown
GV	Massa d'Albe (AQ)	04/13/2018	1.6	2.2	0.22	0.013	Lead subclinical exposure
GV	Tagliacozzo (AQ)	04/14/2018	22	0.45	0.075		Chronic lead exposure
GV	Capraia. Tremiti Islands (FG)	12/05/2018				0.48	Lead clinical exposure
GE	Tizzano Val Parma (PR)	05/11/2018	0.276	0.049	0.007		Anticoagulants

Species	Municipality	Date	Bone	Liver Kidney	Brain	Blood- Clot	Death causes post Lead analysis
GV	Borgorose (RI)	02/19/2019	0.91				Unknown
GE	Spoletto (PG)	03/25/2019	1.912				Poisoning
GE	Spoletto (PG)	03/25/2019	1.305				Poisoning
GE	Frassinoro (MO)	07/08/2019	24.4		0.114		Poaching. lead clinical and chronic exposure
GV	L'Aquila (AQ)	28/12/2019				0.164	Lead subclinical exposure
GV	L'Aquila (AQ)	28/12/2019				0.178	Lead subclinical exposure
GV	L'Aquila (AQ)	04/07/2020	1.5				Unknown
GV	Posta (RI)	01/06/2020	7.4	1.6	0.327		Poisoning. lead subclinical exposure
GV	L'Aquila (AQ)	06/15/2020	0.95	0.39			Unknown
GV	L'Aquila (AQ)	06/17/2020	6				Poisoning
GV	L'Aquila (AQ)	06/17/2020	9.1				Lead subchronic exposure
GV	Cappadocia (AQ)	06/18/2020	2.9				Unknown
GV	Goriano Sicoli (AQ)	03/27/2021	1.6				Poisoning
GV	Goriano Sicoli (AQ)	03/27/2021	0.98				Poisoning
GV	Massa d'Albe (AQ)	12/04/2021	1.6				Unknown
GV	L'Aquila . Roio	03/05/2021	2.3				Unknown
GV	L'Aquila. Bagno	04/05/2021	1.6				Unknown
GV	Collarmele (AQ)	05/17/2021	6.3				Unknown
GV	Cappadocia (AQ)	05/26/2021	0.92				Unknown
GV	L'Aquila. Aragno	11/06/2021	0.39				Unknown
GV	Genova. Molassana	27/11/2021	7.2	1.7	0.114	0.334	Lead subclinical exposure
GE	Vagli Sotto (LU)	02/07/2022	11.4	5.4	0.348	0.012	Lead subclinical and subchronic exposure
GE	Licenza (RM)	02/22/2022	13				Poaching. lead subchronic exposure
GV	Massa d'Albe (AQ)	04/21/2022	3				Unknown
GV	Borgorose (RI)	06/28/2022	6.5				Unknown
GV	Collarmele (AQ)	11/11/2022	0.88	0.14	0.045	0.1	Collision with wind turbines
GV	Cerchio (AQ)	02/12/2022	4.1	0.28	0.057	0.17	Collision wind turbine. lead subclinical exposure
GV	Magliano de' Marsi (AQ)	12/12/2022	0.54	0.22	0.027	0.17	Lead subclinical exposure
GE	Amandola (FM)	before 2023	10.478				Lead subchronic exposure
GE	San Polo d'Enza (RE)	05/01/2023				0.447	Lead clinical exposure
GV	Collarmele (AQ)	04/07/2023	1.1	0.4	0.071		Collision with wind turbines

Species	Municipality	Date	Bone	Liver Kidney	Brain	Blood- Clot	Death causes post Lead analysis
GE	Colle San Magno (FR)	04/17/2023	15.381				Lead subchronic exposure
GV	Collarmele (AQ)	04/26/2023	2.7	0.37	0.052	0.24	Collision wind turbine. lead subclinical exposure
GV	Cocullo (AQ)	05/05/2023		0.56		0.39	Poisoning. lead subclinical exposure
Species	Municipality	Date	Bone	Liver Kidney	Brain	Blood- Clot	Death causes post Lead analysis
GV	Cocullo (AQ)	05/05/2023	6	0.45	0.082	0.42	Poisoning. lead subclinical exposure
GV	Cocullo (AQ)	05/05/2023	4.3	0.3	0.056	0.26	Poisoning. lead subclinical exposure
GV	Cocullo (AQ)	05/05/2023	1.1	0.31			Poisoning
GV	Celano (AQ)	05/09/2023	5	0.22	0.053	0.16	Lead subclinical exposure
GV	Alvito (FR)	07/08/2023	3	0.17	0.076	0.45	Lead clinical exposure
GV	San Donato Val di Comino (FR)	07/08/2023	2	0.21	0.13	0.15	Poisoning? lead subclinical exposure
GV	San Donato Val di Comino (FR)	07/08/2023	1.5	0.12	0.069	0.2	Poisoning? lead subclinical exposure
GV	San Donato Val di Comino (FR)	07/08/2023	1.3	0.23	0.11	0.36	Poisoning? lead subclinical exposure
GV	Avezzano (AQ)	11/16/2023				0.156	Lead subclinical exposure. released
GV	Avezzano (AQ)	02/12/2023	3.9	0.14			Poisoning
GE	Montefortino (FM)	2023	1.837	1.599	0.079	0.224	Lead subclinical exposure
GV	Passignano sul Trasimeno (PG)	25/11/2023 ¹ ; 02/01/2024 ²	0.87	0.17	0.025	0.056 ¹ 0.230 ²	Debilitated, starving; lead subclinical exposure ²

According to Franson & Pain (2011), lead concentrations < 2 mg/kg (wet weight) in the liver and kidney and < 8.33 in the bones are to be considered linked to environmental contamination (background). Values > 6 mg/kg (wet weight) in the liver, > 4 in the kidney and >16.6 in the bones are instead taken as indicators of clinical lead poisoning. Intermediate concentrations reveal subacute and subchronic (potentially subclinical) exposure.

Liver and kidney values are reported to reflect recent exposure to the metal (Pain 1986) while bone concentrations reflect long-term accumulation (Franson & Pain 2011). The highest median lead values were found in bones and this suggests that large necrophagous birds of prey are exposed to numerous

poisoning events throughout their lives. In fact, the level of lead in bone reflects chronic exposure, given that bone contains 84 to 90% of the total weight of lead in the body of birds of prey (García-Fernández et al. 1997). Lead in human bones also has a half-life of 600-3,000 days (Harrison & Laxen 1981) and therefore in birds, which have lower life expectancies than humans, bone is a good indicator of the relationship between lead content and the age of the individual, but for cases of acute poisoning (Pain et al. 2005).

In the absence of specific analyses, the problem of lead accumulation in large birds of prey would have been ignored in almost all cases and the causes of mortality would have been attributed to other factors. This means that although acute lead poisoning manifests itself with rather evident but non-specific clinical signs, such an issue has been totally ignored for several years in wildlife rescue centres, thus delaying the acknowledgement of such a problem in the Apennines, as indeed at national and European level.

To evaluate the areas at greatest risk of lead exposure, maps were developed relating to the quarterly movements in 2023 of 53 griffon vultures equipped with a GPS device (Figures 3-4). We thus visually analysed the distribution of their main movements, relating to 2023 only, in relation to the hunting period, which essentially opens in Italy from mid-September to January 31st. The yellow lines highlight the travelling routes of vultures (1-2 fix/hour, on average) and the abundance of locations outside protected areas, especially to North to East, and to West (Latium, Abruzzi and on the border with Marche region) compared to the 6 breeding colonies marked by blue dots. Movements towards the South and South East are less frequent, but often remain within the perimeter of the protected areas.



Figure 3. Daily movements of 53 griffon vultures equipped with a GPS device in the period September-December 2023, the months in which hunting activity is carried out by approximately 5,056 and 45,872 hunters in Abruzzi and Latium, respectively (data on hunting: CABS 2020).



Figure 4. Daily movements of 53 griffon vultures equipped with a GPS device from January to March 2023. Hunting activity is allowed until January 31st and is carried out by approximately 5,056 and 45,872 hunters in Abruzzi and Latium, respectively (data on hunting: CABS 2020).

6. Bearded vulture and cinereous vulture

Since both species do not currently breed nor regularly occur in the eventual reintroduction area and no individual has been recovered so far, accurate analyses comparable to those collected for golden eagle and griffon vulture are not available. Therefore, we report the main evidence emerging from different regions of central and southern Europe (French Pyrenees, Massif Central and Grands Causses and Italian, Swiss, French and Austrian Alps), largely included into Bassi et al. (2021). For the Alpine region, saturnism in birds of prey was initially investigated by a few authors (Kenntner et al. 2001; Frey 2006) also following the accidental recovery of 7 dead golden eagles intoxicated by lead (Kenntner et al. 2007) and acutely intoxicated bearded vultures (Knollseisen & Greßmann 2006, Bassi & Ferloni in Andreotti & Borghesi 2012). In the following years, once this issue was better focused on, three other bearded vultures were

recovered, both dead or dying from acute saturnism in the Alps. These recoveries immediately raised strong concerns for the conservation of the species and its future possibility of colonisation outside protected areas. The number of bearded vultures already poisoned by lead, from 2005 to 2019 (N= 7), in fact, should never be underestimated for a series of reasons:

- the population is still vulnerable: in the European Alps; in 2021, only 44 young fledged from 72 breeding pairs (Lauper 2022)
- in Italy it is present with only 22-24 territorial pairs but of these, between 4 and 5 pairs have never reproduced successfully (data updated to 2021); the latter are all located outside the national parks in hunting areas where lead is used
- three out of 7 lead-poisoned bearded vultures in the Alps, were recovered only thanks to their GPS device, otherwise it would have been unlikely to locate them; the number of birds of prey actually lethally poisoned is certainly underestimated
- the problem for the Alps was ignored for a long time. Until 2008, the carcasses were never systematically analysed. Today there has been greater attention from wildlife technicians, managers of protected areas and veterinarians, and many recovery events have no longer been recorded under the qualification "unknown cause".

Research by ERSAF-Stelvio National Park and the province of Sondrio has highlighted that, in just over 10 years in the Alps, in addition to the 5 bearded vultures described above, 5 other conspecifics were affected by lead poisoning (acute and chronic, equal to 21.7% out of a total of 23 carcasses analysed) (Bassi et al. 2021). The impact exerted by lead on the still vulnerable Alpine population of bearded vulture is in fact very significant, albeit in percentage terms smaller than that of the golden eagle, but the distribution and abundance of the two species in the Italian Alps is not comparable: 22-24 pairs of bearded vultures (IBM data, Lauper 2022) vs 456-521 pairs of golden eagles (Fasce & Fasce 2017).

Similar reasoning applies to the Massif Central and the French Pre-Alps where the griffon vulture populations are numerically prevalent compared to those of the cinereous vulture (approximately 1,500 pairs of griffon vulture vs 47 of cinereous vulture in 2021, J. Traversier, *pers. comm.*). This proportion also reflects lead exposure in the analysed sample (45% vs 27.7%), but nevertheless the frequency of exposure to lead from hunting ammunition is extremely worrying for the latter too. Likely, a similar situation could also occur in the central Apennines once the cinereous vulture population is re-established through a reintroduction project.

As regards the cinereous vulture, in fact, the situation must be carefully monitored since, as mentioned, there is no data available from the Apennines but only those coming from the Massif Central and the Pyrenees (F), from the Alpine ones (Italian, French and Swiss) and from Sicily. These data show an equally worrying picture with a percentage of lead exposure from hunting of 40.9%. In fact, out of the 22 cinereous vultures analysed so far as part of the international research mentioned above, 9 had at least one tissue with exposure ranging between subacute/subchronic and acute/chronic (Bassi et al. 2021; Bassi unpublished data). Out of these 9 lead-exposed individuals, 5 were exposed to lead at a subacute and/or subchronic level (55.5%) while 4 were exposed to lead at an acute and/or chronic (clinical) level.

Magnitude of lead poisoning risk in relation to small game and ungulates hunting – central Apennines (Abruzzi, Marche and Latium)

In the central Apennines, lead contamination in trophic webs derives from many methods of hunting practised mainly wandering, at fixed spots, or stalking and driving hunts (for ungulates) in a wide variety of environments. For the central Apennines in a terrestrial habitat, the only data available on the dispersion of lead pellets on the ground come from the Marche region where Marini and Forconi (2012) estimated significant lead concentrations in the ground from the number of shots recorded per unit of time. These lead concentrations were elevated near fixed hunting sites, above the critical value of 15 mg/l.

For bullets used for ungulate hunting, recent data on the lack of lead dispersion introduced by a lead ban are available from the Presidential Estate of Castelporziano (Rome). Here, the ban of lead ammunition approved by Ministerial Decree on 17 October 2007, prevented the release in the area of an estimated amount of 2,109 bullets (16.7 kg of missed dispersion in 2019-2022), corresponding to the number of shots for the culling of fallow deer (*Dama dama*) and wild boar (*Sus scrofa*) (G. Landucci, presentation at the national conference “The weight of lead”, Bergamo 2 December 2023). Between 2011 and 2014, a total of 2,301 fallow deer and wild boars were shot exclusively with lead free ammunition (575 animals/year) and current sampling continues in accordance with this rate.

Other areas in the Apennines range from which lead has been totally banned in ungulate control activities are the Frasassi Gorge Regional Park (AN) and the Monti Sibillini National Park. In the first, between 2013 and 2015, 1,156 wild boars were culled and sampling continues at full capacity while in the second, the ban on the use of ammunition containing lead was introduced with act of the Board of Directors no. 25 of 11/20/2012, art. 13, paragraph 1, of the Regulations for the selective harvesting of wild boar. Data on wild boars culled with non-toxic ammunition organised in databases are only available starting from 04/19/2017. From that date to December 2023, 3,014 wild boars were killed. About 10% of shots miss the target and, therefore, the bullet disperses into the environment. In addition to this, almost 5% of the wild boars affected are injured and only a small percentage of these are recovered, with the possible use of a tracking dog.

Finally, for the Abruzzo Region, some regulatory measures are also available that limit the use of lead in fixed-ambush hunting and wild boar control activities, but no other provisions concern “drive” and “turned” hunting, which accounts for approximately 70% of wild boars currently hunted. In particular, the details of two articles (no. 14 and 16) of the Decree May 4th 2017, no. 1, Regulations for the Fauna-Hunting Management of Ungulates. Regional law 28 January 2004, n. 10 (Organic regulations for the exercise of hunting activities, the protection of homeothermic wild fauna and the protection of the environment):

Art. 14 (Individual wild boar hunting from a fixed position without the aid of a dog)

1. Individual hunting from a fixed position with a rifled weapon and aiming optics can be carried out in the areas referred to in art. 7, paragraph 1 and 2, only by hunters in possession of the qualification referred to in the art. 3, paragraph 1, letter c).

2. For this method, only rifled weapons with a calibre greater than 6 millimetres equipped with a sighting scope and non-toxic ammunition can be used.
3. The use of semi-automatic weapons is prohibited.

Art. 16 (Individual wild boar hunting without the aid of a dog)

1. Individual hunting with a rifled barrel and aiming optics can be carried out in the areas referred to in art. 8, paragraph 1, only by hunters in possession of the qualification referred to in the art. 3, paragraph 1, letter c).
2. For this method, only rifled weapons with a calibre greater than 6 millimetres equipped with an aiming telescope and non-toxic ammunition may be used.

The Decree came into force on 07/18/2019.

Table 4 shows a reasoned summary about bag size for the 10 most hunted game species in Abruzzi which could potentially represent an important source of exposure to lead of hunting origin, to the detriment of large birds of prey (griffon vulture and golden eagle). Moreover, wounded animals should be virtually added to such figures, as they are embedded with bullets/pellets, which are not recovered by hunters, dying later on, or not. In both cases, carcasses and animals with embedded lead fragments if consumed by a vulture represent an important source of risk for lead exposure. If for species 1 to 9 the greatest risk is represented by the failure to recover injured animals, for the wild boar this risk is added to that deriving from the traditional habit of hunters of eviscerating the shot wild boar on the hunting site which often, in 56.6 % of cases as recorded in the central Alps, contain highly fragmented lead projectile splinters (Bassi et al. 2014).

All the reported data were from the Piano Faunistico Venatorio Regionale (PFVR)- Regional Wildlife and Hunting Management Plan (Riga & Recchia 2018) - with the exception of the number of wild boars subjected to "hunting" and "stalking" which were deduced also from personal information from wildlife technicians and local coordinators who, on the basis of their experience, guessed that 90% of hunters engaged in wild boar selective hunting and culling make use non-toxic ammunition, while 10% still illegally uses lead. These proportions are absolutely opposite if, in Abruzzi, the number of wild boars taken through "driving" and "turn" hunting (in Italian respectively "braccata" and "girata") is concerned. In such two hunting forms, indeed, only an estimated 10% of hunters are using non-toxic bullets, following a serious regulatory gap that does not address the mandatory replacement of lead for these two forms of hunting. Furthermore, the situation raises concerns because since the entry into force of the regulation to date there have been no investigations by the Supervisory Authority (game wardens and Carabinieri Forestali) and the relevant bodies, nor sanctions against those who have contravened the provisions of the law.

Table 4. Framework of the most important hunted species in Abruzzi considered most at risk in determining lead exposure in large birds of prey. Data from the 11 Ambiti Territoriali di Caccia (ATC; *i.e.*, Hunting Districts): Avezzano, Barisciano, Chietino Lancianese, L'Aquila, Pescara, Roveto Carseolano, Salinello, Subequano, Sulmona, Vastese and Vomano. *The annual average calculated for the wild boar considers three hunting seasons, *i.e.* also the 2017/2018 season. **Selective hunting from fixed position and, on an individual basis, with no dog, requires the use of non-toxic ammunition while this is not foreseen in the other forms of hunting (“driving” and “turn”).

Species	Average annual reductions Seasons 2015/16 and 2016/17	Total Two-year period
N° individuals shot (lead pellets ammunitions only)		
1) Hare <i>Lepus</i> sp.	2,644	5,288
2) Wood pigeon <i>Columba palumbus</i>	24,786	49,573
3) Song thrush <i>Turdus philomelos</i>	19,900	39,800
4) Blackbird <i>Tudus merula</i>	10,673	5,336
5) Skylark <i>Alauda arvensis</i>	5,345	10,691
6) Turtle dove <i>Streptopelia turtur</i>	3803	7,606
7) Red fox <i>Vulpes vulpes</i>	395	789
8) Hooded crow <i>Corvus cornix</i>	380	761
9) Rock partridge <i>Alectoris graeca</i>	183	409
10) Wild boar <i>Sus scrofa</i>	6,746*	20,239**
TOTAL INDIVIDUALS	74,855	140,492
Bullets		
	Shot wild boars/year	Shot wild boars/ three-year period
Wild boar	6,746*	20,239*
Of which per year:	Lead-free bullets	With Lead bullets
	Approximately 1,500 wild boars/year Selective hunting with mandatory non-toxic ammunition**	Approximately 4,500 wild boars/year with prevalent use of lead ammunition in “driving” and “turn” hunting **
Next foreseen red deer and roe deer management plan	Abruzzo Region PFVR 2020- 2024	Nicoloso et al. 2023
Red deer	Estimated next opening 780 animals (339 District 1+ 441 District 2)	
Roe deer	Next opening	

This serious regulatory gap also remains in the very recent regional hunting plan for the season 2024-2025 issued by the Agriculture Department of the Abruzzo Region (Annex III) reporting in the “Prohibitions” section (point 5.e) that “*When hunting ungulates, for the purposes of protecting human health and conserving populations of necrophagous birds of prey, during wild boar hunting, it is recommended to use lead-free ammunition, which remains mandatory during selective hunting of ungulates.*” This lack of prescription can be seen as valid only for selective hunting and control (but not for “driving” and “turn”)

also from another passage of the same Annex III reporting that in the following areas where it was once the presence of the griffon vulture has been ascertained, the use of single-ball ammunition containing lead is not allowed:

- ZSC Cerrete di Monte Arunzo e Monte Arezzo (Natura 2000 Code: IT7110091); - ZSC Monte Salviano (Natura 2000 code IT 7110092); - ZSC Monti Simbruini (Natura 2000 code IT7110207); - SAC Monte Sirente e Monte Velino (Natura 2000 Code: IT7110206); - SIC Gole del Sagittario (Natura 2000 Code IT7110099); - SAC Serra e Gole di Celano-Val d'Arano (Natura 2000 code IT7110075); - SPA Sirente Velino (Natura 2000 code IT7110130).

The use of bullets containing lead within the IBA 115 “Maiella, Monti Pizi and Monti Frentani” is also prohibited, for the purposes of protecting the populations of red kites (*Milvus milvus*). The publication of the IBA 115 Site on the websites of the relevant ATCs and in the municipalities falling within Natura 2000 Sites where the griffon vulture occurs is mandatory.

In addition to hunting, a significant number of wild boar individuals were shot during culling (control) interventions authorised pursuant to art. 19 of LN 157/92 over the last few years. The following table shows the time series for the years 2008-2017 (source PFVR). Pursuant to the legislation in force, culling must be carried out without lead ammunition (Table 5).

Table 5. Wild boars shot in culling plans in Abruzzi (excluding National and Regional parks) for which regional legislation requires the use of non-toxic ammunition.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Teramo	136	411	57	0	69	238	0	370	n.p.	624
Pescara	172	61	46	4	45	91	121	269	321	0
Chieti	0	0	0	0	0	0	87	208	243	937
L'Aquila	0	0	0	0	0	35	160	85	584	650
Totali	308	472	103	4	114	364	368	932	999	2.211

This situation raises further concerns as from autumn 2024, the management of red deer *Cervus elaphus* (and likely of the roe deer *Capreolus capreolus*) would be likely allowed in District 1 (1: 109,248 ha, ATC Avezzano, ATC Sulmona, ATC Subequano, Abruzzo, Lazio and Molise National Park, Gole del Sagittario Regional Reserve, Monte Genzana and Alto Gizio Regional Reserve) and District 2 (131,862 ha, ATC L'Aquila, ATC Barisciano, ATC Subequano, ATC Avezzano, Sirente Velino Regional Park) (Nicoloso et al. 2023).

The Environmental Incidence Assessment (*sensu* V.Inc.A., relevant for Natura 2000 sites) “V.Inc.A. to the Deer Harvesting Plan in the Management District n. 2 - PFVR 2020-2024 - SV 2023/2024” (Masciovecchio & Lo Giudice 2023), reports that each District includes areas subject to differentiated management:

- Protection Areas, *i.e.*, territories in which hunting is not allowed (National Parks, Regional Parks, Nature Reserves, Restocking and Capture Areas, Protection Oasis, etc.);
- Areas with possible hunting management, *i.e.*, territories in which hunting on the species is possibly permitted (planned hunting territory).

Management is achieved through planning that considers the population as a whole, despite the administrative subdivisions of the territory. It provides for differentiated forms of intervention on the faunal component, the habitat and the social component and involves the application of damage prevention methodologies. The sustainable relationship between deer populations and the environment is also achieved through the identification, at district level, of target density values and minimum densities for planning hunting activity. Within protected areas, exceeding the target densities does not imply automatic recourse to control interventions. In addition to the first two, a third management district has been identified, namely District 3: surface 33,263 ha, ATC Pescara, ATC Chietino Lancianese, ATC Sulmona, ATC Subequano, Maiella NP.

The exclusive use of non-toxic, lead-free ammunition, adopting the same obligations deriving from Regional regulation 1/2017 on the management of ungulates, avoids any risk of intoxication due to ingestion of wounded and unrecovered carcasses (Masciovecchio & Lo Giudice 2023). While agreeing with the previous statement, V.Inc.A. did not find an effective strategy of contrast and deterrence that provides for a minimum number of checks and verifications during hunting by the relevant forces or other types of protocols and agreements with provincial police officers and Carabinieri Forestali. In fact, it is particularly dangerous to consider a problem solved in the absence of objective evidence on the adherence to and compliance with the ban or on its partial/total non-compliance by hunters.

Supporting these considerations, we also report the outcome of the analyses carried out on carcasses of golden eagles and griffon vultures recovered in the Italian Alps in the province of Sondrio (2005-2019), where the hunters have been left the possibility of a) using non-toxic ammunition (without the obligation to bury the viscera), or b) using lead ammunition (with the obligation of burying the viscera). The results show that the frequency of intoxicated and lead exposed birds of prey has increased from 6% to 70% between the first period (2005-2011, when the ban was not active yet or because it was only recently introduced) and 2013-2019 (Bassi et al. 2020). With particular regard to the province of Sondrio, the investigation period was therefore divided into two sub-periods of 7 years each (2005-2011 and 2013-2019). It turned out that in the first period high values of chronic exposure to lead were found in only 2 cases out of 5 total while, in the second sub-period, in which the measures limiting the use of lead formally came into force, as many as 7 were recorded cases of chronic and acute lead poisoning out of a total of 10 eagles recovered. Furthermore, in the second sub-period, two griffon vultures were recovered dead in the province of Sondrio, one of which had clinical value due to intoxication. In the province of Sondrio, similarly to what happens in the Abruzzi districts where deer hunting is going to be allowed, the red-deer showed an increasing trend in recent years, doubling the density of animals hunted in the provincial territory, going from an average of 1.4 deer/10 km² in 2000-2005, to 3.5/10 km² from 2010 to 2019 (Province of Sondrio Hunting Plan 2021, not formally approved). These figures are consistent with the magnitude of lead poisoning in Valtellina and Valchiavenna (Sondrio Province) and the rise in the number of poisoned golden eagles and griffon vultures in the last 7 years (2013-2019) compared to the previous period (2005-2011), notwithstanding the introduction of a ban on shooting with lead and the obligation to bury or remove viscera. In 2019, contaminated viscera of roe deer, red deer and chamois *Rupicapra rupicapra* stood at around 1,400. The sharp increase in deer harvest, lacking a widespread action to tackle the use of lead ammunition, has substantially increased the risk of intoxication for large necrophagous raptors (Bassi et al. 2020; Hunting Office Data of the province of Sondrio).

In Sondrio province, the ban on the use of lead was already addressed starting from the environmental impact study for 2008 hunting and wildlife management plan, and resumed in the 2011 assessment. Nonetheless, there were no particular indications of a change in the hunting habits of a substantial number of hunters, who probably continued to use lead bullets without burying, or poorly burying, the viscera, which, moreover, can be unearthed both by mammals and raptors, as demonstrated by footage from camera traps in the Swiss and Italian Alps (Figures 5-6).



Figure 5. Adult golden eagle and lynx (*Lynx lynx*) while feeding on the viscera of red deer killed with a non-toxic projectile in the municipality of Valfurva (SO), in the Stelvio National Park, as part of the control plan managed by ERSAF - Parco Nazionale dello Stelvio. If lead bullets had been used, the risk of poisoning would have been very high for both species, frustrating the principles and conservation objectives underlying the Natura 2000 network. © ERSAF - Stelvio National Park.



Figure 6. March 2019, Valfurva (SO). An adult bearded vulture on the viscera of deer killed with non-toxic copper bullets. This case demonstrates how high the probability is that a lead poisoning event could occur close to a protected area, with detrimental effects on one of the rarest species at both Italian and international level. ©ERSAF-Stelvio National Park.

It is legitimate to assume that the requirement to bury the viscera of ungulates hit by lead bullets or to deliver the whole viscera to the control points, was largely disregarded by the many hunters. Furthermore, the scarcity or the decrease of dedicated police officers in charge of supervision or control of these practices, certainly contributed to the scarce and episodic prevention and control of regulations enforcements.

7. Critical issues in the central Apennines current hunting methods

For the reasons above, despite a first important step by the Abruzzo Region regarding the replacement of lead from selective hunting and wild boar control, and the willingness to use only non-toxic ammunition in Districts 1 and 2 (close to the most important areas for reproduction and feeding of the griffon vultures), there remain some critical issues which need to be fixed, as summarised below:

- 1) the first - as anticipated - concerns the current “driving” and “turn” hunting methods which amount to approximately 70% of the wild boars currently shot for which not only is the use of alternative lead ammunition not foreseen, but it is not even specified the obligation not to release

viscera potentially contaminated by lead bullet splinters onto the ground, or the obligation to deliver the entire carcass to a control centre;

- 2) from authoritative sources, from the entry into force of the Decree (July 2019) to today, no evidence has been collected which testifies that inspections have been actually carried out on the hunting ground by the relevant police officers to verify the use of lead-free bullets, nor is there a certain number of sanctions imposed for use and possession of lead bullets.
- 3) if lack of lead-aimed control and inspections will be maintained for deer and roe deer hunting from the next 2024/2025 season, a considerable increase in cases of griffon vultures and golden eagles intoxicated or subacutely and subchronically exposed to lead is expected;
- 4) this could lead to a series of prejudices towards the first restocking and reintroduction interventions for the target species since, as observed in France and the Alps, the percentages of exposure to lead from hunting origin are particularly high also in the bearded vulture and the cinereous vulture which they are often attracted by the movements of griffons, looking for food;
- 5) currently, the public bodies in charge of supervision, represented by the Provincial Police, are understaffed with a total of 31 officers, divided territorially into the various provinces with 21 units in L'Aquila, 6 in Chieti and 4 in Teramo. In Abruzzi, only a part of the police officers from the various provinces have been transferred to support the Region. In addition to these, there are the Carabinieri Forestali, the PNALM rangers and approximately 30 volunteer hunting guards, present throughout the regional territory. Currently, as mentioned, it does not appear that any investigations have been recorded or sentences issued for the use and possession of lead ammunition in sites and hunts where it is not allowed;
- 6) to date, the obligation to carry out specialised training activities on the topic of lead poisoning for Provincial Police personnel and other Judicial Police officers with at least 2 annual meetings before and after the hunting season has not been introduced.
- 7) to date, the obligation to carry out training and awareness-raising activities for hunters on the topic of lead poisoning through the organisation of at least 1 meeting/year per ATC has not been introduced, but for the training day (not mandatory) organised on April 21st 2024, by Sirente Velino Regional Park (Rocca di Mezzo, L'Aquila), open to wildlife technicians, bodies managing protected areas, hunters and officers of surveillance, within the deer management programme;
- 8) apart from hunting in wetlands, which in Italy was regulated with the entry into force of Regulation (EU) 2021/57 from 16 February 2023, the use of lead in ammunition remains for all other forms of hunting outside of 100 metres from wetland and also in a part of the wild boar hunting (only the hunting conducted without the aid of dogs) in Abruzzi.

8. Waste products from hunting activity (viscera) and their degree of lead contamination

To give a first general indication on the quantity of viscera of ungulates killed in Abruzzi, the data provided by the regional hunting and wildlife management plan (Riga & Recchia 2018) were used for comparison.

As anticipated, presently only wild boar is killed on a regular basis with approximately 6,746 animals per year. Considering as reliable the estimate that approximately 1,500/year are killed with non-toxic material, the remaining 4,500 boars have a high probability of having viscera contaminated by lead. An analysis carried out by the Hunting Office of the province of Sondrio (Del. n° 304 of 28/10/2008) and by the Stelvio National Park - now managed by ERSAF -, in collaboration with the Veterinary Faculty of Milan and the hunters of Alpine Districts and local wildlife hunting companies of Valtellina and Valchiavenna, found lead contamination in **62% out of 153 viscera of ungulates** hit by gunfire, which would have been abandoned on the ground and therefore potentially consumable by birds of prey and other taxa (Bassi et al. 2014).

As regards the failure to recover game hit by firearms, data is often absent or fragmentary, with both reference to ungulates culling plans and to the species being hunted (e.g. Turdidae and other birds) and to problematic and pest species subject to control that may escape recovery by the hunters and the operators.

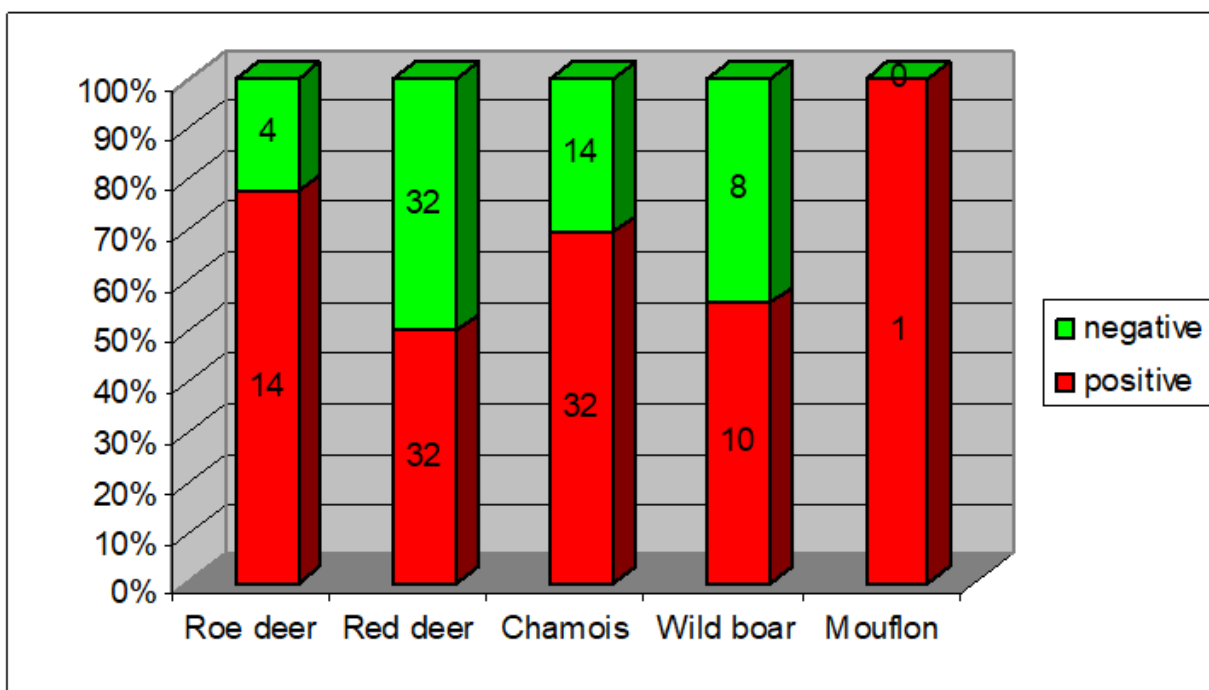


Figure 7. Frequencies in % of viscera divided by species contaminated by fragments of lead ammunition used for hunting in the central Alps (province of Sondrio) analysed using a radiological device by the University of Milan, Faculty of Veterinary Medicine (Bassi et al. 2014).

The results refer to a partial sample of 147 visceral packages, of which 18 from roe deer, 46 from chamois, 64 from deer, 18 from wild boar and 1 from mouflon *Ovis gmelini* (Figure 7). The analysis ascertained the presence of lead fragments in 95 out of 153 viscera (62.1%). Very high frequencies were highlighted in roe deer and chamois (77.7% and 69.6% respectively) and, to a lesser extent, in wild boar (55.6%) and deer

(50%). The higher percentage of deer viscera that do not contain lead fragments (32 out of 64, equal to 50%; deer vs roe deer and chamois $\chi^2=7.1$, 1 gl, $p<0.01$), compared to other ungulates, can be due to the greater size of this species. The greater size on the one hand allows the hunter to aim more precisely at one of the animal's vital points and, on the other, leads to a more limited propagation of splinters due to the substantial muscular and skeletal mass. On the other hand, in deer, percentages of contaminated viscera higher than 60% are found if the bullet has pierced the "Thigh-Back parts" or "Ribcage" region, while this percentage decreases strongly when the "Shoulder-Scapula" and "Anterior Spine" regions are hit, with positive values of 23.1% and 42.9% respectively.

Applying the percentages of contamination for wild boar viscera (55.6%) found in the above study (Bassi et al. 2014), it could be estimated that, considering only the wild boar, 2,502 viscera could be lead-contaminated every year (starting from estimates that every year the killing of approximately 4,500 wild boar in "driving" and "turn" hunts is allowed, a very high value given that they are often still abandoned on the ground without burial).

Regarding the management proposal for red and roe deer in Abruzzi, according to PFVR 2020-2024, Nicoloso et al. (2023) proposed the culling of 441 animals (18.2% of the total minimum ascertained) in District 1, given that 2,412 animals were counted in the best session, of which 1,597 in the territory under the jurisdiction of the Sulmona ATC. As regards District 2, however, where 1,910 animals were counted in the best session, of which 640 in the territory of the Sirente Velino Regional Park alone, the proposed hunting plan corresponds to 339 animals (17.7% of the minimum number ascertained). Given that Sirente Velino Regional Park represents a protected area, culling inside the park should be realised only as a control. This action is considered to be of fundamental importance for the achievement of management objectives considering the strategic importance that the protected area assumes within the District.

By applying the percentages of contaminated offal obtained for red deer in the central Alps, equal to 50% (Bassi et al. 2014), during the next hunting season in Districts 1 and 2, further 390 red deer contaminated viscera/year could be added to the 2,502 wild boar viscera already considered contaminated and abandoned on the ground, if said operations were carried out without a rigorous protocol that provides for a regular series of checks and controls by the relevant authority and police officers (provincial police, carabinieri forestali, etc.).

The Sirente Velino Regional Park therefore becomes a crucial territory for the challenge of lead in ammunition, since District 2 is close to the griffon vulture breeding colonies. Furthermore, by applying the contamination values found species by species in the central Alps to the quantities of animals killed for Italian macro-regions available in Ramanzin et al. (2010), at the level of the central-southern Apennines, the abandonment on the ground of 14,525 viscera contaminated by lead splinters/year is estimated out of a total of 29,050 ungulates killed/year (Figure 8). This value certainly represents an underestimate as the number of ungulates killed has significantly increased compared to the estimates available in 2010 (emblematic of the population demographic boom of the wild boar in the Apennines and in Italy).

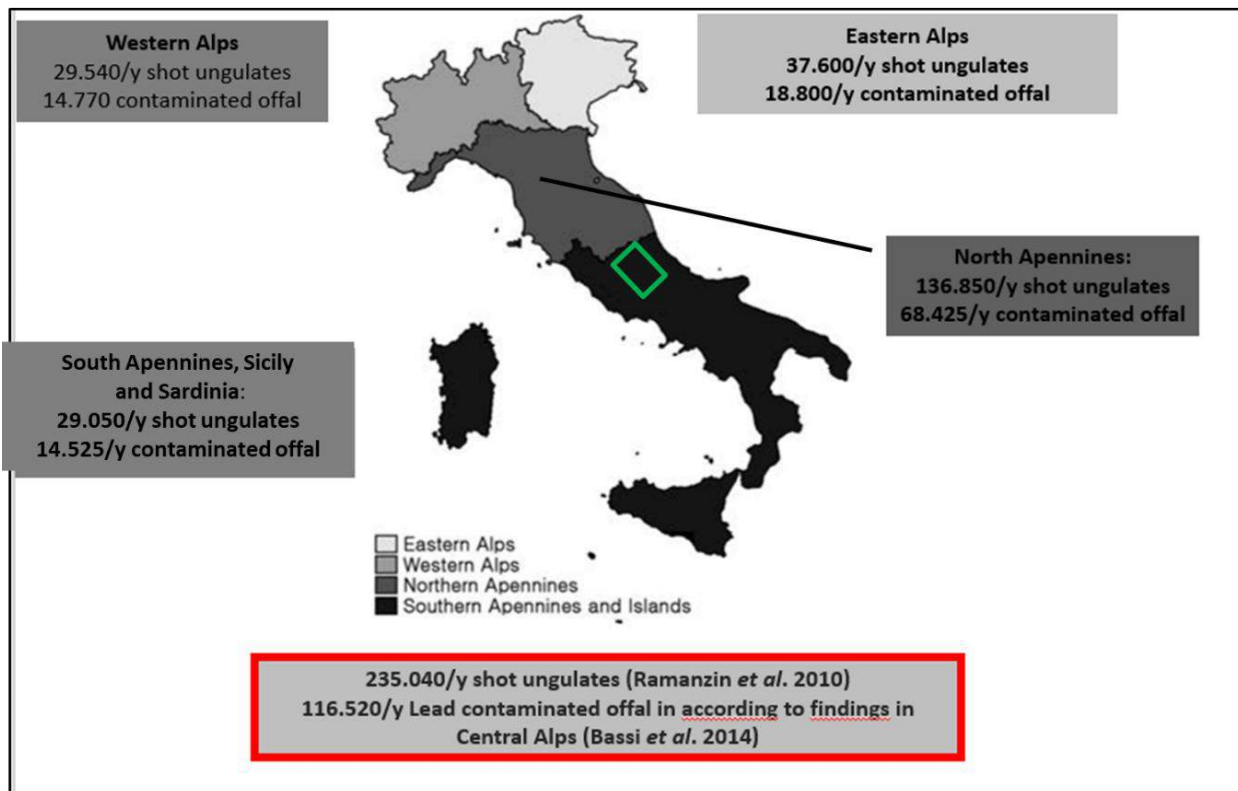


Figure 8. Estimate of the number of viscera contaminated by lead, based on the culling reported by Ramanzin et al. (2010) to which the percentage of species-specific contamination found in the central Alps by Bassi et al. (2014) was applied. The study area (green rectangle) is included in the “southern Apennines and major islands” macro-area.

9. Significance of incidences

The key points of the incidences related to lead ammunition are reported, for an estimate of the significance of the impacts they exert on the target species of the study area:

- the available literature establishes the extremely significant incidence on large birds of prey at the top of the food chain (bearded vulture, griffon vulture, cinereous vulture and golden eagle);
- the extreme danger deriving from the use of highly fragmented lead bullets (ungulates hunting) has been proven by a vast literature and especially for the Italian territory by research conducted in Lombardy, which determines a high frequency of ungulate viscera contaminated by lead (equal to 63% of the total) with different degrees of contamination percentages (from 50% in red deer to 77% in roe deer depending on the species of ungulate affected);
- the danger of lead pellets used for other forms of game which, together to the bullets, determine a high incidence for the conservation of vultures and golden eagles in central and southern Europe with lead exposures equal to 44% on a total of 252 carcasses analysed;

- d) It has been established that the partial ban on the use of lead ammunition is as totally ineffective as the alternative of burying the viscera or removing the entire carcass from the hunting site since this provision has been widely disregarded by hunters in the province of Sondrio. There, in fact, the cases of saturnism and lead exposure in birds of prey doubled in the years in which this alternative was also in force
- e) considering that burying the viscera or their total transport to the control points or game meat processing centres is difficult to practise in the mountain areas not served by a road network, which also fatally coincide with the trophic areas of the mentioned birds of prey;
- f) considering that the verification of the burial of the viscera and the failure to use non-toxic bullets has proven difficult to verify and prosecute by the Sondrio Provincial Police Force, whose personnel have been undersized for years similarly to those of the Abruzzi provinces;
- g) verified the small number of investigations and reports carried out by the provincial police (mostly attributable to episodic events), absolutely insufficient to stem the problem both in the North and in the Abruzzi regarding wild boar hunting;
- h) established that, in addition to the viscera of wild ungulates abandoned on the ground, the injured and unrecovered migratory animals subject to poaching, surviving embedded pellets and unrecovered injured ungulates should also be counted as potentially toxic, it is in fact necessary to adopt an urgent and definitive resolution to the problem.

The points reported represent among the most decisive and fundamental aspects for considering the significant negative impact of the lead contained in ammunition on the damage of the natural environments and wildlife species investigated in this feasibility study.

Lead shows two main negative impacts, both considered classifiable as “medium significant level and therefore mitigable” if, and only if, a regulation is adopted that promotes the exclusive use of **non-toxic** solutions for both types of ammunition (pellet and bullet), respectively used for hunting small game and ungulates (already widely available on the market for several decades).

There are no Nature 2000 sites, natural and national parks which, from this perspective, can be considered safe from lead in food chains, the possible sources of risk can be summarised as follows:

- a) The species of diurnal birds of prey considered here can take lead during feeding activities which can occur inside, near or at a considerable distance from protected areas.
- b) The viscera (even those potentially contaminated by lead splinters) are highly attractive, not only for scavenging bird species but also for numerous mammals, such as wolves and brown bears.
- c) After a few years from the entry into force of the ban on the use of bullets for wild boar hunting and control, no significant progress has been made regarding its extension to the most prevalent forms of hunting which for wild boar consist of “driving” and “turn” and for other species of small game the use of non-toxic pellets (made of steel, bismuth and other alloys). The situation is even more worrying if, starting from 2024, the management of red deer and roe deer is implemented (“Proposal for the management of red deer and roe deer in the Abruzzo Region in implementation of the PFVR 2020-2024 WILDLIFE HUNTING SEASON

2023-2024”, edited by Nicoloso et al. 2023). In the report for the Environmental Impact Assessment relating to the Deer Harvesting Plan in the Management District no. 2 (Masciovecchio & Logiudice 2023) for the 2023-2024 wildlife hunting season, the introduction of the obligation of non-toxic ammunition has been envisaged but, at the moment, it has not yet been implemented in terms of law although it is probable that it will actually be included in the Implementation Regulation of the Plan.

- d) It is believed that these current and hopefully future measures must immediately be accompanied by: 1) mandatory training seminars aimed at hunters and wildlife technicians on the problems caused by lead towards wild birds and on the mandatory adoption of non-toxic ammunition and 2) by an intense supervisory activity demonstrated by a number of investigations and sanctions which makes it difficult for the non-application of the rule to the hunters themselves.
- e) Without the introduction of the management choices described in points e) and f), the opening of red deer and roe deer hunting is considered particularly counterproductive and risky, especially in the more delicate reproductive contexts represented by the griffon vulture colonies of the Sirente Velino and its surroundings and the feeding sites identified by radio telemetry movements between the Abruzzi, Marche and Latium regions.

10. Regulatory experiences to be replicated in Abruzzi regarding lead ammunition

Lombardy

The serious and surprising results of the research conducted on the viscera of ungulates hunted in the province of Sondrio provoked the prompt reaction of the Province which, already in 2008 and in the subsequent 2011 study, activated the partial ban on lead ammunition for hunting ungulates, waterfowl and other species hunted on the valley floor, also appealing to the precautionary principle. Ample space was dedicated to disseminating the problem in the provincial and regional hunting world with conferences, articles and awareness initiatives aimed at hunters. The Sondrio Provincial Police itself has received specific instructions to proceed with its control activities through the exclusive use of non-toxic ammunition.

In April 2021, ERSAF-Stelvio National Park also produced a 10' video documentary entitled “Piombo o Rapaci - Lead or Raptors” in both Italian and English to disseminate the problem in an objective and scientific manner and to broaden the audience of stakeholders informed about the effects that lead causes in wild birds and to denounce the very serious situation facing the regional territory.

Furthermore, in the Plan for the conservation and management of red deer in the Lombardy sector of the Stelvio National Park (2014-2021), the only ammunition used for deer control are non-toxic ammunition made of copper and other materials, by means of which they are already over 3,300 animals killed, and 360 hunters operating in the Lombardy and South Tyrol National Park involved (Pedrotti et al. 2017, 2020).

This extremely important experience unequivocally highlights the feasibility of the transition towards non-toxic ammunition and has already been applied in the province of Sondrio and in Alta Valtellina (Gugiatti et al. 2016).

In the Report entitled “Deer conservation and management plan in the Lombardy sector of the Stelvio National Park. Report on the third year of numerical control activity with conservation purposes in the LO2 ALTA VALTELLINA management unit. December 2019 - February 2020”, edited by Pedrotti L., Gugiatti A., Corlatti L. & A. Zanoli, important decisive considerations are reported to validate the technical feasibility towards the definitive transition in a very short time.

In the aforementioned Report, in fact, the following period is reported verbatim: ***“(…) no differences are highlighted that would suggest a lower efficiency of lead-free ammunition. It seems instead that, compared to the ammunition used, the accuracy of the shot has a preponderant importance on the final results .***

*Even from these data it can be seen that **the percentage of deer for which killing is attained with more than one shot, does not differ depending on the category of ammunition used.** By combining the numbers for the years of use of lead-free ammunition and comparing the data with that deriving from the use of lead ammunition, the percentage ratio becomes **21.1% versus 19.5%.***

As highlighted, in the use of the two categories of ammunition **there are no significant variations in the percentage of animals that require more than one shot to be killed.** *With the two categories of ammunition the percentage of wounded animals (killed with more than one shot) does not vary, confirming that **the most important factor in determining the lethality of a shot appears to be the accuracy of the shot and not the type of ammunition used** (hits to the stomach/intestines in 51% of cases considering the total of six years of use of lead-free bullets, and in 55% of cases with lead bullets).*

Overall, at the end of these first six years of control, since the obligation to use monolithic lead-free ammunition was introduced, it is possible to draw some considerations relating to the effectiveness of these in terms of lethal and “arrest” capacity of the affected animal (...).

*It is important to underline how **the priority element that led to the choice to eliminate the use of lead-containing ammunition is linked to the conservation needs of scavenging animals, which are particularly sensitive to the risks of lead poisoning. The analyses explicitly illustrate how the use of “monolithic” ammunition did not influence the percentage of animals hit and therefore no negative effect was produced on the accuracy of the shots.** It is important to remember that the Regulations establish 200 metres as the maximum permitted shooting distance, even if the data collected confirms that a certain amount of shots are taken at greater distances.*

Finally, in the same report, the Authors show in Table 6 all the calibres and non-toxic ammunition used for the shooting of the first 954 animals analysed.

Table 6. Calibres and ammunition used for culling actions in the period 2014-2019 in the Lombardy sector of the Stelvio National Park. The relative amount of deer killed with each calibre and ammunition is also shown. From Pedrotti et al. 2020.

CALIBRO	2014	2015	2016	2017	2018	2019	TOTALE	MUNIZIONE	2014	2015	2016	2017	2018	2019	TOTALE
7 RM	72	47	27	22	24	16	208	Double cuprum	64	61	44	17	6	1	193
.300 Win Mag	22	41	47	60	56	44	270	RWS Evo Green	35	31	22	28	9	13	138
.370 Win	33	25	23	7	9	14	111	RWS Hit		1	2	4	7	5	19
.308 Win	15	13	22	41	28	13	132	Hasler Ariete	49	46	38	57	43	21	254
30 R blaser	18	9	6	1	5	5	44	Hasler Hunting	27	11	49	51	71	63	272
30-06 Spng	14	11	7	17	12	11	72	Barnes TTSX ST	9	13	2	3	2	3	32
7 x 64	5	7	14	5	5	5	41	Barnes TTX	9	1		4			14
7 x 65 R	7	7	10	12		3	39	Hornady GMX	5	6	2		5	1	19
.300 Wby	2	6	3	1	1		13	Nosler E tip	1		1	1	1	2	6
8 x 68 S	8		1				9	Norma Kalahari				1			1
.270 Wby	3	1					4	Elite Ammo				1		2	3
7 mm Blaser Mag		3					3	Fox UGT						3	3
.270 WSM			1				1								
.284 Win.					4	3	7								
TOTALE	199	170	161	166	144	114	954		199	170	161	166	144	114	954

Overall, in Lombardy:

- **in Stelvio National Park** where, since 2012, 360 hunters have used them for the shooting of over 3,300 deer. The abatement actions are ordinarily followed and verified through the action and control of the Carabinieri Forestali of Bormio,
- **in the province of Sondrio**, where since 2008/2011, partial bans have been in force and the killing of wild boars is also subject to the restriction of the use of lead by qualified operators and provincial police personnel,
- **in the Special Duty Zone in the CAC of Morbegno** where, starting from 2016, the use of non-toxic ammunition is mandatory (with 195 deer killed so far),
- **in the interprovincial Hunting Reserve “Val Belviso-Barbellino”** falling in the provinces of **Sondrio, Bergamo and Brescia** where, from 2020, it is mandatory to use exclusively non-toxic balls for hunting all species of ungulates, under penalty of suspension and/or revocation of the renewal of the concession,
- **in the Hunting Reserve called “Val Bondone - Val Malgina”** in the province of Sondrio, where, from 2020, it is mandatory to use exclusively non-toxic bullets for hunting all species of ungulates, under penalty of suspension and/or revocation of the renewal of the concession,
- In the Colli di Bergamo Regional Park, since 2016 approximately 50 wild boars have been killed in the eradication/control plan within the territory classified as a “Natural Park” with the exclusive use of non-toxic ammunition although the operational protocol provides for the killed animals, with shooting from a fixed position, the recovery and delivery the “whole” to the collection centre, therefore without dispersion of contaminated viscera on the territory. The eradication activity in the Natural Park areas (about 50 animals killed/year) was then accompanied in the huntable territory of the Park, according to the management guidelines defined by the Lombardy Region UTR Bergamo, with wild boar hunting, both in collective and selection forms. Also, in reference to these hunting activities, in recent years the Parco dei Colli has requested the exclusive use of lead-free

ammunition in hunting ungulates.

Therefore, the urgency of intervening with non-toxic ammunition that does not threaten the conservation of the aforementioned species, in accordance with what is already contained in the 2020's Province of Sondrio Hunting Fauna Plan which, although not yet approved, requires the definitive ban on lead ammunition and the ban on keeping them on the hunting ground. This effectively eliminates the alternative of burying the viscera or delivering the whole carcass to control points in the case of the use of lead bullets (a measure which has proven ineffective to combat lead poisoning in birds of prey in the last decade), and in accordance with Decree No. 13690 of the Lombardy Region (approved on 11/11/2020) which incorporates the need to accommodate this change with the necessary urgency in the province of Sondrio. Furthermore, the urgency is enhanced by the belief that the incidence of lead poisoning in necrophagous birds of prey and other avifaunal species can only be mitigated through the progressive introduction of the ban on the use and possession of lead ammunition in the hunting area. Finally, the Province of Sondrio recently approved Decree No. 13690, with the object "Evaluation of the impact of the territorial hunting fauna plan of the Province of Sondrio, pursuant to Presidential Decree 357/97 and subsequent amendments", dated 11/11 /2020, which refers solely to the Hunting Fauna Plan which however has not yet been approved by the Province of Sondrio.

Said Decree specifies the obligation to carry out specialised training activities on the topic of lead poisoning for Provincial Police personnel, other Judicial Police officers (with at least 2 annual meetings) and the obligation to carry out training/ raising awareness of hunters with at least 1 meeting/year per Alpine Hunting District. The obligation starts from the second hunting season after the entry into force of the Hunting Fauna Plan, of the exclusive use of lead-free bullets for killing ungulates, both in hunting activities and in control operations, throughout the provincial territory. Furthermore, it envisages prohibition on the use or possession of bullets containing lead on the hunting site and the obligation for smooth-bore weapons to ban the use of ammunition containing lead throughout the valley floor, up to the foot of the mountain.

The same Decree invites the Province of Sondrio to implement forms of collaboration with the Carabinieri Forestali i and other Police Forces, for the enforcement, first and foremost, of actions to prevent and combat the use of bullets containing lead where and when prohibited, to combat ungulate poaching and verify, from a technical-legal point of view, whether it is possible to provide for a specific administrative violation (*e.g.*, suspension from hunting activity) for detention on the hunting site and the use of lead ammunition where prohibited.

Canton of Grisons (Switzerland)

With a few years of delay compared to the measures adopted in the Province of Sondrio, the neighbouring Canton of Grigioni in Switzerland also decided that all game wardens should use lead-free ammunition from 2014 and that lead used in regular hunting activities should be banned from September 1st 2020, with a transition period of one year.

As of 2021, the transport and use of lead ball ammunition (large animals, animals with special permits and ibex) have been prohibited. Overall, from 2021 to November 2023, 22,949 ungulates (10,801 deer, 5,083

roe deer, 6,041 chamois, 895 ibex *Capra ibex*, 129 wild boars) and 6,785 marmots *Marmota marmota* killed without lead (source: Hunting and Fishing Office of the Department of the Canton of Grisons, Dr. Hannes Jenny).

Piedmont (2015-2021)

The Piedmont Region has also issued specific regulations to stem the problem arising from the use of lead ammunition through the issuing of DGR n. 54-7409 of 7/4/2014 and subsequent amendments “Conservation measures for the protection of the Natura 2000 network of Piedmont”. In art. 3, paragraph 1, letters y bis and y ter. In particular, the process provides that in SCIs, SACs and SPAs **the use of lead ammunition is prohibited starting from 1 August 2015.**

For reasons of protection of the golden eagle and the bearded vulture, the Ossola Protected Areas Management Body has recently introduced further restrictions on lead ammunition also for hunting ungulates (roe deer, chamois and roe deer) while the Val Grande National Park (where hunting activity is prohibited) is activating the Wild Boar Control Plan in the area outside the borders of the protected area by introducing exclusively non-toxic ammunition.

The Mandria Regional Park (in the province of Turin) also uses exclusively non-toxic balls to control wild boars, allocating the surplus in terms of meat and viscera to the supply of two “meat houses” located in a hilly area (for black kites and red kites) and alpine (for vultures and golden eagles).

Autonomous Province of Bolzano

The Autonomous Province of Bolzano has issued the Provincial Law of 17 July 1987, n. 14 in which hunting with lead shot ammunition is prohibited within wetlands, special protection areas (SPAs) and special areas of conservation (SACs). As regards the harvesting of the ibex and the marmot (species in derogation), only lead-free ammunition can be used to prevent the lead of the ammunition from being ingested by eagles and vultures (bearded vultures), to preserve the quality of the meat and facilitate the transport of ungulates. As regards the marmot, killing is permitted exclusively with lead-free ammunition with a minimum calibre of 5.6 mm. In the Stelvio National Park, included in the Province of Bolzano, lead has already been replaced years ago and also by the ammunition adopted by the Bolzano Provincial Forest Service in the control of the coypu and the cormorant. For harvesting by shooting, long weapons with both smoothbore and rifled barrels can be used, exclusively with lead-free ammunition. From the point of view of the sanctioning aspect, article 30 paragraph 4 (criminal sanctions) of Law 11 February 1992, n. 157 provides that: pursuant to article 23 of the consolidated text of the constitutional laws concerning the special statute for Trentino-Alto Adige, approved by decree of the President of the Republic 31 August 1972, n. 670, the criminal sanctions established by this article apply to the corresponding cases as regulated by provincial laws. This means that in the province of Bolzano, hunting with lead ammunition when this is prohibited involves a criminal offence and therefore a violation for hunting with prohibited means.

Valle d'Aosta Autonomous Region

In Valle d'Aosta, starting from 2012, the obligation to use non-toxic bullets for killing animals sold or destined for marketing was introduced, with the request to favour their use in all other cases. This provision has also been envisaged for wild boars killed in culling, destined for game meat processing centres. In the 2023/2024 hunting season, the use of non-toxic bullets within the Natura 2000 sites open to hunting in the regional territory has been made mandatory for all hunters. The art. 7 of the hunting calendar approved by resolution of the Regional Council no. 813 of 24 July 2023 states “To carry out hunting activities within Natura 2000 sites (SPAs and SACs), the use of projectiles that do not allow the release of contaminants (lead) is mandatory. In the remaining regional territory, the use of bullets that do not allow the release of contaminants (lead) in wild animals is mandatory in the case of killing game animals sold or marketed for food use. In general, priority should be given to the use of bullets that do not release contaminants. lead)”. The Natura 2000 sites involved are 28 and cover a total area of 69,480 ha (the agro-silvo-pastoral area of the Aosta Valley, considered huntable, is equal to 241,438.5 ha). For the 2023/2024 hunting season there were 1376 hunters present, of which 1233 chose ungulates *with* plans to shoot 994 chamois, 753 deer, 465 roe deer and 1400 wild boars in selective and “stalking” hunting.

11. Mitigation measures to contrast saturnism

Regulatory provisions on the matter to be extended to the central Apennines

As mentioned, the issue does not only regard the areas in which hunting is practised, but also the protected areas (national and regional parks, reserves and natural parks, etc.), as the species of birds of prey most sensitive to lead make daily movements in search of food and can frequent areas where hunting is practised even located at a considerable distance from the breeding sites. For this reason, it can be said that the lead problem almost completely undermines the system of protected areas and the efforts made to protect the existing populations of griffon vulture and future populations of cinereous vulture and bearded vulture.

It is considered appropriate to extend the obligation of non-toxic ammunition starting from the 2025/2026 hunting season also to the wild boar “drive” and “turn” hunting, providing for a single transition year in which to prohibit the abandonment of viscera on the hunting ground for cautionary reasons. This choice should be accompanied by an adequate number of checks and investigations (through the production of minutes and reports at the end of the hunting season) by the bodies responsible for control (Carabinieri Forestali, Provincial Police, and Voluntary Hunting Wardens) and for the protection of the natural heritage (regional administrations, parks and protected areas).

To this end, on July 9, 2024, Rewilding Apennines and other environmental protection organisations sent a letter to inform the regions of Abruzzi, Latium, Marche, and Molise, as well as other relevant entities

responsible for hunting management and control, about the dangers of lead poisoning. The letter outlined solutions and strategies and requested the involvement of the working group that has produced this feasibility study.

The mitigation measures described (table 7) aim at minimising the negative effects of lead below the threshold of significance if conducted in a progressive and transversal manner for all forms of hunting. Some of the main European research experiences, replacement of traditional lead ammunition and evaluation of the effectiveness of alternative materials for hunting ungulates (*lead-free*) have been entirely developed and already extensively tested in some Italian areas, since they have found a clear success, are to be considered absolutely replicable also for the central Apennines.

On the basis of the available scientific evidence and the results of the investigation carried out by ECHA (European Chemicals Agency), it is believed that hunting carried out with lead-containing ammunition is not sustainable, as it has a negative impact on habitats and species protected in the Directives 2009/147/EC and 92/43/EEC. It is therefore necessary that the Administrations responsible for hunting and environmental protection act as soon as possible to raise awareness among hunters and to foresee the elimination of lead in a short and certain time, following the indications provided by ECHA.

In support of the need for the introduction of urgent mitigation measures for the central Apennines, we report some steps of the fundamental measures on the matter to be adopted also in Abruzzi, Latium and Marche.

Bullet ammunition used in hunting of ungulates

The implementation times for these provisions are those indicated, without prejudice to the maintenance of any previous provisions already in force and any requests in a more restrictive sense, such as the early introduction of the ban, formulated by the Management Bodies on the basis of the Evaluation of Incidence procedure. From the entry into force with differentiated timing of the ban on lead in ungulate hunting and control operations, the alternatives of burying the viscera on the hunting site and the delivery of the whole carcass must be definitively removed. While waiting for the ban to come into force, starting from the 2024/2025 hunting season, we must promote non-toxic ammunition as a priority and extend as a transitional measure only the obligation to provide the whole animal, where non-toxic ammunition is not used throughout the regional territory and not only within the Natura 2000 sites.

Upon entry into force of the notice, it is necessary to carry out verification by the Provincial Police Personnel and other authorised surveillance personnel, through **a number of checks equal to at least 5-10% of the ungulates shot annually** in each of the geographical areas (area opened to deer hunting and the remaining regional territory in which wild boar is killed for all types of hunting) to verify compliance with the ban on the use and possession of lead bullets on the ungulate hunting site and the transitional measures correct delivery of the entire item to the control point.

Once the ban comes into force, hunters are required to submit their weapon for inspection by an authorised expert (gunsmith at a shooting range) for the issue of a certificate proving the effective

calibration of the weapon, compatible with the use of non-toxic ammunition, which will be used on the ungulate hunting site in analogy with what has already been established by ERSAF-Stelvio National Park in the implementation of the control plan for the local deer population.

This geographical and temporal differentiation is widely justified by the strategic that the territory of the province of L'Aquila and the Sirente Velino Regional Park play for the conservation of the most important reproductive nucleus of the griffon vulture at the Apennine level and by the fact that it hosts one of the largest golden eagle populations of central-southern Italy.

Furthermore, we ask for the introduction of the obligation to use exclusively lead-free bullets throughout the regional territory starting from the 2025/2026 hunting season, providing for only 1 year of transition with the obligation to deliver the whole carcass to the checkpoints, which applies also for the wild boars shot with collective driving and turn methods.

It is also requested that all killings planned in control operations (wild boar and deer) and non-toxic ammunition for other invasive species or those subject to control, the use and possession of lead ammunition as part of the same control operations, are prohibited.

It should be underlined that the verification of the correct procedures proposed is strongly affected by the reduced supervision which is understaffed in Abruzzi.

However, it is believed that, to verify compliance with the ban on the use and possession of lead bullets on the wild boar hunting site, it is **necessary to carry out a number of checks equal at least 5%-10% of the annual regional shootings of wild boar or an average number of checks of approximately 337 investigations by Provincial Police personnel and other authorised surveillance personnel (considering the average of wild boar shot equal to 6,746 per year).**

These 337 checks should be increased by at least 50 annual checks by the officers if hunting and control of deer were to be opened in Districts 1 and 2 (estimated overall harvest of 780 deer in 2024/25) and roe deer (for now no data available about harvest estimate).

The need to give priority to hunting ungulates is also justified by the fact that this form of specialisation is the only form of hunting in continuous expansion in the regional territory and, consequently, the number of animals hunted is strongly increasing with the risk of an increase of cases of lead risk for birds of prey, deriving from none or partial burial and delivery of the entire carcass to control centres and the number of injured animals not recovered.

It is important to underline that many animals are killed in the early hours of the morning and most of the control centres instead have late afternoon-evening opening hours and therefore, as happens in some Italian contexts, it is unrealistic to think that the animals are kept whole for a prolonged time which would affect the organoleptic qualities of the meat.

In the province of Sondrio, the deer showed a decidedly favourable trend in recent years, which led to the **doubling of the density of animals killed**, going from the average figure of 1.4 eligible animals/10 km² in the period 2000-2005 to 3.5 heads/10 km² eligible in the period 2010-2019 (Hunting Fauna Plan 2020). Its demographic boom and the consequent rapid increase in the number of killings has probably

influenced in a decisive and exponential way the abandonment of contaminated viscera in the territory **inside and outside the Natura 2000 network** which has consequently doubled the number of large birds of prey contaminated by lead. **This scenario could also occur soon in Abruzzi without the rigorous application of the proposed countermeasures.**

Lead pellets used in hunting of small game

As regards forms of hunting conducted with **smoothbore weapons**, it is also considered essential to intervene with the progressive replacement of lead although with **relative less urgency as compared to hunting ungulates**, without prejudice to the provisions already in force prohibiting lead ammunition for regarding wet areas (EU Regulation 2021/57 of the European Commission of 25 January 2021).

It is believed that each Provincial Police Force, in collaboration with the relevant regional offices, provides an annual report also indicating the number of investigations and reports carried out on “lead” matters. This information, combined with an evaluation of the effectiveness of the non-toxic ammunition and the calibres used, should be included in the annual reports sent to the territorially competent bodies (Region, Province and **managing bodies of the RN 2000 sites possibly included**) **in order to contribute to the collection of useful information and to apply these positive management experiences also in other territorial contexts.**

As regards hunting with ammunition, it is proposed to **start trials** (also on a voluntary basis) on the use of ammunition not containing lead in terrestrial habitats. In fact, it is expected that, even for these forms of hunting, the progressive replacement of lead will be facilitated by the strong improvement in performance terms of new generation weapons, which are already available on the market.

It is believed that only through the application of this progressive replacement of lead, with timescales differentiated by area geographical and type of hunting, the problem of lead poisoning and that of environmental pollution and trophic chains can realistically be considered mitigated.

MITIGATION MEASURE no. 1	Ban of lead ammunition for hunting to ungulates and their control (red deer, roe deer and wild boar)
responsible for implementation	Abruzzo Region
financing methods	None
disturbance and/or interference factors involved	Poisoning of species in Annex I of the DU, other species and ecosystems
parameters that characterise the effects following the proposed mitigation measures	Reduction of the dispersion of lead in environments and the number of cases of acute and subacute poisoning in birds of prey. Decreasing number of reports and assessments at the end of first five years after the introduction of the definitive tender. Definitive conversion of ammunition.
technical-scientific feasibility	Proven effectiveness. Wide availability on the market for all calibres with reduced costs.
effectiveness	Proven effectiveness if the use and possession of lead ammunition in the hunting area is prohibited with the obligation of verification by the surveillance personnel. The effectiveness of the measure would be highly compromised if the possibility of burying the viscera and/or delivering the entire head to the control point was left as an alternative to the ban on lead. The provision of the whole carcass is the only form permitted in the transition period (maximum 1 year) for the forms of hunting (Stalking and Turn) for which there are currently no lead replacement obligations. Effectiveness to be carefully monitored also in the Districts where deer hunting has already been introduced and where deer hunting will be introduced (starting from Districts 1 and 2).
implementation methods	Immediate introduction, without the possibility of extension, of the ban on the use and possession of lead ammunition in Abruzzi in the 2025/2026 hunting season . While waiting for the ban to come into force across the entire Abruzzi region, promote non-toxic ammunition from the 2024/2025 hunting season and extend the obligation to provide the whole carcass as a transitional measure for hunted wild boar hunting. Please remember that for wild boar hunting in “stalking” and “turn” methods not only lead is not yet prohibited (as is the case for hunting from ambush and control) but there is not even an obligation to bury the viscera (measures which are, however, almost ineffective for avoiding the risk).

MITIGATION MEASURE no. 1	Ban of lead ammunition for hunting of ungulates and their control (red deer, roe deer and wild boar)
	<p>Upon entry into force of the ban, it is necessary to carry out verification by the Provincial Police Staff, Carabinieri Forestali and other authorised surveillance personnel, through a number of checks equal to at least 5%-10% of the annual wild boars shot in each of the geographical areas of the regional territory to verify compliance with the ban on the use and possession of lead bullets on the ungulate hunting site and the transitional measures of delivering the whole carcass to the control point in the 2024/2025 season.</p> <p>Obligation to calibrate the weapon used in hunting with non-toxic bullets at an authorised range for the issue of a certificate proving the effective calibration of the weapon to be kept on the hunting site.</p> <p>Obligation for the provincial police and personnel responsible for the control of problematic species (e.g. corvids, wild boar and deer) and alien species (coypus) to use non-toxic ammunition exclusively.</p>
consistency of the populations of the species involved and their level of conservation at the level of each site involved	<p>The issue negatively interferes with 100% of the population of sedentary and erratic griffon vultures and golden eagles. All protected areas are threatened by the risk of contamination from lead of trophic chains.</p>
expected values of the parameters describing the degree of conservation of habitats and species, to be achieved following the implementation of the mitigation measure	<p>Mortality and exposure to lead was reduced by 50% of acute cases in the central Apennines in the first 5 years after the entry into force of the lead ban for hunting ungulates.</p> <p>Mortality will be reduced to non-significant values for this cause of risk only with the completion of the ban on lead pellets for other forms of hunting and control.</p> <p>The role of Supervision is crucial when the ban comes into force.</p>

MITIGATION MEASURE no.1	Ban of lead ammunition for hunting to ungulates and their control (red deer, roe deer and wild boar)
	<p>It is necessary to provide for the verification with a number of checks equal at least 5%-10% of the annual animals shot in Abruzzi with particular regard to the reproductive settlement area of the griffon colonies, in the Natura 2000 sites and on the remaining regional territory, a constant number of infringements and reports in the first 5 years from the entry into force of the notice, which is then destined to decrease significantly in the following period.</p>
<p>methods and duration of management of the areas in which the measure is implemented</p>	<p>Intensify prevention efforts by the Supervision, with ammunition checks which also include the possibility of withdrawing the bullet to verify the actual composition since some lead bullets currently used by ungulate hunters are not externally distinguishable from non-toxic ones (possible confusion). The Abruzzo Region will organise preparatory meetings for the transition, aimed at hunters and Surveillance Personnel (2/year for the District and for the Police Force and Carabinieri Forestali).</p> <p>Verify, from a technical-legal point of view, the possibility of providing for a specific administrative violation (e.g. suspension from hunting activity) for the detention on the hunting site and the use of lead ammunition, following entry into force of the ban on the use and possession of lead bullets on the hunting ground throughout the regional territory.</p> <p>Verify the promotion of forms of collaboration with the Carabinieri Forestali and other Police Forces, aimed at guaranteeing activities to prevent and combat the use and detention on the hunting site of bullets containing lead when and where prohibited.</p>
<p>timetable in relation to the Plan</p>	<p>The implementation times for these provisions are those indicated previously (see Implementation methods).</p>

MITIGATION MEASURE no. 1	Ban of lead ammunition for hunting to ungulates and their control (red deer, roe deer and wild boar)
monitoring programme	<p>Number of birds of prey intoxicated/exposed to lead of hunting origin</p> <p>Use of lead-free ammunition in control operations carried out by surveillance</p> <p>Effective adaptation of hunters to the provisions</p> <p>Increase in large-scale breeding territorial pairs (1,000 km²).</p> <p>Establishment of new breeding colonies of griffon vulture and their numerical increase outside protected areas with successful nesting.</p> <p>No reports/assessments from the Supervisory Authority</p>
Control of implementation	<p>Investigations by the Supervisory Authority</p> <p>Passive ecotoxicological monitoring on the carcasses found of indicator species (diurnal birds of prey) most exposed to lead poisoning.</p>
probability of a positive outcome	50-70% if all the indicated procedures are implemented.

MITIGATION MEASURE no. 2	Ban on lead ammunition for hunting in wetland/terrestrial areas and for the control of supernumerary and alien species
responsible for implementation	Abruzzo Region
financing methods	None
disturbance and/or interference factors involved	Pollution and contamination at an environmental/ecosystem level and poisoning of priority species (diurnal birds of prey). The ammunition to date is probably the one that locally and at a regional level has the greatest impact on exposure to lead by necrophagous birds of prey as hunting of ungulates is currently limited only to the hunting and control of wild boar as demonstrated by the griffon vulture population sampled in alive (blood) and of the analysed carcasses which presented very high values in 45-67% of the analysed sample.
parameters that characterise the effects following the proposed mitigation measures	Reduction of the dispersion of lead in environments and of the number of cases of acute and subacute poisoning in birds of prey. Decreasing number of reports and assessments after the application of EC Regulation 2021/57. Definitive conversion of ammunition.
technical-scientific feasibility	Proven for split ammunition, already used in Italy in wetlands since 2007 and in Natura 2000 sites in the Alps.
effectiveness	Proven progressive effectiveness if the use and possession of lead ammunition in the hunting area is prohibited with effective verification by the surveillance personnel. At the moment in the Abruzzo Region, checks by the Provincial Police in wet areas included are only sporadic. The effectiveness of the ban needs to be carefully monitored. Progressive and definitive replacement of lead ammunition by the fifth hunting season as foreseen by ECHA at EU level.
implementation methods	Replacement of lead pellets in small game hunting and in all numerical control operations.

MITIGATION MEASURE no. 2	Replacement of lead ammunition for other forms of hunting
implementation methods	<p>Hunting season), tests on the use of non-toxic ammunition for all forms of hunting and fixed ambush is underlined.</p> <p>The trials (also on a voluntary basis) will be coordinated by Abruzzi Region and will collect useful elements to improve the ballistic effectiveness of the new ammunition introduced with the ban on the use of lead at the end of the transitional phase on the entire regional territory.</p>
consistency of the populations of the species involved and their level of conservation at the level of each site involved	<p>The problem negatively interferes with 100% of the griffon vultures and golden eagles present on a regional scale.</p>
expected values of the parameters describing the degree of conservation of habitats and species, to be achieved following the implementation of the mitigation measure	<p>Mortality reduced by 20-50% of necrophagous birds of prey that can feed on prey with encysted pellets not recovered during hunting from fixed stands and other forms of hunting.</p>
methods and duration of management of the areas in which the measure is implemented	<p>Since the entry into force of the ban, it is suggested to ensure that preventive surveillance is intensified, with checks on ammunition that also include the possibility of withdrawing the ammunition itself to check its actual composition.</p> <p>It is suggested that Abruzzo Region takes action to organise preparatory meetings for the transition, intended for hunters and supervisory personnel (2/year). Verify, from a technical-legal point of view, the possibility of providing for a specific administrative violation (e.g. suspension from hunting activity) for the detention on the hunting site and the use of lead ammunition, following entry into force of the ban.</p> <p>Promote forms of collaboration with the Carabinieri Forestali and other Police Forces, for actions to prevent and contrast the use of lead.</p>

MITIGATION MEASURE no. 2	Replacement of lead pellets for other forms of hunting
timetable in relation to the Plan	Final replacement of lead ammunition for small game hunting at the end of the transitional phase.
monitoring programme	No. of reports/No. of investigations by the Supervision No. of birds of prey intoxicated/exposed Effective use of lead-free ammunition Effective adaptation of hunters in the ecotoxicological monitoring provisions
Control of implementation	Passive ecotoxicological monitoring on the carcasses found of indicator species (diurnal birds of prey) most exposed to lead poisoning.
probability of a positive outcome	Considering that hunters dedicated to the hunting of pheasants, hares and passerines do not eviscerate the animals shot on the hunting site and that therefore the risk of lead dispersion in the environment and in any food sources for necrophagous birds would be limited to non-injured animals recovered, the probability of a positive outcome for lead replacement in both forms of hunting is considered very high (80%).

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Chapter 13

Collision risk with wind-energy infrastructures

Mario Posillico and Nicolò Borgianni



1. Introduction

Energy production from wind turbines is often regarded as a panacea because of its theoretically limited (though never null) CO₂ release. Furthermore, renewable energy sources are deemed as crucial for combating climate change and the increase of greenhouse gas emissions. However, renewable energy production impacts biodiversity. Specifically, wind power has recognised negative effects on wildlife, especially on birds and bats, directly affecting their survival. In addition, it implies a dramatic transformation of natural and semi-natural landscapes, thus compromising the cultural values of these places. The worldwide demand for wind-power for electricity generation has recently increased dramatically (*e.g.*, by 70% from 2015 to 2019; IPCC 2022). Consequently, because of additional mortality due to collisions, concerns about the impact of this technology are fully justified and supported by evidence, as well as considering its predictable, fast development (*e.g.*, Botha et al. 2017; Thaxter et al. 2017; Serratos et al. 2024).

Diurnal and large-soaring raptors are among the most vulnerable taxa affected by wind farms (Thaxter et al. 2017). They are usually K-selected species (*i.e.*, long-lived, with low reproductive output, higher parental investment), thus population viability is sensitive and strongly constrained by additional, non-natural mortality (Bellebaum et al. 2013, Carrete et al. 2009, Dahl et al. 2012, Duriez et al. 2022). Specifically, vultures are among highly susceptible raptors with respect to collisions with wind turbines, the griffon vulture (*Gyps fulvus*) being the most affected one (Carrete et al. 2012; de Lucas et al. 2012).

Vultures are characterised by a high wing load (the ratio between body weight and wing surface) which implies restricted manoeuvrability on a short-range, such as swift changes in direction. This limitation, along with certain behavioural traits and the presence of frontal blind areas in their visual field while gliding, are responsible for griffon vulture's susceptibility to collide with obstacles located ahead, like wind turbines (Janss 2000; de Lucas et al. 2008; Martin et al. 2012). Wing loading ultimately influences flight type: large raptors mostly use a soaring-gliding flying technique relying on thermal and orographic updrafts to gain altitude with less effort (Duriez et al. 2014, Treep et al. 2016; Shepard 2022). On the contrary, flapping flight holds high energetic costs and it is unsustainable, but for very short bouts (Duriez et al. 2014). Consequently, the availability of thermal and orographic updrafts could directly influence and constrain movements and the dispersal capabilities of soaring birds (Pennycuick 1998). As thermals and updraft currents are mostly generated by masses of hot air rising from heated surfaces or by winds rising over topographical obstacles, landscape morphology plays an important role in determining the energy landscape. This constrains the suitability of an area for soaring-gliding (Péron et al. 2017; Scacco et al. 2023) and, indirectly, affects the susceptibility of birds to collision (de Lucas et al. 2012). In fact, such landscape features and wind conditions make these areas appropriate for both soaring birds and the exploitation of wind and thus, could guide the choice of locations for implementing wind farms.

Within the griffon vulture's steady range in the central Apennines, and around 6 to 19 km from the nearest breeding colony, two wind farms are located with >70 turbines overall (Collarme-le-Pescina-

Cerchio and Cocullo). Another 11 wind farms can be found at the periphery of the core range (Oosterhoff 2023). There is research that shows the impact of wind farms on the griffon vulture within its core range in the central Apennines. Six individuals, or their remains, were found in Collarmente-Pescina Cerchio and Cocullo wind plants from 2007 to 2021. Except for the case of an individual equipped with GPS from the Pollino National Park (which had settled in Abruzzi (Monti et al. 2023)), no structured monitoring aimed at investigating the number of casualties due to collisions with wind turbines was carried out until 2022. From then, Rewilding Apennines has applied a specific and standardised monitoring programme which allowed discovering 8 griffon vultures or vulture remains killed by collision with wind turbines between 2022 and 2023. Therefore, sampling the area without significant effort or at an inadequate frequency provides limited and non-representative results. The mortality rate due to collision with wind turbines, compared to the overall mortality rate estimated from 2017 to April 2023 for the Griffon vulture population, is not negligible and represents between 17% and 20% of the causes of death (Monti et al. 2023; Reparto Carabinieri Biodiversità, 2023 – internal report).

Contrary to acknowledged best practices, there is no formal plan in Italy to locate on-shore wind farms and at the same time minimise the impact on both biodiversity and on the most sensitive wildlife. Accordingly, the creation of a proactive tool, will aim at identifying areas where wind power farms could greatly affect griffon vultures. This approach will not only serve as a conservation tool for the griffon vulture, and it could be also used as a surrogate model species to ascertain collision risk for other related taxa with similar flight behaviour and morphological, anatomical features, e.g., the cinereous vulture (*Aegypius monachus*), and the bearded vulture (*Gypaetus barbatus*). Although morphological, behavioural, and ecological differences between these species exist, this approach currently represents, to our knowledge, the best available approximation. The likelihood of a wind power farm impacting the griffon vulture population at a landscape scale, will be derived by overlapping the predicted probability of occurrence of griffon vultures, modelled after GPS telemetry, with the estimated suitability for wind power plants, retrieved from energy producibility digital layers, similarly to Smeraldo et al. (2020).

2. Methods

The spatial ecology dynamics of griffon vultures, like that of every other sensible raptor species, demonstrates that vultures can be found well outside the steady range in the central Apennines. This is because their movements can be characterised as dispersal, prospective or nomadic movements. During such long-distance bouts, they reach the most southern tip of peninsular Italy (and even Sicily) and the most northern regions towards the Alpine range and neighbouring countries (usually from France to Croatia and beyond). Indeed, many GPS-tagged and ringed vultures in the central Apennines, mostly immatures, undertake such long-range movements *sensu* Poessel et al. (2022) (Breda 2023). Similarly, the occurrence of griffon vultures (and, rarely, cinereous vultures) ringed abroad has been repeatedly reported in the Apennines (e.g., Stoyanov et al. 2019; Reparto Carabinieri Biodiversità unpublished data; Rewilding Apennines unpublished

data), thus indicating that maintaining a viable transboundary connection at a population or meta-population scale could be important for long term viability. Furthermore, it highlights that locally-acting threats could also have an effect on populations elsewhere. Accordingly, in our effort to provide a meaningful planning tool, we extended our effort to identify the risk of collision with wind turbines, and the sensible areas used by griffon vultures, to the whole country. Some raptors show - at least in some circumstances - a certain degree of avoidance behaviour towards areas occupied by wind power plants, such as the black kite (*Milvus migrans*) (Marques et al. 2020), which allows a certain decrease of collision risk, but at the expense of habitat loss and relying on suboptimal habitat. Recently Sassi et al. (2024) showed that the griffon vulture does not display (whatever the scale) avoidance of the areas where wind plants and turbines occur. This emphasises that every proactive approach to effectively decrease collision risk and harmonise the placement of wind turbines according to local emergencies should be mandatory. Given the spreading of the Griffon vultures tagged in the central Apennines through the whole country (Monti et al. 2023; Breda 2023), and their connections with other populations in Italy and abroad, we estimated the probability of occurrence for the Griffon vulture, and contrasted it with suitability for wind plant placement in terms of estimated energy producibility, nationwide.

GPS fixes from 59 vultures from November 2020 to December 2023 were retrieved from movebank.org, from the telemetry projects from Rewilding Apennines and Carabinieri Forestali. We downloaded >600,000 fixes, which were filtered for our specific purposes. After preliminary data curation (*e.g.* removal of duplicates, nighttime, captivity, and cage-trap constrained fixes), locations were retained if the speed was ≥ 4 m/s and HDOP < 4 to maximise the certainty that the vultures were in flight and at the same time providing a minimum expected accuracy of fixes (Sassi et al. 2024). We were purposely interested in estimating the probability of occurrence for vultures undertaking long-range movements as we were concerned not only about collision risk within the core range, but also outside it, thus mostly affecting individuals representing the connection between the central Apennine and the nearby populations. Thus, those fixes not belonging to long-distance movement bouts were discarded from the dataset, obtaining 7,637 GPS positions.

We predicted griffon vultures' probability of occurrence using Maximum Entropy algorithm, as implemented in Wallace 2.0 (Kass et al. 2022). Predictor layers (slope, elevation and ruggedness) were derived from a 30 arcseconds (~ 1 km) digital terrain model (ESA 2021). These are among the most significant terrain physical characteristics influencing thermal updrafts or wind currents which, in turn, restrict movement suitability for vultures.

We ran several models according to the combination of Linear, Hinge Linear-Quadratic features, with regularisation multipliers from 0.5 to 6.5 and with increment = 1. Resulting models were selected according to the small samples Akaike Information Criteria score (AICc), and competing models were considered only if $\Delta AICc \leq 2$. Model diagnostics were referred to the testing dataset and included the average Area Under the Receiver Operator Characteristic Curve (AUC) score, the average Continuous Boyce Index (CBI), the average 10th percentile Omission Rate (OR10) and the average Minimum Training Presence Omission Rate (ORmtp). Accuracy of predictive models was tested by k-fold cross-validation, partitioning the dataset into 4-groups and randomly assigning

fixes to each partition. As the dataset contained only occurrence data, we relied on 10,000 random background points over the whole country. Both continuous (Cloglog) and discrete, binary (0.10 quantile of training presence) potential distribution maps were generated.

Information on suitability of wind conditions, in terms of wind speed (m/s) at 100 height above surface and specific energy producibility (MWh/MW), is the most used tool to plan for wind turbines positioning. These layers were downloaded from <https://dbeta.rse-web.it/>, while information on wind turbine position was accessed at <https://atlanteolico.rse-web.it/>. As, regrettably, available official information on wind plants is incomplete nor it is updated, we included in our analysis wind turbine data as reconsidered by Smeraldo et al. (2020) as an effort to provide a more realistic portrait of extant wind farms/turbines. Likewise, Cerri et al. (in press) highlighted a significant gap in the information available on existing wind turbines in Sardinia. The authors found that imagery-assisted identification of turbines allowed the detection of a considerably higher number of turbines than those reported even in official data bases, concluding that updating open-access information on wind plants and wind turbines is fundamental for planning and conservation purposes (Cerri et al. in press). To explore the degree to which wind speed and energy producibility data represent an affordable surrogate to predict the location of forthcoming turbines or plants, we extracted the estimated speed and energy value corresponding to each turbine, out of a total of 8,729. Interestingly, 94% and 93% of extant turbines fell within the two highest wind-speed or energy producibility classes, suggesting that both wind speed and specific energy producibility data could represent an accurate enough proxy to represent the location of future wind-energy exploitation plants (Annex I).

The collision risk was estimated by weighted overlay, between the probability of occurrence (binary and continuous) and the energy producibility layers. These layers were reclassified to a common scale in five discrete-value classes (1-5) through quantile method (ArcGis, version 10.5). Similarly to Smeraldo et al. (2020) and Bosso et al. (2017) the resulting overlay maps were classified into five risk classes: low, medium–low, medium, medium–high and high. To provide information consistent with the geographic approach adopted in other chapters of this study, we also described our results with reference to the area which has been used to evaluate the carrying capacity in chapter 15. This area, hereafter named ‘overall range’ represents the minimum convex polygon enclosing all telemetry locations of resident griffon vultures (but for eventual sallies) and included the whole surface of municipalities intersecting the minimum convex polygon, accounting for ~25,000 km².

3. Results

Distribution model

The most parsimonious model (as of AICc), included Hinge features and the smallest penalization for complexity (regularisation multiplier = 0.5) (table 1). This griffon vulture distribution model suggested a moderate performance for H0.5 according to average testing AUC (0.77, SD ±0.003)

and OR10 (0.098, SD \pm 0.008), while it ranked third when considering average testing CBI or average testing ORmtp (table 1). Although H0.5 did not always score the best according to all model diagnostics, it anyway ranked within the first three models (table 1). AICc weights (wAICc) showed that H0.5 was, by far, more likely to represent the best model as compared to competing ones, in terms of Kullback-Leibler discrepancy (Wagenmakers and Farrel 2004).

Table 1. Diagnostics and model performance for H0.5 and competing models (\pm SD in brackets) ranked according to increasing AICc.

Features (regularisation multiplier)	AICc	Δ AICc	wAICc	AUC	CBI	ORmtp	OR10
Hinge (0.5)	52,693.34	0	1	0.771 (0.003)	0.986 (0.011)	0.0005 (0.001)	0.098 (0.008)
Linear-Quadratic (0.5)	52,772.90	79.56	5.3e-18	0.77 (0.004)	0.99 (0.005)	0.0005 (0.001)	0.099 (0.012)
Linear-Quadratic (4.5)	53,200.13	506.79	8.9e-111	0.76 (0.007)	0.994 (0.001)	0.001 (0.002)	0.099 (0.004)
Linear (0.5)	54,060.47	1367.13	1.3e-297	0.724 (0.009)	0.032 (0.105)	0.0005 (0.001)	0.1 (0.005)

AUC: area under the receiver operating characteristic curve; CBI: average Continuous Boyce Index; ORmtp: average minimum training presence omission rate; OR10: average 10th percentile omission rate. AUC to OR10 values are averages for the testing datasets.

Ruggedness provided the greatest contribution among predictors, followed by elevation (table 2). The highest predicted probability of occurrence (*e.g.*, \geq 0.60, on a Cloglog scale) is found for ruggedness values from \sim 200 to \sim 1,000 (on a 0 to 1,650 scale). The same pattern holds for elevation, with highest suitability related to elevation in the range 200 to 2,000 m a.s.l. (figure 1). Slope had a minimal effect on predicted occurrence, stabilising at somehow high occurrence values (figure 1).

Table 2. Estimates of relative contributions of the environmental variables to the Maxent model.

Variables	Percent contribution	Permutation importance
Ruggedness	63.9	60.9
Elevation	35.2	35.8
Slope	0.9	3.2

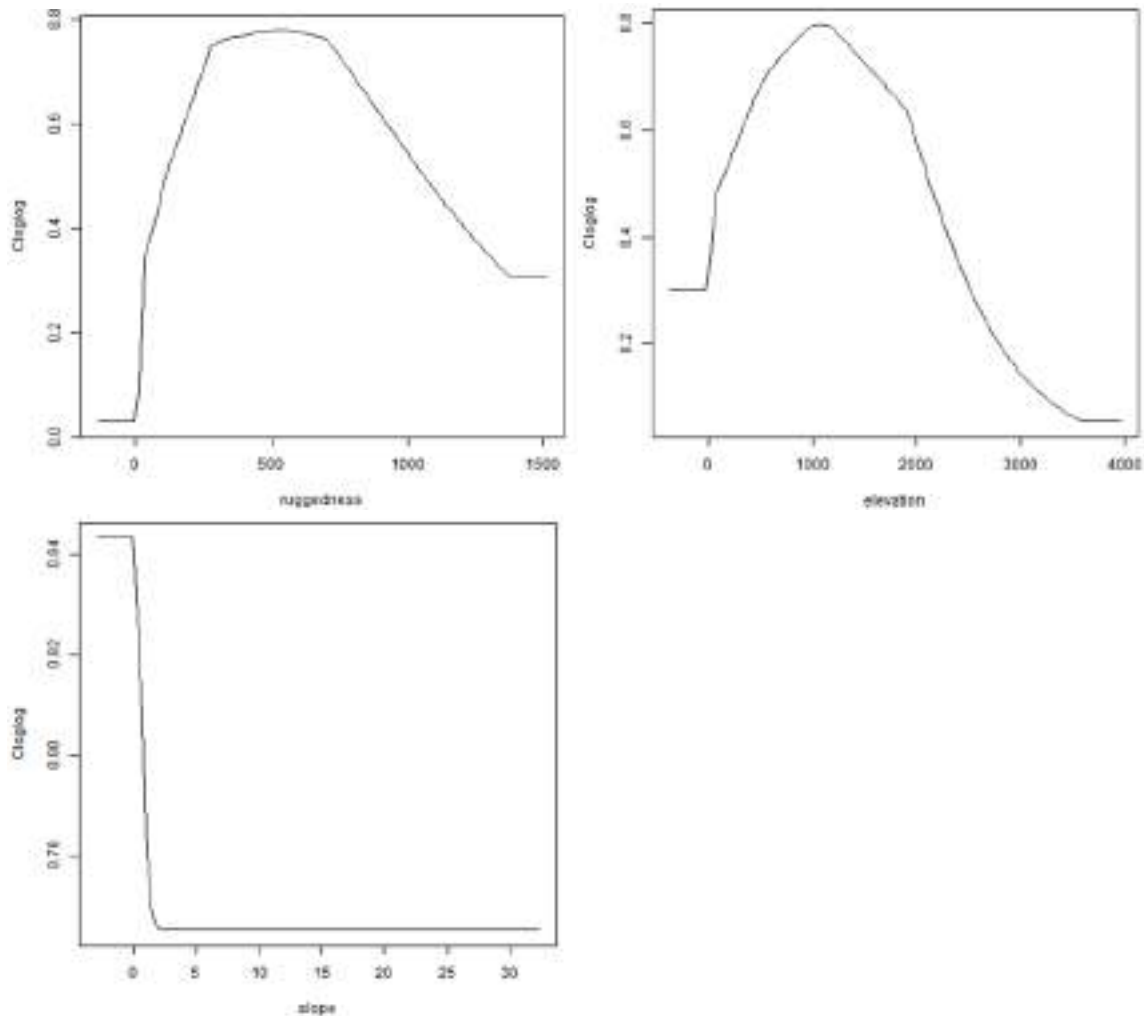


Figure 1. Maxent marginal response curves show the relationships between the modelled response (suitability) and the three predictor variables (when all other variables are held at their medians). Response is on the y-axis (here on a Cloglog scale) and the range of each predictor variable is on the x-axis. Elevation: metres above sea-level; slope: degrees; ruggedness: metres (elevation difference between adjacent cells). Y-axes are represented at different scales, to better portray the trend of the modelled response.

Areas with highest predicted probability of Griffon vulture presence are well and uniformly distributed along the main mountain reliefs, *i.e.*, the Apennines, pre-Alps and the Alps (figure 2). Though we relied upon GPS positions collected during long-distance movements, the core range of Griffon vultures across the Apennine sector of Abruzzi and Latium regions is correctly identified as an area with high probability of presence (figures 2 and 3). Similarly, the model reported a high suitability for the western and eastern Alps and Sicily, where summering steadily occurring griffon vultures in the western Alps are reported, or breeding colonies exist (eastern Alps and Sicily). Comparatively, only a smaller portion of griffon vulture range in north-western Sardinia which is correctly classified with respect to the known occurrence and breeding range there. Pollino National Park (at Basilicata and Calabria border), which has been interested in a griffon vulture reintroduction project, with multiple though not fully successful releases, received a high suitability score, overall (figure 2).

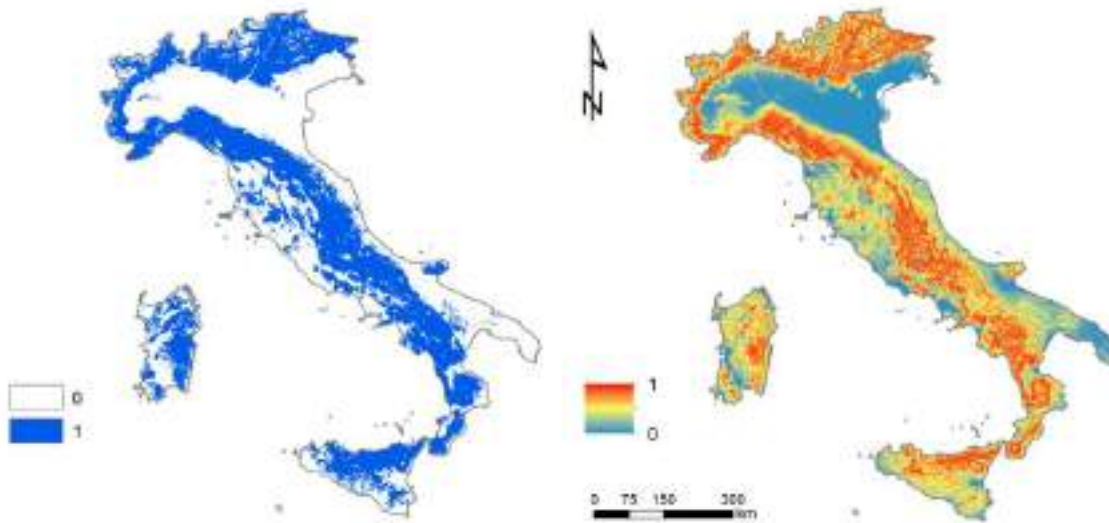


Figure 2. Predicted probability of presence for the griffon vulture in Italy. Maximum entropy algorithm output is represented either as continuous probability of occurrence on the left (Cloglog scale), or as a discrete (0= predicted absent; 1= predicted present), binary output (right), scaled on the 10th percentile of training presence.

The griffon vulture has been predicted to potentially occur across little more than half of national territory, as of the estimated 10th percentile binary classification (154,984 km²), with a regional average suitable landscape surface equal to 57% (± 18.5 , SD; range 12-90%) (table 3). Probability of occurrence is medium-to-high for Latium and Abruzzi, respectively, which represented the stronghold of the griffon vulture in the central Apennine (table 3).

Most of the griffon vulture's overall range (81%) has been estimated as suitable for vultures (binary prediction, $\sim 20,400$ km²). Considering only the highest predicted probability of occurrence (\geq medium-high probability class), a huge amount of this area (72%, 18,000 km²) falls within the overall range (figure 3). Whatever continuous or binary, the surface predicted by the distribution model to be suitable for griffon vultures is uninterruptedly distributed across the landscape. The only partially detached area is located in the Latium region, towards the south-western border of the overall range, to the Tyrrhenian sea (figure 3). However, if we consider the highest potential probability (*i.e.*, \geq medium-high), the landscape where griffon vultures are predicted to occur in the overall range, there is a major discontinuity in the north-central Campania region (figure 3).

Table 3. Potential surface of the national territory suitable to the griffon vulture by administrative regions (km²). Predicted probability of occurrence has been estimated according to Maxent for either binarized (10th percentile threshold, either absent or present) and continuous predicted probability outputs (5 slots: low, medium-low, medium, medium-high and high).

Regions	Predicted occurrence surface	% suitable surface	Low	Medium-low	Medium	Medium-high	High	% \geq Medium-high
Abruzzi	7,994.65	73.81	172.39	1,594.16	2,226.27	2,516.83	4,346.01	63.22
Apulia	2,400.59	12.28	6,794.40	7,978.56	2,500.68	1,089.25	337.04	7.63
Basilicata	6,794.35	67.45	226.63	1,754.93	2,235.96	2,624.01	2,986.87	57.09
Calabria	9,778.63	64.24	349.95	2,590.43	3,060.48	3,833.99	4,233.02	57.34
Campania	8,908.27	65.16	1,592.87	1,589.00	3,188.32	3,773.95	3,030.78	51.65
Emilia-Romagna	9,140.06	40.71	11,016.44	1,914.41	2,761.54	3,283.88	4,192.99	32.27
Friuli-Venezia Giulia	4,132.27	52.56	2,755.72	1,126.70	522.35	1,306.19	2,485.19	46.26
Latium	7,421.30	43.07	2,473.57	5,758.09	2,888.73	2,561.38	3,426.58	35.00
Liguria	4,875.43	90.02	33.57	202.74	962.70	1,977.04	2,239.19	77.86
Lombardy	9,285.98	38.91	12,037.25	3,057.90	2,563.31	3,491.14	4,336.33	30.71
Marche	5,404.23	57.48	178.85	2,802.86	3,163.79	1,848.56	1,913.77	37.97
Molise	3,495.64	78.37	49.07	583.69	987.88	1,688.43	1,122.18	63.43
Piedmont	12,363.88	48.70	5,916.28	6,166.16	4,912.91	4,187.18	5,565.68	36.46
Sardinia	11,826.04	49.07	2,042.90	5,666.41	7,116.59	5,246.72	2,550.40	34.47
Sicily	13,970.94	54.08	946.55	5,171.18	7,257.99	5,628.96	4,318.25	42.65
Trentino-Alto Adige	11,853.80	87.13	285.39	1,530.24	2,883.57	4,537.13	5,468.83	68.04
Tuscany	11,496.75	50.01	2,403.83	6,647.18	5,871.73	4,182.66	4,227.21	36.04
Umbria	5,576.63	65.88	439.70	1,467.61	2,791.24	2,187.53	1,779.47	45.78
Valle d'Aosta	1,800.77	55.22	373.20	938.16	853.58	768.99	555.28	37.95
Veneto	6,463.77	35.12	10,245.51	1,517.33	1,613.53	2,456.13	30,127.0	29.02
Total surface (km²)	154,984					59,190	62,127.8	
	Average	56.5						44.54
	(SD)	(8.5)						(16.40)

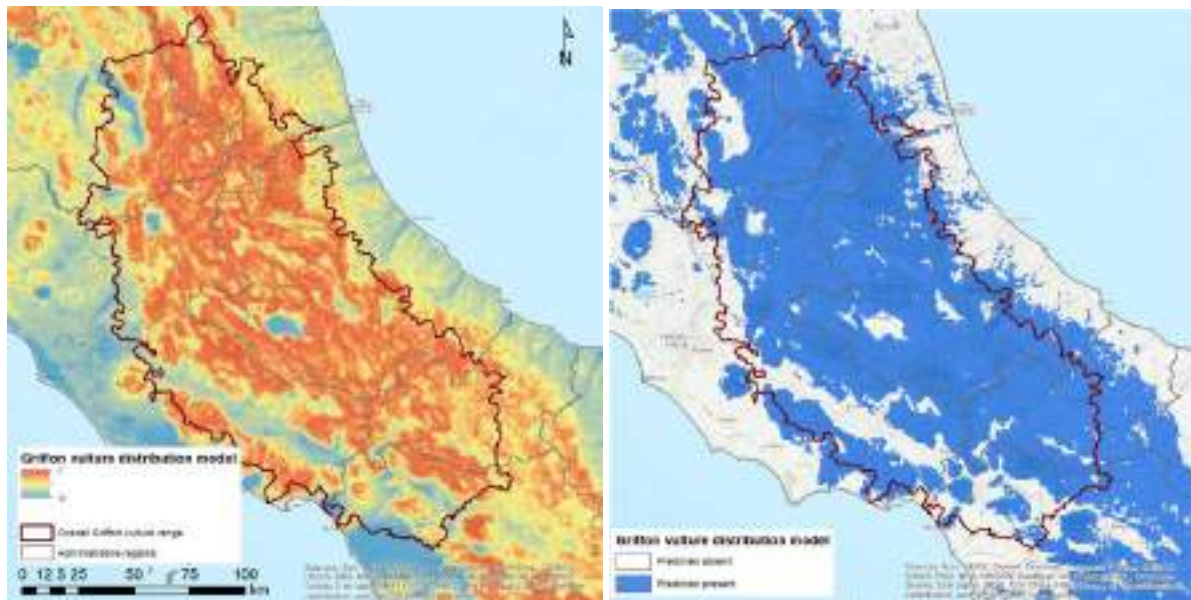


Figure 3. Predicted probability of presence for the griffon vulture in the overall range. Overall range represents the municipalities included (at least partially) within the minimum convex polygon encompassing the telemetry location of resident griffon vultures, excluding sallies. The outcome of the Maximum Entropy distribution model is

represented either as continuous probability of occurrence on the left (Cloglog), or as a discrete, binary output (right), scaled on the 10th percentile of training presence.

Risk assessment

The average regional percent surface for cumulated ‘medium-high’ + ‘high’ collision risk classes was 32% (SD ±19) (table 4; figure 4). Nine regions showed a percent surface where medium-to-high collision risk was higher than the estimated average, including Abruzzi, which is the stronghold for Griffon vultures (together with the adjacent Latium relieves). Sardinia and Sicily also showed a higher-than-average percent surface characterised by ≥ ‘medium-high’ collision risk, which could raise concerns as there are two apparently healthy Griffon vulture’s population thriving, and where restocking has been implemented and is currently ongoing. Latium is the only region bordering the Griffon vultures core range (though partially included in it) where collision risk is lower than average (table 4; figure 4). Notwithstanding its energy specific producibility is higher (45%) than the regional average (Annexes II-III), and the overall binarized probability of occurrence accounted for 43% of the surface, the overlap between areas estimated as suitable for wind-energy producibility and those where the griffon vultures have been estimated to be potentially present is minimal. Actually, in Latium, the relevant areas for the griffon vultures are mainly located along the regional border from Molise (south) to Umbria at north (figure 5).

Regions	Low	Medium-low	Medium	Medium-high	High	≥Medium-high
Abruzzi	1.03	15.62	37.94	41.39	4.02	45.41
Apulia	0.00	15.70	66.72	15.87	1.72	17.59
Basilicata	0.00	5.93	40.40	37.15	16.52	53.67
Calabria	0.00	9.16	37.07	39.80	13.97	53.77
Campania	0.23	19.13	33.18	33.36	14.09	47.45
Emilia-Romagna	21.66	37.74	23.59	15.96	1.04	17.01
Friuli-Venezia Giulia	10.24	38.72	35.70	15.34	0.00	15.34
Latium	1.33	25.67	45.76	25.89	1.35	27.24
Liguria	0.03	4.87	38.13	52.69	4.28	56.97
Lombardy	23.54	38.39	31.88	6.15	0.03	6.18
Marche	0.00	27.81	43.71	19.52	8.96	28.49
Molise	0.00	1.74	31.18	53.20	13.89	67.08
Piedmont	15.13	36.16	39.68	8.87	0.16	9.02
Sardinia	0.00	17.95	36.43	37.84	7.78	45.62
Sicily	0.00	9.33	42.37	36.28	12.03	48.30
Trentino-Alto Adige	0.09	15.18	68.65	15.74	0.35	16.08
Tuscany	1.03	31.93	41.46	22.21	3.37	25.58
Umbria	0.44	19.44	39.84	32.89	7.40	40.29
Valle d’Aosta	0.45	33.60	57.40	8.45	0.10	8.55
Veneto	13.27	52.73	27.54	6.22	0.23	6.45
<i>Average</i>	4.42	22.84	40.93	26.24	5.56	31.81
<i>SD</i>	7.77	13.87	11.56	14.90	5.77	19.43

Table 4. Estimated potential collision risk for the griffon vulture by administrative regions percent surface in Italy. Potential collision risk has been estimated by weighted overlay between energy producibility maps and predicted

probability of occurrence. Both layers have been discretized in 5-increasing producibility or potential distribution classes. Risk spans from low to high. Medium to highest risk percent surface is also shown.

Molise region increasingly hosts griffon vultures, either on their way to the southern Apennines or prospecting across Matese massif (G. Capobianco *ex verbis*), or as steady seasonal foraging visitors during spring and summer. As such, the binarized predicted suitability for vultures in that region, sums up to 79% of the regional surface (table 3; figures 2-3). Correspondingly, slightly more than the 80% of the regional surface is predicted to have a high estimated producibility (Annexes II-III). Thus, and not surprisingly, 67% of the regional surface is predicted to have mid-high to high collision risk. Griffon vultures engaging with southbound long-distance movements could face a higher-than-average collision risk in Campania, Basilicata and Calabria (table 4; figure 4-5). Similarly, northward long-distance dispersing or prospecting griffon vultures are susceptible to face a high collision risk along both the main Apennine and anti-Apennine ridges, as well as in the south-central Tuscany lower mountain massifs (figure 4). Higher-than-average, collision-risk prone regions to the north are Umbria (40%) and Liguria (57%) (table 4); albeit, areas sensible to collision risk could be found continuously along Tosco-Romagnolo and Tosco-Emiliano Apennine, as well as within Marche region (figure 4). Only four regions (Piedmont, Valle d'Aosta, Lombardy, and Veneto) show a percent surface classified as \geq 'medium-high' risk below the national average $- 1$ SD (table 4; figure 4). This is clearly depending upon low estimated producibility (Annexes II-III), as a not negligible amount of their regional surface is predicted as suitable for the griffon vulture (table 3; figure 2).

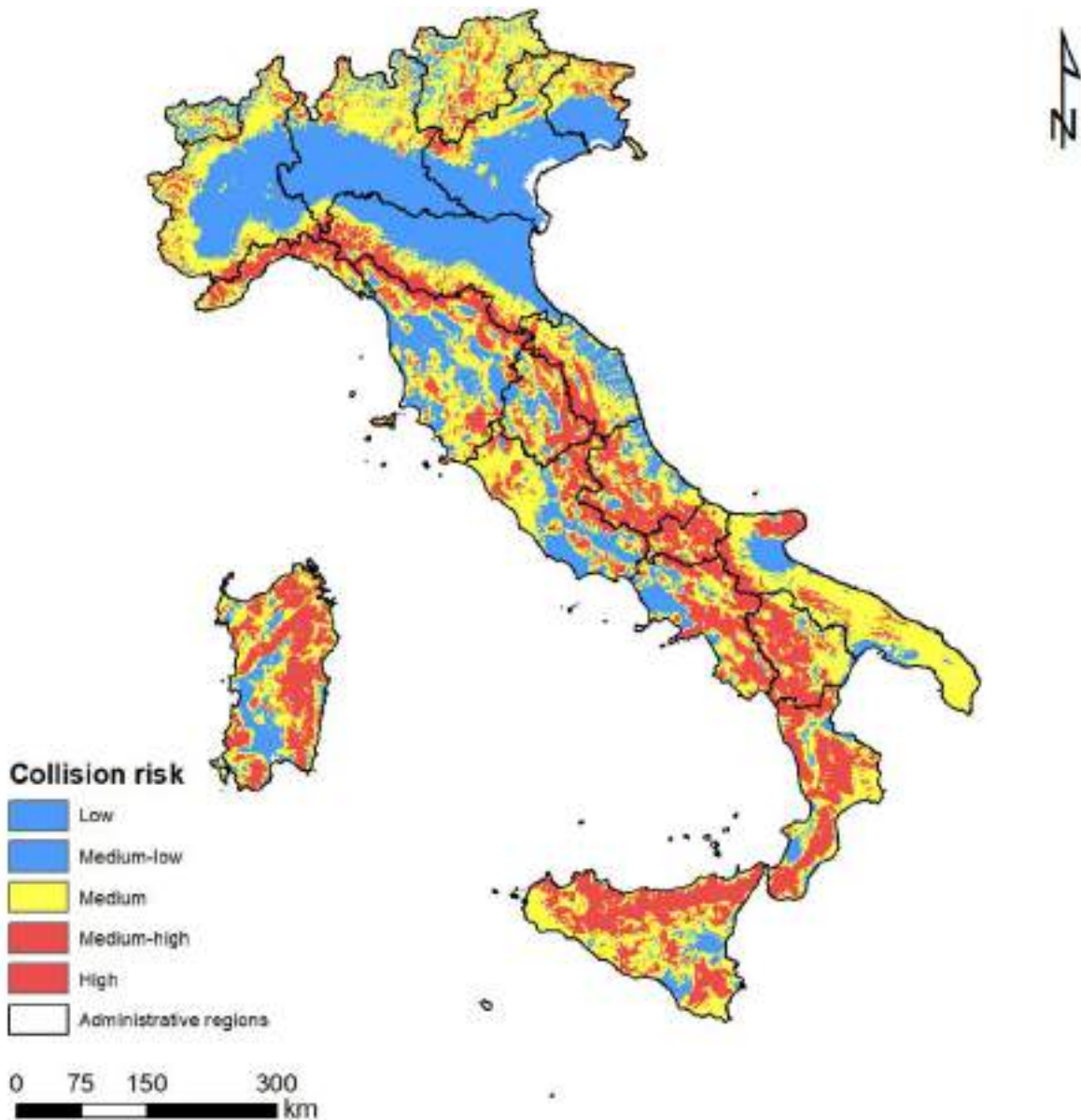


Figure 4. Five-class collision risk for Griffon vultures estimated with weighted overlay procedure for the whole country, comparing specific energy producibility (<https://dbeta.rse-web.it/>) and potential distribution (this study). About 20% of high suitable areas for the Griffon vulture overlap with high producibility landscape.

Only a small fraction of the overall griffon vulture range had a low estimated collision risk (1.3%, ~316 km²), mainly corresponding to the plateaus and largest valleys (table 5; figure 5). Quite the opposite, the portion of the landscape accounting for the highest predicted collision risk (*i.e.*, risk classes ≥ ‘medium-high’) represent a significant portion of the concerned area (53%, ~13,300 km²) (table 5; figure 5).

Table 5. Estimated potential collision risk for the griffon vulture in the overall range. Collision risk has been estimated by weighted overlay between energy producibility maps and predicted probability of occurrence. Both layers have

been discretized in 5-increasing producibility or potential distribution classes. Risk spans from low to high. Medium to highest risk percent surface is also shown.

Overall range	Low	Medium-low	Medium	Medium-high	High	≥Medium-high
km ²	316	3,853	7,678	11,041	2,248	13,289
Percent surface	1.26	15.33	30.55	43.93	8.94	52.87

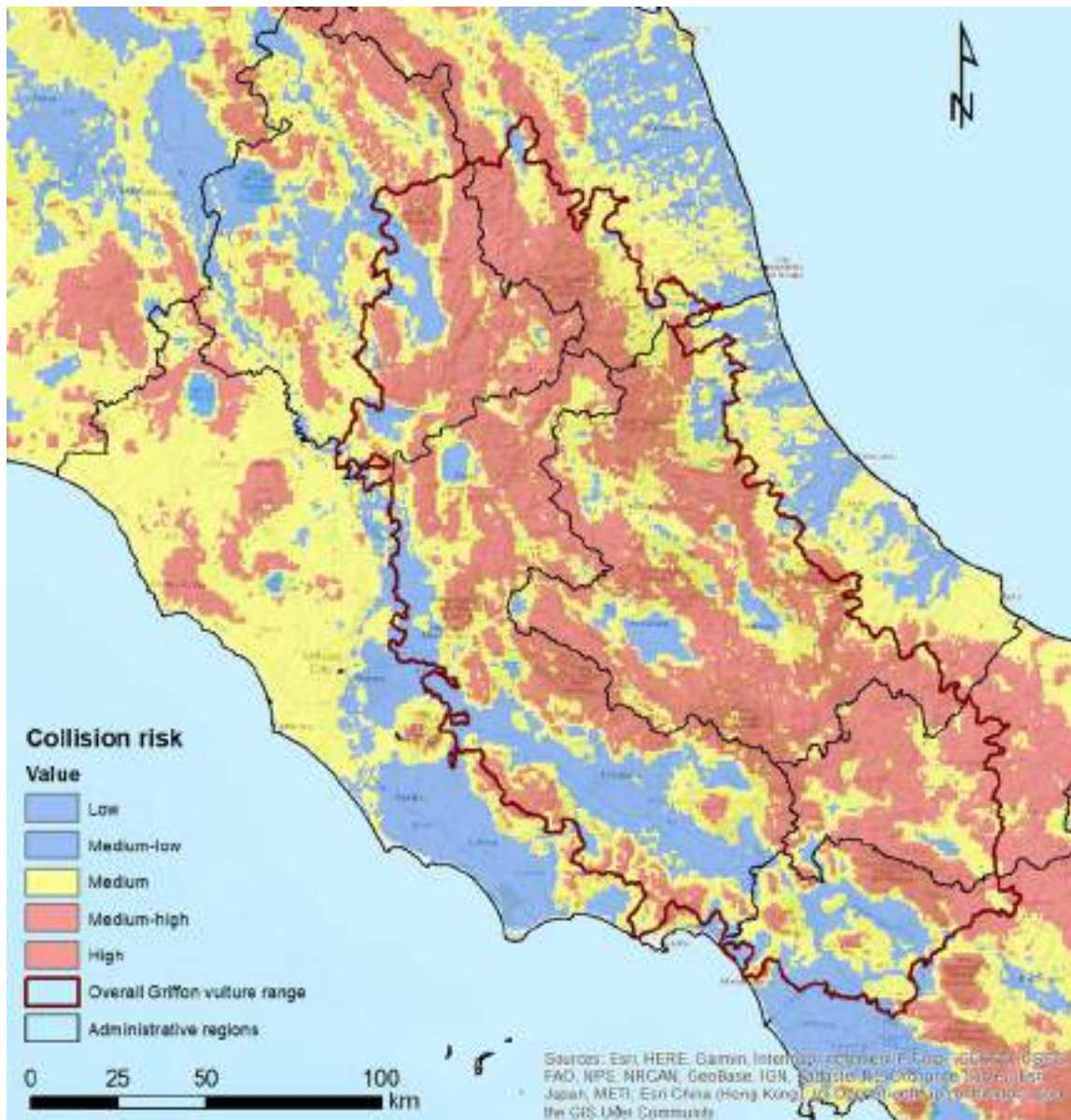


Figure 5. Five class collision risk for Griffon vultures estimated for the overall range, comparing specific energy producibility (<https://dbeta.rse-web.it/>) and potential distribution (this study) through weighted overlay.

4. Discussion

Distribution model

Our griffon vulture distribution model, notwithstanding only a moderate AUC value, could be considered satisfactory both in terms of model diagnostics and performance, and according to predictions when transposed elsewhere (figure 2). Indeed, the areas where the model projected - beyond training data - a high probability of occurrence (Western and Eastern Alps, Sicily, and to a certain extent Sardinia), fit perfectly with the existing breeding or seasonally occurring griffon vultures. Similarly, the high suitability predicted for the current core range and the high percentage of landscape for which presence has been predicted in the overall range, provide further support for the generality and the applicability of our distribution model.

Even if our model did not target the potential for colonisation of further areas by the griffon vulture, the continuous and vast landscape characterised by (even high) predicted occurrence, is encouraging for a future expansion of the griffon vulture population (even if our model only relies on abiotic predictors). A thorough - similar - assessment of potential colonisation should preferably include biotic predictors too, for instance, the abundance of food resources and of land cover. A further refinement of the model, to assess predicted presence, would simultaneously account for foraging, nesting, and roosting, and would include a different selection of telemetry fixes, as well as consistent environmental predictors (*e.g.*, land cover or vegetation, livestock and wildlife abundance).

Landscape colonisation, and therefore range expansion, by the griffon vulture, starting from an extant population, is driven by complex intra-specific interactions and food availability (Martinez *et al.* 2024). The high flight performance of large-sized scavengers like the griffon vultures usually allows daily movements in the order of a few hundred kilometres, especially during the warmer period. Thus, the scale at which spontaneous colonisation (*i.e.* the establishment of new and possibly 'far' breeding sites) takes place is both dependent on the availability of a full range of resources within a certain distance from suitable breeding-roosting sites, and on social aspects. Even when individuals are released in suitable areas, there is a tendency to move and aggregate to the nearest extant colonies when those are located within a few tens of kilometres (Le Gouar *et al.* 2008).

Risk assessment

Our results represent the first approach to identify and map collision risk linked to wind plants and wind turbines for the griffon vulture at a local and national level. In some areas where wind turbines are already in place, and at the relevant scale, collision risk in the central Apennines is already posing a threat to griffon vulture and presumably to other soaring birds (Rewilding Apennines, 2023). Given the predicted increase in wind farms and turbines number, a quota of collision risk should be attributed to forthcoming plants. Furthermore, the cumulative interference and risk, which has not been included in this chapter, should be assessed, considering that the energy distribution network will increase along with the setting of new wind plants.

The reliability of predicted collision risk within our modelling framework, approximations, specific aims and beyond the accuracy of our distribution model, ultimately depends upon how close the location of

forthcoming wind plants matches the information of energy producibility. Information on wind speed and energy producibility usually drives at a medium scale the placement of wind plants, even if other factors linked to logistics, environmental obligation, etc., could ultimately affect actual placement (even in estimated suboptimal wind conditions). Most of the extant wind turbines - as of Smeraldo et al. (2020) increased data set (N= 8,729) - are located in \geq 'medium-high' energy producibility (95% of wind turbines) and wind speed (93% of wind turbines) areas, as reclassified on a 1 (minimum) to 5 (maximum) scale (Annex I). Accordingly, we can postulate that available wind and energy maps provide an affordable estimator of future wind turbines location. In that case, it could be concluded that the collision risk (given the caveats intrinsic to our distribution model and weighted-overlay procedure) is estimated confidently and realistically.

The produced risk map suggests an uneven distribution of collision risk across the whole country. The Apennines, Sicily, Sardinia and in general central southern mountain landscapes represent areas where \geq 'medium-high' risk accounts for a larger surface. Thus, given the distribution of griffon vultures and their predicted suitable habitat, those landscapes represent a real concern. The overall range and the core range of griffon vultures host a relatively limited number of wind turbines and hence wind plants. Consequently, in this area, if no further development of wind energy plants or repowering with larger-sized turbines will take place, the collision risk could remain stable. As animal populations and their habitat are intrinsically dynamic, if changes in the distribution and population size of griffon vultures or in resource abundance or distribution occur, we could expect that the magnitude and the spatial distribution of collision risk could change accordingly. Nevertheless, existing wind plants (*i.e.*, Collarmele-Pescina-Cerchio and Cocullo) near to the griffon vulture breeding colonies represent an immediate concern for vultures' survival, as the information on survival rates and mortality causes clearly point out (Monti et al. 2023; Posillico et al. 2023; Rewilding Apennines 2023).

It is common among vultures and many raptors that juveniles and immatures undertake long-distance movements due to, but not limited to, dispersal, prospection for resources, erraticism, partial migration (*e.g.*, Newton 2010; García-Macía et al. 2023, for the red kite *Milvus milvus*; Breda 2023 for the griffon vulture). Although there is not a lot of research available on this, such displacements in the vulture population represents connections, thus potential genetic interchange with neighbouring populations which could pioneer colonisation or range expansion and allow the detection of further food resources. It is therefore crucial, from a conservation and an evolutionary perspective, to preserve from mortality (collision risk, in our case) both the breeding and the core range as well as the flyways, where most of such long-distance movements occur.

Usually, long-distance movements occur along the Apennines and adjacent mountain ranges, to north-west and south-east. The area subject to higher collision risk is equally large and uniformly distributed in the central-northern and southern Apennines (figure 4 and 5). On the contrary, there is a disproportionately higher number of wind energy plants in the south, representing a concrete risk for griffon vulture survival. It is therefore crucial, given the trajectories undertaken by the animals, that in the southern Apennines mitigation interventions should be realised. Furthermore, some ridgelines in the central Campania region should not receive further allocation of wind energy plants, as they represent a relatively wind plants free flyway to Basilicata and Calabria (figure 6).

Conservation implications

To minimise *a priori* the impact of renewable wind-energy plants on wildlife, a wide-scale based effort to avoid planning wind power plant sites in well-recognised priority areas for wildlife could represent a viable compromise, even though it often lacks confirmative-experimental assessments. Secondly, mitigation measures could be adopted to decrease impacts on wildlife in already settled wind plants (e.g., Tomé et al. 2017). As an effort to counter climate change and the increase of greenhouse gases emission, wind energy production is predicted to grow in the future. According to the International Energy Agency, renewable energy should contribute to 90% of total energy production by 2050 (IEA, 2021). The actual energy production from renewable sources is currently mainly due to energy production from the sun and wind (70%), with an expected increase of an order of magnitude in onshore wind energy production by 2050 (IEA, 2021; International Renewable Energy Agency, 2019). This significant growth will require a proportional adjustment of the energy distribution network, which is estimated to lead to a 5-fold increase in the current distribution network by 2050 in Europe (McKinsey & Company, 2010). Indeed, in the griffon vulture's range in the central Apennines, some wind plants are planned or undergoing authorisation procedures.

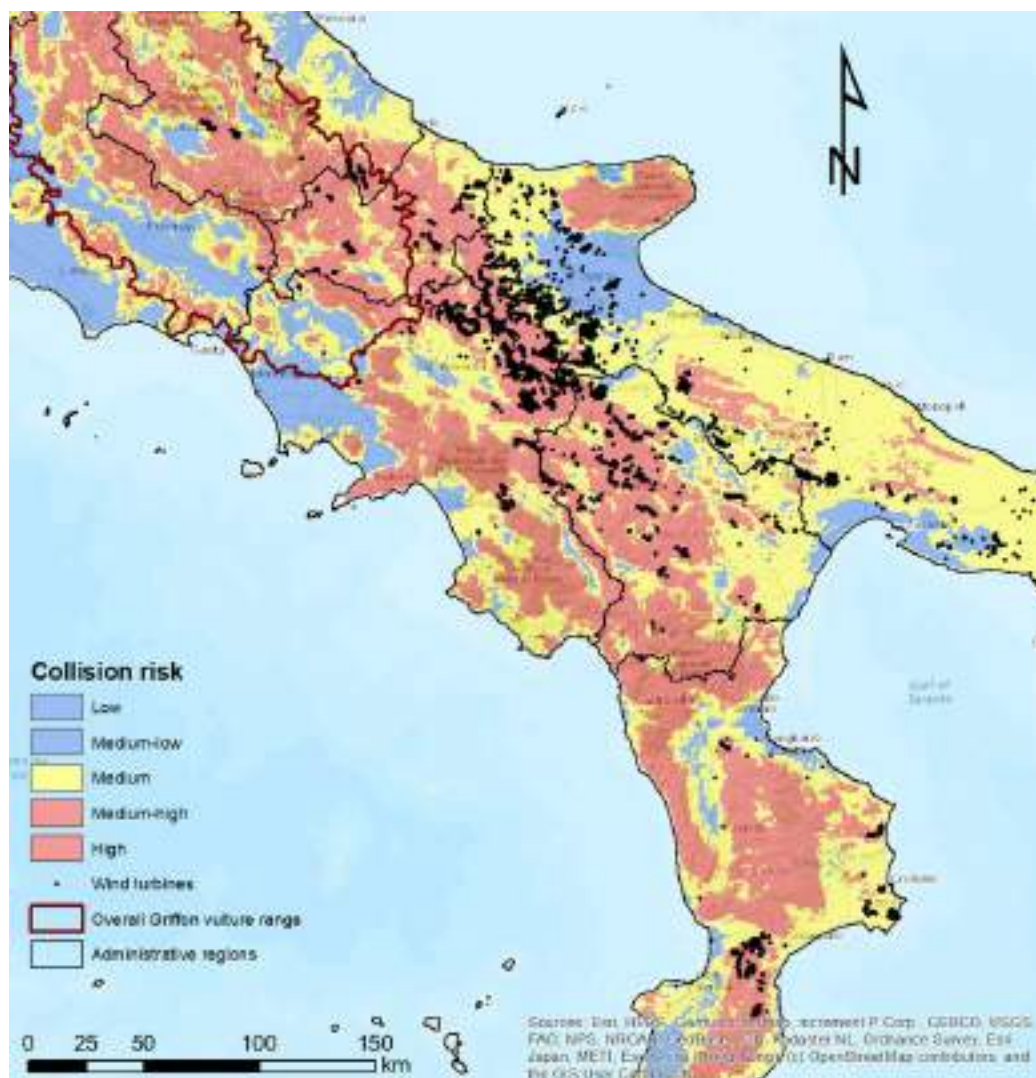


Figure 6. Collision risk for griffon vultures estimated comparing energy producibility (<https://dbeta.rse-web.it/>) and potential distribution through weighted overlay. Wind turbines (Smeraldo et al. 2020 and <https://atlanteolico.rse-web.it/>) are shown. Displacements across north-eastern Campania and bordering sectors of the Apulia region are particularly risky given the very high number of wind turbines. Preserving an alternative flyway through central Campania to the south (Basilicata and Calabria) with no further turbine encroachment is fundamental to decrease collision risk.

The needs of vultures, large-soaring birds and wind energy development greatly overlap where atmospheric conditions and terrain morphology favours the development of windy areas and thermal currents. Thus, not surprisingly, soaring birds are greatly threatened by wind turbines and the development of wind energy plants. Some soaring species, even during migrations, could show an avoidance behaviour of wind plants, which they likely perceive as an alien or unattractive landscape feature (Marques *et al.* 2020). On the contrary, it has been recently shown that griffon vultures do not show habitat avoidance when confronted with the presence of wind plants and wind turbines (Sassi et al. 2024). This makes wind plants even more dangerous for their survival with respect to other species.

Our modelling approach highlighted and ranked collision risk both with reference to energy producibility and potential occurrence, within the core range of the griffon vulture in the central Apennines. According to the outcome of the modelling approach, considering its specific aim and analytical context, we recommend the following approaches.

In the steady occurrence area, no further wind plant should be realised as they represent a concrete, real risk for population survival. Currently, it has been estimated that up to 20% of mortality for the griffon vultures could be due to collision with wind turbines. Therefore, an increase in the number of wind turbines alone could jeopardise conservation efforts and hence griffon vulture survival. Moreover, additional wind turbines will represent an undesirable risk for released cinereous vultures and bearded vultures. Through the study of griffon vultures' movement, the flying paths at an intra-home range scale should be identified, and all the paths (comprising those between roosting/nesting areas and foraging areas) should be maintained free from wind plants and power lines - the latter represents another issue when dealing with collision risk. Already existing energy infrastructures and facilities in such areas need to be urgently and adequately mitigated, and compensatory interventions must be identified and realised now. Similarly, to guarantee survival of long-distance movers, which also warrant for genetic exchange and demographic flow between populations, no wind plants should be set across the flying paths along the Apennines.

Existing wind plants, both in the steady range and along the long-distance movement paths, should be instrumented with all the necessary and effective mitigation measures. Remote sensing of approaching vultures (radar, video cameras) - or direct observation when field crew is regularly involved - should be able to trigger directly or indirectly the shutdown on demand of wind turbines. This technique has been demonstrated useful to avoid or reduce collisions and at the same time limiting significant losses in energy production (Tomé et al. 2017).

Whatever the extant griffon vulture population, or the hopefully reintroduced cinereous and bearded vultures, safe movement capability through their range and along flyways should be guaranteed. As those vultures have non strictly overlapping ecology and movement skills, planning with adequate information

should be carried out for each species. The optimal approach would be to identify potential suitable areas and potential risk areas, then avoid building energy infrastructures there. Site specific solutions could be worked out, but high quality and relevant data should be collected and available well in advance. High quality information should warrant against poor-quality, extemporaneous, and thus unsatisfactory and useless planning.

In territories adjacent to core species range and movement corridors or flyways, a specific and high-profile planning should be considered to foresee potential future risks and pose all the necessary remedies. In general, movement corridors should receive as much attention and protection as landscapes within the steady range. Wildlife dynamically interacts with the environment across temporal scales which go far beyond the reference time for infrastructures planning. Accordingly, an adaptive management strategy considering the average working life of turbines and the evolution of wildlife distribution across the concerned territories, must be considered.

There is a general tendency in the increase in the dimension of wind turbines, as to produce more energy per single turbine. Unfortunately, taller turbines would increase the interference with flying soaring raptors, intercepting a higher range of flying heights. Moreover, longer blades will require a longer time to stop their rotation when shut down is applied. In this case shutdown on demand would be less effective in avoiding collisions.

As a general advice, suitable planning should come before mitigation measures and if properly carried out it could save resources and vultures' lives. However, planning does not exclude that mitigation measures should be implemented. Independent monitoring should be carried out with aims and effort capable of meeting predefined aims.

Although the griffon vulture and the cinereous vulture share a large amount of their habitat requirements and are relatively similar as to morphology and size, there are differences in their ecology and movement characteristics that cannot be ignored. Even more pronounced differences could be found between the bearded vulture and the previous species. While restoring vultures' communities, it is a common practice to start with the more abundant, less specialised griffon vulture, which is classified as a least concern species worldwide and near-threatened in Italy (Gustin *et al.* 2021). This will also provide a useful test to assess the ability to cope with conservation-related issues. The reliability of our modelling results and management indications could be ranked high for the griffon vulture, but their transferability to the two other concerned species remains untested. Although it is reasonable to rely on the griffon vulture as an 'umbrella', at least within the current timeframe and considering the available data, every effort should be done in the future to refine modelling and landscape planning upon collection of good quality information on movement ecology and habitat selection of other reintroduced species.

Information on wind turbines and wind plants (type, location, operation, manufactures, managing company, etc.) represents public data. Wind-energy exploitation infrastructures have an impact on landscape and environmental values, which are important per se, and are also legitimately claimed by the affected (local or global) human communities. Efficient and effective landscape planning, whatever its specific goal, requires the availability of updated and accuracy-checked dataset. Datasets require continuous maintenance, updating and testing, and should be readily accessible to the general public,

researchers, stakeholders, with clear and satisfactory metadata. Presently, this is not the case with wind turbines and wind plants in Italy. Discrepancies in the number of extant wind turbines between publicly accessible data and information, and *ad hoc* efforts to retrieve actual number and position of wind turbines-plant has been clearly underscored by Smeraldo et al. (2020) and Cerri et al. (in press). In agreement with the cited authors, we stress the need to provide accurate, realistic, useful, publicly accessible information - the contrary being unacceptable - at a national and union context.

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6. Annexes

Annex I

Percent of wind turbines (Smeraldo *et al.* 2020 dataset) within five incremental classes (1 to 5) of wind speed and specific energy producibility (data from <https://dbeta.rse-web.it/>)

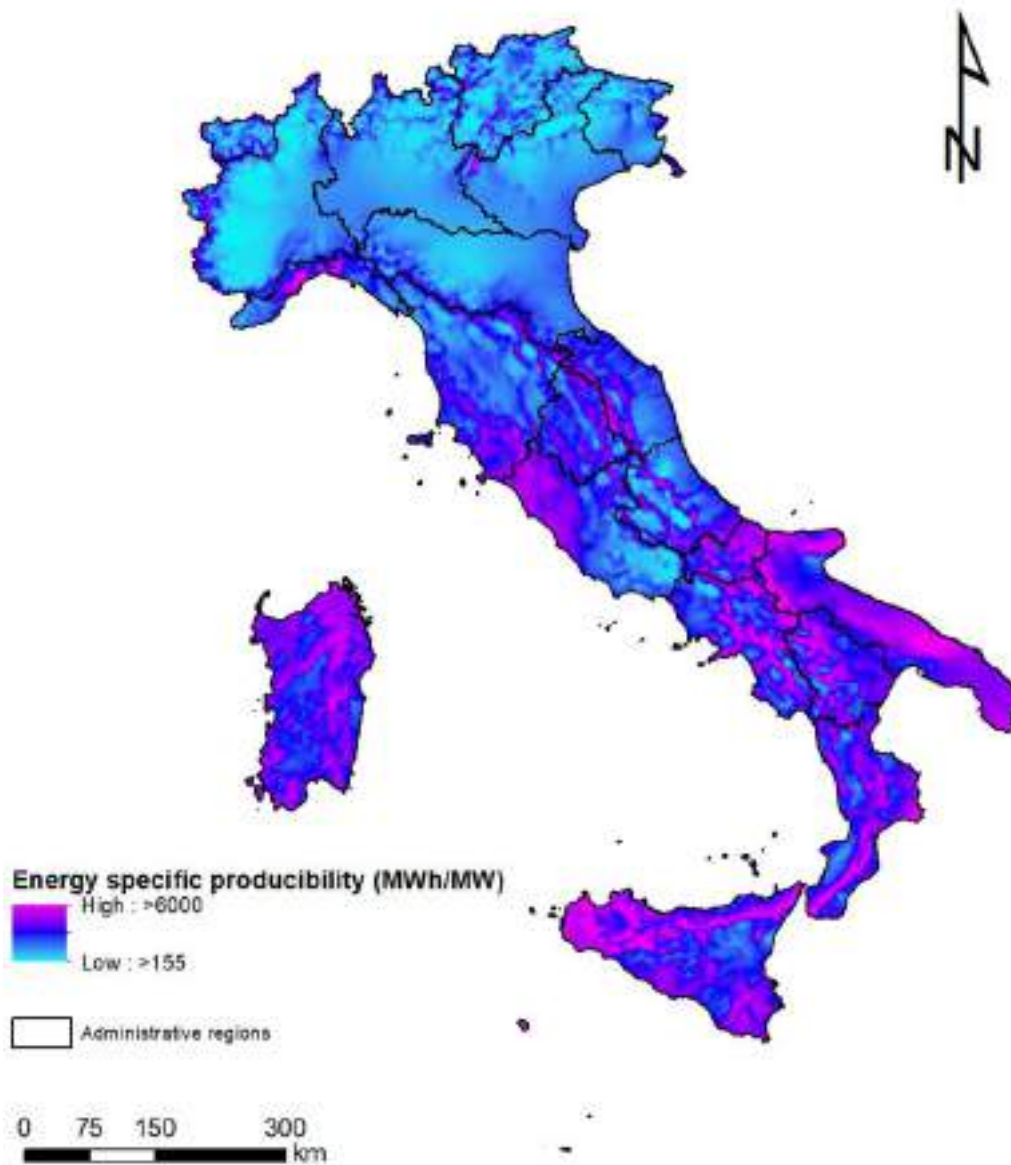
Incremental wind speed and producibility classes	Wind speed	Energy specific Producibility
1	0.22	0.06
2	1.05	0.61
3	4.81	4.95
4	25.49	20.09
5	68.43	74.29

Annex II

Estimated specific wind energy producibility by administrative regions in Italy. Producibility has been estimated discretizing the continuous layer (available at <https://dbeta.rse-web.it/>) in 5 increasing producibility classes. Medium to highest cumulative percent surface is also shown.

Regions	Low	Medium-low	Medium	Medium-high	High	≥Medium-high
Abruzzi	15.44	21.81	28.22	23.97	10.56	34.53
Apulia	0.00	1.03	5.09	25.69	68.20	93.88
Basilicata	0.31	4.40	18.54	45.53	31.22	76.75
Calabria	0.27	6.42	23.19	37.36	32.76	70.12
Campania	2.08	8.34	30.89	26.38	32.31	58.68
Emilia-Romagna	34.17	39.50	19.77	5.28	1.28	6.56
Friuli-Venezia Giulia	41.65	40.72	14.18	3.22	0.23	3.45
Latium	13.74	17.19	23.80	19.80	25.47	45.27
Liguria	3.61	23.93	34.42	21.93	16.10	38.03
Lombardy	49.56	39.67	7.83	2.22	0.72	2.94
Marche	1.96	18.70	44.71	22.32	12.32	34.63
Molise	0.80	2.44	15.49	25.44	55.82	81.26
Piedmont	56.78	23.68	11.49	5.83	2.22	8.05
Sardinia	0.00	0.49	20.98	38.18	40.34	78.52
Sicily	0.32	3.68	21.25	29.43	45.32	74.75
Trentino-Alto Adige	45.57	27.75	18.46	5.83	2.40	8.22
Tuscany	6.93	26.40	31.70	25.36	9.62	34.98
Umbria	1.90	10.42	36.26	37.32	14.10	51.42
Valle d'Aosta	28.96	29.53	24.07	11.92	5.51	17.43
Veneto	35.58	54.12	8.45	0.85	0.99	1.84

Annex III



Estimated specific wind energy producibility in Italy. Producibility is represented with continuous values (data available at <https://dbeta.rse-web.it/>).

Chapter 14

Viability analysis for cinereous and bearded vulture in the central Apennines

Mario Posillico



1. Rationale and aims

Rewilding Apennines, is carrying out a feasibility study fostering the re-establishment of a vulture community in the central Apennines, Italy, through reintroduction and possibly reinforcement.

All vulture species have been reported as breeding populations around XVI century in the northern Marche Region, with the likely exception of griffon vulture (*Gyps fulvus*), described as breeding in Cingoli municipality (Marche region, Macerata province) until the XVII century.

The griffon vulture has been reintroduced in the mid '90s early 2000s in Abruzzo Region (southern than Marche region) and currently occurs mainly in Abruzzi and Latium regions with a slowly increasing breeding population, threatened by unintentional-secondary poisoning. Only a few and sparse records of erratic, dispersing cinereous vultures (*Aegypius monachus*) exist in the central Apennines in about the last 10 years. Those birds came from reintroduction projects or breeding ranges in France and even from Spain. At least one further individual from France, not recorded in the Apennines, has been recovered in Sicily, severely affected by lead poisoning. The cinereous vulture more frequently occurs in the Italian Alps, where estivating, erratic or dispersing individuals are regularly recorded, especially in the warmer months. Occurrence of bearded vultures (*Gypaetus barbatus*) are even rarer than the cinereous vultures. Both species were breeding in Sardinia until the 1960s and 1970s then disappeared mainly because of direct human persecution. The reintroduction of the bearded vulture in the Alps has been a successful project and several breeding pairs reproduce in that area, many of them in Italy.

Population viability analysis (PVA) is a tool to analyse and project wildlife species demography for conservation purposes and simulate the effect of management scenarios or different levels of threats (or uncertainty about variables), under variable/different endogenous states and exogenous pressures (e.g., those associated to the species' habitat in general terms) (Akçakaya & Sjögren-Gulve 2000). The level of confidence of viability projections is, by no means, affected by the availability of affordable, unbiased, and appropriate species and habitat information with reference to the concerned area (Lacy 2019).

The aim of this cinereous and bearded vulture population viability analysis is to assess the minimum number of individuals which should be released in the central Apennines to establish, at least, a minimum viable population (MVP). We will refer to other reintroduction efforts to set realistic scenarios about both project length and number of vultures released, as considerations on logistics and available resources could be as important as biological and ecological issues in wildlife conservation, especially in translocations. Vultures' populations are affected worldwide by non-natural, human-caused mortality, although they play a fundamental role contributing towards ecosystem services and sustainability (Santangeli et al. 2024). Consequently, as a further aim, we will explore the effect of human caused casualties in our simulations. We will consider different frequencies of higher-than-average mortality, as well as its presumed impact (i.e., severity) on reproduction and survival rates. We defined this catastrophe (in PVA jargon) as 'excess mortality' and its frequency and severity degree resulted from Griffon vulture population data in the central Apennines.

We will rely upon reproductive parameters extrapolated from available information on vulture populations and from scientific literature as well. Necessarily, these populations occur in areas with differences in climatic conditions, food base, and in general resources abundance, access, or availability

as well as in human interference or impact. The reference values assigned to these factors will be manipulated to produce different scenarios which will be the input of PVA. This would account for both their uncertain quantification in absolute terms, and to warrant for their variation while extrapolating to our (different) circumstances. Reasonable but arbitrary carrying capacity levels (K) will account for specific scenarios, mostly to explore the effect of wide variations in carrying capacity between scenarios. PVA analyses have been carried out with Vortex (version 10.6) (Lacy & Pollak 2020).

For both the cinereous and the bearded vulture, our aim is to answer the following questions:

- A. to what extent the forecasted viability of the reintroduced species is affected by:
 1. the total number of released vultures?
 2. the release rates?
 3. the length of the release phase?
- B. What is the effect of excess mortality (catastrophes) on the predicted viability of the reintroduced cinereous and bearded vultures?

2. Settings and scenarios

2.1. Cinereous vulture

Parameters for cinereous vulture population viability analysis (PVA) (table 1) have been mainly borrowed from Dimitriou et al. 2021, which carried out a viability assessment for this species in Dardia Forest, northeastern Greece. There, a remnant cinereous vulture population has been subject to conservation actions, also aimed at providing food resources, whose shortage was deemed as one of the main reasons for its decline. Not all parameters have been explicitly stated by Dimitriou et al. 2021; thus, we also relied upon Çakmak (2018), Rousteau (2020), Ivanov (2023) and Salvador (2023) for further information. While considering the status and history of the populations from which the parameters have been drawn, it is worth to be noted that cinereous vultures in Bulgaria and France were reintroduced, while Greek and Turkish populations are native.

Cinereous vulture's range extends from the Iberian peninsula, west, through most of Eurasia to east (Salvador 2023; BirdLife International 2024a) (figure 1). Thus, a high degree of ecological and demographic plasticity, together with habitat variation, is expected and life statistics and demographic parameters relevant to PVA could change accordingly. When available, we relied on information from areas nearest to the central Apennines and to the Spanish population, whose birds would likely represent the available founders.

Based on both uncertainty and plausible variability, we considered different scenarios for **a)** carrying capacity, **b)** supplementation (in terms of the number of released birds, rate of release, length of release phase) and **c)** frequency of 'excess mortality' (increasing severity on survival was only tested for high supplementation rates). The aim with such scenarios is to identify, among those which could be realistically manipulated or managed, which parameters could exert the highest influence on population survival through an individual-based modelling. The main emphasis here is to evaluate (among realistic

options) how many vultures should be released and the rate of release (in terms of n. birds/year) to maximise the chances of population persistence and hence reintroduction success. This has been contrasted for different excess mortality and carrying capacity. We projected a viability assessment for 100 years.

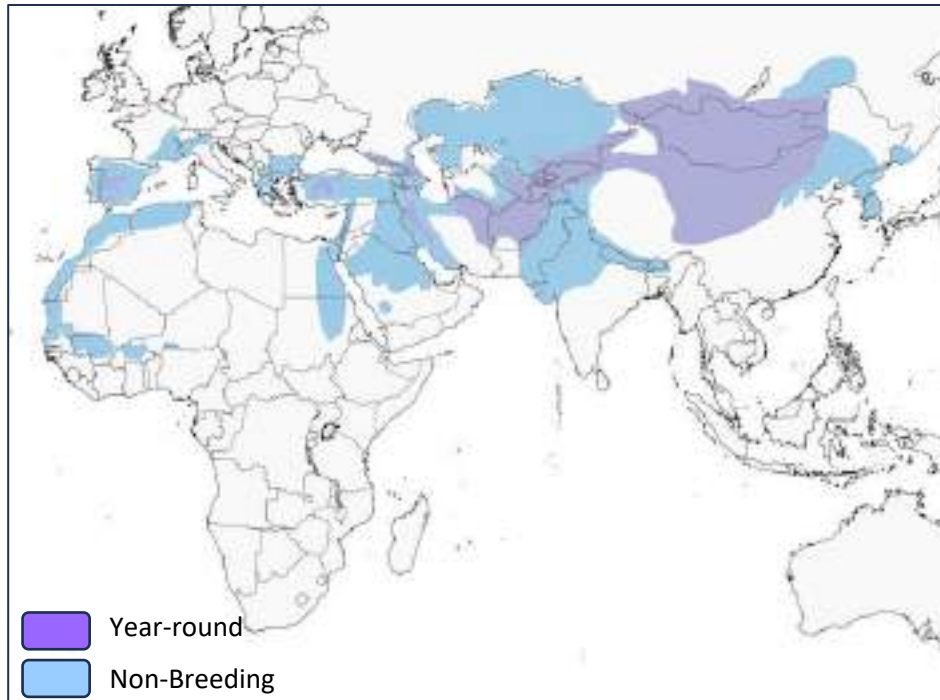


Figure 1. Range map for the cinereous vulture (*Aegypius monachus*). Source <https://birdsoftheworld.org/>

Number of founders and release rate

Along with genetic considerations, the number of available founders could represent an issue for reintroduction planning and implementation. This is especially relevant when source populations are in an unfavourable conservation status, the number of reintroduction projects for the same species is high with respect to available birds, or analogous concerns. We would expect, as a rule of thumb, that the number of released vultures, in a given time, could be related to the population viability of reintroduced birds. To be as realistic as possible, according to the apparent availability of founders and to logistics-available resources as well, we hypothesised that both the total number of released birds and the rate of release (number of birds/year) would be comparable to the projects carried out in France (Rousteau 2020, for a synopsis) and Bulgaria (Ivanov et al. 2023), from 1992 to 2022 overall. Whilst the total number of released birds in all such projects is comparable³⁴ (mean, 52; range, 41-72³⁵; standard deviation, ± 9.15), the rate of release ranged widely from 2.7 to 12.6/year (mean, 5.7; standard deviation, ± 4.7), with reintroductions in Bulgaria receiving three-times more birds/year as compared to France. On the other

³⁴ But for the Verdon area, in all considered French projects, vulture releases had stopped. For Verdon, numbers released and rates have been considered from 2005-2019 (Rousteau 2020).

³⁵ Nine juveniles were released by hacking, and all survivors established abroad.

hand, the duration of the releasing phase was longer in France (13-15 years and more) than in Bulgaria (5 years). As the two subprojects in Bulgaria were contemporaneously subject to the release of cinereous vultures, for our purposes (i.e., assessing how viability quantitatively changes according to the number of released birds) we considered them as a single reintroduction project. Letting everything else be fixed, we considered a scenario where 48 or 72 birds would be released, within 6 or 12 years (table 1). The release rate (4, 6, 8 or 12 vultures/year) and the previous figures have been drawn from Rousteau (2020) and Ivanov et al. (2023) and adapted to our circumstances, also adding a fictitious scenario foreseeing the release of 4 vultures/year within 6 years. Given results from different release methods (hacking vs. aviary) in Bulgaria (Ivanov et al. 2023), we hypothesised that vultures would be released from aviaries while in their 2nd or 3rd calendar year.

Carrying capacity

Carrying capacity (K) is not a trivial figure to be estimated with accuracy and precision. We relied on K scenarios which could be considered representative, according to Dimitriou et al. (2021) and to Çakmak (2018), for extant - though possibly threatened - populations. Furthermore, we assumed here that released cinereous vultures would broadly set in the same area where griffon vultures are located and for which we could presume that food, shelter, nesting should not be limited, as outlined in dedicated chapters in this study. Although this may not be completely true, and the feeding ecology of these species largely but not fully overlap, we are confident that our assumption represents the best available approximation at this stage.

Carrying capacity does not represent just the availability or abundance of food resources. Other resources should be considered such as the availability of nesting areas and specific nesting elements, like those particular individual trees selected for nesting by cinereous vultures. However, the quantitative evaluation of such features is well beyond the aims of such a feasibility plan. Moreover, though in a few surveyed areas (Chapter 8), nesting habitat and sites have been considered available, and, given general habitat characteristics, nesting could be usually facilitated by building *ad hoc* nest platforms. Therefore, both at the scale of general nesting habitat and at the nesting tree level, we considered nesting as a non-limiting factor, and K here is mainly intended as food abundance. In the very first reintroduction steps, food availability could be enhanced by targeted actions (*e.g.*, setting feeding stations) which are a common standard in the reintroduction of vultures.

We considered three scenarios with K set at 300, 150 and 75 cinereous vultures, which would approximately represent, as an educated guess, about 75, 38 and 20 breeding pairs, respectively. For comparison, the population size of griffon vultures in the same area has been estimated as varying from 348 (± 38 , SE) in winter 2020-2021 to 304 (± 33 , SE) birds in winter 2022-2023 (unpublished data), with a slight increase in the number of nesting pairs until 2022 breeding season. Standard deviation of carrying capacity was set at 10% of K, i.e., 30, 15 and 7.5 individuals, respectively.

Mortality, catastrophes

Wildlife populations could be subject to different kinds of events causing a significant and negative effect at the population level. These events, defined as catastrophes in PVA, affect significantly survival or reproduction, more than the usual variability in the environment or of vital-rates. Based on data on griffon vultures in the central Apennines, we included excess mortality as a catastrophe in our modelling exercise.

Similarly to the griffon vulture, we suppose it is mainly caused by secondary poisoning (Posillico et al. 2023). Excess mortality, as a crude index, is the frequency of those years when the annual number of reported dead Griffon vultures is $\geq 75^{\text{th}}$ percentile of the median annual mortality. It has been calculated that from 1995 to 2023, the griffon vulture population experienced excess mortality in 7 out of 29 years, with a 24% frequency overall (Monti et al. 2022; Posillico et al. 2023; Rewilding Apennines and Reparto Carabinieri Biodiversità Castel di Sangro, unpublished records). The occurrence of excess mortality was not evenly distributed in the time frame under scrutiny, and recurred more often from 2020 onwards (when every year was an excess mortality one), peaking in 2023. Dividing the study period in three decades (with the last decade representing 9 years) the frequency of excess mortality changed from 10% (1995-2004), to 20% (2005-2014) and 44% (2015-2023). Presently, we are not able to associate this temporal pattern to any defined, predictable, or recurrent factor, though it includes an obvious human component. Bursts of excess mortality could depend on local circumstances which are triggered by concurrent and even unrelated reasons, or could be linked to sociological aspects. Poor husbandry could be found in some periods or areas (even at farm-level) causing an increase in vulnerability of livestock to depredation, which, along with a possible – though unquantified – increase in wolves and feral dog numbers, could elicit retaliation by some farmers.

In PVA a catastrophe is parameterized according to its effect (presumed, estimated, or measured) in terms of extent (local vs. general), frequency (number of concerned years), and severity (i.e. its quantitative influence on decrease of reproduction performance and survival). Excess mortality is mainly caused by secondary poisoning here, and home range size of cinereous vultures in well studied European populations is usually one-third and even less with respect to that of griffon vultures in the central Apennines. Therefore, we hypothesised that a local effect of catastrophes would be more plausible. Based on the overall occurrence of excess mortality in the central Apennines and its variability, we set three mortality scenarios at increasing frequencies (6%, 12% and 24%). The severity of survival has been set at 0.90 (10% decrease in survival), 0.75 (25% decrease) and 0.50 (50% decrease). After exploratory PVA trials we only simulated 0.75 and 0.50 severities for 6- 12% frequencies. Severity of excess mortality on reproduction was deemed to be marginal, similarly to Dimitriou et al (2021). To estimate severity on reproduction, we regressed the number of annually reported dead griffon vultures with respect to the number of nesting pairs. In four instances (out of 25 breeding years) the number of dead vultures was higher than the corresponding estimated 95% upper confidence interval for such regression. Thus, we took such a figure ($1-(4/25)$) as an estimate of the severity of excess mortality on reproduction.

Table 1. Input parameters for the population viability analysis of the cinereous vulture (*Aegypius monachus*) in the central Apennines, Italy.

Parameters	Input settings
Number of iterations	1,000
Number of years	100
Extinction definition	1 sex remain
Environmental correlation between reproduction and survival	0.5
Reproductive system	Long-term monogamy
Age of first offspring (males and females)	5 years
Maximum age of reproduction	25 years
Maximum lifespan	26 years
Maximum broods per year	1
Maximum progeny/brood	1
Sex ratio at birth	1:1
Density-dependent reproduction	Yes
% Breeding females at low density	P(0) 66.9
% Breeding females at carrying capacity	P(K) 30.49
Allee parameter, A	0
Steepness parameter, B	4
% Males in the breeding pool	100
Standard deviation in % breeding due to EV	18
Distribution of broods per year (%)	B(0) 16.56; B(1) 83.44
Carrying capacity (K) (SD=10% _K)	300-150-75
Initial population size (N)	0
% Mortality (SD)	
<i>from age 0 to 1</i>	8 (10)
<i>from age 1 to 2</i>	30 (3)
<i>from age 2 to 3</i>	15 (3)
<i>from age 3 to 4</i>	15 (3)
<i>from age 4 to 5</i>	15 (3)
<i>from age 5 to 6</i>	15 (3)
<i>> age 6</i>	2 (3)
Catastrophes	Excess mortality
<i>Extent</i>	Local
<i>Frequency (%)</i>	6, 12, 24
<i>Severity (reproduction)</i>	0.84
<i>Severity (survival)</i>	0.90, 0.75, 0.50
Supplementation: number of released vultures/year × total duration of releases	4/year × 12 years (48)
(total number released)	6/year × 12 years (72)
	4/year × 6 years (24)
	8/year × 6 years (48)
	12/year × 6 years (72)

For both species we described the results of PVA according to:

- probability that a population will be extant at each year* P(survive);
- probability of extinction* (PE): the probability that the population becomes extinct at the end of the simulation period (expressed here also as % probability);

- c. *stochastic growth rate* $r(\text{stoch})$: the mean population growth rate experienced in the simulations, averaged across all years in which the population was extant;
- d. *number of extant vultures* $N(\text{ext})$ at the end of simulated time frame, i.e., the mean population size;
- e. *mean time to extinction* $\text{mean}(\text{TE})$: the mean time to first population extinction, out of iterations which suffered extinction.

The minimum viable population size (MVP) was represented by the minimum number of vultures released in the scenarios which resulted in a probability of extinction <1% in 100 years (or in 50 years for the Bearded vulture).

2.2. Bearded vulture

Bearded vulture population viability and demographic drivers were analysed with different approaches by several authors for both European and southern Africa population, including captive populations as well (e.g., Bustamante 1998; Bretagnolle et al. 2004; Brink et al. 2020; Krüger et al. 2022; Margalida et al. 2020; Schaub et al. 2009). In Europe a mosaic of native (e.g., Pyrenees, Corsica and Crete) and reintroduced (e.g., Alps, Andalusia) populations of bearded vultures are present. Long-term, resources-demanding, reintroduction efforts have been carried out and are currently ongoing to re-establish extirpated populations, reinforcing small-isolated contingents. The strategic goal is to link isolated present-day ranges restoring the species across its former range in Europe and establish a European Bearded vulture meta-population, with connections between the current European autochthonous isolated populations (Pyrenees, Corsica and Crete) and the reintroduced populations, in a continuum from northern Africa (Morocco) to Asia (Turkey and the Caucasus). Central to population reinforcement and reintroduction, and hence long-term viability, are the cooperative efforts coordinated by the bearded vulture captive breeding network, managed by Vulture Conservation Foundation on behalf of EAZA's European Endangered Species Programme (bearded vulture EEP). From 1986 to 2022, a total of 381 juvenile bearded vultures have been released into the wild to support local populations across many areas in south-western Europe.

Bearded vultures' range extends across some of the main mountain massifs from central Asia to western Europe, and in Africa (NW Africa, subspecies *barbatus*; NE, E and southern Africa, subspecies *meridionalis*) (Orta et al. 2020; BirdLife International 2024b) (figure 2).

In addition to general PVA concepts and variables which have been analysed and described for the cinereous vulture as well, we will describe here in detail only those features relevant to the bearded vulture.

Number of founders and release rate

As only a very limited number of captive-bred juveniles are available for the reintroduction of bearded vultures, choosing a realistic number of founders is crucial, more than for cinereous vultures. Information from the Vulture Conservation Foundation, allowed us to calculate that in the last 10 years a total of 165 captive-bred fledglings have been released into the wild in several reintroduction projects, at an average

annual rate of 16.5 juveniles/year³⁶. As the length of bearded vulture reintroduction projects depend upon the supplementation from captive breeding and its performance (in terms of number of pairs and breeding success), a coordinated investment to enlarge and optimise the captive breeding network could possibly further support, in the long-term, and facilitate the reintroduction in the central Apennines and elsewhere.



Figure 2. Range map for bearded vulture (*Gypaetus barbatus*).

Source <https://birdsoftheworld.org/bow/species/lammer1/cur/introduction#distrib>. Note: At least some release and breeding areas in Spain (e.g., Andalusia) and southern France are missing here.

Further methods to procure individuals to be released in case of bearded vulture reintroductions (*e.g.*, extracting individuals or eggs from the wild) given the conservation status of most wild populations and disagreements about usefulness (*e.g.*, Margalida et al. 2017) will not be considered at this stage.

Similarly to the viability exercise carried out for the cinereous vulture, hypothesised scenarios as to total number of released birds and the rate of release (number of released birds/year) would consider data from release projects (Annex I). We have accessed the data available from Vulture Conservation Foundation covering releases of bearded vulture from 2008 to 2022³⁷ and grouped them for general area of release (all release sites within a wider geographical region have been considered as a single area, as

³⁶ Summary reports of bearded vulture EEP from 2013 to 2021, and Breeding results EEP (2022), accessed at <https://4vultures.org/our-work/captive-breeding/bearded-vulture-EEP/> on 26/04/2024.

³⁷ Yearly data bases of the captive breeding programme, <https://4vultures.org/our-work/captive-breeding/bearded-vulture-EEP/> accessed on 26/04/2024.

those in Andalusia, or central-southern France), year (project which, for the period under scrutiny, were releasing the last birds or those just starting with translocations, were not considered to set project length), number of released juveniles and release rate (Annex I). From such data, the average annual number of bearded vultures released from 2008 to 2022 in all sites was 14.7 vultures (± 5.2 ; range 4-24), and the average number of vultures released/project/year was 2.7 (± 0.6). Overall, the average number of released vultures for each project was 1-9 birds/year. As we do not have information on the completion nor the date in which each project started, we cannot establish a reference for the duration of releases. However, excluding those at their very beginning and those which, mentioned in the dataset, presumably represented the last releases out of many more birds reintroduced previously, we hypothesised that a time-span of 15 to 20 years would represent a credible length for the reintroduction phase of a translocation project, with releases in Andalusia lasting 14 years, and ongoing. We considered scenarios in which 40, 60 or 80 (and even 30 in an extreme scenario) would be released, in 15 or 20 years, with a minimum release rate of 2, 2.67, 3 or 4 birds/year, as credible figures drawn from projects carried out in Europe (table 2).

Differently from what has been hypothesised for the cinereous vulture based on results from reintroduction in Bulgaria, juvenile bearded vultures will only be released through hacking. This will require further and careful assessment of hacking sites, where logistics, assiduous monitoring and other factors play a fundamental role. As a last remark, as genetic issues even in large and healthy reintroduced populations could remain below desirable levels, it will be important to consider genetic diversity and foster further releases to counteract such a long-term threat (Loercher et al. 2013).

Demography

Age at first reproduction has been indicated as an influential factor for the overall productivity in the bearded vulture and in general in raptors (Morandini et al. 2019). Simulations by Krüger et al. (2022) showed that decreasing the age of first reproduction from 7 to 6 years would result in around 25% increase in the number of vultures alive at the end of the simulation period. Instead, an increasing age (*i.e.*, 8 years) negatively affects the number of vultures alive. Notwithstanding 7 years is a common value for simulation of demographic trajectories in the bearded vulture, Antor et al. (2007) and Margalida et al. (2020) reported higher values for average first successful breeding (≥ 10 years) in wild and captive Bearded vultures, which we relied upon to be conservative.

Carrying capacity

Carrying capacity (K , in term of numbers of bearded vultures which could be sustained by food resources in the release area) has been set according to densities of breeding pairs in Corsica and Crete (Seguin and Bretagnolle 2010; Bretagnolle et al. 2004; Xirouchakis et al. 2001; Xirouchakis and Nikolakakis 2002). We approximately estimated the total number of bearded vultures considering a ratio of breeding adults:nonbreeding adults + immatures of 1:0.53 after Xirouchakis et al. (2001). Such a rate was estimated at 1:0.6 by Krüger et al. (2022) for bearded vultures in southern Africa, yielding a slightly smaller number of total estimated birds.

Bearded vultures occur in Corsica and Crete as native, isolated and remnant populations, in a Mediterranean montane context. In each island the bearded vulture occurs in areas smaller than the

central Apennines (inhabited range in those islands was about 40-60% of total surface, and seasonally variable).

Table 2. Input parameters for the population viability analysis of the Bearded vulture (*Gypaetus barbatus*) in the central Apennines, Italy.

Parameters	Input settings
Number of iterations	1,000
Number of years	50
Extinction definition	1 sex remain
Inbreeding depression	No
Environmental correlation between reproduction and survival	0.5
Reproductive system	Long-term monogamy
Age of first offspring (for males and females)	10 years
Maximum age of reproduction	31 years
Maximum lifespan	35 years
Maximum broods per year	1
Maximum progeny/brood	1
Sex ratio at birth	1:1
Density-dependent reproduction	No
% Males in the breeding pool	98%
Percentage of adult females breeding (%SD)	62
Standard deviation in % breeding due to EV	20
Distribution of broods per year (%)	B(0) 33; B(1) 67
Carrying capacity (K) (SD=10% _K)	130
Initial population size (N)	0
% Mortality (SD)	
<i>from age 0 to 1</i>	16.93 (15)
<i>from age 1 to 2</i>	6.57 (13)
<i>from age 2 to 3</i>	6.57 (13)
<i>from age 3 to 4</i>	6.57 (13)
<i>from age 4 to 5</i>	6.57 (13)
<i>from age 5 to 6</i>	6.57 (13)
<i>from age 6 to 7</i>	6.17 (6)
<i>> age 7</i>	6.17 (6)
Catastrophes	Excess mortality
<i>Extent</i>	Local
<i>Frequency (%)</i>	6, 12, 24
<i>Severity (reproduction)</i>	0.84
<i>Severity (survival)</i>	0.90, 0.75
	2/year × 15 years (30)
Supplementation: number of released	2.67/year × 15 years (40)
vultures/year × total duration of releases (total	2/year × 20 years (40)
number released)	3/year × 20 years (60)
	4/year × 15 years (60)
	4/year × 20 years (80)

Elevation range is comparable to the Apennines, with elevations higher than Crete (Psiloritis, 2456 m a.s.l.) and Corsica (Monte Cinto, 2,706 m a.s.l.). Both populations are decreasing or experienced a recent pronounced decrease. Corsica's bearded vultures dropped from a rather stable number of 8-10 pairs (from 1984 to 2009; Seguin and Bretagnolle 2010) to 4 breeding pairs (in 2023) (Andarelli, 2023), thus

shrinking by about 50-60% within 14 years. In Crete, although estimates are slightly more uncertain, the number of breeding pairs decreased by more than 70% from 14-16 pairs in 1992 to 4 in 2000 (Xirouchakis et al. 2001) and a total guessed number of 24 birds. Accounting for population size before their decline and range size estimated in those two islands (totalling about 9,000-10,000 km²), we could roughly and conservatively suggest that about **22-26 pairs** and a plausible total of **60-80 birds** could be theoretically expected to range in the central Apennines. There, the available mountain range overall could be estimated as extending across 19,000 km². As for Bretagnolle et al. (2004) in Corsica, to calibrate K according to the number of increasingly released birds we divided the maximum guessed total birds (80) by 0.625, setting K at 130 birds (10% SD). As results from exploratory PVA trials, we also set K at 260 for release scenarios considering the maximum foreseeable release effort (4 translocated vultures/year, and 60 or 80 released in total), to test if an increased carrying capacity would affect the population trajectories when availability of birds to translocate is at its highest capacity.

Mortality, catastrophes

We derived age-specific mortality rates from Bustamante (1998 and data therein) and Bretagnolle et al. (2004). Given some pronounced differences in reported values, likely because of different estimation methods and different populations densities and origin (reintroduced or native), we averaged reported mortality rates. We did not consider Krüger et al. (2022) mortality rates for southern Africa, as they are strikingly different in absolute terms from those in Europe, also indicating quite low survival which we have no reason to postulate *a priori*, as well as unexpectedly low survival rate for immature (>1cy) and subadult birds.

Non-natural, human-caused mortality has been suggested and shown to impair survival of bearded vultures as well (Margalida et al. 2008), mostly depending on shooting, unintentional or secondary poisoning, but also accounting a non-negligible effect of collision mostly with wires, and even saturnism. Thus, as for the cinereous vulture and coherently with the prominent role of human-caused mortality as a factor significantly affecting survival as addressed by Bustamante (1998), Krüger et al. (2022) and more generally by Botha et al. (2017), we considered excess mortality as a catastrophe in our Bearded vulture viability modelling, as for the Cinereous vulture. Cinereous vultures usually share habitat and food with the Griffon vulture, and as such the latter could be considered an acceptable proxy to model the effect of some habitat factors - like human encroachment and human-caused mortality. We caution here that this assumption may not be as straightforward as for the Bearded vulture. Resident Bearded vultures' home range size is smaller than griffon vultures' although as almost every vulture and large raptor, immatures and subadult show wider ranges or disperse across wide areas (Krüger et al. 2014; Margalida et al. 2016). Furthermore, resident Bearded vultures also display a certain territoriality. Accordingly, we hypothesised that the effects of catastrophes would be local.

3. Results

3.1. Cinereous vulture

Release effort

For all reintroduction scenarios, whatever carrying capacity, the mean probability of extinction was negligible to null in 100 years, except for the three cases representing the lowest possible translocation effort (4 vultures/years, within 6 years) (ANNEX II). Here, the probability of extinction is >1% (from 2.9% to 4.6%), and increases with decreasing K. Furthermore, in such scenarios, the percent of vultures alive at the end of the simulation period is lower with respect to others (at the same K). In both the lowest and the 48-birds translocation scenarios (at K=300), the number of vultures at the end of the simulation period failed to reach an asymptote, suggesting that vultures would need a longer time to reach and stabilise around K (figure 3a). In all translocation scenarios with K=75, after an initial population growth and a peak reached in the next 20-35 years, the number of vultures predicted to be alive decreased, slowly, but steadily (figure 3b).

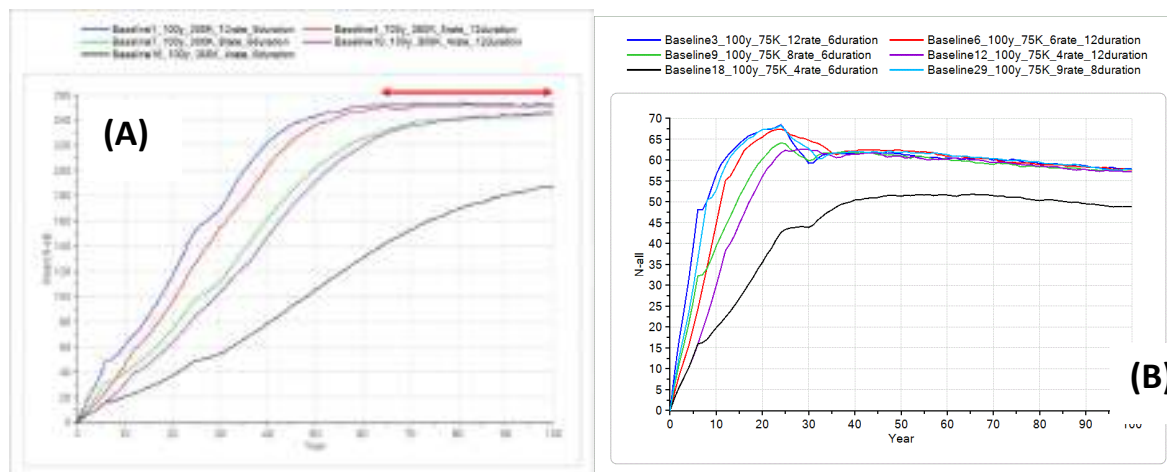


Figure 3. (A): number of cinereous vultures predicted to be alive (100 years simulation, carrying capacity = 300). There is only a marginal difference in the number of vultures alive at the end of the simulation when 48 or 72 are released, although in 48-birds scenarios (Baseline7 and 10) the population is still growing. When less birds are released (N=24) the number of vultures at the end of the simulation period is far from reaching an asymptote, thus vultures would need a longer time, if any, to stabilise around K. (B): in all translocation scenarios with the lowest carrying capacity (K=75), after population growth in the early phases the number of vultures steadily decreased.

Not surprisingly, scenarios predicting the release of 48 vultures (4 birds×12 years, 8 birds×6 years, or 12 birds×4 years) started approaching carrying capacity approximately >30-40 years later than those foreseeing a higher number of birds to be released (72) (figure 3a). Overall, for the same number of released vultures, the performances of different ‘*release rate*’ × ‘*release length*’ scenarios are comparable in terms of extant vultures at the end of the simulation time frame (figure 4), thus suggesting that - within the range of simulated values - the total number of translocated vultures weighs more on viability (and hence on reintroduction success) than the release rate or the length of translocation effort.

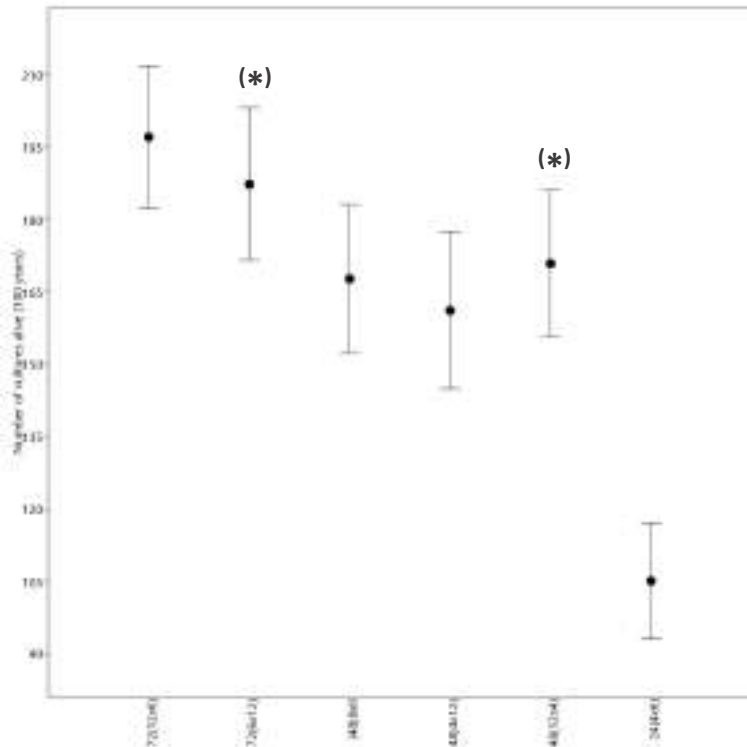


Figure 4. Mean number (\pm SE) of cinereous vultures predicted to be alive at the end of the simulation (100 years) according to translocation scenarios (X axis: total birds released for different release rate and release length settings). Paired statistical comparisons between 72-birds scenarios and 48, 24-birds scenarios were significantly different, but for (*); likewise, 48-birds scenarios significantly differed from 24-birds scenarios.

Excess mortality

Frequency of mortality. Considering the 72-birds (12-birds/year \times 6 years) translocation scenario and lowest severity on survival (0.90, i.e., 10% decrease), at $K=300$, even if the population is subject to the highest foreseen mortality frequency (24%), it still showed a positive overall growth rate. The mean probability of extinction was 3.3%, which is higher than deemed as an acceptable (though arbitrary) probability threshold (figure 5). In this case the population trajectory apparently stabilises at a size which is approximately 39% of carrying capacity (figure 5a). At decreasing ‘excess mortality’ frequencies (12% and 6%), the population is increasing at the end of the simulation, with positive growth rates (Annex II), though it did not reach an asymptote. Mean time to extinction was >100 years at 6%, 91 years at 12%, and 83 years at 24% frequency, thus consistently decreasing with increasing frequency of excess mortality. With respect to the population size in the corresponding translocation scenario, though excluding catastrophes ($N= 251.64$, $SD \pm 26.24$, Annex II), the predicted population size for increasing excess mortality frequency was 94%, 82% and 47% lower. Thus, when severity is low (0.90), an increase in the frequency of excess mortality mainly affects final population size more markedly than the probability of extinction, at least within the considered time-frame. A first tangible consequence is that, notwithstanding carrying capacity is kept high, population size seems to be depressed at an (even much) lower size and K will hardly be reached in 100 years.

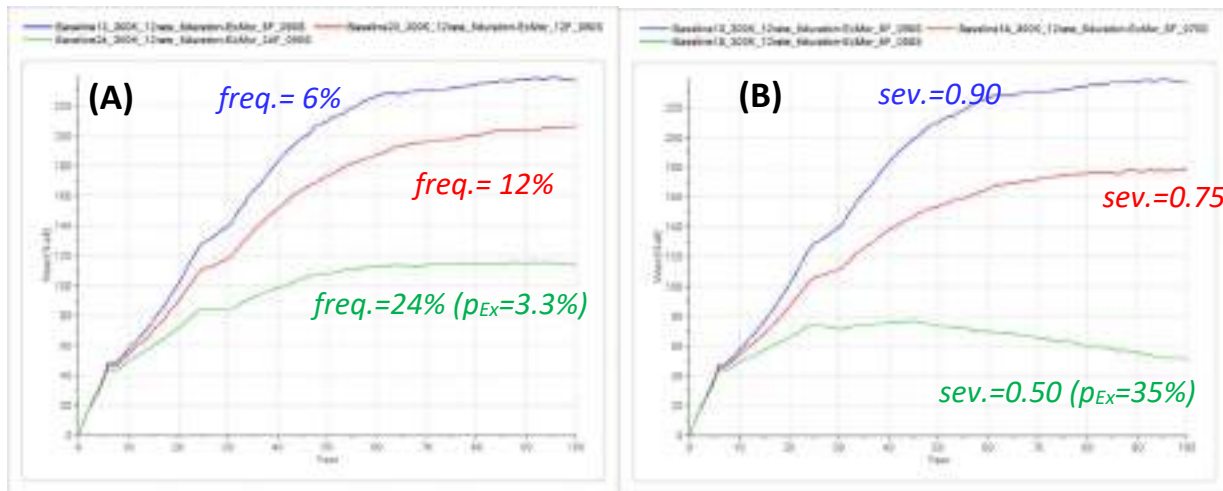


Figure 5. (A): At a fixed, low severity on survival (0.90) for a scenario foreseeing the release of 72 birds in 6 years at $K=300$, an increase in the frequency of ‘excess mortality’ significantly affects the number of vultures alive, but still yielded a slightly positive growth rate ($\lambda=1.023$). (B): For the same carrying capacity, in all translocation scenarios an increase in severity suggested a marked population decline at 0.50 with $\lambda < 1$ and a high probability of extinction (35%), with the mean time to first population extinction, out of iterations which suffered it, at 63 years.

Severity of survival. For the same translocation scenario as above, keeping catastrophe frequency at its lowest level (6%), at increasing severity (0.75 and 0.50, i.e., 25% and 50% decrease in survival, respectively), the simulations showed that the number of extant vultures was still increasing, with a positive growth rate ($\lambda=1.030$), though reaching only 72% (181.36, SD ± 72.69) of baseline scenario size (figure 5b). At the highest severity (0.50) the population trajectory started decreasing after 45 years, with a substantial percent probability of extinction (35%) and mean time to extinction estimated at 65 years (figure 5b). Its growth rate was slightly >1 until population peaked, then $\lambda = 0.982$ was consistent with a population decrease (figure 5b). The population trajectory for 0.75 severity and 12% frequency was similar to those resulting from the previous simulation at 0.50 severity and 6% frequency (Annexes II and III). Both ended with a comparable extant population size, although a highest severity (0.50) though at a lower frequency, resulted in a higher percent probability of extinction (35% vs. 18%) for 0.75 severity (Annexes II and III). All remaining scenarios, marked by an overall negative instantaneous rate of increase, predicted a high probability of extinction (from 88% to 100%), and mean time to extinction from 26 to 60 years (Annexes II and III).

Therefore, at increasing frequencies of excess mortality, population survival in the long term could still be reasonably achieved only if severity is kept acceptably low by management actions. However, at a higher catastrophe frequency, the predicted population size is substantially smaller than expected given carrying capacity or baseline scenario. Thus, it will be more susceptible to extinction through a time frame wider than that simulated.

3.2. Bearded vulture

Release effort

Only for reintroduction scenarios assuming the release of 4 vultures/year (for a total of 15 or 20 years, totalling 60 and 80 birds, respectively) and that foreseeing the translocation of 60 birds in 20 years, the mean probability of extinction was less than or equal to 1% in 50 years (Annex IV). Such an outcome suggests that 60 to 80 vultures, released within 15-20 years, should be regarded as a proxy for MVP size and hence represent the minimum number of birds to release, at the hypothesised carrying capacity ($K=130$). There was no release scenario where the number of vultures at the end of the simulation period reached an asymptote (figure 6). Even for the Bearded vulture, when the total number of released birds is the same, the performances of different *release rate* \times *release length* scenarios, in terms of predicted stochastic growth rate, and number of extant vultures at the end of the simulation time frame, are comparable (figure 6; Annex IV).

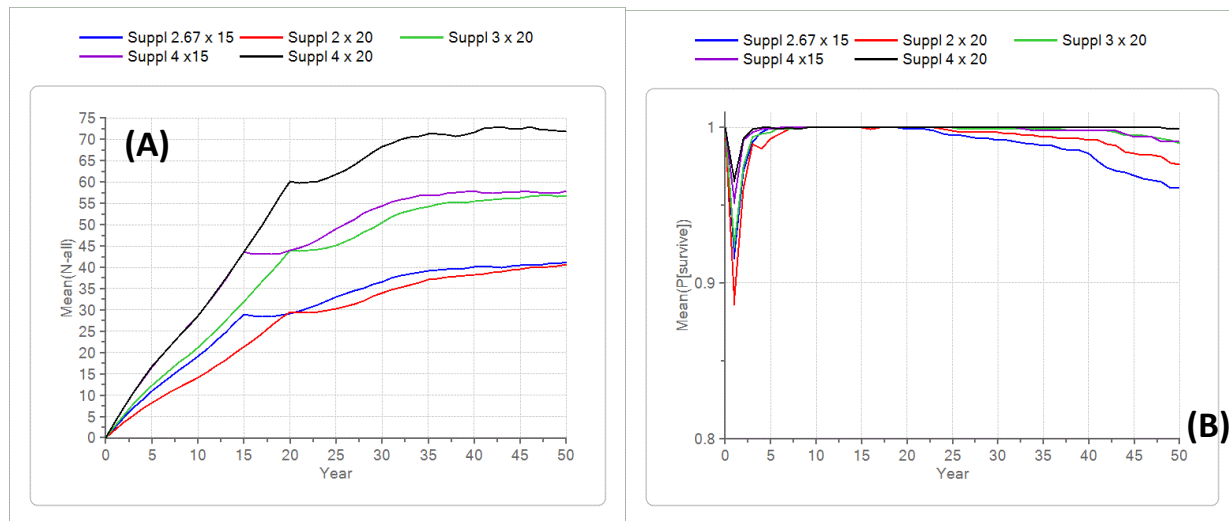


Figure 6. (A): mean number of bearded vultures predicted to be alive at the end of the simulation. None of the predicted population trajectories reached an asymptote, regardless of the number of released birds (40-60-80) and of the length of the release phase (15 or 20 years). **(B):** mean survival probability for the different release scenarios. Both survival probability (and probability of extinction) depended upon the number of released vultures, irrespectively of release length.

Doubling the carrying capacity from 130 to 260 for the *4 birds/year* \times *15 years* (60) and the *4 birds/year* \times *20 years* (80) scenarios did not yield differences in the stochastic growth rate (Friedman $\chi^2=4.34$; $p>0.1$) (figure 7a; Annex IV). The number of vultures alive at the end of the simulation changed according to the increased carrying capacity when comparing the same translocation scenarios: when K is at 260, the number of vultures is not only higher at the end of simulation time for comparable scenarios, but it is still increasing, while at $K=130$ it has apparently reached a population size asymptote (figure 7b). The probability to survive, instead, while approaching the end of simulation years, did not apparently depend upon carrying capacity as much as on the number of released vultures (Kruskal-Wallis, $H_c=47.46$; $p<0.0001$; Dunn's post-hoc, $p<0.001$ for 60 vs. 80 paired comparisons) (figure 8).

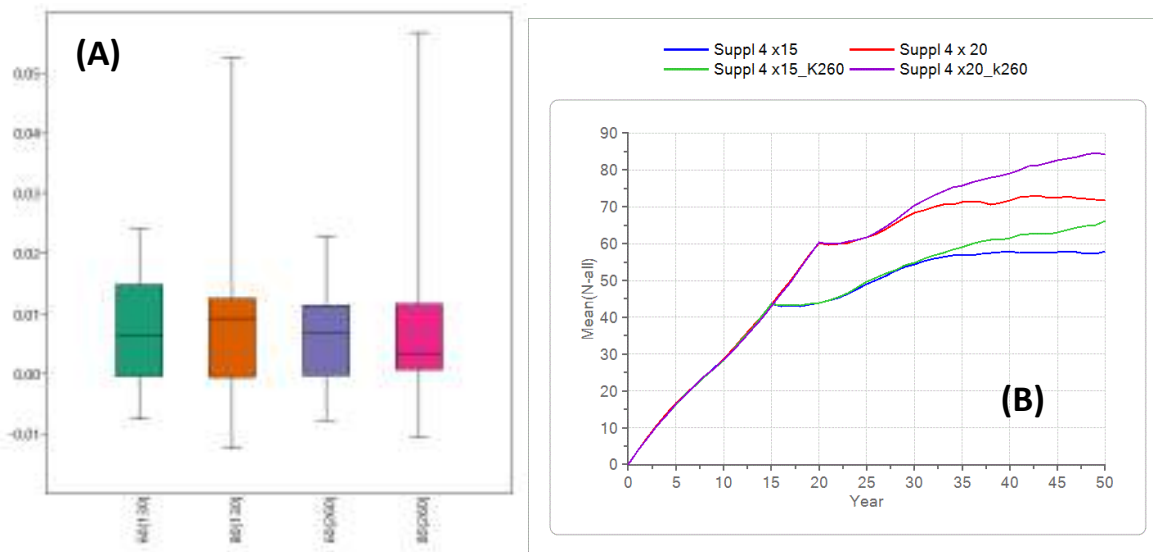


Figure 7. A: instantaneous stochastic growth rate for the translocation scenarios simulated according to the number of released birds (60 or 80) and carrying capacity ($K=130$ or 260) did not show significant differences according to both variables. **B:** mean number of bearded vultures predicted to be alive at the end of the simulation at a constant rate of 4 vultures/year, manipulating K and the total number of released vultures. Doubling the carrying capacity has a small effect on the mean number of vultures alive, and a more marked relationship with the trajectory of the population, but does not affect other estimated demographic parameters.

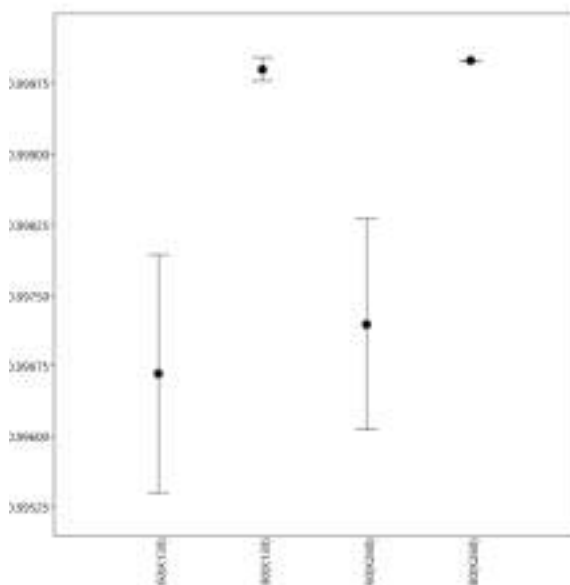


Figure 8. Mean survival probability (\pm SE) (Y-axis) estimated for the different bearded vultures' translocation scenarios (4 birds/year; 60 or 80 birds in 15 or 20 years; $K=130$ or 260) (X-axis). Independently from carrying capacity (K), the estimated survival probabilities are significantly related to the number of released vultures.

Excess mortality

Frequency of mortality. For 60-birds (4 birds/year \times 15 years) translocation scenario and lowest severity (0.90, i.e., 10% decrease in survival), at both carrying capacity levels, at all mortality frequencies, the population growth rate (both r , or λ) describes a decreasing population (Annex IV), which is also paralleled by a decrease in the number of vultures starting at about year 35 (i.e. 15 years after the last releases), after an apparent population maximum in the previous years (figure 9a). Only if mortality frequency is set at 24%, the trajectories at any carrying capacity start decreasing as early as the releasing phase ends (figure 9a). Whatever carrying capacity, when the frequency of excess mortality is $\geq 12\%$, there are no differences in the number of vultures predicted to be alive at the end of the simulation period. On the contrary, for both baseline scenarios and 6% excess mortality frequency, the number of vultures predicted to be alive is significantly different depending on carrying capacity level, with the differences being more pronounced between the baseline scenarios (figure 9a; 95% CIs are not shown for pictures' clarity). The mean probability of extinction was slightly higher than that assumed as acceptable for quantifying MVP (1%) when excess mortality is applied to the baseline scenarios, but for the highest catastrophe frequency (i.e., 24%), when it exceeds 12%, in fifty years (figure 9b; Annex IV). Only if no catastrophe is applied to the baseline scenario both growth rate and population trend show a small increase. Here, the population trajectory apparently stabilises and the number of vultures was at 44% (57.89, SD ± 32.52) of carrying capacity (figure 9a). As for the cinereous vulture, an increase in the frequency of excess mortality affects final population size whatever K. However, at higher mortality frequencies (i.e., 12%), predicted population size is not affected by K. Differently from the number of vultures alive, the extinction probabilities follow an exponential trend with respect to increasing mortality frequency.

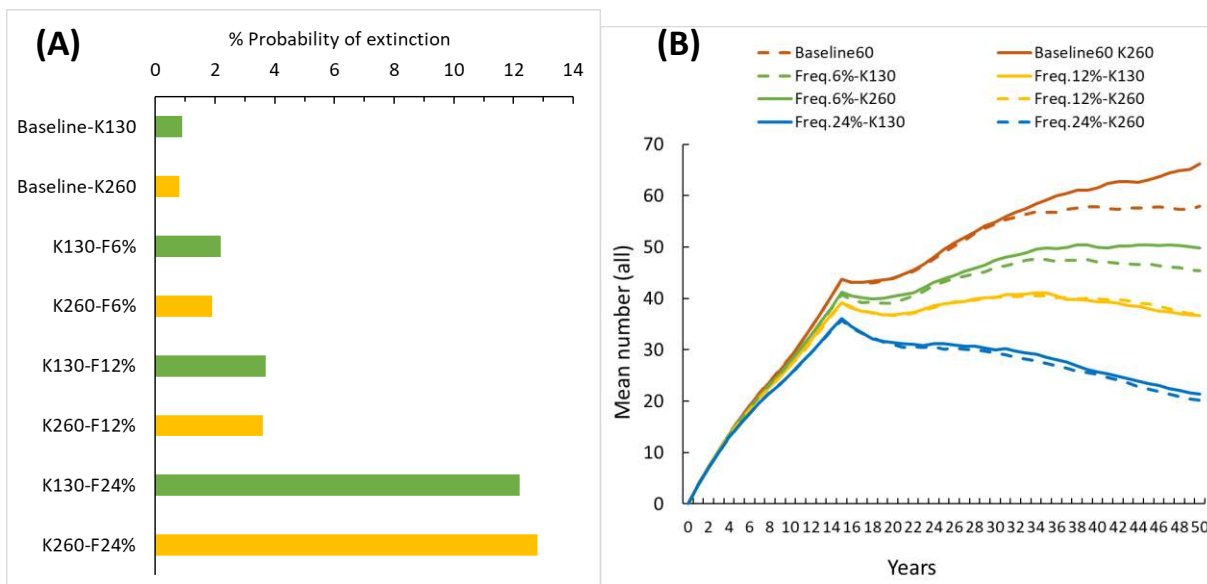


Figure 9. A: projected mean number of bearded vultures alive for a total of 60 translocated vultures by increasing occurrence of excess mortality (6%, 12% or 24%), and considering two hypothesised carrying capacity levels (K=130, dashed lines, or K=260, solid lines). **B:** % probability of extinction of translocated bearded vultures (K=130 green bars; K=260 yellow bars), as paired comparisons for the same excess mortality frequency between different carrying capacity settings. Baseline scenarios (no excess mortality) are shown for reference in both **A** and **B**.

For the scenario foreseeing the release of 80 birds (in 20 years), at low severity on survival (0.90) and for both carrying capacity settings, the population growth rate suggests a rather stable population for the two baseline scenarios, where no excess mortality is present. Whatever the frequency, all excess mortality scenarios had a growth rate indicating a decreasing population (figure 10a). This is also obvious considering the trajectory of the estimated individuals remaining after 50 years (figure 10b). Similarly to the former scenarios foreseeing the translocation of 60 vultures, when frequency of excess mortality is set to 24%, the trajectories at both carrying capacity levels start decreasing as early as the releasing phase ends (figure 10b). However, for mortality frequency equal to 12%, at the highest carrying capacity the number of individuals alive was higher than for $K=130$, which is different from the 60-vultures scenario suggesting a positive effect of the increased number of translocated birds, likely associate to increased carrying capacity (figure 10b). Indeed, even for 12% frequency in excess mortality, the number of vultures predicted to be alive is significantly different depending on carrying capacity. The mean probability of extinction was lower than for corresponding scenarios hypothesising the release of 60 vultures, and it was ≤ 1 or slightly higher even when mortality frequency is up to 12%, although a contradictory pattern emerges as the probability of extinction was higher when $K=260$ than for $K=130$ at excess mortality frequency = 12% (figure 11). This suggests that in 50 years, at low catastrophes frequency, the population still has some chances to survive, though a warning is posed by growth rates showing that a seemingly declining trajectory should not be overlooked.

Overall, considering growth rates, number of vultures alive and probability of extinction together, the 80-vultures scenarios, as far as a mortality frequency not higher than 6% is concerned, depict a more optimistic, though not definitely optimal reintroduction setup. In the baseline scenarios the population trajectory reached a number of vultures accounting for 45% (58.11, SD ± 30.93) and 32% (84.15, SD ± 53.49) of carrying capacity when $K=130$ or 260, respectively (Annexes IV, V). Thus, although reaching a higher absolute number of vultures alive, the $K=260$ scenario accounted for an even smaller fraction of the theoretical sustainable number of vultures. Given the estimated generation time for the modelled population (17-18 years), it is likely that simulating a 100 years trajectory would have shown a better performance. Even in this case, an increase in the frequency of excess mortality affects final population size at different K levels. Both in 80 as in 60 translocated-birds settings, the extinction probabilities follow an increasing exponential trend as mortality frequency rises (figure 11).

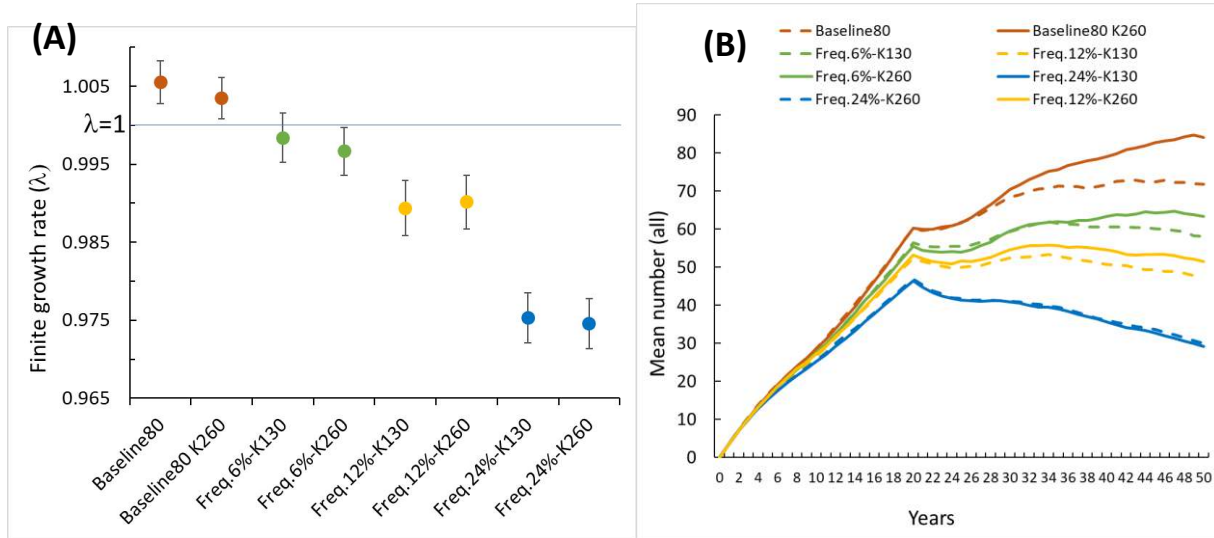


Figure 10. A: finite growth rate for the projected population in the simulation scenarios for the release of 80 vultures in 20 years at different excess mortality frequencies (green= 6%; yellow=12% and blue=24%). Only baseline scenarios (no added catastrophe, brown dots) had a finite growth rate with λ slightly >1 ($\lambda=1$ -blue line- correspond to a stable population) suggesting a rather stable to marginally increasing population. Whiskers represent 95% confidence intervals. **B:** Projected mean number of bearded vultures alive at 50 years for the same scenarios. Vultures alive decreased with increasing excess mortality frequency from 6% to 12%, although at 6% mortality for $k=260$ the decrease is not clear. The final estimated mean number was slightly more dependent on carrying capacity, as at mortality frequency =12% significantly more vultures remain alive for $k=260$ as compared to $K=130$, differently from 60-vultures translocation corresponding projection.

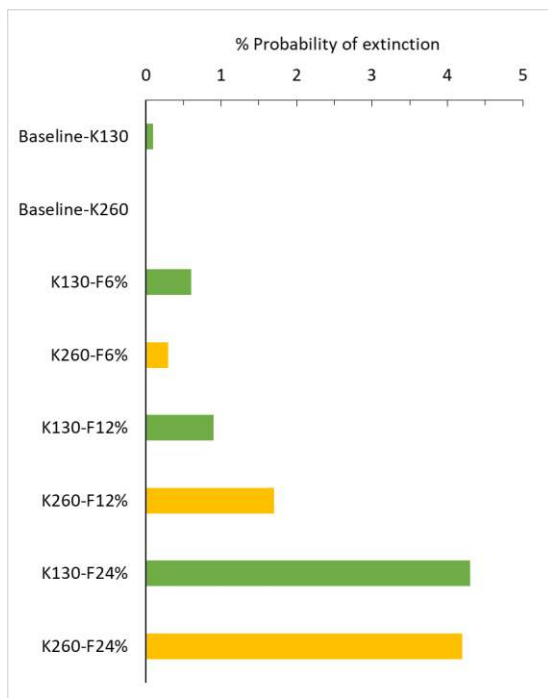


Figure 11. Percent probability of extinction of translocated bearded vultures (K=130 green bars; K=260 yellow bars), as paired comparisons for the same excess mortality frequency between different carrying capacity settings.

With excess mortality at 6%, the number of vultures alive declined by 24.7% (K=260) and 22% (K=130); increasing excess mortality at 12%, caused a pronounced decrease in the number of vultures alive for both K=260 (44%), and K=130 (37%) (figure 12a). A similar pattern was observed in case 80 vultures were released (figure 12b). Not surprisingly, we found a predictable and proportional difference in the number of vultures alive when 80 vultures were translocated instead of 60.

Severity on survival. Assuming the outcome of the previous simulations regarding the frequency of excess mortality, we further applied 0.75 severity (*i.e.*, 25% decrease in survival) to 6% and 12% mortality frequency at both carrying capacity levels. Indeed, it was obvious that a higher severity (0.50, *i.e.* a 50% decrease in survival) would have resulted in a sharp population decline, even at lower mortality frequency (Annex IV).

The simulations showed that the number of bearded vultures after 50 years was decreasing for any 0.75 severity scenario irrespective of carrying capacity or excess mortality frequency (Annex V). Excluding the baseline 60 or 80-vultures scenarios, only 6% frequency x 0.90 severity at both K=130 or 260 had a moderately increasing-to-stable number of vultures alive. Only baseline scenarios (no added catastrophe) had a finite growth rate >1 , suggesting a rather stable to marginally increasing population (figures 13a-b, brown dots), although confidence intervals for 60-birds scenario overlap with the $\lambda=1$ threshold. Scenarios hypothesising the translocation of 80 vultures had slightly higher growth rates, as far as baseline, or 6% mortality frequency and 0.90 severity on survival are concerned (figure 13). There was no apparent effect of carrying capacity on growth rate when comparing the same settings for either 60 or 80 translocated vultures (figure 13).

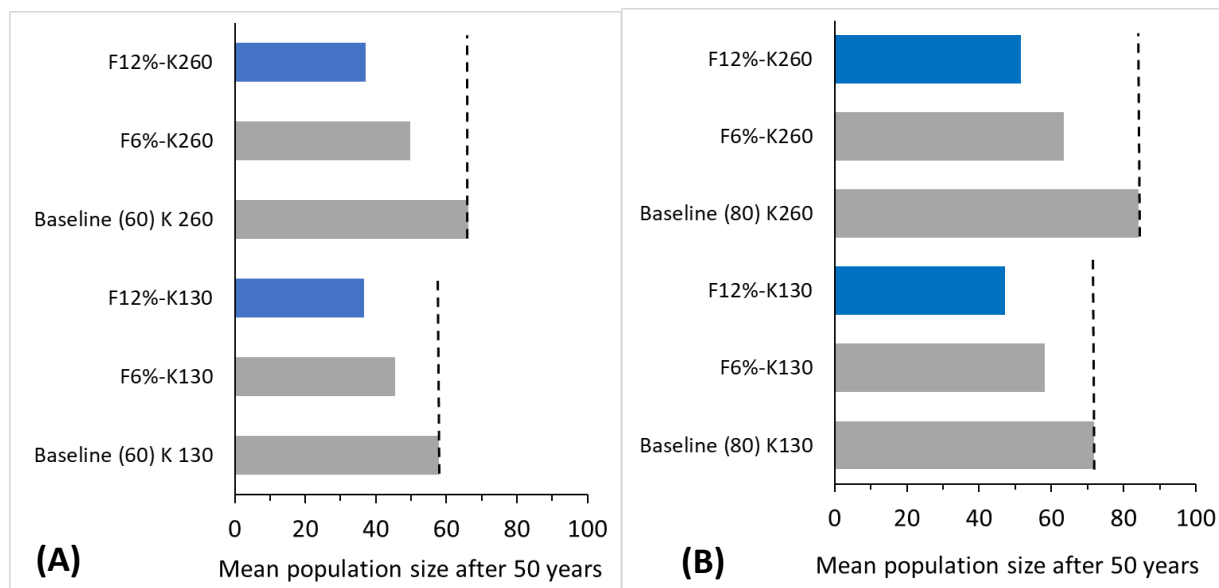


Figure 12. Mean number of bearded vultures alive according to 60 (A) or 80 (B) translocated vultures. Dashed lines represent the mean number alive for baseline scenarios at K=130 or 260. Blue bars represent a $>25\%$ decrease in the number of vultures with respect to baseline settings.

The % probability of extinction, even for the highest tested severity, was lower when the number of released vultures was higher (Annex V). Not surprisingly, the %probability of extinction at highest severity substantially increased (two to >ten-fold) when compared between scenarios at the same catastrophe frequency (Annex V). On the other hand, there was no appreciable difference in % probability of extinction comparing the same *frequency* × *severity* scenarios for increasing carrying capacity (Annex V). These results once again underscore the prevailing effect of severity and mortality frequency on projected populations performance, more than carrying capacity itself.

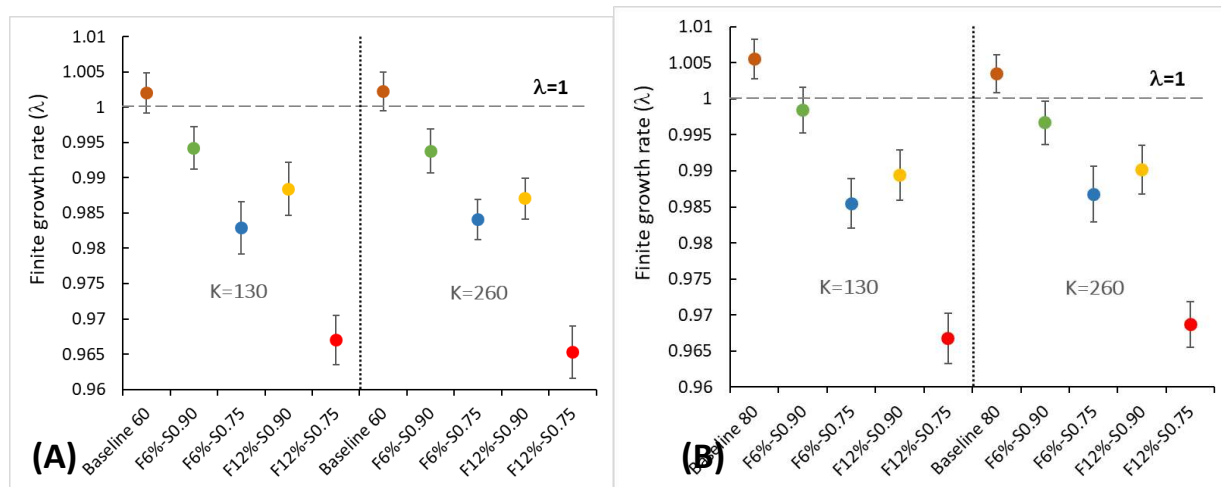


Figure 13. Finite growth rate of the projected population in the simulation scenarios for the release of 60 **(A)** and 80 **(B)** Bearded vultures, with a carrying capacity of either 130 vultures ($\pm 10\%$) (left of the vertical dotted line) or 260 vultures ($\pm 10\%$) (right of the vertical dotted line). Different combinations of frequency of excess mortality with severity on reproduction are shown (green=6%-0.90; blue=6%-0.75; yellow=12%-0.90; red=12%-0.75). Only baseline scenarios (no added catastrophe, brown dots) had a finite growth rate with λ slightly >1 ($\lambda = 1$ - horizontal, dashed line - corresponding to the finite rate of increase of a stable population) suggesting a rather stable to marginally increasing population. Whiskers represent 95% confidence intervals. Scenarios for the translocation of 80 vultures had slightly higher growth rates.

4. Discussion and conclusions

Although a useful tool, the reliability of population viability analysis relies on the precision and accuracy of the data feed to the models. These exercises are particularly useful when threatened species are concerned, but this is often the case when accurate and detailed information are scarce or heterogeneous. Moreover, when reintroductions are foreseen, available information for some species and its habitat is often projected to areas which could be characterised by different environmental conditions both in terms of vegetation, abundance availability and kind of food resources, climate and, last but not most important, human interference and attitude.

To provide conservation useful information we critically reviewed the available literature both to retrieve most convincing information on population life history and reproductive performances, and to be aware of those parameters whose uncertain assessment could greatly influence the output. When confronted with alternatives, we used to choose those providing the most conservative values, if they were in line with the general knowledge of the species under examination, or with the general demographic traits of vultures. Thus, in the case of bearded vultures, we choose a penalising but realistic year at first successful reproduction (i.e. 10 years), but we discarded age-specific mortality rates derived from South Africa, as they were based both on a limited number of dead vultures. Notably, we found no useful reference about average lifespan in the wild, nor about maximum age at which they reproduce, thus we had to rely on an educated guess drawing information from several sources. Realistically, such two last factors should not exert so much influence on results, given the time frame we modelled the population for. Indeed, although we were tempted to project bearded vulture population to 100 years, given a higher uncertainty on some reproductive parameters and on mortality rates, as well as a less straightforward applicability of severity on reproduction which was borrowed from the extant griffon vulture population, we deemed more appropriate to model this species within a more restricted period, which accounted for less than three generations. This does not exclude, in the foreseeable future, a renewed modelling effort if more robust estimations from other areas could be applied to project the viability in the central Apennines, nor a retrospective viability analysis.

As a general lesson from PVA exercises, we were confronted with some broad outcomes which could be applied to both species. First, the success of reintroduction, measured in terms of probability of extinction, number of vultures alive, and growth rate, are more closely associated to the total number of released vultures, than to the length of the releasing period (for the same numbers of translocated birds). This result has some logistical and financial implications, in that for the same number of individuals which will be translocated, the releasing phase of the project could be shortened, saving substantial resources. Nevertheless, even the shortest optimal translocation length will require a substantial commitment.

A typical problem of vultures' conservation is non-natural mortality, which we simulated as a catastrophe (excess mortality). A higher number of released vultures could more efficiently buffer excess mortality: the more birds are released the less the population is prone to extinction. Second, projections show that vultures better tolerate an increase of mortality frequency than of severity, which has a more pronounced and direct effect on survival. How these two facets of non-natural mortality and of population modelling are intercorrelated both quantitatively and functionally would represent an important research target to investigate in vultures' populations, either translocated or not. More generally, an adequate effort should be placed in sound investigation of demography of released individuals and populations. As average generation times for concerned species usually are >15 years, such an effort should extend over a coherent timespan. Once again, we stress that severity on reproduction - locally guessed based on monitoring data for the griffon vulture - would better fit for the cinereous vulture than for the bearded vulture, given the former has habits and life history which resembles relatively more those of the griffon vulture.

Third, carrying capacity in its widest sense, though we restricted its meaning to food resources, is a critical aspect in regulating wildlife populations. Evidence from the extant griffon vulture population in the central Apennines seemingly suggest food is not a limiting factor (see Chapter 15), nor for the cinereous and

bearded vultures, as far as biomass is considered. In our modelling effort carrying capacity (number of vultures $\pm 10\%$ SD) has been purposely varied and set at levels linked with the number of released birds, to test if an increase in carrying capacity, with the other parameters left the same, could be associated with better population performance. While this is generally true for the baseline scenarios (characterised by no excess mortality), when both frequency and severity of excess mortality grow, population performance only marginally benefits by an increase in carrying capacity, if any. This is illustrated by several results in this chapter, according to every index of population performance. Indeed, even when simulated trajectories are showing non decreasing populations, the number of vultures alive at the end of the simulations usually represent only 40% (cinereous vulture) or less than 60% (bearded vulture) of the theoretically achievable population size.

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6. Annexes

Annex I

Number of translocated bearded vultures from 2008 to 2022 from the EEP captive breeding network*.
Data courtesy of Vulture Conservation Foundation

(<https://4vultures.org/our-work/captive-breeding/bearded-vulture-EEP/>)

Release areas	Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Tot. released (area)
Andalusia	Spain	4	5	5		4	5	1	6	7	6	4	9	8	8	4	76
Argentera	Italy	2		2	2	2			2								10
Baronnies	France									2	2	3	2	1		2	12
Berchtesgaden	Germany														2	2	4
Calfeisental	Switzerland			3	3	2	2	1									11
Catalogna	Spain											2	2	2	3	2	11
Cevennes	France					3	2										5
Corsica	France									2	2		2		2	2	10
Grands Causses	France							1	2	2	4		5	5	5	2	26
Hohe Tauern	Austria	2	2	2	2	2		1	2	2		2					17
Melchsee-Frutt	Switzerland								3	2	2	2		2	2		13
Mercantour	France		2				2										4
Sardegna	Italy	3															3
Stelvio	Italy	2															2
Vercors	France			3	2	2	2				2		2	2	2		17
	Tot. released (year)	13	9	15	9	15	13	4	15	17	18	13	22	20	24	14	221

* Data may not be representative of the number of released vultures or of the release areas before year 2008.

Annex II

Scenario	r(stoch)	SD(r)	λ	PrExt	%PrExt	N-all	SD(N-all)	meanTE
K300_N72_(rate12_years6)	0.039	0.112	1.040	0	0	251.6	26.24	0
K150_N72_(rate12_years6)	0.033	0.114	1.034	0	0	123.4	14.13	0
K75_N72_(rate12_years6)	0.028	0.12	1.028	0	0	57.84	10.52	1
K300_N72_(rate6_years12)	0.046	0.12	1.047	0	0	250.7	25.44	1
K150_N72_(rate6_years12)	0.041	0.122	1.041	0	0	122.6	14.36	1
K75_N72_(rate6_years12)	0.035	0.128	1.036	0	0	57.6	10.44	1.1
K300_N48_(rate8_years6)	0.041	0.113	1.042	0.001	0.1	244.8	34.84	13.9
K150_N48_(rate8_years6)	0.036	0.116	1.036	0	0	121.7	15.88	1
K75_N48_(rate8_years6)	0.030	0.121	1.030	0.001	0.1	57.17	10.53	21.8
K300_N48_(rate4_years12)	0.048	0.12	1.049	0.001	0.1	246.2	31.86	1.9
K150_N48_(rate4_years12)	0.043	0.124	1.043	0	0	120.9	15.99	1.2
K75_N48_(rate4_years12)	0.037	0.129	1.037	0	0	57.14	10.74	1.1
K300_N24_(rate4_years6)	0.041	0.123	1.042	0.029	2.9	187.8	81.52	13.9
K150_N24_(rate4_years6)	0.036	0.126	1.037	0.035	3.5	100.8	36.2	14.9
K75_N24_(rate4_years6)	0.031	0.13	1.031	0.046	4.6	48.87	17.88	16.7
K300_N72_(rate9_years8)	0.042	0.115	1.043	0	0	252.1	26.13	1
K150_N72_(rate9_years8)	0.036	0.117	1.037	0	0	123.2	14.49	1
K75_N72_(rate9_years8)	0.031	0.123	1.031	0	0	57.8	10.27	1
K300_N72_(rate12_years6)_Excess_mortality_F6%_Severity0.90	0.036	0.115	1.037	0	0	236.7	35.41	0
K300_N72_(rate12_years6)_Excess_mortality_F6%_Severity0.75	0.030	0.137	1.030	0.013	1.3	179	75.04	74.5
K300_N72_(rate12_years6)_Excess_mortality_F6%_Severity0.50	0.009	0.219	1.009	0.347	34.7	51.02	70.62	64.9
K300_N72_(rate12_years6)_Excess_mortality_F6%_Severity0.25	-0.002	0.349	0.998	0.822	82.2	10.04	37.16	44.8
K300_N72_(rate12_years6)_Excess_mortality_F12%_Severity0.90	0.032	0.119	1.033	0.002	0.2	206.3	56.62	91.5
K300_N72_(rate12_years6)_Excess_mortality_F12%_Severity0.75	0.013	0.166	1.013	0.181	18.1	63.03	67.2	74
K300_N72_(rate12_years6)_Excess_mortality_F12%_Severity0.50	-0.010	0.289	0.990	0.897	89.7	3.06	16.84	50.3
K300_N72_(rate12_years6)_Excess_mortality_F12%_Severity0.25	-0.012	0.475	0.988	0.996	99.6	0.08	1.88	26

Output of cinereous vultures (*Aegypius monachus*) PVA simulations in Vortex. **K**: carrying capacity; **N**: the total number of released vultures; **rate**: the annual number of released vultures; **years**: the number of years in which vultures have been released (we assumed birds were released each year); **F**: % frequency of excess mortality events; **Severity**: effect of severity on survival (0.90= 10% decrease in survival; 0.75= 25% decrease in survival; 0.05 = 50% decrease); **r(stoch)**: stochastic growth rate and Standard Deviation; λ : finite growth rate; **PrExt**: probability of extinction; **%PrExt**: % probability of extinction (same as previous, but as percentage); **N-all**: number of remaining vultures at the end of simulation time, and Standard Deviation; **meanTE**: mean time to extinction.

Annex III

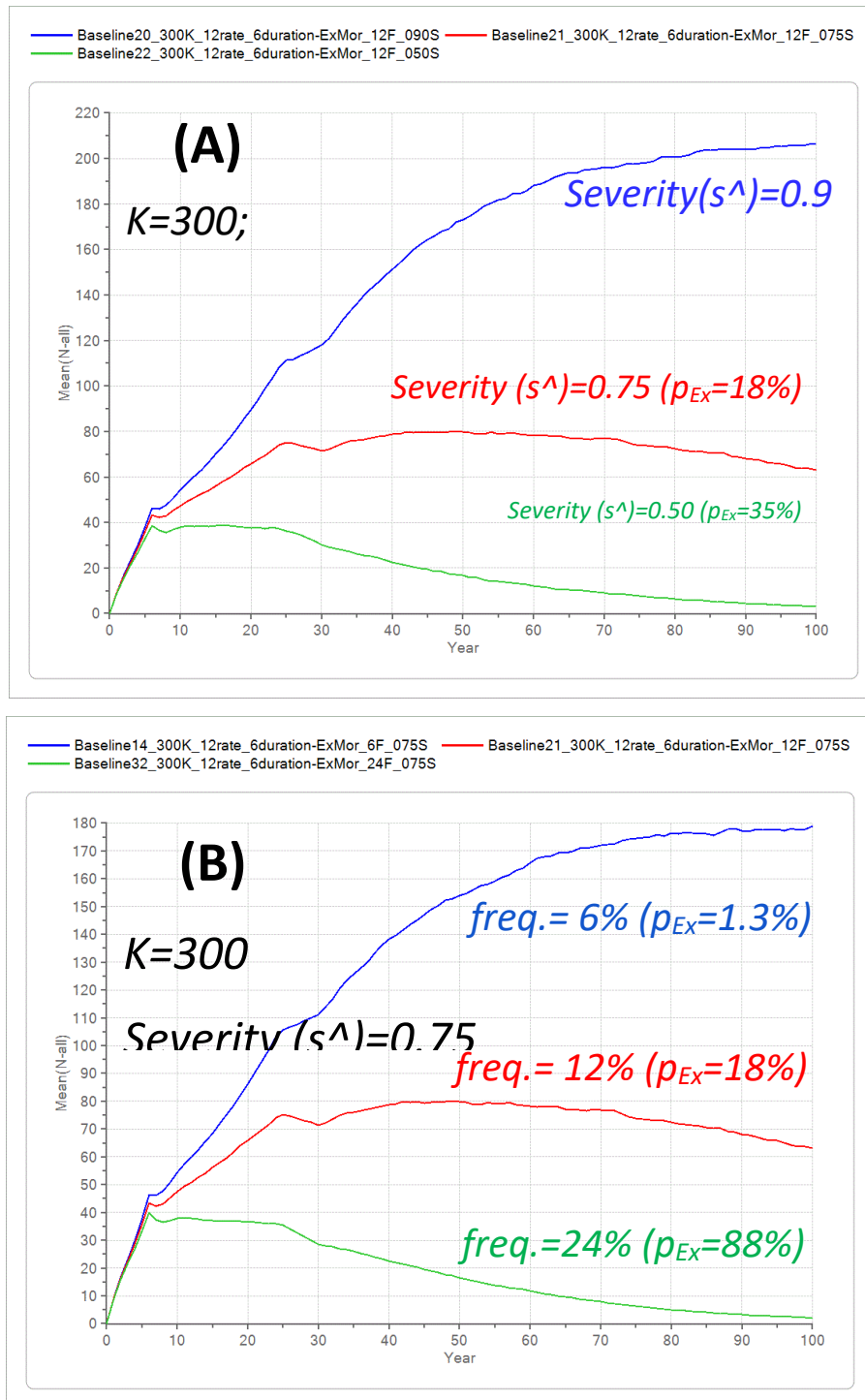


Figure A1. **(A)**: for a scenario foreseeing the release of 72 birds in 6 years at $K=300$ and fixed 12% frequency of excess mortality, a severity increase suggested a marked population decline from severity=0.75, which is characterised by a 18% probability of extinction. **(B)**: for the same baseline scenario, at a fixed 0.75 severity on survival, an increase in the frequency of ‘excess mortality’ significantly affects the number of vultures alive. Differently from a 0.90 severity, 12% frequency now suggests a declining population, while probability of extinction according to desirable minimum population size is slightly higher even at 6% frequency.

Annex IV

Scenario	stoch-r	SD(r)	λ	PrExt	%PrExt	N-all	SD(N-all)	meanTE
K130_N40_(rate2.67 x 15years)	0.053	0.189	1.055	0.039	3.9	41.28	29.3	9.3
K130_N40_(rate2 x 20years)	0.059	0.184	1.061	0.024	2.4	40.63	27.86	5.9
K130_N60_(rate3 x 20years)	0.059	0.186	1.061	0.01	1.0	56.74	32.52	5.1
K130_N60_(rate4 x 15years)	0.054	0.178	1.055	0.009	0.9	57.89	32.52	6.4
K130_N80_(rate4 x 20years)	0.061	0.174	1.062	0.001	0.1	71.84	31.69	2.6
K130_N30_(rate2 x 15years)	0.053	0.189	1.054	0.07	7.0	31.8	25.68	11.1
K260_N60_(rate4 x 15years)	0.054	0.179	1.055	0.008	0.8	66.19	49.41	7.4
K260_N80_(rate4 x 20years)	0.060	0.177	1.061	0	0.0	84.15	53.49	1.3
K130_N60_(rate4 x 15years)_Excess_mortality_F6%_Severity0.90	0.047	0.186	1.048	0.022	2.2	45.43	30.06	11
K130_N60_(rate4 x 15years)_Excess_mortality_F12%_Severity0.90	0.042	0.188	1.043	0.037	3.7	36.7	27.11	18.9
K130_N60_(rate4 x 15years)_Excess_mortality_F24%_Severity0.90	0.031	0.202	1.031	0.122	12.2	21.4	19.77	29
K260_N60_(rate4 x 15years)_Excess_mortality_F6%_Severity0.90	0.047	0.184	1.048	0.019	1.9	49.81	39.81	11.7
K260_N60_(rate4 x 15years)_Excess_mortality_F12%_Severity0.90	0.041	0.188	1.042	0.036	3.6	37.01	30.59	22.5
K260_N60_(rate4 x 15years)_Excess_mortality_F24%_Severity0.90	0.029	0.203	1.029	0.128	12.8	20.18	19.65	28.8
K130_N60_(rate4 x 15years)_Excess_mortality_F6%_Severity0.75	0.038	0.201	1.039	0.064	6.4	32.17	27.26	23.4
K130_N60_(rate4 x 15years)_Excess_mortality_F12%_Severity0.75	0.025	0.222	1.025	0.21	21.0	16.72	18.43	31.1
K260_N60_(rate4 x 15years)_Excess_mortality_F6%_Severity0.75	0.038	0.203	1.039	0.071	7.1	34.68	35.14	22
K260_N60_(rate4 x 15years)_Excess_mortality_F12%_Severity0.75	0.025	0.222	1.025	0.212	21.2	16.61	19.07	30.6
K130_N80_(rate4 x 20years)_Ecess_mortality_6%F_Severity0.90	0.055	0.181	1.056	0.006	0.6	58.11	30.93	5.4
K130_N80_(rate4 x 20years)_Ecess_mortality_12%F_Severity0.90	0.048	0.186	1.049	0.009	0.9	47.23	30.56	7.9
K130_N80_(rate4 x 20years)_Ecess_mortality_24%F_Severity0.90	0.038	0.196	1.038	0.043	4.3	29.26	22.95	18.3
K260_N80_(rate4 x 20years)_Ecess_mortality_6%F_Severity0.90	0.054	0.182	1.055	0.003	0.3	63.36	42.92	2.7
K260_N80_(rate4 x 20years)_Ecess_mortality_12%F_Severity0.90	0.049	0.185	1.051	0.017	1.7	51.58	36.84	9
K260_N80_(rate4 x 20years)_Ecess_mortality_24%F_Severity0.90	0.038	0.196	1.038	0.042	4.2	30.02	24.33	18.7
K130_N80_(rate4 x 20years)_Ecess_mortality_6%F_Severity0.75	0.045	0.197	1.046	0.019	1.9	41.59	29.43	12.8
K130_N80_(rate4 x 20years)_Ecess_mortality_12%F_Severity0.75	0.031	0.220	1.032	0.116	11.6	22.82	21.92	25.3
K260_N80_(rate4 x 20years)_Ecess_mortality_6%F_Severity0.75	0.046	0.197	1.047	0.029	2.9	46.92	38.86	18.4
K260_N80_(rate4 x 20years)_Ecess_mortality_12%F_Severity0.75	0.032	0.219	1.033	0.101	10.1	25.12	25.58	25

Output of bearded vulture (*Gypaetus barbatus*) PVA simulations in Vortex. **K**: carrying capacity; **N**: the total number of released vultures; **rate**: the annual number of released vultures; **years**: the number of years in which vultures have been released (we assumed birds were released each year); **F**: % frequency of excess mortality events; **Severity**: effect of severity on survival (0.90= 10% decrease in survival; 0.75= 25% decrease in survival; 0.05 = 50% decrease); **r(stoch)**: stochastic growth rate and Standard Deviation; **λ** : finite growth rate; **PrExt**: probability of extinction; **%PrExt**: % probability of extinction (same as previous, but as percentage); **N-all**: number of remaining vultures at the end of simulation time, and Standard Deviation; **meanTE**: mean time to extinction.

Annex V

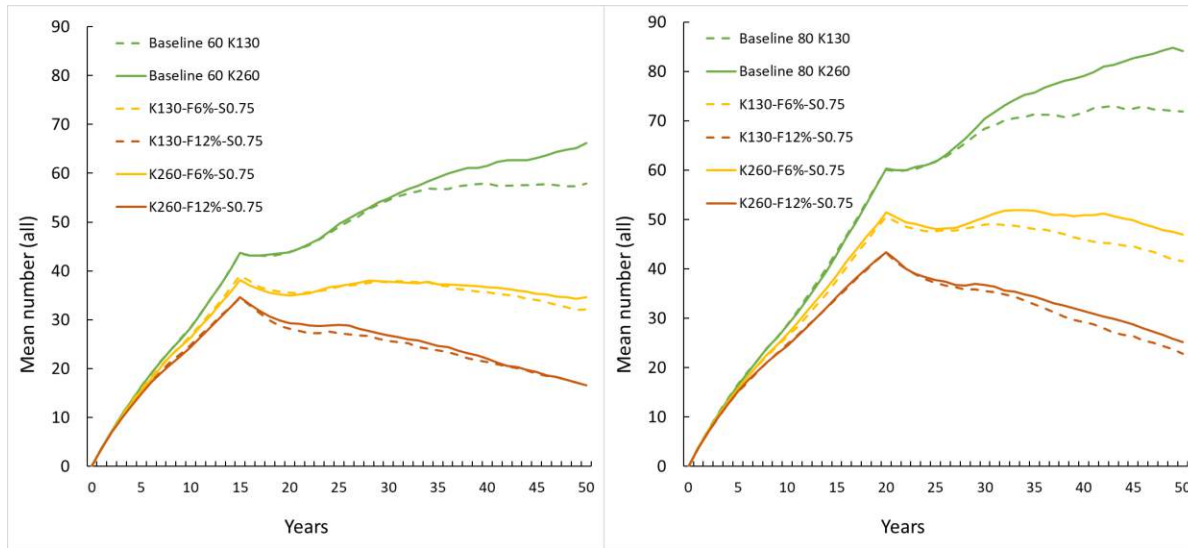


Figure A2. Estimated mean number of Bearded vultures alive after 50 years (left, 60 released; right, 80 released), according to different mortality frequencies (6% and 12%) and carrying capacity (K=130, dashed lines, or 260, solid lines), with 0.75 severity (25% decrease in survival). Results are also displayed with reference to the baseline scenarios (no catastrophe applied). Although a higher number of vultures is reached according to the number of founders, all scenarios projected a decreasing population trend, even at 6% frequency and when the highest K is hypothesised.

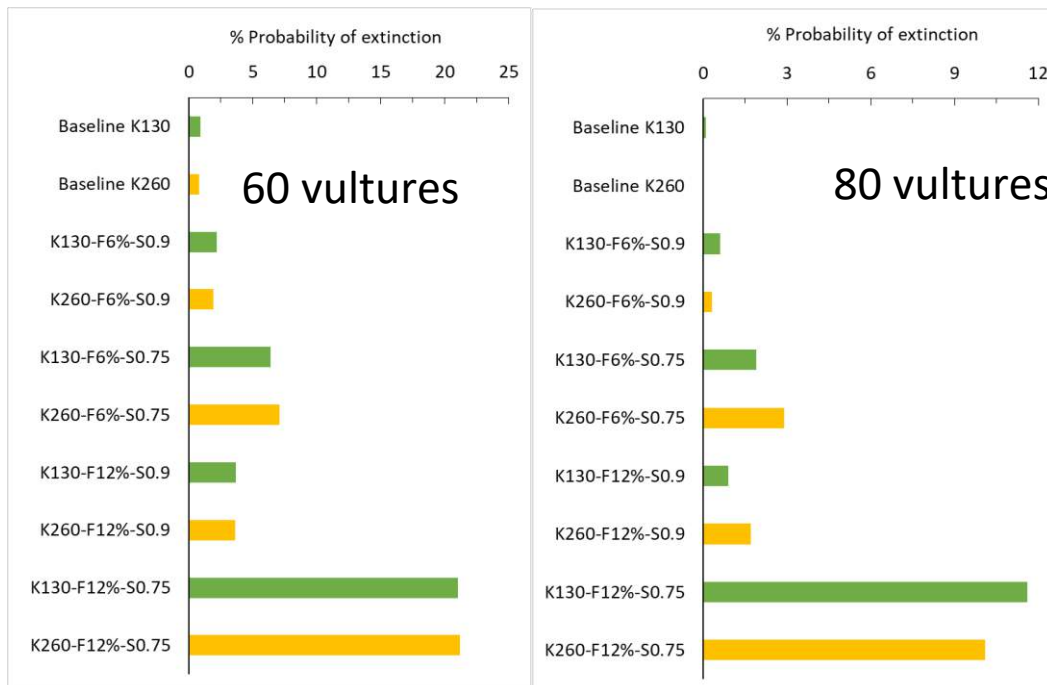


Figure A3. Percent probability of extinction of translocated Bearded vultures. Results are displayed for the baseline scenarios (60 vultures left, 80 vultures right) when no catastrophes (i.e., excess mortality) is applied for combinations of excess mortality frequency (at 6 and 12%) and increasing severity in survival (from 0.90 to 0.75, indicating a survival decrease of 10% and 25%, respectively). Bar colour according to carrying capacity: yellow=130, green=260.

Chapter 15

Carrying capacity

Nicolò Borgianni



1. Introduction

Vultures are the only terrestrial vertebrates to be considered obligate scavengers, thus feeding exclusively on dead animals, with some minor exceptions. Originally, the main food source for vultures came from wildlife carcasses, particularly ungulates. The Neolithic expansion of humans, with the birth of agriculture and the domestication of animals, had a strong impact on the distribution of populations of wild ungulates, modifying their habitats and causing the extinction of megafauna from most of the European continent (Galetti et al. 2018). This has meant that, over time, vulture species in the old-world became increasingly dependent on the presence of domestic grazing livestock as their main source of food. Currently, in the central Apennines the trophic resources exploited by the griffon vulture (*Gyps fulvus*) population mainly depend upon carcasses of domestic livestock raised extensively or semi-extensively. In particular, cattle and horses represent approximately 70% of the total carcasses found (Rewilding Apennines and Reparto Carabinieri Biodiversità Castel di Sangro, unpublished data).

Due to their evolutionary strategy, vultures are considered “K-selected species”, and their numerical consistency is mainly regulated by the “carrying capacity” of the habitat in which they live. Therefore, to estimate the carrying capacity of the area able to support a viable population of the three vulture species covered by this study, it is essential to evaluate the potential availability and distribution of carcasses of domestic livestock and wild ungulates within the study area.

In this survey, the distribution and number of domestic livestock and wild ungulates potentially available for consumption by vultures were estimated. The quantity of biomass generated by the carcasses examined was then calculated to estimate the carrying capacity of the area in terms of the number of specimens of the three vulture species covered by the feasibility study which can potentially be supported by the trophic resources present.

2. Trophic ecology of the Eurasian griffon vulture in the central Apennines

The griffon vulture was reintroduced in Abruzzi by the Forest Service (Corpo Forestale dello Stato, CFS) starting from the early 1990s (Potena et al. 2009). The last, presumably reproductive, population became extinct in the 17th or even 16th century (Avicenna 1644; Pandolfi and Zanazzo 1993) and was located in the Marche Region. Presently, the size of the breeding population is constantly and slowly increasing and there are 6 reproductive colonies located around the Fucino plain (Carabinieri Biodiversity Department, unpublished data). The range of the griffon vulture in the central Apennines extends for approximately 30,000 square kilometres, largely in the Abruzzi Apennines and in the bordering Latium Mountain ranges, from Monte Terminillo, through the Simbruini Mountains, up to the south-western ridges of the Abruzzo, Lazio and Molise National Park. From late spring to early autumn, griffon vultures usually move more widely, often reaching the Sibillini Mountains in the north and the Matese massif in the south. Thanks to

GPS tagging and other monitoring initiatives, exchanges of individuals with the closest Italian and griffon vulture populations abroad have been observed (e.g., Stoyanov et al. 2019).

From 1994 (when the first releases were carried out) to 2008, the griffon vultures were supported with food provided by a feeding station located in the Monte Velino Oriented Nature Reserve, in the “Mandridi” area which is in the municipality of Massa d’Albe (Altea et al. 2016). Subsequently, the management authorities of the reserve decided to reduce food supplementation to evaluate a possible capacity for self-sufficiency. Two feeding stations are currently active, the first located in the “Costa Grande” area, in the municipality of Magliano de’ Marsi, which has been supplied with limited quantities of food since 2009. Its main purpose is allowing continuous monitoring of the population through camera traps as well as facilitating the capture when necessary. The second feeding station is located in the municipality of Massa d’Albe, in the “Mandridi” area. It has been renovated and reactivated by Rewilding Apennines starting from February 2024, and is supplied with carcasses not intended for human consumption coming from local farms for the purpose of monitoring and food integration. The two feeding stations are approximately 800 metres apart in a straight line (see Altea et al. 2016).

The study of the trophic spectrum of the griffon vulture population of the central Apennines has been conducted using satellite telemetry since 2011. Through the analysis of the data obtained thanks to GPS devices applied to the griffon vultures, aggregates of satellite locations (clusters) are identified and then inspected to check for any carcasses. The daily check of the griffon vulture satellite tracking clusters allowed the identification of 1,759 clusters between 2021 and 2023, 1,705 of which (96.9%) were checked through inspections. Animal carcasses or remains were found in 1,269 clusters (74.4% of the total). Following the field verification of the clusters which were associated with a presumably feeding activity of the griffon vultures identified between 2021 and 2023, it was possible to determine the area used by the griffon vultures for feeding (Figure 1). The sites where the carcasses were found are distributed across 98 municipalities, mainly located near the breeding colonies, and particularly those of Monte Arunzo,

Murolungo and Magnola (Figure 2). Most of the carcasses identified were found in Abruzzi, and in the province of L'Aquila (79.9% of the total).

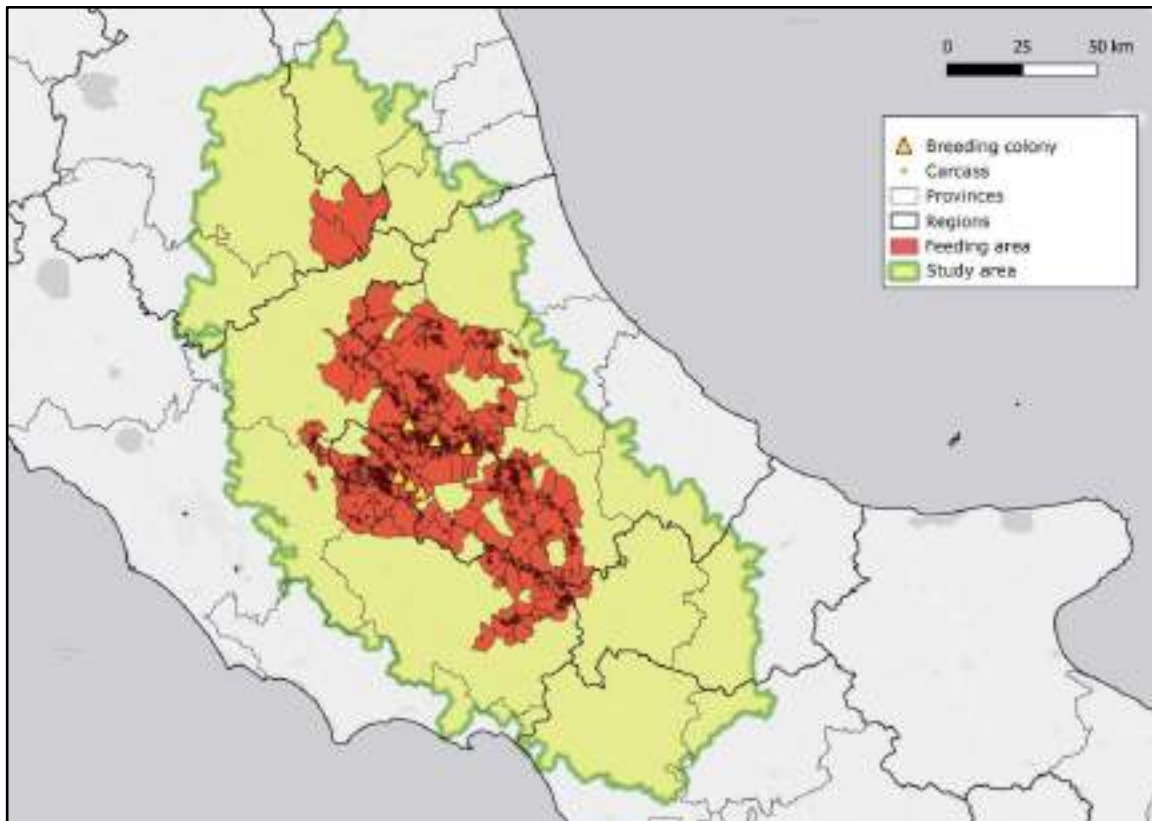


Figure 1. Griffon vulture feeding area identified on a municipal basis. The 6 breeding colonies are represented by yellow triangles and the distribution of the carcasses found through inspections of clusters of satellite locations (data 2021-2023)

Griffon vultures are central-place foragers and feed gregariously to locate carcasses. Therefore, they depend on the presence of reproductive aggregations or collective nocturnal resting sites to maximise the chances of locating carrion, which represent an unpredictable trophic resource (Harel et al. 2017).

In fact, the feeding sites found are not randomly distributed with respect to the reproductive colonies. 50% of feeding events occur within a 10 km radius of breeding colonies, while up to 90% of carrion occurs within 30-40 km (Figure 2, Posillico and Balestrieri, 2023).

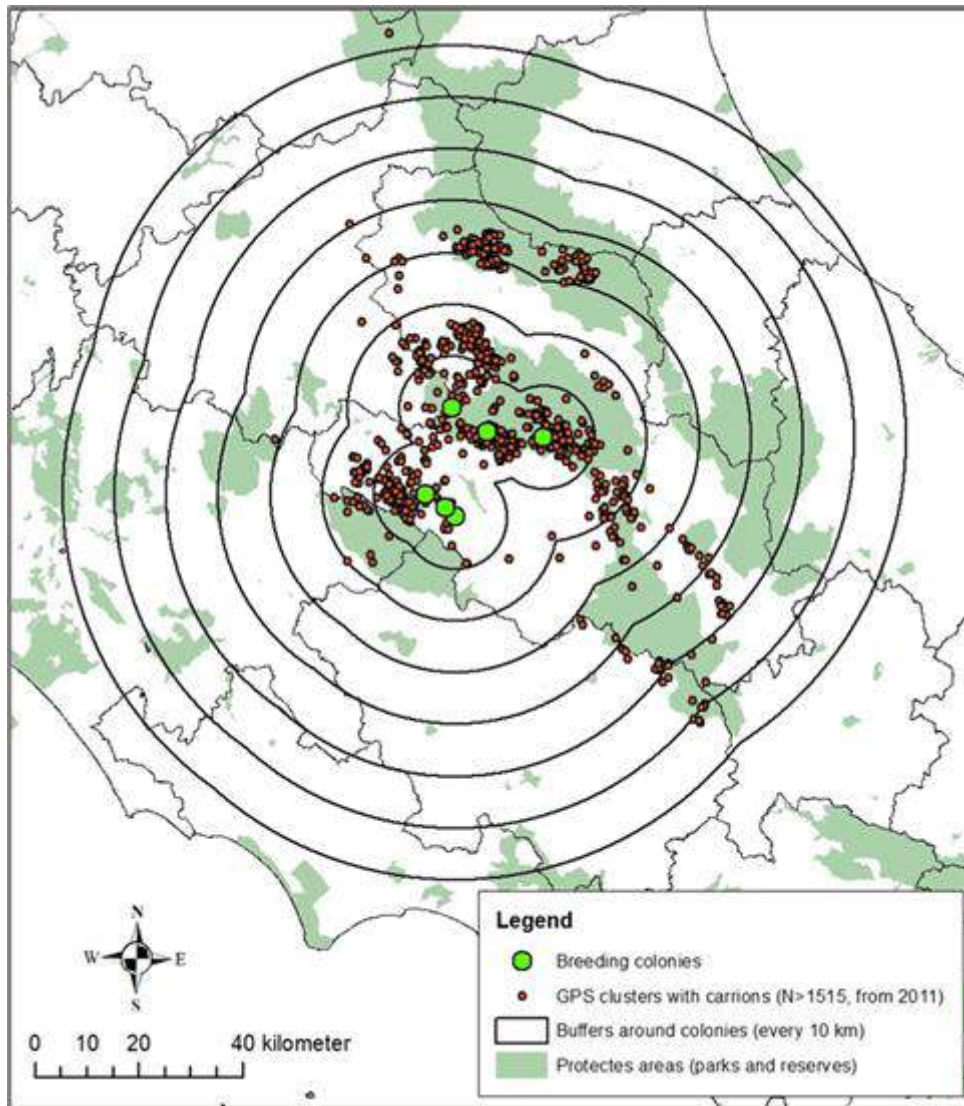


Figure 2. Distribution of feeding sites detected by GPS tracking from November 2010 to December 2021 in the central Apennines (preliminary data) within 10 km buffers built around breeding colonies. Over 75% of the carcasses are found within 20 km of the colonies (from Posillico & Balestrieri 2023).

Seasonality appears to be a determining factor for the distribution and frequency of available carcasses of livestock and wild ungulates (Figure 3). In the period between September and February, in fact, most of them are concentrated within a buffer of 20 km from Monte Velino (near the breeding colonies of Murolungo and Magnola - Figure 2). Between March and August, coinciding with the calving period for livestock and the practice of mountain pasture, there is an increase in the abundance of carcasses located in the main feeding areas (Figure 4).

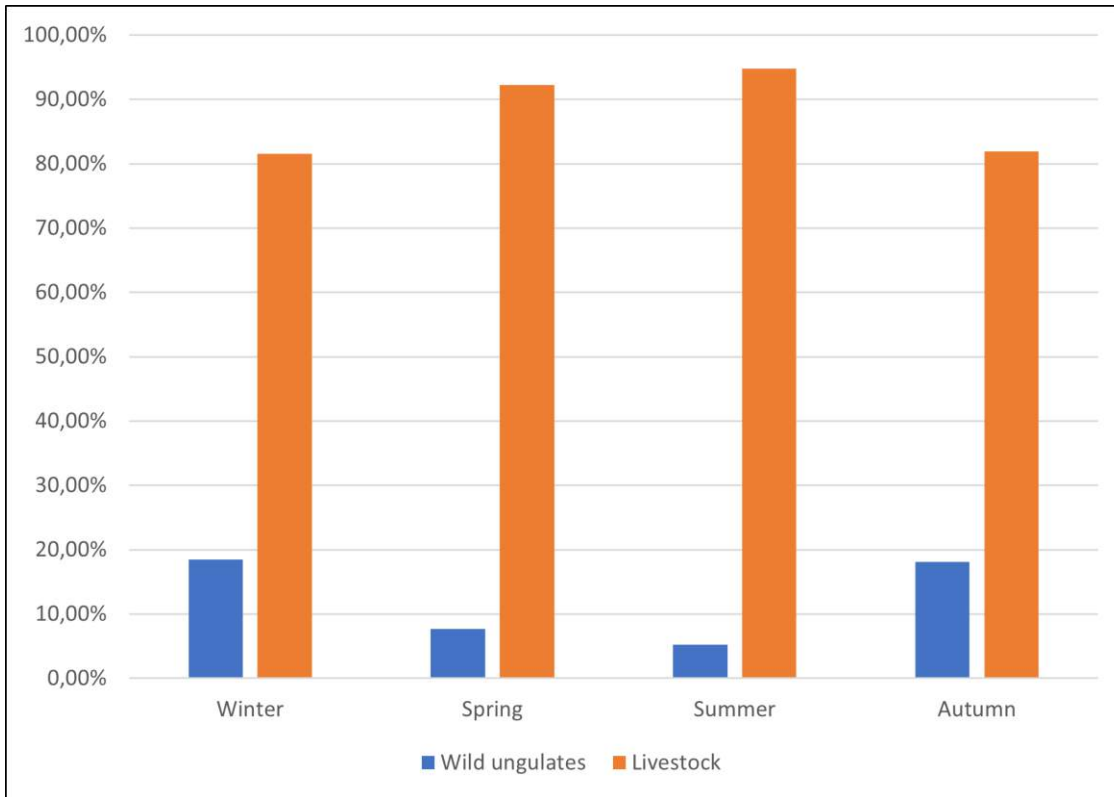


Figure 3. Seasonal distribution in the diet of the griffon vultures of livestock (cow, horse, sheep, goat) and wild ungulates (red deer, wild boar) carcasses identified in 1,269 survey sites by satellite tracking clusters of griffon vultures from 2021 to 2023 in the central Apennines area. The seasons are defined as follows: Winter (December, January, February), Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November).

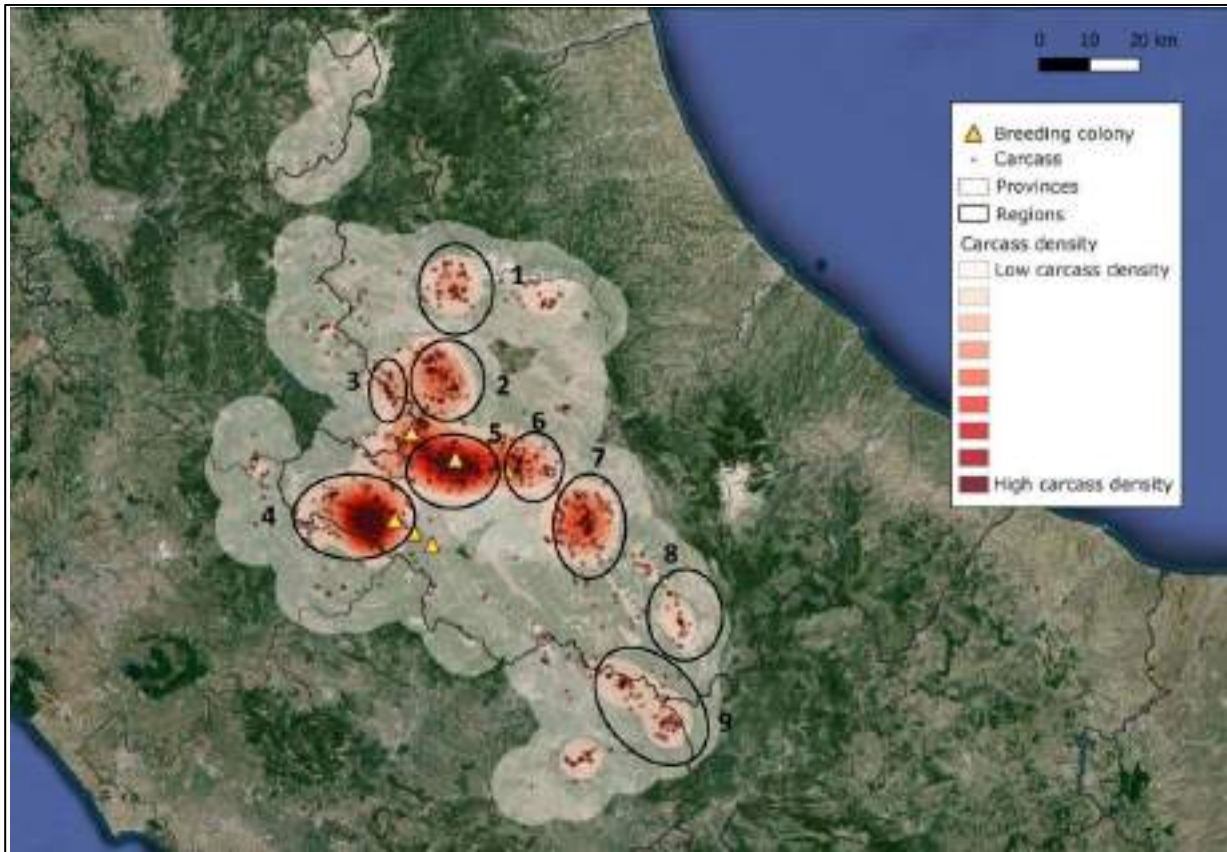


Figure 4. Map of the density (kernel density) of the clusters in which at least one carcass was present, inspected between 2021 and 2023. The ellipses indicate the areas in which the density of carcasses on which the griffon vultures fed is greater. Feeding areas: 1) Pastures north of the city of L'Aquila; 2) Monte Ocre - Monte Cagno and Monti di Bagno; 3) Monte Ruella and Monte Cava complex; 4) Valle della Dogana and Simbruini Mountains; 5) Monte Velino; 6) Mount Sirente; 7) Monte Offermo; 8) Monte Mezzana; 9) Meta Mountains

From our surveys it appears that livestock constitute the majority (around 80%) of the diet of the griffon vulture population of the central Apennines and, in particular, cattle and horses represent around 70% of the carcasses consumed (Figure 5). Such carcasses are accessible to scavenging birds of prey as they are usually difficult to be reached in order to be disposed of by incineration or burial. It should also be considered that livestock, particularly horses and cattle, are often unattended and sometimes widely scattered, allowing vultures to notice the presence of carcasses before farmers.

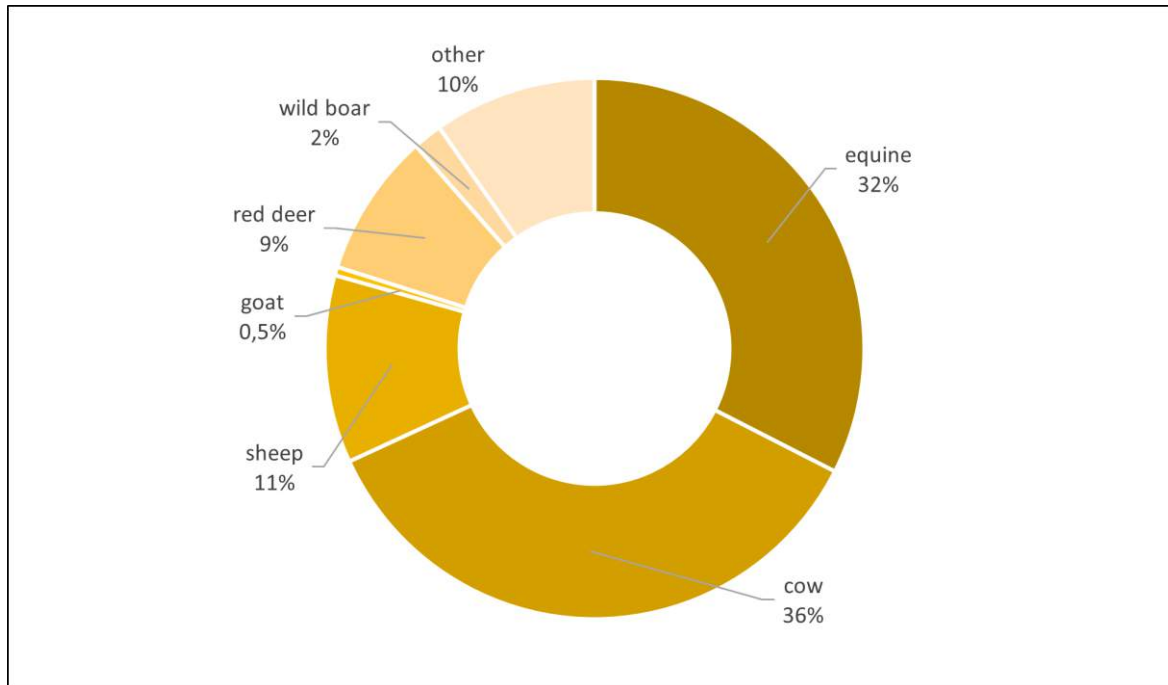


Figure 5. Distribution (%) by species or livestock category of carcasses identified in 1,269 inspection sites identified by satellite location clusters of griffon vultures from 2021 to 2023 in the central Apennines area. The "equine" category includes carcasses of horses, donkeys and mules, while the "other" category includes all species not included in the other categories (e.g., dog, wolf, chamois, etc.).

3. Study area

To identify the area in which to carry out the analysis of food availability (expressed as the biomass accessible for consumption by vultures), satellite locations of 62 Eurasian griffon vultures equipped with GPS transmitters between 2021 and 2023 were used. These transmitters came both from Rewilding Apennines (RA) and the Carabinieri Biodiversity Department Castel di Sangro (RCB) as part of the collaboration agreement for carrying out monitoring and research activities on the Eurasian griffon vulture between the two entities. Long-range movements that are occasionally carried out by predominantly young and immature individuals were filtered (Breda, 2023). From the locations obtained, it was possible to create a minimum convex polygon enclosing the locations of the griffon vultures though conservatively excluding areas where locations have not been recorded. The identified area (Figure 6) includes 6 regions (Abruzzi, Campania, Latium, Marche, Molise, Umbria), 17 provinces (Chieti, L'Aquila, Pescara, Teramo, Rome, Rieti, Latina, Frosinone, Benevento, Caserta, Campobasso, Isernia, Terni, Perugia, Fermo, Macerata, Ascoli Piceno), 628 municipalities and 78 protected areas (including 8 regional parks and 4 national parks).

The extension of the study area was also selected to consider the movements of livestock linked to seasonality in the calculation of trophic availability for vultures. In fact, in the central Apennines, the practice of mountain pasture is relatively common and, starting from the spring period, the livestock are

moved from the winter shelters in the valley towards the high-altitude pastures. In order to include the animals subject to seasonal movement in the calculation of the trophic availability for the vultures, an area was selected that included the municipalities where the livestock remain in the winter.

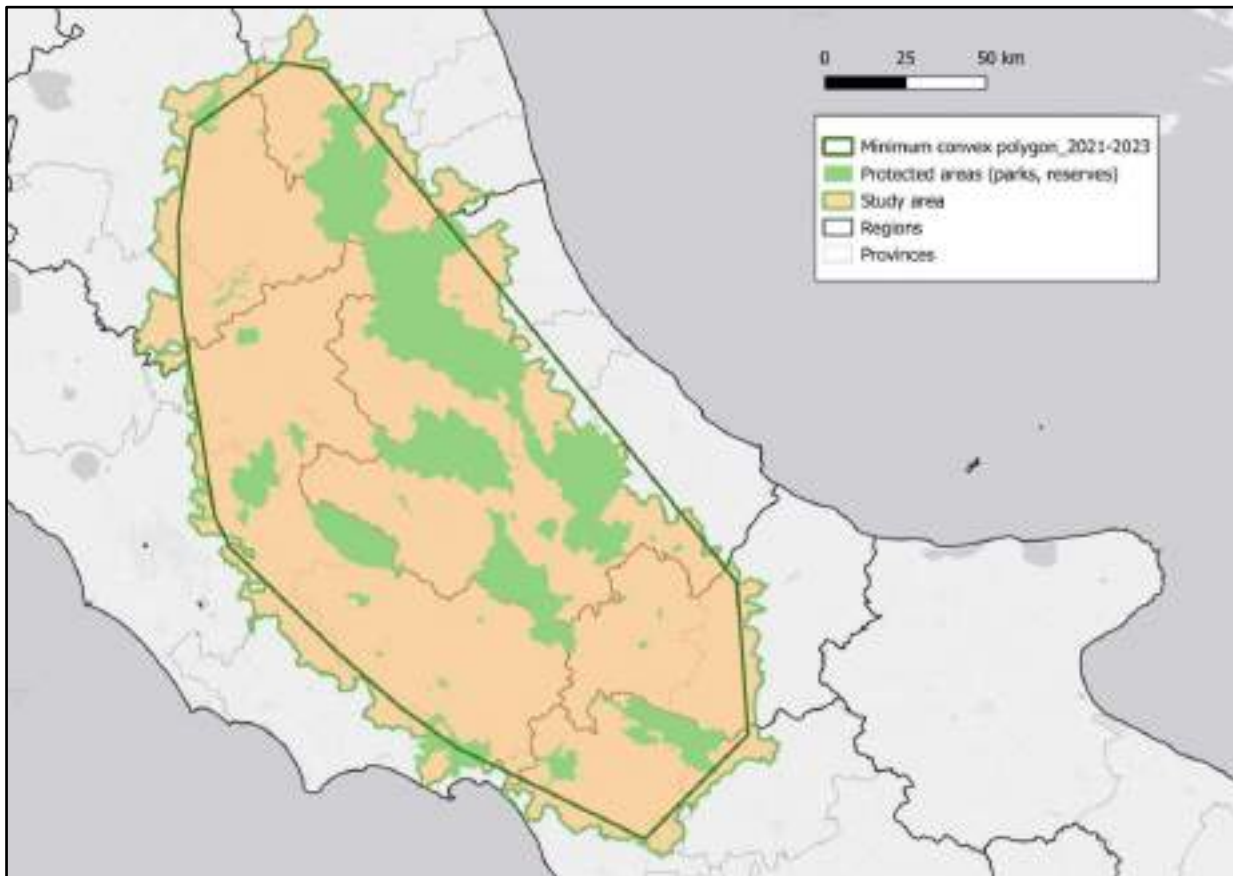


Figure 6. Area identified to assess trophic availability for vultures.

4. Carrying capacity

4.1 Livestock

In Italy the value of livestock production in 2015 was just over 16 billion euros, equal to over a third of the total agricultural production. Among zootechnical food products, meat represents more than 60% of the value of livestock production. Most of the production comes from the intensive system concentrated in some areas of the country. In fact, even if the farms are spread throughout the national territory, over two thirds of the animals are found in the four northern regions: Piedmont, Lombardy, Veneto and Emilia-Romagna. Over the years, the livestock sector has undergone profound changes with a significant decrease (drop of 41%) in the number of farms with livestock between 2000 and 2010. The number of animals has also decreased but to a lesser extent. In terms of UBA (adult bovine unit) the reduction was

6%. The different proportions of these contractions have therefore led to an increase in the average size of the company (Macrì, 2017).

In central-southern Italy, livestock production focuses on the breeding of cattle, pigs, sheep and, to a lesser extent, horses (Table 1). The farming method is predominantly intensive for the first two categories, while the majority of equine and sheep livestock production comes from extensive farming (Macrì, 2017).

Table 1. Number of animals raised for all production orientations for each category of livestock in the regions concerned by this study (2021 - 2023, data by the BDN of the Zootechnical Registry established)

Region	Cattle	Equine	Sheep	Pigs	Total by region
Abruzzi	63,105	17,719	150,164	62,444	293,433
Campania	154,246	19,890	169,747	76,119	420,003
Latium	189,661	48,958	552,916	42,097	833,633
Marche	44,018	10,994	110,720	103,265	268,998
Molise	34,446	4,364	50,283	20,675	109,767
Umbria	56,290	13,473	86,508	184,300	340,572
Total	541,766	115,399	1,120,339	488,901	-

The data regarding the livestock present in the study area and divided by municipality, province and region were downloaded from the National Zootechnical Registry Database (BDN) established by the Ministry of Health at the CSN of the "G. Caporale" Institute " of Teramo (https://www.vetinfo.it/j6_statistiche/#/). The Database includes the number of farms for each category of livestock and the number of animals, by type of production, according to the scheme in table 2.

Table 2. Production orientation of livestock categories in this study (data after BDN of the Zootechnical Registry).

Cattle	Equines	Sheep
Meat*	Meat *	Meat *
Milk	Milk	Milk *
Mixed	Equestrian/Recreational	Mixed *
	Horse Racing/Sports	Wool
	Faunal collection	Faunal collection
	Reproduction	Family

* Livestock production orientations considered in this study for the purposes of calculating the biomass available for consumption by scavenging birds of prey

While estimating carrying capacity, we considered only those livestock categories whose production orientation could actually suggest the animals grazed extensively on pastures (and were therefore available for consumption by scavenging birds of prey in case of death). In this study, data from pigs was not taken into consideration due to the regulations in force regarding actions against African swine fever

(ASF) which regulate grazing and the methods of disposal of carcasses, not making them accessible for consumption by scavengers.

Trophic availability in the study area was expressed as biomass available for consumption by vultures, calculated considering the average weight of each livestock category, the mortality rate of the species and the percentage of biomass available for vultures compared to the total biomass of the entire carcass.

The number of livestock heads of the three categories in the study area is shown in Figure 7. The calculation of the available biomass was performed starting from the number of livestock heads in the three-year period of 2021 to 2023 for cattle and sheep, and in the two-year period of 2022 to 2023 for equines. The data relating to 2021 present in BDN was incomplete.

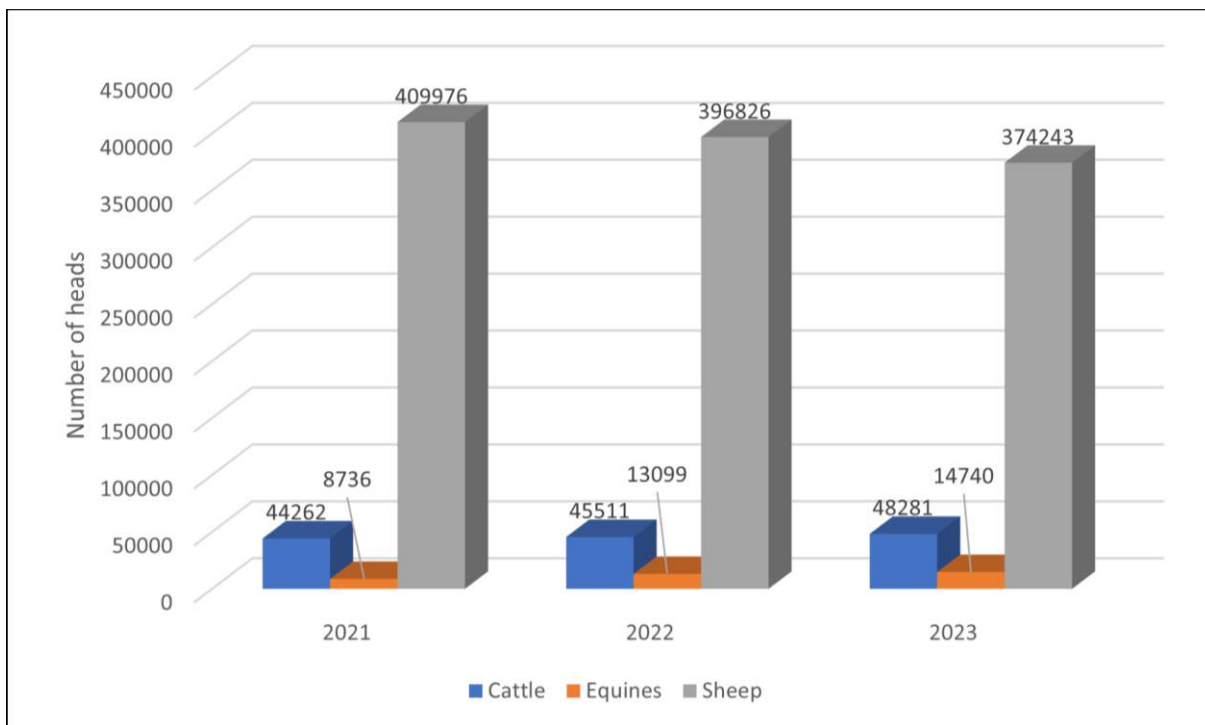


Figure 7. Number of animals bred for each category considered in the study area between 2021 and 2023 (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

4.1.1 Cattle

To calculate the number of cattle potentially available (in the event of their death) for vultures in each municipality, only those cattle with a meat production orientation moved to pasture in the three-year period (between 2021 and 2023) were taken into consideration. This was done by selecting the “heads released to pasture” option present in the BDN of the Veterinary Information System. Only the animals in the municipalities where the cattle graze, and not in those of origin, were selected in order to obtain more accurate information regarding the distribution of the animals in the areas where they are potentially accessible to scavenging birds of prey in case of death (Table 1).

Table 3. Number of grazing cattle in the provinces concerned by this study. Average and standard deviation for 2021-2023 are reported (data provided by the BDN of the Zootechnical Registry established by the Ministry of Health).

REGION	PROVINCE	2021	2022	2023	Mean	SD
Abruzzi	Chieti	1,362	1,462	1,714	1,513	181.39
	L'Aquila	17,852	20,151	21,129	19,711	1,682.29
	Pescara	622	507	464	531	81.69
	Teramo	670	772	752	731	54.05
Total		20,506	22,892	24,059	22,486	1,811.02
Latium	Frosinone	7,111	6,974	6,971	7,019	79.98
	Roma	281	203	96	193	92.88
	Latina	89	101	26	72	40.29
	Rieti	590	532	485	536	52.60
Total		8,071	7,810	7,578	7,820	246.64
Campania	Benevento	676	956	2,945	1,526	1,237.13
	Caserta	3,622	3,479	2,629	3,243	536.81
Total		4,298	4,435	5,574	4,769	700.51
Molise	Campobasso	722	846	873	814	80.53
	Isernia	5,583	4,142	5,022	4,916	726.36
Total		6,305	4,988	5,895	5,729	673.95
Umbria	Perugia	666	585	682	644	52.00
	Terni	161	104	100	122	34.12
Total		827	689	7,82	766	70.38
Marche	Ascoli Piceno	20	41	ND	31	14.85
	Fermo	141	472	470	361	190.53
	Macerata	4,094	4,184	3,923	4,067	132.58
Total		4,255	4,697	4,393	4,448	226.14
Total in the study area		44,262	45,511	48,281	46,028	2,056.91

Furthermore, for each province included in the study area, the number of animals raised according to different methods compared to those with a meat orientation raised on pasture, was calculated (in particular the following methods were considered: “breeding for meat”, “breeding for milk” and “mixed breeding”, Table 3), in order to make a comparison with the number of animals raised exclusively with meat orientation and according to “grazing” methods in the same provinces (Table 2).

Table 5. Number of animals raised with a “meat”, “dairy” and “mixed” production orientation in the provinces of the study area for each region (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the "G. Caporale" Institute of Teramo)

Region	2021	2022	2023
Abruzzi	20,664	23,089	24,165
Latium	8,732	8,345	8,323
Campania	4,605	4,810	5,938

Molise	7,244	6,002	6,565
Umbria	1,376	1,086	1,218
Marche	5,223	5,765	5,334
Total	47,844	49,097	51,543

Table 4. Number of animals raised with meat production orientation and according to grazing methods in the provinces of the study area for each region (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” of Teramo)

Region	2021	2022	2023
Abruzzi	45,792	44,542	42,988
Latium	67,527	98,579	95,152
Campania	42,252	49,420	45,565
Molise	11,221	9,738	10,170
Umbria	7,327	6,738	9,204
Marche	18,548	16,476	19,374
Total	221,175	253,880	252,557

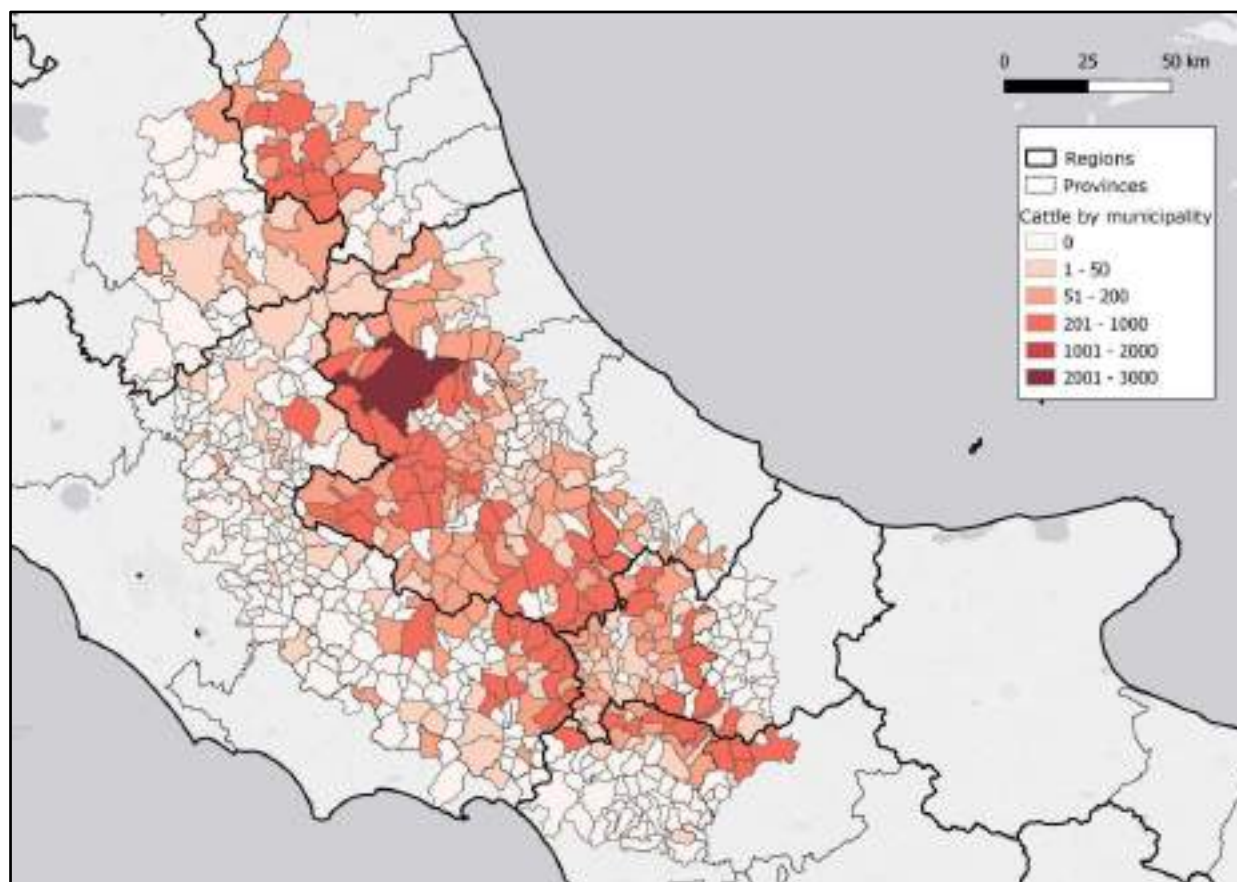


Figure 8. Distribution, on a municipal basis, of the average number of cattle grazing from 2021 to 2023. (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

Cattle in the study area are more numerous along the Apennine ridge in the provinces of L'Aquila, Macerata and Frosinone, as well as in the area that extends between Campania and Molise in the provinces of Caserta, Isernia and Benevento (Figure 8).

From the analysis of the data relating to the three-year period (2021-2023), in the moment of the year when the cattle are taken out to pasture (Figure 9), a strong seasonality emerges, whereby most of the animals (82%) are taken out to pasture between the month of May and the month of July. Considering the period in which it is possible to exercise the right to graze (usually from 15th of May to 31st of October) it is likely that the distribution over time of the trophic resources derived from cattle is not constant throughout the year but concentrated in the spring and summer months. This data is partially compatible with the results of the monitoring activities of the trophic ecology of the griffon vulture population of the central Apennines collected between 2021 and 2023, in which 32% of the cattle carcasses consumed by the griffon vultures are concentrated between the months of May and July.

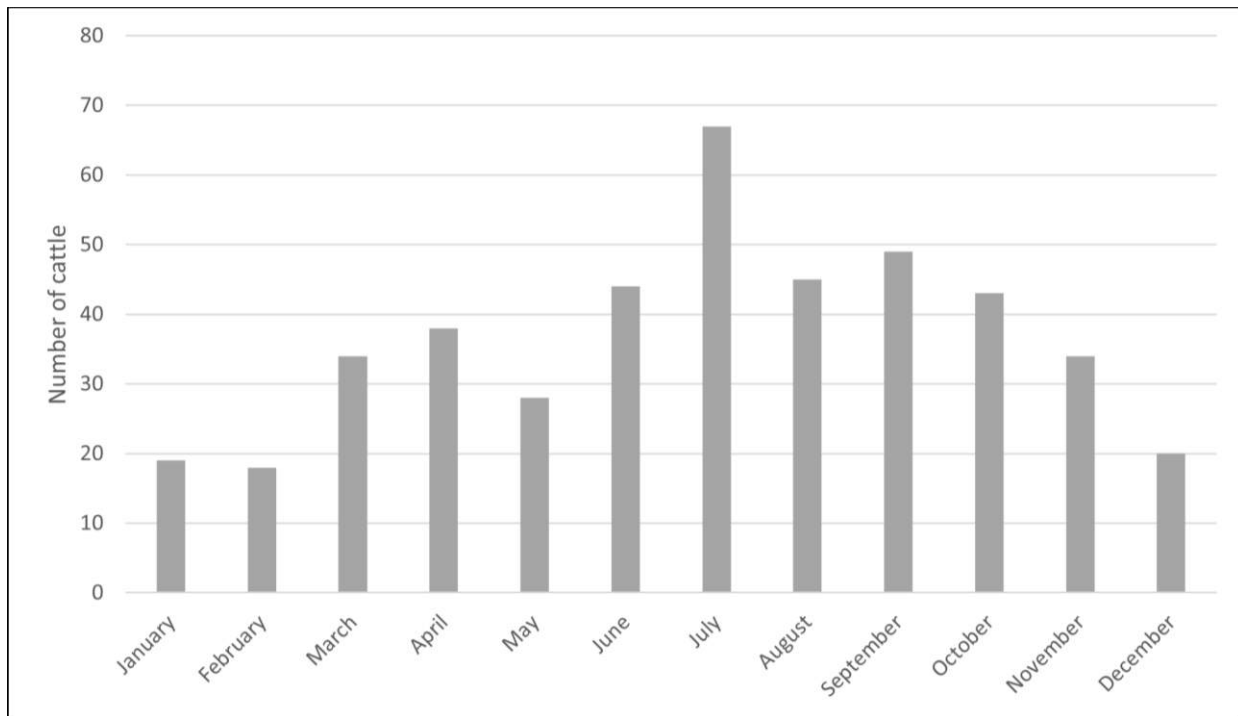


Figure 9. Number of cattle moved to pasture during the year in the three-year period of 2021 to 2023 (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

The number of cattle raised with a “meat”, “milk” and “mixed” production orientation is considerably higher than the number of cattle raised only on pasture (+ 490%). This data is of potential interest to evaluate the trophic availability for scavenging birds of prey deriving from cattle in the event that the use of supplementary feeding stations in the area is implemented in the future.

4.1.2 Equines

In calculating the number of equine animals present, horses, donkeys, mules and hinnies with a “meat” production orientation were considered. These are generally animals raised on extensive pasture and, therefore, potentially available for consumption by scavenging birds of prey in case of death (Table 4). The result probably represents an underestimation of the real availability as the data relating to equine animals bred in 2021 present in the BDN of the Veterinary Information System is incomplete. Therefore, they were not considered for the purpose of calculating the trophic availability. However, to estimate the number of equines, reference was made to the average number of animals calculated for the years 2022 and 2023.

Table 6. Number of equines in the study area. Totals, average and standard deviation for 2022 and 2023 are reported (data provided by the BDN of the Zootechnical Registry established by the Ministry of Health).

REGION	PROVINCE	2022	2023	Mean	SD
Abruzzi	Chieti	5	8	7	2,12
	L'Aquila	3,350	3,592	3,486	171.12
	Pescara	79	152	117	51.62
	Teramo	87	122	106	24.75
Total		3,521	3,874	3,716	249.61
Latium	Frosinone	2,145	2,472	2,322	231.22
	Roma	1,253	1,359	1,313	74.95
	Latina	409	451	432	29.70
	Rieti	1,813	1,931	1,881	83.44
Total		5,620	6,213	5,948	419.31
Campania	Benevento	161	184	174	16.26
	Caserta	584	592	593	5.66
Total		745	776	767	21.92
Molise	Campobasso	110	143	129	23.33
	Isernia	1,086	1,205	1,153	84.15
Total		1,196	1,348	1,282	107.48
Umbria	Perugia	1,424	1,654	1,544	162.63
	Terni	188	170	181	12.73
Total		1,612	1,824	1,725	149.91
Marche	Ascoli Piceno	103	218	162	81.32
	Fermo	46	47	47	0.71
	Macerata	256	440	350	130.11
Total		405	705	559	212.13
Total in the study area		13,099	14,740	13,919	1,160.36

The equine animals bred with a “meat” production orientation in the period considered are mainly distributed between the provinces of L'Aquila, Frosinone, Rieti, and Perugia (Figure 10).

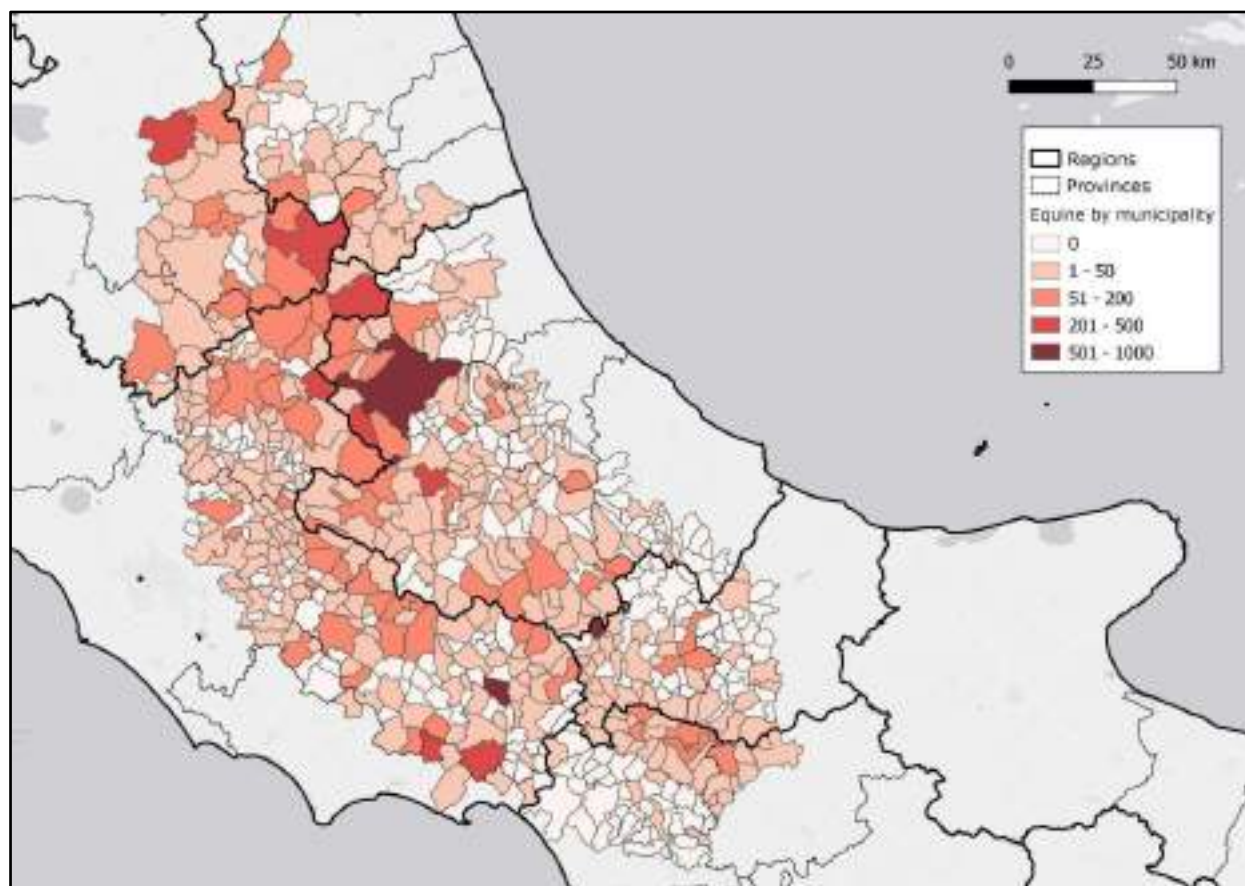


Figure 10. Distribution on a municipal basis of equine animals raised in the study area in the period 2022-2023. (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

4.1.3 Sheep

The data relating to the sheep present in the study area in the three-year period of 2021 to 2023 (Table 5) were downloaded by selecting the “head size” in BDN and selecting those bred with a production orientation for “meat”, “milk” and “mixed”. The number of goats was not taken into consideration since they constitute a minority percentage compared to the total number of sheep and goats present in the study area (equal to approximately 5-10% of the total).

Table 7. Number of sheep in the study area. The annual total number of sheep, average and standard deviation for 2021-2023 is reported (data provided by the BDN of the Zootechnical Registry established by the Ministry of Health)

REGION	PROVINCE	2021	2022	2023	Mean	SD
Abruzzi	Chieti	3,814	3,814	3,770	3,799	25.40
	L'Aquila	86,910	84,672	78,352	83,311	4,438.29
	Pescara	8,859	10,558	10,547	9,988	977.76
	Teramo	21,011	20,065	19,183	20,086	914.19
Total		120,594	119,109	111,852	117,185	4,677.82
Latium	Frosinone	52,113	51,662	50,157	51,311	1,024.24
	Roma	34,824	33,379	31,380	33,194	1,729.41
	Latina	1,858	2,055	2,202	2,038	172.60
	Rieti	50,062	47,996	46,608	48,222	1,738.06
Total		138,857	135,092	130,347	134,765	4,264.39
Campania	Benevento	11,107	10,683	10,207	10,666	450.25
	Caserta	24,952	23,297	21,844	23,364	1,555.09
Total		36,059	33,980	32,051	34,030	2,004.47
Molise	Campobasso	12,374	11,859	11,235	11,823	570.37
	Isernia	26,097	24,501	21,765	24,121	2,190.86
Total		38,471	36,360	33,000	35,944	2,759.16
Umbria	Perugia	35,562	32,939	31,061	33,187	2,260.75
	Terni	8,149	7,615	7,219	7,661	466.70
Total		43,711	40,554	38,280	40,848	2,727.44
Marche	Ascoli Piceno	7,698	7,670	7,053	7,474	364.58
	Fermo	0	0	0	0	
	Macerata	24,586	24,061	21,660	23,436	1,560.02
Total		32,284	31,731	28,713	30,909	1,922.07
Total in the study area		409,976	396,826	374,243	393,682	18,072.82

Sheep are more evenly distributed in the municipalities of the study area than cattle and horses, with a greater number of animals in the municipalities of the province of L'Aquila and Teramo in Abruzzi, in the province of Frosinone in Latium and in the provinces of Perugia, Macerata and Ascoli Piceno between Umbria and Marche (Figure 11).

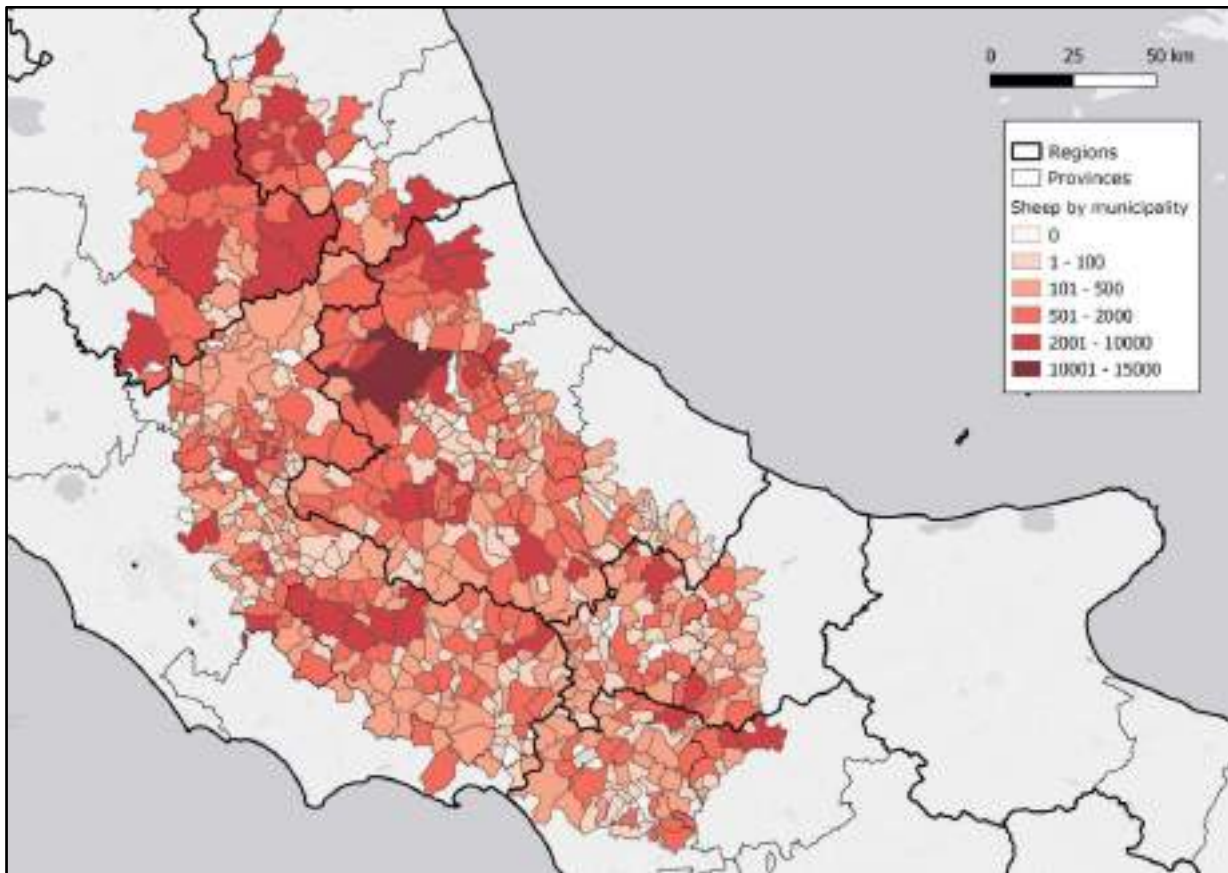


Figure 11. Distribution on a municipal basis of the average number of sheep reared in the study area in the three-year period of 2021 to 2023. (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

4.2 Wild ungulates

In the study area, in addition to the potentially available biomass coming from livestock, the quantity of biomass originating from wild ungulates was evaluated. This could be particularly relevant during the winter period, especially for the bearded vulture (Margalida et al. 2013). In the study area there are wild boars (*Sus scrofa*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and Apennine chamois (*Rupicapra pyrenaica ornata*). Wild boar and roe deer are distributed throughout the study area (Meriggi et al. 2011). The presence of red deer is reported in Abruzzi, Molise, part of Latium, Marche and Umbria, while the Apennine chamois occurs exclusively within the Abruzzo, Lazio and Molise National Park (PNALM), the Gran Sasso and Monti della Laga National Park (PNGSML), the Maiella National Park (PNM), the Monti Sibillini National Park (PNMS) and the Sirente Velino Regional Park (PRSV).

Given the large geographical extension of the study area, the information collected regarding the size and distribution of wild ungulate populations within it, is not uniformly distributed. In particular, the data acquired for the Abruzzi and Latium regions are representative of the entire territorial extension of the respective regions included in the study area, while the information relating to the Campania, Marche, Molise, and Umbria regions is more fragmented. Therefore, where available and accessible, the data obtained have been described on a regional basis.

The data regarding the ungulate species present in the protected areas of the Abruzzo Region (Table 8) were provided, when available, by the management bodies themselves. For the rest of the regional territory, the data concerning red deer and roe deer was reported by Nicoloso et al (2023), and the data for wild boar was reported by Gabini et al. (2023).

The data for the Latium Region (Table 8) was provided by the Monti Simbruini Regional Park (PRMS) for the size of the red deer population within the boundaries of the protected area (Lucarelli 2021). For the Monte Navegna and Cervia Nature Reserve, the data was reported by Genero et al. (2010). The wild boar population estimated in the regional hunting areas (ATC) is indicated by the Regional Plan of urgent interventions for the management, control, and eradication of African swine fever in farmed pigs and in the Wild Boar species [PRIU] (2022). The number of estimated roe deer specimens is described by Filippi (2022) for the ATC of Rieti and by Mastrantonio (2022) for the ATC of Rome.

For the regions of Umbria and Marche, the information was collected by the Monti Sibillini National Park for 2023 (Monti Sibillini National Park, unpublished data), by Genero et al. (2010), by Sergiacomi et al., (2019) and by the Wildlife Management Plan of the Marche Region (2019), (Table 8).

5. Estimation of the available biomass

5.1 Livestock

The available biomass of cattle, horses and sheep was estimated from the abundance of livestock in each category (Table 8). Since the species involved in the feasibility study are scavengers, to obtain an estimate of the biomass useful for vultures it is necessary to estimate livestock mortality. For the calculation of mortality, and therefore the number of carcasses deriving from potentially available livestock, the mortality data in the BDN of the Veterinary Information System was not used, as it was incomplete for certain areas and/or missing for some categories. For sheep, the mortality rate reported in Sardinia by Berlinguer et al. (2021) was equal to 8%. For the calculation of potentially present bovine and equine carcasses, the mortality rate reported by Stoynov et al. (2019) in Bulgaria was used, and equal to 3.1% and 2.3% respectively. The average weight of the cattle and the relative percentage of soft tissue were calculated based on what was reported by Stoynov et al. (2019) (Table 9).

Table 8. Number of wild ungulates in the study area. * Estimated population

Region	Area	Red deer	Roe deer	Wild boar	Apennine chamois
Abruzzi	PNGSML	100*	1,000*	15,000*	1,250
	PNALM	1,919	252	1,500	773
	PNM	800	750	1,500	840
	PRSV	540	300	5,115	70
	Riserva Naturale Monte Genzana e Alto Gizio	100	100	-	-
	ATC Avezzano	1,308	207	3,733*	-
	ATC Barisciano	159	260	2,115*	-
	ATC Chietino-Lancianese	65	601	6,157*	-
	ATC L'Aquila	24	19	558*	-
	ATC Pescara	303	280	6,272*	-
	ATC Roveto-Carseolano	52	88	4,072*	-
	ATC Salinello	9	169	1,503*	-
	ATC Subequano	428	170	2,557*	-
	ATC Sulmona	2,261	201	1,436*	-
	ATC Vastese	10	110	11,338*	-
	ATC Vomano	15	368	3,575*	-
	Total	8,093	4,875	23,115	2,933
Latium	PNRMS	400	-	-	-
	Riserva Naturale Monte Navegna e Cervia	20	891	-	-
	ATC Rieti	-	142*	13,866*	-
	ATC Frosinone	-	-	13,257*	-
	ATC Latina			6,285*	
	ATC Roma		606*	16,380*	
		Total	8,928	8,305	119,200
Marche	PNMS	509	891	1,481	260
	ATC Macerata 2	-	-	2,021	-
	ATC Fermo	-	34	585	-
	ATC Ascoli Piceno	-	72	959	-
	Total	509	997	5,046	260
Umbria	ATC Perugia 2	-	-	5,126	-
	ATC Terni 3	-	-	5,733	-
	Total	-	-	10,859	-
	Total in the study area	9,022	7,511	132,124	3,193

Table 9. Livestock mortality rate by category and average weight of a carcass

Category	Average annual mortality (%)	Average weight (kg)	Average soft tissues (kg)
Sheep	8.0 %	40	34
Cattle	3.1%	250	200
Equines	2.3%	120	100

Table 10. Number of animals raised in the study area for each category considered in the three-year period of 2021 to 2023, the average values and standard deviation are reported.

Category	2021	2022	2023	Mean	SD
Sheep	409,976	396,826	374,243	393,682	18,072
Cattle	44,262	45,511	48,281	46,018	2,056
Equines	-	13,099	14,740	13,919	1,160

The biomass in kg/year (Figure 12) was calculated for each species or category and for each municipality of the study area based on the following formula: number of animals reared x average individual weight x mortality rate x percentage of soft tissues present in the carcass (Table 9).

Table 11. Average number of animals raised for each category considered in the three-year period of 2021 to 2023, relative available biomass based on the respective mortality rates and standard deviation of available biomass compared to the average number of animals. *Estimated for 2022 and 2023.

Category	No. heads (2021 – 2023)	Mortality rate (%)	No. carcasses	Percentage of soft tissue	Available biomass (kg)	Available biomass (SD)
Sheep	393,682	8	31,494	85	1,070,815	49,155
Cattle	46,018	3.1	1,426	80	285,311	12,747
Equines	13,919*	2.3	320	83.33	31,885	2,667
Total	-	-	33,195	-	1,388,011	-

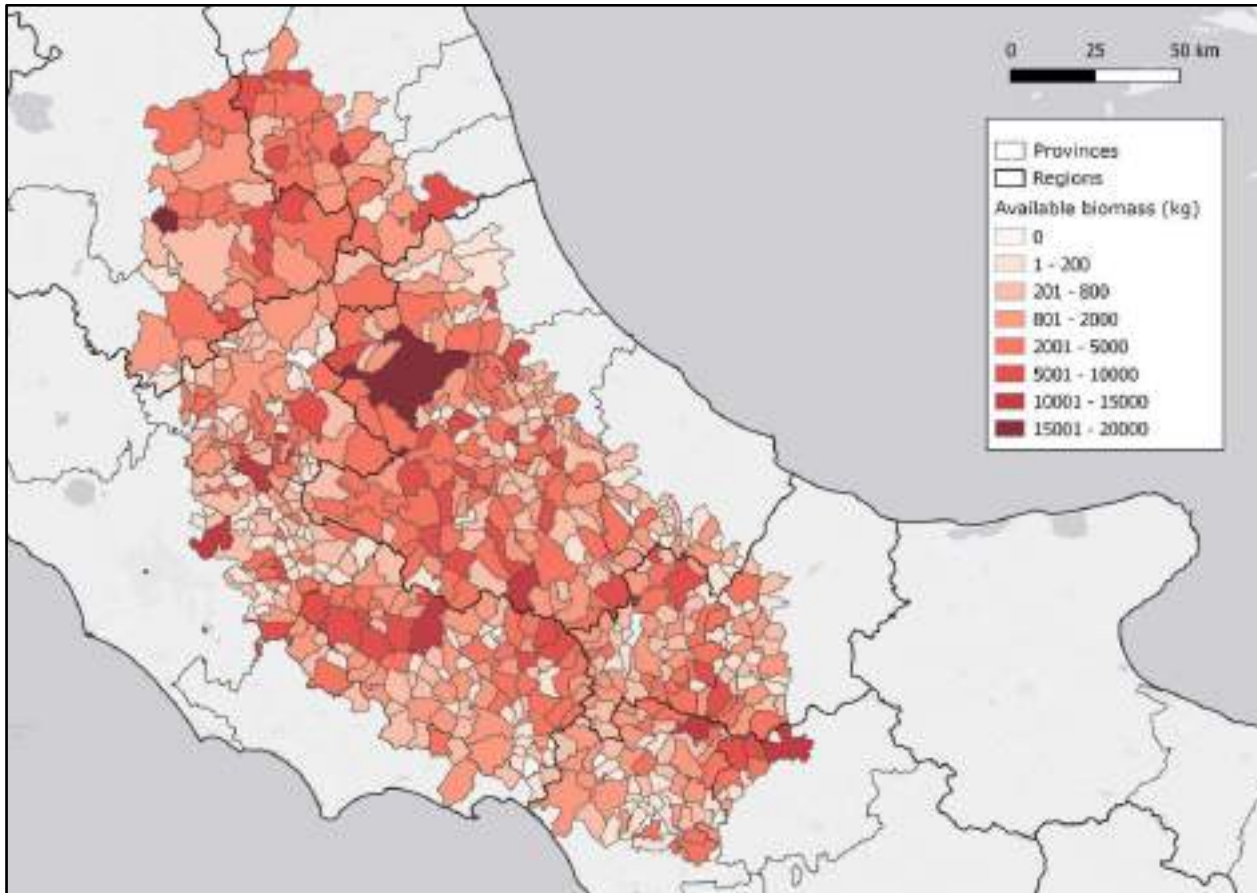


Figure 12. Average available biomass referring to livestock on a municipal basis in the three-year period of 2021 to 2023. (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

To obtain a better approximation of the distribution of biomass in the area, the density of livestock biomass at provincial level was also taken into consideration (Figure 13). This was achieved by dividing the quantity of biomass previously calculated by the surface area of the corresponding provincial segment. The resulting biomass density appears high in the provinces of L’Aquila and Isernia, followed by the provinces of Frosinone and Rieti. This distribution of biomass availability for vultures is consistent with the distribution of carcasses in the feeding area of griffon vultures, except for the province of Isernia where the number of carcasses consumed by griffon vultures is considerably lower than that found in the province of L’Aquila (Figure 1 , Figure 3).

5.2 Wild ungulates

The biomass available for vultures referred to wild ungulates was calculated starting from the average weight of ungulates indicated by Genero et al. (2010) (Table 10 and 10). Mortality rates were conservatively estimated at 3%, considering the component of carcasses potentially unavailable for consumption by vultures as it is not accessible (Berlinguer et al. 2021).

Soft tissue biomass, as reported by Donazar & Fernandez (1990), is equal to 27% of the total weight. The biomass in available kg/year was calculated as: number of animals x average weight x mortality rate x percentage of soft tissues.

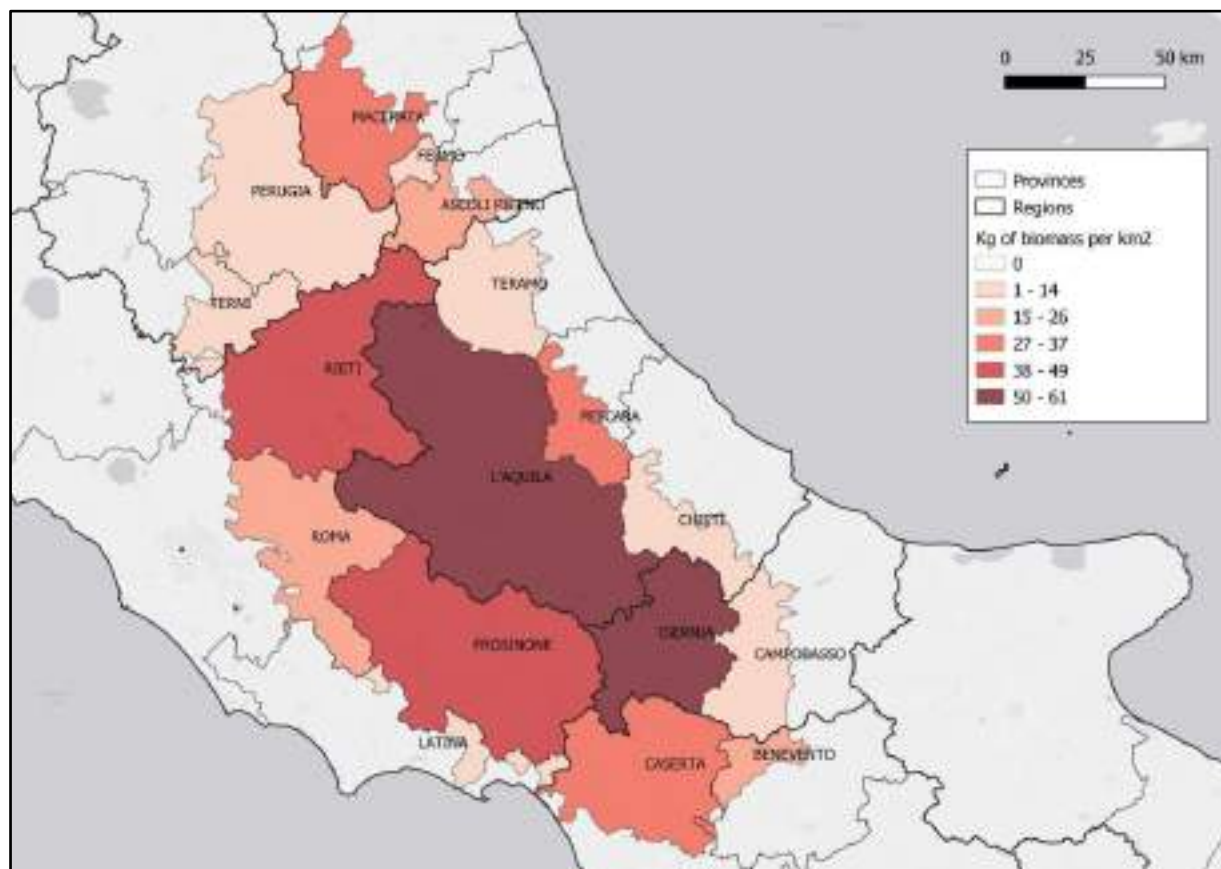


Figure 13. Density of available biomass relating to livestock on a provincial basis (Data provided by the BDN of the Zootechnical Registry established by the Ministry of Health at the CSN of the “G. Caporale” Institute of Teramo)

Table 10. Average weight of the ungulate species in the study area, number of specimens for each species and relative soft tissue biomass based on the mortality rate considered and equal to 3%.

Species	Average weight (kg)	Number	Available biomass (kg)
Red deer (<i>Cervus elaphus</i>)	100	9,022	7,308
Roe deer (<i>Capreolus capreolus</i>)	20	7,511	1,217
Wild boar (<i>Sus scrofa</i>)	50	132,124	53,510
Apennine chamois (<i>Rupicapra pyrenaica ornata</i>)	30	3,193	776

The biomass deriving from wild boar carcasses is predominant (84% of the total). This is probably due to both the actual numerousness and wide distribution of the species within the study area, and to the presence of less complete information regarding the size of the red deer and roe deer populations.

The quantity of biomass resulting from the wild ungulates present in the territory represents a conservative estimate. This is because there is no data available regarding the number of species considered in several areas of the study area. Furthermore, these numbers, when available, represent the minimum reliable number of specimens detected and are therefore not an estimate of the size of the present population. Moreover, the ungulate populations evaluated in the present study appear stable or growing throughout the considered territory (Meriggi et al. 2011). In addition to this, for several potentially palatable species (lagomorphs, small and medium carnivores, dogs, etc.) it was not possible to obtain estimates of abundance or density. The latter species represent a trophic resource of minor importance, however it is not necessarily negligible.

Vultures preferably use areas with the presence of high quantities of trophic resources, consisting of wild ungulates in winter and a mix of wild ungulates and domestic livestock the rest of the year (Martin-Díaz et al. 2020). In the local distribution area of the griffon vulture, even in winter, the percentage of domestic livestock in their diet is predominant (Rewilding Apennines and Carabinieri Biodiversity Department of Castel di Sangro, unpublished data). It is therefore possible that wild ungulates may represent a minority and alternative source of food for vultures in the study area, of greatest importance during the autumn and winter months (Figure 3), when the availability of domestic livestock carcasses may decrease. In this context, the current growth of ungulate populations could represent a further resource for scavenging birds of prey in the future.

6. Food requirements of vultures

The food requirement of the three vulture species was calculated as reported by Donázar (1993) and Bretagnolle et al. (2004) (Table 11). The food requirement in terms of average daily biomass was calculated taking into consideration the minimum and maximum values of the daily biomass requirement at 30 and 0 °C respectively.

Table 11. Vulture's food requirement as a function of environmental temperature (Stoynov et al., 2019).

Species	Temperature (°C)	Daily biomass (kg)	Average daily biomass (kg)	Annual biomass (kg)
<i>Gyps fulvus</i>	30°C	0.47-0.48	0.55	200.89
	0°C	0.61-0.63		
<i>Aegypius monachus</i>	30°C	0.50-0.51	0.57	208.19
	0°C	0.64-0.66		
<i>Gypaetus barbatus</i>	30°C	0.33-0.38	0.41	149.75
	0°C	0.43-0.49		

The food requirement in terms of average annual biomass for the griffon vulture and cinereous vulture is comparable, probably due to the similarities regarding the body mass and trophic habits of the two species. The bearded vulture, on the other hand, requires a lower quantity of biomass, probably due to its lower body mass and because a majority percentage of the species' diet (about 80%, Houston et al. 1994) is made up of bones. For this reason, the total biomass of soft tissues necessary for the bearded

vulture is equivalent to approximately 20% of the total annual biomass (29.95 kg/year/individual). It should also be taken into consideration that the species rarely feeds on the bones of cows and horses (Margalida et al. 2009), therefore, the contribution of these categories of livestock to the necessary biomass in terms of bones for the bearded vulture is minimal and should be considered with caution.

To estimate the biomass necessary to sustain a population of vultures, reference was made to the size of a hypothetical minimum viable population (MVP). MVP is defined as a population that has a probability of extinction $P \leq 0.01$ in the next 100 years. In the case of the cinereous vulture, the MVP considered was equal to 50 individuals, as reported by Dimitriou et al. (2021) for north-eastern Greece (Dadia-Lefkimi-Soufli Forest National Park) (Table 9). As regards the bearded vulture, the minimum viable population considered is 25 birds, based on what is indicated by Genero et al. (2010) for the central Apennines (Table 12), in which a minimum viable population of 10 breeding pairs is considered. However, Bretagnolle et al. (2004) report for Corsica an extinction risk equal to 16.8% for a population of 25 bearded vultures over 50 years. They conclude that to obtain an extinction risk close to 0 it is a population of approximately 50 individuals that is required. Given the existence of a population of griffon vultures in the study area, three possible scenarios were examined for this species: current population, conservative scenario, and desirable value (Table 12).

Table 12. Food requirements of vultures in the study area. For the griffon vulture three population levels were analysed according to extant (325), conservative (425) and desirable (500) number of individuals.

Species (no. of individuals)	TOTAL REQUIRED BIOMASS (kg) /YEAR at both individual and population level				
	Soft tissue/ individual	Bone/ individual	Soft tissue/ population	Bone/population	Bone + soft tissue
<i>Aegypius monachus</i> 50 individuals	208.19	-	10,409	-	10,409
<i>Gypaetus barbatus</i> 25 individuals	29.95	119.18	597	2,979	3,748
<i>Gyps fulvus</i> 325 individuals	200.88	-	65,286	-	65,286
<i>Gyps fulvus</i> 425 individuals	200.88	-	85,374	-	85,374
<i>Gyps fulvus</i> 500 individuals	200.88	-	100,440	-	100,440

Based on the 3 possible scenarios considered for the griffon vulture population, the annual biomass necessary to sustain the populations of the three vulture species is equal to 79,443 kg, 99,531 kg, and 114,597 kg respectively.

As regards domestic livestock raised according to the methods considered in this study and if all potentially present carcasses were made exclusively available to the vultures, a total biomass of 1,388,011

kg/year would be obtained meeting the food requirements of 6,909 griffon vultures (Table 11). From this data it appears that the production of biomass from domestic livestock largely exceeds the current needs of vultures. Based on these estimates, the availability of livestock carcass biomass is not expected to be a limiting factor for the population growth of vulture populations in the study area.

The presence of wild ungulates in the study area is potentially capable of providing 62,811 kg/year of biomass, an amount capable of supporting 313 griffon vultures.

Table 13. Food requirements of vulture populations in the study area and average available soft tissue and bone biomass from livestock and wild ungulates.

	TOTAL REQUIRED BIOMASS (kg)/YEAR			
	Specie	Soft tissues/ population	Bones/ population	Soft tissues+bones
Food requirement (kg)	<i>Aegypius monachus</i> : 50 individuals	10,409	-	10,409
	<i>Gypaetus barbatus</i> 25 individuals	597	2,979	3,748
	<i>Gyps fulvus</i> 425 individuals	85,374	-	85,374
Available biomass (kg)	Livestock (kg)		Wild ungulates (kg)	
	Soft tissues	Bones	Soft tissues	Bones
	1,388,011	266,072	62,811	169,822

7. Conclusions

The data presented in this study highlights the fact that the availability of carcasses does not appear to be a limiting factor for the presence and growth of vulture populations in the central Apennines.

In the present study, to evaluate the biomass available for consumption by vultures, only animals raised in the wild and semi-wild state were considered, as the probability that the vultures can identify the carcasses in this context is greater. Nonetheless, it must be considered that part of this biomass may not be accessible to vultures as it cannot be identified due to the position of the carcass (under tree cover, inside a narrow valley, etc.). Furthermore, the calculation carried out to evaluate the quantity of available biomass does not consider the feeding activity of other facultative scavengers, such as foxes, stray dogs, wolves, wild boars and bears.

It is also necessary to take into consideration that some carcasses of domestic livestock, which currently represent around 80% of the diet of the present griffon vulture population, are disposed of by abandonment at the place of death. This means that an effective control by the relevant health authorities is less likely, contrary to what is established by current legislation.

However, if there are more restrictive controls by the authorities in charge, this could represent a risk factor for populations of scavenging birds of prey as it could cause a sharp reduction in the availability of accessible carcasses for consumption. Populations of wild ungulates, which show a positive growth trend, constitute a potential source of food supplementation for vultures. The number of individuals in the study area reported in this work, although it most likely represents an underestimate of the number of wild ungulates actually present, is insufficient to guarantee the sustenance and growth of the already existing population of griffon vultures and of a possible cinereous vulture population. However, biomass from wild ungulate carcasses appears potentially sufficient to support a viable bearded vulture population, especially considering the significant presence of bone in their diet.

The area examined is home to a considerable number of livestock, and this quantity is even greater if those raised with methods other than extensive and semi-extensive grazing are also considered. The availability of carcasses deriving from livestock for consumption by scavenging birds of prey, however, is largely dependent on the disposal methods widespread in the study area. These methods involve the abandonment of carcasses on the territory often without an effective possibility of control by the health authorities. To guarantee long-term trophic availability for populations of scavenging birds of prey, the use of supplementary feeding stations in the area appears relevant. These would be distributed and managed in such a way as to ensure the spatio-temporal unpredictability of the resources, respecting eco-ethological needs of vultures.

In this sense, and in the near future, it is desirable to implement some of the opportunities contemplated in the European regulations (Regulation (EC) no. 1069/2009, Regulation (EC) no. 142/2011) compared to the rules currently in force. This would allow the use of farm feeding stations for the disposal of carcasses and their release in situ (Posillico & Balestrieri, 2023), if these satisfy the health requirements necessary for consumption by the scavenger raptors. The result would maximise the trophic supply for the vultures.

In this scenario, if the main threats are successfully mitigated, the restoration of a community of scavenging birds in the central Apennines can be considered an achievable goal in the years to come.

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Chapter 16

Health status of grazing livestock

Pietrantonio Costrini



1. Introduction

1.1. General elements

Most food resources for vultures in the central Apennines are represented by livestock, which griffon vultures find in pastures and in natural and semi-natural grassland and shrubland habitats, widely spread across the typical mountain landscape. If we consider both supporting extant griffon vulture population, and future translocation of other vulture species, we must be aware that restocking or reintroduction efforts should be complemented by an adaptive, supplementary feeding strategy. The main source for feeding stations provisioning is represented by livestock from local breeders, and the chances of using this food source for vultures is conditioned by the occurrence of infective or transmissible diseases in livestock. Thus, while analysing and predicting the potential use of livestock carcasses to support translocations, it is important to evaluate the suitability of livestock in farms according to their health status as well as occurrence and concentration of pharmacological residues (*e.g.*, NSAIDs, antibiotics, etc.), considering pathologies or residues which could limit or exclude their employment for supplementary feeding.

In the Abruzzo Region, the health status of grazing livestock is annually investigated by the Regional Department of Animal Health through the local Health Authorities (Dipartimento Regionale di Sanità Animale e Aziende Sanitarie Locali, ASL). The results of these surveys are recorded in the periodic reports of the Department, also considering diseases transmissible to humans - zoonoses - and those contagious among animals.

This document is based on consultation of the latest animal health regional report, published in 2020 (1), and summarises the status of diffusive and dangerous diseases both for the environment and for humans. Additionally, an examination is made of the pharmacological molecules investigated by the Regional Residue Plan (1), which is a direct expression of the National Residue Plan (2).

The reported data should be considered as continuously evolving since the farms in the Region are periodically subjected to inspection and verification according to a risk-based analysis methodology. This means that not all regional farms are investigated, but only those that fall into certain risk categories, while still maintaining an overall minimum annual investigation percentage.

It is also worth noting that the aim of this document is to integrate animal health data with the needs of the feasibility study, namely the reintroduction of scavenging birds in the central Apennines beyond the already present griffon vulture (*Gyps fulvus*). Therefore, the main objective of this analysis is to combine data from the monitoring carried out by the Department of Animal Health of the Abruzzo Region with the hazards resulting from the trophic use of carcasses of grazing animals by obligate and facultative scavenging birds.

Ministerial guidelines, regarding “operational indications for the authorization of feeding stations” drawn up in accordance with Regulations (EC) 1069/2009 (3) and (EU) 142/2011 (4), establish clear procedures to define the suitability of a carcass to be disposed of at a feeding station. These suitability criteria, both chemical and biological, must necessarily be extended, for preventive purposes, to the investigations that are carried out annually by the competent authorities (CAs) in farms.

1.2. Community Regulations 142 and 1069 and Ministerial Guidelines.

The European Community Regulation 1069/2011 (3) constitutes the legal basis for defining animal carcasses, encompassed within the definition of Animal By-Products (ABPs). ABPs are classified into three risk categories – 1, 2, and 3 – based on the danger associated with the transmission of infectious and contagious diseases harmful to humans and other animals, both wild and domestic.

Risk categories:

- ABP 1 - high risk; it is a very broad category, including carcasses potentially affected by TSE (ruminants) or resulting from TSE eradication measures, pets, carcasses from zoos, circus animals, suspected wild carcasses, domestic carcasses from illegal pharmacological treatments, or environmental contamination.
- ABP 2 - medium risk; it includes carcasses of horses, pigs, and rabbits that died from causes other than slaughter and not attributable to poisoning or illegal pharmacological treatment.
- ABP 3 - low risk; it includes carcasses of animals of any species or parts thereof, if ruminants are devoid of specific risk material (SRM), resulting from slaughter for human consumption.

As a matter of regulation, carcasses of animals that died from causes other than slaughter must be disposed of either by incineration or burial, subject to authorization from an approved site. Additionally, carcasses or parts thereof, if free from hazards, may be transformed into other by-products.

According to European Community Regulation No. 1069/2009 (3), pursuant to Article 18, paragraphs 1 and 2, the disposal of Animal By-Products (ABPs), if deemed suitable by the competent authority, is allowed at feeding stations for scavenging birds or for the species listed in implementing Regulation No. 142 (4) of 2011 - Annex VI, Chapter II, Section 2.

In the note No. 29562 dated July 10, 2013 (5), the Ministry of Health provides guidance on the assessment of the suitability of animal carcasses through clinical and anamnestic investigations, or analytical findings that may suggest a diffusive disease. The same note recommends the evaluation of pathogens transmissible between mammals and birds such as *Mycobacterium avium subs avium*, *Chlamydochila pistacci*, *Salmonella* spp., *Bacillus anthracis*, *Campylobacter*.

In a second ministerial note, No. 31238 dated August 1, 2014 (6), the Ministry of Health further specifies that carcasses deemed suitable for feeding scavenging birds must be free from residues, even in traces, of the following drugs: *aceclofenac*, *flunixin melumine*, *enrofloxacin*. These substances are toxic to such species.

2. Animal health data

Animal Health Elements - Abruzzo Region

This draft presents data concerning the animal health status in the registered farms in Abruzzi. These data were extracted from the planned inspections under the Regional Integrated Multi-Year Control Plan

(P.R.I.C.), during the triennium 2015-2018. The P.R.I.C. (7) was proposed and approved by Directorial Determination No. DG/21/51 dated March 31, 2015, and it involves the verification of animal health requirements for all regional farms and other assessments beyond the needs of this draft. The same data will be updated in the ongoing drafting of the 2024 regional report.

The farms registered in Abruzzi are summarised in the following table (table 1), categorised by animal species and Local Health Authority.

Table 1. Number of farms according to species raised under the jurisdiction of the four provincial Local Health Authority (ASL) in Abruzzo Region.

EQUIDS	Local Health Authority (ASL) province of reference				Total
	ASL 1	ASL 2	ASL 3	ASL 4	
Horses	3,114	960	887	1,210	6,171
Asses	134	141	79	78	432
Mules	28	8	2	23	61
Total	3,276	1,109	968	1,311	6,664
OVINE & CAPRINE					
Sheep	1,572	780	1,366	1,144	4,862
Goats	54	369	262	350	1,035
Total	1,626	1,149	1,628	1,494	5,897
BOVIDS					
Bovine	1,373	599	820	1,290	4,082
Buffalos	4	2	2	3	11
Total	1,377	601	822	1,293	4,093
SWINE					
Pigs	2,900	5,255	2,343	5,234	15,732
Wild boar	9	9	4	8	30
Total	2,909	5,264	2,347	5,242	15,762

In the following table (table 2), the livestock heads censused in Abruzzi are distinguished by species or zootechnic category and grouped according to provincial Local Health Authority.

Table 2. Number of livestock heads according to species/zootechnic category raised under the jurisdiction of the four provincial Local Health Authority (ASL) in Abruzzo Region.

	ASL 1	ASL 2	ASL 3	ASL 4	Total
Equids	14,057	2,502	1,780	3,449	21,788
Asses	701	493	210	304	1,708
Mules	784	22	29	289	1,124
Horses	12,569	1,987	1,537	2,856	18,949
Hinnies	3	0	4	0	7
Ovine & Caprine	87,847	13,775	27,102	42,842	171,566
Sheep	86,514	11,337	25,381	40,098	163,330
Goats	1,333	2,438	1,721	2,744	8,236
Bovids	26,100	7,014	10,171	19,971	63,256
Bovines	26,033	7,003	10,164	19,921	63,121
Buffaloes	67	11	7	50	135
Swine	11,578	26,489	9,252	31,292	78,611
Pigs	11,559	26,479	9,252	31,250	78,540
Wild boars*	19	10	0	42	71

*farmed wild boars

3. Infectious Diseases

Within the P.R.I.C. (7) framework, the investigations carried out aimed to assess the incidence of infectious and potentially diffusive diseases in regional farms. The same diseases are addressed in the Veterinary Police Regulation. Below is a description, for each individual pathology, of the data resulting from the regional investigation program.

Bovine Brucellosis

Bovine brucellosis is a worldwide infectious disease, whose etiological agent is the microorganism *Brucella abortus*. It is a zoonosis that is transmitted to humans mainly through direct contact, but also through the ingestion of infected or contaminated food. Controls in the Abruzzo Region have been progressively extended to all cattle farms, covering 99.39% in 2019. For this reference period, out of 2.128 farms inspected, two tested positive, resulting in a prevalence of 0.09%.

Enzootic Bovine Leukosis

Italy is officially recognized as free from Enzootic Bovine Leukosis following EU Decision 2017/19010 (8). This recognition has been achieved because it has been demonstrated that infected farms in the national territory are less than 0.2%, making the risk of infection spread negligible. All Italian regions must implement a surveillance plan with the aim of maintaining the status of being officially free from the disease. In Abruzzi, in 2019, 1,567 farms, out of the total, were inspected.

Bovine Tuberculosis

Bovine tuberculosis (TB) is an infectious disease affecting animals and humans, typically exhibiting a chronic course that, besides reducing animal production, poses risks to human health. The causative agent is a bacterium (*Mycobacterium bovis*) primarily transmitted through the airborne route and less commonly through food. Bovine TB is a disease with serious socioeconomic and public health implications, significantly impacting international trade in animals and animal products. In the Abruzzo Region, control efforts in 2019 covered 4.093 farms out of 2.733 included in the program (100%). The farms testing positive amounted to 1, resulting in a prevalence of 0.03%.

Ovine-Caprine Brucellosis

Ovine-caprine brucellosis is an infectious disease caused by the bacterium *Brucella melitensis*. It is a zoonosis: humans can contract the disease through contact with infected biological material or animals, via airborne transmission (for at-risk professional categories) or through the ingestion of contaminated animal products.

In 2019, two outbreaks occurred among a percentage of inspected farms totalling 99.7%, which is 3.673 farms out of a total of 3.682.

Swine Vesicular Disease

Swine Vesicular Disease (SVD) is a contagious infectious disease that affects pigs. When it manifests in its clinical form, it presents with hyperthermia, lameness, vesicular lesions, and localised erosions on the skin and mucous membranes (feet, snout, lips, and tongue). The etiological agent of the disease is an RNA virus belonging to the *Picornaviridae* family.

In Abruzzi, all inspections conducted in 2019 yielded negative results.

Transmissible Spongiform Encephalopathies

Transmissible Spongiform Encephalopathies (TSEs) are neurodegenerative diseases characterised by a relatively long incubation period and specific neuropathological features upon necropsy examination, such as vacuole destruction of neuronal tissue, loss of nerve cells, and proliferation of glial cells, without evidence of inflammation. The etiological agent of these pathologies has been identified as the prion: a modified protein, with an unnatural three-dimensional conformation, which accumulates within nerve cells until causing their death.

Among the recognized TSEs are scrapie in sheep, goats, and mouflons, bovine spongiform encephalopathy (BSE), better known as mad cow disease, transmissible mink encephalopathy (TME), chronic wasting disease (CWD) in deer, feline spongiform encephalopathy (FSE), and feline TSE. Scrapie and BSE are the most well-known: the former is widespread among European flocks, while the latter gained notoriety due to the epidemic that erupted in the United Kingdom in the mid-1980s, as it is a disease transmissible to humans through the consumption of meat from infected cattle.

In Abruzzi, the last case of a positive rapid BSE test occurred over 13 years ago in a regularly slaughtered Friesian cow; meanwhile, two outbreaks of scrapie were recorded in 2019, in the provinces of L'Aquila and Teramo.

With note No. DGSAF/11885 (9) dated June 12, 2013, the Ministry of Health, upon the opinion of the EFSA - the European Authority responsible for food safety - announces that as of July 1, 2013, in accordance with Decision No. 2013/76/EU, tests on regularly slaughtered cattle are considered suspended. Therefore, surveillance of cattle belonging to risk categories, namely those that died from natural causes, emergency slaughtered, and deferred with an age over 48 months, becomes increasingly important for disease control.

Regarding ovine and caprine, within the surveillance program for animals slaughtered for human consumption, as a percentage as provided by the P.R.I.C., sampling is planned for animals over 18 months of age or with more than two permanent incisors already erupted. The same investigation strategy is applied to animals that died from causes other than slaughter.

Blue Tongue

In the framework of surveillance and control activities for Blue Tongue, the Abruzzo Region implements measures related to the serological and entomological surveillance program. In 2019, there were no recorded outbreaks in Abruzzi.

Avian Influenza

With reference to the National Avian Influenza Plan for 2019 (10), the Abruzzo Region is no longer classified among the regions at risk. However, biosecurity measures continue to be applied in all farms.

Salmonellosis

Monitoring activities have targeted four distinct sectors: laying hens, *Gallus gallus* breeders, breeding turkeys, and broiler chickens. Analyses and investigations have revealed a prevalence of *S. enteritidis* and *S. typhimurium* infection at 8%, aiming to reduce it in the future to a value of 5%.

4. National Residue Plan

The National Residue Plan (PNR) (2) is a control plan implemented in Italy until 2022 to detect residues of pharmacologically active substances and chemical residues in livestock production chains and in the first processing phase of food. The planning of the PNR depended on the Ministry of Health - Directorate General for Food Safety and Nutrition.

The animal categories and animal origin products investigated in the document are as follows: cattle, pigs, sheep and goats, horses, backyard poultry, rabbits, farmed and hunted game, aquaculture, milk, eggs and honey.

Table 3 lists the substances sought, as provided by Legislative Decree No. 158 of March 16, 2006.

These substances are divided into categories A and B, namely prohibited and unauthorised substances and authorised medicines and contaminants, respectively.

Table 3. List of the substances sought in the National Residue Plan, as provided by Legislative Decree N. 158, March 16, 2006.

Category A	Anabolic Effect Substances and Unauthorised Substances
	A1 - Stilbenes, their derivatives, and their salts and esters
	A2 - Antithyroid agents
	A3 - Steroids
	A4 - Resorcylic acid lactones (including zeranol)
	A5 - β -agonists
	A6 - Substances listed in Annex IV of Council Regulation (EEC) No. 2377/90 of 26 June 1990 (now repealed by Regulation (EC) No. 470/2009 and Regulation (EU) No. 37/2010)
Category B	Veterinary Medicines and Contaminating Agents
	B1 - Antibacterial substances, including sulfonamides and quinolones
	B2 - Other veterinary medicinal products
	B2a - Anthelmintics
	B2b - Coccidiostats, including nitroimidazoles
	B2c - Carbamates and pyrethroids
	B2d - Tranquilizers
	B2e - Non-steroidal anti-inflammatory drugs (NSAIDs)
	B2f - Other substances with pharmacological activity
	B3 - Other substances and environmental contaminants
	B3a - Organochlorine compounds, including PCBs
	B3b - Organophosphate compounds
	B3c - Chemical elements
	B3d - Mycotoxins
	B3e - Colorants
	B3f - Others

The objectives of the PNR were as follows:

- Uncover cases of illicit administration of prohibited and unauthorised substances.
- Highlight cases of improper or unlawful use of medicines, *i.e.*, under conditions different from those authorised.
- Verify the compliance of foods with maximum residue limits concerning veterinary drugs, plant protection products, and environmental contaminants.

The PNR (2) stipulated that sampling would be done without prior notice to the recipient of the control, implementing a surprise effect. The samples taken were targeted, *i.e.*, collected with the aim of uncovering illicit treatment and/or verifying that residues were within the maximum limits set by sector regulations. Therefore, in selecting the targeted sample, specific parameters such as the animal's sex, age, species, type of farming, productive stage, and any other parameter that allowed associating the sample with the purpose of the ongoing investigation were considered.

Within the framework of the PNR, investigative activities were grouped into three separate categories:

- Plan;
- Extra Plan;
- Suspected.

The Plan included targeted sampling dictated by the Ministry of Health in compliance with the indications of European standards.

The Extra Plan included additional samplings established by the Ministry of Health in agreement with the Regions, aiming to improve the investigation for certain productive sectors. The Abruzzo Region did not carry out samplings within the Extra Plan.

In case of Suspected, additional investigations were conducted to confirm or refute the identified critical issues and highlight others.

The following table (table 4) summarises the number of samples taken and the number of analytical determinations performed, while table 5 provides an overview of the type of samples taken. The analysis of each sample was carried out using multiparametric techniques aimed at obtaining more data for each investigation.

Table 4. Number of samples taken and number of analytical determinations performed in the National Residue Plan

Type of Plan	Number of samples taken	Number of analytical determinations
Plan	28,427	409,829
Extra Plan	1,125	49,199
Suspected	685	14,118
TOTAL	30,237	473,146

Table 5. Number and type of samples analysed in the National Residue Plan in relation to the type of plan (Plan, Extra Plan, and Suspected) and farming categories.

		Aquaculture	Bovines	Rabbits	Equids	Milk	Honey	Ovine & Caprine	Farmed game	Hunted game	Swine	Eggs	Poultry	Totals
Plan	Livestock farm	624	4,402	28	18	1,181	138	16	21		248	677	810	8,163
	Hunted									102				102
	Slaughterhouse		6,946	190	299			470	93		5,666		6,224	19,888
	Plant-facility	10					59					205		274
	Total													28,427
Extra Plan	Livestock farm	5	4	11		549	68		1		10	61	23	732
	Hunted									7				7
	Slaughterhouse		69	50	22			30	1		81		23	276
	Plant-facility					84	26							110
	Total													1,125
Suspected	Livestock farm	6	227			146					3			382
	Slaughterhouse		236	1	2						62			301
	Plant-facility					2								2
	Total													685
TOTAL		645	11,884	280	341	1,962	291	516	116	109	6,070	943	7,080	30,237

5. PNR detected Nonconformities

Throughout the entire activity of the PNR, 49 non-conforming samples were found, as detailed in table 6. The non-conformities detected included accidental environmental contamination, illegal treatments and failure to comply with withdrawal or withholding periods for plant protection products. In other cases, investigations are still ongoing regarding the reasons for non-conformity. Tables 7a, 7b, and 7c, summarise the non-conformities detected within the investigation scope of the Plan, Extra Plan, and Suspected, respectively.

Table 6. Non conformities detected in the National Residue Plan

Type of Plan	Number of non-conforming samples
Plan	19
Extra Plan	7
Suspected	23
Totals	49

Table 7a. Non-conformities detected within the investigation scope of the Plan sampling

Farming categories	Category	Matrix	Sampling place	Non-compliant parameter	Group		Detected value (µg/kg)	Conclusions
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	4.1	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	2.2	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	3.3	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	6.3	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	6.4	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Sum of malachite green and leucomalachite green	B3e	Colourants	7.3	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Trimethoprim	B1x11	Diaminopyridine derivatives	62	Illegal treatment
Bovines	Young bulls	Muscle	Slaughterhouse	Sum of oxytetracycline and its 4-epimer	B1x2	Tetracycline	115.6	Illegal treatment
Bovines	Young bulls	Liver	Slaughterhouse	Dexamethasone	B2f3	Corticosteroids	46.4	Accidental contamination
Bovines	Young bulls	Liver	Slaughterhouse	Dexamethasone	B2f3	Corticosteroids	290.5	Accidental contamination
Bovines	Young bulls	Muscle	Slaughterhouse	Dexamethasone	B2f3	Corticosteroids	72.5	Unknown causes
Bovines	Young bulls	Muscle	Slaughterhouse	Sulfadimidine	B1x1	Sulfonamides	3,746	Accidental contamination
				Lincomycin	B1x10	Lincosamides	209	
Bovines	Young bulls	Serum	Livestock farm	Estradiol-17-Beta	A3x1	Estrogens	0.097	Accidental contamination
Milk	Bovine	Milk	Livestock farm	Sum of florfenicol and its metabolites measured as florfenicol-amine	B1x7	Florfenicol and associated compounds	13	Other causes
Milk	Bovine	Milk	Livestock farm	Aflatoxin M1	B3d1	Aflatoxins	0.08	Environmental contamination
Swine	Swine	Muscle	Slaughterhouse	Sulfadimethoxine	B1x1	Sulfonamides	310.5	Accidental contaminations
Swine	Swine	Muscle	Slaughterhouse	Sum of oxytetracycline and its 4-epimer	B1x2	Tetracycline	211.9	Suspension period non respected
Swine	Swine	Food	Livestock farm	Aflatoxin B1	B3d1	Aflatoxins	41	Accidental contaminations
Poultry	Chickens	Food	Livestock farm	Aflatoxin B1	B3d1	Aflatoxins	12.1	Unknown causes

Table 7b. Non-conformities detected within the investigation scope of the Extra Plan sampling

Farming categories	Category	Matrix	Sampling place	Non-compliant parameter	Group		Detecte d value (µg/kg)	Conclusions
Rabbits	Rabbits	Muscle	Slaughterhouse	Sum of enrofloxacin and ciprofloxacin	B1x4	Quinolones	124.3	Accidental contamination
Milk	Bovine	Milk	Livestock farm	Aflatoxin M1	B3d1	Aflatoxins	0.069	Environmental contamination
Milk	Bovine	Milk	Livestock farm	Aflatoxin M1	B3d1	Aflatoxins	0.095	Environmental contamination
Milk	Bovine	Milk	Livestock farm	Aflatoxin M1	B3d1	Aflatoxins	0.49	Environmental contamination
Honey	Bees	Honey	Livestock farm	Acetamiprid (sum of acetamiprid and N- desmethyl-acetamiprid (IM-2-1), expressed as acetamiprid)	B3f	Other - other substances and environmental contaminants	200	Accidental contamination
Ovine & Caprine	Sheep	Muscle	Slaughterhouse	Sum of oxytetracycline and its 4-epimer	B1x2	Tetracycline	444.1	Investigation in progress
Poultry	Guinea fowl	Drinking water	Livestock farm	Furazolidone	A6x1	Nitrofurans	1.8	Unknown causes

Table 7c. Non-conformities detected within the investigation scope of the Suspected sampling.

Farming categories	Category	Matrix	Sampling place	Non-compliant parameter	Group		Detecte d value (µg/kg)	Conclusions
Aquaculture	Trout	Muscle	Aquaculture	Trimethoprim	B1x1 1	Diaminopyridine derivatives	226	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Trimethoprim	B1x1 1	Diaminopyridine derivatives	202	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Trimethoprim	B1x1 1	Diaminopyridine derivatives	247	Illegal treatment
Aquaculture	Trout	Muscle	Aquaculture	Trimethoprim	B1x1 1	Diaminopyridine derivatives	170	Accidental contamination
Bovines	Cows	Muscle	Slaughterhouse	Sulfapyridin	B1x1	Sulfonamides	2,444	Illegal treatment
Bovines	Cows	Muscle	Slaughterhouse	Sum of oxytetracycline and its 4-epimer	B1x2	Tetracyclines	2,047	Waiting period non respected
Bovines	Young bulls	Liver	Slaughterhouse	Dexamethasone	B2f3	Corticosteroids	3.55	Other causes
Bovines	Cows	Muscle	Slaughterhouse	Tulathromycin	B1x5	Macrolides	625.4	Illegal treatment
Bovines	Cows	Muscle	Slaughterhouse	Sulfadimidine	B1x1	Sulfonamides	142.6	Illegal treatment
Bovines	Young bulls	Muscle	Slaughterhouse	Sum of oxytetracycline and its 4-epimer	B1x2	Tetracyclines	2,825	Illegal treatment
Bovines	Young bulls	Muscle	Slaughterhouse	Tulathromycin	B1x5	Macrolides	680.3	Illegal treatment

6. PNR data from the Abruzzo Region

As of today, the Abruzzo Region has published the data from the PNR for the year 2019. This publication is included in the 2020 regional report on “Food Safety and Animal Health Controls”. Specifically, 517 samples were taken, including 93 from farms, 417 from slaughterhouses, and 7 from packaging centres. Table 8 below summarises the investigation and its outcome. During the investigation period, only one non-conformity was found, concerning a residue of fipronil in a sample of eggs.

Table 8. Non-conformities detected within the investigation scope of the Suspected sampling.

		Number of samples
Livestock farms	Bovines	40
	Milk	4
	Poultry	18
	Eggs	7
	Honey	9
	Trout	11
	Rabbits	2
	Horses	2
	TOTAL	93
Slaughterhouse	Bovines	42
	Pigs	126
	Sheep and Goats	41
	Poultry	257
	Horses	1
	TOTAL	467
Packaging Centres	Eggs	7
Total samples within National Residue Plan		567

7. Conclusion

Based on the available information, according to zoonoses and transmissible pathologies mandatory for sanitary surveillance, there are very limited concerns - if any- with respect to the potential transmission of diseases to both man and wildlife from livestock raised in the Abruzzo Region. Thus, if we consider both food provision at feeding stations (collective-intensive or farm based) and the strategy of allowing dead livestock to be left in place in mountainous, natural or remote areas, the health and sanitary conditions of livestock could be considered eligible, at least for the monitored pathologies and the time frame considered. However, data extrapolated from regional and national surveys are partly missing some investigation elements, mentioned in the ministerial notes, necessary for the purposes of evaluating the suitability of a carcass to be admitted for consumption by scavenger birds, like for instance NSAIDs. These missing evaluations must be implemented in the future, or relevant surveys should be refined and tailored to adequately match those substances and their concentrations potentially harmful for vultures, and not only dangerous for human health.

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1 – Regione Abruzzo – Dipartimento di Sanità - Servizio Sanità Veterinaria, Igiene e Sicurezza degli Alimenti - Regione Abruzzo

https://sanita.regione.abruzzo.it/sites/default/files/sicurezza_alimentare/relazione_gen_ppric_2020_an_no_2019_d_1.pdf

2 – Piano Nazionale per la Ricerca dei Residui (P.N.R.) - Relazione 2022 - Ministero Della Salute - Direzione Generale per l'Igiene e la Sicurezza degli Alimenti e la Nutrizione, Ufficio 8

https://sanita.regione.abruzzo.it/sites/default/files/sicurezza_alimentare/relazione_gen_ppric_2020_an_no_2019_d_1.pdf

3 - Regulation (EC) No 1069/2009 of the European Parliament and of the Council of 21 October 2009 laying down health rules as regards animal by-products and derived products not intended for human consumption and repealing Regulation (EC) No 1774/2002 (Animal by-products Regulation)

4 - Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive Text with EEA relevance

5- Nota del Ministero Della Salute: DGSAN 00229562 -p -10/07/2023: indicazioni operative per l'autorizzazione dei CARNAI ai sensi dei Regolamenti (CE) 1069/2009 e (UE) 142/2011.

6 – Nota del Ministero Della Salute: DGSAN 0031238-p-01/08/2014 - Regolamento (UE) 142/2011: utilizzo dei sottoprodotti nelle stazioni di alimentazione (carnai) per uccelli necrofagi. Residui farmacologici.

7- Piano Regionale Integrato Pluriennale dei Controlli della Sicurezza Alimentare e Sanità Animale

<https://www.regione.abruzzo.it/delibera/7838336/view>

8- Decisione di esecuzione (UE) 2017/1910 della Commissione, del 17 ottobre 2017, che modifica la decisione 93/52/CEE per quanto riguarda la qualifica di indenni da brucellosi (*B. melitensis*) di alcune regioni della Spagna, la decisione 2003/467/CE per quanto riguarda la qualifica di ufficialmente indenni da brucellosi bovina di Cipro e di alcune regioni della Spagna e di ufficialmente indenne da leucosi bovina enzootica dell'Italia, e la decisione 2005/779/CE per quanto riguarda la qualifica di indenne da malattia vescicolare dei suini della regione italiana della Campania [notificata con il numero C(2017) 6891]

<https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX%3A32017D1910>

9- Nota del Ministero Della Salute: DGSAF 011885-p-12/06/2013: applicazione dec. 2013/76/UE – Sospensione dei test sui bovini regolarmente macellati.

https://www.izs.it/IZS/Engine/RAServeFile.php/f/pdf_vari_grafica_/newsBENV/11885_2013.pdf

10 – Piano Nazionale di Sorveglianza per l'Influenza Aviaria – 2019

<https://www.izsvenezie.it/documenti/temi/influenza-aviaria//piani-sorveglianza/piano-nazionale-influenza-aviaria-2019.pdf>

Chapter 17

Social feasibility study

B er enice Guinel and Jenny Anne Glikman



Executive summary

- This sociological survey has been conducted within the feasibility study for the reintroduction of the cinereous and bearded vultures, as required by the IUCN Guidelines for Reintroductions and Translocations (IUCN, 2013). With this survey, we addressed three main questions to evaluate the social perspective for these potential reintroductions:
 - (i) What are the overall knowledge and attitudes towards the griffon vulture (*Gyps fulvus*), cinereous vultures (*Aegypius monachus*) and bearded vultures (*Gypaetus barbatus*) in the main areas of interest of the project?
 - (ii) In which areas would the release of the two species be the most accepted? Specifically, what are the areas and municipalities showing particularly high or low acceptance rates?
 - (iii) In which areas is the threat of poison considered highest by the local population?
- To answer these questions, we conducted in-person questionnaires with 376 farmers and collected 176 online questionnaires from the general public in the priority areas of the restocking-reintroduction project. The questionnaires were designed to assess 4 primary aspects: (a) the knowledge and (b) attitudes towards the three species of vultures; (c) the interest to collaborate with the NGO on the project (to use a feeding station for farmers, to include a touristic activity for the tourism providers); and (d) the perception about the threat of poison for wildlife.
- The spatial analysis was planned and structured from both a human and an ecological approach. In the human approach, we examined the 4 protected areas identified as priority areas and potential partners for the project at the moment of this study (Abruzzo, Lazio and Molise National Park, Sirente Velino Regional Park, Monti Simbruini Regional Park, Monti Sibillini National Park) and assessed the differences between core, buffer and border areas within each area. In the ecological approach, we looked at the scores according to their distance from the existing colonies of griffon vultures as well as according to their proximity to potential future habitats.

The primary findings derived from the analysis are as follows:

- The knowledge of griffon vultures is on average relatively high. It is much higher among the general public than the farmers, which could partly be explained by the self-selection bias of the general public (Figure 2). However, the knowledge about the two other species of vultures is almost null among the farmers (13 out of 376 could recognize them in pictures) (Figure 2). Regarding the historical presence of the species, it has been found that a majority of farmers believe they have been introduced by humans and were not present in the past.
- Overall attitudes appeared to be quite neutral (neither positive nor negative) towards griffon vultures and were found to be relatively homogeneous across the four protected areas (Figure 2). Indeed, a quote that could sum up the discussions held with the farmers during the interviews would be: "Vultures are the only wild animals that do not bother".
- The interest to use a feeding station appeared to be shared by a majority of farmers in most of the municipalities, though a large number also expressed their fears that the feeding station could attract wolves (Figure 5). Findings indicated that knowledge and attitudes are not correlated with

the interest in using a feeding station, the latter being very often motivated by an economic gain. This is particularly true in the Monti Sibillini National Park, where a large majority of farmers expressed a high interest in using a feeding station, with absolutely no knowledge about the species and quite low average attitudes (Figure 1).

- Among the 4 protected areas studied, the Sirente Velino Regional Park scored the highest levels of knowledge, attitudes and willingness to collaborate (municipalities both within the protected area and at the border, including the ones from the Regional Natural Reserve Montagne della Duchessa) (Figure 2 and Figure 4). When running a comparative analysis of core, buffer and border areas within each protected area, we found no significant difference.
- Looking at the impact of the distance to the colonies, we found lower levels of attitudes closer to the colonies (<10km) and lower knowledge combined with higher willingness to collaborate further away (>40km) (Figure 1).
- Among the potential future habitats identified by the group of experts during the field trip, Vallone Santa Margherita revealed the highest positive attitudes and the Gole della Valnerina, Monte Bove and Monte Vettore area showed the highest willingness to use a feeding station and collaborate (Figure 1).
- Finally, most of the general public (170 out of 176) and a large majority of farmers, answered positively to the question about poison being a threat in the area where they live, stating that it is a threat in their area (for farmers, it was not considered as a threat for wild animals in 9 municipalities out of 47) (Figure 4 and Figure 5).

Implications and recommendations:

- Some widespread misinformation and fears about vultures and feeding stations should be addressed within the communication campaign of the project. This concerns mainly the historical presence of the griffon vultures and the risk of attraction of wolves by the feeding station. Some perception that griffon vultures are an obstacle to receive compensation will require attention, especially in San Biagio Saracinisco.
- Rather than vultures described as “the only animal not bothering too much” many farmers expressed negative attitudes towards wolves and institutions “managing” wildlife and even expressing their will to use poison themselves to protect against them. Further investigation should be conducted to understand the specific factors at play that motivate these attitudes in each area.
- The promotion for the use of the feeding station should be quite straightforward if the economic gain associated is well highlighted. In addition, highlighting that the access to feeding stations is impossible for terrestrial carnivores will be key to disarm some common fears.
- The Sirente Velino Regional Park demonstrated the most pronounced level of knowledge, positive attitudes and willingness to collaborate and presents itself as the most facilitative operational environment. The Monti Sibillini National Park shows promising opportunities for intervention, given the considerable level of interest observed in utilising a feeding station.
- More specifically, the identified areas that showed the highest acceptance rate in their surroundings were the following: Vallone Santa Margherita, Gole della Valnerina, Monte Bove and Monte Vettore Vettore (Figure 1).

	Knowledge	Attitudes	Collaboration
Human approach	<p>Protected Areas</p> <p>■ Monti Sibillini National Park</p>	<p>■ All 4 protected areas</p> <p>■ Outside protected areas</p>	<p>■ Monti Sibillini National Park, Sirente Velino Natural Regional Park, Monti Simbruini Natural Regional Park</p>
Ecological approach	<p>Distance to existing colonies</p> <p>■ > 40km</p>	<p>■ < 10km</p>	<p>■ > 40km</p>
	<p>Proximity to potential future habitats</p> <p>■ Camosciara, Monte Matitone, Monte Greco (southern slopes), Vallone S. Margherita</p> <p>■ Monte Camicia (versante nord), Monte Vettore (versante sud-est)</p>	<p>■ Vallone S. Margherita</p> <p>■ Monte Camicia (versante nord), Monte Bove (versante nord)</p>	<p>■ Golo della Valnorina, Monte Bove (versante nord), Monte Vettore (versante sud-est)</p>

Figure 1. Graphical summary of the knowledge, attitudes and collaboration scores according to the three levels of analysis pursued. Using human administrative borders, we first analysed the three scores in four protected areas and their border areas. We then examined the scores in each municipality according to their distance to existing colonies (< 10km corresponds to the buffer zone where 50% of the feeding events occur; 30-40 km is where up to 90 percent of carrion are; > 40 km corresponds to the less frequented area), as well as to their proximity to some of the potential future habitats identified during the field trips.

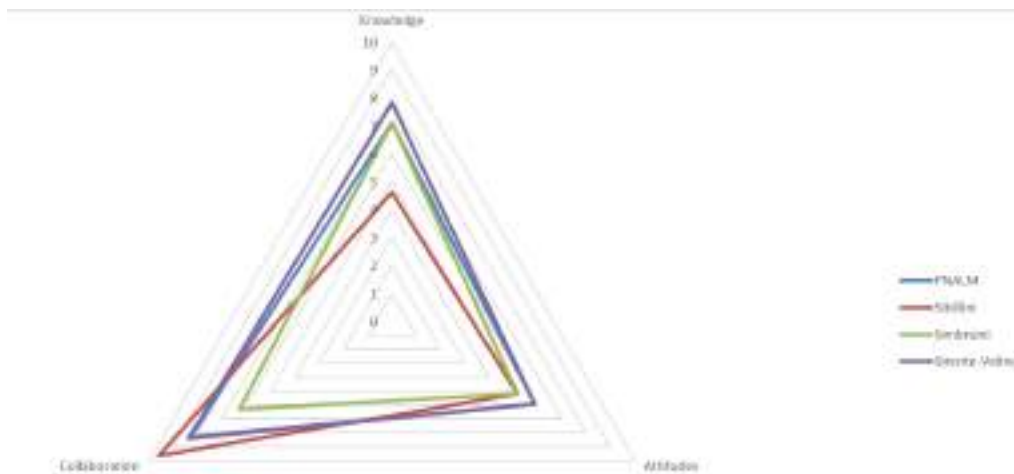


Figure 2. Comparison of the knowledge, attitudes and collaboration scores for each protected area. This figure focuses on the protected area analysis of the three scores and shows that the Sirente Velino Regional Park has the overall highest combined scores and that the Monti Sibillini National Park has the highest willingness to collaborate even though it has the lowest knowledge and positive attitudes scores. This can be explained by their strong interest in the economic gain associated with the use of a feeding station.

Overall scores – positive and negative extremes

Municipalities	PNALM	Sirente Velino	Simbruini	Sibillini	Sirente Velino
	San Biagio Saracinisco, Scanno	Gonano Sicoli, Tomimparte, Magliano de' Marsi	Filettino, Camerata Nuova	Fiastra, Bolognola, Castelsantangelo	Rocca di Mezzo

Figure 3. Municipalities showing very low or very high scores on all three aspects (knowledge, attitudes and collaboration)

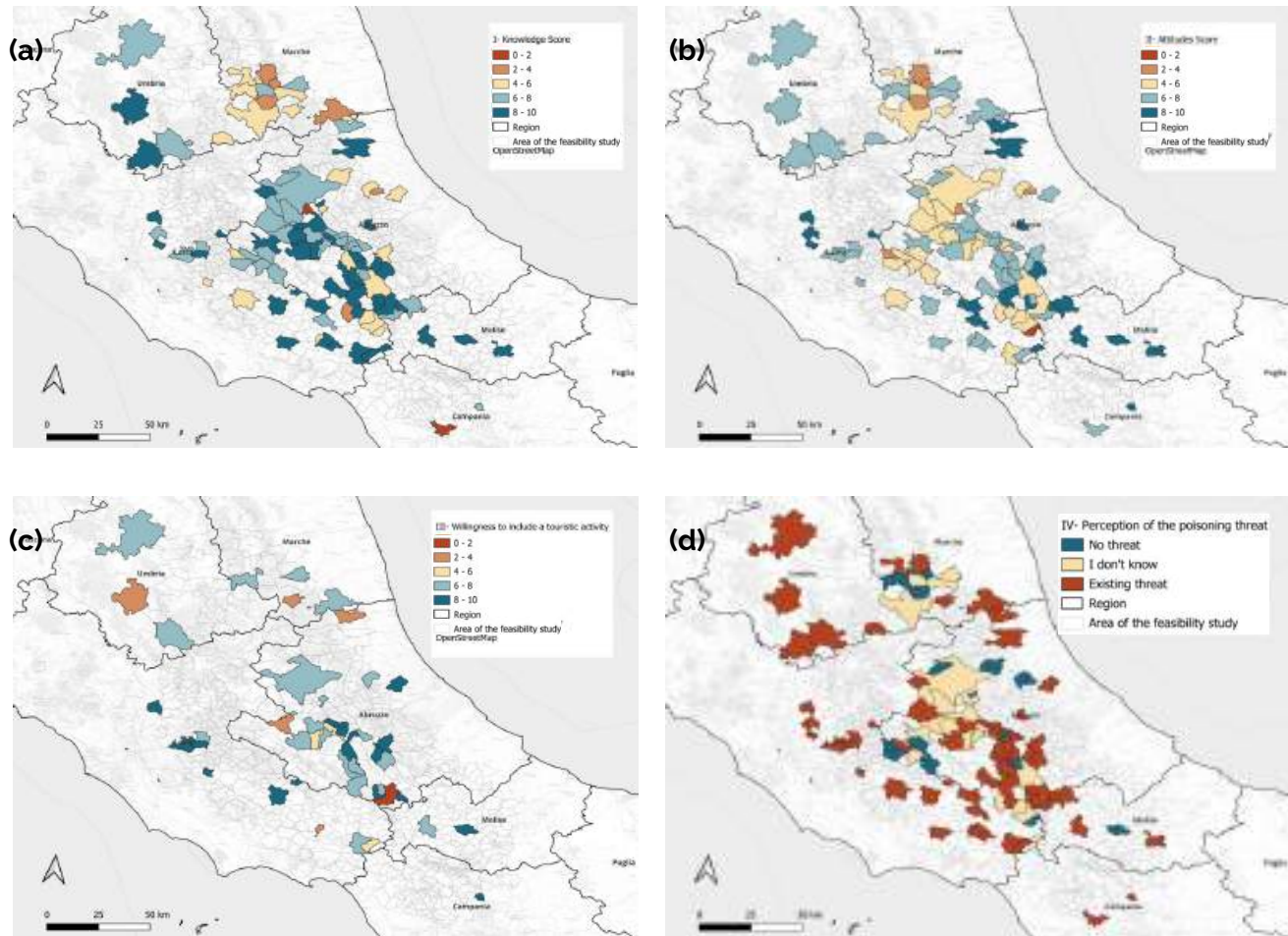
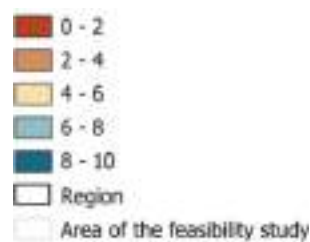
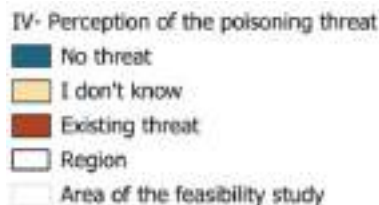


Figure 4. Mean scores attributed to each municipality for both farmers and the general public: (a) the knowledge (from 0-2 red low knowledge, to 8-10 blue scores high knowledge) and (b) attitudes (from 0-2 red negative to 6-8 blue positive) towards griffon vultures; (c) willingness to include a touristic activity related to griffon vultures [only for tourism providers] (0-2 red no interest to 8-10 blue highly interested); and (d) perception of the poisoning threat (from strong threat red to no threat blue).

Legend for scores (a), (b) and (c)



Legend for score (d)



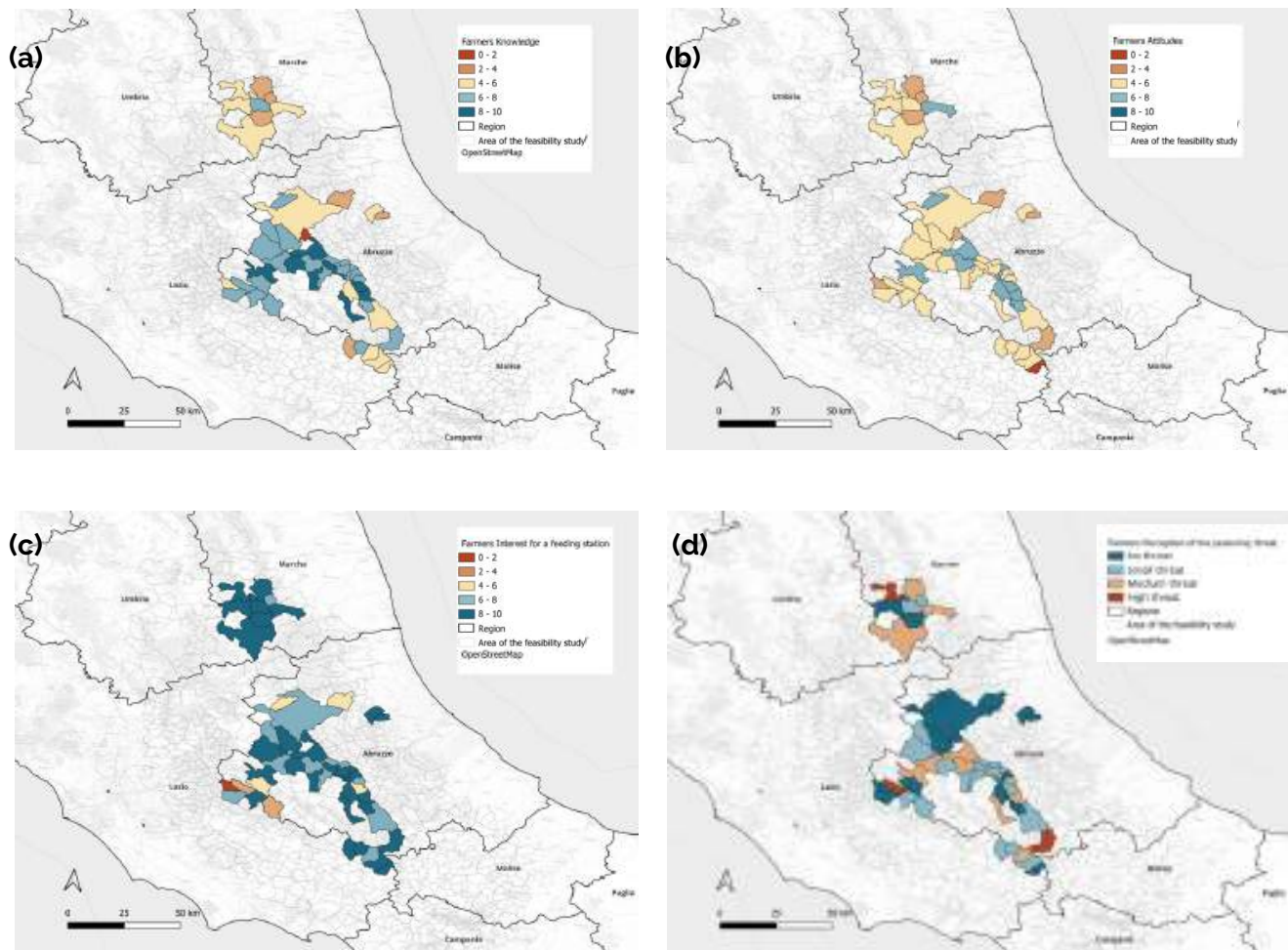


Figure 5. Mean scores attributed to each municipality calculated for farmers: (a) the knowledge (from 0-2 red low knowledge, to 8-10 blue scores high knowledge) and (b) attitudes (from 0-2 red negative to 6-8 blue positive) towards griffon vultures; (c) interest for a feeding station (0-2 red no interest to 8-10 blue highly interested); and (d) perception of the poisoning threat (from strong threat red to no threat blue).

1. Introduction

Since 2013, social feasibility studies are required by the IUCN Guidelines for Reintroductions and Translocations (IUCN, 2013). Since illegal human activities are considered a major threat for the population of vultures (see Chapter 6) and since the construction of feeding stations is considered as a central component of the future strategy to both provide supplementary feeding to vultures and to collaborate with farmers, we have conducted a sociological survey in order to evaluate the social perspective for these potential reintroductions. More specifically, we tried to address three main questions:

(i) What are the overall knowledge and attitudes towards the griffon vultures (*Gyps fulvus*), cinereous vultures (*Aegypius monachus*) and bearded vultures (*Gypaetus barbatus*) in the main areas of interest of the project?

(ii) In which areas would the release of the two species be the most accepted? Specifically, what are the areas and municipalities showing particularly high acceptance rate, and, on the contrary, the ones showing particularly low acceptance rate?

(iii) In which areas is the threat of poison considered highest by the local population?

To answer these questions, we conducted in-person questionnaires with 376 farmers and collected 176 online questionnaires from the general public in the priority areas of the restocking-reintroduction project. The questionnaires were designed to assess 4 primary aspects: (a) the knowledge and (b) attitudes towards the three species of vultures; (c) the interest to collaborate with the NGO on the project (to use a feeding station for farmers, to include a touristic activity for the tourism providers); and (d) the perception about the threat of poison for wildlife.

The spatial analysis was conducted both from a human and an ecological approach. In the human approach, we examined the 4 protected areas identified as priority areas and potential partners for the project (Abruzzo, Lazio and Molise National Park, Sirente Velino Regional Park, Monti Simbruini Regional Park, Monti Sibillini National Park) and assessed the differences between core, buffer and border areas within each park. In the ecological approach we looked at the scores according to their distance from the existing colonies of griffon vultures as well as according to their proximity to potential future habitats.

2. Methods

2.1. Sample, design and distribution of questionnaires/interviews

Design of the questionnaires

The questionnaires were crafted in accordance with the standards outlined in the IUCN Guidelines (IUCN, 2013). We drew inspiration from the questionnaire developed by the Università degli Studi di Sassari for the Life Safe for Vultures project along with social analyses performed in France after the reintroductions of vultures (Efese, 2021; Barbeau, 2017). Furthermore, we also followed previous works conducted in

central Apennines dealing with the attitudes towards wolves and bears (Glikman et al., 2011; Glikman et al. 2019; Glikman et al., 2023). To tailor it to our specific aims, we concentrated on the following primary areas of interest:

- **knowledge** of vultures: their presence in the territory, their diet, picture identification, role in the ecosystem. This was mostly about griffon vultures as they are the only species present at the moment, but some questions about the cinereous and bearded vulture were added,
- **attitudes**: all respondents were asked to give an adjective to define griffon vultures, the general public was also asked about how these species shape their region (tourism and ecosystem),
- **interest in collaboration**: farmers were asked if they were interested in using a feeding station, touristic operators were asked about their interest in including an activity related to vultures,
- **perception of the risk of poisoning**: both groups were asked about how they perceived the risk of poisoning in their area.

Design of the distribution

376 questionnaires were conducted in person with farmers.

- Definition of the area: municipalities were identified and attributed a priority score according to the following criteria:
 - within or close to the four protected areas which have agreed to participate in the project in an early phase: Abruzzo, Lazio and Molise National Park (PNALM), Sirente Velino Regional Park, Monti Simbruini Regional Park, Monti Sibillini National Park. Some municipalities outside of protected areas have also been selected according to the next criteria.
 - their proximity to the existing colonies of griffon vultures, measured by the number of carcasses controlled by Rewilding Apennines in 2022 and 2023. A score of 3 was attributed to the municipalities where more than 17 carcasses were found in 2022 and 2023, a score of 2 was attributed where this number was between 7 and 16, and a score of 1 was attributed for lower numbers.
 - their proximity to potential future habitats for the cinereous and bearded vultures, as identified in the field report available at the time.
- Sampling method through:
 - a first sampling was done using the database of iCribis (informazione-aziende.it): adding up the number of cows, horses, sheep and goats farmers in each municipality.
 - on the field, as we went through the interviews, we observed some significant gaps between the list available on the database and the number of farmers we could find in each municipality (both negative and positive gaps). Hence, we decided to reach out to as many farmers as possible until we reached a saturation point (i.e. when the same names of other farmers kept being mentioned and no other contact could be found). These gaps can notably be explained by the “mafia dei pascoli” system, well investigated by Calandra (2024), whose team discovered that many enterprises have been registered in some territories using some straw men (Calandra, 2024).

- Team of interviewers: one team member from RA (Berenice Guinel) + 3 volunteers (Ilaria Giora, Silvio Mottolese, Antonio Nardi) who joined the RA member for 2 to 3 months. The interviews were first conducted in groups of 2 (RA+1 volunteer) for capacity building and then interviews were conducted individually.
- Timeframe: from August 7th until November 28th 2023.

Online questionnaire for the general public: 176

- Method: [Google form](#)
- Distribution: RA social media (Instagram & Facebook), Abruzzo, Lazio and Molise National Park (Parco Nazionale d’Abruzzo, Lazio e Molise) social media (Instagram & Facebook), Rewilding Apennines events (Rewilding Seminar), Rewilding Apennines team member personal network, and interviewed farmers.

2.2. Spatial framework

We have analysed the data from 4 different spatial perspectives,

- a. municipalities
- b. protected areas
- c. existing colonies
- d. future potential habitats of the cinereous vulture and the bearded vulture.

(i) Spatial analysis based on protected areas

5 main areas

In which zone the release would be the most accepted/would make the most sense?

Within the study area defined by the area frequented by the griffon vultures (see Chapter 15), four areas have been defined as a priority due to highest probabilities of the future vultures releases (ideal habitats, good relationships, possibility of a future feeding station, low conflicts):

- Abruzzo, Lazio and Molise National Park
- Sirente Velino Regional Park
- Monti Simbruini Regional Park
- Monti Sibillini National Park.

All the other municipalities have been grouped under the “Outside of Protected Areas” area (Figure 6). For the Gran Sasso and Monti della Laga National Park area, we administered the questionnaires only to farmers who herd animals outside of the park.

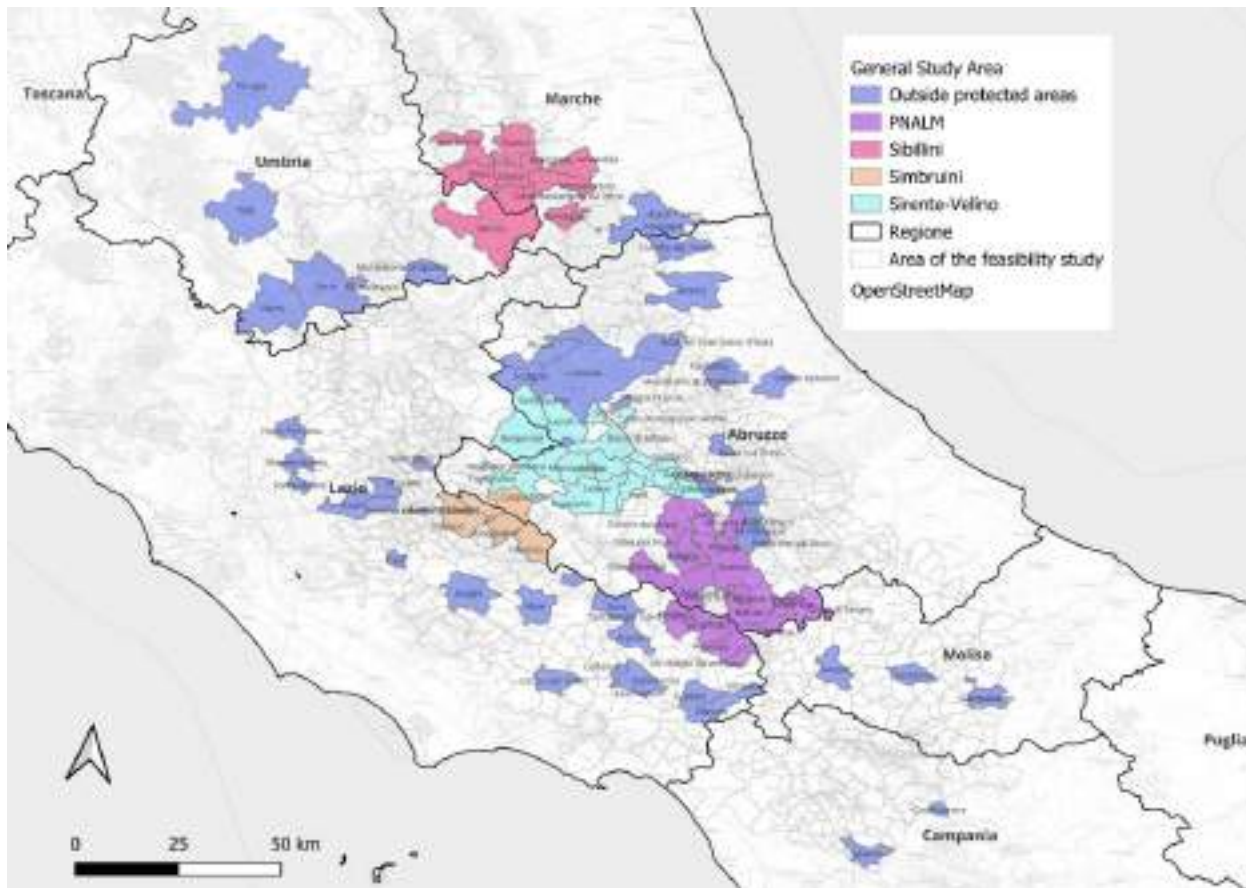


Figure 6. Map of the general study area, showing the 5 sub-areas.

Table 1. Interviews conducted and questionnaires filled, per area, within the study area.

Study sites (N=5)	Number of questionnaires conducted/distributed
Outside Protected Areas	142
Abruzzo, Lazio e Molise national park	93
Monti Sibillini National Park	83
Monti Simbruini Regional Park	32
Sirente Velino Regional Park	202
Total	552

Within each protected area, can we observe some differences of attitudes and interest for the feeding station between the core, buffer and border areas?

Criteria used to define the three zones:

Core area = at least 50% of the territory of the municipality lies within the protected area.

Buffer area = between 30 and 50% of the territory of the municipality lies within the protected area.

Border area = Less than 30% of the territory of the municipality lies within the protected area or municipalities that have a border with a municipality inside the core area or buffer area.

(ii) Spatial analysis based on existing colonies

How does the distance to a colony influence the perception, attitudes and interest to have a feeding station?

We have clustered the data according to three distance classes that reflect the different behaviours of griffon vultures:

- Municipalities within 10 km of at least one colony.
- Municipalities between 10 to 40 km of one colony.
- Municipalities further than 40 km of any colony.

Underlying hypothesis:

"In fact, feeding sites do not appear to be randomly distributed with respect to breeding colonies. Fifty percent of feeding events occur within a buffer zone of 10 km from them, while up to 90 percent of carrion are within 30-40 km (Posillico M. and R. Balestrieri. 2022)."

(iii) Spatial analysis based on future potential habitats

In which municipalities would the releases of the cinereous vultures and bearded vultures make the most sense?

Some groups of municipalities were defined according to the field report and to the group's expertise.

Table 2. Groupings of municipalities according to potential habitat identified for the cinereous and bearded vultures during the working group field trip and Raphaël Néouze field trip.

Field reports	Identified sites	Municipalities	Suitability		Score
			Cinereous vulture	Bearded vulture	
Raphaël Néouze	Gioia dei Marsi	Gioia dei Marsi	X		3/5
Raphaël Néouze	Camosciara	Villetta Barrea, Barrea	X	X	5/5
Raphaël Néouze	Monte Mattone	Villetta Barrea	X		4/5
Raphaël Néouze	Southern slopes of Monte Greco	Barrea		X	3/5
Raphaël Néouze	Vallone Santa Margherita	Pettorano sul Gizio	X		4/5
Field Trip Report	Castrovalva	Anversa, Villalago, Scanno	X		
Field Trip Report	FR/Monte Genzana	Scanno, Introdacqua	X		
Field Trip Report	Gole di San Venanzio	Raiano, Castel di Ieri, Goriano Sicoli, Castelvechio Subequo, Molina Aterno	X		
Field Trip Report	Gole di Celano	Aielli, Ovindoli, Celano	X		
Field Trip Report	Prati del Sirente	Gagliano Aterno, Rocca di Mezzo, Secinaro, Tione degli Abruzzi		X	
Field Trip Report	Valle Majelama/Magnola	Massa D'Albe, Ovindoli, Magliano de' Marsi	X		
Field Trip Report	Malecoste	L'Aquila, Pizzoli	X	X	
Field Trip Report	Monte Camicia (versante nord)	Farindola, Isola del Gran Sasso, Arsita, Castelli		X	
Field Trip Report	Monte Bove (versante nord)	Ussita, Castelsantangelo sul Nera	X	X	
Field Trip Report	Monte Vettore (versante sud-est)	Norcia, Montegallo, Montemonaco		X	
Field Trip Report	Campo di Giove	Campo di Giove		X	
Field Trip Report	Taranta Peligna	Taranta Peligna			
Field Trip Report	Vallone di Taranta Peligna	Taranta Peligna	X	X	
Field Trip Report	Gole di Fara San Martino	Fara San Martino	X	X	
Field Trip Report	Gole della Valnerina	Visso, Preci	X		

2.3. Scores calculations

Knowledge Score (a)

The knowledge score is the average of the scores of the variables listed below. Since the last two questions only concern the farmers, the score has been calculated separately for farmers and for the general public, and both have then been converted to adhere to a 1 to 10 scale.

(i) Have you ever heard of griffon vultures? (ii) How do you know/heard of it? (iii) Can you recognize it from these images? (iv) What do you think griffon vultures feed on? (v) Vultures like the griffon vulture have always been a part of central Apennine environments. (vi) By eating dead livestock, vultures prevent the spread of disease.

Note: we have removed the questions about the recognition of cinereous and bearded vultures as only 13 farmers knew how to recognize them.

- Have you ever heard of griffon vultures?
- How do you know/heard of it?
- Can you recognize it from these pictures?
- What do you think griffons feed on?
- [Farmers only] Vultures such as griffon vultures have always been part of central Apennine environments?
- [Farmers only] By eating dead livestock, vultures prevent the spread of disease.

Attitudes Score (b)

The attitude score has been calculated as a mean of the following 4 questions for the general public and only from the first question for farmers. It was calculated on a scale from -1 to 2 (using the criteria shown further below) and has then been scaled on a range from 0 to 10.

Question asked to both farmers and the general public:

Può indicare un aggettivo che caratterizza il grifone?

Can you name an adjective that characterises the griffon vultures?

Negativo= -1;Neutro/Descrittivo/Non saprei=0;Bello o utile=1;Bello e utile=2

Negative= -1;Neutral/Descriptive/Don't know=0; Beautiful or useful=1; Beautiful and useful=2

Negative

Responses showing negative emotions towards vultures

Examples: animali inutili portano malattie, dannoso, inutile, invasivo (useless animals that bring diseases, harmful, useless, invasive)

Neutral/Descriptive

Responses showing indifference towards the species or using an adjective only describing the animal without showing any positive or negative emotions

Examples: *indifferente, enorme, non dà fastidio, brutto, selvaggio* (indifferent, huge, does not bother, ugly, wild)

Positive: beautiful or useful

Responses focusing on the positive aesthetics of the species or on its function in the ecosystem. By “utile” - useful, we refer to the mention of the importance of the species within the ecosystem. Replies were from the point of view of its direct utility (“spazzino” - *scavenger* is the world that comes out the most, then comes “utile”) or for its general role within the ecosystem

Examples: *bello, simpatico, spettacolare, maestoso, utile, spazzino* (beautiful, nice, spectacular, majestic, useful, scavenger)

Much positive: beautiful AND useful

Replies including both aspects.

Examples: *Maestoso & ecologicamente fondamentale, Maestoso e utile per l'ambiente* (Majestic & ecologically fundamental, Majestic & environmentally useful)

Questions asked only to the general public

- Having vultures/griffon vultures in your region is for you: Completely negative; Negative; Neither negative nor positive; Positive; Completely positive
- I believe that the presence of vultures/griffon vultures in my area can increase tourism
- I believe that vultures/griffon vultures are important in maintaining the balance of nature.

Collaboration Scores (c)

Collaboration scores have been calculated as the mean of the interest to use a feeding station for the farmers and as the interest to include a touristic activity for tourism providers. They have been analysed separately for farmers and the general public. Below are the questions considered for these scores. Both scores have then been scaled on a range from 0 to 10.

(i) Would you be interested in using a feeding station nearby (>60 km) to dispose of carcasses? (ii) Would you be interested in including an activity (tour, observation...) related to griffon vultures in your current tourist activity?

Question asked to farmers

Sarebbe interessato ad avere un carnaio nelle vicinanze (<60 km) per smaltire le carcasse?

Would you be interested in having a feeding station nearby (<60 km) to dispose of carcasses?

No= -1; Non saprei=0; Sì=1

No= -1; Don't know=0; Yes=1

Question asked to the general public

Sarebbe interessato/a ad includere un'attività (tour, osservazione...) legata ai grifoni nella sua attuale attività turistica?

(Would you be interested in including an activity (tour, observation...) related to griffon vultures in your current tourist activity?)

Completamente contrario= -2; Non interessato/a=-1; Né contrario né favorevole =0; Interessato/a=1; Molto interessato/a=2

(Completely opposed= -2; Not interested=-1; Neither opposed nor favourable =0; Interested=1; Very interested=2)

Poison Score (d)

The score of the perception of the poisoning threat represents has been calculated from the following answers to farmers (i) and to the general public (ii) and then scaled from 0 to 10. When both scores of farmers and the general public were analysed together, the replies made by the farmers were simplified as *yes, no or I wouldn't know*.

(i) Do you think that, for vultures in particular, the use of poison is a threat in the area where you live? (ii) Do you think that the use of poison in the area where you live could be a threat to wild animals?

Question asked to the farmers

Pensa che per gli avvoltoi in particolare l'uso del veleno sia una minaccia nella zona in cui vive?[-4;0]

Do you think that, for vultures in particular, the use of poison is a threat in the area where you live?

Grave minaccia= -4; Minaccia media=-3; Piccola minaccia=-2; Nessuna minaccia=-1

(Serious threat= -4; Medium threat=-3; Small threat=-2; No threat=-1)

Question asked to the general public

Lei pensa che l'uso del veleno nella zona in cui vive possa essere una minaccia per gli animali selvatici?[-1;1]

Do you think the use of poison in the area where you live could be a threat to wild animals?

No= -1; Non saprei=0; Si=1 (No=-1; Don't know=0; Yes=1)

2.4. Potential Biases and limits

Self-selection bias of the general public (Bethlehem, 2010): This phenomenon occurs when individuals voluntarily choose to participate in a survey or study, leading to a sample that may not be representative of the broader population because it predominantly consists of people who already agree with or support the organisation conducting the survey. This bias can skew the results, which should be analysed cautiously as they may not accurately reflect the views of the wider population. To limit the impact of this bias, we always looked at the farmers' results separately.

Sampling of the farmers: This bias is due to our own capacity to reach out to the maximum number of farmers as well as to their availability and their willingness to talk to us. Within the Monti Simbruini Regional Park, all the contacts with the farmers have been done by two rangers from the park that were willing to help us. This implies that we might not have reached farmers out of their primary network.

Replies bias:

- Replies from farmers might have been biased as they were discussing with representatives of an environmental NGO (in particular regarding the questions about the poisoning threat).
- Responses might have differed according to the interviewers (4 different personalities).
- Replies from Pettorano sul Gizio are particularly positive, due to the fact that most members of Rewilding Apennines are living there.

3. Results

In total, we received 411 responses, of which 115 were out of the regions considered for the feasibility study, and 120 were within the provinces of the feasibility study but outside the griffon vultures range (as defined in Chapter 15).

3.1. Demographics of the study

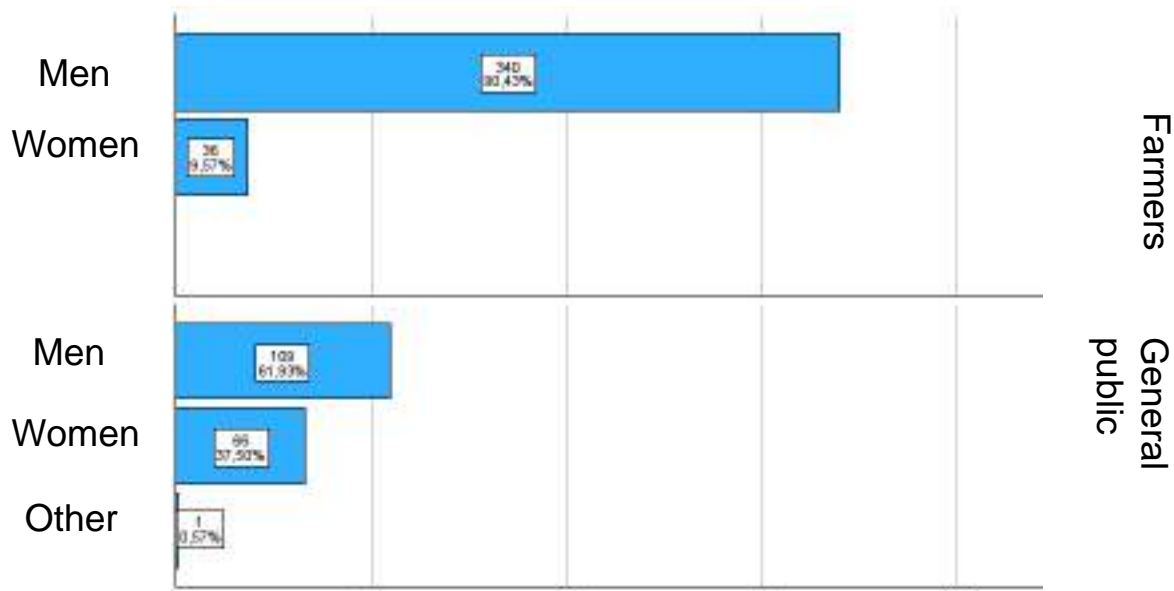


Figure 7. Gender

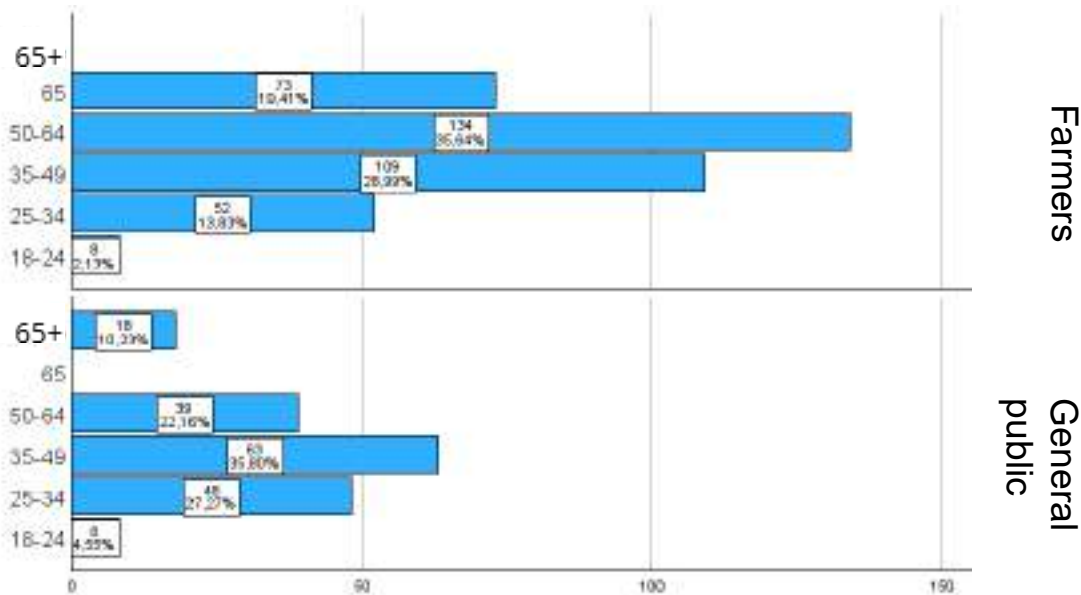


Figure 8. Age groups of respondents

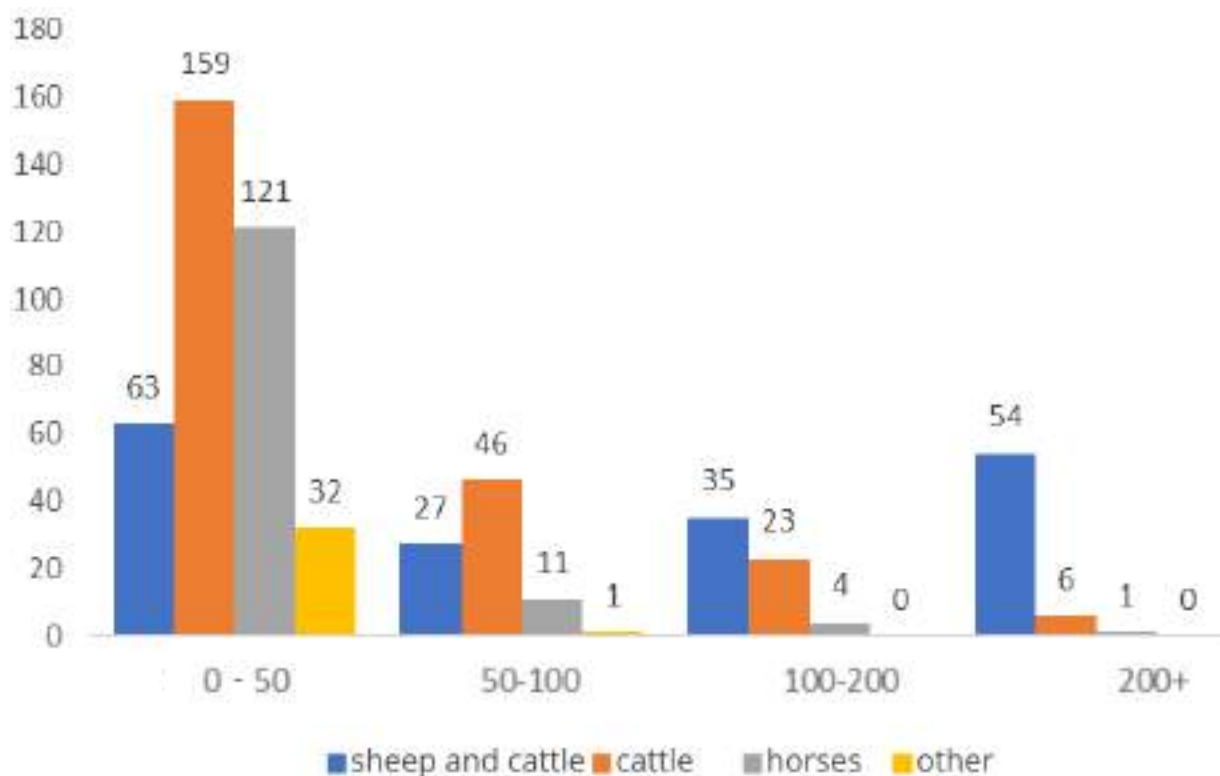


Figure 9. Type and quantity of livestock owned by farmers.

3.2. Statistics summary

Summary tables

Questions	Mean	Standard deviation	Variance
Hai mai sentito parlare dei grifoni?[-1;1] ¹ <i>Have you ever heard of griffon vultures?</i>	0.82	0.57	0.33
Come lo conosce/ne ha sentito parlare?[0;3] ² <i>How do you know/heard of it?</i>	2.25	1.11	1.24
Lo sa riconoscere da queste immagini?[-1;1] ⁸ <i>Can you recognize it from these images?</i>	0.18	0.92	0.85
Di cosa pensa che si nutrono i grifoni?[-2;2] ³ <i>What do you think griffon vultures feed on?</i>	1.51	1.06	1.12
[solo Allev.] Gli avvoltoi come il grifone fanno parte da sempre degli ambienti dell'Appennino centrale.[-2;2] ⁴ <i>[only farmers] Vultures such as griffon vultures have always been part of the central Apennines</i>	-0.32	1.32	1.73
[solo Allev.] Mangiando il bestiame morto gli avvoltoi prevengono la diffusione di malattie.[-2;2] ⁴ <i>[only farmers] By eating dead livestock, vultures prevent the spread of disease</i>	0.8	1.27	1.62

Può indicare un aggettivo che caratterizza il grifone?[-1;2] ⁵ <i>Can you name an adjective that characterises the griffon vultures?</i>	0.80	0.65	0.42
[solo Allev.] Sarebbe interessato ad avere un carnaio nelle vicinanze (>60 km) per smaltire le carcasse?[-1;1] ¹ <i>[only farmers] Would you be interested in having a feeding station nearby (>60 km) to dispose of carcasses?</i>	0.69	0.70	0.49
[solo Allev.] Sarebbe disposto a concedere parte del suo terreno per creare un carnaio?[-1;1] ⁷ <i>[only farmers] Would you be willing to concede part of your land to create a feeding station?</i>	-0.31	0.82	0.68
Lei pensa che l'uso del veleno sia una minaccia nella zona in cui vive?[-1;1] ¹ <i>Do you think the use of poison is a threat in the area where you live?</i>	0.26	0.93	0.87
[solo Allev.] Pensa che per gli avvoltoi in particolare l'uso del veleno sia una minaccia nella zona in cui vive?[-4;0] ⁶ <i>[only farmers] Do you think that for vultures in particular, the use of poison is a threat in the area where you live?</i>	-2.08	1.22	1.50
[solo PG.] Lei pensa che l'uso del veleno nella zona in cui vive possa essere una minaccia per gli animali selvatici?[-1;1] ¹ <i>[only general public] Do you think that the use of poison in the area where you live could be a threat to wild animals?</i>	0.95	0.30	0.09
[solo PG.] Avere avvoltoi/grifoni nella sua regione è per lei: Completamente negativo; Negativo; Né negativo né positivo; Positivo; Completamente positivo [-2;2] ⁹ <i>[only general public] Having vultures/griffon vultures in your region is for you: Completely negative; Negative; Neither negative nor positive; Positive; Completely positive</i>	1.49	0.73	0.54
[solo PG.] Credo che la presenza di avvoltoi/grifoni nella mia zona possa incrementare il turismo.[-2;2] ⁴ <i>[only general public] I believe that the presence of vultures/griffon vultures in my area can increase tourism.</i>	0.91	0.95	0.91
[solo PG.] Credo che gli avvoltoi/grifoni Siano importanti per mantenere l'equilibrio della natura.[-2;2] ⁴ <i>[only general public] I believe that vultures/griffon vultures are important in maintaining the balance of nature.</i>	1.64	0.58	0.34

Table 3. Summary table of the questionnaire

[solo allevatori] = questions asked only to farmers; *[solo PG.]* = questions asked only to the general public

¹No=-1; Non saprei=0; Si=1; ¹No=-1; Don't know=0; Yes=1

²Non sono sicuro=0; Social network/televisione=1; Solo di nome=1; Visto allo zoo=2; Visto in natura=3

²I'm not sure=0; Social network/television=1; By name only=1; Seen in the zoo=2; Seen in the wild=3

³Animali vivi=-2; Non saprei=0; Carcasse&altro=1; Solo carcasse=2; ³Living animals=-2; Don't know=0; Carcasses&other=1; Carcasses only=2

⁴Completamente in disaccordo=-2; Molto in disaccordo=-1; Né d'accordo né in disaccordo=0; Molto d'accordo=1; Completamente d'accordo=2; ⁴Completely disagree=-2; Very much disagree=-1; Neither agree nor

disagree=0; Very much agree=1; Completely agree=2

⁵*No=-1; Neutro/Descrittivo/Non saprei=0; Bello o utile=1; Bello e utile=2; ⁵Negative=-1; Neutral/Descriptive/Don't know=0; Beautiful or useful=1; Beautiful and useful=2*

⁶*Grave minaccia=-4; Minaccia media=-3; Piccola minaccia=-2; Nessuna minaccia=-1;*

⁶*Serious threat=-4; Medium threat=-3; Small threat=-2; No threat=-1*

⁷*No=-1; Non sono proprietario/non risposto=0; Si=1; ⁷No=-1; I am not an owner/no answer=0; Yes=1*

⁸*No/Sbaglia=-1; Non saprei/Nessuna risposta=0; Si=1; ⁸No/Wrong=-1; Don't know/No answer=0; Yes=1*

⁹*Completamente negativo=-2; Negativo=-1; Né negativo né positivo=0; Positivo=1; Completamente positivo=2*

⁹*Completely negative=-2; Negative=-1; Neither negative nor positive=0; Positive=1; Completely positive=2*

Table 4. Descriptive statistics for each of the four scores

Descriptive statistics	Knowledge	Attitudes	Interest to use a feeding station [Farmers]	Interest to include a touristic activity related to vultures [Tourism providers]	Perception of poison
Average	6.9	6.0	8.4	7.4	6.6
Median	7.5	6.7	10.0	7.5	10.0
St. deviation	2.5	2.2	3.5	2.8	4.7
Range	10	10	10	10	10
Minimum	0	0	0	0	0
Maximum	10	10	10	10	10
N	552	552	376	87	552

Knowledge score

- The knowledge of griffon vultures is on average relatively high (6.9), although higher among the general public than the farmers. This could partly be explained by the self-selection bias of the general public.
- On average the general public shows a higher knowledge of griffon vultures than the shepherds ($t(df) = -6.722, p < 0.01$) (Table 4 and Figure 10).
- The knowledge about the two other species of vultures is almost null among the farmers (13 out of 376 could recognize them in pictures) (Table 4).
- Regarding the historical presence of the species, it has been found that a majority of farmers (44.5%) believe they have been introduced by humans and have not always been part of the environment of the central Apennines. Many farmers explained that because they had never heard of their grandparents telling about vultures, they thought they had never been present in the past. 31% of the respondents had no idea about the answer.
- On average, farmers agreed that griffon vultures are preventing the spread of diseases (60%) (Table 3).
- Recognizing griffon vultures on the pictures was the question that got the largest part of wrong answers (Table 3).
- Within the Abruzzo, Lazio e Molise national park, a low knowledge score has been observed in Alvito.



Figure 10. Mean (and 95% confidence intervals) knowledge score of Farmers and the General Public.

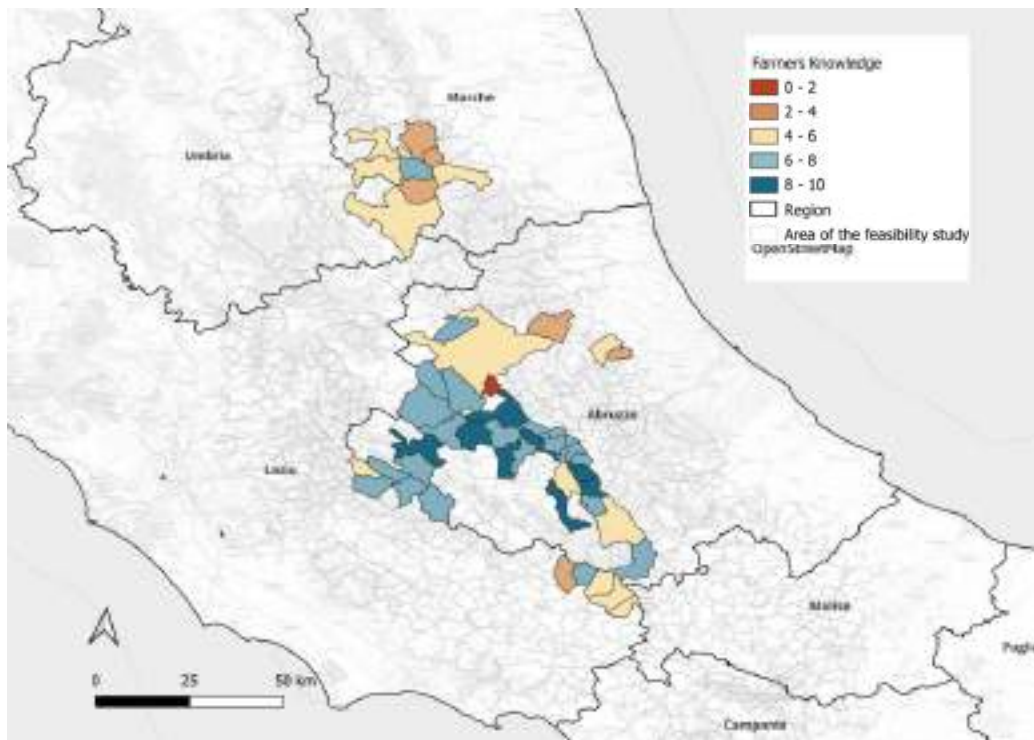


Figure 11. Distribution of farmers' knowledge mean scores attributed to each municipality.

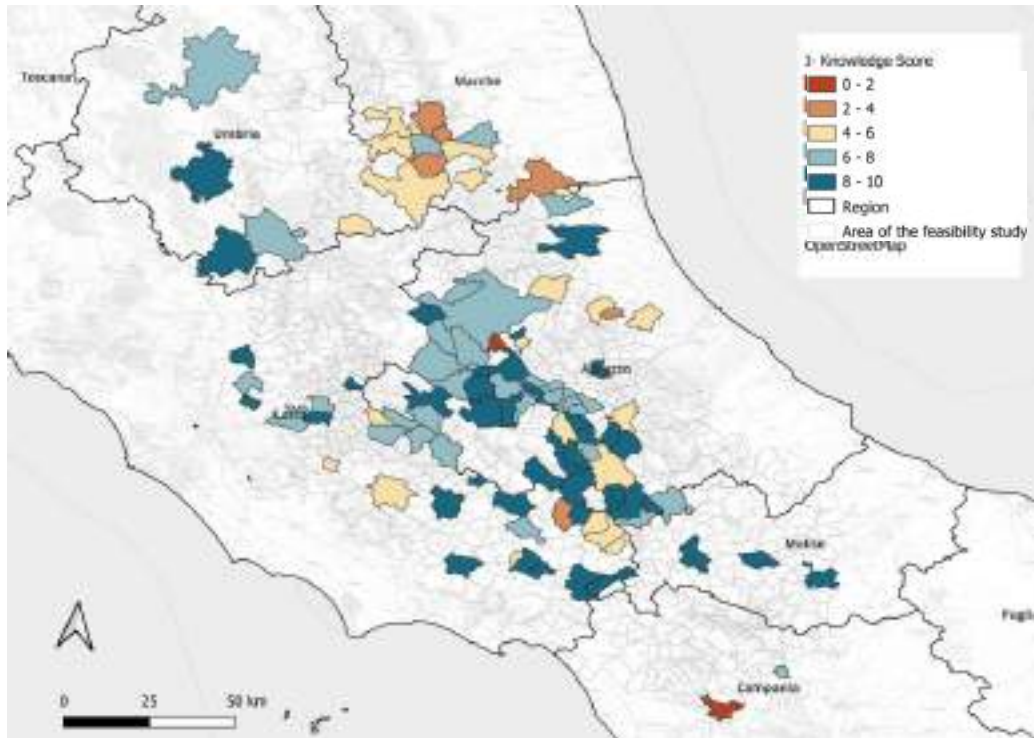


Figure 12. Distribution of both farmers and the general public knowledge mean scores according to each municipality

Attitudes

- Overall attitude quite neutral, i.e. neither positive nor negative (6) (Figure 13).
- We observed a significantly more positive attitude towards vultures from the general public than from farmers (Figure 13).
- On average the general public attributes more positive adjectives than the shepherds ($t(df) = -13.4, p < 0.01$)
- One municipality showed a particularly low score: Ocre. Only a few other municipalities showed low scores (Figure 15).



Figure 13. Mean (and 95% confidence intervals) attitudes of Farmers and the General Public.

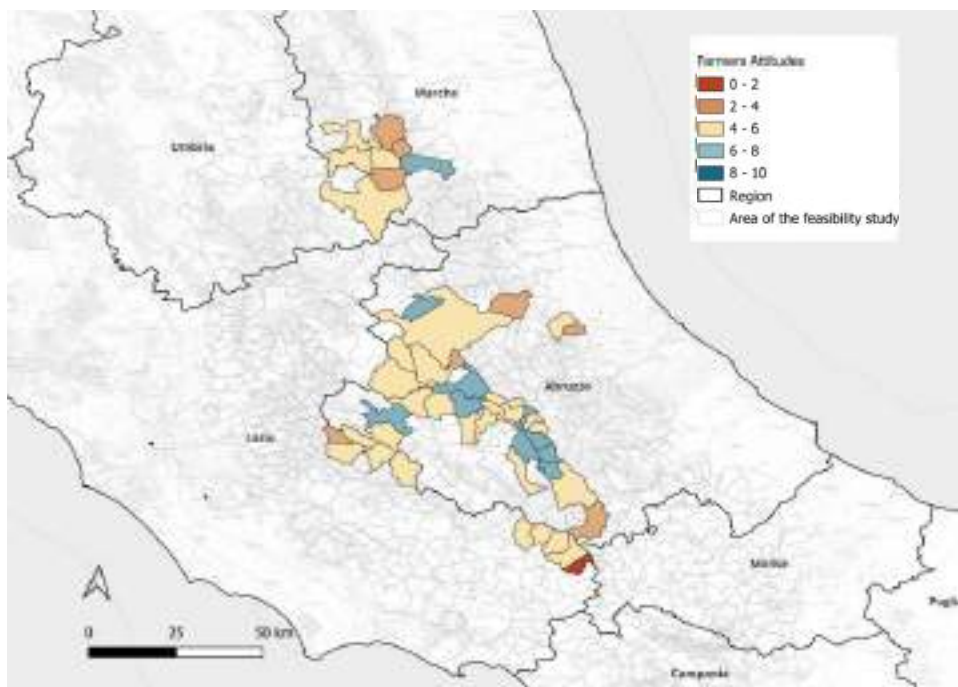


Figure 14. Map illustrating the attitudes mean scores attributed to each municipality for farmers.

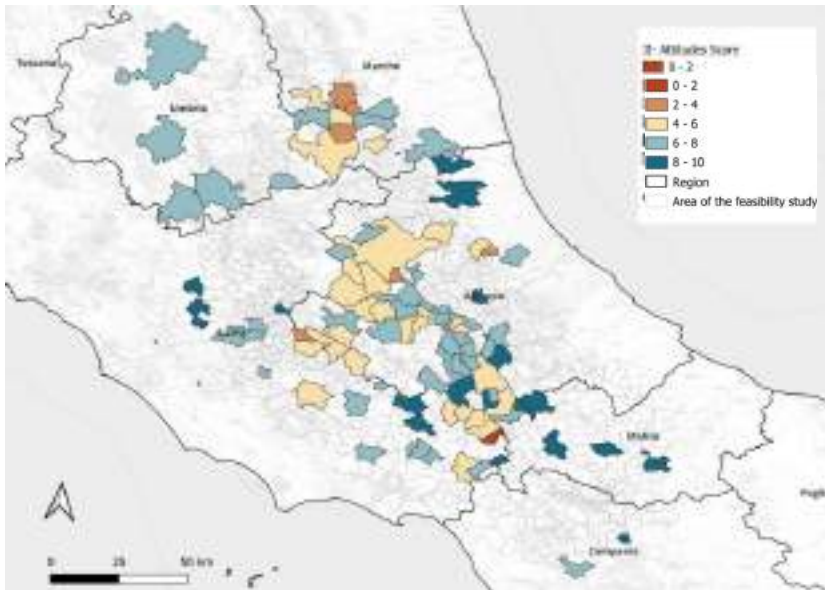


Figure 15. Map illustrating the attitudes mean scores attributed to each municipality for both farmers and the general public

Willingness to collaborate

- Overall high interest to use a feeding station from the farmers, apart from the Simbruini, with a special interest in the Sibillini (Figure 17).
- Overall high willingness to collaborate (Figure 17 and Figure 18).
- Out of the 87 people having a touristic activity who answered the questionnaire, only 2 were against (Barrea and Aielli) and 11 not interested (Figure 16).

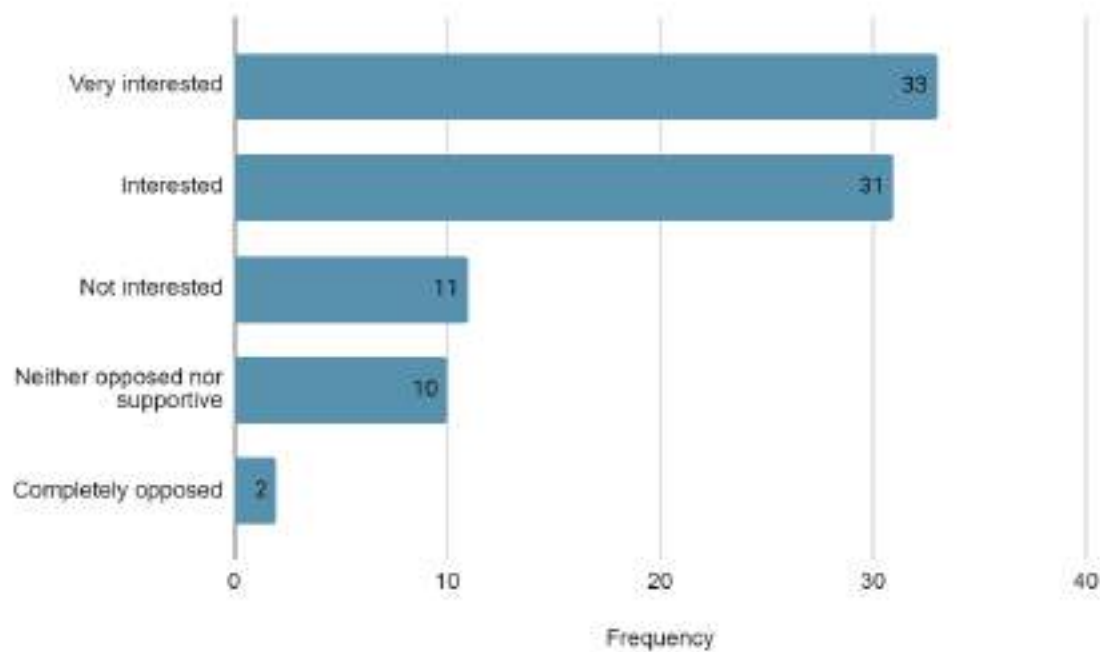


Figure 16. Frequencies of the replies to the question: Would you be interested in including an activity (tour, observation...) related to griffon vultures in your current tourist activity?

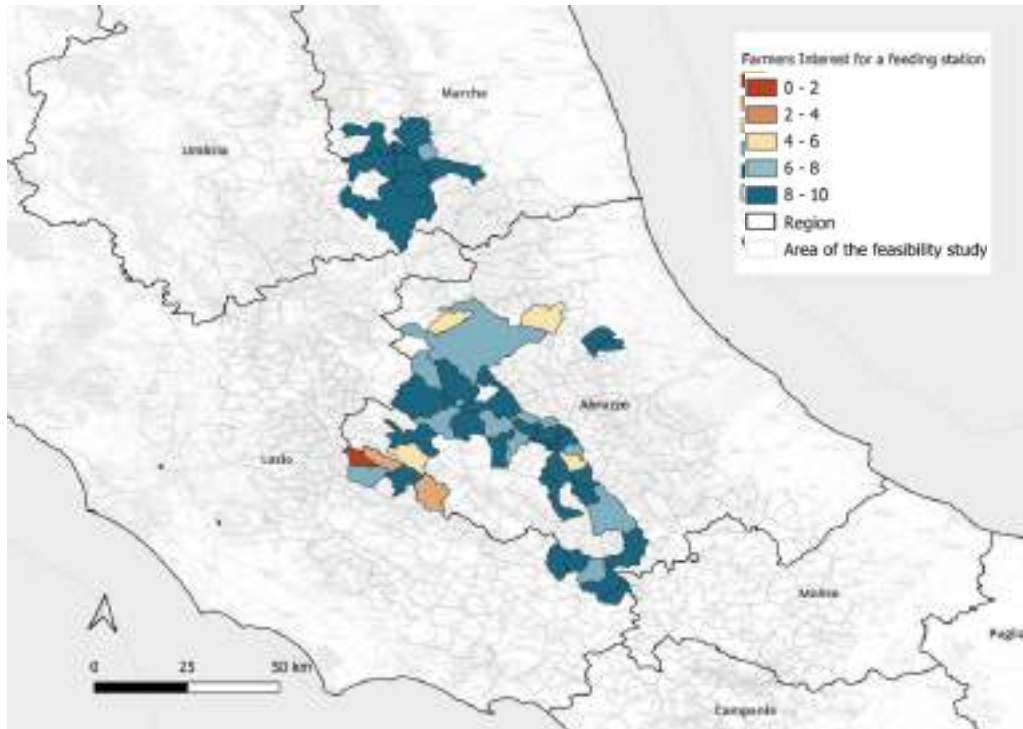


Figure 17. Map illustrating the interest for a feeding station mean scores attributed to each municipality for farmers.

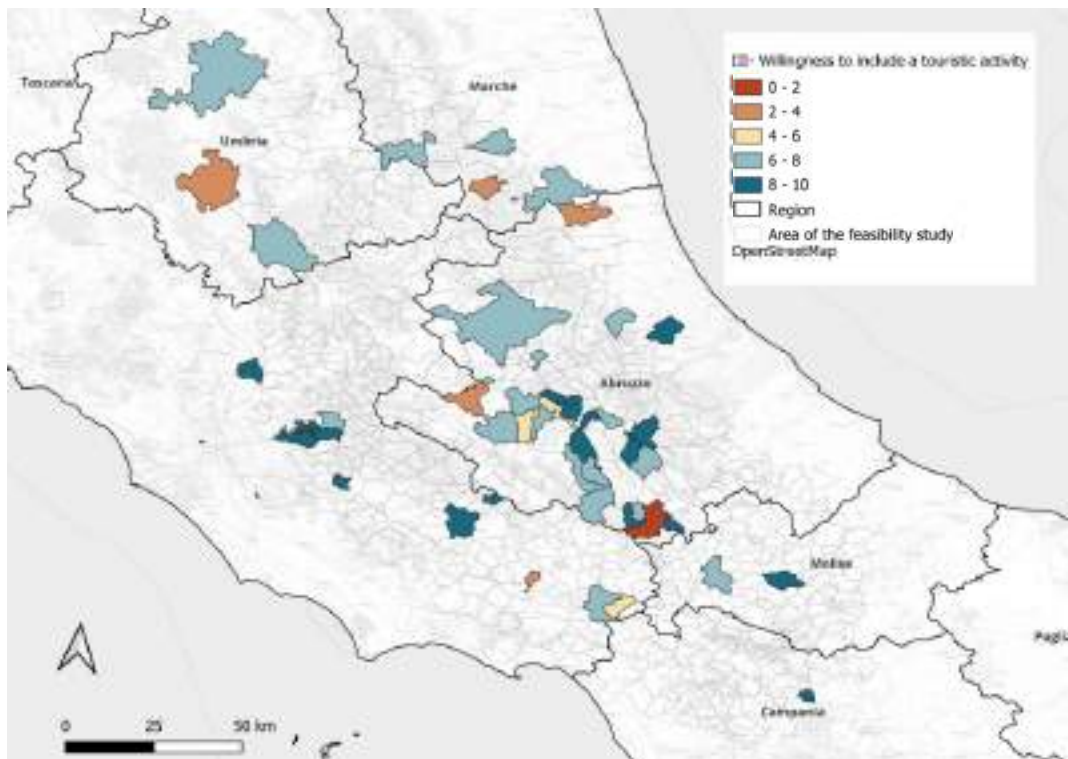


Figure 18. Map illustrating the interest to include an activity related to vultures in their touristic activities attributed to each municipality for farmers.

Perception of poison as a threat

- The use of poison for wild animals is considered as a threat for wild animals by most of the general public (170 out of 176), but only by a small majority of farmers (190 out of 376). On average, the general public tends to say that the poison is a threat to wildlife, much more than farmers do ($t(df) = -11.870, p < 0.01$) (Figure 19).
- For farmers, it is not considered a threat for wild animals in only 9 municipalities out of 47.

Notes: We need to take into account two important elements when analysing the answers of the farmers to the questions about the threat of poisoning for wildlife in the future: (i) we can never be sure of their honesty as they were replying to a person representing an NGO protecting wildlife; (ii) assessing the level of risk of poisoning was not an easy exercise, some typical answers were “there has never been a poisoning case here so this is not a risk”, “with the huge poisoning event of this year in Cocullo this should not happen again”, or “here they put a lot of poison for [truffle] dogs but I am not sure it would be also a threat to griffon vultures”.

Some farmers were also very direct and expressed their wish to use poison themselves.

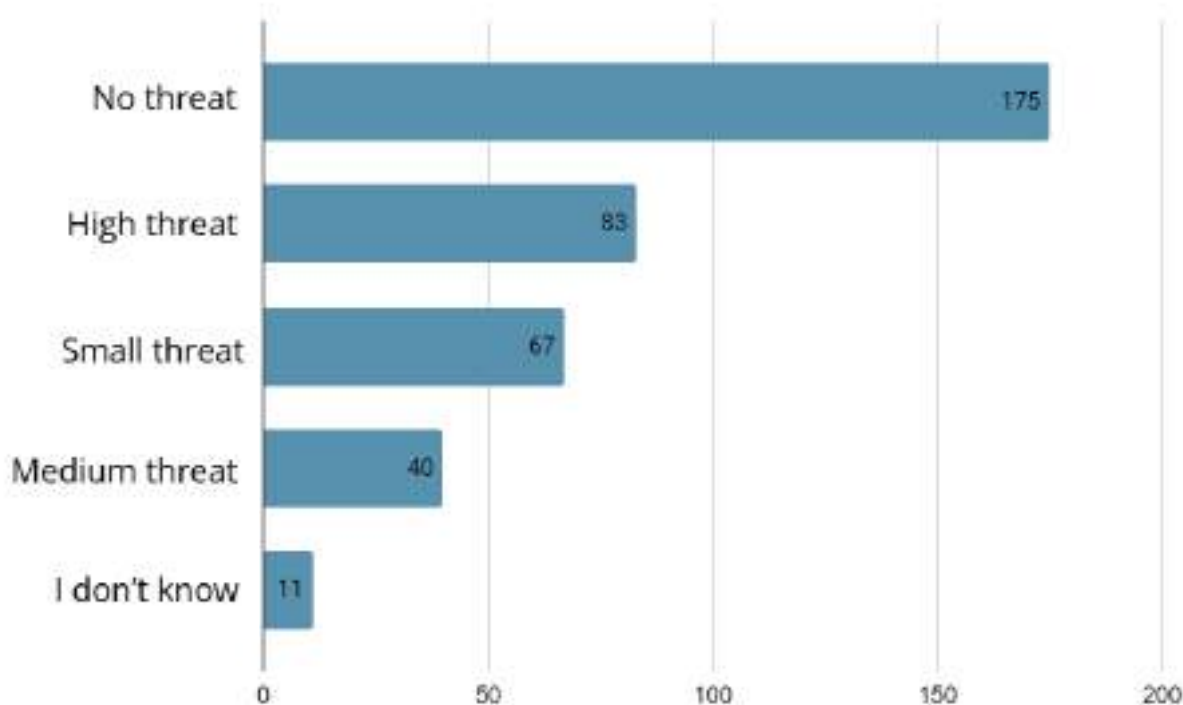


Figure 19. Frequencies of the replies to the question: Do you think the use of poison in the area where you live could be a threat to wild animals?

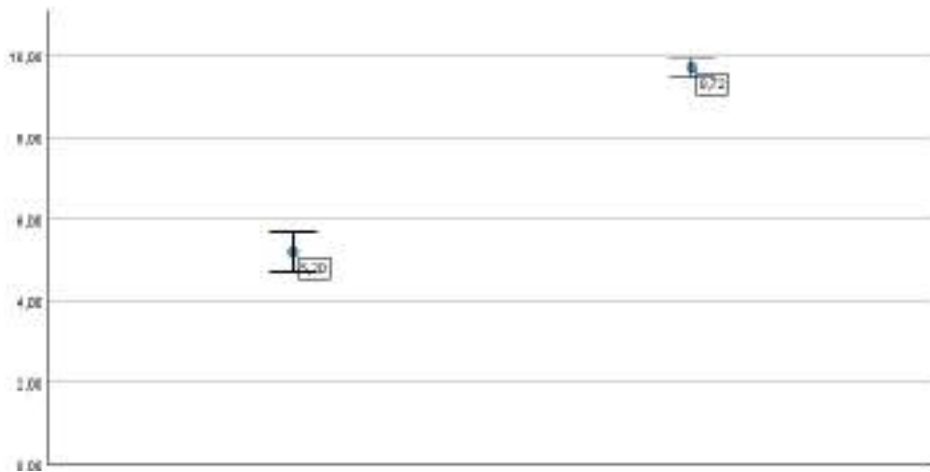


Figure 20. Mean (and 95% confidence intervals) poison perception score of Farmers and the General Public.

3.3. Spatial analysis

(i) Spatial analysis based on protected areas

- We observed a similar level of knowledge within the three protected areas with the exception of Sibillini which showed a much lower score that can be explained by its distance to the current colonies.
- For both farmers and the general public, the Sirente Velino area and municipalities outside of the protected area show a notably higher prevalence of positive attitudes (Figure 21).
- We observed higher positive attitudes in the Sirente Velino and Abruzzo, Lazio e Molise national park than for the other parks (Figure 21)
- Within the Monti Sibillini National Park, even though the knowledge was very low, the interest to use a feeding station was very high and mostly motivated by economic reasons (Figure 21).
- The use of poison was considered as a threat for wildlife in the Abruzzo, Lazio and Molise National Park (7.2), in the Sirente Velino Regional Park (6.9) and outside of Protected Areas (7.6). In the Monti Sibillini National Park and in the Monti Simbruini Regional Park, respondents tended on average to be more uncertain about the threat (Figure 23)

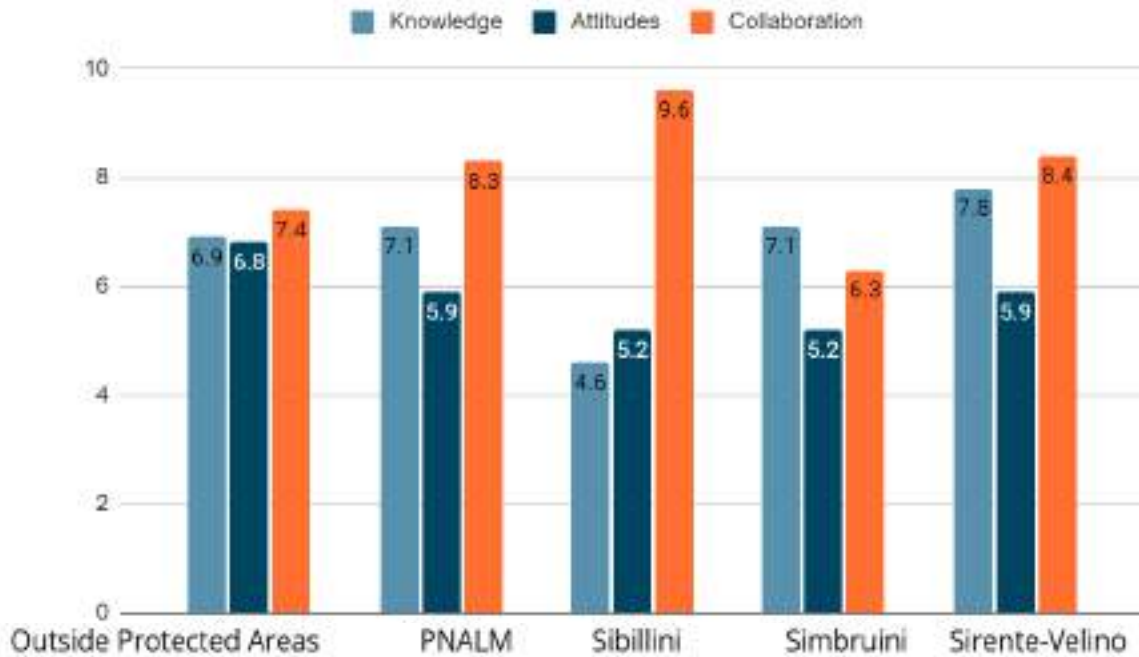


Figure 21. Knowledge, attitudes and collaboration mean scores for each protected area and for the areas out of investigated protected areas for both farmers and the general public.

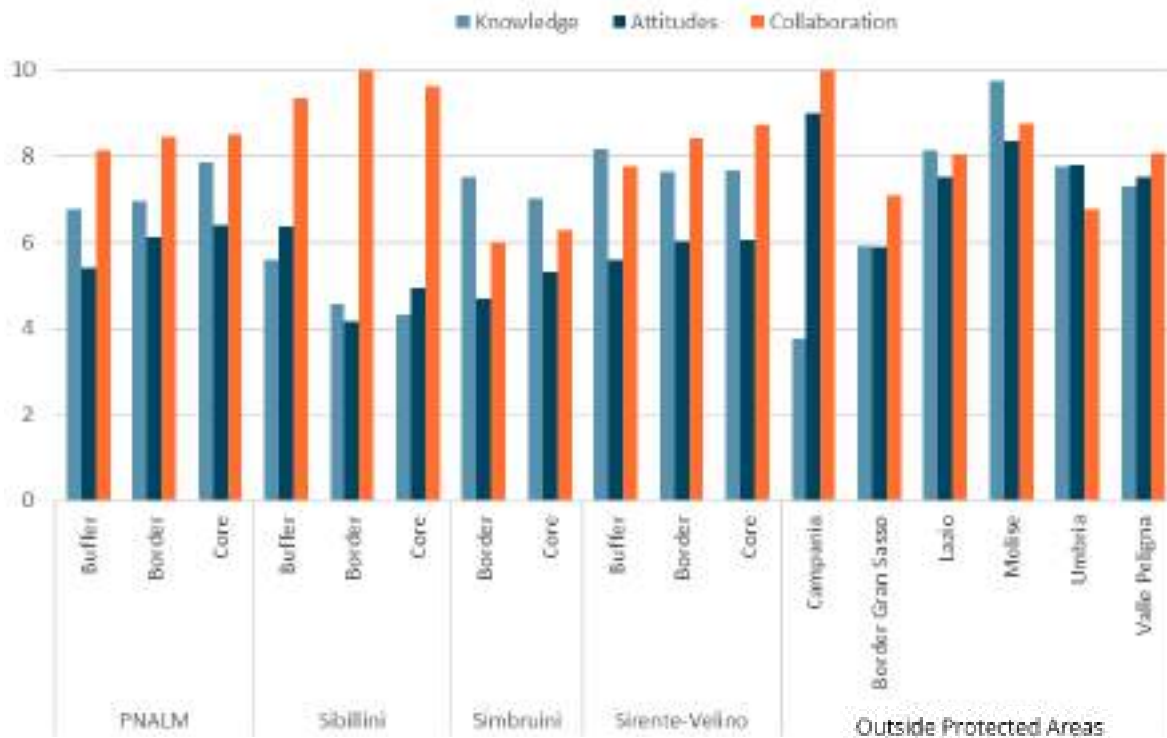


Figure 22. Knowledge, attitudes and collaboration mean scores for buffer, core and border areas within each protected area.

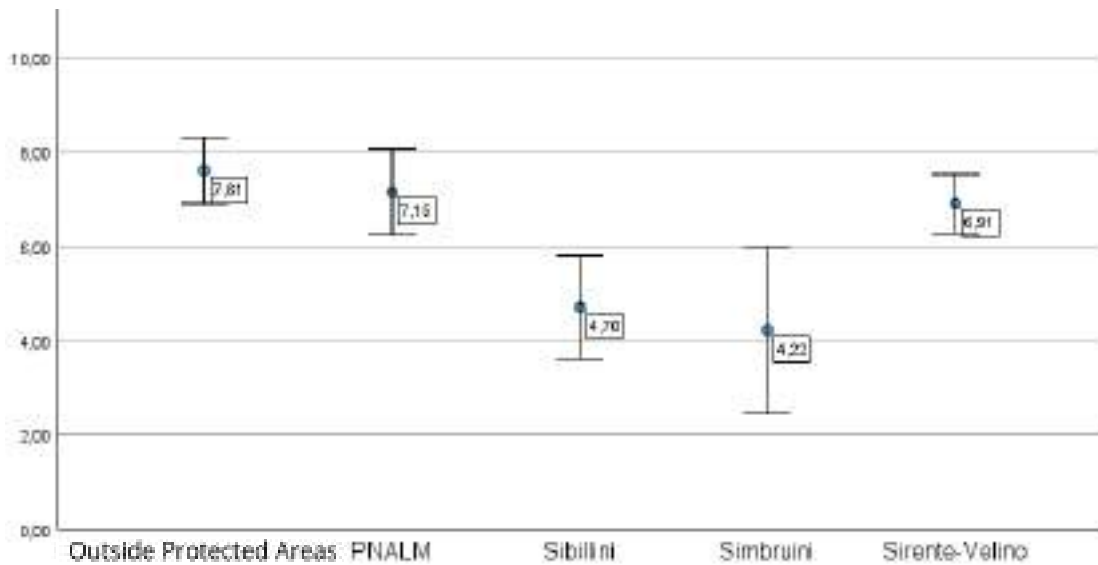


Figure 23. Mean (and 95% confidence intervals) poison scores both outside (F. Zone Protette) and within each of the 4 protected areas, where 10 represents the highest level of threat and 0 the lowest, a score of 5 represents the uncertainty of the respondents.

(ii) Spatial analysis based on existing colonies

- In the areas distant from the colonies (>40km), knowledge is significantly lower than in less distant areas. No significant knowledge difference has been observed in municipalities located less than 10km away from colonies and municipalities located between 10 and 40 km from colonies (figure 24).
- In the areas closer to the colonies (<10km), attitude scores are significantly lower than in more distant areas (figure 24).
- In the areas distant from the colonies (>40km), the willingness to collaborate is slightly higher than in less distant areas (figure 24).
- No significant difference has been found regarding the perception of the poison as a threat for wildlife (figure 25).

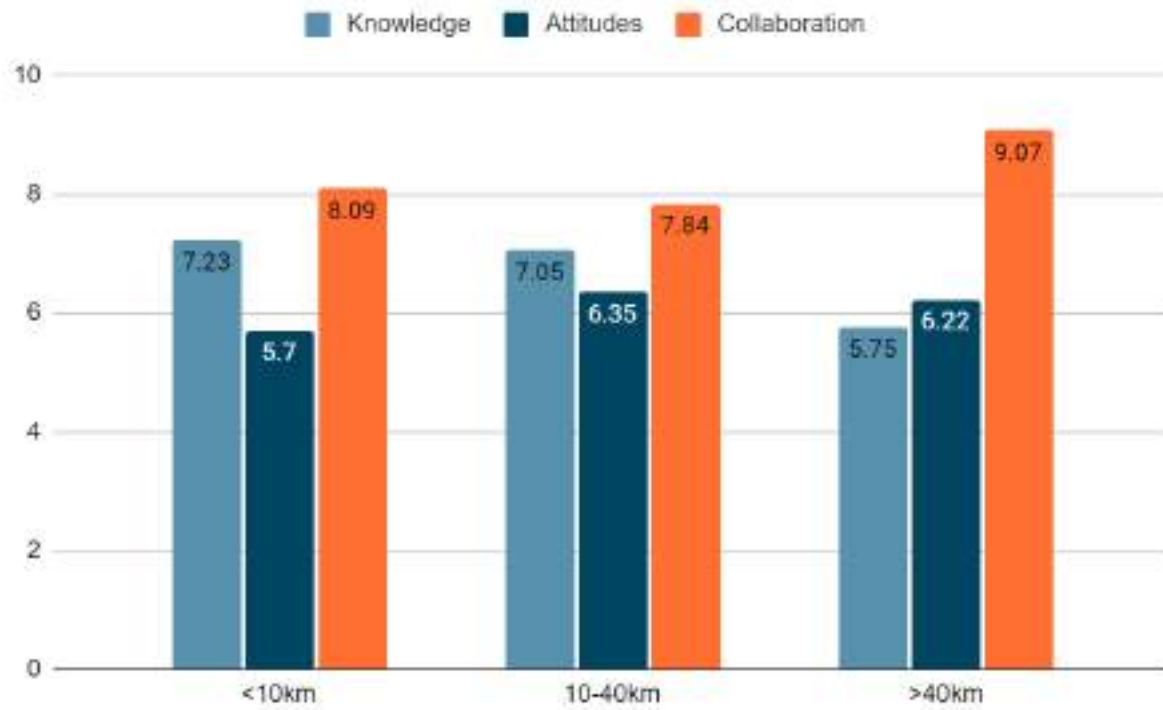


Figure 24. Knowledge, attitudes and collaboration mean scores in relation to the minimum distance to a griffon vulture colony.

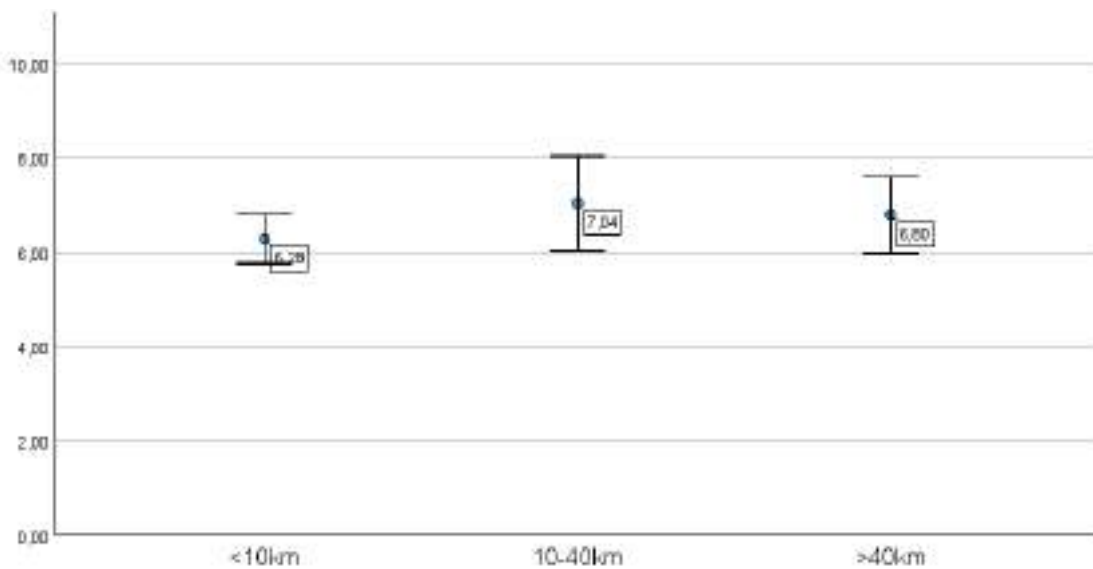


Figure 25. Mean (and 95% confidence intervals) poison perception score in relation to the minimum distance to an existing colony of griffon vultures.

(iii) Spatial analysis based on future potential habitats

Vallone Margherita shows high knowledge and attitudes scores due to the very strong presence of Rewilding Apennines, farmers would need to be interrogated as they were out of the scope of this survey (figure 26).

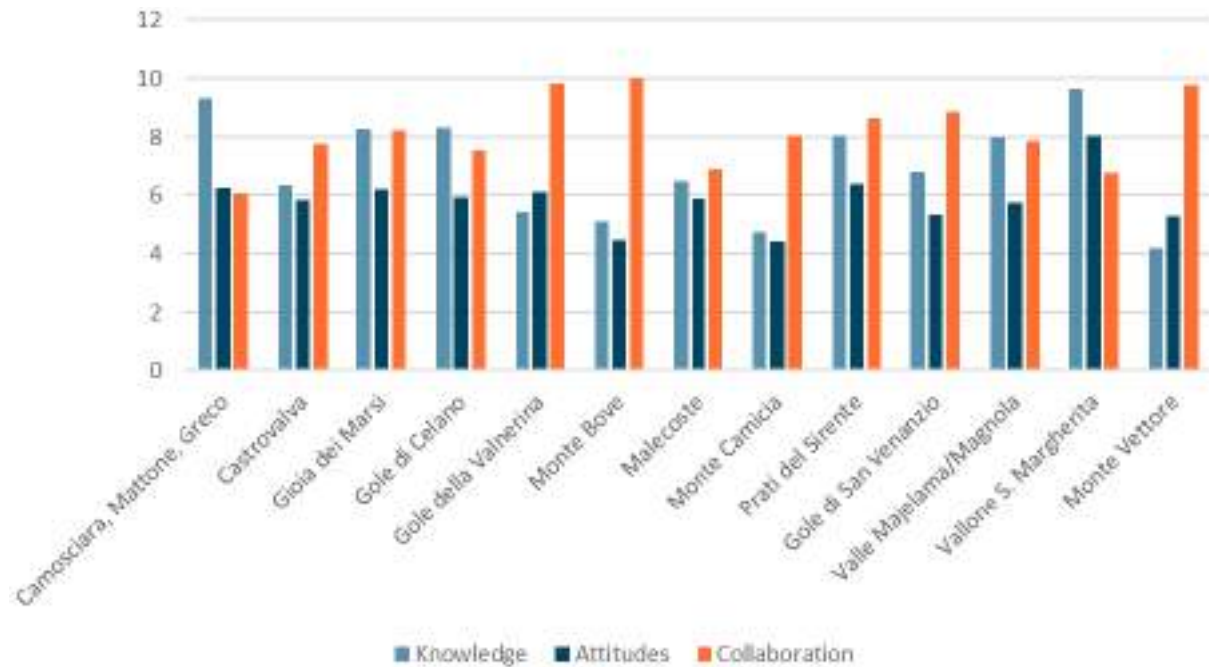


Figure 26. Knowledge, attitudes and collaboration mean scores in relation to the minimum distance to a colony of griffon vultures.

3.4. Qualitative analysis

The following descriptions are summaries of notes taken during discussions held during the interviews. They mostly concern the municipalities that revealed very low scores on all three aspects (knowledge, attitudes and collaboration) and one that revealed particularly high scores.



Figure 27. Municipalities showing very low or very high scores on all three aspects (knowledge, attitudes and collaboration)

Abruzzo, Lazio and Molise National Park

San Biagio Saracinisco (6 respondents)

Knowledge is very low (5) due to the recent presence of griffon vultures (3-4 years); notably negative attitudes, due to perception it is an obstacle to receive compensation for wolf predation (“Il grifone è un problema perché mangia le carcasse prima che arrivino i controlli.”, “Il grifone senza orso o lupo va bene”, *“The griffon vulture is a problem because it eats carcasses before controls arrive.”*, *“The griffon vulture without bear or wolf is fine”*) as well as negative attitudes towards wild animals in general “Non ce li mettete questi altri!”, *“Don't put these others there!”*. Several speeches of farmers were showing strong support to killing wild animals “Ci vuole il fucile”, *“It takes the rifle.”*.

Scanno (12 respondents)

We observed overall low scores, particularly due to a low-level knowledge as griffon vultures are rarely frequenting the area (one even showed confusion with the grey heron), even though there are still some memories from the reintroduction of griffon vultures at Frattura in the 2000-2002s. Attitudes were slightly positive and the interest of using a feeding station fairly positive.

“non fanno parte da sempre dell'Appennino centrale perché sono stati reintrodotti”

“they have not always been part of the central Apennines because they were reintroduced.”

“non voglio un carnaio perché portano malattie brutte”

“I don't want a feeding station because they [griffon vultures] bring bad diseases.”

Sirente Velino Regional Park

Goriano Sicoli (4 respondents)

Average knowledge score and neutral attitudes. Overall, a negative score due to one particularly opposed to wild animals and institutions managing them (in particular the Sirente Velino Regional Park) *“Li sparerei tutti gli avvoltoi. E pure a voi vi sparerei tutti. Vattene”*. *“I would shoot them all the vultures. And I would shoot you all as well. Go away.”*

Tornimparte (19 respondents) only farmers

Knowledge score was just below average and the attitude score was slightly positive. A slight majority is interested in using a feeding station but it seems like almost everyone buries the carcasses, some feed them to dogs. Several farmers also expressed their fears that the feeding station could attract wolves. Another fear that was expressed was the following: “Griffons eat wolves' prey, which they are then forced to prey on again.”; “I am contrary to griffons because they bring nothing good to the land.”

Magliano de Marsi (10 respondents)

Knowledge score was above average and the attitude score was quite low. We noticed a strong dislike from locals with respect to park administration. We heard a lot of complaints about the loss of product

quality, related to the shepherd's trade becoming increasingly difficult as well as strong complaints about wolves.

Rocca di Mezzo (7 respondents, all farmers)

All farmers were particularly willing to dialogue and supportive of the project. They revealed a particularly high knowledge of griffon vultures as well as very positive attitudes. All of them declared they were interested in using a feeding station.

Monti Simbruini Regional Park

Filettino (4 respondents)

The overall knowledge calculated was medium low and attitudes turned out to be fairly positive (respondents saying either that they don't bother or that the species is useful). A majority of farmers interviewed showed no interest in the feeding station as they leave the sheep in the mountains for the dogs/wolves.

Camerata Nuova (6 respondents)

Locals reported several owners who live in Rome and, according to them, do not know much about the area or their own animals, which are cared for by workers.

Farmers showed an average knowledge and fairly positive attitudes. However, the majority was not interested in using a feeding station.

"If there are griffon vultures eating carcasses, wolves are forced to hunt more animals."

"questo non è il loro ambiente naturale"

"this is not their natural environment".

Monti Sibillini National Park

Fiastra (4 respondents)

We observed very little knowledge, quite neutral attitudes and a high interest to use a feeding station. They do not know about vultures but have not complained about reintroductions considering their presence in earlier times and the fact that they do not cause problems for livestock.

Bolognola (4 respondents)

We noticed very little knowledge, negative attitudes (mostly due to a low knowledge) and very slight interest in the feeding station. Two farmers showed their disagreement with the reintroduction project.

Castelsantangelo sul Nera (5 respondents)

Knowledge seems quite poor, with several people thinking griffon vultures carry diseases because they eat carcasses, and very neutral attitudes (no opinion or only mentioning their ugliness). However, all 5 farmers showed an interest in the feeding station.

There is already a feeding station in the municipality but it is unused: some say the mayor never gave the okay to start it, ranchers claim the park threw away or pocketed the construction money.

4. Discussion

This sociological survey provided valuable insights into several key aspects related to the reintroduction of the two species of vultures but also in the protection of griffon vultures. As anticipated, knowledge about griffon vultures is substantial near existing colonies, although awareness of their historical presence in the region prior to reintroduction, as well as their role in disease prevention, remains limited. Additionally, awareness of the other two vulture species is almost non-existent. The survey also underscored the necessity of prioritising efforts toward coexistence with large carnivores.

The maps generated during the analyses are poised to serve as valuable tools for guiding various field activities, including the selection of optimal locations for feeding stations, as well as informing strategic decisions regarding communication efforts and campaign targeting.

Exploratory inquiries into respondents' perceptions of poison as a threat to wildlife in their respective areas revealed widespread concern among farmers, many of whom actually agreed to respond positively to the question. Future investigations should include comparisons with poisoning models and delve deeper into the underlying factors driving this phenomenon to enhance understanding and allow effective interventions. Building on prior research on attitudes toward wolves and bears (Glikman et al., 2011; Glikman et al., 2023), semi-structured interviews could offer further insights into these drivers.

This study served as an initial platform for engaging with farmers across various priority areas for the project, fostering dialogue and demonstrating attentiveness to their perspectives. It also provided an opportunity to explore human-wildlife dynamics beyond the Abruzzo, Lazio, and Molise national park, which was the primary focus of previous efforts.

Further investigations should extend to additional areas, such as the Gran Sasso and Monti della Laga National Park and the Maiella National Park, which were not included in the current survey due to logistical constraints. These regions have been identified as potential habitats and warrant exploration in future research endeavours.

5. Conclusion

The primary findings stemming from the analysis are as follows. Knowledge levels regarding griffon vultures are relatively high on average, with notable disparities between the general public and farmers, potentially influenced by self-selection bias among the former. However, awareness of other vulture species among farmers is exceedingly low, with only a minority able to recognize them in pictures. Additionally, perceptions regarding the historical presence of vulture species indicate a prevailing belief among farmers that they were introduced by humans rather than being indigenous to the region. Attitudes toward griffon vultures were generally neutral, with a consistent sentiment across the four protected areas. Notably, discussions with farmers yielded a prevailing sentiment that vultures are non-

intrusive compared to other wildlife. Interest in utilising feeding stations was widespread among farmers, albeit accompanied by concerns about potential wolf attraction. Particularly, this interest was not strongly correlated with knowledge or attitudes toward vultures, but rather motivated primarily by economic considerations. Farmers from the Monti Sibillini National Park exhibited particularly high interest in feeding station usage despite low levels of vulture-related knowledge and neutral attitudes on average. A majority of the general public, along with most farmers, expressed concern toward the use of poison as a wildlife management tool, although exceptions were noted in select municipalities. Proximity to vulture colonies was associated with lower attitudes, while greater distance corresponded to lower knowledge coupled with higher willingness to collaborate. Identified potential future habitats, such as Vallone Santa Margherita, Gole della Valnerina, Monte Bove, and Monte Vettore, exhibited favourable attitudes and interest in utilising feeding stations and collaboration.

Several implications should be considered for the future reintroduction project. Addressing misinformation and fears surrounding vultures and feeding stations will be crucial within the project's communication campaign, particularly regarding historical vulture presence and concerns about wolf attraction. Perceptions regarding vulture-related compensation issues, particularly in San Biagio Saracinisco, warrant attention. Negative attitudes toward wolves and wildlife management institutions, coupled with poison considered as a major threat, necessitate further investigation to identify specific community concerns and potential intervention strategies. Promotion of feeding station usage should emphasise economic benefits and clarify that terrestrial carnivores cannot access these sites, mitigating common fears. The Sirente Velino Regional Park presents an opportune operational environment, while the Monti Sibillini National Park demonstrates promising intervention prospects given observed interest in feeding station utilisation.

In conclusion, this initial social feasibility analysis offers encouraging insights for the study area for vulture reintroduction efforts. Negative attitudes toward griffon vultures were notably absent, and a significant majority of farmers displayed enthusiasm for feeding station usage. Discussions underscored the prevalence of other wildlife-related concerns, particularly wolves, which merit focused attention during project implementation.

6. References

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7. Annexes

7.1. Spatial analysis based on protected areas - charts for each score

Knowledge

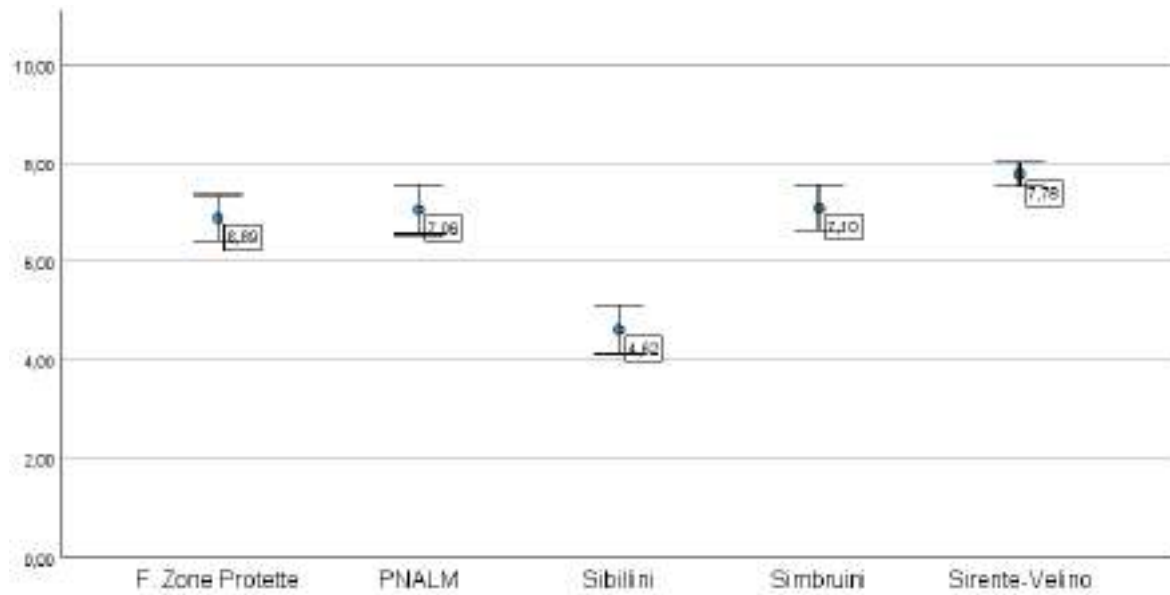


Figure 28. Mean (and 95% confidence intervals) knowledge scores within each of the 4 protected areas and outside (F. Zona Protette).

Attitudes

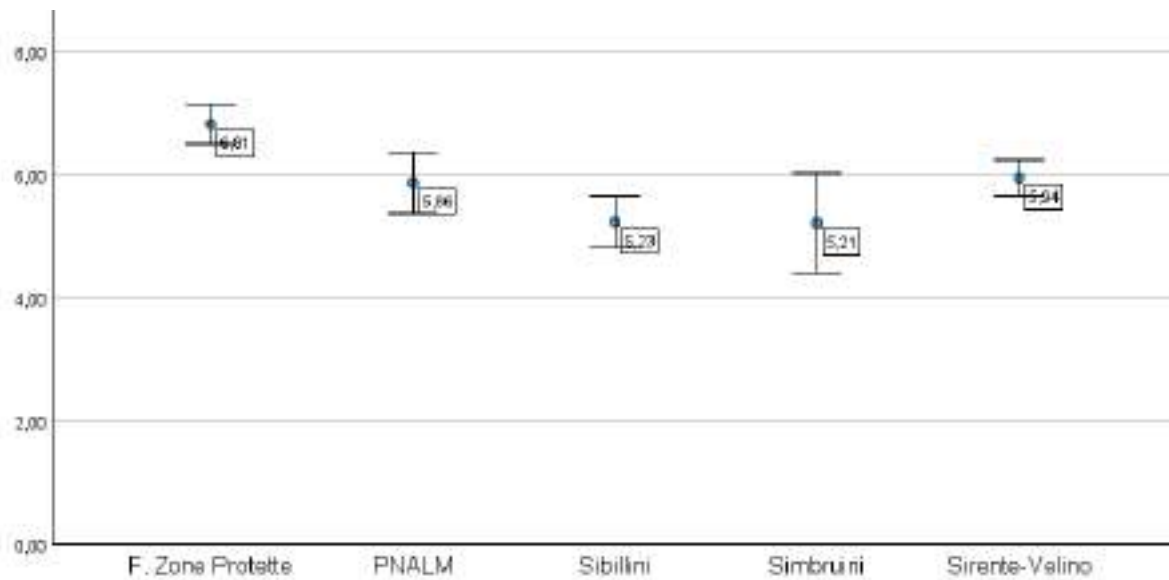


Figure 29. Mean (and 95% confidence intervals) attitude scores within each of the 4 protected areas and outside (F. Zone Protette) with 5% error bars.

Collaboration

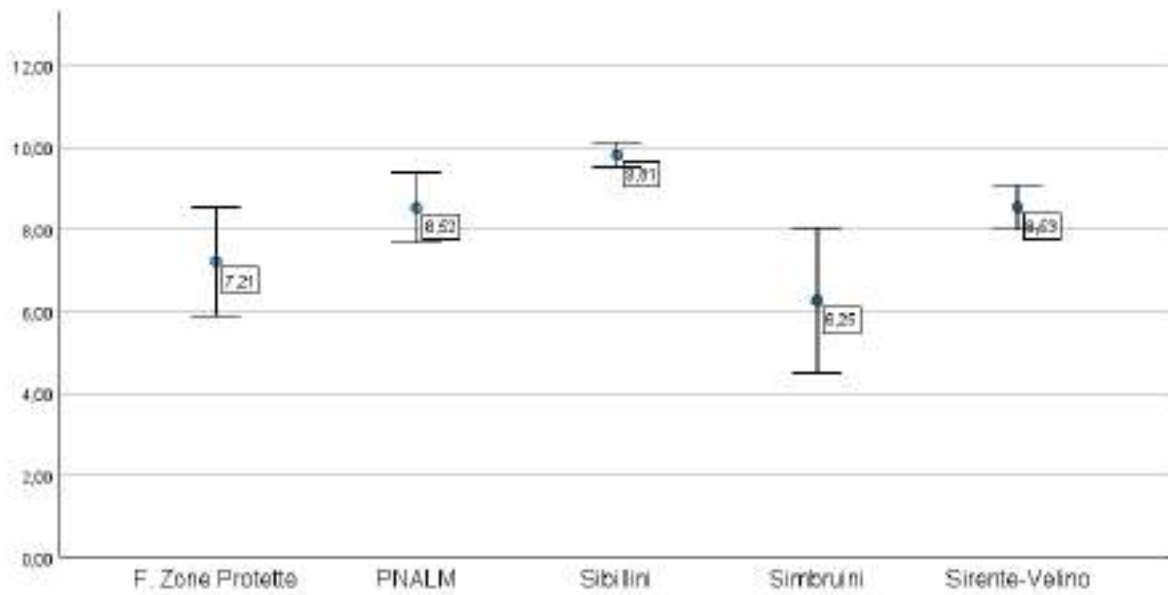


Figure 30. Mean (and 95% confidence intervals) interest to use a feeding station scores within each of the 4 protected areas and outside (F. Zone Protette).

7.2. Spatial analysis based on existing colonies - charts for each score

Knowledge



Figure 31. Mean (and 95% confidence intervals) knowledge score according to the minimum distance to an existing colony of griffon vultures.

Attitudes & tolerance

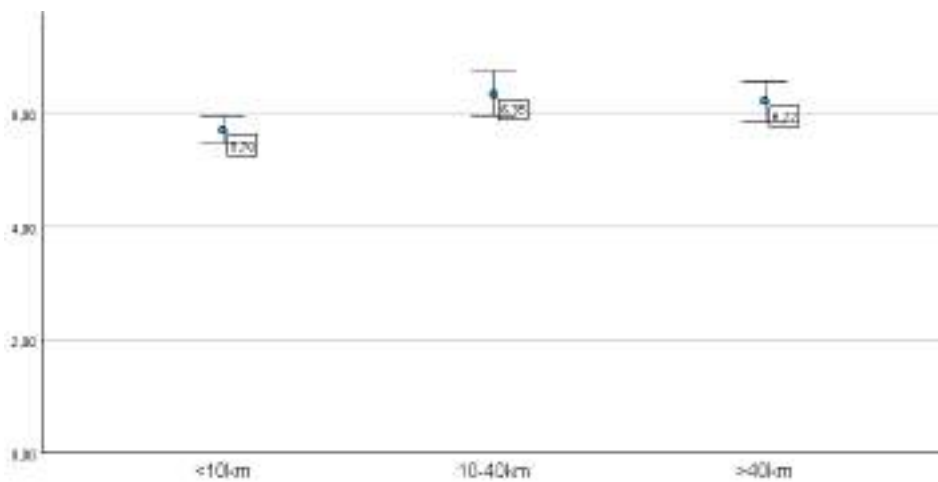


Figure 32. Mean (and 95% confidence intervals) attitude score according to the minimum distance to an existing colony of griffon vultures.

Willingness to collaborate

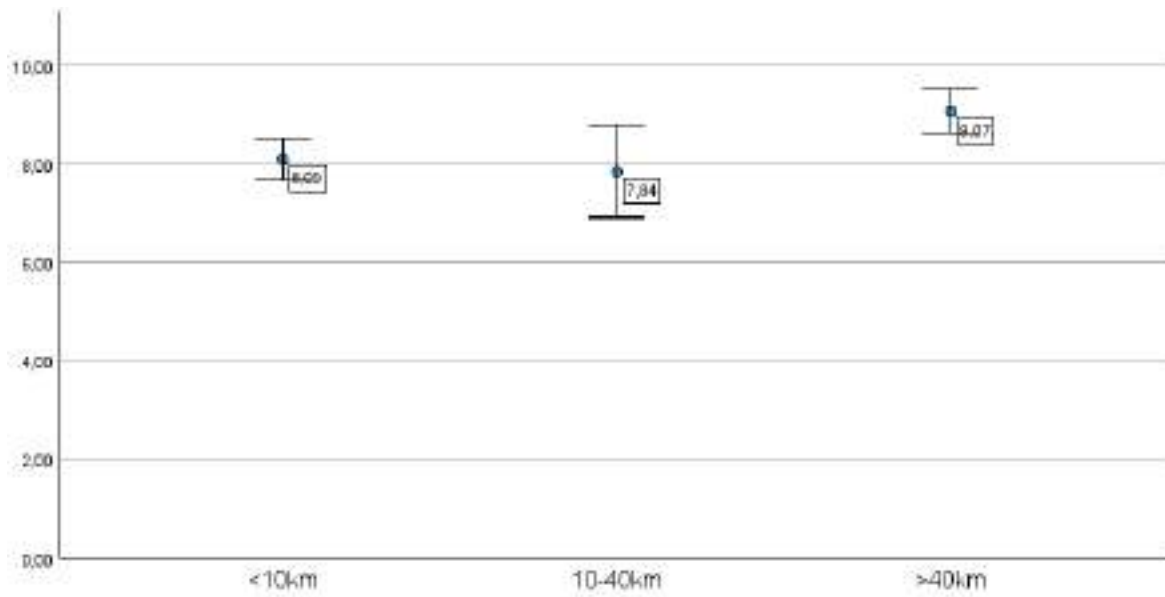


Figure 33. Mean (and 95% confidence intervals) collaboration score according to the minimum distance to an existing colony of griffon vultures.

7.3. Spatial analysis based on future potential habitats - charts for each score

Knowledge

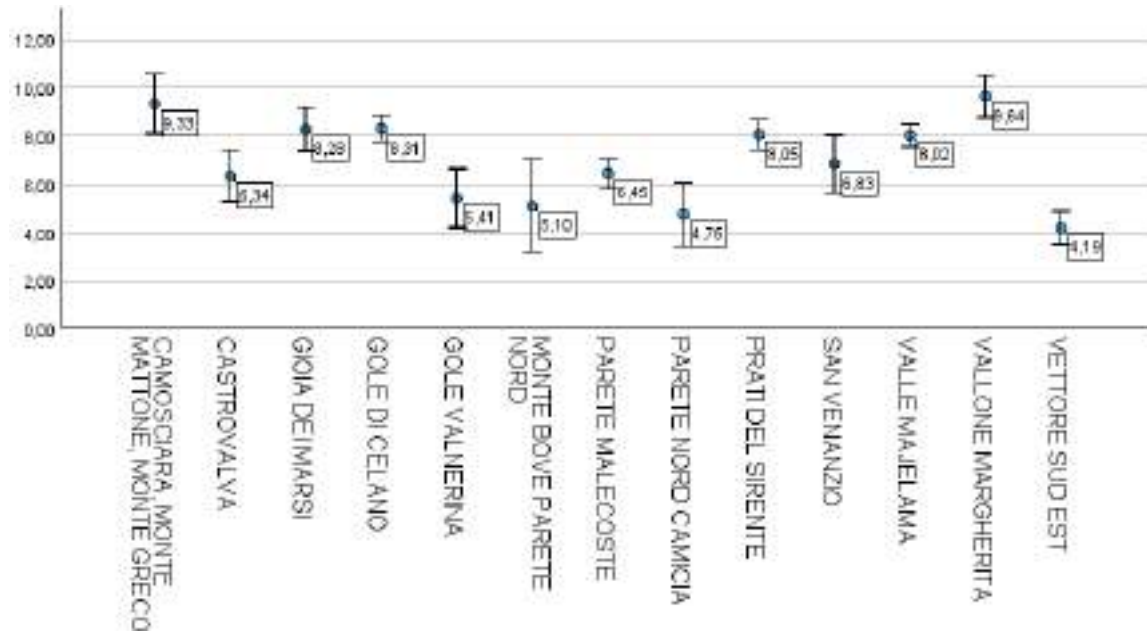


Figure 34. Mean (and 95% confidence intervals) knowledge score within clusters of municipalities close to habitats identified as potentially suitable for the cinereous and/or bearded vultures.

Attitudes

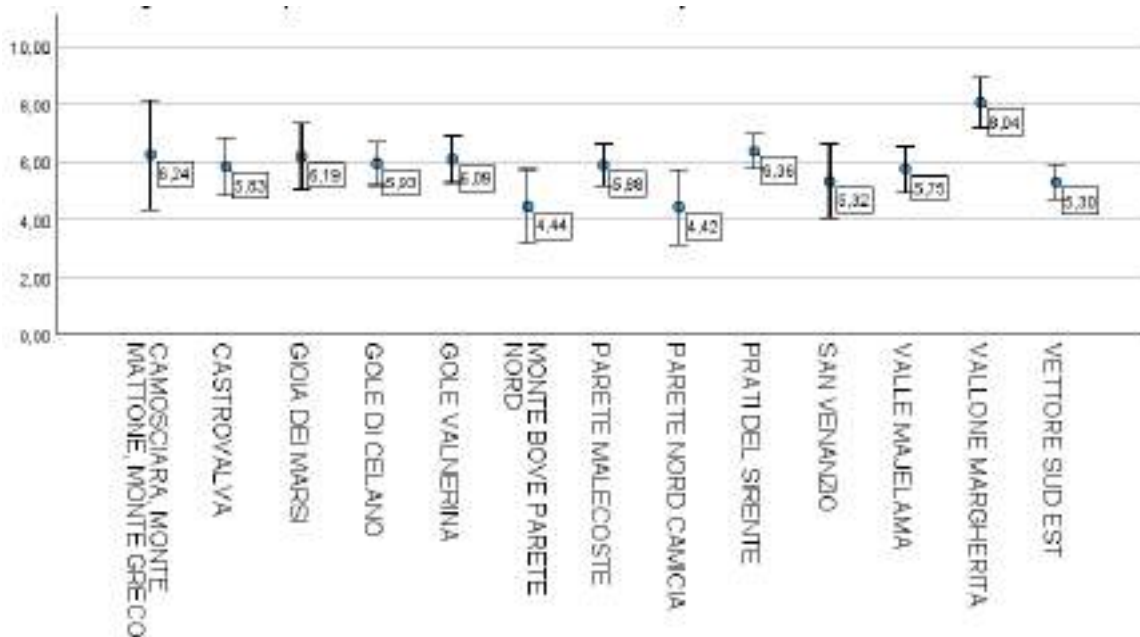


Figure 35. Mean (and 95% confidence intervals) attitude score within clusters of municipalities close to areas identified as potentially suitable for the cinereous and/or bearded vultures.

Willingness to collaborate

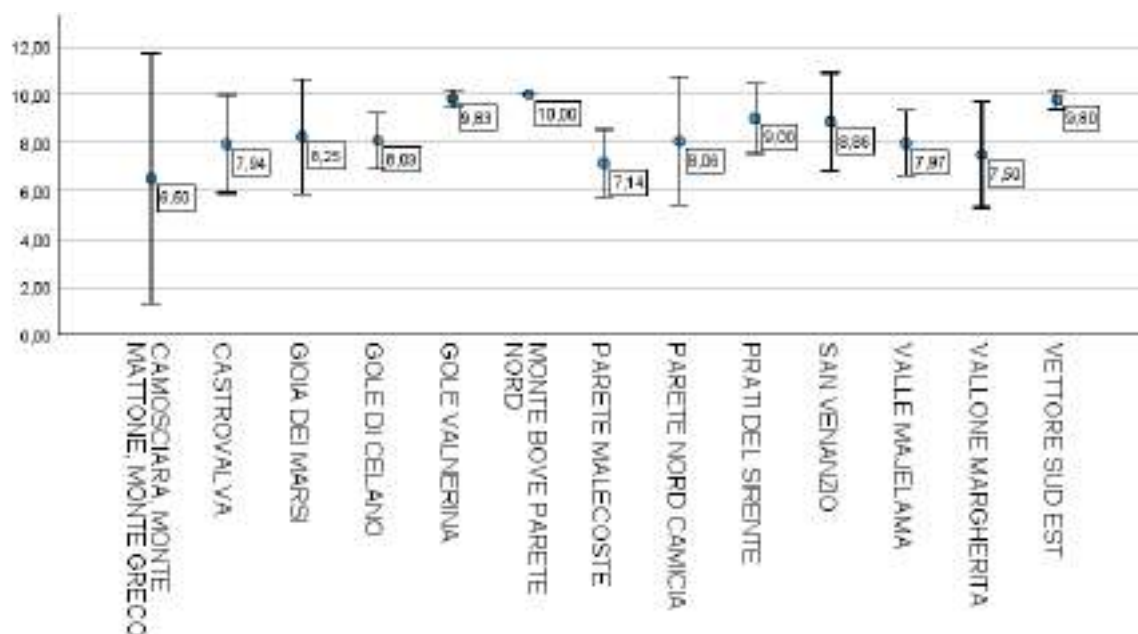


Figure 36. Mean (and 95% confidence intervals) collaboration score within clusters of municipalities close to habitats identified as potentially suitable for the cinereous and/or bearded vultures.

7.4. Methodology - Definition of core / buffer / border areas with respect with respect to investigated protected areas

Criteria used to define the three zones:

- Core area = at least 50% of the territory of the municipality lies within the protected area
- Buffer area = between 30 and 50% of the territory of the municipality lies within the protected area
- Border area = less than 30% of the territory of the municipality lies within the protected area or municipalities that have a border with a municipality inside the core area or buffer area.

Municipalities	Sub-groups ¹	% surface
Aielli	BF SV	41%
Avezzano	Cf SV	2%
Castel di Ieri	Cr SV	100%
Castelvecchio Subequo	Cr SV	100%
Celano	BF SV	46%
Gagliano Aterno	Cr SV	100%
Goriano Sicoli	Cr SV	100%

Lucoli	Cf SV	0%
Magliano de' Marsi	BF SV	38%
Massa d'Albe	Cr SV	73%
Ocre	Cr SV	52%
Ovindoli	Cr SV	100%
Rocca di Mezzo	Cr SV	100%
Secinaro	Cr SV	100%
Tagliacozzo	Cf SV	0%
Tornimparte	Cf SV	0%
Borgorose	Cf SV	0%
San Demetrio ne' Vestini	Cf SV	0%

Table 5. Zones of each municipality of the Sirente-Velino regional park

<https://www.regione.abruzzo.it/system/files/ambiente/tutela-territorio/vinca/172777/relazione-finale-pab-sic-sirente-velino.pdf>

Municipalities	Sub-groups	% surface within the protected area	% outer protection buffer (ZPE)
Alfedena	Cf PNALM	13.2%	0.0%
Anversa degli Abruzzi	Cf PNALM	0.0%	42.1%
Barrea	BF PNALM	43.6%	55.8%
Bisegna	Cr PNALM	98.7%	0.0%
Castel di Sangro	Cf PNALM	0.0%	22.8%
Civitella Alfedena	Cr PNALM	98.0%	2.0%
Cocullo	Cf PNALM	0.0%	39.9%
Gioia dei Marsi	BF PNALM	45.8%	29.8%
Introdacqua	Cf PNALM	0.0%	0.0%
Ortona dei Marsi	BF PNALM	30.8%	40.1%
Pescasseroli	Cr PNALM	98.6%	0.0%
Scanno	Cf PNALM	19.3%	60.0%
Scontrone	Cf PNALM	0.0%	96.9%
Villalago	Cf PNALM	0.0%	91.8%

Villavallelonga	BF PNALM	37.4%	62.2%
Villetta Barrea	Cr PNALM	59.2%	40.7%
Alvito	Cf PNALM	5.7%	18.2%
Picinisco	Cr PNALM	60.2%	28.7%
San Biagio Saracinisco	BF PNALM	39.3%	21.9%
San Donato Val di Comino	Cf PNALM	5.8%	60.7%
Settefrati	BF PNALM	30.6%	52.0%

Table 6. *Zones of each municipality of the Abruzzo, Lazio e Molise national park*

https://www.mase.gov.it/sites/default/files/archivio/allegati/aib/piano_aib_pn_ALM_2017_2021.pdf

Municipalities	Sub-groups	% surface within the protected area
Montegallo	Cr Sibillini	60%
Amandola	BF Sibillini	36%
Montefortino	Cr Sibillini	65%
Bolognola	Cr Sibillini	100%
Castelsantangelo sul Nera	Cr Sibillini	100%
Fiastra	Cr Sibillini	94%
Pieve Torina	Cf Sibillini	3%
Ussita	Cr Sibillini	100%
Visso	BF Sibillini	37%
Norcia	Cr Sibillini	54%

Table 7. *Zones of each municipality of the Sibillini national park*

<https://performance.gov.it/performance/piani-performance/documento/1669>

Municipalities	Sub-groups
Cappadocia	Cf Simbruini
Filettino	Cr Simbruini
Montefortino	Cr Simbruini
Camerata Nuova	Cr Simbruini
Cervara di Roma	Cr Simbruini
Subiaco	Cr Simbruini
Vallepietra	Cr Simbruini

Table 8. *Zones of each municipality of the Simbruini regional park*

7.5. Questionnaires conducted with farmers

#_____

Introduzione

Il seguente sondaggio è stato sviluppato da Rewilding Apennines, Jenny Glikman e Jacopo Cerri, Dottori in scienze sociali, nell'ambito dello studio di fattibilità della possibile reintroduzione di due specie di avvoltoi (l'avvoltoio-monaco e il gipeto) nell' Appennino centrale. Lo scopo del questionario è quello di valutare la conoscenza e la percezione degli avvoltoi nella stessa zona, l'interesse ad attivare punti di alimentazione supplementare per questi uccelli e l'interesse nell'ecoturismo associato.

Il questionario dura circa 5-20 minuti ed è confidenziale: le risposte che fornirete non verranno divulgate a terzi, se non dopo avere rimosso ogni informazione personale. I dati raccolti verranno trattati da Jenny Glikman, Jacopo Cerri e Rewilding Apennines. La raccolta, l'archiviazione e la condivisione dei dati raccolti durante il sondaggio avverranno in linea con il Regolamento Generale per la Protezione dei dati (<https://gdpr.eu/>).

Accettando di partecipare dichiari di 1) aver acquisito le informazioni fornite nell'informativa sulla privacy; 2) accettare volontariamente di accedere al questionario e di fornire le proprie risposte; 3) esprimere il consenso al trattamento dei dati per le finalità indicate.

Lei accetta di partecipare al sondaggio?

Sì No

Nome Cognome

Data e ora dell'intervista_____

Luogo dell'intervista_____

questionario _____

Sezione I: Informazioni personali

In quale comune vive attualmente? _____

Se diverso, in quale comune alleva ? _____

Qual è la sua età? (18-24 / 25-34 / 35-49 / 50-64 / 65 e oltre)

Qual è il suo genere? maschile / femminile

Quali animali allevate (spuntare)?

	Ovini e caprini	Bovini	Equini	Altro
Tra 0 e 50				
Tra 50 e 100				
Tra 100 e 200				
+				

Sezione II: Conoscenza delle specie

Q1: Ha mai sentito parlare di questi avvoltoi?

- Il grifone: Sì / No / Non saprei dire
- Il gipeto: Sì / No / Non saprei dire
- Il monaco: Sì / No / Non saprei dire

>Se no a tutto > andare direttamente alla sezione III

>Se Q1=sì, fare le seguenti richieste per le specie conosciute:

Q2: Come lo conosce/ne ha sentito parlare?

- Il grifone: Visto in natura / Solo di nome / Visto in tv o social network(facebook, instagram, twitter) / Visto allo zoo / Non sono sicuro
- Il monaco: Visto in natura / Solo di nome / Visto in tv o social network(facebook, instagram, twitter) / Visto allo zoo / Non sono sicuro
- Il gipeto: Visto in natura / Solo di nome / Visto in tv o social network(facebook, instagram, twitter) / Visto allo zoo / Non sono sicuro

Q3: Ha già sentito parlare della presenza dei grifoni nell'area in cui lavora/vive?

Si / No / Si ma in passato

Q4: Lo sa riconoscere tra queste immagini? (cf annex)

- Il grifone: Si / No
- Il monaco: Si / No
- Il gipeto: Si / Noo

Q5: Di cosa pensa che si nutrono i grifoni?

- Il grifone: Animali vivi / Carogne (carcasse) / Ossa / Non so
- Il monaco: Animali vivi / Carogne (carcasse) / Ossa / Non so
- Il gipeto: Animali vivi / Carogne (carcasse) / Ossa / Non so

Sezione II: percezione delle specie

Q6: Per ogni specie che conosce, può indicare un aggettivo che lo caratterizza (che aggettivo ti viene in mente? per esempio: utile, timida, minacciosa, iconica)

- Il grifone
- Il monaco
- Il gipeto

Q7: Può dirci quanto è d'accordo con la seguente affermazione? "Gli avvoltoi come il grifone fanno parte da sempre degli ambienti dell'Appennino centrale"

- Completamente in disaccordo
- Molto in disaccordo

- Né d' accordo né in disaccordo
- Molto d'accordo
- Completamente d'accordo

Q8: Può dirci quanto è d'accordo con la seguente affermazione? "Mangiando il bestiame morto, gli avvoltoi prevengono la diffusione di malattie"

- Completamente in disaccordo
- Molto in disaccordo
- Né in accordo né in disaccordo
- Molto d'accordo
- Completamente d'accordo

Sezione III: sull'idea del carnaio

Stiamo valutando la possibilità di costruire punti di alimentazione supplementare (un carnaio) in prossimità di futuri nidi di avvoltoio. Sapendo che gli avvoltoi si nutrono di animali morti, spesso pecore o bovini, questi carnai sarebbero un'opportunità per gli allevatori di smaltire gratuitamente le carcasse.

Q9: Sarebbe interessato ad avere un carnaio nelle vicinanze (<60km) per smaltire le carcasse?

Si / No / Non saprei dire

>Se Q9=no > sezione IV

>Se Q9=sì:

Q10: Sarebbe disposto a concedere parte del suo terreno per creare un carnaio?

Si / No / No, non sono proprietario

>Se Q10=no, sezione IV

>Se Q10=sì:

In alcuni casi è possibile che alcuni turisti siano interessati a visitare i carnai per poter vedere o fotografare gli avvoltoi.

Q11: Se lei avesse un punto di alimentazione sul suo terreno, sarebbe disposto a far pagare un biglietto di ingresso ai turisti che vogliono fotografare gli avvoltoi?

Sì / No, potrebbero vederli gratuitamente / Non saprei dire / No, non vorrei che vengano

>Se Q11=no > sezione IV

>Se Q11=sì:

Q12: Qualora ci fosse la possibilità di far visitare il carnaio ai turisti, lei costruirebbe un capanno di legno, vicino al carnaio, da cui poter osservare o fotografare i grifoni da vicino, senza disturbarli?

Sì / No / Non sarei disposto a costruire un capanno di legno, ma userei volentieri un capanno se mi venisse fornito / Non saprei dire

Q13: Che cifra farebbe pagare al singolo turista? Non saprei dire / 5 Euro / 10 Euro / 20 Euro / 30 Euro / 40 Euro / 50 Euro / 60 Euro / 70 Euro / 80 Euro / 100 Euro / Più di 100 Euro

Q14: Sarebbe disposto a far visitare i carnai a dei turisti accompagnati da una guida escursionistico-ambientale che parli degli avvoltoi e delle altre specie presenti nella zona?

Sì / No / Non saprei dire

Sezione IV: Percezione del veleno come minaccia

Q15: Lei pensa che l'uso del veleno sia una minaccia nella zona in cui lei vive?

Si / No / Non saprei dire

Q16: E pensa che per gli avvoltoi l'uso del veleno sia una minaccia nella zona in cui lei vive?

Nessuna minaccia / Una piccola minaccia / Una minaccia media / Una grave minaccia

Chapter 18

Summary of the study and conclusions



Rewilding Apennines ETS (RA) aims at restoring the ecological processes of the central Apennines landscape to benefit both nature and people. RA is committed to enhancing biodiversity through environmental restoration actions and conservation of keystone species such as the Eurasian griffon vulture (*Gyps fulvus*), Apennine brown bear (*Ursus arctos marsicanus*), Italian wolf (*Canis lupus italicus*), and white-clawed crayfish (*Austropotamobius italicus meridionalis*). Since 2021, RA has been actively collaborating with Carabinieri Forestali to monitor, study and protect the Eurasian griffon vulture in the central Apennines, an area in which the species has been reintroduced in the early 1990s. Following the successful reintroduction of griffon vultures in the area, efforts to reintroduce also the cinereous vulture (*Aegypius monachus*) and the bearded vulture (*Gypaetus barbatus*) in the central Apennines have been considered, taking inspiration also from successful programs in other parts of Italy and European countries (e.g., France, Bulgaria). In Italy, both the bearded vulture and the cinereous vulture disappeared in the early years of the XX century and around mid-XX century, respectively. Subsequently, the bearded vulture has been successfully reintroduced in the Alps. The reintroduction of these species would be aimed at improving their conservation status and to restore the trophic cascade in the central Apennines landscape. Vultures play a crucial role in the ecosystem by reducing carcass decomposition time, boosting nutrient cycling, and competing with other opportunistic scavengers. Their reintroduction will help reduce CO₂ emissions from carcass incineration and conflicts with rural economies from negative interactions between humans and large carnivores being attracted by carrions close to settlements and rural economies. The reintroduction of vultures in the central Apennines would therefore be crucial for the conservation of these species and the restoration of a balanced ecosystem in Italy.

Since the beginning of the initiative, RA has been collaborating and discussing with authorities such as Carabinieri Forestali, as well as national and regional parks, all of whom showed interest in the project to foster adequate partnerships to support the initiative. Representatives of the Italian Institute for Environmental Protection and Research (*Istituto Superiore per la Protezione e la Ricerca Ambientale, ISPRA*) expressed support for the initiative, which aims also at addressing threats to vultures and improving human-large carnivore coexistence. Since RA has already secured fundings for reintroduction from the NGO Rewilding Europe, the next step, upon approval of the feasibility study, would be to find additional sources of funding, e.g., through the EU's LIFE program. This study has therefore been conducted with the goal of evaluating the feasibility for the reintroduction of the cinereous and the bearded vultures in the central Apennines.

Translocations are commonly used tools to restore or preserve plants and animals, but several, even legal, considerations are important when moving wildlife. National and international regulations vary, and uncertainties exist regarding the need for environmental impact assessments for certain species. There are also shortcomings in the legislation concerning bird translocations, creating a need for specific authorizations and scientific-technical planning documents. Collaboration with experts in the field is crucial for addressing these legal and technical challenges. According to existing regulations in Italy, there is no formal requirement for specific guidelines or authorization procedures for the translocation of bird species, a flaw which may have resulted from misinterpretation of previous regulations. However, in this study, a logical and organised approach is being pursued for translocation planning and implementation due to practical and ethical reasons. The reintroductions are planned to be carried out within an international cooperation context, following biologically sound approaches and guidelines, such as those

provided by the IUCN and, specifically for vultures, by the Vulture Conservation Foundation. The project aims to work closely with Natura 2000 sites and protected areas management authorities to ensure a transparent and rational approach, especially in an area with significant human presence and competing interests. Below are the primary findings derived from the feasibility study for the reintroduction of the bearded and cinereous vultures in the central Apennines.

The **project area** defined in the feasibility study according to the steady range of the griffon vulture, covers an extent of more than 25,000 km², predominantly located in the Italian central Apennines, with small portions in the southern Apennines. The project area comprises 6 Italian regions and 19 provinces and includes 78 protected areas and 297 Natura 2000 sites, which partially overlap with the aforementioned protected areas. The Natura 2000 sites cover 10,696.85 km², representing approximately 42% of the study area. The climate in the study area varies from Mediterranean in the south to oceanic in the central part and continental at higher altitudes. The study area is characterised by various forest types depending on elevation, with lower elevations having mixed sclerophyllous evergreen and deciduous oak forests and higher elevations featuring mixed deciduous and pure beech (*Fagus sylvatica*) forests. The topography of the central Apennines includes steep eastern slopes towards the Adriatic coast and shallower western slopes forming foothills towards the west. The study area is covered by forests whose proportion could greatly vary locally, followed by various primary and secondary grassland, cropland, shrubland, and urban areas. Livestock rearing is widespread in the whole area, though not uniformly as to abundance, reared species and husbandry methods. The red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) and especially the wild boar (*Sus scrofa*) are the wildlife species most significant to vultures.

Limited knowledge and evidence exist regarding the **historical presence of vultures** in the Apennine mountains. However, while information about the cinereous vulture and bearded vulture is scarce, the griffon vulture was more widely distributed and known in the past. Nevertheless, historical records suggest that all four European vulture species [(i.e., griffon vulture, bearded vulture, cinereous vulture and Egyptian vulture (*Neophron percnopterus*))] may have coexisted in certain areas. However, there could have been some uncertainty as species may have not been accurately distinguished due to the lack of bird taxonomy knowledge when local people were concerned. Despite some confusion in the historical references and common names, it can be hypothesised that vultures had a wider historical distribution in the Apennines than their current presence suggests, with faunistic, environmental, and biogeographic factors supporting this idea.

Despite the potential habitat suitability also in terms of food resources, and the population projections, it has to be acknowledged that **threats to vultures** exist in the study area. The main threats to vultures worldwide, including both New- and Old-world species, depend upon anthropogenic activities, such as illegal killing and different kinds of intoxication and poisoning, and infrastructures, including electrocution and collisions with energy production (wind turbines) or transportation (wires) facilities. In the central Apennines, anthropogenic mortality accounts for two-thirds of griffon vulture deaths, with indirect poisoning being the most frequent cause. Lead ingestion from hunting ammunition is also a significant concern, with potential for further lead intoxication if hunting in the area increases - e.g., aimed at red and roe deer. Power lines and wind turbines also pose a threat to vultures, causing collisions (up to 20% of known causes) and electrocution. There is a need for stricter regulations on lead ammunition, as well

as mitigation measures for power lines and wind energy infrastructures to reduce vulture mortality. Overall, a comprehensive approach to addressing these threats is necessary to protect vulture populations.

Assessing habitat suitability is essential for feasibility studies, especially for reintroduction projects, as it is crucial for the success of a reintroduction project. The potential of an area to support vultures could be evaluated considering different specific features and scales affecting its suitability. In this study, habitat suitability has been evaluated based on results from both field surveys carried out by a team of experts directly committed with concerned species and vulture reintroduction practice, as well as by stochastic habitat modelling. Clearly, the results of these approaches pertain to different resources and spatial scales, and their output should be integrated.

In spring and autumn 2023 a team of internationally acknowledged cinereous vulture and bearded vulture experts carried out two field surveys in the central Apennines (June and October-November), as south as Abruzzo Lazio and Molise national park, and, to the north, in the Monti Sibillini national park. The field surveys involved the most vulture-experienced staff members of Rewilding Apennines as well as the authors of the feasibility study. The purpose of the field surveys was to evaluate the suitability of some areas, at various spatial extents, according to variables which could be hardly modelled or extrapolated by stochastic modelling, like those affecting nesting suitability at a very fine spatial resolution, e.g. occurrence of potential nesting trees located in adequate sites. Moreover, surveys have provided an expert-based general assessment, by comparing the general characteristics of an area with respect to those sites where cinereous and bearded vulture reintroductions have succeeded in establishing viable populations, also through the direct experience of the experts. The surveys identified 14 sites, out of 20, as suitable for the cinereous vulture and 10 for the bearded vulture, according to the occurrence of several habitat features. Five sites were suitable for both species. The most prominent threats at the analysed sites are the proximity to wind farms and power lines, as well as the use of poison to kill animals deemed harmful, which could greatly affect vultures. Many sites were located within protected areas, both national and regional parks (each one extended ca. 300-750 km²) and in smaller reserves, as well as in Natura 2000 sites, which should grant on average the necessary level of landscape conservation and protection. Overall, although a small sample of possibly suitable sites have been surveyed, the central Apennines, as also referred to in a previous study in *Gran Sasso-Laga* and *Monti Sibillini* national parks, hold the potential to host a viable population of both vulture species. This is indirectly, though partly, confirmed by the extant griffon vulture reintroduced population. However, in such a densely human-populated country, anthropogenic threats raised concerns on the capacity of the hopefully translocated vulture populations to thrive in the long term. The highly-motivated Rewilding Apennines team and the interest from several park authorities and Carabinieri Forestali in this initiative, could provide the basis to create a strong partnership with local key-stakeholders, representing a positive indicator when fostering reintroduction initiatives.

Habitat Suitability Modelling, using algorithms such as MaxEnt, has become a popular method to assess habitat suitability, although several algorithms are available, sometimes providing different or contrasting results. In this study, habitat suitability for the cinereous and bearded vultures in the central Apennines was assessed. For the cinereous vulture, the model showed that habitat suitability increased with reduced temperature seasonality, higher winter precipitation, moderate precipitation during the driest month,

and maximum summer temperatures between 17 and 40°C. The bearded vulture's habitat suitability depended on low precipitation during the driest month, annual precipitation below 2,000 mm, low temperature seasonality, and maximum summer temperatures below 30°C. Both models indicated a high availability of suitable habitats in the study area, with much of the region showing high suitability scores. Variables like precipitation, temperature seasonality, and maximum temperatures were important predictors for habitat suitability for both vulture species. However, it will be important to improve the models considering other factors such as land use, food availability, and human disturbances to provide as reliable and holistic models as possible. Overall, the results of the habitat suitability analysis provide promising outcomes for the reintroduction of the vulture species in the study area. However, interpretations should be made cautiously and in conjunction with other components of the feasibility study and field surveys to ensure a comprehensive understanding of habitat suitability and project feasibility.

Deliberate illegal poisoning is often used as a form of retaliatory killing to control predator populations, but the use of poisoning compounds can have unintended consequences on non-target species. Vultures, in particular, are at risk due to their efficient, gregarious scavenging behaviour and vital ecological role in eating up carcasses. To address the issue of illegal poisoning and reduce the rates of loss of vulture populations, strategies such as integrated preventive measures, legal prosecution of poisoners and educational programs are needed. **Spatial explicit modelling of poisoning risk**, through analytical techniques also applied to evaluate habitat suitability, can support the identification of areas where poisoning events are more likely to occur, to prioritise monitoring efforts, and optimise actions against illegal poisoning. Data on poisoning events in the study area have been collected, revealing that more than half of poisoning events were represented by baits, followed by carcasses of dogs, domestic cats, foxes, wolves and griffon vultures, deceased from directly consuming poisoned baits or carcasses. By analysing data on poisoning events in the study area, two spatial models were developed to predict the risk of poisoning events based on environmental features, one with all the documented cases of poisoning events in the study area, and the second excluding poisoning events occurring close to human settlements. The model produced by using all cases of poisoning events, revealed that presence of paved roads and urban areas were the factors most strongly associated with the likelihood of poisoning events to occur. Unsurprisingly, the spatially-explicit model revealed that areas with the highest human footprint, such as towns, villages and main roads, showed the highest risk of poisoning events to occur. The model produced by removing poisoning events close to urban areas, revealed that unpaved roads and paths were the strongest drivers of high chances of poisoning events. The spatially-explicit model revealed that vast extents of the study area, also within protected areas, are at risk of poisoning. In short, access to wild areas by humans and vehicles contributes to the ease of deploying poisoned baits and carcasses. Tree cover was negatively associated with the risk of poisoning, likely due to poisoning events occurring in open areas where domestic animals graze. These models can help inform conservation efforts and focus resources on areas with the highest risk of illegal poisoning, ultimately protecting wildlife populations, including vultures, from the devastating effects of poisoning.

Power lines and aerial cables also have a significant impact on birds, leading to fatalities through collisions and electrocution. This threat is especially dangerous for medium- and large-sized birds such as raptors and corvids. In Abruzzo, power lines have been identified as a major factor contributing to the

decline of the Eurasian eagle owl (*Bubo bubo*) population, even though the reported cases of griffon vultures injured or killed by impacts with power lines is almost null. The impact of power lines on avifauna is often underestimated due to the high rate of removal of carcasses by scavengers. Mitigation measures, such as installing insulating sheaths on power line supports and affixing signalling devices like spirals and buoys, can help reduce collisions and electrocutions, and should be thoroughly considered and implemented in the context of vulture's reintroduction.

A substantial amount of research has been conducted also on the **issue of lead in hunting activities**, which can lead to severe pollution in ecosystems, food chains, and wildlife, particularly affecting avifauna. Studies have in fact shown high levels of lead contamination in various bird species, particularly in regions like the Alps and the Pyrenees. The impact of lead poisoning on vulnerable bird populations, such as griffon vultures, bearded and cinereous vultures, as well as golden eagle (*Aquila chrysaetos*), has been significant, with high percentages of lead exposure detected in tissue samples. In the Apennines, data on soil lead concentrations near fixed hunting sites have shown elevated levels of lead and concerning levels of lead exposure have been reported in griffon vultures and golden eagles. Therefore, continuing monitoring efforts in the area are urgent to address lead contamination in hunting activities, and mitigation measures, such as the introduction of non-toxic ammunition and increased supervision and enforcement of regulations, are recommended to address the issue of lead pollution in the environment.

Collisions with wind turbines represent a major concern for soaring raptors, and large-sized vultures are particularly sensitive to this risk. Both morphological, behavioural and ecological reasons make vultures particularly prone to collision. The placement of turbines is strictly dependent on the morphology of the landscape and on local wind patterns. These, in turn, are also highly and positively selected by vultures, as their soaring-gliding flight deeply relies on rising thermal currents and on winds. Thus, wind energy development and vultures exploit and rely on the same landscape properties, though for different reasons. Notwithstanding the few wind power plants in the core range of the griffon vultures, collision with such infrastructures has been claimed to be responsible for up to 15-20% of griffon vulture casualties. Moreover, the expected increase in the number of power plants and turbines to meet the goal of energy production from renewable resources, could be responsible in the near future for a harsher conflict with biodiversity conservation and vulture preservation. We estimated the collision risk for griffon vultures -a proxy for the cinereous and bearded vulture- based on GPS instrumented individuals. As vultures usually disperse over long distances, and long-distance movements allow for the functional connection between populations, it is worthwhile analysing such risk both at a country extent and at more local scale, *i.e.*, the project area as previously bounded. We believe this effort is fundamental, as only very recently a general attempt to assess bird sensitivity to collision with wind energy infrastructure has been endorsed for strategic planning at both regional and country scales. A Maximum Entropy potential distribution model has been built to identify landscapes with a great potential for vulture's movement and dispersal. This result has been contrasted with wind energy producibility maps through a weighted-overlay procedure to identify areas where the potential collision risk could represent a concern for vultures. The amount of the landscape accounting for the highest predicted collision risk (risk classes \geq 'medium-high') represent a significant portion of the landscape, whether considering total country (average regional assessment: 32%) or the project area (53%, $\sim 13,300$ km²). Nine regions showed a percent surface where medium-to-high collision risk was higher than the estimated average, comprising

Abruzzi, which is the stronghold of griffon vultures (together with the adjacent Latium and Molise reliefs). Griffon vultures engaging with southbound long-distance movements could face a higher-than-average collision risk in Campania, Basilicata and Calabria. Similarly, northward long-distance dispersing or prospecting griffon vultures could face a high collision risk along the main Apennine and anti-Apennine ridges, as well as in the south-central Tuscany lower mountain massifs. Our results represent the first approach to identify and map collision risk linked to wind plants and wind turbines for the griffon vulture at a local and national level. In the core range, where wind turbines are already operating, collision risk represents a threat to griffon vulture and presumably to other soaring birds. The risk map suggests an uneven distribution of collision risk across the whole country. Presently, the core range of griffon vultures host a relatively limited number of wind turbines. Consequently, in this area, if no further development of wind energy plants or repowering with larger-sized turbines takes place, the collision risk should remain stable, although still capable of exerting a negative population effect. It is common among vultures and many raptors that juveniles and immatures undertake long-distance movements, which ultimately connect populations allowing genetic interchange, and could pioneer colonisation or range expansion. It is therefore crucial to preserve from collision risk both the breeding and foraging range as well as the flyways. To minimise a priori the impact of wind-energy plants on wildlife, a wide-scale based effort to avoid planning wind power plant sites in well-recognised priority areas for wildlife could possibly represent a viable compromise, though it often lacks confirmative-experimental assessments. Afterwards, mitigation measures must be adopted to decrease impacts on wildlife in already settled wind plants and in those that will be anyway realised in sensitive areas. Our risk modelling effort highlighted and ranked collision risk both with reference to energy producibility and griffon vulture potential occurrence. According to its outcomes, we recommend the following approaches: 1) in the steady occurrence area, no further wind plant should be realised as it would represent a concrete, real risk for population survival, jeopardising alone conservation efforts. Moreover, additional wind turbines will represent an undesirable risk for released cinereous vultures and bearded vultures; 2) already existing energy infrastructures and facilities in such areas need to be urgently and adequately mitigated, and compensatory interventions must be identified and realised, now; 3) to guarantee survival of long-distance movers, which also warrant for genetic exchange and demographic flow between populations, no wind plants should be set across the flying paths along the Apennines, and appropriate mitigation measures should be implemented in the existing plants. Whatever the extant griffon vulture population, or the hopefully reintroduced cinereous and bearded vultures, safe movement capability through their range and along flyways exists, and must be guaranteed. Site specific solutions could be worked out, but high quality and relevant data should be collected and available well in advance. High quality information should warrant against poor-quality, extemporaneous, and thus unsatisfactory and useless planning. The intrinsic dynamic of animal populations and of their interactions with the environment, as well as changes in energy needs must be dealt with through an adaptive management strategy, considering, for instance, the average working life of turbines and the evolution of wildlife distribution across the concerned territories.

Although griffon vultures have been reintroduced in several areas in Italy, from north to south, including Sardinia and Sicily, and successfully spread across most of the national territory, but for Pollino national park to the south, cinereous vultures have only been sporadically observed in the central Apennines from 2015 to 2022. **Population Viability Analysis (PVA)** is being used to help determine the minimum number

of individuals necessary for a successful reintroduction program and to project the reintroduction success of these species based on different scenarios of release numbers, rates and lengths, while accounting also for factors such as total number of released individuals, excess mortality due to human causes and carrying capacity. For the cinereous vulture, the number of released individuals seems to have a more significant impact on population viability than the release rate or length of the releasing phases. For all the reintroduction scenarios evaluated, regardless of the carrying capacity hypothesised, the mean probability of extinction was always negligible to null in 100 years, except for those cases in which the minimum translocation effort is undertaken (*e.g.*, 4 vultures/year over 6-years). However, environmental carrying capacity revealed to be important as all the scenarios hypothesising lower carrying capacity, predicted the number of individuals to start decreasing steadily after 20-35 years from the initial translocations. Additionally, with higher environmental carrying capacity, the number of individuals predicted after 100 years failed to reach an asymptote, suggesting that cinereous vultures would need a longer time to stabilise their number around the hypothesised carrying capacity. Human-caused, excess mortality is a critical factor affecting the survival and growth of the reintroduced population. When the prevalence of human-caused excess mortality increases, the population size decreases significantly, even if carrying capacity is high. For the bearded vulture, similar trends are observed in terms of the impact of release numbers on viability. PVA revealed that a minimum of 60-80 individuals released over a period of 15-20 years represent the minimum number to release for allowing the population to increase under stochastic growth rates. This was the case regardless of the carrying capacity tested. However, increasing the environmental carrying capacity would allow for a higher number of individuals to survive, when comparing the same translocation scenarios. Excess mortality frequency and severity have a notable effect on population growth and likelihood of extinction. Carrying capacity, here mainly related to food resources, although it does not seem to be as important as excess anthropic mortality, also played an important role in regulating population dynamics. Overall, the success of vulture reintroduction efforts depends on the total number of released birds, management of excess mortality and carrying capacity considerations.

Besides the availability of suitable habitat, the feasibility study also evaluated the **carrying capacity in terms of biomass potentially available for vultures**, highlighting that livestock and even wildlife abundance in most of the project area and the availability of carcasses does not appear to be a limiting factor for extant griffon vulture population and for the reintroduction and growth of vulture populations in the central Apennines. Because of the heterogeneity of available data and information, only wild ungulates and extensively reared livestock have been considered as available for vultures' food intake but noted that some of this biomass may not be accessible to vultures due to various factors. The biomass of domestic ungulates allowed to estimate a minimum total biomass of 1,388 tons/year (± 6.5 tons, SD) potentially available for consumption by vultures, to which an additional biomass of 63 tons/year from wild ungulates should be added. This would translate into a carrying capacity capable of supporting a population of 6,900 to 7,544 griffon vultures, assuming that calculated biomass would be entirely available to vultures. Our analyses suggest that the biomass from wild ungulates could not sustain by itself the extant griffon vulture population nor its growth, nor that of a possible future cinereous vulture population. On the contrary, biomass from wild ungulate carcasses appears potentially enough to maintain a viable bearded vulture population, especially considering the significant amount of bones in their diet. As to wildlife, our estimates given the lack of information, and the spatial heterogeneity of

available data, likely represent an underestimation of the available biomass. Furthermore, it should be considered that most livestock carcasses, during the grazing season and even further, are disposed of where they die, often without any possibility of control by veterinary authorities. This could represent a risk factor for populations of scavenging raptors if more restrictive controls by the authorities, and subsequent carcass removal, would cause a sharp reduction in the availability of carcasses. However, some regional regulations (e.g. in Abruzzi) formally allow the breeders to leave dead livestock where it is, when the remoteness of the sites makes it impractical or impossible to remove carcasses with ordinary means (e.g. by off-road vehicles or tractors), provided that veterinarians would approve it. Considering that current European Regulations allow the breeders not to remove livestock carcasses dying in pastures, it would be worthwhile to formally implement such an opportunity, starting from protected areas (parks, reserves, Natura 2000 sites), which is actually what has been endorsed in Spain. In this scenario, the use of supplementary feeding stations - which represent a fundamental action to support translocations, would ensure and probably increase food availability for vultures, whilst in the long-term they will provide undoubtful benefits to farmers through farm feeding stations. These will represent, even later on, a beneficial means for the disposal of carcasses, considering that particular attention must be paid to guarantee the space-time unpredictability of the resources, according to the eco-ethological characteristics of vultures, their role in the ecosystems and provided ecological services.

Most food resources for vultures in the central Apennines are represented by livestock, which griffon vultures locate in pastures and in natural and semi-natural habitats. If we consider both supporting extant vultures or future reintroductions, we must be aware that restocking or reintroduction efforts must be complemented by a supplementary feeding strategy. The main source for feeding stations provisioning is represented by livestock from local breeders, whose suitability is conditioned by the occurrence of infective or transmissible diseases. Thus, while predicting the potential use of livestock carcasses to support reintroductions, it is of paramount importance to evaluate the suitability of livestock in farms according to health status and pharmacological residues, considering pathologies or residues which could limit or exclude their employment for supplementary feeding. In the Abruzzo region, which represents a large part of the area concerned with reintroduction efforts and the stronghold of the griffon vulture, the **health status of livestock** is monitored annually by local health authorities (*Aziende Sanitarie Locali, ASL*) within the Regional Department of Animal Health (*Dipartimento Regionale di Sanità Animale*). The results of these investigations are recorded in reports that also consider diseases transmissible to humans (zoonoses) and those diffusive among animals. The data included in the feasibility study, based on the latest animal health report of the Abruzzo Region from 2020, summarises the status of diffusive diseases and pharmacological molecules investigated. The Regional Residuals Plan (*Piano Regionale dei Residui*) focuses on detecting residuals of pharmacologically active substances and chemical residues in livestock production chains. Furthermore, the document provides specific information on the incidence of infectious diseases in regional farms, including bovine brucellosis, enzootic bovine leukosis, bovine tuberculosis, ovine-caprine brucellosis, swine vesicular disease, TSE, blue tongue, avian influenza and salmonellosis. The National Residue Plan (*Piano Nazionale dei Residui*) aims to uncover cases of illicit administration of prohibited substances, improper use of medicines, and verify compliance with maximum residue limits. Overall, the data presented reflects the ongoing efforts for monitoring and surveillance of animal health in Abruzzo, ensuring the safety of livestock, humans, and the environment. Here we integrate animal health data with the feasibility study of reintroducing scavenging birds and

outline the regulations, managing the disposal of animal carcasses, especially at feeding stations for scavenging birds. Based on the available information, according to zoonoses and transmissible pathologies mandatory for sanitary surveillance, there are very limited concerns - if any - with respect to the potential transmission of diseases to both man and wildlife from livestock raised in the Abruzzo region. Thus, if we consider both food provision at feeding stations (collective-intensive or farm based) and the strategy of allowing dead livestock to be left in place in mountainous, natural or remote areas, the health and sanitary conditions of livestock could be considered eligible, at least for the monitored pathologies and the time frame considered. However, data extrapolated from regional and national surveys are partly lacking some investigation elements, mentioned in the ministerial notes, necessary for the purposes of evaluating the suitability of a carcass to be admitted for consumption by scavenger birds, like for instance NSAIDs. These missing evaluations must be implemented in the future, or relevant surveys should be refined and tailored to adequately match substances and concentrations potentially harmful for vultures, and not only dangerous for human health.

Finally, the success of translocation projects in areas as anthropized as the southwestern Europe and the central Apennines, **requires investigating stakeholders' attitude**. Therefore, sociological surveys were conducted to assess the social perspectives on the reintroduction of cinereous and bearded vultures in specific areas. The survey aimed at determining knowledge, attitudes and acceptance levels towards vultures among farmers and the general public in priority areas of the project. Findings revealed high knowledge of griffon vultures but low awareness of the other species among farmers. Overall attitudes were neutral towards vultures, with interest in setting farm feeding stations primarily driven by economic factors. The study identified areas with high acceptance rates and highlighted the need to address misinformation and fears surrounding vultures and feeding stations. Recommendations included tailored communication campaigns aimed at addressing misinformation, as well as further investigations into specific community concerns, especially towards carnivores and wildlife management. Overall, the survey provides valuable insights for the vulture reintroduction project and highlights the importance of deeply engaging with local communities.

Final remarks

Although the vulture community in the central Apennines disappeared a long time ago, around XVI-XVII centuries, in the southern Apennines and main Islands, as well as in the Alps, vultures survived until the early years of the last century, or in even more recent times, like the bearded vulture and the cinereous vulture in Sicily and especially in Sardinia. There, the autochthonous griffon vulture population, although greatly threatened by poisoning, managed to survive until today and is now expanding thanks to efficient implementation of conservation measures, such as translocations and fight against retaliatory poisoning. Anyway, although uncertainties will remain as if they were mostly erratic individuals or there were some remnant breeders, all vulture species occurred to some extent in the XIX and XX century in the central and southern Apennines. Still, the Egyptian and cinereous vultures can be seen in the central Apennines while dispersing or during erratic movements, likewise griffon vultures from many European countries, as far from Greece and Portugal.

Vultures are acknowledged providers of fundamental ecosystem services, as demonstrated by the negative consequences of their sharp decline even on human health in the Indian subcontinent.

Accordingly, re-establishing their populations through translocation, whether in terms of restocking or reintroduction according to the species, is beneficial, and human communities could greatly profit from a wise management of vultures, also on practical, economical grounds.

Provided reintroductions are carried out building long-lasting and well-organised partnerships between concerned actors (non-governmental organisations, public agencies and stakeholders) with a high professional profile, and recognising that adequate resources must be available to support the initiatives for some decades, vulture translocation would represent successful initiatives to restore natural communities and ecological webs, as it has been demonstrated in several European countries in the last 40-50 years. Vultures are K-selected species: they are long-living, with low reproductive rates, and are especially sensitive to non-natural adult mortality. Consequently, we modelled the population viability of the possibly forthcoming cinereous and bearded vultures estimating the number of birds to be released in several time intervals to maximise the chances of population persistence. The predicted number of released individuals could be similar to those released in other countries, which confirms that, if adequate funding and long-term project backup exist, our predictions are realistic. In particular, for the cinereous vulture, which would be the species to release first, to better tackle demographic and habitat stochasticity the release rate and the number of translocated birds should more closely resemble those from Bulgaria than from France, though both countries succeeded in their effort.

Human encroachment, and human-wildlife conflicts represent in most countries the most relevant sources for vulture disappearance and decline. Italy and the Apennines do not represent an exception. Accordingly, we estimated the risks which the extant - and hopefully forthcoming - vultures would face in the central Apennines. Indirect and secondary poisoning are the most significant threats. Thus, a great effort should be put in future projects, gaining knowledge from similar actions in Sardinia and the Balkans, to tackle retaliatory poisoning. This means not only the need to efficiently and effectively prosecute those responsible for poisoning wildlife, but also the implementation of preventive measures (of several different kinds), understanding the causes of human-wildlife conflicts and acting against them, and finally implementing all the necessary knowledge and practical actions linked to human dimensions. The results we gained while modelling poisoning risk represent a useful starting point to identify what factors are involved and where to start with relevant actions. Further investigations on the impact of NSAIDs are urgent.

In the next few years, a boost in the construction of wind power plants is foreseen. Presently there are only two such plants in the core range of griffon vultures, and a few others at its periphery. As a consequence, to provide a logical ground for planning the development of wind energy avoiding as much as possible conflicts with vultures, we identified sensible landscapes. This analysis aims at recognizing areas where the realisation of wind power plants should be avoided given the risk of potential collision is well above the mean. We did it not only with reference to the core and steady griffon vulture range, but also to preserve flyways connecting central Apennines griffon vultures to other Italian and foreign populations.

Rewilding Apennines, together with other NGOs, is actively fostering the process of shifting from lead ammunition to non-toxic ammunition for wild boar and, in the future, for red deer and roe deer hunting.

Preliminary analyses from a wealth of golden eagles and griffon vultures mostly from the central and northern Apennines confirmed that lead intoxications actually represent an issue.

Habitat analysis has been performed on several levels to evaluate the suitability of the central Apennines for the reintroduction of the cinereous and the bearded vulture. Field surveys, carried out with internationally acknowledged cinereous vulture and bearded vulture experts, confirmed that the potential exists for reintroduction of both species in terms of availability of nesting and hacking sites in a substantial portion of the surveyed sites and the overall suitability, expert-opinion based, of the area. From a complementary perspective, stochastic species distribution modelling highlighted that potential habitats exist, with some obvious differences between the two concerned species.

The analysis of carrying capacity, highlighted that the food base for vultures exceeds the needs of the current griffon vulture population (ca. 350 individuals) by more than one order of magnitude. As a consequence, also considering the need to provide released individuals with dedicated feeding stations, the food base for an abundant vulture community does not represent a concern. Anyway, we feel that, in addition to what is the common practice, formally establishing vulture feeding zones where dead livestock could be legally left in pastures would greatly enhance the long-term perspective for a self-sustaining vulture community.

Monitoring health status of livestock by relevant authorities, has assured that there are no concerns regarding infectious diseases and zoonoses, which could elicit constraints in the use of livestock for both feeding stations and 'natural' feeding of vultures in mountain landscapes, where extensive livestock breeding is the prevailing husbandry paradigm.

As already underlined, the success of translocation projects in areas as densely inhabited by humans as southwestern Europe, cannot disregard stakeholders' attitude. The sociological surveys which we ran in the central Apennines revealed overall attitudes were neutral towards vultures, with interest in setting farm feeding stations primarily driven by economic factors. Interestingly, our analysis identified areas with high acceptance rates, though highlighting the need to address misinformation and fears surrounding vultures and feeding stations. Overall, the survey, while indicating specific information campaigns to be addressed, highlighted the importance of deeply engaging with local communities.

The aim of this feasibility study was to investigate and analyse if habitat and threats in the central Apennines, together with the favourable attitude of concerned stakeholders, would have allowed the restoration of a vulture community, by eventual, preliminary reinforcement of the griffon vulture, and further on, reintroducing the cinereous and bearded vultures. We are aware that, once a general consensus has been reached by all relevant actors, further steps should be realised before vultures would finally be released. Accordingly, though recognising that such steps are fundamental, and reasoning about them in the early meetings of this working group when the contents of this feasibility study were defined, we decided to temporarily put them aside, as they represent further preparatory actions addressing the operational-implementation phase of the project itself. Capacity building, genetic considerations on the stock of founders, availability of founders, monitoring aims and needs, exit strategies, animal welfare considerations, animal health, risk of disease transmission, building partnerships for the management of all these topics will represent the future aims to attain when this feasibility study will hopefully move into more practical and enforcement grounds.

According to our investigation, and considering the overall result of the reintroduction of the griffon vulture carried out at the end of XX century, the prerequisite and conditions exist for the release of the cinereous vulture and later on the bearded vulture in the central Apennines. Nevertheless, a further preliminary reinforcement of the griffon vulture population also at the northern edge of its distribution, mainly in the Monti Sibillini National Park and even further in the last historical breeding stronghold of this species, should be realised. Above all, actions and efforts to tackle the most dangerous threats, as shown in this feasibility study, should be readily and effectively accomplished. Reintroducing vultures is an enduring engagement, requiring dedicated long-term efforts and commitment: all actors must be aware and be prepared accordingly.

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