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Short communication

Wind energy and species reintroductions: a call to action for adaptive conservation planning☆

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ABSTRACT

With the recent approval of the Nature Restoration Law and the launch of the RePowerEU plan, the European Union and other international organizations, such as the United Nations, advocate for biodiversity restoration and the decarbonization of energy sources. This dual agenda has led many countries to develop large-scale renewable energy projects while simultaneously funding the reintroduction of threatened species. The reintroduction of the Bearded Vulture in the Maestrazgo region of Spain exemplifies the challenges of balancing biodiversity conservation with renewable energy development. Initiated in 2015, this project aims to reconnect isolated vulture populations, enhancing genetic diversity and reducing extinction risks. Despite significant efforts, the project faces major obstacles. A recent incident involved the death of a reintroduced juvenile vulture that collided with a wind turbine 25 km from the release site, marking the first such case in Spain and the third in Europe. This event, together with other electrocution cases, illustrates ongoing threats that compromise conservation outcomes. At a broader scale, national syntheses indicate ~9000 recorded Griffon Vulture fatalities over the last two decades (~850 per year) in Spain, while in the Maestrazgo region alone 1079 Griffon Vultures died as a result of wind farm installations between 2008 and 2018. These figures underscore the magnitude of the conflict. Plans to install 125 new wind turbines (760 MW) in Maestrazgo further complicate conservation efforts. This communication calls for adaptive management and stakeholder collaboration to reduce risks, stressing the importance of incorporating scientific criteria into planning for sustainable conservation outcomes.

1. Introduction

On June 17th, 2024, the Council of Europe approved the Nature Restoration Law, which includes among its fundamental objectives the increase of biodiversity, the restoration of ecologically functional ecosystems, and the improvement of ecosystem services, among others. This law follows the guidelines set by other international organizations, such as the United Nations, which in 2015 established among its 2030 sustainable development goals the access of humanity to affordable and clean energy sources. In parallel, the European Commission launched in May 2022 the RePowerEU plan (https://commission.europa.eu/topics/energy/repowereu_en), a strategic framework designed to accelerate the deployment of renewable energies and reduce dependence on fossil fuels in response to the climate and energy crisis. RePowerEU explicitly calls for the expansion of wind and solar capacity through simplified and faster permitting procedures, as well as the designation of "go-to" areas for renewable energy development. While this approach aims to strengthen Europe's energy security and decarbonization trajectory, it has also raised concerns about potential regressions in environmental safeguards and the compatibility of renewable energy siting with biodiversity conservation goals. Since the beginning of the current century, European countries have embarked on a process of decarbonizing energy sources through massive investment in renewables, primarily solar and wind. As a result, the amount of electricity produced from wind energy sources worldwide has increased from 31.14 TWh in 2000–2304.44 TWh in 2023 (+7300 %)(Ember, 2024). This transition has significantly reduced dependence on fossil fuel energy sources and has led to a radical shift in the energy production model, commonly referred to as the energy transition.

Biodiversity conservation has also been recognized by the United Nations as a central component of the 2030 Sustainable Development Goals. There is broad consensus that the unprecedented biodiversity loss

☆ Wind energy development threatens vulture reintroduction; science-based planning is vital for effective conservation and policy decisions.

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during the current Anthropocene period is linked to the negative consequences of human activities, primarily the transformation of land for agriculture, industry, and the urbanization of regions that once harbored much of the biodiversity we have lost over the past centuries (Dirzo et al., 2014; Johnson et al., 2017). Climate change further exacerbates these pressures, adding an additional layer of risk for many species (Bellard et al., 2012). This dual challenge highlights the urgent need for strategies that simultaneously mitigate greenhouse gas emissions and safeguard biodiversity. However, if not carefully planned, the rapid deployment of renewable energy infrastructure designed to reduce fossil fuel dependence may itself generate new threats to wildlife populations, creating conflicts between decarbonization policies and conservation objectives.

Spain, with an annual electricity production from wind energy of 64.13 TWh in 2023, is one of the leading countries in energy decarbonization, second only to China, the United States, Germany, Brazil, the United Kingdom, and India in terms of annual wind energy production (Ember, 2024). Since 2005, installed wind power capacity has increased from 9882 MW to 29,813 MW (+202 %) across 1345 wind farms and 22,042 onshore wind turbines distributed throughout the country (Spanish Wind Energy Association, 2024). During the same period, electricity generation from wind rose from 21.18 TWh to 64.13 TWh (+203 %), and a substantial increase is projected for the coming decades. At the same time, Spain harbors exceptionally rich biodiversity within the European context. For instance, regarding scavenging birds, Spain is home to all five vulture species present in Europe, representing between 15 % and 100 % of their continental breeding populations, depending on the species (The IUCN Red List of Threatened Species, 2024). This makes the Iberian Peninsula one of the strongholds for these species, which play a crucial role in providing ecosystem services by recycling nutrients through the consumption of carcasses, primarily from intensive livestock farming. In fact, in Spain alone, scavenging birds prevent the emission of 77,344 tons of CO_2 equivalent annually thanks to their role as recyclers in ecosystems (Morales-Reyes et al., 2015). Beyond this regulating function, vultures also provide additional, well-documented ecosystem services of high public health relevance: they reduce the risk of disease transmission, limit the proliferation of opportunistic scavengers such as feral dogs and rats, and decrease microbial contamination of soil and water (Ogada et al., 2012; Carucci et al., 2022). Together, these sanitary benefits reinforce the ecological and conservation value of vulture populations worldwide.

2. Wind energy and reintroduction projects: the case of the Bearded Vulture

In 2015, a project to reintroduce the Bearded Vulture, one of the most emblematic species within the guild of scavenging birds, was launched in the Maestrazgo region (Eastern Spain). The project is being implemented by the Ministry of the Environment of Spain, in collaboration with the regional governments of Valencia and Aragón and two private foundations: the Vulture Conservation Foundation (VCF, Switzerland) and the Foundation for the Conservation of the Bearded Vulture (FCQ, Spain). This species, with its predominantly osteophagous diet, represents an extreme ecological specialization and occupies an apex position in the trophic chain. Following the successful recovery of populations in the Alps and in southern Iberia, several reintroduction projects are currently underway and others are planned for the near future. These initiatives, technically demanding and economically costly, receive a significant portion of the funding allocated to biodiversity recovery in Europe, primarily through the LIFE programme as well as other national and regional sources. For instance, between 1992 and 2021, the European Union financed 70 projects related to the species with a total budget of €157.41 million, of which €105.39 million came solely from the LIFE programme (European Commission, 2023).

The ultimate goal of the Maestrazgo project is to restore connectivity between Bearded Vulture populations in Europe that until recently remained geographically isolated. This interconnection is expected to enhance genetic exchange, expand the distribution range of the species, reduce the extinction risk of the five remaining subpopulations in Western Europe—two autochthonous (Pyrenees and Corsica) and three resulting from reintroduction projects (Alps, Andalusia, and Picos de Europa)—and, ultimately, to reinforce the recovery of ecosystem functions. More broadly, the Bearded Vulture provides an illustrative case within global reintroduction practice: as a long-lived, slow-reproducing scavenger requiring extensive landscapes, its recovery exemplifies both the potential and the vulnerabilities of species reintroduction when confronted with accelerating land-use change and renewable energy expansion.

However, on June 8th, 2024, one of the two Bearded Vultures chicks reintroduced in Maestrazgo in 2022 was found dead (see Fig. 1). The bird died as a result of a collision with a turbine of a wind farm that was already operational before the reintroduction project was initiated (Fig. 2). The other specimen released in 2022 in southern Aragón died just two months later, on August 27th, due to electrocution on a power line. In total, of the 27 individuals have been released in the project up to 2025, of which 25 in the Region of Valencia and 2 in Aragón. Five juvenile birds released through hacking have died so far: two due to predation by Golden Eagles (*Aquila chrysaetos*), two from electrocution, and the one from collision with a wind turbine, despite the risks explicitly identified in the preliminary habitat viability analysis of the reintroduction project. The collision fatality in Maestrazgo represents the first reported case of a Bearded Vulture killed by a wind turbine in Spain and the third in Europe, following the deaths in 2021 and 2023 in the Netherlands of two individuals released under the LIFE GypConnect reintroduction project in the French regions of Baronnies and Grands Causses, respectively (Rare Bird Alert, 2021, 2023).

Mortality of released individuals is unfortunately a common outcome in reintroduction projects, despite the considerable economic and logistical investment that these initiatives require (Fischer and Lindenmayer, 2000). Nevertheless, as emphasized by both the IUCN and European legislation, the development of reintroduction projects should be contingent upon the elimination or, at a minimum, the substantial reduction of past and present threats that could compromise the species' long-term viability (IUCN/SSC, 2013). In Spain, national syntheses indicate approximately 9000 recorded Griffon Vulture fatalities over the last two decades (~850 per year) (Morant et al., 2024), a figure that far exceeds lower-bound tallies based solely on wildlife rescue-center admissions. In the Maestrazgo region alone, 1079 Griffon Vultures were reported dead as a result of wind farm installations between 2008 and 2018 (SEO/BirdLife, 2023). Moreover, the construction of 127 additional wind turbines (760 MW) is planned precisely in one of the most suitable areas for the reintroduction of the Bearded Vulture in Maestrazgo, of which 85 (approximately 67 %) are located within a designated Site of Community Importance (SCI)(Gil, 2025). As a consequence, in July 2023 the Foundation for the Conservation of the Bearded Vulture (FCQ), one of the entities participating in the reintroduction project, decided to temporarily halt the release of individuals until collision risks associated with new wind farms in the region could be minimized. In addition, since 2024 the project has been challenged in court through an administrative lawsuit filed by four regional organizations, including the FCQ. Nevertheless, despite these risks and ongoing litigation, the remaining partners have opted to continue the programme, and in June 2024 three more individuals were released in Maestrazgo, followed by the release of two additional birds in 2025.

3. Discussion

Ex situ conservation measures, including the captive breeding of Bearded Vultures for reintroduction projects, represent a substantial investment of financial and human resources. Inevitably, this allocation of limited budgets for biodiversity protection implies that other *in situ* conservation actions receive comparatively less funding and media

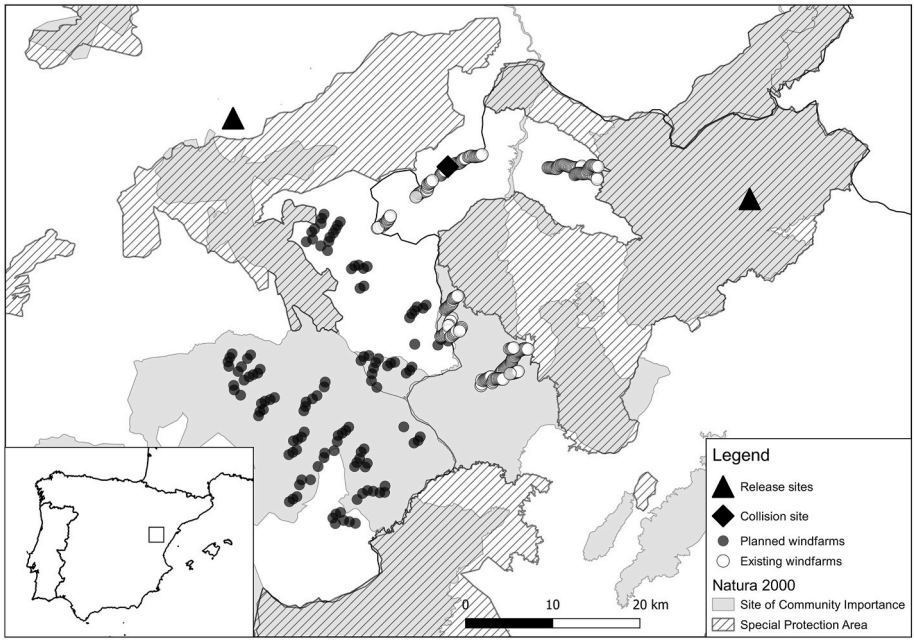

Fig. 1. Spatial context of the Bearded Vulture (*Gypaetus barbatus*) reintroduction project in the Maestrazgo region (Eastern Spain). Release sites (black triangles), the collision site (black diamond), existing wind farms (white circles), and planned wind farms (grey circles) are shown within a 50 km radius of the release area. The map also depicts the Natura 2000 network, including Sites of Community Importance (SCI; light grey shading) and Special Protection Areas for Birds (SPA; hatched areas). The inset map shows the location of the study area within the Iberian Peninsula. The figure illustrates the overlap between planned conservation actions and current and projected renewable energy developments, highlighting the potential risks of wind farm expansion for long-lived scavenger species. Notably, 85 of the 127 newly proposed turbines are located within a designated SCI.

attention. These measures include the correction of power lines, the prosecution of illegal hunting and poisoning, the prohibition of lead ammunition for hunting, and the establishment of legal and economic agreements for the declaration of new protected areas as well as the expansion of existing ones. Therefore, there is an urgent need for proper planning of conservation actions that take into account the risks and threats faced by both extant populations and species targeted for reintroduction.

The case of the Maestrazgo project highlights this challenge. Despite careful planning, the mortality of released individuals due to collisions with wind turbines and electrocution on power lines demonstrates how reintroduction outcomes can be compromised by external pressures that were anticipated but insufficiently mitigated. Given that seven years have passed since the first releases started in 2018, it is timely to implement an adaptive management strategy that reassesses mortality risks based on spatially explicit data from GPS-tagged individuals. Such risk reassessment would help determine whether the project remains viable under current and emerging threats, and would also provide the basis to reconsider the implementation of large-scale wind energy developments in the region that could have severe consequences for biodiversity conservation.

More broadly, the Bearded Vulture exemplifies the vulnerabilities faced by reintroduction programmes worldwide, especially for long-lived, slow-reproducing species requiring extensive landscapes. The rapid expansion of renewable energy infrastructure adds a new layer of risk, which, if not addressed, may jeopardize decades of conservation investment. Recent European policies such as the RePowerEU plan, with its emphasis on accelerating renewable deployment through the designation of "go-to" areas, further underline the need to reconcile decarbonization objectives with biodiversity protection. Poorly designed go-to areas could seriously compromise existing or planned reintroductions, not only in Spain but also across Europe and beyond.

Finally, the lessons from the Maestrazgo project have broader implications. Without proper planning of reintroduction programmes that actively involve all stakeholders, particularly the wind energy sector, it will be difficult to achieve biodiversity conservation objectives (Estellés-Domingo and López-López, 2024). The conflict between restoration and energy transition highlighted here exemplifies the urgent need to integrate reintroduction planning with renewable energy development and other land-use policies. To strengthen the policy relevance of our work, we highlight three priorities: (i) harmonized transboundary planning instruments at regional and international level, (ii) cumulative risk assessments that integrate planned infrastructures across jurisdictions, and (iii) adaptive mechanisms ensuring that, once risks are identified, mitigation and zoning decisions are enforced consistently across regions. Nature restoration, as well as the achievement of Sustainable Development Goals, is possible, but only if based on territorial planning grounded in scientific criteria, transparent stakeholder engagement, and the systematic re-evaluation of risks. Ultimately, the dual objectives of decarbonization and biodiversity conservation can only be reconciled if the deployment of renewable energy is adequately planned, orderly, and fully compliant with European and national biodiversity conservation requirements, alongside the integration of such approaches into restoration projects.

CRediT authorship contribution statement

Pascual López-López: Writing – review & editing, Writing – original draft, Validation, Project administration, Investigation, Conceptualization. **Irene Estellés-Domingo:** Writing – review & editing. **Juan Antonio Gil:** Writing – review & editing, Funding acquisition, Data curation, Conceptualization.

Competing interests

The authors declare no competing interests.

Data availability statement

Non applicable.

Fig. 2. a) The Bearded Vulture named "Masía" was discovered dead following a collision with a wind turbine within a wind farm that was already operational at the start of the reintroduction project. b) Released as a juvenile in 2022, the bird survived for only two years. The wind farm where the animal was found dead is situated 25 km from the release site. Photo credit: Foundation for the Conservation of the Bearded Vulture (FCQ).

Declaration of AI-assisted technologies

During the preparation of this work the authors used ChatGPT (OpenAI) in order to assist with language editing and to improve the clarity and readability of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the final content of the published article.

Declaration of competing interest

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

Data availability

No data was used for the research described in the article.

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