LIFE AEGYPIUS RETURN

REPORT

Spatial guidelines for safeguarding Cinereous Vulture colonies from wind farm expansion.

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

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

Coordinating beneficiary

VCF Vulture Conservation Foundation

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Table of contents

List of figures

ABSTRACT / RESUMO / RESUMEN

Abstract (EN)

The expansion of wind farms poses a significant threat to the conservation of Cinereous Vultures (*Aegypius monachus*). Here, we propose a practical, science-based framework to guide decision-making on wind farm planning and approval near Cinereous Vulture colonies in Portugal, focusing on safeguarding juvenile vultures during the post-fledging dependency period. Using GPS tracking data from 38 juvenile vultures, we estimate the progressive expansion of their home ranges during the dependency period and assess the overlap with circular buffers of increasing radius to determine optimal protection areas. Three conservation scenarios were examined: *Conservation first* (maximizing protection), *Compromise* (balancing protection and demand for wind farm expansion), and *Industry first* (minimizing protection for greater wind farm encroaching). The results suggest that a buffer radius of 21.3 km provides the most robust protection for juvenile vultures, while a radius of 7.7 km confers minimal protection for Cinereous Vultures while privileging wind farm expansion. We mapped these buffer zones across all Cinereous Vulture colonies currently known in Portugal, offering a transparent, scalable tool for authorities and energy stakeholders. The proposed framework balances the protection of breeding colonies with the growing demand for wind energy, enabling informed, science-driven decisions that contribute to the long-term conservation of the Cinereous Vulture in Portugal.

Resumo (PT)

A expansão de parques eólicos representa uma ameaça significativa para a conservação do abutre-preto (*Aegypius monachus*). Neste relatório, é proposta uma abordagem simples e prática para orientar a tomada de decisões durante o planeamento e aprovação de parques eólicos nas proximidades de colónias de abutre-preto em Portugal, com um foco nas necessidades dos abutres juvenis durante o período de dependência em relação aos adultos (i.e., desde o primeiro voo até à emancipação). Foram usados dados de telemetria por GPS de 38 juvenis marcados no ninho, para estimar a expansão progressiva das suas áreas vitais durante o período de dependência. Seguidamente, foi avaliada a sobreposição das áreas vitais com *buffers* circulares de raio crescente para determinar a dimensão das áreas de proteção recomendáveis. Foram examinados três cenários de conservação: *Prioridade à Conservação* (que pretende maximizar a proteção), *Compromisso* (equilibrando a proteção e a pressão crescente para a expansão dos parques eólicos), e *Prioridade à Indústria* (minimizando a proteção para permitir a expansão de parques eólicos). Os resultados sugerem que um *buffer* com um raio de 21,3 km oferece a proteção mais robusta para os juvenis (protegendo as áreas vitais intermédias de 75% dos indivíduos), enquanto um raio de 7,7 km confere uma proteção mínima para os abutres-pretos (protegendo apenas a área vital de 50% dos indivíduos), privilegiando a expansão dos parques eólicos. Estes *buffers* foram mapeados em todas as colónias de abutre-preto atualmente conhecidas em Portugal, oferecendo uma ferramenta transparente e escalável para as autoridades e *stakeholders* no setor energético. A abordagem proposta equilibra a proteção das colónias de reprodução com a crescente procura por energia eólica, permitindo que as decisões tomadas se baseiem em dados científicos e contribuam para a conservação a longo prazo do abutre-preto em Portugal.

Resumen (ES)

La expansión de los parques eólicos representa una amenaza significativa para la conservación del buitre negro (*Aegypius monachus*). En este trabajo se propone un marco práctico, fundamentado en la evidencia científica, para orientar la toma de decisiones en la planificación y autorización de parques eólicos próximos a colonias de buitre negro en Portugal, con especial atención a la protección de los juveniles durante el período de dependencia, especialmente tras el inicio de sus primeros vuelos alrededor del nido. A partir del seguimiento por GPS de 38 buitres juveniles, se estima la expansión progresiva de sus áreas de campeo durante dicho período y se evalúa la superposición con áreas de influencia circulares de radio creciente para determinar las zonas de protección óptimas. Se analizaron tres escenarios de conservación: *Conservación primero* (maximización de la protección de la especie), *Compromiso* (equilibrio entre protección y demanda de expansión eólica) e *Industria primero* (protección mínima para favorecer una mayor implantación de parques eólicos). Los resultados sugieren que un radio de protección de 21,3 km ofrece la cobertura más sólida para los buitres juveniles, mientras que un radio de 7,7 km proporciona una protección mínima para la especie, favoreciendo la expansión de la energía eólica. Se han mapeado estas zonas de protección alrededor de todas las colonias conocidas de buitre negro en Portugal, proporcionando una herramienta transparente y escalable para las autoridades y los agentes del sector energético. El marco propuesto equilibra la protección de las colonias reproductoras con la creciente demanda de energía eólica, permitiendo decisiones informadas y basadas en la ciencia que contribuyen a la conservación a largo plazo del buitre negro en Portugal.

REPORT

1. INTRODUCTION

The growing pressure of wind farm expansion is a major challenge for the conservation of vultures and other soaring birds worldwide (Katzner et al., 2019). Wind farms are rapidly encroaching on habitats that are critical for these species, posing significant challenges for decision makers in harmonising the growing demand for renewable energy with national and international biodiversity conservation commitments (Bounas et al., 2025; Morant et al., 2024). The effective conservation of vultures thus requires science-based tools that can guide authorities and energy stakeholders during the planning and approval of new wind farm projects (e.g., Cervantes et al., 2023; Murgatroyd et al., 2021; Vasilakis et al., 2017).

The post-fledging dependency period is a key stage in the life of juvenile Cinereous Vultures. For about five months (155 ± 32 days; Soares, 2025), young vultures benefit from their parents' care to learn key survival skills, such as flying, finding food, and navigating the environment. During this time, they progressively increase their movements around the colony until reaching full independence. Once they disperse, juveniles from Portuguese breeding colonies range widely across the Iberian Peninsula and even into France and North Africa, facing numerous anthropogenic threats, including wind farms, power lines, poisoning, and food scarcity. Because mortality risk is especially high during the early stages of juvenile Cinereous Vulture life, safeguarding the areas around their colonies is critical for their conservation.

Additionally, Cinereous Vulture colonies play a vital role for the broader scavenger community. Invariably established in prime habitats, these colonies attract large numbers of non-breeding vultures and other raptors, assuming important ecological, social, and functional roles at regional scales. For example, up to 300 Griffon Vultures can regularly be observed at the Herdade da Contenda colony during the non-breeding season (Eduardo Santos, personal observation), while GPS-tagged Griffon Vultures from Spain have been shown to roost at the Vidigueira/Portel colony (Eneko Arrondo, unpublished data; Matos et al., 2024). Protecting these colonies is thus crucial for the consolidation of the recovery of the Cinereous Vulture in Portugal, for ensuring its breeding success and productivity, and for maintaining the health of vulture and raptor populations more broadly, providing a foundation for the conservation of vultures in the wider landscape.

Various strategies have been developed to define critical areas for the conservation of vultures, ranging from complex movement models (Cervantes et al., 2023), to home range estimation using Kernel Density Estimation (KDE) (Curk et al., 2024), and simpler approaches like circular buffer zones (Venter et al., 2019; Zuberogoitia et al., 2008). While sophisticated movement models may provide highly accurate predictions of habitat use and effects of management, they can be impractical to implement due to the technical expertise required and the time-intensive nature of the analyses involved. In contrast, simpler methods like buffer zones may offer a more feasible alternative for the authorities and industry stakeholders (Venter et al., 2019; Watson et al., 2014). Here, we propose a framework for guiding decision-making in wind farm expansion near breeding colonies of Cinereous Vultures. Our main goal is to provide authorities and industry stakeholders a practical, science-based tool to inform decisions on new wind farm projects. Using GPS tracking data from 38 juvenile Cinereous Vultures tagged at their nests, we estimate the progressive expansion of home ranges around the nest during the dependency period. Then, we calculate the overlap between the estimated home ranges and circular buffers of increasing area to assess how large should circular buffers be to protect breeding colonies during juvenile dependency period under three conservation scenarios ('*Conservation first*', '*Compromise*', and '*Industry first*'). Finally, we map the estimated conservation buffer areas in all Cinereous Vulture colonies in Portugal, to help guiding spatial planning of wind energy expansion.

2. METHODS

2.1. Tracking data

We used tracking data of 38 juvenile Cinereous Vultures tagged in the nest between 2018 and 2024, in five breeding colonies in Portugal (Figure 1). We down sampled the tracking data to 1-hour interval, to have regular intervals between locations and similar temporal resolution across individuals, and to reduce spatial auto-correlation in the data, which can grossly underestimate home range areas when using conventional estimators such as KDEs (see below; Silva et al., 2022).

2.2. Juvenile home range expansion throughout the dependency period

We estimated the home ranges of juvenile Cinereous Vultures by calculating Kernel Density Estimators (KDEs), which is the most commonly used method to estimate home-ranges in vultures (Alarcón & Lambertucci, 2018). Kernel Density Estimators (KDEs) model each vulture's movements by smoothing their spatial locations (i.e., GPS tracking data), producing a utilization distribution that highlights areas of higher and lower use. Isopleths (or density curves) are then calculated to delineate regions with different levels of use intensity, offering insight into the bird's typical movement patterns around the nest. Three levels of use were considered: the 50% KDE, representing the core-range, which indicates the area around the nest where the vulture spends approximately 50% of its time; the 75% KDE, reflecting the mid-range, accounting for regular incursions away from the core range; and the 95% KDE, which shows the overall range used by the vulture, encompassing more distant movements away from the nest.

To analyse the gradual expansion of juveniles' home ranges throughout the post-fledging dependence period, we calculated KDEs for every fortnight from the fledging date up to the last fortnight period each bird was at the nest. To avoid overestimating the home-ranges in the last fortnight period, we removed all locations after a juvenile dispersed and did not return to the nest. We opted for estimating home ranges per period, rather than cumulatively (e.g., Hemery et al., 2024), because a cumulative approach could have restricted subsequent home ranges to areas closer to the nest, potentially underestimating the gradual expansion of the areas explored by juveniles as they become more autonomous. Prior to running the KDEs, we removed all locations within a 25 m buffer centered in nest to account for GPS error (~ 25 km) and avoid the home-ranges being constrained by the time each bird spent on the nest (e.g., Eeden et al., 2017; Sharps et al., 2015).

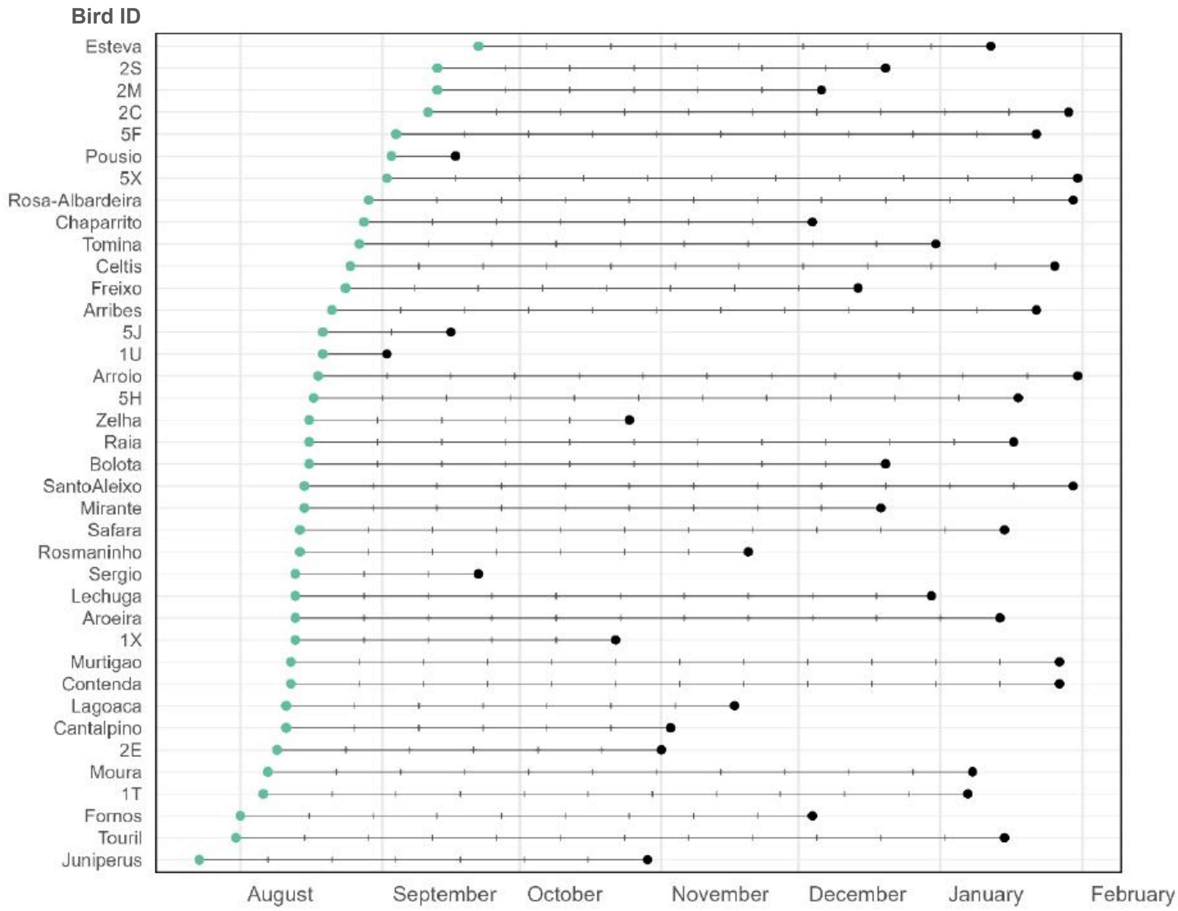

Figure 1. Tracking data of the 38 juvenile Cinereous Vultures used in the analysis, showing the fortnight periods considered for each individual from the fledging day (mean = 19 August; range: 23 July – 22 September). Light dots show the fledging day and black dots mark the end of the period of data considered in the analysis.

2.3. Conservation scenarios

We defined a set of thresholds for juvenile Cinereous Vulture home range protection, designed to represent a range of conservation scenarios, each reflecting varying degrees of commitment that the authorities could exercise when deciding the approval of new wind farm projects. The three proposed scenarios acknowledge the trade-off between protecting critical areas around nests and the ongoing pressure from wind farm encroaching into key habitats, because it would be impractical to fully protect the vast area covered by juvenile Cinereous Vultures during this period. Therefore, each threshold represents a different compromise between safeguarding the species vital areas around the nest and accommodating industry pressure, as follows:

Conservation first: in which the adopted buffer entirely covers the mid-range (75% KDE) of 75% of the juvenile vultures throughout the dependency period. This scenario is expected to provide the highest ecological benefit to young vultures, by securing both the core range and surrounding (mid-range) habitats and therefore minimising the risk of mortality in wind turbines.

Compromise: in which the adopted buffer entirely covers the core range (50% KDE) of 75% of the juvenile vultures throughout the dependency period. This scenario offers a lower level of protection against mortality by collision with wind farms, as it only safeguards the most intensively used areas (i.e., the core range) of a part of the population (75% of the individuals).

Industry first: in which the buffer covers the core range (50% KDE) of 50% of the vultures. While this scenario may meet very basic conservation obligations, the limited protection it offers to juvenile Cinereous Vultures against mortality by collision with wind turbines could threat long term viability of the whole population.

2.4. Estimating conservation buffers sizes for juvenile home ranges

We assessed the size of a circular buffer required to entirely cover the juvenile Cinereous Vulture home ranges by estimating the overlap percentage between increasingly larger buffers, centred on the nest, and the home ranges in each fortnight period (Veltheim et al., 2019; Watson et al., 2014). Starting with a 100 m radius buffer (approximately the area of the smallest estimated core range), we increased the buffer's radius by 100 m up to 40 km. To visualise this relationship, we built individual accumulation curves for each home range level in each fortnight period, showing the percentage of vultures whose home range would be entirely covered by each buffer size. From these accumulation curves we could calculate the size of the buffer needed to satisfy each conservation scenario.

However, these accumulation curves are sensitive to the (limited) sample of tagged individuals used in the analysis, so that adding new tagged vultures – or removing some – could change the estimated buffer coverage and thus affect the buffer size required under each conservation threshold. To assess the uncertainty of our estimates, we applied a bootstrapping approach, resampling the dataset over 1000 iterations to generate simulated accumulation curves and respective recommended buffers. This method captures the variability inherent in the original sample and allows us to quantify uncertainty around each curve and respective recommended buffers, expressed as 50% confidence intervals (i.e., 50% CI: 25th–75th percentiles) in the results.

2.5. Mapping conservation buffer areas in Cinereous Vulture colonies

Finally, to provide guidance for national authorities and industry stakeholders, we mapped the buffers estimated under each conservation scenario over the known nests in each of the five Cinereous Vulture breeding colonies in Portugal. For the Douro Internacional, Serra da Malcata, Tejo Internacional, and Herdade da Contenda colonies we used nest data from 2024, while for the Vidigueira/Portel colony we used nest data from 2025.

2.6. Software and reproducibility

All analysis were conducted in R (version 4.4.3; R Core Team, 2023) using packages *dplyr*, *sf*, *amt*, and *ggplot*. Tracking data is curated by the Vulture Conservation Foundation and stored in MOVEBANK in projects 'Cinereous Vulture Portugal 2018-2022' (ID: 4960264503) and 'Cinereous Vulture Portugal - LIFE Aegypius Return' (ID: 4964980419) (www.movebank.org). Code to produce the analysis can be requested from the author.

3. RESULTS

The home ranges of juvenile Cinereous Vultures increased as the dependency period progressed (Figure 2). As expected, this expansion is gradual, denoting the progressive independency of juvenile birds from their parents. From fortnight period 11 (mean start = 14 December; range: 21 November – 15 January), most birds (60%; n = 23) had already reached their independence and left the nest, and the core, mid-, and overall home ranges increased significantly relatively to the previous periods, suggesting an overall expansion in the amplitude of juveniles movements and an overall independence from their parents (even if still roosting at the nest). Therefore, in subsequent analysis we only considered the ten first fortnight periods.

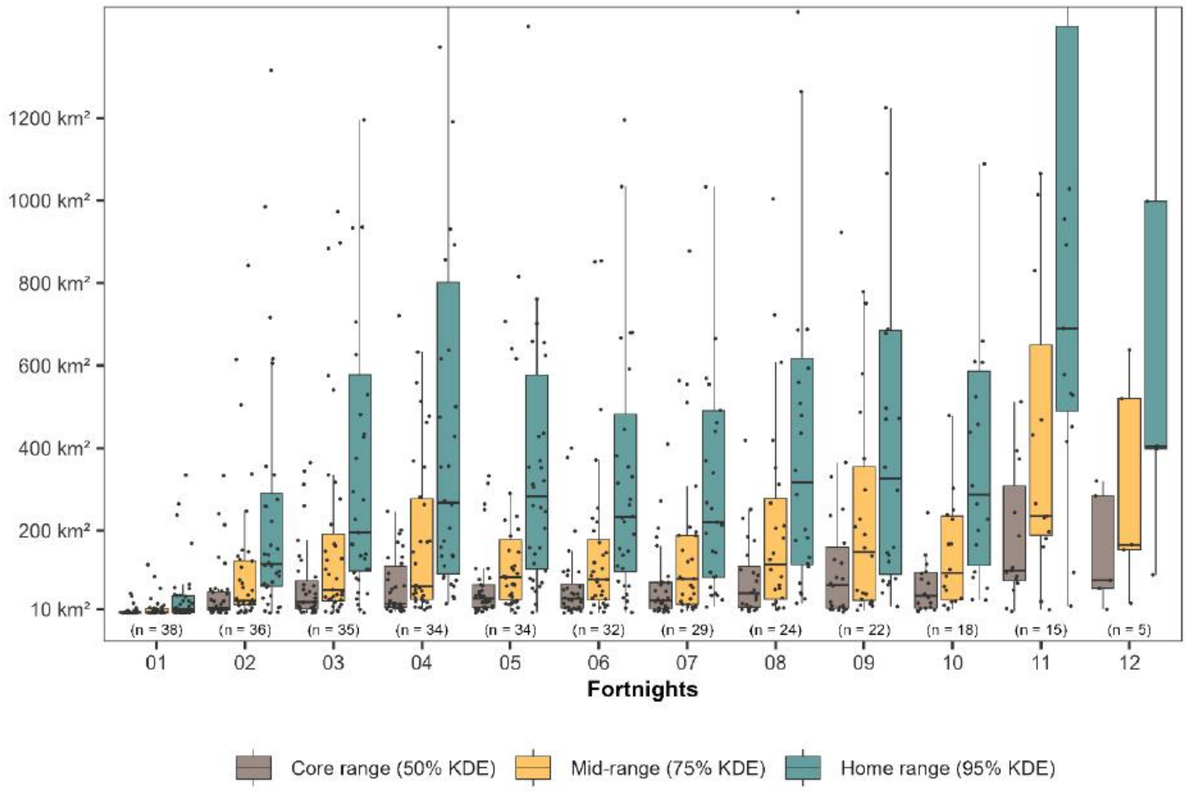

Figure 2. Juvenile Cinereous Vulture home range expansion throughout the dependency period. Boxplots show the distribution of home range areas for juveniles around the nest, in the core range (50% KDE), medium range (75% KDE), and overall home range (95% KDE) in fortnight periods post-fledging. For each fortnight, the boxplot presents the median (central line), interquartile range (25^{th}–75^{th} percentiles; the box), and whiskers indicating the range of values within 1.5 times the interquartile range. Individual data points are overlaid on the boxplot to illustrate the distribution of home range areas.

The size of circular buffers required to entirely encompass juvenile Cinereous Vulture home ranges varied across the dependency period and between home range levels (Figure 3). Accumulation curves revealed that larger buffers were needed to achieve full coverage of home ranges as the dependency period progressed (as juveniles become more independent and perform larger flights away from the nest).

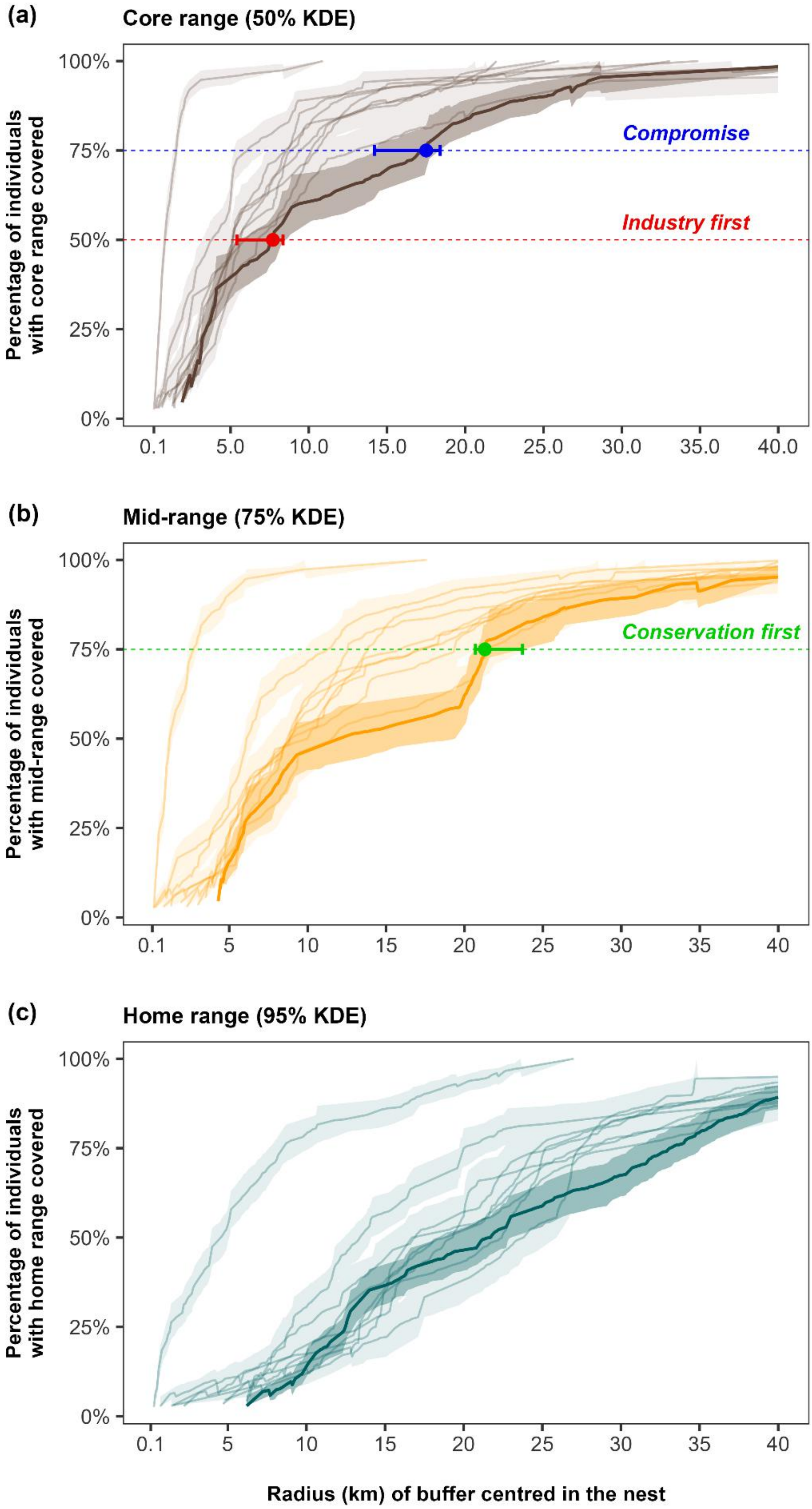
(a)
Core range (50% KDE)
Percentage of individuals with core range covered
100%
75%
50%
25%
0%
Compromise
Industry first
0.1
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
(b)
Mid-range (75% KDE)
Percentage of individuals with mid-range covered
100%
75%
50%
25%
0%
Conservation first
0.1
5
10
15
20
25
30
35
40
(c)
Home range (95% KDE)
Percentage of individuals with home range covered
100%
75%
50%
25%
0%
0.1
5
10
15
20
25
30
35
40
Radius (km) of buffer centred in the nest

Figure 3. Accumulation curves of juvenile Cinereous Vulture individuals and recommended buffer areas under each conservation scenario. Each panel illustrates the percentage of individuals with their home range covered by increasing buffer area, for **(a)** core range (50% KDE), **(b)** mid-range (75% KDE), and **(c)** home range (95% KDE). Each accumulation curves represents data from each fortnight period (periods 1–10; see Figure 1), with the line showing the median, and the shaded area the 50% confidence interval (50% CI; 25th–75th percentiles) of the 1000 bootstrapped estimates. The darkest colour in each panel highlights the period requiring the largest buffers to cover the respective range (see Figure 1). Horizontal lines indicate the conservation scenario thresholds, with dots showing the respective circular buffer radius (median ± 50% CI): ***Conservation first*** (green; panel (b)) safeguards the mid-range of 75% individuals, with a buffer radius of **21.3 km** (50% CI: 20.7 - 23.7 km); ***Compromise*** (blue; panel (a)) protects the core range of 75% individuals, with a buffer radius of **17.5 km** (50% CI: 14.2 - 18.4 km); and ***Industry first*** scenario (red; panel (a)) targets the core range of 50% of individuals, with a buffer radius of **7.7 km** (50% CI: 5.4 - 8.4 km). See Annex I for 95% confidence intervals around the estimates.

Under the *Conservation first* scenario (aiming to fully safeguard the mid-range of 75% individuals), a buffer radius of 21.3 km (50% CI: 20.7 - 23.7 km) was required (Figure 3 and 4). For the *Compromise* scenario (targeting the full protection of the core range of 75% of juveniles) the estimated buffer radius needed was 17.5 km (50% CI: 14.2 - 18.4 km) (Figure 3 and 4). The *Industry first* scenario (targeting only the core range of only 50% of individuals), required a minimum buffer radius of 7.7 km (50% CI: 5.4 - 8.4 km) (Figure 3 and 4; Annex I). These estimates were derived from bootstrapped accumulation curves (1000 iterations), which provided a robust measure of inter-individual variability and sampling uncertainty.

Mapping the estimated buffer sizes provides a visual representation of how each conservation scenario would translate into land safeguarded at the colony level (Figures 5 - 9). As expected, the *Conservation First* scenario produced the largest buffer areas, compared to the *Compromise* and *Industry first* scenarios. In all colonies the buffers required in each of the three scenarios provide continuous areas free of wind farm developments, which is key to reduce collision risk within the colonies and safeguard vital areas for juvenile movement during the dependency period.

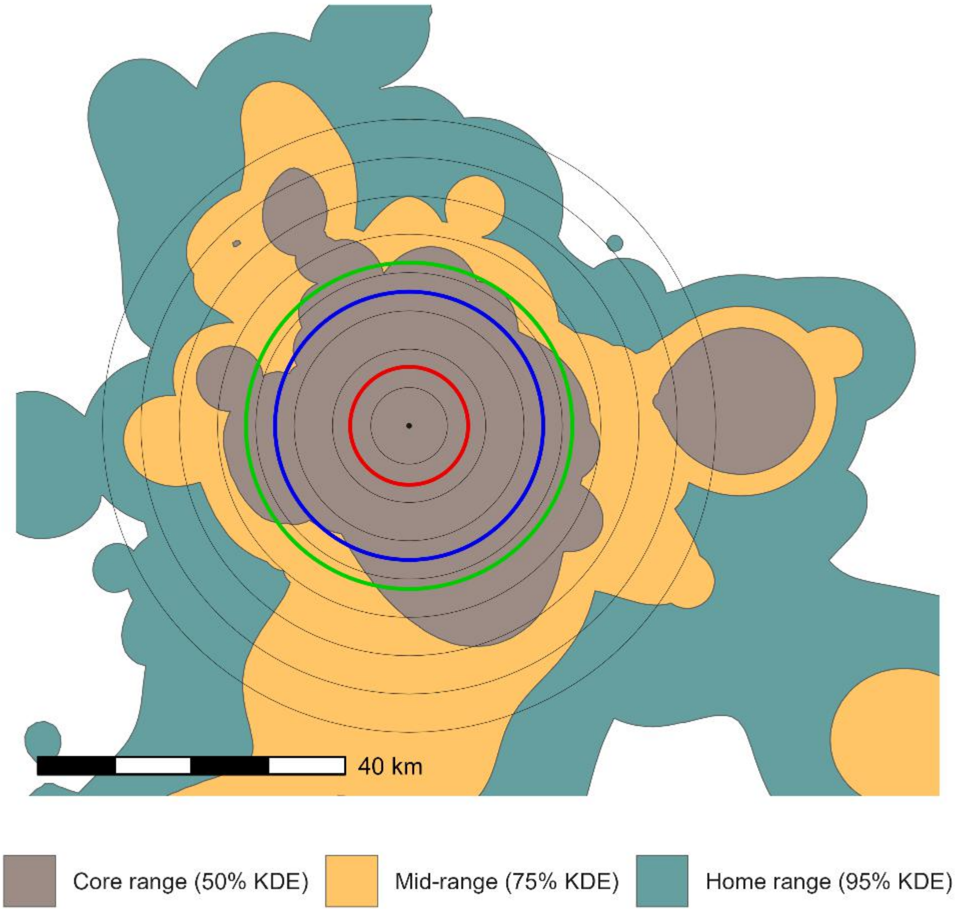

Figure 4. Overlap between conservation buffers and the merged home ranges of all juvenile Cinereous Vultures, with all individual nests and home ranges centred at coordinates (0, 0). Coloured areas represent the combined 50%, 75%, and 95% KDE home ranges across all vultures. Black circles denote hypothetical buffers at 5 km intervals from 5 to 40 km. Coloured lines indicate the buffers estimated for each conservation scenario: *Conservation first* (21.3 km radius; green), *Compromise* (17.5 km; blue), and *Industry first* (7.7 km; red).

Douro Internacional

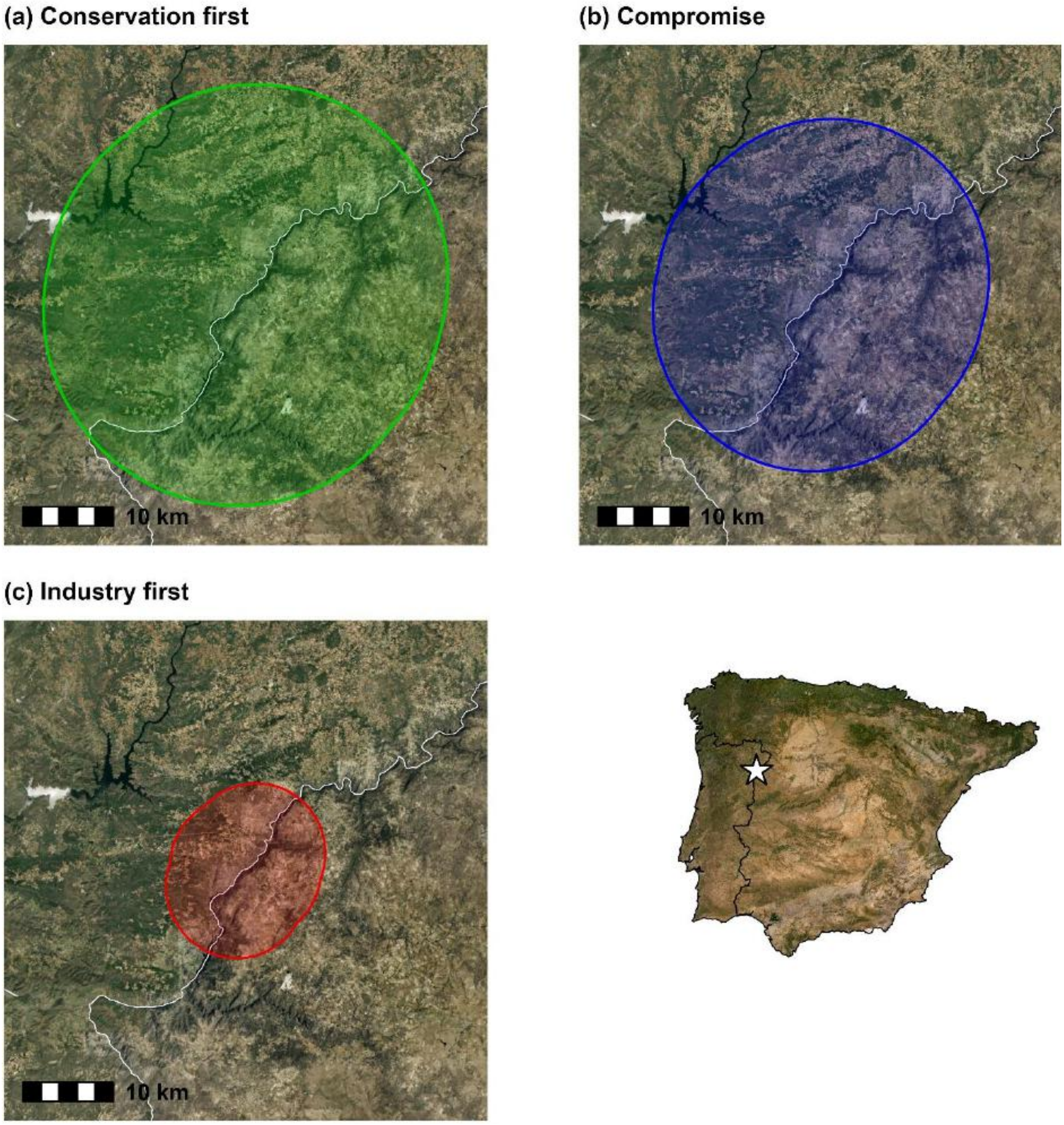

Figure 5. Conservation buffer areas for safeguarding the Cinereous Vulture breeding colony in the Douro Internacional Nature Park during the dependency period from wind farm expansion, under each conservation scenario: (a) *Conservation first* (21.3 km radius; green), (b) *Compromise* (17.5 km; blue), and (c) *Industry first* (7.7 km; red). Buffers were centered on all known used nests (n = 8) for the 2024 breeding season.

Serra da Malcata

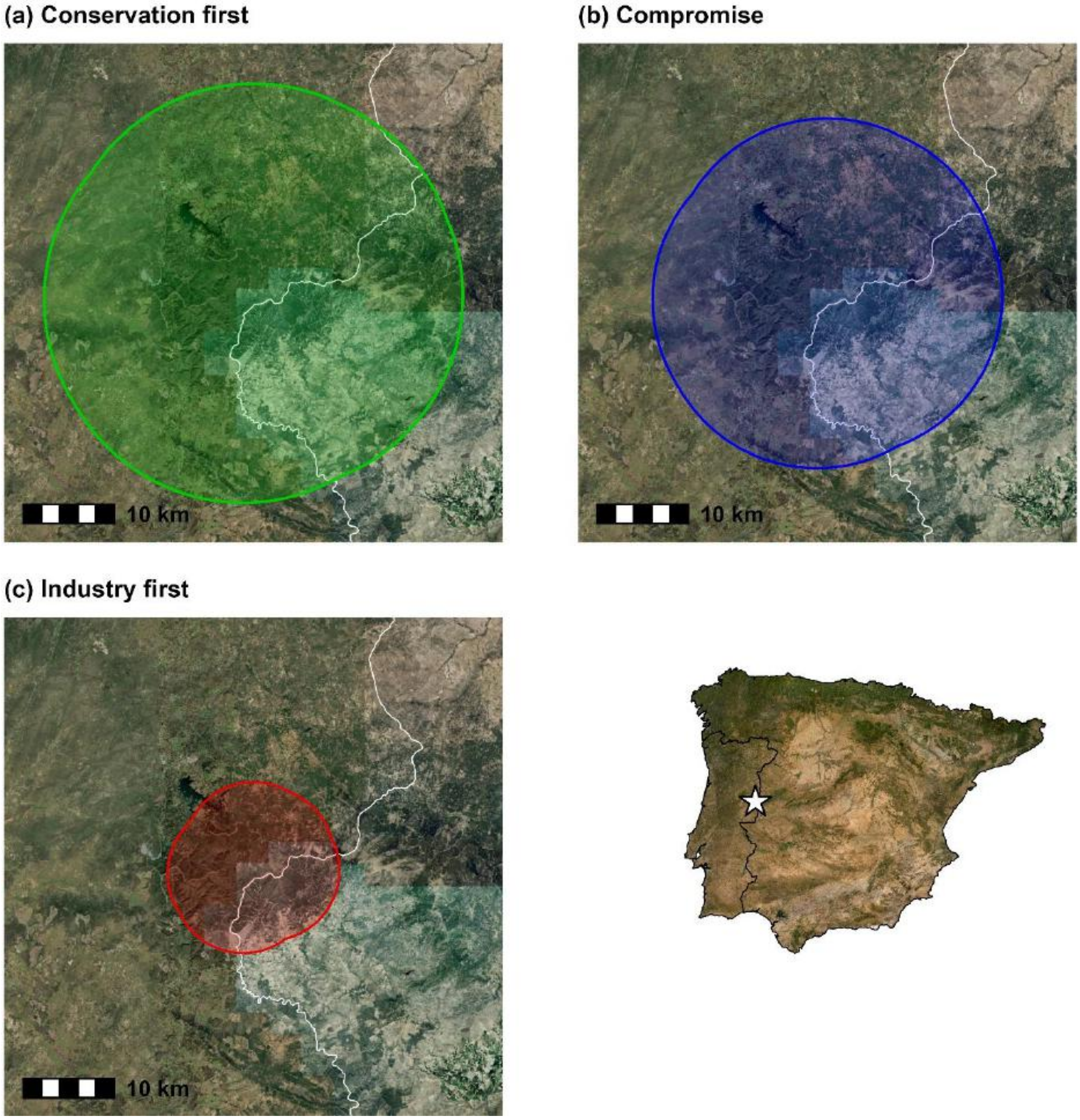

Figure 6. Conservation buffer areas for safeguarding the Cinereous Vulture breeding colony in Serra da Malcata during the dependency period from wind farm expansion, under each conservation scenario: (a) *Conservation first* (21.3 km radius; green), (b) *Compromise* (17.5 km; blue), and (c) *Industry first* (7.7 km; red). Buffers were centered on all known used nests (n = 18) for the 2024 breeding season.

Tejo Internacional

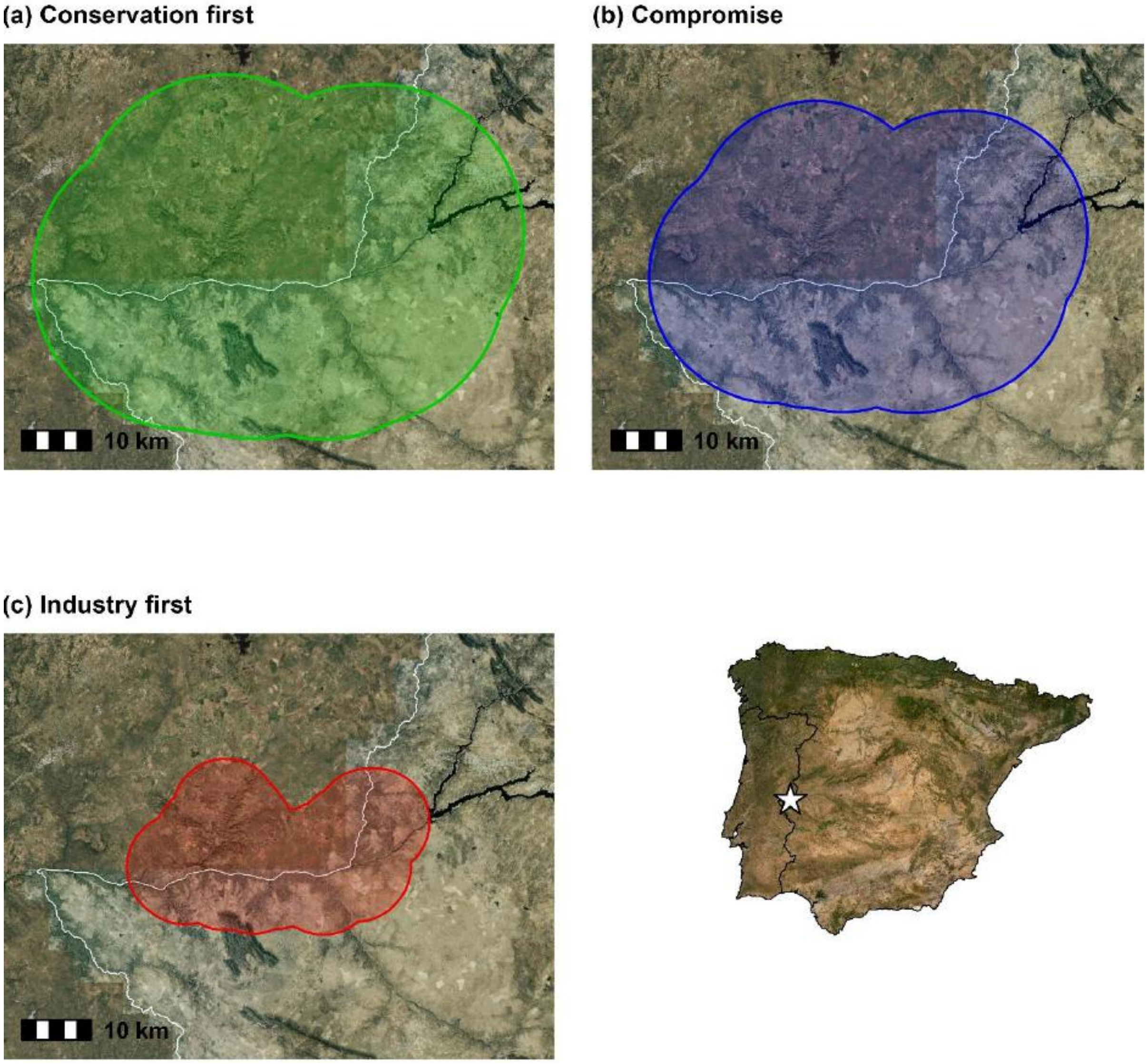

Figure 7. Conservation buffer areas for safeguarding the Cinereous Vulture breeding colony in Tejo Internacional during the dependency period from wind farm expansion, under each conservation scenario: (a) *Conservation first* (21.3 km radius; green), (b) *Compromise* (17.5 km; blue), and (c) *Industry first* (7.7 km; red). Buffers were centered on all known used nests (n = 61) for the 2024 breeding season.

Herdade da Contenda

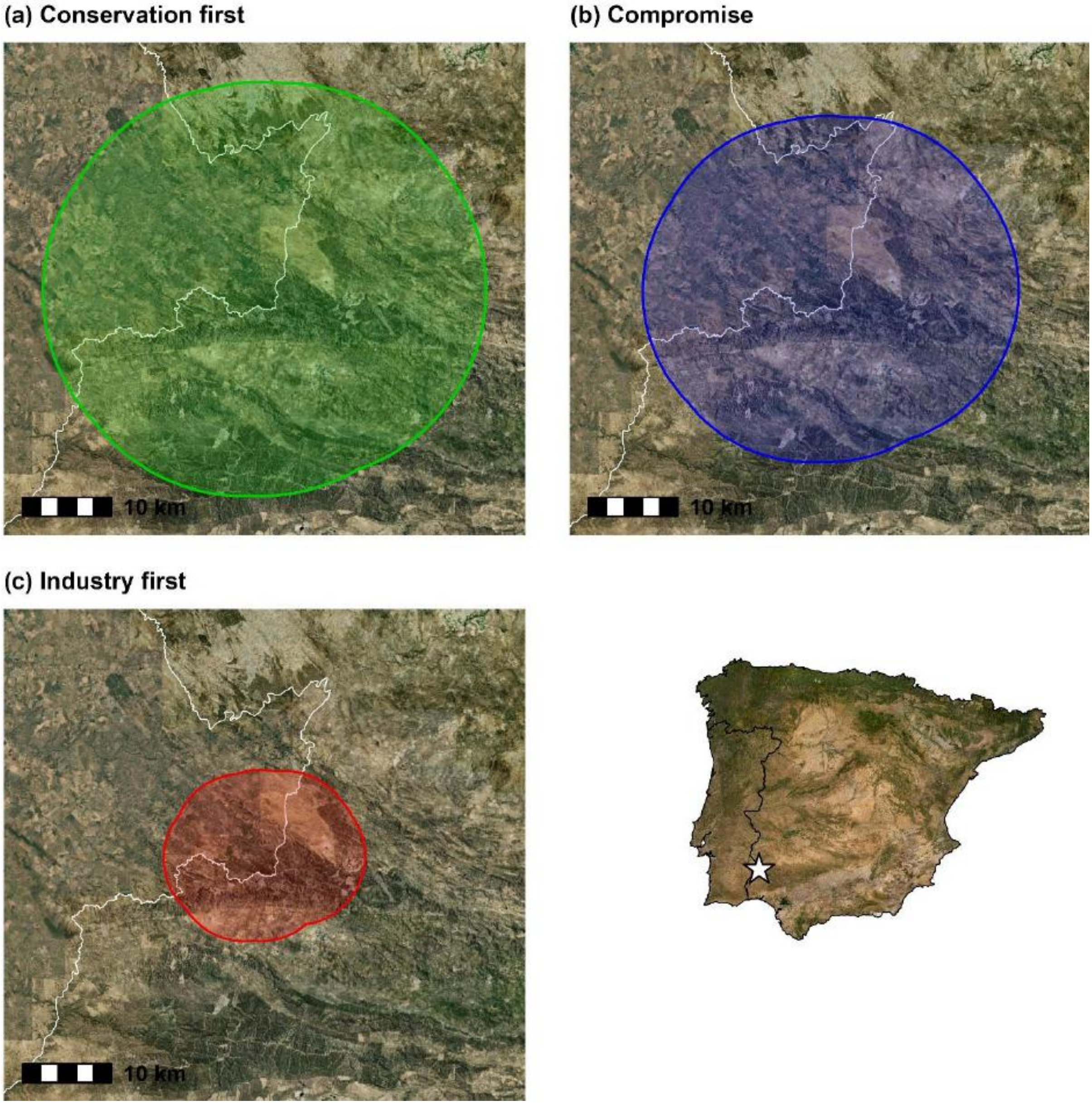

Figure 8. Conservation buffer areas for safeguarding the Cinereous Vulture breeding colony in Herdade da Contenda during the dependency period from wind farm expansion, under each conservation scenario: (a) *Conservation first* (21.3 km radius; green), (b) *Compromise* (17.5 km; blue), and (c) *Industry first* (7.7 km; red). Buffers were centered on all known used nests (n = 20) for the 2024 breeding season.

Vidigueira/Portel

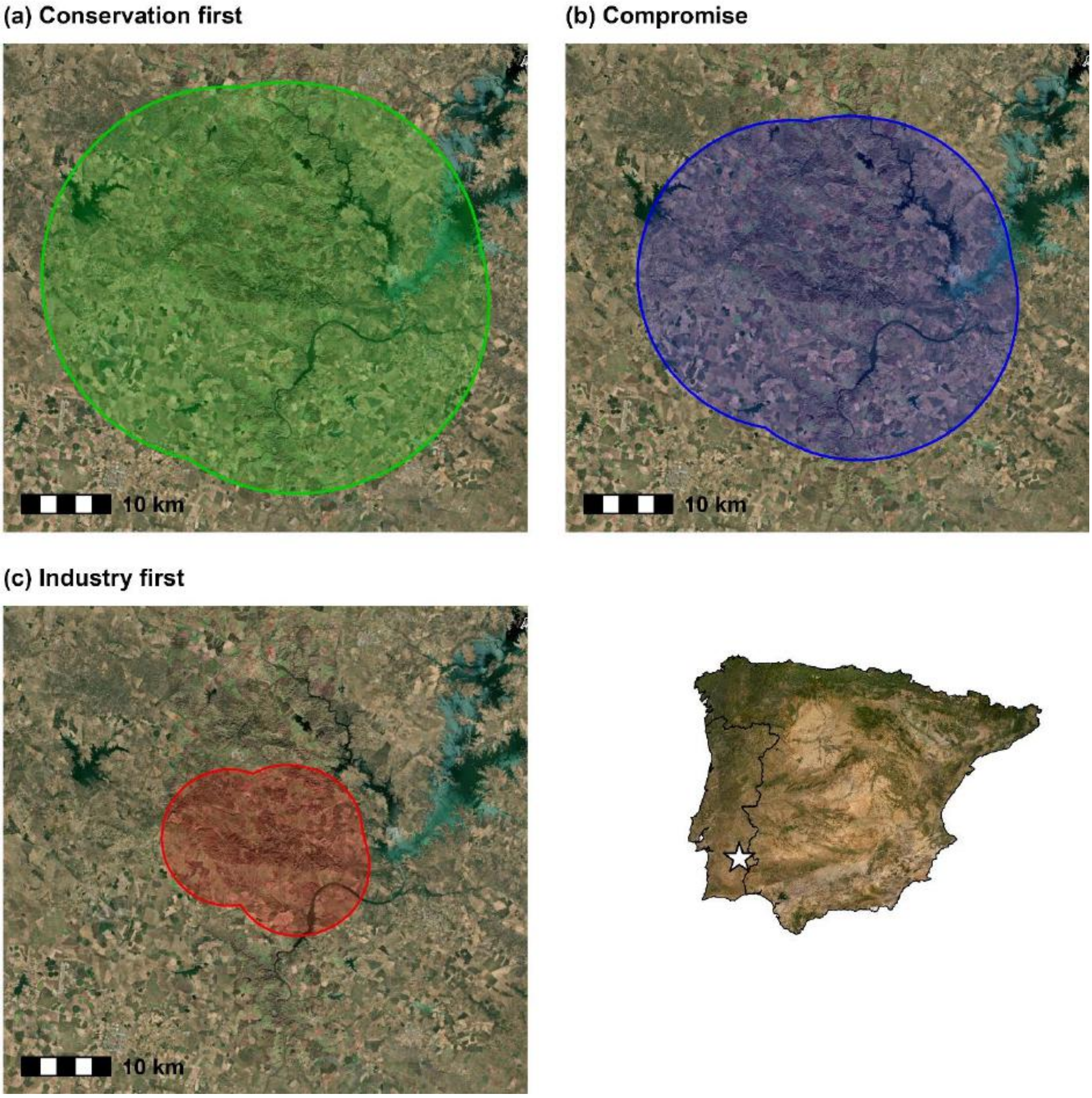

Figure 9. Conservation buffer areas for safeguarding the Cinereous Vulture breeding colony in Vidigueira/Portel during the dependency period from wind farm expansion, under each conservation scenario: (a) *Conservation first* (21.3 km radius; green), (b) *Compromise* (17.5 km; blue), and (c) *Industry first* (7.7 km; red). Buffers were centered on all known used nests (n = 12) for the 2025 breeding season.

4. DISCUSSION

The approach presented in this report provides national authorities and energy stakeholders with a practical and scalable tool to inform wind farm planning and approval near Cinereous Vulture colonies. By linking complex movement patterns of juvenile vultures with simple circular exclusion buffers, we present a set of conservation options – each reflecting a different level of protection – that national authorities can adopt in line with their national and international biodiversity conservation obligations.

Each conservation scenario – *Conservation first*, *Compromise*, and *Industry first* – reflects a different trade-off between biodiversity protection and land availability for wind energy expansion. The *Conservation first* buffer, which fully covers the mid-range (75% KDE) of 75% of juveniles, requires the largest area (buffer radius of 21.3 km), and offers the most robust protection by encompassing both core and surrounding areas used during the entire dependency period. This scenario is the most precautionary, and thus particularly appropriate for areas of high conservation value such as breeding colonies. The *Compromise* scenario (buffer radius of 17.5 km) offers a balance between ecological protection and area for wind farm expansion. It protects the core area used by 75% of juveniles and could be a defensible approach in areas where some development pressure exists around Cinereous Vulture colonies. Finally, the *Industry first* scenario (buffer radius of 7.7 km) only covers the core range of 50% of individuals, minimising the area constraints for wind farm encroachment but leaving a large proportion of juvenile Cinereous Vultures exposed to mortality risk, with potential effects on population viability of the species.

The simplicity and transparency of the buffer-based method we provide is especially useful for early-stage planning, screening, and regulatory guidance. Moreover, a buffer approach can be extremely efficient from a conservation perspective, as Cinereous Vultures breed in colonies and exhibit overlapping movements during the dependency period, which means that protecting these areas ensures the conservation of significant percentage of the population within a relatively small area (Venter et al., 2019). Nevertheless, as Cinereous Vultures use the landscape at immense scales, the strict implementation of a buffer approach may be challenging. More complex models, incorporating habitat quality, feeding sites, topography, cumulative risk, and movement behaviour, could further refine exclusion zones around colonies, with potential better trade-offs for the industry (Murgatroyd et al., 2021; Murgatroyd & Amar, 2025). Nevertheless, while such more complex models are not available, the buffer-based method hereby provided offers a practical and science-based approach, capable of informing the decisions of both national authorities and wind energy industry stakeholders.

5. REFERENCES

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ANNEX

Annex 1.

Accumulation curves of juvenile Cinereous Vulture individuals and buffer areas for each conservation scenario, with 95% confidence intervals.

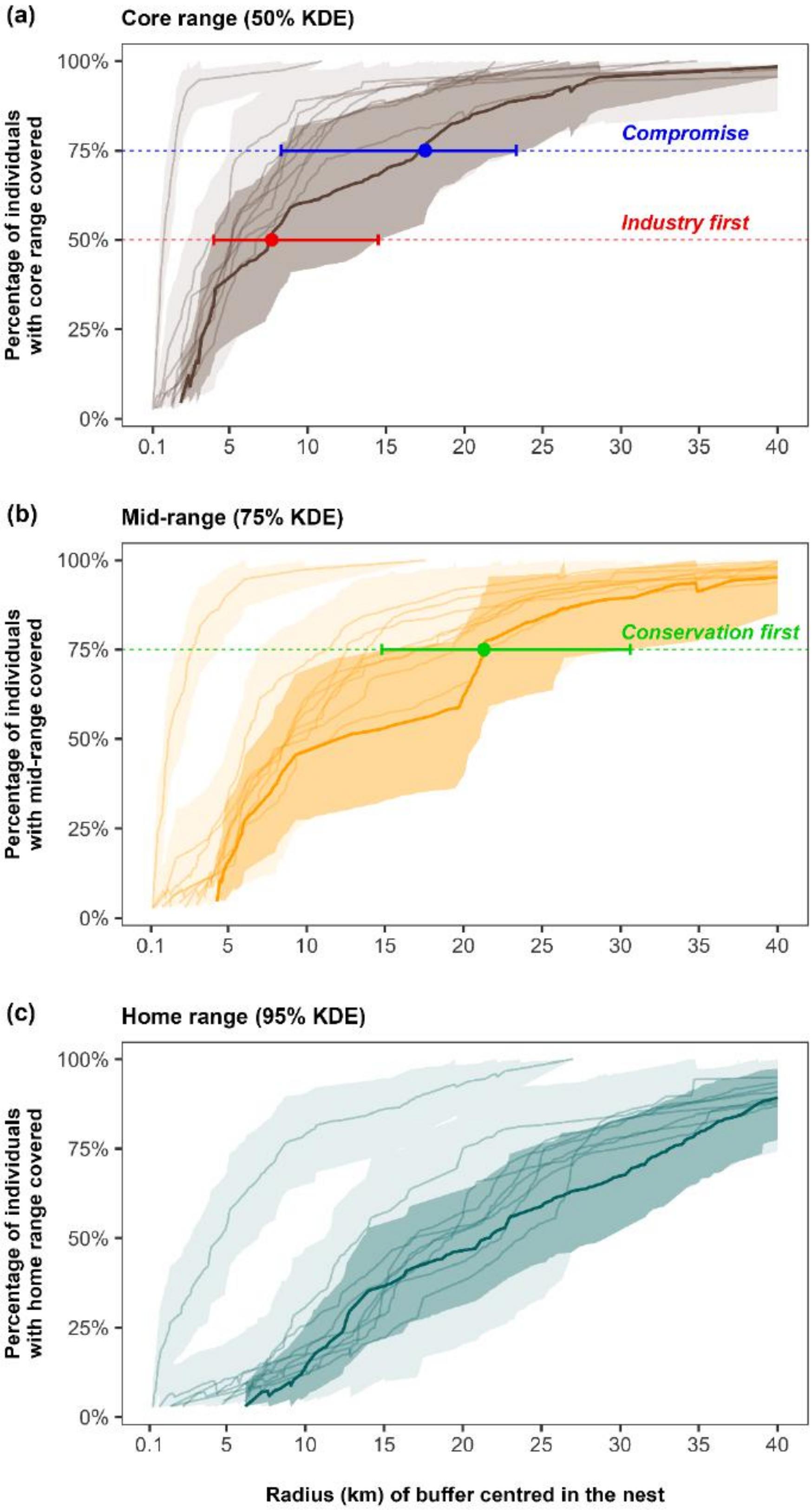

Figure I. Accumulation curves of juvenile Cinereous Vulture individuals and buffer areas for each conservation scenario, with 95% confidence intervals. Each panel illustrates the percentage of individuals with their home range covered by increasing buffer area, for **(a)** core range (50% KDE), **(b)** mid-range (75% KDE), and **(c)** home range (95% KDE). Each accumulation curves represents data from each fortnight period (periods 1–10; see Figure 1), with the line showing the median and the shaded area the 95% confidence interval (2.5th–97.5th percentiles) of the 1000 bootstrapped estimates. The darkest colour in each panel highlights the period requiring the largest buffers to cover the respective range (see Figure 2). Horizontal lines indicate the conservation scenario thresholds, with the dots representing the respective circular buffer radius (median ± 95% confidence interval): *Conservation first* (green; panel (b)) safeguards the mid-range of 75% individuals, with a buffer radius of 21.3 km (95% CI: 14.8 - 30.6 km); *Compromise* (blue; panel (a)) protects the core range of 75% individuals, with a buffer radius of 17.5 km (95% CI: 8.3 - 23.3 km); and *Industry first* scenario (red; panel (a)) targets the core range of 50% of individuals, with a buffer radius of 7.7 km (95% CI: 3.9 - 14.5km).