LIFE SAFE FOR VULTURES

Movements of restocked Griffon Vultures in Sardinia

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First step to the restoration of the vulture guild in Sardinia

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Abstract

Progetto LIFE19NAT/IT/000732
LIFE SAFE for VULTURES
First step to the restoration of the vulture guild in Sardinia
Primo passo verso il ripristino della gilda dei vulturidi in Sardegna

The Griffon Vulture (*Gyps fulvus*) population in Sardinia has recovered through conservation efforts, including those implemented during the LIFE Safe for Vultures project, which focus on habitat protection, threat mitigation, supplementary feeding, and restocking of the population. Here, we report on the movements of two groups of Griffon Vultures released in 2024 in Villasalto, alongside data from Griffon Vultures previously released in Bosa breeding colony. The birds in the first group were released in Villasalto in April 2024 after a 10-month acclimatization period, while the second release group (n = 22) was released in October 2024 following a 6-month acclimatization. We analysed the movements, utilization distributions, feeding events, and roosting sites used by the groups compared to the older group. Results showed different movement patterns between the groups. The first group exhibited strong fidelity to the release area with limited dispersal, likely influenced by acclimatization and available resources. In contrast, the second group dispersed widely across Sardinia, particularly towards the established Bosa and Punta Cristallo colonies, suggesting the role of social cues and possibly seasonal influencing their movement patterns. Overall, survival rates of the translocated birds were robust and comparable to those reported in similar translocation efforts elsewhere. These findings highlight the importance of adaptive release strategies, considering factors like acclimatization, age, and ecological conditions. Continued monitoring is crucial to refine management approaches and ensure the long-term success of the Griffon Vulture population in Sardinia.

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We warmly thank the personnel of Forestas for their dedicated work in managing the animals during the acclimatisation and recovery phases at the Monastir and Bonassai Wildlife Recovery Centres, and in Villasalto aviary. We are also deeply grateful to all those who supported us in the tagging and monitoring of the animals. Our appreciation further goes to the group of volunteers who contributed to monitoring and management activities within the LIFE "Under Griffon Wings" and LIFE "Safe for Vultures" projects.

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Introduction

The Griffon Vulture (*Gyps fulvus*) is a key scavenger species whose populations across Europe have undergone dramatic fluctuations over the last two centuries, culminating in the extinction of several populations (BirdLife International, 2025). In recent decades, coordinated conservation initiatives at both European and regional level have enabled a gradual recovery through restocking, reintroduction and rehabilitation programmes, coupled with actions to mitigate the main threats to Griffon Vultures, namely poisoning, electrocution, and food scarcity.

Sardinia is home to the last native population of Griffon Vultures in Italy, although recent conservation measures have brought the species back to other parts of Italy (e.g., Monti et al., 2023). In the 1930s, the Sardinian Griffon Vulture population numbered 800-1200 individuals, but direct persecution, poisoning, and increasing food scarcity caused a sharp decline in the population, restricting the Griffon Vultures to a single and vulnerable breeding nucleus in northwestern Sardinia, between Bosa and Alghero. The first conservation efforts began in the 1970s with supplementary feeding sites, followed by legal protection and systematic monitoring of breeding birds (Schenk et al., 2008). This was followed by translocations of birds from Spain and France between 1987 and 1995 (Schenk and Aresu, 1992), which helped to increase the population, although mass poisonings in the late 1990s and 2000s undermined these gains (Schenk et al., 2008). From 2016, intensive efforts have focused on restoring a viable, self-sustaining Griffon Vulture population across the island Sardinia. Conservation actions carried out under LIFE Under Griffon Wings (LIFE14/NAT/IT/000484) and, currently, under LIFE Safe for Vultures (LIFE19NAT/IT/000732), tackled major threats (including poisoning, electrocution, and disturbance), increased food availability through centralised and farm feeding stations and secured the protection of key habitats. Combined with a carefully planned restocking programme, these actions have created the foundations for population recovery and long-term viability of a sustainable Griffon Vulture population in Sardinia.

Recent releases under the LIFE Safe for Vultures project aimed to recolonise the breeding colony in Villasalto (southeastern Sardinia), not only to reconnect vultures with their historical range, but also to support a more balanced distribution of the species across the island (Secci et al., 2024). Monitoring the movements of translocated birds is essential to understand the dynamics of recolonisation in Villasalto, the factors that may lead to their attachment to the release site or their dispersal to other areas, their feeding routines and roosting preferences. This knowledge is es-

sential to assess the success of the conservation actions implemented and to adapt management strategies for the future.

Here, we report the movements (up to 1st June 2025) of two groups of Griffon vultures restocked in Sardinia in 2024, within the LIFE Safe for Vultures. The *'first release group'* included 15 Griffon vultures, which were released on 9th April 2024, in Villasalto (SE Sardinia), following an acclimatization period of 10 months. The *'second release group'*, included 22 Griffon vultures, which were released on 9th October 2024, also in Villasalto, following an acclimatization stay of 6 months. We further present the general movements of 29 Griffon vultures that were tagged and monitored previously to the start of the current LIFE project (*'old group'*), most of them restocked during the LIFE Under Griffon Wings. For each group, we analysed the (a) overall movements, (b) Utilization Distributions (core range, 50% UD; mid-range, 75% UD; and overall home range, 95% UD), (c) feeding events (based on accelerometer data); and (d) roost utilization. Finally, to provide a comprehensive overview of spatial use across the population, we mapped the aggregated movements and utilization distributions of the three Griffon vulture groups monitored in Sardinia.

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1. Old group and the Bosa Colony

Griffon vultures forming the *old group* are all those tagged and monitored before the start of the LIFE Safe for Vultures project. This group includes birds from different sources: individuals translocated from Spain (n = 21), birds originating from captive-breeding programmes (n = 7), and Sardina-born birds that were rehabilitated and released after recovery (n = 9) (Table 1). All these individuals were part of the previous efforts started in 2016, to recover the Griffon vulture population and increase their conservation status in Sardinia under the LIFE Under Griffon Wings. The strategy was specifically centred around the Bosa colony in the northwest of the island, the stronghold of the Griffon vulture in Sardinia. Therefore, two birds that were rehabilitated during the LIFE Safe for Vultures and hard released in Bosa in 2024 were included in this group, bringing the total to 39 birds. Overall, these birds exhibited a mean 6-month survival rate of 80.95% and a 1-year post-release survival rate of 74.6% (Berlinguer et al., 2025), both of which fall within the range reported in other Griffon Vulture translocation projects (e.g., Sarrazin et al., 1994; Monti et al., 2023). Analysing the movements and utilization distributions of these *old group* birds, becomes apparent that their range remained largely confined to the release sites within Bosa colony and nearby smaller Punta Cristallo colony. Only limited dispersal to other parts of the island took place (Figure 1a,b). This restricted spatial pattern is most likely influenced by the presence of conspecifics – including more experienced individuals – and availability of reliable foraging grounds around the main roosting sites and breeding cliffs (Cerri et al., 2023). Moreover, the existing supplementary feeding stations (both centralised feeding stations and farm feeding stations) implemented in these areas since 2016 provide a significant amount of predictable carrion for the vultures (LIFE Under Griffon Wings, 2020). This interpretation is reinforced by the clustering of feeding events around Bosa and Punta Cristallo – although this analysis was based only on six tracked birds, which may be under representative of the overall feeding activity by this group (Figure 1c; Fozzi et al., 2025).

Nevertheless, some birds undertook larger movements away from the main colonies (Figure 1a), occasionally roosting in areas well outside their home ranges (Figure 1d). These large-range movements took some of the *old group* Griffon vultures to different sites scattered across Sardinia (Figure 1d), putting in evidence not only their dispersal aptitude but also the need to warrant food availability across the island. While these large-range movements away from the home ranges may not be entirely intentional, and in some cases driven by the weather conditions (Cerri et al., 2025), they are ecologically significant; for example, the use of these roosts, even if sporadically, may indicate favourable sites used by non-tagged conspecifics.

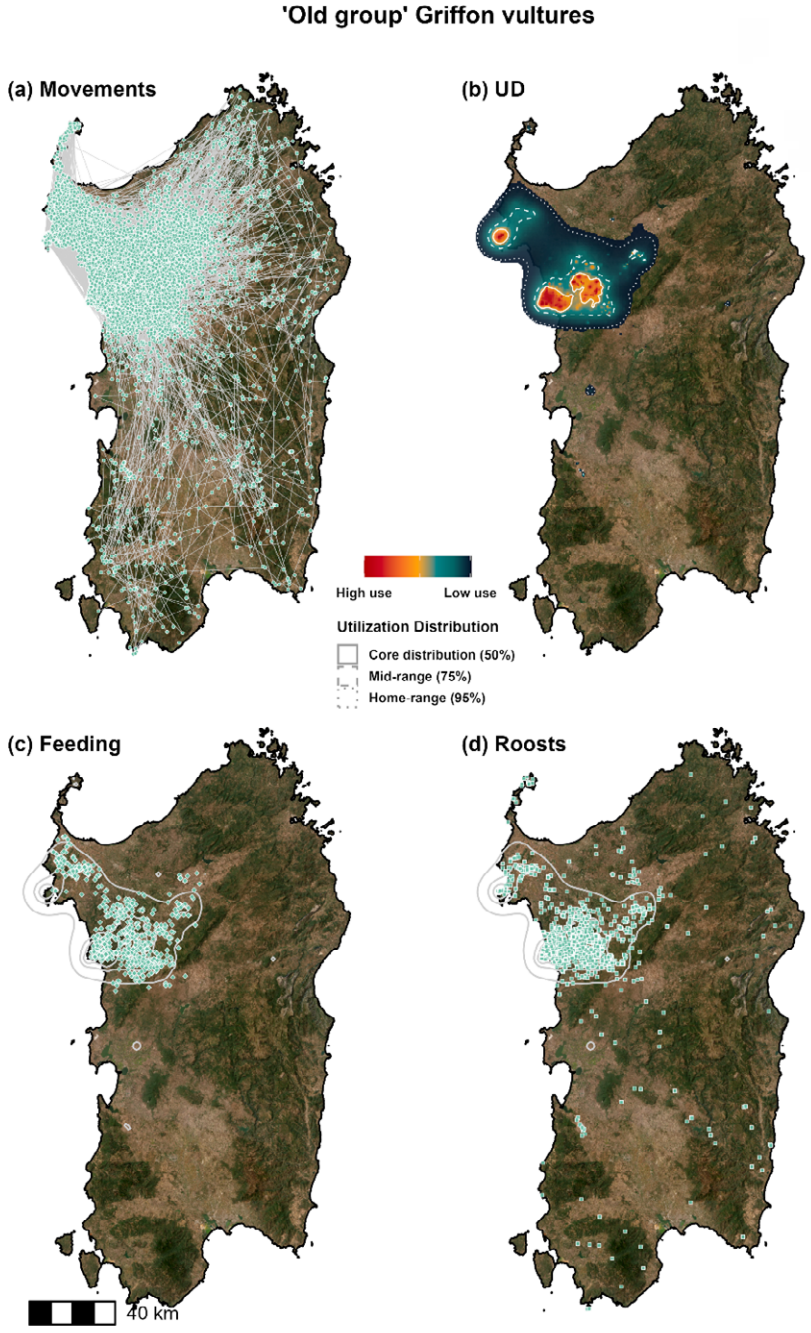

Figure 1

Overall movements and spatial use of 39 Griffon Vultures released in Sardinia before the LIFE Safe for Vultures – *old group* birds: **(a)** all tracked movements illustrated by light-grey lines connecting locations recorded every two hours (light-blue dots; night locations not shown) of released vulture; **(b)** Utilization Distribution (UD), modelled using dynamic Brownian Bridge Movement Models (dBBMMs), with contours representing the core range (50% UD), mid-range (75% UD), and home range (95% UD) within an annual-cycle; **(c)** feeding events revealed using triaxial accelerometer data (n = 6 birds; n = 2239 feeding events); and **(d)** roosts used by the vultures, with each location (n = 14 125 nights) showing a single night used by a single vulture.

2. First release group

The *first release group* of Griffon vultures (n = 15) was released in the Villasalto region on 9th April 2024 following an acclimatization period of 10 month. This was an important milestone in the expansion of the Sardinian reintroduction programme. The *first release group* included birds translocated from Spain (n = 10) as well as Sardinia-born birds that were rehabilitated and released (n = 5). The Villasalto area was targeted for releasing Griffon Vultures for its historical significance as breeding site and, thus, its potential to again support a thriving colony.

The released birds generally remained within a tightly restricted home range, with most birds exhibiting a strong attachment to their release area. Similarly to the behaviour of the *old group*, dispersal of the *first release group* was also relatively limited, with birds' home ranges well established in Villasalto. For most of the monitoring period, their activity remained concentrated within a few kilometres of the release area and only rarely they ventured far from there (Figure 2a,b; Figure 4). Tracking data also confirmed that their foraging activity was concentrated within their home range around Villasalto (Figure 2c; Fozzi et al., 2025). In addition, GPS tracking showed that of the 15 birds released, 11 (66.7%) survived the first 6 months post-release, and of those, 10 (60%) survived to the end of their first year free ranging in Sardinia (Berlinguer et al., 2025).

Only occasional exploratory mid-range flights were observed into nearby areas in the southwestern and central Sardinia, along with just a few long-range movements northward. Notably, however, none of these movements indicated any visit to the other colonies of Bosa and Punta Cristallo. This fidelity to the release area likely reflects the favourable conditions and attractiveness of Villasalto area for Griffon Vultures, including foraging opportunities and availability of safe roosting sites (Figure 2d). It also highlights the effects of long acclimatization in stabilizing home ranges (Fozzi et al., 2023) and synchrony in space use (Cerri et al., 2024) of released birds as they adapt to their new environment.

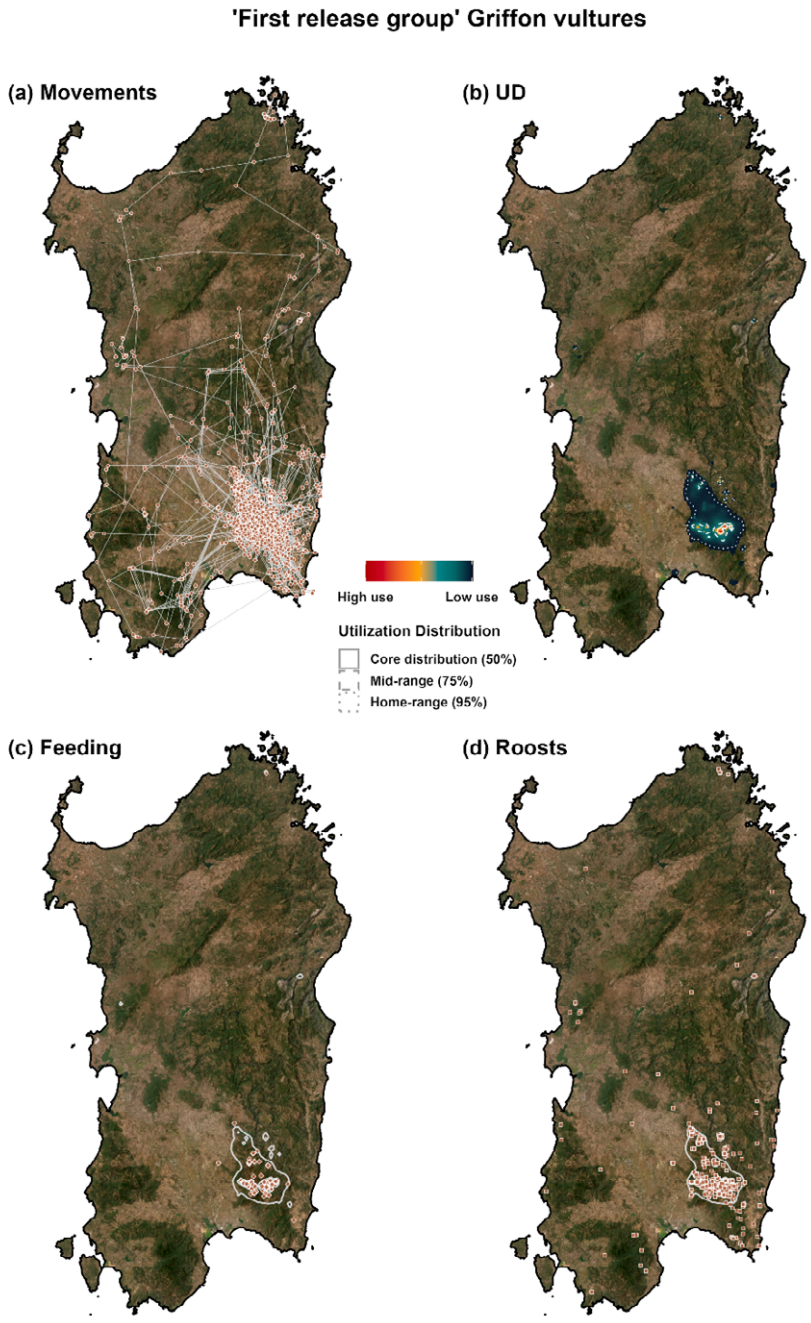

Figure 2

Overall movements and spatial use of 15 Griffon Vultures released in Sardinia on 9 April 2024 – first release group: **(a)** all tracked movements illustrated by light-grey lines connecting locations recorded every two hours (light-blue dots; night locations not shown) of released vulture; **(b)** Utilization Distribution (UD), modelled using dBBMMs, with contours representing the core range (50% UD), mid-range (75% UD), and home range (95% UD) within an annual-cycle; **(c)** feeding events revealed using triaxial accelerometer data (n = 11 birds; n = 2013 feeding events); and **(d)** roosts used by the vultures, with each point (n = 3448 nights) showing a single night used by a single vulture.

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3. Second release group

The *second release group* of Griffon vultures (n = 23) was also released in Villasalto region on 9th October 2024. The Griffon vultures in this group were mostly juveniles translocated from Spain (n = 19), two captive bred birds from France and Mallorca, and two Sardinia-born rehabilitated birds.

In stark contrast to the *first release group*, the second release group exhibited a markedly different pattern of movement. Rather than remaining close to the release area, the majority of the birds engaged in long-range movements across Sardinia covering distances exceeding 150 km from Villasalto (Figure 3a), with most of these movements toward the Bosa and Punta Cristallo colonies in the northwest of the island (Figure 3a). Two main core-ranges were established by these birds, with one in Villasalto and a second in Bosa (Figure 3b). Likewise, both the feeding events and the roosts used by this group were scattered across Sardina, with two main concentration areas coinciding with the two main areas (Figure 3c, d).

Interestingly, the dispersion of the *second release group* birds occurred shortly after their release, and within just a few weeks more than 80% of individuals had dispersed toward the well-established Bosa and Punta Cristallo colonies in the northwest (Figure 4). Despite greater dispersal – and thus increased potential exposure to threats – the 6-month survival rate of the *second release group* was 86.4%, which was 1.3 times higher than that of the *first release group* (Berlinguer et al., 2025).

The divergent movement patterns observed between the two release groups suggest an interplay of acclimatisation period and age shaping vulture movements following releases. The *first release group*, released in early spring, remained largely near the release area, which may reflect the effect of a longer acclimatisation period (10 months) in stabilizing their home ranges (Fozzi et al., 2023). In contrast, individuals from the *second release group*, released in autumn after a shorter acclimatisation period of 6 months (and thus being overall some months younger), dispersed more widely, with several reaching the established colony in Bosa. One the one hand, attraction to more experienced conspecifics may have contributed to this, as more experienced birds in Bosa may offer better clues regarding available resources (Acácio et al., 2024). On the other hand, seasonality may have as well contributed to these northward movements, as weather conditions seem to have a key effect on large-range movements of Griffon Vultures in Sardinia (Cerri et al., 2025). Seasonal differences in food availability, however, are unlikely to play a role on this behavioural difference, as livestock rearing is practiced extensively throughout the year without any expected differences in resources' available. The observed patterns highlight the need for further research into the relative influence of these different factors on post-release movements of vultures.

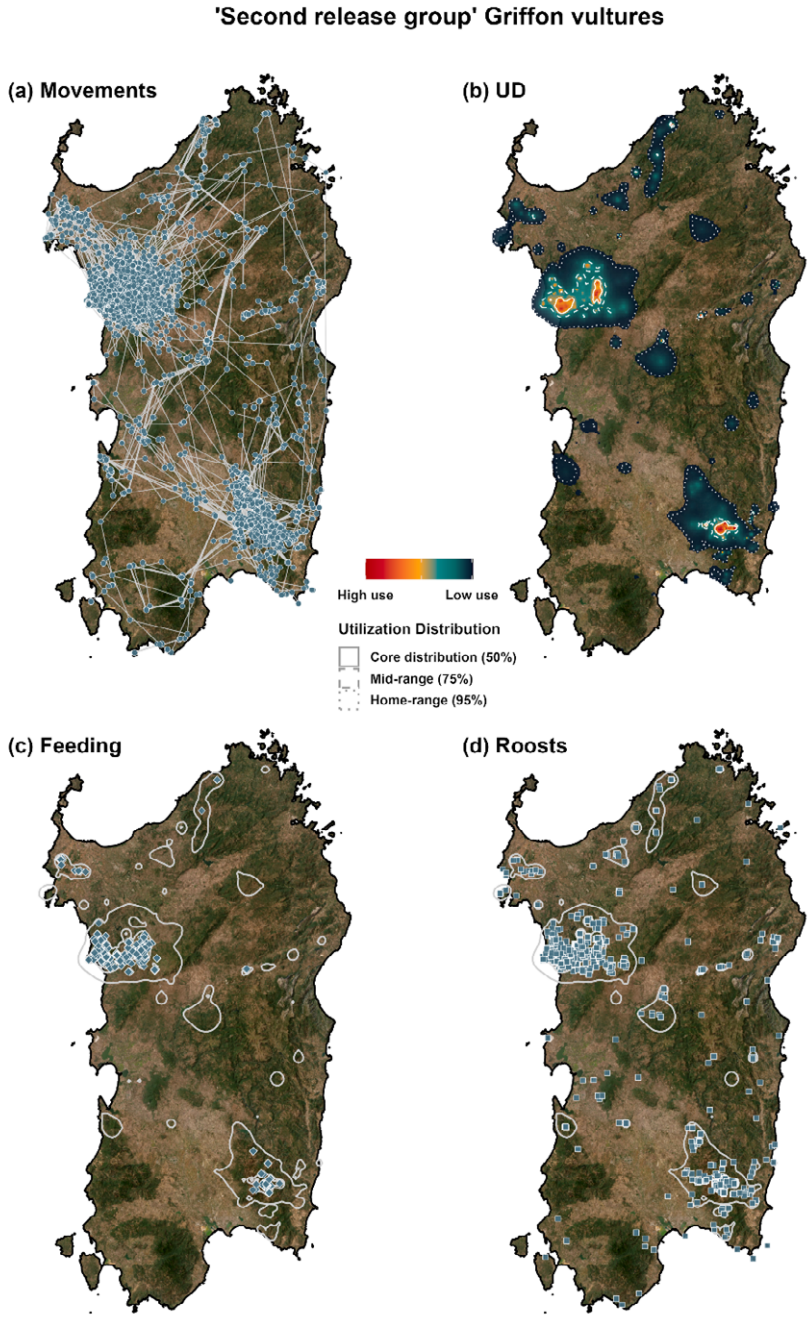

Figure 3

Overall movements and spatial use of 23 Griffon Vultures released in Sardinia on 9 October 2024 – second release birds: **(a)** all tracked movements illustrated by light-grey lines connecting locations recorded every two hours (light-blue dots; night locations not shown) of released vulture; **(b)** Utilization Distribution (UD), modelled using dBBMMs, with contours representing the core range (50% UD), mid-range (75% UD), and home range (95% UD) within an annual-cycle; **(c)** feeding events revealed using triaxial accelerometer data (n = 21 birds; n = 2399 feeding events); and **(d)** roosts used by the vultures, with each point (n = 3982 nights) showing a single night used by a single vulture.

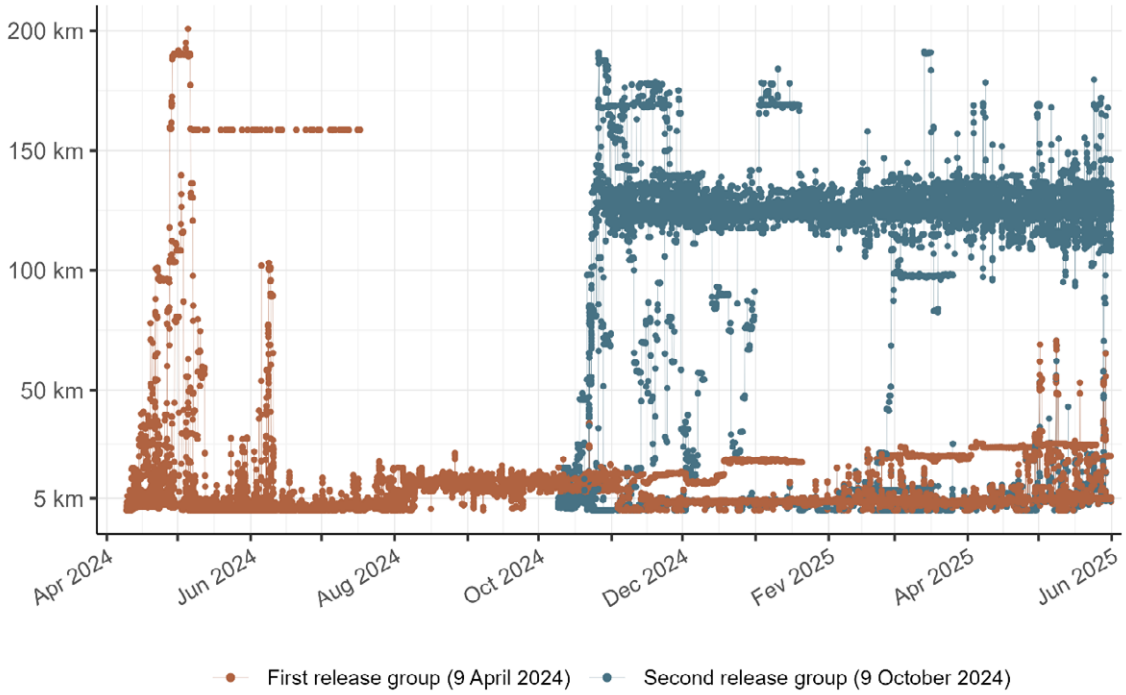

Figure 4

Distances travelled by the *first* and *second release groups* of Griffon Vultures.
Plot shows the distance of each birds' location to the release site in Villasalto with locations coloured per release group.

Discussion

The extensive Griffon Vulture GPS tracking data collected in Sardinia since 2016 offers invaluable insights into the 'where and when' of these vultures' movements throughout the year, revealing the birds' locations and behaviours, feeding sites and roosts. Therefore, the remote monitoring system used by the LIFE Safe for Vultures is effective in obtaining key details about Griffon Vultures' distribution and conservation needs across Sardinia.

There were important differences between the three groups analysed here. While the *old group* largely remained close to the historical colonies of Bosa and Punta Cristallo, the two groups released in Villasalto exhibited strikingly different dispersal behaviours. The *first release group* showed remarkable fidelity to the release site, while the *second release group* dispersed rapidly and extensively toward northwestern Sardinia. These contrasting patterns highlight that reintroduced vultures don't follow a single, predictable strategy but adapt dynamically to local ecological conditions and social cues, revealing both the challenges and opportunities in designing release strategies that balance site attachment with the need to establish new populations in unoccupied areas.

From a management perspective, these findings underline the importance of synchronizing release strategies with ecological conditions and resource availability. Early spring releases following longer acclimatisation periods appear to foster stronger site fidelity and gradual adaptation to the release environment, while autumn releases after shorter acclimatization periods may stimulate wider-ranging exploration and faster integration with established colonies, although this needs further investigation. Regardless, both outcomes have conservation value: anchoring birds in Villasalto supports the establishment of a new colony in southeastern Sardinia, whereas dispersal toward Bosa contributes to the reinforcement of the island's stronghold population. These complementary dynamics suggest that a balanced release strategy, spanning different seasons and supported by adequate supplementary feeding infrastructure, could maximize the overall resilience and connectivity of the Sardinian population.

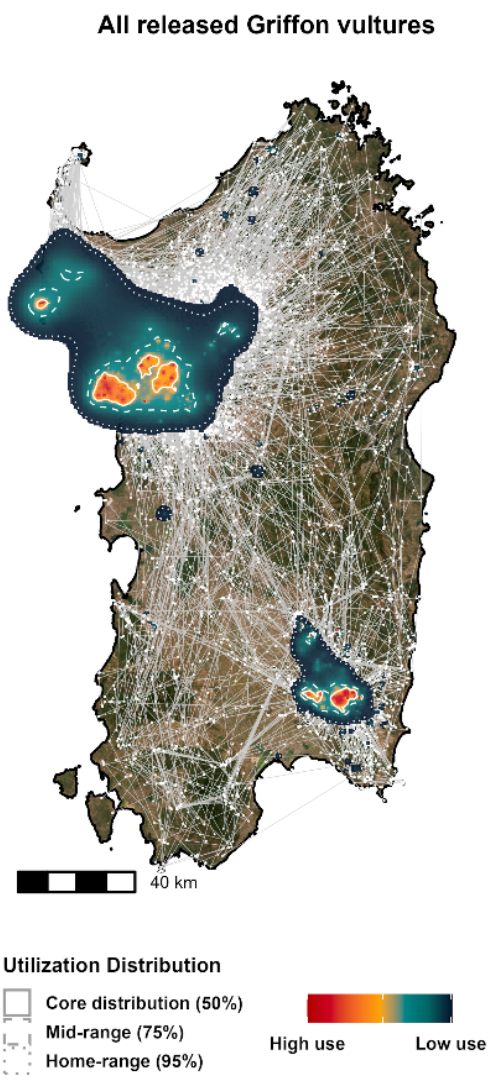

Figure 5

Movements and annual Utilization Distribution (UD) of the 77 Griffon Vultures in Sardinia, modelled using Dynamic Brownian Bridge Movement Models (dBBMM). The contours represent the core range (50% UD), mid-range (75% UD), and home range (95% UD), delineating areas of increasing spatial utilization by the Griffon Vultures from April 2017 to May 2025. Light-grey lines connect locations recorded every two hours (light-grey dots; night locations not shown) of each tracked vulture, illustrating their overall movements throughout the monitoring period.

Finally, a comprehensive picture emerges of how the vultures soar throughout Sardinia by compiling the movements of all studied individuals (Figure 5). The core ranges of the Griffon population are anchored within and around the well-established Bosa and Punta Cristallo colonies, and around the newly established nucleus at Villasalto's historic breeding site. Nevertheless, Griffon vultures explore far and wide across Sardinia, soaring across the island, feeding and roosting in different sites throughout the year (Figure 5). These long-range movements, even if exploratory and occasional, hint for other areas for potential expansion of the Griffon vulture in Sardinia and highlight the importance of securing a broader network of safe habitats across Sardinia for the Griffon vulture. Continued GPS monitoring is thus critical for evaluating long-term survival and breeding success, and to inform adaptive management strategies that warrant a bright future for the Griffon Vulture in Sardinia.

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1. Standardizing the Tracking Data

Our analysis was based on high-quality GPS tracking data from 77 Griffon Vultures tagged in Sardinia during the LIFE Save for Vultures as well as during the preceding LIFE Under Griffon Wings project. Griffon Vultures were tagged at different times during these projects, with the first bird was tagged in December 2016, and movement data considered up until June 2025. Two different tag manufactures were used, Ecotone for the early-tagged birds, and Ornitela from 2018 (initially for some individuals and later for all vultures tagged under the LIFE Safe for Vulture).

Prior to the analysis we standardized the tracking data, so that the tracks from different birds obtained throughout the years with different transmitter models, and working on different settings could be comparable. Tracking data was downloaded from the project LIFE_GriffonVultures_Sardinia (ID 1659758323) in Movebank (www.movebank.org), a global archive for animal movement data (Kays et al., 2022). First, we removed rows with empty or erroneous latitude or longitude. Second, we applied a land mask of Sardinia to remove impossible points falling on the Mediterranean Sea. Third, all tracks were truncated by day of release of each bird to the date of the end of the monitoring (e.g., birds died, tag loss, tag malfunction), and periods during which the birds were in rehabilitation were excluded as well. Fourth, all locations during nighttime were identified and removed from the main dataset and stored in a different file (see identification of roosts). This is standard procedure in vulture studies because only few points were obtained during the night (>1%), and to minimize the influence of the roost sites on home range estimation (Kane et al., 2022). Finally, all tracks were down sampled to an identical frequency of one location every 2 hours.

To guarantee data quality to estimate home ranges with dynamic Brownian Bridge Movement Models (see below), for each bird, only months with at least 10 days of data were retained, and birds with fewer than 100 observations were excluded from the analysis. The standardization process resulted in tracks from 77 individual Griffon vultures available for movement analysis. (Figure 6).

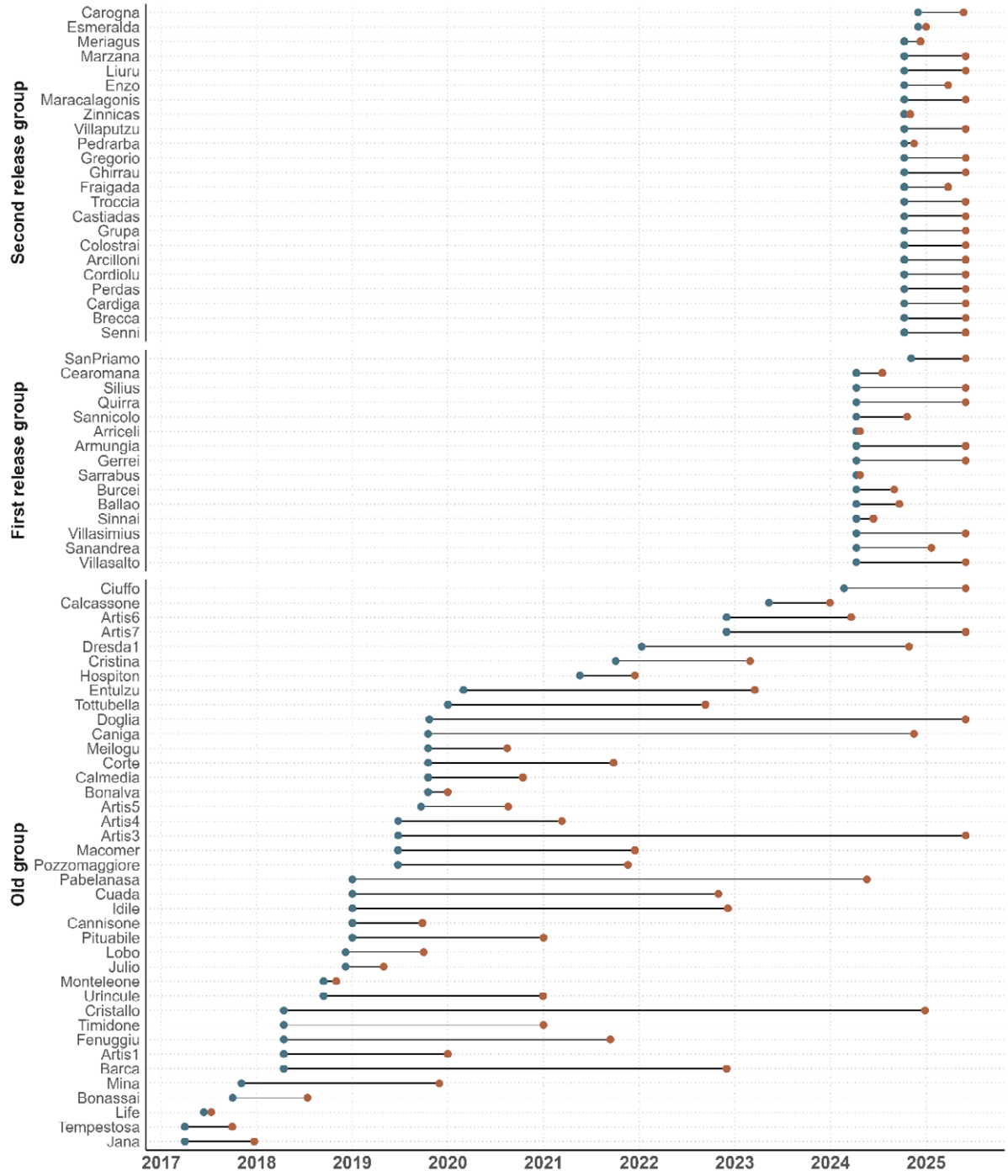

Figure 6

Monitoring period of the 77 Griffon Vultures analysed, with birds grouped by release group and ordered by date of release.

Table 1
Details of the birds included in the analysis of movements

Bird name	Origin	Source	Release area	Release group
Barca	Spain	Translocated	Bosa	Old group
Bonalva	Spain	Translocated	Bosa	Old group
Calmedia	Spain	Translocated	Bosa	Old group
Caniga	Spain	Translocated	Bosa	Old group
Cannisone	Spain	Translocated	Bosa	Old group
Corte	Spain	Translocated	Bosa	Old group
Cristallo	Spain	Translocated	Bosa	Old group
Cuada	Spain	Translocated	Bosa	Old group
Doglia	Spain	Translocated	Bosa	Old group
Fenuggiu	Spain	Translocated	Bosa	Old group
Idile	Spain	Translocated	Bosa	Old group
Macomer	Spain	Translocated	Bosa	Old group
Meilogu	Spain	Translocated	Bosa	Old group
Monteleone	Spain	Translocated	Bosa	Old group
Pabelanasa	Spain	Translocated	Bosa	Old group
Pituabile	Spain	Translocated	Bosa	Old group
Pozzomaggiore	Spain	Translocated	Bosa	Old group
Tempestosa	Spain	Translocated	Bosa	Old group
Timidone	Spain	Translocated	Bosa	Old group
Tottubella	Spain	Translocated	Bosa	Old group
Urincule	Spain	Translocated	Bosa	Old group
Artis1	Netherlands	Captive-bred	Bosa	Old group
Artis3	Netherlands	Captive-bred	Bosa	Old group
Artis4	Netherlands	Captive-bred	Bosa	Old group
Artis5	Netherlands	Captive-bred	Bosa	Old group
Artis6	Netherlands	Captive-bred	Bosa	Old group
Artis7	Netherlands	Captive-bred	Bosa	Old group
Dresda1	Germany	Captive-bred	Bosa	Old group
Bonassai	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Calcassone	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Ciuffo	Sardinia	Wild-born, rehabilitated	Bosa	Old group

Cristina	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Entulzu	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Hospiton	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Jana	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Julio	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Life	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Lobo	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Mina	Sardinia	Wild-born, rehabilitated	Bosa	Old group
Armungia	Spain	Translocated	Villasalto	First release group
Burcei	Spain	Translocated	Villasalto	First release group
Gerrei	Spain	Translocated	Villasalto	First release group
Quirra	Spain	Translocated	Villasalto	First release group
SanPriamo	Spain	Translocated	Villasalto	First release group
Sarrabus	Spain	Translocated	Villasalto	First release group
Silius	Spain	Translocated	Villasalto	First release group
Sinnai	Spain	Translocated	Villasalto	First release group
Villasalto	Spain	Translocated	Villasalto	First release group
Villasimius	Spain	Translocated	Villasalto	First release group
Arriceli	Sardinia	Wild-born, rehabilitated	Villasalto	First release group
Ballao	Sardinia	Wild-born, rehabilitated	Villasalto	First release group
Cearomana	Sardinia	Wild-born, rehabilitated	Villasalto	First release group
Sanandrea	Sardinia	Wild-born, rehabilitated	Villasalto	First release group
Sannicolo	Sardinia	Wild-born, rehabilitated	Villasalto	First release group
Arcilloni	Spain	Captive-bred	Villasalto	Second release group

Brecca	Spain	Translocated	Villasalto	Second release group
Cardiga	Spain	Translocated	Villasalto	Second release group
Castiadas	Spain	Translocated	Villasalto	Second release group
Colostrai	Spain	Translocated	Villasalto	Second release group
Cordiolu	Spain	Translocated	Villasalto	Second release group
Enzo	Spain	Translocated	Villasalto	Second release group
Fraigada	Spain	Translocated	Villasalto	Second release group
Ghirrau	Spain	Translocated	Villasalto	Second release group
Gregorio	Spain	Translocated	Villasalto	Second release group
Grupa	Spain	Translocated	Villasalto	Second release group
Liuru	Spain	Translocated	Villasalto	Second release group
Maracalagonis	Spain	Translocated	Villasalto	Second release group
Marzana	Spain	Translocated	Villasalto	Second release group
Pedrarba	Spain	Translocated	Villasalto	Second release group
Perdas	Spain	Translocated	Villasalto	Second release group
Senni	Spain	Translocated	Villasalto	Second release group
Troccia	Spain	Translocated	Villasalto	Second release group
Villaputzu	Spain	Translocated	Villasalto	Second release group
Zinnicas	Spain	Translocated	Villasalto	Second release group
Meriagus	France	Captive-bred	Villasalto	Second release group
Carogna	Sardinia	Wild-born, rehabilitated	Villasalto	Second release group
Esmeralda	Sardinia	Wild-born, rehabilitated	Villasalto	Second release group

2. Estimating utilization distributions and home ranges

To estimate the utilization distribution of Griffon Vultures we fitted dynamic Brownian Bridge Movement Models (dBBMM; Kranstauber et al., 2012). dBBMMs handle well the temporal autocorrelation found in high-quality GPS tracking data and have been previously used to estimate the occurrence distributions of Griffon vultures in Sardinia (Cerri et al., 2023). Following Cerri eat al. (2023), we parametrized the dBBMMs as follows: GPS location error of 25 m, window size of 31 m, margin of 11 m, and 250 m resolution. One dBBMM was fitted to each individual-year combination, excluding data gaps longer than 5h. To account for differences in the time each bird was tracked per year, each individual-year dBBMM was weighted by the number of days with tracking data. Finally, to obtain the occurrence distribution of Griffon Vultures in Sardinia, we first summed the individual dBBMMs for each year.

Then, the yearly distributions were combined by keeping the maximum value in each cell across years

To visualize the Griffon Vultures' home ranges, we used the 95% isopleth of the utilization distribution (i.e., 95% UD) to represent the home range (i.e., areas regularly used by the birds), the 75% UD to represent the mid-range (i.e., areas of intermediate use), and the 50% UD to represent the core range (i.e., areas where they spent most of their time).

3. Identifying feeding events

To identify feeding events, we used accelerometer data recorded through the GPS tags. Previous behavioural observations of two captive and one wild Griffon Vultures allowed to distinguish and validate different behaviours (e.g., feeding, flapping, and soaring) of the GPS-monitored birds using triaxial accelerometer data (anterior–posterior, dorso–ventral, and lateral). Feeding events were manually annotated and used to train a Random Forest model, using summary statistics derived from the accelerometer data as model predictors (details in Fozzi et al., 2025).

4. Identifying roosts

To map the roosts used by Griffon Vultures, we extracted all nighttime locations from all tagged individuals and, for each night, selected the location closest to midnight, ensuring that only one point was mapped per night.

5. Software

All tracking data standardization, spatial analysis and mapping were conducted in R (R Core Team, 2025) using the packages move and move2 (Kranstauber et al., 2024a, 2024b), amt (Signer et al., 2019), and sf (Pebesma, 2018). All figures were produced with ggplot2 (Wickham, 2009) using the UTM zone 32N projection.

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