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Research paper

Bio-logging shows a central trans-Saharan migration and unknown wintering grounds in Africa of a juvenile griffon vulture from Spain

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Abstract

Bio-logging shows a central trans-Saharan migration and unknown wintering grounds in Africa of a juvenile griffon vulture from Spain. The delimitation of African wintering areas of the griffon vulture *Gyps fulvus* has been established on the basis of ring recoveries, usually from dead individuals and, to a lesser extent, by reading ring and wing marks in human-populated areas. After GPS-tracking of several juvenile griffon vultures from central Spain, we show that a female used an unknown central trans-Saharan migratory route, and spent five months in flooded savannahs and the transition zone with the Guinean forest ecoregion, moving between north-eastern Ivory Coast, northern Ghana and southern Burkina Faso. This area represents an extension of several hundred kilometres to the south and southeast of the known African range of western European griffon vultures. A field survey in Ghana on the same dates recorded no individuals of this species but four other vulture species. Future in-depth bio-logging studies are required to evaluate the migration patterns, the connectivity between the various nuclei, and its implications in the conservation of the griffon vulture and other vulture species in Africa and Europe.

Key words: GPS-GSM tracking, *Gyps fulvus*, Migratory routes, Wintering range, West Africa

Resumen

El seguimiento telemétrico permite detectar la migración transahariana central y zonas de invernada desconocidas en África de un ejemplar joven de buitre leonado procedente de España. La delimitación de las áreas africanas de invernada del buitre leonado, *Gyps fulvus*, se ha establecido a partir de la recuperación de anillas, normalmente de individuos muertos y, en menor medida, de la lectura de anillas y marcas alares en zonas con una elevada población humana. Tras el seguimiento por GPS de varios buitres leonados juveniles del centro de España, pudimos observar que una hembra había utilizado una ruta migratoria transahariana central desconocida y que había pasado cinco meses en sabanas inundables y en la zona de transición con la ecorregión de la selva guineana, desplazándose entre el noreste de Costa de Marfil, el norte de Ghana y el sur de Burkina Faso. Esta zona representa una extensión de varios cientos de kilómetros hacia el sur y el sureste del área de distribución africana conocida de los buitres leonados de Europa occidental. En un muestreo de campo realizado en Ghana en las mismas fechas no se registró ningún individuo de esta especie, pero sí de otras cuatro especies de buitres. Se requieren más estudios de seguimiento telemétrico para evaluar en profundidad los patrones migratorios, la conectividad entre los distintos núcleos y sus implicaciones en la conservación del buitre leonado y otras especies de buitres en África y Europa.

Palabras clave: Seguimiento por GPS-GSM, *Gyps fulvus*, Rutas migratorias, Área de invernada, África occidental

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Introduction

The ongoing development of bio-logging technology is providing detailed knowledge (i.e., daily information on multiple precise locations over several years) of animal movements and activity (Wilmers et al 2015, Sergio et al 2019a, Joo et al 2022). Attaching polyvalent GPS devices to a sample of individuals allows, with little or no damage (Anderson et al 2020), to understand various ecological aspects of a species, such as seasonal changes in its ranges, its migratory patterns, the anthropogenic risks it faces and the main causes of mortality (Cooke 2008, Blanco et al 2018, Sergio et al 2019b, Peters et al 2023), all with important implications for transnational conservation programmes (Lambertucci et al 2014, Zvidzai et al 2022). The enormous amount of information that these devices generate cannot be obtained with traditional methods such as ringing individuals, which requires subsequent monitoring conditioned by the probability of resighting or recapturing them over the years. However, the main source of information used so far to delimit seasonal ranges and infer the migratory pathways of most species comes from information generated by these traditional methods, with their consequent biases and limitations (Cooke 2008, Mitchell et al 2021, Spina et al 2022).

Vultures are soaring birds characterised by their enormous foraging movements in search of spatially and temporally dispersed and unpredictable carrion (Ruxton and Houston 2004). However, and despite the fundamental role vultures play in ecosystems and the fact that several are among the most endangered species in the world (Ogada et al 2012, Safford et al 2019), many basic aspects of their ecology remain unknown. The griffon vulture *Gyps fulvus* is the most abundant obligate avian scavenger species in the western Palaearctic and therefore a keystone species for ecosystem health and functioning (Cortés-Avizanda et al 2015, Blanco and Díaz de Tuesta 2021). Unlike other vultures, this species has been relatively well studied and many aspects of its ecology are known (Salvador 2016, Almaraz et al 2022; Morant et al 2023). However, as is the case for other vulture species, the movements and life-style of young individuals are still poorly understood. Griffon vultures have been marked in relatively high numbers throughout their range, mainly as nestlings and also for release after rehabilitation in recovery centres. Both traditional tagging with metal rings and, more recently, with PCV rings and wing bands for identification at distance have generated scarce information on their movements, mainly biased due to the intensive monitoring programmes at particular breeding colonies and supplementary feeding sites (Zuberogoitia et al 2013, Fargallo et al 2018). The passage of migrating griffon vultures from the Iberian Peninsula to Africa through the Strait of Gibraltar has been known since the 1970s, with a figure of several hundred migrants assigned without further specification (Bernis 1980). A few years later, thanks to the traditional marking methods, two griffon vultures ringed as nestlings in southern Spain were recovered in Senegal, giving clues as to where the wintering quarters of at least a migratory fraction of the species in Africa might be located (Alonso 1984). In 1991-1993, vultures migrating through the Strait of Gibraltar in autumn were quantified for the first time (more than 2,160 birds in the 1993 migratory season), showing that most migrants were first-year old juveniles, with a low proportion of second-year birds and an almost anecdotal representation of older individuals (Griesinger 1996). Iberian griffon vulture populations have grown from the first censuses to the present day (from a minimum of 2,283 breeding pairs in 1979 to more than 30,946 pairs in 2018; Del Moral and Molina 2018). The populations in France and Portugal, which are more limited spatially and numerically, have also grown (BirdLife International 2021). In parallel, counts of individuals crossing from Europe to Africa through the Strait of Gibraltar each autumn have also increased (from 2,160 birds in the 1993 to 11,650 individuals in 2022; Fundación Migres 2023, Onrubia, 2021). Regarding prenuptial migration (March-June), an estimated 6,000 individuals passed from the African to the European coasts in 2017 (El Khamlichi 2017, Ramírez et al 2019).

From ring recoveries and observations in some specific localities of marked migrant griffon vultures born in Western Europe, it is assumed that vultures make a rapid journey to reach the wintering areas (Onrubia, 2021). With this information, the wintering range has been established mainly in the western Sahel, including southern Mauritania, Senegal, Gambia and western Mali (BirdLife International and Handbook of the Birds of the World, 2022). Other areas with wintering vultures in central Africa (Niger, Chad and countries further east) seem to receive individuals from eastern European breeding populations (Clark 2001; Del Hoyo and Collar, 2014; Bildstein, 2022), as confirmed by a GPS-tagged juvenile from Bulgaria (Arkumarev et al 2019). However, the delimitation of African wintering areas has been established on the basis of ring recoveries, usually from dead individuals and, to a lesser extent, by reading ring and wing marks in human-populated areas (Spina et al 2022). Direct observations and citizen science data are also increasing information on wintering areas. This information is available for countries and regions that are most accessible to tourism as observers (usually foreigners) record their observations. Such observations, however, are for limited periods of time and in specific areas, and are becoming scarcer or non-existent in remote regions or where political instability limits tourism and research. Furthermore, in these areas there is a general lack of monitoring programmes as comprehensive and as long-term as those in Europe, so these data provide an unrealistic picture as they are based on occasional observations by birdwatchers and a few research groups.

Here, we provide information on the stay in Africa of a young griffon vulture whose movements during its first year of life add to the general knowledge of migratory routes and distribution of the species, in an almost unknown territory with scarce data on distribution of vultures. The information generated by this GPS-tagged individual was complemented with roadside censuses to assess the presence and abundance of this and other vulture species, identify habitat conditions and possible food sources, and evaluate its suitability as a potential temporary settlement area for the growing population of griffon vultures originating from Western Europe.

Material and methods

In June 2021 and 2022, we marked 14 griffon vulture nestlings (10 in 2021 and 4 in 2022) in their nests in colonies located in the provinces of Segovia and Ávila (Central Spain). When nestlings were approximately 80 days old, the nests were accessed to mark them with metal and PVC rings for distance reading, and to measure, weigh and take a blood sample from the radial vein), and determine sex using molecular methods (details in López-Rull et al 2015). They were fitted with telemetric tracking devices (50 g solar-powered GPS-GSM transmitters; Ornitela, www.ornitela.com) programmed to record fixes (i.e., GPS positions) on a flexible schedule of 5-15 min depending on battery charge (see details of attaching method and fixes-management in Morant et al 2023).

A field survey was carried out in Ghana at the end of February 2021 to assess the frequency and abundance of the griffon vultures in this area. For this purpose, a road census was conducted along roads and secondary tracks (totalling 2,021 km), complemented with non-systematic stops of 5-20 minutes duration for conducting observation from vantage points (n = 80), and walking transects (10 km), recording all vultures observed, their behaviour and the presence of possible food sources. Transects were carried out by two observers (the driver and his co-driver) while driving at low speed (20-40 km/h). Observations were uploaded to the citizen science platform Observation (www.observation.org), from where they can be freely downloaded.

Results

All GPS-tagged nestlings fledged successfully, approximately one month after tagging. They spent the next three months in the nests and on the periphery of the colonies, extending their flight radius day by day. At the end of their dependency period, the GPS-tagged individuals abandoned their breeding colonies and flew to the south of the Iberian Peninsula in October and November. Once in southern Spain, they headed towards the Strait of Gibraltar to make the flight to Africa, via Morocco, during the first half of November.

Of the five individuals that crossed to Africa, four arrived in the Sahel in November by the western route, and spent the wintering period (from November to the beginning of May) in Senegal, Gambia, northern Guinea-Bissau and Guinea-Conakry (authors' unpublished data). One female (PVC ring code 1LV) from a nest in the Ávila mountains crossed the central Atlas in Morocco and the Sahara through Algeria and Mali to reach the west African savannahs of the southern Sahel (fig. 1A), spending 156 days (between 18 November 2021 and 22 April 2022) in Ivory Coast (Comoe National Park), Ghana (Mole National Park), the surrounding of these protected areas, and in southern Burkina Faso (fig. 1B). During this period, this individual travelled a minimum of 26,728 km (a daily average of 171.1 km), prospecting very large areas. These areas mostly correspond to the West Sudanian savannah ecoregion, where it stayed mostly (87 % of time), moving the rest of the time on the transition zone with the Guinean forest-savannah ecoregion (fig. 2). It then flew directly for six days from east to west to the known wintering area along the Gambia River, from where it headed north through the western Sahara in Mauritania to cross the Strait of Gibraltar on 14 May 2022, to reach the Iberian Peninsula after 15 days of travel (fig. 1A).

Coinciding with the period when this tracked juvenile was in Ghana, roadside transects were covered by car from north to south of the country, including the Mole National Park and much of the coastal belt (fig. 3). During this road survey, complemented with observation points and walking transects, four vulture species were observed in variable numbers (17 white-backed vultures *Gyps africanus* on seven occasions, 79 hooded vultures *Necrosyrtes monachus* on 31 occasions, three white-headed vultures *Trigonoceps occipitalis* on three occasions, and seven palm-nut vultures *Gypohierax angolensis* on six occasions), and distributed throughout the various regions and habitats of the country (fig. 2B). No griffon vultures were observed.

Discussion

Here, we show that a juvenile griffon vulture from central Spain tracked by a GPS transmitter spent five months moving between north-eastern Ivory Coast, northern Ghana and southern Burkina Faso, where it arrived following a central trans-Saharan route. The wintering grounds used by this individual represent an extension of several hundred kilometres to the south and southeast of the known African range of western European griffon vultures, where the species had not previously been reported (Onrubia 2021, Boano et al 2022, Avibase 2023, Dowsett et al 2023a, 2023b). This individual travelled from east to west through the wintering area in the Sahel belt, to return to the Iberian Peninsula by the known route in northwest Africa.

The absence of previous records of griffon vultures in a large part of the area covered by the tracked individual may be due to the fact that it is little frequented by foreign birdwatchers and professional ornithologists who record their observations on citizen science portals such as eBird (www.ebird.org) and Observation.org (www.observation.org), where no records of this species appear in the specified area. Other species of the *Gyps* genus, such as the African white-backed vulture and Rüppell's vulture *Gyps rueppelli*, inhabit this area and could be confused with the griffon vulture, especially the juveniles, which could have caused them to have gone unnoticed among the other species similar in plumage, size and habits (Mundy et al 1992, Rodríguez and Elorriaga 2016). However, our road censuses conducted on the same dates that the tracked individual stayed in Ghana did not detect any griffon vulture. Conversely, vultures of four other species were observed, suggesting that griffon vultures are not abundant in this region. In May 2011, two individuals (one adult and one immature) were observed on four occasions in the southern part of the Mole National Park, the same park visited by the juvenile female tracked in this study, representing the only previous records of the species in Ghana

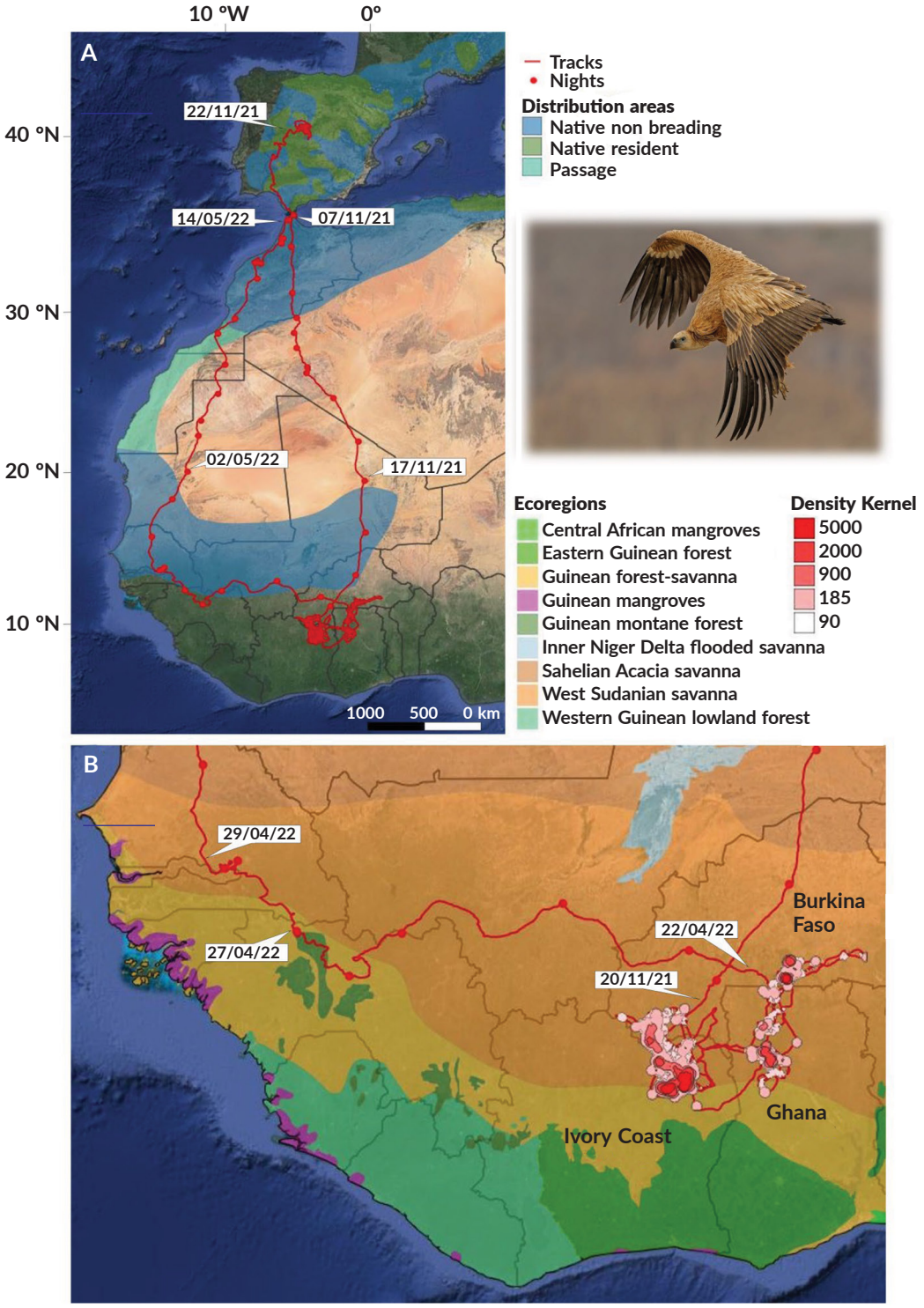

Fig. 1. A, movements of a juvenile female griffon vulture tracked by a GPS-GSM device from its nest in central Spain to an unknown wintering area in Africa. The dates of some events are shown, together with the migration and wintering areas established according to the range maps of BirdLife's species (BirdLife International and Handbook of the Birds of the World (2022), and the places where the vulture stopped for the night during migration. B, detail of the areas used by the vulture in the wintering area, applying a density kernel on the ecoregions used. (Photo credit: Jorge de la Cruz).

Fig. 1. *A, movimientos de una hembra joven de buitre leonado rastreada por un dispositivo GPS-GSM desde su nido en el centro de España hasta una zona de invernada desconocida en África. Se muestran las fechas de algunos sucesos, las áreas de migración e invernada establecidas según los mapas de distribución de especies de BirdLife* (BirdLife International y Handbook of the Birds of the World [2022]) *y los lugares donde el buitre se detuvo a pasar la noche durante los movimientos migratorios. B, detalle de las zonas utilizadas por el buitre en el área de invernada, aplicando un kernel de densidad a las ecorregiones utilizadas. (Fotografía: Jorge de la Cruz).*

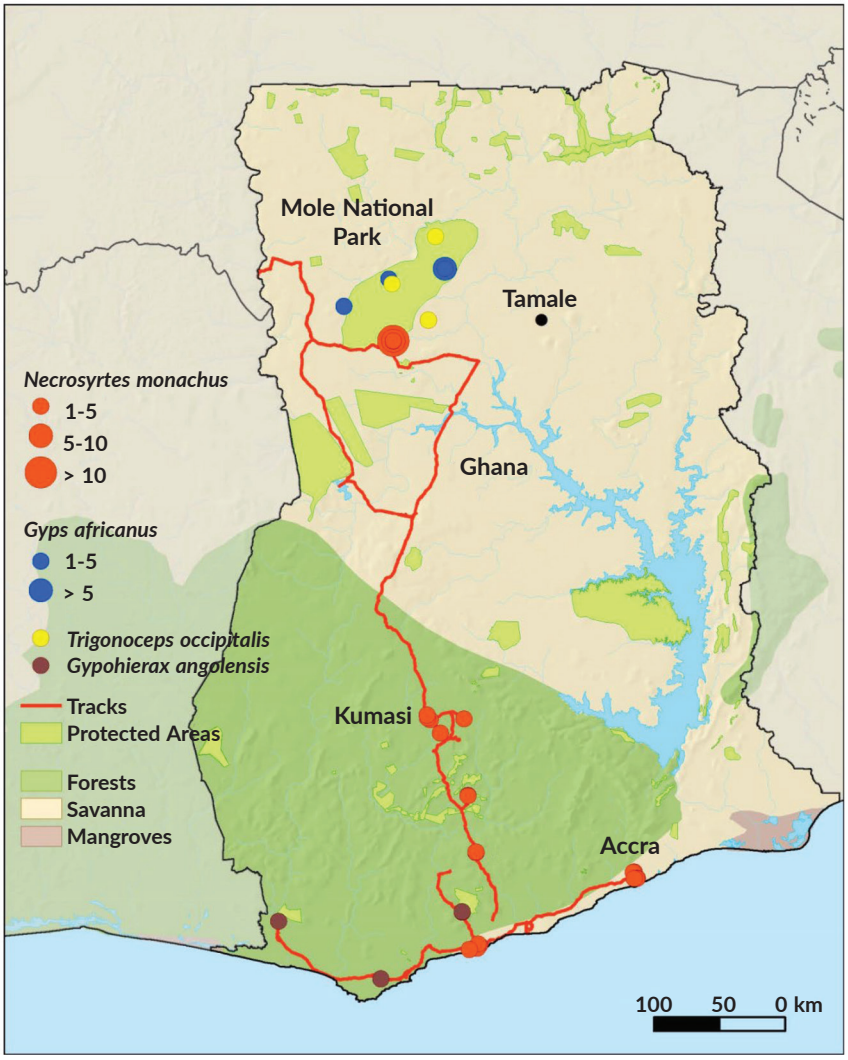

Fig. 2. Map of Ghana, showing the roadside tracks (red lines), and the distribution and number of vultures of each species observed in February 2021. Main habitats and protected areas are shown.

Fig. 2. *Mapa de Ghana en el que se muestran las carreteras utilizadas para los transectos (líneas rojas) y la distribución y el número de buitres de cada especie observados en febrero de 2021. Se muestran los principales hábitats y zonas protegidas.*

(Di Vittorio and Petrozzi 2018). The presence of the griffon vulture in and around Comoe National Park (Ivory Coast) and southern Burkina Faso is, to our knowledge, completely unknown. Observations even further east, in Nigeria (Strandberg et al 2007), could correspond to the wintering range of griffon vultures born in Western Europe but also to breeding areas in North Africa (Algeria, Tunisia), East Europe or the Middle East. In effect, the winter range of the eastern European population has recently been extended after a juvenile griffon vulture from Bulgaria was tracked flying to South Sudan (Arkumarev et al 2019).

The habitats used by the tracked vulture herein corresponds to open savannah with sparse scrubland seasonally flooded and fragmented forest (west Sudanian savannah and Guinean forest-savannah ecoregions; https://ecoregions.appspot.com/). These habitats contrast with the main wintering area delineated based on ringing recoveries in the Gambia riven basin (Spina et al 2022) and the much more arid Sahel belt (BirdLife International and Handbook of the Birds of the World 2022) corresponding to the Sahelian Acacia savannah ecoregion (Brito et al 2014). Road surveys conducted in the region of Ghana used by the tracked bird showed that main food source for vultures in Mole National Park could be large herbivores (Dakwa 2019), but not livestock species, which were absent within the national park but present (especially cows and goats) in unprotected areas in the vicinity (Acquah et al 2017). Thus, like other species of the genus *Gyps* in Africa, griffon vultures may be feeding on wild animals for much of their stay in the savannahs, especially when prospecting protected areas (Mundy et al 1992, Di Vittorio and Petrozzi 2018, Deikumah 2020, Salewski 2021), although the large mammals that would

constitute the majority of their food have greatly declined in recent decades (Scholte 2011). This contrasts with the situation in non-protected areas, where vultures and other avian scavengers rely mostly on livestock carrion and urban refuse (Thiollay 2006, Henriques et al 2018). These potential differences in food type and distribution may have implications for the ecology and conservation of European griffon vulture populations and all African vulture species due to the costs and benefits derived from the exploitation of trophic resources of a contrasting nature (Cortés-Avizanda et al 2016, Ogada et al 2016, Blanco et al 2019, Van Den Heever et al 2021).

Reported movements of a single griffon vulture spending much of its wintering in Africa in a region poorly known for the species may represent an exception (but see Di Vittorio and Petrozzi 2018). However, the scarcity of observers in this area, the low number of juvenile individuals tagged with GPS devices, and the possible confusion with resident vulture species may have caused them to go unnoticed until now. Alternatively, it is possible that the progressive growth of vulture populations in Western Europe in recent decades has promoted a saturation of the carrying capacity in the traditional wintering region in the western Gambia River basin, favouring the movement of individuals to other areas. In support of this hypothesis, it has been shown that the increase in the population of European griffon vultures wintering in Senegal and Gambia has meant that they can be locally more abundant than resident *Gyps* vultures (Roy 2005, Ouweneel 2021). The fact that the tracked juvenile followed a central route directly to the savannahs of the Ivory Coast argues, however, against this possibility because conditions in the western wintering area are unknown to the juvenile migrants prior to their arrival. Other factors, such as wind direction, the existence of a flow of older migrants (Griesinger 1996), and even the possible disorientation of the tracked individual during migration are more likely, although difficult to verify. In this sense, the existence of recoveries of Iberian griffon vultures on the north African coasts of Algeria and Tunisia, east of the Strait of Gibraltar (Spina et al 2022) is remarkable, and could correspond to trans-Saharan migrants using the same central route used by the tracked vulture. Anyway, the fact that this individual returned to Europe by the western route after crossing the Sahelian belt from east to west implies that the known wintering region in the Gambia river basin and that represented by the flooded savannahs and fragmented forest used by the juvenile tracked could be connected. However, this could be a recent process, as suggested by the scarcity of observations and recoveries of ringed birds in the central and eastern Sahel (Onrubia 2021, Spina et al 2022), derived from the increase in breeding populations and the recolonization of areas where the species had become extinct (Dobrev et al 2021). This process could have coincided with the connection on the western and eastern breeding nuclei, as suggested by the recent recoveries of ringed birds and the monitoring of GPS-tracked birds from the Iberian Peninsula to the eastern European range and vice versa (Stoyanov et al 2019, VCF 2023a). Thus, population nuclei with different migratory routes to Africa could now be connected in the wintering area, which could have important implications in conservation by modulating migratory patterns and intermixing of juveniles returning to Europe from each region.

Finally, the fact that the growing European population of griffon vultures in Europe has coincided with the record in the Iberian Peninsula of vulture species resident in the African wintering areas of juveniles of the former species (Gutiérrez et al 2010, Godino and Machado 2015, VCF 2023b) suggests that these two processes could be related (Ramírez et al 2011, Rodríguez and Elorriaga 2016, El Khamlichi and El Haoua 2023). The migratory flow of griffon vultures to Europe could drag young individuals of other vulture species, such as the Rüppell's vulture, for which there are more observations and even breeding records and potential hybridisation with the griffon vulture in Iberia (Elorriaga et al 2022). Our study highlights the importance of tagging juveniles with bio-logging devices throughout their area of origin in order to evaluate in depth their migration patterns, the connectivity between the various nuclei, and their implications in the conservation of the different populations of griffon vultures. This information will also be crucial to evaluate the interaction between the griffon vulture and other vulture species in Africa, and to determine the role of the movements of each species on the distribution range of the others, including Europe.

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Author contributions
F Martínez and G Blanco conceived the original idea of the presented study. F Martínez, J Oltra, P Romero-Vidal, Ó Frías, JL González del Barrio, JM Pérez-García, JL Tella, M Carrete and G Blanco conducted fieldwork. J Oltra conducted the spatial analysis. F Martínez and G Blanco wrote the first draft of this publication. All these authors provided critical feedback and helped to shape the research, analysis and manuscript.

Conflicts of interest
No conflicts of interest declared.

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