

Effectiveness of the use of patagial wing tags for griffon vultures (*Gyps fulvus*) in Spain

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Abstract

Effectiveness of the use of patagial wing tags for griffon vultures (Gyps fulvus) in Spain. We describe the design of patagial wing tags with highly durable lateral readings for marking and tracking griffon vultures. Acclimatized birds were tagged within Projecte Canyet for the recovery of the griffon vulture as a nesting species in the Sierra de Mariola Natural Park (Valencia Region). A total of 193 vultures were tagged at the sampling point between 2000 and 2015. Forty-three individuals were recaptured within an average of 1,362 days (SD \pm 543.78). Half the sample of captured individuals was weighed ($n = 20$) and the average was 9.11 kg (SD \pm 1.14). The area of the scarred perforations was measured, and the mean perforation size was 85.38 mm² (SD \pm 28.61). Wing tags provided highly satisfactory results and enabled a deeper understanding of the patterns of interspecific behaviour and nomadic movements. The design of the tags was satisfactory because it facilitated identification of individuals at a distance. The negative impact on individuals was low and the device did not interfere in the vital life stages of the species. We suggest the model could be useful for other bird species if adapted to size.

Key words: Eurasian griffon, Patagial wing markings, Patagial membrane, Reintroduction, Migratory movements

Resumen

Efectividad del empleo de marcas alares patagiales en el marcaje de buitre leonado (Gyps fulvus) en España. Se describe el diseño de marcas alares patagiales de lectura dorsoventral de alta durabilidad para el marcaje y seguimiento de ejemplares de buitre leonado *Gyps fulvus*. Para ello se marcaron aves aclimatadas dentro del Proyecto Canyet de recuperación del buitre leonado como especie nidificante en el Parque Natural de la Sierra de Mariola (Comunidad Valenciana). Un total de 193 buitres fueron marcados en el período 2000–2015 en el punto de muestreo y 43 individuos fueron recapturados, con un valor medio de 1.362 días (SD \pm 543,78). Del mismo modo, se pesó a la mitad de la muestra de individuos capturados ($n = 20$), siendo el valor promedio de 9,11 kg (SD \pm 1,14). Se midió asimismo el área de las perforaciones cicatrizadas, siendo la superficie media de perforación de 85,38 mm² (SD \pm 28,61). Las marcas alares proporcionaron resultados muy satisfactorios, que permiten profundizar en los patrones de comportamiento interespecífico, así como en

los movimientos de nomadismo. Se ha constatado que el diseño final de estas marcas es adecuado, ya que su identificación a distancia es buena y la incidencia negativa en los individuos es muy reducida. Además, este sistema permite la diferenciación de individuos con una elevada frecuencia. Del mismo modo, se ha constatado que este dispositivo no interfiere en las etapas vitales de la especie y que, adaptándolo convenientemente a escala, resultaría factible para otras especies orníticas.

Palabras clave: Buitre leonado, Marcas alares patagiales, Membrana patagial, Reintroducción, Movimientos migratorios

Resum

Efectivitat de l'ús de marques alars patagials en el marcatge del voltor comú (Gyps fulvus) a Espanya. Es descriu el disseny de marques alars patagials de lectura dorsoventral d'alta durabilitat per al marcatge i el seguiment d'exemplars de voltor comú *Gyps fulvus*. Amb aquest objectiu es van marcar ocells aclimatats dins del Projecte Canyet de recuperació del voltor comú com a espècie nidificant al Parc Natural de la Serra de Mariola (Comunitat Valenciana). Un total de 193 voltors van ser marcats en el període 2000–2015 en el punt de mostreig i 43 individus van ser recapturats, amb un valor mitjà de 1.362 dies (SD \pm 543,78). De la mateixa manera, es va pesar la meitat de la mostra d'individus capturats ($n = 20$), els quals van presentar un valor mitjà de 9,11 kg (SD \pm 1,14). També es va mesurar l'àrea de les perforacions cicatritzades, la superfície mitjana de les quals va ser de 85,38 mm² (SD \pm 28,61). Les marques alars van proporcionar resultats molt satisfactoris, que permeten aprofundir en els patrons de comportament interespecífic, així com en els moviments de nomadisme. S'ha constatat que el disseny final d'aquestes marques és adequat atès que la identificació a distància és bona i la incidència negativa en els individus és molt reduïda. A més a més, aquest sistema permet la diferenciació d'individus amb una freqüència elevada. S'ha constatat així mateix que aquest dispositiu no interfereix en les etapes vitals de l'espècie i que, adaptant-lo convenientment a escala, resultaria factible per a altres espècies ornítiques.

Paraules clau: Voltor comú, Marques alars patagials, Membrana patagial, Reintroducció, Moviments migratoris

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Introduction

In recent decades there has been a significant proliferation in techniques used to mark individual birds. Ornithologists have improved a number of old methods and have also developed new approaches to facilitate field investigations. Many experimental techniques have also been designed for the individual identification of wild birds in the field (Hewitt and Austin–Smith, 1966). Plastic wing tags that are numbered and fixed to the wing facilitate studies of population dynamics and movements (Hester, 1963). Fixing an individually numbered metal or plastic label to the legs or wings of birds is a commonly used approach in the study of wild species.

This approach enables the study of different aspects of the life of birds thanks to the possibility of later sighting, recovering, or recapturing. It can be used for studies on migration, longevity, mortality, population, territoriality, food habits, and other aspects of interest to ornithologists (Cottam, 1956). However, it is particularly important to balance the expected benefits of the tags with the possible risks to the birds (Green et al., 2004). One widely used approach in recent decades has been vinyl strip tags placed on the wing at the humerus, specifically between the secondary and scapular feathers (Wallace et al., 1980).

With regard to the practical applications of individual bird tags, diverse and interesting studies have examined dispersion patterns and seasonal migration routes, for example, in of Delaware gulls (*Larus delawarensis*) (Southern, 1971; Kinkel, 1989), in Marbled teal (*Marmaronetta angustirostris*) in Spain (Green et al., 2004), and in juvenile dispersion of European white-tailed eagles (*Haliaeetus albicilla*) in western Scotland (Whitfield et al., 2009). In some works that have focused on large birds of prey, coloured plastic wing tags that include combinations of letters and numbers have been fixed to the flight feathers. These wing tags allow unequivocal identification with binoculars or telescopes, and avoid the need for recapture (Calvo and Furness, 1992). However, because these tags are fixed to flight feathers, their usefulness is shortened by their loss during moulting.

The Iberian Peninsula hosts the largest population of the griffon vulture (*Gyps fulvus*) in the world (Del Moral and Marti, 2001; Del Moral, 2009). Efforts made by institutions such as the Asturian Fund for the Protection of Wild Animals (FAPAS) have achieved a notable recovery of the species and improved awareness of the species through media campaigns. In the specific case of central regions in the region of Valencia, the nesting sites remain intact. The griffon vulture is one of the raptor species that best tolerates human activity. Disappearance of a vulture species as a nesting species can be influenced by a number of factors: a decrease in food sources because of changes in livestock; rigorous sanitary laws that control the presence of corpses in the fields; electrocution and collision with wind farms; electrical infrastructures; reduction or abandonment of traditional livestock techniques; and poisoning or use of harmful veterinary products (Seguí, 2006; Donázar et al., 2009; Morales-Reyes et al., 2017). Current practices with appropriately managed dumping sites and promotion of reintroduction projects help the recovery of populations that may have become extinct in some regions (Sarrazin et al., 1994, 1996; Sarrazin and Legendre, 2000).

The griffon vulture is a large raptor with a size of 100 to 120 cm, a weight of 7 to 10 kg and a wingspan that can reach 280–290 cm. Its plumage is tawny in young birds, becoming paler as it ages. Flight feathers, however, are black. It has a long neck with thick white feathers and a ruff that goes from a cream colour to white once it reaches sexual maturity at approximately four years. As visual differentiation between males and females has disappeared, techniques of molecular sexing from DNA samples from feathers or blood are necessary to determine gender (Donázar, 1993; Blanco et al., 1997; Bosé et al., 2007).

The griffon vulture is exclusively a scavenger species, specialized in the consumption of carcasses of medium-size and large animals. Although its main source of food today is perhaps domestic livestock, wild ungulates, mainly large game species, are also an important food source for the species in Mediterranean ecosystems (Xirouchakis and Mylonas, 2005; Mateo-Tomás et al., 2015).

To nest and rest, the griffon vulture prefers cliffs, ravines and other rocky outcrops with cornices and caves, but it explores an enormous variety of open and dry lands in search of food. It can be found on lowland crops, semi-arid steppes, plateaus, and mountain plains, and from sea level to 3,000 m a.s.l. (Fernández, 1975; Bertran and Margalida, 2002; García-Ripollés, 2005; Bosé and Sarrazin, 2007).

Regarding the evolution of the population, the species has undergone dramatic drops in its numbers in many countries of Europe and has reached extinction in the Alps and the Carpathians, while in countries of southern Europe the population has increased considerably, and Spain now has the largest European populations (Donázar and Fernández, 1990; Olea et al., 1999; Parra and Tellería, 2004; Del Moral, 2009).

The objective of this work was to analyse the effectiveness of the use of patagial wing tags in vultures and to measure their durability and reading efficiency in the field. Such devices may provide data regarding movements between zones and subpopulations, survival rates of birds reintroduced into the wild after captive breeding or recovery in centres, reproductive behaviour, mortality rates, and habitat use.

Material and methods

Study area

The study was carried out in the Sierra de Mariola, a mountainous region in the southern part of the Region of Valencia in Eastern Spain. It includes part of the areas of *l'Alcoià*, the *Vall d'Albaida*, and the *Comtat*. This sierra is approximately 17,500 hectares and is one of the most extensive mountain ranges in the region (fig. 1). This area was declared a natural park in 2002 and is part of the Natura 2000 network. It is characterized by the beauty of the enclaves and various biotic and abiotic elements, and its botanical characteristics are of special importance.

The Sierra de Mariola has a high level of animal and plant biodiversity. The population density is high for several species of omnivorous animals and scavengers, particularly wild boar (*Sus scrofa*), jackdaw (*Corvus monedula*), crow (*Corvus corax*), magpie (*Pica pica*) and fox (*Vulpes vulpes*). Griffon vultures have become common in the area as a result of the dumping site installed in the Projecte Canyet. Moreover, considering the bioclimatic and biogeographical conditions, the climax vegetation is the evergreen oak forest (*Hedera helicis*–*Quercetum rotundifoliae* subas. *ulicerosum parviflorae*) (Belda and Bellod, 2006).

The project has been running since 2000 thanks to the voluntary collaboration of a multidisciplinary group of citizens from Alcoi and environs that includes biologists, forestry engineers, forestry agents, veterinarians, falconers, and farmers. With this background, we have implemented several initiatives aiming to achieve our objective, that is, to consolidate a stable breeding population of griffon vultures in the mountainous areas of the region of *l'Alcoià*, *Comtat*, *Marina Alta* and *Marina Baixa*.

Methods

Several methods were developed to deepen our understanding of the behavioural patterns (intraspecific and interspecific displacements and relationships), distribution, and threats these scavengers currently face. We aimed to contrast the effects these methods had on the ethology and health of the species. Sampling was carried out between 2000 and 2009. Several techniques were used. Photographic evidence showed the birds had no stressful reaction on entering the cage and feeding inside the trap–cage continued with relative normality, including the typical skirmishes (fig. 2).

Capture method

Specimens were captured at dumping sites and other places within the study area by means of a specifically designed trap–cage. This cage is adaptable to different substrates and slopes and can be assembled in approximately 90 minutes. It can hold up to 40 birds. The trap has two, one–way openings. The investigators can enter the cage through a third door to remove the birds for tagging, to record biometrics, and to take analytical samples. To avoid injury and damage to the plumage of the birds, the roofing consists of nylon netting at a height of 1.5 m.

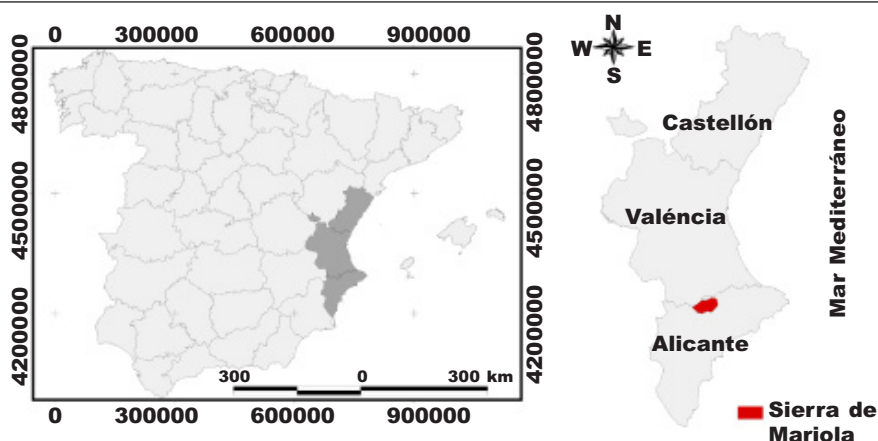


Fig. 1. Sierra de Mariola Natural Park.

Fig. 1. Parque Natural de la Sierra de Mariola.

The bait used to entice the birds consisted of medium-sized carrion fixed to a platform in the centre of the cage to prevent the birds dragging it to the sides and enabling other vultures to feed from the outside. To attract the vultures, small pieces of meat were placed at the front part of the enclosure and between the bars.

Capture and handling procedure

We followed a protocol for safe and simultaneous capture and marking of several dozen birds. Once the trap was installed and primed in the early morning, one or more members of the team observed the activity by telescope from a reasonable distance. When the first birds arrived, these first team members contacted the capture and marking team (at least five people). Photographic evidence showed the birds had no stressful reaction on entering the cage and feeding inside the trap–cage continued with relative normality, including the typical skirmishes.

As soon as the marking equipment vehicle reached the trapping site, the front of the trap was covered with opaque raffia, so that the captured vultures could not see the vehicles or the people. The tables and all the marking material were set up. Two team members wearing leather gloves and protective goggles then entered the enclosure through the side door and captured the birds two at a time using a large aluminium–nylon sac. As soon as a bird was removed from the sack, its head was covered with a cap and it was passed to the marking tables, where it was placed on its back to facilitate sampling (hemography and coprology), taking of biometrics, placement of metal rings, placement of PVC bands distinguishable at a distance, and placement of patagial wing tags. A 3 m measuring tape was set into the upper edge of the tables to measure wing span, and birds were weighed manually using a spring dynamometer.

Dorsoventral patagial wing tags

Permits and authorization for the tagging and ringing were provided by the Ministry of the Environment and endorsed by the Bird Migration Centre (CMA). PVC rings were acquired in accordance with the Banding Office of the Doñana Biological Station.



Fig. 2. Trap designed for scavenger birds.

Fig. 2. Trampa dissenhada para aves carroñeras.

The wing tags proposed to eliminate difficulty in identifying birds in flight or birds at rest with their backs to the ornithologist. This approach can also be helpful when PVC rings are hidden by vegetation, or during busy feeding sessions. Following communication with ornithologists in the US, Greece, and Israel, we used patagial wing tags for dorsoventral readings (Mod. Pat. 20070022). Made of high strength polyurethane, the tags were fixed to the patagial membrane using plastic crotals with a brass tip. They are commonly used with pigs (fig. 3).

The markings on the tags include the same alphanumeric combinations as the corresponding PVC ring issued by the Doñana Biological Station, and the reverse side provides contact details of the project (telephone, email, etc.) in case of recovery due to capture or death of the animal (Seguí, 2006).

Design of the wing tags

We designed and tested three models of wing tags for dorsoventral readings. All models were the same size. The three alphanumeric characters were also the same size. When defining the size of the wing tags, it was essential that the species' specific characteristics (size, wing area, etc.) were taken into account to ensure the tag would not interfere in the birds' habits and life cycles. The flight system of these large birds enabled the use of large dorsoventral wing tags in colors that could be relatively easy to read when the birds were in flight. The aerodynamic behaviour of the birds had to be considered as the tags had to remain attached during flight in all types of circumstances (e.g. turbulence, gliding, take off, landing).

We determined that the length of the tags should not exceed the area occupied by the infracober feathers in the ventral region of the extended wing, or the larger supracobars of the folded wing at rest. Thus, the dorsoventral reading tags (two-sided) were rectangular, 400 mm in length and 80 mm in width. Plastic material was avoided because of the risk of tearing during rotation of the dorsal and ventral parts of the wing around the tag. The devices were thus a single piece, with the front and back joined using same material. In this way, wear at the fixing point was reduced. The union between the two parts by the central part (the part that embraces the patagial membrane) is 40 mm wide and has seven cuts of 4 mm in length on both sides (antiabrasion fringes) to produce a soft, non-abrasive

surface contour on contact with the patagial membrane. Two perforations were made for the fixation, each of 13 mm diameter and 60 mm separation between them. The digits were designed to be 40 by 35 mm high and were arranged vertically in descending order with a separation of 10 mm. During the field tests (in optimal light and climatological conditions), complete readings of the three digits included in the alphanumeric combinations of the wing marks were obtained at distances of 480 m (prismatic 10 x 42) and 780 m (20–60 x 77). All the models were fixed by means of the same commercial Allflex circular pieces of 28 mm in diameter, manufactured with high resistance polyurethane and equipped with a brass tip that drills a 7 mm diameter hole. To facilitate the placement of the wing marks, circular marks were incorporated that corresponded to the profile of the tag, guaranteeing the perfect alignment of the wing mark perforations. The dorsoventral reading tag 'Model I' was made of yellow PVC tarpaulin of 670 gr/m² presenting the alphanumeric digits overprinted in black. The dorsoventral reading tag 'Model II' was made with PVC canvas of 670 gr/m² and with punched alphanumeric digits, incorporating a piece of black tarpaulin (contrast canvas) of 540 gr/m² longitudinally thermo-sealed at the bottom along the entire wing mark. With this, the identification digits of the bird were legible for a much longer time. The dorsoventral reading tag 'Model III', was made of PVC canvas of 670 gr/m² with die-cut alphanumeric digits. Unlike the two previous models and in order to reduce the rigidity of the contact area with the patagium, the black canvas piece (contrast canvas) was inserted underneath the surface occupied by the alphanumeric digits (fig. 3).

Placement of the wing tags

To attach the wing tags to the patagial membrane, we used commercial tags Allflex® for swine. These tags are made of high strength polyurethane and have a brass tip for easy placement. As placement is an invasive technique, and since the placement of the tags inevitably involves a 7 mm diameter perforation, measures of prophylaxis were adopted. Prior to labelling, the male ends (with metal tip) were immersed in a 50% solution of povidone-iodine cutaneous solution and alcohol 96°. The patagial membrane of each bird was then disinfected, soaking the insertion area of the tag with the same solution. By soaking the down of the ventral part of the patagium, vision of the limits of the patagial membrane and its degree of vascularization was clear. Immediately before the tag was placed and at the specific point of drilling (conveniently away from the fold axis of the wing), we applied a cutaneous spray used to treat wounds and skin infections in livestock. The perforation was thus disinfected and so would heal more quickly. As verified during the recapture and removal of the tags, the feathers introduced during the perforation around the stem of the male of the tag, gave rise to an inert material called a 'feather cone' (fig. 3).

Laboratory durability tests

The suitability of the wing tags Models II and III (models consisting of heat-sealed pieces and digits defined by die-cutting) was evaluated at the time of their use in the marking and monitoring of long-lived ornithic species such as the griffon vulture, and modeling behaviour during years of harsh weather conditions. This task was carried out by of the Technological Textile Institute of Alcoy, in whose laboratories the wing marks were subjected to different tests following standardised protocols and standards. Three samples of these thermo-sealed models were used, one sample without pretreatment, one sample with pretreatment of immersion in fresh water (rain) and one sample with pretreatment in salt water to simulate the wear in a seabird. During the wet test cycles, the samples were continuously sprayed with fresh and/or saline water during exposure to radiation. Specifically, the tags were subjected to oxidation tests by exposure to sunlight according to the UNE-EN ISO 4892-2: 2000 Standard (Method A). As indicated, two of the samples were pretreated to evaluate their resistance to fresh and saline water, immersing the samples in river water and in seawater



Fig. 3. Models of patagial wing tags. Placement process.

Fig. 3. Modelos de marcas patagiales alares. Proceso de colocación.

(salinity of 3.5%) for 24 hours before proceeding with the aging in sunlight test. For the test, an approved apparatus was used; this device reproduces outdoor conditions in dry and humid cycles (rainy day, sunny day) of solar exposure (wavelength of 340 nm and irradiation of 0.50 W/m²). A Xenon Arc Weather–Ometer CI 3000 (serial number 19816) with internal and external borosilicate filter was used. The test conditions aimed to model the aging of the wing tags for 365 days so as to extrapolate the results to consecutive years, with an equivalent of one year for each hour of exposure in the laboratory. Therefore, the samples were subjected to a total of 365 hours of exposure. Model I was not analysed because it did not follow this method of identifying figures by heat sealing the pieces.

Veterinary exploration in recaptured birds

The cicatricial response resulting from the perforation of the tag on the patagial membrane was examined in recaptured specimens whose wing tags were removed. The response was similar to the scarring observed in livestock species such as rabbits, goats and sheep for which the commercial tags are used. In the case of vultures, the perforations produced a small, more or less circular wound that healed in a normal way.

Results

Results in the field

A total of 193 vultures were tagged. Forty–three individuals were recaptured and the average number of days that the marks were worn was 1,398 days (SD ± 551.78). We weighed approximately half the sample of captured individuals (n = 20), taking weight as an indicator of the physical state; average weight was 9.11 kg (SD ± 1.14). The tags were removed and the diameters of patagial perforations were measured to analyse the physiological response of the membrane to the insertion of the plastic tags. The average area of the perforations produced by the tag was 85.38 mm² (SD ± 28.61). All measures corresponded to the left wing. Only three of the recaptured individuals (7%) presented some type of lesion in the area of the tag insertion. These anomalies appeared in the form of eschar, abrasions, or hyperkeratosis. One specimen (vulture 9) showed a bulge near the perforation region.

DEGRADACIONES / CHANGE IN COLOUR
5.- MUY BUENA – EXCELENTE VERY GOOD - EXCELLENT
4.- BUENA / GOOD
3.- MEDIANA – REGULAR / FAIR
2.- MALA – DEFICIENTE / POOR
1.- MUY DEFICIENTE / VERY POOR

Fig. 4. Grayscale used to assess the solidity according to report number 2009AN0410 of the Textile Technological Institute of Alcoi.

Fig. 4. Escala de grises utilizada para valorar la solidez conforme al número de referencia 2009AN0410 del Instituto Tecnológico del Textil de Alcoi.

Results of laboratory durability tests

After the light aging tests, the treated samples were compared to the original wing tags. The value of the degradation index was assessed with solidity indexes using grey scales. The wing tags tested showed no physical degradation in the form of separation of the heat sealed parts. The colorimetric degradation of the samples was assessed by the Technological and Textile Institute of Alcoy (report number 2009AN0410) with a coefficient of 4 out of 5, which is equivalent to a response of 'Good' to 'Very Good–Excellent' (fig. 4). After modelling the wear on the wing tags tested, a minimum durability of eight to 10 years was estimated in all weather conditions. The manufacturers of high–strength polyurethane plastic Allflex tags claim they generally remain fixed throughout the life of the target animals, which in the case of dairy cows can exceed 20 years.

Result of testing in captive birds

An indispensable tool in the sedentarization of the birds included in the Canjeet Recovery Project as a nesting species in the Valencian central regions was the establishment of a large aviary of about 700 m². Here, groups of up to 30 young vultures from state wildlife recovery centres were regularly housed, generally following admission for malnutrition during the postnuptial period. The large dimensions of these facilities enabled the birds to be subjected to a controlled situation of captivity coinciding with the sedentarization stage prior to their reintroduction after around 12 months in captivity. During this period, the birds made short flights, bathed, and participated in carrion feeding sessions, constituting an optimal opportunity to verify the interaction of the wing tags in the life processes of the species. During periods of sedentarization, all the birds were fitted with metal rings, PVC reading rings, and patagial wing tags with dorsoventral readings approximately four weeks before their release. During this time and thanks to an observatory installed in the acclimation aviary, the birds' reaction to the implantation of the wing markings in their various daily acts was observed. Apart from some initial reactions of strangeness by some tagged birds, all the birds reacted positively to the wing tags, with their beaks often naturally passing over the edges of the wing tags as they repositioned plumage. During sunbathing sessions, the birds were sometimes seen pecking the wing tags of other birds, seemingly out of curiosity.

Results of field work on released birds

During the sampling period, 21.7% of the birds were sighted and recovered. All these birds were tagged and released within the monitoring work of the project. Acclimatized birds were

tagged before their release at the project dump site, located at *Les Canteres de Sant Cristófol* (38° 42' 40" N 00° 30' 23" W). A total of 79 birds visited the area during the autumn. Twenty-three chicks hatched in the colony.

A female specimen from the recovery centre in Extremadura (Sierra de Fuentes, Cáceres) and that had been transferred to the recovery centre of the NGO GREFA in Majadahonda, Madrid, was later transferred once again to the NGO FAPAS–Alcoi for the reintroduction project of Alcoi, Alicante. From here, at two years of age, the bird was released on 28/12/2004 after a sedentarization period in an aviary, and after patagial dorsoventral tagging (38° 42' 40" N 00° 30' 23" W). On 15/02/05, this vulture was observed perched on a cliff of Cape Huertas, Alicante (38° 21' 13" N 00° 24' 25" W) at a linear distance of 40 km from the site of release. On 14/04/2005, the bird was found and photographed feeding on a goat carcass in *Vallfogona del Ripollés*, Girona (42° 12' 32" N 02° 18' 12" E) at a linear distance of 479 km from the site of release. Between 03/03/2006 and 22/07/2007 (showing wing tags with completely erased digits) it was located more or less continuously and intermittently in the Alcoi mulandar. On 02/06/2008 it was photographed in the Italian town of Trevi del Lazio, province of Frosinone (41° 51' 46" N 13° 12' 16" E) inside the Parco Naturale Regionale dei Monti Simbruini, about 80 km from Rome and at a linear distance of about 1,500 km from the place of acclimatization and release (the wing tags were missing but it was identified by its PVC ring on its left tarsus). After 28/04/2008, it was again located in the Alcoi dump site, where it was recaptured on 29/11/2008 and the wing tags were replaced with a higher resistance model). After this date, the bird paired with a male in the reintroduction project and became established in the colony; attempts to reproduce with this same male in 2009 and 2010 were unsuccessful.

A young male from the recovery centre of wild fauna at *Forn del Vidre*, Castellón, managed by the *Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge*, was tagged and released on 17/01/2006 at the Alcoi dump site (38° 42' 40" N 00° 30' 23" W). On 13/04/2006 the bird was recovered by the SEPRONA unit of the Civil Guard police on a road in a private estate in the municipality of Albacete (39° 00' 40" N 01° 54' 07" W) at a linear distance of approximately 125 km of the release point. The vulture was transferred to the recovery centre at Albacete managed by the Ministry of Environment and Rural Development, where it weighed 8 kg. The bird had presented a dislocated carpo–metacarpal joint with the phalanx and possible fracture in the proximal part of the phalanx. The specific date of its later release from the Albacete recovery centre is not known, but it was located on 17/01/2007; it appeared to have fully recovered and was a member of a colony at Barranc del Cint, Alcoi (38° 42' 42" N 00° 29' 37" W), where it has remained continuously since 2008.

A three-year old male picked up in Moraleja de En Medio, Madrid, was admitted to the recovery centre of the NGO GREFA de Majadahonda, Madrid, in October 2003. The vulture was tagged and placed in the reintroduction project, and was freed in the Alcoi dump site (38° 42' 40" N 00° 30' 23" W) on 17/01/2006 after a year of acclimation in aviary. After disappearing from the release zone on 21/04/2006, the bird was located and photographed on 01/06/2006 at the Raptor Refuge of Montejo de la Vega, Segovia (41° 32' 08" N 03° 37' 17" W) at an approximate linear distance of 410 km from the release site. The vulture reportedly remains in the area and has settled permanently in the Refugio de la Hoces del Riaza.

A young vulture trapped in autumn at the Alcoi dump site (38° 42' 40" N 00° 3' 23" W) was tagged on 04/11/2007. After the last sighting in the area of capture and release on 24/01/2008, it was sighted on 08/08/2009 in the Parc National des Ecrins, in the French Alps, 50 km south of the city of Grenoble (44° 54' 44" N 06° 18' 38" E) at a linear distance of 930 km approximately (partially erased wing tags). On 19/11/2009 the vulture was again located at the dump site of the reintroduction project of Alcoi.

A young male vulture from the recovery centre of the NGO GREFA de Majadahonda, Madrid, was transferred from a recovery centre in Navarra and ceded to the NGO FAPAS for incorporation into the reintroduction project of Alcoi, Alicante. The bird was released on 11/07/2000 with ALV printed patagial wing tags on the dump site of the Alcoi project

(38° 42' 40" N 00° 30' 23" W). It remained in the release zone until 26/12/2000. On 28/08/2003 the bird was located in *Diois*, Alpes–Maritimes of France (44° 40' 42" N 05° 19' 59" E) at an approximate linear distance of 835 km from the place of release. On 13/04/2004, the vulture was located again in the dump site of the reintroduction project of Alcoi. He joined an unpaired female in 2004 and was finally lost from tracking on the 10/12/2005.

A young specimen from the Wildlife Recovery Center of Santa Faz, Alicante, managed by the Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge, was tagged and released on 27/10/2006 in the Alcoi dump site (38° 42' 40" N 00° 30' 3" W). It was sighted in the same area until 15/11/2006. On 15/06/2007 the bird was found drowned in the irrigation pond of a farm near a landfill in Morocco, about 10 km SW of the border with the city of Ceuta (35° 49' 33" N 05° 25' 23" W), at a linear distance (across the strait) of approximately 570 km of the release point.

A female specimen from the recovery centre of the NGO GREFA de Majadahonda, Madrid, was ceded to the NGO FAPAS–Alcoi for its incorporation into the reintroduction project of Alcoi. The bird was released on 25/12/2002, in its second year of life, after a period of sedentarization and provided with patagonal LDV tags within the Alcoi project (38° 42' 40" N 00° 30' 23" W). The bird settled permanently in the release zone, forming a stable partner with a marked male and was reintroduced on 29/11/2001. In 2005 it settled in the new colony of *Barranc del Cint*, Alcoi (38° 42' 42" N 00° 29' 37" W), giving rise to the hatching of the first chick of the reintroduction project. In its third season as a breeder, the vulture was located on 04/08/2008 feeding on the RAMAC dump site in the Puerto de las Palomas, Cazorla Segura and Las Villas Natural Park, Jaén (37° 56' 46" N 02° 55' 19" W) at an approximate linear distance of 230 km from the breeding colony. On that date the vulture had a 138–day–old chick in the nest and it did not leave the platform until 08/09/2008.

Effects of wing marking on reproductive success

Within the follow–up work of this newly created colony, we located 18 breeding pairs between 2005 and 2009 and obtained the initial reproductive parameters of the *Barranc del Cint* colony (Alicante). Estimates of productivity (0.47) and reproductive success (0.41) were low, possibly reflecting the precocity of these first–time couples (source: IV National Census of Griffon Vulture 2008). Birds of only four years of age (EURING 8 or 9) were frequently established as breeders, increasing the cases of reproductive failure up to 63% due to the infeasibility of laying and chick mortality during the first days of life.

Tagged birds accounted for 69.4% of the 18 pairs studied during the study period. The remaining 30.6% were not tagged. In nine of the pairs, both parents were tagged, in seven of the pairs one of the two adults was tagged, and in the two remaining pairs neither members of the pair were tagged. Regarding the five chicks that died before leaving the nest, two of them were tagged. Of the total number of chicks found dead or missing, three corresponded to pairs in which both individuals bore tags, one corresponded to couples with one of the parents tagged and the remaining chicken was found dead in a nest of untagged breeders. This seems to indicate that the wing tagging did not influence the survival rate of the chicks and therefore the reproductive success of the vultures.

Result of birds marked in nest

As a result of the reintroduction project begun in 2000, in 2005 two birds hatched in freedom in the newly created colony in the calcareous walls of the *Barranc del Cint*, showing that the griffon vulture had recovered as a nesting species in the province of Alicante. As part of the nest tagging and follow–up of the reintroduction project, all the chicks born in the colony were banded and tagged. We then proceeded to tag the nests and monitor the 23 chicks hatched between 2005 and 2009; this enabled the study of possible interference caused by

wing marks in the development or survival rate of chicks. The average number of days of life at the time of tagging was 71.87 days (SD \pm 14.51). Likewise, the reactions of the parents to the presence of these devices in the chicks marked at different ages were observed.

The first chick hatched in the colony, in the *Barranc del Cint* (38° 42' 42" N 00° 29' 37" W), as a result of the aforementioned reintroduction project was ringed and equipped with wing tags in the nest on 06/11/2005 at 52 days of age. On 19/09/2005 a young female left the nest and was located and photographed in perfect conditions at the dump site of the project. In the 2009 breeding season, at the age of four years (EURING 9), it paired with a wild male, laying and incubating with normality. On 17/05/2009 the chick hatched and was ringed on 30/06/2009 at 44 days of age but it was found dead in the nest on 27/07/2009 at 71 days of age due to unknown causes.

The second chick born in the *Barranc del Cint* colony (38° 42' 42" N 00° 29' 37" W) was ringed and tagged in the nest on 10/07/2005 at 64 days of age. The bird developed normally to adulthood. On 08/10/2007 the vulture was located in the dump site of the Sierra de Mingarnao (38° 09' 36" N 02° 20' 10" W), in the municipality of Nérpio, province of Albacete, at an approximate linear distance of 172 km. On 14/08/2007, the vulture was located again in the Alcoi dump site as a five-year-old adult bird (EURING 10).

One of the chicks born in the *Barranc del Cint* colony (38° 42' 42" N 00° 29' 37" W) in 2008 was ringed and tagged in the nest on 012/06/2008 at 77 days old. On 10/08/2008 it left the nest and was last seen in the Alcoi area on 10/02/2008. On 12/02/2008 it was identified from its wing markings by photographic trapping at a supplementary feeding point for black vulture managed by the BVCF (Black Vulture Conservation Foundation) at *Puig Gross de Ternelles* (39° 53' 23" N 03° 00' 12" W), Mallorca, at a linear distance of about 328 km from the site of tagging. The bird was found among a group of 60 to 100 specimens that were swept in by a strong storm in early November that year and remained in Mallorca for weeks, sharing food with the black island vultures.

Two of the fledglings were rescued after nest tagging chick number 23 was found at the foot of the colony by hikers, and chick number 22 was recaptured after perching on a roof of the town of Alcoi. The tags were removed and the perforations of both specimens were examined. A satisfactory result of the perforation healing process was observed, suggesting incidents of this type during the first flights are a natural process and are not related to the tagging of the birds.

Veterinary examination in recaptured birds

In most cases the perforation produced a scar of less than 10 mm with smooth edges and a thickness similar to that of the original patagial membrane. In two cases, the scar hole was slightly larger than 10 mm, although it was smooth and the edges were not thickened.

In four of the recaptured birds, the hole from the scarred perforation was not completely circular, but oval or slightly elongated in shape, probably due to the slight traction undergone by the wing tag on the days after the tag was placed, when the perforation was healing. However, this aspect does not seem to have more significance than that of its graphic description, since it does not indicate a real possibility of tearing of the patagial membrane of birds.

Regarding the lesions observed in three of the recaptured specimens, these appeared in the form of erosions of varying consideration as an organic response to abrasions in the area of contact between the patagial membrane and the central part of the wing tag. Specifically, in the left wing of one specimen, thickening was observed at the ventral medial edge due to abrasion in the distal area of the membrane, where the tag was in contact with the patagial membrane when the bird was resting with the wing folded, causing loss of infracober feathers and hyperkeratosis or thickening on the skin of the membrane. In the right wing of this same specimen, the lesion appeared on both sides of the contact zone between the membrane and the central part of the wing tag. These lesions presented in the form of loss

of infracober feathers in the contact area, hyperkeratosis, as well as two localized ulcerations that coincided with both contact zones between the central edges of the wing mark and the patagial membrane.

Another specimen showed loss of infracober feathers, hyperkeratosis on the skin of the membrane, and ulceration in the contact area of the patagial membrane with the distal edge of the wing tag.

In a third bird, hyperkeratosis of the skin of the patagium located caudally to the scar hole was observed, giving rise to a small cyst of fibrous consistency, although its formation could not be directly related to the healing process.

Cause of the injuries and preventive measures proposed

The location of the injury in these birds indicates that the abrasion did not occur during flight but when the bird was resting. Because the point of insertion of the tag was interfering in the area of wing fold there was a continuous contact between the propatagial tendon and the outer edges of the central part of the wing mark.

It is thus recommended to avoid any possibility of continuous contact between the edges of the wing tag and the propatagial tendon of the membrane, ensuring that the insertion point of the plastic tag is sufficiently far from the fold axis of the wing (in front of the elbow of the bird). Likewise, and as a complementary measure to avoid displacement of the fixation point towards the distal part of the patagial membrane, we propose that the PVC of the contact area is soft and non-abrasive.

Discussion

Bird wing tags have shown to be an effective tool in the study of birds as they can be used in research on avian ecology and conservation in general, and of the griffon vulture in particular. They enable the follow-up of reintroduction programmes and also aid in studies about behaviour patterns and dispersive movements of individuals.

Patagial wing tags attached by perforation of the patagial membrane were used successfully in waders in the early 1960s (Anderson, 1963, Knowlton et al., 1964). Bartelt and Rusch (1980) marked specimens of American coot (*Fulica americana*) with wing tags fixed by nylon thread to the patagium. They reported good durability of the device and did not observe an increase in mortality in the marked individuals. Mossman (1976) used livestock tags as attachments in vultures, although he did not specify how he fixed these, or what results they showed, except for the infrequent sightings of six adult American red-necked vultures (*Cathartes aura*) that he captured and tagged in Wisconsin (Wallace et al., 1980). Little progress has since been made in improving such marking elements.

If we compare plastic patagial tags with the more simple wrap-around tags at the height of the humerus, the former have several advantages. Patagial tags are more quickly and easily placed, and also more visible because the tag is not hidden among the secondary feathers when the bird is sitting, as often occurs with humeral markings. Furthermore, patagial markings can be used to mark vulture chicks at an early age, barely 35 days after hatching and as soon as they are sufficiently large to accommodate the tag securely. In contrast, the earliest age at which chicks can undergo humeral tagging would be about 75 days (approximately two weeks before being fully fledged), because flight feathers must be present to keep the vinyl tags in the right position. The fact that humeral marks are often partially hidden in the plumage has traditionally limited the individual marking of birds almost exclusively to the use of colours and symbols. The possibility of incorporating digits that are fully visible both in resting birds and in birds in flight overcomes the limitations of humeral tags, and makes high variability (colours and alphanumeric codes) compatible with the necessary homogeneity to enable efficient and coordinated monitoring programmes (Seguí, 2006). However, it is inter-

esting to complement these studies with GSM/GPS transmitters, devices that are increasingly being used in ornithological studies (Kendall and Virani, 2012), because despite their relative expense, they provide precise data concerning the route taken by migratory birds

Tagged individuals have been frequently recognized through the use of various devices. No alterations have been reported at an ethological level in any of the vital stages of the species. In the specific cases in which injuries have been observed, the causes have been analysed and appropriate corrective measures have been adopted. The marking tag model (dorsoventral reading tag Model III) used in the present study is considered appropriate as it meets the following criteria: i) absence of adverse effects on behaviour, longevity, and social life of birds; ii) quick and simple application; iii) visibility of digits at a distance; iv) guarantee of durability that facilitates use in long-living species; v) relatively inexpensive. The technique of wing tag marking in the current study provided highly satisfactory results and enabled a greater understanding of the patterns of behaviour and movement of this species. The design of these wing tags was appropriate for the griffon vulture as remote identification was good and the negative incidence on individuals was slow. Considering that only 6.97% of the sample presented some type of anomaly, we conclude that this technique is effective. Furthermore, progress has been made to reduce these adverse effects. To avoid the formation of calluses, the so-called 'abrasion fringes' are incorporated and the perforation point is moved distally so that it does not coincide with the fold axis of the wing. This system of marking enables a fairly accurate differentiation of individuals when compared with other techniques, and it eliminates the need to capture the individual for identification.

This device was not found to interfere in the vital stages of the species (feeding, flight, copulations, incubation, etc.). One of the many advantages of the method is that it can be designed individually for specific species, playing with shapes and colours, and always avoiding discomfort for the animal. In addition, the design can be applied in any part of the world in a homogeneous way and coordinated by the competent organisms. We conclude that the perforations of the tags on the patagium produced minimal adverse reactions and did not produce any dysfunction in the flight capacity or on the physiology of the birds in any case. Furthermore, when the wing tags were removed, we verified the effectiveness of the prophylaxis and disinfection measures in the insertion area. Specifically, the effectiveness of the previously applied products on the membrane and covering feathers was also verified. The inevitable introduction of some of these feathers during the insertion of the tag caused no risk of infection, and the material surrounding the stem of the tag gave rise to a harmless 'feather cone'.

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