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# Status, habitat and diet of breeding Barbary falcons from a rugged oceanic island in the western limit of its distribution

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During 2015 and 2016, we conducted the first systematic study of the size of the breeding population, distribution, habitat and diet of the Barbary Falcon *Falco peregrinus pelegrinoides* on La Palma, Canary Islands. We found a minimum of 28 territories (3.9 territories/100 km$^2$) at an average distance of 3.6 km (range 1.7–7.7 km) from their nearest neighbours. The territories were distributed throughout the island, but there were more in the northern half, probably due to a greater availability of large cliffs. Falcons selected high cliffs situated in scrub-covered areas close to the coast with relatively high levels of human infrastructures. However, this picture could be biased due to the inherent difficulties in surveying the rugged innermost parts of the island, where some territories may not have been detected. The nine monitored nests were situated in natural cavities or ledges at heights ranging from 35 to 110 m above ground level. Egg-laying probably takes place in late March, later than in the rest of the Canarian archipelago, perhaps due to the rainier climate of this island. On average, almost two chicks fledged per nest, a similar rate to nearby populations. Diet was composed of at least seven bird species, with *Columba livia* being the most frequently hunted and the most important prey item (93.9% of diet biomass). As falcons prey upon domestic racing pigeons (a popular activity on the island), direct persecution could be one of the main threats for the Barbary falcons on La Palma. There is a widespread but false idea that these raptors are not native, and that their presence is due to deliberate releases of foreign falcons by local government bodies. Thus, a human-wildlife conflict has arisen with pigeon fanciers whose solution requires more reliable information on the scale of the predation on pigeons and an environmental education campaign.

Key words: *Falco peregrinus pelegrinoides*, census, status, spatial distribution, food spectrum, Canary Islands.

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Monitoring the status, distribution and life history traits of wild populations is an essential part of wildlife conservation (Sutherland *et al.* 2004, Sodhi & Ehrlich 2010). This is of special relevance in the case of small and isolated populations – for example, on islands – that are often threatened by environmental, stochastic, demographic or human-related factors (Donázar *et al.* 2005, Wood *et al.* 2017). This is the case of certain endangered birds of prey on several islands in the Canarian archipelago such as La Palma, where information about their status is based on both non-systematic monitoring and nonrigorous studies.

Despite the fact that some authors consider the Barbary Falcon to be a full species (*Falco pelegrinoides*) (Ferguson-Lees & Christie 2001, Fuchs *et al.* 2015), the most recent molecular studies indicate that it is so closely related to the Peregrine Falcon *F. peregrinus* (Wink 2018) that it should be classified as a subspecies, *F. p. pelegrinoides*, of this falcon. Nonetheless, Barbary falcons do have marked phenotypic differences, including their small size, paler coloration and

rufous nape patches, all of which allow them to be distinguished from other peregrine subspecies (Shirihai *et al.* 1998, White *et al.* 2013).

With the exception of a few studies carried out on the Canary Islands regarding its breeding biology and habitat selection (Rodríguez & Siverio 2006, Rodríguez *et al.* 2007, 2011; Siverio *et al.* 2011, Rodríguez *et al.* 2018a), basic knowledge of the biology and ecology of the Barbary Falcon is still scarce throughout its range (Ferguson-Lees & Christie 2001, Rodríguez *et al.* 2009, White *et al.* 2013). This falcon is a bird-feeding specialist that usually breeds on the highest available cliffs; many aspects of its behaviour and life history traits seem to be generally similar to those of other well-known peregrine subspecies (see Ratcliffe 1993, Ferguson-Lees & Christie 2001, White *et al.* 2013). In the Canary Islands as a whole, this sedentary raptor occupies all kinds of habitats from the coast to up 2,000 m a.s.l. and its breeding density is highly dependent on the availability of cliffs and areas of scrub (Rodríguez *et al.* 2007, 2018a; Rodríguez & Siverio 2006). In this archipelago, egg-laying is concentrated mainly between 20 February and 10 March and the percentage of successful pairs (i.e. raising at least one fledging) exceeds 80%. Its mean productivity (mean number of fledging per territorial pairs) estimated for some islands and years varies between 1.62 and 2.53 (Delgado *et al.* 1999, Rodríguez *et al.* 2007, 2009, 2018a, 2019; Siverio *et al.* 2011).

Populations of the Barbary Falcon have been naturally increasing in recent decades in the Canary Islands, rising from seven known pairs in the Eastern islands in 1987–1988 (Hernández *et al.* 1991) up to 180 over the entire archipelago by 2018 (Rodríguez *et al.* 2007, Rodríguez & Siverio 2006, Siverio *et al.* 2009, 2011; authors' unpubl. data). On La Palma, the species was considered rare during the 20th century (Thanner 1908, Polatzek 1909, Cullen *et al.* 1952, Bannerman 1963, Morphy 1965), a judgement based on personal observations and opinions rather than formal surveys. Although in the late 1990s the population probably only consisted of 8–10 breeding pairs (Delgado *et al.* 1999, Martín & Lorenzo 2001), recent estimates of its population size based on observations conducted during 1997–2007 suggest that there is a minimum of 20 breeding pairs (Rodríguez & Siverio 2007).

This raptor faces still several human-related threats on the Canary Islands (Rodríguez *et al.* 2009, 2010, 2019) and so is classified as Endangered in the Spanish national and regional catalogues of threatened species (Siverio & Concepción 2004). In addition to collisions with man-made structures, this species is directly persecuted by hunters and pigeon-fanciers and some birds have been shot in recent decades (Siverio & Concepción 2004, Rodríguez *et al.* 2010). The feeding habits of raptors often lead to conflicts of interest with certain human activities, mainly because they prey on game and/or domestic species (Kenward 1999, Galbraith *et al.* 2003, Valkama *et al.* 2005, Donázar *et al.* 2016). In this context, the conflict between pigeon-fanciers and birds of prey is well known, as illustrated by the cases of Bonelli's eagle *Aquila fasciata* in the Iberian Peninsula (Palma *et al.* 2006, Moleón *et al.* 2011) and the Peregrine Falcon in England (Dixon *et al.* 2003, Shawyer *et al.* 2003, Parrott *et al.* 2008). A third threat comes from the recent increase in popularity of falconry in the Canary Islands. Nest-robbing and the genetic introgression of escaped falconer's birds into native falcon populations could be playing a role in genetic shaping and population dynamics (Rodríguez *et al.* 2009, 2011, 2019).

The aim of the present study was to examine the status, distribution, habitat features and diet of the Barbary Falcon on La Palma. The information gathered here will serve as a foundation for future studies and may help in the assessment of its conservation status and needs.

## Material and methods

### *Study area*

The study was conducted on La Palma (area: 708 km$^2$; maximum altitude: 2,426 m a.s.l.), the northwesternmost island of the Canarian archipelago (Figure 1c). Its landscape is characterized by rugged terrain, dominated by large sea cliffs and deep ravines, although there are also some coastal platforms, often occupied by banana plantations and human settlements. The vegetation is influenced by altitude and the northeast trade winds (del Arco *et al.* 2006). In 2015, the human population was 82,346, concentrated above all in the towns of Santa Cruz

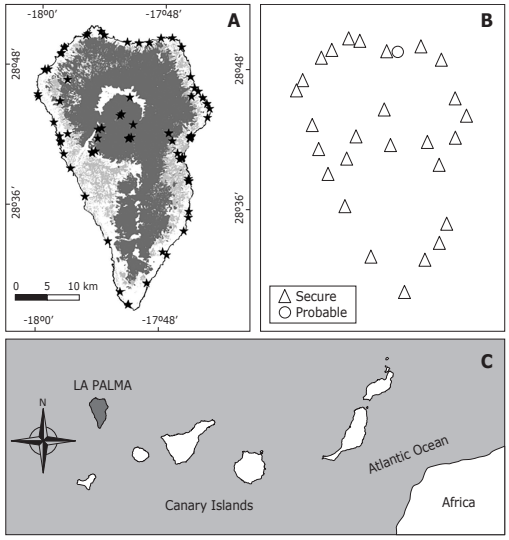


**Figure 1.** Distribution of the 93 observation sites (A: stars) and breeding territories (B) of Barbary falcons on La Palma in the 2015 and 2016 breeding seasons. Urban or human transformed areas are shown in light grey and forested areas in dark grey on map A. For conservation reasons breeding territories are not shown on the map B. C) Location of La Palma within the Canary Islands.
*Distribució dels 93 llocs d'observació (A; estrelles) i territoris de cria (B) de falcó berber a La Palma durant l'època de reproducció de 2015 i 2016. Les àrees urbanes o transformades per l'home es mostren en gris clar, mentre que les àrees forestals en gris obscur al mapa A. Per raons de seguretat els territoris de cria no els mostrem en el mapa (B). C) Localització de La Palma a les Illes Canàries.*

de La Palma and Los Llanos de Aridane (ISTAC 2018). Currently, the island's economy is based on agriculture and tourism (Martín-Ruiz 2001).

## *Field procedures*

Fieldwork was conducted during the 2015 and 2016 breeding seasons and was based initially on the sites of known territories (Delgado *et al.* 1999, Rodríguez *et al.* 2009). In 2015, observations were made during the chick-rearing period (May) but in 2016 observations were carried out during the entire breeding season (February–July). We selected 93 (53 in 2015 and 40 in 2016) vantage points distributed across the island (Figure 1) to check known breeding territories or search for potential cliff-nesting sites. Field surveys were conducted by at least two observers (up to four on some occasions) using binoculars and 20–60x field telescopes. A total of 113 hours of direct observation were performed: 48 hours in 2015 (mean duration of observations: 53 min) and 65 hours in 2016 (mean duration: 97 min). By end of the study, all the known breeding sites and potential cliffs had been visited at least once. We recorded all information regarding falcon presence (flying and/or perching birds, fresh droppings, plucking sites, fledglings, etc.) and whenever possible age, sex and evidence of breeding behaviour was also recorded for detected birds. All breeding sites were categorized as either *sure* or *probable* based on evidence gathered in the field (see Hardey *et al.* 2007). The locations of territories (breeding sites) were georeferenced considering the nest when it was known, or the most suitable judged site capable of holding a nest. Coordinates were obtained using a handheld Garmin GPS unit, 1:25,000 scale topographic maps or a Geographical Information System (GIS).

## *Habitat features*

We employed eleven variables commonly used to describe nesting cliffs and their surroundings (e.g. Rodríguez & Siverio 2006, Rodríguez *et al.* 2007; Table 1). We arbitrarily set a radius of 1.5 km around the nesting sites (roughly half of the mean nearest neighbour distance between occupied territories on La Palma) as the area most likely to be used by falcons (authors' unpubl. data) to describe vegetation types and land use in the vicinity of territories (del Arco *et al.* 2006, Table 1). We also measured the same variables in 30 randomly chosen unoccupied cliffs (e.g. see Sergio *et al.* 2004 for a similar approach) by generating random locations using a GIS and selecting the nearest apparently suitable cliffs for nesting falcons (> 35 m, the minimum height of cliffs used for nesting by falcons on La Palma). Geographical analyses were conducted using Qgis v3.6 (Open Source Geospatial Foundation Project, http://qgis.osgeo.org).

Variables used to describe occupied and unoccupied cliffs were compared with a non-parametric Mann-Whitney *U*-test as they do not fit normality and homocedasticity assumptions (tested using Shapiro-Wilk and Levene tests). We used generalized linear models (GLM), with logit link function and binomial error distribution, taking unoccupied *vs*. occupied cliffs by falcons as the

**Table 1.** Mean values (± standard deviation-SD) of variables measured at Barbary falcon territories and on unoccupied cliffs on La Palma in the 2015 and 2016 breeding seasons. Statistical results of univariate tests between the two samples are shown (* confidence intervals not including 0). Distances and heights are in metres. Landscape variables are expressed as a percentage of the whole territory.
*Valors mitjans (± desviació estàndard-SD) de les variables mesurades als territoris del falcó berber i als penyasegats desocupats de La Palma durant les temporades de reproducció de 2015 i 2016. Es mostren els resultats estadístics de les proves univariants entre les dues mostres (* intervals de confiança que no inclouen el 0). Les distàncies i les alçades són en metres. Les variables del paisatge s'expressen en % del territori.*

| Variable | **Occupied** ***Ocupat*** (*n* = 28) | | **Random** ***Aleatòria*** (*n* = 30) | | **Lower CI** ***IC inferior*** | **Upper CI** ***IC superior*** |
|---|---|---|---|---|---|---|
| | **Mean ± SD** ***Mitjà ± SD*** | **Range** ***Rang*** | **Mean ± SD** ***Mitjà ± SD*** | **Range** ***Rang*** | | |
| Nearest neighbour distance<br>*Distància al veí més proper** | 3617.9 ± 1525.2 | 1770 - 7743 | 2933.9 ± 1772.0 | 957 - 7623 | 129 | 1644 |
| Cliff height<br>*Alçada penya-segat** | 100.0 ± 41.8 | 35 - 195 | 72.8 ± 19.6 | 35 - 115 | 5 | 45 |
| Distance to sea<br>*Distància al mar** | 1207.6 ± 2591.4 | 25 - 9.168 | 2292.4 ± 2304.9 | 14 - 7237 | -2418 | -210 |
| Distance to roads<br>*Distància a carreteres* | 322.6 ± 316.0 | 18 - 1.340 | 253.7 ± 351.8 | 15 - 1478 | -17 | 182 |
| Built-up areas<br>*Àrees humanitzades* | 6.1 ± 11.5 | 0 - 57 | 1.2 ± 1.7 | 0 - 6 | 0.2 | 3 |
| Forests<br>*Boscos** | 14.4 ± 31.0 | 0 - 100 | 38.7 ± 36.1 | 0 - 100 | -48 | -6 |
| Shrublands<br>*Matollars** | 28.2 ± 12.9 | 0 - 47 | 19.7 ± 16.5 | 0 - 52 | 1 | 19 |
| Grasslands<br>*Herbassars* | 4,8 ± 4.9 | 0 - 17 | 3.0 ± 4.2 | 0 - 13 | -0.2 | 3 |
| Other land-uses<br>*Altres usos de la terra* | 16.0 ± 12.8 | 0 - 47 | 23.3 ± 18.4 | 0 - 75 | -14 | 1 |
| Sea<br>*Mar** | 36.5 ± 18.3 | 0 - 58 | 15.3 ± 18.2 | 0 - 48 | 7 | 39 |
| Protected areas<br>*Zones protegides* | 46.4% (*n* = 13) | | 36.7% (*n* = 11) | | | |

response variable (0/1). As predictors, we used only those quantitative variables showing significant differences according to univariate tests, i.e. with 95% confidence intervals not including the zero (Table 1). Predictors were standardized (mean = 0, SD = 1) prior to running the models. We performed multimodel inference based on the corrected Akaike's information criterion (AICc) of each model (Burnham & Anderson 2002). To avoid multicollinearity, we removed from the full model variables with variance inflation factors above 2. Thus, percentage of forest and distance to sea were not included in the full model. Statistical tests were conducted in R (version 3.5.3; R Core Team 2018).

### *Breeding rates*

We recorded all possible information relating to breeding but were unable to finally estimate the fledging rate of the 12 breeding attempts (mean number of fledglings per successful breeding attempt; Rodríguez *et al.* 2007, Siverio *et al.* 2011) due to the fact that the majority of territories were visited only once. We estimated laying dates within ten-day intervals based on chicks' ages (Monneret 2000) and this falcon's 28-day incubation period (Delgado *et al.* 1999, Shafaeipour *et al.* 2016).

### *Diet composition*

In 2016 we climbed up to nests and the surrounding areas in four occupied territories (one of them held by a single female) to collect prey remains (feathers, bills, skulls, legs and bones) and pellets. To avoid disturbance, visits were carried out after chicks had fledged. Whenever possible, remains were identified to species level using our reference collections of bones

**Table 2.** Age and sex of Barbary falcon individuals or pairs (♂♀) sighted on La Palma during the 2015 and 2016 breeding seasons.
*Edat i sexe dels falcons berbers observats a La Palma durant l'època de reproducció de 2015 i 2016. Les parelles s'indiquen a la columna ♂♀.*

| **Age** / ***Edat*** | **Sex** / ***Sexe*** | | | | **Total** |
|---|---|---|---|---|---|
| | ♀♀ | ♂♂ | ♂♀ | **Unknown** | |
| Adult *Adult* | 26 | 14 | 16 | 8 | 64 |
| 2nd calendar year *2n any calendari* | 3 | 2 | | | 5 |
| Fledgling *Volander* | 3 | 3 | | 24 | 30 |
| Unknown *Desconegut* | | | | 6 | 6 |
| Total *Total* | 32 | 19 | 16 | 38 | 105 |

and feathers or field guides (Jenni & Winkle 1994, Svensson *et al.* 2010, Demongin 2016). Prey remains and pellet data from each locality were combined (Oro & Tella 1995) to calculate the minimum number of individuals and their relative importance in terms of biomass, using the weight data given by Snow & Perrins (1998). For Barolo's Shearwater *Puffinus baroli*, weights were obtained from Bécares *et al.* (2015), while for the Plain Swift *Apus unicolor* and the Atlantic Canary *Serinus canaria* we used unpublished data obtained during ringing on Tenerife ($n = 4$ and $n = 140$, respectively; D. P. Padilla pers. comm.). We excluded three unidentified prey individuals (an unidentified bird, a dove *Streptopelia* sp. and a passerine) from the biomass analysis. We also documented all prey captured or consumed by falcons recorded in the field.

## Results

### *Abundance and distribution*

During the 2015–2016 breeding seasons, we recorded 83 observations of falcons (105 individuals) of different ages (Table 2). There were at least 28 breeding territories (27 *sure* and one *probable*; Figure 1 and Table 3) on the island giving a minimum density of 3.9 territories/100 km$^2$. The mean (±SD) nearest distance between neighbouring territories was 3,617 ± 1,525 m (range 1,770–7,743 m, $n = 28$; Table 1). The territories are mainly located on and around sea cliffs and, to a lesser extent, in rugged inland areas such as La Caldera de Taburiente National Park, where at least three nesting territories were identified (Figure 1).

### *Habitat features*

All territories were located on cliffs, the majority (85%) in coastal areas, at a mean height of around 100 m (Table 1). Falcons selected tall cliffs situated in areas close to the coast, where there are relatively greater concentrations of human infrastructure, less forest cover and more shrub cover, and a greater proportion of sea surrounding the nest site (Table 1). The multimodel inference suggests that the probability of a cliff being occupied by falcons increased with its height, closeness to sea and percentage of land covered by human infrastructures (Tables 4 and 5).

Nests ($n = 9$) were located in natural crevices or on ledges at a mean height of 63.0 ± 24.5 m (range 35–110 m). Cliffs holding nests faced southwest ($n = 3$), north ($n = 2$), northeast ($n = 2$) or east ($n = 2$). Two out of five monitored pairs changed nest sites, one staying on the same cliff, the other moving to a nearby one.

**Table 3.** Evidence of breeding in Barbary falcon territories on La Palma detected in 2015 and 2016.
*Evidències de reproducció als territoris de falcó berber detectats a La Palma durant 2015 i 2016.*

| **Category** ***Categoria*** | **Evidence** ***Evidència*** | ***n*** | **%** |
|---|---|---|---|
| SURE *SEGUR* | Nest / *Niu* | 9 | 32.1 |
| | Fledglings / *Volanders* | 7 | 25.0 |
| | Adults associated near a cliff with fresh droppings / *Adults en penya-segat amb excrements frescos* | 11 | 39.3 |
| PROBABLE *PROBABLE* | Adults flying close to a suitable cliff / *Adults volant prop de penya-segats adequats* | 1 | 3.6 |

**Table 4.** Candidate models for estimating the probability of Barbary falcon cliff occupation on La Palma in the 2015 and 2016 breeding seasons. See Table 1 for more details of the explanatory variables.
*Models candidats a l'estimació de la probabilitat d'ocupació de penya-segats pels falcons berbers dels penya-segats a La Palma durant l'època de reproducció de 2015 i 2016. Per a més detalls sobre les variables predictores, vegeu Taula 1.*

| **Model** | **logLik** | **AICc** | **ΔAICc** | **Weight** ***Pes*** |
|---|---|---|---|---|
| Cliff height + Sea + Built-up area | -16.72 | 42.20 | 0.00 | 0.65 |
| Cliff height + Nearest neighbour distances + Sea + Built-up area | -16.14 | 43.43 | 1.23 | 0.35 |

### *Breeding rates*

Mean (±SD) fledging rate was 1.9 ± 0.8 chicks (range 1–3, $n$ = 12). We were able to estimate chick age for ten broods. All laying dates were in March: four in the first ten-day period, four in the second and two in the third.

### *Diet composition*

Combining direct observations and an analysis of prey remains, we recorded 75 prey items belonging to a minimum of seven species (Table 6). Pigeons *Columba livia* were the most consumed species, both in number and biomass (Table 6). Based on retrieved rings, at least four pigeon carcasses found in two territories were racing pigeons, although, interestingly, none of them had been ringed on La Palma (two on Tenerife, one on La Gomera and one on Lanzarote) according to data provided by the Federación Canaria de Colombofilia (2017).

## Discussion

### *Status and distribution*

On La Palma, our study – the first conducted using an appropriate survey methodology – detected at least 27 breeding territories, the largest figure ever estimated for this island (Delgado *et al.* 1999, Martín & Lorenzo 2001, Rodríguez & Siverio 2007, Carrascal *et al.* 2008, Siverio *et al.* 2009). However, the true population is probably somewhat larger, maybe reaching as many as 30–35 pairs. Although the rugged terrain of this island hinders any detailed prospection of all potential nesting cliffs, our results do confirm the recovery of the Barbary Falcon on the Canary Islands. Although all causes remain unknown, we believe that legal protection and the increase in prey availability (e.g. feral and domestic pigeons) have both played some role in this process (Rodríguez *et al.* 2009, Siverio *et al.* 2009; authors' unpubl. data).

**Table 5.** Multimodel inference results for the probability of Barbary falcon cliff occupation on La Palma in the 2015 and 2016 breeding seasons. Weights, averaged coefficient estimates and confidence intervals (95% CI) of the explanatory variables are shown. Variables are sorted by importance according to their weight and averaged coefficients (* confidence intervals not including 0).
*Els resultats de la inferència multimodel sobre la probabilitat d'ocupació pels falcons berbers dels penya-segats a La Palma durant l'època de reproducció de 2015 i 2016. Es dona importància (pes de l'evidència), estimacions del coeficient mitjà i intervals de confiança (IC del 95%) de les variables predictores. Les variables es classifiquen per importància segons el seu pes de l'evidència i els coeficients mitjans (* intervals de confiança que no inclouen el 0).*

| **Variables** ***Variables*** | **Weight** ***Pes*** | **Estimate** ***Estima*** | **SE** ***SE*** | **Lower CI** ***IC inferior*** | **Upper CI** ***IC superior*** |
|---|---|---|---|---|---|
| Intercept *Intercepció* | | -1.8740 | 1.0550 | -3.9415 | 0.1933 |
| Cliff height *Alçada penya-segat** | 1.00 | 2.2770 | 0.6697 | 0.9647 | 3.5899 |
| Sea *Mar** | 1.00 | 1.9790 | 0.6718 | 0.6623 | 3.2958 |
| % Built-up area *% Àrea urbanitzada** | 1.00 | 0.4995 | 0.2335 | 0.0419 | 0.9571 |
| Nearest neighbour distance *Distància al veí més proper* | 0.35 | 0.0001 | 0.0002 | -0.0003 | 0.0008 |

**Table 6.** Composition and biomass of prey items in the diet of the Barbary Falcon according to observations (9 nests) and prey-remains analysis (3 nests) on La Palma in 2015 and 2016. Unidentified prey items were excluded from the biomass analysis.
*Composició de presses i la seva biomassa de la dieta del falcó berber en base a observacions (9 nius) o les nàlisis de restes (3 nius) a La Palma durant 2015 i 2016. Les preses no identificades van ser excloses de l'anàlisi de la biomassa.*

| **Prey** / ***Presa*** | **Observed** ***Observat*** | **Prey remains** ***Restes*** | **Total** | **%** | **Biomass (%)** ***Biomassa (%)*** |
|---|---|---|---|---|---|
| *Columba livia* | 14 | 48 | 62 | 82.7 | 93.9 |
| *Apus unicolor* | 3 | 1 | 4 | 5.3 | 0.6 |
| *Streptopelia decaocto* | | 2 | 2 | 2.7 | 2.7 |
| *Serinus canaria* | | 2 | 2 | 2.7 | 0.2 |
| *Scolopax rusticola* | | 1 | 1 | 1.3 | 1.5 |
| *Puffinus baroli* | | 1 | 1 | 1.3 | 1.1 |
| *Streptopelia* sp. | | 1 | 1 | 1.3 | |
| Unidentified bird *Ocell no identificat* | | 1 | 1 | 1.3 | |
| Unidentified passerine *Passeriforme no identificat* | | 1 | 1 | 1.3 | |
| Total *Total* | 17 | 58 | 75 | | |

The mean distance estimated between neighbouring territories on La Palma (3.6 km) is low compared to other peregrine populations worldwide (e.g. White *et al.* 2002, Zuberogoitia *et al.* 2002, Rizzolli *et al.* 2005, Brunelly & Sarrocco 2018). In fact, the mean distance estimated for the Tenerife and El Hierro Barbary falcon populations several years ago, when they were still becoming established, exceeded 5 km (Rodríguez & Siverio 2006, Rodríguez *et al.* 2007). On Tenerife, there are some areas with high quality habitat (e.g. the Teno massif) where mean distances between neighbours are less than 2 km (Rodríguez *et al.* 2007, Siverio *et al.* 2011, Rodríguez *et al.* 2018b) and so we believe that the population of this falcon on La Palma could increase.

Breeding territories are distributed across the island but seem to be scarcest in the southern coastal area (Figure 1). In fact, 22 out of 28 territories were located in the northern half of the island, where there are coastal sectors with neighbouring nests at distances of less than 2 km. The availability of high cliffs is one of the most important factors affecting the distribution and density of peregrine and Barbary falcons worldwide (Ratcliffe 1993, Jenkins 1994, Gainzarain *et al.* 2000, Rodríguez & Siverio 2006, Rodríguez *et al.* 2007, 2018b). Thus, there is room for this population to grow, as there are many suitable coastal sectors where no falcons have yet been detected.

### *Habitat features and breeding biology*

Many studies have concluded that peregrine and Barbary falcons actively select the tallest cliffs (e.g. Mearns & Newton 1988, Ratcliffe 1993, Sergio *et al.* 2004, Wightman & Fuller 2005, Brambilla *et al.* 2006, Rodríguez *et al.* 2007). The relief on La Palma is very steep, dominated by deep ravines and large sea cliffs, and so there are a large number of suitable nest sites for these falcons. It has been suggested that the choice of highest cliffs is related to the better vigilance and defence possibilities they offer against conspecific or interspecific competitors (e.g. Common Buzzard *Buteo buteo* or Common Raven *Corvus corax*), and to better hunting opportunities, given that pairs of falcons occupying the tallest cliffs have the highest breeding and hunting success (Ratcliffe 1993, Jenkins 2000, Wightman & Fuller 2006).

When hunting, falcons usually avoid heavily forested areas and positively select for the presence of water bodies. This is probably linked to the fact that prey items are less vulnerable in forests – where they can escape by hiding in

vegetation – than those who have to fly over water to escape (Sergio *et al.* 2004, Wightman & Fuller 2005, Brambilla *et al.* 2006, Rodríguez *et al.* 2007). The distribution of breeding territories on La Palma seems to fit this general pattern, as the majority of territories are located on sea cliffs. La Caldera de Taburiente National Park, a very rugged but also forested area, apparently holds only three pairs. However, due to the inherent difficulties in surveying this inner part of the island, it is possible that we failed to detect some territories in this sector.

Peregrine falcons tolerate a remarkable level of anthropic activity in the vicinity of their nesting territories as the tall cliffs and buildings they occupy provide them with sufficient security (e.g. Beran *et al.* 2018). Indeed, they successfully breed on high buildings in densely populated cities all over the world (Drewit 2014). In the Canary Islands, no Barbary falcons are known to have bred in a city, although some pairs do occupy cliffs adjacent to urban centres (authors' unpubl. data), which is probably due to the high availability of suitable natural high cliffs for nesting close to built-up areas. On La Palma, most of the human population is in coastal areas and therefore the percentage of land covered by human infrastructures is higher in the areas surroundings the cliffs occupied by falcons than on randomly selected cliffs.

As egg-laying only occurs in March (according to our estimates) on La Palma, mainly after the tenth day of the month, it is very likely that local meteorological conditions play a role in shaping breeding phenology (i.e. egg-laying delayed some weeks compared to the rest of the archipelago), as this is one of the rainiest islands in the Canaries (Martín-Ruiz 2001). Certain studies have demonstrated the negative effects of heavy rains on the breeding performance of peregrine falcons (Anctil *et al.* 2014, Zuberogoitia *et al.* 2018) and so falcons may be favoured by delaying their breeding periods on La Palma. By contrast, the average fledging rate obtained on La Palma falls within the range of previously estimated values for other islands (see Delgado *et al.* 1999, Rodríguez *et al.* 2007, Siverio *et al.* 2011).

### *Diet*

Although the diet of the Barbary Falcon has not yet been rigorously studied in the Canary Islands, available information demonstrates that this raptor preys on at least 36 bird species, as well as a few mammals and insects (Rodríguez *et al.* 2009; authors' unpubl. data). Pooling our information with previously published reports, the trophic spectrum on La Palma during the breeding season is composed of a minimum of eight prey species (red-billed chough *Pyrrhocorax pyrrhocorax* has been mentioned as a prey by Rodríguez *et al.* 2009). Despite the small sample size, our results show to some extent the low availability of potentially suitable-sized prey for breeding Barbary falcons on this island (authors' unpubl. data).

As in the rest of the archipelago (Rodríguez *et al.* 2009; authors' unpubl. data), the main prey of the Barbary Falcon on La Palma was the rock pigeon, which includes wild, feral and domestic individuals. This taxon also forms the bulk of the diet of many other European populations of Peregrine Falcon (Ratcliffe 1993, Zuberogoitia *et al.* 2002, Shawyer *et al.* 2003, Parrott *et al.* 2008, López-López *et al.* 2009), as it does in the rest of the Canary Islands (Rodríguez *et al.* 2009; authors' unpubl. data).

Pigeon racing is a popular activity in the Canary Islands (Antequera 2003, Federación Canaria de Colombofilia 2017). However, the proportion of domestic pigeons (used in pigeon racing) in the falcons' diet on the Canary Islands has never been determined precisely. In the UK, domestic pigeons are the basis of peregrines' diets and domestic pigeons are fundamental for peregrine conservation (Dixon *et al.* 2003). In this sense, estimates made in the UK using different methods indicate that 3.5% of homing pigeons in the country are consumed by these raptors every year (Shawyer *et al.* 2003). However, this figure may rise to 7–23% depending on the locality (Parrott *et al.* 2008).

### *Conservation remarks*

Our study shows that the Barbary falcon population is currently well established on La Palma. However, as on other islands in this archipelago, it still faces several human-related threats, namely, collisions with man-made structures or illegal shooting (Siverio & Concepción 2004, Rodríguez *et al.* 2009, 2010; Montesdeoca *et al.* 2016). Other threats such as poisoning (Luzardo *et al.* 2014, Ruiz-Suárez *et al.* 2014, 2015), nest-

robbing and genetic introgression from escaped falconer's birds (Rodríguez *et al.* 2019) have been detected on other islands and therefore they could be operating on La Palma too.

Quantitative information on the negative factors affecting the Barbary Falcon on La Palma is scarce. Of the 17 falcons admitted to the islands' rehabilitation centre in 2002–2017, the most frequent cause (58.8%) was collision with man-made structures (Medina 2014, F. M. Medina pers. comm.). Although only one case of a wild falcon kept in captivity (2015) is known (F. M. Medina pers. comm.), we cannot exclude nest robbing by falconers as a threat, as vigilance is scarce and there is no official list of falconry birds as there is on the other islands such as Tenerife (Rodríguez *et al.* 2019). Nevertheless, it is worth highlighting that, due to the decline of these falcons over most of past century, and their subsequent and rapid recovery, there is a false belief among local people that they are not native and that, rather, their presence is due to the releases of foreign falcons by local government bodies. This has caused a conflict between pigeon fanciers, hunters and falcons (Rodríguez *et al.* 2009) and so direct persecution could currently be an important threat for La Palma's Barbary falcons. To implement effective mitigation measures (e.g. changing the racing season, routes and timetables of training flights), it will be necessary to first precisely determine the location of the affected pigeon lofts and their main flight routes and release zones (Kenward 1999, Dixon *et al.* 2003, Galbraith *et al.* 2003, Shawyer *et al.* 2003). Our study reveals that at least a part of the racing pigeons hunted by falcons on La Palma came from other islands and were probably associated with competitive releases. Finally, as well as more precise technical studies, the setting up of environmental education campaigns will be a crucial step towards encouraging the conservation of this raptor on La Palma.

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## Resum

### Estatus, hàbitat i dieta dels falcons berbers reproductors en una illa oceànica abrupta al límit occidental de la seva distribució

En el present treball es descriuen els resultats del primer estudi sobre la mida de la població, la distribució, l'hàbitat i la dieta del falcó berber *Falco peregrinus pelegrinoides* a l'illa de La Palma (Illes Canàries). Durant les temporades de cria de 2015-2016 es van constatar un mínim de 28 territoris (3,9 territoris / 100 km$^2$), amb una mitjana de 3,6 km (rang 1,7-7,7 km) de distància entre els territoris veïns més propers. Tot i que els territoris estaven distribuïts per tota la superfície insular, va ser en el sector nord on es va concentrar la major part d'ells, fet que probablement es relaciona amb una major disponibilitat de grans penya-segats. Els falcons seleccionaren les parets més altes, situades en zones amb una relativa alta concentració d'edificacions i àmpliament cobertes per matoll. Tots els nius ($n$ = 9) van correspondre a cavitats i lleixes naturals a una alçada respecte al terreny transitable de 35 a 110 m. En comparació amb les poblacions de la resta de l'arxipèlag, les postes es van produir una mica més tard, al març, però la taxa de vol va ser similar. La dieta es va compondre per almenys set espècies d'aus, essent el colom roquer *Columba livia* la més consumida (91,7% de la biomassa total). Malgrat que els falcons depreden freqüentment sobre coloms emprats en columbofília, un esport molt arrelat a l'illa, la seva proporció en la dieta és encara totalment desconeguda. És probable que la major amenaça per als falcons de La Palma sigui la persecució directa, atès que hi ha la creença popular que aquestes rapinyaires no són natives i que, en realitat, van ser alliberades per les autoritats locals i provocaren tot plegat un conflicte

d'interessos. A més d'una campanya d'educació ambiental, especialment dirigida als cercles columbòfils i de caçadors, la solució d'aquest problema implicaria el desenvolupament d'estudis específics per conèixer l'abast real de la depredació exercida sobre els coloms domèstics per part dels falcons.


## Resumen

### Estatus, hábitat y dieta de los halcones tagarotes reproductores en una isla oceánica abrupta en el límite occidental de su distribución

En el presente trabajo se describen los resultados del primer estudio sobre el tamaño de la población, la distribución, el hábitat y la dieta del halcón tagarote *Falco peregrinus pelegrinoides* en la isla de La Palma (islas Canarias). Durante las temporadas de cría de 2015-2016 fue constatado un mínimo de 28 territorios (3,9 territorios/100 km$^2$), con una media de 3,6 km (rango 1,7-7,7 km) de distancia entre territorios vecinos más próximos. A pesar de que los territorios estaban distribuidos por toda la superficie insular, fue en el sector norte donde se concentró la mayor parte, lo que probablemente se relaciona con una más alta disponibilidad de grandes acantilados. Los halcones seleccionan las paredes más altas, situadas en zonas con una relativa alta concentración de edificaciones y ampliamente cubiertas por matorral. Todos los nidos ($n = 9$) correspondieron a cavidades y repisas naturales cuya altura con respecto al terreno transitable es de 35 a 110 m. En comparación con las poblaciones del resto del archipiélago, las puestas se produjeron un poco más tarde, en marzo, pero la tasa de vuelo fue similar. La dieta estuvo compuesta por al menos siete especies de aves, siendo la paloma bravía *Columba livia* la más consumida (91,7% de la biomasa total). Aunque los halcones depredan frecuentemente sobre palomas usadas en el marco de la colombofilia, un deporte muy arraigado en la isla, su proporción en la dieta es aún totalmente desconocida. Es probable que la mayor amenaza para los halcones de La Palma sea la persecución directa, dado que existe la creencia popular que considera que estas rapaces no son nativas y que, en realidad, fueron liberadas por las autoridades locales, provocando todo ello un conflicto de intereses. Además de una campaña de educación ambiental, especialmente dirigida a círculos colombófilos y de cazadores, la solución a este problema implicaría el desarrollo de estudios específicos para conocer el alcance real de la depredación ejercida sobre las palomas domésticas por parte de los halcones.


## References


**Anctil, A., Franke, A. & Bêty, J.** 2014. Heavy rainfall increases nestling mortality of an arctic top predator: experimental evidence and long-term trend in peregrine falcons. *Oecologia* 174: 1033–1043.

**Antequera, F.C.** 2003. *La Colombofilia en La Palma*. La Laguna: Centro de la Cultura Popular Canaria.

**Bannerman, D.A.** 1963. *Birds of the Atlantic Islands. Vol. 1. A History of the Birds of the Canary Islands and of the Salvages*. Edinburgh & London: Oliver & Boyd.

**Bécares, J., Gil-Velasco, M., Morales, E. & Aguilar, N.** 2015. *Conservación de Cetáceos y Aves Marinas en Canarias*. La Laguna: Grupo de Investigación de Cetáceos. Informe inédito.

**Beran, V., Vrána, J. & Horal, D.** 2018. Population trends and diversification of breeding habitats of Peregrine Falcon (*Falco peregrinus*) in the Czech Republic since 1990. *Ornis Hung.* 26: 121–129.

**Brambilla, M., Rubolini, D. & Guidali, F.** 2006. Factors affecting breeding habitat selection in a cliff-nesting peregrine *Falco peregrinus* population. *J. Ornithol*. 147: 428–435.

**Brunelli, M. & Sarrocco, S.** 2018. Breeding population of Peregrine Falcon (*Falco peregrinus*) in Lazio, Central Italy: 1983–2017. *Ornis Hung.* 26: 114–120.

**Burnham K.P. & Anderson, D.R.** 2002. *Model Selection and MultimodelInference: A Practical Information-Theoretic Approach*. New York: Springer-Verlag.

**Carrascal, L.M., Palomino, D. & Polo, V.** 2008. Patrones de distribución, abundancia y riqueza de especies de la avifauna terrestre de la isla de La Palma (islas Canarias). *Graellsia* 64: 209–232.

**Cullen, J., Guiton, P., Horridge, G. & Peirson, J.** 1952. Birds on Palma and Gomera (Canary Islands). *Ibis* 94: 68–84.

**Del Arco, M., Wildpret, W., Pérez, P.L., Rodríguez, O., Acebes, J.R., García, A., Martín, V.E., Reyes, J.A., Salas, M., Díaz, M.A., Bermejo, J.A., González, R., Cabrera, M.V. & García, S.** 2006*. Mapa de Vegetación de Canarias*. S/C de Tenerife: GRAFCAN.

**Delgado, G., Concepción, D., Siverio, M., Hernández, E., Quilis, V. & Trujillo, D.** 1999. Datos sobre la distribución y biología del Halcón de Berbería (*Falco peregrinus pelegrinoides*) en las Islas Canarias (Aves: Falconidae). *Vieraea* 27: 287–298.

**Demongin, L.** 2016*. Identification Guide to Birds in the Hand*. Paris: Privately Published.

**Dixon, A., Richards, C., Lawrence, A. & Thomas, M.** 2003. Peregrine (*Falco peregrinus*) predation on racing pigeons (*Columba livia*) in Wales. In Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. (eds.): *Birds of Prey in a Changing Environment*. Pp. 255–561. Edinburgh: Scotish Natural Heritage, The Stationery Office.

**Donázar, J.A., Gangoso, L., Forero, M. & Juste, J.** 2005. Presence, richness and extinction of birds of prey in the Mediterranean and Macaronesian islands. *J. Biogeogr*. 32: 1701–1713.

**Donázar, J.A., Cortés-Vizanda, A., Fargallo, J., Margalida, A., Moleón, M., Morales-Reyes, Z., Moreno-Opo, R., Perez-Garcia, J.M., Sanchez-**

**Zapata, J.A., Zuberogoitia, I. & Serrano, D.** 2016. Roles of raptors in a changing world: from flagships to providers of key ecosystem services. *Ardeola* 63: 181–234.

**Drewit, E.** 2014. *Urban Peregrines*. Exeter: Pelagic Publishing.

**Federación Canaria de Colombofilia** 2017. *Federación Canaria de Colombofilia* [WWW Document]. URL http://www.fedcancol.es/index.html (accessed 7.20.12).

**Ferguson-Lees, J. & Christie, D.A.** 2001. *Raptors of the World*. London: Christopher Helm.

**Fuchs, J., Johnson, J.A. & Mindell, D.P.** 2015. Rapid diversification of falcons (Aves: Falconidae) due to expansion of open habitats in the Late Miocene. *Mol. Phyl. Evol.* 82: 166–182.

**Gainzarain, J.A., Arambarri, R. & Rodríguez, A.F.** 2000. Breeding density, habitat selection and reproductive rates of the Peregrine Falcon *Falco peregrinus* in Álava (northern Spain). *Bird Study* 47: 225–231.

**Galbraith, C.A., Stroud, D.A. & Thompson, D.B.A.** 2003. Towards resolving raptor-human conflicts. In Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. (eds.): *Birds of Prey in a Changing Environment*. Pp. 527–535. Edinburgh: Scotish Natural Heritage, The Stationery Office.

**Hardey, J., Crick, H., Wernham, C., Riley, H., Etheridge, B. & Thompson, D.** 2007. *Raptors. A field guide to survey and monitoring*. Edinburgh: Scottish Natural Heritage.

**Hernández, E., Delgado, G., Carrillo, J., Nogales, M. & Quilis, V.** 1991. A preliminary census and notes on the distribution of the Barbary Falcon (*Falco pelegrinoides* Temminck, 1829) in the Canary Islands. *Bonn. zool. Beitr.* 42: 27–34.

**ISTAC** 2018. *Anuario estadístico de Canarias* [WWW Document]. URL www.gobiernodecanarias.org/istac/ (accessed 1.30.18).

**Jenkins, A.R.** 1994. The influence of habitat on the distribution and abundance of peregrine and lanner falcons in South Africa. *Ostrich* 65: 281–290.

**Jenkins, A.R.** 2000. Hunting mode and success of African Peregrines *Falco peregrinus minor*: does nesting habitat quality affect foraging efficiency? *Ibis* 142: 235–246.

**Jenni, L. & Winkler, R.** 1994. *Moult and Ageing of European Passerines*. London: Academic Press.

**Kenward, R.E.** 1999. Raptor predation problems and solutions. *J. Raptor Res*. 33: 73–75.

**López-López, P., Verdejo, J. & Barba, E.** 2009. The role of pigeon consumption in the population dynamics and breeding performance of a peregrine falcon (*Falco peregrinus*) population: Conservation implications. *Eur. J. Wildlife Res*. 55: 125–132.

**Luzardo, O.P., Ruiz-Suárez, N., Henríquez-Hernández, L.A., Valerón, P.F., Camacho, M., Zumbado, M. & Boada, L.D.** 2014. Assesment of the exposure to organochlorine pesticides, PCBs and PAHs in six species of predatory birds of the Canary Islands, Spain. *Sci. Total Environ*. 472: 146–153.

**Martín-Ruiz, J.-F.** 2001. *Geografía de Canarias. Sociedad y Medio Natural*. Las Palmas de Gran Canaria: Ediciones Cabildo de Gran Canaria.

**Martín, A. & Lorenzo, J.A.** 2001. *Aves del archipiélago canario*. La Laguna: Lemus Editor.

**Mearns, R. & Newton, I.** 1988. Factors affecting breeding success of peregrines in South Scotland. *J. Anim. Ecol.* 57: 903–916.

**Medina, F.M.** 2014. Rehabilitación de fauna silvestre en la isla de La Palma durante el periodo 2002-2009. *Revista de estudios generales de la Isla de La Palma* 6: 85–98.

**Moleón, M., Sánchez-Zapata, J.A., Gil-Sánchez, J.M., Barea-Azcón, J.M., Ballesteros-Duperón, E. & Virgós, E.** 2011. Laying the foundations for a human-predator conflict solution: Assessing the impact of Bonelli's eagle on rabbits and partridges. *PLoS ONE* 6: e22851.

**Monneret, R.-J.** 2000. *Le Faucon Pèlerin*. Paris: Delachaux et Niestlé.

**Montesdeoca, N., Calabuig, P., Corbera, J.A. & Orós, J.** 2016. Causes of admission for raptors to the Tafira Wildlife Rehabilitation Center, Gran Canaria Island, Spain: 2003–2013. *J. Wildlife Dis*. 52: 647–652.

**Morphy, M.J.** 1965. Some birds on northeast La Palma, Canary Islands, August-September 1963. *Ibis* 107: 97–100.

**Oro, D. & Tella, J.L.** 1995. A comparison of two methods for studying the diet of the Peregrine Falcon. *J. Raptor Res*. 29: 207–210.

**Palma, L., Beja, P., Pais, M. & da Fonseca, L.C.** 2006. Why do raptors take domestic prey? The case of Bonelli's eagles and pigeons. *J. Appl. Ecol*. 43: 1075–1086.

**Parrott, D., Henderson, I.G., Deppe, C. & Whitfield, P.** 2008. Scottish racing pigeons killed by peregrine Falcons *Falco peregrinus*: estimation of numbers from ring recoveries and Peregrine daily food intake. *Bird Study* 55: 32–42.

**Polatzek, J.** 1909. Die Völgel der Canaren. *Ornithologisches Jahrbuch* 20: 202-210.

**Ratcliffe, D.A.** 1993. *The Peregrine Falcon*. Calton: T. & A.D. Poyser.

**Rizzolli, F., Sergio, F., Marchesi, L. & Pedrini, P.** 2005. Density, productivity, diet and population status of the Peregrine Falcon *Falco peregrinus* in the Italian Alps. *Bird Study* 52: 188–192.

**Rodríguez, B. & Siverio, M.** 2006. Density and breeding habitat characteristics of an insular population of barbary falcon *Falco peregrinus pelegrinoides* (El Hierro, Canary Islands). *Ardeola* 53: 325–331.

**Rodríguez, B. & Siverio, M.** 2007. Halcón Tagarote *Falco pelegrinoides*. In Lorenzo, J.A. (ed.): *Atlas de las aves nidificantes en el archipiélago canario (1997- 2003)*. Pp. 183–187. Madrid: Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología.

**Rodríguez, B., Siverio, M., Rodríguez, A. & Siverio, F.** 2007. Density, habitat selection and breeding success of an insular population of Barbary Falcon *Falco peregrinus pelegrinoides*. *Ardea* 95: 213–223.

**Rodríguez, B., Siverio, F., Siverio, M., Rodríguez, A. & Hernández, J.J.** 2009. Pasado y presente del halcón de Berbería en las islas Canarias. *El Indiferente* 20: 12–21.

**Rodríguez, B., Rodríguez, A., Siverio, F. & Siverio, M.** 2010. Causes of raptor admissions to a Wildlife Rehabilitation Center in Tenerife (Canary Islands). *J. Raptor Res*. 44: 30–39.

**Rodríguez, B., Siverio, F., Siverio, M. & Rodríguez, A.** 2011. Variable plumage coloration of breeding

Barbary falcons *Falco* (*peregrinus*) *pelegrinoides* in the Canary Islands: do other Peregrine falcon subspecies also occur in the archipelago? *Bull. B.O.C.* 131: 140–153.

**Rodríguez, B., Bécares, J., Lorenzo, J.A. & Rodríguez, A.** 2018a. Inter-island movements of two Barbary Falcon (*Falco peregrinus pelegrinoides*) juveniles in the Canary Islands. *J. Raptor Res*. 52: 503–510.

**Rodríguez, B., Rodríguez, A., Siverio, F. & Siverio, M.** 2018b. Factors affecting the spatial distribution and breeding habitat of an insular cliff-nesting raptor community. *Curr. Zool.* 64: 173–181.

**Rodríguez, B., Siverio, F., Siverio, M. & Rodríguez, A.** 2019. Falconry threatens Barbary Falcons in the Canary Islands through genetic admixture and illegal chick harvest. *J. Raptor Res*. 53: 189–197.

**Ruiz-Suárez, N., Henríquez-Hernández, L.A., Valerón, P.F., Boada, L.D., Zumbado, M., Camacho, M., Almeida-González, M. & Luzardo, O.P.** 2014. Assessment of anticoagulant rodenticide exposure in six raptor species from the Canary Islands (Spain). *Sci. Total Environ*. 485-486: 371–376.

**Ruiz-Suárez, N., Boada, L.D., Henríquez-Hernández, L.A., González-Moreo, F., Suárez-Pérez, A., Camacho, M., Zumbado, M., Almeida-González, M., del Mar Travieso-Aja, M. & Luzardo, O.P.** 2015. Continued implication of the banned pesticides carbofuran and aldicarb in the poisoning of domestic and wild animals of the Canary Islands (Spain). *Sci. Total Environ*. 505: 1093–1099.

**Sergio, F., Rizzolli, F., Marchesi, L. & Pedrini, P.** 2004. The importance of interspecific interactions for breeding-site selection: peregrine falcons seek proximity to raven nests. *Ecography* 27: 818–826.

**Shafaeipour, A., Siverio, M. & Siverio, F.** 2016. Data on habitat and breeding biology of the Barbary Falcon, *Falco peregrinus pelegrinoides* Temminck, 1829, from South-western Iran. *Acta Zool. Bulg*. 68: 85–88.

**Shawyer, C.R., Clarke, R. & Dixon, N.** 2003. Causes of racing pigeon (*Columba livia*) losses, including predation by raptors, in the United Kingdom. In Thompson, D.B.A., Redpath, S.M., Fielding, A.H., Marquiss, M. & Galbraith, C.A. (eds.): *Birds of Prey in a Changing Environment*. Pp. 263–268. Edinburg: Scotish Natural Heritage, The Stationery Office.

**Shirihai, H., Forsman, D. & Christie, D.A.** 1998. Field identification of large falcons in the West Palearctic. *Brit. Birds* 91: 12–35.

**Siverio, M. & Concepción, D.** 2004. Halcón Tagarote *Falco pelegrinoides pelegrinoides*. In Madroño, A., González, C. & Atienza, J.C. (eds.): *Libro Rojo de Las Aves de España*. Pp. 171–173. Ministerio de Medio Ambiente-SEO/BirdLife, Madrid.

**Siverio, M., Rodríguez, B. & Siverio, F.** 2009. El halcón tagarote en Canarias. In del Moral, J.C. (ed.): *El halcón peregrino en España. Población reproductora en 2008 y método de censo*. Pp. 52–58. SEO/BirdLife, Madrid.

**Siverio, M., Siverio, F., Rodríguez, B. & Rodríguez, A.** 2011. Long-term monitoring of an insular population of Barbary Falcon *Falco peregrinus pelegrinoides*. *Ostrich* 82: 225–230.

**Snow, D. & Perrins, C.M.** 1998. *The Birds of the Western Palearctic. Vols. I and II*, *Concise Ed*. Oxford: Oxford University Press.

**Sodhi, N. & Ehrlich, P.** 2010. *Conservation Biology for all*. New York: Oxford University Press.

**Sutherland, W.J., Pullin, A.S., Dolman, P.M. & Knight, T.M.** 2004. The need for evidence-based conservation. *Trends Ecol. Evol.* 19: 305–308.

**Svensson, L., Mullarney, K. & Zetterström, D.** 2010. *Birds of Europe*, 2nd edition. New Jersey: Princenton University Press.

**von Thanner, R.** 1908. Sammelansflug nach La Palma, Hierro und Fuerteventura. *Ornithologisches Jahrbuch* 19: 198–215.

**Valkama, J., Korpimäki, E., Arroyo, B., Beja, P., Bretagnolle, V., Bro, E., Kenward, R., Mañosa, S., Redpath, S.M., Thirgood, S. & Viñuela, J.** 2005. Birds of prey as limiting factors of gamebird populations in Europe: a review. *Biol. Rev*. 80: 171–203.

**White, C.M., Cade, T.J. & Enderson, J.H.** 2013. *Peregrine Falcons of the World*. Barcelona: Lynx Edicions.

**White, C.M., Clum, N.J., Cade, T.J. & Hunt, W.G.** 2002. Peregrine Falcon (*Falco peregrinus*). In Poole, A. & Gill, F. (eds.): *The Birds of North America*. Philadelphia, PA.: The Birds of North America, Inc.

**Wightman, C.S. & Fuller, M.R.** 2005. Spacing and physical habitat selection patterns of Peregrine Falcons in Central West Greenland. *Wilson Bull.* 117: 226–236.

**Wightman, C.S. & Fuller, M.R.** 2006. Influence of habitat heterogeneity on distribution, occupancy patterns, and productivity of breeding peregrine falcons in Central West Greenland. *Condor* 108: 270–281.

**Wink, M.** 2018. Phylogeny of Falconidae and phylogeography of Peregrine Falcons. *Ornis Hung.* 26: 27–37.

**Wood, J., Alcover, J.A., Blackburn, T., Bover, P., Duncan, R.P., Hume, J.P., Louys, J., Meijer, H.J.M., Rando, J.C. & Wilmshurst, J.** 2017. Island extinctions: processes, patterns, and potential for ecosystem restoration. *Environ. Conserv.* 44: 348–358.

**Zuberogoitia, I., Ruiz, J.F. & Torres, J.J.** 2002. *El Halcón Peregrino*. Bizkaia: Diputación Foral de Bizkaia.

**Zuberogoitia, I., Morant, J., Castillo, I., Martínez, J.E., Burgos, G., Zuberogoitia, J., Azkona, A., Guijarro, J.R. & González-Oreja, J.A.** 2018. Population trends of Peregrine Falcon in Northern Spain. Results of a long-term monitoring project. *Ornis Hung.* 26: 51–68.