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SHORT COMMUNICATIONS

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FALCONRY THREATENS BARBARY FALCONS IN THE CANARY ISLANDS THROUGH GENETIC ADMIXTURE AND ILLEGAL HARVEST OF NESTLINGS

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ABSTRACT.—Peregrine Falcons (*Falco peregrinus*) on the Canary Islands are considered to be of the Barbary Falcon subspecies (*F. p. pelegrinoides*). Here we report on lost falconry birds present among the wild population of resident falcons, and provide rough approximations of their abundance for Tenerife, the largest island of the Canaries. We observed lost falconry birds breeding with natural wild falcons, with at least one mixed pair producing fledglings. Only 54.1% of the breeding adults that we studied on the island showed typical Barbary Falcon plumage. Some nest sites were systematically poached, affecting the overall productivity of the population. Our findings suggest that the original Canarian Barbary Falcon population could be suffering from genetic mixing due to the presence of individuals originating from outside the population and from illegal harvest of nestlings. We recommend that local authorities continue to assess the degree of genetic admixture that occurs in this population, modify the current falconry regulations, implement management actions to prevent new escapes, eradicate exotic raptors, and put a stop to illegal nestling harvests.

KEY WORDS: *Peregrine Falcon*; Falco peregrinus; *Barbary Falcon*; Falco peregrinus pelegrinoides; *conservation*; *exotic species*; *birds of prey*; *genetic pollution*; *hybridization*; *introgression.*

LA CETRERÍA AMENAZA A *FALCO PEREGRINUS PELEGRINOIDES* EN CANARIAS DEBIDO A LA INTROGRESIÓN GENÉTICA Y AL EXPOLIO DE NIDOS

RESUMEN.—Se considera que los halcones peregrinos (*Falco peregrinus*) de las islas Canarias corresponden a la subespecie *F. p. pelegrinoides* (halcón de Berbería). En este trabajo proporcionamos información sobre el escape de halcones de cetrería en Tenerife, la isla de mayor superficie del archipiélago canario, así como sobre su abundancia dentro de la población de halcones nativos. Comprobamos que individuos escapados de cautividad se emparejan con halcones nativos y que al menos una de estas parejas mixtas produjo pollos. También advertimos que solo el 54.1% de los adultos reproductores estudiados en la isla mostraban el plumaje típico de halcón de Berbería. Asimismo, confirmamos que algunos lugares de nidificación fueron expoliados de manera sistemática, hecho que afectó a la productividad de la población. Nuestras observaciones sugieren que la población canaria original de halcones de Berbería puede estar sufriendo la mezcla genética asociada al reclutamiento de individuos exóticos y la colecta ilegal y persistente de pollos. Por ello, instamos a las autoridades locales competentes a propiciar estudios que evalúen el grado de mezcla genética que posee la población canaria de halcones. Recomendamos, además, la modificación de

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la actual regulación de la cetrería en las islas, la urgente implementación de acciones para prevenir nuevos escapes, la erradicación de rapaces exóticas del medio natural y llevar a cabo una vigilancia eficaz para detener la colecta ilegal de pollos.

[Traducción de los autores editada]

Falconry activities have been associated with changes to local raptor populations, sometimes with adverse effects (Fleming et al. 2011, Wyatt 2011). Though hybridization or introgression between falcon species or subspecies occurs naturally among members of wild populations (Oliphant 1991, Angelov et al. 2006, McCarthy 2006, Zuberogoitia et al. 2009), it can also occur when lost falconry birds from genetically distinct subspecies or exotic species enter wild populations (Lindberg and Nesje 2002, Eastham and Nicholls 2005, Jacobsen et al. 2008, Cugnasse et al. 2017). Those lost falconry birds that have the ability to survive in the wild can pair with individuals from wild populations, producing offspring that may be hybrids and, in some cases, may be fertile (Everitt and Franklin 2009, Fleming et al. 2011, Cozic 2016, Cugnasse et al. 2017). Other potential adverse effects on wild populations due to falconry occur where there is demand for raptors, especially falcons (*Falco* spp.), illicitly obtained for falconry and captive collections (Fleming et al. 2011, Wyatt 2011, Stretesky et al. 2018). Despite the possibility of buying inexpensive falcons from legal captive-breeding operations, unscrupulous traders sometimes take falcons and others birds illegally from the wild (Wilson-Wilde 2010, Wyatt 2011, Stretesky et al. 2018).

The Peregrine Falcon (*Falco peregrinus*) is a cosmopolitan raptor species with at least 19 subspecies recognized worldwide, although some are of uncertain taxonomic status (White et al. 2013). The Barbary Falcon, which inhabits scattered areas of North Africa from the Canary Islands to the Arabian Peninsula, is considered by some authors a full species with two subspecies (*F. pelegrinoides pelegrinoides* and *F. p. babylonicus*). Others consider it a subspecies of the Peregrine Falcon (*F. peregrinus pelegrinoides*; White et al. 2013), which is the taxonomic status we adopt here. The Barbary Falcon shows a slimmer body shape (Vaurie 1961) and a characteristic plumage color pattern differentiated from other peregrine subspecies, although some overlap occurs (Rodríguez et al. 2011, White et al. 2013). The Barbary Falcon is one of the smallest and palest of peregrine subspecies and adult birds can usually be separated in the field from other subspecies by their head pattern (pale forehead, red nape stripes, narrow malar stripes and large white cheeks), pale blue upperparts, and minimally barred underparts (Clark and Shirihai 1995, White et al. 2013).

With the exception of Eleonora's Falcons (*Falco eleonorae*), all breeding falcons from the Canary Islands have traditionally been considered Barbary Falcons (Rodríguez et al. 2009 and references therein). However, wintering records for Peregrine Falcon individuals showing phenotypic characteristics consistent with other subspecies (i.e., not Barbary Falcons) have been documented in this archipelago (Rodríguez et al. 2009). Concurrent with the rise in the popularity of falconry in the Canaries (Castillo 1992, Gobierno de Canarias 2011), several falcons of unknown origin sighted in recent decades have appeared distinct from typical Barbary Falcons, with darker upperparts and deeply barred underparts (Rodríguez et al. 2011). Although Canarian Barbary Falcons are generally increasing in number and their range is expanding, this taxon is listed as "Endangered" in the Spanish National and Regional catalogues of threatened species, and the subspecies faces several threats related mainly to collisions with human-made structures, shooting, recreational climbing and illegal nestling harvest (Siverio and Concepción 2004, Rodríguez et al. 2009, 2010).

Falconry is regulated in the Canary Islands under general hunting laws (Falconry Law, hereafter FL; Gobierno de Canarias 2012). Briefly, the main features of the FL are: (1) falconers and raptors dedicated to hunting must be registered by insular and regional governments (therefore, falconers who do not use their birds for hunting are in a legal vacuum if they make outdoor flights); (2) all birds used must be individually identified through closed rings or microchips; (3) only raptors that do not naturally breed on the Canary Islands may be used (e.g., Peregrine Falcons are allowed but not Barbary Falcons); (4) the attachment of radio transmitters is mandatory during free flights; and (5) falconers must immediately communicate the loss of a bird to local authorities (Gobierno de Canarias 2012).

We here report the presence of exotic Peregrine Falcons that pair and breed with wild falcons on Tenerife, the major island of the Canarian Archipelago. We also quantify the abundance of falconry birds (lost falcons), the number of Peregrine Falcons and Barbary Falcons in the breeding population of Tenerife, and the rate of illegal nestling harvest. We discuss the conservation implications of escaped falconry birds and the management actions required to mitigate these threats in the Canary Islands.

METHODS

The Canary Islands comprise seven major islands and several islets that form a volcanic archipelago situated approximately 100 km from northwestern Africa. Tenerife is the largest island (2034 km^2, with its highest point 3718 masl) and holds 891,000 inhabitants (Instituto Canario de Estadística [ISTAC] 2018). The Barbary Falcon population on Tenerife has increased from two pairs in 1993 to approximately 60 pairs recently (Siverio et al. 2009, B. Rodríguez unpubl. data). Fieldwork was conducted during the 2016 and 2017 breeding seasons on Tenerife Island.

Table 1. Number of medium and large falcon species (*Falco* spp.) of captive origin (and with potential risk of hybridization or introgression with Barbary Falcons according to McCarthy [2006]). WRC = La Tahonilla Wildlife Rehabilitation Center, Cabildo de Tenerife; Lost falcons were those reported by falconers to the Wildlife Rehabilitation Center; Falcons observed in the field were on Tenerife Island (number of individuals holding a territory indicated in parentheses). Raw data are available at the institutional repository of Consejo Superior de Investigaciones CientÚficas (CSIC) (Rodríguez et al. 2018 dataset: DOI: http://dx.doi.org/10.20350/digitalCSIC/8560).

SPECIES/TAXA	FALCONS ADMITTED TO WRC (1998–2017)	LOST FALCONS (2007–2017)	FALCONS OBSERVED IN THE FIELD (1993–2017)	TOTAL
F. peregrinus (unknown subspecies)	5	13	6 (2)	24
F. peregrinus babylonicus	-	1	-	1
F. peregrinus pelegrinoides	2	-	1 (1)	3
F. peregrinus × *F. rusticolus*	-	2	-	2
F. biarmicus	2	4	-	6
F. biarmicus × *F. peregrinus*	1	-	-	1
F. rusticolus	1	1	-	2
F. rusticolus × *F. mexicanus*?	-	1	-	1
F. cherrug	-	4	3	7
Falco spp.	-	4	2	6
Total	11	30	12	53

However, we also included casual observations of lost falconry birds (free-flying birds with anklets and/or falconer's rings) detected since 1993 within monitoring programs particularly focused on density, breeding rates, diet and behavior of nesting Barbary Falcons (see Rodríguez et al. 2007, 2009, 2011, Siverio et al. 2009, 2011; Table 1). We studied a total of 32 nesting sites, which were arbitrarily selected to be distributed throughout the island both in protected natural areas ($n=23$) and outside them ($n=9$) based on historical records. Sample size differs for each analysis because it was not possible to record all data (see below) for each nest every year.

We used photographs, binoculars (10×) or scopes (20–60×) to identify and note any distinguishing features of 37 breeding adult falcons from 21 nesting sites during 2016 to 2017. We classified each falcon as "Barbary-type" or "Peregrine-type" according to their general appearance (see Rodríguez et al. 2011) and assessed the percentage of birds in the breeding population showing Barbary-type or Peregrine-type coloration (see Fig. 1). To compare with previous rates of appearance of the Barbary-type birds for Canarian populations, we used photos to classify the eight falcon specimens collected in the Canary Islands between 1902 and 1917 (Rodríguez et al. 2009), which were deposited at the American Museum of Natural History (New York: two males and four females), the Natural History Museum (Tring, UK: one male) and the Alexander Koenig Museum (Bonn, Germany: one female). We used a chi-square test to evaluate differences in sex proportion by phenotype.

During 2016 to 2017, we also estimated breeding and poaching rates by monitoring 43 nesting attempts at 29 nesting sites (see Table 2). Pairs were monitored beginning in February to determine territory occupancy (by observing copulation or courtship behaviors, perching adults, refurbished nests, etc.). We calculated breeding success as the percentage of territorial pairs producing at least one fledgling, and productivity as the number of fledglings per territorial pair. When we detected the loss of a clutch or brood, we looked for evidence of human disturbance consistent with removal of eggs or nestlings (e.g., climbing bolts, broken rocks, or damaged vegetation) on the cliff and its surroundings, usually in comparison with previously taken photos (Fig. 2).

To complement our field data, we used annual counts of admissions of raptor species to La Tahonilla Wildlife Rehabilitation Center, which is supported by the local insular government (Cabildo de Tenerife; WRC hereafter). Raptors admitted with signs of having been kept in captivity (falconer rings, anklets, plumage damaged, or unusual beak shape), along with nonnative species, were assumed to have been lost falconry birds, and this information was considered a proxy for falconry (see definition below) activity over the last 20 yr (1998–2017). As we could not distinguish the actual use of escaped captive birds, we considered "falconry" to include any activity involving the keeping of raptors for hunting, training, recreation, or collection, and consequently we included all species belonging to families Accipitridae, Falconidae, Tytonidae, and Strigidae that matched our above description of formerly captive birds. Species of the families included are widely used in the Canary Islands for such purposes (Rodríguez et al. 2010, B. Rodríguez unpubl. data). These species are susceptible to becoming lost, mixing, or hybridizing with native conspecifics or related species. In addition, legal falconers must report losses to the WRC in an effort to recover lost birds and to comply with the Canarian falconry regulations (Gobierno de Canarias 2012). Thus, to assess the frequency of lost falconry birds, we used the records kept at the WRC as a minimum rate.

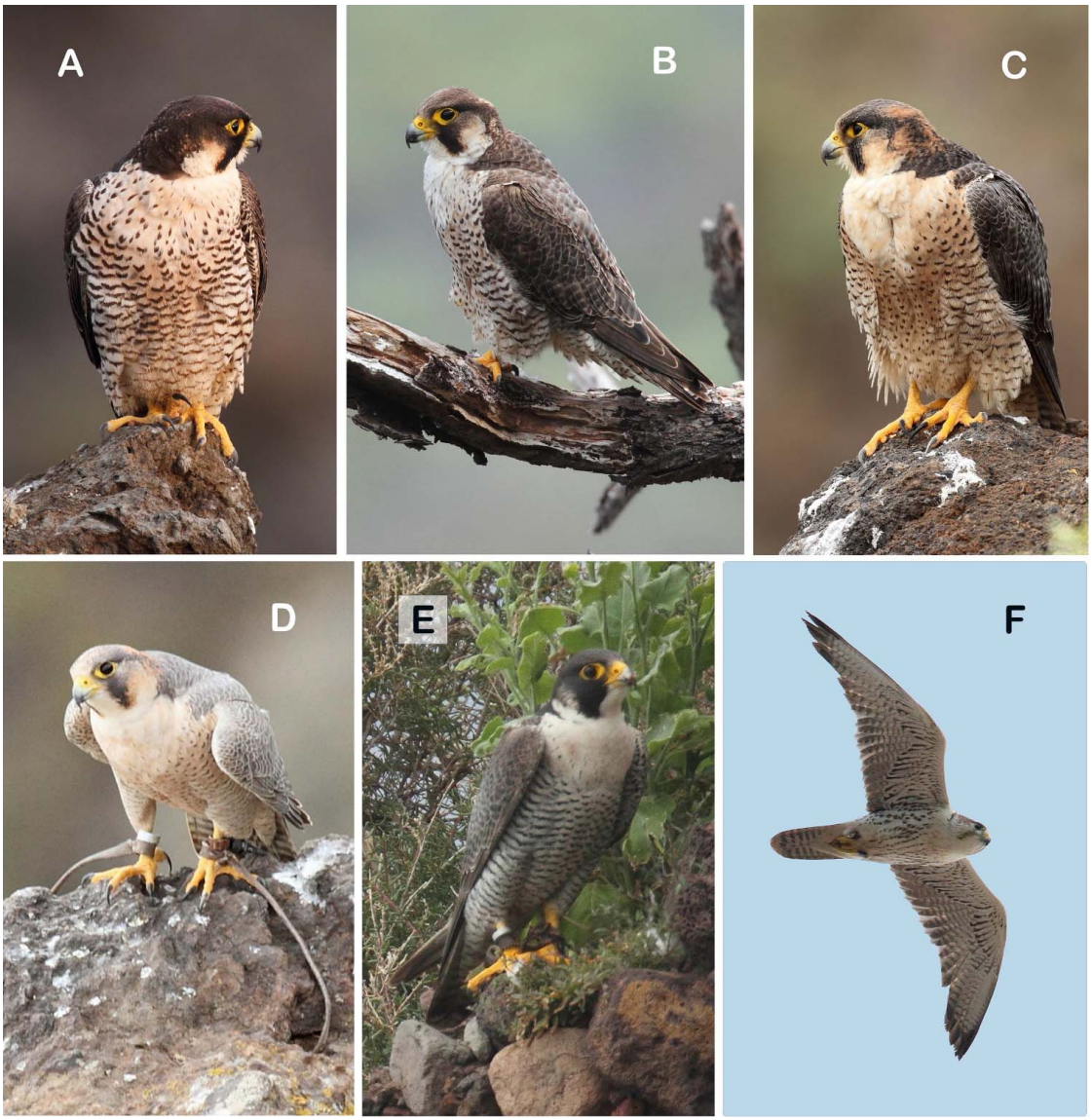

Figure 1. Examples of wild falcons (A-C) and lost falconry falcons (D-F) observed on Tenerife Island in the last decade: (A) a presumed Peregrine Falcon (*Falco peregrinus*), April 2017; (B) Barbary Falcon (*F. peregrinus pelegrinoides*), an individual with dark coloration, May 2011; (C) Barbary Falcon (*F. peregrinus pelegrinoides*), an individual with typical coloration, February 2015; (D) Barbary Falcon (*F. peregrinus pelegrinoides*), single female, February 2011; (E) Peregrine Falcon (*F. peregrinus*), paired male, April 2011; and (F) Saker Falcon (*F. cherrug*), presumed male, January 2012. Photos by Beneharo Rodríguez.

RESULTS

From 1993 to 2017, we observed a total of 12 falcons (*Falco* spp.) carrying falconry equipment (and assumed to be lost falconry birds) at locations scattered throughout Tenerife Island. Seven of these birds belonged to the *F. peregrinus* complex, three were Saker Falcons (*F. cherrug*), and two were unidentified falcons (Table 1, Fig. 1). Three of these *F. peregrinus* individuals were detected on territories: one an unmated Barbary Falcon and two with

Table 2. Breeding parameters, percentage of poached nests, and minimum number of poached young recorded at 29 nest sites of wild Barbary Falcons (*Falco peregrinus pelegrinoides*) on Tenerife Island during 2016 to 2017. Breeding success was defined as the percentage of territorial pairs producing at least one fledgling; productivity was defined as the number of fledglings produced per territorial pair; P = including all nesting attempts; NP = excluding poached nesting attempts.

	Nesting Attempts		Nestlings	Breeding Success (%)		Productivity	
Season	Monitored	Poached (%)	Poached	P	NP	P	NP
2016	15	3 (20.0)	3[a]	66.7	83.3	1.21	1.55
2017	28	3 (10.7)	6	71.4	80.0	1.50	1.70
Total	43	6 (14.0)	9	69.8	81.1	1.40	1.65

[a] Three nestlings from one nesting site and an indeterminate number of eggs or nestlings from the other two.

typical, non-Barbary, Peregrine-type appearance. In January 2007, we detected one of these two breeders, a Peregrine-type female that was paired with a typically colored Barbary Falcon male, but we made no further visits to confirm the breeding outcome. During March and April 2011, we detected the second individual; a very dark Peregrine-type male with anklets (Fig. 1E) observed holding a territory and copulating with an unmarked second-year female, which also had the non-Barbary Peregrine-type appearance. During 2014, this male moved to another nesting cliff 4.5 km from the former location, and occupied that cliff with a non-ringed female also

Figure 2. A Barbary Falcon (*Falco peregrinus pelegrinoides*) nest poached after incubation on Tenerife Island: (A) incubating female on 5 March 2016, and (B) empty nest on 1 April 2016, with surrounding vegetation damaged after climbing activity (white arrow). Photos by Beneharo Rodríguez.

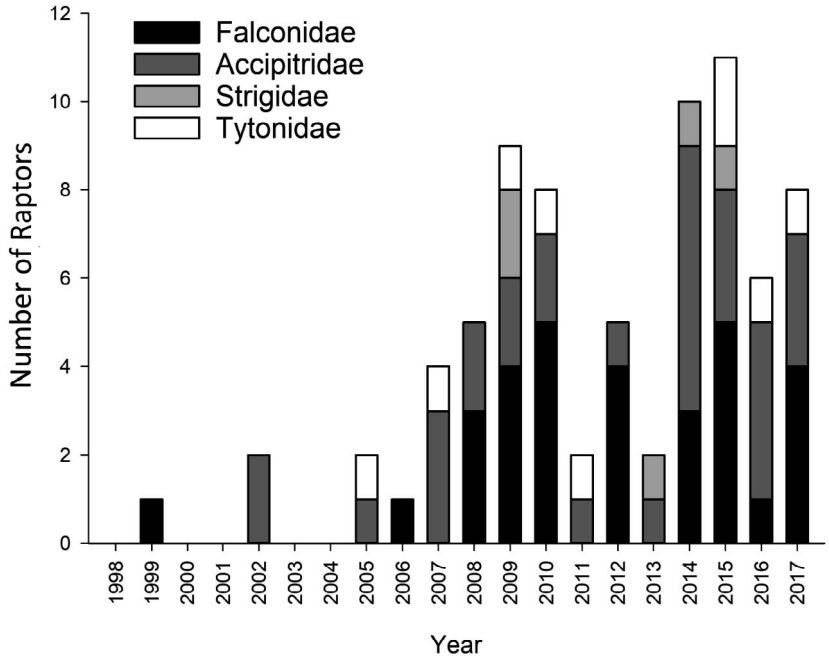

Figure 3. Trends in numbers of lost falconry birds (families Falconidae, Accipitridae, Tytonidae, and Strigidae) admitted to La Tahonilla Wildlife Rehabilitation Center, Cabildo de Tenerife (local government), on Tenerife Island (1998–2017).

showing a Peregrine-type appearance (probably the same female detected during 2011, based on her appearance) until the 2017 breeding season. The breeding output of this pair was two fledglings in 2014, two four-egg clutches but no fledglings in 2015 and 2016, and four fledglings in 2017. Based on our records, at least 1.6% of the current breeding pairs on Tenerife (i.e., 1 of 60 pairs) include at least one lost falconry bird.

Only 54% (7 females and 13 males) of all breeding individuals detected (21 females and 16 males) in 2016–2017 displayed a Barbary-type appearance. There was an association between sex and phenotype, such that males showed the Barbary-type coloration more often than females ($\chi^2 = 8.395$, $P < 0.01$). With the exception of one female, all museum specimens collected from the archipelago during the early 1900s showed typical Barbary-type plumage.

Of the 43 monitored nesting attempts during 2016 to 2017, we categorized six (14%) as having been poached, with the same three nesting sites being poached each year. With the exception of one Peregrine-type male, these three sites were occupied by Barbary-type adults. These three nesting sites were located on relatively small and accessible cliffs in the south of the island and only one was within a Natural Protected Area. All sites had evidence of human activity (see details in Methods section). From these nests a minimum of three nestlings and an unknown number of eggs were illegally taken in 2016 along with six nestlings in 2017. Breeding success for our monitored sites that were not disturbed by humans was 81.1% and productivity was 1.65 fledgling/territorial pair. When we included the poached nests, these figures decreased to 69.8% and 1.40 fledgling/territorial pair, respectively (Table 2).

According to the WRC admission database, falconry activity seems to have increased during 1998 to 2017 on Tenerife; a total of 76 raptors with falconry origins were admitted, representing seventeen species and one hybrid (Fig. 3). The number of individuals admitted increased up to a maximum of 11 birds in 2015 (Fig. 3). Eleven lost falcons (representing four species and three hybrids) with potential to hybridize with Barbary Falcons were admitted to the WRC, and nine of these were recovered by their owners. Another 30 falcons (*Falco* spp.) were noted as lost by falconers during 2007–2017, and only six of these were reported as recaptured (Table 1).

DISCUSSION

Our observations demonstrate that lost falconry birds are present in the breeding population of Barbary Falcons on the island of Tenerife. We identified individuals that belonged to the *F. peregrinus* complex carrying falconry equipment that were defending territories and pairing with

native falcons, resulting in the production of viable offspring. In addition, the WRC database includes admitted Barbary Falcons that had signs of being used for falconry, and we confirmed illegal nestling- and egg-harvesting at nesting sites of Barbary Falcons on this island.

The identification of subspecies within the *F. peregrinus* complex is a challenging task in the current Canarian environment, where many local breeders exhibit intermediate phenotypes between Peregrine and Barbary Falcons (Rodríguez et al. 2011). We cannot rule out the possibility that some wild Peregrine Falcons are dispersing to the Canary Islands from nearby populations (Brosset 1986) and contributing to changes in the phenotypic frequencies of Canarian falcons. However, the relatively low proportion of Barbary-type breeding adults detected in 2016 to 2017 may be related to some degree of genetic admixture with lost falconry birds, or a combination of these two factors. A small number of individuals, especially females, with high reproductive fitness can modify the morphological and genetic characteristics of falcon populations in a short time period (White et al. 1995). The effect of these breeders may be stronger in small and isolated populations, such as the Tenerife population, which had approximately 60 pairs in 2017 (B. Rodríguez unpubl. data). The relatively high proportion (66.7%) of Peregrine-type females (usually larger than the Barbary-type females) could be a consequence of the higher success of larger female raptors, as they are more likely to be recruited to the breeding population and successfully fledge offspring than smaller females (McDonald et al. 2005, Pérez-Camacho et al. 2015). In addition to genetic introgression, lost falconry birds may interfere with native individuals by competing for breeding territories or food, preying on them, disturbing their nesting sites, or favoring the propagation of infectious diseases (Krone et al. 2004, Naldo and Samour 2004, Cugnasse et al. 2017).

We confirmed poaching at three sites on Tenerife during 2016 and 2017, so 14% of the monitored nesting attempts were affected (Table 2). The long-term demographic effects of the current rate of poaching detected on Tenerife must be evaluated and any associated falcon trade must be curbed to protect the local population. Multifaceted solutions that include field surveillance, port and airport controls, and stricter law enforcement are needed in this effort (see Wyatt 2011).

Like falcons, other raptors represented by endemic subspecies in the Canary Islands or evolutionarily significant units (i.e., the Eurasian Sparrowhawk [*Accipiter nisus granti*], the Eurasian Kestrel [*Falco tinnunculus canariensis*], the Northern Long-eared Owl [*Asio otus canariensis*] or the Barn Owl [*Tyto alba*]) may be suffering the same threats caused by lost falconry birds as the admission data to the WRC suggest (Fig. 3).

Molecular studies are needed to assess the genetic variability of the Canarian falcons, the current genetic admixture, and the role of falconry birds in the genetic introgression which may be occurring (Nittinger et al. 2007, Jacobsen et al. 2008, Randi 2008, vonHoldt et al. 2018). An update of regulations under the FL could include: (1) provisions that reduce the potential successful breeding between native and exotic falcons through restricting falconers to the use of birds in the subgenus *Hierofalco*, requiring sterilization, and/or mandating human sexual imprinting of all falconry birds (Cugnasse et al. 2017); (2) mandatory use of color-rings or similar devices to enhance the identification of lost falconry birds in the wild (Cugnasse et al. 2017); and (3) the creation of an official register of all captive raptors present on the archipelago (only those birds used for hunting must be registered according to FL). A further recommendation would be the removal of escaped falcons currently present in the wild (Genovesi 2007, Simberloff 2009). It may be necessary to shoot individuals that are impossible to catch (Everitt and Franklin 2009, Cozic 2016), but the use of falconry trapping techniques should be first attempted to capture them alive (Cugnasse et al. 2017). Similarly, a public awareness campaign about the biology and conservation of native falcons would contribute to the avoidance of human-wildlife conflicts. This is necessary to correct the common perception that current falcon population increases are a result of deliberate releases of captive-bred falcons by local authorities, a misconception that led to some falcons being illegally shot (Rodríguez et al. 2010). Finally, given the relevant natural heritage of the Canary Islands, we suggest that authorities actively discourage the possession of raptors (especially those at high risk of mixing with native taxa) for recreational purposes. The measures mentioned above will improve the chances for successful conservation of this fragile and threatened falcon population.

DATASETS

Rodríguez, B., F. Siverio, M. Siverio and A. Rodríguez (2018). Medium and large falcon species (*Falco* spp.) of captive origin detected on Tenerife Island [Dataset]. Digital.CSIC, DOI: http://dx.doi.org/10.20350/digitalCSIC/8560

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