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Individual recognition of territorial peregrine falcons *Falco peregrinus*: a key for long-term monitoring programmes.

Iñigo Zuberogoitia[1,2], *José Enrique Martínez*[3], *Jabi Zabala*[4]

Abstract

Research on avian population dynamics necessitates significant time and effort in order to mark and control a sufficient number of individuals in the monitored population to obtain an adequate sample for analysis. Various recognition techniques which facilitate population monitoring have been documented, with photography being one of the most useful tools. We used photography, drawings and alphanumeric coloured rings in order to identify peregrine falcons (*Falco peregrinus* Tunstall 1771). We described eight principal characters which allowed us to identify individual peregrines in the field, including the shape, length and size of the moustache and the dark marks that extend from the nape to the cheek and neck; design, size, density and distribution of the spots on the breast, throat, neck and cheek; and the colour of the breast and neck. From 1997 to 2013 we identified 83 males and 96 females in 35 territories. We found phenotypic variation among individuals when the combination of the possible subgroups of identification characters was considered, which constitutes an opportunity to recognise individual hawks without marking them with artificial tags.

• **Key words:** Individual recognition, capture and recapture programs, population dynamics, peregrine falcons.

[1] *Estudios Medioambientales Icarus S.L., Pintor Sorolla 6, 1º C • 26007 Logroño. Spain*

[2] *Sociedad de Ciencias Aranzadi / Aranzadi Zientzia Elkartea*
Ornithology Department
Zorroagagaina 11 • 20014 Donostia / San Sebastián

[3] *Bonelli´s Eagle Study and Conservation Group, Apdo. 4009 • 30080 Murcia. Spain.*
e-mail: jemartinez64@gmail.com

[4] *Faculty of Science and Technology, Department of Zoology and Animal Cell Biology, UPV/EHU, Sarriena • E-48940 Leioa, Bizkaia. Spain*

Contact e-mail: zuberogoitia@icarus.es

RESUMEN

Los estudios de dinámica de poblaciones requieren de grandes dosis de tiempo y energía para marcar y controlar un número suficiente de individuos de la población estudiada, así como para obtener un tamaño muestral adecuado para los análisis. Son varias las técnicas de reconocimiento individual que han sido descritas, siendo la fotografía una de las más utilizadas. Nosotros empleamos las fotografías, los dibujos individuales y las anillas de color para identificar a los halcones peregrinos (*Falco peregrinus* Tunstall 1771). Describimos ocho caracteres principales que permitían identificar a los halcones en el campo, entre los que se incluyen la forma, longitud y tamaño de la bigotera y las marcas oscuras que ocupan el espacio entre la nuca y la mejilla y el cuello; el diseño, tamaño, densidad y distribución de las motas del pecho, garganta, cuello y mejilla; y el color del pecho y el cuello. Entre 1997 y 2013 identificamos 83 machos y 96 hembras en 35 territorios. Encontramos diferencias significativas entre individuos cuando se empleaba la combinación de todos los poisbles subgrupos de caracteres de identificación. Siguiendo el protocolo de identificación individual fuimos capaces de detectar cambios del fenotipo individual.

• PALABRAS CLAVE: reconocimiento individual, programas de captura y recaptura, dinámica de poblaciones, halcón peregrino.

LABURPENA

Populazioen dinamikari buruzko ikerketek denbora eta energia asko eskatzen dute, aztertzen ari den populazioko ale nahikoa markatzeko eta kontrolatzeko, eta bai analisietarako gutxieneko lagin kopurua lortzeko. Banakoak ezagutzeko hainbat teknika deskribatu dira eta horietatik argazkiak egitea da erabilienetakoa. Guk, belatz handiak (*Falco peregrinus* Tunstall 1771) identifikatzeko, argazkiak, banakoen ma-rrazkiak eta koloretako eraztunak erabiltzen ditugu. Zelaietan, belatz handiak identifikatu ahal izateko zortzi ezaugarri deskribatzen ditugu: bibotearen forma, luzera eta tamaina eta garondo, masail eta lepoaren arteko espazioa betetzen duten orban beltzak; bularreko, eztarriko, lepoko eta masaileko orbanen diseinu, tamaina, dentsitatea eta banaketa. 1997 eta 2013 urteen artean 35 lurraldetan 83 ar eta 96 eme identifikatu genituen. Identifikaziorako ezaugarrien azpitaldeen konbinazio posible guztiak erabiliz gero, banakoen artean desberdintasun nabarmenak aurkitu genituen. Banakoak identifikatzeko protokoloa jarraituz, banakoen fenotipoan aldaketak antzemateko gai izan ginen.

• **GAKO-HITZAK:** banakoen ezagutza, harrapaketa eta berrarrapaketa programak, populazio dinamika, belatz handia.

Introduction

Research on population dynamics requires a lot of time and effort in order to mark and control enough individuals in the monitored population and obtain an adequate sample size for analysis (see Hernández-Matías *et al.*, 2011). Recognisable, natural, external features are used less frequently than artificial marks (rings, wing-tags and others) for accurate individual identification of animals because not all species have suitable features, or there is insufficient phenotypic variation between individuals for these purposes (Murn, 2012). However, photo-identification is a commonly used technique in the identification of individuals of different species, cetaceans and large carnivores being amongst the most well-known examples (see Wüsing & Jefferson, 1990; Anderson *et al.*, 2007; Mackey *et al.*, 2008; Hibby *et al.*, 2009). During recent years several authors have shown that it is also possible to recognize individuals of some bird species using their particular phenotypic marks. Nowadays, photography has also been used for individual identification of some birds (Chardine, 2002), including large raptors (Bretagnolle *et al.*, 1994; Murn, 2012). Krüger and Lindström (2001) sketched and photographed 106 female and 132 male common buzzards (*Buteo buteo*) in order to individually recognize them year to year without marking and subsequently to analyse reproductive success considering variables such as individual variation, occupancy and permanency.

Ratcliffe (1993) recognized that the size and shape of the moustache in the peregrine falcon (*Falco peregrinus* Tunstall 1771) varies greatly between individuals and is useful for identification, though often only reliable in photographs. Nonetheless, all the examples relating to population dynamics described by this author were based on marked peregrines and we found no relevant literature for peregrines following, for example, the method used by Krüger and Lindström (2001) for their studies on population dynamics of common buzzard.

The phenotypic variation of peregrine falcons in Biscay, Northern Spain, was described by Zuberogoitia *et al.* (2009a). The male morph-types are regularly shared between three moustache classes and almost every type of spot pattern and colour, although authors did not find males showing heavily spotted breast, while 27.6% of the females present this type of spot pattern. Moreover, there are significant differences in the spot distribution between sexes. In fact, the half of the males does not show spots on the upper-breast and only 17.2% of the females present this pattern. On contrast, 65.5% of the females show fully marked breast and only 17.9% of the males. As regards of the moustaches, 62.1% of the females show moderately wide type, 24.1% wide type and 13.8% hooded pattern. Finally, the colour pattern of the upper breast show differences between sexes, since authors did not find rufous females and only three rufous and one orange male, whilst 57.1% of the males are predominantly white and 68.9% of the females are cream.

Therefore, considering the phenotypic variation of peregrine falcon described by ZUBEROGOITIA *et al.* (2009a), our main goal is to describe an identification guide for the recognition of individual peregrines in the field using phenotypic traits.

MATERIALS AND METHODS

STUDY AREA

The study zone covered the area of Biscay (Basque Country, northern Spain; extent = 2,384 km^2; coordinates from 43°11'00'' to 43°12'70''N and from 3°12'70'' to 2°13'10''W). The landscape is hilly and steepness (maximum altitude is 1,480 m a.s.l.) and characterised by the presence of extensive urban and industrialised areas. Forests, pastures, small villages and densely populated cities make up the bulk of the province. More than 50% of the area is dedicated to forestry, mainly plantations of *Pinus radiata* and *Eucalyptus* spp., which cover the region at the expense of traditional small-scale farming. The weather is temperate, with an annual rainfall of 1,000–1,300 mm and mean annual temperatures of 11–12° C (Loidi, 1987).

FIELD PROCEDURE

The peregrine falcon population in Biscay was systematically surveyed each year from 1997 to 2013. During this period we focused our monitoring efforts on 35 territories (see Zuberogoitia *et al*., 2009b). Each year we started surveying falcons 30 days before the earliest local laying date recorded for the population, 20th February (Zuberogoitia *et al.*, 2002). At this time of year breeding pairs can be readily located because they frequently engage in courtship displays. Nests can also be found by observing displaying individuals near the crags and sea cliffs where they will eventually breed.

From February to June we monitored every breeding territory, searching for adult peregrines and for nests. We used three different identification methods: (1) 660 nestlings and 30 subadults and adults were ringed with official and alphanumeric colour metal rings. (2) We took individual photographs of peregrines perched in the nesting cliff in order to identify non-ringed peregrines using their individual natural markings. Equipment consisted of a Canon 7D camera with 50–500 mm lens or a digiscope arrangement with a Swarovski 20x60 ATS80 telescope. (3) We drew the details and colour of the face, moustache and breast in a notebook from direct observations in the field, as well as recording any behavioural aspects of the territorial peregrines which helped facilitate individual recognition.

We identified eight main external physical characters (Fig. 1) for distinguishing individual territorial birds: 1- The shape of the moustache: the area of the mous-

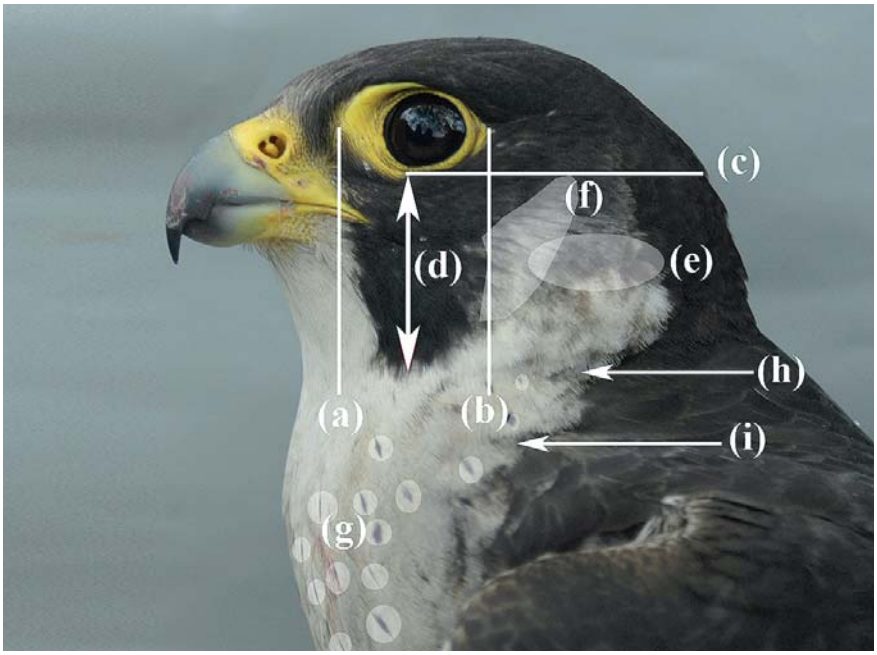

Fig. 1- A typical image of a perched peregrine, in this case an adult (3cy) male. The following parameters are used to identify individuals: Moustache shape between (a) the projection from the origin of the ocular cere and (b) from the lachrymal, and the angle between the lower point of the moustache and the upper side of the cheek and its distance from the horizontal projection of the eye (c). Length of the moustache (d). Design of the dark shapes (e) and white area in the cheek (f). Design, size, density and distribution of the spots in the breast, throat, neck and cheek (g). Shape and size of the dark horizontal lines from the shoulder to the neck (h and i). General colour of the breast and neck.

Fig. 1.- Típica imagen de un macho posado, en este caso un macho adulto (3cy). Los siguientes parámetros son utilizados para identificar individuos: Forma de la bigotera entre (a) la proyección desde el origen de la cera ocular y (b) desde el lacrimal, y el ángulo entre el punto inferior de la bigotera y la parte superior de la mejilla y la distancia desde la proyección horizontal del ojo (c). Longitud de la bigotera (d). Diseño de las formas oscuras (e) y el área blanca de la mejilla (f). Diseño, tamaño, densidad y distribución de las manchas en el pecho, garganta, cuello y mejilla (g). Forma y tamaño de las líneas oscuras horizontales desde los hombros hasta el cuello (h e i). Coloración general del pecho y el cuello.

tache between (a, in Fig. 1) the projection from the origin of the ocular cere and (b) from the lachrymal, and the form of the edge of the moustache (i.e. triangular, square, rounded). 2- The angle between the edge of the moustache and the upper side of the cheek and its relative distance from the horizontal projection of the eye (c). 3- The length of the moustache compared to the size of the orbicular basin (d). 4- The design of the dark shapes found in the area between the nape and the cheek (e). 5- The form of the white area of the cheek (f). 6- The shape and length of the dark horizontal lines that run from the shoul-

der to the breast (h and i). 7- The distribution (breast, throat, neck, cheek), size (fine, intermediate, thick) and density (no spots, low, intermediate, high density) of the spots (g). 8- The colour of the breast and the neck (white, beige, rufous, orange).

As an example to illustrate the methodology, we considered the portraits of 12 trapped and ringed peregrines (Fig. 2) and gave them values following the above-mentioned identification methodology. In order to simplify the process we subdivided the eight characters as follows: The shape of the moustache is inside the projections (a, b, c, d, e, f, g, h, i, j, l in Fig. 2) or it is wider than the projections (k). The edge of the moustache is width rounded (b, k), narrow rounded (d, e, h), triangular (c, g, i), mixed between square and rounded (f, l)

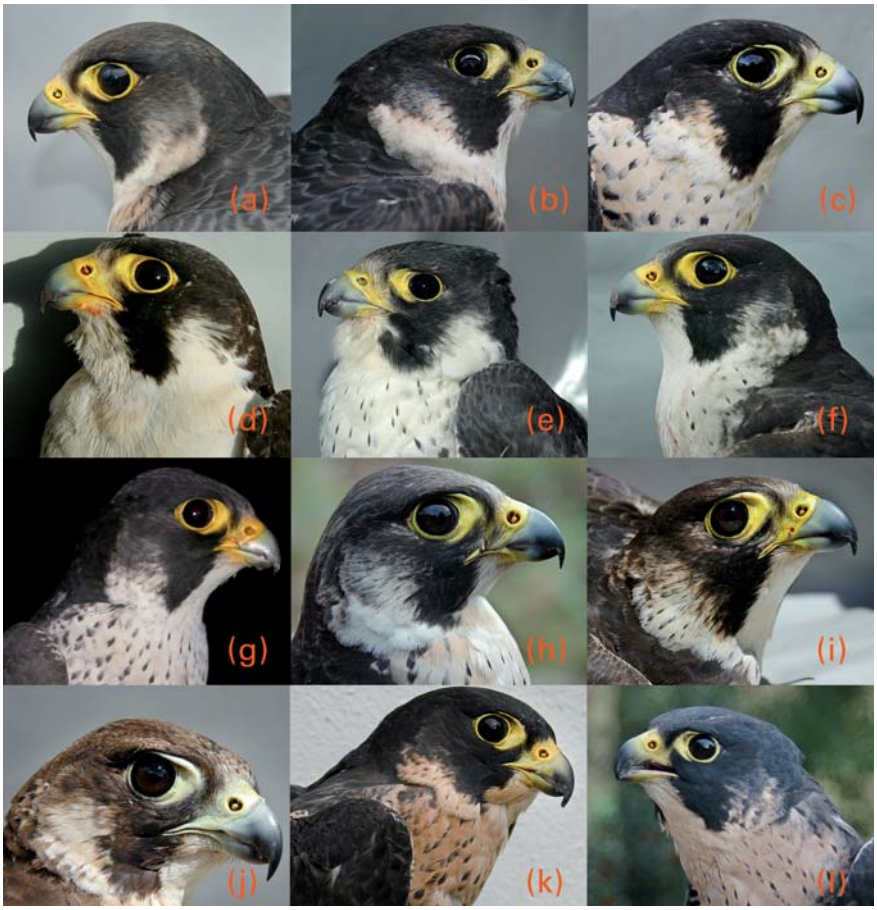

Fig. 2.- Photos of six different adult females (a, b, c, i, k, l), five adult males (d, e, f, g, h) and one juvenile female (j), taken in the study area.

Fig. 2.- Fotos de seis hembras adultas (a, b, c, i, k, l), cinco machos adultos (d, e, f, g, h) y una hembra juvenil (j), tomadas en el área de estudio.

or pointed towards the throat (a). The moustache runs towards the cheek just below the horizontal projection (b, c, d, f, g, h), further down (a, k, l), or above the horizontal projection (e, i, j). The black shape found within the white cheek area is small (c, i, j), medium (b, f, h), semi-hooded (g, k), hooded (a, l) or entirely absent (d, e). The cheek has a narrow white zone (b, g, k), an intermediate sized zone (c, f, h, i), a wide white zone (d, e, j) or no white at all (a, l). As regards the presence and size of the horizontal lines from the nape towards the breast: absence of the line H (a, b, d, e, g, h, I, j, k), an intermediate line H (c, f), a large line H (l), and absence of the line I (c, d, e), an intermediate line I (f, g, h, l) or a large line I (a, b, i, j, k). No spots on the breast (d), fine spots (a, b), intermediate spots (e, f, g, h, i, j, l) or thick spots (c, k). The presence (i, k) or absence (a, b, c, d, e, f, g, h, j, l) of spots on the cheek. A low density (a, b, f, h), intermediate density (e, k) or high density (c, g, I, j, l) of breast spots. The colour of the breast, white (b, d, e, f), beige (a, c, g, h, I, j) or rufous (k, l). In order to measure dissimilarities between individuals, Bray Curtis Ordination using Euclidean distance (see Zuur *et al.*, 2007), with the 12 individuals in rows and phenotypic variables in columns, were performed using PAST v2.10 (Hammer *et al.*, 2001).

Results and discussion

During the study period we identified 83 males and 96 females in 35 territories, from which 30 males (36.14%) and 15 females (15.65%) were ringed birds, and 33 males (39.76%) and 32 females (33.33%) were photographed (13 males and 18 females were photographed in high quality and 20 males and 14 females were photographed using digiscoping). We also made individual drawings of all of them following the figure 1, in order to describe and store individual marks in the database.

We could not confirm the identity of all the territorial adults each year due to some field inconveniences: (1) breeding failures, which meant that adults were not permanently present on a particular nesting cliff, (2) large distances between the observer and the adult birds, which made it difficult to take photographs or even reliable drawings, and (3) temporarily deserted territories.

The cluster analysis (Fig. 3) shows significant dissimilitude between the 12 selected portraits when the combination of the possible subgroups of the eight identification characters was considered. The closest match was found between male f and male h, which are quite similar falcons, but they differ in the morph, the position and size of the black patches of the cheek, and the size, density and position of the spots on the breast, neck and throat. The only other close match we found was between the bird e and j. However, there were other obvious differences between them, since one was an adult male and the other

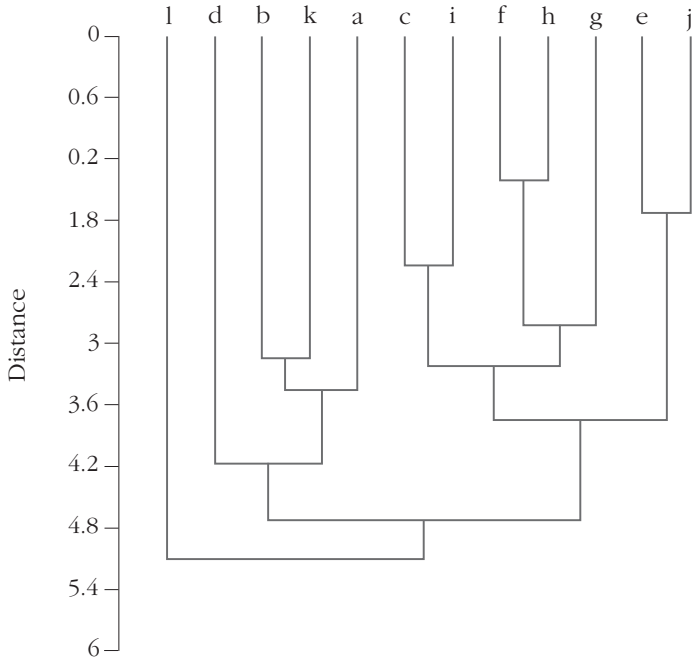

Fig. 3.- Bray Curtis Ordination using the Euclidean distance, applied to the phenotypic characters of the 12 peregrines presented in Fig. 2.

Fig. 3.- Ordenamiento de Bray Curtis basado en la distancia Euclídea, aplicado a los caracteres fenotípicos de 12 halcones. Estos caracteres son los mostrados en la Fig. 2.

was a juvenile female. In fact, we did not consider the age and the gender in the current analysis or the presence of marks (rings). Accounting for these factors would have increased the differences between individuals, as it normally occurs in the field.

Individual markings remain stable once the falcon has its adult plumage (2nd cy onwards, Ratcliffe, 1993). From then on the plumage characteristics do not change and once a territorial adult has been drawn or photographed it is unlikely that it will be mistaken for another bird in the same territory (see Fig. 4). With increasing age the barring of the underparts becomes finer and may almost disappear in old males (Forsman, 1999), although we have not seen it in a 13 years old male monitored every year and other younger males from six to ten years old. Therefore, following the identification methodology (Fig. 1) it is possible to detect slight changes in the individual phenotype. Moreover, different individuals displayed characteristic behaviour (favourite perches, sleeping site, relationships with humans or mate behaviour) which can be a complementary characteristic to support identifications (Treleaven, 1998). Additionally, if we consider that approximately 25% of the monitored adults were ringed, use of

Fig. 4.- An adult female photographed during the breeding season of 2008 (a), the same female in 2012 (b) and a different female during the breeding season of 2013 (c). Note the differences in the shape and the angle of the moustache and the size, form, colour and density of the breast markings between (a) and (c).

Fig. 4.- Una hembra adulta fotografiada durante el periodo de cría de 2008 (a), la misma hembra en 2012 (b) y una hembra diferente durante el periodo de cría de 2013 (c). Nótense las diferencias en la forma y el ángulo de la bigotera, así como el tamaño, forma, color y densidad de las marcas del pecho entre (a) y (c).

this factor would make it even easier to distinguish between non-ringed/ringed peregrines and vice versa.

Hurley *et al.* (2013) analyze six capture-mark-recapture (CMR) techniques in order to select the best benchmark method for long-term monitoring programmes. They find that the use of visual identification (VID) metal bands for a long-term CMR study is highly appropriate for peregrine falcons and the best technique selected for monitoring their populations. However, the importance of improving the quality and efficiency of longitudinal long-term studies requires methods that let researcher monitor the whole target population. In this sense, it is almost impossible to keep every territorial breeder ringed since peregrines show long dispersive distances and local population are supported by foreigners which normally are not marked (Zuberogoitia *et al.*, 2009b). In such case, every time a territorial breeder is replaced by a non-marked adult the long-term dataset is interrupted until the falcon is trapped and marked. However, marking an adult is not always easy task and it needs time, effort and extra-financial resources to carry on (see Varland et al., 2007; Zuberogoitia *et al.*, 2008). However, following the Krüger and Lindström (2001) work with common buzzards, and thanks to the individual recognition protocol we can include non-marked peregrines in research into population dynamics from the first moment and build life tables in order to analyse survival, occupancy, fidelity, senescence, lifetime reproductive success and other variables.

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