Stable isotope analysis is a reliable method for identifying migrants and residents in a partial migratory European hoopoe (*Upupa epops*) population in southern Spain

Mercè Palacios [1], María Herrero[2], Elena Arriero[1], Ana López-Rodríguez[1], Francisco Pulido[1], Juan J. Soler[3], Manuel Martín-Vivaldi[2], David Martín-Gálvez[4]

[1] Department of Biodiversity, Ecology and Evolution - Complutense University of Madrid, Madrid, Spain
[2] Department of Zoology - University of Granada, Granada, Spain
[3] Arid Zones Experimental Station (EEZA) - Spanish National Research Council (CSIC), Almería, Spain
[4] Department of Animal biology - University of Málaga, Málaga, Spain

Introduction

Partial migratory populations allow to study differences between migrants and residents and the persistence of these behaviours. Using as model system a non-passerine, transaharian, long-distance bird as the hoopoe[1] opens new possibilities in avian migration studies.

Aims

- Study intrapopulation trends of migratory behaviour.
- To find the most informative feathers to identify migrants and residents.
- To explore phenotipical variation and its relation with migratory strategy, sex and age.

Methods

(a) Stable isotopes analysis

Five types of feathers were collected from 71 individuals in Guadix (Spain)

Deuterium values were obtained through the comparative equilibrium method [2]

We performed a linear model to rescale the deuterium isoscape in relation with known origin feathers samples [3]

On this own isoscape (isotopic landscape), we calculated posterior probabilities density maps for own samples via bayesian inversion method (Fig.1)

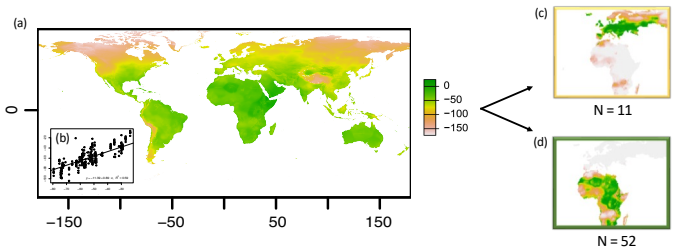

Fig.1. a) Calibrated specific global distribution of deuterium values, **b)** linear regression model and two examples of probability density maps that were used to assign our own data: **c)** european isotopic profile, **d)** african isotopic profile. For an individual, If some feather shows african signal, it is classified as migrant bird; if all feathers show european signal it is classified as resident bird.

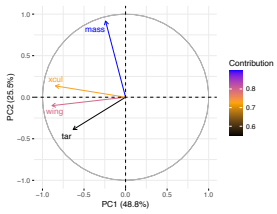

Fig.2. Variables contribution to each dimenssion. PC1: shape, PC2: size. Proximity between arrows indicates degree of correlation and their length the wellness of representation

(b) Phenotypic variation analysis

Shape and size of individuals were extracted from the principal components of a PCA of the morphological measurements (Fig. 2)

Body condition was calculated as the residuals of mass – tarsus regression.

9 models were tested for these and other phenotipic variables in order to assess if behaviour could be a relevant influence factor. All combinations were tested including first and second order interactions.

Then we selected the ones that explained more variance through AICs comparison and explored the significant differences.

Moreover, we performed frequency analysis to test the independence of the variables, to characterize the migratory behaviour in the present subgroups of age and sex and to avoid bias in our analysis.

Results

Fig.3. Mosaic plot representing the composition of the population in terms of individuals assigned to each behaviour by groups of sex and age. Numbers inside boxes are sample sizes. (Migrants = 73.24%; Residents = 15.49%; Uncertain = 11.27%)

Fisher's exact test

	odds ratio	*p* - value
age	1.325	1
sex	2.062	0.394

Table 2. Analysis of frequencies through contingency tables.

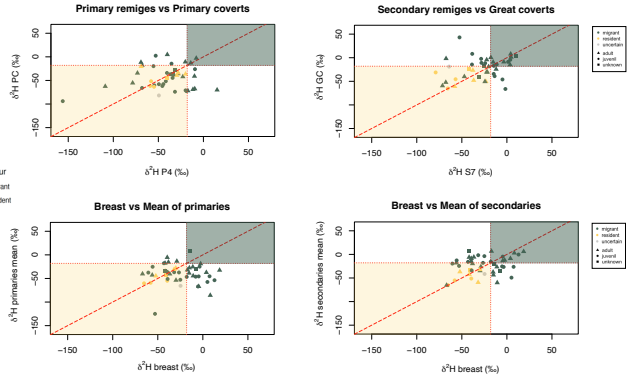

Fig.4. Correlation of deuterium ratio values in groups of feathers. Colored rectangles correspond with the areas where migrants (green) or resident (yellow) individuals are expected. Slashed diagonal red line indicates x=y assuming a perfect correlation between feathers.

Mutual independance

	χ^2	*p* - value
Likelihood ratio	6.210	0.184
Pearson	5.885	0.208

Conditional independance

	χ^2	*p* - value
sex		
Likelihood ratio	0.382	0.826
Pearson	0.398	0.820
age		
Likelihood ratio	1.003	0.606
Pearson	1.228	0.541

Tables 3 and 4. Results of loglinear models for testing independance: Mutual indep = pairwise; conditional indep = behaviour is independent of sex given age and then viceversa.

Variable	Best model	AICc	R^2 *adj*	*p* -value
Size	~ sex	160.34	0.023	0.136
	~ age	162.01	-0.007	0.428
	~ sex + behaviour	162.21	0.013	0.268
Shape	~ sex	127.40	0.719	**<0.001**
Condition	~ age	368.46	- 0.010	0.505
	~ sex	368.89	-0.018	0.855
	~ age + behaviour	370.39	-0.022	0.666
Num of black dots in crest	~ sex	264.34	0.082	**0.031**

Table 5. Results of models selection. *p*-values in **bold** are significant for variables tested. In those cases where more than one model is listed as the best, it indicates AICc values lower than 2 between them, so we couldn't select just one.

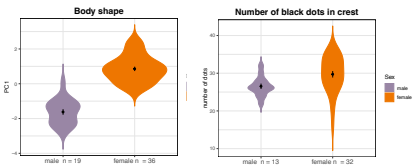

Fig.5. Violin plots of variables that showed significant differences in models selected. Black dot represents mean and lines crossing it represent standard deviation.

Main Findings

- Origin of feathers samples were efficiently identified combining stable isotopes analysis and posterior bayesian probabilities assignments.
- Different types of feathers of resident birds correlated in deuterium values.
- Variation in morphological traits was not explained by migratory behaviour.
- Migrants were more frequent than residents without differences in sex and age.
- Migratory behaviour might be more plastic that expected and other traits as physiology or genetics could be associated (next steps).

References

1 Reichlin, T., Hobson, K., Van Wilgenburg, S., Schaub, M., Wassenaar, L., Martín-Vivaldi, M., Arlettaz, R. & Jenni, L. (2012). Conservation through connectivity: Can isotopic gradients in Africa reveal winter quarters of a migratory bird?. *Oecologia,* 171, pp. 591-600.

2 Wassenaar, L. & Hobson, K. (2003). Comparative equilibration and online technique for determination of non-exchangeable hydrogen of keratins for use in animal migration studies. *Isotopes in Environmental and Health Studies*, 39 pp. 211-217.

3 Ma, C., Vander Zanden, HB., Wunder, MB., Bowen, GJ. (2020). assignR: An R package for isotope-based geographic assignment. *Methods Ecol Evol,* 11 pp. 996 – 1001.

More info:

Contact: mariamep@ucm.es

Fundings

Mercè Palacios is funded by a "FPI grant" from Ministry of Science and Innovation of the Spanish government. Research project reference number: PID2020-116934GB-I00.