

Title	Habitat segregation by breeding origin in the declining populations of European Robins wintering in southern Iberia
Authors	de la Hera, Iván;Fandos, Guillermo;Fernández-López, Javier;Onrubia, Alejandro;Pérez-Rodríguez, Antón;Pérez-Tris, Javier;Tellería, José Luis
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**University College Cork, Ireland**  
Coláiste na hOllscoile Corcaigh

## SUPPLEMENTARY MATERIAL

De la Hera *et al.* Habitat distribution by breeding origin in the declining populations of European Robins wintering in southern Iberia.

### 1) Habitat distribution according to the individual morphology of Robins

**Table S1.** Distribution between habitats, sites, populations (according to their morphology) and age (adult and juvenile) of the 149 Robins captured during winter in Campo de Gibraltar region. The assignation of the migratory behaviour of Robins is based here on the morphological classification functions (MCF) described in Pérez-Tris *et al.* (2000). These MCF consider the overall P8 length and the primary distances of the 9 longest primaries (excluding the vestigial outermost primary: P10), the so-called wing formula, for the estimation of the migratory behaviour of Robins. Primary distance was defined as the distance from the tip of each primary to the tip of the longest primary with the wing folded, with a value of zero for the primary (or primaries) constituting the wingtip. To facilitate the comparison between the morphological and isotopic methods of population differentiation, we also provided in brackets the distribution of Robins based on the  $\delta D_f$  values (see Table 1 in the manuscript).

	Migratory Robins		Sedentary Robins		Total
Sites	Adults	Juveniles	Adults	Juveniles	
<i>Woodlands</i>					
San Carlos Carretera	6 (11)	5 (13)	17 (12)	12 (4)	40
San Carlos Tiradero	7 (7)	9 (15)	14 (14)	13 (7)	43
<i>Shrublands</i>					
Almodóvar	10 (17)	5 (17)	7 (0)	13 (1)	35
Betis	8 (14)	3 (16)	7 (1)	13 (0)	31

## 2) Estimating wing shape parameters in wintering Robins

We used transformed values of the primary distances described above to estimate the variation in the wing shape of Robins wintering in Campo de Gibraltar region. For this purpose, we opted for transforming primary distances (P1-P9) into distances from the carpal joint (cP1-cP9) by subtracting, for each primary, its primary distance from the wing length. These transformed distances (cP1-cP9) were then standardized according to the method suggested by Senar et al. (1994), which provides more reliable measurements (cP1\*-cP9\*) that correct for the among-individual variation in wing size. These standardized values were used in a Principal Component Analysis (PCA) that gave rise to two principal components (KMO = 0.77; Bartlett's test of sphericity:  $\chi^2_{36} = 857.9$ ,  $P < 0.001$ ). PC1\* was interpreted as an index of wing concavity (eigenvalue = 4.07; explained variance = 0.45; factor loadings: cP9\* = 0.17, cP8\* = 0.19, cP7\* = 0.17, cP6\* = -0.12, cP5\* = -0.37, cP4\* = -0.44, cP3\* = -0.45, cP2\* = -0.44, cP1\* = -0.40); while PC2\* reflected variation in wingtip shape (eigenvalue = 1.97; explained variance = 0.22; factor loadings: cP9\* = 0.52, cP8\* = 0.58, cP7\* = 0.50, cP6\* = -0.16, cP5\* = 0.03, cP4\* = 0.12, cP3\* = 0.16, cP2\* = 0.20, cP1\* = 0.20).

**Senar, J.C., Lleonart, J. & Metcalfe, N.B.** 1994. Wing-shape variation between resident and transient wintering siskins *Carduelis spinus*. *J. Avian Biol.* **25**: 50–54.

### 3) Bird morphology and its relationship with $\delta D_f$ values in migrants.

We explored the relationship of the development of flight morphology (PC1), structural size (PC2), wing concavity (PC1\*) and wingtip shape (PC2\*) with  $\delta D_f$  in the 110 migratory Robins wintering in Campo de Gibraltar. For this purpose, we performed Linear Mixed Models that analysed these variables (PC1, PC2, PC1\* and PC2\*) in relation to age, sex and their interaction as fixed effects,  $\delta D_f$  as continuous predictor, and year as a random effects factor. Results for each morphological trait are shown below:

#### a. Results for the analysis of the development of flight morphology (PC1)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 0.3351773 1.153982

Fixed effects: PC1 ~ 1 + age + sex + age:sex + i sot

	Value	Std. Error	DF	t-value	p-value
(Intercept)	0.6110034	0.6019319	104	1.015071	0.3124
agej uv	-0.5651009	0.2733171	104	-2.067566	0.0412
sexmal e	2.2143418	0.3550023	104	6.237541	0.0000
i sot	0.0103854	0.0071875	104	1.444938	0.1515
agej uv: sexmal e	0.0911411	0.4706501	104	0.193649	0.8468

#### b. Results for the analysis of structural size (PC2)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 0.222351 0.9446133

Fixed effects: PC2 ~ 1 + age + sex + age:sex + i sot

	Value	Std. Error	DF	t-value	p-value
(Intercept)	1.4898703	0.4792318	104	3.108872	0.0024
agej uv	-0.1738395	0.2236716	104	-0.777209	0.4388
sexmal e	-0.2334712	0.2904189	104	-0.803912	0.4233
i sot	0.0210896	0.0058831	104	3.584750	0.0005
agej uv: sexmal e	-0.0651280	0.3852394	104	-0.169059	0.8661

#### c. Results for the analysis of wing concavity (PC1\*)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 7.861797e-05 1.88228

Fixed effects: PC3 ~ 1 + age + sex + age:sex + i sot

	Value	Std. Error	DF	t-value	p-value
(Intercept)	-2.0649240	0.8977056	104	-2.3002241	0.0234
agej uv	0.3885365	0.4445330	104	0.8740331	0.3841
sexmal e	0.4612881	0.5751271	104	0.8020629	0.4243
i sot	-0.0332648	0.0117174	104	-2.8389206	0.0054
agej uv: sexmal e	-0.9298825	0.7672414	104	-1.2119817	0.2283

**d. Results for the analysis of wingtip shape (PC2\*)**

Random effects:

Formula: ~1 | year  
 (Intercept) Residual  
 StdDev: 0.06590182 1.168917

Fixed effects: PC4 ~ 1 + age + sex + age:sex + isot

	Value	Std. Error	DF	t-value	p-value
(Intercept)	0.5434921	0.5599454	104	0.9706162	0.3340
agej uv	0.7984189	0.2761976	104	2.8907520	0.0047
sexmale	-0.5395059	0.3575834	104	-1.5087555	0.1344
isot	0.0096474	0.0072773	104	1.3256870	0.1878
agej uv: sexmale	0.4430462	0.4765132	104	0.9297670	0.3546

#### 4) Variation between habitats in the morphological characteristics of migratory Robins.

We tested for differences between habitats (shrublands vs. woodlands) in the development of flight morphology (PC1), structural size (PC2), wing concavity (PC1\*) and wingtip shape (PC2\*) in the 110 migratory Robins wintering in Campo de Gibraltar. For this purpose, we performed Linear Mixed Models that analysed these variables (PC1, PC2, PC1\* and PC2\*) in relation to age, sex, habitat and their two-way interaction as fixed effects, and year as a random effect factor. Results for each morphological trait are shown below:

##### a. Results for the analysis of the development of flight morphology (PC1)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 0.2837229 1.165277

Fixed effects: PC1 ~ 1 + age + sex + habitat + age:sex + age:habitat + sex:habitat

	Value	Std. Error	DF	t-value	p-value
(Intercept)	-0.2459673	0.3172294	102	-0.775361	0.4399
agejuv	-0.5399119	0.3287123	102	-1.642506	0.1036
sexmale	2.2172294	0.3971552	102	5.582779	0.0000
habitatwoods	0.3647179	0.3869094	102	0.942644	0.3481
agejuv:sexmale	0.0185935	0.4786796	102	0.038843	0.9691
agejuv:habitatwoods	-0.0456698	0.4580340	102	-0.099708	0.9208
sexmale:habitatwoods	0.0424203	0.4856511	102	0.087347	0.9306

##### b. Results for the analysis of structural size (PC2)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 0.208793 0.9857652

Fixed effects: PC2 ~ 1 + age + sex + habitat + age:sex + age:habitat + sex:habitat

	Value	Std. Error	DF	t-value	p-value
(Intercept)	-0.0693375	0.2549520	102	-0.2719629	0.7862
agejuv	-0.1322375	0.2780068	102	-0.4756629	0.6353
sexmale	-0.3574871	0.3359634	102	-1.0640654	0.2898
habitatwoods	0.1660262	0.3268262	102	0.5079955	0.6126
agejuv:sexmale	-0.2513887	0.4049097	102	-0.6208513	0.5361
agejuv:habitatwoods	0.0450224	0.3874730	102	0.1161950	0.9077
sexmale:habitatwoods	0.5243292	0.4103784	102	1.2776723	0.2043

##### c. Results for the analysis of wing concavity (PC1\*)

Random effects:

Formula: ~1 | year  
(Intercept) Residual  
StdDev: 8.372387e-05 1.91513

Fixed effects: PC3 ~ 1 + age + sex + habitat + age:sex + age:habitat + sex:habitat

	Value	Std. Error	DF	t-value	p-value
(Intercept)	0.5157192	0.4032550	102	1.2788909	0.2038
agejuv	0.0345225	0.5385727	102	0.0641000	0.9490
sexmale	0.8177916	0.6524814	102	1.2533562	0.2129
habitatwoods	-0.5718823	0.6239014	102	-0.9166229	0.3615
agejuv:sexmale	-0.6104467	0.7859893	102	-0.7766603	0.4392
agejuv:habitatwoods	0.6424007	0.7527642	102	0.8533890	0.3954
sexmale:habitatwoods	-1.2695223	0.7867493	102	-1.6136301	0.1097

**d.** Results for the analysis of wingtip shape (PC2\*)

Random effects:

Formula: ~1 | year

(Intercept) Residual

StdDev: 5.203198e-05 1.134659

Fixed effects: PC4 ~ 1 + age + sex + habitat + age:sex + age:habitat + sex:habitat

	Value	Std. Error	DF	t-value	p-value
(Intercept)	-0.4735655	0.2389170	102	-1.9821345	0.0502
agejuv	1.0008093	0.3190888	102	3.1364604	0.0022
sexmale	-0.5688229	0.3865764	102	-1.4714371	0.1443
habitatwoods	0.9235074	0.3696436	102	2.4983727	0.0141
agejuv:sexmale	0.3570352	0.4656760	102	0.7667031	0.4450
agejuv:habitatwoods	-0.5383149	0.4459910	102	-1.2070084	0.2302
sexmale:habitatwoods	0.1293235	0.4661262	102	0.2774430	0.7820