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Biometric differentiation of breeding and non-breeding Song Thrushes at the southwestern limit of their distributional range

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ABSTRACT
The migratory behaviour of European Song Thrush (*Turdus philomelos*) populations ranges from resident in the south and west to partly or totally migratory in northern, central and eastern Europe. This varied migratory behaviour could be reflected in morphological adaptations, with migrants having a proportionally longer wing, lower tail:wing ratio, and, if foraging more on fruits, deeper and wider bills. We used data from Song Thrushes captured during the breeding season and in winter in northern Iberia to test for morphological variations between these two periods. In three consecutive years (2014–16), Song Thrushes were captured with mist nests in a region of southern Navarra (Spain) during the breeding season (from May to July) or in the winter period (October to February), during a period of four hours starting at dawn per sampling day. We consider the winter population to be composed of a high proportion of visitors. Breeding Song Thrushes showed proportionally longer tails for given wing lengths, even though wing length did not vary between the two periods. Moreover, winter visitors showed narrower and less deep bills than breeding Song Thrushes. Potential explanations for these results are discussed.

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Migration is one of the main evolutionary drivers shaping morphology in birds (Mönkkönen 1995, Berthold 1996). In general, migrant birds show a proportionally longer, more pointed wing than residents (e.g. Calmaestra & Moreno 2001). In fully migratory birds, those moving longer distances show more pronounced migratory characteristics than those making shorter displacements, a phenomenon that has been observed both between and within species (Lockwood *et al* 1998, Arizaga *et al* 2006, Förschler & Bairlein 2010, Arizaga & Barba 2011). Specifically, tail:wing ratio has been shown at least in some species to decrease with increasing migratory distance (Fiedler 2005); thus migrants can have proportionally longer wings for given tail lengths, or shorter tails for given wing lengths, than resident or less migratory populations.

Adaptation to migration can influence other morphological traits as well as the flight apparatus. Avian migrants often need large fuel reserves to complete their long bouts of flight and so must consume large amounts of energy-rich food in short time periods (Alerstam & Lindström 1990). Frugivory is considered to be an adaptation to such requirements (Bairlein 2002, Newton 2008), as it exploits a food source that, although patchily distributed (Tellería & Pérez-Tris 2007), can be very abundant at a local level and allows rapid weight increases at stopover sites. Many insectivorous birds become total or partly frugivorous during the migration period (Cramp 1988, 1992). If migrants develop a feeding apparatus more adapted to foraging on fruits, they should be expected to have deeper, wider bills than those birds that would feed more on invertebrates (Tellería & Carbonell 1999, Navarrete & Cuenca 2016).

The Song Thrush (*Turdus philomelos*) is one of the most common Palaearctic passerines, well distributed across much of Europe (including Britain and Ireland), and into central Asia (Cramp 1988). The migratory behaviour of European populations ranges from resident in the south and west to partly or totally migratory in northern, central and eastern regions (Cramp 1988, Milwright 2006). This varied migratory behaviour could be reflected in morphological adaptations, with migrants having a proportionately longer mean wing length and, if foraging more on fruits, a deeper and wider bill.

Iberia hosts resident Song Thrush populations as well as populations that arrive in winter from a broad range of northern Europe (Tellería *et al* 1999). We

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used data from Song Thrushes captured during the breeding and winter periods in an area of northern Iberia to test whether winter visitors have a lower tail: wing ratio than residents, or a different bill morphology.

Methods

This study was carried out over three consecutive years (2014–16) at a number of sampling sites in southern Navarra, northeastern Spain. The climate in this area is meso-Mediterranean, with mean annual precipitation of 400 mm, and a mean annual temperature of 12°C. The habitat at the study sites consisted chiefly of a cultivated mosaic of olive crops, almond tree groves, vineyards and cereals, with small patches of natural vegetation. Natural vegetation comprised oaks *Quercus* spp, rose bushes *Rosa* spp, *Juniperus oxycedrus*, rosemary *Rosmarinus officinalis*, and a riparian forest dominated by poplars *Populus* spp.

Song Thrushes breeding in Navarra, and in the sampling area in particular, are resident (DV pers obs), though post-breeding dispersal or even displacement (or perhaps true migration) to milder areas in southern Spain cannot be discounted (Tellería *et al* 1999).

Song Thrushes were captured with mist nests from May to July (breeding season) or from October to February (winter period), during a period of four hours starting at dawn. We used sound lures to increase the captures of birds in active nocturnal migration (Aranguren *et al* 2009). Once captured, Song Thrushes were ringed and aged (according to Svensson 1996) and a number of morphological measures were recorded: wing length (method III of Svensson 1996; to the nearest 0.5 mm), tail length (0.5 mm), length of the 8th primary feather (numbered descendently, 0.5 mm), tarsus length (0.2 mm) and bill length, width and depth (0.2 mm). Furthermore, thrushes caught as breeders were sexed, when possible, by looking for signs of active breeding such as a brood patch in females or a cloacal protuberance in males. All measurements were made by the same ringer (DV).

We selected for the analyses only birds aged as adults and with all measurements recorded, to avoid the differences associated with age classes that have been shown in other thrushes (Sim & Graham 2003).

We conducted a *t*-test for each variable in order to compare characteristics between the two seasons, breeding and winter. As well as the seven variables listed above, we included tail:wing ratio as a compound variable. Additionally, we also ran *t*-tests to check whether there were differences between sex classes. For this purpose we used only the subset of breeding thrushes where the sex had been determined (six males and four females).

All analyses were made using R (R Core Team 2014).

Table 1. Mean ± sd for the biometric variables of Song Thrushes caught during the breeding and winter periods in Navarra (mm). Means of the two samples were compared with a *t*-test (significant *P* values are in bold).

Variable	Breeding (n = 11)	Winter (n = 91)	*t*	*P*
Wing length	119.0 ± 3.4	118.6 ± 2.9	0.137	0.893
Tail length	84.5 ± 4.2	81.1 ± 3.5	2.547	**0.026**
Tail:wing ratio	0.71 ± 0.04	0.68 ± 0.03	2.389	**0.035**
P3 length	88.5 ± 2.5	89.1 ± 2.4	0.727	0.481
Tarsus length	32.8 ± 1.0	32.8 ± 1.3	0.137	0.893
Head length	46.9 ± 1.2	47.7 ± 3.2	1.688	0.101
Bill length	22.1 ± 1.1	22.1 ± 1.3	0.001	0.999
Bill width	7.3 ± 1.4	5.4 ± 0.8	4.367	**0.001**
Bill depth	6.4 ± 0.6	6.0 ± 0.5	2.564	**0.025**

Results

Single-variable analyses revealed significant differences for only four variables (tail length, tail:wing ratio, bill width and bill depth; Table 1). Breeding Song Thrushes showed longer tails, higher tail:wing ratios and wider, deeper bills than birds captured during the winter period.

Breeding Song Thrushes did not show any significant morphological differences between sex classes (all *P* values > 0.05).

Discussion

We believe that this is the first study comparing morphological variation between Song Thrushes captured during the breeding and winter periods in Iberia. Even though the sample sizes were small, especially for the breeding season, our results are consistent with the existence of differences between the two samples, in line with the idea that the morphology of those birds captured during the winter period showed adaptations to migration, in particular a lower tail:wing ratio. Sexes were pooled for the analyses, though biased sex ratios between the breeding and non-breeding birds could cause a misinterpretation of these results given that there might be biometric variation between the sexes. However, although our analyses must be interpreted with caution due to the low sample sizes, we found no evidence supporting such differences between sexes.

Breeding Song Thrushes showed proportionately longer tails for given wing lengths, even though wing length did not vary between the breeding and winter periods. Thus, rather than winter visitors (i.e. migrants) having a longer wing, it can be concluded that in this case the relatively shorter tail may be an adaptation to migration. Longer tails might facilitate manoeuvrability (Thomas & Balmford 1995, Clark & Dudley 2009), but hamper flight performance in long-distance displacements (being energetically costly; Evans & Thomas 1992) and impair predator evasion (Thomas 1996, Fitzpatrick 1999). Even though the winter Song Thrushes captured in Navarra have a very broad potential range of origin, from France to Scandinavia and the eastern European countries (Santos 1982), it is true that these migratory birds have longer migration distances overall than those breeding in Navarra. Overall, our results may be in agreement with other studies where populations with longer migration distances were observed to have lower tail: wing ratios (Fiedler 2005).

We also found that winter visitors showed narrower, less deep bills than breeding Song Thrushes. Within Iberia, Tellería & Carbonell (1999) observed that southern resident Blackcap (*Sylvia atricapilla*) populations, which eat more fruit, showed deeper and wider bills than the northern, migratory populations. Thus, our results may be in agreement with the idea that southern Song Thrushes were more specialised foragers on fruits, whilst northern birds might be more adapted to feed on invertebrates (Tellería & Carbonell 1999). But this is just a possible explanation that should be tested by further study, since bill morphology can also vary within individuals across the season, for example through wear (Gosler 1987).

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