Construction materials reveal nest building behaviour in the European Robin (*Erithacus rubecula*)

Aina Taberner Cerezo[1*] and D. Charles Deeming[2]

[1]Departamento de Microbiología y Ecología, Facultad de Biología, Universidad de Valencia, c/ Dr Moliner 50, 46185 Burjassot, Valencia, Spain; [2]School of Life Sciences, University of Lincoln, Joseph Banks Laboratories, Green Lane, Lincoln, LN6 7DL, UK

*Corresponding author: email: aitace@alumni.uv.es

Abstract

The various roles that birds' nests play are widely discussed and there is increasing interest in developing a better understanding of how they achieve these roles. The insulatory properties of nests have been investigated in a variety of songbird species and in some instances have been shown to relate to temperature and latitudinal variations. However, data are not available for a wide range of species. Here, we study the variations of the insulatory properties of European Robin nests in conjunction with the morphology and composition of materials. As well as describing these nests for the first time, we test the hypothesis that there is a latitudinal effect on nest insulation. Robin nests have a cup structure that is quite distinct, and easily separated, from the nest base. Although the cup and nest base shared similar construction materials discriminant analysis showed that they can be distinguished on the basis of their differing proportions of leaves. Unlike other songbirds of comparable size that nest in nestboxes, European Robins appear to be able to use plant-derived materials rather than animal-derived materials to effectively insulate their nests.

1. INTRODUCTION

Over recent years there has been considerable interest in the functional properties of bird nests. This interest has considered the various roles of nests (Moreno, 2012; Mainwaring *et al.*, 2014a; Deeming and Mainwaring 2015) as well as quantitative analysis of materials used in construction, which can be used to distinguish nests between species (Britt and Deeming, 2011; Crossman *et al.*, 2011; Biddle *et al.*, 2015, 2016). Moreover, there are significant relationships between environmental conditions and nest composition with individuals of species nesting in colder, high latitude environments building better insulated nests (Crossman *et al.*, 2011; Britt and Deeming, 2011; Mainwaring *et al.*, 2012, 2014b; Deeming *et al.*, 2012). It is becoming increasingly clear that there is intraspecific plasticity in nest construction (Walsh *et al.*, 2010, 2011; Britt and Deeming, 2011; Mainwaring *et al.*, 2014b; Biddle *et al.*, 2015) and that birds can make an assessment of the mechanical properties of nest materials used during construction (Bailey *et al.*, 2014a; Biddle *et al.*, 2015, 2016). Whilst, in general terms it is known that nest structure varies between species (Ferguson-Lees *et al.*, 2011), there are relatively few species where quantitative data exist for nest materials (reviewed by Deeming and Mainwaring, 2015). This situation hampers development of a broader understanding of nest construction and function across species and research is needed for a wider range of species in order to gauge the degree of inter-specific variability in nest construction behaviour.

This study investigated the materials used in nests of the European Robin (*Erithacus rubecula*) with particular reference to their role in determining the insulation afforded by the wall structure. As well as providing data on a previously unstudied species we tested the hypothesis that latitude would affect insulatory properties (Mainwaring *et al*., 2012, 2014b) and investigated whether these characteristics correlated with any particular construction material, as has been shown to be case in Common Blackbird (*Turdus merula*) nests (Mainwaring *et al*., 2014b). Here we report the results of analysis of a sample of nests collected from a variety of locations in Great Britain and we report the insulatory values of the whole nest, which was then deconstructed to its component parts. We tested the hypotheses that insulatory values would reflect 1) geographical location, and 2) particular nesting materials.

2. METHODS

Twelve nests of European robin (*Erithacus rubecula*) were collected after nest abandonment at the end of the breeding season over several years from various locations in United Kingdom (Table 1). Dates of nest construction varied, as well as nest location and nest site (Table 1). All nests were frozen at -20°C for at least 4 days in order to kill any biting invertebrates present within the nests before being stored dry wrapped in plastic bags within cardboard boxes at room temperature (20–22ºC) prior to investigation.

Nests were placed in a controlled condition environment chamber (Sanyo MLR- 351H, Osaka, Japan) set at 23°C and 50% humidity for a minimum of 7 days (following McGowan *et al.* 2004; Mainwaring *et al.* 2012) before the insulatory properties were measured in a room at 20°C using iButton® (Maxim: DS1922L) temperature loggers. Two temperature loggers were heated to 80ºC in a water bath prior to one being introduced into the base of the nest cup so that it was enclosed by the materials (Figure 1). The second temperature logger was placed 19 cm away on an adjacent hard surface alongside the nest and at the same height as the temperature logger within the nest. The temperature loggers were left to cool for 35 min, while they automatically recorded the temperature every 20 seconds.

Cooling rates were obtained for each nest by fitting the empirical temperature data to logistic models (see McGowan *et al.* 2004; Mainwaring *et al.* 2012, 2014b). The nest insulatory property of the nest was calculated as the difference in cooling rates (c) of the temperature loggers placed within the nest or alongside; a large positive difference indicated high nest wall insulation (following McGowan *et al.* 2004; Mainwaring *et al.* 2012, 2014b). The insulatory property of all nests was quantified three times, with the temperature loggers placed in the same place each time, and the mean of the three scores was used in the analyses.

Five aspects of nest morphology (illustrated in Figure 1) were recorded using digital callipers (± 0.5 mm): external nest diameter (cm) was the averaged maximal and minimal diameters of the whole nest. External nest height (cm) was the averaged maximal and minimal height. Nest wall thickness (cm) was obtained by averaging eight measurements reflecting nominal compass positions on the nest as viewed from above: north, north-east, east, south-east, south, south-west, west, and north-west. Nest-cup diameter (cm) was the average of the internal minimal and maximal diameters of the nest-cup. Nest-cup depth (cm) was the maximal internal depth. Volume of the nest cup was determined by lining the cup with domestic cling film and then filling the space with 4.76 mm diameter acrylic beads which were then weighed (Biddle *et al.* 2015). Using a previously established calibration curve between mass and volume, we calculated obtained the volume (cm^3) from the mass of the beads. This procedure was repeated three times per nest and the volume values averaged for each nest (Biddle *et al.* 2015).

The lining of the cup formed a definable structure, the 'cup structure', that could be easily separated from the walls and base of the nest, *i.e.* the 'nest base' (see Figure 1). Both parts were weighed on an electronic balance (Sartorius CP3202s, Goettingen, Germany) to the nearest 0.05 g before the nests were deconstructed and separated into the component parts, which were categorised according to the materials used and weighed to the nearest 0.05 g (Britt and Deeming, 2011; Mainwaring *et al*. 2014b). All measurements were taken by one observer (ATC) to minimise error due to inter-observer variability. All dust was recorded (Britt and Deeming, 2011) and there was a category called 'others', which represented the small fragments from materials and artificial materials that could not easily and confidently be partitioned into the other material categories.

Data were analysed using the SPSS 21.0 statistical package (IBM Corp., NY). Data were tested for normality using the Kolmonov-Smirnoff test prior to analysis. Comparisons of structural dimensions and relationships with insulatory or geographical parameters were made using Pearson correlations depending on the normality of the samples. A Bonferroni correction was applied to results of correlational analysis, which reduced the significance level to 0.002. Data was converted to proportion values and normalized using the arcsin transformation before using discriminant analysis to determine whether the nest base and cup structure could be distinguished by their composition.

3. RESULTS

Mean mass of intact Robin nests 28.8 g with the nest base forming on average ~82% of the mass with the rest being associated with the cup (Table 2). The nests were twice as wide as they were deep with average wall thicknesses of 3.4 cm (Table 2). A similar proportion was shown for cup diameter to depth and its volume averaged 68.4 cm³ (Table 2). The insulatory properties of the nests averaged $0.054°C·20s^{-1}$ (Table 2). In general variation between mass and nest dimensions was large (% coefficient of variation was highest for cup mass and smallest for nest diameter).

The types and masses of materials found in the nest base and the cup are shown in Figure 2. The only animal-derived materials were long hairs, most likely from horses (or humans), which predominately found within the cup (Figure 2). The rest of the nest was constructed of plant-derived materials including: moss, grass, leaves, which formed the bulk of the nests (Figure 2). In addition there were smaller amounts of twigs, conifer (mostly cypress leaves and a few pine needles), and lint (mainly from plants but also a little artificial material). Dust was found in all nests whereas a few nests had small amounts of mud.

Conversion of data to percentages (Figure 3) reduced the effect of absolute mass allowing us to determine where there relative differences between the 'nest base' and the 'cup structure'. There was relatively more grass in the cup and more moss and leaves in the nest base (Figure 3). Stepwise discriminant analysis of transformed data showed that only leaves and moss had a significantly higher percentages (leaves: $\lambda = 0.891$, $F_{1,22} = 5.732$, $P = 0.026$; moss: $\lambda = 0.793$, $F_{1,21} = 6.305$, $P = 0.007$) in the 'nest base' relative to the 'cup structure'. No other materials exhibited a significant discriminant effect for 'cup structure' against the 'nest base'.

For structural variables, insulatory properties showed no significant correlation with any of the linear dimensions of the nests. The insulatory property of the whole nest exhibited a positive correlation with the leaves present in the 'cup structure' (Pearson's Rho = 0.600, df = 10, P = 0.039) but this was not significant under the Bonferroni correction. There was no correlation with leaves present in the 'nest base'. There were no other significant correlations with any other material type.

Latitude of nest construction showed no significant correlation with either insulatory property or with any structural variable. For the materials present in the nest, there was a positive correlation between latitude and the amount of grass present in the 'cup structure' (Pearson's Rho = 0.650, df = 10, P = 0.022) but this was not significant under the Bonferroni correction. No other associations were significant.

4. DISCUSSION

European Robins construct nests with mainly plant-derived materials with only a limited amount of animal-derived material, which is limited to the cup. The cup and nest base were distinctively different structures and were made of differing proportions of the various materials. There was a suggestion that insulatory property of the nests correlated with the mass of leaves in the cup rather than the nest base.

The dimensions of the Robin nests are comparable to previously published data (Cramp, 1988). Variability in dimensions was much greater in the nest base rather than the cup, which reflects the fact that the cup dimensions will more closely reflect the size of the bird that will sit within it (Deeming, 2012). The nest base is more variable because it is less constrained by the physical dimensions of the bird. The mass of the nest was on average approximately twice the mass of the average mass of female Robins (Cramp, 1988) and repeats the pattern seen in tits and Common Blackbirds where nest mass is much heavier than the bird that builds it (Deeming and Mainwaring, 2015).

Robins nest in enclosed areas or within open-fronted nestboxes and so are intermediate between cavity nesting species like tits (Paridae) and those songbirds nesting in more open situations. The materials used in the nests were similar to other small songbirds with moss, grass and leaves often forming a significant part of the nest (see Deeming and Mainwaring, 2015) but animal-derived material was a minor part of the Robin nests and was restricted to the cup. Møller (1984) suggested that the use of feathers was more prevalent in cavity-nesting species but did not collect data on other animal derived materials. Animal-derived materials, *i.e.* hair, fur, wool, feathers, are commonly a significant proportion of nests of cavity-nesting species but are much less prevalent in open-nesting species (see Deeming and Mainwaring, 2015). The reason for this difference is not clear for although animal-derived materials have higher insulatory properties than plant-derived materials (Hilton *et al*., 2004) in Robin nests these materials are generally physically separated and buffered from extremes in the environment by the walls of the surrounding nestbox structure. Despite being a cavity-nesting species Robins seem to err towards using a range of materials more typically found in the open-nesting situation. The reasons for this pattern are not clear. It is possible that cavity-nesters actively select animal-derived materials – Blue Tits (*Cyanistes caeruleus*) seem to prefer feathers whereas Great Tits (*Parus major*) seem to prefer fur or wool (Britt and Deeming, 2011) – or open-nesting species may actively avoid these materials, perhaps because the materials would perhaps make a nest more conspicuous. This situation will only be resolved by further data collection to quantify the materials used in a much wider range of species.

Studies investigating the cognitive processes underlying nest construction suggest that captive Zebra Finches (*Taeniopygia guttata*) have an appreciation of physical characteristics of the materials they use in their nests (Bailey *et al*., 2014a, 2014b). Moreover, studies that deconstruct nests have shown that the characteristics of the various materials in different parts of the nest provide an indirect insight into the decisions made by birds during nets building. For instance, Common Blackbirds have an outer scaffolding layer, a mud cup and a layer lining this cup, which indicates a chronological awareness of the types of materials used in the various parts of nests (Biddle et al., 2015). Robins certainly change behaviour in nets building to produce a physically distinct cup structure that contains different materials to the nest base. Unfortunately, detailed descriptions of nest construction are relatively rare (Healey *et al*., 2015) and so it is hard to relate the structural and compositional differences seen in nests to the behaviours that produced the finished structure. There is an urgent need to have a more systematic approach to the study of nest-building behaviours which can be related to the materials used.

The average insulatory value for the Robin nests was towards the higher end of the range exhibited by nests of other small songbirds (see Deeming and Mainwaring, 2015; Deeming and Gray, 2016). The insulatory value for Robin nests was correlated with the mass of leaves, but not hair, in the nest cup, which contrasts with the results of Hilton *et al.* (2004) showed that grass had poorer insulatory properties than animal-derived materials. However, in Common Blackbird nests grass showed a strong positive correlation with nest insulation (Mainwaring *et al*., 2014b). Unfortunately, factors affecting the variability between species have yet to be explored in any great detail, largely because of the lack of data from a range of species. Deeming and Biddle (2015) showed that vacuum-packing nests to remove air trapped within the walls significantly reduced the insulatory values of the nests but by only about 20% on average for four different species. Biddle *et al.* (2015) showed that air gaps may be an important part of Bullfinch nests because they may allow convection currents through the walls. In Robin nests the presence of leaves may have trapped air, which acted in part as nest insulation but whether this idea is correct requires further investigation. Attentiveness during incubation, including these data for Robins, seems to correlate with insulatory value (Deeming and Gray, 2016) and suggests that nest construction plays a role in nest insulation. However, the lack of a clear effect of nesting material or latitude in our study suggests that we need to have more information before we can confidently conclude how nest construction affects nest insulation in European Robins.

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Table 1. Geographical location and other information about the nests used in this study. Latitude was obtained from Ordnance Survey grid references.

Nest code	Date of collection	Date first seen	Location	Latitude °N	Site	Fledging success
R1	05/07/07	22/05/07	Little Shelford	52.144.458	Wall	4 chicks
R2	29/06/07	17/02/07	Alcester	52.220.146	Nest Box	None
R3	24/08/14	09/07/14	Doncaster	53.481.079	Nest Box	6 chicks
R4	05/07/07	16/06/07	Great Shelford	52.146.123	Conifer tree	4 chicks
R7	18/08/07	12/05/07	Little Shelford	52.140.838	On ground	5 chicks
R8	16/07/07	27/06/07	Great Shelford	52.151.275	On ledge	4 chicks
R9	28/06/14	13/06/14	Suffolk	52.088.654	Bush	5 chicks
R11	30/06/14	Unknown	Leicestershire	52.670.897	On ground	None
R12	06/06/14	18/03/14	Plymouth	50.448.677	Hole in wall	4 chicks
R15	2009	15/07/09	Lillington	52.303.722	Hedgerow	5 chicks
R17	2007	19/04/07	Riseholme	53.270.127	Beech roots	None
R18	2014	Unknown	Hebburn	54.972.283	Unknown	None

Table 2. Mean, standard deviations, and range of structural variables and the insulatory property of the intact European Robin nests (N = 12).

Variable	**Mean**	**SD**	**Range**
Total nest mass (g)	28.8	10.8	16.2 – 50.6
Nest base mass (g)	23.7	9.6	11.8 – 37.0
Cup structure mass (g)	5.2	3.0	2.4 – 13.5
Nest height (cm)	5.9	1.4	3.8 – 8.0
Nest diameter (cm)	13.3	1.5	10.8 – 15.0
Nest wall thickness (cm)	3.4	0.6	2.7 – 4.6
Cup depth (cm)	2.9	1.0	1.1 – 4.9
Cup diameter (cm)	6.6	1.3	4.5 – 8.3
Cup volume (cm^3)	68.4	29.8	29.4 – 137.8
Insulatory property ($^{o}C \cdot 20s^{-1}$)	0.054	0.005	0.046 – 0.061

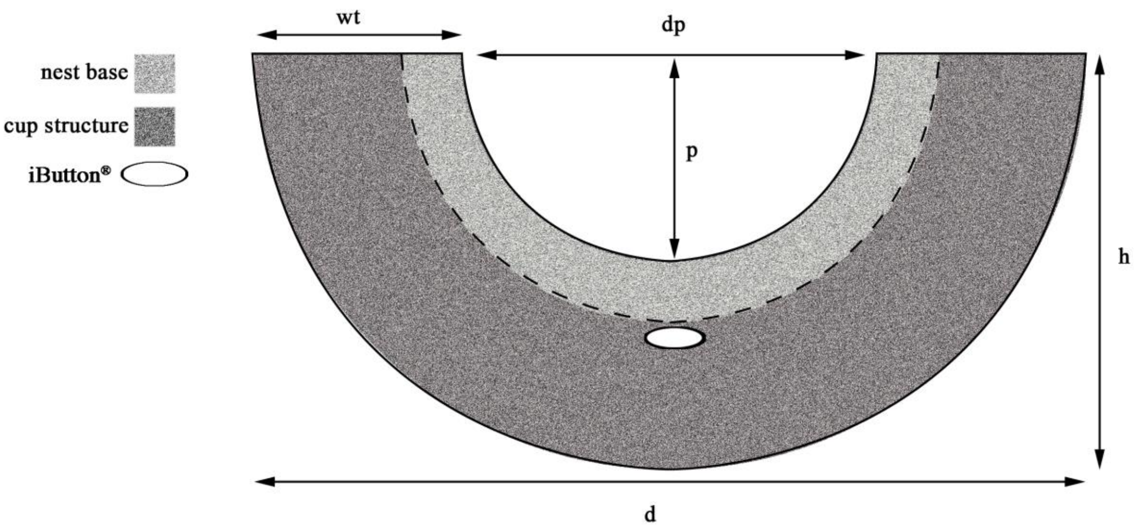

Figure 1. Sketch of a European Robin nest in section showing the linear variables measured in the nest structure together with the position of the *i*Button® (white oval) within the nest. Key: d = nest diameter; dp = cup diameter; h = nest height; p = cup depth; and wt = wall thickness.

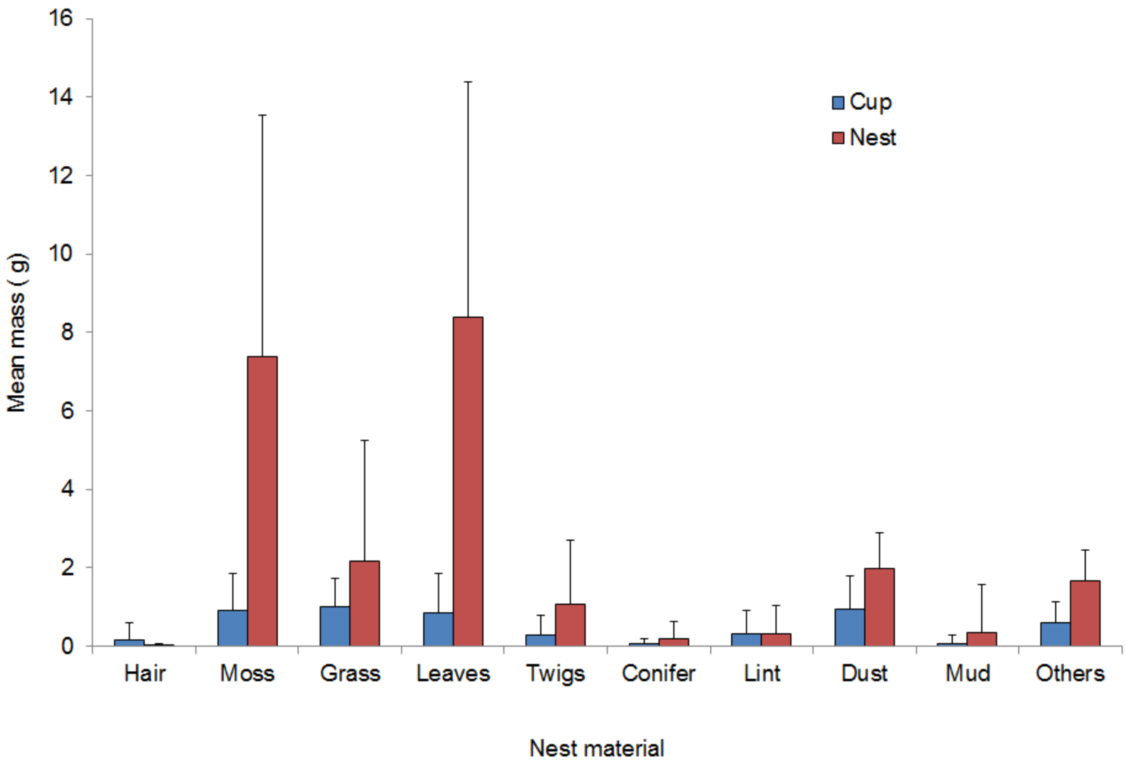

Figure 2. Mean (+SD) mass (g) of the various materials present in ‘cup material’ (blue columns) and in the ‘base nest’ (red columns).

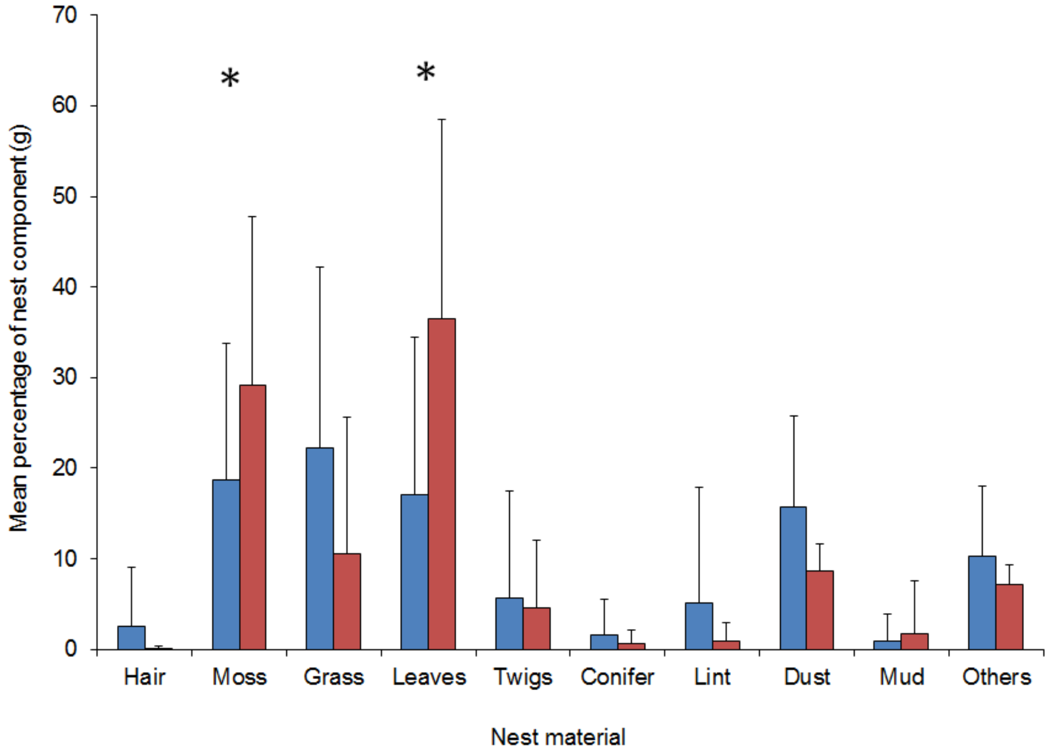

Figure 3. Mean (+SD) of the percentage that each type of material present in 'cup material' (blue columns) and in 'base nest' (red columns) formed or the total nest mass. The asterisks mark the significant differences identified by the discriminant analysis (p = 0.018).