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Notas Breves

WOODCRETE NESTBOXES: ARE THEY ADEQUATE FOR MULTIBROODED SPECIES?

NIDALES DE CEMENTO: ¿SON ADECUADOS PARA ESPECIES CON NIDADA MÚLTIPLE?

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Summary.—Higher temperatures are found in the interior of woodcrete nest boxes than in wooden ones and this supposes benefits for the birds which breed in these, especially at the beginning of the breeding season. Nevertheless, this advantage could be reflected in energetic costs (thermal stress, hyperthermia) in the case of species where the breeding season is prolonged during several months, particularly in hot regions such as the Mediterranean basin. In this study we examined the existing differences between woodcrete and wooden nest boxes with regard to the microclimate of the nest and the reproductive parameters of the tree sparrow, a multi-nesting species (three clutches from April until the beginning of August). Larger clutches and chicks with a smaller body mass were found in the woodcrete nests, this latter probably due to a greater transpiration rate to counteract higher temperatures. Nevertheless, there was no difference between breeding success between box types. The results suggest that, considering a full breeding season, the virtues of woodcrete nest boxes outweigh the inconveniences and account for its great acceptance in the colony.

Resumen.—En el interior de los nidales de cemento se alcanzan temperaturas más elevadas que en los de madera y esto puede suponer beneficios para las aves que crían en ellos, especialmente al comienzo de la época de cría. Sin embargo, esta ventaja podría revertir en costes en términos energéticos (estrés térmico, hipertermia) en el caso de aquellas especies cuyo período reproductor se prolonga durante varios meses, particularmente en regiones cálidas como la cuenca Mediterránea. En este estudio se abordan las diferencias existentes entre nidales de cemento y nidales de madera en cuanto a microclima del nido y parámetros reproductivos de una especie con nidada múltiple (tres puestas, desde abril hasta comienzos de agosto), el gorrión molinero. Se encontraron puestas más grandes y pollos con menor masa corporal en los nidales de cemento, esto último probablemente debido a una

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mayor tasa de transpiración para hacer frente a las altas temperaturas. Sin embargo, el éxito reproductor no difirió entre ambos modelos. Los resultados sugieren que, aún considerando una estación de cría completa, las virtudes de los nidales de cemento compensan sus inconvenientes y de ahí su gran aceptación dentro de la colonia.

The thermal environment of the nest can have a strong influence on breeding constraints of parents and offspring development in hole-nesting birds. It has been suggested that ambient temperature could acts as a trigger to fine-tune the onset of egg-laying (short-term effect *sensu* Perrins and McCleery, 1989) and thus, a slight increase in nest temperature could lead to earlier clutches (e.g. O'Connor, 1978) and fewer interruptions in laying (Yom-Tov and Wright, 1993). Nest microclimate also affects egg viability (Webb, 1987), incubation behaviour of parents (e.g. Conway and Martin, 2000) and energy budgets of nestlings (e. g. Dawson *et al*., 2005). For these latter, the thermal environment of the nest is crucial since altricial young, newly hatched, respond to changes in ambient temperature as do ectotherms. After nestlings begin to thermoregulate on their own (4 - 6 d old) they must face a trade-off between investing in thermoregulation or growth. On basis of the former, it is evident that factors as nest orientation (e.g. Ardia, *et al*. 2006) or insulation properties of natural cavities and nestboxes (Wiebe, 2001) could play an important role in the development of the breeding performance.

Elsewhere (García-Navas *et al.*, 2008a) we have presented evidence that tree sparrows (*Passer montanus*) prefer woodcrete nestboxes than wood and this could be explained on basis of thermal advantages that woodcrete boxes confer to birds at the beginning of the reproductive period when these small birds are subjected to high energetic demands (e.g. Perrins, 1970). In the above mentioned study we found that woodcrete nestboxes reached temperatures 1.5 ºC higher on average than those of the wooden ones during the first brood period (mid March- mid May). Considering only the first breeding attempts, we also found that birds that bred in woodcrete nestboxes had earlier clutches, a shorter incubation period and a higher breeding success than birds that nested in wooden boxes. However, benefits derived from thermal properties of woodcrete nestboxes may turn into disadvantages with the advance of the season, especially in southern latitudes (e.g. Mediterranean region) where young are exposed to warm and dry environments which increases the hyperthermia risk (e.g. Belda *et al.*, 1995, Greño *et al.*, 2008). Most of hole-nesting birds that can potentially occupy woodcrete nestboxes (tits *Parus* and *Cyanistes* spp., nuthatches *Sitta* spp., flycatchers *Ficedula* spp., bluebirds *Sialia* spp., redstarts *Phoenicurus* spp. and wrens *Troglodytes troglodytes*) raise one or two broods per season (at the most) and thus, before summer begins young already have left the nest. But what of species which frequently exhibit a long reproductive period? In this study, we address the effect of nestbox type on breeding parameters of a multibrooded species, the tree sparrow *Passer montanus*, breeding in central Spain.

Our study was conducted at the Castilla-La Mancha University campus, located in the surroundings of Toledo (central Spain, 39º 51' N, 04º 01' W), on the north-bank of the Tagus River. The study area covers gardens and undisturbed areas of riverside forest in which there are fifty pairs of nestboxes. Each pair consists of a wooden and woodcrete nestbox (Type 1B, Schwegler) placed in the same tree or a very short distance (< 5 m) from each other and with the same orientation (fig. 1).

FIG. 1.—Nestbox models used in this study. Interior dimensions (breadth × length × height) of the wooden nestboxes are 12 × 11.5 × 16.5 cm. Woodcrete nextboxes have a cylindrical shape with a base radius 11 cm and height 19.5 cm. The thickness of the side wall is 20 and 31 cm for wooden and woodcrete boxes, respectively. Both models have a entrance hole 32 mm in diameter. *[Modelos de caja-nido utilizados en este estudio. Las dimensiones internas (anchura × longitud × altura) de los nidales de madera son 12 × 11,5 × 16,5 cm. Los nidales de cemento tienen forma cilíndrica, con un radio de 11 cm en la base y 19,5 cm de altura. El grosor de las paredes es de 20 y 31 cm en madera y cemento, respectivamente. Ambos modelos tienen un orificio de entrada de 32 mm de diámetro.]*

Since 2002, we have monitored a tree sparrow colony breeding in this nestbox plot (García-Navas *et al.*, 2008a, b). In Spain, this species raises one to three broods per season from April to mid-August (Sánchez-Aguado, 1984; Cordero, 1985). The study described here comprises first, second and third breeding attempts (i.e. the entire breeding season) corresponding to the springs and summers of 2006 and 2007.

By means of frequent inspections, we recorded for each nest the following parameters: laying date (1 = 1 April), clutch size (CS), length of the incubation period, hatching success (proportion of eggs hatched), brood size (BS), and breeding success (proportion of eggs that resulted in fledged young). At the age of 10 days we measured body mass, tarsus and wing length of nestlings. Also, we collected a sample of blood (50 μl) from the brachial vein of each chick for the determination of the haematocrit level (for more details see García-Navas *et al.*, 2008b). Haematocrit, or packed cell volume, can be affected by factors including nutrition and hydration. Increase in haematocrit has been suggested as an adaptive response to enhance oxygen uptake during periods of increased thermogenesis (Saino *et al.*, 1997). Values above 55 % are frequently associated with a decrease in the total volume of the plasma, caused by dehydration (see Fair *et al.*, 2007 and references therein). Therefore, we expected to found higher haematocrit values from nestlings raised in woodcretes nestboxes than those in wooden boxes late in the season.

Microclimate data only were collected for the 2007 breeding season, from 20 March to 7 August (beyond this date only three nests were found containing young). Daily temperature data (mean, maximum, minimum) inside nestboxes were obtained by means of temperature data-loggers (Escort Junior) recording at 1 h intervals. We placed six loggers in the tops of three woodcrete and three wooden nestboxes paired and dispersed over the research area. Nestboxes were emptied and the hole entrance was obstructed with a thin plastic strip to prevent it from being occupied by birds and bats. Nest microclimate data were compared with ambient temperatures recorded at the nearest meteorological station at Toledo, which is 1 km from the study area. Temperature data were divided into two periods: from 20 March to 20 May (the approximate duration of the majority of first broods) and from 21 May to 7 August (time for second and third broods). Since thermal differences between both nestbox types during the first brood period already have been shown in a

previous study (García-Navas *et al*., 2008a) we focussed on the second period of breeding season. Differences in temperature between nestbox types were assessed by means of Student's *t*-tests. We also calculate for each nestbox type the number of readings (hours) that exceeded 37 ºC, the upper critical ambient temperature beyond which activity leads to hyperthermia in house sparrows *Passer domesticus* (Kendeigh, 1969). To test the influence of nestbox type on breeding parameters (clutch size, nestling condition and reproductive success) we used General Linear Models. A total of 214 nests (woodcrete: 1st broods $n = 74$, 2nd broods $n = 60$, 3rd broods $n = 29$; wooden: 1st broods $n = 24$, 2nd broods $n = 17$, 3rd broods $n = 11$) were included in the analyses. Full models included nestbox type (woodcrete, wooden), study year (2006, 2007), breeding attempt (Ba; first, second, third) and its interactions as factors and CS or BS (as necessary) as continuous covariables. The nest location (= pair) was included as random effect. The models reported are de minimum adequate models resulting from a step-down simplification procedure. Statistics for the variable of interest (nestbox type) are shown in all analyses. Degrees of freedom differ between analyses because we did not have all measurements for all birds. To allow the use of parametric tests, hatching success, breeding success and haematocrit level were arcsine square root-transformed. All values are given as means ± SD unless stated otherwise.

Mean (woodcrete: 25.62 ± 4.28, wooden: 23.63 ± 4.10), maximum (woodcrete: 34.78 ± 6.35, wooden: 30.88 ± 5.75) and minimum temperatures (woodcrete: 17.21 ± 2.97, wooden: 16.28 ± 2.95) were significantly higher in woodcrete than in wooden nestboxes (all $P < 0.01$). There was a significant difference between nestbox types in the number of readings that exceeded 37 ºC (woodcrete: 3.46 %, wooden: 1.45 %; $\chi^2 = 25.25$, $P < 0.001$). The thermal difference between woodcrete and wooden boxes increased with increasing ambient temperature as the season progressed (Pearson's correlation; $r = 0.76$, $F_{141} = 1.00$, $P < 0.001$).

Clutch size decreased seasonally and differed significantly between nestbox types being on average larger for the woodcrete model (fig. 2; table 1). The length of the incubation period decreased with clutch size (–0.20 ± 0.07) and was not affected significantly by

TABLE 1

Effects of nestbox type (wooden, woodcrete), study year (2006, 2007) and breeding attempt (first, second and third broods) on main breeding parameters of tree sparrow at Toledo (central Spain). Results from final models are shown.
[Efectos del modelo de nidal (madera, cemento), año de estudio (2006, 2007) y nidada (primeras, segundas y terceras puestas) sobre los parámetros reproductivos del gorrión molinero en Toledo. Se muestran los estadísticos resultantes de los modelos finales.]

	d.f.	F	P
Clutch size			
Nestbox type	1,205	4.60	0.03
Breeding attempt	2,190	4.83	0.009
Length of the incubation period			
Nestbox type	1,199	< 0.01	0.96
Breeding attempt	2,199	7.76	< 0.01
Year	1,199	4.13	0.04
Year × breeding attempt	2,199	14.81	< 0.001
Clutch size	1,199	7.34	0.007
Hatching success			
Nestbox type	1,203	0.04	0.84
Clutch size	1,207	5.78	0.02
Breeding success			
Nestbox type	1,207	0.05	0.82
Breeding attempt	2,193	2.28	0.10
Year	1,202	0.44	0.51
Year × breeding attempt	2,189	4.94	0.008

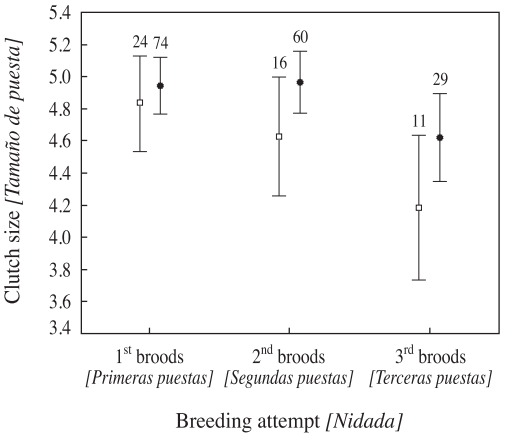

FIG. 2.—Differences in mean clutch size between woodcrete (filled circles) and wooden (open squares) nestboxes considering two entire breeding seasons (2006-2007; first, second and third breeding attempts) for a tree sparrow colony of central Spain. Sample sizes are given above the bars.
[Diferencias en el tamaño medio de puesta entre nidales de cemento (círculos rellenos) y de madera (cuadrados vacíos) considerando dos estaciones de cría completas (2006 - 2007; primeras, segundas y terceras puestas) para una colonia de gorrión molinero del centro de España. Sobre las barras se dan los tamaños de muestra.]

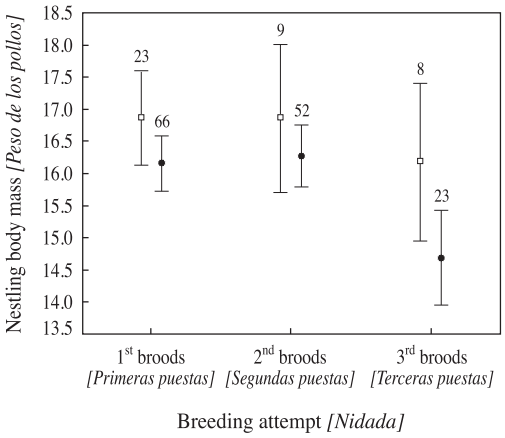

FIG. 3.—Differences in mean nestling body mass (g) between woodcrete (filled circles) and wooden (open squares) nestboxes considering two entire breeding seasons for a tree sparrow colony of central Spain. Sample sizes are given above the bars.
[Diferencias en el peso medio de los pollos (g) entre nidales de cemento (círculos rellenos) y de madera (cuadrados vacíos) considerando dos estaciones de cría completas para una colonia de gorrión molinero del centro de España. Sobre las barras se dan los tamaños de muestra.]

nestbox type (table 1). There was a significant interaction between study year and breeding attempt for this parameter (table 1). Neither hatching success was affected by nestbox type (table 1). Such variable was negatively related to clutch size (–0.08 ± 0.03). Breeding success did not differ significantly between woodcrete and wooden boxes (table 1). However, a significant interaction between study year and breeding attempt was found (table 1). The body mass of nestlings varied between nestbox types (fig. 3; $F_{1,176} = 7.09$, $P < 0.01$) and breeding attempts ($F_{2,160} = 8.35$, $P = 0.001$); nestlings raised in wooden nestboxes were heavier than those in woodcrete boxes even controlling for the tarsus length ($F_{1,162} = 188.71$, $P < 0.001$). Significant differences were not found between woodcrete and wooden nestboxes either in nestling tarsus length (Nestbox type: $F_{1,169,} = 0.64$, $P = 0.42$; Ba: $F_{2,150} = 3.39$, $P = 0.036$), wing length (Final model, all $P > 0.05$) or haematocrit level ($F_{2,144} = 0.08$, $P > 0.5$). Nestling haematocrit varied between years ($F_{1,149} = 16.11$, $P < 0.001$) and decreased with the advance of the breeding season ($F_{2,136} = 22.56$, $P < 0.001$). Also, two-way interactions resulted statistically significant for this variable (Year × Ba: $F_{2,134} = 5.08$, $P < 0.01$, Year × Nestbox type: $F_{2,149} = 7.38$, $P < 0.01$).

As expected, woodcrete nestboxes registered higher temperatures than those of wood and differences in temperature between nestbox types increased during the second and

third brood period due to rise in radiant energy (i.e. daylength and level of incident radiation). Considering the breeding season as a whole, we found that birds bred in woodcrete nestboxes laid more eggs than those did in wooden nestboxes. It is likely that differences in parental quality could be responsible for clutch size variation. Neither length of the incubation period nor hatching success differed between nestbox types. This latter result is interesting since it is know that above 40.5 ºC (upper lethal temperature), embryo malformations develop, and death occurs with prolonged exposure (Lundy, 1969, quoted in Conway and Martin, 2000). The clucthes laid in woodcretes nestboxes were exposed to high temperatures more frequently than that in wooden nestboxes although, in both cases few recordings exceded 37 ºC. Embryo mortality due to exposure of eggs to elevated temperatures together with other factors such as clutch size adjustment (neglect of the last-laid eggs) under adverse conditions (e. g. Lobato *et al*., 2006) or decrease of parental care linked to reduced chances of recruitment of later broods (Stearns, 1992) are assumed as causes for the seasonal decline in hatching success. In addition, the interaction found between study year and breeding attempt on the length of the incubation period and breeding success was due to the adverse weather conditions occurred during the first brood period (April-mid May) of the 2007 breeding season, a very cold and exceptionally rainy spring.

Concerning nestling body condition, neither wing length nor tarsus length differed between nestbox types but the body mass did so. At elevated temperatures, nestlings resort to mechanisms such as panting or evaporative cooling to get rid of excess heat. The ability to dissipate heat by evaporation enables the nestlings to overcome periods of heat stress. The evaporative water loss increases and thus, nestlings lose mass as a consequence of dehydration and consumption of energetic reserves (Mertens 1977, Nager and Wiersma 1996). Our results suggest that nestlings raised in woodcrete nestboxes are forced to evaporate more water to cope with the required heat loss than those raised in wooden nestboxes and therefore exposed to lower temperatures. To this effect also contributes the higher brood size registered inside woodcrete nest-boxes since the internal temperature increases with the number of nestlings. Despite this, breeding success seems to be not affected by nestbox type. That is, productivity (in terms of reproductive success) of woodcrete nestboxes did not suffer late in the season when harsh conditions could jeopardize the survival of offspring. However, it should be noted that nestlings fledged from woodcrete nestboxes were lighter in comparison with those than in wooden boxes. In this sense, several studies have found evidence that post-fledging survival is affected by fledging mass; heavier fledgings have higher recruitment rates than lighter ones (e.g. Tinbergen and Boerlijst, 1990). But this effect seems to be less important under hot temperatures (Greño *et al*., 2008). On the other hand nestling haematocrit level varied significantly between years and contrary to our expectations, a decreasing trend from April to August was found (all values > 50 % corresponded to nestlings from first and second broods). There was no effect of nestbox type on nestling haematocrit values. This said, it is important to point out that the use of haematocrit as an indicator of condition in wild birds has been recently questioned (e.g. Cuervo *et al*., 2006). According to several studies (see Fair *et al.*, 2007 for a review) the relationship between haematocrit and physical condition of birds may only be truly accurate when there is an extreme deviation from normal condition that might be evident by simple visual examination. That being so, the absence of significant differences in nestling haematocrit between woodcrete and wooden nestboxes is not surprising.

It has been shown that certain nestbox types would be not suitable for species whose

breeding period extends into summer, especially in hot and dry environments like those of the Mediterranean region (Tella *et al*., 1994). On basis of data here and elsewhere (García-Navas *et al.*, 2008b) shown, we believe that the principal handicap (overheating) that may offset the advantages of woodcrete nestboxes (reduction of nest predation, durability) with respect to wooden boxes does not to seem to be sufficiently detrimental to advise against its use in species whose breeding period extends for several months. In conclusion, woodcrete nestboxes seem to be the most suitable nestbox type even for multi-brooded species breeding in warm regions such as the tree sparrow.

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