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The thermal properties of some nests of the Eurasian Tree Sparrow *Passer montanus*

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Abstract

Using an electronic apparatus simulating a bird roosting in a nest at night, we examined the insulating qualities of Eurasian Tree Sparrow (*Passer montanus*) nests built in nest boxes under winter conditions. Nests of different construction were compared with an empty box, and with roosting in open air. Energy savings in an empty box accounted for 18%, in boxes with incomplete nests for 23% and in boxes with complete nests up to 36%. The insulating value of nests mostly depended on their completeness and the proportion of feathers in the lining.

Keywords: Nest; Thermal properties; Experiment with artificial simulation; Winter; *Passer montanus*; Eurasian Tree Sparrow

1. Introduction

A critical period for small birds living in a cool climate is survival through long winter nights. Energy savings of even a few percent can influence survival (Houston and McNamara, 1993). Birds can save energy in several ways: (1) by storing food (Andreev, 1980; Pravosudov and Grubb, Jr. 1997; Källander and Smith, 1990), (2) by accumulating fat reserves during the seasonal and daily cycles (Blem, 1976, 1990; Pravosudov and Grubb, 1997), (3) by developing nocturnal hypothermia (Reinertsen, 1983, 1988, 1996), (4) by increasing the insulating properties of the plumage (Steen, 1958; Andreev, 1980; Chaplin, 1982), (5) by forming aggregations at night time (Busse and Olech, 1968; Gavrilov, 1991; Du Plessis and Williams, 1994), and (6) by searching for shelters preventing heat loss (Walsberg, 1985, 1986; Du Plessis et al., 1994).

Previous analyses of the insulation of shelters (tree holes, nest-boxes) focused on comparing the energy savings of birds roosting at night in shelters with those roosting without shelters (Kendeigh, 1961; Buttermer et al., 1987; Ferguson et al., 2002), or by comparing temperature inside and outside shelters (Caccamise and Weathers, 1977; Andreev, 1980; Askins, 1981), or on measuring the effects of wind on temperature in shelters (Buttermer et al., 1987; Du Plessis et al., 1994). Insulation of open nests during the breeding season has been extensively studied (Palmgren and Palmgren, 1939; Ponomareva, 1971; Whittow and Berger, 1977; Walsberg and King, 1978a,b; Skowron and Kern, 1980; Dolnik, 1995), while insulation of nest boxes was examined by Mertens (1977).

However, no information is available on nest insulation from tree holes or nest boxes in relation to the type and moisture of the material used for nest construction, the stage of nest construction, and the number of broods reared. Also, the period of nest construction is important—whether it was built in the period of autumn sexual display

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or in the breeding season, and whether it was placed in an empty box or in a box containing an old nest from the breeding season.

We examined nests of the Eurasian Tree Sparrow (*Passer montanus*). These birds can rear 2–3 broods in a season, and during the autumn display may rebuild the nest they used for breeding, or construct a new one (Pielowski and Pinowski, 1962; Pinowski, 1965, 1966, 1967, 1968). A nest built in autumn can serve as a winter nocturnal roosting site for the pair of Eurasian Tree Sparrows (Pinowski, 1967; Pinowski and Noskov, 1981), and is likely to reduce heat losses on frosty winter nights. If nocturnal roosting in nests contributes to energy savings by Eurasian Tree Sparrows during winter, the autumn display and, despite incurring costs, nest construction in autumn may be promoted by natural selection.

A complete nest of Eurasian Tree Sparrow consists of three layers: a base made of coarse grass stems, a lining of fine grass stems, plant down and feathers forming the nest cup itself, and a dome of coarse stems. The nest is not always covered with a dome, and an incomplete nest may also consist of the base and the dome, but lack a lining. After the breeding season, lining may be destroyed and polluted with faeces of nestlings (Wasylik and Pinowski, 1970). Eurasian Tree Sparrows, unlike, for example, Starlings (*Sturnus vulgaris*) do not remove old nests, but they can make a new lining (Deckert, 1962; Fetisov et al., 1981). Often, a new nest is built upon the old nest in such a way that all the layers of the old nest form the base of the new nest. In the period of autumn sexual display, adult birds often use the sites of their breeding (Pinowski et al., 2006) and repair the old nests in the way described above, whereas young birds, especially those from the second and third broods that attain maturity later, often do not complete their nests but they build only the base, or the base and the lining, or the base and the dome (Pinowski, 1967). If old nests are not removed by man each year, the nest box typically fills up with debris (Pinowski, unpublished observations).

2. Material and methods

An electronic apparatus was used that simulates the presence of a live bird in the nest. A similar method had previously been used by Andreev (1980), who measured energy expenditure in the Siberian Jay *Perisoreus infaustus* roosting at night on a branch, and by Palmgren and Palmgren (1939), who used the rate of heat loss from a bottle filled with warm water as an index of nest insulation. The basic idea of our experiment was to determine the power needed by an electric heater to maintain a steady temperature for an object physically similar to a roosting bird in nests of various construction, in nest boxes under different external conditions. The results should reveal energy savings with respect to the type of the nest in which the bird roosts at night.

When using this method, an obvious requirement is a good simulation of the situation experienced by the Eurasian Tree Sparrow at winter nights. To meet this condition we compared our data with energy budgets of the Eurasian Tree Sparrow in winter published by Nakhodkin (1988).

2.1. Description of nests

One empty nest box and nine Eurasian Tree Sparrow nests built in nest boxes near Warsaw, Poland, were used in this experiment. The boxes selected for the experiment were removed in October or December. Boxes, however, differed in size (Table 1), because a main criterion of the selection was nest structure and history. After measurements, the nests were sized and the weight and number of individual components of nest material, including water content, was determined. Apart from water content, which was similar in all the nests (8–13%), there were many differences in the structure and composition of nest material (Table 1). Thus, these nests differed in their insulation. The base of most nests consisted of plant parts such as stems and spikes of grasses, bracts of lindens, and less often contour feathers. The dome contained similar materials. The lining, with some exceptions (described lower), was made mostly of feathers. Feathers, especially down, effectively reduce heat loss (Wainwright et al., 1976; Andreev, 1980; Møller, 1984; Lombardo et al., 1995; Hansell, 2000). Eurasian Tree Sparrows typically use down in the lining, and sometimes small amounts of contour feathers in the base and dome. In tables, nests are arranged by increasing insulation. Three groups of nests are distinguished, according to some common properties within each group, respectively.

Group A consists of nests nos. 1–4. All these nests, except for nest 4, had no dome, or they had a beginning of it. Nest 1 was built of loose plant material. Nest 3 is an autumn nest made up almost exclusively of contour feathers that formed the base and a thin lining. Other nests of this group were almost without feathers. Nests 2 and 3 contained little material (Table 1).

Group B consists of nests 5 and 6, placed in large boxes, without domes, with very thick base (Table 1).

Group C consists of nests 7–9. Nests 7 and 9 were complete, made up of three layers: the base, lining, and dome. Nest 8 had no dome, but at the back the chamber was partially covered with nest material. All of them contained many feathers (Table 1). Nest 9 had a very thick lining containing felt hair and feathers merging into the base so that they could not be separated, and a dome supplemented in autumn with a thick layer of grasses.

2.2. Description of experiments

Experiments were undertaken at Łomianki–Dąbrowa (52°19′N, 20°53′E) near Warsaw, Poland from November 2004 to February 2005. The experimental nest boxes were attached to a log 1 m long, hanging on a chain. They were

Table 1
Size and composition of studied nests

Nest group	Nest number	Box size[a]	Dome[b]	Lining[b]	Status[c]	Nest height (cm)[d]	Nest depth (cm)[e]	Nest mass (g)	Number of feathers	Mass of feathers (g)
A	1	10 × 12 × 21; 13	–	–	Post-breeding, no success	10	6	215	0	0
	2	10 × 12 × 21; 13	–	–	Post-breeding	6	5	34	40	0.8
	3	10 × 12 × 21; 13	–	–	Autumnal	5	4	33	186	6.1
	4	10 × 12 × 21; 13	+	+	Post-breeding	15	4	306	0	0
B	5	14.5 × 14.5 × 40; 25	–	+	Autumnal	25	5	154	155	6.8
	6	14.5 × 14.5 × 40; 25	–	+	Autumnal (overtopping starling nest)	13	5	251	110	3.4
C	7	10 × 12 × 21; 13	+	++	Post-breeding, renewed	9	5.5	223	250	12.7
	8	13 × 13 × 29; 16	–	++	Autumnal	5	2.5	25	417	16.1
	9	10 × 12 × 21; 13	+	++	Post-breeding, renewed	8[f]	4.5	38	Impossible to count	8.5[g]

[a]Box size: internal diameters of the box: width × length(front-back diameter) × height; distance from bottom to opening; all in cm.
[b]Dome, Lining: – absent, + present, ++ present (rich).
[c]Status: Post-breeding—nest built in breeding season, nestlings reared except of nest no. 1; Autumnal – nest built during autumnal courtship; renewed: nest material added to post-breeding nest during autumnal courtship.
[d]Nest height: from bottom of box to edge of chamber.
[e]Nest depth: from bottom of chamber to edge of chamber.
[f]16 cm to top of dome, in other nests with dome present (nos. 4 and 7.) nest dome closes to box ceiling.
[g]Including hair and plant down, as it was impossible to segregate (see text for details).

placed at a height of about 1.5 m, lower than usual, to facilitate access. As we have had only one set of instruments, the measurements were taken sequentially. We tried to test every nest in various external circumstances.

The measurements were taken with an apparatus constructed specially for this purpose. Its basic component was a heater in the form of a coil made of 0.2 mm thick, enameled manganite wire of 22.4 Ω, practically temperature independent resistance, bifilarly wound on a perspex spool, placed inside a tanned Eurasian Tree Sparrow skin. (Skins were collected according to Ministry of Environment permission no. DoPog-4201-03-205/04/al). Size of the coil was 8 mm × 25 mm, wrapped inside a sheet of aluminum foil additionally filled with heat-conducting grease. The space between the skin and the heater was filled with pieces of aluminum foil, in order to secure good thermal contact between the heater and the skin. An electronic digital thermometer (Maxim Dallas Semiconductors DS 18B20) and a 1 kΩ, glass protected thermistor were fixed to the coil. The thermistor was connected to an adjustable electronic circuit with feedback loop to maintain a constant, pre-determined temperature of the coil; this temperature (usually about 40 °C, which corresponds to the body temperature of Eurasian Tree Sparrow, see Steen, 1958) could be manually adjusted by the operator according to the readings of the thermometer. The thermal and electronic time constants were suitably matched to avoid any spurious oscillations of unacceptable amplitude. In addition, a bundle of 4 or 6 digital thermometers (Maxim Dallas Semiconductors DS 18B20), fixed inside pencil-like plastic fittings could be inserted in various parts of the nest to determine spatial distribution of temperature. One of these thermometers was located under the nest-box in order to measure the outer temperature. All outdoor connectors of the system were golden-plated and protected against contact with atmospheric water by placing them in plastic boxes. Power supply cables were made of thick copper wire with over-all resistance about 0.5 Ω at room temperature; its thermal variations were negligible. This resistance was taken into account when determining the power consumption by the heater. The time series of all measured parameters (voltage, temperatures) were smoothed with low pass filter (band less than 100 Hz) and recorded in digital form on a computer. Power consumption was then determined from the drop of voltage on the coil, according to the formula $P = (\Delta V)^2 R_h / R_c^2$ (where: P—power, ΔV—drop of voltage, R_h—resistance of the heater, R_c—resistance of the whole circuit between the points or voltage measurement). Before starting the experiment, all thermometers were tested and compared to introduce suitable corrections if necessary. Records were taken every two minutes. Voltage was measured using the program developed by Dr A. Grodzki, which was supplied with the apparatus, and also calculated the power (resistances of heater and whole circuit were constants of the program, and they could be adjusted, if

Table 2
Relationship between power consumption by the heater and the difference between temperature of the heater (from 38 to 40.5 °C) and external temperature, as calculated by the method of linear regression without free term

Nest group	Nest number	Wind speed under the threshold of sensitivity of the anemometer				Stronger wind (over 1 m/s)				Energy saving (%) during still or weak wind in relation to:		Wind promoted increase in over-all heat transfer coefficient (%)
		Range of external temperatures		Number of records	Over-all heat transfer coefficient β (mW/K)	Range of external temperatures		Number of records	Over-all heat transfer coefficient β (mW/K)	Out of nest	Empty box	
		Minimum (°C)	Maximum (°C)			Minimum (°C)	Maximum (°C)					
Out of nest		−12.7	+3.45	1768	22.5	−5.22	+2.81	90	23.8	—	—	6
Empty box		−16.6	+2.13	2376	18.5	−3.91	+2.35	370	19.6	18	—	6
A	1	−15.1	+6.69	4279	17.31	−0.83	+6.65	1009	19.9	23	6	15
	2	−9.82	+4.17	4529	17.25	−2.03	+3.28	370	19.0	23	6	10
	3	−12.8	+7.20	4799	17.25	−3.19	+7.26	499	19.3	23	6	12
	4	−7.35	+3.60	4397	16.7	−4.72	+3.44	363	18.1	26	10	8
B	5	−16.8	+2.75	2666	16.4	−10	+2.70	158	16.8	27	11	2
	6	−4.95	+7.83	3391	15.7	+0.65	+8.13	372	15.9	30	15	1
C	7	−6.57	+8.95	2200	15.1	−6.58	+8.95	901	15.4	33	18	3
	8	−5.96	+3.14	2583	14.9	−3.70	+3.14	60	15.1	33	18	1
	9	−14.5	+1.88	3533	14.3	−6.40	+1.83	108	14.6	36	22	3

necessary). Temperature was measured by the program "Lampomittäri" developed by Timo Sara-Aho (Finland) available in Internet (Sara-Aho, 2003). For comparison, we also took measurements with the heater placed outside the box, which simulated the situation when the bird roosted at night outside the nest.

Wind may be an important factor in chilling the nest-box, mostly by promoting convection inside the nest chamber. This effect depends both on wind speed and direction. A Robinson anemometer with digital output was installed in the system and the number of revolutions per minute was recorded, but we could only determine wind speed greater than 1 m/s. We did not obtain data of wind direction.

If temperature of the bird, or the heater simulating the bird, is maintained at a stable level, the power consumption, that is the rate of energy use, equals the rate of heat loss. Under stable conditions, the flow of heat linearly depends on differences in temperature between the study object and the surrounding air according to the formula

$$P = \mathrm{d}Q/\mathrm{d}t = \beta\Delta T,$$

where P is the power, Q is the heat, t is the time, ΔT is the difference in temperature, β is the constant that depends on conditions of the experiment (as shape, spatial distribution, thickness or thermal conductivity of different layers of the insulating material in the nest), called the over-all heat transfer coefficient. This coefficient can be considered as a synthetic measure of thermal insulative properties of nest-and-heater system (nest-and-bird system, respectively). The lower the value of this coefficient, the better thermal insulation. The value of β was determined by using linear regression without free term, with the difference in temperatures between the heater and air surrounding the nest-box as the independent variable and the power taken by the heater as the dependent variable. It was calculated using all measurements for a given nest, made after the temperature in the nest became stable, and omitting periods when wind speed exceeded the threshold of sensitivity of the anemometer. The measurements made when the wind was strong enough to be recorded were used to determine an analogous coefficient, which could be compared with the previous one to obtain a rough estimate of effects of the wind on nest isolation properties. The method of calculation used makes it difficult to compare statistically the over-all heat transfer coefficients (β) between the nests. However, using non-parametric methods, statistical analysis of effects of some structural nest characteristics on this coefficient have been provided. Spearman's and Pearson's correlations have been used. The data volume is too small to analyse cross-effects of different parameters.

3. Results

3.1. Dependence of energy savings on nest type

The over-all heat transfer coefficient (β) was determined under "no wind" conditions for the heater placed outside the nest, an empty box, and all the nests used in the experiment. The value of β ranged from 22.5 mW/K for the heater outside the nest to 14.3 mW/K for the best insulated nest (no. 9, see Table 2). The empty box reduced heat loss by 18% compared with the outside measurements, and different types of nests by between 23% and 36% (Table 2).

Protection from wind depended upon nest type. The wind promoted increased heat loss by the "artificial tree sparrow" ranged from 1% to 15%, and was the highest in incomplete nests of subgroup "A" with worst insulation (Table 2) and with open nest chambers located relatively close to the entrance. General insulative properties of these nests during wind, measured with β, were similar to those of empty box. Insulation properties of nest no. 4, which was complete, but with rather poor lining and nest chamber located just behind the nest-box entrance, changed during the wind in slightly smaller degree. Nests of subgroup "B", placed in big boxes, had their nest chamber deeper under the entrance and, although they had incomplete domes, the nest chamber was partially covered (these characterise also nest 8 from subgroup "C"). In these nests, as well as in nests 7 and 9 of subgroup "C" with nest chambers covered with domes and placed deep under box entrance, coefficient β showed very little reaction to wind. These results suggest that during wind, the energy demands for maintenance of a stable body temperature increased only slightly in complete nests, whereas incomplete nests lose their insulative advantage over empty nest boxes (Table 2).

Nest height, nest depth and feather quantity seem to be independent of each other (Spearman's $R^2 < 10\%$). Among these parameters however, only the feather quantity has visible effect on nest insulative properties. Pearson's correlation coefficient squares between mass of feathers (in case of nest 9, all feather-like material, as in its lining down feathers, hairs and plant down were impossible to separate) and over-all heat transfer coefficient (β) were 55.6% for windless conditions, 54.7% during wind. Also wind-promoted change in the β coefficient significantly depended of feather mass ($R^2 = 45.3\%$). The more feathers, the better were both general insulation of nest and its wind resistance (Fig. 1). The exception was an autumn nest 3, where feathers contributed 50% of the material, but insulation was poor because this nest was incomplete. The amount of feathers was related to their supply. Boxes 3, 7, and 8 were originally placed at courtyards with hens, guinea fowl, and turkeys.

3.2. Temperature distribution in nests

Values of the mean temperatures inside the nest box, the heater temperatures and the external temperature are presented in Table 3. They roughly characterise the temperature distribution inside the nest box, and the heat conduction through the nest material. With our instruments, we can only compare downward heat flow between nests, though most heat probably escapes upwards,

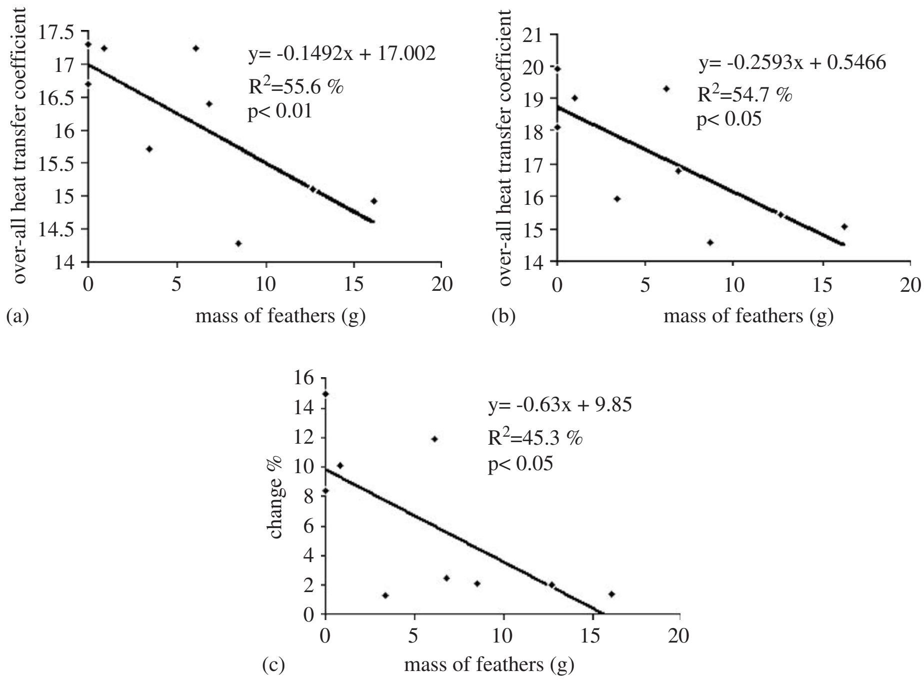

Fig. 1. Dependence of insulative properties of nests on the mass of feathers in nest material: (a) windless conditions, (b) during wind, and (c) wind promoted change. The lower is the over-all heat transfer coefficient, the better is the nest insulated. The lower is the change, the better the nest protects from wind.

especially from incomplete nests. Temperatures measured at the bottom of the nest cavity (under the belly of the "artificial tree sparrow"), in the material of the base, and at the bottom of the nest box form a decreasing gradient (Table 3), and the differences between these temperatures, presented as the percentage of the temperature difference between the heater and the external temperature characterise the contribution of nest material to the insulation of the whole nest (Table 4). It can be seen that in the three-layer nests (nos. 6, 7, and 9), a relatively thin lining maintains a greater temperature difference than a relatively thick base (Tables 3 and 4). In nest 1, made of loose plant material, temperature dropped almost evenly along the column of nest material (Tables 1, 3 and 4), indicating the value of lining for insulation of the nest as a whole.

3.3. *Comparison of the present experimental results with the estimated energy expenditure of the Eurasian Tree Sparrow*

Daily energy expenditure in the Eurasian Tree Sparrow at an ambient temperature of $-9\,^{\circ}C$ accounts for 25.6 kcal (Nakhodkin, 1988). This value, with ca. $50\,^{\circ}C$ difference between the body temperature (ca. $41\,^{\circ}C$) and the ambient temperature ($-9\,^{\circ}C$), can be interpreted as a mean power consumption per degree of temperature difference equal to 24.8 mW/K. Thus, our results of 22.5 mW/K, for the "artificial tree sparrow" outside the nest approach the probable costs of roosting at night of a live bird under such conditions. It may, thus, be argued that savings of energy estimated in this experiment correspond to those of Eurasian Tree Sparrows roosting at night in nests of a given structure.

4. Discussion

Energy savings of a bird roosting at night in an empty nest box, or in a nest box containing a nest, stem from a reduction of heat loss both by radiation and by convection caused by wind (small entrance hole to the box), and also from a reduction of thermal conductance due to additional layers isolating the body from the external environment, with a consequent reduction of the temperature difference between the bird and its direct surroundings (Moore, 1945; Birkebak, 1966; Walsberg, 1985, 1986, and others).

Most papers on nest insulation concern open nests during incubation (Palmgren and Palmgren, 1939; Ponomareva, 1971; Whittow and Berger, 1977; Walsberg and King, 1978a; Skowron and Kern, 1980). Relatively few deal with the insulation of nests in tree holes, nest boxes, and other shelters of this kind (Mertens, 1977).

A critical period for small birds living in moderate and cool climatic zones is the long winter night, and energy savings of even a few percent may determine survival (Houston and McNamara, 1993). The body weight of Eurasian Tree Sparrows in winter varied from 21.4 to 26.2 g, including 1.46–3.02 g of fat. At an ambient temperature of $-10\,^{\circ}C$, the smallest fat amount is hardly enough for a bird to survive the night, while the fattest Eurasian Tree Sparrows would have an energy store for only ca. 24 h at this temperature (Pinowski and Myrcha, 1970). Winter fat storage of most small birds is seldom

Table 3
Mean temperatures (°C) in different layers of nests ("no wind" conditions; records registered on full hours only)

Nest Group	No.	Number of records	Temperature of heater	SD	External temperature	SD	Nest-box top	Upper part of nest cavity	Bottom of nest cavity	Under lining	Nest-box bottom
A	1	140	40.12	0.61	0.46	5.10	1.7	4.51	4.29	2.46	1.06
	2	151	39.50	0.19	−1.85	3.00	−0.99		7.7		1.23
	3	165	40.07	0.23	1.31	4.45	1.95		3.96		2.7
	4	146	40.21	0.04	0.07	2.38	1.7	3.41	4.63	1.14	0.38
B	5	92	40.06	0.49	−2.47	4.09	−0.15	−0.76	−0.37	−1.88	−2.21
	6	109	39.94	0.28	0.37	3.33	1.05	7.19	7.15	2.71	0.92
C	7	71	40.03	0.23	0.35	5.05	0.91	4.34	9.32	4.52	1.74
	8	89	40.00	0.23	−1.59	5.41	Error in thermometers' placement				
	9	121	40.10	0.24	−5.56	7.78	−5.17	6.88	2.85	−2.96	−3.95

extensive enough to permit survival for more than overnight plus part of the following day (Blem, 1976; Lehikoinen, 1986; Jenni and Jenni-Eiermann, 1987; for reviews: Blem, 1990; Dolnik, 1995). In the daily cycle, natural selection promotes amassing optimal energy reserves for the prevailing temperature, winds, predation pressure, social structure, etc. (Carrascal et al., 1998; Gosler, 1996, 2002). Consequently, birds must use other solutions (see Section 1) that facilitate survival through the night without storing excessive fat reserves. One is using shelters for night, including nests.

Energy savings in the Siberian Tit (*Parus cinctus*) at an ambient temperature of −18 °C were 40–45% when roosting in narrow tree cavities (Andreev, 1980). The House Sparrow (*Passer domesticus*) roosting at night in a box half-filled with nest material including a thick layer of hen feathers can save 13.4% of heat at a temperature of −30 °C and 11% at −8 °C (Kendeigh, 1961). Other small species of birds can save up to 14.5% dependently to size, temperature, wind velocity and radiation (Gavrilov, 1991; Walsberg, 1985;Caccamise and Weathers, 1977).

The purpose of this study was to examine the effect of nest construction during the autumn sexual display on energy savings. Of course, our imitation of a Eurasian Tree Sparrow roosting in a tree cavity, in the form of a thermostatic heater, was not ideal. We were unable to imitate adaptive abilities of a living bird (changing isolating properties of the plumage, hiding the head under the wing, hypothermia, etc.) (Andreev, 1980; Reinertsen, 1983, 1988, 1996; Reinertsen and Haftorn, 1984, 1986). The most important property of the "artificial tree sparrow" is the comparability of the results obtained for different nest types built in nest boxes. Even an empty box saved 18% of energy compared with the heater placed on a branch, and the greatest savings of 36% were provided by the nest filling the box, and overtopped by the autumn nest (nest 9, Table 2). The range of energy savings in our measurements falls within the range that is known from the literature (see above), and the saving greatness depends on nest type (Table 2).

The fact that the over-all heat transfer coefficient (β) determined for our heater placed outside is close, to that calculated from the Nakhodkin (1988) data for a living bird, supporting the suggestion that energy savings calculated for box-nest-heater system in our experiment also should be similar to those by true Eurasian Tree Sparrow in similar conditions.

Although nest moisture is probably important factor influencing isolative properties of a nest, in our material it was not enough differentiated to consider its effects in our study.

Our observations show that nest type is important for roosting Eurasian Tree Sparrows, as it provides protection from wind. Depending on the nest type, heat loss by the "artificial tree sparrow" increased from 1% to 15% during wind, and it was the highest in incomplete nests with poorest insulation (Tables 1 and 2). In the Acorn

Table 4
Estimation of nest layers' significance for thermal insulation

Nest group	Nest number	Base + lining thickness (cm)[a]	Drop of temperature through the layer as % of total temperature difference				
			Feathers of skin (on heater)	Lining	Base	Lining + base	Bottom wall of nest-box
A	1	5	90.3	4.6	3.5	8.1	1.5
	2	1	76.9	—	—	15.6	7.4
	3	1	93.2	—	—	3.3	3.6
	4	11	88.6	8.7	1.9	10.6	0.8
B	5	16	95.1	3.6	0.8	4.3	0.6
	6	8	82.9	11.2	4.5	15.7	1.4
C	7	4	77.4	12.1	7.0	19.1	3.5
	9	4	81.6	12.7	2.2	14.9	3.5

[a]Distance between nest-box bottom and bottom of nest cavity.

Woodpecker, roosting on a branch at a temperature of 0 °C, the wind of 5 m/s increased heat loss by 38% compared with windless conditions (Du Plessis et al., 1994). In Verdins (*Auriparus flaviceps*) that construct closed nests with a narrow entrance opening of 25 mm (Taylor, 1971) only 2% of the external wind reaches the nest (Buttermer et al., 1987).

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