ENERGY OF BIRDS CONSERVED BY ROOSTING IN CAVITIES

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Nighttime is a critical period in the resistance of birds to winter cold at high latitudes because this is generally the coldest time of the day, and is a period when diurnal birds are unable to feed. Numerous notes in the literature describe how birds seek dense vegetation or cavities of various sorts for roosting purposes (Frazier and Nolan, 1959). Shelter obviously gives them protection from the wind and decreases the rate of heat lost from their bodies, but quantitative measurement of the benefits thus obtained has rarely been obtained (Gerstell, 1942).

The present study was stimulated by observing a House Sparrow (*Passer domesticus*) going night after night into a bird nesting box attached to the side of the Vivarium Building on the University of Illinois campus. An attempt was made to determine the difference between the temperature inside the box while the bird was roosting in it at night and the temperature immediately outside the box.

Observations on the roosting of the House Sparrow have been reported by Labitte (1937), Dunsheath and Doncaster (1941), and Swaine (1945), among others. Dunsheath and Doncaster many times observed apparently paired birds roosting together. Swaine reports that the House Sparrow often roosts in its own nests during the winter. He usually found only one bird in a nest at a time, but on four occasions found pairs of birds using the same nest, and on one occasion three birds. I never suspected more than one bird to be using the box in this study, but at different times observed a male and a female at the box at roosting time.

The box was made of ¾-inch pine lumber. Inside dimensions were 6 inches front to back, 4 inches side to side, and 5 inches top to bottom. There was a flat top hinged on one side. An entrance-way with a diameter of 1½ inches was located in the front, ½ inch below the top, and the entire front could be tipped open on a pivot near the top. The box was on the south side of the building approximately 40 feet from the ground. Since it was placed under the rather wide eaves of the roof, it was well protected from precipitation. The box-cavity was about one-half filled with old nesting material, and the nest-cavity, in the rear half of the nesting material, was lined thickly with chicken feathers. The bird presumably roosted in the nest-cavity, but this was not verified.

PROCEDURE

Two thin insulated copper-constantan thermocouples were prepared and when tested against a standardized mercury thermometer gave identical average readings at 22.9° and –13.4°C and a standard deviation for 24 individual readings of ± 0.15°C. One thermocouple was fastened inside the box directly over the nest-cavity with the sensitive junction projecting slightly so as to record the air and not the wall temperature. There was no suspicion that the thermocouple was in a heat stream. The other thermocouple was fastened to the middle of the east side of the box on the outside with the junction projecting into the air. This junction was protected from direct solar radiation at all times of the day.

The two thermocouples at the box were connected to thick copper and constantan leads that extended 200 feet to a Leeds and Northrup recording potentiometer inside the building. The potentiometer registered over a range of –40° to + 160°C with the chart graduated in 2°C intervals. Temperature recordings were interpolated to 0.5°C for analysis. Experience with this potentiometer has shown that while individual readings could be in error by ± 1.0°C, averages were dependable within ± 0.5°C. A daily check on the accuracy of the recording was obtained by the outside and inside thermocouples registering identical temperatures while the bird was absent during the daylight hours. The three thermocouple outlets of this potentiometer were interconnected so that two consecutive readings were taken of the inside box temperature, then one of the outside temperature, each at one-minute intervals, with this cycle being repeated continuously.

RESULTS

Complete 24-hour per day recordings were obtained for 23 days, beginning 20 December 1949, and ending 11 January 1950. The bird entered its roost, on the average, a few minutes after 4:00 PM and left it a few minutes after 7:00 AM, CST. This gave a roosting period of 15 hours per day. On 1 January, the sun sets at 4:38 PM and rises at 7:15 AM.

When the bird first entered the box, inside box temperatures registered higher for a period of one-half to one hour than during most of the night, presumably due to restlessness of the bird (Fig. 1). The temperature record indicates that thereafter the bird was quiet for periods up to two hours or longer during which the box temperature remained uniform. These quiet periods were terminated by short abrupt rises in box temperature, occasionally amounting to over 3°C. These temporary rises in temperature are unexplained, but must have resulted from some activity of the bird. As the outside air temperature fell during the night, the difference between the temperatures inside and outside the box regularly became greater. For one-half to one hour before the bird left in the morning, restlessness, apparently, again brought a higher box temperature, similar to that in the evening after the bird entered. After the bird left the box, the box temperature fell rapidly, but required up to 45 minutes to reach the outside air temperature.

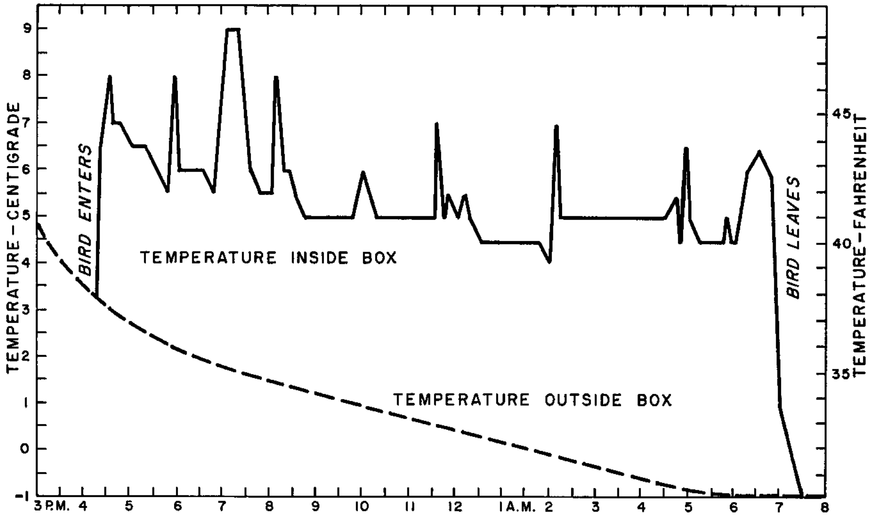

FIG. 1. Temperatures inside and outside the box on a representative night, 10–11 January 1950.

The night of 21–22 December 1949, was unusual in that air temperatures dropped from around 11°C a little before 11:00 PM to −3°C at 8:00 AM, this drop being accompanied by rain (Fig. 2). Inside box temperatures fell from about 13.5°C to + 3°C. Here again it is evident that the difference between the temperatures inside and outside the box was less at the higher than at the lower temperatures.

It is obvious from Fig. 2, but not from Fig. 1, that a pronounced change in the outside air temperature will bring a change in the inside box temperature. In order to show the relation between inside box and outside air temperatures the nightly mean of each of the two temperatures was obtained for each of the 23 days. The means were computed only for the hours 6:00 PM to 6:00 AM, inclusive, in order to avoid the restless periods of the bird after entering and before leaving the box each night. One temperature was read from the chart for each hour on the hour, an average value being recorded if the temperature was fluctuating at the time.

When the differences between the two temperatures are plotted against the temperatures outside the box (Fig. 3), a linear relation is evident ($b = -0.19°C$; $P = < .001$). The same regression line is obtained by plotting the differences between the hourly temperatures rather than the differences between the mean nightly temperatures. The lower the outside air temperature, the greater the difference between outside and inside box

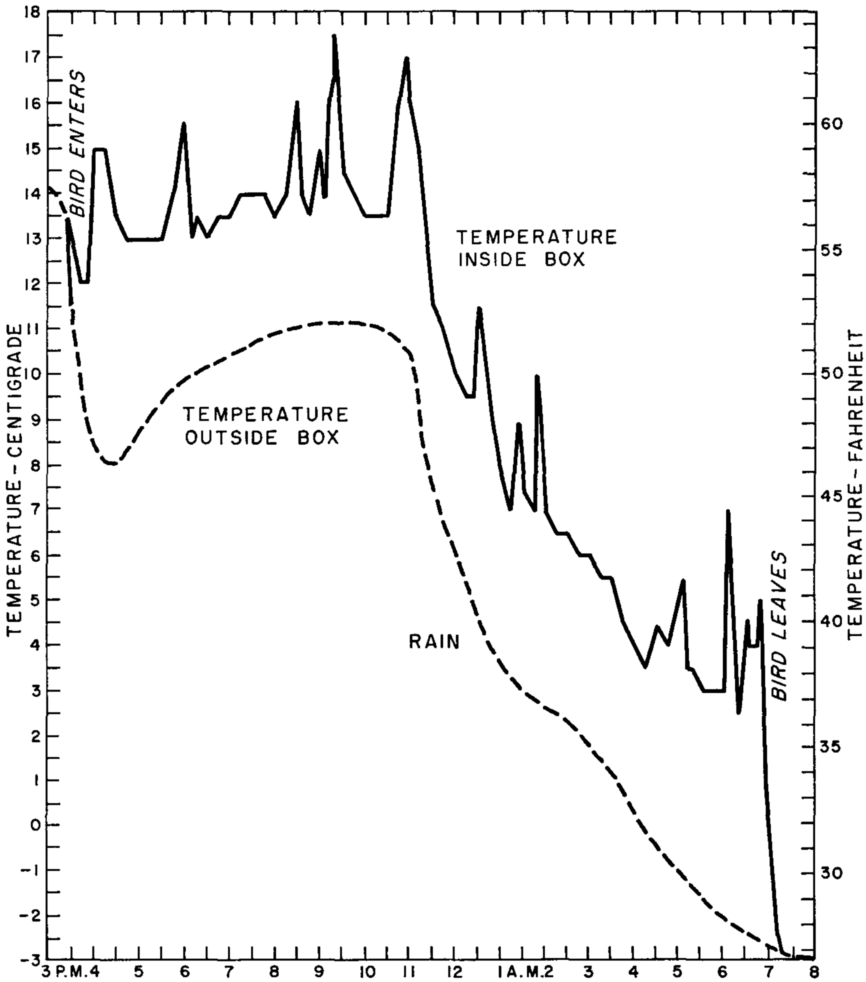

FIG. 2. Temperatures inside and outside the box on an unusual night, 21–22 December 1949.

temperatures, although the increase in the difference does not equal the drop in the air temperature, for instance:

Outside air temperature	+ 17°C	−8°C
Difference	1.5	6.2
Inside box temperature	18.5	−1.8

An extension of the line in the upward direction indicates that the bird would not raise the box temperature at air temperatures of 24.7°C and above. At these higher air temperatures, the resting metabolism of the

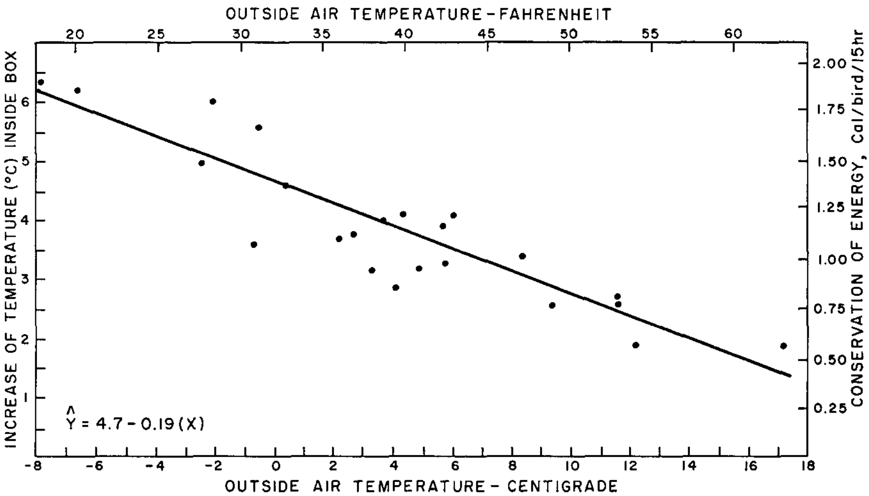

FIG. 3. Relation between box temperatures and outside air temperatures correlated with the amount of energy conserved by the bird.

bird would be so reduced that apparently the low rate of heat loss from the bird would have no measurable effect on the box temperature.

DISCUSSION

Temperature relations inside a well-insulated cavity, like this box, are complicated (Moore, 1945). The resting bird at night probably has an internal body temperature of about 40°C. Skin temperatures beneath the feathers would be about one degree less (Baldwin and Kendeigh, 1932). Conduction of heat along or across the feathers to the outside of the plumage would be very slow, so the temperature on the surface of the plumage would be considerably below the skin temperature. Roosting birds in cold weather commonly fluff out their feathers and place their heads under the scapular feathers. This increase in the thickness of the plumage greatly reduces the rate of heat conduction away from the body. The low surface temperature would greatly diminish the amount of heat radiation from the bird to the walls of the box. Heat conduction from the body and legs of the bird to the nest-material in the box would be very small. Likewise, evaporation of moisture in the respiratory system would account for only a small loss of heat. The principal pathway of heat loss from the bird would doubtless be convectional, partly by the air being warmed by the heat conducted to the surface of the plumage, but to a greater extent by the expiration of heated air from the body in each breathing cycle. This would warm the box cavity until a temperature was reached where the loss of heat from the box to the air balanced the heat loss from the bird to the box. Radiation of heat from the box to the sky during clear weather was doubtless reduced because of the position of the box under the eaves of the roof.

Wood is a poor heat conductor. The temperatures of the inside surface of the walls of the box, although not measured, may have approached the inside air temperature. The temperature of the outside surface of the walls of the box probably approximated the outside air temperature. A temperature gradient must therefore have occurred in the ¾-inch wall, equal approximately to the difference in box and air temperature. Heated air rises and there was doubtless an exchange of warm for cold air through the small entrance-way and the crack between the top lid of the box and the side walls. The insulation of this roost-site was probably better than that of most species but perhaps not as good as for some, as for instance woodpeckers.

The resting or standard metabolism of the House Sparrow at night is lower than it is during the daytime. Seven measurements obtained at night at constant temperatures from −19°C to + 31°C (Kendeigh, 1944) indicate a straight-line relation between resting metabolism and temperature ($b = -0.699$ small calories per gram per hour; $P = < .001$). If we assume the mean weight of House Sparrows in December and January to be 28.5 grams and the roosting period per day to be 15 hours, then for each rise of 1°C in inside box temperature there would be a daily conservation of 0.30 large calories of energy to the bird. These caloric values have been incorporated in Fig. 3. The resting metabolism of the bird in large calories ($\hat{Y}$), when X is temperature, follows the equations:

$$\hat{Y} = \frac{25.6 - 0.699(X - 11.3) \times 28.5 \times 15}{1000} \quad \text{or} \quad \hat{Y} = 3.4 - 0.299X$$

At + 17°C, the raising of the roosting temperature by 1.5°C would conserve 0.45 kcal or only 4.9 per cent of the total required by the resting bird. At −8°C, however, the difference of 6.2°C would mean a saving of 1.86 kcal or 11.1 per cent. Were nightly temperatures to drop to −20°C, an extension of the curvilinear line (Fig. 4) indicates that 12.6 per cent of the total energy required for roosting would be conserved, at −30°C the saving would be 13.4 per cent. The species regularly experiences air temperatures as low as these. An extension of the line in the other direction indicates that no energy would be saved at 24.7°C.

It would certainly appear that roosting in cavities has an advantage at low temperature which increases in extent, but not directly proportionally, with the drop in air temperature. The amount of energy thus conserved may make the difference between survival and death during periods of extreme weather during the winter. Likewise, roosting in cavities may enable a

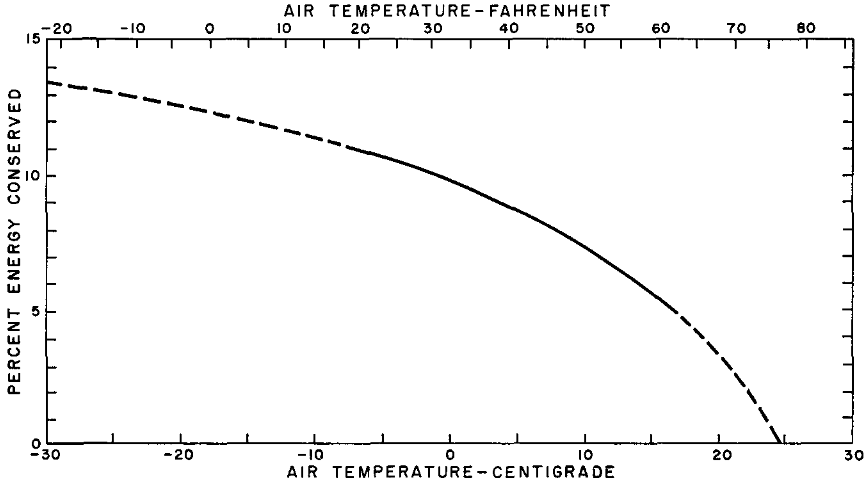

FIG. 4. Relation between per cent of energy conserved by roosting in cavities and air temperature.

species to occur farther north during the winter than it otherwise would. Further studies along these lines should be made with refined techniques.

CONCLUSIONS

1. The temperature inside a box cavity used for overnight roosting by a House Sparrow was higher than the outside air temperature at air temperatures below 24.7°C ($\hat{Y} = 4.7 - 0.19 X$).

2. The difference between temperatures inside and outside the box cavity increased with a drop in temperature ($b = -0.19$°C).

3. The energy conserved by roosting in a cavity compared with roosting in the open varies curvilinearly from zero at + 24.7°C to 13.4 per cent at −30°C.

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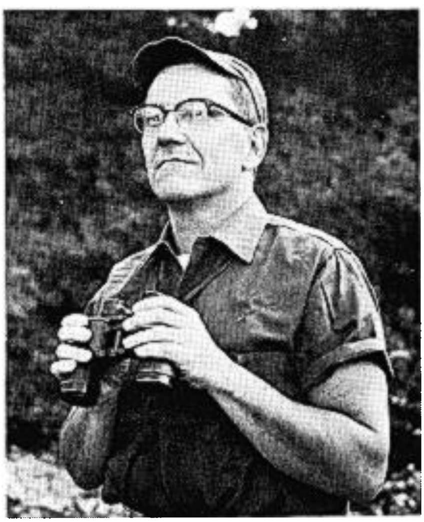

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