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Temperature in the nocturnal shelters of the redpoll (Acanthis flammea L.) and the Siberian tit (Parus cinctus Budd.) in winter

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Temperatures in open or closed snow burrows of the Siberian tit and the redpoll were examined experimentally in northern Finland. In addition, the value of tree holes and snow burrows as shelters for the Siberian tit was compared on the basis of the observed thermal conditions. Both the snow burrows and the tree holes warmed to a constant temperature within half an hour. The difference in temperature between the snow burrows or the tree holes and the ambient air increased as the air became colder. In spite of the higher temperature in the snow burrows the Siberian tit preferred to spend the night in tree holes. Neither redpolls nor Siberian tits could always remain for long in closed snow burrows; some birds died if forced to remain there for more than one hour.

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1. Introduction

Small passerine birds sometimes burrow in the snow to escape the cold in climatic conditions similar to those in winter in Finland. This kind of behaviour is probably more common in Siberia (Sulkava 1969, Novikov 1972). However, snow burrows of small passerine birds may be more common than generally assumed, since they are difficult to identify: they resemble the air vents made by some vole species (Sulkava 1969). Birds which nest in tree holes perhaps use the holes during the winter, too, as shelters against cold and wind. For instance, the Siberian tit *(Parus cinctus)* can use both snow burrows and tree holes as shelters. Steen (1958) assumes that sheltering among small birds is so common that they are, in fact, adapted to temperatures higher than those prevailing outdoors, because they are not exposed to outside night temperatures during winter.

In this study, the temperatures in the snow burrows of two passerine species, the redpoll *(Acanthis flammea)* and the Siberian tit *(Parus cinctus)* were measured experimentally to find an explanation for the fact that cold-tolerant species of the grouse family use snow burrows more frequently — even when the snow is soft — than small passerine birds, which often suffer from the cold during severe frosts. In addition, the utility of the two shelter types of the Siberian tit are compared.

2. Methods

The work was carried out at the Kilpisjärvi Biological Station (69°03′ N, 20°50′ E) from 14th January to 11th February, 1980. Forty-two redpolls *(Acanthis flammea)* (weight 9—12 g) and 12 Siberian tits *(Parus cinctus)* (weight 10—14 g) were captured with nets for the investigation. A maximum of 11 birds at a time were kept outdoors in small pens (0.5 × 0.5 × 0.5 m), 3—5 birds in each. The redpolls were fed with sunflower seed, maize and linseed. The Siberian tits also received lard and tallow. Water or snow was always available.

Temperature was measured in the snow burrows using a method described by Volkov (1968). This method, with small modifications, was also used when snow burrows of the willow grouse were examined by Korhonen (1980), but the experimental pen for these small birds was now only 6 × 6 × 13 cm. The pen was suitable for both the redpolls and the Siberian tits. The inside diameter of the experimental hole, a wooden, cylindrical nest box, was 10 cm, and the walls were about 3 cm thick. The height of the box was about 35 cm, and the cavity inside 13 cm high. Only Siberian tits were used in this experiment.

The temperatures were measured with a Wallac EP-400 thermohygrometer with a flat probe. This was inserted in a plastic tube to prevent the birds from touching it.

Because the experimental pens were so small in comparison to the probe, only wall temperatures were measured in both the snow burrows and tree holes. Readings were taken to the nearest 0.5°C. Air temperature was measured at a height of 100 cm above the snow surface, and snow temperature at a depth of 9 cm. Temperature measurements in boxes were made with one or two tits sitting in the hole at the same time. Each experiment lasted a maximum of three hours, and they were made only at night-time.

It was very difficult to keep the birds quiet in the snow burrows, and measurements often had to be interrupted because the birds struggled to get out of the burrow. Redpolls sometimes showed their restlessness by singing in the snow burrows. In contrast, the Siberian tits usually sat quiet and slept in the tree holes.

Snow density was measured by taking a sample for weighing from the snow surface to a depth of 10 cm with a 100 cm^3 cylinder. During measurements the snow was always either flake-like or fine-grained soft snow. The density of the snow varied from 0.050 g/cm^3 to 0.120 g/cm^3.

The experimental pens and boxes were placed out of the wind. Air temperature varied from —10°C to —35°C, and temperature in the snow from —10°C to —31°C; during any single experiment, however, the variation was not greater than 1°C.

3. Results

The difference in temperature between the snow burrows or tree holes and the ambient air increased as it became colder. The greatest difference observed was 19°C with a redpoll in an open burrow, and 21°C with a redpoll in a closed burrow (ambient air temperature —35°C). A tree hole with two Siberian tits inside warmed to a maximum of 7°C above the ambient temperature. There was no significant difference between the temperatures in the snow burrows of the two species. The temperature in the burrows and holes reached quite a constant level in half an hour. Movements of the birds might cause small variations which were not greater than about 1°C.

The relationship between the temperatures of the burrow/hole and the air can be described by linear regression lines. Of the variation in the shelter temperature, 85—99 % was explained by changes in the ambient temperature (Fig. 1). In comparable conditions the snow burrows were always warmer than the nest box even when there were two birds in the box. In spite of the fact that closed burrows were the warmest shelters, neither redpolls nor Siberian tits were able to stay there for extended periods. If they were not allowed to leave the burrows they might die within approximately one hour. This actually happened to eight birds confined in closed burrows during measurements. Because of this the measurement often had to be restricted to a half an hour period. No birds died in the other shelters, not even when the birds were kept there for three hours, and sometimes struggled to get out. Birds placed facing the back wall of open burrows often turned to face the opening.

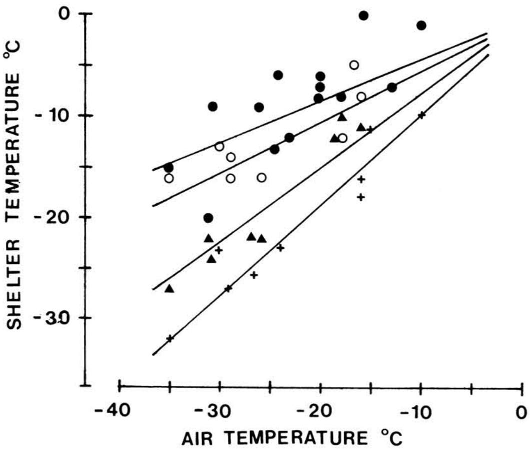

Fig. 1. Comparison of the shelter temperatures. Measurements during 1/2 h. Snow density varied from 0.050 g/cm^3 to 0.120 g/cm^3, newly fallen or fine-grained snow. Temperatures in the snow burrows of *Acanthis flammea* and *Parus cinctus* were the same in the range of ± 0.5°C. Regression equations for shelter temperature (y) in relation to air temperature (x): Closed burrow (●): $y = 0.22 + 0.41\,x$, $n = 28$, $r^2 = 85$ %. Open burrow (○): $y = 0.10 + 0.51\,x$, $n = 16$, $r^2 = 98$ %. Tree hole with two birds (Δ): $y = 0.25 + 0.75\,x$, $n = 18$, $r^2 = 99$ %. Tree hole with one bird (+): $y = 0.10 + 0.92\,x$, $n = 19$, $r^2 = 99$ %. For each line $b \neq 0$, $P < 0.001$.

4. Discussion

On the basis of these results, tree holes with no nest material do not offer very effective protection against cold for single Siberian tits during calm freezing weather. Of course, they provide excellent shelter against wind, and if many birds are present inside a hole at the same time they may warm each other. Such huddling behaviour, however, was not observed in Siberian tits at Kilpisjärvi during the three winters of 1977, 1979 and 1980. Redpolls often slept perched side by side in their cages. The redpolls also seemed to experience discomfort when sheltering in snow.

The cause of death during measurements in closed burrows could not be explained. In nature, small birds perhaps do not spend long periods in closed burrows. In fact, the thermal advantage of the closed burrows was only a little greater than provided by the open ones. Sulkava (1969) has established a structural difference between the snow burrows made by passerine and gallinaceous birds: the former did not close the opening after having dug into the snow whereas the burrows of the tetraonid birds were often closed. For example, in an experimental situation, willow grouse were able to stay in a closed snow burrow for at least 14 h without any sign of discomfort (Korhonen 1980). The oxygen consumption of small passerine birds is much higher in relation to body weight than that of the bigger gallinaceous birds. However, suffocation was probably not the cause of death because some birds were able to stay in closed burrows for at least three hours. The burrow temperatures were far below the thermoneutral zone of redpolls and Siberian tits. Although the wall temperature was higher in a closed burrow, the heat loss from the birds was perhaps even greater than in the open burrows or in the tree hole because of the close proximity of the bird to the snow in the narrow experimental pen. The thermal conductivity and cold content of snow are greater than that of still air. Johnson (1957) observed that during severe frosts *Acanthis* species often retracted their legs and *Parus atricapillus* "walked" on the snow surface using their wings to avoid contact with the cold snow. The snow layer where small birds can shelter, about 10 cm thick, is still very cold. Possible reduction in the body temperature during experiments could not be measured with the equipment available. If handling had caused shock it would obviously have occurred in other experimental situations, too.

The final temperatures in the snow burrows of these small birds did not differ very much from those in the burrows of some gallinaceous birds (Volkov 1968, Andreev 1979, Korhonen 1980). Differences between the results may have been caused by differences between the methods, and by local snow or climatical conditions (Andreev & Krechmar 1976). However, a small bird seemed to warm its burrow more rapidly than a gallinaceous bird. It would be an oversimplification to estimate the thermal advantage of shelters on the basis of the temperatures alone, because the environmental "effective" temperature is affected by factors such as insulation properties of the bird and the thermal properties of the medium. So, in spite of the evident similarity in microclimate, the snow burrows may not be as advantageous for small birds as for the larger well-insulated gallinaceous birds. In any case, the use of different kinds of shelter diminishes heat loss significantly (Kelty & Lustick 1977), but it is not clear whether the saving gained by sheltering is always greater than that of other behavioural or physiological adjustments, e.g. huddling, balling up, and nocturnal hypothermia.

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