

WINTER NIGHT HABITS OF BIRDS

BY A. D. MOORE

AS Kendeigh (1934:343) has pointed out, "much more needs to be learned about the night habits of birds, particularly in winter." Kendeigh summarizes what is known of the winter roosting habits of a number of species. Some birds creep into the space between loose bark and the tree trunk; some cling in trunk depressions; some pass the night in natural cavities in trees, while others chisel out their own cavities. English Sparrows, alone or by groups, use thick bushes, vines next to buildings, or space in buildings. Other species find shelter in clumps of cattail or grass, or under clods. Some species gather in large numbers and spend the night close together in thick trees.

HEAT PRODUCTION AND TEMPERATURE REGULATION

Birds, in common with other warm-blooded animals, have a temperature-regulating mechanism that keeps body temperature at suitable levels. In a given case, the bird makes an adjustment to cold surroundings by first selecting a roosting place, and then by fluffing the feathers, placing the head under the scapular feathers, and perhaps huddling with other individuals. There will then be a certain demand placed on the bird because of the heat being lost. If the demand is low, it may be balanced by heat produced by the bird's lowest metabolism rate. When the demand is greater, physiological responses cause the regulating mechanism to act. Metabolism rises; that is, energy originally taken in as food is turned into heat at a greater rate, to meet the greater demand, and body temperature is maintained. If the demand (heat loss) is extreme, body temperature may be permitted to fall somewhat, and loss of heat is thereby reduced; but even so, there is danger that the bird's available store of energy will be used up, with death ensuing during the night.

This paper is not concerned with the physiological aspects of heat production and temperature regulation; but the foregoing makes it plain that since the bird's ability to produce heat is limited, its survival will often depend on its ability to keep heat loss within bounds.

HEAT LOSS MECHANISMS

In order to know what to look for when observing the winter night habits of birds, the mechanisms or means whereby the bird loses heat should be clearly understood. The heat first travels by *conduction* from the warm skin, through the plumage, to the outer surface of the plumage. This heat is then taken away from the outer surface by two mechanisms, *radiation* and *convection*. Wherever outer surfaces of feet or plumage touch solid objects, there will also be loss by *conduction*, but this is usually small. The heat lost by radiation and con-

vection, added together, equals the heat conducted out through the feathers. Any adjustment by which the bird can reduce the effect of any of these heat loss mechanisms will, of course, help the bird to survive night exposure to a cold environment.

Conduction. The coat of a bird, consisting of air entrapped by overlapping feathers, is an excellent insulator; that is, it is a poor conductor. Nevertheless, it does conduct heat. When the feathers are "normal" (neither pressed down, nor fluffed out) the air is almost perfectly entrapped. The heat is then conducted from warm skin to colder outer plumage surface both by means of the entrapped air and the feather material itself.

Fluffing of the feathers is the very efficient means whereby the bird can secure a large increase in thickness of the insulating coat. With the feathers erected, the coat becomes several times as thick as in the normal state.

When the feathers are completely fluffed, they cannot do a perfect job of entrapping air among them, and movement of air through the feathers would reduce the insulating effect. Nothing is known about the extent to which fluffed feathers prevent this air movement. In my opinion, air movement through fluffed feathers will be nearly negligible if the bird is completely sheltered from the wind; and there is probably not much of it, even in a fair breeze, if the bird is headed into the breeze and the fluffing is not at its extreme degree.

Convection. When the outer plumage surface is warmer than the air, the surface loses heat to the air by convection. Convection will be one or the other of two kinds,—natural, or forced.

Natural convection occurs when the air and the bird are both still: there is no wind, and the bird is quietly sitting or sleeping. The only air movement will then be that of a natural circulation that is established. The warmer surface of the plumage warms the surrounding cooler air; the warmed air, becoming less dense, rises; a sluggish natural circulation is established, and the air removes heat from the surface by natural convection. (It will be necessary to modify these remarks later, when dealing with birds in very confined quarters.)

If the bird is directly exposed to a wind, the sluggish air movement of natural convection is wiped out. The wind gives forced convection cooling. The warmed air close to the bird is now rapidly replaced by cool air. For any given temperature difference between outer surface and air, the higher the wind velocity, the greater will be the forced convection heat loss.

Radiation. Loss of heat from the outer plumage surface by radiation cannot be taken up here in full technical detail. Nevertheless, some explanation of what takes place is necessary, because much that has been written about it is confusing and erroneous. The very term

radiation has suffered a great deal of misuse in many quarters. It is regrettably common to speak of all the heat that is dissipated by, for example, a "radiator" in a room, as *radiated* heat, even though such a body loses heat both by true radiation and by convection.

Radiant energy emitted by any surface travels in straight lines like light, and with the speed of light. At night, all of the radiant energy affecting the bird is in the long wave length (infra red) part of the spectrum. Such waves are emitted by the bird's outer plumage surface; by the ground, snow, twigs, leaves, enclosing walls of a cavity, and so on; by clouds overhead; and, in varying degrees, by the water vapor and carbon dioxide in the atmosphere, even with a perfectly clear sky.

If a bird is completely enclosed in a wooden box, or in a tree cavity, or cave, and *if* the temperature of the outer plumage surface is the *same* as the temperature of the walls of the complete enclosure, there will be *no* net loss (or gain) of heat by radiation. The outer plumage surface will emit, and therefore lose, heat by radiation; but the radiation coming from the walls will be absorbed by the plumage surface; the gain by absorption will just balance the loss by emission.

Or again, place the bird in the open, exposed to level ground below and to low, thick clouds above. If the bird's outer plumage surface should happen to be at the same temperature as the ground, and if weather conditions were not extreme, it could happen that radiation emitted by the ground and sent generally upward to the bird, plus radiation emitted by the atmosphere below the cloud and by the cloud itself and sent generally downward to the bird, might exactly balance the bird's radiation, and no net radiation loss would occur.

Or yet again, preserve the preceding conditions, except that we now remove the cloud and have a perfectly clear night sky. Radiation still comes downward from the water vapor and carbon dioxide in the clear atmosphere; but the amount of it will range from fully as much as when the low cloud was there, to somewhat less than half as much—depending, in an extremely complicated way, on ground temperature, relative humidity, and vertical distribution of temperature in the atmosphere. The highest air temperatures and humidities will cause the greatest downward radiation. Furthermore, the presence of haze complicates the situation. Haze increases the downward night radiation. Unfortunately, the relationships are so very complex that it is quite impossible to reduce atmospheric radiation to a simple set of rules.

The absence of haze and clouds usually means lessened downward radiation; low temperature and low humidity still further reduce it. Thus, on clear, cold winter nights, downward radiation being received by the bird's upper surfaces may be much less than the radiation emitted by those surfaces. A severe net loss of radiation energy will ensue. Thus the bird finds it necessary to *get under* an opaque cover—and it

is important for us to increase the accuracy of our observations on the nature of that cover.

If the cover is thick (or if made up of numerous layers of thin leaves) the temperature of the lower layers of the cover will closely approach the temperature of the air and ground; or, if these are different, it will be intermediate between the two temperatures. Such a cover will send downward much more radiation than would come from a clear, cold sky.

If a bird is found sleeping apparently directly exposed to the sky, but in a deep ravine, then it is receiving ground radiation from below, from the sides, and even to some extent from above. Exposure to the sky is of small consequence if the area of sky, as viewed from the bird's position, is small.

If a flock of birds settles in a tree, the individuals need not be in contact in order to reduce radiation losses. From the position of any one bird, if the view in all directions is largely covered by other birds, then the birds are effectively radiating to each other: a *completely* surrounded view would result in no radiation loss whatever. However, the outermost birds would radiantly lose heat from their exposed-view surfaces. (Do the outermost birds sometimes move in after a while, and let others take turns at exposure?)

ENCLOSED ROOSTS

A complete enclosure, such as a tree cavity with one small opening, insures freedom from wind. Instead of high loss from forced convection, there is the lesser natural convection effect that transfers heat from the bird to the air, and then from the air to the walls. This double-step transfer (bird to air, then air to walls) occurs when there is plenty of air space. But another complication arises. If the cavity is small, with perhaps an inch or less of air space between bird and wall, free natural convection currents may be largely slowed down by interference effects; the air would be relatively stationary, and the heat going by air would largely be *conducted* by air from bird to wall. The situation is misleadingly simple. Apparently, all we have is a warm bird, cold walls, and some air between; but the heat transfer problem is really highly complicated. As in the case of the atmospheric radiation problem, there is no hope of reducing it to simple rules.

In addition to the heat loss across the air by convection or conduction, as the case may be, there will, of course, be radiation loss, for the walls will be colder than the outer plumage surface.

If the wall of a tree cavity is hard unrotted wood, one small bird could do little toward raising the wall temperature. But if the wall has an insulating layer of dry rot or other lining, the wall itself would conduct heat outward less fast; and if the bird fits the cavity fairly well (or if several birds crowd in to add their heating effects), the temperature of the walls may very well rise appreciably through the

night and serve to reduce the loss on critical nights to a rate permitting the birds to survive.

Another factor is the size of the tree or branch in which the cavity is located. More often than not, winter night temperatures are lower than day temperatures. As the night progresses, a tree will cool. The larger the tree size at cavity level, the less the cavity wall will drop in temperature during the cooling process.

Still another factor is cavity size as related to fluffing ability. Rowan (1925:299), who has done a great deal of work with small birds in the very cold winters of Alberta, should be quoted: "... a friend who keeps a food-tray on her window-sill throughout the winter at Red Deer, Alberta, has informed me that Chickadees frequently come to feed in the early mornings during the very cold spells, with patches of ice on the head, particularly around the eyes. From the curled condition of their tail-feathers it is evident that they have spent the night huddled in holes." Now, if the hole is only small enough to curl the tail-feathers, no harm is done; but if it is so small that fluffing of the body feathers is seriously interfered with, the full effectiveness of the bird's natural insulating coat is not realized.

OPEN ROOSTS

Wind. A bird choosing not to sleep in a complete enclosure is exposed to wind. Observations on the wind actually affecting a bird offer great difficulty. However, the "wind facts" are of great importance to the bird. I have found nothing recorded in the literature about actual air movements past a sleeping, exposed bird in the natural state. Here, certainly, is a difficult but fruitful field for observation.

We do have weather station records of wind velocities. If a bird should consent to roost for the night next to the whirling anemometer cups, then the wind velocity records usually available would have considerable meaning. But the bird sleeps in a more suitable habitat. What is the wind velocity where the bird actually roosts?

A great deal of work has been done in recent years on the structure of winds. I have had to study some of the published research, and I think it will be well to mention some examples.

A wind sweeping over bare, flat ground at 10 miles per hour, 5 feet up, may typically be going at from 3 to 5 m.p.h. half a foot above the ground; and, at 25 feet above (where it might be measured by a weather station), it moves at from 12 to 18 m.p.h.

Next consider a wind which, like the one above, has a speed of 10 m.p.h. at 5 feet from the ground; but in this case, there is a brushy bush growth 3 feet high. Among the bush tops, the velocity may be only 1 or 2 m.p.h.; and further down, if the bushes are thick, it might drop to far less. At the 25-foot level, the speed may be somewhere around 25 m.p.h.

One series of tests covered an orchard situation, the trees being in rows. Tree height was 10 feet. A 27 m.p.h. wind at the 25-foot level resulted in a 10 m.p.h. wind between the tree rows. The velocity through the leafy trees themselves was probably between 2 and 5 m.p.h.

To cite one more situation, a 10 m.p.h. wind at the 5-foot level blows over 6-inch grass. A little above grass-top level, the velocity is about 2.5 m.p.h. But down in the grass, depending on level and thickness of grass, the velocity would be anything from perhaps 1 m.p.h. near the tips, down to a very low value close to the ground.

Further, the bird may be counted on to take advantage of ground irregularities, valleys, cliff indentations, and so on; and, if in a tree, to seek the leeward side of the trunk or entanglements of leaves.

Think of a bird nestled down in a thick clump of grass. Ten miles away, a weather station located on a stretch of flat ground is recording a low temperature and a night wind of 25 m.p.h. But the bird is located on the lee side of a forested hill, where the velocity at the 5-foot level may be only 5 m.p.h., and a few inches above the ground, inside the bird's grassy shelter, the actual wind speed may be less than half a mile per hour. If drifting snow has covered the windy side of the clump, the bird may experience no wind whatever.

It is out of the question to suggest that all observers of winter night habits of birds should always take to the field equipped with instruments for measuring wind speeds at the actual site. But the fact is that an "educated guess" at wind speed at the site would be more significant than a wind speed as measured at a weather station somewhere else in the same county. Better yet, there will be many situations and occasions when the timing of a bit of fluff or a puff of smoke will yield valuable information. Smokers are always ready to produce the smoke. Others can light punk, or oily rags. A stopwatch can be used for timing; or one can learn to count seconds quite accurately. The distance can be measured off, or paced.

If a roosting place is in a tree, the smoke source should be elevated on a pole, in order to measure the velocity at the roost level as nearly as may be, and through the site itself. If the roost is in a bush, it would be well to measure at a level one foot above the bush top, and again, if possible, through the bush at roost level. If the bird is in a grass clump, measure at one foot above grass-top level, or at whatever level is practicable; also, release some smoke on the windy side of a typical clump, and observe the smoke entering the clump,—how much does the smoke hang around inside the clump?

In making these suggestions, it is realized that some may have trouble in carrying them out; and further, so much variation occurs in ground contours, cover, and so on, that the suggestions are quite incomplete. What we need is ideas growing out of experience.

Finally, when there is a very cold wind at night, the bird that is in a complete enclosure of some kind will experience little or no wind;

and the bird not so enclosed may usually be expected to have found a lee, or a place in a thicket in a ravine, where the wind amounts to little more than an occasional puff and some irregular eddying. Such an irregular, occasional flow may be difficult to measure; but at least, the general behaviour of some released smoke can be described. Any information of this kind will be new and valuable.

Temperature. Here again, data from a distant weather station can be very misleading. Owing to differences in altitude, types of wind, exposure to clear sky, air stratification, and so on, there may be several, and sometimes many, degrees difference between a weather station temperature, and the temperature at the spot where the bird is. If a steady wind is blowing at the site, the air temperature taken within a few feet of the level of the bird's roost will probably be near enough. The more nearly windless the site is, the more necessary it is to place the thermometer at about the level of the bird's location, and not more than 10 or 20 feet distant horizontally. In any case, one must wait for the thermometer to stabilize its reading.

The thermometer is affected by radiation. Radiation effects sometimes cancel out, permitting the thermometer to record the true temperature of the air. However, one certainly cannot count on this happening. In the daytime, with a thermometer placed in the sunlight, the reading may be increased very considerably above air temperature. But even at night (especially with full exposure to clear skies) radiation can affect the reading. If the temperature is taken with the thermometer unshielded, it should be so recorded—along with the amount of sky exposure.

In weather station work, air temperatures are obtained by mounting the thermometer in a ventilated box. Such a box would hardly be portable, but a simple shielding device that will be far better than nothing, can be made from a piece of heavy cardboard. Punch a hole in the middle, and insert the bulb end of the thermometer through the hole until the bulb is perhaps an inch from the cardboard. When the cardboard is held horizontally, the bulb can be adjusted to be completely shielded from the sky.

OBSERVING, RECORDING, REPORTING

Eventually, accumulated experience will enable someone to develop a record-form for field use. The development and use of such a form would be most desirable. But so many variables enter in that I, at least, do not feel able to attempt the design of a form at this stage. It is quite possible that a single, general form would turn out to be a nuisance, and that we may have to develop particular forms for groups of related species. The next best thing, a list of suggested items to cover, is presented below.

Geographical location.

Dates and exact times of observations.

Lay of the land: General description for a mile or so around, with notes on forestation, etc.

Habitat: Elements of growth, local ground formation in relation to shielding from sky, from wind, etc. Hill top, valley bottom, or intermediate situation. Nearness to bodies of water which might prevent extreme fluctuations in temperature.

Site: Description of tree roost, cavity, clump, bark shield, etc.

Radiation cover: Overhead cover—description; in what degree does it shut off view of sky?

Weather station data: Location of nearest station. (Wind, temperature, and precipitation data should be reported from it when possible. This will help to emphasize the fact that the bird's survival may depend upon highly localized conditions.)

Temperature: How measured and where.

Wind: Velocity, how measured and where.

Number of birds: Estimate if accurate count is impossible.

Spacing of roosting birds: Average distance between the members of a group or flock. In close contact or not?

Adjustment of body feathers: Degree of fluffing (direct measurements and flashlight photographs are needed). If exposed, is the bird pointed into the wind?

DISCUSSION

Kendeigh (1934), Baldwin and Kendeigh (1932), and Benedict (1938) will serve to introduce the reader to the large and growing literature on the bird's metabolism and temperature regulation. The literature relative to heat loss mechanisms is enormous and scattered through many fields in physics and engineering; reference to such literature is therefore omitted here.

Gathering of pertinent data on the survival of birds on cold nights is an almost virgin field of endeavor. If the bird's thermal problem is approached as an engineering problem to which a numerical solution is desired, it bristles with difficulties; but even an amateur can acquire a good understanding of the factors affecting heat loss, thereby becoming competent to observe and record much-needed data. Critical comparison of the data will be certain to yield illuminating results.

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COLLEGE OF ENGINEERING, UNIVERSITY OF MICHIGAN, ANN ARBOR