ABSORPTION OF RADIANT ENERGY IN REDWINGED BLACKBIRDS (*AGELAIUS PHOENICEUS*)

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Previously (Lustick 1969) it was shown that blackbirds could use insolation to thermoregulate, and that the thermal neutral zone was decreased at least 10° C in those birds receiving artificial insolation. It was hypothesized (confirmed by Heppner 1969, 1970) that the downward shift in thermal neutrality was due to an effective increase in insulation; that is, a decrease in the thermal gradient from the surface of the skin to the surface of the feathers, thus decreasing conductive heat loss. This suggests that the bird is an endotherm (all heat being produced by metabolism) and, under these conditions, loses heat more slowly. Cowles et al. (1967) has stated that "under the usual conditions prevailing in and around endotherms, and particularly in birds, the thermal gradient usually slopes steeply from the body toward the environment." It is obvious that at air temperatures higher than the body temperature the bird is no longer strictly endothermic since the temperature gradient is toward the bird (bird gains heat from the environment). The question arose as to whether birds are strict endotherms when receiving insolation at high air temperatures below body temperature, or whether they could possibly be heliotherms (gain heat from solar radiation), like the reptiles from which they evolved. This study was conducted to determine if, in blackbirds receiving insolation, the net heat flow could be reversed (heat flowing into the bird) at air temperatures below body temperature, and if so, at what ambient temperature the birds change from strict endotherms to heliotherms.

METHODS AND MATERIALS

The experimental setup was similar to that of Lustick (1969) and consisted of a plexiglass chamber (22 × 22 × 32 cm) fitted with four thermocouples, and two air vents (6 mm in diameter). Centered in the top surface of the chamber was an opening (15 × 15 cm) over which a glass plate 3 mm thick was sealed with stopcock grease. During the experiment the chamber containing the bird was submerged in an Aminco temperature-controlled bath of circulating water (185 liter capacity) so that the glass window was covered by 1 cm of water. The radiation source, a General Electric infrared lamp (R-40, 250 w clear end), was centered over the window 40 cm above the floor of the chamber. The bird in the chamber received light of wavelengths 400–1400 nm, the upper limit of infrared passing through one cm of water (Ruttner 1963:13).

The per cent transmittance of the glass window was measured with a Beckman spectrophotometer and found to range from 80 to 90 per cent over the spectrum of 400–1400 nm, with the highest transmittance at 500 nm. With the radiation source on, the birds received approximately 0.9 cal cm^{-2} min^{-1} at 7 cm above the floor of the submerged radiation chamber. No air was passed through the chamber (thus reducing convective heat loss) but the vents were open to the outside. Redwinged Blackbirds (*Agelaius phoeniceus*) with a mean weight of 52.4 g were lightly anesthetized with 0.02 cc sodium pentobarbital (60 mg/ml) and placed in the center of the chamber so that their dorsal surfaces were exposed to the radiation source. Only birds whose body temperatures remained in the normal range (40–42.5° C) were used. If birds were overanesthetized their body temperatures dropped to 37° C. Body temperatures were recorded from a thermocouple placed 2.5 cm into the cloaca, skin temperatures from a thermocouple surgically implanted under the skin of the mid-dorsal surface, surface temperatures from a thermocouple placed just under the top layer of feathers and directly above the skin thermocouple (there being several layers of feathers between them), and ambient temperatures from a shielded thermocouple in the bottom of the chamber. All temperatures were continuously recorded on a Leeds and Northrup Speedomat potentiometer. There was no noticeable change in feather erection during the test, and thus, no altered heat flow occurred from changes in feather orientation. The birds were tested with and without artificial insolation over an air temperature range of 13–37.1° C.

RESULTS

The data in table 1 shows that, at air temperatures below 30° C, the thermal gradient (net heat flow) was always out (heat lost to environment), regardless

TABLE 1. Heat flow into and out of Redwinged Blackbirds with and without artificial insolation.

					Radiation				
					On		Off		
	Temperature (°C)				Gradient (°C)[a]				
Bird no.	A[b]	sur.	sk.	B	B-sk.	sk.-sur.	B-sk.	sk.-sur.	Time (min)
1	13	22.8	38.1	41.6	-3.5		-3.5	-15.3	10
1	13	34.0	38.4	41.6	-3.2	-4.4			10
1	13	33.4	39.5	42.2	-2.7	-6.1			30
2	20.0	26.5	34.5	42.2			-7.7	-7.9	10
2	20.0	35.0	36.7	42.2	-5.5	-1.7			10
3	20.0	23.9	38.9	41.7			-2.8	-15.0	10
3	20.0	28.9	38.5	41.7	-3.2	-9.6			10
3	22.2	23.4	38.9	41.1			-2.2	-15.5	10
4	20.6	28.4	37.8	41.6			-3.8	-9.4	10
4	21.6	37.8	38.9	42.2	-3.3	-1.1			10
5	26.1	31.6	40.0	41.7			-1.7	-8.4	10
5	26.1	40.0	39.5	40.6	-1.1	-3.3			10
5	26.1	40.5	41.2	41.7	-0.5	-0.7			30
6	30.0	33.3	37.7	41.0			-4.4	-3.3	10
6	30.0	44.5	43.0	41.7	+1.3	+1.5			20
6	30.0	45.6	43.4	42.2	+2.2	+1.2			25
6	30.0	45.6	43.6	42.2	+2.0	+1.4			40
6	30.0	33.8	38.3	41.9			-4.5	-3.9	50
7	33.9	36.1	40.0	41.4			-1.4	-3.9	10
7	33.9	45.6	43.3	42.2	+1.1	+2.3			10
8	32.2	32.2	37.2	41.6			-4.4	-5.0	10
8	34.1	45.2	43.8	42.2	+1.6	+1.7			10
9	36.0	36.0	37.8	40.8			-3.0	-1.8	10
9	37.8	46.3	44.5	41.6	+2.9	+1.8			10
10	36.1	47.2	45.0	42.2	+2.8	+2.2			10

[a] + = gradient into the bird (heat gain from insolation); - = gradient out of the bird (heat lost to environment).
[b] A = ambient; sur. = surface; sk. = skin; B = body.

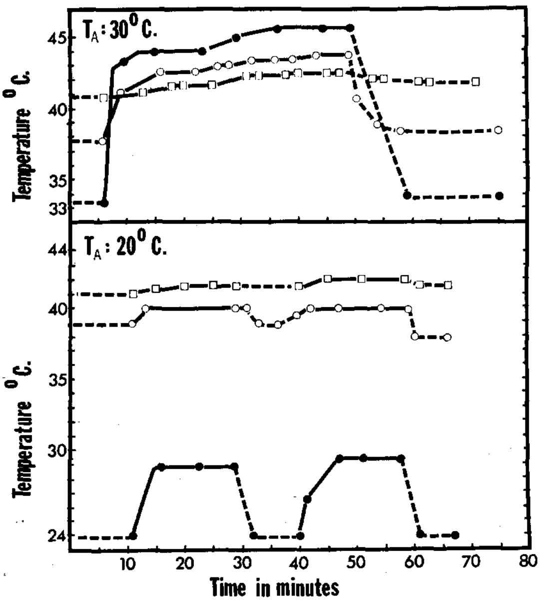

FIGURE 1. Typical curves showing the body temperature (open squares), skin temperature (open circles), and surface temperature (filled circles) of two male redwings, one at an ambient temperature of 30° C, the other at 20° C. The dashed line = radiation source off; the solid line = radiation source on.

of whether the radiation source was on or off. It can also be seen in table 1 and figure 1 that, at air temperatures below 30° C in birds receiving radiation, there is usually a reduction in the thermal gradient from body temperature to skin temperature and skin temperature to surface temperature. This reduction in the thermal gradient acts as an effective increase in insulation, minimizing heat loss and, as shown previously (Lustick 1969), reducing the metabolic requirements necessary to maintain a constant body temperature. More important though is the fact that, at air temperatures above 30° C and below the body temperature in redwings receiving insolation, the amount of energy absorbed is greater than the amount reradiated off (that is, the thermal gradient is reversed and the net heat flow is into the body).

DISCUSSION

The shift from strict endothermy to heliothermy occurs at approximately the lower critical temperature (28° C) of the Redwinged Blackbird (Lewies and Dyer 1969). Since the shift from endothermy to a heliothermy takes place at an air temperature above the lower critical temperature, the bird can no longer regulate body temperature by reducing metabolic rate (heat production) as it could below the lower critical temperature. It should be pointed out that convective heat loss was at a minimum (no air flow) during the experiment and that surface temperature would be dependent not only on radiation but on convective heat loss. Thus, in a flying bird receiving solar radiation (or a bird on a windy day), the thermal gradient might not be reversed at air temperatures above 30° C but below body temperature.

Although in Redwinged Blackbirds evaporation (panting) is an effective means of heat loss, it requires energy, and at the same time increases the gradient from surface to body (lower body temperature), thus enhancing heat gain in birds receiving solar radiation. Evaporation as a means of heat loss is used mainly when ambient temperature exceeds body temperature or the bird is active. An efficient way of minimizing heat gain from solar radiation would be to withstand a slight hyperthermia. At air temperatures of 30° C and above, the birds, when receiving radiation, had a higher body temperature (fig. 1 and table 1). Of course the most efficient means of regulating body temperature at high air temperature below body temperature would be behavioral regulation, that is simply to get out of the sun into the shade, and one can see from figure 1 that when the insolation source is turned off, simulating moving to the shade, the body temperature drops. This reversed thermal gradient explains why on warm sunny days most birds tend to be active in early morning and late afternoon when solar radiation is less intense. This does not mean that a blackbird cannot operate in open sunlight on a hot day, since increased convective heat loss might increase the temperature at which the thermal gradient is reversed, and evaporative cooling can maintain the body temperature below the lethal temperature. It should also be pointed out that only blackbirds were used in this study, and, as shown previously (Lustick 1969), a white bird (albino Zebra Finch) reflects approximately 90 per cent of the solar radiation impinging on its surface, compared to 5 per cent for a blackbird. One can conclude that, below their lower critical temperature, blackbirds receiving insolation are strict endotherms and show a decreased heat loss due to a decreased thermal gradient from surface of skin to surface of feather, whereas in blackbirds receiving insolation above their lower critical temperature (but below body temperature), the thermal gradient is reversed and the bird is no longer strictly an endotherm since it gains heat from insolation. The next step will be to repeat this experiment, varying the air flow (convective heat loss) through the chamber and thus determine the effects of convection on heat gain from insolation.

SUMMARY

Ten Redwinged Blackbirds (*Agelaius phoeniceus*) were used to determine if the net heat flow could be reversed at air temperatures below body temperature while receiving insolation.

It was found that at air temperature below the lower critical temperature (30° C), the bird was still an endotherm, the net heat flow being out of the bird, although the outward thermal gradient was decreased in birds receiving insolation. At air temperatures above the lower critical temperature, the thermal gradient was reversed, the net heat flow being into the bird. Thus, a blackbird sitting in the sun at air temperatures above its lower critical temperature shifts from strict endothermy to a combination of endothermy and heliothermy.

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MARBLED GODWIT AND YELLOW-THROATED WARBLER IN COLOMBIA, SOUTH AMERICA

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On 24 December 1969 at 14:15 we observed two Marbled Godwits (*Limosa fedoa*) with nine other species of shorebirds on a mudflat on the Caribbean coast at Puerto Colombia, Atlantico, Colombia. The birds were studied at leisure for 40 min with 8 × 40 binoculars and a 20× scope. They were also flushed so that wing and tail pattern could be observed. R. M. de Schauensee (The birds of Colombia. Acad. Nat. Sci. Philadelphia, Livingston Publ. Co., Narberth, Penn., 1964) does not list this species. However, the occurrence of *L. fedoa* in Colombia is not surprising since Eisenmann (Trans. Linnaean Soc. New York, 7:29, 1955) lists this species as wintering in Middle America and southward along the Pacific Coast to northern Chile. R. M. de Schauensee (The species of birds of South America. Acad. Nat. Sci. Philadelphia, 1966) states that some *L. fedoa* take a more easterly course through Barbados and have been recorded from Trinidad and Tobago. Probably this species has been previously overlooked in Colombia. On 23 December 1969 at 07:00 we observed a Yellow-throated Warbler (*Dendroica dominica*) near Hotel El Prado, Barranquilla, Atlantico, Colombia. The bird was studied for 15 min as it crept about on the trunks and branches of trees (palms, etc.). During winter in the Everglades at Flamingo, Florida, we have observed similar feeding habitat and behavior for this species. R. M. de Schauensee (1966 op. cit.) does not mention this species from anywhere in South America. Eisenmann (op. cit., p. 90) records the eastern race *dominica* as wintering in Florida and the West Indies and *albilora* as wintering in Middle America to Costa Rica. Airline distance from Costa Rica to Barranquilla, Colombia, is about 570 mi.

Although no specimens or photographs were secured of either species, their identity was unmistakable. Both of us are very familiar with these species in the United States. This note should alert future ornithologists in Colombia as to the possible occurrence of these birds. Appreciation is extended to R. Meyer de Schauensee for correspondence concerning these records.

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