CUTANEOUS WATER LOSS IN THE ROADRUNNER AND POOR-WILL

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Avian physiologists have generally assumed that since birds lack sweat glands, cutaneous evaporation is negligible. However, recent data indicate that the skin represents a major avenue of evaporative water loss (EWL) in the Painted Quail (*Excalfactoria chinensis*), Village Weaver (*Ploceus cucullatus*), Budgerigar (*Melopsittacus undulatus*), Zebra Finch (*Poephila castanotis*) (Bernstein 1969, 1970, 1971a, b), and the Domestic Pigeon (*Columba livia*) (Smith 1969; Smith and Suthers 1969). Not all birds lose large amounts of water through the skin. Schmidt-Nielsen et al. (1969) state that the skin plays a minor role in EWL in Ostriches (*Struthio camelus*), contributing less than 2 percent of total evaporation at 40°C.

The purpose of this study was to examine cutaneous evaporation in two North American desert-inhabiting birds, the Roadrunner (*Geococcyx californianus*) and the Poor-will (*Phalaenoptilus nuttallii*). Oxygen consumption and EWL have been studied previously in both species over a wide range of ambient temperatures (Bartholomew et al. 1957; Bartholomew et al. 1962; Calder and Schmidt-Nielsen 1967; Lasiewski 1969; Lowe and Hinds 1969).

MATERIALS AND METHODS

One adult Poor-will and 14 Roadrunners (six adults, four chicks 1–3 days old, four chicks 7–10 days old) were used in this study. The adult birds were maintained outdoors in Los Angeles under natural photoperiod during July and August 1970. Nestling Roadrunners were maintained in a constant temperature cabinet at 35°C (±1°C) under a simulated natural photoperiod. Adult Roadrunners were fed whole mice and chicken parts; nestlings and the Poor-will were fed baby mice, beef hearts, dog food, and *Tenebrio* larvae.

The methods for measurement of cutaneous and respiratory EWL were similar to those described previously (Bernstein 1970). A postabsorptive bird was placed in a Plexiglas chamber partitioned into two compartments. A close-fitting dental dam collar, stretched across a hole in the partition through which the head protruded, prevented air flow between the two compartments. A Plexiglas pillory secured to the partition prevented the bird from withdrawing its head from the forward compartment. The bird stood on a hardware cloth platform above a pool of mineral oil 1 cm deep, so that if excreta were voided they would fall through the platform and be covered by the oil.

Three chambers were used to accommodate the different sizes of birds. The volumes of the head and body compartments were 4.4:12.3, 2.0:2.5, and 0.7:0.7 liters. Adult Roadrunners were studied in the large chamber, 7–10-day-old nestlings in the medium chamber, and 1–3-day-old nestlings and the Poor-will in the small chamber.

The Plexiglas chamber was placed in a temperature control cabinet and maintained at 30° or 35°C (±0.5° C). Temperatures in the chambers were monitored with 30-ga copper-constantan thermocouples connected to a potentiometric recorder. Separate streams of dry, CO_2-free air were directed into each compartment (250 cc/min for 1–3-day-old nestlings, 1000 cc/min for 7–10-day-old nestlings and the Poor-will, and 2000 cc/min for the adult Roadrunners). The flow rates were sufficient to maintain the water vapor pressures below 7.5 mm Hg (calculated by the formula of Lasiewski et al. 1966). The outflow air from each compartment was directed through pre-weighed U-tubes filled with Drierite and through U-tubes filled with Ascarite. An aliquot of each air stream was directed through a Beckman G-2 paramagnetic oxygen analyzer. The pre-weighed Drierite tubes were placed in the lines for precisely-timed intervals (approximately 15–20 min) and their weight gain was taken as EWL.

Control experiments were conducted, using chambers without birds, since we found that Plexiglas is

TABLE 1. Evaporative water loss of the Poor-will (*Phalaenoptilus nuttallii*) and the Roadrunner (*Geococcyx californianus*).

					Evaporative water loss [mg H_2O (g × hr)$^{-1}$]				
							Cutaneous		
Age (days)	$\bar{x}$ wt. (g)	No. birds	T_A °C	O_2 consumption cc O_2 (g × hr)$^{-1}$	Total $\bar{x}^a \pm$ SD	Respiratory $\bar{x} \pm$ SD	$\bar{x} \pm$ SD	% of Total	Cutaneous $\frac{E}{H} \times 100^b$
Phalaenoptilus nuttallii									
Adult	43.2	1	35	1.8 ± 0.15	5.9 ± 1.11	2.9 ± 0.80	3.0 ± 0.35	51.3	20.1
Geococcyx californianus									
1–3	19.8	4	35	1.1 ± 0.13	3.2 ± 1.19	1.5 ± 0.60	1.7 ± 0.62	54.0	18.7
7–10	89.2	4	35	2.3 ± 0.46	5.5 ± 0.94	2.7 ± 0.86	2.8 ± 0.37	52.0	14.7
Adult	274.2	6	35	1.0 ± 0.16	2.9 ± 0.60	1.4 ± 0.47	1.5 ± 0.32	51.0	18.1
Adult	269.3	6	30	1.2 ± 0.26	2.7 ± 0.78	1.3 ± 0.43	1.4 ± 0.55	51.0	14.1

[a] Means ± SD of at least four determinations.
[b] The % metabolically produced heat (H) dissipated by cutaneous evaporation (E), assuming 1 mg $H_2O = 0.58$ cal and 1 cc $O_2 = 4.8$ cal.

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TABLE 2. Cutaneous evaporation in birds.

			Evaporative water loss [mg H_2O (g × hr)$^{-1}$]		
Species	Body wt. (g)	T_A (°C)	Total	Cutaneous as % of total	Reference
Poephila castanotis	12.5	30	8.9	62.9	Bernstein 1971
Melopsittacus undulatus	31.6	30	9.0	58.9	Bernstein 1971
Excalfactoria chinensis	42.3	30	4.7	44.7	Bernstein 1971
Ploceus cucullatus	42.6	30	6.7	50.8	Bernstein 1971
Phalaenoptilus nuttallii	43.2	35	5.9	51.3	Present study
Columba livia	299.9	35	13.6	74	Smith 1969*
Geococcyx californianus	274.2	35	2.9	51.0	Present study
Struthio camelus	88,000	40	2.2	<2	Schmidt-Nielsen et al. 1969

* Estimated from figs. 19 and 20 of Smith.

capable of taking up and giving off small amounts of water. We checked the possibility that appreciable evaporation was occurring from the cloacal region by inserting greased plugs in and over the cloaca of an adult Roadrunner and then covering the cloacal region with adhesive tape. Values for EWL from this bird were indistinguishable from those from untreated birds.

RESULTS AND DISCUSSION

Cutaneous evaporation accounted for slightly more than half of the total EWL in all cases (table 1). Values for total EWL and oxygen consumption of adult Roadrunners at 30 and 35°C were similar to those reported by Calder and Schmidt-Nielsen (1967). Values for total EWL and oxygen consumption of the Poor-will were more than twice those reported by Bartholomew et al. (1962) and Lasiewski (1969) and were probably caused by struggling due to restraint.

Estimates of cutaneous EWL are now available for seven species of small birds ranging in weight from 12.5 to 300 g (table 2). All of these smaller birds lose 45 per cent or more of their total EWL via the skin at 30 and 35°C. There is no clear correlation between the level of cutaneous evaporation and habitat in the species studied. The xerophilic Budgerigars, Zebra Finches, Poor-wills, and Roadrunners do not differ markedly in this respect from the more mesophilic Painted Quail, Village Weaver, and Domestic Pigeon. The loss of a much smaller proportion of total EWL through the skin of the Ostrich contrasts sharply with the values for smaller birds (table 2).

The marked changes in morphology of Roadrunners during ontogeny were not reflected in changes in the cutaneous proportion of total EWL. This is similar to the situation of the much smaller Painted Quail, for which the cutaneous percentage of total EWL does not change appreciably between hatching and adulthood (Bernstein 1970, 1971a).

Birds evaporate more water from the skin than had been assumed previously. This has important implications in several areas of avian physiology (e.g., calculations of respiratory volumes, avenues of heat loss).

Minimum respiratory volumes can be calculated from data on EWL, respiratory rate (f), and ambient and body temperatures (T_A, T_B), assuming that expired air is saturated with water vapor. Schmidt-Nielsen et al. (1970) have described a temporal counter-current heat exchanger in the nares of small birds, which at lower T_A cools the exhaled air, resulting in water and heat conservation. On the basis of their results, we assume that, at a T_A of 35°C, the air exhaled by adult Roadrunners averages 37.5° (T_B = 40°). The minimum tidal volume calculated from our data on respiratory EWL in adult Roadrunners is 4.9 cc (assuming f to be 28.9; Calder and Schmidt-Nielsen 1967). A preliminary equation derived by Lasiewski and Calder (1970) predicts a tidal volume of 3.3 cc for a 274.2-g bird. Earlier calculations of minimum respiratory volumes of Roadrunners by Calder and Schmidt-Nielsen (1967) resulted in a much higher tidal volume (11.5 cc at T_A of 36°), based on the assumptions that all EWL was from the respiratory tract and that air was exhaled at T_B.

Cutaneous evaporation may represent a major avenue of heat dissipation in many species of birds. Evaporation via the skin accounts for the loss of 14–20 per cent of metabolic heat production at 30 and 35°C in the Roadrunner and Poor-will (table 1). Bernstein (1970) reported that cutaneous EWL increased with heat stress in Painted Quail along with evaporation due to panting and gular flutter. This phenomenon probably occurs in other birds.

Further work in this area is required and should be profitable.

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LEAN-SEASON FAT IN A SOUTH AMERICAN POPULATION OF BLACK-NECKED STILTS

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Up to the present time, very little information is available concerning variations of weight and fat content in bird species residing permanently in tropical areas. Odum and Perkinson (1951) write: "Deposition of lipids and increase in weight in wild birds may occur seasonally during regular periods, especially (1) prior to migration in spring and fall and (2) in winter. The former deposition, or migratory fat, is lacking in non migratory birds, and the latter, or winter fat, is probably absent from birds wintering or residing permanently in the Tropics, although there are few data." Nevertheless, according to Ward (1964, 1965a, 1965b), Grant (1965, 1966), and Britton (1967), in the case of sedentary birds in tropical areas, we may expect some variations of weight and fat content in correlation with reproductive activities and availability of food. In order to investigate these variations, I collected specimens of the Black-necked Stilt (*Himantopus mexicanus*), a sedentary species of northeastern Venezuela.

LOCALITY AND METHODS

The specimens of Black-necked Stilt were shot near Cumaná (Laguna San Luis and El Peñón) and Chiguana, between January 1966 and April 1967. Cumaná, capital of the State of Sucre in northeastern Venezuela, is located at the mouth of the Gulf of Cariaco (10°25′42″ N and 64°11′36″ W). Chiguana on the other hand is about 60 km E of Cumaná, at the head of the Gulf of Cariaco (10°30′ N, 63°40′ W). A full description of the lagoons where the birds were taken is given by McNeil (1968, 1970).

As far as possible, groups of three or four individuals were collected at intervals of 10–15 days. However, this objective was not always attained because of the low number of birds in some periods of the year. Shooting hours varied between 07:00 and 10:00; these hours were maintained because of the possibility of diurnal variations in weight and fat content. Such variations have been reported by Helms (1963) in some species of Fringillidae.

In the laboratory, I used a modification of the lipid extraction method proposed by Odum (1960) and Odum et al (1961). McNeil and Carrera de Itriago (1968) describe their fat extraction method as follows: "The dry weight was obtained by drying the specimens in a hot air oven at 80°C for 2 days. After storage for 2 days in a cold petroleum ether bath (10 cc/g dry material), the specimens were removed and boiled for 30 min in a Soxlet apparatus containing petroleum ether. After a second 1-day drying period, the lean dry weight was obtained. Dry weight and lean dry weight were determined to 0.01 g. The difference between dry weight and lean dry weight gave the fat content; likewise the difference between fresh weight and dry weight gave the water content." In the case of Black-necked Stilts, because of the size of the species, the drying time was four days instead of two. For a more detailed description of this method, see McNeil (1968, 1969, 1970).

RESULTS AND DISCUSSION

The Black-necked Stilt (Recurvirostridae) is a very common sedentary species in northeastern Venezuela, especially in fresh and brackish water lagoons, in saltwater lagoons surrounded by mangrove forest, and also in flooded lowlands during the rainy season. According to my observations, the calendar of

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