A COOLING MECHANISM OF THE TEXAS NIGHTHAWK

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The maintenance of body temperatures within the often very narrow limits permitting normal metabolic rates is one of the foremost problems faced by terrestrial organisms. In the vertebrates, both the ectothermal cold bloods and also the warm-blooded, endothermic birds and mammals, thermoregulation often is so important that many species have augmented their intricate physiological adaptations with others involving behavior.

The present discussion is concerned with an adaptation of the Texas Nighthawk, *Chordeiles acutipennis texensis*, for maintaining a proper body temperature in spite of the extreme environmental heat to which it is exposed during the daytime throughout the greater part of its summer range. This species commonly breeds in the Lower Sonoran Zone of the southwestern United States. The majority of the nesting activity of these birds takes place in June when the temperatures on the desert are approaching their maximum, which on the surface in full sun frequently ranges upward of 50° or 60°C. The eggs are incubated in the open, on the ground, where the heat would rapidly kill the embryos; therefore, the adult birds must shield them and while doing so they must remain in the open, exposed to the full daytime temperatures which prevail throughout the nesting season. Because of this, it seems probable that their problems in matters of temperature control would be greater than those of other desert birds which may resort to shade during the heat of the day. On logical grounds it would not seem unwarranted to conclude that this species must possess some positive adaptation to withstand the severe temperatures described. To discover what this might be, the study here reported was undertaken.

Methods.—The most difficult problem was that of procurement of live individuals for purposes of observation and experiment. Because the nighthawks feed exclusively while in flight, the use of traps seemed precluded, and their wide dispersal in desert areas and their inconspicuousness while resting on the ground made them practically unobtainable by any ordinary procedures. It was therefore necessary to attempt their capture by shooting them while they were in flight. In order to reduce killing to a minimum, the birds were shot at long ranges. The more severely wounded were immediately sacrificed after temperature records were taken, and these and the occasional killed birds were then skinned in order to obtain the figures given below for the ratio of mouth to body surface. Birds that were only slightly wounded were used in experiments from which were derived the majority of the data presented here. When a wounded individual was procured, it was placed in the sun where its body temperature was recorded at intervals and its actions observed.

Results.—The most striking behavior was observed when the nighthawks were exposed to the sun. At first they remained quiet, but as body temperatures increased, they would open their mouths. Soon after this the gular areas would be fluttered rapidly. If the day was hot enough, this procedure was invariably followed and the action was interpreted as being a means of heat dissipation in a manner analogous to panting. In order to test this analogy it was necessary to examine critically the action of the mouths of the nighthawks under varying conditions.

Like that of other species of caprimulgids, the gape of the nighthawk is a conspicuous feature of its anatomy. Although this has always been considered an adaptation for aerial feeding, it is also clear that every time the mouth is opened a considerable area of moist surface is exposed. The observed expansion and fluttering of the gular area would appear to facilitate evaporation from this surface. Thus morphologically the mouth area would seem to be an ideal cooling mechanism. Associated with the extent of the mouth area it was also noted that there was a considerable change in the vaso-dilatation in this area and this appeared to be correlated with gross temperature changes. The mouth is well supplied with blood vessels, both on the roof and floor, and following vaso-dilatation the high degree of vascularity is readily perceived.

The accompanying table shows the various temperature records obtained in the course of this investigation. In all but a few cases both cloacal and oral temperatures were taken. The recorded differences are notable in certain instances. Quite possibly the relative humidity and temperature of the air at the time the records were obtained are responsible for the wide variations in the amount of difference.

Air temperature	Cloacal temperature	Oral temperature	Degrees difference	Morning or evening flight
40.4° C.	43.6° C.	35.0° C.	8.6° C.	P.M.
40.4° C.	41.6° C.	......	......	P.M.
38.0° C.	41.2° C.	38.0° C.	3.2° C.	P.M.
37.0° C.	42.2° C.	38.5° C.	3.7° C.	P.M.
17.4° C.	41.0° C.	30.0° C.	11.0° C.	A.M.
34.0° C.	40.0° C.	38.0° C.	2.0° C.	P.M.
32.0° C.	40.2° C.	36.0° C.	4.2° C.	A.M.
32.0° C.	41.0° C.	39.0° C.	2.0° C.	A.M.
32.0° C.	41.9° C.	38.0° C.	3.9° C.	A.M.
20.0° C.	42.0° C.	27.0° C.	15.0° C.	A.M.
20.0° C.	41.0° C.	......	......	A.M.

In every instance it was noted that the oral temperature was lower than that of the cloaca. As will be noted from the table, the differences range in value from 2°C. to 15°C.

To illustrate the importance of this temperature difference in thermoregulation during the heat of the day, and probably in periods of intense activity, the ratio of the area of the bird's oral to its total body surface was computed. These ratios were obtained by skinning the bird and computing the area of the skin, then comparing this with the area of the oral surfaces. The value for this ratio was approximately 15 per cent. It is probable that the estimated value of 15 per cent is conservative, owing to the unavoidable stretching of the skin while being removed from the body. The ratio of areas was determined by tracing on graph paper and the number of squares included in each tracing computed, thus yielding the values from which this ratio was derived. The fact that the moist oral surfaces of the nighthawk represent so large an area, well supplied with blood vessels and capable of being fluttered on occasion, is suggestive of their function in the control of body temperatures.

In order to obtain quickly a sufficiently high environmental temperature, the first nighthawk was placed in a one-quart jar. A quick-registering mercury thermometer was used in order to record the cloacal temperatures. From an initial body temperature of 40.5°C., that of the bird four hours after its early morning capture, the temperature increased until, eleven minutes later, it became constant at 42.9°C. Two minutes prior to reaching this level, the bird had started to flutter its gular area; and between 21 and 24 minutes after inception of the experiment, the cloacal temperatures began to decline. The environmental temperatures within the jar dropped rapidly from 44°C., and thereafter throughout the rest of the experiment the temperatures ranged between 42° and 40°C. Condensation of water on the surfaces of the jar indicated a high relative humidity. The bird was removed from the jar, for photographic purposes, and thereafter all experiments were conducted in the open in full sunlight.

In rather sharp contrast to the results obtained with the first bird are those procured from a second one which was not placed in a jar. This bird's temperature did not go as high as the former's and was reduced more rapidly. During the observation it was placed on some light-colored sand, the temperature of which was 50°C. This temperature was hotter than that of the jar at the beginning of the first experiment.

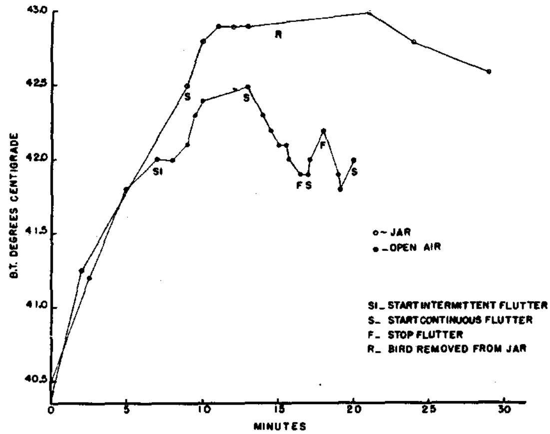

Fig. 1. Graph showing effect of gular fluttering on cloacal temperature of two Texas Nighthawks kept in sun, one for part of time in glass jar. Zero minutes is time at which birds were placed in sun.

The bird began to flutter its throat when its body temperature reached 42°C. This fluttering was intermittent and did not prevent a further rise to 42.5°C. At this point the throat was being fluttered continuously, and within a minute the body temperature began to decrease. When it had fallen to 41.9°, three and a half minutes later, the fluttering stopped. In approximately 30 seconds, pulsations were resumed. Within one minute the body temperature increased to 42.2°, and at this time fluttering ceased and almost simultaneously the temperature began to fall.

The difference in the temperature records obtained from these two birds probably can be explained on the basis of the difference in the humidity of the interior and the exterior of the jar. The respiration of the animal in the jar would increase the water content of the air inside and this would therefore tend to lessen the effectiveness of evaporative cooling. Further work is contemplated in an attempt to obtain temperature records, using some improved instruments.

In order further to determine the effectiveness of the gular fluttering as a cooling mechanism, the bill of the second bird was held closed, thus effectively stopping the fluttering of the gular region. At the end of 50 seconds the bird began to struggle and its bill was then released. During this time its temperature remained between 42.8° and 42.9°. Thirty seconds after release of the bill, the gular fluttering began and approximately 55 seconds later the body temperature began to decrease rapidly, leveling off 40 seconds later to 42.5°. One and a quarter minutes later the flutter momentarily ceased. At this time it was noted that the bird was facing into a mild breeze and that this was causing increased movement of the air within the mouth. The fluttering was resumed and continued until the body temperature had dropped to 42.2°, some six minutes after the bill had been released to permit gular cooling.

Discussion.—The amount of vascularity and the area of the oral surfaces of the nighthawk, coupled with the observations presented here concerning the effect of the gular flutter on the body temperature of this bird, form three lines of evidence which suggest the importance of this area in temperature control by this species. This, together with the insulating and reflective properties of its plumage are undoubtedly factors that enable it to remain in the full sun without need to resort to shade.

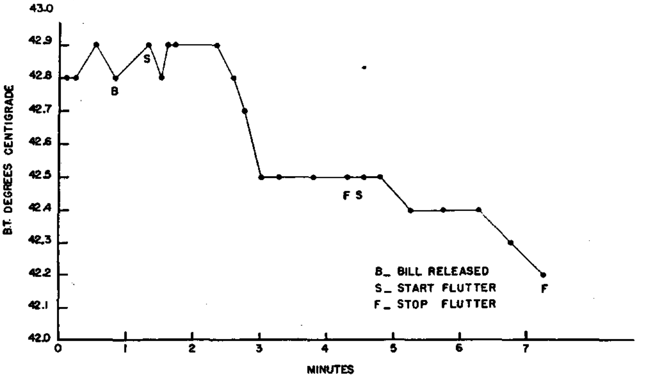

Fig. 2. Graph showing cloacal temperature of a nighthawk kept in the sun with bill held shut part of time to prevent gular fluttering. Zero minutes is time at which bill was closed.

That the nighthawk resorts to this evaporative cooling to withstand the extreme temperatures with which it is faced is not without complications. Temperature control of this nature means an extravagant amount of water loss in areas which are typically very arid. A question quite as important as temperature controls is how this species meets its water requirements.

For the birds with which we were dealing this is comparatively easy. They avail themselves of water from the Colorado River. In the evening hundreds of them can be seen on the horizon, all flying toward this source of water. The flight toward the river may continue for almost an hour and a half, and it certainly represents movements of individuals from some distance away. For birds in other areas the answer may not be so simple, although there is the chance that they too may avail themselves of distant sources of water. However, if surface water is not accessible for considerable periods of time, they must survive on the moisture they obtain from their food, either directly or by means of metabolic water. The fact that insects are most abundant near sources of water may serve to restrict the nighthawk populations to near-by areas, thus indirectly limiting them to nesting sites within flying distance of water.

Since this cooling mechanism appears to be important in the ecology of this species, it would seem to offer a profitable line of investigation in this as well as in other caprimulgids, such as the Poor-will. A comparative study of *Chordeiles minor* would appear to be of particular value.

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