BODY TEMPERATURES IN CALIFORNIA AND GAMBEL'S QUAIL

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THE paucity of data on the body temperatures of small gallinaceous birds prompts us to report miscellaneous observations which we have made over the past several years on the body temperatures of the California Quail, *Lophortyx californicus*, a common resident in grassland and chaparral from southern Oregon to southern Baja California, and the Gambel's Quail, *L. gambelii*, a resident in the desert regions of southwestern United States and northwestern Mexico. The habitats of both species are characterized by high summer temperatures and moderate winter conditions. We have therefore paid particular attention to capacity for temperature regulation in hot environments. We found that when ambient (environmental) temperature rose, the birds' body temperature could rise by as much as 4° C. (7.2° F.), without ill effects. Ability to maintain above normal body temperatures higher than ambient temperatures facilitates transfer of excess body heat to the environment. It is probably a major avian adaptation to hot conditions.

The data presented were acquired incidental to work on other species and for that reason are not comprehensive, but they serve to characterize aspects of temperature regulation in quail.

MATERIALS AND METHODS

The observations were made on 8 adult and 2 juvenile California Quail captured on the Los Angeles campus of the University of California, and on 5 adult and 2 juvenile Gambel's Quail captured in the Colorado Desert, three miles south of Calipatria, Imperial County, California. The captive animals of both species were housed in cages of half-inch wire mesh which measured 12 x 12 x 24 inches and had sand-covered floors. Mixed bird seed, water, cuttlebone, and bird gravel were continuously available and occasionally the birds were given *Tenebrio* larvae. The windowless, ventilated room in which the birds were kept was illuminated by fluorescent lights and the photoperiod was controlled by an automatic timer. The temperature in the room averaged 22° C. (71.6° F.) during the winter and 25° C. (77° F.) during the summer; fluctuations during any one day were usually less than 3° C. (5.4° F.). The birds seemed to do well under these conditions and to maintain their weight, which usually approximated 150 gms. in the adults.

Temperatures were measured with silver-soldered thermocouples made of duplex 30-gauge copper-constanstan wire coated with baked insulating enamel, and were recorded to the nearest 0.1° C. on a recording potentiometer. A stepping switch driven by an electric motor allowed sequential recording from several thermocouples. During the experiments the ambient temperature was controlled to within 1° C. by an insulated chamber equipped with heating and cooling units, a blower, lights controlled by a clock-driven switch, and an insulated glass port for observation. Long-term temperature records were obtained from thermocouples which had been implanted in the pectoral muscles between the keel of the sternum and the left ventral feather tract as described previously (Bartholomew and Dawson, 1954). Short-term records of deep body temperature were obtained either from an implanted thermocouple or from a thermocouple sheathed in vinyl tubing and inserted through the the cloaca into the large intestine and held in place by clipping it to the rectrices. Skin temperatures were obtained from thermocouples secured in place by adhesive tape. During the period of measurement, the bird was housed in an 8 x 8 x 14 inch cage of half-inch wire mesh. The thermocouple leads were secured to the roof of this cage with rubber bands which acted as shock absorbers. Food and water were available during the long-term, but not the short-term measurements. The birds appeared to experience no particular discomfort from the thermocouples. Recording from intramuscular thermocouples was not commenced until 24 hours after implantation.

RESULTS

A clear-cut diurnal cycle of body temperature was apparent in both adult and juvenile California and Gambel's Quail maintained at ambient temperatures between 24° and 26° C., as indicated by records for representative birds (Figs. 1 and 2). Their body temperatures usually fluctuated between 40° and 41.5° C. (104° F. and 106.7° F.) during the day and were approximately 1.5° C. (2.7° F.) cooler during the night. The diurnal difference in temperature appears primarily correlated with level of activity; the cycle of body temperature coincides with the light cycle imposed upon the birds in the laboratory.

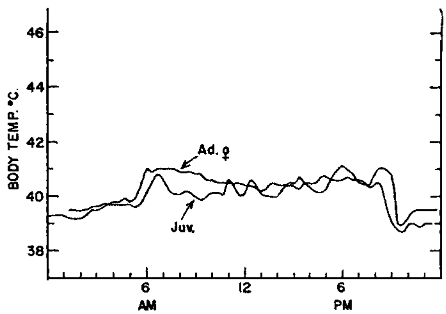

FIGURE 1. Continuously recorded body temperatures of undisturbed California Quail in ambient temperatures of 24° to 26° C. Weight of adult female, 145 gms.; weight of juvenile, 47 gms. Photoperiod, 5:30 a.m. to 8:20 p.m.

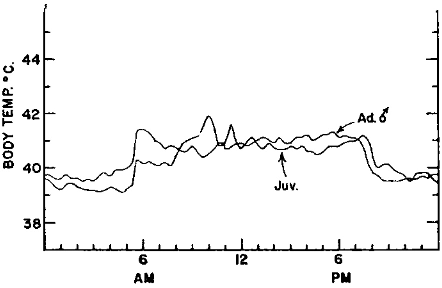

FIGURE 2. Continuously recorded body temperatures of undisturbed Gambel's Quail in ambient temperatures of 24° to 26° C. Weight of adult male, 151 gms.; weight of juvenile, 46 gms. Photoperiod, 5:30 a.m. to 8:20 p.m.

When these quail were maintained in a rapidly warming environment (Figs. 3 and 4), their body temperature rose as ambient temperature exceeded 40° C. In some cases they became as much as 4° C. (7.2° F.) warmer under these conditions without any apparent ill effect. Leg (tarsometatarsus) temperature in the California Quail approximated ambient temperature while the latter was increasing, but remained relatively high when the ambient temperature was returned to a moderate level (25° C. – 77° F.). Leg temperature did not return to its prior level

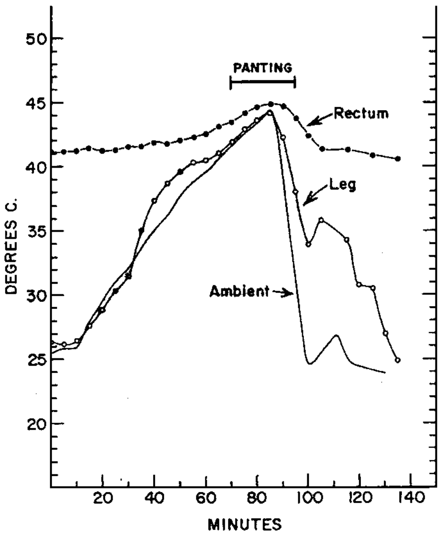

FIGURE 3. Effects of increasing ambient temperatures on rectal and leg (tarsometatarsus) temperatures of an adult female California Quail. Period in which panting occurred designated by horizontal bar. Animal maintained in dark throughout experiment. These data obtained with assistance of W. G. Reeder.

until the heat stored by the bird during exposure to the high ambient temperatures had been dissipated. Panting was not observed in the California Quail until body temperature exceeded 43.5° (110.3° F.). In the single experiment in which a Gambel's Quail was exposed to rapidly increasing ambient temperatures, body temperature did not exceed 43.5° C. and panting was not observed.

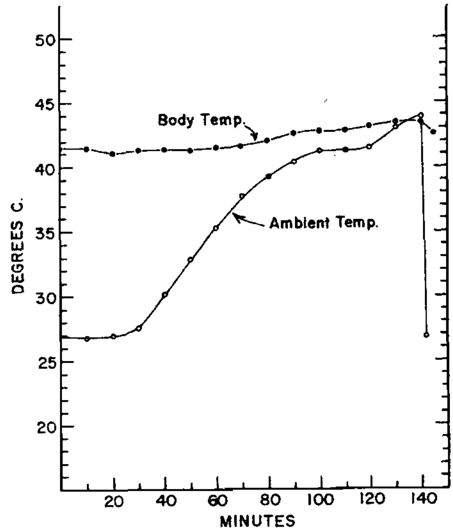

FIGURE 4. Effects of increasing ambient temperatures on body (pectoral muscle) temperature of an adult male Gambel's Quail. Animal maintained in dark throughout experiment.

A diurnal cycle of body temperature was still apparent in the Gambel's Quail maintained in an environment at 39° C. (102.2° F.) but was reduced in amplitude from that observed at lower ambient temperatures. Nighttime temperatures were about 1° C. (1.8° F.) above the level maintained in cooler environments, whereas daytime body temperatures were scarcely elevated. No California Quail were studied during long-term exposures to 39° C.

DISCUSSION

Perhaps the most striking feature of temperature regulation in California and Gambel's Quail is that it results not in a single level of body temperature, but in the restriction of body temperature to a range of several degrees centigrade. Body temperature in these quail is influenced by their activity; the contrast between nighttime and daytime levels of activity appears to underlie their pronounced diurnal temperature cycles. This condition is similar to that long known in birds of other groups (Simpson and Galbraith, 1905; Baldwin and Kendeigh, 1932). In view of this, citation of a single value as representative of the body temperature of a species has obvious limitations.

Body temperature in these quail is readily increased by as much as 4° C. (7.2° F.) in ambient temperatures in excess of 40° C. (104° F.). However, in a sustained environmental temperature of 39° C. (102.2° F.) the daytime level of body temperature in the Gambel's Quail was not elevated above the level normally maintained in the absence of heat stress. The occurrence of hyperthermia (higher than normal body temperature) at high ambient temperatures indicates that these quail have the same response to heat as birds of other orders. We interpret this to mean that the major task of birds in hot environments is not to maintain body temperature constant but to prevent it from rising above some upper critical limit, which is usually at least 4° C. above the normal level. This tolerance of elevated body temperature allows the establishment of a favorable condition for heat transfer from body to environment even when environmental temperature equals the level of body temperature characteristically maintained by birds in cool environments. Thus tolerance of elevated body temperature plus behavioral patterns which minimize metabolic heat production or heat gain from the environment must comprise the basic avian adaptations to hot environments.

The fact that birds store heat in hot environments and consequently undergo a rise in body temperature results mainly from the inability of their panting to produce adequate evaporative cooling (Kendeigh, 1944; Wallgren, 1954; Dawson, 1954). Panting in these quail does not commence until body temperature has exceeded 43.5° C. (110.3° F.). This is somewhat higher than the level observed in the Mourning Dove, *Zenaidura macroura*, (Bartholomew and Dawson, 1954), in the Rock Dove, *Columba livia*, (Randall, 1943), in the Domestic Fowl (Randall and Heistand, 1939), and the Sparrow Hawk, *Falco sparverius*, (Bartholomew and Cade, 1957). We do not know whether or not this difference has any significance. The fact that the temperature of the tarsometatarsus of California Quail can remain considerably warmer than the environment after the termination of experimental heat stress suggests that this portion of the limb can function as a site for dissipation of heat as does the comb of the chicken (Yeates, *et al.*, 1941). The legs could therefore be useful in the dissipation of heat accumulated during very hot days or during flight.

So far we have found that tolerance of hyperthermia is the most conspicuous adaptation to environmental heat in the birds which we have studied (gulls, herons, pelicans, hawks, doves, nighthawks, passerines). Thus the quails' responses to high temperature provide yet another instance of what appears to be a general avian pattern.

SUMMARY

A conspicuous diurnal cycle of body temperature that is correlated with level of activity exists in both juvenile and adult Gambel's and California Quail at moderate ambient temperatures. Body temperatures vary between 40° and 41.5° C. (104° and 106.7° F.) during moderate activity and are about 1.5° C. (2.7° F.) lower during the night. Long-term exposure of Gambel's Quail to 39° C. (102.2° F.) diminished the amplitude of the diurnal cycle but did not abolish it. Short-term exposure to ambient temperatures increased to more than 40° C. (104° F.) resulted in elevated body temperatures in individuals of both species. Panting occurred only after body temperature exceeded 43.5° C. (110.3° F.). These quail resemble birds of other groups in their storage of heat at high ambient temperatures. Their demonstrated tolerance of body temperatures as much as 4° C. (7.2° F.) in excess of normal levels appears to be of primary importance in their survival in hot environments.

ACKNOWLEDGEMENTS

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ERRATUM

The Auk, 75(1):

p. 103, l. 41. "Allen" R. Phillips should read "Allan."

p. 108, l. 17. "Portuguese" should read "Brazilian". Our apologies to Dr. Pinto.