Temperature Relationships of Two Oklahoma Lizards

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During a study of the comparative ecology and behavior of the lizards *Sceloporus undulatus* (Fence Lizard) and *Cnemidophorus sexlineatus* (Six-lined Racerunner) in Oklahoma, sponsored in part by The National Science Foundation, the cloacal temperatures were taken of all captures, where possible. These temperatures concern primarily populations near the University of Oklahoma Biological Station in south-central Station in south-central Oklahoma. (Carpenter, 1959a, 1959b).

A quick-reading Schultheis Reptile Thermometer with a small bulb which could be inserted into all lizard cloacae, except for the small hatchlings, was used. Only cloacal temperatures which could be taken within 10 seconds after capture were recorded. In the field this thermometer was readily available at all times. Other temperatures taken in the field included air temperature, three feet above the surface, in the open and in the shade, the ground surface temperature in the open and in the shade, and subsoil temperature.

The body temperature (cloacal temperature) of a lizard was generally related to two factors, and it was the interplay of these that determined the temperature of a lizard at any particular time. The first of these was the environmental temperature, in particular, that of the substrate on which the lizard was found. The other was the behavior of the lizard in selecting areas of the habitat where it could either raise or lower its temperature. In this way a lizard was able to voluntarily control its body temperature within limits.

This activity, called behavioral thermoregulation (BTR), accounted for certain daily patterns of behavior. The stimulus which initiated the first activity of a lizard in the morning was related to more than the warming of the ground; other factors involved were probably light, along with diurnal cyclic responses (Barden, 1942). However, once the lizard had stirred from his nocturnal retreat, his next actions were usually related to raising his body temperature. In this respect, *Cnemidophorus* and *Sceloporus* used the same method, but modified to their specific habitat niche.

Cnemidophorus was frequently observed beginning to emerge from its burrows in the morning. This was a gradual process. The first evidence was the appearance of a lizard resting at the burrow entrance with only his head visible. Individuals were observed holding this position for as long as fifteen to twenty minutes. Other individuals emerged completely from the burrow, but rested, flattened out, just outside the burrow entrance. In either position, this was the warming-up period when the lizard was absorbing heat from the sun (and probably ground also). Then the lizard began to make short sorties away from the burrow and to forage often returning to the burrow and resting again, flattened out in the sun. It was quite evident that lizards observed later in the morning moved more rapidly than those of early morning.

By mid-morning the ground temperature had risen considerably and the sunning behavior decreased as the amount of continuous activity of the lizards increased. The peak of activity for *Cnemidophorus* was usually reached in the late morning between 10:00 a.m. and 11:00 a.m. (Fig. 1.)

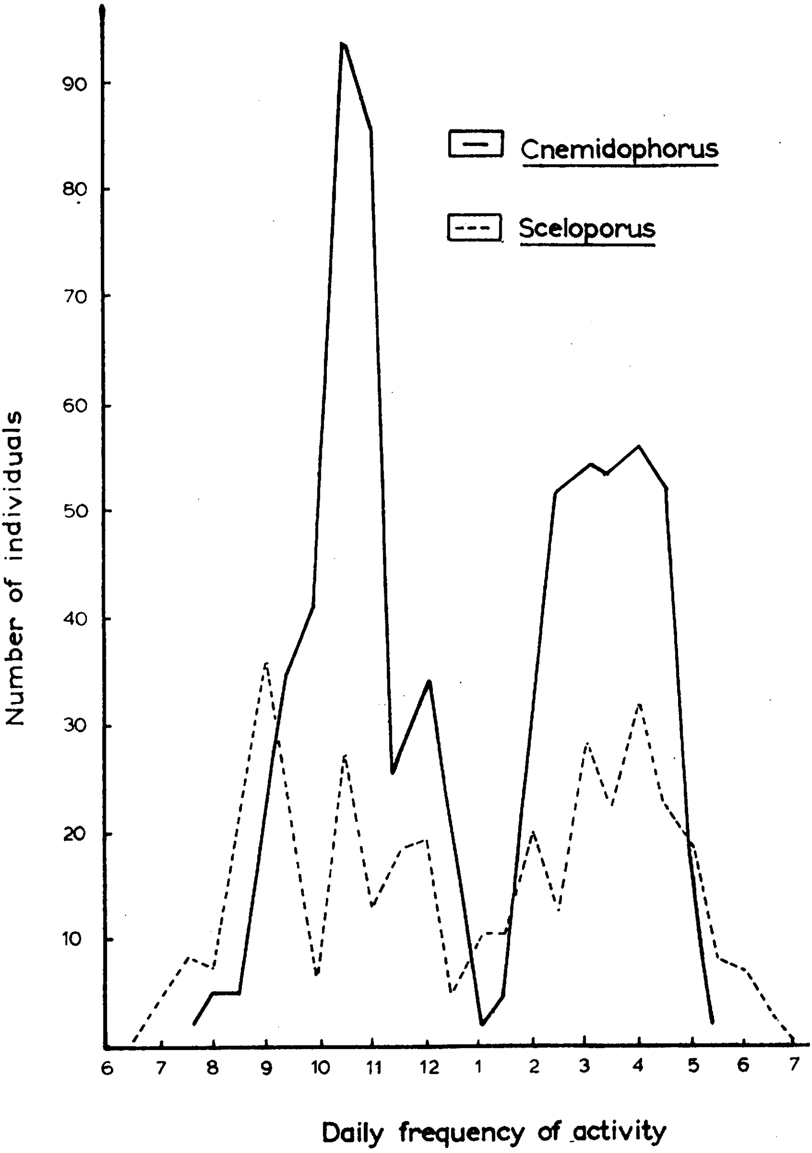

Figure 1. Periods of daily activity for *Cnemidophorus sexlineatus* and *Sceloporus undulatus* in Oklahoma.

On hot days the open ground surface temperature usually exceeded 50°C. If cloacal temperatures of these lizards were to reach this, they would be lethal. Thus, on these days in particular, the pattern of activity shifted as the soil surface became too hot.

The *Cnemidophorus* now moved in a pattern which indicated the desire to lower body temperature rather than raise it. A foraging *Cnemidophorus* spent varying amounts of time moving over the ground in its short-spurt manner and intermittently moved into the shade to rest. The amount of shade used was variable, but could be as little as the shadow cast by a leaf of a ragweed *(Ambrosia).* The soil surface (sand) temperature variations between the open unshaded areas and the shaded were frequently measured to determine the value of such shade to the lizard. The thermometer was laid on the soil, the bulb pressed against the soil.

On June 26, 1956, the temperature of the open sand surface in bright sunlight measured 130° F. (54.4°C) while the soil surface in the shade of a branch of ragweed, less than two square inches and an inch away measured only 100° F. (37.7°C). This was repeated many times on different days with approximately the same results. This small patch of shade was cooler than the temperature of many lizards and could be used to lower body temperature by conduction.

On such days when the soil temperatures reached above 50°C (as high as 58.5°C), the activity of *Cnemidophorus* on the unshaded areas was curtailed. Lizards moving over this hot sand, moved very rapidly between shaded areas. If they did stop, they showed discomfort by immediately moving on. By late morning, when the soil temperatures were high, *Cnemidophorus* activity was rapidly declining, as the lizards retreated to the shade or into their burrows (Edgren, 1955), a possible adaptation to such environmental changes.

A peculiar toe action, seemingly associated with high temperatures, was very characteristic of *Cnemidophorus* when pausing on hot sand. A lizard which had moved rapidly over the hot surface of the sand suddenly stopped and as it did so rested its belly on the sand, extended the legs slightly and at the same time raised the toes of both the forefeet and hindfeet off the ground. Since this behavior was regularly observed for individuals moving over hot sand, it may be a thermoregulatory mechanism. Perhaps the toes are more sensitive to the high temperatures and are thus pulled away, leaving the less temperature-sensitive legs and belly in contact with the ground. On the other hand, the vascular toes offer a proportionally greater surface area than other parts of the body and, thus the toe-rasing could act as a cooling mechanism. This resting position with the toes raised is not held for extended periods of time (a few seconds, the usual, up to 15 to 20 seconds).

Cnemidophorus was observed toe-raising in an indoor laboratory cage where surface temperatures would not have been in any way uncomfortably warm for the lizard. The sand was cooler than the air temperature; 26.5°C and 27.6°C, respectively. Such observations might indicate either conditioned behavior or an innate behavior pattern for toe raising.

When resting in the sun in the morning, *Cnemidophorus* oriented its body to expose the greatest amount of surface to direct rays of the sun. In the laboratory, these lizards often tipped their bodies towards the direct rays of the sun lamp.

A second, but much lower, peak of activity for *Cnemidophorus* appeared in late afternoon (Fig. 1), after which activity dropped very sharply; no significant *Cnemidophorus* activity was observed under natural conditions after 5:00 p.m., even in mid-summer. This dropping off of activity may be related to preferred body temperature, which the lizard found difficult to maintain after the above time.

The initial activity of *Sceloporus* in the morning followed a pattern related to raising the body temperature. They were first seen as they crawled from within cavities, crevices, or from the underside of logs, stumps, and similar objects onto the top of these objects. Here they flattened out, head lowered, and rested directly exposed to the sun. The body was oriented towards the sun so as to expose the greatest body surface. They frequently moved from such lookout or resting spots to investigate another area of the log or object occupied, then either returned to the original point to rest and sun, or flattened and rested at some other exposed point. This gave a pattern of rest, move, rest, move, rest, move.

Within a half hour to an hour after this activity began, a noticeable increase in a lizard's activity was apparent. The periods of rest became shorter as the lizard began to forage away from the spot where he first appeared. However, this alternating pattern of activity and rest continued to be the characteristic behavior for this lizard and was undoubtedly partly associated with the maintenance of the optimal body temperature. When too cool, it would sun; when too hot, it sought shade.

Sceloporus was frequently observed active in very hot weather and it was characteristic to see this lizard under such conditions on a raised object, but this time raised on all four legs away from the object beneath, with his mouth slightly open.

During the summer *Sceloporus* activity began slowly at 7:00 a.m. and increased to a peak between 9:00 and 10:00 a.m., then slowly diminished till near noon when there was very little activity (Fig. 1.). Another but less pronounced activity period appeared in late afternoon at 4:00 p.m. Some *Sceloporus* activity continued as late as 7:00 p.m.

As a result of taking hundreds of cloacal temperatures in the field, the field worker was soon able to predict rather closely what the temperature of a lizard would be. This suggested that each species had a thermo-activity range (TAR) within which the great majority of body temperatures would fall for active individuals.

The cloacal temperature data for *Sceloporus undulatus* indicated an approximate TAR from 25°C. to 38°C. (Fig. 2). The three races for which these data were available varied but these variations were accountable when the period of greatest sampling was recognized. *S. u. consobrinus* had the highest range and these records had their greatest frequency during June, July, and August, in contrast to the other two races, *S. u. garmani* and *S. u. hyacinthinus* where the observed records were for spring and late summer with only scattered records for June through August.

For the same reason, the PBT (average cloacal temperature) for the three races varied, the PBT of *S. u. consobrinus* being the highest (34.77°C), as compared to *S. u. garmani* (30.04°C) and *S. u. hyacinthinus* (30.89°C). The PBT for the combined data for all races was 31.91°C.

Examination of the range-frequency diagrams indicated that this PBT should be a little higher. The low cloacal temperatures, which tended to pull the PBT down, included lizards which were active, but sluggish, and thus actually should not form part of the TAR. The PBT of *S. u. consobrinus* probably approximated a more accurate PBT which was estimated to be between 34° C and 35° C.

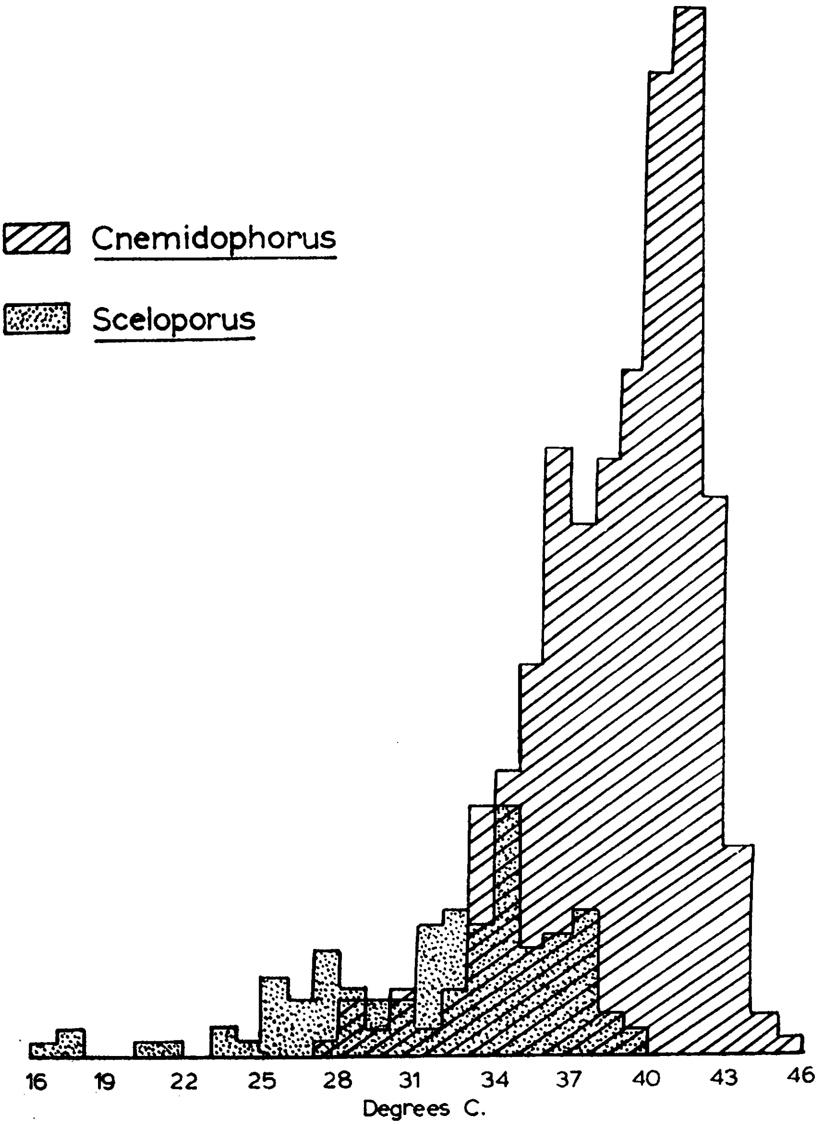

Figure 2. Comparison of cloacal temperature records for *Cnemidophorus sexlineatus* and *Sceloporus undulatus* in Oklahoma.

The cloacal temperature data for *Cnemidophorus sexlineatus* indicated an approximate TAR from 32° C to 43° C, and PBT of 38° C. (Fig. 2).

The significant point of these data was the difference in TAR and PBT between *Cnemidophorus* and *Sceloporus* (Fig. 2), where *Cnemidophorus* had the higher TAR and PBT and *Sceloporus* the lower PBT and a much broader TAR. These findings compare favorably with daily (Fig. 1) and seasonal activity patterns. *Sceloporus* (more cold tolerant) was active earlier and later in the day, had an earlier morning activity peak and a later afternoon activity peak. *Sceloporus* was also active much earlier in the spring and much later in the fall. *Cnemidophorus* (more heat tolerant) had its activity peak later in the day when temperatures were higher and appeared later in the spring and disappeared earlier in late summer and fall.

The preferred body temperatures, as indicated by the thermoactivity ranges of lizards and snakes, are now known to demonstrate generic relationships independent of geographical range. Thus, the thermoactivity ranges of the two species presented in this paper show values close to lizards of the same genera studied by Bogert (1949, 1959) in the southwestern United States and Mexico, and by Fitch (1959) in Kansas.

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