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Activity Patterns and Thermoregulatory Behavior of the Egyptian Tortoise *Testudo kleinmanni* in Israel

ELI GEFFEN[1] AND HEINRICH MENDELSSOHN

Department of Zoology, Tel-Aviv University, Ramat-Aviv, 69978, Israel

ABSTRACT. — In Israel, *Testudo kleinmanni* is active during winter. In summer the tortoises retreat to rodent burrows and their activity decreases. Decline of populations resulting from commercial collecting has resulted in its status as an endangered species. The behavior, activity, and thermal requirements of the species are examined.

The Egyptian tortoise *Testudo kleinmanni* has a very limited distribution ranging from north central Libya eastward to Israel and to the south to about 200 km inland from the Mediterranean coast (Flower, 1933; Iverson, 1986). Loveridge and Williams (1957) reported that this tortoise inhabits desert areas in northwestern Egypt and that in the northern Sinai it is found among bushes near brackish lagoons. In Israel this tortoise inhabits areas of sandy soils and dunes with some cover of bushes and shrubs (Mendelssohn, 1982).

In Egypt, *Testudo kleinmanni* is active throughout the winter (Lortet, 1887). Mendelssohn (1982) reported that the main activity period in Israel is from December to March, first-active individuals being observed as early as October. Rodent burrows were used as cover sites during the activity period if ambient temperature became unsuitable (Mendelssohn, 1982).

The Egyptian tortoise is an endangered species, whose decline is the apparent result of commercial collecting in Egypt (Buskirk, 1985) and destruction of habitat in Israel (Mendelssohn, 1982). This paper describes the annual activity, thermal habits, and behavior associated with aestivation in the Egyptian tortoise; these data are essential to an understanding of the ecology of the species in Israel.

METHODS

The study was carried out at Holot Agur, about 15 km north of Beer-Milka (63375, 42435; U.T.M. Grid), in the northwestern Negev Desert, on an area of 3 km². This area is characterized by east-west trending sand ridges separated by deep valleys. Mean annual air temperature is 20°C (Israel Meteorological Service, unpubl. data) with mean maximum temperature of 30°C in the hottest month (July) and a mean minimum of 12°C in the coldest month (January). Subzero temperatures are rare. Large fluctuations in air temperature (10–15°C) are common during the day. Most precipitation (100–200 mm) occurs between October and March.

Vegetation cover averages 20–30% and consists primarily of the *Artemisia monosperma* plant association (Waisel et al., 1982). Other common plants are *Retama raetam, Panicum turgidum, Stipagrostis scoparia, Lycium europaeum, Echiochilon fruticosum, Neurada procumbens,* and *Moltkiopsis ciliata.*

Data were obtained from nine radio-tagged adult tortoises (five males and four females), and from randomly collected individuals. Activity-sensing transmitters were glued with dental acrylic to the posterior carapace. The weight of transmitter and glue totalled 15–17 g, roughly 5–10% of body weight (males and females were about 150 and 300 g, respectively). Males carried transmitters for 18, 16, 10, 9, and 5 months; females for 16, 14, 5, and 4 months. Tortoises were monitored with AVM LA12-DS

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[1] Present Address: Department of Zoology, South Parks Road, Oxford OX1 3PS, England.
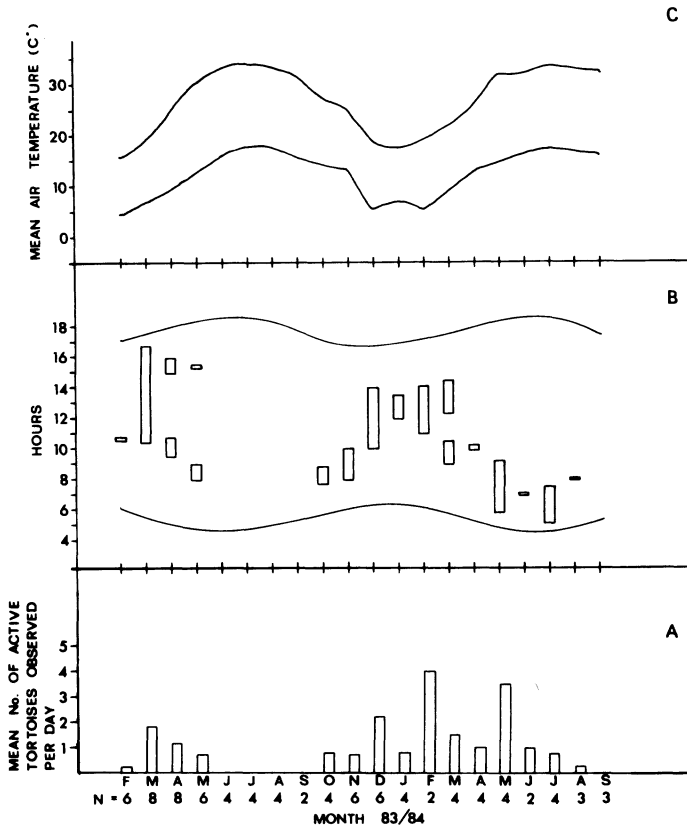
FIG. 1. (A) Mean number of active tortoises observed per day by month, between February 1983 and September 1984. N = number of observation days per month. (B) Daily activity range during each month between February 1983 and September 1984. Solid lines represent times of sunrise and sunset. (C) Mean monthly minimum and maximum air temperatures at the study site during the observation period (data from Meteorological Service of Israel).

or Telonics TR-2 receivers and a three element Yagi antenna. Randomly-collected individuals were found mainly by following fresh tracks on the sand; only a few were discovered accidentally.

Between February 1983 and September 1984 the study area was visited once or twice monthly. During each visit (of 36 hours each) radio-tagged tortoises were monitored at intervals of 2–3 hours during daytime, and random searches for active tortoises were made.

Air temperature was taken with a digital thermometer (Wescor TH-65, accurate to ±0.1°C) in the shade, 50–60 cm above the ground. Surface temperature was measured 1 cm deep in unshaded sand. Body temperature was taken with a thermometer probe by insertion between the tortoise's withdrawn front legs and under the ventral side of the head. The ability of this species to close the movable posterior plastron made cloacal temperature cording impractical. This method did not give results significantly different from a few cloacal temperatures which were taken simultaneously ($t = 0.7$, N = 12, $P > 0.05$). Body temperature was taken from all

randomly-collected tortoises and once a day from animals with transmitters; ambient, surface and body temperatures were taken simultaneously.

Burrows occupied by tortoises were measured (length = distance of tortoise from the burrow entrance, depth = distance of tortoise from ground level, and diameter = width of entrance). Air temperature in the burrow was taken by inserting a thermometer probe to the location of the tortoise. Body temperatures of tortoises in burrows were taken by the procedure described above, immediately after individuals were dug out. Body temperatures of three tortoises with transmitters were not taken during the summer of 1984. These individuals were used as controls to evaluate the effect of body temperature on activity pattern.

RESULTS

The largest numbers of active tortoises were seen during winter and spring. Peaks in mean number of active individuals per day were observed in March and December 1983 and in February and May 1984 (Fig. 1A). A notable
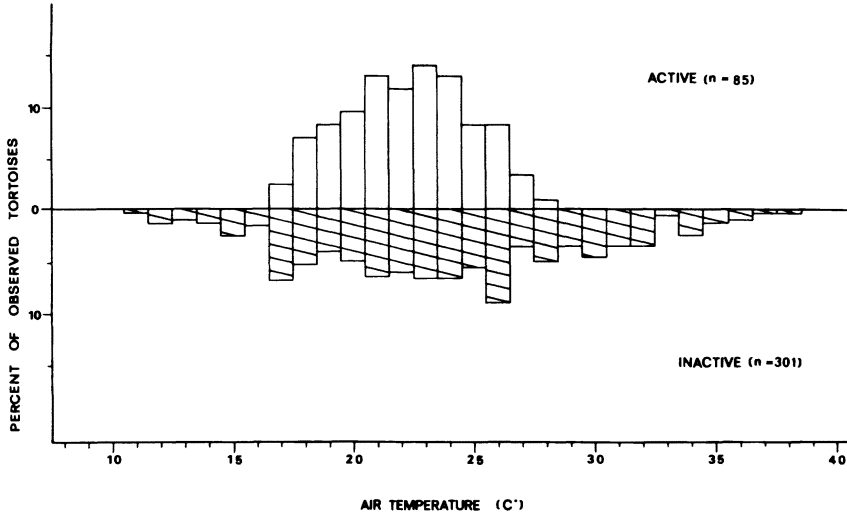
FIG. 2. Percent of active (upper part of figure) and inactive (lower part of figure) tortoises observed in air temperature range indicated; N = numbers of tortoises observed.

decrease in tortoise activity occurred during the summer. From June through September of 1983 no active tortoises were seen and in 1984 a gradual decrease in the numbers observed occurred towards July; none was seen in September.

During the month of March 1983 and from December through February 1984 active individuals were seen mainly between 1000 and 1400 hr. Active individuals were observed in the morning and afternoon during spring (April–May 1983 and March 1984). During the summer months activity was restricted to the very early morning hours (Fig. 1B). No active tortoises were observed after dark. Activity ceased on cold, cloudy, or rainy days in the winter and during overcast and extremely hot, dry days in spring.

No correlation existed between mean number of active tortoises per day and: (1) The monthly ($r = 0.22, P > 0.05$) or the previous month's ($r = 0.28, P > 0.05$) precipitation; (2) The mean monthly relative humidity at 0800 and at 1400 ($r = 0.12, P > 0.05$ and $r = 0.21, P > 0.05$, respectively). An increase in tortoise activity was observed in October, which is usually the first month of the rainy season (Fig. 1A).

Active tortoises were found at air temperatures ranging from 17–28°C; 52% of these animals were active within a range of 21–24°C. However, large numbers of individuals were inactive in the same air temperature range (Fig. 2). Active tortoises were found over a wider range of surface temperatures (17–45°C). Body temperatures of active individuals ranged from 18–36°C ($\bar{x} = 29.72 \pm 4.53$ [SD], N = 67), but 61.5% of all active individuals had body temperatures between 28–32°C. A significant correlation was found between the body temper-

ature of active tortoises and that of the air ($r = 0.51, df = 51, P < 0.001$) and surface ($r = 0.82, df = 59, P < 0.001$).

During the activity periods inactive individuals were usually found under small shrubs in shallow excavations they had dug (Fig. 3). Some individuals were found under very small and even dry shrubs, especially during mid-winter. No inactive tortoises were found in the open. Seventy-seven percent of the 218 individuals located under bushes during winter and spring were found on the east or south side of the bush; 15% were facing north and 8% west.

During inactive periods (June–September) most tortoises were located in rodent (Gerbilus and Meriones spp.) burrows. Burrows were especially abundant in the valleys, either under bushes or in harder soil. Burrows tended to have several entrances and a complex system of rooms and corridors. No correlation was found between the diameter of the burrow entrance and the carapace length of the occupant ($r = 0.32, df = 34, P > 0.05$). Tortoises were not observed digging or widening burrows, or blocking burrow entrances with sand. Only one individual was found in each of the occupied burrows. All tortoises in burrows were located at a distance of 10–100 cm ($\bar{x} = 43.8 \pm 22.5$, N = 64) from the entrance and at a depth of 5–40 cm ($\bar{x} = 18.4 \pm 7.1$, N = 58). Mean burrow diameter was 10 cm $\pm$ 1.9, N = 35. Mean burrow temperature during summer was 29.5°C $\pm$ 3.2 (N = 64) while mean body temperature of tortoises occupying burrows was 29.5°C $\pm$ 3.0 (N = 64). A significant correlation was found between the body temperature of the resident tortoise and the burrow temperature ($r = 0.91, df = 63, P < 0.001$). The relation between burrow (B) and body (Y) temperatures was best represented by the equation

$Y = 1.03B - 1.29$; this slope was not significantly different from a slope of 1.0 ($F = 0.75$, df = 1,125, $P > 0.05$).

Tortoises that occupied burrows during the summer (mid-June to September of 1983 or 1984) lost weight at a mean rate of 0.30 g $\pm$ 0.27 (N = 6) per day, and a total of about 15–20% of body weight during the summer.

DISCUSSION

In contrast with most other Israeli reptiles, Egyptian tortoises are most active during the winter and spring (Mendelssohn, 1982). The following factors may promote a selective advantage for winter activity:

1. Annual plants are the major food of this tortoise (Geffen, 1985). Feeding on the protein- and water-rich annuals, available only during winter and spring, might enable this tortoise to save large amounts of water that would be needed to excrete potassium concentrations found in dry annual plants during summer (Minnich, 1977).

2. Several of the potential predators of this tortoise are not active in the Negev during winter. Some such as the short-toed eagle *Circaetus galicus* and the Egyptian vulture *Neophren percnopterus* are summer visitors (Mendelssohn, 1982; Meir, 1986). Others such as the gray monitor *Varanus griseus* hibernate (Stanner, 1983).

3. The very small body size of the Egyptian tortoise enables it to reach optimal activity temperature rapidly, even on relatively cool winter days.

Change in diel activity pattern from unimodal during mid-winter to bimodal towards spring (Fig. 1B) has been observed in many desert reptiles (Heatwole, 1976) including some tortoises (Auffenberg and Weaver, 1969; Rose and Judd, 1975; Lambert, 1981). The decrease in activity following rising ambient temperatures reflected the strong influence of environmental temperature on the activity of the Egyptian tortoise, as was found in other desert species (Rose and Judd, 1975; Voigt and Johnson, 1976). This connection was also emphasized by the strong correlation between air and soil surface temperature and body temperature of active individuals. Activity was not correlated with monthly precipitation or humidity, but emergence from burrows in the fall appeared to be stimulated by the first rainfall (Fig. 1). Initiation of activity following the first rain is found in *Gopherus agassizii* (Rose and Judd, 1975). The mean body temperature of active tortoises was 29.7°C $\pm$ 4.5 (SD) (N = 67); similar values have been reported for other European tortoises (Meek and Inskeep, 1982; Meek and Jays, 1982). The use of bushes for cover is known in *Gopherus agassizii* (Burge, 1978). McGinnis and Voigt (1971) explained that the morning body temperature of
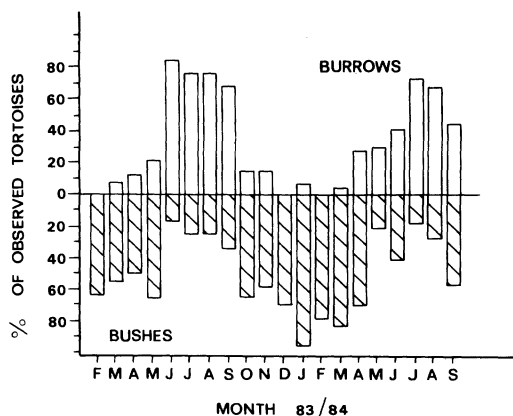

FIG. 3. Percent of inactive tortoises observed in burrows (upper part of figure) and under bushes (lower part of figure) during each month between February 1983 and September 1984. Numbers of tortoises observed under bushes = 218, and in burrows = 106.

a desert tortoise (*Gopherus agassizii*) that stayed overnight under a bush is likely to be lower than that of a individual which spent the night in a burrow. This lower body temperature could permit more activity time before maximum body temperature is reached. This might explain the preference for bush and shrub cover during the winter and spring. In addition, Egyptian tortoises tend to stay on the east or south side of a bush, so the minimum activity temperature can probably be reached early in the day. Bushes also supply shade which is vitally important in the habitat of many tortoise species (Swingland and Lessells, 1979) especially for desert forms.

The use of burrows for cover is well known in small land tortoises, particularly in the genus *Gopherus* (Voigt and Johnson, 1976; Burge, 1978; Douglass and Layne, 1978). The small body size of the Egyptian tortoise enables it to use the many rodent burrows in the area. This provides a great advantage over the burrow-digging species, considering the energetic cost of burrow excavations (Woodbury and Hardy, 1948). In burrowing tortoises a significant correlation exists between body length and burrow diameter (Alford, 1980). The lack of such correlation in the Egyptian tortoise follows from the observation that the individuals at our study site used burrows already excavated by rodents. Only a few observations of *Testudo kleinmanni* digging burrows are known (Mendelssohn, 1982), and those occurred in areas where rodent burrows were scarce. During summer midday hours, burrows offer ambient temperatures below the lethal point for *Gopherus agassizii* (McGinnis and Voigt, 1971). The lack of a significant difference between burrow tempera-

ture and body temperature of Egyptian tortoises indicates that individuals were not thermoregulating actively, perhaps due to the lower ambient temperature in the burrow. Burrows also offer high and relatively stable humidity (Warburg, 1964), which would reduce loss of body water (Minnich, 1977).

Two major factors seem to stimulate the onset of aestivation in the Egyptian tortoise: rising ambient temperature and withering of food plants. Mean maximum ambient temperatures over 30°C produced a distinctive decrease in activity (Fig. 1), similar to that seen in other tortoises (Voigt and Johnson, 1976). Captive individuals at the Canadian Center of Ecological Zoology at Tel-Aviv University remained active during summer, despite occasional ambient temperatures over 30°C, as long as succulent food was offered. Similar behavior was observed in other tortoises (Auffenberg and Weaver, 1969). This might suggest that withering of annual plants in late spring is the major factor influencing the onset of aestivation in the Egyptian tortoise. A similar response is known in *Gopherus berlandieri* (Douglass and Layne, 1978).

It is clear that bushes and rodent burrows are vitally important to the survival of the Egyptian tortoise (Fig. 3). Destruction of the native vegetation by overgrazing and agriculture, and of rodent burrows by off-road vehicles will result in a decline of the tortoise population in the affected areas (Mendelssohn, 1982; Geffen, 1985). We hope our findings will stimulate the declaration of Holot Agur (300 km²) as a Nature Reserve, a conservation step which we feel could ensure the continued existence of the Egyptian tortoise in Israel.

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Relative Abundance of Herpetofauna Among Eight Types of Maine Peatland Vegetation

SARAH S. STOCKWELL AND MALCOLM L. HUNTER, JR.

Wildlife Department, University of Maine, Orono, Maine 04469, USA

ABSTRACT. — Amphibians and reptiles were captured in nine Maine peatlands using drift fences and pit
traps. Traps were operated from April to September. Animals were trapped in eight types of vegetation
(lagg, forested bog, wooded heath, shrub heath, moss-*Chamaedaphne*, pools, streamside meadow, and
shrub thicket). In 8733 trap nights, 2182 individuals of 12 amphibian and one reptilian species were caught.
Anurans represented 94% of all captures, salamanders 5%, and snakes <1%. Numbers of species ranged
from 5 to 10 per vegetation type, and evenness ranged from 0.21 to 0.78. *Rana sylvatica* was the most
abundant species in five vegetation types and comprised 59% of all captures. *Rana clamitans* was the most
abundant species in two vegetation types, and the second most abundant species in four types, comprising
30% of all captures. Average capture rates of each species ranged from 0.1 to 146.8 per 1000 trap nights,
and average capture rates in each vegetation type ranged from 95 to 485 per 1000 trap nights. Juveniles
comprised 82% of all captures, and were most abundant in July and August.

In northern temperate zones, herpetofaunal
assemblages may contain few species, but the
number of individuals inhabiting various eco-
systems may be quite high. For many years,
autecology has been emphasized by ecological-
ly-oriented herpetologists but fewer research-
ers have been studying herpetofaunal assem-
blages (Scott and Campbell, 1982). Peatlands, in
particular, have received little attention, al-
though they may be of particular importance
to amphibians. Because of increasing interest in
mining peatlands for peatmoss and fuel, infor-
mation on the distribution of rare and common
species in peatlands is needed before their hab-
itat is altered or lost. In this paper we compare
the occurrence and relative abundance of am-
phibian and reptile species among eight vege-
tation types of Maine peatlands. We were es-
pecially interested in whether species
composition and relative abundance varied
markedly among the eight vegetation types.

METHODS AND STUDY AREA

Study Sites.—We used peatlands of central
Maine for our study because a variety of vege-
tation types occur there in close proximity. Most
of the vegetation types occur widely over sev-
eral different geomorphic-developmental peat-
land types. We censused amphibians and rep-
tiles in three regions of the state, each with
eight types of peatland vegetation representing
minerotrophic, ombrotrophic, and transitional
sites (see Davis et al., 1983) (Table 1). Minero-
trophic sites receive nutrient input from both
surrounding groundwater and precipitation,
whereas ombrotrophic sites depend entirely
upon precipitation for nutrient input (Moore
and Bellamy, 1974). Transitional sites are inter-
mediate.

Descriptions of the vegetation types were
based on Davis et al. (1983) and on observations
made using the relevé technique (Mueller-
Dombois and Ellenberg, 1974). At each 10 m²
relevé plot we recorded the percent cover and
sociability of every plant species in each of four
strata: ground, herb, shrub, and tree, and char-
acterized each stratum by its height, dominant
lifeform, and overall coverage. The following
eight vegetation types were identified; more de-
tailed information can be found in Stockwell
(1985).

Moving from the perimeter to the center of