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HOME RANGE USE AND SEASONAL MOVEMENTS OF THE EGYPTIAN TORTOISE (*TESTUDO KLEINMANNI*) IN THE NORTHWESTERN NEGEV, ISRAEL

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ABSTRACT: Five male and four female Egyptian tortoises (*Testudo kleinmanni*) were monitored with radio transmitters for 4-18 mo. Individuals had well-defined home ranges. Male and female home ranges were ($\bar{x} \pm 1$ SD) 34.9 ha \pm 24.6 and 15.7 ha \pm 8.6, respectively, and they did not differ significantly from each other. Considerable overlapping was found between the home ranges of different males and between those of males and females. Even though large parts of the home range were visited during the period of observations, a much smaller area was visited more frequently. Home range use varied significantly between seasons. The greatest areas were used during winter and spring, the time of main activity, while only small areas were used during summer. A similar pattern was observed in distances covered daily during each season.

Key words: *Testudo kleinmanni*; Home range; Habitat use; Radiotelemetry; Polygon, convex

THE Egyptian tortoise (*Testudi kleinmanni*) is a small terrestrial tortoise which occurs from northwestern Libya through northern Egypt and Sinai to the northern Negev in Israel (Flower, 1933; Iverson, 1986; Mendelssohn, 1982). In Israel, it is restricted to sandy areas and dunes with some cover of small bushes. This tortoise is active mainly during winter. In summer, tortoises or their tracks are rarely seen (Mendelssohn, 1982). Mendelssohn (1982) reported that the longest straight-line distance covered in the activity period by one female tortoise was 400 m. No other data concerning home range or movements of the Egyptian tortoise for Egypt or Israel are available.

The species is threatened throughout its range, primarily because of commercial collecting in Egypt (Buskirk, 1985) and in Israel by destruction of habitat by off-road army vehicles, overgrazing, and agriculture (Mendelssohn, 1982). These factors resemble the well-known conservation problems of *Gopherus agassizii* in the United States. Although the Egyptian tortoise is fully protected by law in Israel, this protection is useless due to the factors influencing its population existence. Unless several large nature reserves are established in the northern Negev desert, no large tortoise populations will survive in a few years. In Egypt, the tortoise is not

legally protected (Buskirk, 1985), and its status in Libya is unknown. This paper describes movements, home range size, and habitat use of male and female Egyptian tortoises, data essential to conservation of the species in Israel.

METHODS

Study Area

All data were collected in a 3-km² area, 15 km north of Beer Milka (63375, 42435; U.T.M Grid), Holot-Agur, near the Israeli-Egyptian border in the northwestern Negev Desert. The land formation consists of high sand ridges separated by valleys with stable soils. Vegetative cover averages 20-30% and consists primarily of an *Artemisia monosperma* plant association (Waisel et al., 1982). Other common plant species are *Retama raetam*, *Panicum turgidum*, *Stipagrostis scoparia*, *Lycium europaeum*, *Echtochilon fruticosum*, *Neurada procumbens*, and *Molikiopsis ciliata*.

Mean annual air temperature is 20 C (Israel Meteorological Service, unpublished data), with a mean maximum of 30 C and a mean minimum of 12 C. Subzero temperatures are rare even in winter, but daily fluctuations of 10-15 C are common. Most precipitation (50-150 mm) occurs between October and March. Mean annual rainfall for 1981-1987 in the area was 90.0 \pm 22.9 mm.

Field Methods

Nine tortoises (five males and four females) were fitted with activity-sensing transmitters (Biotrack), glued with dental acrylic to the posterior end of the carapace. Mass of transmitters and glue totalled 15–17 g, 5–10% of the tortoise's mass. Individuals carried transmitters for 4–18 mo (Table 1). Five transmitters failed after 6 mo due to higher battery drainage than expected, but fortuitously four tortoises were later relocated. One other tagged tortoise was killed (probably by a crow), and only its empty carapace was found. Tortoises were located with an AVM model LA12-DS and a Telonics TR-2 receiver, with a three element Yagi antenna.

The study area was visited once or twice monthly for 18 mo, between February 1983 and September 1984. At each visit, lasting 36 h, all tortoises with transmitters were located 2–3 times. Tortoises were located by triangulation of azimuths, taken with a sighting compass from known land-marks. Inaccuracies were minimized by measuring azimuths to the nearest land-marks. During each visit, two or three tortoises were followed for about 1 h while being active. Individuals were observed from a distance of 10–20 m with binoculars and their behavior was recorded.

Data Analysis

Home range size was estimated by the convex polygon method, involving the connection of outermost recapture points for each individual to form a polygon. The area of each polygon was calculated using the mapmaker's equation (Jennrich and Turner, 1969). Home range sizes were bias-corrected for unequal numbers of relocation points following the Jennrich and Turner (1969) method. Square root transformation was applied when male and female home range estimates were compared. Stability of home range sizes was determined by plotting size of home ranges against increasing numbers of relocation points (Rose, 1982). The use of home range areas of individuals was determined by a three-dimensional home range method (Macdonald et al., 1979). This method in-

TABLE 1.—Home range size of five males and four females of the Egyptian tortoise, based on the convex polygon method.

| Carapace length (mm) | Body mass (g) | No. of location points | Home range size (ha) | Bias correction (ha) | Tracking period (mo) |
|----------------------|---------------|------------------------|----------------------|----------------------|----------------------|
| Males | | | | | |
| 92 | 170 | 21 | 6.6 | 14.1 | 5 |
| 103 | 165 | 23 | 18.0 | 36.4 | 10 |
| 96 | 155 | 19 | 9.8 | 21.9 | 9 |
| 94 | 170 | 47 | 16.9 | 25.8 | 18 |
| 95 | 155 | 41 | 47.5 | 76.5 | 16 |
| Females | | | | | |
| 114 | 310 | 39 | 11.0 | 18.0 | 14 |
| 106 | 220 | 45 | 2.0 | 3.1 | 16 |
| 116 | 335 | 17 | 7.8 | 18.7 | 5 |
| 113 | 315 | 13 | 8.0 | 22.9 | 4 |

volves the division of the home range into equal-sized squares. The number of times each square was visited is represented by a pyramid over the square, so the greater the number of visits the higher the pyramid. Home ranges were divided into 30 × 30 m squares, because the mean straight daily travel distance during activity periods was about 30 m.

Areas used by individuals in different seasons were determined by calculating areas of convex polygons formed by relocation points observed during each season, and expressing this area as a percent of the total home range (Burge, 1977; Madsen, 1984). Four seasons were defined: winter (December–February), spring (March–May), summer (June–August), and autumn (September–November). Percent overlap of home ranges of each two individuals was expressed as $100(\text{Overlap}/H_1)$ and $100(\text{Overlap}/H_2)$, with H_1 and H_2 the home range sizes of the individuals.

Daily travel distances were determined by measuring the straight-line distance between capture locations observed before the beginning and after the end of activity. Spring and summer mean travel distances and home range use of males and females were compared following two-way ANOVA with equal numbers within rows (Snedecor and Cochran, 1967; Sokal and Rohlf, 1969). Seasonal data for both years (1983–1984) were pooled because the fo-

TABLE 2.—Percent overlap of home ranges for nine Egyptian tortoises. Values show the size of overlapping area between each individual in the left column with those on the top of the table, as a percent of the home range area of the left column individuals.

| Tortoise no. | Males | | | | | Females | | | |
|----------------|-------|------|------|------|-------|---------|------|------|-----|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Males | | | | | | | | | |
| 1 | — | 30.5 | 47.5 | 0 | 91.8 | 81.4 | 0 | 0 | 4.6 |
| 2 | 12.8 | — | 32.8 | 13.9 | 100.0 | 25.4 | 0 | 7.2 | 0 |
| 3 | 31.9 | 60.3 | — | 0 | 84.9 | 41.2 | 0 | 0 | 0 |
| 4 | 0 | 14.9 | 0 | — | 51.2 | 0 | 11.2 | 36.7 | 0 |
| 5 | 12.7 | 38.0 | 17.6 | 18.2 | — | 21.8 | 0 | 15.4 | 0.4 |
| Females | | | | | | | | | |
| 6 | 48.9 | 41.6 | 36.7 | 0 | 93.9 | — | 0 | 0 | 5.5 |
| 7 | 0 | 0 | 0 | 94.8 | 0 | 0 | — | 0 | 0 |
| 8 | 0 | 16.6 | 0 | 79.3 | 93.7 | 0 | 0 | — | 0 |
| 9 | 3.9 | 0 | 0 | 0 | 2.2 | 7.6 | 0 | 0 | — |

cus of the analysis was to show seasonal differences between sexes. Each seasonal datum was treated as an independent observation. Autumn and winter were not included in the above analysis due to the small sample size.

RESULTS

Home range size for nine tortoises is shown in Table 1. Home range areas were neither correlated with carapace length ($r = 0.33$, $n = 9$, $P > 0.05$) nor with live body mass ($r = 0.38$, $n = 9$, $P > 0.05$). Although no significant difference was found between sizes of male and female home ranges (Mann-Whitney U -test, $U = 14$, $P > 0.1$) (Sokal and Rohlf, 1969), the home range size of males was twice the size of females ($\bar{x} \pm 1$ SD = 34.9 ha \pm 24.6 and 15.7 ha \pm 8.6, respectively).

Stability in home range size was achieved in five of the nine individuals after collecting 20–25 location points. One male showed increase in home range size even after locating 47 such points. All male home ranges overlapped with at least one other male, with mean overlap of 73.18% \pm 27.0 SD (Table 2). Home ranges of two males each overlapped with four other males, two overlapped with three other males, and one male overlapped with two others. Three female home ranges overlapped substantially (94.1% \pm 0.5 SD) with at least one male home range. Little overlap

(3.27% \pm 3.8 SD) occurred between female home ranges (Fig. 1).

Analysis of use of home ranges showed that certain subsections of every range were visited more frequently than others (Fig. 2). The more frequently visited areas were located in valleys, between the sand ridges, but no specific entity (e.g., a bush or a burrow) was identified. During summer, a preference for valleys was observed. Only one individual spent the summer of 1984 under a bush on top of a dune. In other seasons, no such preference was observed.

In summer, the percent of home range used was at its lowest, and in spring it was at its highest (Table 3). Home range use differed significantly between seasons ($F = 17.02$, $df = 1,20$, $P < 0.001$) but not between sexes ($F = 0.77$, $df = 1,20$, $P > 0.1$). Maximum daily travel distance was 340 m for males and 155 m for females. Mean daily travel distances in summer were the shortest, while those in spring were the longest (Table 4). Mean travel distances differed significantly between the sexes ($F = 7.38$, $df = 1,22$, $P < 0.05$) and between seasons ($F = 76.47$, $df = 1,22$, $P < 0.001$). Interaction existed between sexes and seasons ($F = 4.39$, $df = 1,22$, $P < 0.05$). Males travel significantly greater distances than females in spring ($t = 2.66$, $df = 11$, $P < 0.05$) but not during summer ($t = 0.77$, $df = 11$, $P > 0.4$). Spring and winter movements were mainly for pur-

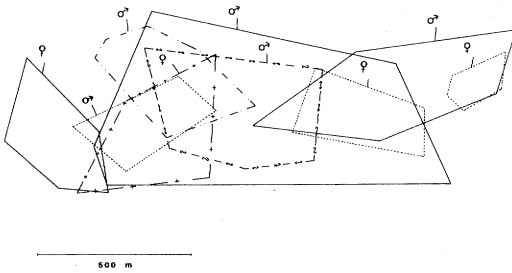


FIG. 1.—Home range of the the five male and four female Egyptian tortoises in the study site at Holot-Agur.

poses of feeding and possibly for seeking mates, while in summer, infrequent short movements were made from one burrow to another.

DISCUSSION

The Egyptian tortoise exhibited well-defined home ranges over time periods of up to 18 mo. Well-defined home ranges were also found in other tortoises (Auffenberg and Weaver, 1969; Bertram, 1979a,b; Rose and Judd, 1975). The home range size of the Egyptian tortoise is larger than in *Gopherus berlandieri* (2.57 ha for males, 1.42 ha for females) (Judd and Rose, 1983) or *Kinixys belliana* (1.86 ha) (Bertram, 1979a). However in some populations of *G. agassizii*, individuals hold larger home ranges (Berry, 1986; Burge, 1977). The results showed that in most individuals final home range size was obtained after collecting 20–25 location points. Similar results were obtained for *Testudo hermanni* in France (Swingland et al., 1986).

Differences in home range size were found within each sex, but these differences may be due to individual variation. Abundance of food plants and burrows or bush density might also influence home range size (Rose and Judd, 1975). In the case of the Egyptian tortoise, all home ranges included some valley and dune habitats. The available food plants are adequate in quantity in both habitats during winter and early spring, with even a few millimeters of rain causing the appearance of annuals on the valley floor. Bushes and

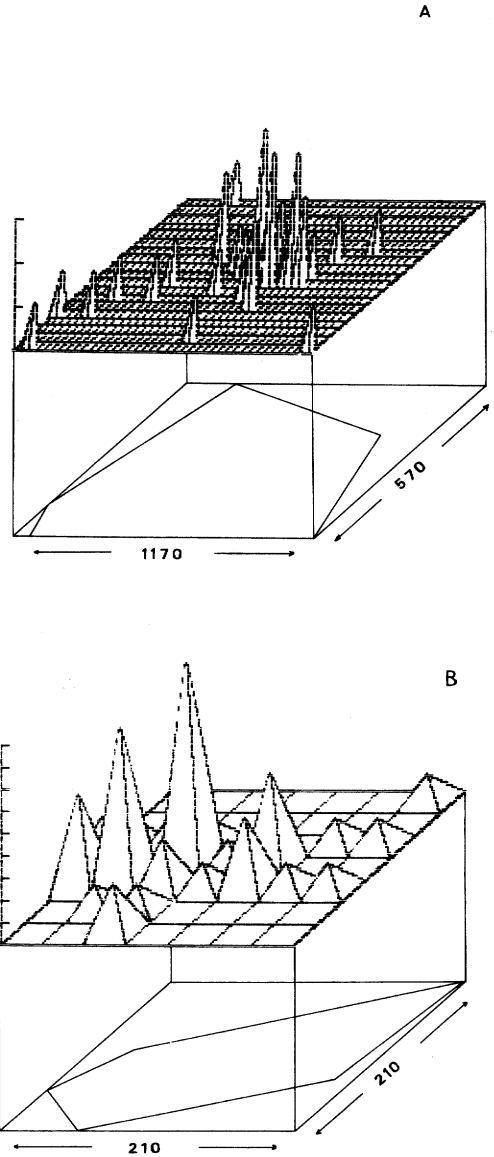


FIG. 2.—An example of home range use by (A) a male and (B) a female, between February 1983 and September 1984.

rodent burrows, used as cover sites, are abundant, especially in the valleys.

The lack of a significant difference between home range size of males and females is probably due to the small sample size (nine individuals). The greater mean home range size of males suggests that

TABLE 3.—Percent ($\bar{x} \pm 1$ SD, n) of home range area use during four seasons, by both sexes of the Egyptian tortoise; n = number of individuals monitored during the season.

| Season | Males | Females | Total |
|--------|--------------------|--------------------|---------------------|
| Spring | 34.2 \pm 34.0, 6 | 50.6 \pm 33.9, 6 | 42.4 \pm 33.5, 12 |
| Summer | 1.5 \pm 2.1, 6 | 2.3 \pm 2.4, 6 | 1.9 \pm 2.2, 12 |
| Autumn | 17.9 \pm 21.8, 2 | 0.9, 1 | 12.2 \pm 18.3, 3 |
| Winter | 18.6 \pm 8.9, 4 | 48.3 \pm 17.5, 2 | 29.0 \pm 17.8, 6 |

males have larger home ranges than females, as was found in other tortoises (Berry, 1986; Burge, 1977; McRae et al., 1981; Rose and Judd, 1975).

The considerable overlap of home ranges suggests that only certain resources in the home range are defended, as was suggested for *Gopherus agassizii* (Berry, 1986) or that the Egyptian tortoise is not territorial. We found no evidence that individuals patrolled or protected the boundaries of their home range. Two adult males were seen fighting in one instance only. Utilization of the home range area in all individuals revealed a smaller preferred core area. A similar utilization pattern was found in *Kinixy belliana* (Bertram, 1979a). The preference for spending the summer in valleys is probably due to the abundance of rodent burrows there.

The seasonal intersexual interaction in travel distances is probably due to difference in travel distances between the sexes during spring. The results suggest that during spring, the mating season (Mendelssohn, 1982), males travel greater distances than females, probably in search of mates.

Mean percentage of area used and distances covered at different seasons clearly show that the principal activity period is winter and spring. The marked decrease in area used and distances travelled during summer were due to near cessation of ac-

tivity. Sample size in autumn was too small to show clearly the pattern of home range use. Activity in summer was restricted to short movements between rodent burrows. The reason for these movements is unknown but probably is related neither to parasites nor to food. Contrary to other seasons, no ticks or other ectoparasites were found on the tortoises. No food (annuals) is available for tortoises in summer, but short movements may reflect water drinking activity on misty mornings (Auffenberg, 1963).

In conclusion, the Egyptian tortoise, a small species specialized for living in arid sandy regions, shows some similarity to other arid zone tortoises in having a relatively large home range and a marked decrease in activity during hot and dry periods. The Egyptian tortoise is completely different from the arid zone *Gopherus* species in its annual activity pattern even though they are both living on the same latitude.

Home range size, overlap, and distances of annual movements combined with population size estimations are highly significant in setting nature reserve size needed to ensure the survival of the large tortoise population in Israel. Declaration of a large nature reserve for those tortoises around the study site, as well as for other animal life, is now in progress. The importance of

TABLE 4.—Daily travel distances (m) during four seasons ($\bar{x} \pm 1$ SD, n), by the Egyptian tortoise; n = number of individuals monitored at each season.

| Season | Males | Females | Total |
|--------|--------------------|--------------------|---------------------|
| Spring | 38.4 \pm 12.6, 7 | 22.6 \pm 7.5, 6 | 31.1 \pm 13.0, 13 |
| Summer | 4.2 \pm 4.2, 7 | 2.8 \pm 2.0, 6 | 3.6 \pm 3.3, 13 |
| Autumn | 50.1 \pm 50.6, 2 | 2.8, 1 | 34.3 \pm 45.0, 3 |
| Winter | 36.1 \pm 17.0, 4 | 33.2 \pm 38.2, 2 | 35.1 \pm 21.6, 6 |

this reserve is emphasized by the fact that in its entire range, the Egyptian tortoise is legally protected nowhere but in Israel.

Acknowledgments.—We thank Yoram Yom-Tov, Frederick B. Turner, Jim R. Buskirk, and Israel Sidis for critically reading the manuscript, Ezer Farchi for his assistance with the computer analysis, and Shuli Geffen for drawing figures. This work has been supported by a grant from the Israel Cohen Chair of Environmental Zoology at Tel-Aviv University.

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Accepted: 3 August 1987

Associate Editor: Raymond Semlitsch

DATE OF PUBLICATION

Herpetologica, Vol. 44, No 2, was mailed 6 May 1988.

Herpetological Monographs, No. 2, was mailed 6 May 1988.