Chelonian Conservation and Biology, 1997, 2(3):358–362

Home Range Characteristics of Radiotagged Gopher Tortoises on Kennedy Space Center, Florida

REBECCA B. SMITH[1], DAVID R. BREININGER[1], AND VICKIE L. LARSON[1]

[1]*The Dynamac Corporation, NASA Biomedical Operations Office, Mail Code DYN-1, Kennedy Space Center, Florida 32899 USA [Fax: 407-867-2502; E-mail: rebecca.smith-1@ksc.nasa.gov]*

ABSTRACT. – **Data from 10 male and 4 female radiotagged gopher tortoises on the Kennedy Space Center were analyzed to determine home range sizes, the number of burrows used by each individual, and the preferential use of habitats within the home ranges. Home range size averaged 1.7 ha, which was larger than the average home range sizes reported for gopher tortoises elsewhere. Home ranges of males tended to be larger than those of females and males tended to use more burrows, but there was considerable overlap between sexes. We found no discriminating relationship between the habitats in the home range and home range size. Use of burrows within different habitats was proportional to the amounts of habitat, except that swales and open disturbed areas had few burrows. The use of individual burrows by several tortoises at different times and occupation of individual burrows by two tortoises at the same time were documented.**

KEY WORDS. – **Reptilia; Testudines; Testudinidae; *Gopherus polyphemus*; tortoise; ecology; telemetry; home range; burrow; habitat; Florida; USA**

The gopher tortoise (*Gopherus polyphemus*) is a burrowing species that occupies a variety of well-drained habitats with loose, sandy soils, and low-growing herbaceous plants. It ranges from extreme southern South Carolina and eastern Louisiana throughout much of mainland Florida. The gopher tortoise is listed as a Species of Special Concern by the Florida Game and Fresh Water Fish Commission (Wood, 1986). Loss of habitat, exploitation by humans, and disease have contributed to the tortoise's continuing population decline (Diemer, 1992a).

Previous studies on Kennedy Space Center (KSC) have shown that gopher tortoises occur across a range of scrub types (Breininger et al., 1991). Gopher tortoise densities are not consistently higher in well-drained habitats as compared to poorly drained habitats (Breininger et al., 1994), in contrast to expectations, and densities are highest in disturbed scrub habitat characterized by an open canopy and areas of bare sand. Herbaceous cover in the scrub is an unreliable indicator of tortoise density, possibly because of the close proximity of swale marshes with abundant food. Correction factors (multipliers used to estimate the number of tortoises based on the number of burrows) are generally lower on KSC than the standard correction factor of 0.614 developed in north Florida (Auffenberg and Franz, 1982), and fewer than 20% of the burrows were occupied during March through November when tortoises are most active (Breininger et al., 1991). This study of adult gopher tortoises on KSC had four objectives: 1) determine home range sizes for males and females; 2) quantify the number of burrows used by individual males and females; 3) quantify habitat composition within home ranges; and 4) investigate correlations between habitat composition and home range size.

STUDY SITE

Kennedy Space Center (KSC) is located on the east central Florida coast and consists of 57,000 ha of land and estuary owned by the National Aeronautics and Space Administration (NASA). About 2000 ha are used to support space operations; the remaining 55,000 ha are managed by the U.S. Fish and Wildlife Service as Merritt Island National Wildlife Refuge. This refuge provides the largest area of protected habitat for the gopher tortoise on the Atlantic coast. KSC is a barrier island complex with a geological history that produced longitudinal ridges of scrub and flatwoods alternating with shallow freshwater swales. Elevation ranges from 0 to 3 m. Depth to the water table in scrub is less than 1.5 m, even during the dry season (Schmalzer and Hinkle, 1992a). Scrub and flatwoods biota are adapted to periodic fire and composition is altered little by burning (Schmalzer and Hinkle, 1992a, 1992b; Breininger et al., 1994, 1995).

Our study was conducted in two areas used for long-term wildlife research on KSC: the Happy Creek site and the Tel-4 site. Habitat maps were created by aerial photo interpretation that was field verified and digitized into ARC/INFO coverages (Environmental Systems Research Institute, 1992). Six habitat types were identified at the Happy Creek site: forest, open disturbed, swale, and three types of scrub (Table 1). The scrub habitat occurs on a moisture gradient where oak species (*Quercus geminata* and *Q. myrtifolia*) dominate the drier soils ("oak scrub") and saw palmetto (*Serenoa repens*) dominates the wetter soils ("palmetto/lyonia/wax myrtle") (Schmalzer and Hinkle, 1992a). The Tel-4 site is generally classified as slash pine flatwoods, which is similar to scrub but has a sparse slash pine (*Pinus elliotii*) over-

Table 1. Descriptions of habitat types mapped from infrared aerial photographs of the Tel-4 and Happy Creek study sites on Kennedy Space Center, Florida.

Habitat Type	Description
oak scrub	> 50% oak cover
oak palmetto scrub (o/p scrub)	31–50% oak cover
palmetto/lyonia/wax myrtle (p/l/wm)	0–30% oak cover
mesic woody	usually occurring along disturbed edges; often dominated by wax myrtle
open disturbed	includes mowed grass, fire breaks, pastures, and citrus groves
swale	freshwater marshes
forest	> 66% tree canopy cover

story. The six habitat types identified at Happy Creek also occur at Tel-4, as well as mesic woody habitat (Table 1).

METHODS

Gopher tortoises were trapped in five-gallon buckets placed flush with the ground in holes dug at the mouth of active burrows. We checked traps twice daily and took captured tortoises to the lab for transmitter placement. Dental acrylic was used to attach a 30 g transmitter package to the carapace at the junction of the anterior marginals and costals, where it would not interfere with normal activities. The whip antenna was extended toward the rear of the tortoise and glued to the upper edge of the carapace. Each radiotagged tortoise was released at the site of capture and was located twice per week with a portable receiver and hand-held antenna. Each location event, the vast majority of which occurred in burrows, was numbered and marked on 1:1200 scale infrared aerial photograph in the field. Burrow locations were digitized as point coverages for each tortoise on a Geographic Information System (GIS). We used ARC/INFO to analyze home range sizes and spatial features of burrow locations within the habitat types. A home range was determined for each tortoise by screen digitizing a minimum convex polygon based on the outermost burrows used (i.e., location events). Burrow point coverages were overlaid on the habitat maps for each study site to determine the habitat types associated with burrow locations.

Nine female and 13 male adult tortoises were tracked between July 1988 and March 1990. Tracking times for each tortoise ranged from 4 to 16 months. Data from 4 females and 10 males that were tracked for at least 8 months, including the active season (March through November), were used to estimate the home range sizes and the number of burrows used. Data from all 22 tortoises were appropriate for determining burrow use during individual months.

Home range size and the number of burrows used were log transformed for normality, and differences between Happy Creek and Tel-4 tortoises were tested with the Student's t statistic. There was no significant difference in home range sizes ($p = 0.11$) or the number of burrows used ($p = 0.47$) between the two study sites; therefore, data from the two sites were combined for analysis. Differences between males and females in home range sizes and the numbers of burrows used were tested with the Mann-Whitney U statistic. The Mann-Whitney U statistic was also used to test the difference in home range sizes between the tortoises in the present study and data gathered by Diemer (1992b). The relationship between home range size and the habitats occurring within the home range was determined with Spearman's rank correlation coefficient. The significance level for all tests was $\alpha = 0.05$.

RESULTS

Home range size averaged 1.7 ha ($n = 14$, s.d. = 1.5). The average home range size for males (1.9 ha) tended to be larger than that for females (0.6 ha), but 2 of the 4 females had home ranges larger than 4 of the males (Table 2). The difference between home range sizes for males and females was not statistically significant (U = 31, critical value = 35). Males used an average of 16.6 burrows (s.d. = 9.6) and females used 8.8 burrows (s.d. = 5.9) (Table 2), but this was not significantly different (U = 32.5, critical value = 35). The average number of burrows used was highest for both sexes in March, August, and September (Fig. 1). During the winter (December through February), burrow use greatly decreased, with 18 of 22 tortoises using three or fewer burrows.

Three of the Spearman's rank correlation coefficients between home range size and the amounts of the habitat types within the home range were positively correlated.

Table 2. Home range size, number of burrows used, and number of tracking events for radiotagged gopher tortoises on Kennedy Space Center, Florida, July 1988 – March 1990 (listed by sex and decreasing home range size).

Tortoise I.D.	Sex	Home Range (ha)	# Burrows Used	# Tracking Events
173	M	5.3	35	107
902	M	3.7	32	101
935	M	2.9	20	79
706	M	2.6	11	69
701	M	2.2	16	135
51	M	2.2	8	67
3	M	0.8	12	73
502	M	0.5	11	67
197	M	0.5	9	101
603	M	0.3	12	105
Mean ± s.d.	**M**	**1.9 ± 1.6**	**16.6 ± 9.6**	
929	F	1.1	8	108
399	F	0.9	17	107
481	F	0.3	7	101
209	F	0.3	3	124
Mean ± s.d.	**F**	**0.6 ± 0.4**	**8.8 ± 5.9**	

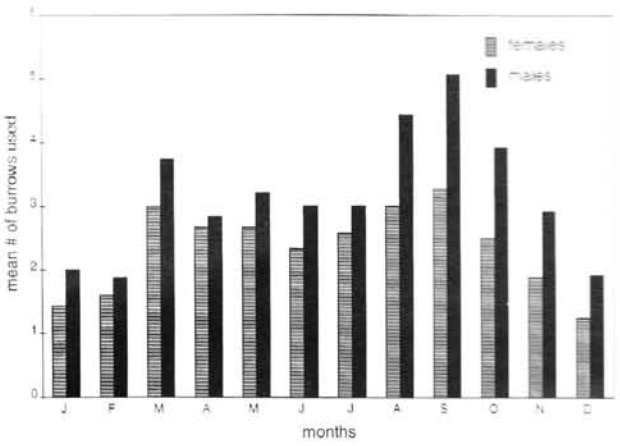

Figure 1. Mean number of burrows used per month by radiotagged gopher tortoises on Kennedy Space Center, Florida, July 1988 – March 1990.

These included oak scrub (r = 0.8945, p < 0.001), oak palmetto scrub (r = 0.8857, p < 0.001), and palmetto/lyonia/wax myrtle (r = 0.7275, p = 0.003). There was no significant negative correlation between home range size and any habitat type. Habitat use by the tortoises (i.e., the percent of tracking locations within each habitat type) was generally in proportion to the amounts of the habitat types that were available in the home ranges, except that there were no locations in swales and very few in open disturbed areas (Table 3).

Fifty-eight percent (n = 106) of the burrows at both study sites were used by only one radiotagged tortoise; however, use of burrows by two or more tortoises (not necessarily at the same time) was not uncommon. Thirty-one percent (n = 56) were used by two tortoises, 9% (n = 17) by three tortoises, and 2% (n = 3) by four tortoises. There were 10 instances of two tortoises being observed in a burrow at the same time. Males # 603 and # 902 were found together during September 1988 and then again in a different burrow in March 1989. Male # 902 was also found with female # 399 in another burrow in September 1988. Male # 197 occurred with an untagged tortoise in July 1989. Females # 749 and # 752 were together in two different burrows during August and September 1989; female # 749 was also with an untagged tortoise in one of those burrows in August 1989. Males # 701 and # 328 were found together on three separate occasions in three different burrows during September and October 1989. This phenomenon occurred at both study sites and always during the active season. In seven of eight cases when the sex of both tortoises was known, both were of the same sex.

DISCUSSION

The home range sizes found in this study tended to be larger than those reported for adult gopher tortoises studied elsewhere (Table 4). Home range sizes in southwest Georgia (McRae et al., 1981), determined from telemetry and mark-recapture studies, ranged between 0.04 and 0.14 ha for adult females and between 0.06 and 1.44 ha for adult males. Home range sizes determined by telemetry for adult tortoises at Sanibel Island also tended to be smaller than those of KSC tortoises and were significantly smaller for Sanibel females than for Sanibel males (McLaughlin, 1990). Telemetered adult tortoises in north Florida (Diemer, 1992b) had significantly smaller home range sizes than the KSC tortoises in this study (U = 164.5, critical value = 151). Adult female tortoises from Ordway Preserve (Smith, 1995) had an average home range size very similar to Diemer's (1992b) female tortoises, which was approximately one-half the home range size of KSC female tortoises.

The mean number of burrows used per tortoise in this study was much greater than the numbers used by tortoises in southwest Georgia (McRae et al., 1981) and north Florida (Diemer, 1992b) (Table 4). In an earlier study on KSC, fewer than 20% of the active and inactive burrows actually contained tortoises during the active season (Breininger et al., 1991). The data gathered in this study re-emphasize the need for site-specific, season-specific correction factors (Burke, 1989; McCoy and Mushinsky, 1992), because a single tortoise can cause many burrows to appear active over a short period of time.

The variability in home range sizes and the variability in the numbers of burrows used between studies (Table 4)

Table 3. Percents of habitat types and percent tracking locations per habitat (Locs) within each individual tortoise's home range. See Table 1 for a description of habitat types. HR = home range; O/P = oak palmetto scrub; P/L/WM = palmetto/lyonia/wax myrtle.

Tortoise (sex)	HR Size (ha)	Oak Scrub	Locs	O/P Scrub	Locs	P/L/ WM	Locs	Total Scrub	Locs	Mesic Woody	Locs	Forest	Locs	Open Ruderal	Locs	Swale	Locs
173 (m)	5.3	56.0	54.0	34.9	45.0	3.1	1.0	94.0	100.0	0.0	0.0	0.0	0.0	5.6	0.0	0.3	0.0
902 (m)	3.7	16.9	36.0	8.2	8.0	19.3	15.0	44.4	59.0	10.7	20.0	32.8	19.0	5.1	2.0	6.9	0.0
935 (m)	2.9	46.2	52.0	8.7	12.0	32.5	23.0	87.5	87.0	0.0	0.0	0.0	0.0	12.0	0.0	12.5	0.0
706 (m)	2.6	68.0	6.0	0.6	3.0	15.3	91.0	83.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	0.0
701 (m)	2.2	7.4	56.0	5.5	0.0	71.0	44.0	84.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0
51 (m)	2.2	50.3	36.0	14.0	64.0	24.9	0.0	89.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	10.8	0.0
929 (f)	1.1	46.9	31.0	10.1	0.0	26.5	69.0	83.6	100.0	2.8	0.0	0.0	0.0	0.0	0.0	13.5	0.0
399 (f)	0.9	28.4	47.0	11.8	4.0	32.9	48.0	73.1	99.0	12.5	2.0	0.0	0.0	0.0	0.0	14.5	0.0
3 (m)	0.8	56.0	45.0	31.8	45.0	2.3	10.0	90.0	100.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0
502 (m)	0.5	28.1	11.0	0.0	0.0	71.6	89.0	99.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
197 (m)	0.5	22.8	50.0	1.5	0.0	9.5	3.0	33.8	53.0	26.5	2.0	19.2	45.0	20.4	0.0	0.0	0.0
481 (f)	0.3	26.2	13.0	55.3	87.0	5.6	0.0	87.1	100.0	0.0	0.0	0.0	0.0	12.9	0.0	0.0	0.0
603 (m)	0.3	24.6	27.0	8.8	5.0	9.8	6.0	43.2	38.0	0.0	0.0	56.8	62.0	0.0	0.0	0.0	0.0
209 (f)	0.3	71.2	3.0	0.2	0.0	0.0	0.0	71.4	3.0	1.2	0.0	0.3	97.0	27.1	0.0	0.0	0.0

Table 4. Mean home range sizes (minimum convex polygons) and mean numbers of burrows used by gopher tortoises in this and previous studies.

Home Range (ha) female	male	Burrows Used female	male	Study
0.08	0.44	4	7	McRae et al., 1981
0.06	1.05	n/a	n/a	McLaughlin, 1990
0.31	0.88	3	8	Diemer, 1992
0.38	n/a	n/a	n/a	Smith, 1995
0.65	1.92	9	17	Present study

may be a function of differences in habitat. The home range sizes reported by McLaughlin (1990) from Sanibel Island were extremely variable and confounded by many factors related to the highly developed, disturbed condition of the site. Gopher tortoise movements and herbaceous cover are negatively correlated (Auffenberg and Iverson, 1979), and tortoise density and herbaceous cover are positively correlated (Breininger et al., 1994). The study site in Georgia (McRae et al., 1981) was maintained by controlled burning and characterized as being open. Diemer (1992b) stated that the habitat was less suitable at her north Florida study site than at the Georgia site (McRae et al. 1981) and that this difference was responsible for the larger home range sizes that she documented at her site. It was not clear from our results that the amount of any particular habitat type allowed a tortoise to decrease its home range size. These differences may occur at a smaller scale than we measured. Smith (1995) suggested that the distribution of food resources within the home range may influence home range size. The larger home ranges and greater number of burrows used by KSC tortoises may be indicative of the dense shrub layer and sparse herb cover associated with KSC scrub (Schmalzer and Hinkle, 1992a, 1992b). Our tortoises may have to move more and move farther in order to find ample forage.

In our study scrub habitat was preferred by most tortoises for burrowing; no burrows occurred in swales and few occurred in open disturbed habitat (Table 3). The longitudinal bands of swale marshes interspersed throughout the KSC scrub are used by tortoises for feeding (Breininger et al., 1988; Smith and Breininger, *pers. obs.*), and many burrows are located adjacent to swales (Breininger et al., 1988). Open disturbed habitats, such as grassy road shoulders and firebreaks, are also heavily used by tortoises for feeding (Smith and Breininger, *pers. obs.*). Solely protecting gopher tortoise burrow habitat may not preserve adequate resources needed to support a population.

Forty-two percent of the tagged tortoises' burrows were used by more than one tortoise (not necessarily at the same time) during the course of the study. Tortoise density estimates derived using correction factors imply that burrows contain a single tortoise. This assumption could lead to inaccurate estimates of density in populations where use of burrows by multiple tortoises is a common occurrence.

Co-occupation of a burrow has been observed in several instances involving adult male and female tortoises (McRae et al., 1981; Diemer, 1992b), immature tortoises (McRae et al., 1981), adult male tortoises (Douglass, 1986; Diemer, 1992b), and a juvenile tortoise with an adult (Smith and Seigel, *pers. obs.*). In our study co-occupation was observed 10 times; at least 7 of those occurrences involved tortoises of the same sex. Finding two tortoises in a burrow at the same time could result from a tortoise being frightened by the investigator into an occupied burrow. However, these occurrences reported in our study may suggest that co-occupation is a social phenomenon unrelated to reproduction. Camera surveys of burrows during the spring found co-occupation to be rare (Breininger et al., 1991), but large numbers of burrows have not been surveyed during other seasons. As in the case with burrow use by multiple tortoises, co-occupation could lead to erroneous estimation of a tortoise population if correction factors are used.

In summary, gopher tortoises on KSC appeared to have larger home ranges and use more burrows than gopher tortoises studied in other areas. Use of burrows within the home range generally occurred in proportion to the amounts of the different habitat types that were present. Observations of feeding tortoises and other signs indicate that some habitats are important even though few burrows were located in them. Finally, density estimates derived using correction factors should be viewed with caution because a single tortoise may use many burrows and more than one tortoise may be using a single burrow.

Acknowledgments

This study was funded by the NASA Biomedical Operations Office at KSC, and we thank Burt Summerfield and Bill Knott of NASA for their support. The work was conducted under a Refuge Use Permit from the Merritt Island National Wildlife Refuge. We benefited from the advice of Mary Jo Barkaszi, Joan Berish, Paul Moler, and Rich Seigel. Doug Britt, Ross Hinkle, Paul Schmalzer, and two anonymous reviewers improved the draft manuscript with their thoughtful comments. Field, computer, and statistical support were provided by Resa Reddick, Judy Rodda, and Paul Schmalzer.

LITERATURE CITED

AUFFENBERG, W., AND FRANZ, R. 1982. The status and distribution of the gopher tortoise (*Gopherus polyphemus*). In: Bury, R.B. (Ed.). North American Tortoises: Conservation and Ecology. U.S. Fish and Wildlife Service, Wildlife Research Report 12, pp. 95-126.

AUFFENBERG, W., AND IVERSON, J.B. 1979. Demography of terrestrial turtles. In: Harless, M., and Morlock, H. (Eds.). Turtles: Perspectives and Research. New York: John Wiley and Sons, pp. 541-569.

BREININGER, D.B., LARSON, V.L., DUNCAN, B.W., SMITH, R.B., ODDY, D.M., AND GOODCHILD, M.F. 1995. Landscape patterns of Florida scrub jay habitat use and demographic success. Conservation Biology 9:1442-1453.

BREININGER, D.B., SCHMALZER, P.A., AND HINKLE, C.R. 1991. Estimating occupancy of gopher tortoise (*Gopherus polyphemus*) burrows in coastal scrub and slash pine flatwoods. J. Herpetology 25:317-321.

BREININGER, D.B., SCHMALZER, P.A., AND HINKLE, C.R. 1994. Gopher tortoise (*Gopherus polyphemus*) densities in coastal scrub and

slash pine flatwoods in Florida. J. Herpetology 28:60-65.

BREININGER, D.B., SCHMALZER, P.A., RYDENE, D.A., AND HINKLE, C.R. 1988. Burrow and habitat relationships of the gopher tortoise in coastal scrub and slash pine flatwoods on Merritt Island, Florida. Florida Game and Fresh Water Fish Commission, Nongame Wildlife Program Final Report, 238 pp.

BURKE, R. 1989. Burrow-to-tortoise conversion factors: comparison of three gopher tortoise survey techniques. Herpetological Review 20:92-94.

DIEMER, J.E. 1992a. Gopher tortoise, *Gopherus polyphemus*. In: Moler, P.E. (Ed.), Rare and Endangered Biota of Florida. Vol. 3. Amphibians and Reptiles. Gainesville, FL: University Presses of Florida, pp. 123-127.

DIEMER, J.E. 1992b. Home range and movements of the tortoise *Gopherus polyphemus* in northern Florida. J. Herpetology 26:158-165.

DOUGLASS, J.F. 1986. Patterns of mate-seeking and aggression in a southern Florida population of the gopher tortoise (*Gopherus polyphemus*). Proc. Symp. Desert Tortoise Council 1986:155-199.

ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE. 1992. ARC/INFO User's Guide. Redlands, CA.

MCCOY, E.D., AND MUSHINSKY, H.R. 1992. Studying a species in decline: gopher tortoises and the dilemma of "correction factors." Herpetologica 48:402-407.

MCLAUGHLIN, G.S. 1990. Ecology of gopher tortoises (*Gopherus polyphemus*) on Sanibel Island, Florida. M.S. Thesis, Iowa State University, Ames, IA.

MCRAE, W.A., LANDERS, J.L., AND GARNER, J.A. 1981. Movement patterns and home range of the gopher tortoise. American Midland Naturalist 106:165-179.

SCHMALZER, P.A., AND HINKLE, C.R. 1992a. Species composition and structure of oak-saw palmetto scrub vegetation. Castanea 57:220-251.

SCHMALZER, P.A., AND HINKLE, C.R. 1992b. Recovery of oak-saw palmetto after fire. Castanea 57:158-173.

SMITH, L.L. 1995. Nesting ecology, female home range and activity, and population size-class structure of the gopher tortoise, *Gopherus polyphemus*, on the Katherine Ordway Preserve, Putnam County, Florida. Bull. Florida Mus. Nat. Hist. 37(1):97-126.

WOOD, D. 1986. Official lists of endangered and potentially endangered fauna and flora in Florida. Tallahassee: Florida Game and Fresh Water Fish Commission, 19 pp.

Received: 6 January 1996
Reviewed: 6 August 1996
Revised and Accepted: 16 November 1996