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Winter Survey of a Gopher Tortoise Population in South Carolina

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Gopher tortoises (*Gopherus polyphemus*) are large fossorial chelonians that construct extensive underground burrows throughout their range in the southeastern USA (Louisiana to South Carolina). Besides serving as refugia for gopher tortoises, these burrows, which can remain intact for decades (Guyer and Hermann, 1997), provide habitat for many other animals (Jackson and Milstrey, 1989; Guyer and Bailey, 1993). Consequently, the gopher tortoise has often been referred to as a keystone species (Eisenberg, 1983; Means and Grow, 1985). The gopher tortoise is protected by state regulations throughout its range and is listed by the federal government as "threatened" in the western portion of its range (USFWS, 1987). The IUCN (1996) considers the gopher tortoise "vulnerable" to extinction. Because of habitat alteration, gopher tortoises now occur primarily in disjunct populations (Auffenberg and Franz, 1982; Mushinsky and McCoy, 1994). Most research on gopher tortoise ecology has been conducted in Florida, where the species is most abundant, and in the western portion of its range, where it is federally protected. Relatively little is known about gopher tortoise ecology in the northeastern portion of its range (i.e., South Carolina).

The most frequently used method of population estimation is based on burrow counts. With this method, an area is surveyed for tortoise burrows and each burrow is categorized as either "active," "inactive," or "abandoned" based on its external appearance (Auffenberg and Franz, 1982; McCoy and Mushinsky, 1992a). Because tortoises frequently use more than one burrow (McRae et al., 1981; Diemer, 1992a), resulting in more burrows than tortoises, correction factors have been developed that describe the relationship between the number of presumably active and inactive burrows and the actual number of tortoises (Auffenberg and Franz, 1982). However, correction factors vary among habitats, regions, seasons, years, and with the presence of large burrowing mammals (Breininger et al., 1991; Diemer, 1992b; McCoy and Mushinsky, 1992a; Breininger et al., 1994;). Also, frequent inspection of 50 marked burrows during the summer in Florida revealed that burrows can frequently change categories during the tortoise activity season: 60% of active and 28% of inactive burrows changed categories at least five times, and 10% of abandoned burrows changed categories once over a three-month period (Mushinsky and Esman, 1994). The use of infrared burrow cameras (Buskirk and Fiedler, 1986; Spillers and Speake, 1988) permits verification of the presence of tortoises within burrows, thus providing a more accurate estimate of population size (Burke, 1989; Breininger et al., 1991). In addition, because the size of burrows generally reflects the size of occupant tortoises (Alford, 1980), measurements of burrows can be used to make inferences regarding size structure of tortoise populations (Burke and Cox, 1988).

The purpose of this study was to examine the demography of a gopher tortoise population on a public natural area preserve in southeastern South Carolina during winter. Our specific objectives were to determine: 1) the number of intact tortoise burrows; 2) the size structure of the population based on measurements of burrows; and 3) the percent of intact burrows occupied by gopher tortoises.

Methodology. — This study was conducted on the Tillman Sand Ridge Heritage Preserve (TSRHP) in Jasper County, South Carolina. The preserve encompasses 381 ha of floodplain and sand ridge habitat near the Savannah River, and is currently owned and managed by the South Carolina Department of Natural Resources. The preserve corresponds to Sandhills Study Area II as described by Wright (1982). The primary upland habitat is xeric and composed of longleaf pine (*Pinus palustris*), slash pine (*P. elliottii*), and turkey oak (*Quercus laevis*), with a ground cover dominated by wiregrass (*Aristida stricta*; Murphy and Coker, 1992; Tuberville, 1998). The preserve habitat lacks saw palmetto stands (*Serenoa repens*), which can make burrow surveys difficult in other portions of the tortoise's range. Canopy cover is low (approximately 10%; Murphy and Coker, 1992), and swales that occasionally hold water are scattered throughout the uplands. Growing-season burns are periodically conducted to reduce hardwood invasions and increase diversity of the herbaceous ground cover. No timber harvesting is currently conducted but longleaf pine has been planted in some areas. Previous surveys for gopher tortoises in South Carolina by Franz in 1974–75 (Auffenberg and Franz, 1982) and Wright in 1977–79 (Wright, 1982) indicated that the area now encompassed by the preserve supports the largest known population of gopher tortoises in South Carolina and one of the most northeastern populations of the species.

On 17 January 1998 we conducted a complete burrow survey of 30% of the approximately 211 ha of upland sandhills habitat. Rather than surveying a random subset of burrows across the upland habitat, we selected the management compartments that have historically and anecdotally supported the greatest density of tortoises (Murphy and Coker, 1992; Tuberville, 1998). All burrows encountered during the survey were marked, and on 20–30 January, we revisited each marked tortoise burrow to characterize its external appearance.

We conducted this study during the winter, when tortoises are relatively inactive, to minimize effects of tortoise

movement or construction of new burrows on estimates of burrow occupancy. Additionally, reduced vegetation during the winter increased the visibility of potential tortoise burrows and thus our ability to detect them. Because our study was conducted when tortoises are relatively inactive, our burrow categories differ from those traditionally used in the literature (see Auffenberg and Franz, 1982). The latter depend on the movement of tortoises outside their burrows, a rare phenomenon during winter (Douglass and Layne, 1978; McRae et al., 1981; Diemer, 1992a), especially at the northern limit of their range.

We classified a burrow as "collapsed" if the burrow had collapsed within 1 m of the entrance. These burrows ($n = 92$) were eliminated from our analyses. The remaining intact burrows were characterized as either "maintained" or "unmaintained." We classified a burrow as "unmaintained" if its entrance was eroded or the tunnel completely plugged with leaf litter. A burrow was considered "maintained" if its entrance and tunnel were unobstructed by debris and its apron well-defined. Our "maintained" designation is similar to the "active" and "inactive" categories used during active-season surveys (Diemer, 1992b; McCoy and Mushinsky, 1992a) but not directly comparable because our designation was not dependent on finding signs of recent tortoise activity (e.g., feces, tracks) at the burrow entrance.

We used infrared burrow cameras to determine burrow occupancy rates. Because it is more difficult to classify the condition of burrows when tortoises are inactive, we inspected both maintained and unmaintained burrows. Occasionally, the small size of juvenile burrows, obstructions such as roots, or sharp turns prevented complete inspection of a tunnel with the burrow camera. For each burrow, we recorded presence or absence of a tortoise and noted if complete examination with the burrow camera was prevented and why. We also measured the height (BH) and width (BW) of all intact burrow entrances, and calculated burrow shape index (BH/BW), as described by Doonan and Stout (1994). Each burrow was assigned to one of five size classes based on the width of its entrance. When we reached the end of burrows, we recorded the length of burrows (using the tube of the burrow camera) to the nearest 0.25 m. We used single-factor ANOVA (alpha = 0.05) to compare measurements between maintained and unmaintained burrows.

Maximum adult population size (x) for the TSRHP was estimated using the following formula: $n/x = p$, where n is the number of tortoises observed in the survey area and p is the proportion of the preserve surveyed (0.30).

Results. — We located and marked a total of 328 intact burrows (not including collapsed burrows) — 202 (61.6%) were characterized as maintained, 126 (38.4%) were unmaintained. Burrow entrance widths ranged from 7.2–44.5 cm (overall $\bar{x} = 24.2$cm). Mean width of maintained burrows ($\bar{x} = 25.7$ cm) was significantly greater than that of unmaintained burrows ($\bar{x} = 21.7$ cm; $F_{1,326} = 163.9$, $p < 0.0001$; Fig. 1). The mean burrow shape index was 0.51,

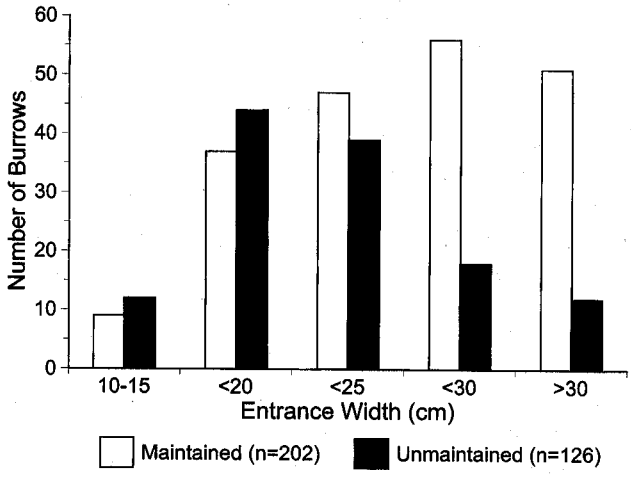

Figure 1. Size-class frequency distribution for entrance widths of gopher tortoise burrows. Maintained ($n = 202$; open bars) burrows had significantly wider burrow entrances than did unmaintained ($n = 126$; solid bars) burrows (ANOVA: $F_{1,326} = 163.9$, $p < 0.0001$).

the same as reported by Doonan and Stout (1994) for central Florida.

We were able to inspect 244 burrows (74% of all marked intact burrows) using infrared video cameras — 88% of maintained burrows and 54% of unmaintained burrows. Maintained burrows were usually longer than unmaintained burrows ($F_{1,242} = 247.0$, $p < 0.0001$; Fig. 2). We observed 41 tortoises in 178 maintained burrows (23% occupancy) and eight tortoises in 66 unmaintained burrows (12% occupancy). Tortoises were encountered an average of 2.8 m (range 1.0–5.0 m, SD = 1.11) from the entrance of the burrow. Tortoise tracks were observed at two maintained burrows, but there was no evidence that any tortoise made inter-burrow movements during our survey period (tracks were confined to the apron). Based on the number of tortoises observed during this study and the proportion of area surveyed, we estimate the maximum adult population on the preserve to be 163 tortoises.

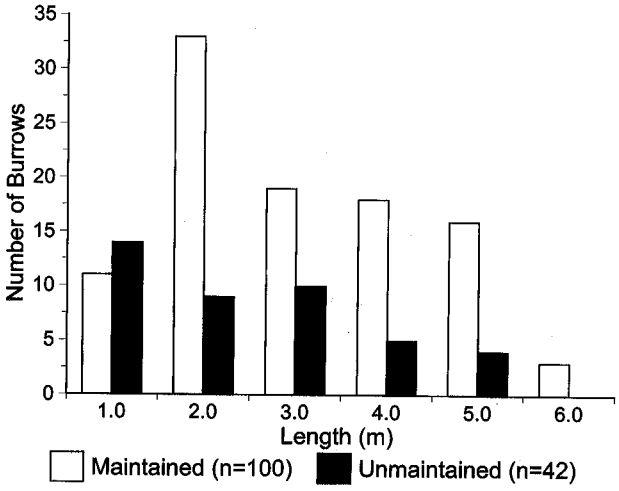

Figure 2. Size-class frequency distribution for burrow lengths. Maintained ($n = 100$; open bars) were significantly longer than unmaintained ($n = 42$; solid bars) burrows (ANOVA: $F_{1,242} = 247.0$, $p < 0.0001$). Burrows which we were not able to completely inspect with the burrow camera were not included in the analysis.

Discussion. — We observed a relatively high proportion (38%) of unmaintained burrows on the preserve (McCoy and Mushinsky, 1992b; Witz et al., 1992), which may indicate a recent decline in the adult tortoise population, a lack of burrow fidelity by gopher tortoises (Diemer, 1992b; Aresco and Guyer, 1999), or extended burrow longevity following abandonment (Guyer and Hermann, 1997). Without detailed movement data on individual tortoises or long-term monitoring of marked burrows, we cannot make conclusions regarding specific causes for the observed ratio of maintained to unmaintained (202:126) burrows on the preserve. Auffenberg and Franz (1982) noted that population densities of gopher tortoises along the Savannah River in South Carolina were very low in the 1970s, but based on the number of destroyed burrows they found, they also concluded that densities were formerly very high.

We are cautious about estimating the number of hatchling and juvenile burrows and tortoises on the preserve for the following reasons: (1) hatchling burrows (< 5 cm width) are easily overlooked, even under optimal search conditions (Burke and Cox, 1988; Diemer, 1992b); (2) fallen leaf litter during winter is more likely to obscure the entrances of hatchling and juvenile burrows than adult burrows; (3) juvenile tortoises do not always dig their own burrows, but may instead take refuge under leaf litter, other vegetation, or in adult-sized burrows (Douglass, 1978; Burke and Cox, 1988; Diemer, 1992a); and (4) inspection with the infrared burrow camera of burrows less than 10 cm width was not possible during this study. We therefore restrict our remaining discussion to the adult population.

Unmaintained burrows were smaller (in width and length) than maintained burrows, probably due in part to debris deposition over time in the former. Within the maintained category, burrow widths were skewed toward larger size classes, as has been reported in other studies (Alford, 1980; Spillers and Speake, 1988). Both Alford (1980) and Martin and Layne (1987) reported a high correlation between burrow width and carapace length of the tortoise occupying the burrow. Based on inspection of burrows in several populations, Auffenberg and Franz (1982) also concluded that tortoise populations in southeastern South Carolina consisted mostly of older individuals. Trapping of tortoises by Wright (1982) in southeastern South Carolina, including at our study site, revealed that populations were dominated by medium (20–24 cm carapace length; 47%) and large-sized (16%) adults. Therefore, the TSRHP tortoise population may be comprised primarily of larger, older individuals.

Although not directly comparable to correction factors calculated for activity season surveys, our observed occupancy rates are considerably (2–4 times) lower than most reported in the literature and those commonly used to estimate tortoise populations from burrow counts (Auffenberg and Franz, 1982; Diemer, 1992b; Witz et al., 1992; but see Burke, 1989; Breininger et al., 1991). Possible reasons for the low burrow occupancy rates include poor habitat conditions or depleted food resources (Auffenberg and Iverson, 1979; Auffenberg and Franz, 1982; Aresco and Guyer, 1999), a seasonal shift in habitat or burrow use (McRae et al., 1981; Means, 1982; Breininger et al., 1991), co-occupancy of burrows (Diemer, 1992a; Smith et al., 1997), or misinterpretation of "occupancy" in other studies in which burrow cameras were not used for confirmation. Wilson and Mushinsky (1995) suggested that a low occupancy rate of "active" and "inactive" burrows (i.e., "maintained" burrows in our study) may be indicative of a stressed tortoise population.

This region of South Carolina is well-known to reptile collectors, and removal of adult gopher tortoises for consumption or pets has been documented (Auffenberg and

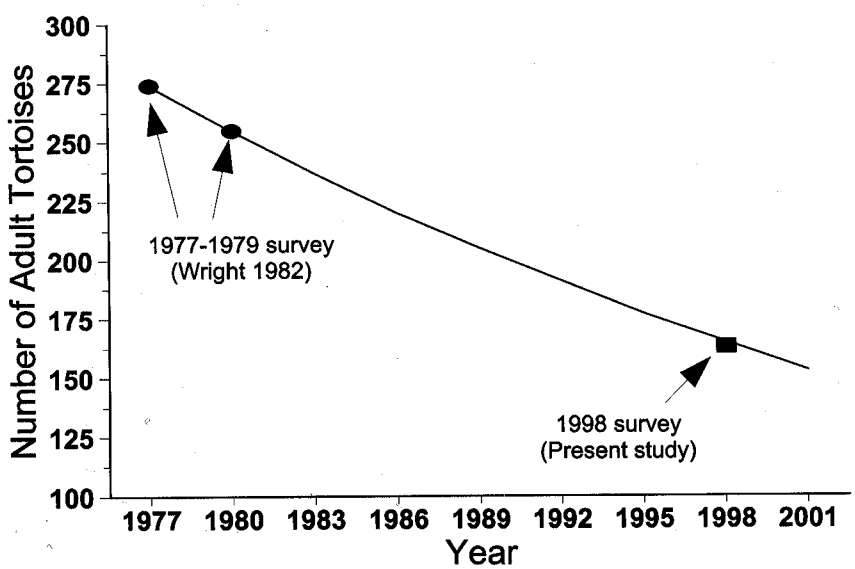

Figure 3. The projected change in adult gopher tortoise population size on the Tillman Sand Ridge Heritage Preserve from 1977 to 2001. The projection assumes an initial population size in 1977 of 274 individuals as estimated by Wright (1982) and an average 2.33% loss per year in the adult population, which was observed by Wright during 1977–79 (indicated by circles), leading to a projected population of 165 individuals in 1998. Based on our 1998 survey, we estimated the maximum adult population size at 163 tortoises (indicated by square).

Franz, 1982; Wright, 1982). Based on studies from 1977–79, Wright (1982) estimated the adult tortoise population at our study site (Sandhills Area II in his study) to be 274. However, he also concluded that adult mortality exceeded adult recruitment at Sandhills Area II and surrounding properties, with an overall loss of 7% of the adult population during his study (average 2.33% loss per year). All adult mortality was attributed to habitat destruction and human predation (Wright, 1982). If we project the hypothetical changes in the preserve's tortoise population from 1977 through 2001, assuming there were 274 adults in 1977 and an overall loss of 2.33% of adults per year (Fig. 3), we obtain an estimate of 165 adults remaining in the population in 1998, which corresponds very closely to our maximum population size estimate (163) for 1998.

Long-lived species, such as tortoises, that exhibit low reproductive recruitment, delayed sexual maturity, and low adult mortality rates (Auffenberg and Iverson, 1979; Iverson, 1980), become vulnerable to population declines and extirpations when unusually high adult mortality rates persist for long periods (Congdon et al., 1993, 1994). Although the tortoise population on the TSRHP is now formally protected and human-caused mortality has been theoretically eliminated, there may be a long lag time before a population recovery becomes evident (Congdon et al., 1993). In addition, recovery could potentially be hindered by illegal collecting and unsuitable management practices on adjacent properties that result in habitat degradation or direct mortality of tortoises.

It is noteworthy that 12% of burrows we classified as unmaintained (i.e., abandoned) harbored tortoises during the winter survey. This is slightly more than half the occupancy rate of maintained burrows (23%). In most other surveys, the abandoned or unmaintained burrows are generally assumed not to harbor tortoises and thus, are not investigated. However, by investigating the unmaintained burrows with the infrared burrow camera, we were able to estimate the tortoise population size more accurately. We are aware of only one other study that reported occupancy rates of abandoned burrows. In west-central Florida, Witz et al. (1991) found 6 tortoises during the activity season in 116 excavated tortoise burrows classified as abandoned (5% occupancy). Future studies, during both activity and inactivity seasons, should investigate unmaintained (i.e., abandoned) burrows for possible occupancy.

Our study provides baseline data on the current population size structure of gopher tortoises on the TSRHP. These data, when combined with future survey efforts, will be important in detecting possible shifts in the population structure that could signify changes in the population's demographics (e.g., McCoy and Mushinsky, 1992b; Mushinsky and McCoy, 1994). McCoy and Mushinsky (1992b) suggested that land managers should be alert to early signs of a population decline, such as even slight reduction in the proportion of juvenile-sized active burrows, so that they may address the decline in its early stages.

Our results provide justification for continued research and monitoring of gopher tortoises in South Carolina and other regions where demography of this vulnerable species is poorly understood. In addition, our study demonstrates that tortoise surveys conducted in winter, when vegetation is sparse and tortoise activity is minimal, can be valuable in monitoring tortoise populations, and that abandoned or unmaintained burrows, as classified solely on the appearance of the mouth of the burrow, may actually harbor a significant portion of the population.

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