Residential Development and Habitat Fragmentation Effects on Gopher Tortoise (*Gophorus polyphemus*) Population Densities

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Abstract

Gopher Tortoises (*Gophorus polyphemus*) rely on the same upland ecosystems as humans, which leads to competition for resources. Habitat loss and associated reduction of forage area is a principal concern for tortoise conservation. Using tortoise populations in Volusia County, Florida, we examined the impacts of habitat fragmentation and reductions in land permeability on burrow densities. Existing research on minimum fragment size is inconsistent, however findings suggest that disruption in landscape continuity negatively affects tortoise population viability. Our study area consisted of seventeen individual and variously sized fragments throughout Volusia County: eleven occupying private residential neighborhoods, and six occupying publicly owned lands. Burrow densities were found to positively correlate with increased land impermeability, suggesting that conservation efforts should not only consider tortoise numbers but also the usable land area available to them.

Introduction

Although considered a species of concern in Florida, threats to the gopher tortoise (*Gopherus polyphemus*) continue to materialize as their habitats are increasingly compromised by fragmentation. Classified as a keystone species of xeric communities, their burrows provide a distinct microenvironment for over 330 other species (Jackson and Milstrey 1989). With preferences for dry sandy soils and limited canopy cover, gopher tortoise needs conflict with human desires. As these characteristics appear consistently with pine flatwoods, the gopher tortoise is undoubtedly at odds with human enthusiasms for recreation, agriculture, and development (Diemer 1986, Ashton and Ashton 2004). Consequently, suitable tortoise habitat has undergone considerable fragmentation, threatening current and future populations of gopher tortoises (BenDor et al. 2009).

The desire to know more about the impacts of land use on tortoise densities motivates this study; do tortoise densities increase with decreasing land availability as a result of habitat fragmentation? Because tortoises living within wildlife preserves have optimal, continuously managed habitat available, burrows should be less dense than those in developed, unmanaged areas with smaller fragmented habitats that are connected by limited corridors.

Literature Review

Studying habitat fragmentation as it affects gopher tortoises is significant to studying the overall health of longleaf pine ecosystems, and understanding the effects of fragmentation on the gopher tortoise illuminates the effects on pine ecosystems as a whole. Together, their relatively large size and mild behavior make gopher tortoises an ideal study species for any experiment regarding habitat health.

Gopher Tortoise Natural History

Gopher tortoises generally favor the well-drained sandy soils associated with Florida's longleaf pine (*Pinus palustris*) and oak (*Quercus spp*.) uplands, xeric hammock, sand pine (*Pinus clausa*) and oak ridges (including beach scrub), and ruderal communities such as roadsides, grove edges, fencerows, clearings, and old fields (McRae et al. 1981, Diemer 1986, McCoy and Mushinsky 1988, Russell et al. 1999, Rostal and Jones 2002, FWC 2007). Individual tortoises ordinarily feed in a nearly circular or elliptical pattern around the burrow: not typically exceeding a 33-meter radius (McRae et al. 1981). However, the tortoise home range inversely relates to the extent of herbaceous ground cover, suggesting that anthropomorphic endeavors can directly affect tortoise behavior (Diemer 1986).

Habitat Fragmentation and Population Density

Little is documented about the effects of habitat fragmentation on gopher tortoise populations specifically, but existing research suggests negative effects. Habitat loss and fragmentation generally result from the expansion of urban and agricultural land uses. Road construction, suburban development, and agricultural growth may isolate and eliminate local populations (Zanette et al. 2000, Aponte et al. 2003, BenDor et al. 2009). Fragmentation affects populations in two ways: loss of original habitat and insularization—the increased isolation between habitat patches (Wilcox 1980, Bennett et al. 2009).

Research suggests that fragmentation imposes island effects on species diversity and population demographics. Such effects can cause both decreases and increases in population density as compared to the homogeneous landscapes consistent with protected lands (MacArthur et al. 1972). Habitat islands generally possess lower species diversities than their mainland counterparts, and as a result lower interspecific competition for resources (Crowell 1962). Population densities can also be affected by the tendency for habitat fragments to generate edge factors (MacArthur et al. 1972, Fagan et al. 1998, Tischendorf et al. 2005). Edge habitat can put individuals at risk to predators, inadequate forage, and even increase the potential for contact with roadways, increasing overall mortality (Boarman and Sazaki 2006). Edge habitat can also increase emigration rates as a result of increasing perimeter to area ratios (Tischendor et al. 2005). Such emigration raises the possibility for dispersing individuals to come into contact with an isolated patch; having multiple, small fragments may increase the likelihood of encountering stranded individuals (MacArthur et al. 1972, Tischendorf et al. 2005).

Estimates for minimum fragment sizes needed by gopher tortoises range from 19 to 100 hectares (McCoy and Mushinksy 2007); the inaccuracy of this baseline suggests that the severity of human disturbance is not yet entirely understood. Density measures are frequently used to assess habitat quality and success of management regimes. High densities generally suggest that ecological necessities such as foraging, home territory, and demographic behaviors are within tolerable ranges.

However decreased fragment sizes can also yield density increases, though the threat of such increases is frequently overlooked because high densities are generally considered a direct measure of habitat health. Van Horne (1983) suggests three, less desirable, mechanisms that may also increase densities: summer populations are not always maintained throughout winter, densities may be reflective of temporary conditions as opposed to long-term habitat quality, and social interaction between dominant and subdominant individuals. As Florida does not undergo considerable weather changes during the winter months, reason one most likely has little effect.

Van Horne's second and third mechanisms may result from land development. Habitat fragmentation would relate to the second of Van Horne's alternative mechanisms, potentially causing short-term population density spikes. Other research supports Van Horne's third mechanism that high densities may result from social interactions between adults and juveniles. In areas where ideal habitat is limited, juveniles may be forced to emigrate to inferior habitats where breeding occurs and population densities are temporarily elevated (Lidicker 1975, Van Horne 1983). Such phenomena have been reported in various small mammals (States 1976, Van Horne 1983) and numerous bird species (Kock 1969, Krebs 1971, Van Horne 1983), suggesting that the dynamic occurs across a variety of taxa, and may be manifesting in gopher tortoises inhabiting developed landscapes. Perhaps residential neighborhoods are providing a refuge for juvenile tortoises. However if a refuge fragment lacks sufficient resources, increased density exacerbates resource competition stressing both the tortoises and the environment (McCoy and Mushinsky 2007). Such density increases may not persist over the long term.

Individual tortoises have a variable home range, spanning anywhere between 0.2 to 4.7 acres (FWC 2004), and foraging conventions that rarely exceed a circular perimeter of thirty-three meters around the burrow. Reducing fragment areas can compromise foraging behaviors. Insufficient corridors further contribute to the isolation of tortoise populations, leaving them unable to move freely between potential mating populations (Jones and Dorr 2004). Variations in tortoise ranges have been exhibited in isolated fragments, making tortoises more susceptible to potential predators and restricting their eligibility for suitable mates; isolation can inhibit young male tortoises from emigrating and settling new populations. Over time, such factors may leave populations susceptible to inbreeding depression, reducing a population's overall genetic diversity (BenDor et al. 2009).

Study Area

The gopher tortoise is a member of the upland xeric community, a habitat type found extensively in eastern and western Volusia County. Our study area includes eleven residential neighborhoods dispersed throughout Volusia County's urban communities. These sites were selected to assess the effects land accessibility has on burrow density; rather than continuous habit, but these sites are characterized by inconsistent forage and habitat availability as a result of homes, driveways, roadways, etc. To contrast these areas, we studied seven publically protected land parcels, of which we personally surveyed Lake Woodruff National Wildlife Refuge. These sites offer large continuous expanses of habitat that regularly undergo conservation management regimes, including prescribed burns. Though these sites are not entirely free of fragmentation, the intentional management of habitat for wildlife should promote healthier tortoise populations.

Methodology

Seventeen tortoise populations were selected from data provided by the Volusia County Department of Environmental Management; eleven occupying private residential neighborhoods and six occupying publicly owned lands (Table 1 and Figure 1).

Site sizes are inconsistent as much of the county data is a result of call-and-confirm sightings; residents call the county to report a tortoise, and a county employee visits the residence to confirm burrow presence and to enter a location into the County database. To reduce the chance

of incomplete population numbers, populations were selected only if all burrow locations were confirmed on the same day; those with spotty confirmation dates were eliminated.
With the help of the Volusia County Environmental Specialist, a seventeenth population was added from data personally collected from Lake Woodruff National Wildlife Refuge. The study area was randomly chosen from a much larger portion of upland habitat located on the southern portion of the refuge and referred to as the Volusia Tract. Transects were used to complete a full area survey and were spaced fifteen feet apart, across an approximately 3,490 m2 area. As burrows were sighted, they were catalogued on a GPS and later uploaded to GIS where they were then added to the existing county data along with corresponding area polygons and burrow densities.

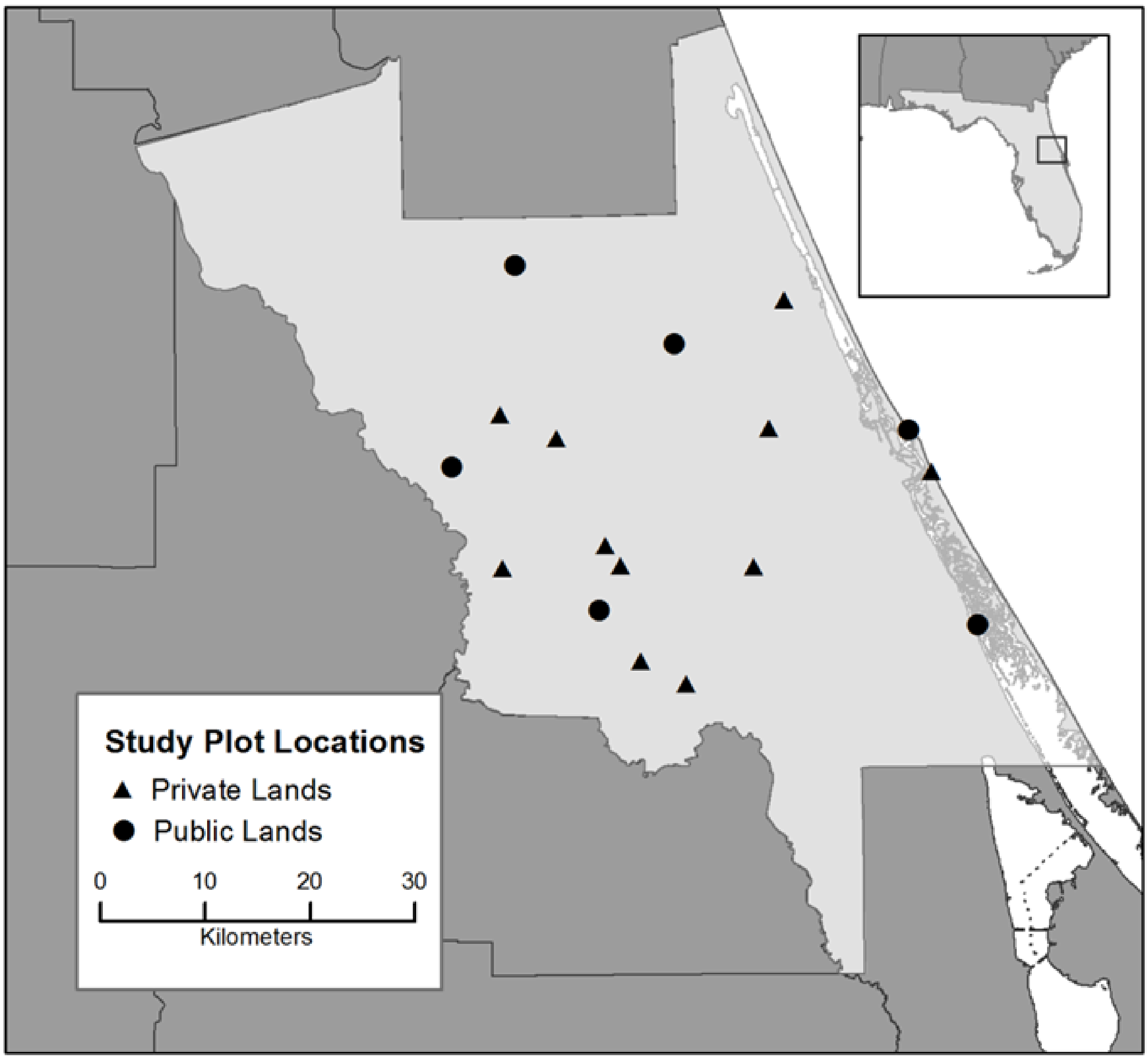

Figure 1. Study area in Volusia County Florida.

Public[a]	Private[b]
1. Canaveral National Seashore	7. Spruce Creek
2. Ponce Inlet	8. Quail Roost Ranches
3. Tomoka Wildlife Management Area	9. New Smyrna Neighborhood
4. Tomoka Wildlife Union Camp	10. Fragmented area near Black Lake
5. Lyonia Preserve	11. Louise Lake Neighborhood
6. Lake Woodruff Burrows	12. Embry Riddle
	13. Sterling Sports Complex Neighborhood
	14. Fragmented area near Blue Springs
	15. Glenwood
	16. King Pond population 1
	17. King Pond population 2

Table 1. Burrow populations corresponding to each of the two studied land categories.

Using GIS, area polygons were drawn around the outermost burrows for each population and the polygon's corresponding densities (burrows/m2) were recorded in an attribute table. As the land contained within the private domain is obstructed by impermeable anthropogenic development such as houses, driveways, roadways, swimming pools, et cetera, these areas cannot be considered continuous. Using GIS, ten homes within each private land area were randomly selected. The square footage of each dwelling (built home structure not including driveway, shed, or other impermeable surfaces) was obtained from the Volusia County Property Appraiser database. The built-structure areas were averaged and then multiplied by the total number of houses contained within each sample plot. This area was subtracted from the total area to give the maximum area available for a given population, called here the Available Area (AA).
Given the complications in accounting for all impermeable patches—those areas associated with structures not described by the appraiser database—each land area was also multiplied by scalars for 60%, 50%, and 40% to signify the amount of viable land available for burrowing under increased development. Each percentage represents permeable land, or land unobstructed by anthropogenic structures, within each selected area. These would be the areas available as tortoise habitat.
All data were run through Prism, a statistical analysis program, to test for significance. A Welch's unpaired, one-tailed t-test was chosen for analysis, because each group was assumed to display unequal variances (Ruxton 2006). Burrow densities for six populations inhabiting publicly owned, protected lands were analyzed against eleven tortoise populations inhabiting privately owned residential lands using a Welch's unpaired T-test. Populations for public and private lands were organized into multiple groups to determine the level at which land permeability began to significantly impact burrow density.

Results

Data were first analyzed using all seventeen populations of both public and private lands; no population was omitted from analysis. When burrow densities for all populations were analyzed together, and consideration for homes was the only source of land impermeability measured

(AA), the average density was greater on public lands, but not significantly. As effects for land impermeability were increased on private parcels, densities increased on private lands generating statistically significant differences (Figure 2).

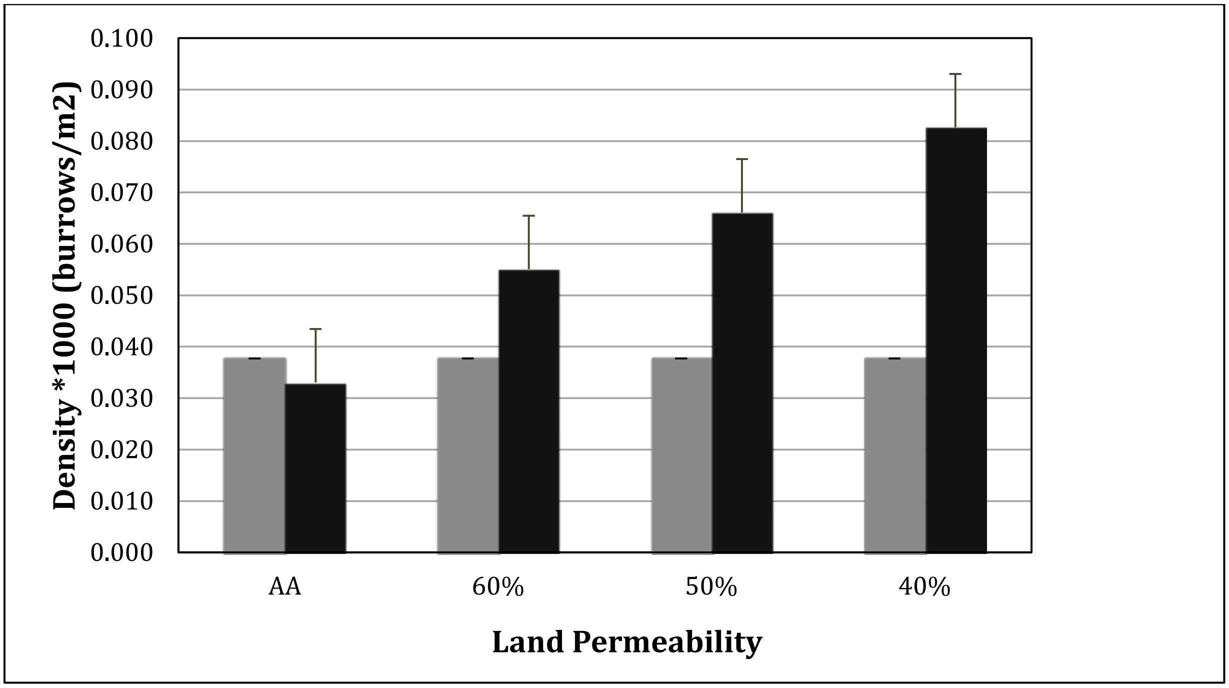

Figure 2. Mean densities for public and private land groups when all populations were considered.

A more nuanced analysis is achieved by testing the tolerances of statistical significance by adding parcel groups individually to the model. Table 2 shows the most robust combinations of areas exhibiting significant differences in density for the various land availability scenarios. As expected, a greater number of populations significantly differed among public and private lands as lower levels of habitat availability in private areas were applied to the model. Only six populations, statistically differed from one another in the models with maximum available area (AA). As assumed habitat availability decreased, as shown by Groups 2, 3 and 4, the number of populations with statistically different densities increased and the burrow densities in private land areas increased.

Public Lands	Private Lands
Group 1 (AA)[a]	
1. Canaveral National Seashore	8. Quail Roost Ranches
3. Tomoka Wildlife Management Area	16. King Pond population 1
5. Lyonia Preserve	17. King Pond population 2
Group 2 (60%)[b]	
1. Canaveral National Seashore	7. Spruce Creek
3. Tomoka Wildlife Management Area	8. Quail Roost Ranches
4. Tomoka Wildlife Union Camp	9. New Smyrna Neighborhood
5. Lyonia Preserve	11. Louise Lake Neighborhood
6. Lake Woodruff Burrows	16. King Pond population 1
	17. King Pond population 2
Group 3 (50%)[c]	
1. Canaveral National Seashore	7. Spruce Creek
3. Tomoka Wildlife Management Area	8. Quail Roost Ranches
4. Tomoka Wildlife Union Camp	9. New Smyrna Neighborhood
5. Lyonia Preserve	11. Louise Lake Neighborhood
6. Lake Woodruff Burrows	16. King Pond population 1
	17. King Pond population 2
Group 4 (40%)[d]	
1. Canaveral National Seashore	7. Spruce Creek
2. Ponce Inlet	8. Quail Roost Ranches
3. Tomoka Wildlife Management Area	9. New Smyrna Neighborhood
4. Tomoka Wildlife Union Camp	10 Fragmented area near Black Lake
5. Lyonia Preserve	11. Louise Lake Neighborhood
6. Lake Woodruff Burrows	12. Embry Riddle
	13. Sterling Sports Complex Neighborhood
	16. King Pond population 1
	17. King Pond population 2

Table 2. Population groups displaying significantly different densities between public and private lands.

Discussion

The dry, sandy soils that occur in upland habitats make them ideal for both tortoise and human residences. Unfortunately, threats to the gopher tortoise are inevitable. Tortoises are forced to adapt to new environments, which are often comprised of deficient resources and undersized, impermeable patches. This study sought to assess the effects of primary edifices on burrow density in private land areas. Accurate measurements for structures not included in appraisal records, e.g., swimming pools, sheds, driveways, roadways, and other impermeable structures would improve population density modeling for the gopher tortoise. It is also likely that burrow densities in each neighborhood are actually higher than the figures used for this study. Privately held lands do not allow researchers the access required for accurate burrow surveys that is a given for public lands. Further, the quality of the forage in developed areas may not be equivalent to that in conservation lands.

Consequently, densities used in this analysis for public lands are likely accurate while densities for private lands are likely less than true values. It is possible that these high densities in private lands may only reflect a temporary elevation in population numbers, and not a long term survival rate, while densities on public lands represent viable populations. Conservation efforts should thus incorporate greater consideration of habitat quality in private areas if we are to envision conservation occurring in areas other than publically held lands.

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