THE STATUS OF GOPHER TORTOISES (*GOPHERUS POLYPHEMUS*) IN ALABAMA, WITH SPECIAL REFERENCE TO THREE IMPORTANT PUBLIC PROPERTIES

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Executive Summary:

The longleaf pine ecosystem is one of the world's most imperiled forested landscapes types, with less than one percent of this forest type remaining in its old-growth form (Simberloff 1993). Many rare animal species are found in longleaf pine, especially those adapted to burrowing in the loose soils that characterize the region. For these reasons, restoration of this forest type is one of the most challenging conservation problems in North America.

Within longleaf pine forests, the Gopher Tortoise (*Gopherus polyphemus*) is thought to be a keystone species, principally because of the burrows that this species creates. These holes are thought to assist in maintenance of the unusually rich flora and fauna of longleaf pine forests relative to other pine forests (Guyer and Bailey 1993). For these reasons, Gopher Tortoises are crucial to the success of conservation plans for much of the southeastern United States.

Thanks to 20 years of proactive management on properties in south Alabama, significant progress has been made in recreating important aspects of old-growth longleaf pine forests. On top of these efforts, the state of Alabama has invested in significant properties in the Lower Coastal Plain that align with extensive properties in Florida that create a unified corridor of restorable longleaf habitat stretching from south Alabama to the Gulf coast. Despite success in improving habitat structure, Gopher Tortoise populations on these properties have not recovered to densities observed in old-growth forests. Additionally, newly purchased properties will require great effort to begin the restoration process. The slow recovery of tortoises makes it difficult to create features that will allow recovery of missing species such as the Eastern Indigo Snake (*Drymarchon couperi*), Southern Hognose Snake (*Heterodon simus*), and Eastern Pocket Gophers (*Geomys pinetis*). For this reason, active management of Gopher Tortoise populations will be needed as a primary step toward restoration of state, federal, and private properties and to position Alabama as a leading figure in current efforts to conserve Gopher Tortoises throughout their geographic range.

In this report we establish that:

- Alabama likely once had 2 million tortoises
- Alabama now likely has 30,000 – 130,000 tortoises

- Geneva State Forest once likely had 2,800 tortoises and now likely has 75-250 individuals
- Geneva State Forest has one extensive area of priority soils that should be the focus of developing a viable tortoise population
- Perdido River Longleaf-Hills Tract once likely had 4,100 tortoises and now likely has 140-1,000 individuals
- Perdido River Longleaf-Hills Tract has four areas of extensive priority soils that could be the focus of establishing viable tortoise populations
- Conecuh National Forest once likely had 27,000 tortoises and now has about 5,200 individuals
- Conecuh National Forest populations appear to be viable and the six sites used in previous studies of management effects on tortoise populations should be the focus of management to maintain viable populations
- The state should target a minimum of 10 sites on public lands that will be managed to maintain viable tortoise populations; these should span the geographic range within the state

OBJECTIVES

Our objectives in the project were to:

1. Estimate the area of priority, suitable, and marginal soils for Gopher Tortoises throughout its range in Alabama and on three properties of high conservation value within Alabama - Conecuh National Forest (CNF), Geneva State Forest (GSF), and Perdido River-Longleaf Hills Tract (PRT).

2. Project, from Gopher Tortoise populations on the best remaining longleaf tracts, the likely ancestral abundances of tortoises in Alabama and on the three conservation tracts.

3. Compare estimated ancestral densities of Gopher Tortoises to estimates generated from literature values and estimates from field surveys of the three conservation tracts.

METHODS AND PROCEDURES

Soil Surveys

<u>State of Alabama</u> – We used the range map in Mount (1975) as an estimate of the area occupied by Gopher Tortoises (*Gopherus polyphemus*) in Alabama's ancestral and modern landscape. This map (Figure 1) indicates the presence of tortoises in essentially the entire area of 16 counties (Barbour, Baldwin, Clarke, Coffee, Conecuh, Covington, Crenshaw, Dale, Escambia, Geneva, Henry, Houston, Mobile, Monroe, Pike, and Washington) and half of the area of four counties (Bullock, Butler, Choctaw, and Russell). Within each county we estimated the area covered by priority, suitable, and marginal soils as defined by McDearman (2005). In this classification system, priority soils are those that are deep sands (>1 m) and where burrow densities are highest. Suitable soils consist of sandy loams that are not as deep as priority soils (0.5-1 m) and, therefore, have reduced burrow densities relative to priority soils. Finally, marginal soils are shallower sands (<0.5 m) and have higher clay content, causing them to have the lowest densities of tortoise burrows. We included all soil types listed by McDearman (2005) as well as those listed in published accounts of Gopher Tortoises from throughout their

geographic range (Appendix 1). Estimated areal extent was determined for each county by querying the National Resources Conservation Service (NRCS) Soil Series Extent Mapping Tool (http://www.cei.psu.edu/soiltool/semtool.html; accessed 9/30/2011). For Bullock, Butler, Choctaw, and Russell counties we assumed these soils were distributed randomly throughout the county and divided the extent of each soil type in half to estimate the area of soils in these counties that were likely to be occupied by tortoises. No data from NRCS were available for Washington County. Therefore, we estimated the mean areas of priority, suitable, and marginal soils in each of the other 19 counties, expressed these as a percentage of the average area of the counties, and multiplied these percentages by the area of Washington County. The sum of the area of priority, suitable, and marginal soils for all 20 counties was used as an estimate of the area once occupied by Gopher Tortoises within Alabama.

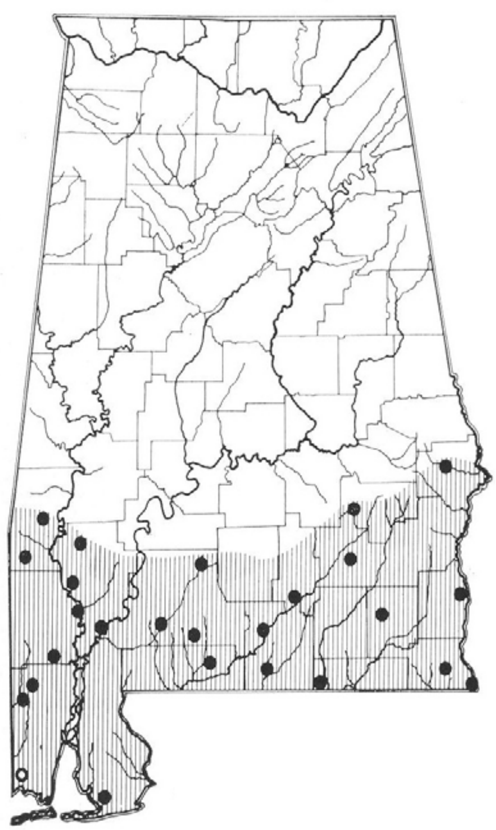

Figure 1. Map of distribution of *Gopherus polyphemus* in Alabama. Dots represent known collection localities and shaded area is presumed geographic range according to Mount (1975).

Conservation Properties – We used GIS layers for each conservation property (CNF, GSF, and PRT) to generate maps of priority, suitable, and marginal soils within each property. Additionally, these maps served as the basis for establishing transects for complete inventories of burrows (GSF and PRT) or samples of burrows (CNF).

Burrow Surveys

State of Alabama – To estimate the number of burrows that were likely to occur in the ancestral landscape of Alabama, we used the total extent of tortoise soils and multiplied this by an estimate of tortoise density achieved on two tracts of land managed to retain features of old-growth longleaf pine forests. These two sites were Green Grove on the Jones Ecological Research Center (Boglioli et al. 2000) and the Wade Tract (Guyer and Hermann 1997). Both are located in southern Georgia, contain a mixture of priority and suitable soils, and therefore, represent reasonable sites from which to generate tortoise densities expected of the ancestral longleaf pine forests of Alabama. We used data published in Jones and Dorr (2004) for lands managed for timber production in Mississippi and Alabama as estimates of the density of burrows likely to be achieved on priority, suitable, and marginal soils across the entire current landscape of Alabama. Because much of this region is managed for timber production, these data are reasonable estimates of current levels of tortoise abundance.

Conservation Properties - Comprehensive burrow surveys were done on GSF and PRT. These surveys were performed in areas that had been burned, mulched, or both burned and mulched within the last three years. All other areas were omitted because fire suppression and resultant plant growth, especially of the shrubs layer, made the areas impenetrable by the field crew. Maps of these two sites were used to determine the areal extent of each soil category and to position starting points for surveys. We then used a Trimble® GEOXT GPS unit with WAAS sub-meter precision to project transect lines separated by 20 m. A person with the GPS unit walked this projection while a second person walked a parallel transect 10 m from the GPS baseline. The two investigators searched for characteristic burrow openings made by Gopher Tortoises. Upon detection, burrow location was recorded and burrow status was assessed [active: foot prints or plastral slide marks at entrance, presence of scat, and signs of activity within the past week; inactive: shape of tortoise shell, but no foot prints or fresh slide marks, but signs of activity within the past year; abandoned: entrance occluded with leaves, eroded burrow shape, round shape (invaded by armadillo), or other evidence suggesting lack of use by a tortoise within previous year]. A measure of burrow width was recorded at a depth of 0.5 m below the opening to assess the size of the tortoise that created it. If, during a transect sample, vegetation became too dense to traverse, coverage of the transect was suspended, the perimeter of the impenetrable area was traversed and recorded in the GPS unit, and the transect was resumed at the opposite side of the area. All measures of coverage eliminated these impenetrable areas from the summary statistics.

The comprehensive surveys yielded a measure of area covered for priority, suitable, and marginal soils, the total number of burrows encountered in each soil type, and the size distribution of those burrows. We also estimated the occupancy rate of those burrows by examining a large sample of them with a video camera. The camera was a TView® Car Rear View Camera (T200NV) encased in a 55-mm diameter PVC housing that was attached to a 25-ft section of hydraulic tubing. The camera was powered via a long RCA cable running through the tubing and plugged into an external 12V battery for powering the LCD lights and a Haier® 7” Digital LCD TV (HLT71) screen. The screen provided a picture of the burrow contents. Burrows were categorized as containing a tortoise, if one appeared on screen; unoccupied, if no tortoise was seen but the end of the burrow was detected; or uncertain, if no tortoise was observed but the end of the burrow was not detected. We recorded burrow width (described above) and length (measured along hydraulic tubing) for each burrow examined with the video system.

Because of its large size and the appearance of publications describing a statistically-defensible survey method that is superior to comprehensive surveys (Smith et al. 2009; Stober and Smith 2010), we used a different method to assess tortoise abundance on CNF. Here, we employed line transect distance sampling to derive a tortoise population estimate. Suitable tortoise soils were identified utilizing the soil series maps in the GIS for CNF and this soils map was used to create a sampling frame for the property. A pilot survey was then conducted across the sample frame by randomly placing transects across the forest. The purpose of the pilot survey was to determine the tortoise encounter rate (tortoises observed per mile of transect) from which we could estimate the amount of survey effort needed to generate a robust population estimate. Pilot survey transects were of variable length and orientation and were located in a range of suitable habitats across the CNF. The pilot survey was conducted with a crew of 3 people; all burrows encountered were searched with a burrow camera (described above) to determine if a tortoise was present. Eleven transects covering 9115 m were traversed yielding observation of 39 burrows, 16 of which contained a tortoise.

Based on the pilot survey, we placed a systematic, east-west oriented, set of transects across the entire sampling frame using Hawth's tools and X tools, respectively, in ArcGIS. The transects consisted of pairs of parallel 500 m segments that were 60 m apart creating a pseudo-circuit design, which allowed for greater sample efficiency. Pairs of transects (pseudo-circuits) were separated by 1300 m east-west and 1200 m north-south across the sampling

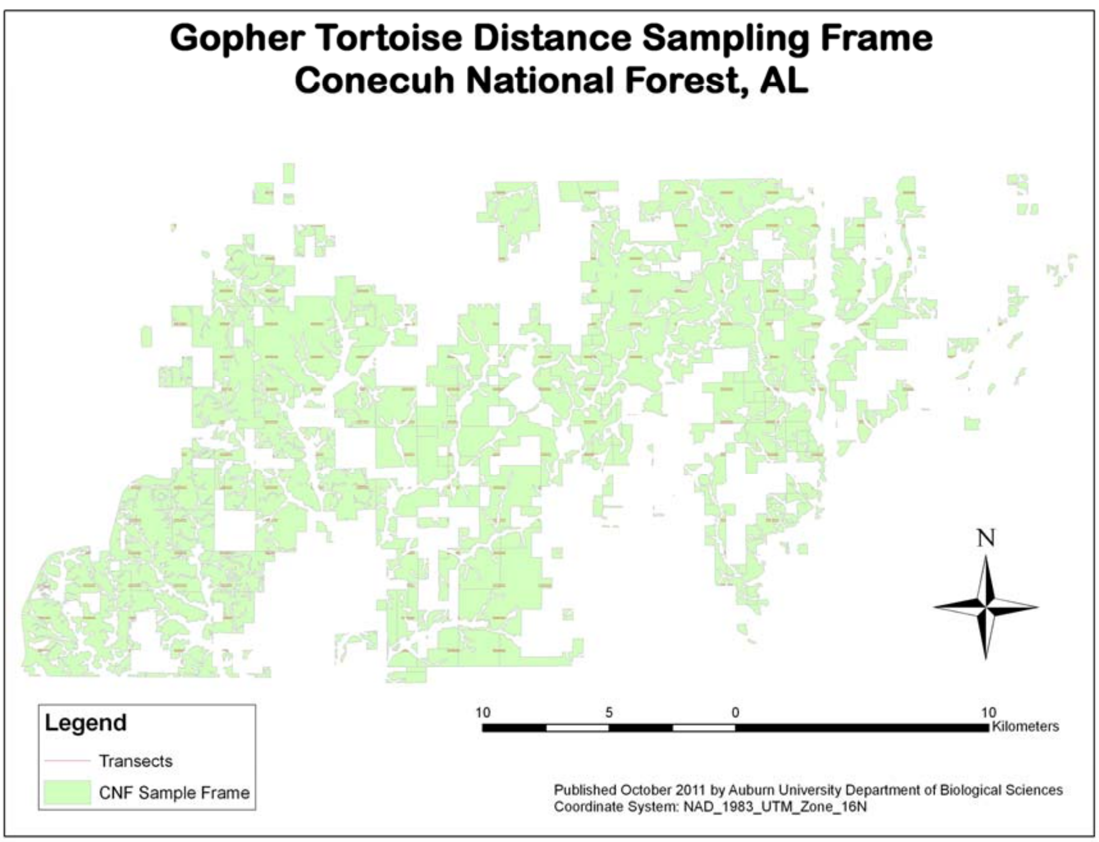

Figure 2. Distribution of circuits (transects) across the Conecuh National Forest.

frame. The paired transects were organized in a Systematic Segmented Grid Sampling design (Buckland et al. 2001) across the sample frame to provide an unbiased but systematic coverage of the entire sample frame (Figure 2).

For each circuit, we used a survey crew that included 3 observers, with one navigating the transect centerline and searching it and the area close to the centerline for burrows. This person used a Trimble GeoXT Field computer/Global Positioning System with Terrasync and post processed data in Pathfinder Office to maintain proper positioning of the crew along the circuit. The other two observers searched for burrows on either side of the centerline. The primary responsibility of the person on the centerline was to detect all burrows on or close to the centerline; the second and third observers thoroughly surveyed the area on each side of the centerline. This process was used to determine the location of each burrow (GPS unit described above) and to record the status of each as to occupancy by a tortoise, burrow width, and burrow length (see above). When impenetrable vegetation was encountered on a transect, a point was taken and marked as being unsuitable habitat. The surveyors then crawled through the dense vegetation, staying as close to the line as possible, until emerging in vegetation that was suitable for surveying, at which point the transect was resumed.

Actual transect locations and measurements of total transect length were generated using Hawth's and X tools, respectively, in ArcGIS. The transects were created as lines traveled by the observer on the center line; these were then smoothed into straight lines in the GIS editor by taking the beginning and ending vertex and removing all intermediate observations to represent the transect surveyed. Perpendicular distances from the transect centerline to each burrow opening were determined using the NEAR function in ArcGIS. Field data, including transects and burrow observations, were uploaded into Program Distance (Version 6.0, Release 2) for analysis. Program Distance was used to derive a population and density estimate that included estimates of the coefficient of variation and 95% confidence intervals for each estimate.

In the analysis, we used burrows as a surrogate for tortoise observations. Occupied and unoccupied tortoise burrows were indistinguishable based on external appearance, hence the need to examine each burrow with a camera. Scoping burrows allowed us to use an objective criterion for determining whether a burrow was occupied and/or usable by a tortoise. Usable burrows were those that were not collapsed, and therefore suitable for tortoise occupation. Burrows were excluded from analysis if they were collapsed less than a meter from the mouth of the burrow. The usable burrows were employed to build a detection function for the population estimate. By using burrows (rather than tortoises) to derive a detection function we lowered the variance and had more confidence in the model fit. We used the occupied burrows only for calculating the encounter rate. Additionally, we used the cluster size estimation technique in Program Distance to calculate the number of occupied burrows and the tortoise density and population estimate based on the number of tortoises observed in burrows (Buckland et al. 2004). The cluster size of occupied burrows was equal to 1, whereas for unoccupied burrows the cluster size was 0. Proportion of occupied burrows was calculated using cluster size estimation with mean of observed clusters. The greatest 5% of observations were removed from the analysis to aid in model fitting. We ran multiple models in Program Distance to derive estimates of abundance and density, each with key function and series adjustment terms (Buckland et al., 2001); we used Akaike's Information Criterion (AIC) to select the best model for inference (Burnham and Anderson 2002).

RESULTS AND DISCUSSION

State of Alabama

We estimate that tortoise soils cover 1.87 million ha (4.62 million acres) of Alabama, 1.61 million ha (3.99 million acres) of which are priority or suitable (Table 1). Assuming that tortoise density of the ancestral landscape is comparable to that of Green Grove and the Wade Tract (1.14 tortoises/ha = 0.46 tortoises/acre), Alabama likely had 2.12 million tortoises, if marginal soils are included, or 1.83 million tortoises, if marginal soils are excluded. Tortoises can be found on marginal soils, but at very low densities (e.g. Jones and Dorr 2004) and we suspect they invade these soils because habitat management in surrounding priority and suitable soils drives tortoises to marginal soils when canopy closure and growth of a brushy understory invades forested lands due to lack of fire. Therefore, we prefer the estimates based on priority and suitable soils only. In either case, roughly 2 million tortoises likely inhabited Alabama before invasion by settlers of European descent.

Alabama's modern landscape has been altered extensively from the ancestral landscape. To estimate the current extent of Gopher Tortoise habitat, we used Hoctor and Beyeler (2010), who used remote imaging and GIS layers to infer the primary habitat (open pine forests on tortoise soils), secondary habitat (all other habitats on tortoise soils), and foraging habitat (any habitat, regardless of soil type, that is within 300 m of primary or secondary habitat) available for tortoises. Based on Hoctor and Beyeler (2010), Alabama currently contains between 250,000 ha (617,763 acres; based on estimate of potential primary habitat) and 1,000,000 ha (2,471,054 acres; based on estimate of potential primary, secondary, and foraging habitat) of tortoise habitat available. We assume that the proportions of tortoise soils associated with these lands are the same as those derived from Table 1 [priority (0.28), suitable (0.58), and marginal (0.14); values derived from column totals]. Assuming that the densities of tortoises on current properties mimic those published by Jones and Dorr (2004) for managed forests (0.17 tortoises/ ha = 0.07 tortoises/acre for priority; 0.12 tortoises/ha = 0.05 tortoises/acre for suitable, and 0.10 tortoises/ha = 0.04 tortoises/acre for marginal soils), the current landscape has as few as 33,482 to as many as 133,929 tortoises.

Compared with the estimates for the ancestral landscape, our estimates of the total number of tortoises that are likely to be present in the state represent a reduction of from 93 to 98%. These values are quite high and we hope will trigger comprehensive planning to prevent further decline. The cause of the decline is the same as that for a variety of longleaf-specialist taxa that rely on extensive tracts of open pine forests with a carpet of grasses and forbs as the understory (Guyer and Bailey 1993). A loss of such areas through removal of fire and intensive harvesting activities has imperiled this fauna. Stand thinning and prescribed fire are two management tools that can re-create the desired structure of old-growth longleaf pine forests. But, use of these tools may take decades to achieve that goal. So, mulching and judicious use of herbicides can be useful in increasing the speed with which the goal is reached. The area required for such efforts has become clearer with recent publication of estimates of the size of tortoise populations (McCoy and Mushinsky; Styrsky et al. 2010). Current estimates indicate that there are 150-275 individuals in tortoise populations and these are distributed across areas that average about 730 ha (1800 acres) in size. However, these populations are also occupying habitats that are not being managed for tortoise populations and, therefore, the densities based on these data (0.20 - .37 tortoises/ha = 0.08 - 0.15 tortoises/acre) are far below the densities achieved on areas managed to maintain the structure of old-growth longleaf pine (1.14 tortoises/ha = 0.46 tortoises/acre). Therefore, initial planning for conservation areas should seek areas on the order of 400-800 ha (1000-2000 acres), but the final reserve areas needed to maintain a population of tortoises may be on the order of 120-240 ha (300-600 acres) if the habitat is managed exceptionally well.

Table 1. Area (acres) of tortoise soils in 20 Alabama counties within the geographic range of *Gopherus polyphemus*. Data for Bullock, Butler, Choctaw, and Russell Counties adjusted for acreage outside the range of *Gopherus*.

COUNTY	PRIORITY	SUITABLE	MARGINAL	TOTAL
Baldwin	174090	167041	67604	408735
Barbour	23253	131164	27779	182196
Bullock	39334	168	30705	70207
Butler	28228	87529	31276	147033
Clarke	65169	202654	30595	298418
Choctaw	6914	127102	28890	162906
Coffee	46716	149359	33121	229196
Conecuh	100984	147422	28920	277326
Covington	81707	221722	66701	370130

Crenshaw	22581	116771	18585	157937
Dale	106201	82161	9842	198204
Escambia	65509	239166	72730	377405
Geneva	39485	164120	22548	226153
Henry	79447	129247	0	208694
Houston	28582	170305	25092	223979
Mobile	185696	181792	41270	408758
Monroe	4221	119194	38178	161593
Pike	66089	57438	0	123527
Russell	39819	17398	10690	67907
Washington	89083	184530	44543	129204
TOTAL	1293108	2696283	629069	4618460

Geneva State Forest

Based on soil layers for the GSF, we estimate that 2,506 ha (6,193 acres) have soils that are habitable by Gopher Tortoises (Figure 3). Assuming 1.14 tortoises/ha (see above) in the ancestral

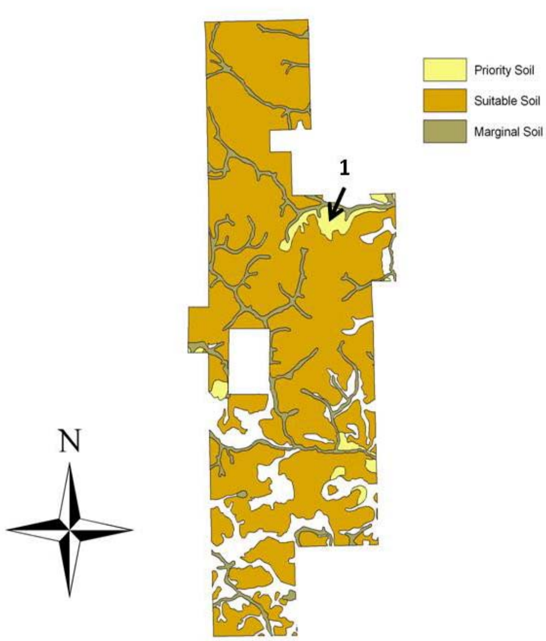

Figure 3. Map of priority, suitable, and marginal soils on the Geneva State Forest. Number is proposed site for Gopher Tortoise conservation.

landscape, GSF has the potential to contain 2,844 tortoises.

We discovered 519 burrows on 695 ha (1,719 acres) of censused habitat. Of these, 194 were active, 115 were inactive, 155 were abandoned, and 55 were invaded by an armadillo. Of the 111 burrows that were examined completely with the video camera, 21 were occupied by Gopher Tortoises, an occupancy rate of 0.14. This allows projection of 73 tortoises on the lands that we censused, which converts to a density of 0.10 tortoises/ha (0.04 tortoises/acre).

The area that we were unable to census had been fire suppressed for so long that we expect few tortoises occupy it. Nevertheless, if our estimate of density is projected across the entire GSF area, then as many as 248 tortoises may occupy the entire property. Thus, the GSF population of Gopher Tortoises represents a 91-97% reduction over the population expected of old-growth forest.

The distribution of burrow sizes on GSF was bimodal, with a dominant mode of 300-349 mm and a minor mode of 50-99 mm (Figure 4). This pattern indicates a population dominated by large adults, but with substantial reproduction.

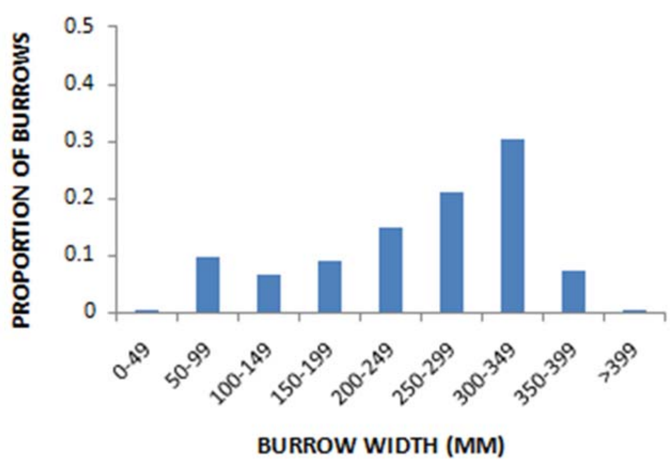

Figure 4. Distribution of burrow widths of Gopher Tortoises on the Geneva State Forest.

The GSF holds great promise as a site for conservation of Gopher Tortoises in Alabama. However, the current forest structure is not acceptable for long-term maintenance of this species on this property. In fact, we estimate densities of 0.10 tortoises/ha (0.04 tortoises/acre) on priority and suitable soils, a value below the density at which population viability may be lost due to reproductive failure (0.12-0.40 tortoises/ha = 0.05-0.16 tortoises/acre; Guyer et al. in review). Therefore, although tortoises are present on the site, no population is likely to be viable, despite evidence of reproduction.

The area south of Flat Creek and east of the Harrison Road bridge over Flat Creek is the best location on GSF to establish a viable population of Gopher Tortoises because it has the most extensive region of priority soils (about 50 ha = 120 acres) and is contiguous with a ridge of suitable soils to the south of this site, indicating that 120-240 ha (300-600 acres) of high-quality habitat might be created there. The area currently is heavily forested and would require thinning and mulching to prepare it as habitat for Gopher Tortoises. Aggressive fires (every other year) would then be required to maintain an open aspect suitable for Gopher Tortoises. We recommend that the current population of Gopher Tortoises be consolidated onto this reserve. This will rearrange the current animals from an arrangement that likely is unviable into an arrangement that might become viable. The estimated number of tortoises currently on the property (73-248) is close to the lower value of abundance expected for a population of tortoises (Styrsky et al. 2010). So, consolidation of these individual on to a reserve where they might interact more broadly with each other should improve reproduction above current levels.

Perdido River Longleaf-Hills Tract

Based on soil layers for the PRT, we estimate that 3,660 ha (9,042 acres) have soils that are habitable by Gopher Tortoises (Figure 5). Assuming 1.14 tortoises/ha (see above) in the ancestral landscape, PRT has the potential to contain 4,159 tortoises.

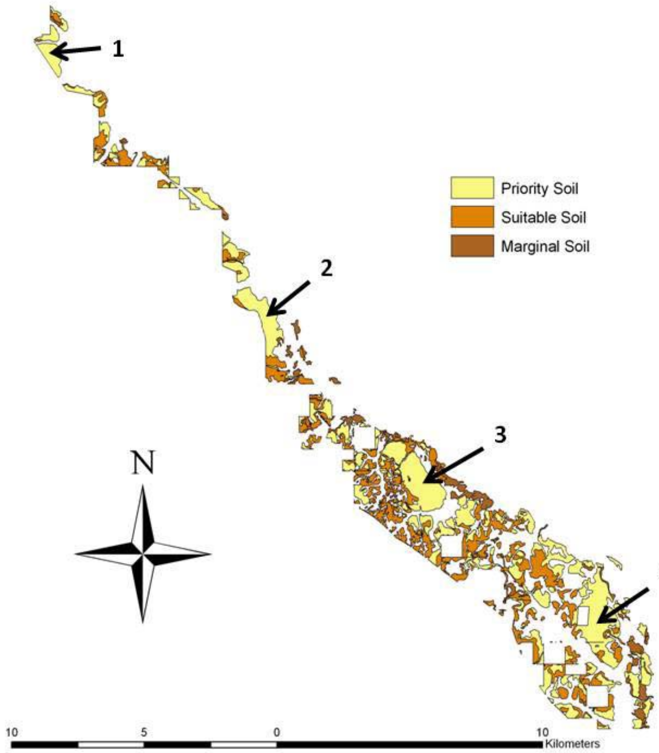

Figure 5. Map of priority, suitable, and marginal soils on the Perdido River Longleaf-Hills Tract. The numbered sites are proposed areas for conservation of Gopher Tortoises.

We discovered 512 burrows on 498 ha (1,233 acres) of censused habitat. Of these, 178 were active, 171 were inactive, 101 were abandoned, and 62 were invaded by an armadillo. Of the 497 burrows that were examined completely with the video camera, 135 were occupied by Gopher Tortoises, an occupancy rate of 0.27. This allows projection of 139 tortoises on the lands that we censused, a value that converts to a density of 0.27 tortoises/ha (0.11 tortoises/acre).

The area that we were unable to penetrate represents a mosaic of areas with canopy closure and shrub invasion and areas suitable for tortoises. Tortoises undoubtedly inhabit these areas, but we expect the density to be less than that of the area that we were able to census. However, if we project our observed density across the entire landscape of tortoise soils, then as many as 1,019 tortoises may occur on the entire property. This represents a 75% or greater reduction over the population predicted for old-growth conditions.

The distribution of burrow sizes on PRT was unimodal, with a mode of 300-349 mm and a right skew (Figure 6). This pattern indicates a population dominated by large adults, but with persistent reproduction.

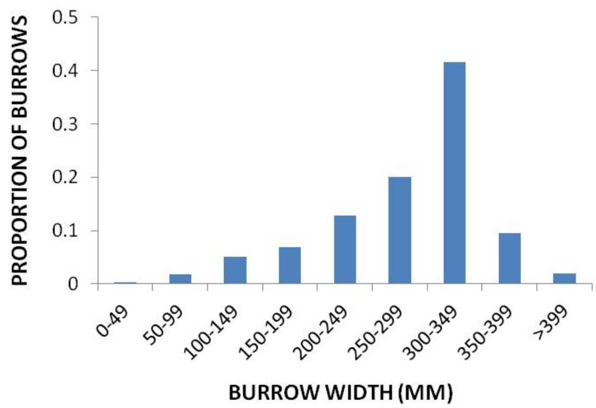

Figure 6. Distribution of burrow widths for Gopher Tortoise burrows on the Perdido River Longleaf-Hills Tract.

The PRT has considerable potential to serve as an important site for Gopher Tortoise conservation in Alabama. Relative to the other two sites that we surveyed, PRT is dominated by priority soils, the primary feature suggesting conservation potential. These soils are consolidated into extensive regions that could be converted into forest structure that should allow existing populations to increase in abundance. In particular, we note four such areas (Figure 5) that are distributed from the extreme northwestern portion of PRT to the extreme southeastern portion of the site. Each of these four areas of priority soil encompasses 57-311 ha (140 – 770 acres), sizes that appear to be large enough to support viable populations of Gopher Tortoises for the southern three sites; additional area will be required for the northern site to be large enough, when converted to high quality habitat, to maintain a population of tortoises.

The PRT currently retains Gopher Tortoises at a density that is within the range of values suggestive of reduced reproductive potential (Guyer et al. submitted). Thus, adult females may have limited diversity of available mates. Additionally, the overall habitat quality is far from that expected of the ancestral landscape. This suggests that remaining clusters of tortoises have reduced interconnectivity relative to the ancestral landscape. These factors indicate that careful management will be required to assure that the remaining tortoises increase in abundance.

Conecuh National Forest

We estimated that there are 24,056 ha (59,444 acres) of habitable tortoise soils on the CNF. Assuming a density of 1.14 tortoises/ha in the ancestral landscape, the CNF has the potential to support 27,344 tortoises.

We surveyed 442 transects totaling 84.592 km (52.6 miles) within the sample frame (Fig. 2). Based on a uniform cosine model, our transect data suggest that we detected 58% (51.7-64.0 CI) of actual usable burrows. The effective strip width (transect half width as determined by Program Distance) was 10.85 ± 0.58 (SE) m with a CV of 5.4 % and 95% CI of 9.74-12.0 m. These values assure that each circuit represents independent samples of burrows (Figure 7).

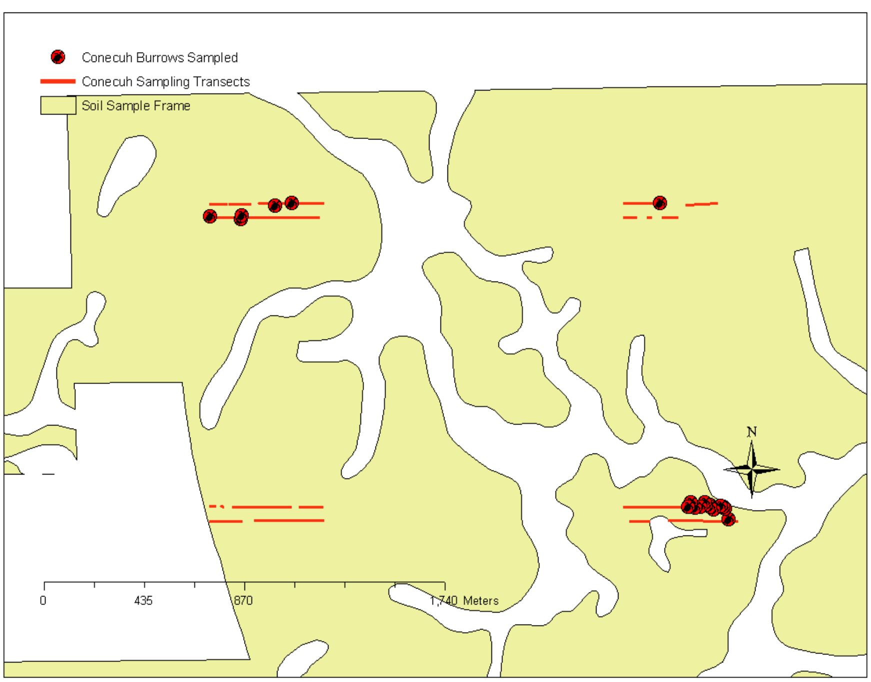

Figure 7. Map of four representative transect circuits. Shaded area is priority, suitable, and marginal soils. Red circles indicate location of Gopher Tortoise burrows.

We discovered 145 burrows on transects. Of these, 70 were active, 20 were inactive, 30 were abandoned, and 16 were invaded by an armadillo. Of the 140 burrows that were examined completely with the video camera, 44 were occupied by Gopher Tortoises, yielding an occupancy rate of 0.34 ± 0.04 (SE) when we accounted for detectability across the sample frame. Tortoise density was 0.721 ± 0.044 (SE) tortoise/ha (CV= 20.22%, 95% CI = 0.147-0.322). Because our transects represent an unbiased sample of the available tortoise habitat on CNF, our data represent a model for the entire property. Our data indicate that density is 63% of the density expected of old-growth forest (see above). Projected from these variables, we estimate the CNF to contain 5,242 ± 1,060 (SE) tortoises (95% CI = 3,538-7,768, Table 2).

Table 2. Model output and tortoise population estimates for Gopher Tortoises at Conecuh National Forest generated from Program Distance (ver. 6.0). Analyses were developed with data collected using line transect distance sampling for 122 usable burrows and 44 tortoise observations. *Model best fitted to data.

Model	AIC	Tortoise Density			Burrow Density			Tortoise Abundance	
		D	95% CI[1]	CV	*D*	95% CI	CV	*N*	95% CI
Uniform cos*	648.33	0.218	0.147-0.323	20.2	0.632	0.447-0.834	15.6	5242	3538-7768
Uniform simple poly	649.14	0.219	0.145-0.330	21.1	0.635	0.459-0.879	16.7	5266	3498-7929
Hazard-rate cos	649.67	0.193	0.128-0.292	20.9	0.561	0.404-0.779	16.8	4651	3081-7805
Half-normal cos	649.93	0.216	0.144-0.324	20.9	0.627	0.445-0.865	16.5	5201	3465-7805

[1]Confidence intervals for estimates based on distance sampling presumed a log-normal distribution; hence the probability limits are skewed (not symmetric about the point estimate) as compared to limits based on a more traditional assumption of normality (Buckland et al. 2001).

Burrows and tortoises were not uniformly distributed across the CNF (Figure 8 & 9). Most were found in the northeastern portion of the property. This area generally is within the Blue Springs Wildlife Management Area. Significant areas in the southwestern portion of the property, including areas that have been managed to create the open, park-like structure of old-growth forests, have few burrows and essentially are devoid of tortoises. Our estimate of density suggests that tortoises in these areas are sufficiently abundant eventually to allow populations to expand in these areas. However, this process is likely to require decades (Ashton et al. 2008) and continued aggressive management will be needed to maintain high habitat quality for tortoises.

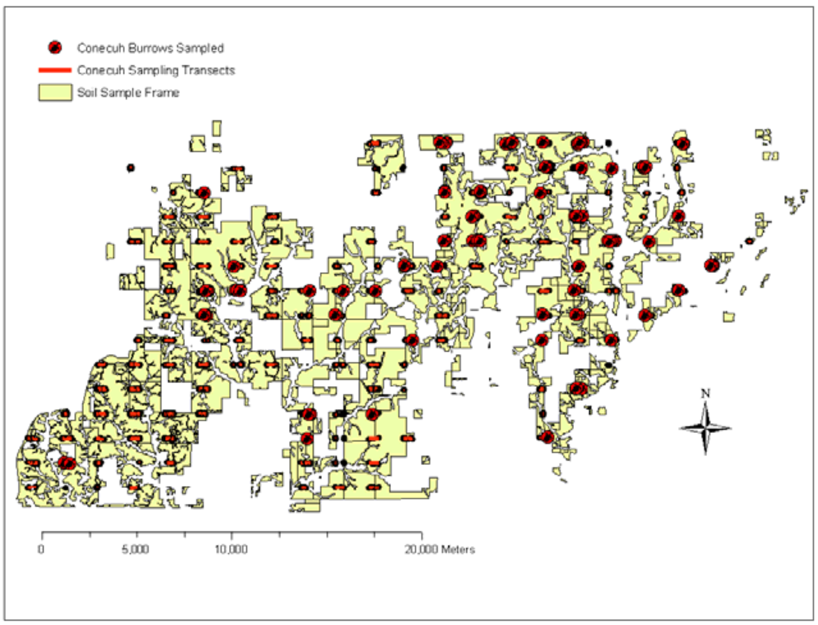

Figure 8. Distribution of *Gopherus polyphemus* burrows across the Conecuh National Forest.

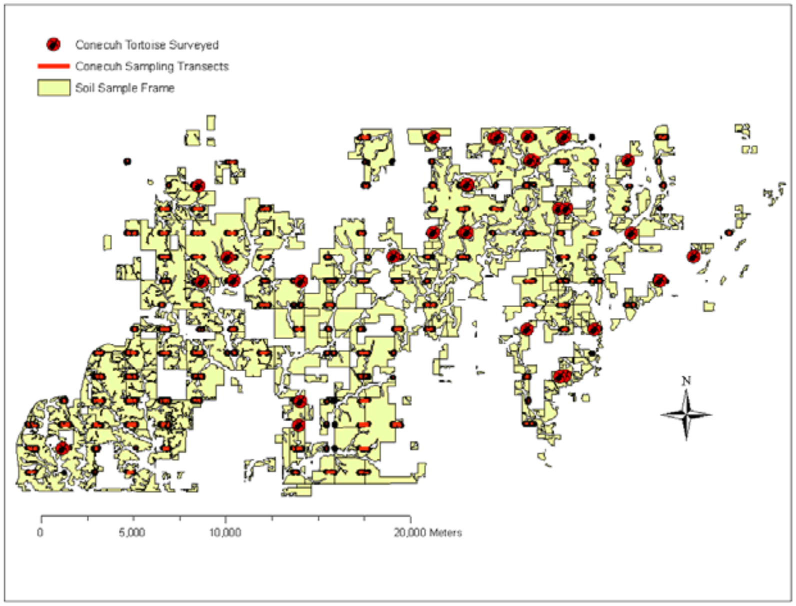

Figure 9. Distribution of *Gopherus polyphemus* across the Conecuh National Forest.

The distribution of burrow sizes on the CNF was unimodal, with a mode of 300-349 mm and a right skew (Figure 10). This pattern indicates a population dominated by large adults, but with persistent reproduction.

Densities are well above the values suggested to indicate loss of reproductive viability (Styrsky et al. 2010). So, current populations on the Conecuh appear to be viable. However, the current landscape likely contains 37% fewer tortoises than the ancestral landscape.

The CNF contains six areas used previously to test the effect of stand thinning and growing-season fire on Gopher Tortoises (Table 3). We recommend that these six sites be managed as independent tortoise populations. This includes three sites within the Blue Springs Wildlife Management Area and three sites in the western and southwestern portions of the CNF. The goal of management on these sites should be to increase density by stand thinning and implementation of biennial prescribed fire, preferably during the growing season.

SITE NUMBER	LAT	LONG
1	31.159194	-86.554467
2	31.104322	-86.525516
3	31.038421	-86.642695
4	31.039081	-86.669959
5	31.082349	-86.674236
6	31.115277	-86.506212

Management Recommendations

The state of Alabama is estimated to retain a relatively large number of Gopher Tortoises (30,000-130,000), but this is far less than the 2 million individuals that likely once inhabited the state. To assure retention of the species in the landscape, aggressive management will be required to maintain viable populations on public lands. Two of the three sites that we surveyed had densities of tortoises that were at or below the densities suggested by Guyer et al. (in review) to yield reduced reproductive opportunities for female tortoises. These data suggest that, as is the case in Florida (McCoy et al. 2006), public lands in Alabama are failing to retain tortoise populations even in places that currently possess the species. McCoy et al. (2006) noted that these lands have timber stands planted at densities that are too high and are burned at intervals that are too long to maintain the open savannah vegetation required by Gopher Tortoises and many other longleaf specialists. If viable populations of Gopher Tortoises are to be retained in Alabama in sufficient numbers to obviate a need for federal protection throughout its geographic range, then careful selection of conservation areas and aggressive management of those areas will be required.

We recommend that a minimum of 10 areas be identified on public lands in Alabama where management will be implemented to increase Gopher Tortoise densities to levels expected of old-growth forests (1.14 tortoises/ha). If these sites are to retain populations of tortoises, then they will need to be 400-800 ha (1000-2000 acres) in area while they are being established, but might eventually be reduced to core areas of 120-240 ha (300-600 acres). Such areas may be surrounded by lands used for timber production and single tree selection forestry is compatible with management on the core areas. Additionally, in our experience, hunting, especially for quail and turkey, are compatible with lands managed for dense populations of Gopher Tortoises.

Our surveys of three public properties identify 11 areas that might be focused on Gopher Tortoise conservation. On GSF, we suggest that only a single population might reasonably be managed. Although we estimate that there currently may be as many as 250 tortoises on the property, the extensive areas of dense overstory and midstory vegetation makes it more likely that tortoise abundance is closer to 75, our more-restricted estimate. Assuming this is the case, management of tortoises on GSF should consider moving the current individuals to a reserve area and possibly supplementing these from waif tortoises from Geneva County until a base population of 150-275 individuals is reached.

On PRT, four extensive areas of priority soils were selected that span the length of the protected lands. Tortoise populations on this property probably are closer to our high value (1000) than our low value (140) because the area is such a complex mosaic of forest structure. Therefore, we infer that, with appropriate management, tortoise populations will increase rapidly enough that relocation of animals within the property will not be warranted. However, efforts should be made to avoid clear-cutting of pine timber. Instead, retention of seed trees to allow natural regeneration and to provide fine fuels to carry frequent fire will be crucial to reversing what appears to be a slow decline of tortoise abundance on PRT.

The CNF retains tortoises at densities that are most likely to yield viable populations. It also contains extensive areas that have benefitted from stand thinning and frequent application of prescribed fire. This site may contain the only growing populations of Gopher Tortoises in Alabama. However, some areas of high-quality habitat contain no tortoises. Because these areas are outside management areas, and therefore receive lesser protection from conservation officers, they may suffer from continued predation by humans. Alternatively, these areas may be so far from source populations that repatriation efforts would be warranted. We selected six sites on the CNF that are known to have enough individuals to create growing, source populations. All will require more frequent fire (every two years) and careful thinning practices to maintain input of pine needles to generate fine fuels to carry such fires.

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Appendix 1. List of soils known to be used by *Gopherus polyphemus*.

PRIORITY	SUITABLE	MARGINAL
ALAGA	BAMA	ALAPAHA
ALPIN	BENNDALE	BASIN
BIGBEE	BONNEAU	BIBB
BLANTON	CUTHBERT	BOSWELL
EUSTIS	FACEVILLE	FALKNER
LAKELAND	FUQUAY	FREEST
LAKEWOOD	FLORALA	GRADY
TROUP	HARLESTON	LEEFIELD
WADLEY	HEIDEL	LYNCHBURG
	IZAGORA	MASHULAVILLE
	LUCY	MYATT
	LUCEDALE	OCILLA
	MCLAURIN	OSIER
	NORFOLK	QUITMAN
	ORANGEBURG	SAUCIER
	POARCH	SUSQUEHANNA
	PRENTISS	
	RUSTIN	
	SHUBATA	

	SMITHDALE	
	SUFFOLK	
	SUNSWEET	
	WAGRAM	