Gopher Tortoise Survey, Population Evaluation, and Habitat Suitability

Final Report to Georgia Department of Natural Resources

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Introduction

Line transect distance sampling (LTDS; Buckland et al. 2001, Buckland et al. 2004) was used to derive baseline gopher tortoise population estimates (density and abundance) at 20 sites identified in the 2007 Request for Proposals (Table 1) and to identify potential habitat and population management options for the sites. Survey data from a sub-set of these sites were used to compare estimates derived using LTDS to estimates obtained using area-constrained (belt transect) methods as proposed in Florida's Gopher Tortoise Management Plan (FFWCC 2007).

Methods

LTDS Gopher Tortoise Population Surveys: Pilot surveys were conducted to determine the tortoise encounter rate and to refine the extent of the survey area before conducting full surveys. We attempted to sample the breadth of available upland habitats on each site and to observe 5-15 tortoises. During pilot surveys, three observers (one person on center line, and one on either side of center line) walked transects searching for tortoise burrows. All burrows observed were scoped with a burrow camera (Sandpiper Technologies, LTD) to determine whether a tortoise was present. We then calculated the tortoise encounter rate (number of tortoises observed per meter of transect surveyed) for each site.

The encounter rate as described above was used to determine the total length of transect required to obtain approximately 60 - 80 observations of tortoises in the full survey. This sample size was the approximate minimum needed to obtain abundance and density estimates with a reasonable degree of precision (CV < 20%; Table 2). Transects were systematically distributed across suitable habitat based on a GIS shapefile (provided by Georgia DNR) using DISTANCE 5.0 software (http://www.ruwpa.st-and.ac.uk/distance/). Transects and 1999 DOQQs were uploaded to a Nomad PDA

(Trimble Navigation, Ltd.), which was equipped with a GPS antenna (Crescent A100 Hemisphere GPS) with sub-meter accuracy.

We used a field crew of three individuals for the full surveys. In the field, the survey team opened an ArcPad (ESRI, version 7.1) project and navigated to the start of each transect with the Nomad PDA/GPS, which was then used by the team leader to follow the transect center line. A GPS location was taken at the beginning and end of each transect surveyed. The team leader searched the transect center line and the area around it for burrows. The two additional observers searched for burrows on either side of the center line up to approximately 20 m from the center line. When a burrow or tortoise was observed, a GPS point was collected and attributes (see below) were recorded. ArcGIS software (ESRI, Near command) was later used to determine the perpendicular distance from the transect centerline to the burrow opening or tortoise.

At each burrow, we used a burrow camera to determine if a tortoise was present. All burrows searched with the camera were categorized as either: 1) tortoise observed, 2) no tortoise observed for entire length of burrow, or 3) unable to determine if occupied (i.e., undetermined). "Undetermined" burrows were those that could not be searched completely because of an obstruction, sharp curve, recent wash in, or those burrows that were too small to scope with the burrow camera (generally < 10-12 cm in width). If we were unable to scope a burrow because it had completely caved in, we recorded the burrow as unoccupied (Tortoise= 0). Burrow width was measured 50 cm inside the opening using burrow calipers (± 1 cm). All burrows were assigned one of three activity categories following methods of Auffenberg and Franz (1982): active, inactive, or old. In addition, observations of amphibians and reptiles encountered during surveys were recorded. All data were entered directly into the Nomad PDA in the field.

Population Evaluation and Habitat Suitability. We calculated tortoise density (tortoises/ha) and abundance (the number of tortoises based on density and the amount of suitable habitat) for survey sites using Distance 5.0 software. We created size class distribution graphs for each site using width measurements for occupied burrows. Burrow width is closely correlated with carapace length (CL) in gopher tortoises, which is related to age (Alford 1980). Tortoises in Georgia reach sexual maturity at 23 cm CL

(Landers et al. 1982). Therefore, burrows > 23 cm in width are likely inhabited by adult tortoises, whereas those < 23 cm are occupied by juveniles and subadults.

To characterize the habitat, we took digital photographs in four cardinal directions at points along survey transects. At each of these points we recorded the approximate height of hardwood midstory (< 2 m, 2 - 4 m and > 4 m), presence or absence of wiregrass; and basal area (measured with a 10 Basal Area Factor (BAF) prism; Forestry Suppliers, Inc.). Sites were then ranked based on the tortoise population size/density and general habitat quality. We ranked each of the 20 sites as follows:

1) **High quality**: Likely a viable population in suitable habitat. Site requires continued management, but no population manipulation/augmentation is necessary.
2) **Medium quality- viable:** Likely a viable population, but habitat needs management/restoration of natural vegetation. No population manipulation necessary.
3) **Medium quality- not viable**: Population likely not viable at current size and demographic conditions, but habitat is suitable without need for extensive restoration. Augmentation with translocated tortoises should be considered.
4) **Low quality**: Population likely not viable at current size or demographic conditions and habitat is in need of extensive restoration to support more tortoises. Site should be considered for future augmentation with translocated tortoises.
5) **Low quality- unsuitable:** Tortoises present on site in low numbers, but site is generally unsuitable for tortoise population (e.g., poorly drained soils).

Comparison of LTDS and Florida Survey Methodology. Data from ten of the 20 sites was used to compare results obtained with LTDS method to those obtained with the area-constrained (belt transect) methodology proposed in Florida's Gopher Tortoise Management Plan (FFWCC 2007). For the belt transect method, we used data collected with LTDS, but limited the analysis to burrows within 8 m on either side of the center

line (i.e., 16 m wide belt transects as recommended in the Florida Gopher Tortoise Management Guidelines). We then applied a 50% occupancy rate to the total number of "active" and "inactive" burrows to calculate tortoise abundance and density as required under the Florida Survey Methodology. Nine of the ten sites included in this portion of the study were surveyed during the tortoise activity season (e.g., March-October).

Results

Pilot survey results are presented in Table 2; full survey results are presented in Table 3. Tortoise densities ranged from 0.206 ± 0.035 SE at Ohoopee Dunes NA to 1.646 ± 0.366 SE tortoises/ha at General Coffee SP. Population size estimates ranged from 48 ± 9 SE tortoises at Little Ocmulgee SP to 321 ± 43 SE at Barrington Property. At seven of the 20 sites (Broxton Rocks Preserve, Flat Tub WMA, Little Satilla WMA, Moody Forest NA, Penholloway WMA, Silver Lake WMA, and Yuchi WMA) we were unable to detect a sufficient number of tortoises to generate accurate population estimates. For example, at Yuchi WMA, we did not observe any tortoises on 12.7 km of transect during the pilot surveys. If we had seen at least one tortoise on this length of transect, a conventional distance sampling survey would have required more than 1,300 km of transect to obtain a CV of < 20% (Table 2). Upon discussion with Ga DNR staff, we agreed to survey approximately 5% of the suitable habitat on these sites. Observations of burrows and tortoises at these sites are presented in Table 4.

Burrow size class distributions for the survey sites are presented in Figures 1a-n. Juvenile burrows (< 23 cm in width) were observed at 11 sites, whereas at three sites (Fall Line Sandhills NA, Little Ocmulgee SP, Townsend WMA), no juvenile burrows were observed. Juvenile tortoise burrows are difficult to locate because of their small size and their numbers are often underrepresented in surveys. However, their absence from three survey sites may be cause for concern. The population at Townsend WMA, in particular, is truncated toward adult tortoises and has a very small population (n = 99). The long term viability of this population may be low.

Habitat suitability rankings are presented in Table 5. We ranked six sites as high quality, with likely viable tortoise populations; however, for several of these sites, e.g., Doerun NA, General Coffee SP, RG Daniels, and Seminole SP, the amount of suitable

habitat was limited and highly fragmented. Many of the properties surveyed, such as Ohoopee Dunes NA, Townsend WMA, and Flat Tub WMA were bisected by riparian topographic features or non-contiguous landownership patterns which resulted in a patchy distribution of tortoises. River Creek WMA, which was ranked as a medium quality- viable population, had an interesting distribution of burrows. Most burrows were located along the edges of the property, along a topographic incline adjacent to the Ochlocknee River and other smaller drainages. With prescribed fire and thinning of pines on the site, tortoises should gradually move into additional areas with suitable habitat.

A summary of habitat data collected at photo points along survey transects is presented in Table 6. Most sites reflect the past management of industrial forest management with a high prevalence of off-site pine species. Wiregrass (*Aristida stricta*) was observed at 18 of the 20 sites, and at the highest quality sites, e.g., Doerun NA, RG Daniels, Seminole SP, and Ohoopee Dunes NA, wiregrass was observed at > 50% of all habitat points. Other sites, e.g., Silver Lake WMA had abundant wiregrass, but low tortoise densities. Many of the sites had highly disturbed ground cover, e.g., Fall Line Sandhills NA (outside the geographic range of wiregrass) and Townsend WMA, which would benefit from more frequent prescribed fire.

Incidental sightings of amphibians and reptiles are included in Table 7. The eastern diamond-backed rattlesnake (*Crotalus adamanteus*) was the most frequently encountered species (five sites). Toads (*Bufo* sp.) were observed in gopher tortoise burrows at six sites.

The field surveys required a crew of three workers approximately 51 days (153 person-days). Transects were surveyed at a rate of 890 m/hr for a total of 408.2 km surveyed across 12,267 ha of suitable habitat. A burrow camera was used to scope 1,876 burrows with 764 tortoises observed (Table 8). On average, we were able to confirm whether a burrow was occupied or unoccupied 90% of the time. However, we encountered significant problems scoping burrows at Fall Line Sandhills NA because surveys were conducted in early spring following a heavy rain event. Loose soil had washed into many of the burrows and we were unable to determine whether 64 of the 156

burrows scoped (41 %) were occupied. Therefore, population size and density for this site were very likely underestimated.

Comparison of Line Transect Distance Sampling and Florida Survey Methodology. Population parameters produced using FFWCC's survey methodology versus line transect distance sampling methodology are presented in Tables 9 and 10. Population estimates derived from both methods were similar for five sites, including Barrington Property, General Coffee SP, River Creek WMA, RG Daniels, and Townsend WMA. For the remaining five sites, estimates obtained using the arbitrary 50% occupancy rate overestimated density and abundance by as much as 49% when compared to estimates derived using actual tortoise observations: 10% for George L. Smith SP, 43% for Ohoopee Dunes NA, 46% for Seminole SP, 49% for Fall Line Sandhills NA, and 49% for Little Ocmulgee SP (Table 9, Table 10). Actual occupancy rates obtained using the burrow camera ranged from 30 to 52 % (Table 9).

Conclusions and Recommendations

We were able to derive tortoise population estimates for 13 sites using LTDS methodology. For the remaining seven sites we provided a tortoise encounter rate and an assessment of the effort necessary to produce a population estimate using conventional LTDS. We also assessed the status of the tortoise populations and the general suitability of the habitat for the 20 sites. We ranked six of the sites as "High Quality", while the remainder of the sites need increased fire frequency and a reduction in midstory hardwoods and pines to improve habitat conditions for gopher tortoises. Since a large proportion of the sites were once industrial pine plantations or have a history of fire suppression, aggressive annual fire régimes and mechanical removal of hardwood midstory and thinning of pines should be considered to open the canopy and improve ground cover conditions at these sites.

Moody Forest NA, Silver Lake WMA, Townsend WMA and Yuchi WMA are possible candidate sites for augmentation with translocated tortoises. Each of these properties has specific management challenges that need to be addressed before possible population augmentation. Much of Yuchi WMA has been clear cut and replanted in longleaf pine. Frequent prescribed fire will maintain an open canopy needed for gopher

tortoises, and will prevent encroachment of hardwoods. The few remaining tortoises on this property are concentrated at road edges; it is unlikely that this population will persist without augmentation. At Silver Lake WMA, an aggressive prescribed fire management plan with a 9-18 month fire return interval for four years and thinning of remaining pine plantations could quickly prepare the site for augmentation. Townsend WMA would require aggressive thinning of pine plantations and 3-4 prescribed fires in advance of augmenting the tortoise population. While Moody Forest NA has been aggressively managed with prescribed fire, the density of timber resources carried across the property is too high (93 ft^2, range 10-185 ft^2) to support large numbers of tortoises. Reducing pine basal area to a minimum target of 50-70 ft^2 and removing some of the hardwood mid-story should be a precondition if this property is to be considered for augmentation with translocated tortoises.

We do not recommend augmentation of tortoise populations at Little Satilla WMA, Flat Tub WMA and Penholloway WMA because the soils on these sites are generally poorly drained or otherwise unsuitable for gopher tortoises, and they likely never supported high densities of tortoises. If augmentation is ever considered on these sites, it will be necessary to identify areas of suitable soils, pines would need to thinned, and tortoise stocking densities should be relatively low.

Population density and abundance estimates derived using the methods in Florida's Gopher Tortoise Management Plan (FFWCC 2007) differed from those derived with LTDS by as much as 49%. The LTDS estimates were based on tortoise observations rather than a subjective assessment of burrow occupancy; the Florida Survey Methodology requires use of a 50% occupancy rate, whereas actual burrow occupancy ranged from 30-52% in this study. In addition, the Florida Methodology requires sampling 15% of the suitable habitat, regardless of the size of the site, which may also bias population estimates. On average, we had to survey 39 % (range 24% - 81%) of the suitable habitat using LTDS to derive precise tortoise population estimates. Therefore, the value of population estimates derived with the Florida Survey Methodology is questionable, at best. Most importantly, estimates derived with these methods cannot reliably be used to monitor changes in tortoise population size or density over time. Although, in some cases LTDS might require more field effort than the

Florida Survey Methodology, the advantage is that LTDS provides estimates of detectability, precision (CV) and confidence intervals around all estimates. These three variables can also be determined with area-constrained surveys (i.e., belt transects), such as those required in the Florida methodology, if a double-observer method is used (Nomani et al. 2008); however, it is critical that the survey rely on actual tortoise observations rather than a standard occupancy rate.

This evaluation of tortoise populations and general habitat conditions at the 20 survey sites can provide a baseline for assessing the status of tortoise populations over time. We recommend resurveying the sites, using the same transects, after 5-10 years to assess changes in tortoise populations relative to management and restoration activities. Most of the sites will require an assessment of current prescribed fire management and timber harvest, where possible.

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Table 1. Gopher tortoise survey sites in Georgia, including approximate acreage of suitable upland habitat and predicted abundance, as provided by Georgia Department of Natural Resources.

Site	County	Estimated upland habitat (ac)	Estimated upland habitat (ha)	Predicted Tortoise abundance
Barrington Property	McIntosh	1500	607.0	moderate-high
Broxton Rocks Preserve (TNC)	Coffee	400	161.9	moderate
Doerun NA	Colquitt	375	151.8	moderate-high
Fall Line Sandhills NA	Taylor	800	323.7	moderate-high
Flat Tub WMA	Coffee	1900	768.9	low
General Coffee SP	Coffee	500	202.3	moderate-high
George L. Smith SP	Emanuel	730	295.4	high
Little Ocmulgee SP	Wheeler	215	87.0	moderate
Little Satilla WMA	Wayne	3000	1214.1	moderate
Moody Forest NA	Appling	1800	728.4	low
Ohoopee Dunes NA	Emanuel	1900	768.9	moderate-high
Okefenokee NWR - Trail Ridge	Charlton	1800	728.4	low-moderate
Penholloway WMA	Wayne	2500	1011.7	low
RG Daniels Preserve (TNC)	Candler	150	60.7	moderate-high
River Creek WMA	Thomas	1300	526.1	moderate
Seminole SP	Seminole	380	153.8	moderate-high
Silver Lake WMA	Decatur	7445	3013.0	unknown
Townsend WMA	Long	1750	708.2	moderate-high
Williams Bluffs Preserve (TNC)	Early	980	396.6	moderate
Yuchi WMA	Burke	4600	1861.6	low
Total		**27,030**	**13,769.5**	

Table 2. Pilot survey summary data. n_o was the number of tortoises observed during pilot surveys; L_o was the total length of transect surveyed during pilot surveys (in meters); the dispersion factor (*b*) was 3. The full survey effort (total transect length; L) was determined based on a CV of 17% (in bold).

Site	n_o	L_o	L_o/n_o	Suitable habitat (ha)	L for 15%	**L for 17%**	L for 20%	Transect surveyed
Barrington Property	9	2,000	222.2	447	29,630	**23,068**	16,667	24,908
Broxton Rocks Preserve*****	8	6,820	852.5	252	113,667	**88,495**	63,938	6,823
Doerun NA	18	5,000	277.8	144	37,037	**28,835**	20,833	28,272
Fall Line Sandhills NA	8	5,000	625.0	350.7	83,333	**64,879**	46,875	43,985
Flat Tub WMA*	6	9,803	1,633.8	776	217,844	**†169,602**	122,538	9,803
General Coffee SP (West)	4	300	75.0	55.5	10,000	**7,785**	5,625	8,486
George L. Smith SP	11	1,300	118.2	262	15,758	**12,268**	8,864	17,538
Little Ocmulgee SP	14	1,620	115.7	86.4	15,429	**12,012**	8,679	14,533
Little Satilla WMA*	9	3,370	374.4	1,046	49,926	**38,870**	28,083	6,556
Moody Forest NA*	4	14,200	3,550	1,076	473,333	**†368,512**	266,250	14,200
Ohoopee Dunes NA	7	4,900	700.0	679	93,333	**72,664**	52,500	41,970
Okefenokee NWR	12	5,556	463.0	271	61,733	**48,062**	34,725	25,328
Penholloway WMA*****	6	13,403	2,223.8	896	297,844	**†231,886**	167,538	13,403
RG Daniels Preserve	8	1,747	218.4	52.5	29,117	**22,669**	16,378	11,581
River Creek WMA**	10	7,100	710.0	438	94,667	**73,702**	53,250	46,050
Seminole SP	7	1,600	228.6	163	30,476	**23,727**	17,143	18,082
Silver Lake WMA*	14	4,996	356.9	3,013	47,581	**37,044**	26,764	35,241
Townsend WMA	4	1,500	375.0	166	50,000	**38,927**	28,125	10,973
Williams Bluffs Preserve	20	4,400	220.0	199	29333	**22,837**	16,500	17,766
Yuchi WMA*, **	0	12,700	12,700.0	1,894	1,693,333	**†1,318,339**	952,500	12,700

*Surveyed ≤ 5% of the site due to overall low tortoise densities

** surveys were developed based on double the number of actual observations; for Yuchi WMA an observation 1 tortoise was used to derive full survey effort

† Projected transect length.

Table 3. Gopher tortoise population density and abundance estimates derived using line transect distance sampling (LTDS) for 20 sites in Georgia. # Obs = total number of tortoises observed; Area (ha) = estimate amount of suitable habitat; ESW = effective strip width (m); *D* = density (tortoises/ha); *N*= abundance (tortoises x size (ha); *CV* = coefficient of variation; *P*= probability of observing a tortoise in defined area; *PCV* = CV for the probability of observing a tortoise within the defined area.

Site	#obs	Area	ESW	***D***	95% CL	***N***	95% CL	*CV*	*P*	*PCV*	model
Barrington Property	79	447	22.1	**0.718**	0.546– 0.943	**321**	244-422	13.6	1	0	un_simp5%
Broxton Rocks Preserve*											
Doerun NA	43	144	10.0	**0.758**	0.423 – 1.359	**109**	61-196	29.1	0.54	0.07	un_cos5%
Fall Line Sandhills NA	47	351	20.6	**0.259**	0.186 – 0.361	**91**	65-127	16.2	1	0	un_cos5%
Flat Tub WMA*											
General Coffee SP (West)	57	56	20.4	**1.646**	1.015 – 2.670	**91**	56-148	22.2	1	0	un_cos5%
George L. Smith SP	38	144	22.3	**0.486**	0.327 – 0.723	**127**	86-189	19.6	1	0	un_cos5%
Little Ocmulgee SP	36	86	22.1	**0.560**	0.383 – 0.821	**48**	33-71	18.6	1	0	un_cos5%
Little Satilla WMA*											
Moody Forest NA*											
Ohoopee Dunes NA	37	679	21.1	**0.206**	0.147 – 0.289	**140**	100-196	16.9	1	0	un_cos5%
Okefenokee NWR	26	271	14.8	**0.346**	0.233 – 0.514	**94**	63-139	19.9	0.76	0.12	un_simp5%
Penholloway WMA*											
River Creek WMA	107	438	16.2	**0.715**	0.483 – 1.060	**313**	211-464	19.9	0.84	0.1	hn_simp5%
RG Daniels TNC	44	53	18.4	**1.032**	0.735 – 1.449	**54**	39-76	16.8	1	0	un_simp5%
Seminole SP	55	163	15.6	**0.975**	0.750 – 1.267	**159**	122-206	12.7	1	0	un_cos5%
Silver Lake WMA*											
Townsend WMA	24	166	18.4	**0.594**	0.368 – 0.960	**99**	61-159	22.3	1	0	un_cos5%
Williams Bluff TNC	75	199	14.4	**1.471**	0.959 – 2.255	**293**	191-449	21.1	0.6	0.08	un_cos5%
Yuchi WMA*											

*= ≤ 5% survey.

Table 4. Survey results for the seven low density gopher tortoise survey sites where we attempted to cover 5% of the suitable habitat. *Assumes a strip width of 20 m (total= 40 m).

			Number of Burrows						
Site	Transect length (m)	% Area*	Active	Inactive	Old	Total	# Scoped	#Tortoise	% Occupied
Broxton Rocks Preserve	6,823	10.8	7	24	8	39	39	8	20.5
Flat Tub WMA	9,803	5.1	0	5	10	15	14	6	42.9
Little Satilla WMA	6,556	2.5	18	1	2	21	20	16	80.0
Moody Forest NA	14,200	5.3	16	3	3	22	16	13	81.3
Penholloway WMA	13,403	6.0	3	21	5	29	29	6	20.7
Silver Lake WMA	35,241	4.7	29	18	14	61	54	20	37.0
Yuchi WMA	12,700	2.7	0	1	1	2	1	0	0

Table 5. Population evaluation and habitat suitability rankings for gopher tortoise surveys sites in Georgia. (1) High quality: Likely a viable population in suitable habitat. Site requires continued management, but no population manipulation/augmentation is necessary; (2) Medium quality- viable**:** Likely a viable population, but habitat needs management/restoration of natural vegetation. No population manipulation necessary; (3) Medium quality- not viable: Population likely not viable at current size and demographic conditions, but habitat is suitable without need for extensive restoration. Augmentation with translocated tortoises should be considered; (4) Low quality: Population likely not viable at current size or demographic conditions and habitat is in need of extensive restoration to support more tortoises. Site should be considered for future augmentation with translocated tortoises; (5) Low quality-unsuitable**:** Tortoises present on site in low numbers, but site is generally unsuitable for tortoise population (e.g., poorly drained soils).

Site	Survey Type	Ranking	Comments
Barrington Property	full	2	Canopy needs to be thinned (pine), ground cover looks good, needs more frequent prescribed fire.
Broxton Rocks Preserve	5%	5	Some thinning of pines needed. Soils not appropriate for tortoises in many areas (rocks or poorly drained).
Doerun NA	full	1	Well managed for pitcher plants with prescribed fire, good native ground cover.
Fall Line Sandhill NA	full	2	Pines need to be thinned, more frequent fires needed, many areas bedded and planted in pine, which has disturbed native ground cover, but still lots of burrows.
Flat Tub WMA	5%	4	Pines need to be thinned, uplands burned more frequently, but some areas are just not suitable for gopher tortoises because of soils (rocks and poorly drained).
General Coffee SP- West	full	1	Western part of property well-managed with fire and need some midstory hardwood removal. Eastern section (not surveyed) needs management to improve habitat for tortoises.
George L. Smith SP	full	2	Property east of the river has good habitat (sandy soils, open canopy, little understory); west of the river is mostly dense mixed hardwood/pine with poorly drained soils; a few of the upland parcels have been clearcut. Pines and hardwoods in some areas need thinning.
Little Ocmulgee SP	full	2	Upland habitat east of river has dense ground cover and good understory; no thinning necessary; needs more frequent fire.
Little Satilla WMA	<5%	4	Soils poorly drained, largely unsuitable habitat except for a few areas in the northern portion of the property.
Moody Forest NA	5%	3	Several patches of good habitat, but pines on much of the site need to be thinned; some areas may be too poorly drained. Possible site for augmentation.

Ohoopee Dunes NA	full	1	Nice open canopy, mostly longleaf pine and wiregrass is present, truly a xeric sandhill.
Okefenokee NWR	full	1	Good habitat around entrance drive, good soils, well managed with prescribed fire for RCWs. Soils poorly drained and inappropriate for tortoises to the south.
Penholloway WMA	5%	5	Suitable habitat is restricted to northern bluffs; most of the site is poorly drained (swamp).
River Creek WMA	full	2	Needs additionally thinning of pines and more frequent fire. Good habitat overall (except for drainages) despite low tortoise densities.
RG Daniels TNC	full	1	Both sections of the property contain excellent tortoise habitat; very high quality.
Seminole SP	full	1	Good habitat in general, but some areas would benefit from thinning pines and more frequent fire. Midstory hardwood removal on western parcel of park.
Silver Lake WMA	5%	3	Portions of the site adjacent to the lake are only marginally suitable (poorly drained soils). In driest soils, the site needs more frequent fire and thinning of pines.
Townsend WMA	full	3	Hardwoods dominate the mid-story, not much quality ground cover. Needs thinning and burning. Much of the suitable habitat is fragmented by wetland drainages. Possible site for augmentation.
Williams Bluff TNC	full	2	Good habitat overall. Needs hardwood removal in some areas, as well as frequent fire.
Yuchi WMA	<5%	3	Tortoises are restricted to roadsides. Much of the site has been clearcut and replanted in longleaf, needs frequent fire and future hardwood control. But looks good in general. Possible site for augmentation.

Table 6. Habitat data at 18 gopher tortoise survey sites in Georgia. Data were not collected at Broxton Rocks Preserve and Yuchi WMA.

Site	# Habitat points	% of points with wiregrass	Basal Area (ft^2)
Barrington Property	12	25	n/a
Doerun NA	25	68	30-210
Fall Line Sandhills NA	16	0	0-80
Flat Tub WMA	9	22	16-200
General Coffee SP-West	8	100	15-80
George L Smith SP	18	67	0-115
Little Satilla WMA	6	33	0-135
Little Ocmulgee SP	15	40	25-95
Moody Forest NA	13	31	10-185
Ohoopee Dunes NA	11	82	20-80
Okefenokee NWR	7	57	0-45
Penholloway WMA	15	7	0-140
RG Daniels	6	100	0-65
River Creek WMA	29	41	0-135
Seminole SP	19	95	20-130
Silver Lake WMA	17	65	0-130
Townsend WMA	6	0	10-120
Williams Bluff NA	7	29	29-110

Table 7. Checklist of amphibian and reptile species observed during tortoise surveys at 20 gopher tortoise survey sites in Georgia.

	BAR_TNC	BR_TNC	DR_NA	FLS_NA	FT_WMA	GC_SP_West	GLS_SP	LO_SP	LSAT_WMA	MF_NA	OD_NA	OTR_NWR	PEN_WMA	RC_WMA	RGD_TNC	S_SP	SL_WMA	TOW_WMA	WB_TNC	YUC_WMA
Agkistrodon piscivorus																	X			
Anolis carolinensis											X									
Bufo quercicus												X		X						
Bufo terrestris	X																			
Bufo sp.									X								X	X		
Coluber constrictor									X								X			
Crotalus adamanteus	X			X										X			X		X	
Crotalus horridus											X						X			
Crotalus sp.							X													
Elaphe obsoleta	X																			
Eumeces sp.									X								X			
Heterodon platyrhinos			X																	
Masticophis flagellum															X	X				
Rana sp.											X									
Sceloporus undulatus											X									X
Sistrurus miliarius												X					X			X
Terrapene carolina			X											X					X	

Table 8. Field effort for a team of three conducting line transect distance sampling (LTDS) for gopher tortoises at 20 sites in Georgia. Area (ha)= suitable habitat; ESW= effective strip width (m) for full survey sites.
* field time estimated

Site	Survey Type	Number of Transects	Transect Length(m)	Area (ha)	ESW	Percent of Area Covered	Burrows Scoped	Field Time (hr)	Survey Rate (m/hr)
Barrington Property	full	43	24,908	447	22.1	24.6	159	29.3	850
Broxton Rocks Preserve	5%	9	6,823	252	20	10.8	23	*12	569
Doerun NA	full	26	28,272	144	6.7	26.3	140	36	785
Fall Line Sandhills NA	full	28	43,985	351	20.6	51.7	156	23.3	1888
Flat Tub WMA*	5%	6	9,803	776	20	5.1	14	17.5	560
General Coffee SP West	full	12	8,486	56	20.4	62.4	125	15	566
George L. Smith SP	full	29	17,538	262	22.3	29.9	83	20.75	845
Little Ocmulgee SP	full	25	14,533	86	21.8	73.3	101	14.08	1032
Little Satilla WMA	<5%	7	6,556	1046	20	2.5	20	12.25	535
Moody Forest NA	5%	4	14,200	1076	20	5.3	16	9.75	1452
Ohoopee Dunes NA	full	51	41,970	679	21.1	26.1	96	32.01	1311
Okefenokee NWR	full	28	25,328	271	14.4	26.9	74	*22.3	1136
Penholloway WMA	5%	6	13,403	896	20	6.0	29	19.75	679
River Creek WMA	full	43	46,050	438	16.3	34.2	245	41.5	1110
RG Daniels TNC	full	34	11,581	53	18.4	81.2	152	13.5	858
Seminole SP	full	24	18,082	163	13.7	30.4	183	25.18	718
Silver Lake WMA	5%	6	35,241	3013	20	4.7	54	33.5	1052
Townsend WMA	full	13	10,973	166	18.4	24.3	49	16.83	652
Williams Bluff TNC	full	22	17,766	199	14.4	25.7	156	36	494
Yuchi WMA	<5%	13	12,700	1894	20	2.7	1	18	706
Totals or Averages			408,198	12,267			1876	385	889.9

Table 9. Abundance (*N*) and occupancy (Ψ) estimate comparison of belt transect methods proposed in Florida's Gopher Tortoise Management Plan and line transect distance sampling (LTDS) for ten properties across South Georgia from October 2007 – October 2008.

		Belt Transect Method Estimates			LTDS Estimates						Difference
Site	Survey Months	Ψ (%)	*n*	***N***	Ψ (%)	*n*	***N***	L 95% *CI*	U 95% *CI*	*CV*%	**%**
Barrington Property	Apr, Aug	50	57	**320**	52	79	**321**	244	422	13.6	**< 5**
Fall Line Sandhills NA	Mar	50	71	**177**	32	47	**91**	65	127	16.2	**49**
General Coffee SP- West	Apr	50	43	**88**	46	57	**91**	56	148	22.2	**< 5**
George L. Smith SP	Mar	50	30	**140**	48	38	**127**	86	189	19.6	**10**
Little Ocmulgee SP	Apr	50	36	**93**	38	36	**48**	33	71	18.6	**49**
Ohoopee Dunes NA	Oct	50	47	**238**	40	37	**136**	96	193	16.9	**43**
River Creek WMA	Feb, Mar, Jul, Aug	50	108	**321**	46	107	***313**	211	464	19.9	**< 5**
RG Daniels-TNC	Apr	50	42	**59**	30	44	**54**	39	76	16.8	**< 5**
Seminole SP	Oct	50	105	**296**	32	55	**159**	122	206	12.71	**46**
Townsend WMA	Oct	50	21	**99**	51	24	**99**	61	159	22.3	**< 5**

*Detection probability (*p*) = 0.84

Table 10. Density (*D*) and occupancy (*Ψ*) estimates for belt transect methods (BTM) proposed in Florida's Gopher Tortoise Management Plan and line transect distance sampling (LTDS) for ten properties across South Georgia from October 2007 – October 2008.

		Belt Transect Method Estimates			LTDS Estimates						Difference
Site	Survey Months	*Ψ (%)*	*n*	***D***	*Ψ (%)*	*n*	***D***	L 95% *CI*	U 95% *CI*	*CV*%	**%**
Barrington Property	Apr, Aug	50	57	**0.72**	52	79	**0.72**	0.55	0.94	13.6	**< 5**
Fall Line Sandhills NA	Mar	50	71	**0.50**	32	47	**0.26**	0.19	0.36	16.2	**49**
General Coffee SP- West	Apr	50	43	**1.58**	46	57	**1.65**	1.02	2.67	22.2	**< 5**
George L. Smith SP	Mar	50	30	**0.54**	48	38	**0.49**	0.33	0.72	19.6	**10**
Little Ocmulgee SP	Apr	50	36	**1.08**	38	36	**0.56**	0.34	0.82	18.6	**49**
Ohoopee Dunes NA	Oct	50	47	**0.35**	40	37	**0.21**	0.15	0.29	16.9	**43**
River Creek WMA	Feb, Mar, Jul, Aug	50	108	**0.73**	46	107	***0.72**	0.48	1.06	19.9	**< 5**
RG Daniels-TNC	Apr	50	42	**1.13**	30	44	**1.03**	0.74	1.45	16.8	**< 5**
Seminole SP	Oct	50	105	**1.82**	32	55	**0.97**	0.75	1.27	12.7	**46**
Townsend WMA	Oct	50	21	**0.60**	51	24	**0.59**	0.37	0.96	22.3	**< 5**

*Detection probability (*p*) = 0.84

Figure Headings

Figures 1a-n. Burrow size distribution for gopher tortoise survey sites in southern Georgia, October 2007-October 2008. Data are presented only for occupied burrows. The "0" size class category refers to burrows that were too small to scope with a burrow camera system; therefore, occupancy could not be determined. These burrows were generally < 10-12 cm in diameter.

Figure 1a. Barrington Property (TNC)

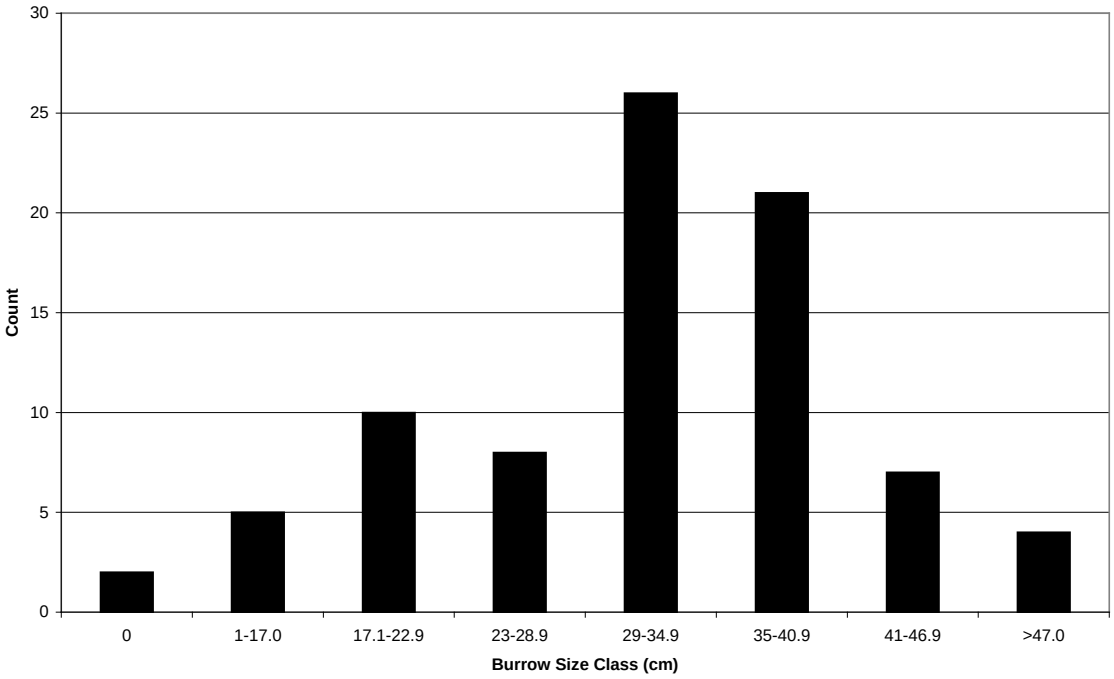

Figure 1b. Doerun NA

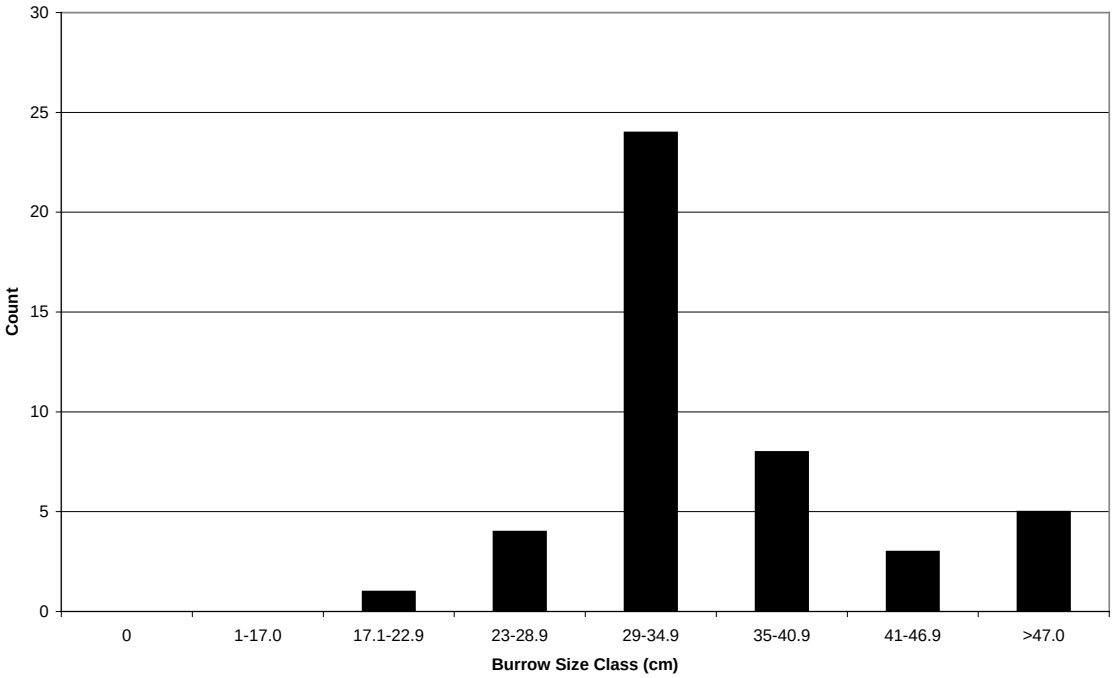

Figure 1c. Fall Line Sandhills NA

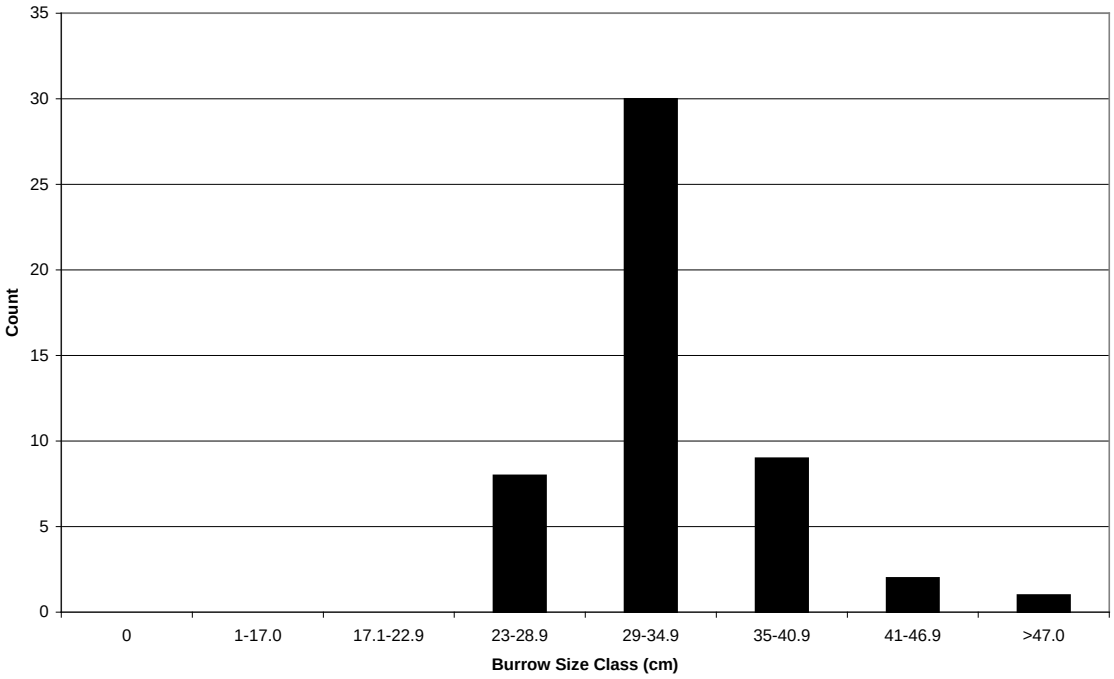

Figure 1d. General Coffee SP

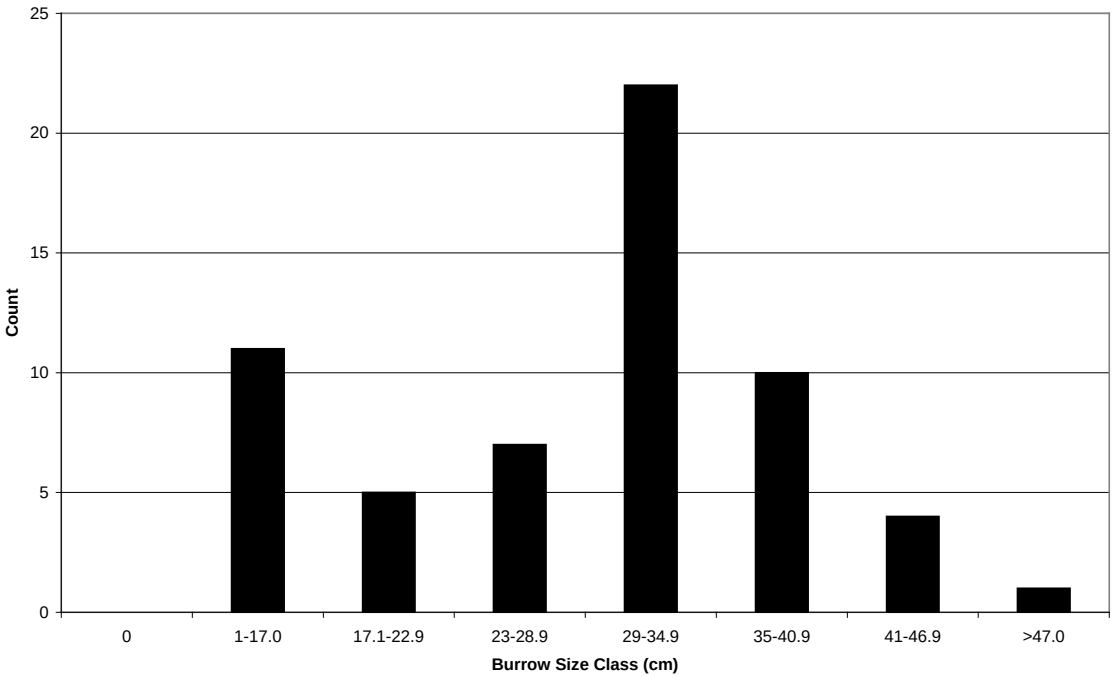

Figure 1e. George L. Smith SP

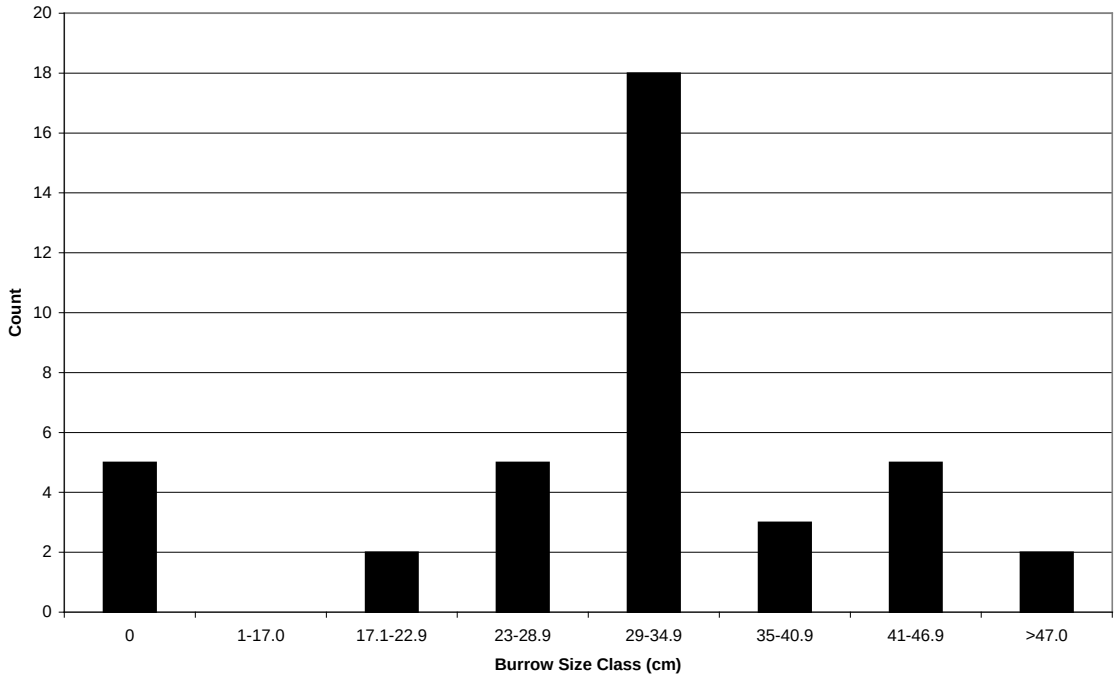

Figure 1f. Little Ocmulgee SP

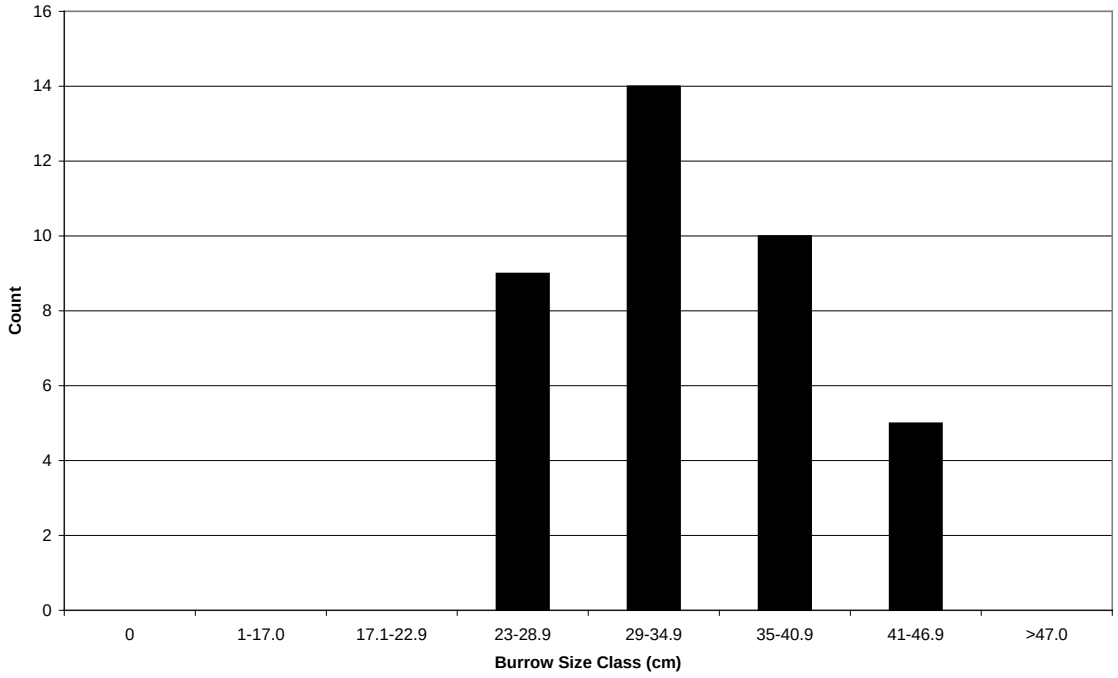

Figure 1g. Ohoopee Dunes NA

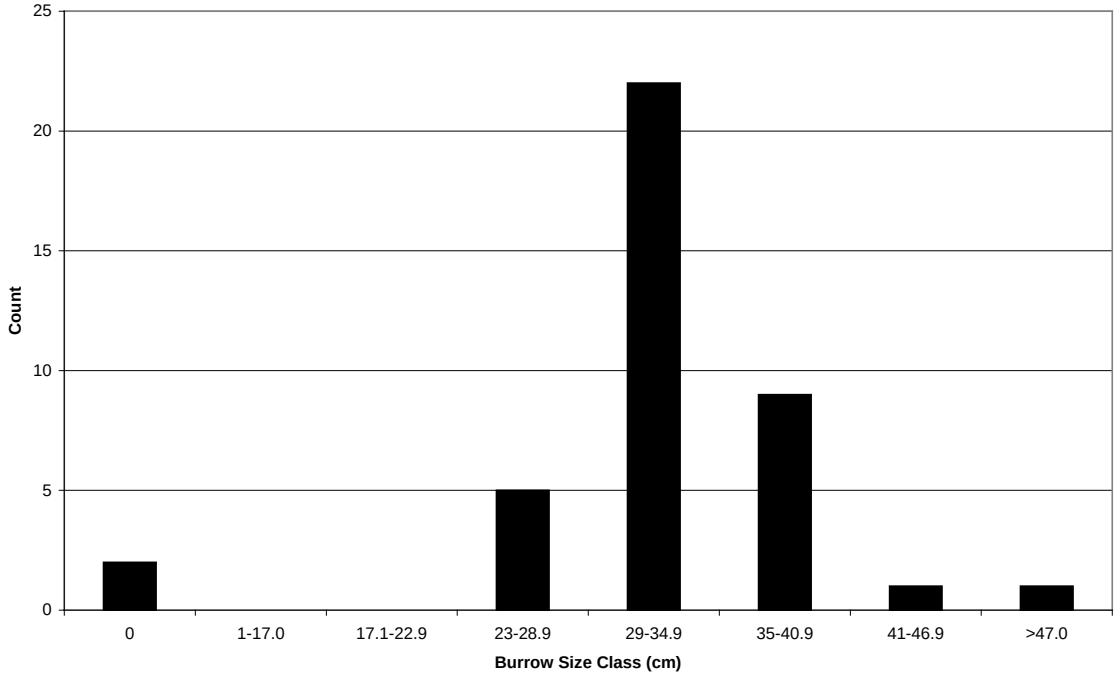

Figure 1h. Okefenokee NWR

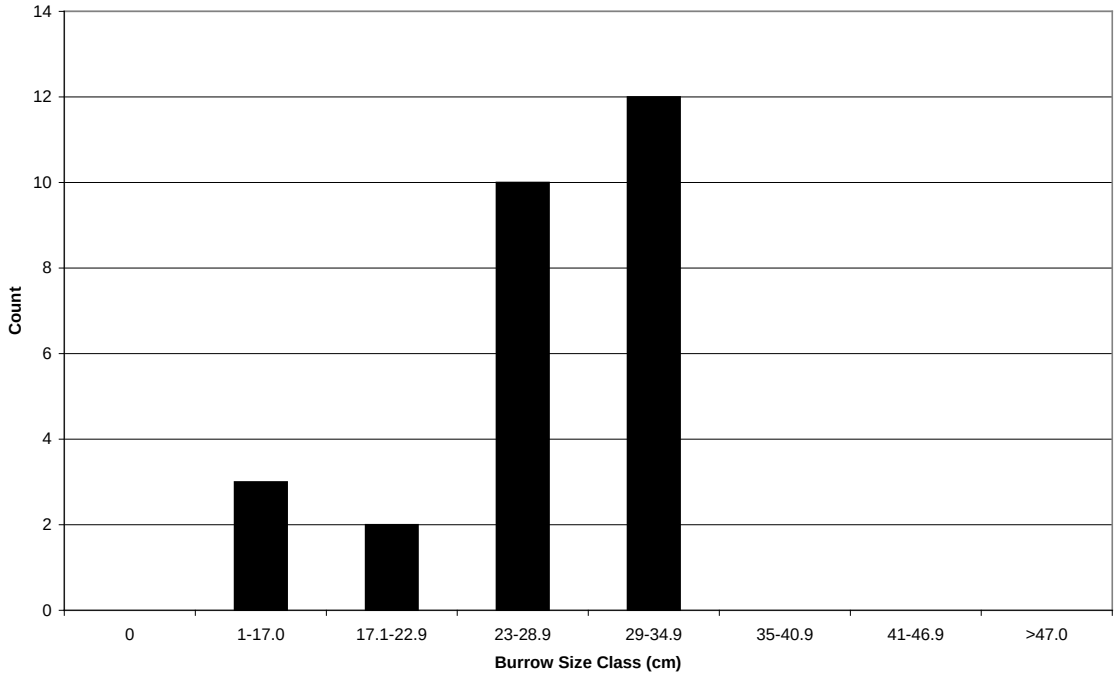

Figure 1i. RG Daniels Property

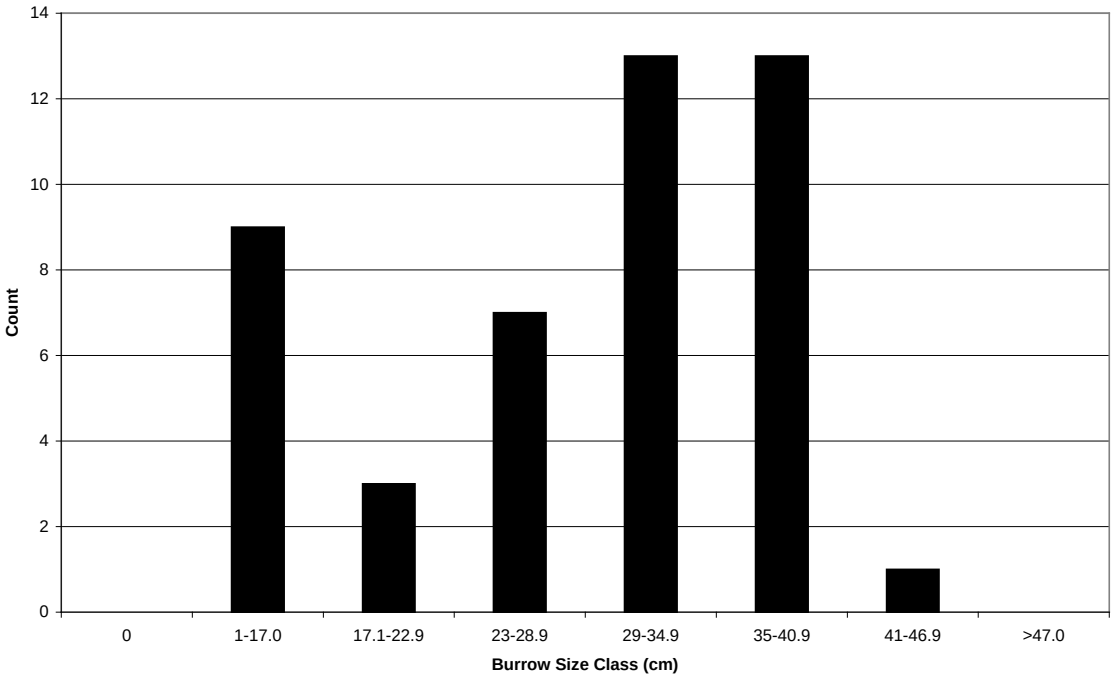

Figure 1j. River Creek WMA

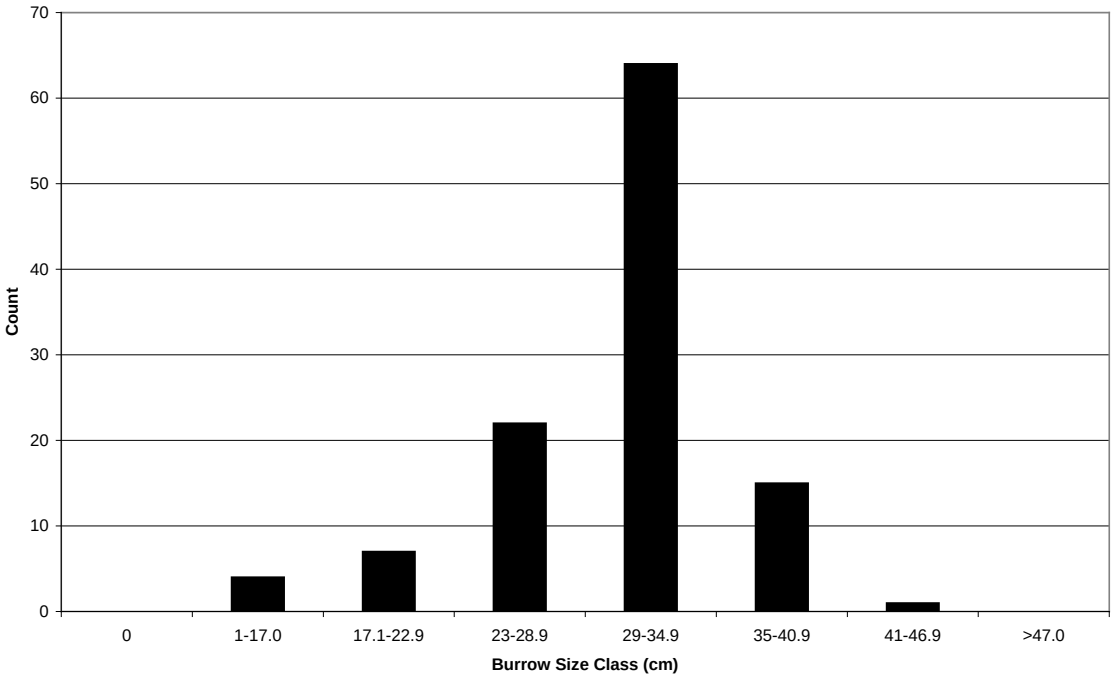

Figure 1k. Seminole SP

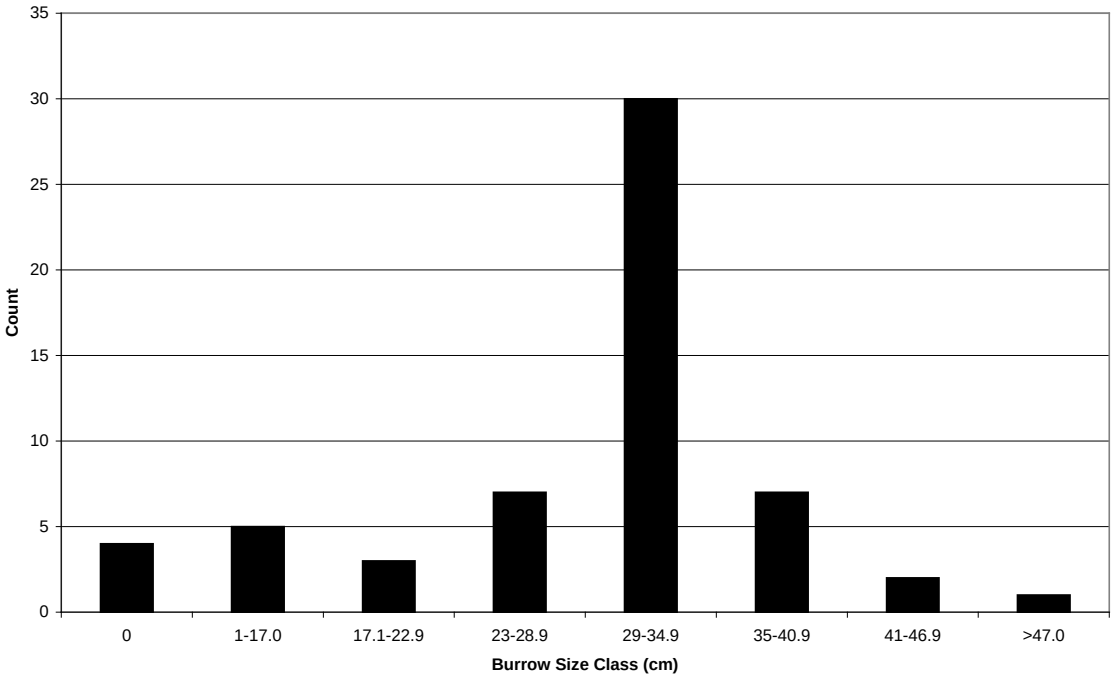

Figure 1l. Silver Lake WMA

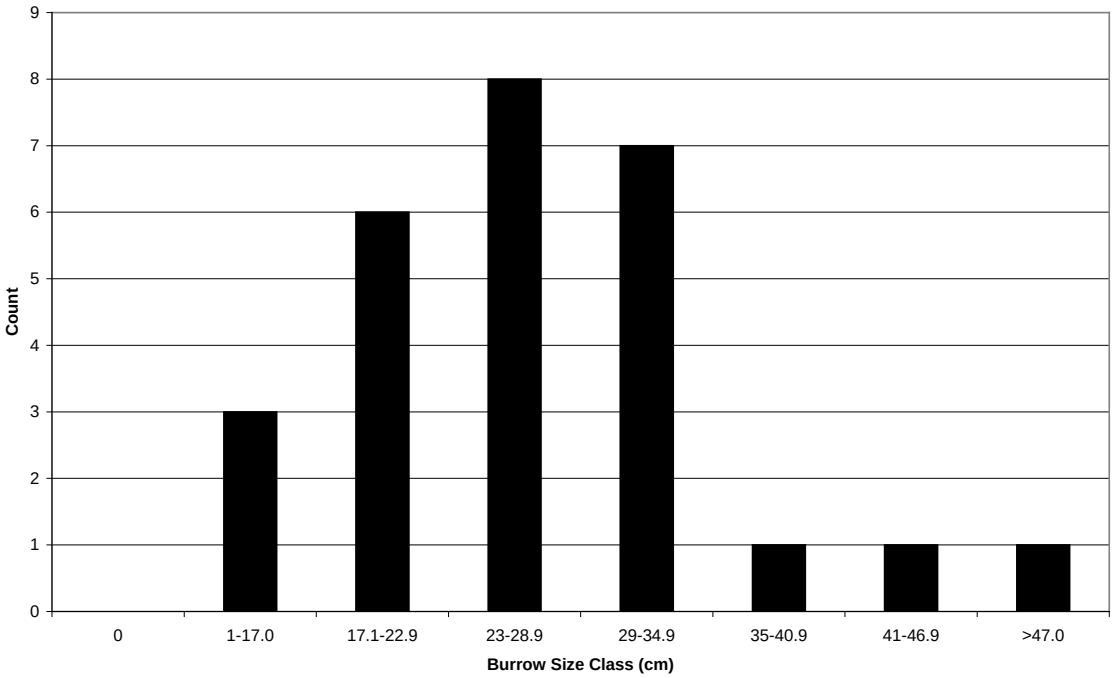

Figure 1m. Townsend WMA

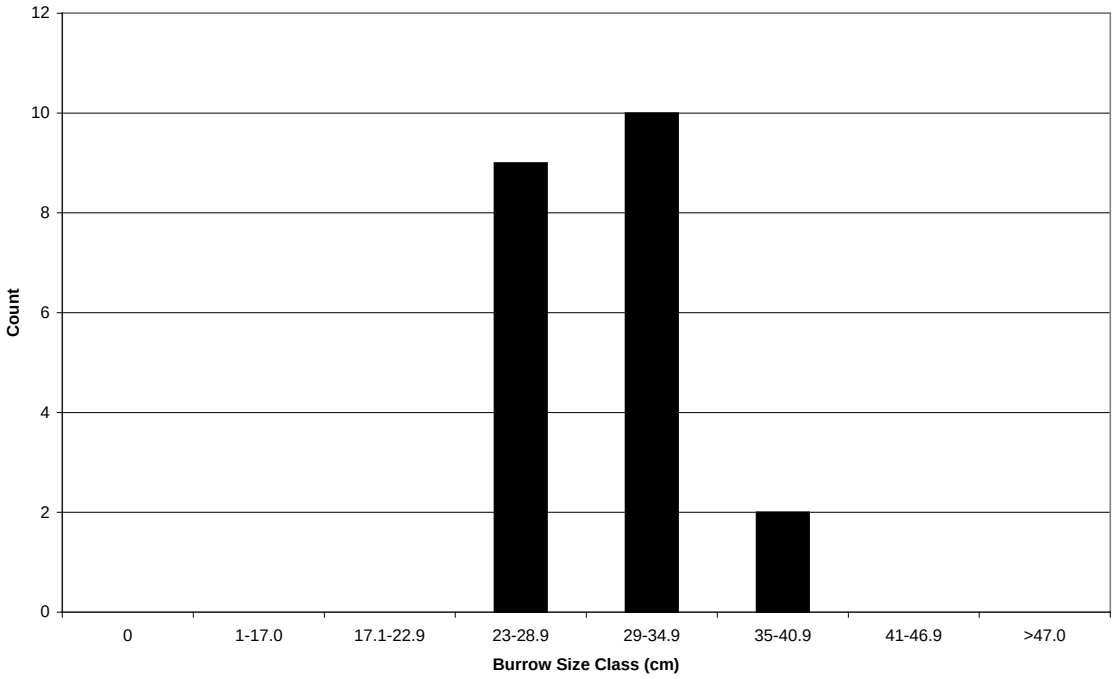

Figure 1n. Williams Bluff (TNC)