*Gopher Tortoise Burrow Disturbance effects on Microhabitats and Vegetation in Florida Sandhill*

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**Abstract**

Gopher tortoises are known to create microhabitat scale disturbance and environmental heterogeneity in Florida Sandhill. Many plant species found in Florida Sandhill are gap specialists, adapted to a frequent fire regime and heterogeneous vegetation openings. Vegetation communities and individual plant species may also positively respond to gopher tortoise disturbance. The effects of gopher tortoise activity on native and non-native plant species and communities in two years post-burned sandhill was investigated to see if their disturbance positively influenced plant populations. Active and abandoned burrow aprons were mapped for size, characterized by leaf litter, vegetation coverage, and plant species communities. Leaf litter coverage and species richness significantly increased in aprons after burrows were abandoned, but vegetation cover did not differ significantly. Plant species diversity was highest in active burrow aprons, indicating higher evenness and less interspecies competition. The population of a common gopher tortoise food source, *Pityopsis graminifolia* was significantly different among active, abandoned, and control sites, with the population higher and more variant in active aprons than abandoned. Burrow aprons did not significantly affect other plant species populations of note, including *Aristida beyrichiana,* the endangered *E. longifolium var gnaphalifolium,* or invasive grasses. The aprons' distance to road also did not affect populations or presence of invasive species. These results conclude that gopher tortoises significantly alter leaf litter coverage and plant communities, however, a larger sample size is required to determine whether they also influence individual plant species of interest.

**Key Words:** Gopher tortoise, Biodiversity, Community Structure, Competition, Invasive Species, Succession, Sandhill, Archbold Biological Station, Disturbance

## 1. Introduction

Considered an ecological keystone species, the gopher tortoise *(Gopherus polyphemus)* is the only tortoise found in the eastern portion of the United States and are common to sandy xeric upland habitats (Kaczor and Hartnett, 1990; Macdonald, 1996). Their characteristic burrowing behavior and foraging may significantly impact microhabitats and local plant communities. By foraging vegetation and seeds, excreting seeds in scat, and trampling, they likely influence seed dispersal, germination, vegetation composition, and plant growth throughout their range (Kaczor and Hartnett, 1990; Carlson et. al 2003). Gopher tortoises' burrowing and mound developing behavior creates environmental disturbance and heterogeneity in their respective habitats. Burrowing and disturbance has been found to impact microhabitats by decreasing competition, increasing resource availability, and creating a "regeneration niche", which may positively influence plant richness and diversity (Kaczor and Hartnett, 1990; Rogers et al. 2001; Grubb, 1977; Reichman and Smith, 1985). In a previous study, richness was highest in old gopher tortoise mounds, supporting both early annual colonizers and later successional herbaceous species (Kaczor and Hartnett, 1990). Being also commonly found in Florida's scrub and sandhill habitats, the Gopher tortoise is part of a pyrogenic ecosystem which thrives on a frequent fire regime. Many endemic and rare plant species favor the presence of fire-created gaps for continued recruitment and survival (Menges et. al 2008; Weekley and Menges, 2003; Menges and Hawkes, 1999). Gopher tortoises may also have a positive influence on endemic, pyrogenic sandhill plant species by creating small scale open patches.

The Archbold Biological Station's sandhill property, known as Red Hill, is home to a highly monitored community of gopher tortoises and their burrow locations. Portions of Red Hill's sandhill habitat has undergone recent restoration efforts including mowing and fire treatments. Disturbance-thriving invasives including *Melinis repens, Sporobolis indicus, Crotalaria pallida, Abrus spp.,* and *Paspalum notation* are also found on the property. They are most common along road and fire-lane edges, and species such as *Melinis repens* have been collected in significantly greater biomass at these locations (David and Menges, 2011). Although gopher tortoise burrow activity may benefit native species to Florida sandhill, they may also prolong higher densities of invasive species along roadsides.

This study aims to assess the environmental differences and vegetational composition changes created by gopher tortoise burrow microhabitat disturbances. It will evaluate and compare active burrows, abandoned burrows, and local control sites to answer the following;

1. Does gopher tortoise activity significantly alter microhabitat variables including percent litter coverage and percent canopy coverage?
2. Does gopher tortoise activity significantly alter overall vegetation communities including species richness and diversity?
3. Do gopher tortoise mounds support native and/or rare plant species of interest?
4. Do abandoned mounds along roadsides prolong invasive species presence?

## 2. Methods

*2.1 Study area and burrow site selection*

15 active, 15 abandoned gopher tortoise burrows, and 15 control sites were assessed in burn units 2A and 4A. Both burn units were completely mowed and burned in 2016, and are consistent sandhill habitat structure, dominated by low-growth palmetto and oak species. All active burrows assessed had openings of 30 cm diameter or greater to be considered in the analysis, verifying that the resident tortoise was an adult. Using historical monitoring data obtained from the Archbold Biological Station's herpetology laboratory, abandoned burrow sites were chosen if the opening at any point before abandonment was 30 cm or greater.

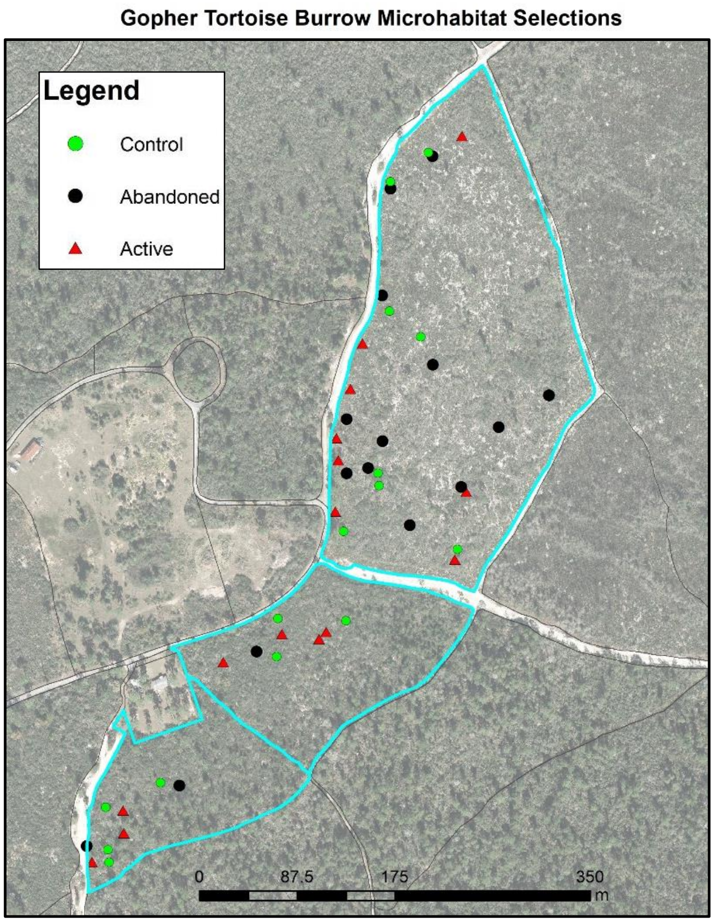

**Figure 1.** Map of adult Gopher Tortoise (*Gopherus Polyphemus*) burrow locations and control sites used for microhabitat assessment and analysis.

Control burrow sites were chosen from random points generated on ArcGIS within a 5-20 m buffer distance from the sampled active and abandoned burrow sites. All burrow and control locations were mapped in ArcGIS (Fig. 1).

### *2.2 Burrow apron size selection*

All active burrow locations used in the analysis were initially mapped for their apron area and entrance openings were measured. Extent of the apron was determined by the presence of yellow, loose sand. 8 radii were taken at each burrow location to determine their area and average radii. All microhabitat data was taken from the apron's full extent. Because the largest historical extent of abandoned aprons could not be accurately determined on site, their extent was predicted using active apron data. Initial modeling of average apron radii in comparison to their corresponding opening size resulted in a positive correlation.

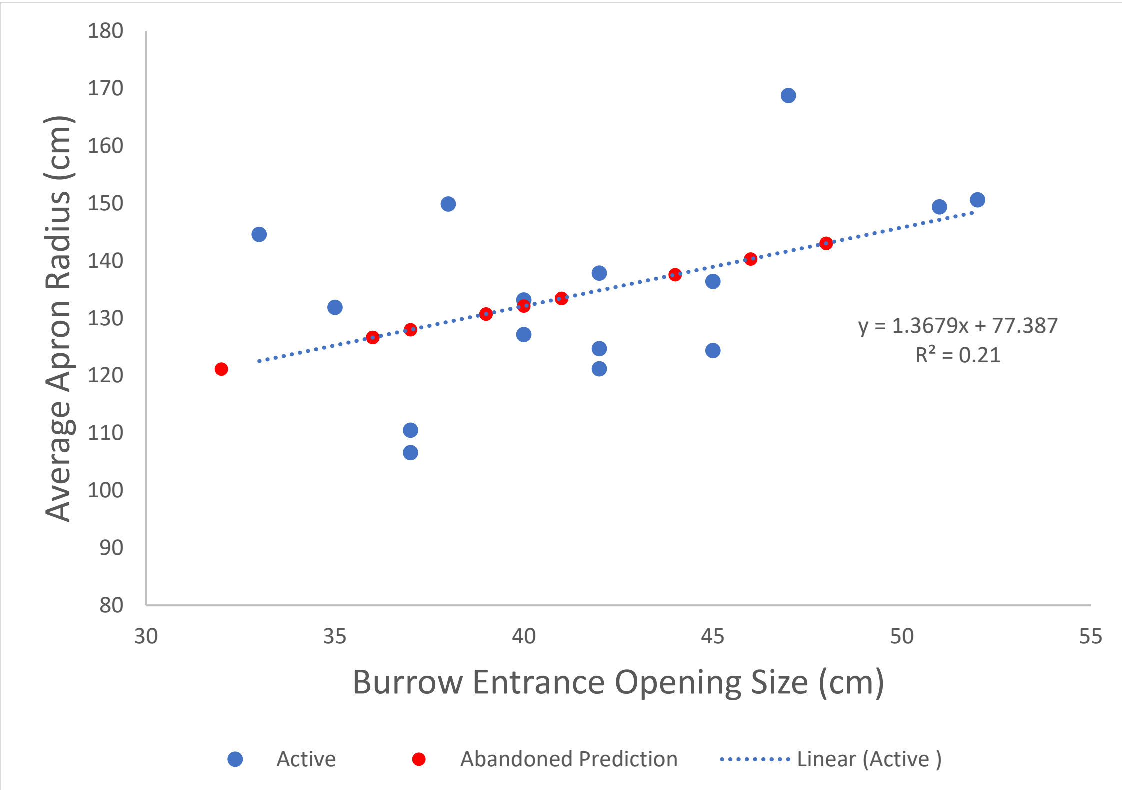


**Figure 2.** Linear correlation model of active burrow site apron extent (cm) and burrow entrance opening size (cm). Abandoned apron extents were predicted along the linear regression fit based on largest recorded entrance opening size.

The predicted size of abandoned burrows was determined using the slope of the correlation's linear fit and the largest past recorded entrance opening diameter (cm) (Fig. 2). The predicted abandoned apron size was then used as the extent for microhabitat analyses. For control sites, the average radii of sampled active burrows was used as their sampling extent.

### *2.3 Microhabitat vegetation sampling*

At active, abandoned burrow aprons, and control sites, microhabitat vegetation sampling took place between March – April 2018 to gather canopy cover, leaf litter cover, light intensity, and species present. Canopy cover below 1 m was sampled by measuring the length of live vegetation intersecting two apron diameter extending transect tapes. Canopy cover above 1 m was sampled with a spherical densitometer facing each cardinal direction (Lemmon, 1956). Leaf litter coverage was sampled by measuring the length of litter intersecting two apron diameter extending transect tapes. All plant species and the number present were recorded to determine plant diversity and richness. Clonal oaks were designated as individual "clumps" if they were over 15 cm apart. Wiregrass were considered individuals by clump. Population counts of species were standardized by the size of their apron by dividing the number of species by the apron's area. Individual species were grouped into guilds for different analyses, designated as either woody, woody vines, legumes, palmettos, forbs, or graminoids.

### *2.4 Statistical analyses*

An initial Numerical Multidimensional Scaling (NMS) Ordination using Pearson and Kendall Correlations was performed using percent litter, percent vegetation, and standardized count totals of species guilds. Percent cover, total percent vegetation cover, species richness, and log transformed species diversity (H') were calculated for active, abandoned, and control sites using Microsoft Excel 2013. These variables' relationship with active, abandoned, and control sites were calculated using One-Way ANOVA and post-hoc tukey analysis. Standardized, non-normal species counts were analyzed for their relationship with active, abandoned, and control sites using non-parametric Kruskal-Wallis one-way analysis of variance. The closest distance of sites from roadsides was determined in meters using ArcGIS measure tool. Standardized, non-normal species count sums of invasive species *Sporobolis indicus* and *Melinis repens* and their relationship to distance from roadsides was determined by calculating Pearson's Correlation coefficient in respective active, abandoned, or control sites. All statistical analysis was performed using IBM SPSS Statistics 22.

## 3. Results

*NMS*

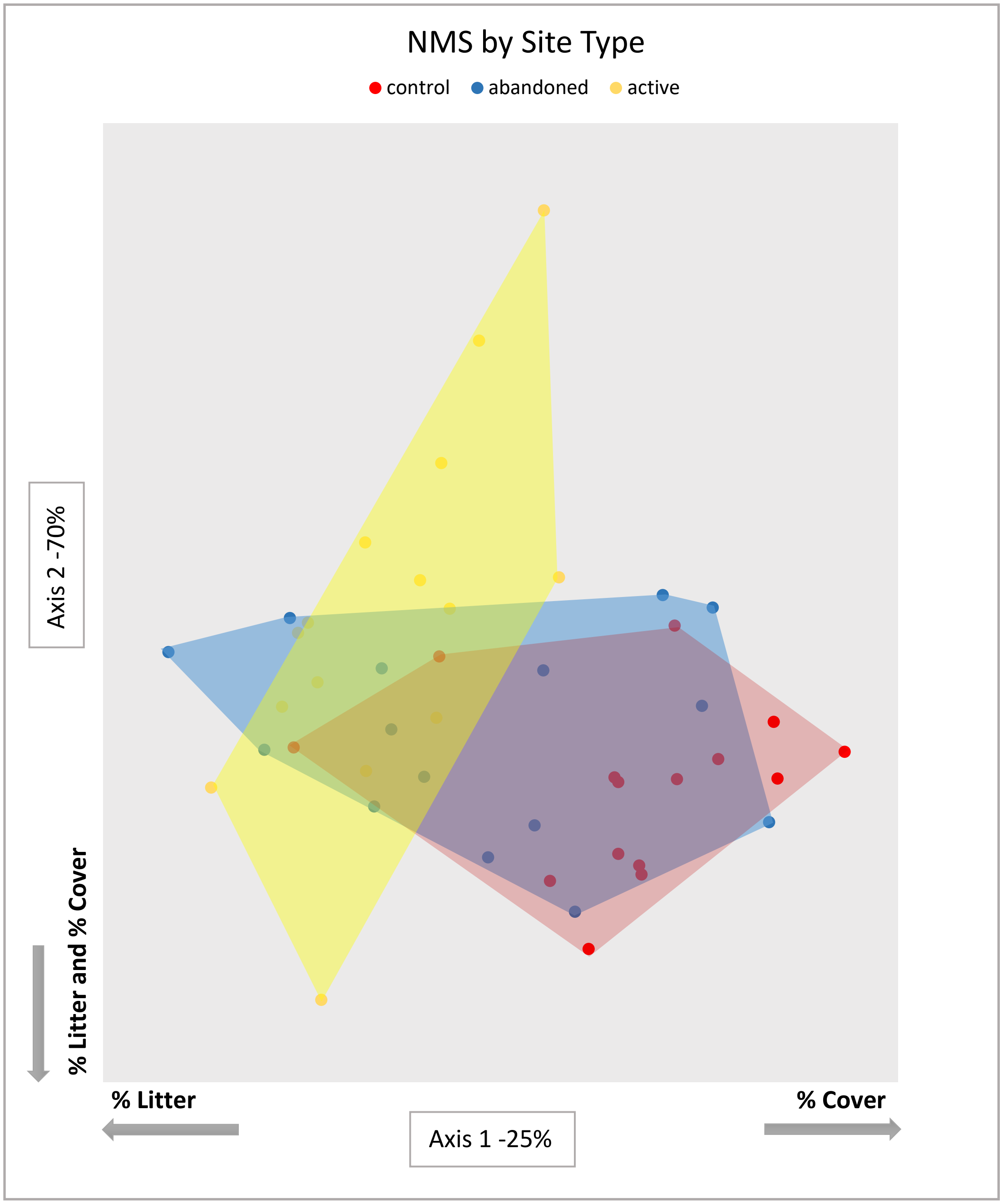


**Figure 3.** NMS graph output using Pearson and Kendall Correlation Axes.

Initial NMS ordination was able to determine a cumulative 95.8% of variation among active, abandoned, and control sites using two axes. Coefficients of determination for correlation between ordination and Sorensen (Bray-Curtis) original distances ($R^2$) was 0.251 in Axis 1 and 0.708 in Axis 2. Among individual variables, 80% variation (Axis 1) and 71.1% variation (Axis 2) was determined by percent litter coverage. Percent plant cover determined 44% (Axis 1) and 72% (Axis 2). The NMS ordination results and correlations are visualized in graphical format (Fig. 3).

**Fig. 3** NMS

*Microhabitat Variables*

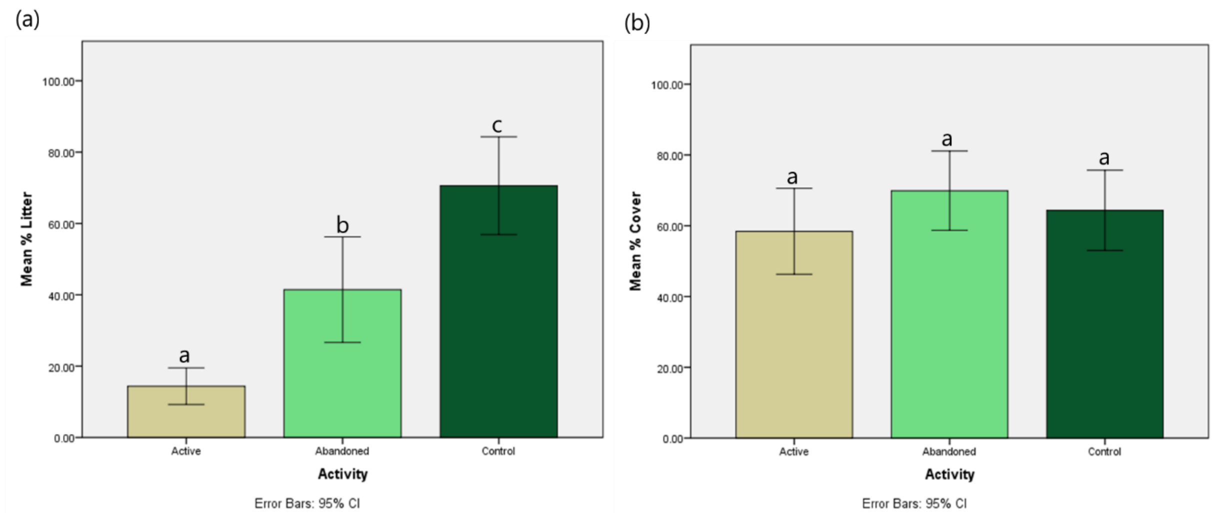


**Figure 4.** Mean bar graphs representing (a) percent litter and (b) vegetation cover (< 1 m) among active, abandoned, and control sites. Letters indicate means among site types which are statistically significant ($p < 0.05$).

Analysis of variance (ANOVA) test results found a significant difference among all sites for percent litter ($F(2,44) = 22.108$, $p < 0.0001$), and significantly different between each site type as supported by a Tukey HSD analysis (Fig. 4a). Active mounds contained the lowest percentage of litter, increasing after abandonment, and highest in control sites. Percent vegetation < 1 m was not significantly different among active, abandoned, and control sites ($F(2,44) = 1.135$, $p > 0 .331$) (Fig. 4b).

*Community Variables*

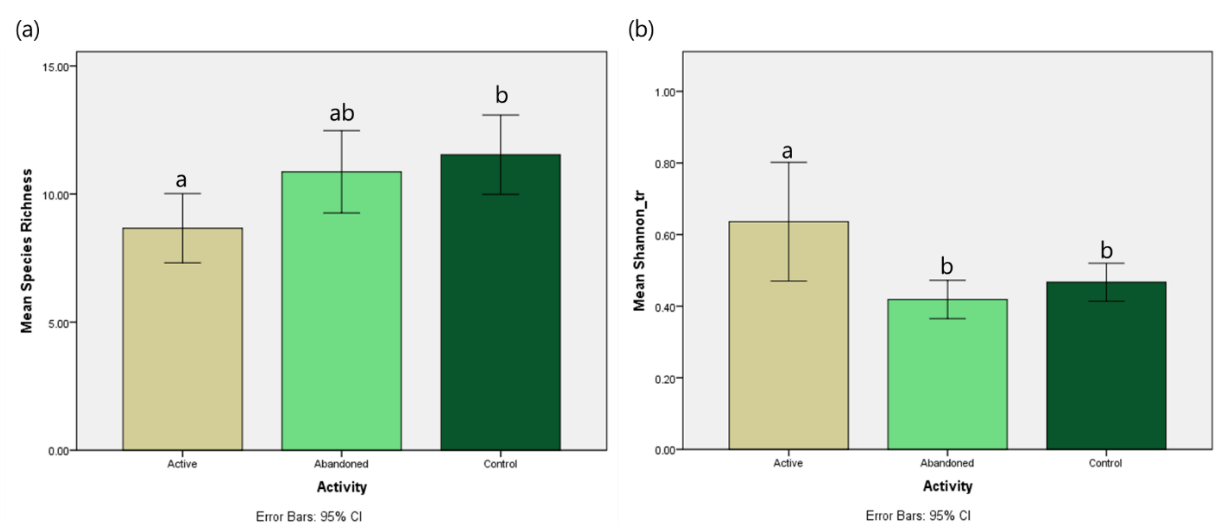


**Figure 5.** Mean bar graphs representing (a) species richness litter and (b) Shannon's species diversity index (H') among active, abandoned, and control sites. Letters indicate means among site types which are statistically significant ($p < 0.05$).

Analysis of variance (ANOVA) found mean species richness lowest in active sites, increasing after abandonment and highest in control groups ($F(2,44)=4.562$, $p < 0.05$). Tukey HSD found significant differences between active and control sites ($p < 0.05$) (Fig. 5a). Mean Shannon's diversity index (H') significantly different among site types ($F(2,38)=5.578$, $p < 0.05$). Tukey HSD further supported active mounds to be significantly higher than abandoned ($p < 0.05$) and control sites ($p < 0.05$) (Fig. 5b).

*Plant Species of Interest*

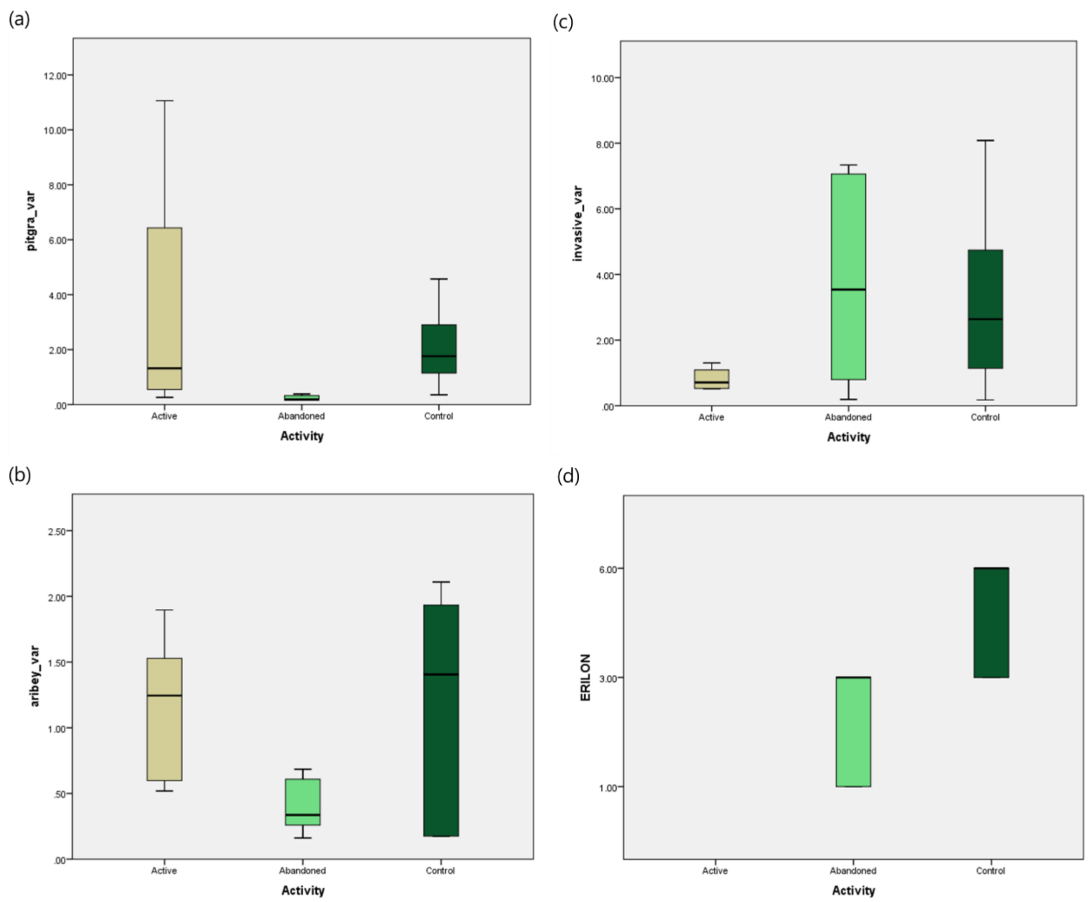


**Figure 6.** Boxplots representing (a) *P. graminifolia*, (b) invasive species (*S. indicus, M. repens*), (c) *A. beyrichiana,* and (d) *E. longifolium* among active, abandoned, and control sites.

Individual counts of *Pityopsis graminifolia* were significantly different among active, abandoned, and control sites ($\chi^2$ (2) = 9.221, $p < 0.05$) (Fig. 6a). Highest median individual counts were found in control sites, and the greatest variation represented in active. A significant difference was not found among site types for the sum of *Sporobolis indicus* and *Melinis repens* individual counts (invasive species) ($\chi^2$ (2) = 2.541, p = 0.281) or for *Aristida beyrichiana* ($\chi^2$ (2) = 3.806, p = 0.149) (Fig. 5b; c). Rare species *Eriogonum longifolium* was only minimally present in abandoned and control sites (Fig. 5d).

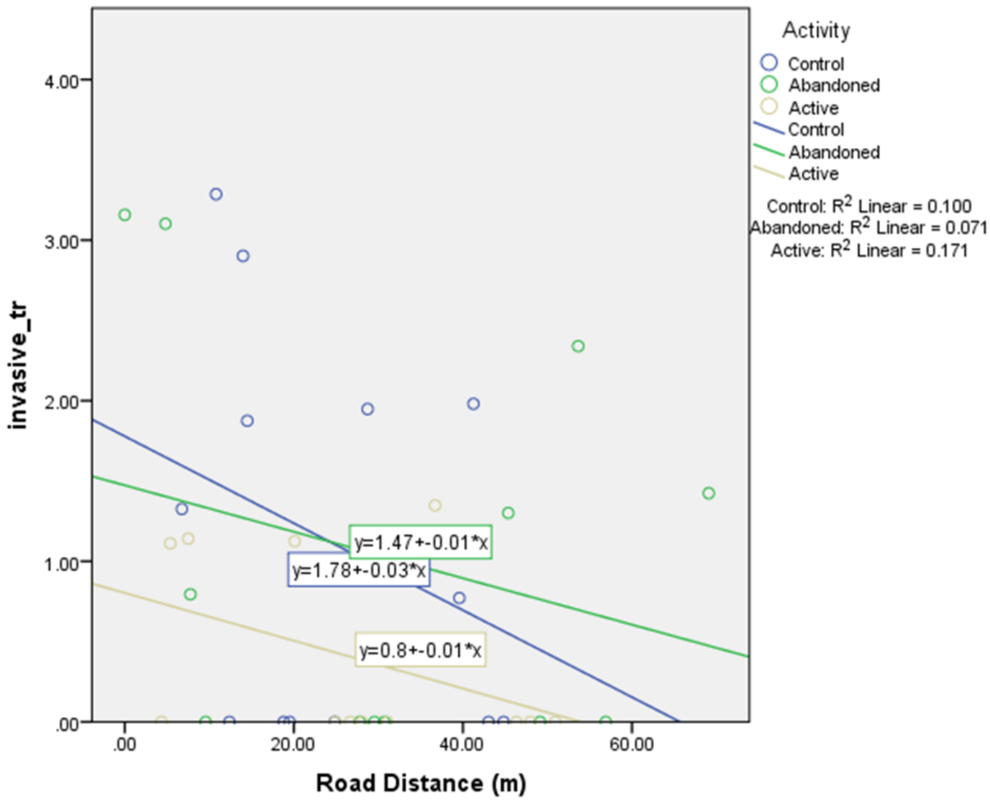


**Figure 7.** Scatterplot and linear $R^2$ regression of transformed invasive species counts according to active, abandoned, and control sites against distance from road (m).

Bivariate Pearson's correlation found non-significant decline in invasive species counts as distance from road increased (Active: r=-0.414, n=12, p=0.403; Abandoned: r=0.266, n=12, p=0.403; Control: r=-0.316, n=14, p=0.271). Results are summarized as a scatterplot and linear regression (Fig. 7).

## 4. Discussion

Gopher tortoises create significant microhabitat-scale disturbance, displacing and burying leaf litter in aprons surrounding their burrows. Leaf litter coverage returns in abandoned sites and has the highest percentage in undisturbed sites, as expected with decreased burrowing activity. Coverage of overall vegetation < 1 m was insignificant however. Given the recent 2-year post-fire regime of both study units, low and patchy vegetation cover was observed present in all sites. If young, but larger oaks or palmettos were present in the microhabitat studies, they were likely present before tortoise inhabitation and unaffected by local disturbance. Finer scale plant cover designation by multiple plant heights may better explain how disturbance affects vegetation coverage in these microhabitat locations.

Regarding community structure, plant species richness increased after burrows were abandoned and was highest in undisturbed sites. The increased presence of individual species after abandonment correlates with lowered disturbances and indicates microsuccessional regeneration. This however did not follow the same trend as a previous investigation of gopher tortoise mounds (Kaczor and Hartnett 1990). Richness was found to be highest in their old mounds, supporting the "regeneration niche" model and gap dynamics (Rogers et al. 2001; Platt, 1975; Grubb, 1977; Pickett, 1980; Denslow, 1985). The discrepancy between results may be due to differing successional stages of study sites. The two-year post fire regime, still containing open patches and little to no canopy, likely supports higher resource availability and reduced competition in undisturbed sites than late-successional sandhill forest. Endemic herbaceous species are known to take advantage of post-fire regimes, recruiting from the seed bank in newly opened patches (Weekley and Menges 2003; Menges and Hawkes 1999). Disturbance by gopher tortoises therefore, may increase microhabitat diversity and endemic herbaceous recruitment in successionally older sites, having less fire-produced gaps, higher interspecies competition, and a larger proportion of dominant species.

Activity in gopher tortoise burrows and mounds had an opposite effect on plant species diversity, with the highest index found in active mounds. Species evenness was therefore highest in active mounds, indicating less interspecies competition and dominant species presence due to continuous disturbance. Prior studies indicate that burrowing disturbance lowers competition and increases resource availability by removing impeding belowground root mass (Rogers et al. 2001; Reichman and Smith, 1985). From a successional standpoint, abandoned and undisturbed sites have had more time for multiple plant species to establish, increasing interspecies competition and species dominance, and lowering plant diversity.

Individual species presence of interest was difficult to accurately draw conclusions from. This was due in part because of sporadic presence and absence of plant species, and patchiness of their growth. Although some trends can be ascertained, they must be interpreted with reservation as they only represent a small portion of the species' population in these units. It is very likely that presence and the size of individual plant species populations in these sites are predicated on proximity to a larger population patch, life histories, and varied distances the species are able to disperse.

*Pityopsis graminifolia* was the only species with significant individual count differences. Undisturbed sites contained the largest population densities, which could be due to lower foraging pressure by nearby gopher tortoises, lessened disturbance, or larger populations may simply have been in closer proximity to these random sites than abandoned or active sites. Active sites contained the second highest median population, but with high variation among sites. This variation may be a result of timing differences in foraging and recruitment. Assessment of *P. graminifolia* in Kaczor and Hartnett (1989) similarly found more adults in undisturbed sites but had the highest recruitment of new seedlings in abandoned mounds. Low median population density results in abandoned aprons of this study may be due to different factors, including timing of seedling germination or proximity to a larger population. A longer study period investigating seedling recruitment and herbivory of individual *P. graminifolia* in active and abandoned sites may better inform their relationship with gopher tortoise dispersal and foraging.

*E. longifolium* was too minimally represented to draw patterns from, however, the units on Red Hill in this study had not been managed with mowing or prescribed burning until 2016. Presence, even minimally, in undisturbed sites as well as abandoned sites indicates that *E. longifolium* may be able to successfully populate mounds post-disturbance. Furthermore, lowered leaf litter coverage burned off by fire has shown positive impacts on *E. longifolium* recruitment (McConnel and Menges, 2002) and leaf litter coverage is similarly lower in abandoned aprons. Although there are many other factors influencing *E. longifolium* success, the potential microhabitat suitability for *E. longifolium* in gopher tortoise mounds could be further investigated with a larger sample size.

Invasive species presence was insignificant among site types as well as highly variable in both presence and absence and population density per area. Regarding *M. repens,* previous studies have found higher presence and preference for high litter microhabitats, yet undisturbed plots were less likely to be invaded than roadsides (David and Menges, 2011). Undisturbed sites in this study were high in litter content, which may explain highly variable populations. The growth patterns of invasive species populations were also observed in the field to be highly patchy. Both species being graminoids, *S. indicus* and *M. repens* population patches potentially follow spatial patterns rather than random distribution. When *S. indicus* or *M. repens* was present in a site, it could equally be a small and scattered population or a dominant, dense one.

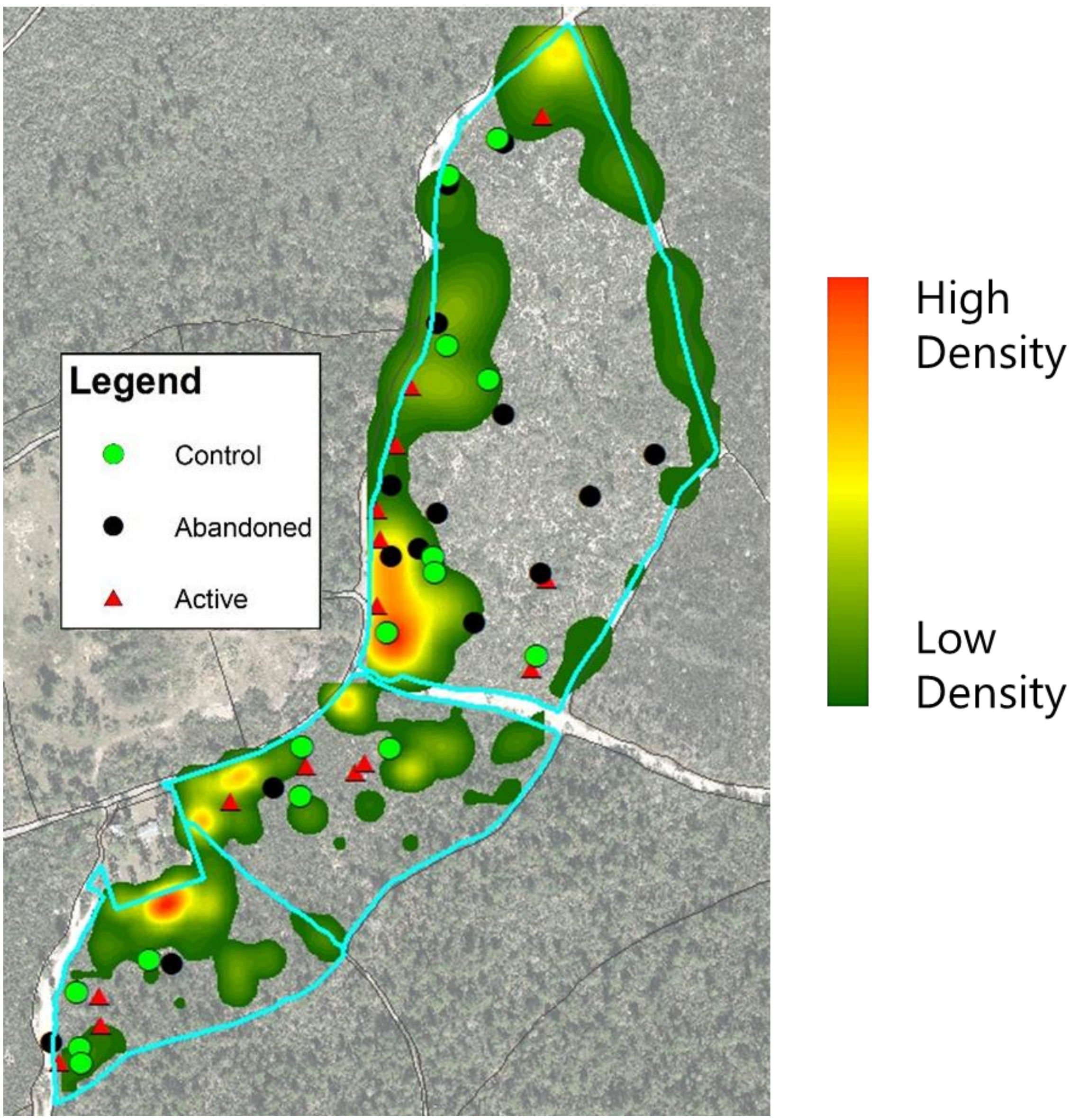


**Figure 8.** ArcGIS kernel density heatmap of invasive species presence and density in Red Hill units 2A and 4A from a 2016 survey, overlaid by this study's site locations.

Previous data from 2016 which measured presence and density of invasive species every 10 meters in both units supports this patchy growth trend. For better visual comprehension, a kernel density heatmap of these mapped populations was created and overlaid by the sites investigated in this study (Fig. 8). Because these density surveys were not current with this study, they could not be compared to invasive species presence in adjacent study sites. They do however support the potential for patchy population distributions in these units and indicate a potential reason for variable results. This also informs future investigations of the relationship between tortoise activity and invasive species such as *M. repens.* Patchy population densities and proximity of apron sites to these high or lower density areas must be accounted for as a potentially determining variable when gathering a robust sample size.

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**Literature Cited**

Carlson, Jane E., Menges, Eric S., Marks, Peter L. 2003. Seed dispersal by Gopherus Polyphemus at Archbold Biological Station, Florida. Florida Scient. 66(2):141-146.

David, Aaron S., Menges, Eric S. 2011. Microhabitat preference constrains invasive spread of non-native natal grass (Melinis repens). Biological Invasions. 13:2309.

Denslow, J.S. 1985. Disturbance-mediated coexistence of species, p. 307-323. In: S.T. A. Pickett and P.S. White (eds.). The ecology of natural disturbance and patch dynamics. Academic Press, San Diego.

Grubb, P.J. 1977. The maintenance of species richness in plant communities: the importance of the regeneration niche. Biol. Rev., 52:107-145

Kaczor, Sue A. and Hartnett, David C. 1990. Gopher Tortoise (Gopherus Polyphemus) Effects on Soils and Vegetation in a Florida Sandhill Community. Am. Midl. Nat. 123:100-111.

Lemmon, P.E. 1956. A spherical densiometer for estimating forest overstory density. For Sci 2: 314–320.

Macdonald, Laurie Ann. 1996. Reintroduction of Gopher Tortoises (Gopherus Polyphemus) to Reclaimed Phosphate Land. Florida Institute of Phosphate Research. No. 03-105-126.

McConnell, K., and Menges, Eric. 2002. Effects of fire and treatments that mimic fire on the Florida endemic scrub buckwheat (Eriogonum longifolium Nutt. var. gnaphalifolium Gand.). Natural Areas Journal. 22. 194-201.

Menges, E. S., and C. V. Hawkes. 1998. Interactive effects of fire and microhabitat on plants of Florida scrub. Ecol. App. 8: 935-946.

Menges, E.S., A. Wally, J. Salo, R. Zinthefer, and C.W. Weekley. 2008. Gap ecology in Florida scrub: Species occurrence, diversity, and gap properties. Journal of Vegetation Science 19:503–514.

Pickett, S.T.A. 1980. Non-equilibrium coexistence of plants. Bull. Torrey Bot. Club, 107:238-248.

Platt, W.J. 1975. The colonization and formation of equilibrium plant species associations on badger disturbances in a tallgrass prairie. Ecol. Monogr., 45:285-305.

Reichman and Smith, S. C. 1985. Impact of pocket gopher burrows on overlying vegetation. J. Mammal., 66:720-725.

Rogers, William E., Hartnett, David C., Elder, Bradley. 2001. Effects of Plains Pocket Gopher (Geomys bursarius) Disturbances on Tallgrass-prairie Plant Community Structure. Am. Midl. Nat. 145:344-357.

Weekley, Carl W. and Menges, Eric S. 2003. Species and vegetation responses to prescribed fire in a long-unburned, endemic-rich Lake Wales Ridge scrub. Journal of the Torrey Botanical Society. 130(4):265-282.