JOURNAL OF HERPETOLOGY

Comparison of Gopher Tortoise (*Gopherus polyphemus*) Burrow Density in Zones Exposed to Variable Fire Frequency in Jonathan Dickinson State Park, Florida

ALEJANDRO GARCIA[1], JULIANA OSORIO[1], JESSICA MILES[1,3], AND NATASHA WARRAICH[2]

[1]*Department of Environmental Science Technology, Palm Beach State College, Palm Beach Gardens, Florida 33410 USA*

[2]*Jonathan Dickinson State Park, Hobe Sound, Florida 33455 USA*

[3] *Corresponding Author. Email: milesj@palmbeachstate.edu*

ABSTRACT.— Gopher Tortoises (*Gopherus polyphemus*) are threatened throughout much of their range, and their populations are under review in Florida and other locations. Fire is a very important aspect of this species' ecology because it supports the growth of the grasses and soft-stemmed plants Gopher Tortoises depend on for food. We conducted transect surveys in Jonathan Dickinson State Park, Florida to determine Gopher Tortoise burrow density in scrubby flatwoods habitat located in zones that were exposed to fire, through prescribed burning, of variable temporal frequency. Additionally, we examined the percentage of burrows that were active, inactive, or abandoned in the zones of variable fire frequency. We found that there were significantly more Gopher Tortoise burrows in transects conducted in high burn frequency zones than in low burn frequency zones, showing that a higher burn frequency for a habitat positively impacts Gopher Tortoise populations. There was no significant difference in the percentages of active, inactive, and abandoned burrows related to burn frequency of the habitat, suggesting that individual burrowing behavior of Gopher Tortoises is not affected by burn frequency.

Key words: Fire; Flatwoods; Prescribed burn; Transect survey

Gopher Tortoises (*Gopherus polyphemus*) are currently listed by the U.S. Fish and Wildlife Service (USFWS) as threatened for populations occurring west of the Mobile and Tombigbee Rivers in Alabama, Mississippi, and Louisiana, and is under review in Florida and other locations (Auffenberg and Franz, 1978; Florida Fish and Wildlife Conservation Commission, 2007). Although threats to the species vary regionally, there is a critical need for information on the status and trends of populations across the range (McCoy and Mushinsky, 1992; Mazzotti et al., 2006; US Army Corps of Engineers, 2009; Berish et al., 2012). Abundance estimates are a prerequisite for the listing or delisting of a species and for monitoring the recovery progress; furthermore, estimates of abundance are needed for understanding density-dependent relationships, for parameterizing and evaluating population models, and for formulating or evaluating management programs (Nomani et al., 2008).

Although there are a variety of management practices in use for Gopher Tortoises, one of the most important is prescribed fire (Yager et al., 2007; Ashton et al., 2008). Burning xeric habitats reduces hardwood coverage and also stimulates grass growth (Carlson et al., 1993), which is a major food source for the tortoise (Diemer, 1986; State of Florida Department of Environmental Protection Division of Recreation and Parks, 2000). Gopher Tortoises are not the only wildlife that benefit from prescribed fires, as significant increases in land use in recently burned areas have been observed from other wildlife (Main and Richardson, 2002). There are suggestions that Gopher Tortoises will emigrate from an area as the suitability of their habitat decreases (McCoy and Mushinsky, 1994).

Populations of *Gopherus polyphemus*, an important (“keystone”) species in upland habitats, have been declining at an alarming rate throughout Florida for some time (McCoy et al., 2006; Smith et al., 2013). However, Gopher Tortoises has been found in scrub, sandhills, wet flatwoods, and disturbed sites within Jonathan Dickinson State Park (JDSP), Florida, which supports many unique natural features and significant cultural resources (State of Florida Department of Environmental Protection Division of Recreation and Parks, 2000).

One commonly used method of estimating Gopher Tortoise populations is by conducting direct counts of burrows (Doonan and Epperson, 2001; Waddle et al. 2006). The population counts can involve transect surveys that cover a percentage of the whole area being surveyed or full site surveys covering the entire area can be completed (Smith and Stober, 2010). Based on the survey data, various correction factors are implemented, and Gopher Tortoise populations are then calculated subject to the number of active and inactive tortoise burrows (McCoy and Mushinsky, 1992).

The purpose of this study was to calculate the density of Gopher Tortoise burrows in select scrubby flatwoods habitats throughout JDSP and to compare the burrow density to the burn frequency of the selected zones. Although Gopher Tortoises have been documented in scrubby flatwoods, as well as various other habitat types at JDSP, this study represents a more exacting examination of Gopher Tortoise population density at the park in this habitat type. It is predicted that more burrows will be found in zones that have been burned more frequently since suitable Gopher Tortoise habitat depends on a regular interval of prescribed fire to reduce shrub and hardwood encroachment and to stimulate growth of soft-stemmed plants serving as groundcover and food (Carlson et al., 1993; State of Florida Department of Environmental Protection Division of Recreation and Parks, 2000; Florida Fish and Wildlife Conservation Commission, 2013). This study aims to improve knowledge related to how Gopher Tortoise burrow density is correlated to habitat burn frequency and in the determination of how effectively these areas are being managed, in regard to prescribed burning, for the protection and support of Gopher Tortoise populations.

This study also examined the ratio of active, inactive, and abandoned burrows in transects in high burn frequency zones compared to transects in low burn frequency zones. We hypothesized that there would be significantly more inactive and abandoned burrows in transects in low burn frequency zones, suggesting that Gopher Tortoises are prone to relocate more frequently in these zones in an attempt find a suitable habitat (McCoy and Mushinsky, 1994; Yager et al., 2007; Ashton et al., 2008). This study's results could be a potential source of knowledge for other state parks or managed areas where Gopher Tortoises are found, helping land managers decide if they want to reintroduce prescribed burning in fire suppressed areas and/or increase or decrease the burn frequency to sustain or influence Gopher Tortoise populations.

MATERIALS AND METHODS

We conducted this study at Jonathan Dickinson State Park (JDSP), which is located in Martin and Palm Beach counties, 19 km south of Stuart on U.S. Highway 1, and covers an area of 46,421,247.21 m^2 (State of Florida Department of Environmental Protection Division of Recreation and Parks, 2000). We surveyed Gopher Tortoise burrow density at JDSP in select land management burn zones that differed in burn frequency as a result of management decisions for prescribed burning at the park. Most zones contain more than one habitat, therefore, only certain portions of each zone were relevant for our study. We sampled zones D06, D07, G05, B15, B19, B26 and C10 because they contained enough scrubby flatwoods habitat to complete at least one full transect and represented varied burn frequency (Fig. 1). Zones D06, D07, B26, and G05 consisted of mostly mesic flatwoods and scrubby flatwoods and had relatively high burn frequency. Zones B15, B19, and C10 consisted of mostly scrub and scrubby flatwoods, and had relatively low burn frequency. This is because there was less scrubby flatwoods in each high frequency burn zone than in each low frequency burn zone, therefore more zones were needed to complete equal amount of transects as those done in low burn frequency zones. Although there is an unequal number of high frequency burn zones to low frequency burn zones, the number of transects were eight for each. Table 1 provides the total area of each zone in meters squared, the

Commented [E1]: Journal of Herpetology wants everything in SI units.

total area of scrubby flatwoods in each zone in meters squared, the number of times each zone has been burned since 1972, and the most recent burn date.

Data were collected for this study by Line Transect Distance Sampling (LTDS), which is the most statistically reliable sampling method when an accurate measurement of tortoise population number is needed (U.S Army Corps of Engineers, 2009; Smith and Strober, 2010). As recommended by the Florida Fish and Wildlife Conservation Commission (FWC), transects of 16 m (52.5 ft.) wide x 250 m (820 ft.) long (for a 4,046.9 m^2, or 1 acre area) were used to survey each of the zones. The width of each transect was measured using a tape measure, having two people hold both ends of the tape until the 16 m were reached. The length of each transect (250 m) was measured using a GPS unit (GARMIN eTrex Legend).

Sixteen transects were completed in total; eight in areas of high burn frequency and eight in areas of low burn frequency (Table 1). These transects were placed on a map using Google Earth Pro. Google maps and a compass were also used to help with orientation and location.

At each burrow found, we created and logged a GPS waypoint, took width measurement of the burrow, noted surrounding vegetation, and categorized and recorded the burrow as “Active”, “Inactive”, or “Abandoned” that are defined by the Florida Fish and Wildlife Conservation Commission (2008) as:

> Abandoned burrow – burrow appears unused and dilapidated. The entrance is partially or completely collapsed, and the burrow is partially or completely filled with leaves or soil. Recent rains, or recent activity by livestock or humans, do not appear to be the primary reason for burrow collapse. There are

no trails into the burrow that might indicate that a tortoise recently passed through the leaf litter or that a small tortoise is using a dilapidated, adult burrow.

Active burrow – burrow is in good repair, has the classic half-moon shaped entrance, and appears to be in use by a tortoise. These burrows generally have tortoise tracks or plastron scrapes clearly visible on the burrow floor or on the mound. The burrow floor often contains loose soil caused by tortoise activity. The burrow mound is usually clear of vegetation, and it may contain recently excavated soil. For burrow surveys and tortoise density determination, active burrows are combined with inactive burrows to create the potentially occupied classification.

Inactive burrow – burrow is in good repair, but does not show recent tortoise use. The lack of tortoise activity may be because of weather or season. These burrows have the classic halfmoon shaped entrance, but the soil on the burrow floor is usually hard-packed, as is the burrow mound. There are no tortoise tracks or recently excavated soil, either on the burrow floor or on the mound. The burrow mound may have vegetation growing on it or be partially covered with fallen leaves. For burrow surveys and tortoise density determination, inactive burrows are combined with active burrows to create the potentially occupied classification. (p.vi, viii)

After collecting data in each transect, the total number of Gopher Tortoise burrows for each transect was totaled. Using Microsoft Excel, we performed a Student T-test, assuming unequal variance, at an $\alpha = 0.05$, of the total number of Gopher Tortoise burrows in each transect located in zones of low burn frequency and areas of high burn frequencies. Because active burrows are a good predictor of Gopher Tortoise numbers across populations ($r = 0.90$), we calculated Gopher Tortoise density by dividing the number of active burrows by the area surveyed (McCoy and Mushinsky, 1992). We also performed a Student T-test analysis, assuming equal variance at an $\alpha = 0.05$, of the percentages of active, inactive, and abandoned burrows in high burn frequency zones versus low burn frequency zones.

RESULTS

We found significantly more ($P = 0.00024$) Gopher Tortoise burrows in high burn frequency transects as compared to areas of low burn frequency (Fig. 1), with a total of 23 burrows and a mean of 2.75 burrows in low burn frequency zones compared to a total of 90 burrows and a mean of 9.38 burrows in high burn frequency zones. There was a density of four Gopher Tortoises per transect done in high burn frequency zones, and a density of 1.375 Gopher Tortoises per transect done in low burn frequency zones (Fig. 2). There was no significant difference in the percentage of active ($P = 0.95$), inactive ($P = 0.75$), and abandoned burrows ($P = 0.31$) in zones of high burn frequency versus zones of low burn frequency (Fig. 3).

DISCUSSION

The results show that frequent burns are beneficial to Gopher Tortoises. These results support the stated hypothesis. Frequent burns prevent the growth of hardwoods and stimulate the growth of grasses and other soft-stemmed plants (Carlson et al., 1993). We observed this repeatedly during the surveys. Many times it was difficult to walk the transects in the zones of low burn frequency because of the heavy density of tall woody shrubs. Grasses were infrequently observed in the low burn zones, and the ground was often shaded by the shrubbery above and covered in a layer of leaf litter. This is important given that grasses are a major food source for

Commented [E2]: The Journal wants the value of *p* in each context.

Gopher Tortoises, sunlit ground is needed for nesting, and loose soil is needed for burrow construction (Diemer, 1986). It is also worth noting that the dense shrubbery we observed would likely greatly hinder Gopher Tortoise maneuverability.

Other research regarding fires in this habitat type state that the greatest benefits come from the most frequent fires, showing that burning an area as often as the fuel within the area permits causes the greatest growth of grasses and other herbaceous plants (Glitzenstein et al., 2003). The present study's data support this hypothesis because Gopher Tortoise burrows were most frequently found in high burn frequency zones.

Gopher Tortoise populations have been shown to migration from unsuitable habitat to one that is more suitable (Mushinsky and McCoy, 1994). Previous research has found that Gopher Tortoise density dropped from nine individuals per hectare to zero after 16 years of fire suppression, and other researchers have observed that Gopher Tortoises will migrate to more recently burned areas and establish new burrows (Yager et al., 2007; Ashton et al., 2008).

The fact that there was no significant difference between the percent of burrows that were active, inactive, and abandoned between the two groups may suggest that, although the size of Gopher Tortoise populations may differ, the burrowing behaviors of the tortoises in each group is the same. It would appear that the rate that Gopher Tortoises build new burrows, neglect already built burrows, and abandon burrows is not affected by the frequency of fire in their location. One explanation for the possible incongruity of this finding with previous studies showing tortoises emigration and, by extension, burrow abandonment in areas of low burn frequency may involve the locations in which we conducted our surveys. Two of the three low frequency burn zones (B15 and B19) we selected did not border zones of high burn frequency. The other burn zone (C10) bordered by a zone with a relatively higher burn frequency (C09);

however, most of the habitat usable to Gopher Tortoises in C09 is not accessible to them from C10 because of a long stretch of swamp close to the border of the two zones. Therefore, it is possible that an increased number of abandoned burrows in transects done in these low burn frequency zones was not observed because Gopher Tortoises will only migrate to more frequently burned habitats if these habitats are in close proximity to their current location. Further research is needed in this regard.

This study suggests that for the management of JDSP to improve the density of Gopher Tortoises in the park, it would do well to match the frequency of burns in zones of low frequency with that of zones of high burn frequency. Further studies are needed to support this, as well as to determine if a higher burn frequency throughout the park as a whole could benefit Gopher Tortoise populations. Future research could aim to establish the optimum burn frequency for this habitat type and for this species and that finding would assist land management teams in encouraging an increase in their population size for areas where they are depleted or declining.

Acknowledgments — The authors thank R. Rossmanith and C. Kerkela for logistical help and assistance in site selection. We thank A. Collins, C. Kerkela, S. Tedford, A. E. Birdsong, J. A. Adams, J. Cummings, S. Svec, and S. Kim with assistance with the field work. We express our appreciation to Florida Department of Environmental Protection for the permit for research within Jonathan Dickinson State Park (01201545).

LITERATURE CITED

Ashton, K. G., Engelhardt, B. M., & Branciforte, B. S. (2008). Gopher Tortoise (*Gopherus polyphemus*) abundance and distribution after prescribed fire reintroduction to Florida scrub and sandhill at Archbold Biological Station. Applied Herpetology 42:523-529.

Auffenberg, W. and Franz, R. (1978). *Gopherus polyphemus* in Catalog of American Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles. pg. 215.1.

Berish, J. E. D., Kiltie, R. A., & Thomas, T. M. (2012). Long-Term population dynamics of gopher tortoises (*Gopherus polyphemus*) in a pine plantation in northern Florida. Chelonian Conservation and Biology 11:50-58.

Carlson, P. C., Tanner, G. W., Wood, J. M., Humphrey, S. R. (1993). Fire in Key Deer habitat improves browse, prevents succession, and preserves endemic herbs. The Journal of Wildlife Management 57:914-928.

Diemer, J. E. (1986). The ecology and management of the gopher tortoise in the southeastern United States. Herpetologica 42:125-133.

Doonan, T. J., Epperson, D. M. (2001). Gopher tortoise *(Gopherus polyphemus)* populations on Naval Air Station Cecil Field, Florida: structure, prevalence of upper respiratory tract disease, and activity patterns. Florida Fish and Wildlife Conservation Commission Bureau of Wildlife Diversity Conservation.

Florida Fish and Wildlife Conservation Comission (FWC). (2008). Gopher tortoise permitting guidelines (*Gopherus polyphemus)*

Florida Fish and Wildlife Conservation Commission (FWC). (2013). A landowner’s guide managing habitat for gopher tortoises.

Glitzenstein, J. S., D. R. Streng, and D. D. Wade. (2003). Fire frequency effects on longleaf pine (*Pinus palustris*) vegetation in South Carolina and north-east Florida, USA. Natural Areas Journal 23:22-37.

McCoy, E. D., and H. R. Mushinsky. (1992). Studying a species in decline: Gopher Tortoises and the dilemma of "correction factors' Herpetologica 48:402-407.

McCoy, E. D., Mushinsky, H. R., & Lindzey, J. (2006). Declines of the gopher tortoise on protected lands. Biological Conservation128:120-127.

Mushinsky, H. R., and E. D. McCoy. 1994. Comparison of Gopher Tortoise populations on islands and on the mainland in Florida. In R. B. Bury and D. J. Germano (eds.), Biology of North American Tortoises, pp. 39^17. U.S. Fish and Wildlife Service, Fish and Wildlife Research Report 13, Washington, DC.

Nomani, S. Z., Carthy, R. C., & Oli, M.K. (2008). Comparison of methods for estimating abundance of gopher tortoises. Applied Herpetology5:13-31.

Smith, L.S., Stober, J., Balbach, H.E., and Meyer, W.D. (2009). Gopher Tortoise Survey Handbook. US Army Corps of Engineers.

Smith, L.L., Stober, J.M. (2010). Total counts verses transects for estimating abundance of small gopher tortoise populations. The Journal of Wildlife Management, 74:1595-1600.

Smith, L. L., Steen, D. A., Connor, L. M., Rutledge, J. C. (2013). Effects of predator exclusion on nest and hatchling survival in the gopher tortoise. Journal of Wildlife Management 77:352-358.

State of Florida Department of Environmental Protection. Jonathan Dickinson State Park: Approved Unit Management Plan. Division of Recreation and Parks, 2012.

U.S. Fish & Wildlife Service. (2013). Southeast region fire management.

Waddle, J. H., Mazzotti, F. J., and Rice, K. G. (2006). Changes in abundance of gopher tortoise burrows at Cape Sable, Florida. Southeastern Naturalist, 5:277-284

Yager, L. Y., Hinderliter, M. G., Heise, C. D. Epperson, D. M. (2007). Gopher tortoise response to habitat management by prescribed burning. The Journal of Wildlife Management,71:428-434

Table 1. Burn zone attributes of areas studied at JDSP, including the total area of the zone, area of scrubby flatwoods habitat type (Area SF), year of last burn (YLB), and number of burns since 1972 (No. Burns).

Burn Zone Attributes				
Burn Zone	Total Area (m^2)	Area SF (m^2)	YLB	No. Burns
B15	752,715	364,217	2008	3
B19	303,514	149,734	2012	2
B26	232,694	25,293	2015	6
C10	252,928	126,667	2012	3
D06	398,615	50,181	2013	7
D07	238,765	84,984	2013	7
G05	918,636	89,031	2013	7

Table 2. Total number of Gopher Tortoise burrows (including active, inactive, and abandoned) found in each transect in high burn frequency zones compared to low burn frequency zones.

Number of Gopher Tortoise Burrows	
High Burn Frequency Transects	Low Burn Frequency Transects
12	2
11	3
11	3
11	3
8	5
12	2
6	4
4	0

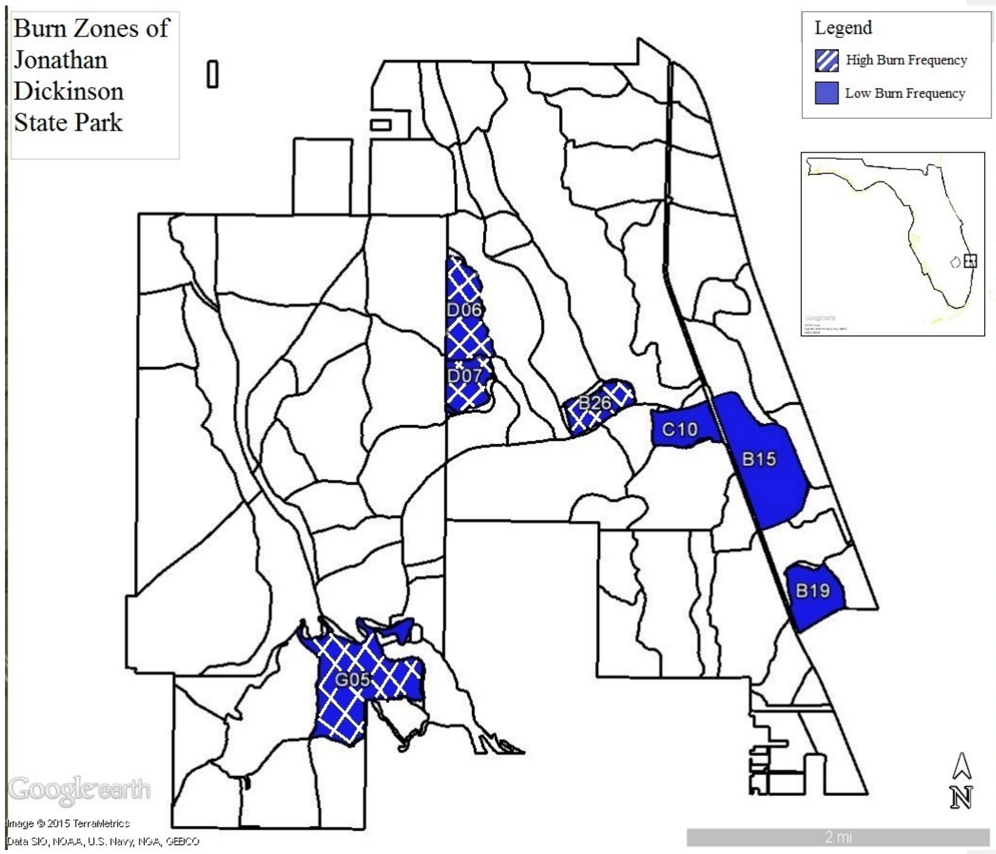

FIG. 1. — Surveyed burn zones of JDSP, showing the zones that were categorized as high burn frequency versus low burn frequency.

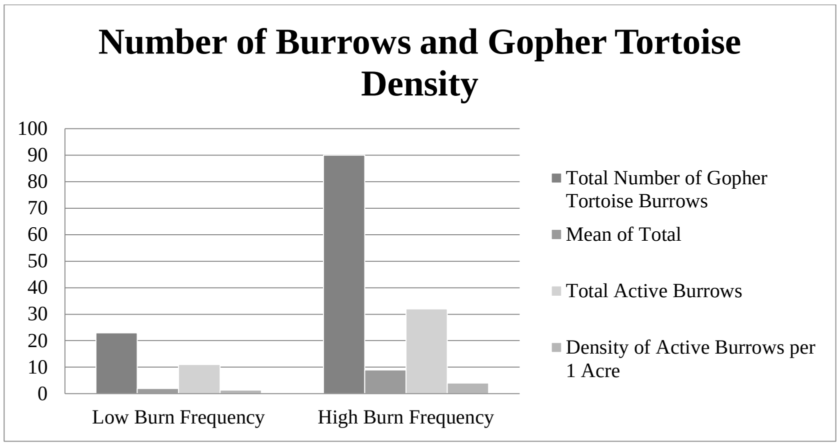

FIG. 2 — Total number of Gopher Tortoise burrows (including active, inactive, abandoned), total number of active burrows only, the mean of the total number of burrows found, and the average density of active Gopher Tortoise burrows per transect (4046.9 m^2) found in zones of high burn frequency and zones of low burn frequency.

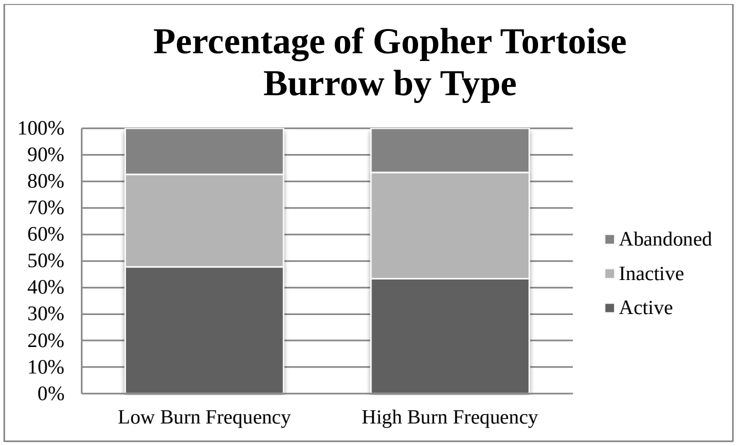

FIG. 3. — Percentage of Gopher Tortoise burrows by type (active, inactive, or abandoned), in low burn frequency zones and high burn frequency zones.

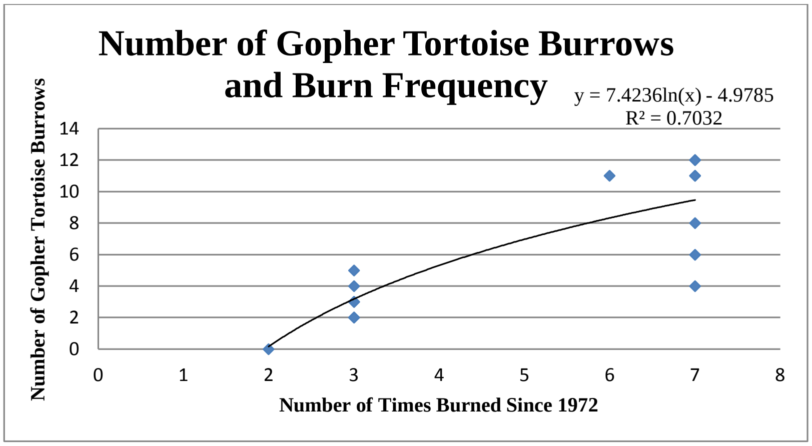

Figure 4. Scatter plot with a logarithmic trend line and r^2 value of the total number of gopher tortoise burrows per transect related to the total number of burns in that zone since 1972.