SUPPLEMENTAL INFORMATION

GOPHER TORTOISE (*GOPHERUS POLYPHEMUS*) DENSITIES AND HABITAT SUITABILITY ACROSS A XERIC-MESIC GRADIENT IN PENINSULAR FLORIDA, USA

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Detection Model Comparisons

We assessed the fit of each detection model listed in Table 2 using Kolmogorov-Smirnov tests and by examining the shape of the detection curve and the linearity of the quantile-quantile plot (Thomas et al. 2010; Buckland et al. 2015). Detection plots show fitted detection functions (lines) and a histogram of detection distances, scaled so that the area under the histograms matches that of the detection functions. It should be noted that the scaled histograms of detection distances should not be interpreted as detection probability. Quantile-quantile plots display the expected distribution of distances predicted by the model against the observed distribution. Well-fitted models will follow a 1:1 ratio. When models were equally well supported, as indicated by Akaike's Information Criterion (ΔAIC_C) ≤ 2, we deemed the model with the lowest coefficient of variation (CV) and/or the one with the most probable detection curve to be the best model for estimating tortoise density and population size.

The following figures display the detection plots (left panels) and quantile-quantile plots (right panels) of competing models ($\Delta AIC_C \leq 2$) estimating abundance of adult- and subadult-sized Gopher Tortoises in scrub, pine, and prairie communities on Avon Park Air Force Range. We also provide histograms of perpendicular distances of tortoise detections (scrub and pine communities) and burrow detections (prairie communities) that were used in modeling detection probability.

Scrub Communities

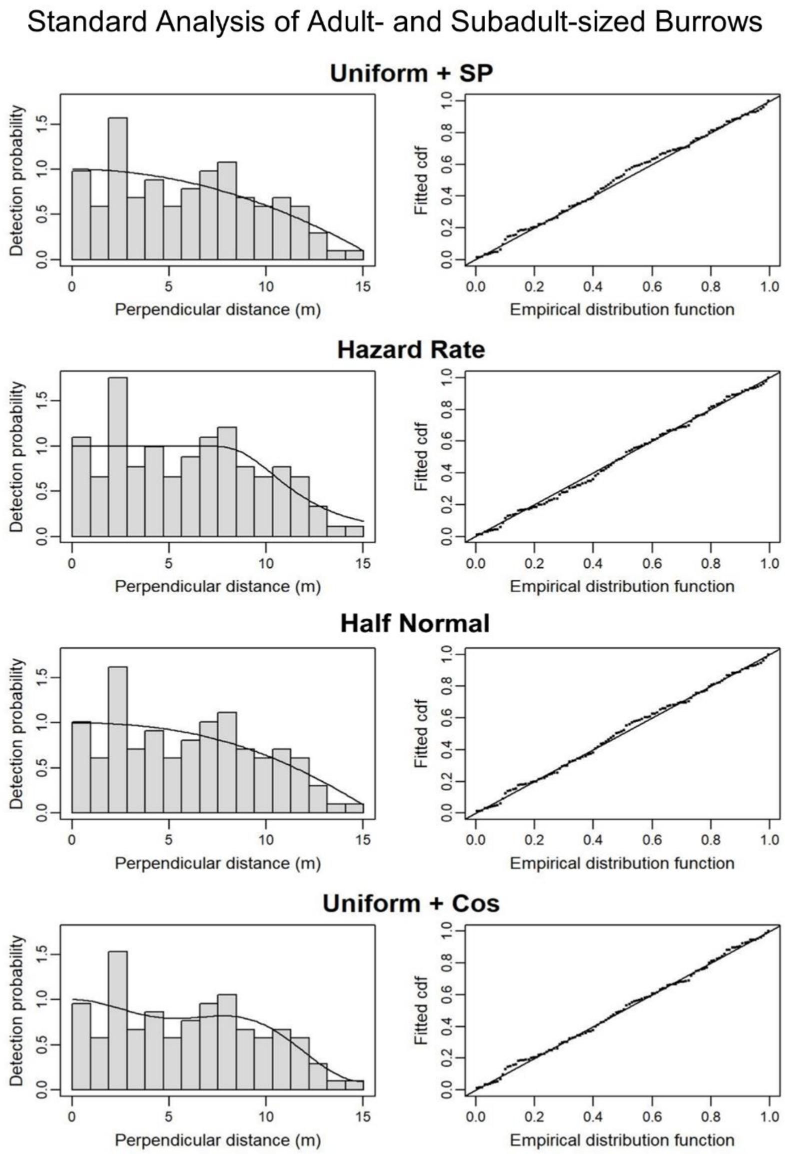

Figure S1. Models used a standard analysis of n = 114 subadult- and adult-sized occupied burrow detections (after 5% truncation) from LTDS surveys completed in scrub communities January−April 2022. Plots are ordered by decreasing model support (ΔAIC_C values from 0 to 2). We identified the shape of the detection curves resulting from the Uniform + Simple Polynomial and the Half Normal models to best match our methodology. Based on the lowest CV, we chose the Uniform + Simple Polynomial model as the best fit to our data.

Pine Flatwoods and Plantation Communities

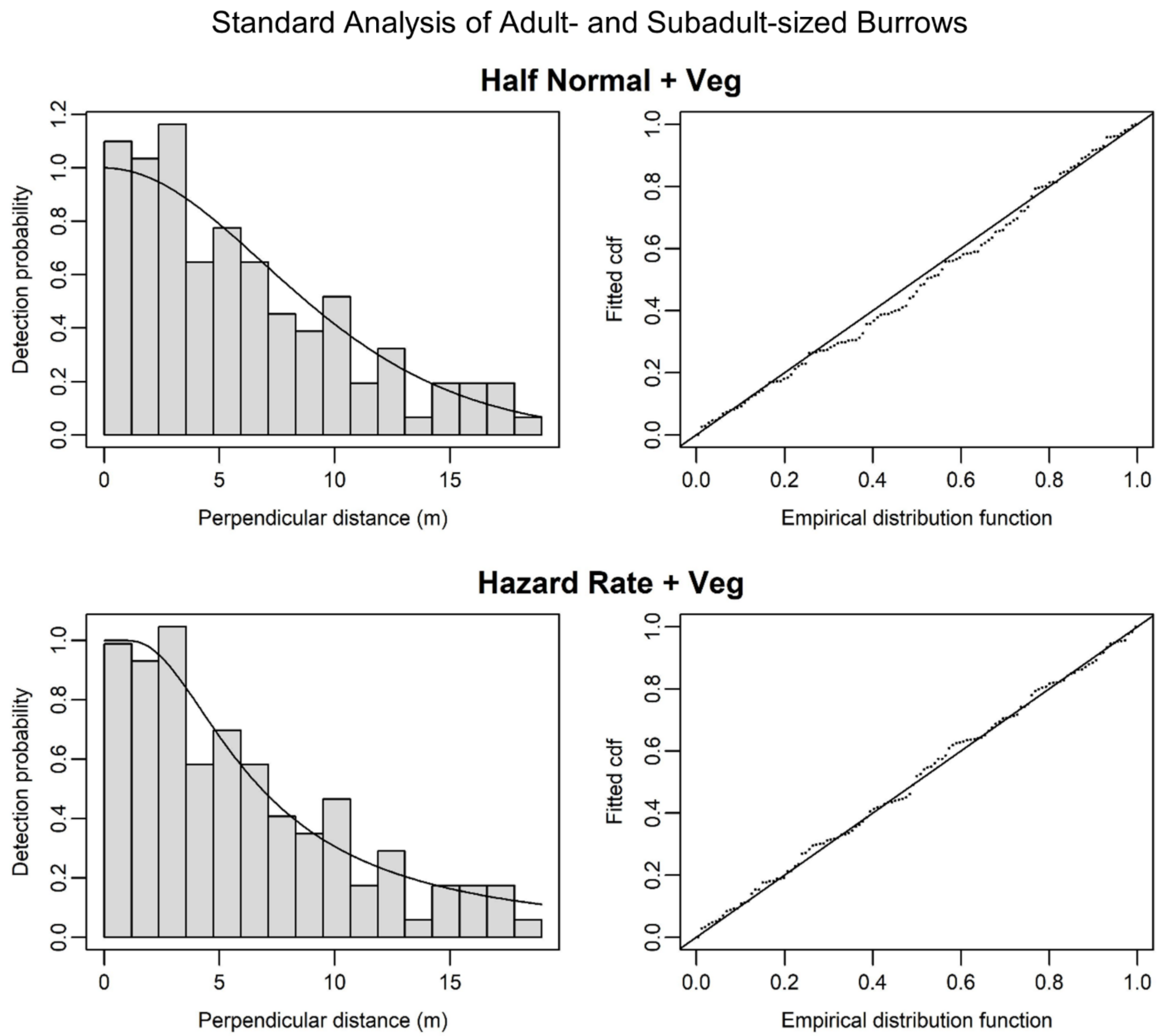

Figure S2. Models used a standard analysis of n = 123 subadult- and adult-sized occupied burrow detections (after 5% truncation) from LTDS surveys completed in pine communities March−May 2023. Models included vegetation concealment as a covariate. Plots are ordered by decreasing model support (ΔAIC_C values from 0 to 2). We chose the Hazard Rate + Vegetation Concealment model as the best fit to our data as it had higher goodness-of-fit compared to the Half Normal model.

Prairie Communities

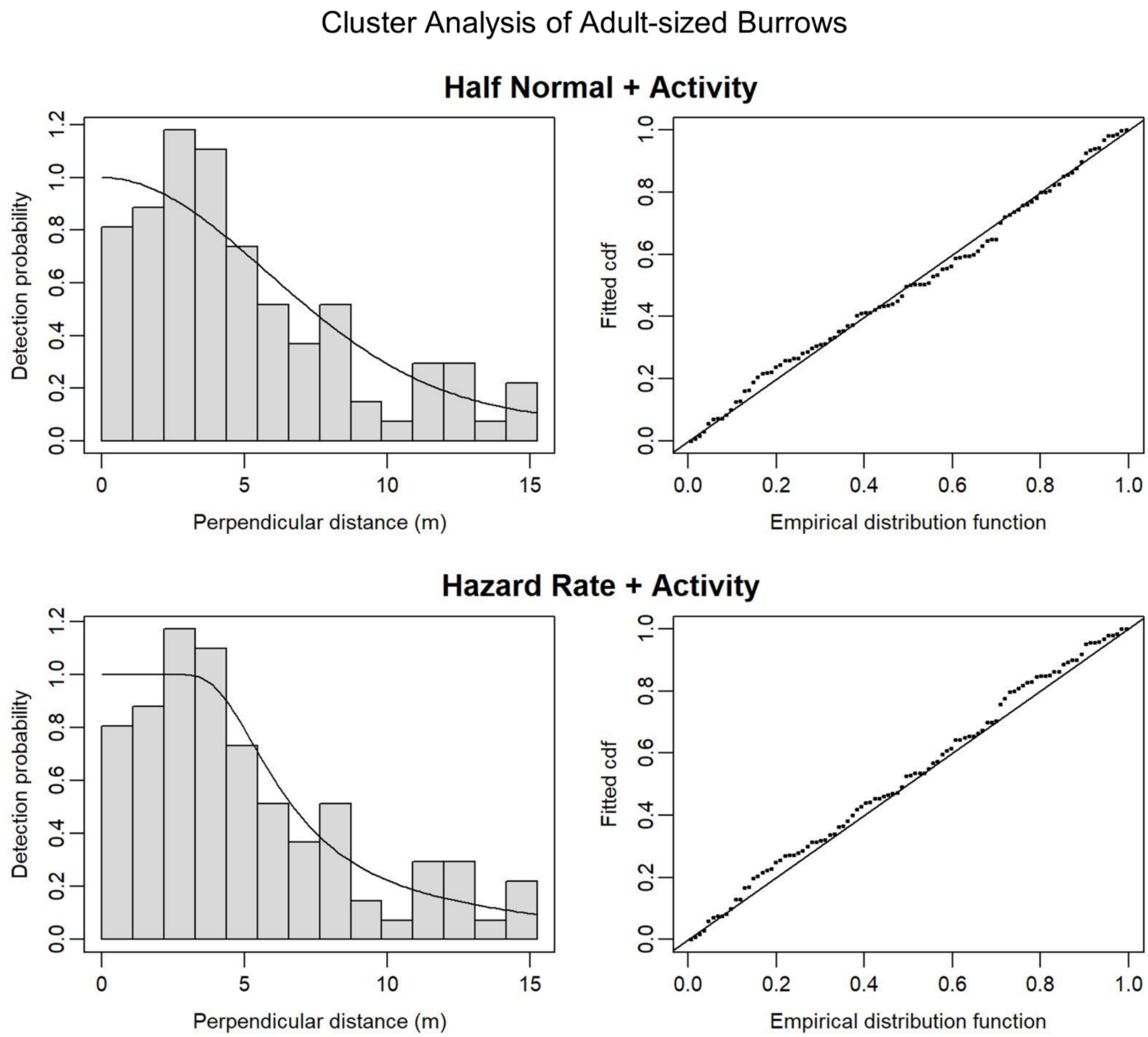

Figure S3. Models used a cluster analysis of n = 98 adult-sized usable burrows and n = 19 adult tortoise detections (after 5% truncation) from LTDS surveys completed in prairie communities May 2022. Models included burrow activity status as a covariate. Plots are ordered by decreasing model support (ΔAICC values from 0 to 2). We chose the Half Normal model as the best fit to our data based on shape and goodness-of-fit.

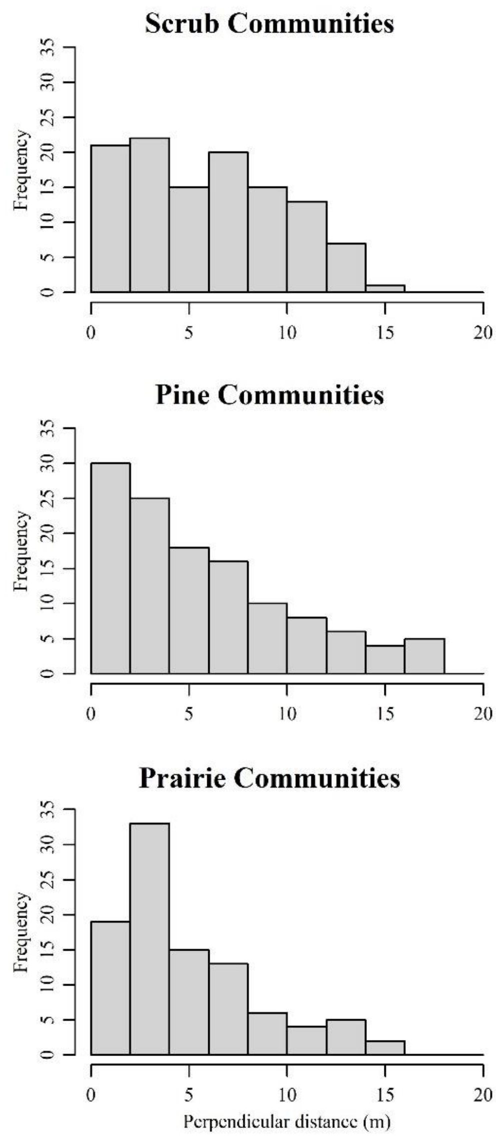

Figure S4. Histograms of perpendicular distances of tortoise detections (scrub and pine communities) and burrow detections (prairie communities) that were used in modeling detection probability. These plots are often used to indicate whether model assumptions are met, i.e., all burrows on the transect itself are detected and detection probability decreases with increasing distance from the transect. The spike of detections in prairies approximately 3 m from the transect line indicates possible violations of these assumptions. Prairies were characterized by high density of grasses that often draped over the entrances and aprons of burrows, making them hard to see from above and possibly resulting in imperfect detection on the centerline. On the other hand, 3 m from the transect corresponds to an overlap in search area between the center and side observers, possibly resulting in an increased detection probability. Although we cannot confidently explain this observation, we moved forward with our analysis to obtain preliminary data for this poorly studied habitat.

Combining density and variance estimates across geographic strata

Prepared by Kameron C. Voves in communication with Eric Rexstad

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Density Estimation

When the study area of interest consists of multiple geographic regions, each of which has an associated density estimate ($\widehat{D_i}$), the density within the entire study area ($\widehat{D}$) is a weighted average of the individual regional densities.

$$\widehat{D} = \sum \frac{A_i}{A_{total}} \widehat{D}_i$$

Where $\widehat{D_i}$ and A_i are the density estimates and areas of each geographic region, and A_{total} is the size of the entire area of interest.

Variance Estimation

The variance of the density estimate for the study area is the accumulated variance in the region-specific density estimates (the squares of the standard errors) using the same weighting factor in the density estimate calculation.

$$Var(\widehat{D}) = \sum \left(\frac{A_i}{A_{total}}\right)^2 Var(\widehat{D}_i)$$

Confidence Interval Estimation

Having obtained $Var(\widehat{D})$ and $\widehat{D}$, an approximate log-based confidence interval can be calculated using z_a as the critical value where the right-tailed area under a standard normal distribution is equal to alpha. We used z_a = 1.96.

$$\widehat{D} \div C, \widehat{D} \times C$$

Where $$C = exp\left[z_a \times \sqrt{\{\widehat{var}(log_e\widehat{D})\}}\right]$$

And $$\widehat{var}(log_e\widehat{D}) = log_e\left[1 + \frac{\mathrm{Var}(\widehat{D})}{\widehat{D}^2}\right]$$

This is the method used by DISTANCE, except z_a is replaced by a slightly better constant that reflects the actual finite and differing degrees of freedom of the variance estimates. It should be noted that, "the use of the normal distribution to approximate the sampling distribution of $log_e\widehat{D}$ is generally good when each component of $log_e\widehat{D}$ (e.g. $Var(n)$ and $Var[\widehat{f}\ (0)]$) is based on sufficient degrees of freedom (say 30 or more)…When component degrees of freedom are small, it is better to replace z_a by a constant based on a t- distribution approximation," (Section 3.6.1 of Buckland et al. 2001).

Coefficient of Variation Estimation

Having obtained $Var(\widehat{D})$ and $\widehat{D}$, a coefficient of variation for the entire study area can also be estimated.

$$\widehat{CV} = \frac{\sqrt{var(\widehat{D})}}{\widehat{D}}$$

Estimation of global density and variance for Avon Park Air Force Range

Note: The final calculations were completed using more significant figures than shown here. Some discrepancies may arise if the following calculations were to be duplicated.

Step 1: Estimate global density $(\widehat{D})$**and variance** $Var(\widehat{D})$

Habitat	A_i	$\widehat{D}_i$	$Var(\widehat{D}_i)$	$\frac{A_i}{A_{total}}\widehat{D}_i$	$\left(\frac{A_i}{A_{total}}\right)^2 Var(\widehat{D}_i)$
Scrub	2,493	0.9541	1.315E-02	0.2613	9.862E-04
Flatwoods	3,211	0.7324	1.216E-02	0.2583	1.513E-03
Plantations	1,244	0.4433	1.507E-02	0.0606	2.814E-04
Dry-mesic prairie	905	0.3654	1.435E-02	0.0363	1.418E-04
Mesic prairie	1,252	0.0422	1.010E-03	0.0058	1.908E-05
Column sums	A_{total} = 9,104			$\widehat{D}$ = 0.6223	$Var(\widehat{D})$ = 2.942E-03

Table S1. Values used to estimate global density $(\widehat{D})$ and its associated variance $Var(\widehat{D})$ across habitat strata on APAFR. Units of measurement are ha (area) and adult and subadult tortoises per ha (density).

Step 2: Estimate the confidence interval around the global density $(\widehat{D})$

$$\widehat{var}\left(log_e\widehat{D}\right) = log_e\left[1 + \frac{\mathrm{Var}(\widehat{D})}{\widehat{D}^2}\right] = log_e\left[1 + \frac{2.942\mathrm{E}{-03}}{(0.6223)^2}\right] = 7.568\text{E-03}$$

$$C = exp\left[z_a \times \sqrt{\left\{\widehat{var}\left(log_e\widehat{D}\right)\right\}}\right] = exp\left[1.96 \times \sqrt{7.568\mathrm{E}-03}\right] = 1.186$$

$$\text{Lower bound} = \widehat{D} \div C = 0.6223 \div 1.186 = 0.5247 \text{ tortoises/ha}$$

$$\text{Upper bound} = \widehat{D} \times C = 0.6223 \times 1.186 = 0.7380 \text{ tortoises/ha}$$

Step 3: Estimate the corresponding coefficient of variation

$$\widehat{CV} = \frac{\sqrt{var(\widehat{D})}}{\widehat{D}} = \frac{\sqrt{2.942\text{E}{-03}}}{0.6223} = 0.0872$$

Step 4: Estimate abundance within the total area of suitable habitat

Table S2. We estimated abundance for pine communities by multiplying the densities and associated confidence intervals (generated using Program Distance) by the total area of suitable habitat for each community. We similarly estimated abundance across all communities on APAFR by multiplying the global density and associated confidence interval (calculated above) by the total area of all suitable habitats on APAFR. Units of measurement are ha (area), number of adult and subadult tortoises per ha (density), and number of adult and subadult tortoises combined (abundance).

Habitat	**Suitable habitat (ha)**	**Tortoise density**		**Tortoise abundance**	
		D	**95% CI**	**N**	**95% CI**
Flatwoods	7,018	0.7324	0.5457 – 0.9830	5,140	3,830 – 6,899
Plantations	3,302	0.4433	0.2592 – 0.7581	1,464	856 – 2,503
All communities	15,053	0.6223	0.5247 – 0.7380	9,367	7,899 – 11,109