Accuracy of Red Imported Fire Ant (Hymenoptera: Formicidae) Mound Density Estimates

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ABSTRACT We compared red imported fire ant (*Solenopsis invicta* Buren) mound population density estimates in the Texas Coastal Prairie using distance sampling, belt transects, and complete counts. Complete counts were conducted after vegetation on the plots had been removed using prescribed burning. Mean *S. invicta* mound population density estimates did not differ among the three methods (F = 1.22; df = 2, 14; P = 0.344). Estimates of detectability of *S. invicta* mounds within the belt transects were 89.9-100%. We report estimated transect lengths required for determination of *S. invicta* mound densities at given levels of precision with distance sampling.

KEY WORDS belt transects, distance sampling, prescribed burning, line transect, red imported fire ant, *Solenopsis invicta*

The red imported fire ant (*Solenopsis invicta* Buren) is projected to eventually expand its range to include nearly 25% of the United States (Vinson and Sorenson 1986). This invasion has impacted production of agricultural crops (Adams et al. 1983, 1988) and wildlife resources (Allen et al. 1994) throughout the southeastern United States. Assessing the effects of *S. invicta* requires accurate and efficient techniques for determining its abundance.

Because ants are social insects, estimates of ant abundance are often based on colony population densities. Each *S. invicta* colony is characterized by a mound of bare soil that averages 5-7 cm high within 90 d of colony founding and 25-30 cm high after 3 yr (Markin et al. 1973). Researchers have estimated mound population densities by sampling with belt transects (Porter et al. 1992) and circular plots (Allen et al. 1995). The accuracy of these techniques may be influenced by differences in mound detection caused by variable plant density. Researchers typically assume that all *S. invicta* mounds are counted within sample areas or that their estimates are biased negatively to the extent that mounds are overlooked.

Biologists frequently estimate the proportion of objects or individuals that were overlooked, or conversely, their detectability, to improve accuracy of density estimates. One method for estimating detection functions and resultant densities is distance sampling (Buckland et al. 1993). Distance sampling is typically conducted along a line transect. The technique assumes that all objects on the transect line are detected, but probability of detection declines as distance increases from the transect line. The detection function can be constructed individually for each sample based on its characteristics. Thus, distance sampling can incorporate variability of detection into density estimates and may provide more accurate estimates of ant mound population densities, particularly in areas with dense vegetation.

The effect of vegetation density on detectability of *S. invicta* mounds may be determined by resampling after removal of vegetation. Prescribed burning is often used to improve habitat for wildlife and livestock, and is an effective technique for removing herbaceous vegetation. The objective of this study was to assess the accuracy of ant mound density estimates based on belt transects and distance sampling. We compared fire ant mound density estimates based on sampling with belt transects and distance sampling with true densities obtained by counting *S. invicta* mounds after removing vegetation with prescribed burning.

Materials and Methods

Study Area. We conducted this experiment in Refugio County, Texas. Climate was subtropical, with dry, mild winters (average daily temperature of approximately 14°C), and hot, humid summers (average daily temperature of approximately 28°C) (Guckian 1988). Average annual precipitation was approximately 97 cm. Soils were primarily deep, alkaline to slightly acid clays and sandy loams. Vegetation was typical Texas Coastal Prairie (Gould 1975).

Plot selection. We selected five, 150- x 150-m plots from areas with sandy loam soils and enough fine fuel for a prescribed burn. Plots were surrounded by a 7-m-wide disked strip, which served as a firebreak. Prior to burning, we delineated a 100- x 100-m core area in the middle of each plot within which *S. invicta* sampling was conducted.

Data collection/analysis. We estimated *S. invicta* mound population densities prior to burning using belt transects and distance sampling (Buckland et al. 1993). Nine, 100-m transects were sampled within each core area. We randomly placed the first transect 5-15 m from one side of the core area. The remaining eight transects were set parallel to the previous transect at a distance of 10 m. We measured the perpendicular distance (" 1 cm) to the center of all active ant mounds within 5 m of the transect line. Active mounds were identified as mounds with >15 *S.*

invicta present. All data were used to estimate mound density with distance sampling; mounds within 1 m of transects were used for belt transect estimates. The uniform cosine estimator of program DISTANCE was used to estimate ant mound density based on the perpendicular distance of ant mounds from the transect line (Laake et al. 1996).

Prior to burning, fine fuel load on each plot was determined from four, 0.25 m^2 quadrats clipped to ground level, oven-dried at 60°C, and weighed. Plots were burned on 2 March 1998 using the strip headfire technique to combust herbaceous standing crop and remove visual obstructions (Wright and Bailey 1982). All burns were completed on 2 March 1998. Fine fuel load on the five burned areas ranged from 2,340 to 3,170 kg/ha. Fire intensity was low, with ambient air temperatures of 21-24/C, relative humidities of 32-42%, and light winds (4-10 km/h). We counted all active mounds on the 100- x 100-m core areas within five days of burning using 5- x 100- m belt transects.

The experiment was analyzed as a randomized block design with five replicates (plots) and three treatments (sampling method). Estimated mound density in each plot for belt transect, distance sampling, and complete count data were compared using analysis of variance. Significance was assessed at α=0.05. Assumptions of normality and no block-treatment interaction were tested using the Shapiro-Wilk test (Shapiro and Wilk 1965) and Tukey's test for nonadditivity (Tukey 1949), respectively. Means are reported " 1 SE.

Results and Discussion

Mound density estimates of the three methods did not differ significantly (F = 1.22; df = 2, 14; P = 0.344; Table 1). Detection of ant mounds decreased with distance from the line transect for plots 1, 2, and 5. Based on the detection function derived by Program DISTANCE for these plots, we recorded 89.9, 97.3, and 98.1% of fire ant mounds within 100 cm and 70.8, 89.9, and 92.7% of fire ant mounds within 200 cm of the line transects, respectively.

The 2-m belt transects and distance sampling are accurate estimators of *S. invicta* mound densities in grassland habitats. Although distance sampling is more time consuming, it does not require the assumption that all fire ant mounds are observed. This benefit was not obvious in this study because of the similarity of our sites and the high detectability of fire ant mounds within the 2-m belt transects. Accuracy of belt transects would decrease if wider transects were used and/or if detectability of fire ant mounds was lower, such as in denser vegetation.

Buckland et al. (1993:298-312) provided guidelines for designing distance sampling surveys. Their equation for estimating required total transect length was based on the desired precision of the survey, the anticipated encounter rate, and an estimate of the variability of the data. Our encounter rates were 0.085-0.236 fire ant mounds per m of line transect and estimates of the variance component of this equation (*b* of Equation 7.1 in Buckland et al., 1993:303) were 0.6-2.5. For the largest variance estimate and the smallest encounter rate, estimated total transect lengths are 11,764, 2,941, and 735 m for 5, 10, and 20% coefficients of variation, respectively. For the largest variance estimate and the highest encounter rate, estimated total transect lengths are 4,237, 1,059, and 265 m for 5, 10, and 20% coefficients of variation, respectively. These estimates should be useful for researchers who are planning to survey fire ant mounds using distance sampling.

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Table 1. *S. invicta* mound population densities (mounds per ha) " 1 SE based on belt transects, distance sampling, and complete counts after removal of vegetation.

Plot	Belt Transects	Distance Sampling	Complete Counts
1	305.6 " 48.2	291.6 " 43.3	239.0
2	422.2 " 34.5	404.3 " 34.0	477.0
3	105.6 " 31.7	98.9 " 11.0	135.0
4	66.7 " 23.6	85.6 " 7.3	193.0
5	172.2 " 27.8	162.0 " 23.6	176.0
mean[a]	214.5a " 65.9	208.5a " 61.0	244.0a " 60.6

[a]. Mean densities followed by the same lower case letter within rows are not significantly different (ANOVA: F=1.22; df= 2, 14; P=0.344).