Geospatial Distribution of Ants Across Land-use Types

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Abstract

Ants play key roles in altering and enriching the ecosystems in which they're found. Due to their global prominence, ants have been used as bioindicators for decades, such as being used to measure the effects of rangeland grazing. This study examines the variation in the geospatial distribution of ants in the *Formica fusca* species group on the National Bison Range in Moiese, MT across three land-use types: lightly-grazed, cattle-grazed, and natural-grazed. In each land-use type, 3 50mx50m plots were surveyed for ant mounds, with mound location, volume, and inhabiting species recorded for each. The 144 total mounds found exhibited a dispersed distribution, possible due to territoriality among ant colonies, with mounds in the cattle area being more spread apart. No clustering with regard to volume was found, indicating established mounds aren't likely to be destroyed by large bovids.

Introduction

Ants (family Formicidae) are an ever-present, widely distributed eusocial insect, with nearly 1,000 species of ant occurring in North America alone (Fisher and Cover 2007). They play key roles in the ecosystems they inhabit, altering local soil conditions, changing vegetation communities, and enriching their surrounding area (Jones et al. 1994). There have been several studies that have examined the effect of ants on the vegetation surrounding their mounds. Beattie and Culver found that forb abundance around mounds drops off roughly 3.5m away from the nests (1977). A study by Carlson and Whitford (1991) suggests that the plant community composition adjacent to the nests is heavily influenced by myrmecochory (seed dispersal by ants). Additionally, a study performed at the National Bison Range found that the presence of *Peromyscus* *maniculatus* burrows further alter the plant community around an ant mound (Collins 2008). Though ants have been studied extensively in Europe, there is a general need for studies to be done on ants in North America, particularly the *Formica rufa* group, as relatively little is known about their role in the ecosystem and under what conditions they are likely to occur (Jurgensen et al. 2005).

With regards to their occurrence, several studies have found that ant mounds exhibit a clustered distribution (Risch et al. 2007, Dreyer and Park 1932), while others have found a uniform distribution of ant mounds (Carlson and Whitford 1991). Factors that have been found to influence the distribution of ant mounds in area include average annual precipitation, elevation, slope, vegetation type, productivity, light condition, soil type, disturbance, temperature, predation (primarily by bears), and competition from other species of ants (Risch et al. 2007, Kilpelainen et al. 2005, Jurgensen et al. 2005, Auger et al. 2004, Dreyer and Park 1932). Furthermore, mound size tends to increase with increasing age and growth of a population of ants (Dreyer 1942).

Due to their global prominence, ants have been used as ecological indicators for several decades. Particularly, studies have looked the indirect effects of rangeland grazing on ant community assemblages, finding that grazing alters the vegetative composition of an area, which consequently, has an effect on the ant communities (McIntyre 2003, Hoffmann 2010). In a recent literature survey on the responses of ant communities to grazing, Hoffmann (2010) found that, in 10 studies that looked at the effect of grazing on mound densities, 6 found densities decreased and 4 found that density did not change in response to an increased grazing regime. The same literature survey, however, found that soil type and vegetation composition exert more of an effect on ant communities than does disturbance (i.e. grazing). Of particular note, all 40 of the studies included in the literature survey looked only at the effect of grazing by livestock and not native ungulates.

A previous study conducted in grazed and lightly-grazed landscapes found that the presence of ants and/or *Peromyscus* spp. burrows altered the vegetation surrounding ant mounds in different ways, with distinctions becoming sharper in the cattle-grazed habitat (Collins 2008). In this study, I am examining the differences in geospatial distributions of ant mounds across three land-use types: lightly-grazed, cattle-grazed, and natural-grazed. Additionally, I will examine the variations in sizes, distances to nearest neighbors, and densities of ant mounds across the land-use types. I propose the following hypotheses: (I) Ant mounds in all land-use types should exhibit a clustered distribution, though the areas with less disturbance should be clustered to a greater degree than the more disturbed areas (lightly-grazed>natural-grazed>cattle-grazed) (II) Areas of higher disturbance should have lower densities of mounds that are further apart from each other than in areas of lower disturbance (III) Areas with higher grazing should have smaller (younger) mounds due to more frequent destruction by grazers (i.e. trampling, wallowing).

Materials and Methods

Study Sites

Data was collected from 19 July 2010 to 3 August 2010. Ant mounds were surveyed in several areas in and around the National Bison Range in Moiese, MT: the Alexander Basin area, the research triangle, and a private cattle-grazed pasture adjacent to the triangle (Figure 1). The triangle and cattle-grazed areas were used in a previous study as "lightly/non-grazed" and "cattle-grazed" areas, respectively (Collins 2008). Native ungulate grazers include mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), pronghorn antelope (*Antilocapra americana)*, and bison (*Bison bison).* The triangle site is an approximately 8ha enclosed area that excludes only bison. The Alexander Basin area is a "natural-grazed" site that does not disclude any native forager from the area. All three sites are next to each other, thereby controlling for differences in elevation and local climate.

Sampling

In each land-use type, ant mounds were chosen to be the center of a 50m x 50m plot, with 3 non-overlapping plots in each area (Figure 2). Each plot was surveyed for active ant mounds by walking North-South transects across the plot, using a compass affixed to a meter stick to ensure straight lines were followed. For each mound found, its GPS location was recorded using a Garmin eTrex Legend H and mound diameter and height were recorded. Additionally, each mound was aggravated to provoke the ants to swarm, allowing for collection of several individuals. Collected individuals were brought back to the lab and preserved by placing them in the freezer for several hours. With the aid of a dissecting microscope, ants were identified to genus using Fisher and Cover (2007).

Analysis/Statistics

As in Carlson and Whitford 1991, volume for each mound was calculated by assuming a conical shape. Each ant mound was mapped using ArcGIS 9.3. Each mound point identified the location of the mound, the ant species, volume, diameter, and height.

The Near analysis in ArcGIS was used to calculate the distance to the nearest mound for each mound. Additionally, the Average Nearest Neighbor tool was used to calculate the Average Nearest Neighbor ratio for each plot. The ratio represents the observed mean distance between each feature and their nearest neighbor divided by the expected mean distance for the features given a random pattern. Density of mounds per hectare was also calculated for each plot. Moran's I was calculated to examine clustering by volume in each plot (table 1). SYSTAT 13 was used to perform the following tests: Randomized blocks ANOVA of volume by land type, blocked by plot; regression analysis of volume versus distance; ANOVA of average nearest neighbor values by land type; Kruskal-Wallace and Randomized blocks ANOVA of distance by land, blocked by plot; ANOVA of density by land type; Kruskal-Wallace of Moran's I by land type.

Results

In total, 144 ant mounds were surveyed across the 3 land-use types. All mounds contained colonies of ants from the *Formica fusca* species group. Additionally, the slave maker of *F. fusca*, *Polyergus breviceps*, was collected from 3 of the mounds in the triangle area. To normalize the data, volume was log transformed and distance-to-nearest-mound ("distance") was square root transformed for all analyses. Analysis of variance, blocked by plot, was used to compare mound volume across landscape type, revealing nonsignificant differences among landscape types ($F_{2,6}$=0.455, p=0.635). Linear regression analysis of volume versus distance revealed no statistically significant relationship (R^2=0.003, p=0.527). An ANOVA of Average Nearest Neighbor values by land-use type revealed no statistically significant differences ($F_{2,6}$=0.286, p=0.183)

(Figure 3). Distance exhibited a Shapiro-Wilk p-value=0.048. A Kruskal-Wallace test of distance across land-use types yielded statistically significant differences among land-use types (Kruskal-Wallace test statistic:8.181, p=0.017). An ANOVA, blocked by plot, of the distance by land-use type, yielded a significant result ($F_{2,135}$=4.678, p=0.011) (Figure 4). The lack of difference between the parametric and nonparametric indicates the large sample size and the near-normality of the data makes up for the violation of normality, allowing for the use of parametric statistics. A Tukey's HSD test revealed that the distance between mounds is statistically significantly greater in the cattle-grazed area than in either the lightly-grazed (p=0.012) or natural-grazed (p=0.010) areas (no statistically significant difference between the lightly-grazed and natural-grazed areas with regard to distance). Analysis of variance revealed that density varies across habitat types ($F_{2,6}$=0. 7.971, p=0.02) (Figure 5). Tukey's HSD revealed that mound density is statistically significantly lower in the cattle-grazed area than in either the lightly-grazed (p=0.036) or natural-grazed (p=0.028) areas (no statistically significant difference between the lightly-grazed and natural-grazed areas with regard to distance). The Moran's I values that were calculated were compared across land-use types using a Kruskal-Wallace test, which found no statistically significant differences among land-use types (Kruskal-Wallace test statistic: 0.356, p=0.837).

Discussion

Though there were no statistically significant differences in the Nearest Neighbor ratios across land-use types, all ratios were above 1, indicating a tendency towards a dispersed distribution (≈1 indicates random, <1 indicates clustering) for all sites, with a nonsignificant trend towards the cattle-grazed site being more dispersed than the other two land-use types. However, when the distance between mounds and their nearest neighbors was analyzed, the mounds in the cattle-grazed area were found to be further apart than in either the triangle area or the Alexander Basin area. A prior survey of the three areas found statistically significantly lower species richness and statistically significantly higher bare ground in the cattle-grazed area than in other areas of the study, with the percent grass, forbs, and bare ground being similar between the Alexander Basin area and the research triangle (UNDERC-West 2010, unpublished data). Hoffmann (2010) found that soil and vegetation factors are the primary determinants of ant community composition, so the observation of statistically significantly lower densities and higher distances between mounds in the cattle-grazed area could be attributable to its sparse and less varied soil and vegetation conditions (relative to the other areas).

The dispersed distribution was contrary to the original hypothesis. Assuming constant climactic factors across plot in each of the sites, one would expect the vegetation and soil conditions in each plot to dictate the spatial distribution of the mounds (Risch et al. 2007, Kilpelainen et al. 2005, Jurgensen et al. 2005), with colonies clustering around preferred vegetation, as vegetative communities were not homogenous within each land-use type. What may be influencing the spatial distribution is territoriality of ant colonies, as intraspecific aggression is common among colonies of granivorous ants has been found to play an important role in the spatial distribution of ant mounds (Buckley 1982).

In previous studies that found a clumped distribution, across the survey area, areas with mounds were found to be clustered by precipitation, elevation, slope, aspect, and vegetation (Risch et al 2007), as well as proximity to forest and sunlight intensity, with mounds being situated in such a way as to maximize the amount of direct sunlight received (Dreyer and Park 1932). In finding a dispersed distribution, Carlson and Whitford (1991) made no mention of variation in climatic and light conditions within each of their sites. They instead attributed the dispersion to territoriality and aggression among ant colonies, which is likely to be the case in this study as well, as each site was in open grassland with elevation, slope, aspect being relatively constant within each plot. The trend towards a higher average nearest neighbor ratio in the cattle-grazed site suggests that each mound controls a larger territory in order to obtain enough resources, as the lower species richness of the cattle-grazed area likely has less favorable or lower quality vegetative resources than does the natural-grazed or the lightly-grazed areas. The statistically significant lower density of mounds in the cattle-grazed area supports this conclusion. Significantly lower density of mounds in the cattle-grazed area also lends credence to Hoffmann's (2010) literature review of 6 studies that found an increased grazing regime lowers mound density.

With the territoriality exhibited by ant colonies, it could be inferred that larger mounds, which are older and generally have larger populations (Dreyer 1942), would potentially need a larger territory in order to gather enough resources. However, regression analysis of volume by distance indicates no relationship between the two factors. Additionally, a lack of consistency within and among land-use types with regards to Moran's I measurements of volume seems to indicate there is no overall clustering by volume. Throughout all sampling plots, 2 plots from each land-use type exhibited a random distribution of volume. The remaining plot in each land-use type exhibited a tendency towards clustering by volume. These results seem to indicate that established mounds, once a mound is established, disturbance of an area by large bovids (cattle, bison) tends to not eliminate ant mounds from an area. Furthermore, these data indicate that, for this area, larger mounds do not prevent the establishment of new adjacent colonies, provided all mounds are still dispersed. It could, however, be more of an issue if the mounds were clustered around a resource, as competition for limited resources would be greater.

This study is unique in that it documents the response of ants to an increased grazing regime by both native ungulates and livestock, as all other literature on ant response to grazing look solely at livestock grazing (Hoffmann 2010). With the use of ant communities as bioindicators for disturbance, this study demonstrates that grazing by native ungulates disturb the environment statistically significantly less than cattle. More specifically, bison grazing (Alexander Basin area) was not found to exert a statistically significant impact on the distribution of ant mounds, while cattle grazing was found to significantly alter ant community dynamics, when compared to area that excludes bison and cattle (triangle area).

The lack of different species in the plots was surprising. With all 144 mounds, across the three different land-use types, all containing the same type of ant (*F. fusca* group), the species of ant dominated the area. In other areas ecosystems on the range, however, other genera of ants were collected, including *Camponotus* and *Lasius*, potentially indicating *F. fusca* tends to dominate open grassland areas. Future studies could perhaps examine ant communities across different ecosystems and elevations to see their effects on ant species assemblages. Additionally, all mounds surveyed were conspicuous aboveground nests, which is not the case for all types of ant, such as 19 of the 24 species of ants in the *Formica rufa* species group, which cover their mounds with organic debris (Jurgensen et al. 2005). The method of sampling in this study is limited to only sampling conspicuous, aboveground mounds observed within the plots. This constraint limits much potential analysis of ant species dynamics. However, given the conspicuousness of *F. fusca* mounds across land-use types, they are still a valuable metric in analyzing changes of community dynamics.

Another issue with this study is sampling methodology. Plot centers were not chosen randomly; as such, bias may have been introduced. Additionally, some plot centers in the Alexander Basin area had to be moved for safety reasons due to proximity to bison, potentially introducing even more bias. Ideally, sampling plots would have been chosen randomly and sample size increased to capture a more complete picture of the ant community dynamics in each study area. Also, being able to sample in areas where a large herd of bison is present (or recently present) would be preferred, as density of bison in an area would be able to be compared directly with the density of a herd of cattle. In the Alexander Basin area using in this study, individual bison were present in and around sample plots, while the main herd was in an adjacent paddock and when they were last in the study site is unknown.

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Tables and Figures

Table 1. Summary of data for density, Moran's I, and Nearest Neighbor Ratio. For Moran's I, if the p-value is not significant, the feature value (in this case, volume) is randomly distributed. Where significant, a positive value indicates clustering for the feature value, while a negative value indicates dispersion. For Neighbor Ratio, values above 1 indicate clustering, while values below 1 indicate dispersion.

Type	Plot	#mounds/ha	Moran's I	Moran P	Neighbor Ratio
C	C1	32	-0.12988	0.962066	1.571559
C	C2	36	0.943843	0.008923	1.695905
C	C3	36	0.025382	0.485874	2.324034
T	T1	88	0.31585	0.017097	1.426695
T	T2	80	0.232666	0.130068	1.10196
T	T3	64	-0.03962	0.807337	1.918271
AB	AB1	56	0.619671	0.005859	1.312408
AB	AB3	80	-0.05062	0.990738	1.255352
AB	AB2	104	-0.04386	0.97896	1.311736

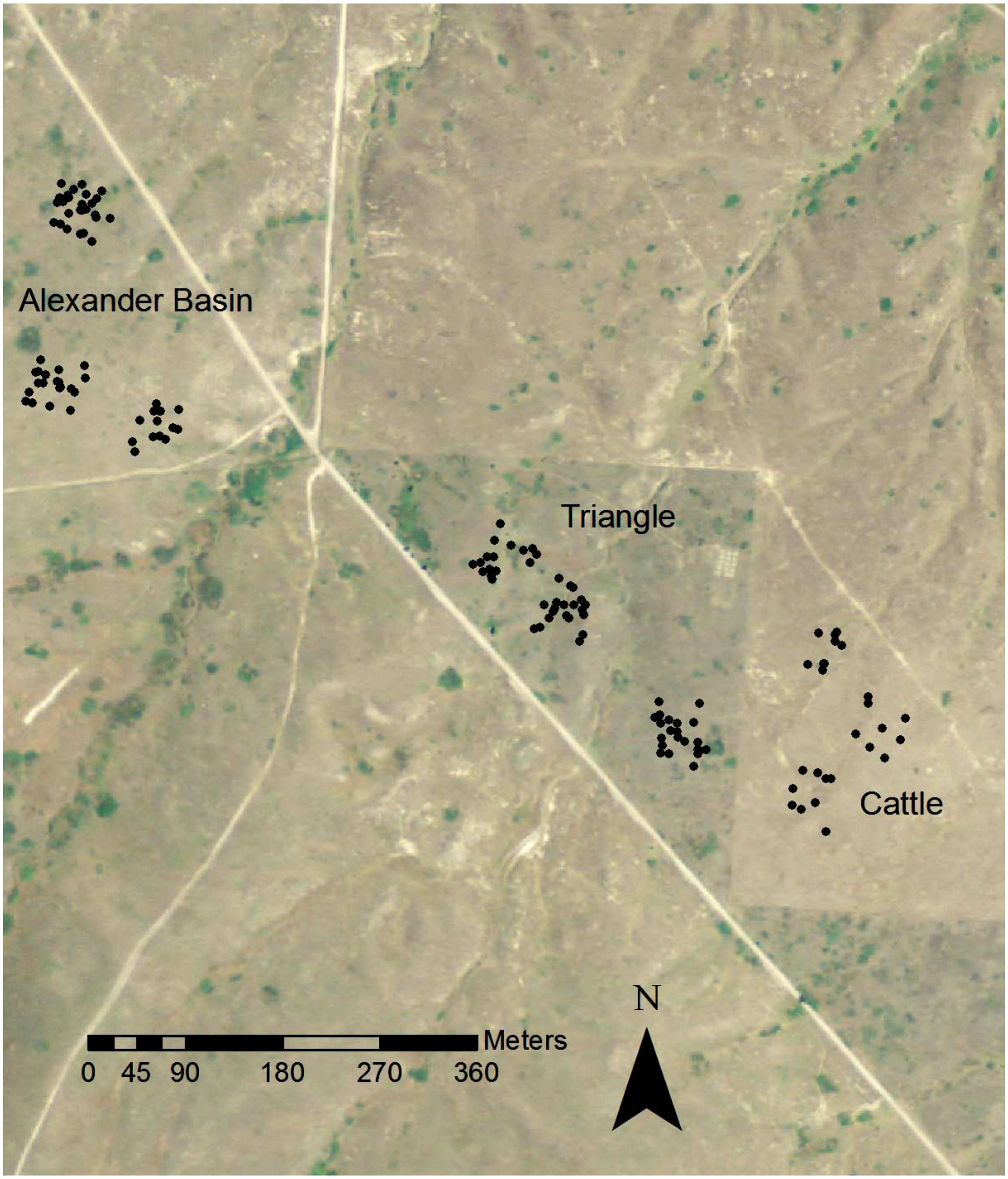

Figure 1. Plot of ant mounds used in the study, with study areas labeled. Aerial photography obtained from the Natural Resource Information System of Montana. http://nris.mt.gov/gis/

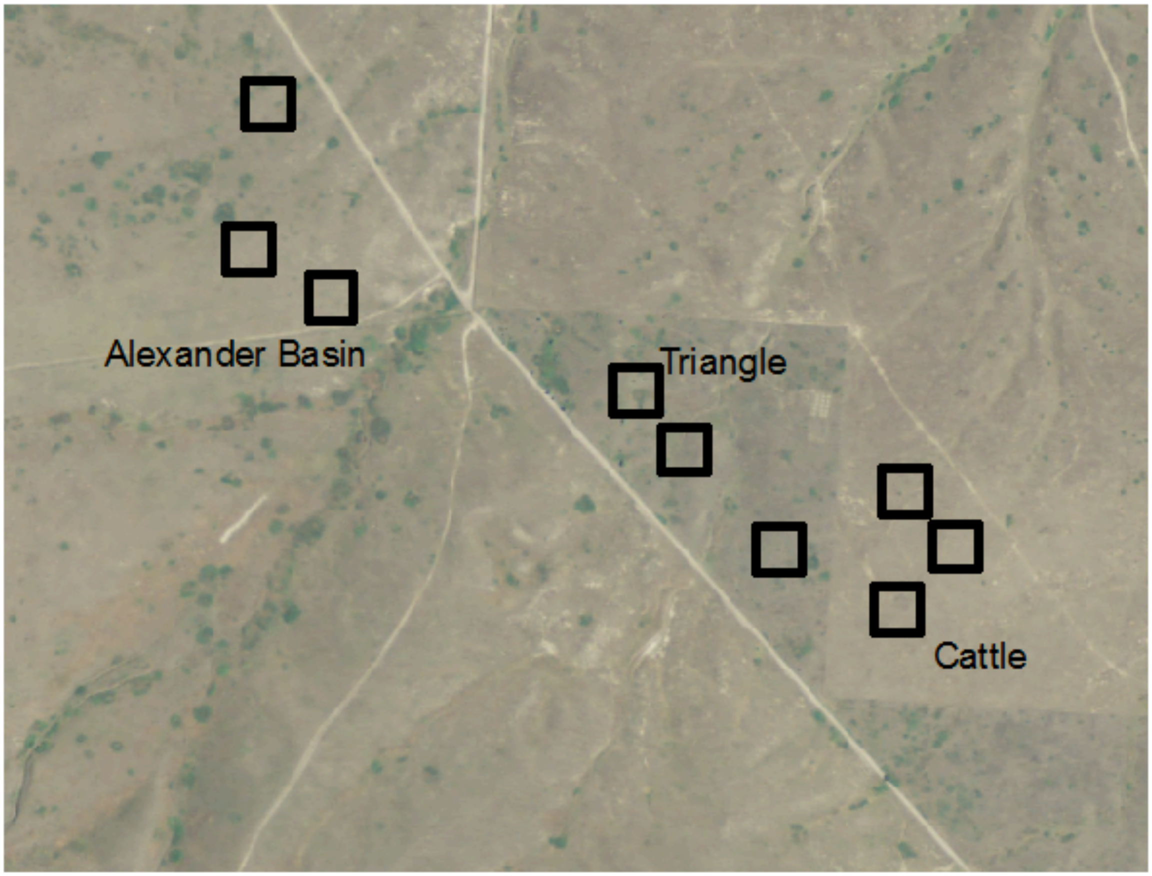

Figure 2. Map of study sites, labeled by area. Black squares represent 50mx50m plots surveyed for ant mounds. Aerial photography obtained from the Natural Resource Information System of Montana. http://nris.mt.gov/gis/

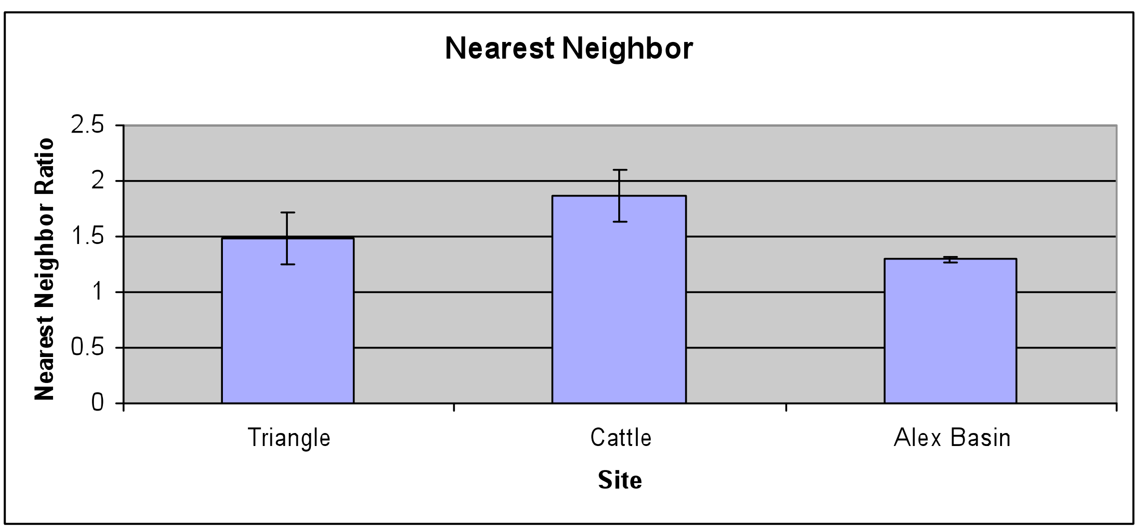

Figure 3. Log-transformed volume by land-use type. Error bars are SE. There are no statistically significant differences among the sites (p>0.05).

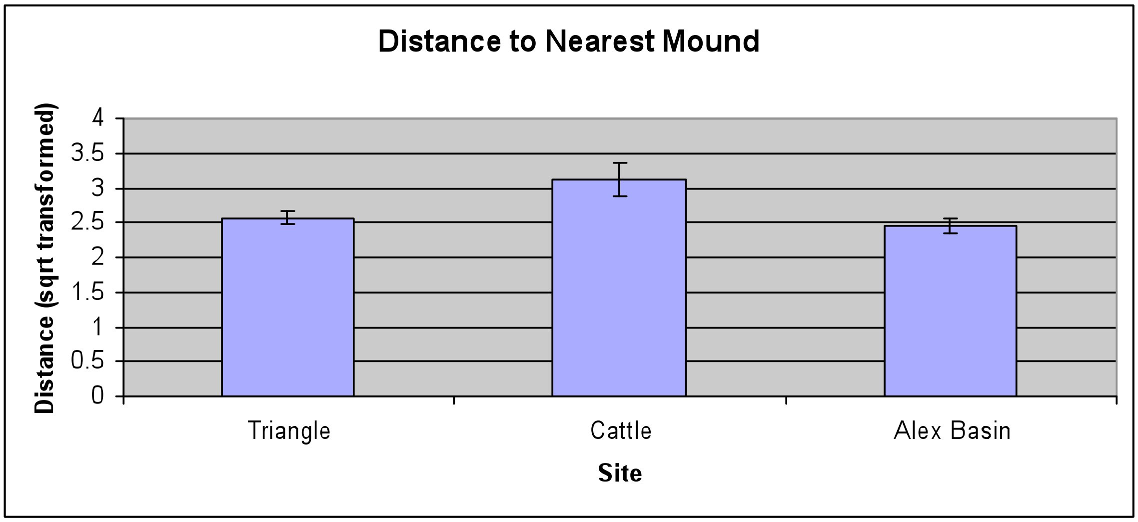

Figure 4. Square root-transformed distance by land-use type. Error bars are SE. Mounds in the cattle area are statistically significantly further apart from each other than in the triangle ($p=0.012$) and the Alexander Basin site ($p=0.010$). Error bars are SE.

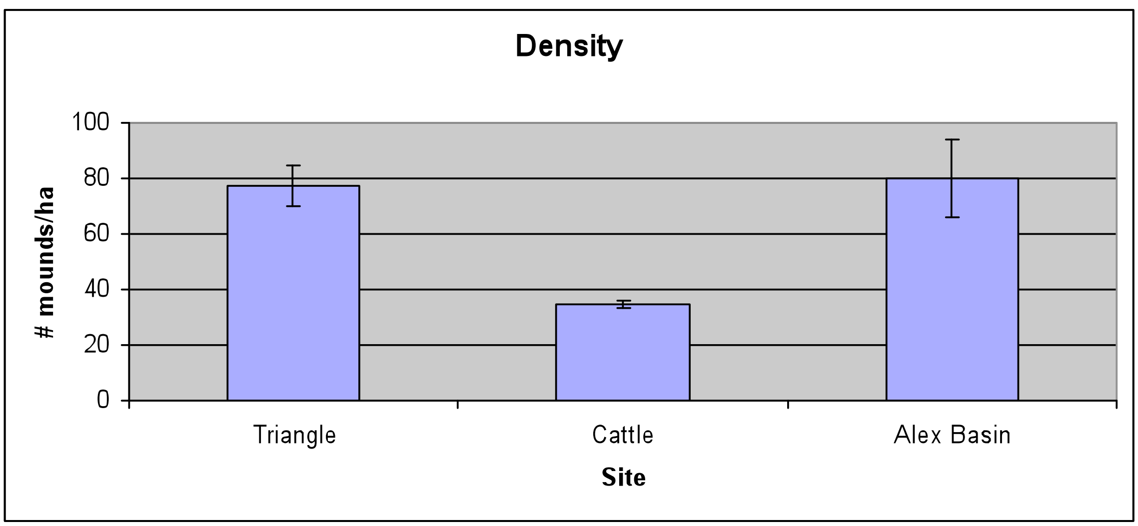

Figure 5. Density of mounds (per hectare) by land-use type. Mound density is statistically significantly lower in the cattle-grazed site than in the triangle ($p=0.036$) and the Alexander Basin site ($p=0.028$). Error bars are SE.