Effects of wallowing disturbance on forb biodiversity and prevalence of exotic plant species of Palouse prairies of the National Bison Range

BIOS 35503: Practicum in Field Biology

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Abstract

I investigated the impact of wallowing disturbance on forb biodiversity and prevalence of exotic plant species inside the wallow and in the surrounding prairie. The study developed a regression function for estimating forb biodiversity inside and surrounding bison wallows. Significant variable included wallow size, percent exotic forb species, percent moisture, and position of plot. The study also analyzed percent exotic species at different distances from the center of the wallow. Mean percent exotic forb species was significantly greater at the edge and outside of the wallow than it was inside the wallow. This result indicates that bison disturbance may aid in decreasing exotic forb species' ability to fully outcompete native forb species.

Key words: bison wallows, forb biodiversity, National Bison Range, invasive species, native species

Introduction

Ecosystem patchiness can play very important roles in maintenance of biodiversity and overall environmental health. Many ecosystems rely on animals to provide these disturbances which aid in preserving ecosystem heterogeneity and increasing plant diversity (Gibson, 1989). These mammalian biopedturbations can also greatly impact an ecosystem's vegetative composition and soil nutrients (Whitford & Kay, 1999). Historically, the American Bison (*Bison bison)* was one of the principal creators of biopedturbation disturbances in the Great Plains region of the United States, as an estimated 30 to 60 million individuals would have roamed the area as few as 200 years ago (Knapp et al., 1999). The most distinct form of bison soil disturbance occurs in the form of wallows. These disturbances are called indigenous disturbances, so termed because they have an evolutionary history in an area (Denslow, 1985 qtd. as cited in Larson, 2003). This means that the plant community would be well adapted to the presence of the disturbance.

Bison create wallows when they paw and roll on the ground (Knapp et al., 1999), with the purpose of procuring respite from the irritation of insects and heatv(B. R. McMillan, 1999). Regular wallowing by *Bison bison* in the same area creates an ovular depression in the ground

(Polley, 1984). This animal generated disturbance differs from other mammalian biopedturbations in that it causes a compaction of soil rather than decreased soil density (Gibson, 1989). Bison wallows may be a more impactful form of biopedturbation than those produced by other mammals, as they are considerably larger than most other forms, (i.e. rodent burrows, fossorial mounds, and foraging pits) and often create areas with little to no vegetation. This implication is due to the significant positive relationship between size and longevity of biopedturbation (Whitford & Kay, 1999).

This study was performed to address the effects of *Bison bison* biopedturbation in the form of wallowing disturbances on the overall health of Western Montana's intermountain region Palouse prairie. The effect of wallowing on prairie vegetation and soil environment has been studied considerably on tallgrass prairie environments (B. R. McMillan, 1999; Brock R. McMillan, Pfeiffer, & Kaufman, 2011; Trager, Wilson, & Hartnett, 2004), but not on Palouse prairie. I want to discover a possible relationship between distance from the center of a wallow, where trampling by bison would supposedly be greatest, and plant biodiversity. In addition, I wish to assess whether there is a relationship between distance from the center of a wallow, and therefore degree of trampling, and prevalence of exotic plant species. It is expected that the vegetation further away from the center of the wallow will be more homogeneous. It is also expected that there will be a higher prevalence of exotic species closer to the center of the wallow.

Methods

Site description. – This study was conducted July 6 through July 28 of 2018 in the intermountain region Palouse grasslands of the National Bison Range (lat 47° 22' N, long 114° 15' W) in Charlo, Montana. The National Bison Range consists of 7,600 hectares of rolling Palouse prairie and coniferous forest (USFWS, 2017). The 30-year (1988-2017) average annual precipitation (Round Butte, Montana, AgriMet Weather Station) was 321.9 mm. A total of 3.302 mm of precipitation fell during the study period (USBR, 2018).

Seventeen active and four inactive wallows were chosen in the Lower Pauline pasture, Mission Creek Pasture, and Upper South Pasture. Inactive wallows were characterized by presence of significant (>5%) vegetation cover in the center vegetation plot. Wallows were a minimum of 50 meters apart.

Experimental Design. – Transect tapes were used at each wallow to measure the long axis and the axis perpendicular to that axis. Area of each wallow was calculated using the equation for area of an ellipse. Latitude, longitude, and elevation of wallows was obtained using the Garmin eTrex 10 Hiking GPS Navigator. Slope face and status of wallow- either active or inactive- was recorded. Five 25 x 25 cm plots were positioned along a transect that ran east from the center of the wallow. Plots were located in the center of the wallow, a meter in from the edge of the wallow, on the edge of the wallow, a meter out from the edge of the wallow, and two meters out from the edge of the wallow.

Forb Species Composition. – In each plot, forb richness and evenness was recorded. Forbs were identified to species when possible. Forbs were then identified as native or introduced using the United States Department of Agriculture's Natural Resources Conservation Service's Plants Database. Unidentifiable plants were put into a third category labeled unknown. These plants were either too young or too dead to identify definitively, but were recognizably different from other species present in the plot. The total number of forb species of each category was then converted to a percentage of the total species.

Percent Gramineous Cover. – Percent cover of each plot of plants in the grass family was estimated and classified into one of twenty 5% cover class intervals, the first being 0-4.99%.

Soil Compressive Load. – Soil compressive load was measured in each plot using the E-280 pocket penetrometer. Values were obtained by pushing the loading piston of the penetrometer 0.25 inches into the soil and taking the reading above the friction ring. Compressive strength was recorded to the nearest 0.25 ton/ft^2.

Soil Moisture. – Soil moisture was measured in each plot using an HSM50 Precision Digital Soil Moisture Meter. The reading was recorded when the meter was inserted a minimum of 10 cm into the soil. The soil moisture value from one meter outside wallow six in the Upper South Pasture was obtained using the oven drying method due to an inability to penetrate the hard soil with the probe. A soil sample was collected at the site and brought back to the lab, where it was massed before and after a 24-hour period in the drying oven. Percent moisture was then calculated using the percent change formula, $(\frac{m_i - m_f}{m})$.

Data Analysis. – Biodiversity was calculated using the Shannon Wiener diversity index, H, where H = $\sum p_i * lnp_i$ and p_i is the proportion of individuals of species *i* relative to the total number of individuals of all species present. A multiple regression test was run to determine an equation to fit Shannon-Weiner diversity. An analysis of variance test was also run on this result.

Results

Forb diversity

A total of 50 forb species were identified throughout the study. *Figure* 1 shows the average species richness of all plots. Plots A and B (the center of the wallow and one meter inside the wallow, respectively) vary significantly from all other plots. Plots C through E do not differ significantly from each other. 21 different forb species were sampled inside the wallow (plots A and B), and 41 forb species were sampled outside the wallow (plots D and E). This is consistent with *figure 2*, which shows that the average number of forb species within the wallow was 1.12 ± 0.35, while the average number of forb species outside the wallow was 6.00 ± 0.45. A t-test analysis shows that this difference was found to be significant ($t_{(1, 42)}$=-8.649, p=5.70E-13). *Figure 3* shows the top six most commonly found forb species inside and outside sampled wallows. Four of the six most common species found inside the wallow were introduced, while three of the six found outside the wallow were introduced.

Linear regression model for Shannon Diversity

The backwards regression model was used to determine factors significant in estimating Shannon-Wiener diversity, H. It indicated that percent gramineous cover, elevation, and soil compressive load were not significant factors in explaining the relationships. Percent soil moisture, percent exotic forb species, and size of wallow, however, were significant factors, cumulatively resulting in a multiple R value of 0.770. The least square means regression reads as follows,

$$H = -0.127+0.030(wallow\ size) + 0.991(exotic) + -0.022(moisture) + 0.082(position),$$

Where a p-value < 0.15 was necessary for inclusion. The analysis of variance showed that the least square means regression accounted for 59.3% of the variance in predicting Shannon-Wiener diversity. *Figure 4* shows the positive relationship between the average Shannon's H and distance from the center of the wallow. The average Shannon's H of plots A and B vary significantly from all other plots. Plots C through E do not differ significantly from each other. *Figure 5* shows the negative relationship between soil moisture and distance from the center of the wallow. Average percent moisture of plots A and B vary significantly from all other plots. Plots C through E do not differ significantly from each other. Finally, *figure 6* shows the average percent exotic species in each plot. Average percent exotic species of plots A and B vary significantly from all other plots. Plot E differs significantly from plot D. Plots C and D and D and E do not differ significantly from each other.

Discussion

The forb composition of the plots outside wallows was found to be significantly richer than that inside wallows. This could be a result of the fact that vegetation cover within 17 of the 21 wallows was very low (<5%). Frequently, plots A and B would not have any vegetation at all. This discrepancy was most likely a result of wallowing activity of the bison inhibiting growth within the wallow. As was expected, inactive wallows had greater forb richness inside the wallow than active wallows. These wallows had more growth in their centers due to lack of recent bison activity. Four of the six forb species most commonly found within wallows were introduced species. Inversely, the percentage of exotic species found inside the wallow, shown in *figure 6,* was significantly lower than the percentage found outside the wallow.

The least squares regression equation developed to fit the Shannon-Wiener diversity index was best explained using soil moisture, percent exotic forb species, size of wallow, and plot position. Soil moisture and Shannon's H were inversely related. Average moisture values were highest in the center of the wallow, which may be caused by ephemeral potholes during the rainy season (Polley 1984). These potholes are a result of the depression of the soil by the bison. Although there is an increase in moisture, bison activity still suppresses plant growth. Plots outside the wallow, which had the highest forb biodiversity, also had the highest percentage of exotic forbs.

Researchers have found that, in some cases, disturbance may decrease exotic forb cover, promoting native forb evenness (Collins & Barber, 1986; Driscoll, 2017). I found that wallows with greater areas had higher biodiversity. Areas near the edge of larger wallows and smaller wallows are not be affected equally; thus greater biopedturbation is concentrated closer to the center of the wallow. Concentration of biopedturbation at the center of the wallow also explains the positive relationship between diversity and plot distance from the center of the wallow.

Although significant trends were identified, future studies should consider controlling for additional variables, such as slope face, elevation, and soil composition. Edaphic variables in particular could have had a large effect on vegetation composition (Polley 1984). In addition, multiple sampling periods would be beneficial for identifying plants in different stages of their reproductive cycle.

In conclusion, bison wallows are unique mammalian disturbances that are an integral part of Palouse prairie ecosystems because they encourage biodiversity of native plants. Though simple and unsuspecting, Bison wallows play an active role in maintaining their surrounding environment. Management decisions of palouse prairie should consider the benefits of wallows as they are in their natural state.

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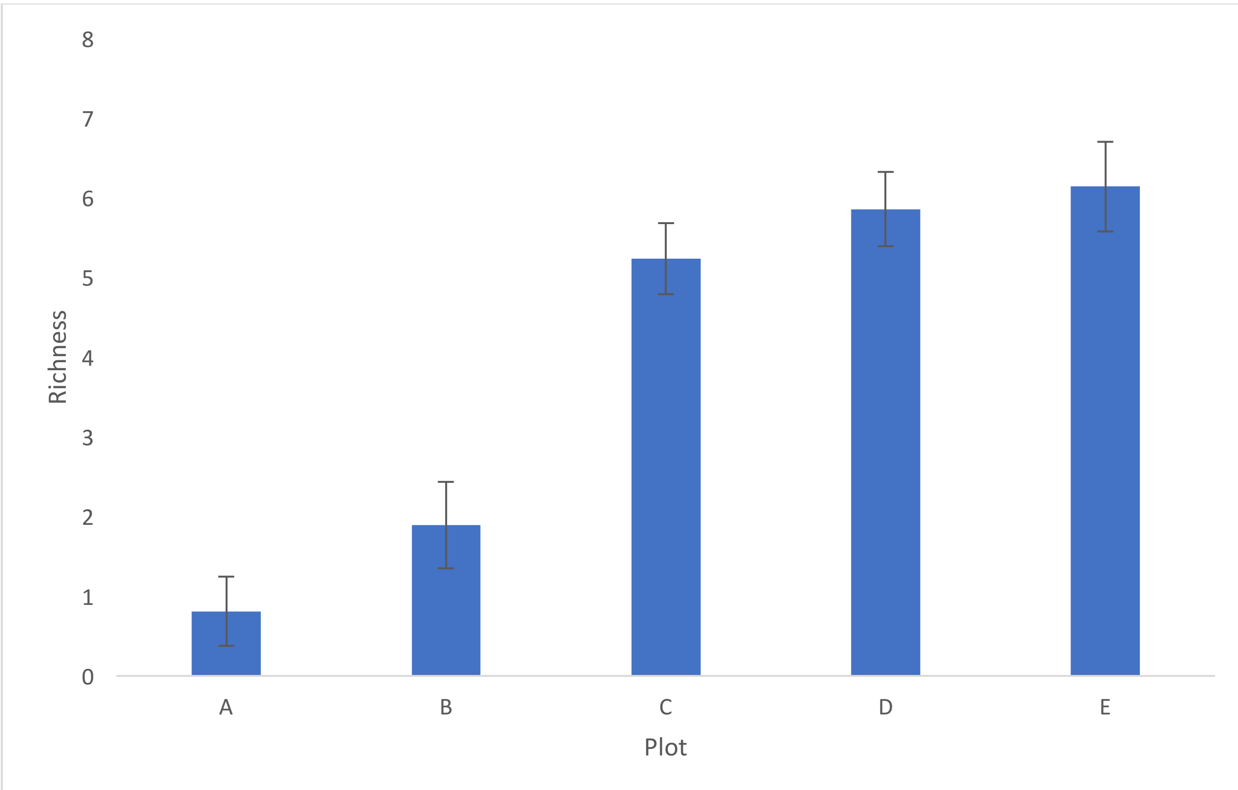

Figure 1. Average species richness by plot. This bar graph show the average species richness by plot with standard error bars, where plot A is the center plot, plot B is the plot 1 meter inside the wallow, plot C is the edge plot, plot D is the plot 1 meter outside the wallow, and plot E is the plot 2 meters outside the wallow.

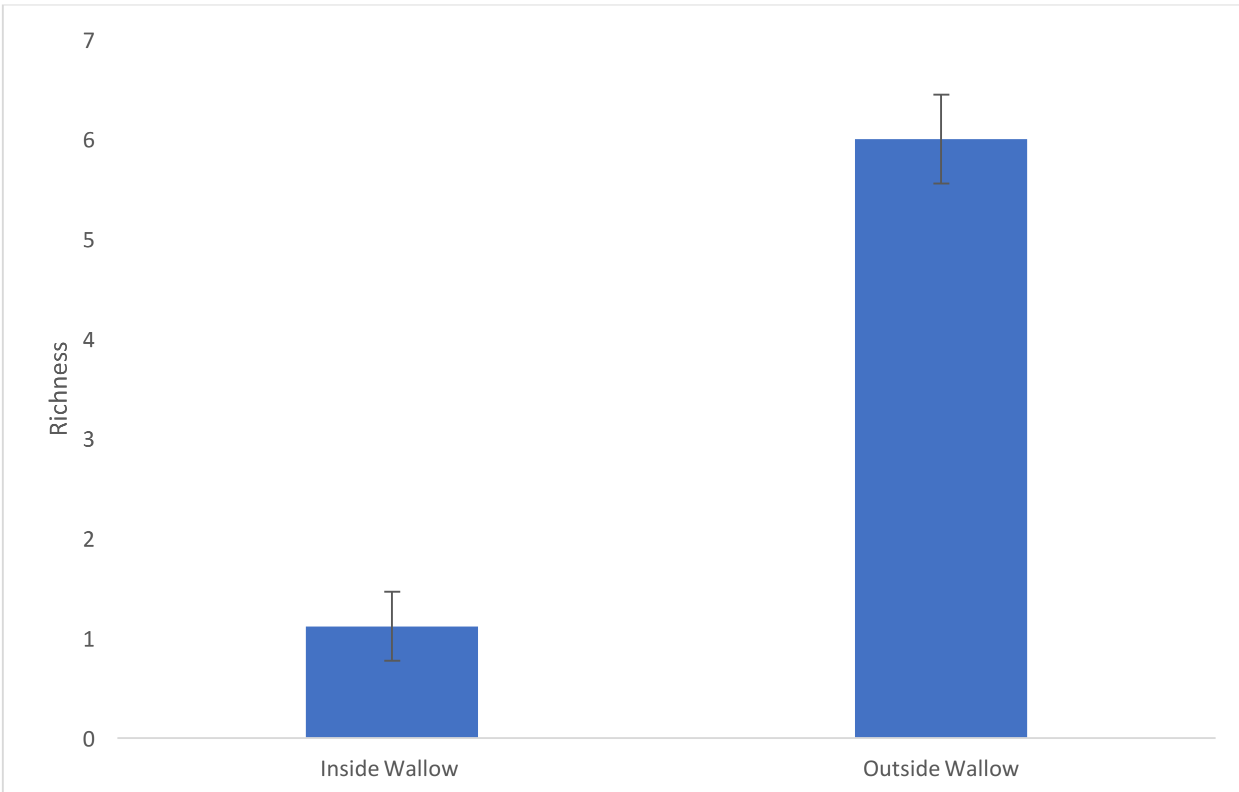

Figure 2. Average species richness of plots inside and outside wallow. This bar graph show the average species richness inside (plots A and B) and outside (plots D and E) sampled wallows, with standard error bars.

Inside Wallow			**Outside Wallow**		
Forb Species	**Count**	**Status**	**Forb Species**	**Count**	**Status**
Erodium cicutarium	234	I	*Veronica americana*	2313	N
Logfia arvensis	149	I	*Logfia arvensis*	921	I
Heterotheca villosa	66	N	*Arenaria serpyllifolia*	336	I
Lepidium perfoliatum	51	I	*Galium aparine*	249	N
Arenaria serpyllifolia	51	I	*Lepidium perfoliatum*	246	I
Veronica americana	34	N	*Achillea millefolium*	102	N

Figure 3. Most abundant forb species inside and outside wallows. This table show the most abundant forb species inside (plots A and B) and outside (plots D and E) sampled wallows. Included is the corresponding count for each forb and its native status. A status of "N" indicates "native", whereas a status of "I" indicates "introduced."

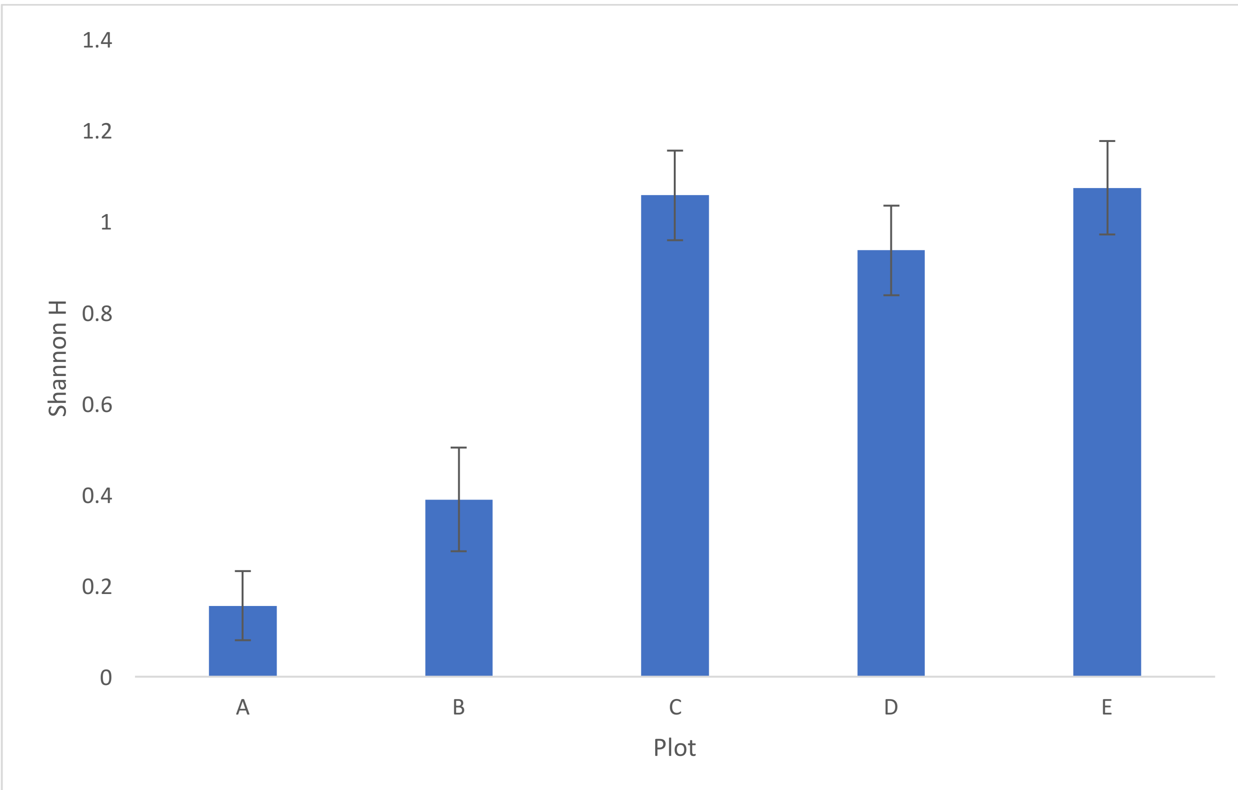

Figure 4. Average Shannon H' by plots. This bar graph show the average Shannon Wiener diversity index, H, by plot with standard error bars. A, B, C, D, and E refer to plot distances (See *figure 1*).

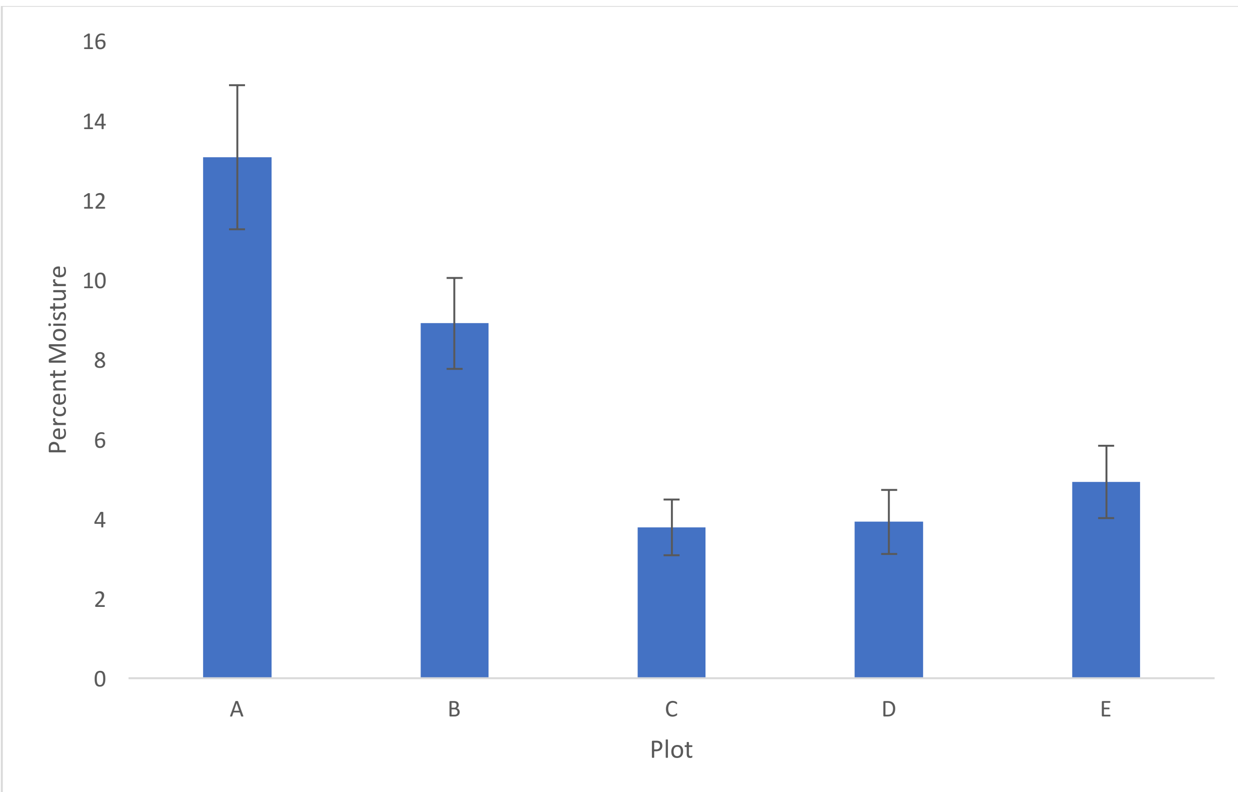

Figure 5. Average percent moisture. This bar graph show the average percent moisture by plot with standard error bars. A, B, C, D, and E refer to plot distances (See *Figure 1*).

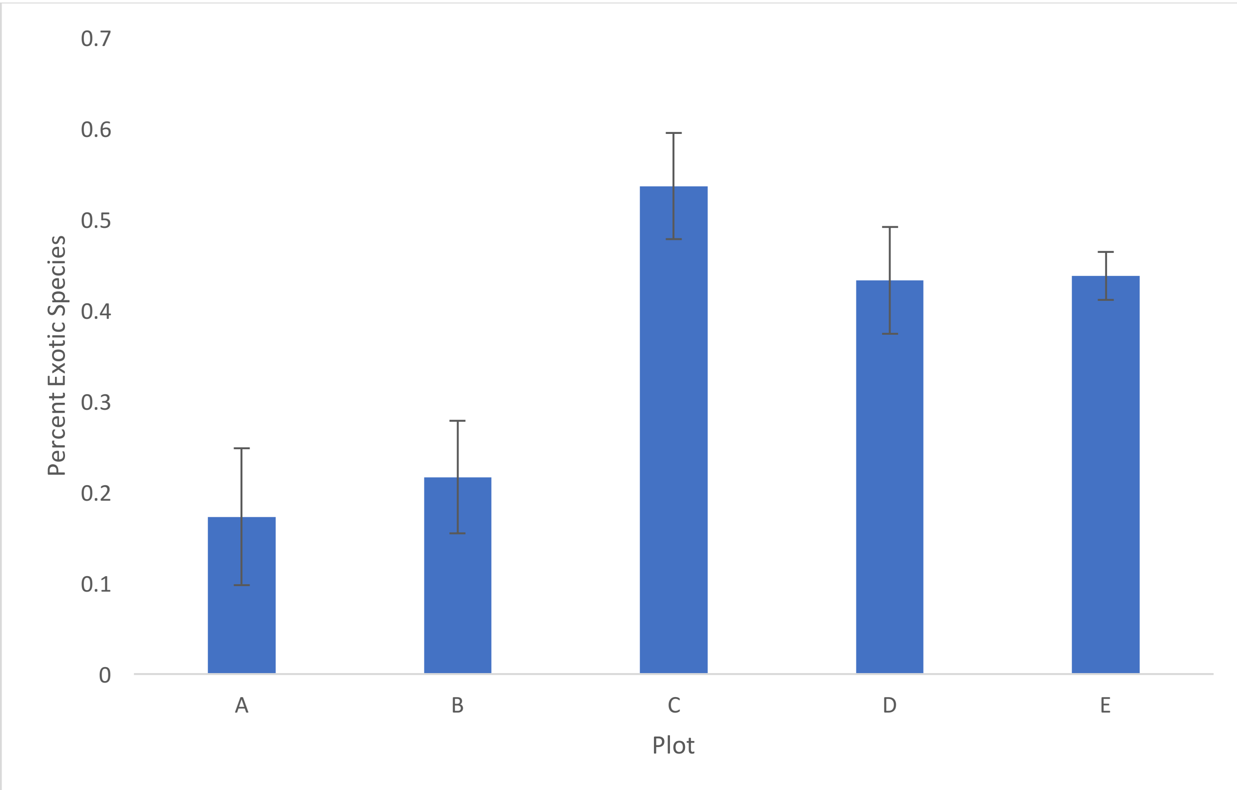

Figure 6. Average percent exotic species. This bar graph show the average percent exotic species by plot with standard error bars. A, B, C, D, and E refer to plot distances (See *figure 1*).