Cattle rangeland effects on plant heterogeneity and Coleoptera diversity and abundance

Kym Sutton
UNDERC—West 2017
Mentor: Jose Carlos Wharton Soto

Abstract:

Cattle rangeland and agriculture has taken over much of the native prairie in North America. Cattle disturbance has been shown to be detrimental to plant abundance, soil compaction and nutrient availability. If it is true that cattle affect plant heterogeneity they may also affect insect populations that rely on the plants. Coleoptera have been shown to be good indicators of disturbance but have not been investigated in the scope of cattle rangeland. This study looks at beetle diversity and evenness as a factor of plant heterogeneity driven by cattle disturbance. Natural prairie land and cattle rangeland were selected and sampled using pitfall traps and “toe point” methods. The cattle land did not affect the plant communities but did affect two species of beetles: the margined burying beetle (*Nicrophorus marginatus*) and the small spotted dung beetle (*Onthophagus nuchicornis*). Plant heterogeneity did not influence beetle abundance, diversity or evenness. There is evidence showing that this effect was confounded by other factors so further investigation is required.

Introduction:

Prairies are the largest vegetative province in North America but are shrinking due to human agricultural use (Samson and Knopf 1994). Particularly in the western United States both cropland and cattle rangeland development play a large role in prairie erosion (Sampson 1981). The cattle disturbance can minimize plant abundance, lower nutrient availability, and compact soil (O’Neill et al. 2003, Samson and Knopf 1994). With the introduction of disturbed areas, such as cattle rangeland, flora communities have been altered which may further alter arthropod communities (Quinn et al. 2004). Since disturbance causes such large problems its influence is summarized in the Intermediate Disturbance Hypothesis (IDH), which predicts that more heterogeneous landscapes will have the most species richness and abundance (Wilkinson et al. 1999). If rangeland disturbance decreases plant heterogeneity then it may lower species richness and abundance in other areas of the ecosystem.

Insects are instrumental to ecosystems by being key nutrient cyclers and staples of the food chain (Stanley et al. 2010). In order to better understand the conservation concerns raised by cattle rangeland it is important to understand the disturbances impact to the invertebrate communities. Coleoptera are a great study order to model invertebrate response to disturbance because beetles have been found to be indicators of disturbance by shifting diversity in different disturbance regimes (Scheffler 2005, Ribera et al. 2001, Niemel et al. 2002). They also are sensitive to heterogeneity changes that come with landscape use (Ribera et al. 2001). Coleopteran abundance and diversity have been shown to be altered due to botanical features from disturbed area and can reliably signal land use changes (Vanbergen et al. 2005). The specific effects of cattle rangeland have not been investigated but if we know that cattle grazing affects plant life it is very possible that it may affect beetle populations.

This study aims to investigate the impact of rangeland's use for cattle grazing on Coleoptera by looking at general species abundance and richness. In addition this study will investigate rangeland's influence on plant heterogeneity and compare it to Coleoptera abundance and diversity. This will give insight into how rangeland is affecting plant heterogeneity and, in turn, Coleoptera.

I hypothesized that Coleopteran abundance and diversity is reduced by a decrease in plant heterogeneity driven by rangeland disturbance. This will be true if these three predictions are true: 1) Coleopteran abundance and diversity will decrease with rangeland disturbance. 2) Plant heterogeneity will decrease with presence of rangeland disturbance. 3) Coleopteran abundance and diversity will decrease with lessening plant heterogeneity. These results are expected via the IDH and how rangeland decreases plant abundance. If rangeland decreased plant abundance it may decrease heterogeneity as well. If this is true then the Coleopteran communities may be negatively affected by this heterogeneity decrease as well. We have reason to hypothesis this because Coleoptera are impacted by changes in plant communities in disturbed areas (Vanbergen et al. 2005). This study will further investigate the how plant communities are disturbed and how, in turn, beetles are affected.

Methods:

Study Sites

Four sites of native grassland and four grassland sites of cattle rangeland were chosen with similar elevation. Native study sites were on the National Bison Range (NBR) in Charlo, Montana. The National Bison Range is a federally managed land established in 1908. The grassland of the range is one of the last publically owned native grasslands and is managed to be a native, natural area. Cattle rangeland sited were chosen from non-irrigated private and Flathead Indian Reservation Tribal land. The chosen sites are areas with recent or current cattle grazing. The cattle sites were non-irrigated in order to be compared to the natural prairie landscape. Soil moisture and elevation of cattle sites were measured and NBR sites were chosen to have (as close as possible) similar soil moisture and elevation. Every site chosen was greater than 20 m from any road to avoid boundary effect. At each site a 15m by 15m plot was constructed and divided into numbered 1m x1m sections.

Coleopteran Collection

Four pitfall traps were placed in four random m^2 sections in each plot. Each pitfall trap was a 16 oz. plastic cup filled with 4-6 cm of soapy water and buried so the lip is flush with the ground. A 5-inch x 5-inch wire screen with ½ inch holes was garden stapled across the top of the trap to reduce mice and vole interaction. Two times within the study period the traps were emptied and counted for a total of three weeks throughout the study period (Vanbergen et al. 2005). The first collection was after 14 days and the second collection was after 7 days. The specimens were collected and preserved in 70% ethanol to be later separated into morphospecies. One specimen of each morphospecies was pinned to preserve color. The most commonly collected groups were identified to species.

Additional Factors

To understand the indirect effects of cattle grazing on beetles each site were monitored for plant community, soil moisture and an index of large herbivore abundance. At each plot four random $1m^2$ sections were surveyed for plant species abundance via "toe point method" (Hansen 1998). Each site has soil moisture measured via an Omega® HSM50 Time-Domain Reflectometry (TDR) probe. The entire plot was walked and large herbivore scat counted. Each scat was categorized by species.

Statistics

Diversity of beetles was calculated using a Shannon Wiener diversity index and evenness based off the Shannon Wiener calculation (Shannon Wiener diversity index/Maximum diversity possible). The statistical tests were run using R for Mac OS X GUI 3.3.0. Data was tested using a Shapiro-Wilk's normality test. Insect count data, plant count data and herbivory indexes were non-normal but were able to be centered using scale function. Principle Coordinate Analysis (PCOA) was used for plant diversity, beetle diversity and for beetle diversity based on plant differentiated sites. This separated the sites based on three target communities and showed significant differences between sites of species abundance. A follow up of Permutational Multivariate Analysis of Variance Using Distance Matrices was ran to see what species differed between sites. A Generalized Linear Model for Multivariate Abundance was used to test for specific species differing between sites. Important species abundances were ran using an ANCOVA to test for confounding factors effects. When ANCOVAs could not be run due to significance of the factor and covariate interaction multiple linear regressions were used. Two-way Independent T-Tests were ran to test if the diversity and evenness of plants and beetles differed between land use. Multivariate Linear Regressions were run to test effects of herbivory index on insects and plants. Finally ANCOVAs were utilized for confounding factors effects on the diversity and evenness of plants and beetles.

Results:

PCOA of Insect Abundance

A PCOA was run using beetle count data and Bray-Curtis Distances (Figure 1). A Permutational Multivariate Analysis of Variance using Distance Matrices showed no clear significance between beetle count data and the overall treatment groups (p=0.589, DF=7, F Model=0.58918). Between the sites themselves four beetle species varied significantly: *Saprinus pennsylvanicus* (p=0.008), *Thanatophilus lapponicus* (p=0.034), *Heterosilpha ramosa* (p=0.011) and *Nicrophorus marginatus* (p=0.005) (Figure 1). To look at specific species abundance between sites a Generalized Linear Model for Multivariate Abundance was ran showing significance differences in two beetle species: *N. marginatus* (p=0.05, DF=7, Dev. =9.63), *Onthophagus nuchicornis* (p=0.05, DF=7, Dev. =10.44).

The PCOA suggests that there are confounding factors that are affecting certain beetle species abundance between sites. To investigate this an ANCOVA was run testing beetle abundance, total and individual for the specified species, using the moisture and elevation as the covariates. General beetle abundance and moisture was significantly influenced by elevation (P=0.004, F value = 61.621, DF=3) and moisture (p=0.010, F value= 34.621, DF=3). *N. marginatus* is significantly altered by elevation (p= 0.00953, F value = 35.305, DF=3), moisture (p=0.016, F value = 24.746, DF=3) and the interaction of moisture and elevation (P= 0.049, F value = 10.292, DF=3). To understand the interaction slopes were determined for the interaction (y= -21207.96 -0.772x, R^2= 0.9241, p=0.011), moisture (y=-1477.41 + 233.26x, R^2 = 0.7776, p=0.004) and elevation (y=2618.90 +1.092x, R^2= 0.463, p=0.063). Moisture and elevation had a positive relationship with *N. marginatus* abundance (respectively: slope= 233.26, 1.092) the interaction slope was lower than either (slope = 0.772x) and a strong fit (R^2=0.9241). *O. nuchicornis* had a significant interaction term with the land use type so an ANCOVA could not be used. Instead a linear regression was run for each land use type for both elevation and moisture. Elevation has a significant (p=0.006, t value= 6.889, DF=3) positive relationship (y=-1.074e+ 4.088e-02, R^2 = 0.940, p=0.006) with *O. nuchicornis* abundance on cattle rangelands only. Moisture also has a significant (p<0.001, t value = 19.33, DF= 3) positive relationship (y= -33.120+ 4.975x, R^2= 0.992, p<0.001) with *O. nuchicornis* abundance on cattle rangelands.

T-Test of Beetle Diversity and Evenness

To determine significance of beetle diversity between cattle and natural land Independent Two-Way T-Tests were ran. Between the land types neither diversity of beetles ($p=0.7443$, $t = -0.70839$, $DF= 5.8507$) or evenness of diversity ($p=0.3808$, $t = -1.2244$, $DF= 5.8262$) was significant (Figure 4: a and b).

PCOA of Plant Abundance

Plant species abundance was investigated using a PCOA showing no significance between beetle count data and the overall treatment groups ($p=0.197$, $DF=7$, $F = 1.4735$) (Figure 3). Between sites there was significance in abundance of bare ground ($p=0.012$) and three plants: *Bromus tectorum* ($p=0.042$), *Ventenata dubia* ($p=0.018$) and *Apera interrupta* ($p=0.003$). No specific species differed between land use types via a Generalized Linear Model for Multivariate Abundance ($p>0.05$, $DF=7$, Dev.= 50.08).

The variance between specific plant abundances at sites in the PCOA may suggest that there are confounding factors affecting plant abundance. The measured confounding factors (moisture and elevation) were tested on the ratio of total plants to bare ground via an ANCOVA and showed no significance ($P>0.05$, $DF=3$). In addition the three plant species that differed significantly between sites were also ran with elevation and moisture covariates. *B. tectorum* showed a significant alteration via moisture ($p= 0.018$, F value = 22.429, $DF=3$) and the interaction of moisture and elevation ($p=0.0339$, F value = 13.8015, $DF = 3$). To understand the nature of the interaction each slope was determined for elevation ($y= 3.149e-01- 5.169e-05x$, R^2 0.008, $p=0.835$), moisture ($y=-0.205+ 0.046x$, R^2= 0.231, $p=0.228$) and their interaction ($y=7.705 + 0.0002x$, R^2= 0.7117, $p=0.140$). *V. dubia* showed significant interaction term with land use type ($p= 0.0346$, F value 13.59, DF=3) so ANCOVA could not be ran. Instead a linear regression of elevation and *V. dubia* to total plant ratio was used showing a significant relationship for elevation of cattle rangeland and the plant's ratio ($p<0.001$, $t= 18.89$, DF=3). The slope shows a positive relationship ($y=-3.293e-01 +1.219\ e-04$, $R^2= 0.992$, $p<0.001$) *A. interrupta* was only significant dependent on moisture ($p= 0.041$, F value = 22.429, DF=3).

T-Test of Plant Diversity and Evenness

Independent Two-Way T-Tests were run to determine significance of plant diversity and evenness between land use types. Between the land types neither diversity of plants ($p=0.0992$, $t = 1.1133$, DF=5.352) or evenness of diversity ($p=0.2012$, $t=1.1713$, DF=4.7459) was significant (Figure 4: c and d).

Relationship of Plants and Insects

To determine the possible influence of plant abundance on beetle abundance a PCOA was ran with sites locations determined by plant abundance and beetle vectors added. No insect showed significance between sites or treatment groups. Multivariable linear models were run to determine the effects of plant diversity and evenness on either beetle diversity or evenness. Plant diversity and evenness did not correlate with beetle diversity ($p=0.7491$, DF=5, $R^2=0.1091$) or evenness ($p=0.8707$, DF=5, $R^2=0.004783$). To test the effects of plant diversity and evenness on insect abundance between land use types an ANCOVA was run. This test showed no significant influence ($p>0.05$, DF=3) from either elevation or moisture.

Effects of Herbivore Abundance

To test large herbivore abundance effects on beetle and plant diversity and evenness multivariate linear regressions were ran using the total dung, bison dung and deer dung found in the correlating plot. None of these tests showed significance ($p>0.05$, DF=4, $R^2<0.4$). In addition an ANOVA was run testing the effect of total dung, bison dung and cow dung on *O. nuchicornis* and was significant ($p<0.001$, F value = 176.37, DF= 4: $p=0.011$, F value =32131, DF=4: $p=0.014$, F value= 23.633, DF=4).

Other Variables/Confounding Variables

To test for other confounding variable four ANCOVAs were run: 1) beetle diversity between land use as influenced by moisture and elevation 2) beetle evenness between land use as influenced by moisture and elevation 3) plant diversity between land use as influenced by moisture and elevation 4) plant evenness between land use as influenced by moisture and elevation. None were significant ($p>0.05$, DF=3).

Discussion:

Insect Abundance and Diversity

It was hypothesized that Coleopteran abundance and diversity decreases with rangeland disturbance. The PCOA and Permutational Multivariate Analysis of Variance Using Distance Matrices ran suggest no overall control of beetle abundance by land use type. However the PCOA does show that four species vary significantly by site (Figure 1). This suggests that there are other confounding factors, other than land use, dictating beetle diversity. However when tested via ANCOVA the factors monitored (moisture, elevation) are not shown to control beetle diversity or evenness with the exception of *N. marginatus*. This suggests that there are other factors at play that were not measured in this study.

The overall abundance of beetles did not differ significantly between land use types. However, there is evidence that shows two species differing in abundance between land use types. Both species, the margined burying beetle (*N. marginatus)* and small spotted dung beetle (*O. nuchicornis),* decreased in abundance on cattle rangeland (Figure 2: a and b). The margined burying beetle had the interaction between elevation and moisture as inhibitory factors, but not when factored by land use type. Separately moisture and elevation had a positive relationship with *N. marginatus* abundance. This influence however was not determined by the land use. Perhaps the confounding factors of moisture and elevation are too strong of an influence that the land use has little or no influence on the beetle population. Cattle grazing decreases soil moisture (Deng 2013) but the effect of bison grazing on moisture is unknown. On the other hand the small spotted dung beetle, *O. nuchicornis*, is influenced by elevation, moisture, and their interaction with an influence from land use. The interaction of elevation and moisture for this beetle species is inhibitory. This is due to the elevation and moisture slopes (respectively: slope= 0.045, 6.27) are more than the interaction slope (slope = 03- 3.794e-02) and a strong fit (R^2=0.9925). Here the beetle is positively influenced by elevation and moisture only on cattle rangeland. *O. nuchicornis* requires dung, usually cattle dung, for reproduction (Floate 1998). Here the beetles were more abundant on the natural grassland where cattle dung is not present. The small spotted dung beetle was to found to correlate with total dung, cow dung and bison with a significant effect from land use. The type of dung is important to this species and bison dung is associated with higher beetle numbers than the cattle dung. However there is no evidence to show that insect diversity or evenness changes between land use types. So the hypothesis in accordance to diversity is not supported whether or not plant heterogeneity decreases.

Plant Abundance and Diversity

The land use type did not directly alter the overall plant diversity and abundance. There may be confounding factors affecting the abundance of certain plant species. These significantly different species are *B. tectorum, V. dubia,* and *A. interrupta*. *B. tectorum* and *A.* interrupta were found to be affected by other confounding factors but not by land use type. The African oatgrass, *V. dubia*, was important as it is affected by elevation on cattle rangeland. African oatgrass was only found on bison range sites. Since it is an invasive grass this may be due to its spread in the area. A high human activity area such as the bison range may have a quicker spread than that of cattle rangeland. (McKinney 2002). This could explain the difference in African oatgrass between the two land use types.

Effects of Plant Heterogeneity on Beetles

No relationship was found between plant diversity, evenness and both on beetle diversity, evenness or abundance. Cattle rangeland did not affect plant heterogeneity.

Conclusion and Future Research:

Overall this studied showed cattle land lowers abundance of two beetle species, *N. marginatus* and *O. nuchicornis*. The effects of these two abundances were confounded by other factors meaning understanding these populations will require more in depth study. The hypothesis based on the IDH was unsupported for this system as overall plant heterogeneity was not affected by land use and did not affect beetle populations. However the presence of *V. dubia* was more common on bison range. This is of concern for the natural land as this is a strong invasive. If there are traits or treatments of the cattle land that reduces this species then it would be useful to understand and implement them to help our natural lands.

This study was limited by the presence of confounding factors. Although elevation and moisture were kept as constant as the landscape allowed they still were large confounding factors. Future studies should be more controlled on the factors or specifically engage them to better understand their effects. Purposeful sites of varying elevation and moisture could test for the covariate effects of these factors in tangent with land use types. Also, this study only looked into diversity and abundance of beetle populations. This is only the beginning to understanding how cattle land affects beetle populations. Other land use studies have found beetle morphology, such as wing length and body size, to be altered by different human land use (Hanson 2016). Further studies into morphology, behavior and seasonality could give a more thorough understanding of the effects of cattle rangeland on beetles. It is important to understand the effects of cattle and agricultural land as much of the American natural prairies are disappearing to these areas (Samson and Knopf 1994). With a better understanding we can aim our conservation efforts more efficiently at specific areas of concerns.

Acknowledgements:

Thank you to the Bernard J. Hank Family Endowment for funding this project. The Confederated Salish and Kootenai Tribes, National Bison Range and Dan Hartung allowed my research to be done on their land and for that I am very grateful. Also thank you to David Flagel, Jose Carlos Wharton Soto and Kate Barrett for their advice and aid in getting this project going.

References:

Deng, L., et al. (2013). Grassland Responses to Grazing Disturbance: Plant Diversity Changes with Grazing Intensity in a Desert Steppe. *Grass and Forage Science*, 69, 3, 524–533.

Floate, K. D., & Gill, B. D. (1998). Seasonal activity of dung beetles (Coleoptera: Scarabaeidae) associated with cattle dung in southern Alberta and their geographic distribution in Canada. *The Canadian Entomologist*, 130(2), 131-151.

Hansen, J.D. (1988). Trapping methods for rangeland insects in burned and unburned sites: a comparison. *The Great Basin Naturalist*, 383-387.

Hanson, H. I., Palmu, E., Birkhofer, K., Smith, H. G., & Hedlund, K. (2016). Agricultural land use determines the trait composition of ground beetle communities. *PloS one*, 11,1.

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *Bioscience*, 52,10, 883-890.

Niemel, J., Kotze, D.J., Venn, S., Penev, L., Stoyanov, I., Spence, J. et al. (2002). Carabid beetle assemblages (Coleoptera, *Carabidae*) across urban-rural gradients: an international comparison. *Landscape Ecology*, 17, 387-401.

O'Neill, K.M., Olson, B.E., Rolston, M.G., Wallander, R., Larson, D.P. & Seibert, C.E. (2003). Effects of livestock grazing on rangeland grasshopper (Orthoptera: Acrididae) abundance. *Agriculture, Ecosystems & Environment*, 97, 51-64.

Quinn, M.A. (2004). Influence of habitat fragmentation and crop system on Columbia Basin shrubsteppe communities. *Ecological Applications*, 14, 1634-1655.

Ribera, I., Doldec, S., Downie, I.S. & Foster, G.N. (2001). Effect of land disturbance and stress on species traits of ground beetle assemblages. *Ecology*, 82, 1112-1129.

Sampson, R.N. (1981). Farmland or wasteland: a time to choose. Rodale Press, Emmaus, PA.

Samson, F. & Knopf, F. (1994). Prairie conservation in North America. *Bioscience*, 44, 418-421.

Scheffler. P. Y. (2005). Dung Beetle (Coleoptera: Scarabaeidae) Diversity and Community Structure across Three Disturbance Regimes in Eastern Amazonia. *Journal of Tropical Ecology* 21, 1, 9–19.

Stanley, E.H., Powers, S.M. & Lottig, N.R. (2010). The evolving legacy of disturbance in stream ecology: concepts, contributions, and coming challenges. *Journal of the North American Benthological Society* 29, 67-83.

Vanbergen, A.J., Woodcock, B.A., Watt, A.D. & Niemelä, J. (2005). Effect of land-use heterogeneity on carabid communities at the landscape scale. *Ecography*, 28, 3-16.

Wilkinson, D.M. (1999). The disturbing history of intermediate disturbance. *Oikos*, 145-147.

Figures:

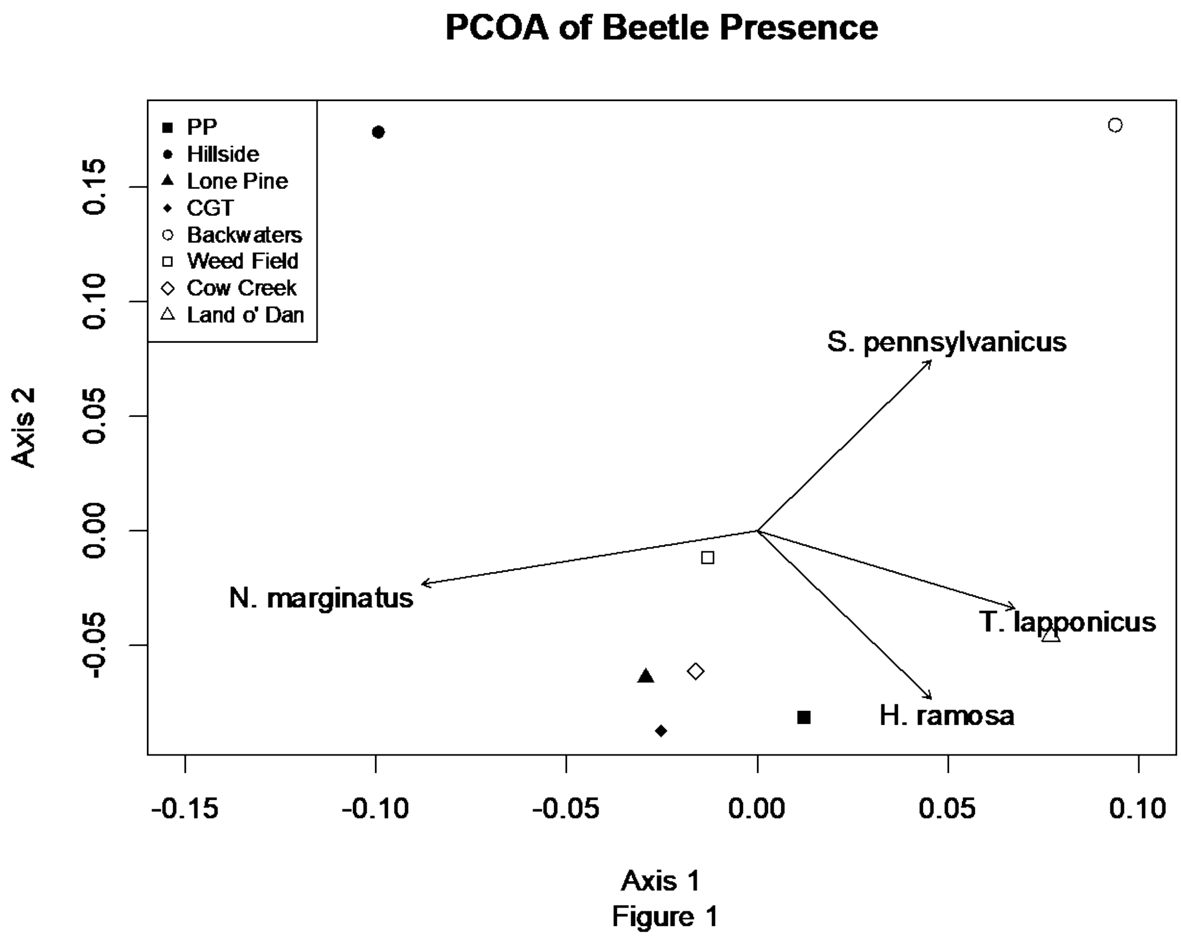

Figure 1: The Principle coordinates analysis (PCOA) of sites based on beetle abundance. Vectors are beetles significantly differing per site.

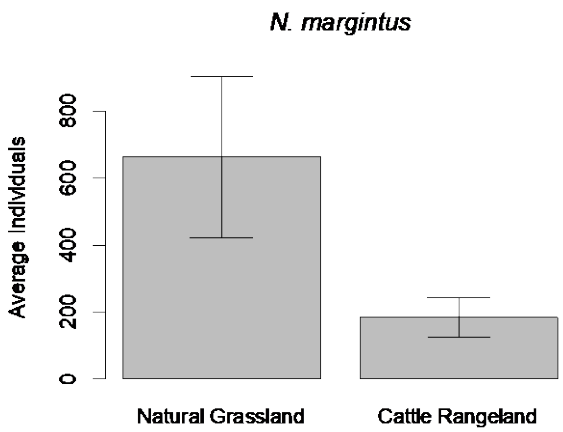

Figure 2a

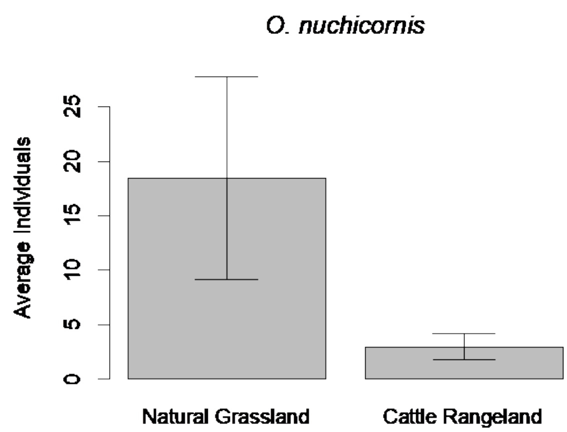

Figure 2b

Figure 2a: Average *N. margintus* abundance on natural grassland and cattle rangeland sites. Error bars show standard error.
Figure 2b: Average *O. nuchicornis* abundance on natural grassland and cattle rangeland sites. Error bars show standard error.

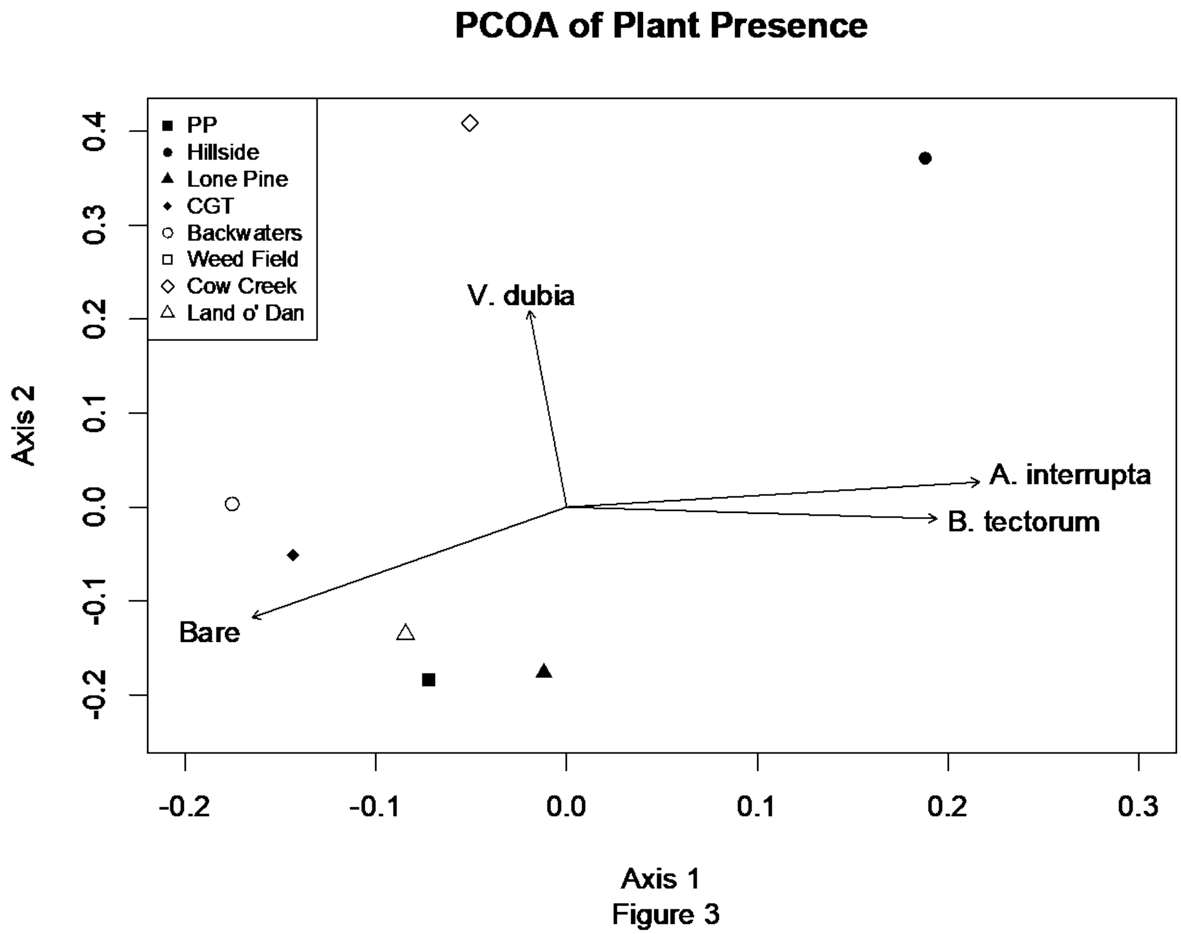

Figure 3: The Principle coordinates analysis (PCOA) of sites based on plant abundance. Vectors are beetles significantly differing per site.

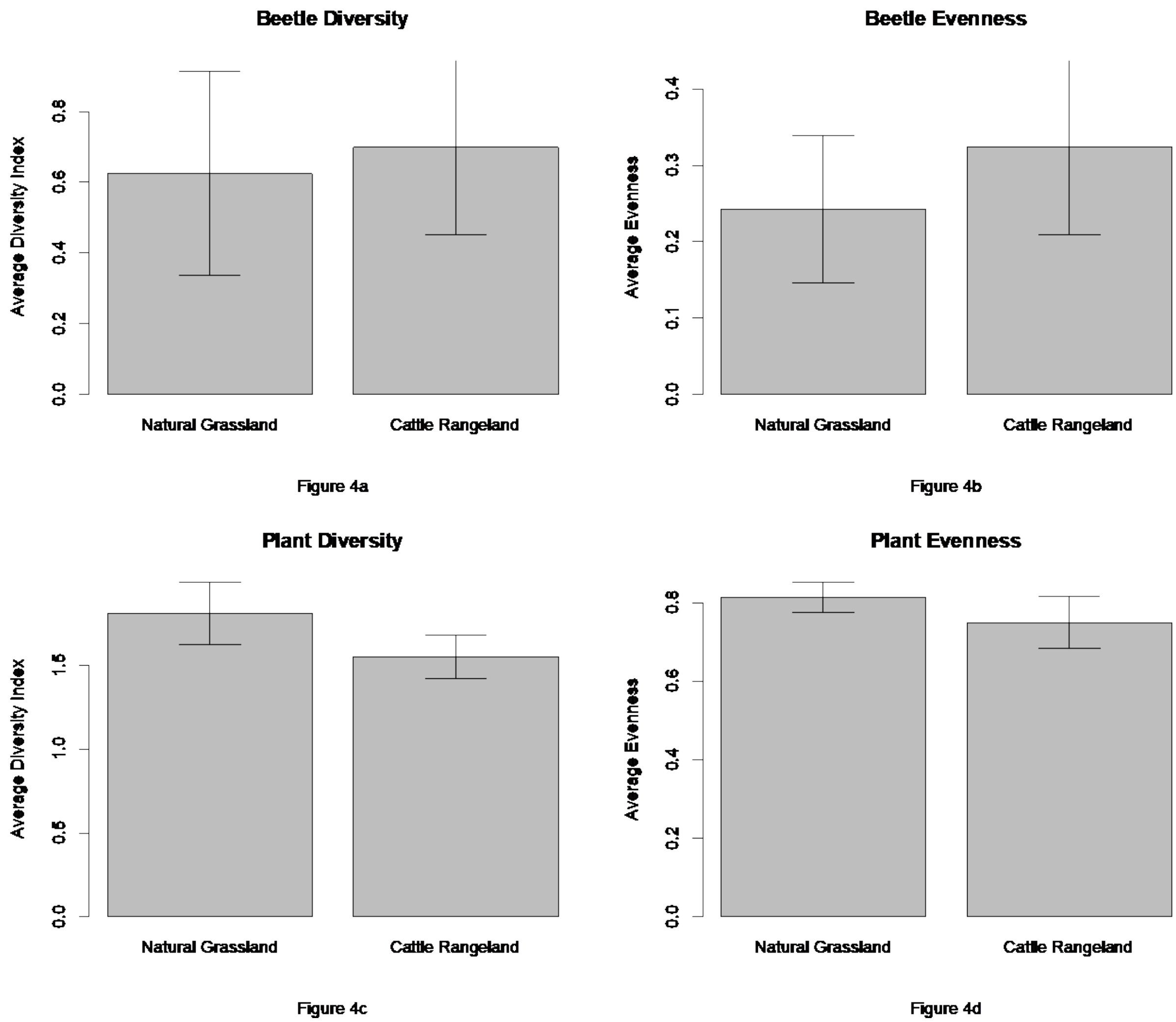

Figure 3a: Average beetle diversity (based on Shannon Wiener diversity index) on natural grassland and cattle rangeland sites. Error bars show standard error. **Figure 3b:** Average beetle (based on Shannon Wiener diversity index) evenness on natural grassland and cattle rangeland sites. Error bars show standard error. **Figure 3c:** Average plant diversity (based on Shannon Wiener diversity index) on natural grassland and cattle rangeland sites. Error bars show standard error. **Figure 3d:** Average plant (based on Shannon Wiener diversity index) evenness on natural grassland and cattle rangeland sites. Error bars show standard error.