Grasshopper biodiversity among three sites with differing herbivory regimes in the National Bison Range.

Veronica M. Velez Reyes
UNDERC WEST 2008

Veronica Velez
UNDERC WEST
2008

Grasshopper biodiversity among three sites with differing herbivory regimes in the National Bison Range.

Abstract: Ungulates can change cause changes in the plant community composition, and biomass present in an area due to their foraging activity, and both grasshoppers and ungulates share the same food resources. A study composed of multiple field surveys and one controlled experiment took place in The National Bison Range to look at how ungulate presence affected grasshopper biodiversity. Results showed that a intermediate amount of ungulate abundance provided the highest vegetation bio diversity, abundance and biomass not only because of the intermediate hervibory activity, but because of the species of ungulate present, the bison. The vegetation conditions in the site that contained bison created habitat for more grasshoppers, increasing biodiversity. Grasshopper abundance however is dependent on other factors such as interspecific competition, and species specialization.

Introduction:

The National Bison Range was established in 1908 and is administered by the U.S. Fish and Wildlife. The refuge consists mainly of native prairie, but also found here are forests, wetlands and streams which provide a wide range of habitats for local creatures. Elk, deer, pronghorn, mountain goats, bison and big horned sheep are the main large ungulates present in the area. Some of these herbivores were brought in by humans to inhabit the range, be it for esthetic purposes or conservational purposes, and were not originally native in this area. Herbivore movement in the park is restricted and controlled with fences dividing areas in the part. The park is also home to various species of grasshoppers, such as *Ageneotixx deorum*, *Camnula pellucida*, and *Melanoplus sanguinipes*. In grassland habitats, such as the one present in the Bison Range, grasshoppers are the dominant insect herbivore, and are among the most important plant-eater found in these habitats because of the role they partake in various ecological processes. Grasshoppers are mayor players in energy flow; they generate and transport nutrients and are major primary consumers (Jonas, 2007). As such they are good indicators of certain threatened habitats and have been used in the conservation and preservation of various natural areas and an indicator in land use.

Although the National Bison Range is a protected park, areas near it are subject to domestic grazing by cattle. Introducing cattle to habitats that are not very suitable for agriculture is a common practice (Cognolo, 2002), and in turn heavy grazing is one of the several activities that threaten grasslands. Grasslands that are managed for livestock grazing are usually subjected to disturbances that cause changes in the habitats of herbivorous insects. Trampling, consumption of vegetation by ungulates, and the presence of animal waste change the soil composition, the nutrients present, and so they affect the food sources available for other herbivores (Debano, 2006). The changes provoked in the plant community can cause changes in the composition and diversity of invertebrate communities that are associated, in fact insect abundance and diversity has been reported to decrease following grazing (Cagnolo, 2002). There are some special interest groups that hold the extreme view that grazing is beneficial to grassland species as it increases community productivity. This argument has been utilized to justify heavy livestock activity on private and public areas (Painter and Belsky, 1993).

In this study I will attempt to survey plant biomass and diversity, ungulate diversity and abundance, and grasshopper diversity and abundance along some areas in and around the Bison Range to see if there is a connection between the diversity of ungulates and the diversity of grasshoppers present in an area. I will focus on areas that contain different ungulates, since due to the park's management policies, some of these have been contained into zones that house different species. These "corrals" enclose most of the ungulates into specific areas, with the exception of deer which are fence jumpers and are nearly impossible to contain. These herbivores all intake different plants, for example deer and pronghorn prefer forbs but will also consume grasses at certain stages. Elk, cattle and bison are herbivores that can be classified as generalist foragers although they have been observed to show selective feeding depending on what food sources are available (Plumb and Todd, 1993). Grasshopper species also exhibit preferences in vegetation foraging, with some species being generalists, others preferring forbs, and other species being mainly grass eaters. Both groups, the ungulates and the grasshoppers in an area would share their food resources. So this leaves us the question; how does grasshopper biodiversity differ in areas that contain different ungulates?

To answer this question, a study among three sites with differing ungulate diversity will be done. One site can be accessed only by deer, the second site by cattle and deer and the third site can be accessed by bison, elk, deer and pronghorn antelope. A combination of field surveys and a controlled experiment will be done during the course of this research. Surveys for plant diversity, abundance and plant biomass will be done at each site, as well as surveys for ungulate abundance and grasshopper biodiversity and abundance. A side experiment will be done utilizing the grasshoppers *Ageneotixx deorum*, *Camnula pellucida*, and *Melanoplus sanguinepes*. In this experiment grasshopper survivability among the three study sites will be measured. The results that are expected of the surveys and experiments are as follows:

<u>-Plant Diversity and Abundance:</u>

Sites with higher ungulate abundance will have lower diversity and abundance. The site with deer only present will have higher levels due to the low amount of herbivory activity. The site with the higher diversity of ungulates will have the lowest levels.

<u>-Vegetative Biomass:</u>

The site accessed by deer only will have higher biomass due to more plants being present. Sites with higher herbivore abundance will have lower levels of plant biomass.

-Ungulate Abundance:

Due to being accessed by multiple ungulates, there will be more activity in site accessed by bison, antelope, deer and elk.

-Grasshopper Diversity and Abundance:

Grasshopper diversity and abundance will be the highest in site accessed by deer only, due to the higher levels of plant abundance and biomass. The site with the higher ungulate diversity, the bison, antelope, deer and elk site will have the lowest grasshopper diversity and abundance.

-Grasshopper Survivability:

Grasshopper species are situated in a site because it offers them a suitable environment for growth and development. (Food resources, cover, etc.) Species from a specific site should survive better in cages placed in that area, than in the ones placed in other sites.

Study Area:

This study took place on 3 sites on and near the National Bison Range. The sites varied by location, with one being inside the penned area designated as "The Second Triangle", another being in a private property just next to the Bison Range and the third site being located near a service road. Although the sites were not strictly right next to each other they were all near and all shared the same palouse prairie environment. The study sites were named after their respective ungulates: DO Site standing for "Deer Only Site", CD Site standing for "Cattle-Deer Site" and finally BADE Site, standing for "Bison, Antelope, Deer, Elk Site."

Methods:

I. Field Study:

Three transects where set up in each site, for a total of 9 transects. Flagging tape was used to mark out two sets of points in each transect, one for vegetation the other for fecal surveys. For vegetation survey points were placed at 0m, 10m, 25m and 50m, while points were marked at 0m, 20m, 40m,60m for the fecal surveys (Fig.11). Near each transect, one 30m x 30m plot was placed for grasshopper abundance surveys (Fig.11). The surveys were al conducted in mid July. Once all the data was collected it was analyzed through the use of ANOVAs, and graphs made in SyStat and Excel.

<u>-Vegetation Survey:</u>

-Biomass Clippings: At each of the sampling points, biomass clippings were taken. The clippings were done a meter away from the sampling point to ensure that the area sampled wasn't trampled by the researchers. A 20cm radius was laid out by embedding a small spike with a 20cm chain attached to it in the soil. Using a pair of clippers vegetation approximately 1.5cm above the soil was taken and stored into plastic bags. Upon returning to the laboratory the samples were moved to paper bags, labeled and placed in a drying oven at 60C for a period of 48 hours. Once this period was over, the biomass was weighted in a scale and the results recorded

-<u>Toe-Point surveys:</u>

The toe point survey was done by utilizing a 100cm long meter stick that was placed at each side (Both left and right.)of the 0m, 10m, 25m or 50m sampling point. Every 5cm on the meter stick would indicate a point where species recording was to take place. The species that could not be identified out in the field were brought back to the lab for identification. Those that could not be identified following this method were given a code name that served as their identification. Species surveyed were classified into “forbs”, “grasses” or “brush”. Litter and bare ground fell into the “other” category. The species information obtained in this survey was utilized to calculate a Shannon H for all sites.

-Fecal Survey:

To measure animal abundance, a team of 2 people stopped at every 0m, 20m, 40m and 60m point. While one individual stood on the point holding one end of a measuring tape, the other individual held the other end of the tape and walked away to a distance of 10m. Here a 10m sampling radius was created around the point, and fecal piles were counted and identified to their corresponding ungulate.

-Grasshopper Biodiversity Survey:

Utilizing sweep nets, as well as other more rudimentary methods such as “capturing by hand”, grasshoppers were surveyed in the areas around the transects. Every time a new species was found it was entered in a Site Species List.

-Grasshopper Abundance Survey:

A team of 2 people surveyed the three 30 x 30 plots at each site. The plots were divided in half at 15m, allowing each person to sweep one half of the plot. Two five minute sweeps were done in each sampling plot, the first involving a north to south sweep of the plot, the second involving an east to west sweep of the plot. Grasshoppers were totaled as well as identified by species in this sweep survey.

II. Survivability Experiment:

For this test one 8m by 6m plot was marked out in each study site, and in it eighteen .01m squared x .8 m in height mesh cages were placed approximately 2 meters between each other. To place a cage, a square first had to be dug out using a sturdy shovel. The initial dug out lines were then made deeper utilizing garden spades. The cage was then placed over the square area, making sure that the edges fit inside the dugout area. Soil was used to pack in the cages, successfully sealing the bottom of the cages, while the mesh tops were sealed using clips. Sample sweeps were done near the transects to determine what species was the most numerous in the area. Empty and washed milk jugs were used to transport the captured grasshoppers into the laboratory where they were housed in terrariums and fed dandelion during their stay. *Ageneotixx deorum*, *Camnula pellucida*, and *Melanoplus sanguinipes* were the species that appeared more numerous during the initial sweeps, with *A.deorum* being more numerous in the CD site, *C.pellucida* in the DO site, and *M.sanguinipes* in the BADE site (Fig.10).

After 450 individuals of each species were collected, ten grasshoppers of each species were then placed in jars and labeled according to the site they came from. Each study site had 15 cages : 5 stocked with 10 *M.sanguinipes*, 5 stocked with 10 *C.pellucida* and 5 stocked with 10 *A.deorum*. The remaining 3 cages served as control and had no grasshoppers. The cages were randomly stocked and followed no pattern. The day following stocking of all 45 cages, grasshopper mortality was at an almost 50% high. This might have been due to stress induced by handling, and by their stay in the terrarium. The cages were then restocked directly from the field with no further handling during one massive sweeping and stocking day. After this last stocking, the initial survivability was cut down and the cages were inspected and grasshopper survival was surveyed once every other day. This experiment ran for 12 days, ending in late July, and once the cages were taken down, the biomass remaining in the cages was clipped and stored in plastic bags. Once taken to the laboratory, they were transferred to paper bags and placed in a drying oven at 60C for a 48 hour period. Once this period was over the biomass was weighted.

Results:

I. Field:

-Plant Diversity, Abundance and Biomass:

After completing the plant vegetation surveys, the data was ran through an ANOVA to determine the relationship between the number of species(Fig.1), abundance(Fig.2a) and biomass(Fig.2b) per location. In all cased plant diversity abundance and biomass was highest at BADE, while the lowest was CD. The p-values for number of species vs. site was a ($P > 0.048$) making it statistically significant. For the Shannon H test we also obtained statistical significance ($P > 0.027$), but for the biomass comparison we only approached significance ($P > 0.078$). The p-value is close enough that it can be considered as being statistically significant.

-Ungulate Abundance:

After tallying the fecal surveys it was discovered that the CD site has the highest abundance, while BADE had medium abundance and DO had the lowest(Fig.3)

-Grasshopper Diversity and Abundance: .

The BADE site had the highest grasshopper diversity while CD had the lowest (Table 2). The results from the abundance sweeps yielded significant results ($P > 0.00$), in which DO had the lowest abundance, CD had the highest and BADE was an intermediate (Fig.4). A Shannon H index was calculated utilizing the grasshoppers caught in this abundance sweep but no statistically significant results were reached (Fig.5). A bar graph was made to analyze the abundance of species in each site, and it was discovered that the reason for the results in the Shannon H index was the species *M.sanguinipes* was highly abundant on all sites, coming second to *T.kiowa* in the CD site only (Fig.6). The rest of the sites also seemed to have one species that was dominant after *M.sanguinipes*, while the rest of the species failed to achieve numbers that were as numerous.

II. Survivability Experiment:

In the grasshopper survival experiment the same pattern in all cases. *A.deorum* was the better survivor, followed by *M.sanguinipes* and *C.pellucida*. A second method was used to more clearly view this data, ,the graphing of asymptotes to view the survival number were the number of grasshoppers per cage evened before depleting further and hitting 100% mortality. Utilizing asymptotes revealed that the grasshoppers did tend to do better in the cages that were located in the site where they had been captured (Fig.8). The analysis of biomass per cage and site proved to show no statistical significant results. (Fig. 9)

Discussion:

At the beginning of this study, it was thought that the diversity of ungulates would be the principal factor influencing biomass, plant abundance and diversity and in turn grasshopper abundance and biodiversity. So many of the predictions revolved around the BADE site having the lowest amount of diversity and abundance due to it containing 4 species of ungulates that fed on forbs, grasses and brush. Interestingly enough, the surveys done in the BADE site failed to encounter any elk feces or deer feces (Table 1). This indicates that although they had access to the site, their abundance in it was minimal. The scat results in BADE indicated an area that was mainly utilized by bison and visited sparsely by antelope. While all sites are penned in some way, their overall area differed. The BADE site was situated in an expansive area, this in turn allowed for a wider range of foraging for the ungulates. So although they might have access to the area, they are not forced to all congregate in the same zone. The CD site area had a high abundance of animals, and being a site utilized for the commercial use of cattle it is not surprising that the ranchers would stock their pasture with as much cattle as was feasible at one point. The owners of said pasture might also be responsible for some of the vegetation growing in it such as the high amount of *Agropyrum cristatum.* Extensive use by cattle in this site had left the soil in many parts hard and cracked, unsuitable for most plants except for a few forbs such as *Logfia arvensis* and some grasses. The DO site was only browsed and grazed by deer, and being able to jump fences, they were never trapped and contained in the area, giving way to low abundance in the site. The DO site contained a fair amount of grasses, and a higher amount of forbs than the CD site.

Not surprisingly the environment due to the high levels of disturbance brought about by the high number of cattle in the CD site plant biodiversity, abundance and biomass was the lowest out of all three sites. DO was the intermediate one in all accounts, containing more biodiversity, abundance and biomass, but not as much as the BADE site offered with its higher amount of grass species, and noticeable increase in forb species. As was stated earlier, BADE site had mainly bison present with other ungulates passing through in much lower abundances. Some studies have managed to establish a link between the presence of bison and the increase of forbs in an area, in comparison to a decrease of forbs were cattle are present (Damhoureyeh 1997). Selective grazing by bison has been shown to increase the biomass in areas, due to increased light availability to the remaining plants and forbs that are not grazed upon, and due to the reduction of leaf areas allowing more moisture to reach the soil (Fahrestock, 1993).

More forbs and grasses present in an area, create more microhabitats and offer more food sources for grasshoppers to inhabit. This directly correlates to the BADE site having the highest results in the vegetation surveys as well as containing the highest grasshopper diversity. The diverse grasses and forbs in the area allowed for forb-eating grasshoppers such as *Melanoplus dawsoni* and *Melanoplus bivittatus* to inhabit the area, as well as grass-eaters such as *Trachyrhachys kiowa* and *Ageneotettix deorum* to settle in the area. Generalist grasshoppers such as *Melanoplus sanguinipes* and *Melanoplus femurubrum* were present in all sites, although *M.femurubrum* was present in lower numbers due to it being a late hatcher.

The grasshopper abundance sweeps were biased in nature, due to sweep nets only skimming the surface of areas and missing all the grasshoppers that hid among the vegetation cover and litter. As such it was to be expected that more were found in the CD site, as due to its low vegetative cover there is a tendency to capture more grasshoppers using sweep nets in areas that have been heavily grazed. (Holmes 1979)

In the survival experiments, the patterns can be explained as follows. *M.Camnula* were a poor choice of grasshopper to represent the DO site, as in the time of year where this experiment was being concluded, their numbers are dropping naturally die to their lifecycle. Interenstingly enough, the intermediate survivor in the cages, *M.sanguinipes*, was dominant in the field, while the best cage survivor *A.deorum* was only found in the CD and BADE sites. *M.sanguinipes* is generally a generalist, it can change its feeding habits depending on the food sources available and is a good competitor out in the field, competing for food with other grasshoppers (Chase 1996a). In areas where *A.deorum* and *M.sanguinipes* are present together *A.deorum* gets outcompeted for food and its survival goes down (Chase 1996b). So while in the cages by itself it survives best, once out in the field it becomes part of interspecies competitions and dynamics that lower its survival.

Conclusions:

Intermediate amount of ungulate abundance in the BADE site provided the highest vegetation bio diversity, abundance and biomass not only because of the intermediate hervibory activity but because of the ungulate present, in this case the bison. The vegetation conditions in the BADE site created habitat for more grasshoppers, increasing biodiversity. Grasshopper abundance however is dependent on other factors such as interspecific competition, and species specialization.

Acknowledgements:

The National Bison Range for allowing this study to occur. Many thanks also go to Gary Belovsky, Gretchen Gerrish and to fellow researchers Kelly Collins, Charles Volgenheim and Stephanie Doerries.

Resources:

Belovsky, GE & Slade, JB 2000, 'Insect Herbivory Accelerates Nutrient Cycling and Increases Plant Production', *Proceedings of the National Academy of Sciences of the United States of America*, vol. 97, no. 26, pp. 14412-14417

Blumer, P & Diemer, M 1996, 'The Occurrence and Consequences of Grasshopper Herbivory in an Alpine Grassland, Swiss Central Alps', *Arctic and Alpine Research*, vol. 28, no. 4, pp. 435-440.

Branson, DH & Sword, GA 2007, 'Grasshopper Herbivory Affects Native Plant Diversity and Abundance in a Grassland Dominated by the Exotic Grass Agropyron cristatum', *Society for Ecological Restoration International*, doi: 10.1111/j.1526-100X.2007.00343.x

Cagnolo, L, Molina, SI & Valladares, GR 2002, 'Diversity and guild structure of insect assemblages under grazing and exclusion regimes in a montane grassland from Central Argentina', *Biodiversity and Conservation*, vol. 11, pp. 407-420.

Chase, JM 1996a, ‘Differential Competitive Interactions and the Included Niche: An Experimental Analysis with Grasshoppers’, *Oikos*, vol. 76, no. 1, pp. 103-112.

Chase, JM 1996b, ‘Varying Resource Abundances and Competitive Dynamics’, *The American Naturalist*, vol. 147, no. 4, pp. 649-654.

Damhoureyeh, SA & Hartnett, DC 1997, ‘Effects of Bison and Cattle of Growth, Reproduction, and Abundances of Five Tallgrass Prairie Forbs’, *American Journal of Botany*, vol. 84, no. 12, pp. 1719-1728.

Debano, SJ 2006, ‘Effects of livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona’, *Biodiversity and Conservation*, vol. 15, pp. 2547-2564.

Fahnestock, JT & Knapp, AK 1993, ‘Water Relations and Growth of Tallgrass Prairie Forbs in Response to Selective Grass Herbivory by Bison’, *International Journal of Plant Sciences*, vol. 154, no. 3, pp. 432-440.

Fleischner, TL 1994, ‘Ecological Costs of Livestock Grazing in Western North America’, *Conservation Biology*, vol. 8, no. 3, pp. 629-644.

Gebeyehu, S & Samways, MJ 2002, ‘Grasshopper assemblage response to a restored national park (Mountain Zebra National Park, South Africa)’, *Biodiversity and Conservation*, vol. 11, pp. 283-304.

Jonas, JL & Joern, A 2007, ‘Grasshopper (Orthoptera: Acrididae) communities respond to fire, bison grazing and weather in North America tallgrass prairie: a long-term study’, *Oecologia*, vol. 153, pp. 699-711.

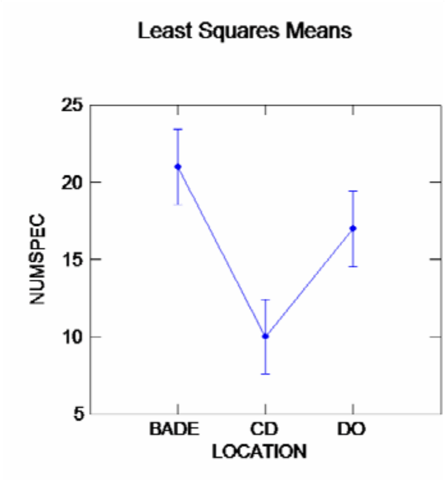
McMahan, CA 1964, ‘Comparative Food Habits of Deer and Three Classes of Livestock’, *The Journal of Wildlife Management*, vol. 28, no. 4, pp. 789-808.

O’Neill, KM, Olson, BE, Rolston, MG, Wallander, R, Larson, DP & Seibert, CE 2003, ‘Effects of livestock grazing on rangeland grasshopper (Orthoptera: Acrididae) abundance’, *Agriculture, Ecosystems and Environment*, no. 97, pp. 51-64.

Painter, EL & Belsky, AL 1993, ‘Application of Herbivore Optimization Theory to Rangelands of the Western United States’, *Ecological Applications*, vol. 3, no. 1, pp. 2-9.

Plumb, GE & Dodd, JL 1993, ‘Foraging Ecology of Bison and Cattle on a Mixed Prairie: Implications for Natural Area Management’, *Ecological Applications*, vol. 3, no. 4, pp. 631-643.

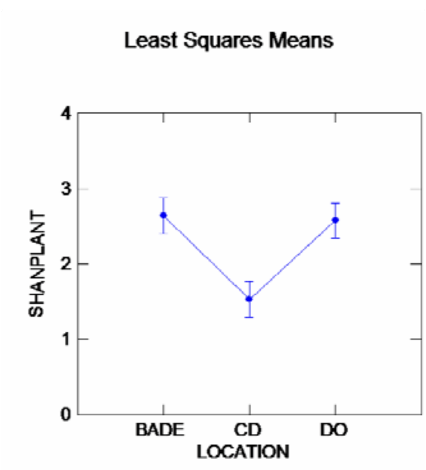
Figures:



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	186.000	2	93.000	5.264	0.048
Error	106.000	6	17.667		

Fig.1 Number of Plant Species among Study Sites

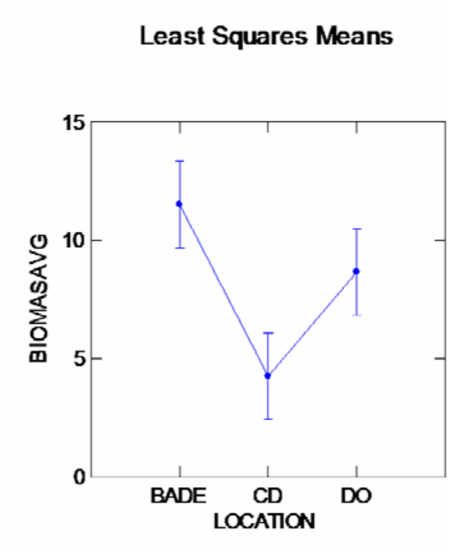
The number of plant species is highest at BADE, and is lowest at CD. P-value of 0.048 shows us there is significance.



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	2.335	2	1.168	6.998	0.027
Error	1.001	6	0.167		

Fig.2a Vegetation Shannon H among Study Sites ANOVA

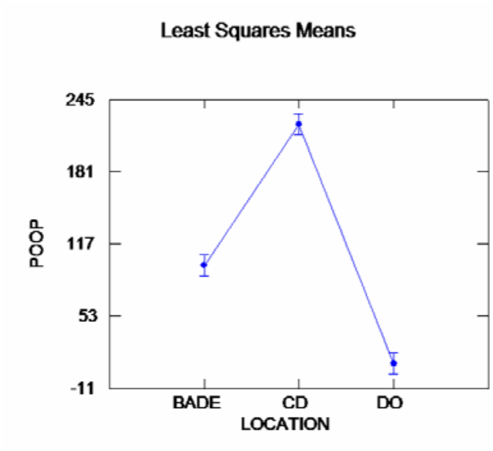
The Shannon diversity index has a p value of 0.027 showing us significance. It follows the same pattern as Fig.1.



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	80.164	2	40.082	4.021	0.078
Error	59.808	6	9.968		

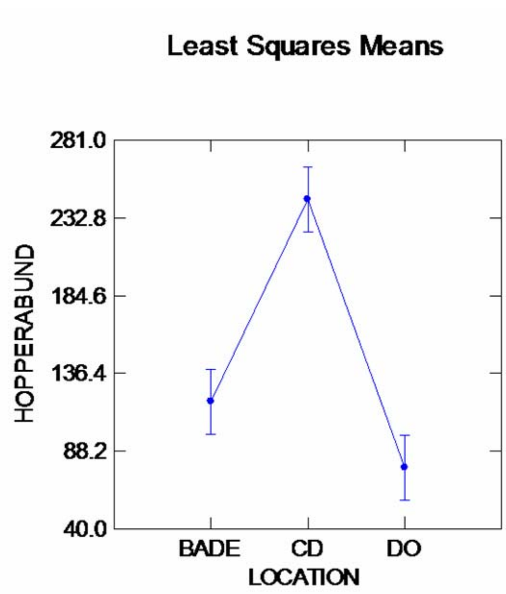
Fig.2ab Biomass among Study Sites ANOVA

Biomass is highest at BADE, and is lowest at CD. P-value of 0.048 shows us there is significance.



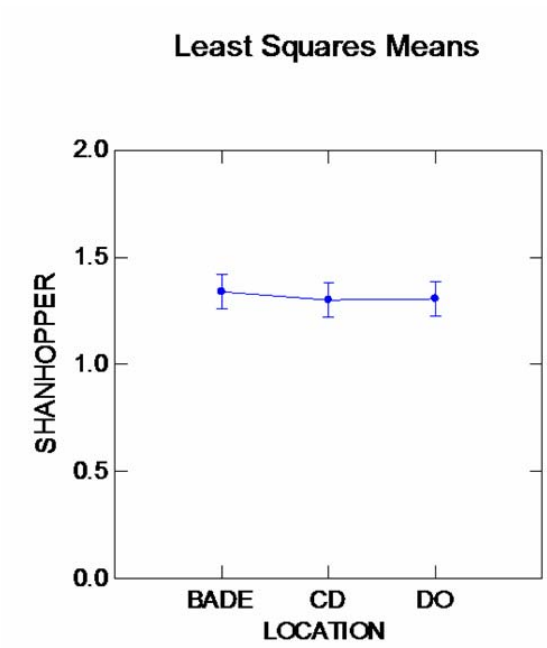
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	68138.000	2	34069.000	126.494	0.000
Error	1616.000	6	269.333		

Fig.3 Ungulate abundance based on fecal matter ANOVA
The fecal count is highest at CD, and is lowest at DO. P-value of 0.000 shows us there is high significance.



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	45056.222	2	22528.111	18.504	0.003
Error	7304.667	6	1217.444		

Fig.4 Grasshopper abundance among study sites ANOVA
The grasshopper abundance is highest at CD, and is lowest at DO. P-value of 0.003 shows us there is high significance



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	0.003	2	0.001	0.068	0.935
Error	0.114	6	0.019		

Fig.5 Grashopper Shannon H among study sites ANOVA
Very little variation among sites, and a p-value of 0.975 makes it not significant.

Grasshoppers: Relative Abundance among Study Sites

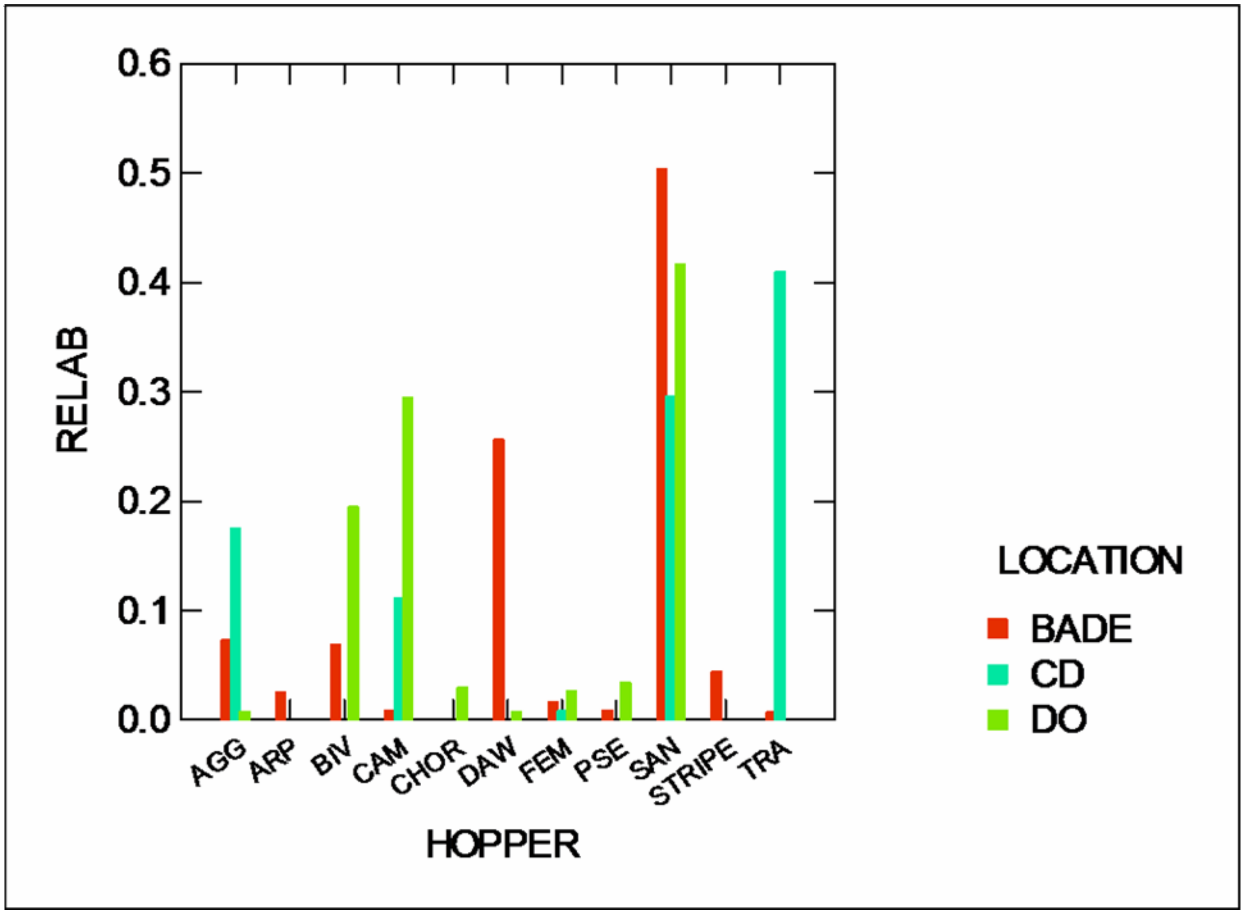


Fig.6 Relative abundance of grasshopper species among sites

Just a couple of species dominate the abundance, for example M.sanguinipes is abundant in all sites .

Grasshoppers: Survival among Study Sites

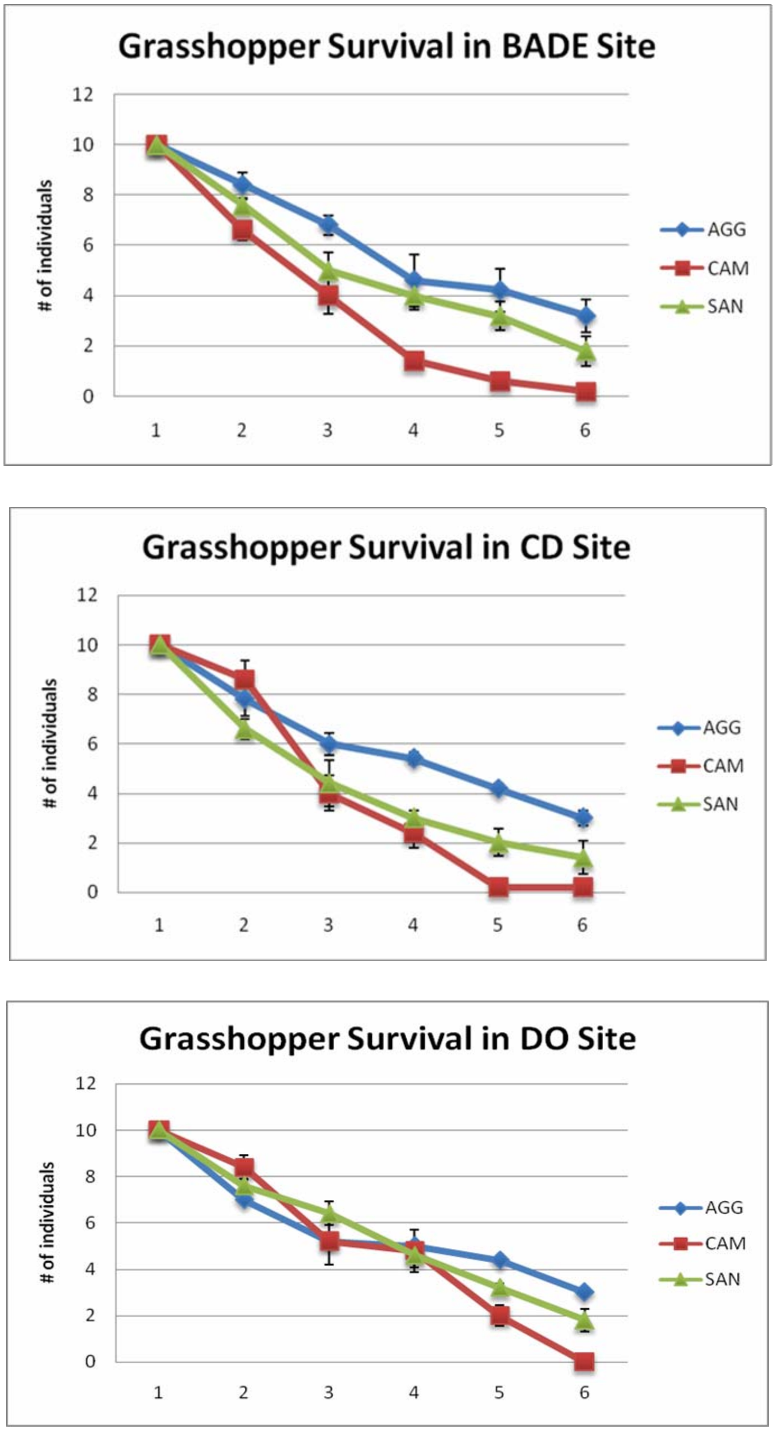
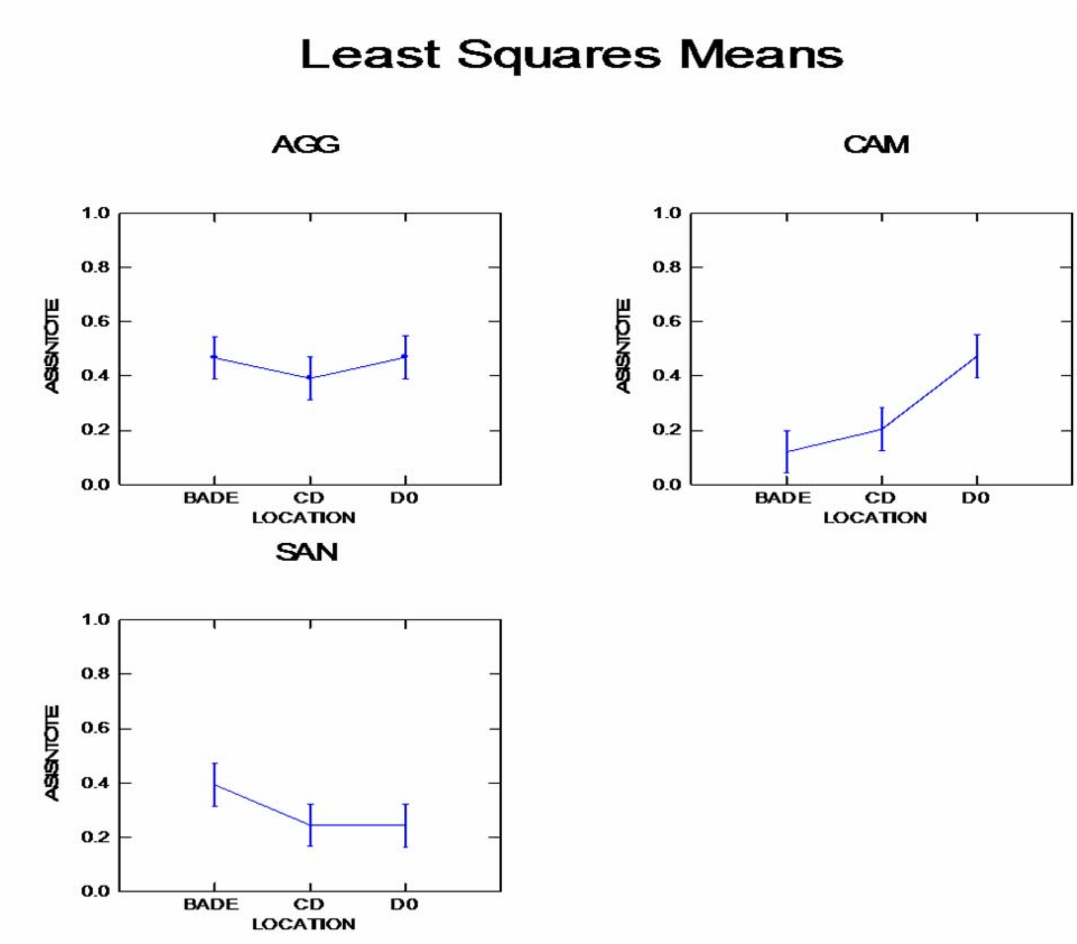
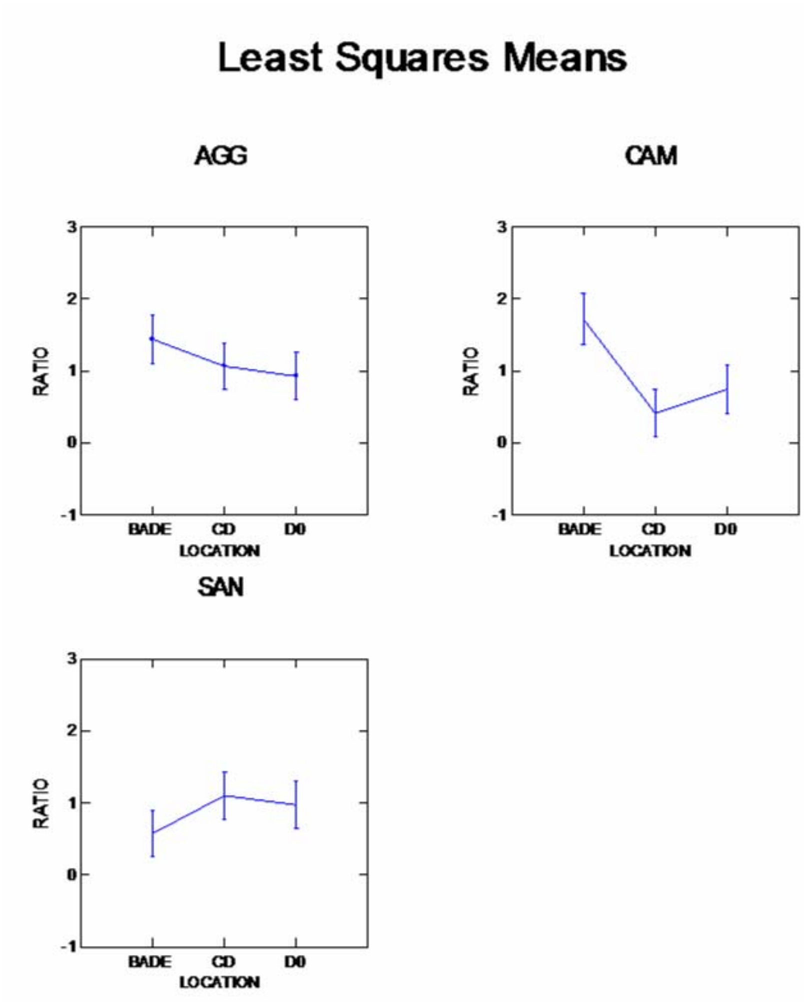


Fig.7 Grashopper Survival Experiment
All species followed similar trends, with AGG being the better survivor SAN following after and CAM being the last.



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	0.101	2	0.050	1.651	0.206
HOPPER$	0.271	2	0.136	4.441	0.019
LOCATION$*HOPPER$	0.333	4	0.083	2.727	0.044
Error	1.099	36	0.031		

Fig.8 Grashopper Survival Experiment- Asymptote
Utilizing asymptotes to calculate the survival rate, results were similar to those expected. SAN did best in BADE, and CAM did best in DO. The p-values show the results are significant.



Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
LOCATION$	**1.406**	**2**	**0.703**	**1.378**	**0.265**
HOPPER$	**0.442**	**2**	**0.221**	**0.434**	**0.652**
LOCATION$*HOPPER$	**4.200**	**4**	**1.050**	**2.059**	**0.107**
ASINTOTE	**0.600**	**1**	**0.600**	**1.176**	**0.286**
Error	**17.848**	**35**	**0.510**		

Fig9. Biomass Clipping per cage
The biomass inside the cages was too varied to calculate an adjusted biomass that could yield statistically significant results.

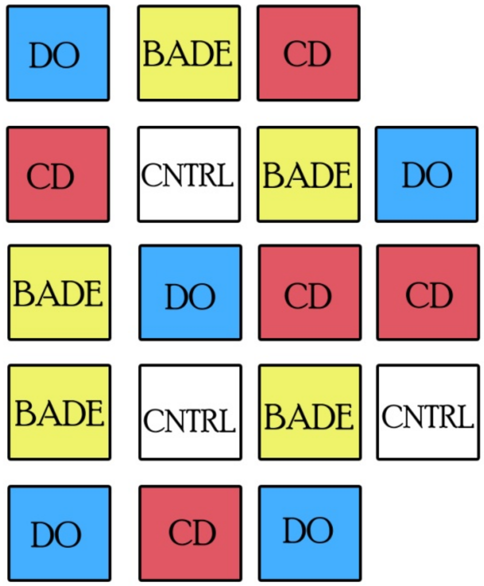


Fig.10 Grashopper Survival Experiment-CAGES diagram
A top view of how the plot for the cage experiments would have looked. Squares represent cages that contain the different species of grasshopper and the controls.

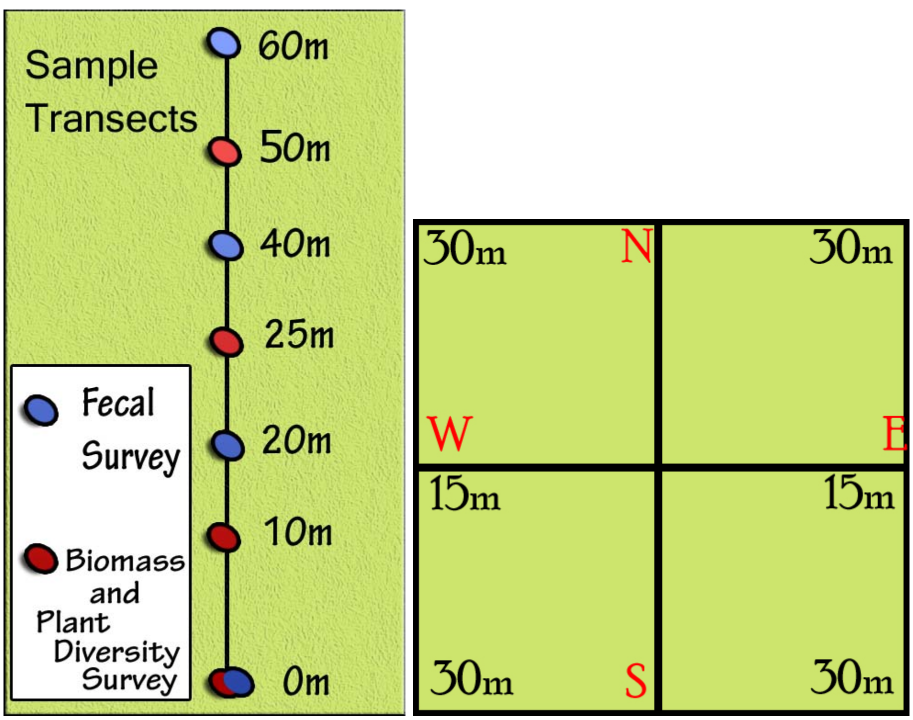


Fig.11 Diagram of Vegetation and Fecal Survey transect and Grasshopper Abundance plot.