Native Grass Characteristics within Xeroriparian Communities of the Sonoran Desert National Monument

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ABSTRACT

Native grasses have been identified as an important conservation element in the Sonoran Desert National Monument (SDNM) and adjacent areas. Our previous projects were designed to assess the overall ecological condition of natural communities in the SDNM and did not contain enough data on native grass abundance within the valley xeroriparian scrub communities to conduct an adequate analysis of native grass abundance and distribution within these communities.

In the fall of 2005 and the spring of 2006, we established and collected field data from 56 permanent research plots within the *Valley Xeroriparian Scrub* and *Braided Channel Floodplain* natural communities to determine answers to the following questions:

1) Are there differences in native grass species composition, cover, and density within a xeroriparian community with distance from an active water development?
2) Are there differences in native grass species composition, cover, and density between xeroriparian communities with different adjoining matrix communities?
3) Are there differences in native grass species composition, cover, and density between xeroriparian communities in different BLM grazing allotments north of Interstate 8 on the SDNM?
4) Are there differences in native grass species composition, cover, and density between xeroriparian communities that contain different amounts of non-native grass (and prominent non-native forbs) species richness and cover?

We used statistical analysis techniques (ANOVA, correlation analysis and linear regression tests) to analyze statistically significant relationships between native grass cover, stem density, and diversity in relation to distance from water development, BLM grazing allotment, adjoining matrix community, and exotic grass cover. Statistically significant relationships were found for the following variables:

Native grass stem density and the adjoining matrix community
Native grass species composition and the BLM grazing allotment
Native grass cover and the BLM grazing allotment
Native grass stem density and the BLM grazing allotment
Native grass species composition and amount of exotic grass cover

We also analyzed exotic grass cover and total grass cover by the same criteria, as well as cattle activity indicators. We found statistically significant relationships for the following variables:

Exotic grass cover and distance from water source
Total grass cover and BLM grazing allotment
Exotic grass cover and BLM grazing allotment
Number of cow hoof prints and distance from water source
Number of cow trails and distance from water source
Number of cow hoof prints and the BLM grazing allotment
Native grass cover and the amount of cow hoof prints

Our analyses indicate that there is a correlation between the amount of native grass cover and the amount of grazing activity. The Bighorn allotment showed the highest levels of grazing activity

and contained the lowest levels of native grass cover, stem density, and diversity. It also contained the least amounts of exotic grass cover and total grass cover.

The amount of native perennial grasses measured within the 56 sample plots was extremely low, and we were not able to conduct adequate statistical analyses on this category of grass. Perennial native grass cover within the northern part of the SDNM was less than we found previously in the same natural community types in the nearby Barry M. Goldwater Range (BMGR).

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Introduction

Native grass diversity and abundance were identified as important indicators of natural community ecological conditions based upon ecological condition studies we conducted in the Sonoran Desert National Monument (SDNM) during the spring of 2003 (Morrison et al., 2003). That same year, native grasses within the SDNM were determined to be important conservation features during an interdisciplinary meeting of Bureau of Land Management (BLM) and The Nature Conservancy (TNC) and other experts about Conservation Elements of the Sonoran Desert National Monument. Subsequently, in 2004 we further analyzed the ecological condition data we collected during the spring of 2003 to attempt to determine if significant relationships existed between native grass distributions and various ecological influences (Snetsinger and Morrison, 2004). Analyses conducted in 2004 revealed that additional field data was needed to effectively determine significant native grass distribution patterns within the *Valley Xeroriparian Scrub* and *Braided Channel Floodplain* natural communities.

In 2005, this project was established through Nature Conservancy Contract # AZFO-040816, to conduct field research within the *Valley Xeroriparian Scrub* and *Braided Channel Floodplain* natural communities of the Sonoran Desert National Monument and determine if significant relationships exist between native grass distributions and particular landscape features (see Appendix A for descriptions and information about the *Valley Xeroriparian Scrub* and *Braided Channel Floodplain* natural communities (from Morrison et al 2003)). More precisely, this project was set up to determine answers to the following questions:

1) Are there differences in native grass species composition, cover, and density within a xeroriparian community with distance from an active water development?
2) Are there differences in native grass species composition, cover, and density between xeroriparian communities with different adjoining matrix communities?
3) Are there differences in native grass species composition, cover, and density between xeroriparian communities in different BLM grazing allotments north of Interstate 8 on the SDNM?
4) Are there differences in native grass species composition, cover, and density between xeroriparian communities that contain different amounts of non-native grass (and prominent non-native forbs) species richness and cover?

Our previous field work in the SDNM, Barry M. Goldwater Range (BMGR) and Tohono O'odham Nation (TON) (Morrison 2003, Morrison et al 2003, Snetsinger and Morrison 2004) identified areas within the *Valley Xeroriparian Scrub* and *Braided Channel Floodplain* natural communities that contain high amounts of native perennial grass cover (Photos 1 and 2). Byron Lambeth (BLM) also has noted a few xeroriparian areas in the SDNM that contain native perennial grass. We visited two such areas in the northern part of the SDNM containing significant perennial native grass with Byron and others on a joint TNC/PBI/BLM/USAF field trip in October 2004 (Photo 3). The knowledge of such areas and interest on the part of TNC, BLM and PBI to locate more xeroriparian areas with perennial native grass were a driving force behind the creation of this project. There was also a desire from all participants in that field trip to develop a better understanding of the factors that may control the distribution of native grasses in xeroriparian areas. Although most of the known xeroriparian areas with high perennial grass cover occur on the BMGR, this project was designed to investigate the frequency of occurrence of similar areas within the four northern grazing allotments of the SDNM and to explore the various factors that control grass abundance, diversity and distribution in xeroriparian areas.

Photo 1. A healthy patch of *Muhlenbergia porteri*, a summer perennial growing along a small wash in a *Paloverde Mixed Cacti – Mixed Shrub on Bajadas* natural community of the western portion of the Vekol Valley in Area A - observed on joint TNC/PBI/BLM/USAF field trip in October 2004.

Photo 2. Xeroriparian area with abundant native perennial grass in the East Tactical Range of the BMGR.

Photo 3. A rare example of the perennial native grass, *Pleuraphis rigida*, growing along a small *Valley Xeroriparian Scrub* community in the northern part of the SDNM. This small xeroriparian grass patch was explored on a joint TNC/PBI/BLM/USAF field trip in October 2004.

Terms and Definitions

Table 1. Definitions of some of the terms inherent to the questions stated in the project introduction.

Term	Definition
species composition	The number of species occurring within a given area or spatial element (i.e. natural community or plot). This is a measure of species diversity.
species cover	The amount of area covered by a given species' above ground live vegetated canopy within a given area or spatial element (i.e. natural community). This is measured as the percent of the total area of a particular species canopy cover divided by the total given area.
species density	The amount of individual organisms of a given species present within a given area or spatial element (i.e. natural community). This is the number of individuals divided by the total given area.
active water development	Specific sites mapped by the BLM as currently used for providing water to cattle in the desert rangeland.
BLM grazing allotments	Land owned and managed by the BLM that is allotted to private ranchers for cattle grazing. In this project we focused on 4 separate allotments: Hazen, Conley, Bighorn, and Beloat).
natural community	A broad ecological association as described in Hall et al. 2001 and Morrison et al. 2003.
adjoining matrix communities	Landscape dominant natural communities abutting a xeroriparian area. In this project, the two major matrix communities encountered were Creosote Bush – Bursage Desert Scrub (CB) and Paloverde - Mixed Cacti - Mixed Scrub on Bajadas (PVMCB).
CB	Creosote Bush – Bursage Desert Scrub
PVMCB	Paloverde - Mixed Cacti - Mixed Scrub on Bajadas
SDNM	Sonoran Desert National Monument
ANOVA	Analysis of variance

Methods

In order to capture data with which to deduce grass distribution patterns and trends in the xeroriparian communities of the Sonoran Desert National Monument, we developed a plot sampling design similar to the natural community vegetation plots we established in the SDNM in 2003, though we adapted the design to better fit the information needs of this project. We have titled this plot design "permanent native grass monitoring plots". As required under our project contract, field surveys were conducted twice for each plot we established. In order to ensure accurate resurveying of the exact same location between survey dates, and to aide in locating the plots for possible future surveys, we used rebar stakes to permanently mark plot centers. Initial surveys were conducted in November of 2005, while the second round of surveys were conducted the following March in 2006. We followed the same protocols for each survey session.

Stratification and Distribution of Survey Plots

The permanent native grass monitoring plots were distributed throughout the northern reaches of the SDNM based on the following criteria contained in our project work agreement:

(1) All plots were to be located on the SDNM north of Interstate 8.
(2) Distribute and locate the plots according to the following stratification:
  a) Adjoining matrix community: *Creosotebush-Bursage Desert Scrub* and *Paloverde-Mixed Cacti-Mixed Scrub on Bajadas.*
  b) Distance from an active water development: 2 distances: 1 km and 4 - 6 km
  c) Allotment: the four allotments of interest to BLM north of I-8.
(3) We attempted to achieve a sample size of at least 3 replicates per treatment.

Plot locations were determined and mapped before field surveys began based on the above criteria. Plot locations were selected manually using GIS to evaluate a wide range of constraints. We incorporated natural community maps from 2003, rangeland improvements data from the BLM, grazing allotment maps from BLM, land ownership maps, and BLM roads and trails maps to determine plot locations that were efficiently accessible and met the specifications of our survey criteria.

In the end, we were able to create and inventory 56 permanent native grass monitoring plots during the course of this project. Tables 2 – 5 and Figures 1 - 3 illustrate the stratification elements and distribution of these plots.

Table 2. Number of plots surveyed within each of the 14 treatment groups.

Stratification Group (Allotment / Natural Community / Distance from Water Source)	Number of Plots
Beloat / CB / 1 km	6
Beloat / CB / 4 - 6 km	7
Beloat / PVMCB / 4 - 6 km	1
Bighorn / CB / 1 km	6
Bighorn / CB / 4 - 6 km	5
Bighorn / PVMCB / 1 km	1
Bighorn / PVMCB / 4 - 6 km	1

Stratification Group (Allotment / Natural Community / Distance from Water Source)	Number of Plots
Conley / CB / 1 km	6
Conley / CB / 4 - 6 km	5
Conley / PVMCB / 1 km	1
Conley / PVMCB / 4 - 6 km	2
Hazen / CB / 1 km	6
Hazen / CB / 4 - 6 km	7
Hazen / PVMCB / 4 - 6 km	2

Table 3. Number of plots surveyed within the two distance from water development categories.

Distance From Water Development	Number of Plots
1 km	26
4 - 6 km	30

Table 4. Number of plots surveyed within the two matrix community categories.

Natural Community	Number of Plots
CB	48
PVMCB	8

Table 5. Number of plots surveyed within the four BLM grazing allotments.

Allotment	Number of Plots
Beloat	14
Bighorn	13
Conley	14
Hazen	15

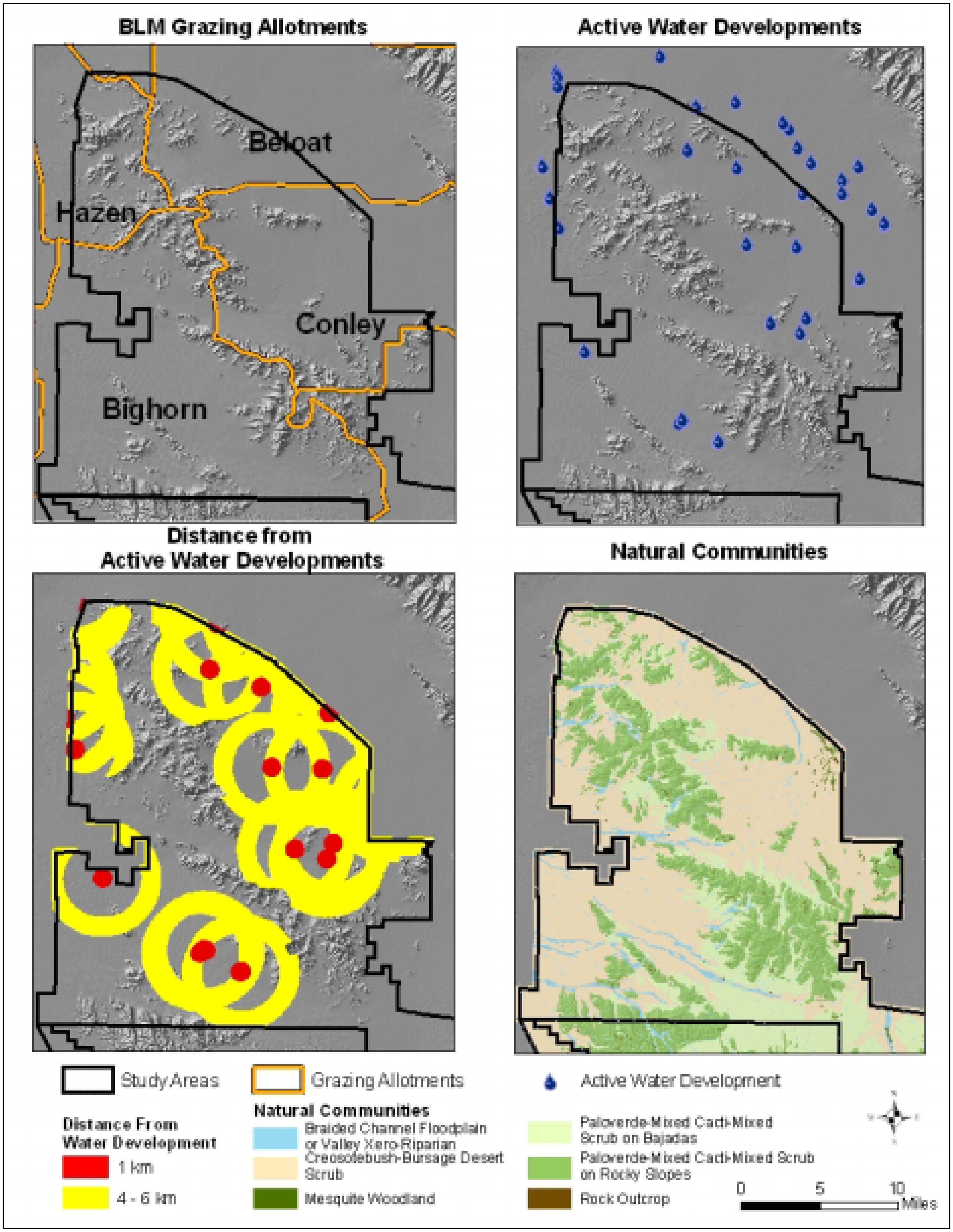


Figure 1. Spatial illustrations of the stratification elements used to determine plot distributions.

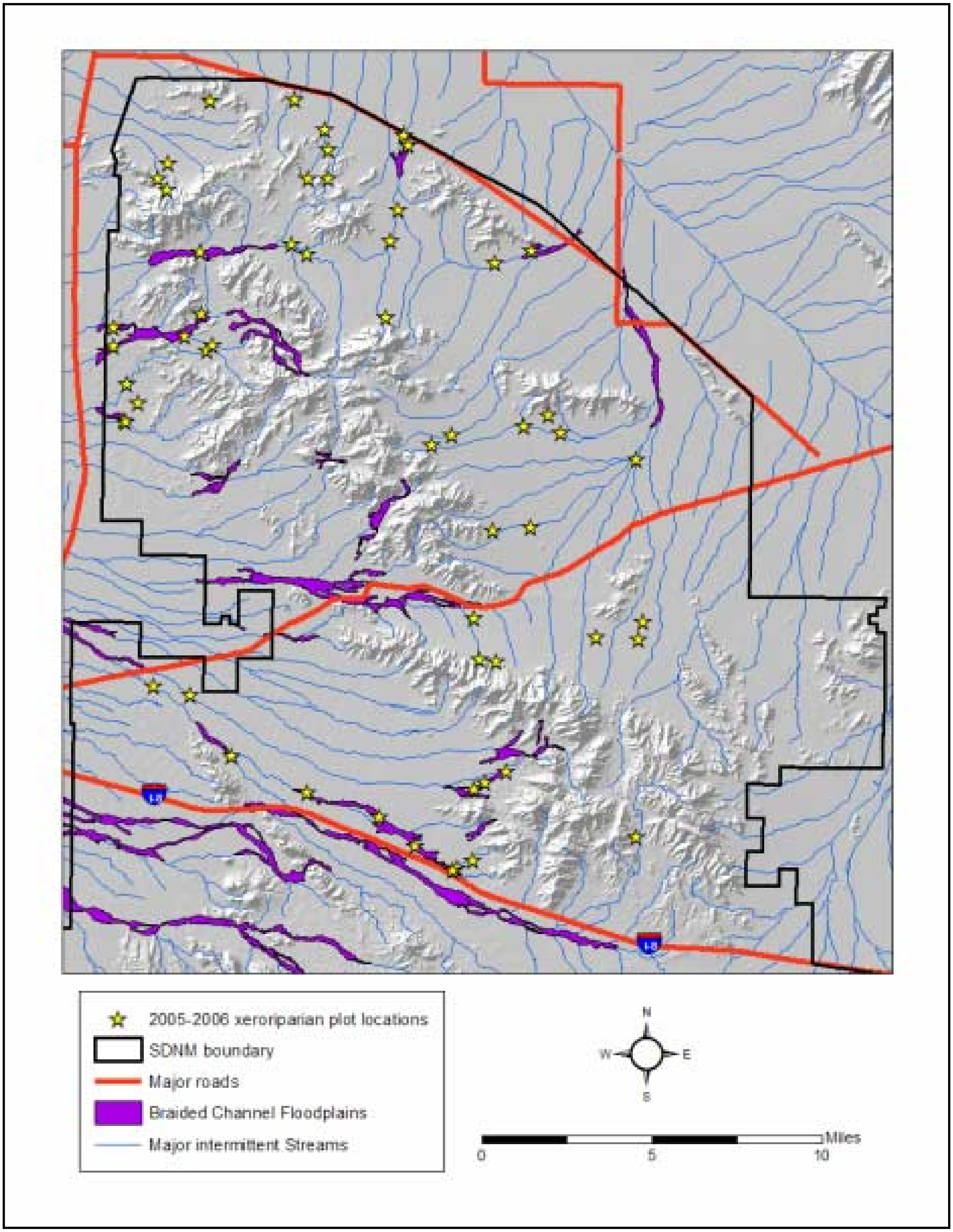


Figure 2. Xeroriparian plot locations within the SDNM (north of I-8).

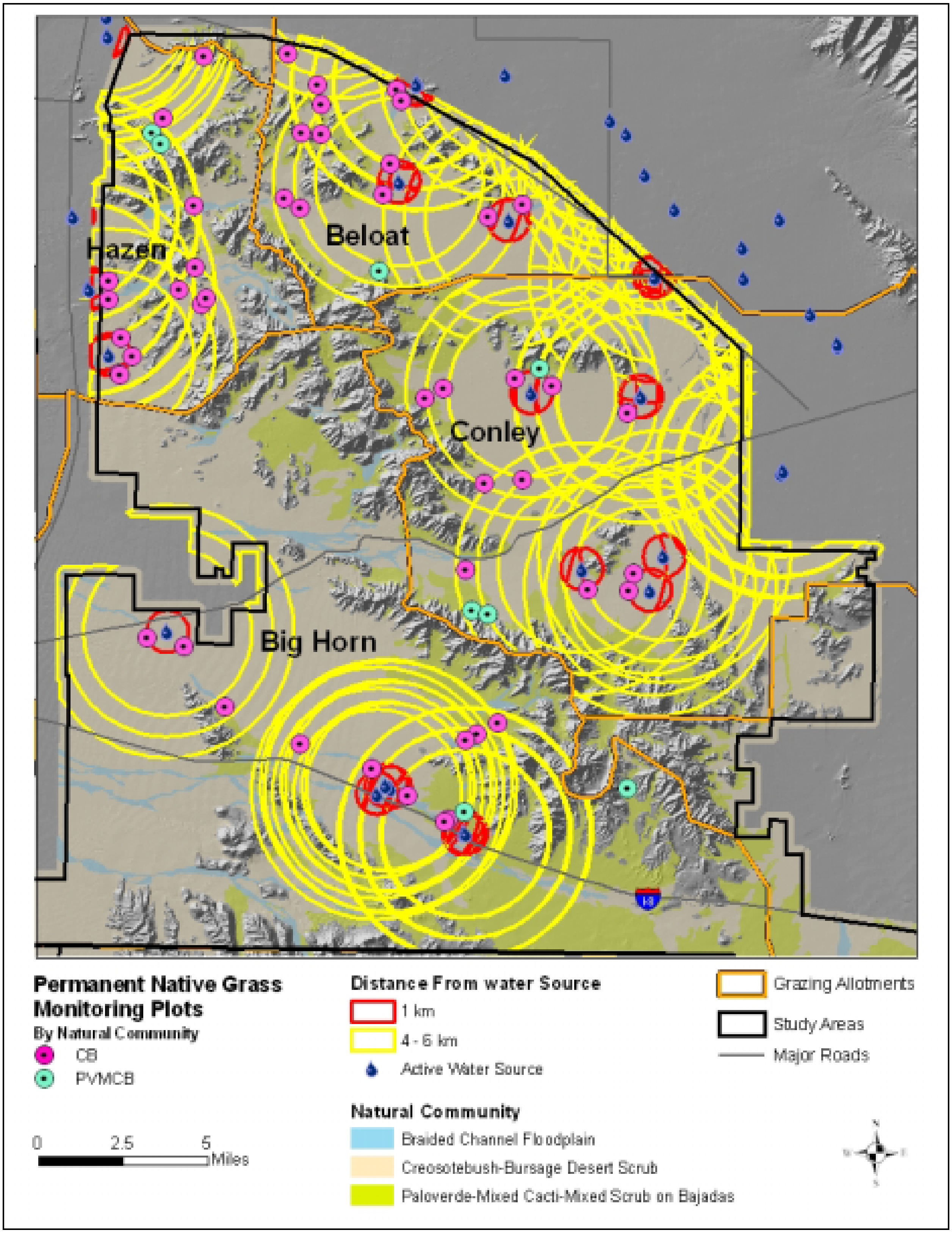


Figure 3. Spatial illustration of the Xeroriparian plot locations in relation to the stratification elements used to determine plot distributions.

Data Collection Methods

We incorporated a field data collection methodology similar to the survey design we developed in 2003 to characterize the natural communities of the Sonoran Desert National Monument (Morrison et al., 2003). As with the 2003 methods, we used GPS units to guide us to the plot locations, which had been determined prior to field sampling. The permanent plot center was marked with a rebar stake. From the plot center, we measured out the circular boundary of the plot. However, unlike the 2003 plots which used a 12.5-m radius, these plots boundaries were measured at a radius of 25 meters from plot center. This plot radius worked better to capture more of the unique xeroriparian vegetation that borders the non-vegetated dry wash beds. At the time of the survey for each plot, the plot boundary was marked with survey flags and/or flagging tape which were then removed at the completion of the inventory so that only the rebar stake remained as the permanent plot location marker in the landscape. Many of the xeroriparian plots contained dense brush and trees, which made plot establishment challenging (Photo 4). In other cases, the plots were fairly open (Photo 5) and plot establishment was relatively easy.


Photos 4 and 5 Measuring xeroriparian plot boundary in dense vegetation (left) and more open vegetation (right).

Once the plot boundary was established, we took notes and measurements on the character of the substrate, including information about the surficial geology type and the dominant soil aggregate size. We estimated to the nearest percent the cover of different groups of abiotic and non-living plant or animal material. We calculated slope and aspect for the plot using a compass. We also recorded the presence of any apparent site disturbances or activities that had impacted the soil or the living plants, including fire, flooding, and grazing.

Photos were also taken at each plot location. At the very least, four photos were taken from just behind plot center aiming toward plot center in the cardinal directions starting from North and ending facing East. We used WAAS enabled GPS units (Garmin GPS 60) to capture a more accurate location for the plot center using waypoint averaging methods. This enabled us to obtain GPS plot centers with a locational accuracy between 1- 3 meters.

We estimated the total percent of the plot's area covered by each identifiable grass species' canopy. All other vascular plants' canopy cover was estimated by life form groups, consisting of the categories of trees, shrubs and vines, herbs – spike mosses and ferns, and cacti. All plant species with dominant cover within the plot were noted in the comments section of the survey form.

Within the plot area, we established five grass density measurement quadrats. The quadrats consisted of square shaped boundaries measured at 1.5 meters by 1.5 meters. Four of the quadrats were placed at the set measurement distance of 10 meters away from plot center along the cardinal directions. Standing at plot center facing out, the quadrats' left edges are what bordered the cardinal lines, and the perpendicular edge nearest to plot center was placed at the 10 meter distance mark. The fifth quadrat occurred at plot center with plot center itself representing the actual center of the quadrat. Figure 4 illustrates the plot layout and quadrat distributions for the permanent native grass monitoring plots. Photos 6 and 7 illustrate how the grass density plots were laid out in the field.

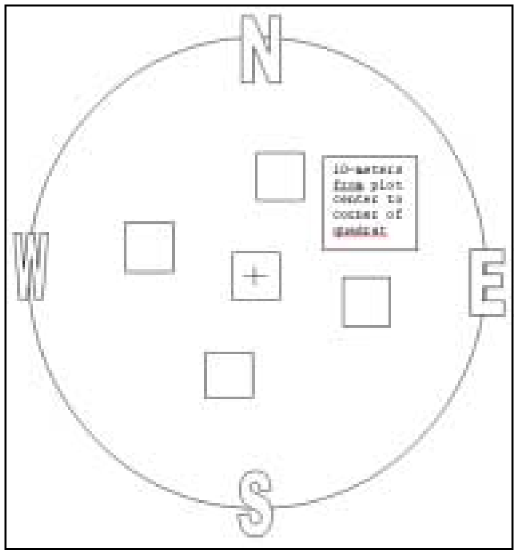


Figure 4. Xeroriparian plot diagram illustrating the layout of quadrats within the larger 25 meter radius plot

Photos 6 and 7. Laying out a grass density plot using bamboo poles (left) and a grass density plot located at plot center of one of the xeroriparian plots (right).

A complete tally of individual grass stems and/or clumps (meaning a clump of grass, perennial or annual, that shared the same root base and apparently sprouted from the same cotyledon) was conducted for each species of native grass present within each quadrat. The percent of the area covered within each quadrat by any grass species present was also recorded. We tallied individual grass stems and/or clumps for all species of grass (both native and exotic) within quadrats along the East cardinal line in each permanent native grass monitoring plot.

Appendix B contains an example of the xeroriparian community plot form and the grass density quadrat plot form. Appendix C contains the UTM coordinates for the xeroriparian plot locations.

During our fieldwork we used numerous botanical references to aid in the identification and verification of plant species encountered in natural community plots. These references include Baldwin et al (2002), Benson and Darrow (1981), Benson (1969), Felger (2000), Kearney and Peebles (1960), Turner et al (1995), Turner et al (2000), Hickman (1993), Epple and Epple (1995), Earle (1980), Jaeger (1941), and Arizona Rare Plant Committee (no date).

Data Analysis Methods

Data Preparation

Our field data forms for all the plots we surveyed in 2005 and 2006 were entered into two separate Microsoft Access databases, one for the spring survey and one for the fall survey. The database entries were checked for accuracy against the field data forms to eliminate typing errors and other data entry errors.

Prior to conducting the field surveys, and even after the surveys were completed, we considered a variety of approaches of how to best analyze the different seasons' data with respect to one another. Unfortunately, a significant drought occurred between the spring and fall survey seasons, where no rain fell between October 18, 2005 and March 11, 2006 (145 days). Typically, winter rains in the SDNM provide enough residual soil moisture to allow annual plants to germinate in the spring, however annual plant germination witnessed by our field crews during the spring of 2006 was near to none. The effect of the drought, no doubt, had significant effects on our xeroriparian grass data. Due to these effects, we decided that a cross seasonal analysis of the data would not be useful in determining answers to the questions originally sought by this project. Thus, we did not incorporate grass cover, herb cover, and grass density estimates from field data collected in the spring of 2006 in our data analysis. For other vegetation cover data such as the trees, and shrubs and vines cover estimates, we averaged the values for each plot between the two field seasons.

We prepared the grass density data for analysis by summarizing the total grass stems between all quadrats contained within a given survey plot. The sum was then divided by 11.25 (the total area surveyed between all the quadrats in a given plot) to obtain the average number of grass stems counted per square meter within each plot.

We analyzed our data for possible outliers. We plotted the sample distributions of various cover estimate variables and calculated summary statistics to indicate the central tendency and the scatter/dispersion of the observations. This led us to removing one plot from our analysis due to the extremely high amount of native grass cover relative to the other plots. As it happened, that plot was located in a region where the adjoining matrix community type was originally thought to be Creosote Bush – Bursage Desert Scrub, but upon our field visits we determined it was a unique extension of the Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes community.

We also decided to remove three plots from the Conley allotment where an intense fire in 2005 had burned and killed most of the vegetation. Believed to be human caused, the fire took advantage of the left over dried grasses and herbs from the prosperous spring bloom of earlier that year. Figure 5 illustrates the location of this unusual desert wildfire.

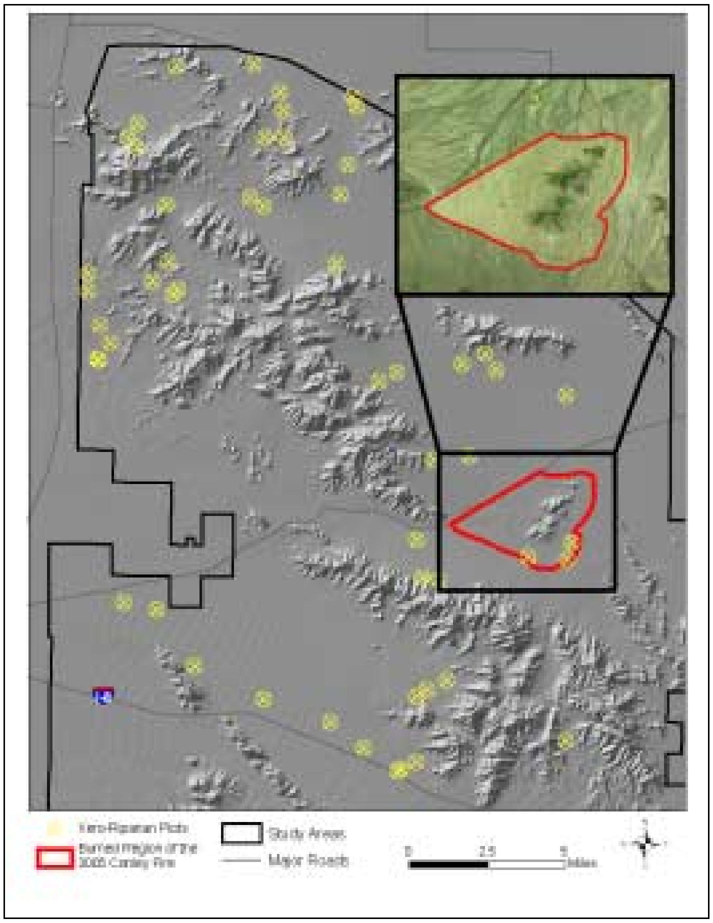


Figure 5. Location of the 2005 wildfire that burned in the Conley allotment and the location of 3 permanent native grass monitoring plots that were surveyed within that fires perimeter.

Tables 6 – 9 illustrate our plot distributions within the required strata after removing these four plots from our sample set.

Table 6. Adjusted number of plots analyzed within each of the 14 treatment groups as a result of the removal of outliers.

Stratification Group (Allotment / Natural Community / Distance from Water Source)	Number of Plots
Beloat / CB / 1 km	6
Beloat / CB / 4 - 6 km	7
Beloat / PVMCB / 4 - 6 km	1
Bighorn / CB / 1 km	6
Bighorn / CB / 4 - 6 km	5
Bighorn / PVMCB / 1 km	1
Bighorn / PVMCB / 4 - 6 km	1

Stratification Group (Allotment / Natural Community / Distance from Water Source)	Number of Plots
Conley / CB / 1 km	3
Conley / CB / 4 - 6 km	5
Conley / PVMCB / 1 km	1
Conley / PVMCB / 4 - 6 km	2
Hazen / CB / 1 km	6
Hazen / CB / 4 - 6 km	6
Hazen / PVMCB / 4 - 6 km	2

Table 7. Adjusted number of plots analyzed within the four BLM grazing allotments as a result of the removal of outliers.

Allotment	Number of Plots
Beloat	14
Bighorn	13
Conley	11
Hazen	14

Table 8. Adjusted number of plots analyzed within the two matrix community categories as a result of the removal of outliers.

Natural Community	Number of Plots
CB	44
PVMCB	8

Table 9. Adjusted number of plots analyzed within the two distance from water development categories as a result of the removal of outliers.

Distance From Water Development	Number of Plots
1 km	23
4 - 6 km	29

Statistical Analysis

Analysis of variance (ANOVA) tests were used to look for significant relationships between the nominal landscape variables (distance from water development, grazing allotment, and adjoining matrix community) and the percent cover of native and exotic grasses. We only conducted single-factor ANOVA tests with our data, thus we did not look for significant relationships between combinations of nominal landscape variables. Our prepared data was exported from Microsoft Access into an Excel spreadsheet. There, we used the Excel add-on program Analyze-it to conduct automated ANOVA tests of the data. We ran 1-way between subjects ANOVA and computed contrasts on all combinations of paired groups.

We also incorporated a Pearson correlation test of the native grass cover in relation to exotic grass cover to test for relationships of significance between these two variables. This test was also run using an automated function within the Excel add-on program Analyze-it. We ran Pearson correlation of native grass cover (dependent variable – y) as the variable dependent upon exotic grass cover (independent variable – x) with a confidence interval of 95%.

Results

Effects of Drought

Perhaps the most noticeable result of our study was the severe effects of the combination of both long-term and short-term drought on the vegetation of the Sonoran Desert. During our spring 2006 field season, nearly all herbaceous and annual vegetation was absent. Most of the desert areas that we sampled had not received any precipitation for over 6 months. As a result, we were forced to record zeros for herbaceous and grass vegetation in most of our plots during the spring of 2006. Trees, shrubs and cacti also showed signs of severe drought stress by the spring of 2006 In many cases some dieback was evident. The effects of drought were also quite evident in the fall of 2005. But we based our measurements on growth that occurred during the spring and summer 2005 growing seasons. The spring 2005 growing season had ample moisture and plant response, while the summer was drier than normal. For the analyses we conducted below, we used data from the fall of 2005, which was reflective of growth during the 2005 growing season.

Distribution and abundance of basic grass types

We first looked at the distribution of native annual, native perennial and exotic annual grasses by general grass type across the two matrix communities that intermittent streams cross in the lowlands of the Sonoran Desert National Monument. We found a distinct difference in abundance between the three grass types in our study area (Table 10, Figure 6). Most importantly, we found very few sites where perennial native grasses occurred in the *Valley Xeroriparian Scrub* (VXR) communities. In most plots we found no perennial native grasses. We found trace amounts of perennial native grasses in about 30% of the plots. The highest amount of cover of perennial native grasses that we found during the study was 2% cover, which was found in only one plot. Exotic grasses were by far the most abundant grass type. In the VXR communities, which cross the *Creosote Bursage Desert Scrub* (CB) matrix community, exotic grasses averaged 19% cover and most of this was Arabian grass (*Schismus arabicus*) or Mediterranean grass (*Schismus barbatus*) - both widespread throughout the Sonoran Desert. In contrast, perennial native grasses amounted to only a mean cover of 0.15% in the VXR communities, which cross the *Creosote Bursage Desert Scrub* (CB) matrix community. Native annual grasses are much more abundant (3.7% cover in CB and 6.3% cover in PVMCB) than the perennials in the VXR communities that we studied. Because the perennial native grasses were so rare in the VXR communities, we did not separate them in the rest of the analyses that we did in this study, but instead analyzed annual and native grasses together as one dependent variable.

Table 10. Comparison of three basic grass types.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native Annual Grasses, Native Perennial Grasses, Exotic Grasses by Natural Community				
	n	Mean	SD	SE	95% CI of Mean
Native Annual Grasses by Natural Community - CB	44	3.739	4.1261	0.6220	2.484 to 4.993
Native Annual Grasses by Natural Community - PVMCB	8	6.300	5.7161	2.0210	1.521 to 11.079
Native Perennial Grasses by Natural Community - CB	44	0.150	0.3861	0.0582	0.033 to 0.267
Native Perennial Grasses by Natural Community - PVMCB	8	0.125	0.3536	0.1250	-0.171 to 0.421
Exotic Grasses by Natural Community - CB	44	19.227	14.3460	2.1627	14.866 to 23.589
Exotic Grasses by Natural Community - PVMCB	8	8.000	4.9857	1.7627	3.832 to 12.168

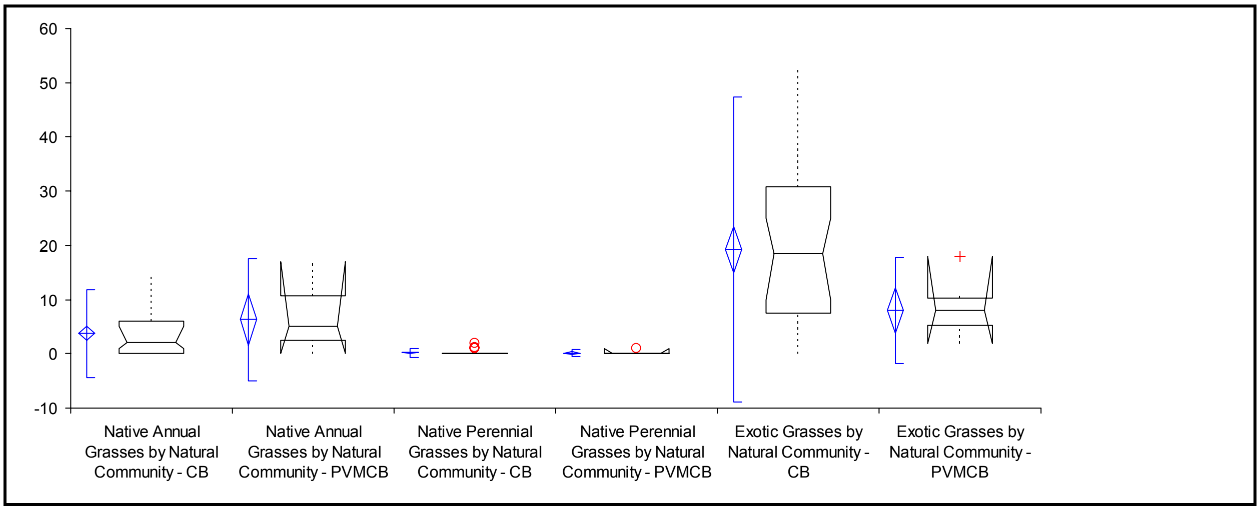


Figure 6. Box plot illustrating the central location and scatter/dispersion of the percent cover within our plots of the three grass types as related to natural community.

Question 1. Are there differences in native grass species composition, cover, and density within a xeroriparian community with distance from an active water development?

We addressed this question through a series of statistical tests. Tables 11 and 12, and Figure 7 illustrate our findings from the statistical analyses of the relationship between native grass cover and the distance from water development. Tables 13 and 14, and Figure 8 illustrate our findings from the statistical analyses of the relationship between native grass diversity (occurrence) and the distance from water development. Tables 15 and 16, and Figure 9 illustrate our findings from the statistical analyses of the relationship between native grass stem density and the distance from water development.

These results show that no significant difference exists in native grass species cover, composition, or stem density within xeroriparian sites considering distance from an active water development.

Table 11. Comparative descriptives for native grass cover as related to distance from water development.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native Grass Cover by Distance from Water				
Native Grass Cover by Distance from Water	**n**	**Mean**	**SD**	**SE**	**95% CI of Mean**
1 km	23	4.122	4.8474	1.0108	2.026 to 6.218
4 – 6 km	29	4.403	4.2827	0.7953	2.774 to 6.033

Native Grass Cover by Distance from Water	Median	IQR	95% CI of Median
1 km	2.100	7.450	0.100 to 7.100
4 – 6 km	4.000	5.000	1.100 to 6.100

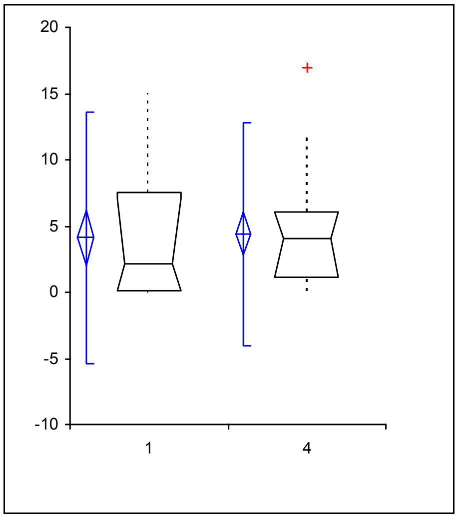


Figure 7. Box plot illustrating the central location and scatter/dispersion of native grass cover within our plots as related to distance from water development.

Table 12. ANOVA results for native grass cover as related to distance from water development.

Test	**1-way between subjects ANOVA**				
	XR Grass Study				
Comparison	Native Grass Cover by Distance from Water: 1 km, 4 – 6 km				
n	52				
Native Grass Cover by Distance from Water	n	Mean	SD	SE	
1 km	23	4.122	4.847	1.0108	
4 – 6 km	29	4.403	4.283	0.7953	
Source of variation	SSq	DF	MSq	F	p
Distance from Water	1.018	1	1.018	0.05	0.8250
Within cells	1030.509	50	20.610		
Total	1031.527	51			
		Tukey			
Contrast	Difference	95% CI			
1 km v 4 – 6 km	-0.282	-2.828 to 2.264			

Table 13. Comparative descriptives for native grass diversity as related to distance from water development.

Test	**Comparative descriptives**				
	XR Grass Study				
Variables	native-occurrence by Distance from Water				
native-occurrence by Distance from Water	n	Mean	SD	SE	95% CI of Mean
1 km	23	1.8	1.24	0.26	1.2 to 2.3
4 – 6 km	29	2.1	0.83	0.15	1.8 to 2.5
native-occurrence by Distance from Water	Median	IQR	95% CI of Median		
1 km	2.0	2.0	1.0 to 3.0		
4 – 6 km	2.0	1.0	2.0 to 2.0		

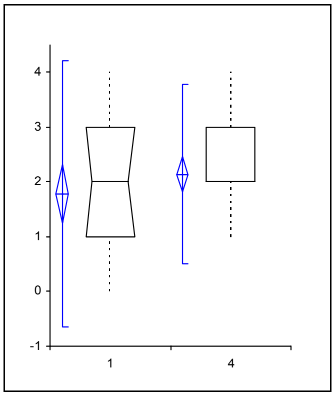


Figure 8. Box plot illustrating the central location and scatter/dispersion of native grass diversity within our plots as related to distance from water development.

Table 14. ANOVA results for native grass diversity as related to distance from water development.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	native-occurrence by Distance from Water: 1, 4				
n	52				
native-occurrence by Distance from Water	n	Mean	SD	SE	
1 km	23	1.8	1.2	0.26	
4 – 6 km	29	2.1	0.8	0.15	
Source of variation	SSq	DF	MSq	F	p
Distance from Water	1.6	1	1.6	1.52	0.2238
Within cells	53.4	50	1.1		
Total	55.0	51			
Contrast	Difference	Tukey 95% CI			
1 km v 4 – 6 km	-0.4	-0.9 to 0.2			

Table 15. Comparative descriptives for native grass stem density as related to distance from water development.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native stem density (per sq. meter) by Distance from Water				
Native stem density (per sq. meter) by Distance from Water	n	Mean	SD	SE	95% CI of Mean
1 km	23	11.35	15.670	3.267	4.58 to 18.13
4 – 6 km	29	10.73	14.134	2.625	5.35 to 16.11
Native stem density (per sq. meter) by Distance from Water	Median	IQR	95% CI of Median		
1 km	3.20	15.80	0.10 to 14.90		
4 – 6 km	6.30	12.70	1.60 to 11.90		

Figure 9. Box plot illustrating the central location and scatter/dispersion of native grass stem density within our plots as related to distance from water development.

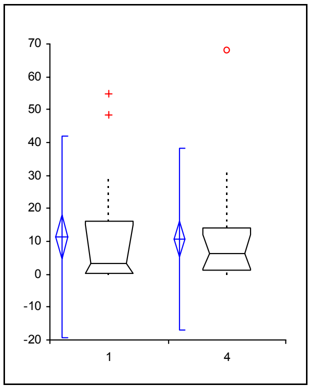


Table 16. ANOVA results for native grass stem density as related to distance from water development.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Native stem density (per sq. meter) by Distance from Water: 1, 4				
n	52				
Native stem density (per sq. meter) by Distance from Water	n	Mean	SD	SE	
1 km	23	11.35	15.67	3.267	
4 – 6 km	29	10.73	14.13	2.625	
Source of variation	SSq	DF	MSq	F	p
Distance from Water	4.95	1	4.95	0.02	0.8814
Within cells	10995.08	50	219.90		
Total	11000.03	51			
Contrast	Difference	Tukey 95% CI			
1 km v 4 – 6 km	0.62	-7.70 to 8.94			

Question 2. Are there differences in native grass species composition, cover, and density between xeroriparian communities with different adjoining matrix communities?

Tables 17 and 18, and Figure 10 illustrate our findings from the statistical analyses of the relationship between native grass cover and the adjoining matrix community. Tables 19 and 20, and Figure 11 illustrate our findings from the statistical analyses of the relationship between native grass diversity and the adjoining matrix community. Tables 21 and 22, and Figure 12 illustrate our findings from the statistical analyses of the relationship between native grass stem density and the adjoining matrix community. Figure 13 illustrates the amount of native grass stems per square meter found in our survey plots overlaying the natural communities map for the SDNM.

These results show that no significant difference exists in native grass species composition and cover between xeroriparian sites considering the adjoining matrix community. A significant variance in means does exist for native grass density between xeroriparian sites considering the adjoining matrix community.

Table 17. Comparative descriptives for native cover as related to adjoining matrix community.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native Grass Cover by Natural Community				
Native Grass Cover by Natural Community	n	Mean	SD	SE	95% CI of Mean
CB	44	3.889	4.2179	0.6359	2.606 to 5.171
PVMCB	8	6.425	5.6441	1.9955	1.706 to 11.144
Native Grass Cover by Natural Community	Median	IQR	95% CI of Median		
CB	2.150	6.700	1.000 to 5.000		
PVMCB	5.100	7.475	0.100 to 17.000		

Figure 10. Box plot illustrating the central location and scatter/dispersion of native grass stem density within our plots as related to distance from water development.

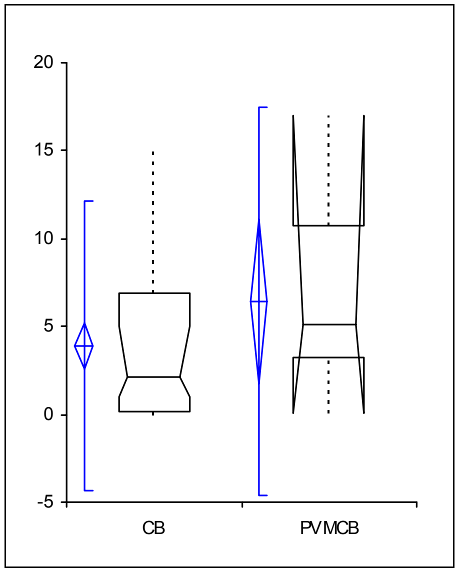


Table 18. ANOVA results for native grass cover as related to adjoining matrix community.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Native Grass Cover by NaturalCommunity: CB, PVMCB				
n	52				
Native Grass Cover by NaturalCommunity	n	Mean	SD	SE	
CB	44	3.889	4.218	0.6359	
PVMCB	8	6.425	5.644	1.9955	
Source of variation	SSq	DF	MSq	F	p
NaturalCommunity	43.547	1	43.547	2.20	0.1439
Within cells	987.979	50	19.760		
Total	1031.527	51			
Contrast	Difference	Tukey 95% CI			
CB v PVMCB	-2.536	-5.968 to 0.895			

Table 19. Comparative descriptives for native grass diversity as related to adjoining matrix community.

Test	Comparative descriptives				
	XR Grass Study				
Variables	native-occurrence by Natural Community				
native-occurrence by Natural Community	n	Mean	SD	SE	95% CI of Mean
CB	44	2.0	1.11	0.17	1.6 to 2.3
PVMCB	8	2.0	0.53	0.19	1.6 to 2.4
native-occurrence by Natural Community	Median	IQR	95% CI of Median		
CB	2.0	2.0	2.0 to 2.0		
PVMCB	2.0	0.0	1.0 to 3.0		

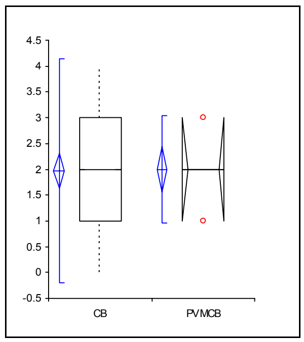


Figure 11. Box plot illustrating the central location and scatter/dispersion of native grass diversity within our plots as related to distance from water development.

Table 20. ANOVA results for native grass diversity as related to adjoining matrix community.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	native-occurrence by Natural Community: CB, PVMCB				
n	52				
native-occurrence by Natural Community	n	Mean	SD	SE	
CB	44	2.0	1.1	0.17	
PVMCB	8	2.0	0.5	0.19	
Source of variation	SSq	DF	MSq	F	p
Natural Community	0.0	1	0.0	0.00	0.9553
Within cells	55.0	50	1.1		
Total	55.0	51			
Contrast	Difference	Tukey 95% CI			
CB v PVMCB	0.0	-0.8 to 0.8			

Table 21. Comparative descriptives for native grass stem density as related to adjoining matrix community.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native stem density (per sq. meter) by Natural Community				
Native stem density (per sq. meter) by Natural Community	n	Mean	SD	SE	95% CI of Mean
CB	44	9.27	12.711	1.916	5.41 to 13.14
PVMCB	8	20.54	21.361	7.552	2.68 to 38.40
Native stem density (per sq. meter) by Natural Community	Median	IQR	95% CI of Median		
CB	3.90	11.28	1.10 to 8.00		
PVMCB	16.30	16.78	0.10 to 68.10		

Figure 12. Box plot illustrating the central location and scatter/dispersion of native grass stem density within our plots as related to adjoining matrix community.

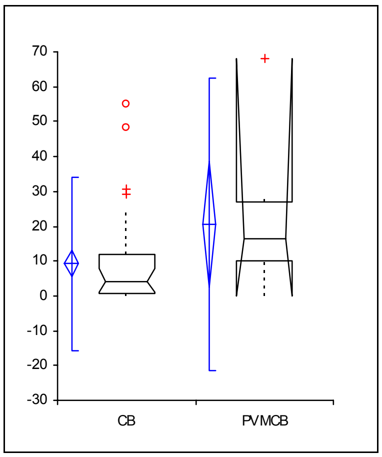


Table 22. ANOVA results for native grass stem density as related to adjoining matrix community.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Native stem density (per sq. meter) by Natural Community: CB, PVMCB				
n	52				
Native stem density (per sq. meter) by Natural Community	n	Mean	SD	SE	
CB	44	9.27	12.71	1.916	
PVMCB	8	20.54	21.36	7.552	
Source of variation	SSq	DF	MSq	F	p
Natural Community	858.98	1	858.98	4.24	0.0448
Within cells	10141.05	50	202.82		
Total	11000.03	51			
Contrast	Difference	Tukey 95% CI			
CB v PVMCB	-11.26	-22.26 to -0.27		(significant)	

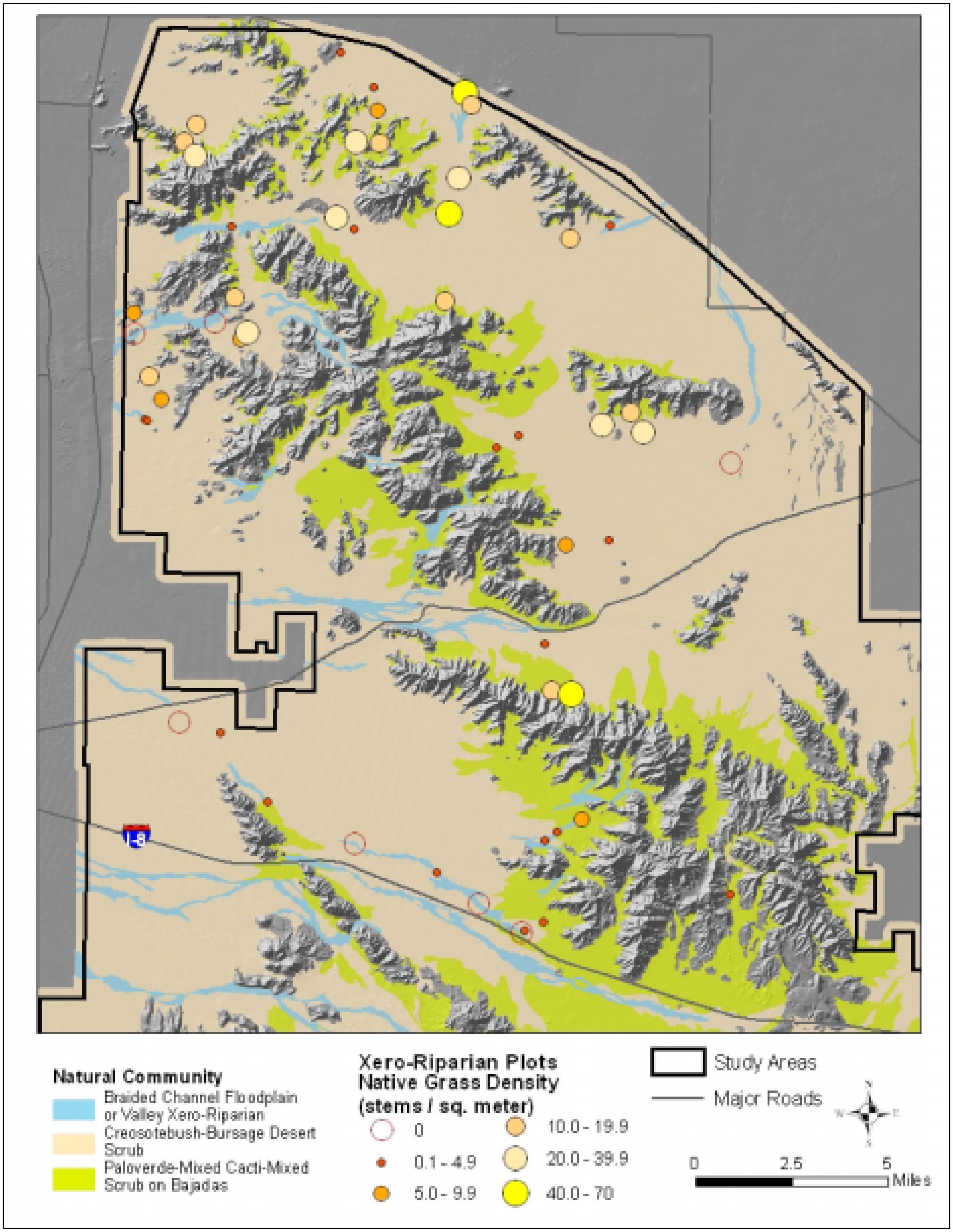


Figure 13. Map illustrating the amount of native grass stems per square meter within our survey plots as related to the adjoining matrix community.

Question 3. Are there differences in native grass species composition, cover, and density between xeroriparian communities within different BLM grazing allotments north of Interstate 8 on the SDNM?

Tables 23 and 24, and Figure 14 illustrate our findings from the statistical analyses of the relationship between native grass cover and the BLM grazing allotments. Tables 25 and 26, and Figure 15 illustrate our findings from the statistical analyses of the relationship between native grass diversity and the BLM grazing allotments. Tables 27 and 28, and Figure 16 illustrate our findings from the statistical analyses of the relationship between native grass stem density and the BLM grazing allotments.

These results show that significant differences exist in native grass species composition and cover between xeroriparian sites considering the grazing allotment in which the site occurs. There is less significant difference in native grass stem density according to our results. Almost all significant variance in dependent variable means occurs in comparing the Bighorn allotment to any of the other grazing allotments we sampled. Figure 17 spatially illustrates the percent native grass cover per plot within the four different grazing allotments we studied.

Table 23. Comparative descriptives for native grass stem cover as related to BLM grazing allotment.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Native Grass Cover by Allotment					
Native Grass Cover by Allotment	n	Mean	SD	SE	95% CI of Mean	
Beloat	14	5.479	4.0186	1.0740	3.158	to 7.799
Bighorn	13	0.162	0.2873	0.0797	-0.012	to 0.335
Conley	11	6.264	4.9109	1.4807	2.964	to 9.563
Hazen	14	5.343	4.6386	1.2397	2.665	to 8.021

Native Grass Cover by Allotment	Median	IQR	95% CI of Median	
Beloat	5.050	5.350	1.300	to 9.000
Bighorn	0.100	0.000	0.000	to 0.100
Conley	6.100	6.100	1.100	to 11.000
Hazen	4.500	5.450	1.000	to 10.000

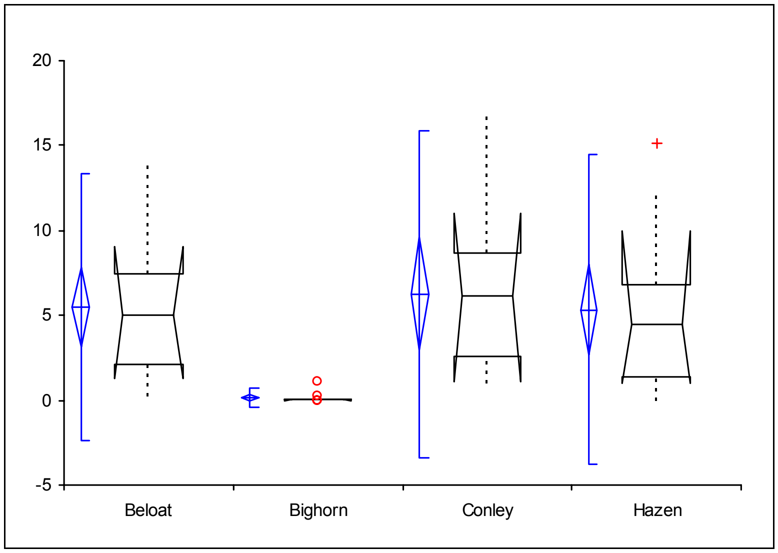


Figure 14. Box plot illustrating the central location and scatter/dispersion of native grass cover within our plots as related to BLM grazing allotment.

Table 24. ANOVA results for native grass cover as related to BLM grazing allotment.

Test	1-way between subjects ANOVA				
Comparison	XR Grass Study Native Grass Cover by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				
Native Grass Cover by Allotment	n	Mean	SD	SE	
Beloat	14	5.479	4.019	1.0740	
Bighorn	13	0.162	0.287	0.0797	
Conley	11	6.264	4.911	1.4807	
Hazen	14	5.343	4.639	1.2397	
Source of variation	SSq	DF	MSq	F	p
Allotment	299.713	3	99.904	6.55	0.0008
Within cells	731.814	48	15.246		
Total	1031.527	51			
Contrast	Difference	Tukey 95% CI			
Beloat v Bighorn	5.317	1.315	to 9.320	(significant)	
Beloat v Conley	-0.785	-4.972	to 3.402		
Beloat v Hazen	0.136	-3.792	to 4.063		
Bighorn v Conley	-6.102	-10.359	to -1.845	(significant)	
Bighorn v Hazen	-5.181	-9.184	to -1.179	(significant)	
Conley v Hazen	0.921	-3.266	to 5.108		

Table 25. Comparative descriptives for native grass diversity as related to BLM grazing allotment.

Test	Comparative descriptives				
Variables	XR Grass Study native-occurrence by Allotment				
native-occurrence by Allotment	n	Mean	SD	SE	95% CI of Mean
Beloat	14	2.9	0.77	0.21	2.4 to 3.3
Bighorn	13	0.9	0.64	0.18	0.5 to 1.3
Conley	11	2.1	0.70	0.21	1.6 to 2.6
Hazen	14	2.0	0.96	0.26	1.4 to 2.6
native-occurrence by Allotment	Median	IQR	95% CI of Median		
Beloat	3.0	1.0	2.0 to 4.0		
Bighorn	1.0	0.0	0.0 to 1.0		
Conley	2.0	0.5	1.0 to 3.0		
Hazen	2.0	0.0	1.0 to 3.0		

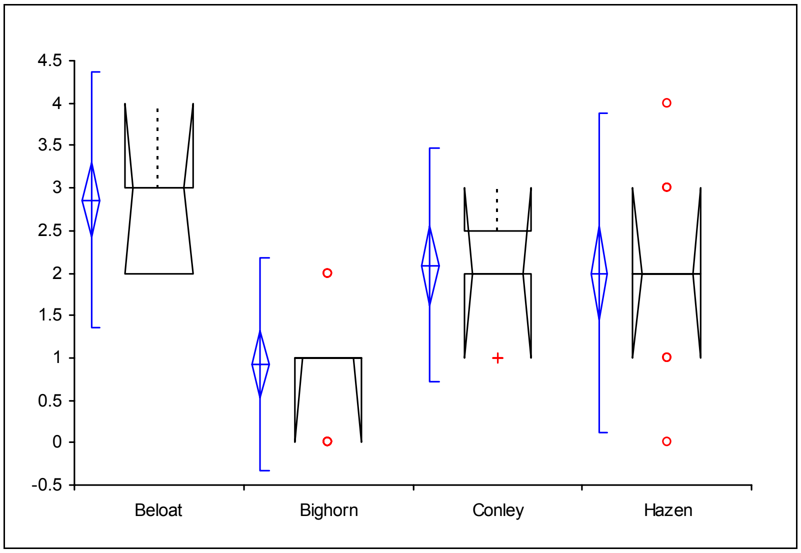


Figure 15. Box plot illustrating the central location and scatter/dispersion of native grass cover within our plots as related to BLM grazing ollotment.

Table 26. ANOVA results for native grass diversity as related to BLM grazing allotment.

Test	**1-way between subjects ANOVA**				
	XR Grass Study				
Comparison	native-occurrence by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				
native-occurrence by Allotment	**n**	**Mean**	**SD**	**SE**	
Beloat	14	2.9	0.8	0.21	
Bighorn	13	0.9	0.6	0.18	
Conley	11	2.1	0.7	0.21	
Hazen	14	2.0	1.0	0.26	
Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Allotment	25.4	3	8.5	13.77	<0.0001
Within cells	29.5	48	0.6		
Total	55.0	51			
Contrast	**Difference**	**Tukey 95% CI**			
Beloat v Bighorn	1.9	1.1	to 2.7	(significant)	
Beloat v Conley	0.8	-0.1	to 1.6		
Beloat v Hazen	0.9	0.1	to 1.6	(significant)	
Bighorn v Conley	-1.2	-2.0	to -0.3	(significant)	
Bighorn v Hazen	-1.1	-1.9	to -0.3	(significant)	
Conley v Hazen	0.1	-0.8	to 0.9		

Table 27. Comparative descriptives for native grass stem density as related to BLM grazing allotment.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Native stem density (per sq. meter) by Allotment				
Native stem density (per sq. meter) by Allotment	n	Mean	SD	SE	95% CI of Mean
Beloat	14	18.79	16.855	4.505	9.06 to 28.52
Bighorn	13	1.38	2.161	0.599	0.07 to 2.68
Conley	11	14.79	20.019	6.036	1.34 to 28.24
Hazen	14	9.19	8.705	2.326	4.16 to 14.21

Native stem density (per sq. meter) by Allotment	Median	IQR	95% CI of Median
Beloat	14.45	18.63	3.60 to 30.80
Bighorn	0.50	1.60	0.00 to 2.50
Conley	8.00	20.10	1.10 to 24.80
Hazen	8.00	11.13	0.10 to 14.90

Figure 16. Box plot illustrating the central location and scatter/dispersion of native grass stem density within our plots as related to BLM grazing allotment.

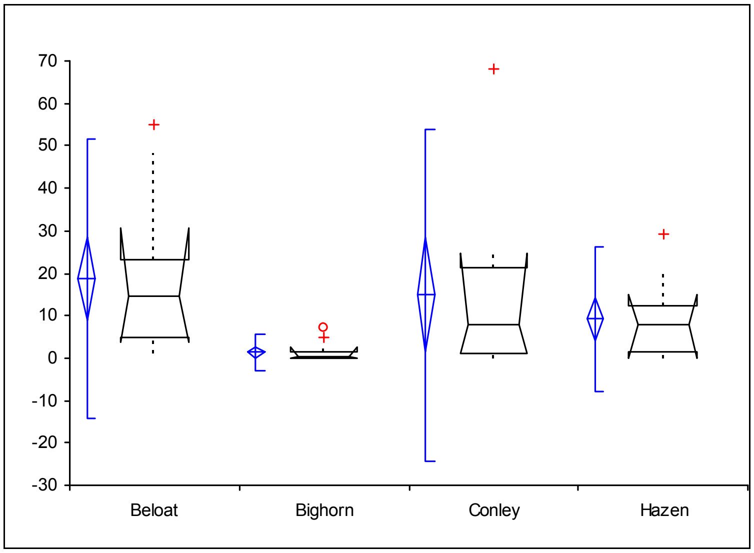


Table 28. ANOVA results for native grass stem density as related to BLM grazing allotment.

Test	**1-way between subjects ANOVA**				
	XR Grass Study				
Comparison	Native stem density (per sq. meter) by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				

Native stem density (per sq. meter) by Allotment	**n**	**Mean**	**SD**	**SE**
Beloat	14	18.79	16.85	4.505
Bighorn	13	1.38	2.16	0.599
Conley	11	14.79	20.02	6.036
Hazen	14	9.19	8.70	2.326

Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Allotment	2258.21	3	752.74	4.13	0.0110
Within cells	8741.82	48	182.12		
Total	11000.03	51			

Contrast	**Difference**	**Tukey 95% CI**		
Beloat v Bighorn	17.42	3.58	to 31.25	(significant)
Beloat v Conley	4.00	-10.47	to 18.47	
Beloat v Hazen	9.61	-3.97	to 23.18	
Bighorn v Conley	-13.41	-28.13	to 1.30	
Bighorn v Hazen	-7.81	-21.64	to 6.02	
Conley v Hazen	5.61	-8.87	to 20.08	

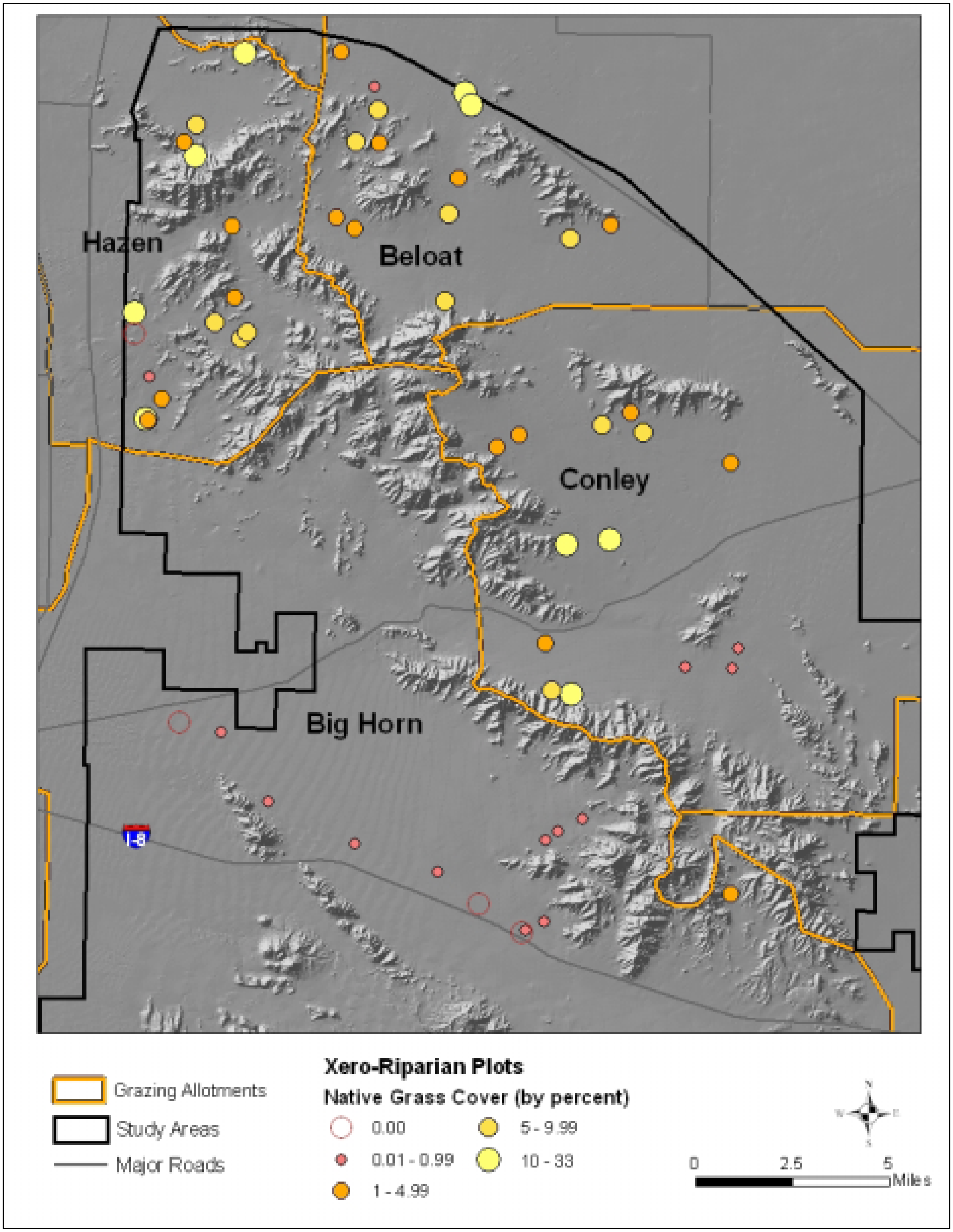


Figure 17. Map illustrating the percent native grass cover per plot in relation to the BLM grazing allotments.

Question 4. Are there differences in native grass species composition, cover, and density between xeroriparian communities that contain different amounts of non-native grass (and prominent non-native forbs) species richness and cover?

Table 29 and Figure 18 illustrate our findings from the statistical analyses of the relationship between native grass cover and the amount of cover of exotic grasses. Tables 30 and 31, and Figures 19 and 20 illustrate our findings from the statistical analyses of the relationship between native grass diversity and the amount of cover of exotic grasses. Table 32 and Figure 21 illustrate our findings from the statistical analyses of the relationship between native grass stem density and the amount of cover of exotic grasses. Our analysis shows that no correlation exists between native grass cover or stem density in relation to exotic grass cover. A weak positive correlation between native grass diversity in relation to exotic grass cover was determined.

Table 29. Pearson correlation analysis of native grass cover related to exotic grass cover.

Test	Pearson correlation XR Grass Study	
Alternative hypothesis	Exotic Grasses ≠ Native Grass Cover	
n	52	
r statistic	0.00	
95% CI	-0.27	to 0.28
2-tailed p	0.9802	(t approximation)

Figure 18. Scatter plot graph of native grass cover versus exotic grass cover per plot.

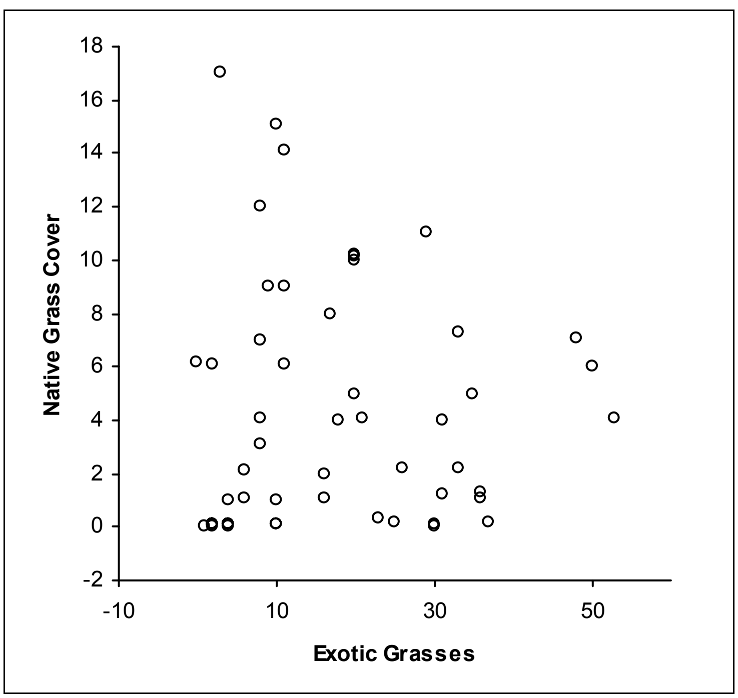


Table 30. Pearson correlation analysis of native grass diversity related to exotic grass cover.

Test	**Pearson correlation**	
	XR Grass Study	
Alternative hypothesis	Exotic Grasses ≠ native-occurrence	
n	52	
r statistic	0.49	
95% CI	0.24	to 0.67
2-tailed p	0.0003	(t approximation)

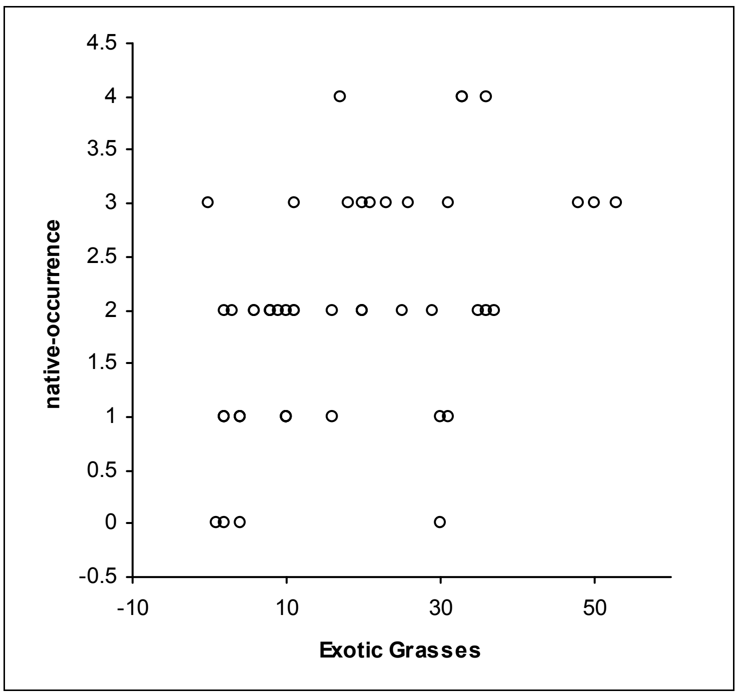


Figure 19. Scatter plot graph of native grass diversity versus exotic grass cover per plot.

Table 31. Linear regression analysis of native grass diversity related to exotic grass cover.

Test	Linear regression				
	XR Grass Study				
Fit	native-occurrence v Exotic Grasses				
n	52				
R^2	0.24				
Adjusted R^2	0.22				
SE	0.9170				

Term	Coefficient	SE	p	95% CI of Coefficient	
Intercept	1.3474	0.2055	<0.0001	0.9345	to 1.7602
Slope	0.0362	0.0092	0.0003	0.0177	to 0.0547

Source of variation	SSq	DF	MSq	F	p
Due to regression	12.9	1	12.9	15.39	0.0003
About regression	42.0	50	0.8		
Total	55.0	51			

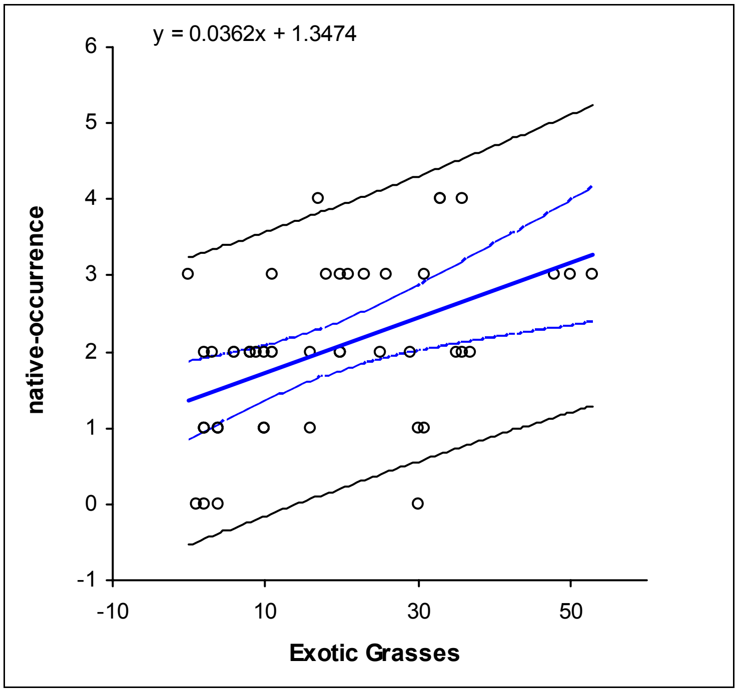


Figure 20. Result of linear regression analysis displayed over scatter plot graph of native grass diversity versus exotic grass cover per plot.

Table 32. Pearson correlation analysis of native grass stem density related to exotic grass cover.

Test	Pearson correlation	
	XR Grass Study	
Alternative hypothesis	Exotic Grasses ≠ Native stem density (per sq. meter)	
n	52	
r statistic	-0.02	
95% CI	-0.29	to 0.25
2-tailed p	0.8663	(t approximation)

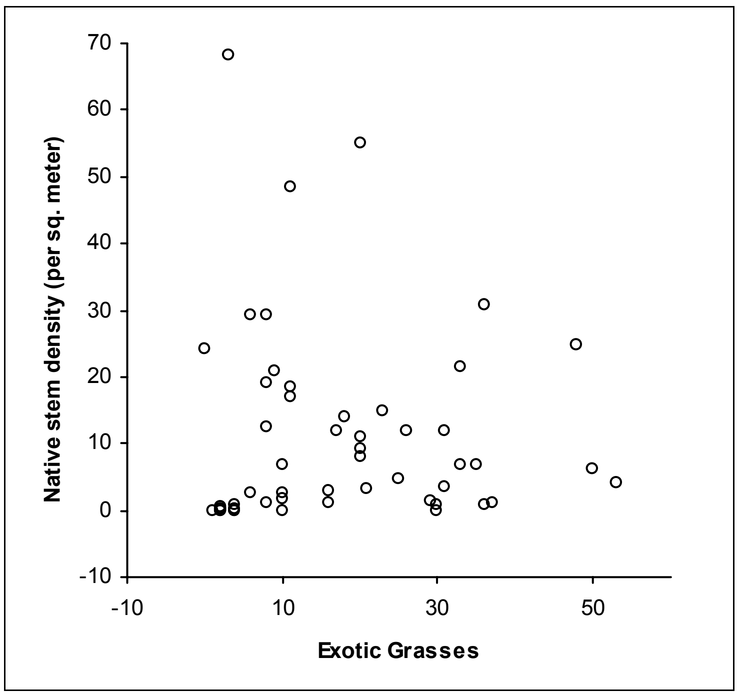


Figure 21. Scatter plot graph of native grass stem density versus exotic grass cover per plot.

Additional Analyses

We did some analyses of exotic grass cover estimates and total grass cover estimates. We also analyzed some of the cattle activity indicators we collected field data on for each plot. The following charts and tables illustrate the results of the analyses that showed significant relationship between variables. These analyses may shed further light on the ecological condition of xeroriparian areas in the SDNM.

First, we looked at the distribution and abundance of exotic grasses and total cover grass of all grass species. Tables 33 and 34, and Figure 22 illustrate our findings from the statistical analyses of the relationship between exotic grass cover and the adjoining matrix community. Tables 35 and 36, and Figure 23 illustrate our findings from the statistical analyses of the relationship between exotic grass cover and the distance from water development. Tables 37 and 38, and Figure 24 illustrate our findings from the statistical analyses of the relationship between total grass cover and the BLM grazing allotments. Table 39 illustrates our findings from the statistical analyses of the relationship between exotic grass cover and the BLM grazing allotments.

Nearly twice as much exotic grass was found at 4km from a water source as was found at 1km from a water source. We found significantly less total grass cover on the Bighorn allotment than on the other three allotments. However, we found no statistically significant difference between the total grass cover on the Hazen, Beloat and Conley allotments. Exotic grass cover was significantly lower on Bighorn than on Beloat and Hazen allotments, and lower on Conley than on Beloat.

Second, we looked at the distribution and amount of livestock activity signs, such as fresh hoof prints and cow trails. Tables 40 and 41 and Figure 25 illustrate our findings from the statistical analyses of the relationship between the amount of cattle hoof prints in an area and the distance from an active water development. Tables 42 and 43 and Figure 26 illustrate our findings from the statistical analyses of the relationship between the amount of cattle hoof prints in an area and the BLM grazing allotment. Tables 44 and 45 and Figure 27 illustrate our findings from the statistical analyses of the relationship between the amount of cow trails in an area and the distance from an active water development. Tables 46 and 47 and Figure 28 illustrate our findings from the statistical analyses of the relationship between the amount of cattle hoof prints in an area and the cover of native grass.

We found significantly more hoof prints and cow trails on plots closer to water developments. Bighorn had more hoof prints than any of the other three allotments, but there were no significant differences between those other three. There was a significant negative correlation between the amount of cattle hoof prints in an area and the cover of native grass.

Table 33. Comparative descriptives for exotic grass cover as related to adjoining matrix community.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Exotic Grasses by Natural Community					
Exotic Grasses by Natural Community	**n**	**Mean**	**SD**	**SE**	**95% CI of Mean**	
CB	44	19.227	14.3460	2.1627	14.866	to 23.589
PVMCB	8	8.000	4.9857	1.7627	3.832	to 12.168
Exotic Grasses by Natural Community	**Median**	**IQR**	**95% CI of Median**			
CB	18.500	23.250	10.000	to 25.000		
PVMCB	8.000	5.000	2.000	to 18.000		

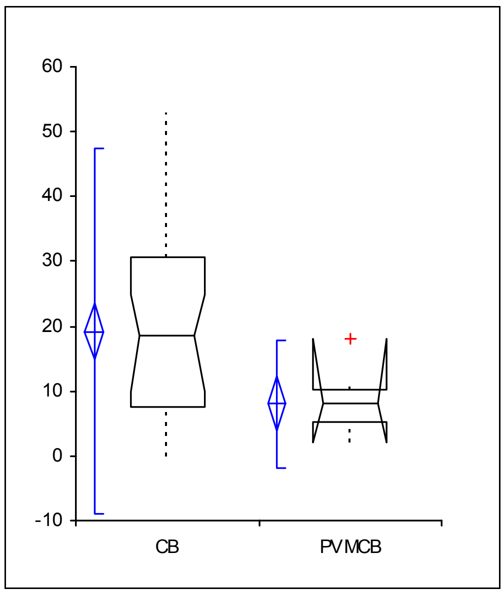


Figure 22. Box plot illustrating the central location and scatter/dispersion of exotic grass cover within our plots as related to adjoining matrix community.

Table 34. ANOVA results for exotic grass cover related to adjoining matrix community.

Test	**1-way between subjects ANOVA**				
	XR Grass Study				
Comparison	Exotic Grasses by Natural Community: CB, PVMCB				
n	52				

Exotic Grasses by Natural Community	**n**	**Mean**	**SD**	**SE**
CB	44	19.227	14.346	2.1627
PVMCB	8	8.000	4.986	1.7627

Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Natural Community	853.273	1	853.273	4.73	0.0344
Within cells	9023.727	50	180.475		
Total	9877.000	51			

Contrast	**Difference**	**Tukey 95% CI**		
CB v PVMCB	11.227	0.856	to 21.598	(significant)

Table 35. Comparative descriptives for exotic grass cover as related to distance from water development.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Exotic Grasses by Distance from Water					
Exotic Grasses by Distance from Water	n	Mean	SD	SE	95% CI of Mean	
1 km	23	12.565	12.2987	2.5644	7.247	to 17.884
4 – 6 km	29	21.414	14.0726	2.6132	16.061	to 26.767
Exotic Grasses by Distance from Water	Median	IQR	95% CI of Median			
1 km	10.000	17.000	4.000	to 20.000		
4 – 6 km	20.000	22.000	10.000	to 31.000		

Figure 23. Box plot illustrating the central location and scatter/dispersion of exotic grass cover within our plots as related to distance from water development.

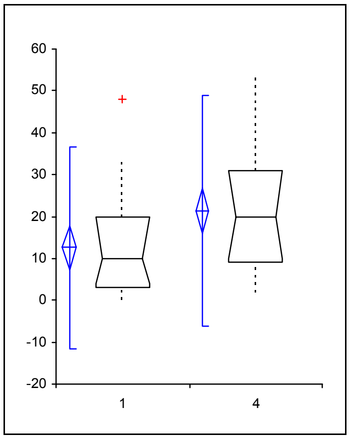


Table 36. ANOVA results for exotic grass cover related to distance from water development.

Test	1-way between subjects ANOVA					
	XR Grass Study					
Comparison	Exotic Grasses by Distance from Water: 1, 4					
n	52					
Exotic Grasses by Distance from Water	n	Mean	SD	SE		
1 km	23	12.565	12.299	2.5644		
4 – 6 km	29	21.414	14.073	2.6132		
Source of variation	SSq	DF	MSq	F	p	
Distance from Water	1004.313	1	1004.313	5.66	0.0212	
Within cells	8872.687	50	177.454			
Total	9877.000	51				
Contrast	Difference	Tukey 95% CI				
1 km v 4 – 6 km	-8.849	-16.319	to -1.378	(significant)		

Table 37. Comparative descriptives for total grass cover as related to BLM grazing allotment.

Test	Comparative descriptives				
	XR Grass Study				
Variables	Total Grass Cover by Allotment				
Total Grass Cover by Allotment	**n**	**Mean**	**SD**	**SE**	**95% CI of Mean**
Beloat	14	31.071	13.8089	3.6906	23.098 to 39.044
Bighorn	13	7.923	9.2327	2.5607	2.344 to 13.502
Conley	11	24.636	14.6169	4.4072	14.817 to 34.456
Hazen	14	25.214	10.3566	2.7679	19.235 to 31.194
Total Grass Cover by Allotment	**Median**	**IQR**	**95% CI of Median**		
Beloat	29.000	12.000	20.000 to 40.000		
Bighorn	4.000	8.000	2.000 to 10.000		
Conley	18.000	20.500	11.000 to 40.000		
Hazen	25.000	10.750	18.000 to 35.000		

Figure 24. Box plot illustrating the central location and scatter/dispersion of total grass cover within our plots as related to BLM grazing allotment.

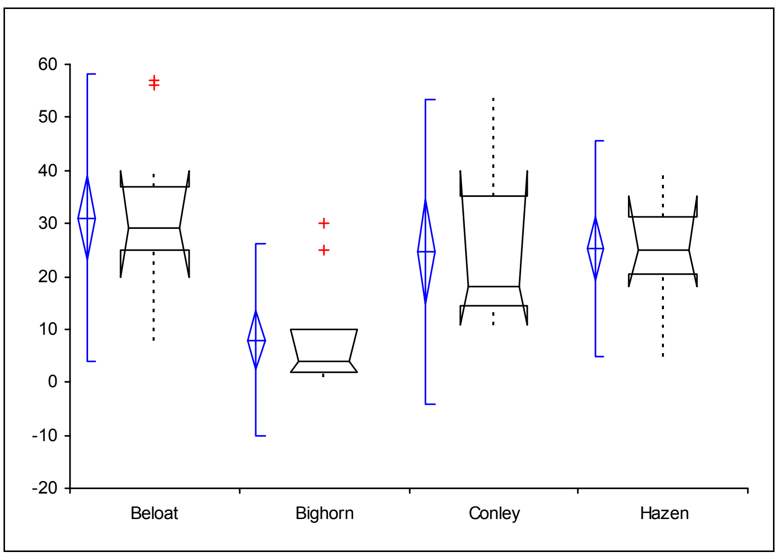


Table 38. ANOVA results for total grass cover related to BLM grazing allotment.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Total Grass Cover by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				
Total Grass Cover by Allotment	**n**	**Mean**	**SD**	**SE**	
Beloat	14	31.071	13.809	3.6906	
Bighorn	13	7.923	9.233	2.5607	
Conley	11	24.636	14.617	4.4072	
Hazen	14	25.214	10.357	2.7679	
Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Allotment	3943.015	3	1314.338	8.97	<0.0001
Within cells	7032.754	48	146.516		
Total	10975.769	51			
Contrast	**Difference**	**Tukey 95% CI**			
Beloat v Bighorn	23.148	10.741	to 35.556	(significant)	
Beloat v Conley	6.435	-6.544	to 19.415		
Beloat v Hazen	5.857	-6.319	to 18.033		
Bighorn v Conley	-16.713	-29.911	to -3.516	(significant)	
Bighorn v Hazen	-17.291	-29.699	to -4.883	(significant)	
Conley v Hazen	-0.578	-13.557	to 12.402		

Table 39. ANOVA results for exotic grass cover related to BLM grazing allotment.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Exotic Grasses by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				
Exotic Grasses by Allotment	n	Mean	SD	SE	
Beloat	14	25.714	14.974	4.0020	
Bighorn	13	7.846	9.245	2.5642	
Conley	11	15.364	13.485	4.0660	
Hazen	14	19.929	11.861	3.1700	
Source of variation	SSq	DF	MSq	F	p
Allotment	2288.977	3	762.992	4.83	0.0051
Within cells	7588.023	48	158.084		
Total	9877.000	51			
Contrast	Difference	LSD 95% CI			
Beloat v Bighorn	17.868	8.131	to 27.605	(significant)	
Beloat v Conley	10.351	0.165	to 20.536	(significant)	
Beloat v Hazen	5.786	-3.769	to 15.341		
Bighorn v Conley	-7.517	-17.874	to 2.839		
Bighorn v Hazen	-12.082	-21.819	to -2.345	(significant)	
Conley v Hazen	-4.565	-14.751	to 5.621		

Table 40. Comparative descriptives for the amount of cattle hoof prints in an area and the distance from an active water development.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Cowprints by Distance from Water					
Cowprints by Distance from Water	n	Mean	SD	SE	95% CI of Mean	
1	23	45.435	67.3342	14.0401	16.317	to 74.552
4	29	11.552	30.7380	5.7079	-0.140	to 23.244
Cowprints by Distance from Water	Median	IQR	95% CI of Median			
1	20.000	65.000	0.000	to 50.000		
4	0.000	0.000	0.000	to 0		

Figure 25. Box plot illustrating the central location and scatter/dispersion of the amount of cattle hoof prints within our plots as related tothe distance from an active water development.

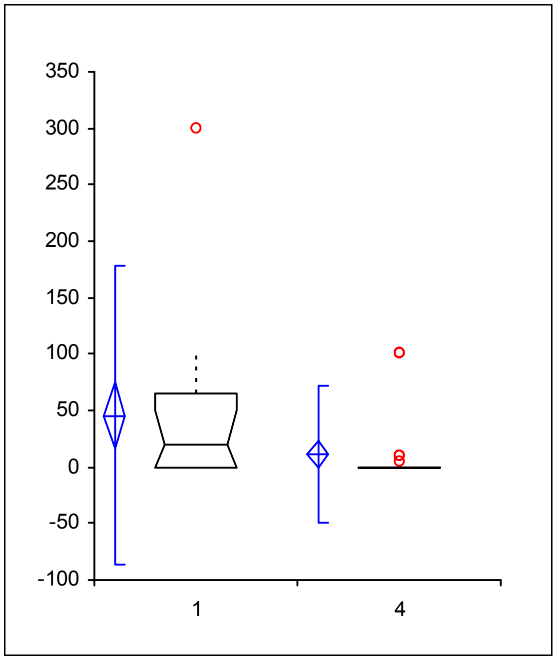


Table 41. ANOVA results for the amount of cattle hoof prints in an area and the distance from an active water development.

Test	**1-way between subjects ANOVA**				
	XR Grass Study				
Comparison	Cowprints by Distance from Water: 1, 4				
n	52				
Cowprints by Distance from Water	**n**	**Mean**	**SD**	**SE**	
1	23	45.435	67.334	14.0401	
4	29	11.552	30.738	5.7079	
Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Distance from Water	14726.098	1	14726.098	5.83	0.0194
Within cells	126200.825	50	2524.016		
Total	140926.923	51			
Contrast	**Difference**	**Tukey 95% CI**			
1 v 4	33.883	5.708	to 62.058	(significant)	

Table 42. Comparative descriptives for the amount of cattle hoof prints in an area and the BLM grazing allotment.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Cowprints by Allotment					
Cowprints by Allotment	n	Mean	SD	SE	95% CI of Mean	
Beloat	14	10.714	23.9275	6.3949	-3.101	to 24.530
Bighorn	13	77.692	79.2837	21.9893	29.782	to 125.603
Conley	11	12.727	31.3340	9.4475	-8.323	to 33.778
Hazen	14	5.714	13.9859	3.7379	-2.361	to 13.789
Cowprints by Allotment	Median	IQR	95% CI of Median			
Beloat	0.000	5.000	0.000	to 10.000		
Bighorn	100.000	80.000	10.000	to 100.000		
Conley	0.000	0.000	0.000	to 40.000		
Hazen	0.000	0.000	0.000	to 10.000		

Figure 26. Box plot illustrating the central location and scatter/dispersion of the amount of cattle hoof prints within our plots as related to the BLM grazing allotment.

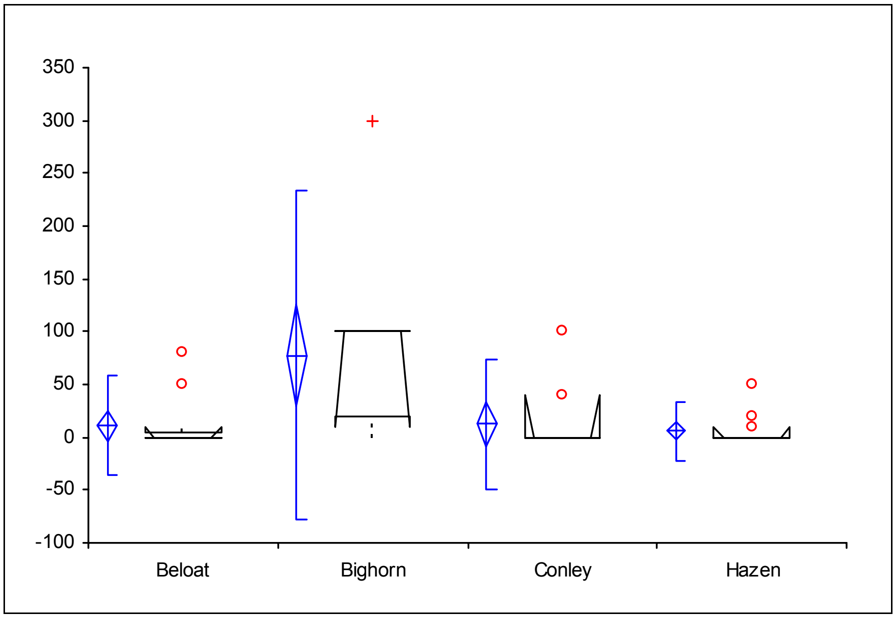


Table 43. ANOVA results for the amount of cattle hoof prints in an area and the BLM grazing allotment.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Cowprints by Allotment: Beloat, Bighorn, Conley, Hazen				
n	52				
Cowprints by Allotment	**n**	**Mean**	**SD**	**SE**	
Beloat	14	10.714	23.928	6.3949	
Bighorn	13	77.692	79.284	21.9893	
Conley	11	12.727	31.334	9.4475	
Hazen	14	5.714	13.986	3.7379	
Source of variation	**SSq**	**DF**	**MSq**	**F**	**p**
Allotment	45692.258	3	15230.753	7.68	0.0003
Within cells	95234.665	48	1984.056		
Total	140926.923	51			

Contrast	Difference	Tukey 95% CI		
Beloat v Bighorn	-66.978	-112.637	to -21.319	(significant)
Beloat v Conley	-2.013	-49.776	to 45.750	
Beloat v Hazen	5.000	-39.806	to 49.806	
Bighorn v Conley	64.965	16.400	to 113.530	(significant)
Bighorn v Hazen	71.978	26.319	to 117.637	(significant)
Conley v Hazen	7.013	-40.750	to 54.776	

Table 44. Comparative descriptives for the amount of cow trails in an area and the distance from an active water development.

Test	Comparative descriptives					
	XR Grass Study					
Variables	Cowtrails by Distance from Water					
Cowtrails by Distance from Water	**n**	**Mean**	**SD**	**SE**	**95% CI of Mean**	
1	23	1.391	2.4446	0.5097	0.334	to 2.448
4	29	0.103	0.3099	0.0576	-0.014	to 0.221
Cowtrails by Distance from Water	**Median**	**IQR**	**95% CI of Median**			
1	0.000	2.000	0.000	to 1.000		
4	0.000	0.000	0.000	to 0		

Figure 27. Box plot illustrating the central location and scatter/dispersion of the amount of cow trails in an area as related to the distance from an active water development.

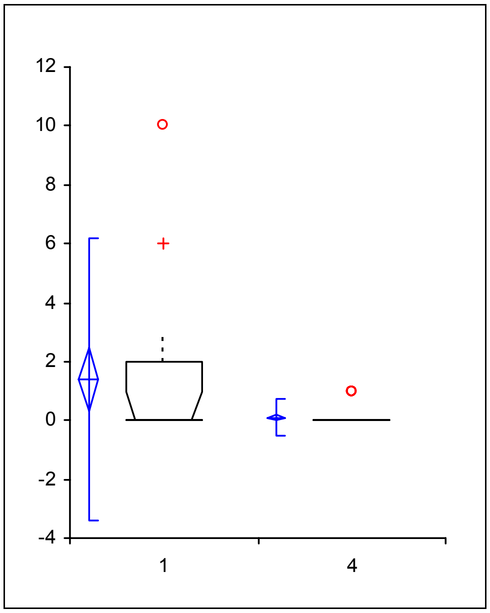


Table 45. ANOVA results for the amount of cow trails in an area and the distance from an active water development.

Test	1-way between subjects ANOVA				
	XR Grass Study				
Comparison	Cowtrails by Distance from Water: 1, 4				
n	52				
Cowtrails by Distance from Water	n	Mean	SD	SE	
1	23	1.391	2.445	0.5097	
4	29	0.103	0.310	0.0576	
Source of variation	SSq	DF	MSq	F	p
Distance from Water	21.274	1	21.274	7.93	0.0069
Within cells	134.168	50	2.683		
Total	155.442	51			
		Tukey			
Contrast	Difference	95% CI			
1 v 4	1.288	0.369 to 2.207		(significant)	

Table 46. Pearson correlation analysis of the amount of cattle hoof prints related to native grass cover.

Test	**Pearson correlation**	
	XR Grass Study	
Alternative hypothesis	Cowprints ≠ Native Grass Cover	
n	52	
r statistic	-0.37	
95% CI	-0.59	to -0.11
2-tailed p	0.0062	(t approximation)

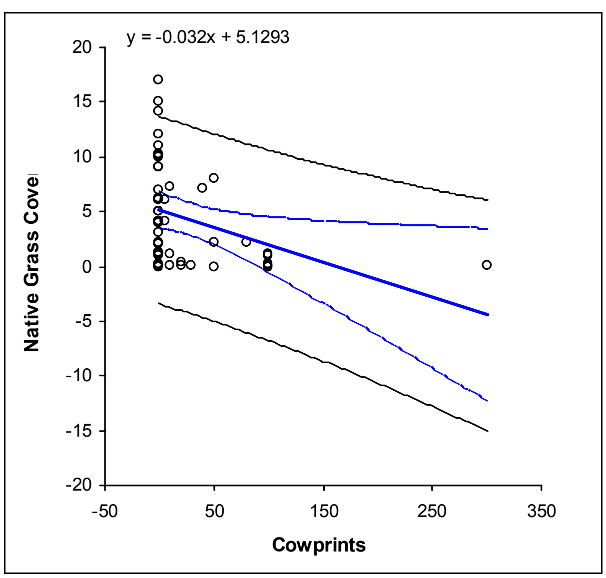
Table 47. Linear regression analysis of the amount of cattle hoof prints related to native grass cover.

Test	**Linear regression**
	XR Grass Study
Fit	Native Grass Cover v Cowprints
n	52
R^2	0.14
Adjusted R^2	0.12
SE	4.2114

Term	Coefficient	SE	p	95% CI of Coefficient	
Intercept	5.1293	0.6555	<0.0001	3.8127	to 6.4460
Slope	-0.0320	0.0112	0.0062	-0.0546	to -0.0095

Source of variation	SSq	DF	MSq	F	p
Due to regression	144.735	1	144.735	8.16	0.0062
About regression	886.792	50	17.736		
Total	1031.527	51			

Figure 28. Result of linear regression analysis displayed over scatter plot graph of the amount of cattle hoof prints versus the native grass cover per plot.



Discussion

We found mixed results in identifying statistically significant relationships between native grass cover, stem density, and diversity in relation to distance from water development, BLM grazing allotment, adjoining matrix community, and exotic grass cover. The following discussion focuses on the significant relationships we discovered for each question that this project was designed to address. We also discuss related issues to the analysis procedure and to the general ecological condition of xeroriparian areas on the SDNM.

Validity of active water source data

During our 2005 and 2006 field surveys, we found that some of the water sources that had been identified by BLM as active water sources were in disrepair and did not show any sign of use within the last few years. Some of the "active" water sources appeared to be abandoned and appeared to have not been used for at least five years (Photos 8-11). Several of the "active" water sources are wells, which were completely dry during the 2005-2006 period. Because our contract and work plan did not include investigation of the current status of the water sources on the SDNM, we were able to only collect sporadic information on the water sources when our routes intersected these areas.

empty water trough

ungrazed areas around water trough

abandoned metal tanks and plumbing

holes rusted through tank

Photos 8, 9, 10 and 11. An abandoned water source in the Hazen allotment, showing signs of long-term neglect and lack of recent livestock activity in vicinity. We were told by the BLM that this water source was "active."

The lack of reliability in the "active" water source data was a serious confounding factor in the statistical analysis of native grass abundance, diversity and density as it relates to distance from water source. Since some of the water sources were clearly not active during the growing seasons of 2005 and 2006, and some had been in disrepair for some time, the analysis of the effect of livestock grazing as it relates to distance from water source was confounded by unreliable data.

1) Are there differences in native grass species composition, cover, and density within a xeroriparian community with distance from an active water development?

There was not found to be any significant difference in native grass species composition, cover, and density related to distance from an active water development. As noted above, however, it is possible that deficiencies in the active water development source data used to calibrate the plot distributions negatively influenced this portion of the study. We obtained from the BLM the most current available spatial data showing which water developments were active just prior to mapping our plot locations in 2005. Nonetheless, observations in the field made the active water development data seem to be of questionable accuracy. We did not attempt a quantitative analysis of the accuracy of the BLM's water development data, nor did we assess the status of every water development on which we based our plot distribution. It is possible that inaccurate labeling of which water developments are currently active flawed the establishment of adequate plot locations to successfully analyze this treatment.

2) Are there differences in native grass species composition, cover, and density between xeroriparian communities with different adjoining matrix communities?

It appears that native grass stem density in xeroriparian areas is influenced by the adjoining matrix community according to our analysis. The PVMCB plots averaged over twice the native grass density per square meter than the CB plots (respective means of 20.54 vs. 9.27). While this is a statistically significant relationship, the significance is relatively low, with a P value of 0.0448.

A similar statistically significant relationship between native grass **cover** and the adjoining matrix community was not realized. It was found that the PVMCB plots averaged almost twice the percent cover of native grass compared to the CB plots (respective means of 6.425 vs. 3.889), but the P value (0.1439) indicated this is not a significant relationship. This is surprising considering that the relationship between percent **cover** of native grass and the **stem density** of native grass is intuitive and also statistically significant. Table 48 and Figure 29 illustrate the statistically significant linear regression relationship between these two variables.

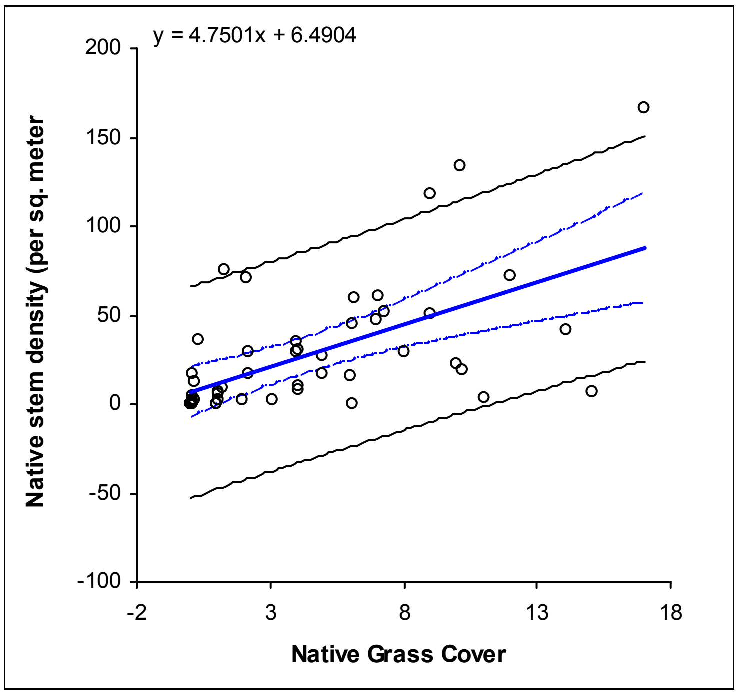
Table 48. Linear regression results for native grass stem density related versus native grass cover.

Test	**Linear regression**
	XR Grass Study
Fit	Native stem density (per sq. meter) v Native Grass Cover
n	52
R^2	0.36
Adjusted R^2	0.34
SE	29.0148

Term	Coefficient	SE	p	95% CI of Coefficient	
Intercept	6.4904	5.5796	0.2503	-4.7165	to 17.6973
Slope	4.7501	0.9034	<0.0001	2.9356	to 6.5646

Source of variation	SSq	DF	MSq	F	p
Due to regression	23274.82	1	23274.82	27.65	<0.0001
About regression	42092.85	50	841.86		
Total	65367.67	51			

Figure 29. Result of linear regression analysis displayed over scatter plot graph of native grass stem density versus native grass cover per plot.



Based on this statistically significance regression model, we entered the native grass cover means for each matrix community treatment into the regression equation to get:

$$\text{Average native grass stems per square meter within CB} = CB(y) = 4.7501(3.889) + 6.4904$$

$$CB(y) = 24.96$$

And

$$\text{Average native grass stems per square meter within PVMCB} = PVMCB(y) = 4.7501(6.425) + 6.4904$$

$$PVMCB(y) = 37.01$$

$$PVMCB(y) - CB(y) = 12.05$$

This is interesting because the difference between mean native grass stem density per square meter between adjoining matrix community is 11.26, which is very close to 12.05.

So, even though we cannot say that there is direct significance in relating native grass cover to adjoining matrix community at a confidence interval of 95%, we can say there is more native grass stem density in areas adjoining PVMCB and that native grass stem density and native grass cover seem to have a positive correlation.

3) Are there differences in native grass species composition, cover, and density between xeroriparian communities within different BLM grazing allotments north of Interstate 8 on the SDNM?

It is apparent from our analysis that significant relationships exist between native grass cover and composition with regards to the BLM grazing allotments. The Bighorn allotment contained far less native grass cover, diversity, and density than the other grazing allotments. Exotic grass cover and total grass cover were also drastically reduced in the Bighorn allotment. Our analysis of the relationships of cattle activity indicators versus the different BLM allotments indicated that higher intensity cattle activity seemed to be occurring throughout the Bighorn allotment relative to the other areas surveyed. We consider this substantial proof that greater amounts of grazing are taking place within the Bighorn allotment, and we infer that native grass cover and density are being reduced due to this activity. Exotic grass cover and total grass cover are being affected as well.

Qualitatively, the Bighorn allotment is the only allotment where cattle were observed regularly in the valley bottom natural communities during our 2005 and 2006 field surveys. The level of grazing appeared to be fairly intense and forage abundance appeared to be very low. We observed numerous cattle carcasses on the Big Horn allotment during the 2006 field season, and suspect that the cattle mortality was due to drought and absence of forage.

4) Are there differences in native grass species composition, cover, and density between xeroriparian communities that contain different amounts of non-native grass (and prominent non-native forbs) species richness and cover?

We did not find any correlation between native grass species cover and stem density when compared to exotic grass cover. The Pearson *product-moment* correlation (*r*) for the correlation tests between these variables came out at or very near to zero, meaning that these variables lack any correlation.

Surprisingly, we did find a positive correlation relating native grass diversity to the amount exotic grass cover. This relationship had strong P values indicating a high level of significance, though the R^2 value is low, meaning that much variation is still not accounted for and that the regression line is a poor fit.

At least two possible explanations exist to account for this positive correlation. The first possibility relates to the significant relationship we found between distance from water development and the percent cover of exotic grasses. It seems that exotic grass cover increases as the distance from a water development increases. Assuming cows are not selective between exotic and native grasses as forage, and assuming that the potential for exotic grass cover remains even throughout the valley bottom xeroriparian areas, it is possible that this pattern can be explained by the amplitude of grazing, where areas nearer to water sources get grazed more frequently. In this scenario, the higher amplitude of cattle grazing is affecting the percent cover of the dominant grass types, which are the exotic grasses. Native grasses are also being grazed in these areas, but their percent cover is already very low, so the relative impact of increased grazing amplitude on native grass cover is negligible. But the increased grazing amplitude might be enough to affect native grass diversity, since the ability to remove a particular species from a specific site without affecting overall grass cover is high when the cover of that particular species is very low to begin with. This scenario is weakly supported in our analysis of native grass diversity as related to distance from water developments. The average amount of native grass diversity at sites closer to a water development is less than the average amount at sites further away from a water development. Though not proven a statistically significant relationship, the trend at least is not counterintuitive to the concept presented above.

Another possible explanation relies on the idea that unknown variables influencing site productivity are simultaneously promoting both greater exotic grass cover and native species diversity on some sites. It is possible that changes in soil conditions throughout the landscape, such as soil depth, particle size, structure, chemical composition, and mycorrhizal associations have influence on site productivity. Because we did not take field measurements of these potentially influential variables, we can not adequately speculate about any relationships taking place on the landscape.

Conclusions

Perhaps the most significant finding in our study of the xeroriparian areas of the SDNM north of I-8 is that the abundance of exotic grasses is very high and native grass abundance, particularly for perennial native grasses, is very low. However, this should not be taken as evidence that perennial native grasses are characteristically absent in Sonoran Desert xeroriparian areas. We have found evidence in previous studies (Morrison et al 2003, Snetsinger and Morrison 2004) that perennial native grasses are more abundant in the xeroriparian scrub communities of adjacent parts of the BMGR and TON, providing an exception to the pattern we observed during this project. The xeroriparian scrub areas on the BMGR and TON should be considered of high conservation value as they represent important examples of the native grass conservation element within xeroriparian communities.

Recommendations for Further Studies

Additional Analyses Based on Existing Data

A great wealth of data has been collected by PBI during four years of study of the SDNM and surrounding areas. Further analysis of these data would produce products that could be useful to BLM's management of the SDNM and to others that have interest in the management of the larger study area. Some of the possibilities for further study using existing data are listed below.

Conduct analysis of grass distribution and abundance by species rather than by general grass types

Each grass species has unique preferences for moisture, temperature, shade, sunlight and soil conditions. In this study we separated exotic grasses from native grasses and annual grasses from perennial grasses. Although these gross separations into basic grass types help reveal patterns in the distribution and abundance of grasses, a much better way to conduct the analyses presented here would be to analyze each species separately. Although this analysis would be more time consuming, it is quite possible that significant relationships between factors would be revealed for some species that are masked by lumping the grasses into basic grass types. This analysis would include:

- Maps of the occurrence and relative abundance of each native grass species.
- Analysis of the factors that influence the distribution and abundance of each native grass species.
- Ranking of the native grass species by rarity and sensitivity to disturbance factors

Develop a set of management recommendations for maintenance of native grass diversity and the native grass conservation element within xeroriparian areas

A clear set of recommendations should be developed to guide management of the SDNM and adjacent areas to ensure the maintenance of the diversity and abundance of native grasses in xeroriparian areas. These management recommendations can be developed through a synthesis of PBI's existing studies of the area and other relevant literature.

Future Research Requiring Additional Data Collection

This study has identified data gaps and areas where future research is needed. Future research that expands the results of this study could be useful to the BLM's management program for the SDNM, and to others that have interests in the management of the larger study area. Some of the possibilities for future research are listed below.

Expand the study of xeroriparian native grasses to include ungrazed areas

The study that we conducted on the SDNM north of I-8 only included areas within active grazing allotments. These allotments may have had differing grazing histories, but active grazing of the low elevation xeroriparian areas has occurred throughout the area during the last 20 years. There were no ungrazed areas in this project's study area, therefore it was difficult to assess the baseline condition of native grasses in ungrazed areas. We recommend expansion of the xeroriparian grass study area to include areas in the BMGR and perhaps the TON that have not been grazed for many years. This would enable a better evaluation of the effect of livestock grazing on xeroriparian native grass abundance and diversity.

Long-term monitoring program for native grass abundance and ecological condition of xeroriparian areas in the SDNM and BMGR

We have put into place an extensive network of permanent xeroriparian ecology monitoring plots during the course of our studies in the SDNM and BMGR. We recommend that all (or many) of these plots be resurveyed in subsequent years to collect data on the response of the vegetation to changes in climate, grazing levels and other variables. Repeated sampling of these permanent plots should be part of a long-term management strategy for the SDNM and BMGR. Analysis of the resample data can yield a more comprehensive view on the population dynamics of native and exotic grass species and insight into the ecological effects of climate change.

Analysis of satellite imagery on a seasonal basis to assess changes in forage abundance and range condition

Satellite imagery can be very helpful in determining vegetation response to precipitation. It is used widely to monitor crop growth and yield. We recommend that BLM utilize the readily available information collected by the MODIS and ASTER satellite sensors that reside on the Earth Observation System platform. With this data, it is possible to determine the amount of photosynthetically active vegetation from the spectral responses received by the satellite sensors. Comparison of images from one season to the next can reveal significant changes in abundance of photosynthetically active vegetation. Analysis of this information could be useful in assessing forage abundance and range condition prior to decisions regarding ephemeral allotment stocking levels. We recommend that BLM explore the use of MODIS and ASTER satellite imagery to aid in rapid assessment of the appropriate livestock stocking levels for specific sites or allotments.

Conduct enhanced xeroriparian natural community mapping

The xeroriparian communities of the study area were mapped using 1:100,000-scale hydrography data (Morrison 2003 and Morrison et al 2003), which was the only data available at the time this work was completed. The extent of the xeroriparian communities is seriously underestimated using this data layer. Our field sampling and analysis of the CIR DOQQs indicates that the actual number and extent of xeroriparian areas is more than 3 times that which was mapped using existing hydrography data. This results in a significant underestimation of the extent of these important natural communities. We used the CIR DOQQs extensively to locate the plots that we sampled as part of the current xeroriparian grass study.

We recommend that work be undertaken to rectify the deficiency in xeroriparian area mapping. This could be accomplished through two approaches. The first approach would be to use 1:24,000 scale hydrography data, once this data is available from the USGS or other sources. The use of this data will rectify at least part of the problem, as it will more accurately delineate the intermittent streams and will include some of the smaller streams. The usefulness of 1:24,000 scale hydrography data depends in large part on the accuracy and currentness of the source data used in its development. The second approach would be based on a combination of automated and manual interpretation of CIR DOQQs using a new image processing approach we have developed to extract this information from the DOQQs. This new approach would probably yield more accurate and current delineation of the xeroriparian communities than the use of standard 1:24,000-scale hydrography data.

Further field studies and analysis of the cattle activity indicators and native grasses in the adjoining matrix communities

It would be interesting to know if cattle are using the xeroriparian areas proportionally higher than the adjoining matrix communities given a standardized distance from a water source. If cattle are grazing in and traveling through the xeroriparian communities more than the matrix communities, the effects of livestock may be amplified in the xeroriparian communities. We recommend a study to determine the relative amount of livestock use, travel and effects on native grasses and ecological condition in xeroriparian areas vs. the adjacent matrix community. This could be accomplished by sets of paired plots within the xeroriparian communities and the adjacent matrix community.

Locating and documenting areas within the xeroriparian communities containing areas of native perennial grass abundance

Because we were unable to locate much native perennial grass using our plot distribution design for the 2005/2006 surveys, it may be necessary to more systematically search for areas within the northern portions of the SDNM that contain higher amounts of native perennial grass. Locating and studying such sites may yield important clues to the factors that control native perennial grass abundance in the SDNM xeroriparian areas.

Further field studies and analysis of native grass cover, stem density, and diversity within xeroriparian communities adjoining the Paloverde-Mixed Cacti-Mixed Shrub on Bajadas community

Due to the nature of our plot distribution constraints for this project, we sampled far more plots in the CB matrix community than in the PVMCB matrix. Further field data collection in this matrix community may yield more significant results between the CB and PVMCB communities.

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APPENDIX A – Descriptions of valley xeroriparian scrub and braided channel floodplain natural communities

Valley Xeroriparian Scrub

Description and Composition

The *Valley Xeroriparian Scrub* community is found along nearly all, low gradient, intermittent streams that flow across the bajadas and desert flats. As we have defined this community, *Valley Xeroriparian Scrub* occurs along the intermittent drainages that cross unconsolidated, alluvial deposits composed of gravels and sands. These drainages are not confined by bedrock outcrops and can change course due to bank cutting, channel migration, channel blockage and reformation during debris flows. It is contrasted with the *Mountain Xeroriparian Scrub* community (discussed later in this paper), which occurs adjacent to steeper gradient streams flowing across rocky slopes and upland communities. The streams of the *Mountain Xeroriparian Scrub* community flow across bedrock and rocky substrates and are largely confined by bedrock where channel migration only occurs on a geologic time scale.

This community occurs as a narrow, linear patch community within the *Creosotebush–Bursage Desert Scrub* and *Paloverde - Mixed Cacti - Mixed Scrub on Bajadas* communities. The vegetation composition is highly variable and depends on the matrix community, the relative size of the drainage system and the dynamic hydrologic and geomorphic processes that control this community. The community is normally characterized by the overstory dominance of xeromorphic, deciduous trees including *Olneya tesota, Parkinsonia florida, and Prosopis velutina* (Hall et al 2001). *Parkinsonia microphylla* is also common in the overstory, but not as abundant and common as *Parkinsonia florida*. *Phoradendron californicum* is a common epiphytic parasite associated with the leguminous trees in the overstory. The presence of herbaceous and woody perennial vines are also common in this community (Hall, 2001)

In our field plots, *Parkinsonia florida* was the dominant plant (8.37% mean cover) but *Larrea divaricata tridentata* had the highest constancy, occurring in 92% of the plots. *Larrea divaricata tridentata* is not, however, an indicator species for this community, having a mean percent cover of only 2.77%. Rather, it is a common component of the surrounding matrix communities. *Ambrosia deltoidea,* another common member of the matrix community, also occurs in most of the plots (68% constancy) but in lower abundance. Other shrubs with either high constancy or cover include: *Acacia greggii, Acacia constricta, and Ambrosia ambrosioides.*

The shrubs listed above contribute to a dense understory that is also composed of sub-shrubs, vines, cacti and herbs. Also included in this understory, according to data from our field plots are: *Schismus arabicus, Lycium* spp., *Celtis pallida pallida, Krameria grayi,* several native grass species*, Cryptantha spp., Lesquerella gordonii, Camissonia spp., Justicia californica, Hyptis emoryi, Hymenoclea salsola, Erodium cicutarium, Bebbia juncea aspera, Sphaeralcea ambigua, Lyrocarpa coulteri,* and *Janusia gracile*. This is one of the most diverse natural communities in this region of the Sonoran Desert.

Larger floodplain systems that have multiple braided channels and overland flow between channels are described later in this paper as the *Braided Channel Floodplain* community. Some of the species occurring in that community also occur in the larger washes that lie within the *Valley Xeroriparian Scrub* community.

Structure

The average vegetative cover in the *Valley Xeroriparian Scrub* community measured in our field plots was 76.5%, which is nearly equal to the average vegetative cover in the other xeroriparian communities and much higher than all the upland communities except for the *Mountain Uplands*. This community typically has three strata: an open overstory of small trees, a dense to sometimes sparse medium to small shrub layer, and a mix of smaller shrubs, grasses and herbs in the understory. Spring annuals often cover some of the bare sand, gravel and soil that is exposed in the wash bottom, but at other times of year the wash itself is devoid of vegetation.

Function and Disturbance Processes

Episodic stream flow along the channels within the *Valley Xeroriparian Scrub* community is the dominant ecological and geomorphic process that controls the composition and structure of this community. Debris flows also occur along the channels during infrequent, high amplitude storms. During the high amplitude flood and debris flow events, some channels can abruptly change course or become more deeply scoured. The frequency, volume and duration of flow events along the channels in this community are a function of catchment area and regional rainfall regime (Warren and Anderson 1985, Hall et al 2001). Geologic substrate, distance from mountain range and stream gradient are also important factors that influence frequency, volume and duration of flow events.

Landscape Context

This community forms long, narrow, sinuous patches within the low gradient bajadas and gentle valley bottoms within the *Creosotebush-Bursage Desert Scrub* and *Paloverde - Mixed Cacti - Mixed Scrub on Bajadas* matrix communities. The stream gradients in this community are nearly always less than 9% (5 degrees) and the community is normally found below 600 meters in elevation. Some valleys and gentle bajadas in which this community is embedded extend over 800 meters in elevation within the Sand Tank Mountains.

Mapping Methods and Biophysical Modeling Parameters

In the initial mapping provided by TNC, the xeroriparian communities were mapped as linear features along all of the streams delineated on the 1:100,000-scale hydrography data. Unfortunately, the 1:100,000-scale hydrography data is not an adequate depiction of the hydrography of the SDNM and surrounding area. Most drainages that exist in this area are not shown in this hydrography data. Sometimes even the major channels are not shown, or minor channels were depicted instead. The initial mapping underestimates the extent of the xeroriparian communities on the SDNM by a factor of at least three. Higher resolution hydrography data (at least 1:24,000-scale) is necessary to adequately map these communities based on the approach taken in the initial mapping. However, hydrologic data at this scale has not yet been produced by the USGS for this part of Arizona. Because of this fact, we also had to rely on the 1:100,000-scale hydrography data for our mapping. We mapped areas where 1:100,000-scale streams flowed across the valley bottom areas (bajadas and desert flats) as *Valley Xeroriparian Scrub*. We did not add any channels to this GIS layer beyond what was contained in the 1:100,000-scale stream layer. We made the assumption that a buffer of 10-meters around the stream arcs represented the location of this community. This is the best we could do with existing data and the constraints of this project.

The *Valley Xeroriparian Scrub* community could be accurately mapped by photo interpretation of the DOQQs, but this would require over a year of work and is well beyond what was possible within the timeframe and budget for this project.

Relationship to Plant Community Classification Systems

This community has a wide range of vegetation types and is not well captured by most vegetation classification systems. Components of the community are included in both the Creosotebush-Bursage series (154.11) and Paloverde-mixed cacti series (154.1215R) of Brown and others (1979). This community encompasses several alliances in the National Vegetation Classification System (TNC 1998), including the *Parkinsonia florida*, *Prosopis velutina*, and *Olneya tesota* alliances. It also shares some characteristics of the *Cercidium floridum-Prosopis glandulosa-Ambrosia ambrosioides* association (154.1215R) of Warren and others (1981).

Braided Channel Floodplains

Description and Composition

The *Braided Channel Floodplain* community has many similarities to the *Valley Xeroriparian Scrub* community but differs in regard to width, dominant geomorphic/hydrologic processes and vegetation composition. This community occupies relatively broad floodplain areas within the mountain valleys and along major washes on the bajadas. Multiple, cross-braiding channels characterize the *Braided Channel Floodplain* community. Significant island areas and adjacent floodplain zones often exist that are inundated by floodwaters during high flow events. These areas are much wider than the typical xeroriparian communities and often bear some resemblance to river floodplains along major perennial rivers throughout the world.
A cross-section of the *Braided Channel Floodplain* community often consists of many different surfaces with varying vegetation and disturbance frequency (Figures A1-A3).

Vegetation composition of the *Braided Channel Floodplain* community is similar to the *Valley Xeroriparian Scrub* community. Nearly all species that are found in the *Valley Xeroriparian Scrub* community are also found in the floodplain community. But the floodplain community differs considerably from the xeroriparian community in the abundance of some species. *Hymenoclea salsola* is one of the most abundant perennial species in the *Braided Channel Floodplain* community with an average cover of 2.68% in our field plots. It also occurred in 42.9% of our plots within this community. In contrast to this, *Hymenoclea salsola* had a mean cover of 0.96% and a constancy of 20% in our plots within the *Valley Xeroriparian Scrub* community. Other species that were largely or solely found within the *Braided Channel Floodplain* community include: *Bebbia juncea aspera, Hyptis emoryi, Sebastiania bilocularis, Chilopsis linearis arcuata* and *Baccharis sarothroides.*

Parkinsonia florida is the dominant tree in the *Braided Channel Floodplain* community (as it is within the Valley Xeroriparian Scrub community). *Parkinsonia microphylla*, *Olneya tesota* and *Prosopis velutina* also contribute to the overstory tree canopy. *Phoradendron californicum* is a common epiphytic parasite associated with the leguminous trees in the overstory. Overall tree cover is less in this community (12.82%) than it is in the *Valley Xeroriparian Scrub* community (24.26%). This may be due to the more active flooding and scouring within the floodplain which tends to favor shrubs like *Hymenoclea salsola*, *Bebbia juncea aspera*, *Hyptis emoryi*, *Sebastiania bilocularis*, *Chilopsis linearis arcuata* and *Baccharis sarothroides* over tree species that require more stable substrates to become established and survive. All of the above-mentioned shrub species have adaptations such as small flexible, multiple stems and deep roots, which contribute to survival in the floodplain environment.

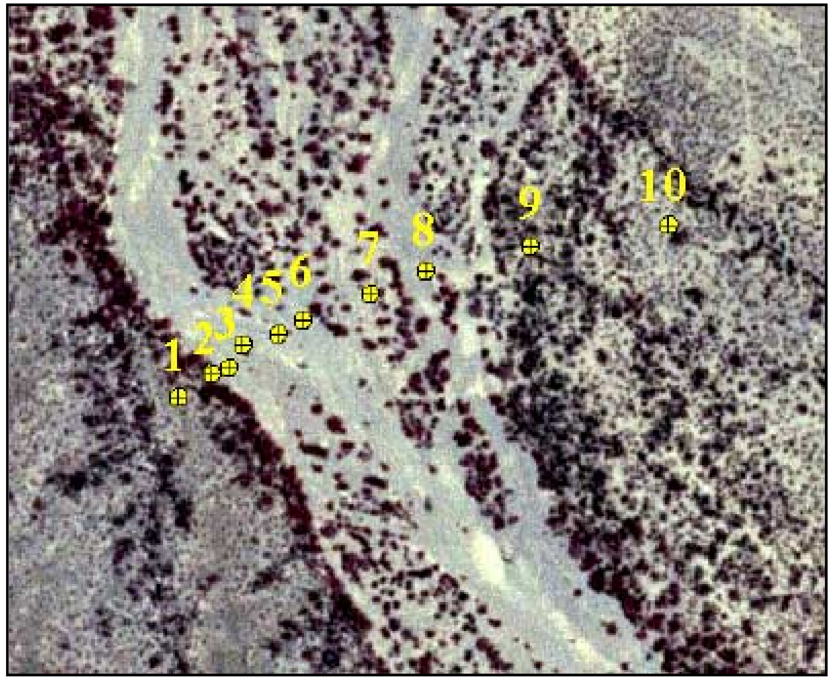


Figure A1. Layout of transect across floodplain in the middle Vekol Valley, with natural community plot locations in yellow.

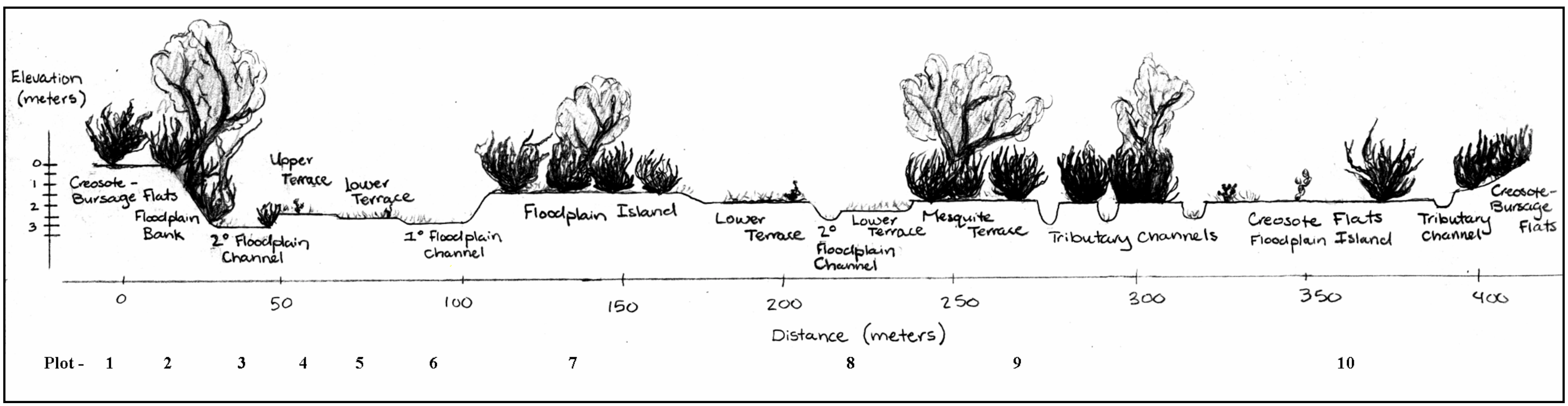


Figure A2. Illustration of the floodplain transect shown in Figure 38 as a cross-section with various flood and channel surfaces and various sub-communities on each surface

Plot 2 – floodplain bank

Plot 3 – active wash channel

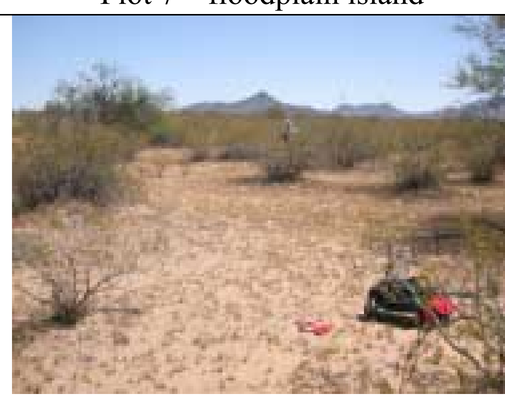
Plot 4 – flood terrace

Plot 5 – lower terrace

Plot 6 – primary active wash

Plot 7 – floodplain island

Plot 9 – mesquite terrace



Plot 10 – floodplain island

Figure A3. Photos of plots along the floodplain transect.

It is worth noting that some of the community sub-class 1 examples of the *Mesquite Woodland* community we have mapped on the SDNM occur as inclusions within the *Braided Channel Floodplain* community and are controlled by the same geomorphic/hydrologic processes that function in this community.

Other species found in our field plots in this community include: *Acacia greggii*, *Ambrosia ambrosioides*, *Justicia californica*, *Lycium* spp., *Larrea divaricata tridentata*, *Eriogonum fasciculatum*, *Carnegiea gigantea*, *Ambrosia deltoidea, Acacia constricta, Amsinckia intermedia, Lepidium lasiocarpum, Cryptantha* spp., and *Pectocarya* spp.

Structure

The structure of this community is unique among the xeroriparian communities in the SDNM. The community is composed of four major elements:

1. Major and minor wash channels that braid through the community
2. Islands that are regularly inundated with floodwaters and have regular deposition and/or erosion
3. Adjacent off channel floodplain areas that are occasionally inundated with floodwaters and subject to deposition and/or erosion
4. Xeroriparian scrub vegetation that lines the banks of many of the wash channels and is above the zone that is subject to regular inundation

Overall vegetation cover is slightly less than the other xeroriparian communities (around 66%) and tree cover is lower than in those communities. Significant areas of the most frequently inundated areas of the floodplain are covered with small to medium sized shrubs.

Function and Disturbance Processes

The *Braided Channel Floodplain* community is influenced by episodic stream flow along the main channels and less frequent flood events that inundate islands and off channel areas. The episodic flow volumes in the floodplain areas are generally higher than experienced in channels within the *Valley Xeroriparian Scrub* community. The intermittent stream flows and floods are the dominant ecological and geomorphic processes that control the composition and structure of this community. During high amplitude flood events, many of the wash channels that braid through the floodplain may change course or become more deeply scoured. Due to these factors, this community is probably the most dynamic community in the SDNM.

Landscape Context

The *Braided Channel Floodplain* community occurs along major wash systems that flow out of mountain ranges within the SDNM. Floodplain areas may be adjacent to *Creosotebush-Bursage Desert Scrub*, *Paloverde - Mixed Cacti - Mixed Scrub on Bajadas,* or *Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. Some of the floodplains occur at the base of mountain slopes on relatively flat canyon bottoms (Figure 41 and 42) while others have formed at the bottom of broad valleys (Figures 43-45). The *Braided Channel Floodplain* community is connected to *Valley Xeroriparian Scrub* and *Mountain Xeroriparian Scrub* communities through the intermittent stream network that feeds the channels that flow through the floodplain.

Mapping Methods and Biophysical Modeling Parameters

These floodplain communities are distinguished from other xeroriparian communities by their overall width, presence of multiple, braided channels and presence of off channel areas inundated by floods. The xeroriparian communities were mapped as linear features while these floodplain communities were mapped as polygon features. We restricted the floodplain communities that we mapped on the SDNM to areas that generally maintain a width of over 100 meters. They are also only associated with relatively low gradient channels.

The *Braided Channel Floodplain* community that we mapped should not be confused with the *Valley Bottom Floodplain Complex* community that was mapped in the BMGR (Hall et al 2001). The latter community has a less active channel system, is considerably wider and is largely dominated by infrequent overland flow.

Relationship to Plant Community Classification Systems

This community has a wide range of vegetation that is not well captured by most vegetation classification systems. Components of the community are included in both the Creosotebush-Bursage series (154.11) and Paloverde-mixed cacti series (154.1215R) of Brown and others (1979). Within the National Vegetation Classification System (TNC 1998), vegetation falls into the Deciduous Shrubland and Evergreen Shrubland formations. The Deciduous Shrubland formation includes a *Hymenoclea monogyra* Shrubland alliance, but not a *Hymenoclea salsola* alliance, which would better describe much of the vegetation in this community.

APPENDIX B - SDNM Xeroriparian Plot Form

Plot Number______	Date	AS	ELEV	SL	Sample Area	GPS Unit Number	
Observer___________					Location	GPS Waypoints	
Matrix Community 1						Camera #	
Matrix Community 2						Photo #s	n e
						(take 4 photos @ cardinal directions)	s w

Description

Geology	Bedrock		
Soil Texture	Rock		
Landform	Gravel		
	Sand		
Comments	Soil		
	Litter		
	Biotic crust		
	Moss		

Plot Diagram

Disturbances

Cowtrails	
Cowprints	
Cow & horse dung	
Horse prints	Camp Site
Trash	
Fence	

Roadway	
Car tracks	
Motorcycles tracks	
Wildfire	
Water Erosion	
Wind Erosion	
Flooding	
Plant pedestaling	

Plant Growth Form	Canopy Cover
All Grasses	
Herbs / Forbs / Ferns	
Shrubs / Vines	
Cacti	
Trees	

Total Grass Cover by Species and Grass Density Quadrats Data Form								
Status	**Species Name**	**Common Name**	**Cover**	**Density1**	**Density2**	**Density3**	**Density4**	**Density5**
	Aristida adscensionis	sixweeks threeawn						
	Aristida parishii	Parish's threeawn						
	Aristida purpurea var. nealleyi	blue threeawn						
	Aristida ternipes var. gentilis	spidergrass						
	Aristida ternipes var. ternipes	spidergrass						
@	*Avena fatua*	wild oat						
	Bothriochloa barbinodis	cane bluestem						
	Bouteloua aristidoides	needle grama						
	Bouteloua barbata	sixweeks grama						
	Bouteloua curtipendula	sideoats grama						
	Bouteloua repens	slender grama						
	Bouteloua gracilis	blue grama						
	Bromus arizonica	Arizona brome						
@	*Bromus catharticus*	rescuegrass						
	Bromus carinatus	California brome						
@	*Bromus rubens*	red brome						
@	*Cynodon dactylon*	Bermuda grass						
	Digitaria californica	Arizona cottontop						
	Elymus elymoides	squirreltail						
	Enneapogon desvauxii	nineawn pappusgrass						
	Eragrostis cilianensis	stinkgrass						
@	*Eragrostis lehmanniana*	Lehmann lovegrass						
	Erioneuron pulchellum	fluff-grass						
	Hordeum murinum	mouse barley						
@	*Hordeum pusillum*	little barley						
	Heteropogon contortus	tanglehead						
	Leptochloa panicea ssp. *mucronata*	mucronate sprangletop						
@	*Melinis repens*	natal grass						
	Muhlenbergia microsperma	littleseed muhly						
	Muhlenbergia porteri	bush muhly						
	Panicum hirticaule	Mexican panicgrass						
@	*Pennisetum ciliare*	buffelgrass						
@	*Pennisetum setaceum*	fountain grass						
@	*Phalaris minor*	canary grass						
	Poa bigeloviii	Bigelow's bluegrass						
	Pleuraphis jamesii	James' galleta						
	Pleuraphis mutica	tobosa grass						
	Pleuraphis rigida	big galleta						
@	*Schismus arabicus*	mediterranean grass						
@	*Schismus barbatus*	mediterranean grass						
	Setaria vulpiseta	plains bristlegrass						
@	*Sorghum halepense*	Johnson grass						
	Sporobolus cryptandrus	sand dropseed						
	Tridens muticus	slim tridens						
@	*Triticum aestivum*	common wheat						
	Trisetum interruptum	prairie false oat						
	Vulpia octoflora	sixweeks fescue						

APPENDIX C – Positional Coordinates of the Permanent Xeroriparian Sample Plots

UTM Zone 12N Nad83 meters

XR Plot Number	Northing	Easting
1	3670413.61	361369.40
2	3668924.05	360999.77
3	3673926.64	361635.73
4	3673425.73	361879.59
5	3668460.91	367687.90
6	3667885.92	365983.90
7	3673227.24	358079.70
8	3668266.94	357072.94
9	3668747.84	356335.49
10	3671836.19	358087.61
11	3671871.37	357114.78
12	3665278.54	360833.78
13	3647418.82	351553.70
14	3647828.60	349803.90
15	3639210.22	364149.71
16	3639092.64	363982.40
17	3640294.45	362188.65
18	3641619.31	360503.23
19	3643279.52	365507.14
20	3642806.71	357072.28
21	3644515.84	353489.88
22	3642943.08	364978.22
23	3643784.68	366494.58
24	3640686.99	372651.41
25	3659825.97	369041.34
26	3660162.07	367310.05
27	3658545.49	372663.68
28	3650127.91	370744.15

XR Plot Number	Northing	Easting
29	3650884.20	372959.54
30	3650066.35	372726.74
31	3659716.39	363910.72
32	3655187.26	365839.70
33	3651056.75	364970.15
34	3659245.09	362989.81
35	3649112.60	365226.37
36	3648977.59	366040.11
37	3660393.46	348429.74
38	3661240.27	349095.55
39	3660342.08	348518.31
40	3662141.53	348574.28
41	3664822.39	347948.20
42	3663917.03	347951.25
43	3665442.93	352100.36
44	3663710.95	352350.51
45	3668387.61	352016.02
46	3675543.63	352511.04
47	3671866.50	350025.18
48	3671326.37	350467.29
49	3639575.92	364903.92
52	3660662.41	368500.84
54	3655373.24	367655.77
56	3675618.58	356512.58
57	3674164.08	357897.57
58	3672581.60	350529.78
59	3664419.40	351318.55
60	3663982.98	352624.39