 

Assessment and Guidelines for Determining Effectiveness and Longevity of Buffelgrass Treatments in Southern Arizona

Final Report

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Abstract

Buffelgrass (*Pennisetum ciliare*, syn. *Cenchrus cilaris*) is an invasive grass species that poses a critical threat to native plant and animal communities in southern Arizona. This species threatens the Sonoran Desert primarily through its potential to serve as a fuel source for wildfires and due to its ability to out-compete native plant species. It poses a major threat to the economy of the area and to personal safety and private property within the growing wildland urban interface. Due to its potential to transform the nearly fire-proof Sonoran Desert into a savanna with a cyclic fire regime, buffelgrass has been the focus of regional and local interagency groups that have been organized to control its spread in southern Arizona. Over the past decade, control efforts have accelerated. Many chemical and manual treatments on public and private lands by employees of the various agencies, roadside management crews, landscape contractors, and volunteers have met varying degrees of success. The purpose of this study is to evaluate effectiveness of treatment techniques for buffelgrass as well as environmental factors that determine success or failure of buffelgrass control efforts. The focus of the project is past treatments in Saguaro National Park and to a lesser degree Organ Pipe Cactus National Monument. Buffelgrass control treatments were less effective on south-facing aspects and on steep slopes. Treatments were more effective in seasons with higher rainfall. Buffelgrass was effectively controlled when multiple treatments occurred in consecutive seasons and when both manual and chemical treatments were used.

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Introduction:

Buffelgrass (*Pennisetum ciliare*, syn. *Cenchrus cilaris*) is an invasive grass species that poses a critical threat to native plant and animal communities in southern Arizona. It threatens the Sonoran Desert primarily through its potential to serve as a fuel source for wildfires and due to its ability to out-compete native plant species. It poses a major threat to the economy of the area and to personal safety and private property within the growing wildland urban interface. Buffelgrass, by creating a significant fuel source, is of great concern to public land managers in southern Arizona, including Saguaro National Park (SNP) and Organ Pipe Cactus National Monument (OPCNM). Low-desert plant communities are not adapted to wildfire, and the saguaro cactus (*Carnegiea gigantea*), and organ pipe cactus (*Stenocereus thurberi)*, two of the signature plants of the desert and the name sakes of these southern Arizona National Parks, are among many desert species that may be severely damaged or killed by fires (Rogers 1985; Wilson et al. 1996). Recent research has shown that vegetative recovery within fire-damaged areas in the Sonoran Desert only occurs after about 50 years (Abella, 2010).

Over the past decade, control efforts have accelerated. Many chemical and mechanical treatments on public and private lands by agency employees, roadside management crews, landscape contractors, and volunteers have met varying degrees of success. In the absence of monitoring standards and protocols, assessments of the effectiveness and longevity of past treatments had been mostly *ad hoc*. Assessments of past treatments are needed to determine treatment effectiveness, treatment longevity, and factors that influence treatment success. The purpose of this study is to evaluate buffelgrass abundance in past treatment areas to determine success of treatments. Factors such as treatment type (chemical vs. manual), treatment regime (frequency and timing of treatments), rainfall, and other site variables were evaluated to determine how they influence treatment success.

Significant buffelgrass infestations have been documented in many areas of central and southern Arizona, though the vast majority of treatments and perhaps the worst invasions are concentrated in Pima County. For the purposes of this study, the focus is on control efforts in SNP and to a lesser degree OPCNM. Executive Order 13112, signed in 1999 and dealing with invasive species, in part enabled SNP and OPCNM to initiate buffelgrass control treatments for the purposes of protecting iconic cacti species and the park unit name sakes, the saguaro cactus and the organ pipe cactus. Thus, each park unit has been implementing control treatments for over a decade.

Study objectives:

1) Assess the long-term effectiveness of different buffelgrass control treatments (i.e. manual pulling, herbicide application) on National Park lands in southern Arizona.

2) Determine how buffelgrass treatment effectiveness is impacted by factors such as treatment type, treatment timing, treatment frequency, and site characteristics.
3) Identify key uncertainties associated with effectiveness of treatments.
4) Provide recommendations for monitoring of future treatments.

<u>Methods:</u>

Study sites

Control efforts date back as early as 1996 in SNP. An extensive survey of buffelgrass in SNP in 2002 estimated approximately 175 acres of buffelgrass. Currently the buffelgrass infestation is estimated at about 2,000 acres in the Park. Since 2004, the Park has chemically or manually treated over 800 acres. Both chemical and manual (pulling) treatments have been implemented in the winter and summer seasons. Prior to treatment implementation, park personnel collect data on buffelgrass patch size and buffelgrasss density and cover within a patch, using predetermined classes.

In OPCNM, buffelgrass control treatments have been implemented since 1994. This included a study where buffelgrass was pulled from 17 10m X 10m plots along the southern border of the Monument. These plots were reassessed for two years after treatments were implemented. Unfortunately, conditions along the southern border have prevented park personnel from revisiting these plots to assess long-term effectiveness of the treatments. Since 2009, the buffelgrass control efforts in OPCNM have focused on areas in the Ajo Mountains. The buffelgrass control treatments involve use of volunteers to pull buffelgrass plants, which are then left on site. Treatments typically take place in the winter, when volunteers are available, and sites are revisited once a year. Volunteers keep track of number of adults and seedlings pulled, thus OPCNM has estimates of buffelgrass density for each site visited. No data on patch size or buffelgrass cover is collected. Currently, no herbicide is used.

Using the geospatial database of treated buffelgrass patches provided by SNP staff, a raster file of buffelgrass patches by frequency for treatments starting in fall 2006 and going through winter 2010 was developed. These included patches that were subject to herbicide treatments only or a combination of manual and herbicide treatments. All patches that experienced manual and herbicide treatments were subject to manual treatments first. This map was then used to select buffelgrass patches to revisit for collection of field data on treatment effectiveness. Treated buffelgrass patches were chosen at random in each of the treatment regime and treatment type categories listed in table 1. Two treatment seasons were defined for the purpose of this study, winter and summer. The winter treatment season was defined as October – May and the summer treatment season was defined as June – September. Initial data analysis showed that there was no difference in buffelgrass abundance metrics for similar treatment regimes that started in different seasons (i.e., two consecutive treatments starting in winter vs. two consecutive treatments starting in summer). Thus, similar treatment regimes occurring in different seasons were combined, resulting in four treatment regime categories (table 1). Treatments along roadsides were not included in the study. See attached maps of buffelgrass treated patches that were examined in the study. In all, 106 treated patches were revisited in the Tucson and Rincon Mountain Districts of SNP in the summer of 2010.

Treatment types and regimes to examine were more limited in OPCNM since only manual treatments are used and they typically occur in the winter months. Data from manual treatments that occurred in three consecutive winters (2009, 2010, and 2011) in five different sites throughout the monument were used to evaluate treatment effectiveness.

Table 1: Treatment frequency/timing categories

Treatment regime	**Treatment type**	**Number of patches**	**Description**
Three consecutive treatments	Chemical	15	Three herbicide treatments occurring in consecutive seasons.
Three consecutive treatments	Chemical + manual	11	Three treatments (one manual followed by two herbicide) occurring in consecutive seasons.
Two consecutive seasons	Chemical	28	Two herbicide treatments occurring in consecutive seasons.
Two consecutive seasons	Chemical + manual	15	Two treatments (one manual followed by one herbicide) occurring in consecutive seasons.
One skipped season	Chemical	15	Two herbicide treatments occurring in nonconsecutive season (one winter or summer season skipped)
One skipped season	Chemical + manual	10	Two treatments (on manual followed by one herbicide) occurring in two nonconsecutive seasons (one winter or summer season skipped)
Two skipped seasons	Chemical	12	Two herbicide treatments occurring in nonconsecutive seasons (one winter season and one summer season skipped)

Data collection

The following data were collected at each patch: buffelgrass patch size, buffelgrass percent cover (using cover classes), buffelgrass density (using density classes) and dominant buffelgrass stage (adult, yearling, seedling). Dominant aspect and percent slope for each patch were obtained from a digital elevation model. Precipitation data from SNP were compiled and total rainfall one month prior to treatment data was calculated for each treated patch. In addition, time since last treatment was calculated in months. No additional data were collected at OPCNM. Instead, adult and seedling buffelgrass density in 2011 was used to assess buffelgrass treatment effectiveness.

Data analysis

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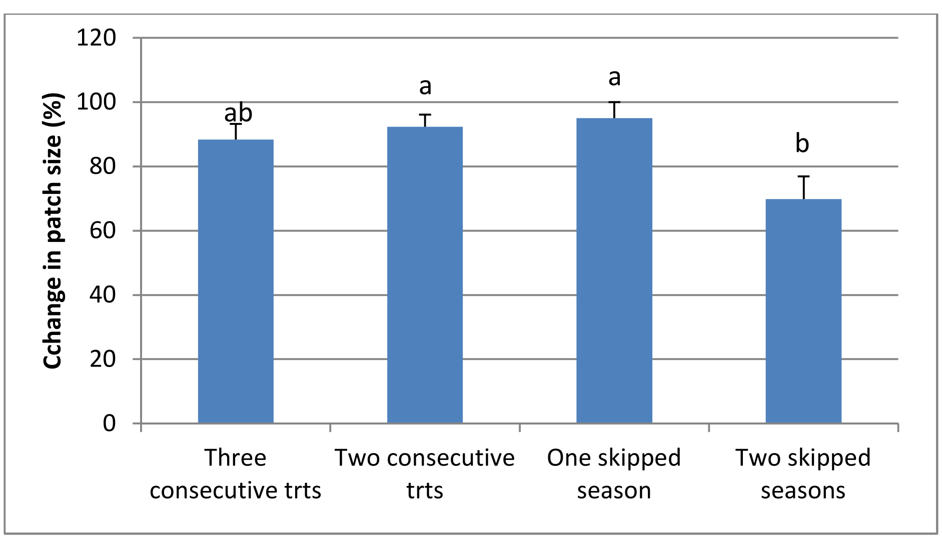
Five different dependent variables were used to represent effectiveness of buffelgrass control treatments: percent change in buffelgrass patch size, percent change in buffelgrass density, percent change in buffelgrass area coverage, current density, and current area coverage. Percent change in buffelgrass patch size, density, and area coverage were calculated by comparing these variables at the time of the last treatment to the summer of 2010. Buffelgrass density was assessed as number of individuals per square meter which was calculated by dividing measured buffelgrass density by patch size. This allowed buffelgrass density to be comparable across patches of different sizes. Buffelgrass coverage area was calculated by multiplying percent cover by buffelgrass patch size. Similarly, this allowed for comparison of buffelgrass cover over time. For the OPCNM data, adult and seedling buffelgrass density were examined over time to evaluate treatment effectiveness.

The analysis determined how six different variables influenced effectiveness of buffelgrass control treatments. Categorical variables included treatment regime and type (see table 1) and dominant aspect, which was defined as north, east, south, or west. Continuous variables included slope (%), time since last treatment (months), and total rainfall falling one month prior to treatment (inches). Because data did not meet the assumptions of traditional statistical tests, non-parametric tests such as the van der Waerden chi square test (for >2 categories) and the Wilcoxon test (for two categories) were used for assessing categorical variables. Continuous variables were tested using Spearman's correlation. Similar statistical tests were not conducted for data from OPCNM as similar data were not available.

<u>Results</u>

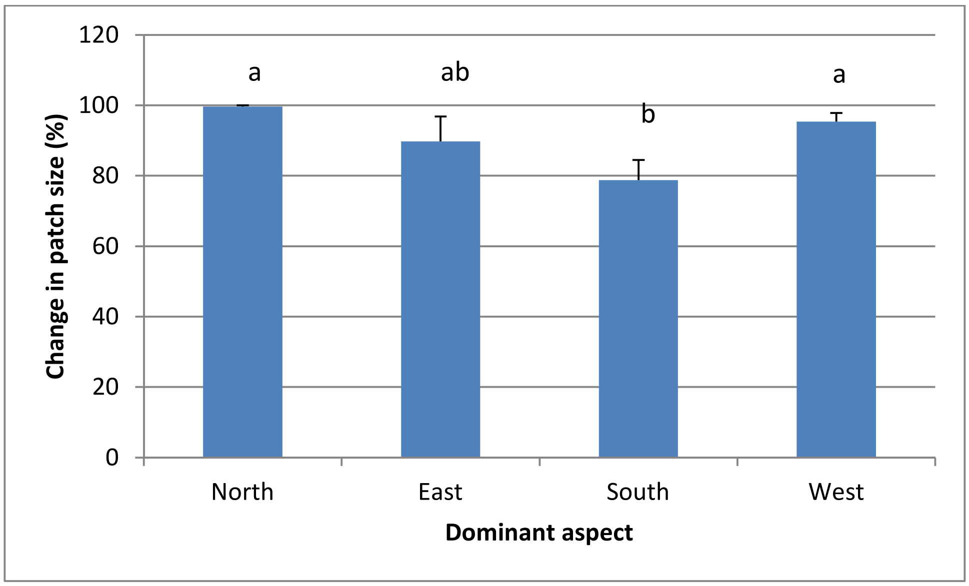
There was a significant difference in percent change in patch size with treatment regime (χ^2 = 9.21, df = 3, p = 0.03). Areas where treatments were skipped for two full seasons had lower percent change in patch size compared to other treatment regimes (figure 1).

Figure 1: Average change in buffelgrass patch size (%) for different treatment regimes. Error bars represent one standard error. Different letters represent significant differences among treatment regimes (p < 0.05).



There was also a significant difference in change in patch size with aspect ($\chi^2 = 18.02$, df = 3, $p < 0.001$). Percent change in buffelgrass patch size was lowest on south-facing aspects (figure 2).

Figure 2: Average percent change in buffelgrass patch size for different dominant aspects. Error bars represent one standard error. Different letters represent significant differences among dominant aspects ($p < 0.05$).



There was a significant negative correlation between percent change in buffelgrass patch size and percent slope (table 2). There was no significant correlation between change in buffelgrass patch size and time since last treatment or total rainfall one month prior to treatment. There was also no significant difference in change in patch size for different types of treatment (Z = 1.47, p = 0.14).

Table 2: Matrix of spearman's correlation coefficients between continuous variables measured in the study. Values are only given for significant correlations ($p < 0.05$). NS = not significant.

	Slope (%)	One month rainfall (inches)	Time since last treatment (months)
Change in patch size (%)	-0.24	NS	NS
Change in density (%)	-0.30	NS	NS
Change in coverage (%)	NS	0.27	NS
Current density (individuals m^{-2})	0.32	-0.23	NS
Current coverage (m^2)	0.35	-0.20	NS

There was no significant difference in percent change in density by treatment regime (χ^2 = 6.58, df = 3, p = 0.09, df = 3), treatment type (Z = 0.71, p = 0.48), or aspect (χ^2 = 7.37, df = 3, p = 0.06). There was a significant correlation between percent change in buffelgrass density and percent slope (table 2). There was no significant correlation between percent change in density and time since last treatment or total rainfall one month prior.

There was no significant difference in percent change in buffelgrass coverage area by treatment regime (χ^2 = 7.09, df = 3, p = 0.07), treatment type (Z = 1.8, p = 0.07) or aspect (χ^2 = 5.32, df = 3, p = 0.15). There was a significant positive correlation between percent change in buffelgrass coverage and total rainfall falling one month prior to treatment (table 2). There was no significant correlation between percent change in buffelgrass coverage and time since last treatment or percent slope.

There was no significant difference in current buffelgrass density per square meter and treatment regime (χ^2 = 7.18, df = 3, p = 0.07). There was a significant difference in buffelgrass density by treatment type (Z = -2.21, p = 0.03) and aspect (χ^2 = 10.10, df = 3, p = 0.02). Buffelgrass density was significantly higher in areas with only chemical treatments compared to areas that experienced manual and chemical treatments (figure 3). Buffelgrass density was significantly higher on south-facing aspects compared to north- and west-facing aspects (figure 4).

Figure 3: Average buffelgrass density per square meter measured in the summer of 2010 by treatment type. Error bars represent standard error.

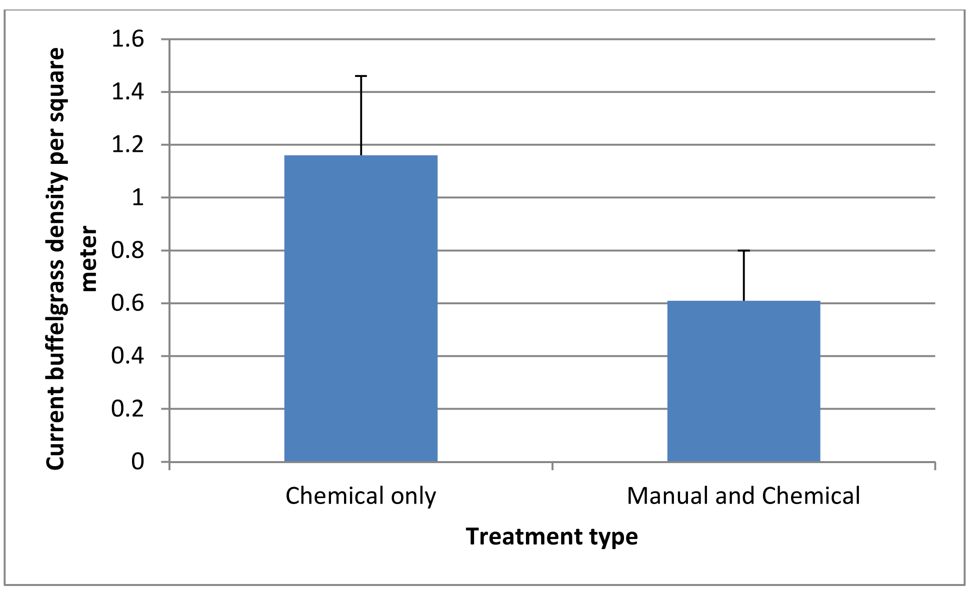
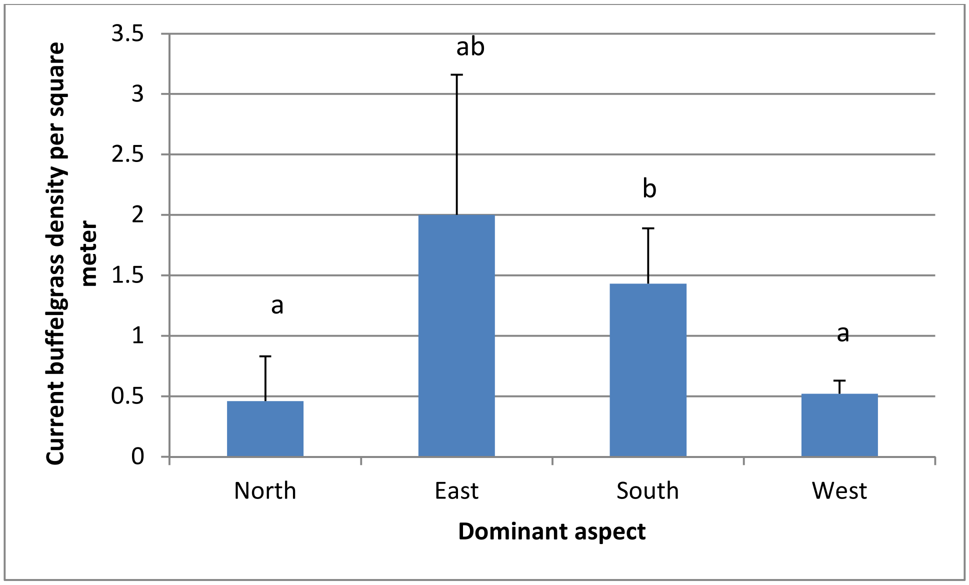


Figure 4: Average buffelgrass density per square meter as measured in the summer of 2010. Error bars represent standard error. Different letters represent significant differences among dominant aspects.



There was a significant positive correlation between current buffelgrass density and percent slope (table 2) and a significant negative correlation between current density and total one month rainfall (table 2). There was no significant correlation between current buffelgrass density and time since last treatment.

There was no significant difference in current buffelgrass coverage area by treatment regime ($\chi^2 = 3.50$, df = 3, p = 0.32). There was a significant difference in buffelgrass coverage area by treatment type (Z = -3.40, p < 0.001) and dominant aspect ($\chi^2 = 11.80$, df = 3, p = 0.01). Current buffelgrass coverage was significantly lower in areas that experienced both manual and chemical treatments compared to areas that experienced chemical treatments only (figure 5). Current buffelgrass coverage was higher on south-facing aspects compared to other dominant aspects (figure 6).

Figure 5: Average buffelgrass coverage area (m^2) as measured in the summer of 2010. Error bars represent standard error.

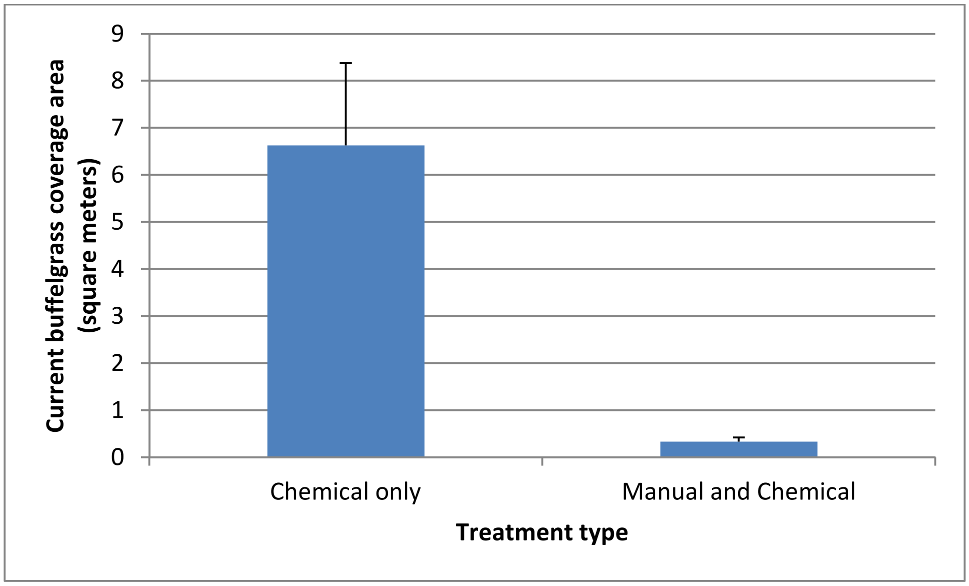
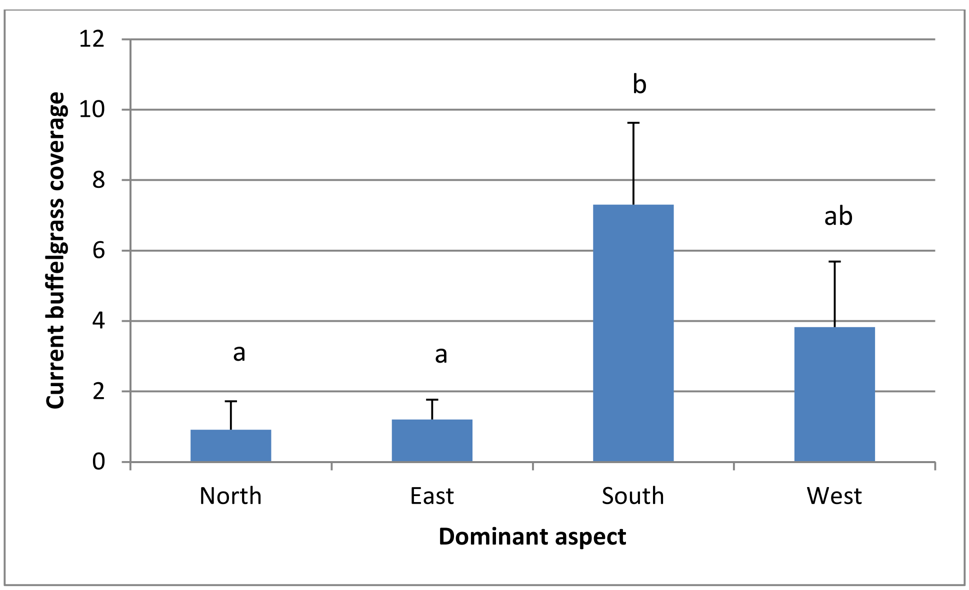


Figure 6: Average buffelgrass coverage area as measured in the summer of 2010 by dominant aspect. Error bars represent standard error. Different letters represent significant differences among aspects.



There was a significant correlation between current buffelgrass coverage and percent slope and a significant negative correlation between buffelgrass coverage and total one month rainfall

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(table 2). There was no significant correlation between buffelgrass coverage and time since last treatment.

In OPCNM, manual treatments occurring in the winter months appear to be very successful. While there is some variability in different areas of the Monument, both the number of buffelgrass adults and seedlings appear to decrease dramatically over time (figures 7 and 8).

Figure 7: Density of buffelgrass seedlings in five different areas throughout OPNM over time.

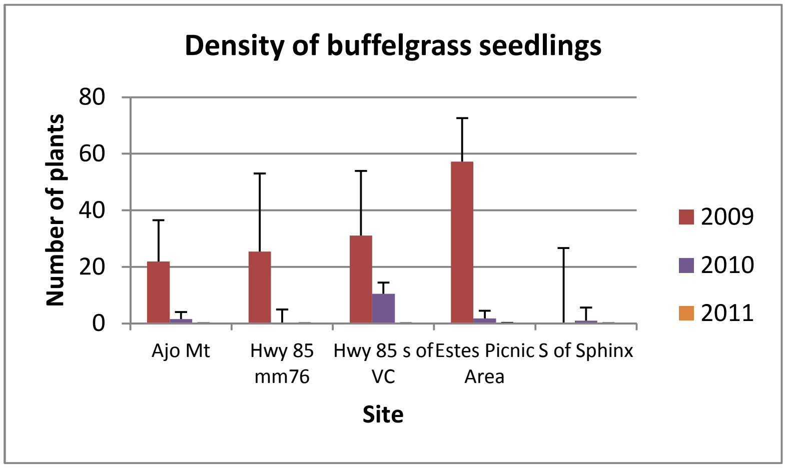
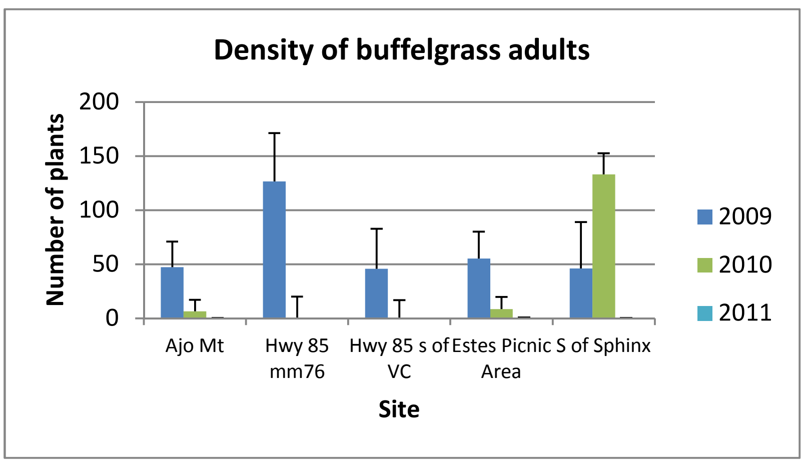


Figure 8: Density of buffelgrass adults in five different areas throughout OPNM over time.



<u>Discussion</u>

Factors that influence successful buffelgrass control

Overall, it appears that buffelgrass control measures in SNP are successful. The vast majority (83%) of plots showed reductions in patch area greater than 90%. The same is true for OPCNM (figures 7 and 8). However, there are a handful of areas on the landscape where control efforts have been less successful. This study was an attempt to determine what factors might influence treatment success.

There is some indication that skipping two full treatment seasons (one winter and one summer season) results in less successful control of buffelgrasss. However, this was only evident in the change in patch size. For other measures of buffelgrass control effectiveness, treatment regime was not a significant factor. Combination treatments (manual followed by chemical) may be slightly more effective than chemical only treatments. However, this was only evident in current measures of buffelgrass abundance (density and cover). For variables that assessed how buffelgrass abundance changed over time, treatment type was not a significant determinant, thus these data should be interpreted with caution.

Buffelgrass abundance measures were consistently higher on south-facing aspects compared to other dominant aspects. Change in patch size was lower on south-facing aspects and current measures of buffelgrass abundance (density and cover) were higher on south-facing aspects. This suggests that buffelgrass grows better and that treatment efforts should be more aggressive on south-facing aspects.

Percent slope was consistently significantly correlated with measures of buffelgrass abundance. Percent slope was negatively correlated with percent change in patch size and buffelgrass density, indicating that control treatments were less effective on steeper slopes. Current buffelgrass density and coverage were positively correlated with percent slope, indicating that current buffelgrass abundance tends to be higher on steeper slopes. This may be because steeper slopes are more difficult to treat completely, leading to less successful treatments. Or, there may be something about slope steepness that encourages buffelgrass growth and spread. For example, buffelgrass seeds may be more easily transported via gravity on steep slopes. Whatever the cause of the trend, it does indicate care should be taken to assure treatments on slopes are thorough and/or aggressive.

Rainfall amount also seems to influence success of buffelgrass control treatments. Percent change in buffelgrass coverage was positively correlated with total rain falling one month prior to treatment. Current buffelgrass density and coverage were negatively correlated with total one month rainfall. This indicates that higher amounts of rainfall prior to treatments lead to more successful control. Higher amounts of rainfall likely lead to greater buffelgrass growth and greenness, which should increase effectiveness in killing the grass.

Time since last treatment was the only variable that did not explain any variation in buffelgrass abundance or change in abundance. The treatment program in the Park is relatively young, thus time since last treatment included a small range (12-29 months). However, these results are still encouraging as it indicates that treatments can have some longevity through time. If treatments are successful to begin with, these data suggest that that success can last for up to two years.

Uncertainties associated with buffeglrass control

This study included only a few variables that could influence success of buffelgrass control treatments. It is possible that factors not considered are also influential. Some examples of factors that were not considered include distance to roads/trails/drainages, soil type, and temperature. The success of manual only treatments was assessed at OPCNM, but not SNP. This type of treatment seems to be successful at OPCNM, but it is unclear if similar results would be seen at SNP. A flush of seedlings can often be seen after initial treatments in SNP, but the same effect is not typically seen in OPCNM (Sue Rutman, personal communication). This may be an effect of the slightly different climates of these areas.

Monitoring guidelines

The monitoring procedure used by SNP proved sufficient for the purposes of assessing effectiveness of buffelgrass control treatments. Buffelgrass patch size, density and cover are useful metrics for assessing success of buffelgrass control treatments. However, difficulties in assessing data arose because size of measured patches changed over time. Buffelgrass density and cover are dependent on patch size, thus comparison of these metrics over time is difficult as patch size changes. In this study, this problem was overcome by calculating metrics of buffelgrass density and cover that took into account patch size. However, for a monitoring program, I would recommend establishing fixed area plots within buffelgrass patches in which density and cover could be measured. This would allow for buffelgrass density and cover to be compared across patches and through time. Plot size should be large enough to be representative of a particular patch, but small enough so that density and cover could be easily assessed. For very large patches, multiple plots should be established to be representative of a patch.

References

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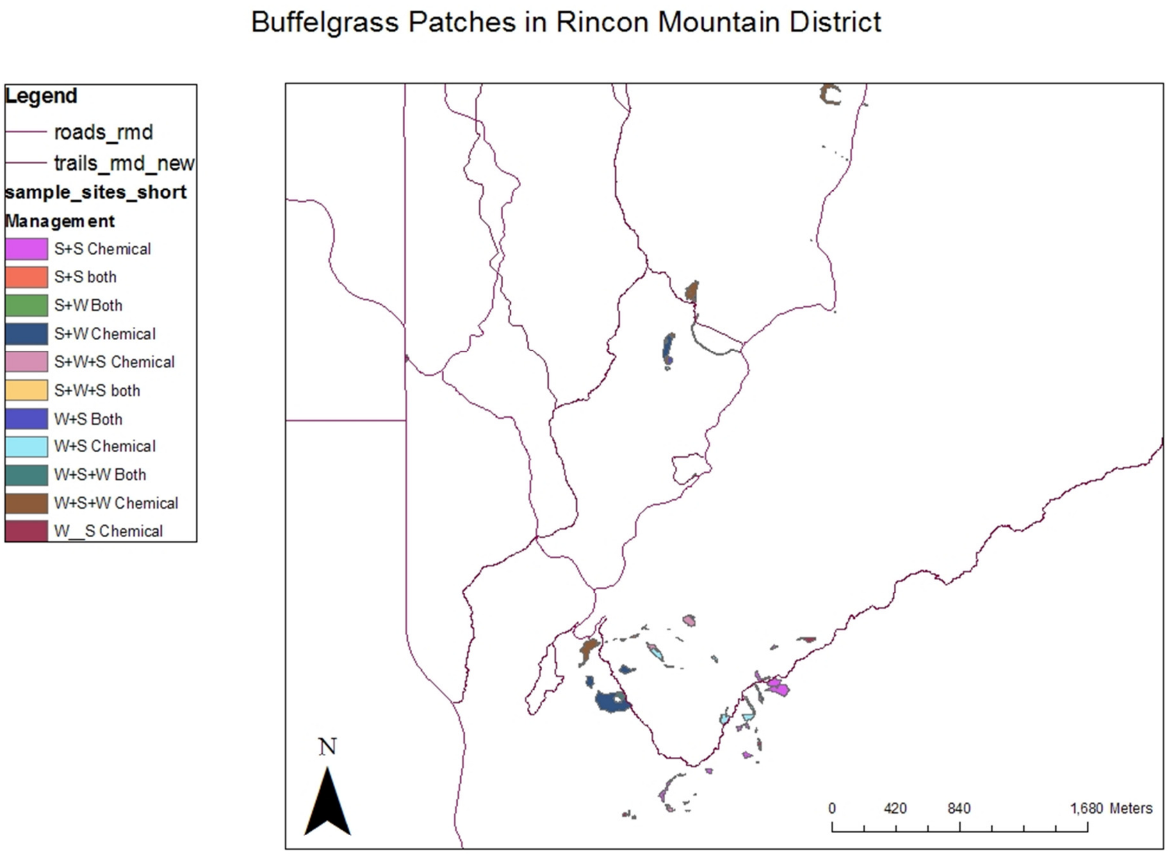
Appendix – maps of treated buffelgrasss patches examined in the study



Buffelgrass Patches in Tucson Mountain District