

Chaco Culture National Historic Park

Exotic Flora Species Inventory

Final Report

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Introduction

Chaco Culture National Historical Park (CHCU), first designated as Chaco Canyon National Monument in 1907, was established in northwestern New Mexico to preserve the unique archaeological features located in Chaco Canyon. National Park Service policies also indicate that the 'Service will seek to perpetuate native plant life as part of natural ecosystems' (NPS 2001). Resource management personnel at the park have recently identified a need to evaluate the status of invasive, non-native (exotic) plant species within CHCU, therefore an effort is underway to understand the magnitude of the threat from invasive plant species (Brad Shattuck, personal communication). This pilot study will characterize the current state of invasive species outside the riparian corridor in the "bottomland" of Chaco Canyon.

Background

One of the most important ecological events now occurring in the world is a sweeping change in the distributions of plant and animal species. Many species are dwindling in numbers, occupying a smaller range, or becoming extinct, while others are exploding in numbers and moving into new ranges that they never before occupied. The major driving force behind these changes is human activities. Humans are creating new kinds of habitats (e.g., large patches of bare ground), altering disturbance regimes (e.g. encouraging grazing by domestic animals) and transporting species into places they never could reach before. A particular concern in high desert shrublands of the southwestern United States is colonization by plant and animal species that formerly did not exist in this region following intensive grazing (Floyd et al 2003).

Colonization by new species is not necessarily a bad thing. In fact, it is a natural process. Elk evolved in Eurasia and did not exist in North America until they migrated across the Bering land bridge during the Pleistocene. Piñon and ponderosa pine were both absent from the Colorado Plateau region during the last ice age, and only entered the southwest within the last 10,000 years. Nobody would refer to elk, piñon, or ponderosa pine as “alien” or “exotic” or “bad” species in this region. However, the rate at which new species are arriving in the Colorado Plateau has accelerated dramatically in the last few hundred years, and some of the new arrivals have distinctly undesirable characteristics: they displace the native species and alter ecosystem processes in ways that reduce the ecological integrity of local ecosystems. Our concern rests with these latter species.

Undesirable non-native plants are often referred to as “weeds.” However, this term is vague and loaded with many different connotations. Non-native species also may be called “exotics” or “aliens” – terms that may be similarly loaded. Here, we refer to undesirable non-native species as *invaders*. These are species that can enter even relatively intact natural communities, where they displace the dominant native species or alter ecosystem processes. Invader species can sometimes invade undisturbed ecological communities, but their invasion often is enhanced by disturbances to the native community, i.e., by natural or human-caused processes that kill some of the dominant native plants or even clear the vegetation from a piece of ground. Native biodiversity is valued highly by ecologists, resource managers, and conservation biologists.

A contentious debate surrounds the role of biodiversity on ecosystem functioning and stability, especially with regard to the system’s ability to resist invasion by exotics (Dukes 2001, Higgins et al. 1998, Hughes and Petchey 2001, Grime 1998, Levine 2000, McCaen 2000). Community stability, the life history of natives and invasive species, fertility, and disturbance patterns are among those attributes whose variation influences invasibility (Prieur-Richard and Lavorel 2000). Recent studies contrast the role of species richness in either protecting communities against invasion, supporting the “diversity-resistance hypothesis” originally proposed by Elton (Kennedy et al 2002, McCann 2000) or,

conversely, other studies document a pattern of increasing invasibility with increasing species richness (Levine 2000, Stohlgren et al 2003, Higgins et al 1998). These seemingly opposite trends may reflect the scale of the study (Hughes and Petchey 2001, Kennedy et al 2002). Neighborhood analyses support a positive relationship between species diversity and resistance (Kennedy et al 2002), or functional diversity and resistance (Dukes 2001), while regional or landscape scales often reflect a negative relationship between species diversity and resistance. In the latter, more diverse communities are targets of increasing levels of invasion (Higgins et al 1999, Levine 2000, Stohlgren et al 1997). Regardless of the relationship between biodiversity of natives and invasives, it is clear that species richness alone cannot account for inter-community differences in invasibility (Prieur-Richard and Lavorel 2000). In fact, species richness has become discounted as the key parameter that dictates invasibility, while diversity and characteristics of functional groups or trophic levels are often deemed a more important deterrent of invasives (Dukes 2001, Lehman and Tilman 2001, Tilman et al 1997). Few studies illuminate mechanisms that allow particular species to invade particular communities. It is important that confounding variables impacting natives and invasive species, including patterns of herbivory (Prieur-Richard et al 2002), spatial patterns in the invaded landscape, and fertility (With 2001) and disturbances (Prieur-Richard and Lavorel 2000) be considered. In this study, patterns of disturbance from grazing (Floyd et al 2003) and roads or trails, and soil characteristics are of focus.

The objectives of this study were to identify the exotic species that are currently threatening the park and to evaluate potential control strategies for these species through a literature review. Through field investigations, we begin to identify biophysical factors that influence or facilitate occurrence of exotic species. This will provide a means to prioritize areas of concern for potential control efforts. Therefore in this study we will:

Objective 1: Search the primary literature to create "short list" of potential invasive species. Identify level of threat by species and suggest treatment if possible from relevant literature.

Objective 2: To ultimately aid in creation of a weed management plan by Resource Management, we will sample populations of invasive plant species and determine characteristics of invasible sites in the canyon bottoms of Chaco Canyon.

Objective 3: Create a map of most likely sites for current and future invasions.

Methods

Field investigations were conducted to identify the most common exotic species occurring in the park and to assess their current distribution. GIS analyses were performed to evaluate factors that may facilitate the occurrence and establishment of these species.

Field Studies:

A stratified random sampling strategy was employed to locate the sample plots. The strata were identified based upon three criteria; 1) soil type (as defined by the Zschetzsche and Clark, 2004), 2) time since last grazed (Floyd et.al 2003) and 3) the canyon bottom as it receives the heaviest impact from visitation. These parameters were considered potentially the most influential in the establishment of exotic species and time and funding constraints precluded an exhaustive field investigation of the entire park. These strata were delineated spatially using existing GIS data themes.

One thousand locations were randomly distributed across the park and a subset of these was selected for data collection. The decision for selecting sample locations was based upon acquiring an adequate sample in each grazing treatment and soil type.

Trimble GeoExplorer 3® GPS units were used to navigate to each sample site based upon coordinates extracted from the GIS. At the site, two 10m X 10m plots were established. The first was centered on the randomly generated position. The second plot

was centered 30m to the east. The location of each sample plot was recorded using the GeoExplorer 3 GPS units and differentially corrected using post-processing techniques of the Trimble Pathfinder Office® software. These locations were exported to create a GIS theme as a shapefile for ArcView®.

Within each plot, the following data were recorded:

1. Every species occurring in the plot was recorded and given a cover and abundance value based upon the Braun-Blanquet scale (Mueller-Dombois and Ellenburg, 1984)
2. All exotic species were listed and the number of individuals in the plot was recorded for each. This provided a density estimate for the exotic species.
3. Independent variables recorded included, the time-since-grazing strata (<10yr, >60yr and currently grazed), soil texture (sandy, silty, gravelly, cobbly) and an estimate of the condition of microbial crust development and color (absent, physical crust, initiated, moderately developed, or well-developed; natural color, or black).
4. Soil types were extracted from the NRCS coverage for each sample plot.

All data were entered into a Microsoft Excel® spreadsheet file and then transferred to SPSS® statistical package for analysis.

Results

Objective 1. Results of Literature Searches on Invasive Species

Through literature searches, we determined that the following invasives are potential species for the Chaco Canyon region. Starred species were actually located in the Park, and relevant information on these species follow.

Acroptilon repens
Bromus tectorum *
Cardaria draba
Carduus nutans
Centaurea diffusa
Centaurea maculosa
Centaurea solstitialis
Cirsium arvense
Convolvulus arvensis
Cynoglossum officinale
Halimolobos glomeratus *
Kochia scoparia *
Lactuca serriola
Linaria vulgaris
Marrubium vulgare
Ranunculus testiculatus
Salsola kali *

Bromus tectorum

Bromus tectorum, cheatgrass, invaded a wide variety of ecosystems over a vast geographic area during a relatively short time period in the early twentieth century (Mack 1986). The plant is so named because it greens up early in the spring, giving an illusion of abundant future forage for livestock and wildlife, but soon it becomes dry and unpalatable. It owes its success in part to its extremely flexible life history characteristics. It can complete its life cycle in a single summer, function as a winter annual, or even be biennial, depending on moisture conditions. Seed germination occurs over a period of several months, ensuring that an entire cohort will not be eliminated by a single period of drought (Mack and Pyke 1986). This invasive grass has been expanding its range during the recent

drought in the southwest. Ongoing work by Jayne Belnap and Matt Brooks, USGS, has begun to identify soil nutrient characteristics that allow cheatgrass invasions (Belnap, personal communication)

Cheatgrass is also of concern because of its potential to drastically alter the natural fire regime (Mack 1986). Cheatgrass has the potential to change future fire behavior in ways that would threaten the recovery of native vegetation. Frequent fires in burned areas now dominated by cheatgrass and other invader species could prevent normal recovery of the native desert shrublands and grasslands of Chaco, and lead to extensive stands of vegetation dominated by non-native plant species. We regard this rapid proliferation and spread of cheatgrass as a very serious threat to the long-term ecological integrity of park ecosystems. A winter annual, cheatgrass grows rapidly during late winter and early spring, potentially consuming much of the soil moisture needed by later-growing native plants. When dense stands of cheatgrass die and cure in early summer, they provide a continuous bed of highly flammable fuel which can readily carry a relatively low-intensity but fast-moving fire. If cheatgrass continues to spread into high deserts and shrublands of the Colorado Plateau, it may cause a switch from the previous fire regime of infrequent fires that occurred only during extremely dry periods, to a new fire regime of frequent fires.

Salsola kali

Salsola kali, Russian thistle, is the most abundant invasive species in Chaco Canyon National Historic Park. *Salsola kali* originated in Eurasia and is now distributed throughout North America, often an early post-disturbance invading species. The non-mycorrhizal Russian thistle has been shown to enhance the regeneration of later succession seres which benefit from fungal symbionts. The declining Russian thistles provide suitable microhabitats for other species, although it is known to persist in some areas for a decade. Yet, at Mesa Verde National Park, Russian thistle invaded post-fire environments but did not persist beyond 5 years in high densities (unpublished data). The

large dried plants break at the stem-root junction and blow long distances where they can accumulate and cause problems by obstructing drains or waterways and developing into fuel patches. Seed maturation occurs in the fall, each plant can produce over 250,000 seeds, dispersal is effective by wind, and germination takes place the following spring under a wide temperature range. It is favored in well-drained soils in barren or disturbed sites that lack competitors. Barren and alkaline soils are common in Chaco Canyon, especially in the canyon bottom, hence *Salsola kali* is common. However, it is likely that as disturbances are minimized and native shrubs *Sarcobatus vermiculatus*, *Atriplex canescens*, and others invade these sites, *Salsola kali* will decline. If some areas require faster removal of *Salsola*, the FEIS website www.fs.usda.gov/database/feis/plants/forb/salkal/all.html+Salsola+kali suggests the following control mechanisms:

“Burrill and others reported that either 2,4-D or bromoxynil used in combination with dicamba was 80 to 94 percent effective in controlling Russian-thistle, and metribuzin used in combination with chlorsulfuron gave 95 to 100 percent control. Young and Whitesides reported only 12 percent control of Russian-thistle with 2,4-D.

Insects from the genera *Coleophora*, *Microlarinus*, and *Trichosirocalus* are being tested as biological control agents of Russian-thistle. Insect populations of these genera have established in California, but preliminary results suggest that of the three genera, only *Trichosirocalus* is able to establish in cold climates. *Trichosirocalus horridis* has been successfully introduced in Canada for Russian-thistle control. To date, there are no data regarding the effectiveness of these insects as control agents”.

We have identified particularly dense areas of *Bromus tectorum* and *Salsola kali* that might be suitable for release of biological control agents (for *Salsola*), or might be areas that need further monitoring (Figure 2).

Halogeton glomeratus

Halogeton glomeratus is an exotic annual forb in the family Chenopodiaceae. A native of Eurasia, halogeton has become widely established across the western United States. It is a ruderal, early successional species that occurs in a wide variety of soil types (e.g. heavy clays, clays, and sandy loams), but has the ability to invade highly saline and alkaline soils that are disturbed by grazing and other anthropogenic sources (Mack 1986). This provides a competitive advantage in many disturbed areas. It is a succulent, prostrate forb with a taproot that can penetrate 50 cm or more. Larger plants become erect towards maturity (Whitson 1987), a characteristic that facilitates wind dispersal as dry plants break off at the base becoming “tumbleweeds.” (Yensen 1980). *Halogeton* is known to be highly toxic to livestock and wildlife (i.e. Welsh et.al. 1987, Mueggler 1970).

The best control for this species appears to be the re-establishment of native perennials and the elimination of disturbance practices (Pemberton 1986, Blaisdell and Holmgren 1984). Much of this work has focused on rangelands and the introduction of other, less toxic non-native perennials such as *Kochia prostrata*, *Agropyron cristatum*, and *A. desertorum* (MacArthur et.al 1989). While these studies emphasized the re-establishment of forage on rangelands, we do not recommend their use in the park. However, seeding of native, salinity tolerant species may be an effective means of slowing the spread of Halogeton and restoring disturbed areas. Several insect species have been released for control of halogeton with limited success. The stem boring beetle *Coleophora porthenica*, has been released but failed to establish (Pemberton, 1986) while *C. triplecivora* has been found on halogeton with unknown effects. However, Moore and Stevens (1984)

have shown the case-bearing moth (*C. triplecivora*) to reduce foliage and seed production in *Atriplex canescens* a native shrub to CHCU. This would obviously limit its effectiveness in the park.

Chemical control of halogeton is of questionable effectiveness. The species is susceptible to application of 2,4-D however, native plants are also highly effected and application must be repeated for many years to control subsequent germination from the seed bank. This has proven to be too expensive for the marginal rangelands that halogeton inhabits and the saline-alkaline nature of the soils limits the species that can replace halogeton (Pemberton, 1986; Platt, 1959). In view of these limitations, chemical control of halogeton is not recommended and the most effective approach is likely the use of mechanical removal when feasible and the aggressive re-seeding with native perennials immediately post-disturbance.

Kochia scoparia

Kochia scoparia, Chenopodiaceae, is an invasive annual forb with origin in Eurasia and is now spread over much of the United States. It has been called “naturalized” in the Great Basin and western states (FEIS website). Although reportedly confined to above 6200 foot elevations in New Mexico), *Kochia* is found in the canyon bottom of CCNHP. This drought tolerant plant produces about 14,000 seeds per plant (average under good precipitation conditions) and is wind dispersed in a full plant “tumbleweed”. Viability of the numerous seeds does not last into the second year. The deeply rooted plants typically persist in disturbed habitats for two years. Research is on-going at University of Montana into the herbicide resistance of this species, which is particularly hard to kill with triazine and sulfonllyurea herbicies or phenoxy herbicides. No biological control is known. Mechanical removal of plants prior to seed production might limit their establishment in selected, local, areas in CCNHP; herbicide treatments would not be recommended.

Objective 2. Statistical Analysis of Chaco Invasive Species Project

During the 2004 field season, we investigated factors that can be used to predict weed populations in Chaco Canyon National Historic Park. Measured variables are in bold italics.

1. The influence of soil texture on patterns of plant invasions

When all invasive species are considered together (called “weeds”) there was a significant difference in the ***weed density*** across the different ***soil textures*** ($F=5.6$, $p=.001$, Appendix A). Silty soils had the highest weed density, followed by sandy soils. Weeds were absent from cobbly and bouldery soils. This trend is primarily due to the presence of *Salsola kali*; when *Halogeton* and *Kochia* are considered separately, their densities are not significantly different across soil textures.

The diversity of invasives species is also significantly different in the different soil textures ($F=10.4$, $p<.001$, Appendix A), with the highest diversity in silty soils.

2. The influence of soil type on plant invasions

There was a significant difference in ***weed density*** when comparing ***soils types*** ($F=3.4$, $p<.001$, Appendix A). The highest weed density if found in the Notal Silty Clay Loam, the Battlerock-notal complexes. High values were also supported by Razito-Shiprock Complex and Yelives-Beebe Fine Sandy soils. When *Kochia* and *Salsola* are considered separately, they also show this trend; *Halogenton* density is not different across soil types, although it was only found in appreciable density in Razito-Shiprock soils.

There was a significant difference in ***diversity*** of native shrubs ($F=10.6$, $p<.001$), native grasses ($F=4.4$, $p<.001$), native forbs ($F=4.7$, $p<.001$), the total number of native species ($F=7.5$, $p<.001$) as well as invasive species ($F=5.7$, $p<.001$) when compared across

soil types (Appendix B). The highest diversity of invasive species is found on the Yelives-Beebe fine sandy and Razito-Shiprock complexes.

3. The influence of biotic crusts on invasibility

One of the most promising predictors for invasives is in the **development of microbial crusts**. These are biological communities that consist of black, red and pink lichens, several bryophytes, and numerous cyanobacteria. The **weed density** is strongly influenced by the presence of microbial crusts ($F=3.9$, $p=.005$, Appendix C). There were fewer weeds on the moderately developed and well developed than the initiated crusts and physical crusts. If crusts are absent, the average density reached the highest levels in this study.

4. Influence of physical characteristics and disturbances on invasibility

Weed density correlates negatively but weakly with **distance from roads** in Chaco, $r=-.2$, $p=.014$. but not with **distance to trails** $r=-.09$, $p=.2$ (Appendix D).

Weed density decreases as **slope** increases, $r=-.23$, $p=.004$. There were fewer weeds in higher **elevations**, $r=-.28$, $p<.001$. The **diversity of weeds** also goes down with steeper slopes, $r=-.28$, $p<.001$, and higher elevations, $r=-.325$, $p=.001$. These correlations suggest that most of the weeds are on the flat, bottomland habitats, clustered particularly near the roads but not near hiking trails.

The **diversity of native species** goes up with steeper slopes, $r=.21$, $p=.01$, and higher elevations, $r=.301$, $p=.002$.

Objective 3—spatial prediction of weed invasions

The highest weed densities were found in the Notal Silty Clay Loam, the Battlerock-notal complexes. High values were also supported by Razito-Shiprock Complex and

Yelives-Beebe Fine Sandy soils. These soils have been isolated from the less susceptible soils in the GIS and their distribution is illustrated in Figure 2. Several areas of especially high weed concentrations (see Figure 2) were also mapped during field sampling.

Discussion

Our survey of invasive species at Chaco Canyon National Historic Park has identified four species of concern out of a potential list of 17 invasive species known from this geographic area. *Salsola kali* is the most pervasive invasive species, occurring throughout much of the bottomland adjacent to Chaco Wash, the area also most heavily impacted by visitation. *Halogeton glomeratus* is abundant in limited areas, especially Razito-Shiprock soils. *Kochia scoparia* is common, although rarely in high densities. *Bromus tectorum* occurs throughout the lower elevations of Chaco Canyon and is most common along roadsides. Although we were not able, with the limited funding available, to look exhaustively at factors that might promote invasions of these habitats, our pilot data suggest strongly that soil type and texture is important in determining which sites in the bottomland of CHCU will be susceptible to invasions of exotics. Two soils-- Notal Silty Clay Loam, the Battlerock-notal complexes—are the most susceptible. Also, the presence of moderate or well developed microbial crusts correlated with lower invasive densities. Finally, the constant disturbance that is inherent with roads (and visitation of archeological sites that those roads facilitate) in the canyon bottomland contributes to invasions.

We used these criteria, along with locations of high density weedy areas, to develop a working spatial model of the most invasible sites. This spatial representation is preliminary, and can be modified over time as invasive populations are treated by Resource Management, expand into new areas, or disappear due to competition from native species.

Active management of two species may help control expansion, but in two other species it is unlikely to be helpful. *Bromus tectorum* is particularly widespread in the Park and has been spreading in the region (perhaps due to high precipitation in the fall and a

warming trend in winter months during the last few years). While herbicides are used on cheatgrass, the widespread nature of patches in Chaco Canyon would preclude their usefulness. Although primarily restricted to roadsides and the canyon bottom, cheatgrass was also found on above the canyon bottom along the Pueblo Bonito loop trail. These occurrences may warrant additional investigation and possibly control efforts, although we cannot recommend any specific treatment at this time. *Kochia scoparia* does not respond well to herbicides and no biological controls are known. On the other hand, *Salsola kali* may be treated with biological control agents, and *Halogeton glomeratus* may respond to mechanical treatments. The current state of our knowledge about invasive species in Chaco Culture National Historic Park leads us to recommend that control measures be focused on areas of very high infestation of *Salsola kali* and *Halogeton glomeratus* where biological controls or mechanical controls might be effective. *Salsola kali* may be treated with biological controls, particularly in areas of high infestation (one area where *Salsola kali* was found in especially high densities is located in the east end of Chaco Canyon, Figure 2). Treatments for *Halogeton glomeratus* are possible because it appears to be restricted to highly disturbed areas and these are not widespread. Mechanical removal may be effective coupled with aggressive re-seeding with native grass species (this invasive has been shown to be out-competed by various non-native grasses in rangeland studies, yet work with native species is lacking). Biological controls for *Halogeton glomeratus* have not proven to be effective in the long-term and there is some indication that control species may have detrimental effects on desirable native species as well (e.g. *Atriplex canescens*). In particular, areas of high visitation and use (e.g. the ruins loop, visitor center, campground and residence area) might benefit from control efforts for this species.

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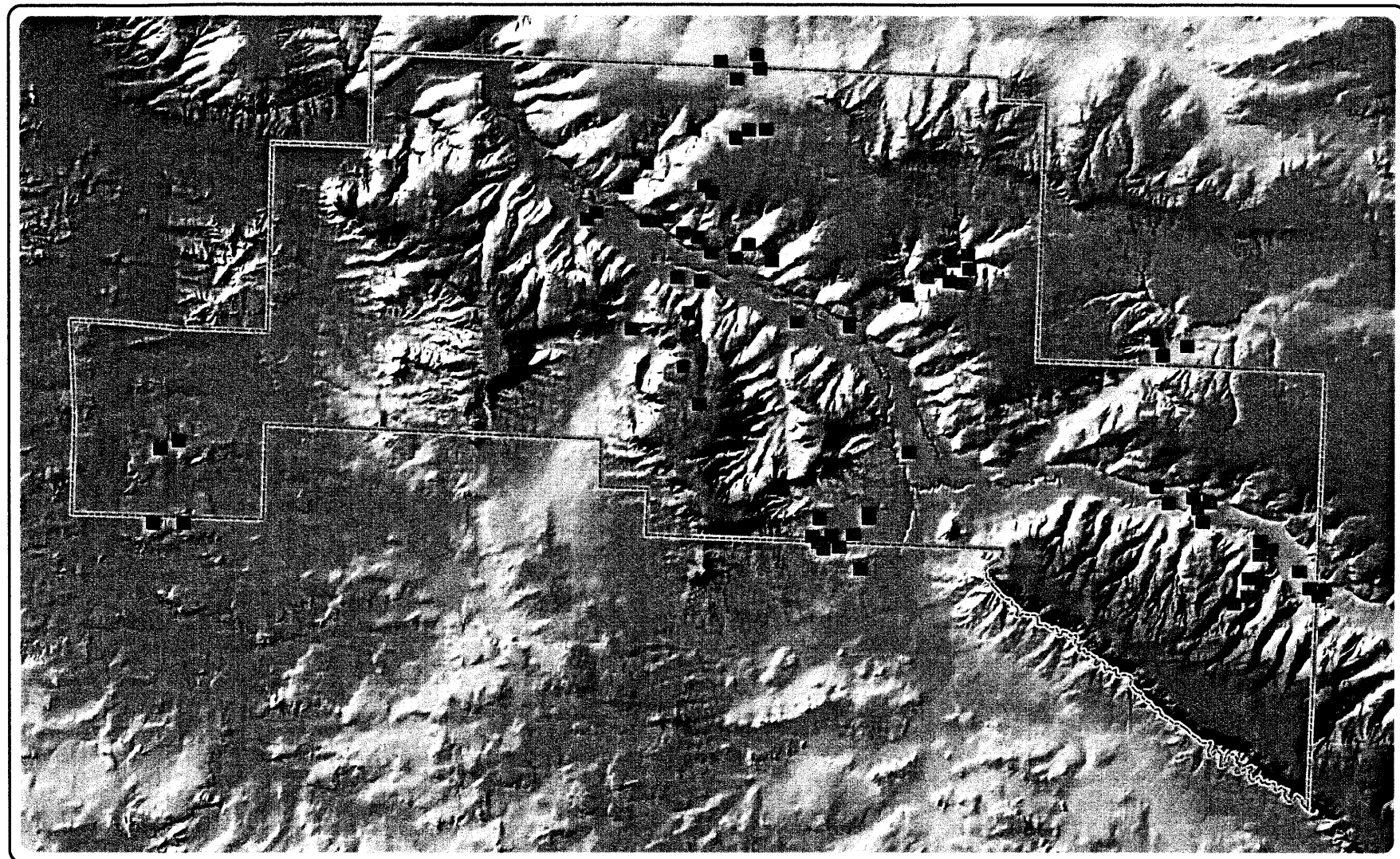
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Figure 1.

Soils Correlated with Exotic Species

Chaco Culture National Historic Park
McKinley County, New Mexico



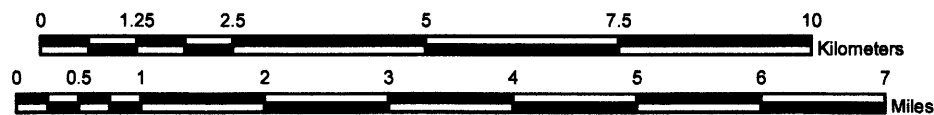
Legend

■ Releve locations

— Park Boundary

2100 meters

1800 meters



Universal Transverse Mercator Coordinates
Zone 12, NAD27

Field sampling was conducted
during May, June and August

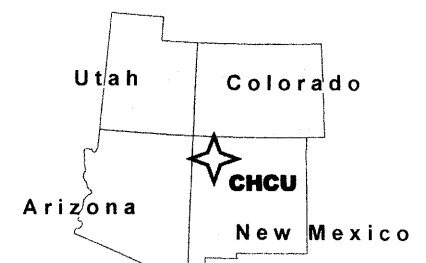
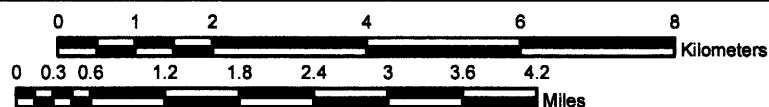
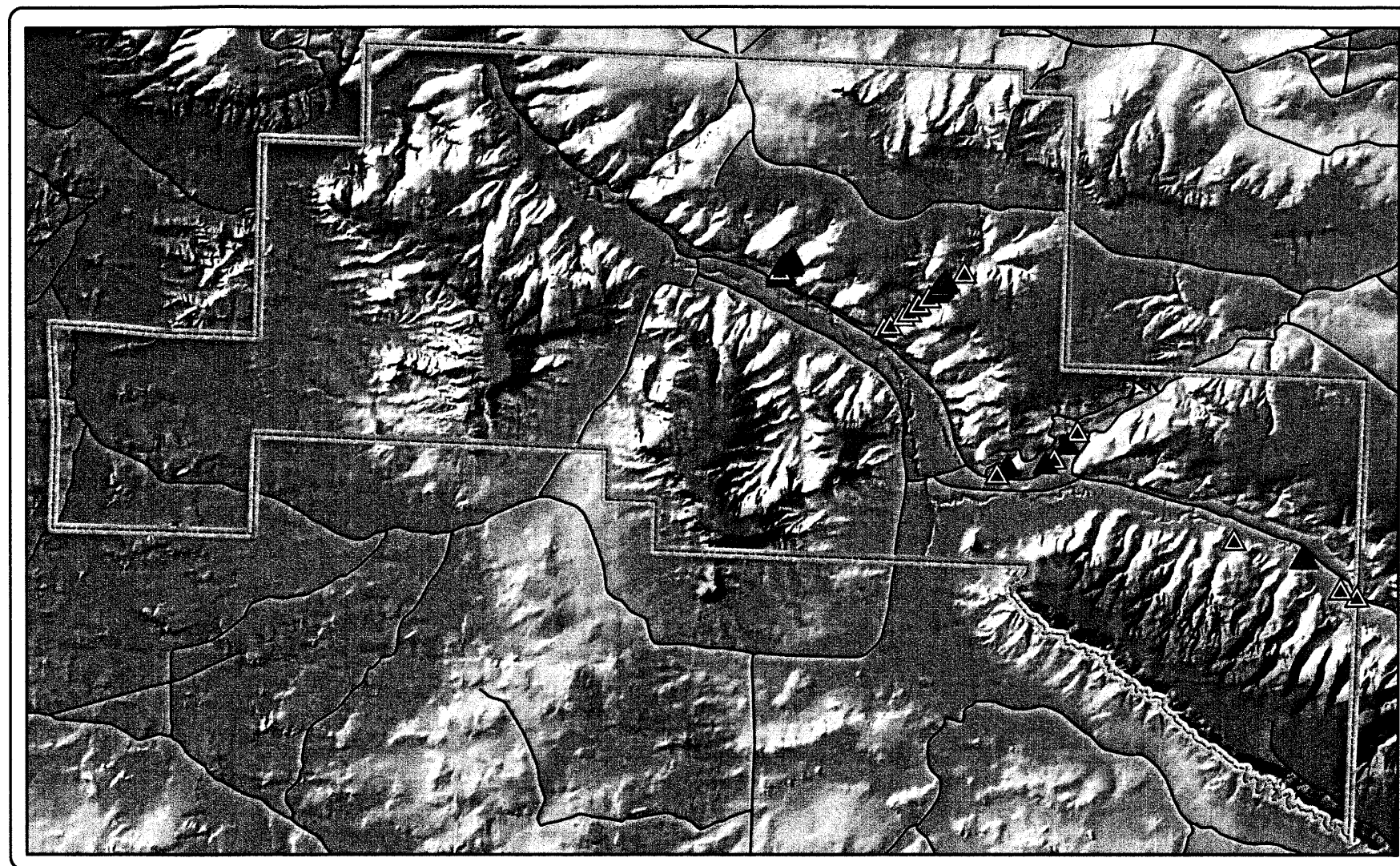


Figure 2.

Soils Correlated with Exotic Species

Chaco Culture National Historic Park
McKinley County, New Mexico



Legend

Invasive Soils

- BATTLE ROCK-NOTAL COMPLEX
- NOTAL SILTY CLAY LOAM
- RAZITO-SHIPROCK COMPLEX
- YELIVES FINE SANDY LOAM
- YELIVES-BEEBE FINE SANDY LOAMS

Exotic Concentrations

- Bromus tectorum*
- Salsola kali*

Park Boundary

Roads

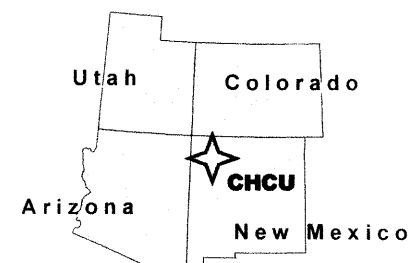
Elevation

2100m

1800m

campground

Universal Transverse Mercator Coordinates
Zone 12, NAD27



Field sampling was conducted
during May, June and August

October 17, 2004

Appendix A. Analysis of Chaco Canyon National Historic Park invasive species data.

Is there a significant differences in various weed densities when comparing soil textures?

		Sum of Squares	df	Mean Square	F	Sig.
HALOGETO	Between Groups	138.138	3	46.046	1.215	.307
	Within Groups	5610.539	148	37.909		
	Total	5748.678	151			
KOCHIA_S	Between Groups	55538.307	3	18512.769	1.134	.337
	Within Groups	2415974.957	148	16324.155		
	Total	2471513.263	151			
SALSOLA	Between Groups	238198.550	3	79399.517	3.913	.010
	Within Groups	3003231.845	148	20292.107		
	Total	3241430.395	151			
NO_ALIEN	Between Groups	25.160	3	8.387	10.427	.000
	Within Groups	119.044	148	.804		
	Total	144.204	151			
Density of all invasive species combined	Between Groups	61.910	3	20.637	5.591	.001
	Within Groups	542.542	147	3.691		
	Total	604.452	150			

		N	Mean	Std. Deviation	Std. Error
HALOGETO	silty	46	.02	.147	.022
	sandy	82	1.93	8.322	.919
	cobbly	21	.00	.000	.000
	bouldery	3	.00	.000	.000
	Total	152	1.05	6.170	.500
KOCHIA_S	silty	46	54.89	138.291	20.390
	sandy	82	21.50	138.572	15.303
	cobbly	21	.00	.000	.000
	bouldery	3	.00	.000	.000

SALSOLA	Total	152	28.21	127.936	10.377
	silty	46	114.24	205.085	30.238
	sandy	82	45.79	117.091	12.931
	cobbly	21	.00	.000	.000
	boudlery	3	.00	.000	.000
NO_ALIEN	Total	152	59.28	146.514	11.884
	silty	46	1.20	.806	.119
	sandy	82	1.05	1.053	.116
	cobbly	21	.00	.000	.000
	boudlery	3	.00	.000	.000
Density of all invasive species combined	Total	152	.93	.977	.079
	silty	46	1.8511	2.51094	.37022
	sandy	81	.7586	1.79870	.19986
	cobbly	21	.0000	.00000	.00000
	boudlery	3	.0000	.00000	.00000
	Total	151	.9709	2.00741	.16336

Is there a significant difference in various weed densities comparing soil types (NRCS classifica

		Sum of Squares	df	Mean Square	F	Sig.
KOCHIA_S	Between Groups	567862.729	11	51623.884	3.376	.000
	Within Groups	1773590.990	116	15289.577		
	Total	2341453.719	127			
Density of all invasive species combined	Between Groups	132.903	11	12.082	3.358	.000
	Within Groups	413.735	115	3.598		
	Total	546.639	126			
HALOGETO	Between Groups	1.438	11	.131	.625	.805
	Within Groups	24.281	116	.209		
	Total	25.719	127			
SALSOLA	Between Groups	620221.114	11	56383.738	2.717	.004
	Within Groups	2407684.379	116	20755.900		
	Total	3027905.492	127			

		N	Mean	Std. Deviation	Std. Error
KOCHIA_S	Battlerock-Notal	19	189.32	313.244	71.863
	Beebe-Silty Loam	1	.00	.	.
	Yelives-Beege Fine Sandy	24	1.88	4.675	.954
	Farb-rock outcrop complex	13	.00	.000	.000
	Chacoan Shiprock loamy	19	.00	.000	.000
	Chaco-Kimnoli Fine Loam Sands	2	.00	.000	.000
	Notal Silty Clay Loam	2	.00	.000	.000
	Doak Silt Loam	4	.00	.000	.000
	Rock Outcrop Persay	19	.84	3.671	.842
	Razito-Shiprock	15	12.53	21.804	5.630
	Hospah-Skyvillage	4	.00	.000	.000
	Rock Outcrop				
	Rock-outcrop				
	Westimion Sky-village	6	.00	.000	.000

Density of all invasive species combined	Total	128	30.05	135.782	12.002
	Battlerock-Notal	19	2.7068	3.44029	.78926
	Beebe-Silty Loam	1	.0000	.	.
	Yelives-Beege Fine Sandy	23	1.4930	1.84990	.38573
	Farb-rock outcrop complex	13	.0000	.00000	.00000
	Chacoan Shiprock loamy	19	.0221	.03952	.00907
	Chaco-Kimnoli Fine Loam Sands	2	.0000	.00000	.00000
	Notal Silty Clay Loam	2	3.4800	1.07480	.76000
	Doak Silt Loam	4	.2300	.18055	.09028
	Rock Outcrop Persay	19	.5363	1.29122	.29623
	Razito-Shiprock	15	1.7813	2.59279	.66946
	Hospah-Skyvillage Rock Outcrop	4	.0000	.00000	.00000
	Rock-outcrop Westimion Sky- village	6	.0000	.00000	.00000
	Total	127	1.0313	2.08288	.18483
HALOGETO	Battlerock-Notal	19	.00	.000	.000
	Beebe-Silty Loam	1	.00	.	.
	Yelives-Beege Fine Sandy	24	.00	.000	.000
	Farb-rock outcrop complex	13	.00	.000	.000
	Chacoan Shiprock loamy	19	.05	.229	.053
	Chaco-Kimnoli Fine Loam Sands	2	.00	.000	.000
	Notal Silty Clay Loam	2	.00	.000	.000
	Doak Silt Loam	4	.00	.000	.000
	Rock Outcrop Persay	19	.00	.000	.000
	Razito-Shiprock	15	.33	1.291	.333
	Hospah-Skyvillage Rock Outcrop	4	.00	.000	.000
	Rock-outcrop Westimion Sky- village	6	.00	.000	.000
	Total	128	.05	.450	.040
SALSOLA	Battlerock-Notal	19	80.42	176.141	40.409
	Beebe-Silty Loam	1	.00	.	.
	Yelives-Beege Fine Sandy	24	127.21	182.272	37.206
	Farb-rock outcrop complex	13	.00	.000	.000

Chacoan Shiprock loamy	19	1.26	3.784	.868
Chaco-Kimnoli Fine Loam Sands	2	.00	.000	.000
Notal Silty Clay Loam	2	348.00	107.480	76.000
Doak Silt Loam	4	15.75	23.472	11.736
Rock Outcrop Persay	19	24.37	104.053	23.871
Razito-Shiprock	15	159.73	250.250	64.614
Hospah-Skyvillage Rock Outcrop	4	.00	.000	.000
Rock-outcrop Westimion Sky- village	6	.00	.000	.000
Total	128	64.24	154.408	13.648

Appendix B. Analysis of variance testing for differences in the diversity of native shrubs, forbs, grasse diversity of invasives when comparing soil types (NRCS classification).

		Sum of Squares	df	Mean Square	F	Sig.
NATIVESH	Between Groups	200.098	11	18.191	10.579	.000
	Within Groups	199.457	116	1.719		
	Total	399.555	127			
NATIVEFO	Between Groups	397.846	11	36.168	4.712	.000
	Within Groups	890.373	116	7.676		
	Total	1288.219	127			
NATIVEGR	Between Groups	69.235	11	6.294	4.372	.000
	Within Groups	167.007	116	1.440		
	Total	236.242	127			
NO_NATIV	Between Groups	854.535	11	77.685	7.463	.000
	Within Groups	1207.457	116	10.409		
	Total	2061.992	127			
NO_ALIEN	Between Groups	44.468	11	4.043	5.719	.000
	Within Groups	82.001	116	.707		
	Total	126.469	127			

		N	Mean	Std. Deviation	Std. Error
NATIVESH	Battlerock-Notal	19	1.53	.841	.193
	Beebe-Silty Loam	1	5.00	.	.
	Yelives-Beege Fine Sandy	24	2.17	.963	.197
	Farb-rock outcrop complex	13	4.23	1.166	.323
	Chacoan Shiprock loamy	19	2.58	1.170	.268
	Chaco-Kimnoli Fine Loam Sands	2	4.50	.707	.500
	Notal Silty Clay Loam	2	1.00	.000	.000
	Doak Silt Loam	4	.75	.957	.479
	Rock Outcrop Persay	19	4.05	1.985	.455
	Razito-Shiprock	15	2.00	1.134	.293

NATIVEFO	Hospah-Skyvillage Rock Outcrop	4	4.75	2.500	1.250
	Rock-outcrop Westimion Sky- village	6	5.50	1.643	.671
	Total	128	2.84	1.774	.157
	Battlerock-Notal	19	6.05	1.779	.408
	Beebe-Silty Loam	1	1.00	.	.
	Yelives-Beege Fine Sandy	24	8.17	3.130	.639
	Farb-rock outcrop complex	13	8.77	2.651	.735
	Chacoan Shiprock loamy	19	5.16	1.167	.268
	Chaco-Kimnoli Fine Loam Sands	2	8.50	4.950	3.500
	Notal Silty Clay Loam	2	3.00	.000	.000
	Doak Silt Loam	4	7.00	1.826	.913
	Rock Outcrop Persay	19	8.21	3.614	.829
	Razito-Shiprock	15	9.40	3.562	.920
	Hospah-Skyvillage Rock Outcrop	4	4.00	3.559	1.780
	Rock-outcrop Westimion Sky- village	6	5.00	1.673	.683
	Total	128	7.17	3.185	.282
NATIVEGR	Battlerock-Notal	19	1.95	1.026	.235
	Beebe-Silty Loam	1	1.00	.	.
	Yelives-Beege Fine Sandy	24	1.92	1.100	.225
	Farb-rock outcrop complex	13	3.31	1.653	.458
	Chacoan Shiprock loamy	19	2.53	.841	.193
	Chaco-Kimnoli Fine Loam Sands	2	4.00	.000	.000
	Notal Silty Clay Loam	2	2.00	1.414	1.000
	Doak Silt Loam	4	2.25	1.500	.750
	Rock Outcrop Persay	19	3.47	1.645	.377
	Razito-Shiprock	15	1.47	.990	.256
	Hospah-Skyvillage Rock Outcrop	4	3.00	.816	.408
	Rock-outcrop Westimion Sky- village	6	1.50	.548	.224
	Total	128	2.38	1.364	.121
NO_NATIV	Battlerock-Notal	19	9.53	2.144	.492
	Beebe-Silty Loam	1	7.00	.	.
	Yelives-Beege Fine Sandy	24	12.29	3.196	.652

NO_ALIEN	Farb-rock outcrop complex	13	16.38	2.959	.821
	Chacoan Shiprock loamy	19	10.26	1.939	.445
	Chaco-Kimnoli Fine Loam Sands	2	17.00	4.243	3.000
	Notal Silty Clay Loam	2	6.00	1.414	1.000
	Doak Silt Loam	4	10.00	.816	.408
	Rock Outcrop Persay	19	15.74	5.064	1.162
	Razito-Shiprock	15	12.87	3.583	.925
	Hospah-Skyvillage Rock Outcrop	4	11.75	2.986	1.493
	Rock-outcrop Westimion Sky-village	6	13.83	2.317	.946
	Total	128	12.49	4.029	.356
	Battlerock-Notal	19	1.16	.688	.158
	Beebe-Silty Loam	1	.00	.	.
	Yelives-Beege Fine Sandy	24	1.58	1.176	.240
	Farb-rock outcrop complex	13	.00	.000	.000
	Chacoan Shiprock loamy	19	.42	.507	.116
	Chaco-Kimnoli Fine Loam Sands	2	.00	.000	.000
	Notal Silty Clay Loam	2	1.00	.000	.000
	Doak Silt Loam	4	1.25	.500	.250
	Rock Outcrop Persay	19	.84	1.119	.257
	Razito-Shiprock	15	1.53	.990	.256
	Hospah-Skyvillage Rock Outcrop	4	.00	.000	.000
	Rock-outcrop Westimion Sky-village	6	.00	.000	.000
	Total	128	.89	.998	.088

Appendix C. Analysis of variance testing for differences in the density of invasive species across sites & development of biotic crusts.

Density of all invasive species combined

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	57.498	4	14.375	3.860	.005
Within Groups	547.388	147	3.724		
Total	604.886	151			

Density of all invasive species combined

	N	Mean	Std. Deviation	Std. Error
absent	20	1.7570	2.38006	.53220
initiated	70	1.3551	2.44328	.29203
physical	14	.7471	1.09157	.29173
moderately developed	27	.2259	.68818	.13244
well-developed	21	.0167	.05102	.01113
Total	152	.9665	2.00147	.16234

Appendix D.

Correlations of densities of weeds with distances to roads (DIST 2R) and distance to trails (DIST2TR), slope, and elevation (GPS HEIGHT).

		Density of all invasive species combined	SALSOLA	BROMUS_T	HALOGETO	DIST_2_R	DIST2TRA
Density of all invasive species combined	Pearson Correlation	1	.759(**)	.130	-.030	-.198(*)	-.096
	Sig. (2-tailed)	.	.000	.111	.713	.014	.241
	N	152	152	152	152	152	152
SALSOLA	Pearson Correlation	.759(**)	1	.004	-.043	-.203(*)	-.102
	Sig. (2-tailed)	.000	.	.959	.601	.012	.209
	N	152	153	153	153	153	153
BROMUS_T	Pearson Correlation	.130	.004	1	-.018	.133	.048
	Sig. (2-tailed)	.111	.959	.	.829	.101	.555
	N	152	153	153	153	153	153
HALOGETO	Pearson Correlation	-.030	-.043	-.018	1	.088	.398(**)
	Sig. (2-tailed)	.713	.601	.829	.	.280	.000
	N	152	153	153	153	153	153
DIST_2_R	Pearson Correlation	-.198(*)	-.203(*)	.133	.088	1	.335(**)
	Sig. (2-tailed)	.014	.012	.101	.280	.	.000
	N	152	153	153	153	153	153
DIST2TRA	Pearson Correlation	-.096	-.102	.048	.398(**)	.335(**)	1
	Sig. (2-tailed)	.241	.209	.555	.000	.000	.
	N	152	153	153	153	153	153

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

		Density of all invasive species combined	BROMUS_T	HALOGETO	SALSOLA	SLOPE	GPS_HEIG	NO_ALIEN	NO_NATIV
Density of all invasive species combined	Pearson Correlation	1	.130	-.030	.759(**)	-.230(**)	-.280(**)	.436(**)	-.017
	Sig. (2-tailed)	.	.111	.713	.000	.004	.000	.000	.832
	N	152	152	152	152	152	152	152	152
BROMUS_T	Pearson Correlation	.130	1	-.018	.004	.190(*)	-.001	.096	.179(*)
	Sig. (2-tailed)	.111	.	.829	.959	.019	.990	.236	.027
	N	152	153	153	153	153	153	153	153
HALOGETO	Pearson Correlation	-.030	-.018	1	-.043	-.034	-.136	.139	-.208(**)
	Sig. (2-tailed)	.713	.829	.	.601	.673	.094	.087	.010
	N	152	153	153	153	153	153	153	153
SALSOLA	Pearson Correlation	.759(**)	.004	-.043	1	-.219(**)	-.242(**)	.484(**)	.072
	Sig. (2-tailed)	.000	.959	.601	.	.007	.003	.000	.373
	N	152	153	153	153	153	153	153	153
SLOPE	Pearson Correlation	-.230(**)	.190(*)	-.034	-.219(**)	1	.183(*)	-.246(**)	.206(*)
	Sig. (2-tailed)	.004	.019	.673	.007	.	.024	.002	.011
	N	152	153	153	153	153	153	153	153
GPS_HEIG	Pearson Correlation	-.280(**)	-.001	-.136	-.242(**)	.183(*)	1	-.384(**)	.283(**)
	Sig. (2-tailed)	.000	.990	.094	.003	.024	.	.000	.000
	N	152	153	153	153	153	153	153	153
NO_ALIEN	Pearson Correlation	.436(**)	.096	.139	.484(**)	-.246(**)	-.384(**)	1	.107
	Sig. (2-tailed)	.000	.236	.087	.000	.002	.000	.	.186
	N	152	153	153	153	153	153	153	153
NO_NATIV	Pearson Correlation	-.017	.179(*)	-.208(**)	.072	.206(*)	.283(**)	.107	1
	Sig. (2-tailed)	.832	.027	.010	.373	.011	.000	.186	.
	N	152	153	153	153	153	153	153	153

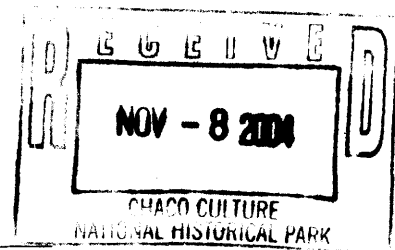
** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).



Prescott College

FOR THE LIBERAL ARTS AND THE ENVIRONMENT



Oct 28

Brad-

Dave is preparing metadata.
If you have comments or things you'd
like changed, please let us know.

What do you know about veg. ^{mapping} study
for next year??

Isa + Dave