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Investigating three decades of vegetation change in a Mojave Desert mountain range

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INVESTIGATING THREE DECADES OF VEGETATION CHANGE IN A
MOJAVE DESERT MOUNTAIN RANGE

BY

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2003

A thesis submitted in partial fulfillment
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ABSTRACT

Investigating Three Decades of Vegetation Change in a Mojave Desert Mountain Range

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This project is a vegetation change study spanning 29 years in the Newberry Mountains of Southern Nevada. Long term monitoring data are crucial for understanding the effects of climate change on vegetation dynamics. Successful management intervention in vegetation change will require identification of early indicator plant species and their responses to climatic cues. This project is one of the oldest comparisons of resurveyed Mojave vegetation community plots with repeatable methodology and the longest survey interval reported for the southeastern Mojave Desert. 103 plots were relocated and resurveyed based on data methods in Jim Holland's thesis titled "A Vegetative Analysis of the Newberry Mountains, Nevada." We compared measures of species abundance and measures of community composition between the survey years of 1979 and 2008 and further investigated if changes were related to numerous environmental gradients present in the mountain range. Community composition, as measured by relative cover, was the only abundance measure found significantly different between survey years ($A = -0.0031$, $p = 0.04$). Mountain soils derived from granitic residuum and colluvium showed significantly higher community composition change compared to the alluvial soil of bajadas. Certain plant species, such as *Coleogyne*

ramosissima, associated with specific soils and higher elevations report significant decreases across multiple abundance measures. Other species such as *Ferocactus cylindraceus* were found to have increased significantly across abundance measures. We address inferred scenarios for changes to species across environmental gradients as well as the suitability of each species and various abundance measures as early indicators of vegetation community change. Overall we found negligible change for most plant species and vegetation communities as represented by multiple abundance measures between survey years. In addition, the analysis provided useful information on the natural history and current status of species within this unique mountain range. Future resurvey efforts with permanently established plots and shorter intervals have exciting potential for more predictive information relating to vegetation change.

TABLE OF CONTENTS

ABSTRACT.....	iii
LIST OF TABLES.....	vii
LIST OF FIGURES.....	ix
CHAPTER 1 INTRODUCTION.....	1
CHAPTER 2 LITERATURE REVIEW.....	4
<u>Introduction</u>	4
<u>Regime Shift</u>	4
<u>Vegetation Change across Elevation Gradients</u>	5
<u>Vegetation Change at Ecotones</u>	8
<u>Vegetation Change across Soils</u>	10
<u>Historic Mojave Vegetation Change</u>	12
<u>Current Mojave Vegetation Change</u>	16
<u>Mojave Desert Climate Change</u>	19
<u>Other Stochastic Vegetation Change</u>	21
CHAPTER 3 PROJECT PURPOSE AND SPECIFIC AIMS.....	25
CHAPTER 4 RESEARCH QUESTIONS.....	28
CHAPTER 5 METHODS.....	30
<u>Created Variables</u>	32
<u>Statistical Analysis</u>	34
<u>Non Metric Multidimensional Scaling (NMS) ordination</u>	36
CHAPTER 7 RESULTS.....	38
<u>Qualitative Description of Re-photography</u>	38
<u>Site Characteristics</u>	42
<u>Changes in Community Diversity</u>	43
<u>Plot Occupancy by Density</u>	46
<u>Plot Occupancy by Frequency</u>	49
<u>Individual Species Changes across Plots</u>	51
<u>Individual Species Change within Plots</u>	57
<u>Correlation Matrix Results</u>	64
<u>Non-Metric Multidimensional Scaling</u>	64
<u>Multiple Response Permutation Procedure Results</u>	69
<u>Computed Dissimilarity Measures</u>	70
<u>Stepwise Multiple Linear Regression Results</u>	83
CHAPTER 8 DISCUSSION.....	85

<u>Differences in Species Abundance</u>	85
<u>Differences in Community Composition</u>	90
<u>Study Context and Limitations</u>	92
<u>Implications for Further Research</u>	94
APPENDICES.....	96
<u>Appendix 1 Comparison of Mean Density and Mean Relative Density</u>	97
<u>Appendix 2 Comparison of Mean Frequency and Mean Relative Frequency by Species, 1979 and 2008</u>	99
<u>Appendix 3 Comparison of Mean Cover and Mean Relative Cover by Species, 1979 and 2008</u>	101
<u>Appendix 4 Correlation Matrix for Environmental Variables And Selected Species</u>	103
BIBLIOGRAPHY.....	125
VITA.....	132

LIST OF TABLES

Table 1	Site Characteristics and Measures of Diversity, 1979 and 2008.....	43
Table 2	Most Abundant Species by Total Density and Mean Cover per Quadrat, 1979 and 2008.....	46
Table 3	Plot Occupancy by Density, 1979 and 2008.....	48
Table 4	Plot Occupancy by Frequency, 1979 and 2008.....	51
Table 5	Mean Density and Mean Relative Density by Species, 1979 and 2008.....	54
Table 6	Mean Frequency and Mean Relative Frequency by Species, 1979 and 2008.....	55
Table 7	Mean Cover and Mean Relative Cover by Species, 1979 and 2008.....	57
Table 8	Paired Plot Changes in Density and Relative Density, 1979 and 2008.....	60
Table 9	Paired Plot Changes in Frequency and Relative Frequency, 1979 and 2008.....	62
Table 10	Paired Plot Changes in Cover and Relative Cover, 1979 and 2008.....	63
Table 11	Multiple Response Permutation Procedure Results.....	70
Table 12	ANOVA Results for Dissimilarity measures Calculated with Density Values by Elevation and Vegetation Association, 1979 and 2008.....	73
Table 13	ANOVA Results for Dissimilarity measures Calculated with Relative Cover Transformed Values by Soil Type, 1979 and 2008.....	74
Table 8	ANOVA Results for Dissimilarity measures Calculated with Relative Cover Values by Elevation and Vegetation Association, 1979 and 2008.....	75
Table 9	ANOVA Results for Dissimilarity measures Calculated with Relative Cover Values by Soil Type, 1979 and 2008.....	76
Table 10	ANOVA Results for Dissimilarity measures Calculated with Density Transformed Values by Elevation and Vegetation Association, 1979 and 2008.....	77
Table 17	ANOVA Results for Dissimilarity measures Calculated with Density Transformed Values by Soil Type, 1979 and 2008.....	78
Table 11	ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Elevation and Vegetation Association, 1979 and 2008.....	79
Table 12	ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Soil Type, 1979 and 2008.....	80
Table 20	ANOVA Results for Dissimilarity measures Calculated with Density Values by Elevation and Vegetation Association, 1979 and 2008.....	81

Table 13	ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Soil Type, 1979 and 2008.....	82
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LIST OF FIGURES

Figure 1	Re-photography shows 1979 view (top) and 2008 view (bottom) toward Spirit Mountain.....	39
Figure 2	Re-photography shows 1979 view (top) and 2008 view (bottom) of chaparral/woodland.....	40
Figure 2	Re-photography shows 1979 view (top) and 2008 view (bottom) of chaparral/woodland.....	41
Figure 4	2-dimensional diagram (axis 1 and 2) of successional vectors translated to origin (1979) displaying magnitude and direction of community composition change, as measured by relative cover, of plots between 1979 and 2008 with color coded groups denoting vegetation types.....	66
Figure 5	2-dimensional diagram (axis 1 and 3) of successional vectors translated to origin (1979) displaying magnitude and direction of community composition change, as measured by relative cover, of plots between 1979 and 2008 with color coded groups denoting vegetation types.....	67
Figure 6	2-dimensional diagram (axis 2 and 3) of successional vectors translated to origin (1979) displaying magnitude and direction of community composition change, as measured by relative cover, of plots between 1979 and 2008 with color coded groups denoting vegetation types.....	68

CHAPTER 1

INTRODUCTION

This project is a 29-year vegetation change study of the Newberry Mountains, southern Nevada. Jim Holland established vegetation plots across multiple environmental gradients within the mountain range in 1979 (Holland, 1982). In 2008, 29 years later, these transects were relocated and resurveyed. This project is one of the oldest comparisons of resurveyed Mojave vegetation community plots with repeatable methodology and it is the longest survey interval reported for the Southeastern Mojave Desert. Vegetation community types surveyed include low elevation xeric scrub (creosote/ambrosia), mid elevation mixed shrub communities and relatively high elevation chaparral with open woodland (chaparral/woodland). Vegetation on the isolated mountain range includes granite substrate obligate species, uncommon interior chaparral species and a large proportion of Sonoran Desert associated species relative to the interior Mojave Desert region (Holland, 1982). Changes in high elevation chaparral/woodland composition and dynamics between the Colorado subdivision of the Sonoran Desert and the Mojave Desert are of specific research interest. Survey work yields base-line information from modeled distributions of plant species and vegetation communities in the Newberry Mountains. Differences between current (2008) status of species and past (1979) status may indicate that vegetation has changed and the degree of change. The establishing of permanent plots for long term monitoring will produce prognostic information from the analysis of trending distributions in species and community compositions over time.

Long-term monitoring data are crucial for understanding the effects of climate change on vegetation dynamics. However, landscape scale vegetation change in the context of recent climate change in the Mojave Desert remains particularly understudied. The consequences of vegetation community change to precarious ecosystem services in this most arid region of North America are potentially catastrophic (Webb et al., 2009). Future landscape conditions in the Mojave region have implications to resource management, public health and recreation in a region with significant population growth. This study will add to the increasing knowledge of the effects of climate change on vegetation throughout the Mojave Desert region.

Vegetation change is expected to occur in the Mojave Desert region due to documented change in a range of biotic communities corresponding with a climate change, and an increased incidence of stochastic events associated with anthropic pressure. We do not know if vegetation in the Mojave Desert is changing in a comprehensible and directional trajectory as would be inferred from historical vegetation change known largely from *Neotoma* spp. (packrat) midden analysis. Climate exerts the dominant pressure on biome development and responses of vegetation to a warming and/or drying climate include directional shifts upwards in elevation and toward northern latitudes (Kupfer & Cairns, 1996; Thomas et al., 2004; Bertin, 2008). These linear responses to climate change are modified by complex biophysical interactions at regional scales (Burkett et al. 2005). Furthermore, responses of vegetation to current climate change are also modified by novel anthropogenic pressures such as invasive species, livestock grazing, increased fire frequency and increased atmospheric nitrogen deposition (Webb, 2009). Vegetation change occurs as a suite of species' individualistic responses

(Gassman et al. 2005). Nonlinear vegetation change and differential responses across environmental gradients also need to be identified for successful management intervention of vegetation change (Burkett et al., 2005; Gassman et al. 2005). For example, long-term monitoring research in the Mojave Desert has documented sustained die off events for dominant plant species during periods of extreme drought. The effects of these events on vegetation community composition are sustained and are accepted as an important mechanism for vegetation change in the Mojave Desert.

CHAPTER 2 LITERATURE REVIEW

Introduction

Many studies utilize extant data sets as baseline conditions for long term monitoring and vegetation change analysis. Length between plot survey intervals is variable and some studies have spanned 170 years (Turner, 1990; Bennie et al., 2006; Damschen et al., Primack et al., 2009; 2010; Munson et al., 2011). These long term studies are largely reporting measurable change in plant species phenology and distribution along environmental gradients including rare soil edaphic environments (Walther, 2002; Bennie et al., 2006; Bertin, 2008; Crimmins 2008; Primack et al., 2009; Damschen et al., 2010). The research cited here reports warming climate as the major driver of these changes. Responses of vegetation to a warming climate include directional shifts upwards in elevation and toward northern latitudes (Kupfer & Cairns, 1996; Bertin, 2008).

Regime Shift

The magnitude of species change may signal ecological regime shift; a regional whole-scale reorganization of vegetation community dynamics (Carpenter & Brock, 2006, Contamin & Ellison, 2009). Regime shift occurs when biotic and abiotic processes, which maintain a recognized plant community, become altered. These alterations create feedbacks that change the successional trajectory of the whole ecological system. This concept, also known as “state and transition modeling”, is currently being developed nation-wide to describe both drivers and changes in soil specific vegetation community regime shift (Bestelmeyer et al., 2011). Current vegetation community regime shift will

likely lead to novel systems due to anthropogenic effects such as non-native plant invasion, altered fire frequencies and soil disturbance due to recreation and economic development (Berry, 2006; Archer & Predick, 2008). Regime shift is of concern because of the public health implications of poor air quality, loss of economically important ecosystem services, as well as the economic impacts of management actions. If processes of ecological regime shift are understood for a community, early transition is the ideal time for management intervention in ecosystem dynamics. Successful intervention is suggested to require 20 years advance action to significantly halt regime shift (Contamin & Ellison, 2009). Hence, successful intervention requires knowledge of early indicators of transition. Early indicator plant species and their responses to climatic cues need to be identified for interpretation of vegetation change.

Transitions to new regimes are spatially explicit (Gosz, 1992; Peters, 2002; Bestelmeyer et al., 2011). Vegetation changes on a contiguous landscape can occur at different rates due to differing environmental gradients, land forms and soil types. In heterogeneous landscapes such as mountain ranges with varied topography this potentially slows whole ecosystem transition because similar community patches in various locations transition at different rates (van Ness & Scheffer, 2004). However, shifts in patches can portend shifts in the entire community due to domino or contagion effect (Bestelmeyer et al. 2011). Analysis of long term monitoring data from sites located across multiple environmental gradients in the landscape can reveal these patch dynamics and early indications of regime shift.

Vegetation Change across Elevation Gradients

Adiabatic processes are pronounced in vegetation community composition in Mojave Desert Mountains (Amundsen et al., 1989; Webb et al., 2009). Adiabatic process is the correlation of increasing elevation with atmospheric temperature and explains why mountains and high elevations receive more precipitation during summer convection storms as well as night time temperature inversions which are known to occur in Mojave Desert mountain ranges (Rundel & Gibson, 1996). Along with solar insolation, adiabatic lapse rate is an important variable describing evapotranspiration rates, soil temperature and moisture regimes as well as the associated biotic responses of community composition, vegetation abundance, evapotranspiration rates, and soil microbial activity. This elevation gradient creates a stark gradation between relatively high elevation, chaparral/woodland communities and low elevation creosote/bursage communities. Generally, minimum elevation limits of species distribution reflect soil moisture requirements and maximum elevation limits reflect minimum temperature tolerance (Amundsen et al., 1989).

Increasing temperatures have effects on both upper elevation limits to creosote/bursage communities and lower elevation limits of chaparral/woodlands; the current ecotone between these woodlands and desert scrub is perhaps the most important areas to monitor vegetation change in Mojave Desert Mountains. In a western Mojave Desert study, Kelly & Goulden, 2008 found lower and upper elevation limits of communities along an elevation gradient transect moved upslope an average of 64.7 m. within 29 years. Species members of chaparral/woodland and desert scrub communities moved in unison with their community associates. However the three species with highest elevation gain (>100m) were associated with creosote/bursage communities at the

lowest elevations (Kelly & Goulden, 2008). This study occurred from 1977 to 2006 which is nearly concurrent to the Newberry Mountains survey interval and shares many of the same vegetation communities and plant species. Application of these findings in the western Mojave Desert however is limited due to the increase in average annual precipitation and precipitation variability in this region coinciding with warming climate as opposed to decreasing precipitation noted in the eastern Mojave Desert. In fact higher precipitation coupled with warmer temperatures can create unfavorable conditions for many xeric adapted species and these conditions can cause downward shifts in species toward smaller precipitation and temperature ratios (Rundel & Gibson, 1996).

Diminishing habitat upslope leads to concerns of species extirpation and extinction. This is especially true for isolated mountain ranges such as the Newberry Mountains. Many studies report local extirpation of species with limited distributions or inability to cope with new pressures (Thomas et al., 2004). Thomas et al., 2004 found that species distribution models using minimum projected increases in global temperatures predicted at least 18% of global species to be “committed to extinction” by 2050. Nearby the Newberry Mountains, Epps et al., 2005 documents recent extirpation of bighorn sheep in mountains ranges below critical habitat elevations and predicts future extirpations in a continually decreasing mountain top habitat.

Further, the dynamics of species populations in high elevations are also influenced by mountain size and the ameliorating effects of connectivity with other mountain ranges. These effects include seed immigration potential and effects of mountain size on local climate known as the Massenerhebung effect (Peters, 2002; Van Ness & Scheffer, 2004, Richardson & Friedland, 2009). The Massenerhebung effect

describes the occurrence of high elevation species at lower elevations due to climatic effects of isolated mountain ranges. Epps et al., 2004 found that the size of a contiguous high elevation habitat within a mountain range is the major variable describing extinction of subpopulations of desert bighorn sheep across Mojave Desert mountain ranges of Southern California. Models from this data predict a range of 85-254 m loss of elevation associated bighorn habitat using minimal and extreme climate change scenarios respectively (Epps et al., 2004). Isolated, mid elevation, desert mountain ranges or ‘sky islands’ such as the Newberry Mountains are therefore at higher risk of regime shift.

Vegetation Change at Ecotones

Research is mounting on the differential effects of current climate change on vegetation within regional and bioregional landscapes. Ecotones between these regions are especially important areas to monitor because changes along these biotic borders may predict the nature of whole scale regime shift to the directionally neighboring biome (Gosz, 1992; Neilson, 1993; Peters, 2002). In a southern Mojave Desert ecotone, researchers have predicted the loss of the iconic Joshua tree in Joshua Tree National Park within the next century due to a loss in climatic conditions favorable for regeneration (Cole 2011). These ecotones are considered global hotspots of biodiversity with species living near outer limits of core populations containing high genetic diversity (Araujo, 2002). These edge species are expected to have increasing or decreasing vulnerability and become directionally responsive to climate change (Peters 2002). Still, the locations of ecotones, regardless of the extant plant community are considered stable due to physiological factors which can slow vegetative transition across these barriers (Neilson, 1993; Kupfer & Cairns, 1996).

The Newberry Mountains occurs along a roughly latitudinal summer maximum precipitation and winter minimum temperature transition belt corresponding to a biotic transition between the Sonoran and Mojave Deserts. The Newberry Mountains vegetation communities are exemplary of ecotone assemblages having a variety of species associated with Sonoran, Mojave, Great Basin Deserts and Interior chaparral. Holland, 1982 reports 30% of species inventoried in the Newberry Mountains were Sonoran associated. This is a high percentage of Sonoran plants in the Newberry Mountains relative to adjacent mountain ranges which are not in contact with the lower Colorado River trough (Holland, 1982). The Newberry Mountains are adjacent to the lower Colorado River trough, a low elevation northern heat incursion which is long known as a corridor for radiation of desert species such as those Sonoran species found deep into the Grand Canyon (Van Devender & Spaulding, 1979; Brown, 1994). The lower Colorado River trough is described in biotic terms as the Colorado Desert subdivision of the Sonoran Desert (Van Devender & Spaulding, 1979). This is the hottest and most arid desert in North America. Endemic and thus indicator species of the Colorado Desert are *Nolina bigelovii*, *Peucephyllum schottii*, and *Hesperocallis undulata* (Brown, 1994). These species represent habitats of high and low elevation and all three species are common in the Newberry Mountains. The Colorado Desert is distinguished from Eastern Sonoran subdivisions by lacking Sonoran sub-tropical thorn scrub due to less summer precipitation. Rather this region is dominated by species depauperate creosote bursage communities very similar to those in the Mojave Desert. The current ecotone between the Colorado and Mojave Deserts is loosely defined as the Northern distribution of large woody Sonoran species (Bradley, 1966). Many of these species including *Psoralea*

spinosus, *Foquieria splendens* and *Parkinsonia microphylla* terminate their geographical ranges near or within the Newberry Mountains (Bradley, 1966).

Vegetation Change across Soils

Soils present further physiographic constraints to vegetation community composition. Vegetation change has been documented differentially across soil types. For example, edaphic soils are reported to be more resistant to changes in community composition due to climatic change and yet more vulnerable to species extirpation due to an inability to shift across soil gradients (Damschen et al., 2010; Briles et al., 2011). In the Mojave Desert, Hamerlinck and McAuliffe (2008) found plant responses to an extreme drought event were more pronounced on less developed soils which actually promote rapid growth during favorable precipitation events.

Soils in the mountainous portion of the Newberry Mountain study area are regionally unique with coarse grained gravels derived from the highly felsic Spirit Mountain granites (Walker Jr., et al., 2007). These soils occur across the entire elevation gradient of the Newberry Mountains from the western escarpment of the Spirit Mountain batholith to the Colorado River and are further characterized by the soil temperature regimes; hyperthermic, thermic and mesic (NRCS, 2006). Soils are considered young with shallow granite gravels derived from mechanically weathered residuum and colluvium often in direct contact with bedrock. Shallow soils in contact with bedrock lack the long term water storage capacity of older soils with petrocalcic horizons. Mechanical weathering of felsic granites creates more down-slope erosion relative to other parent materials and plants must be able to endure this (Parker 1991). Granite also modifies common Mojave communities. For example, blackbrush, *Coleogyne ramosissima*,

communities which occur in pure stands at high elevations throughout the Mojave are less contiguous on these young surfaces.

Limestone soils have been demonstrated to harbor more arid Chihuahuan vegetation on soil islands within Sonoran communities associated with granite soils (Wentworth, 1981). Conversely, soil islands composed of granite, such as the Newberry Mountains, harbor Sonoran associated species within finer soils and older surfaces more typical of the Mojave Desert. These granitic soils can intake precipitation from summer convection storms that is largely lost to soils with petrocalcic development. Conversely, shallow precipitation is quickly evaporated from porous gravelly granitic soils.

High elevation interior chaparral and woodlands have mesic soil temperature regimes and are of special management concern due to unique assemblages and potential as early indicators of climate change. The rare chaparral/woodland communities of the Newberry Mountains which are distributed along the elevation transition between the Sonoran and Mojave Deserts are obligate to granitic soils (Brown, 1994). The unique qualities of Spirit Mountain granites are evidenced by a visible distinction between wooded chaparral/woodland vegetation on more felsic granites and more typical Mojavean mixed shrub on the darker, mafic granites where these soils contact on the North side of Spirit Mountain (Walker Jr. et al., 2007). Mafic granites and gneiss are chemically weathered and associated soils are fine textured. Interior chaparral and woodland communities of the Newberry Mountains do not occur in adjacent mountain chains with soils derived from more mafic granites and gneiss (Holland, 1982). These soil specific restraints represent a vulnerability of mesic soil associated communities in

the Newberry Mountains to climate change without the ability to shift distribution along elevation and latitudinal gradients.

At lower elevations, more mafic granites occur as exposed dikes where visibly different communities associated with hyperthermic conditions occur among thermic associated Mojave Desert scrub communities. Low elevation, hyperthermic arid soils communities are of special management concern due to unique assemblages and potential as early indicators of climate change. Hyperthermic arid soils occur where soil temperatures at 50 cm below surface or at paralithic contact are above 22° C; vary seasonally by more than 5° C and receive less than 250 mm in average annual precipitation. In the Newberry Mountains, these soils are noted by vegetation communities dominated by the perennial shrub, *Encelia farinosa*. Although these communities are species poor, many of the uncommon Sonoran associated species occurring at the northern limits of their ranges in the Newberry Mountains are restricted to these soil conditions e.g. *Tetradococcus halli* and *Ditaxis neomexicana*. These communities are expected to increase in area due to increasing climatic conditions which form hyperthermic arid soils; a process known as desertification. For example, Turner (1990) documents the 55-100% mortality of *Larrea tridentata* and a subsequent substantial increase in *Encelia farinosa* populations in a remote area of the Colorado Desert due to extreme drought events. This is a potential scenario for desert scrub occupying thermic soils in the Newberry Mountains.

Historic Mojave Vegetation Change

A review of the natural history of vegetation communities represented in the Newberry Mountains is also helpful in hypothesizing the biotic response to climate

change. Past Mojave vegetation change is known largely from packrat midden analysis. From this research it is understood that plant species within the Colorado River drainage have retreated north in a latitudinal gradient 400-700 km and upwards 700-900 m in elevation since the Holocene beginning, around 10,000 years before present (ybp) (Cole, 1990). Successively more arid adapted vegetation has radiated from the Gulf of California throughout the Holocene (Cole, 1990; Koehler et al., 2005). Because of this radiation, the Mojave Desert has been considered by some as a transitional band between the Sonoran and Great Basin Deserts rather than a distinct biome (Brown, 1994). The most recent of these vegetation radiations is the wide ranging creosote/bursage communities occupying the lowest elevations of the Newberry Mountains at ~8,000 ybp. Alternately, the oldest plant community represented in the Newberry Mountains is a remnant Utah juniper, *Juniperus osteosperma*, grove at the highest point in the range and on a slope with northern exposure.

Interior chaparral communities are also considered remnant throughout the ecotonal distribution of granitic mountains terminating in the Baja peninsula (Rhode, 2002). These communities are estimated to have covered ~55% of the central and southern Mojave Desert at the beginning of the Holocene and now occupy ~15% of this same area (Smith, 2000). Leskinen, (1975) studied the contraction of this community within the Newberry Mountains by comparing the current limited distribution of the uncommon oak, *Quercus chrysolepsis*, with a ~ 9,500 year old distribution known from midden analysis at lower elevations. Leskinen, 1975 reports a 900 meter upslope retreat over this time period. Interestingly, several large individuals of the species were found

incidental to this project's surveys within suitable habitat at approximately 450 meters below the elevation reported by Leskinen, 1975.

Van Devender (2000) provides the following description of the unique type chaparral/woodland that occurs in the Newberry Mountains:

“During the last half of this glacial period (from 45,000 to 11,000 years ago)... Woodlands with single-leaf pinion (*Pinus monophylla*), junipers (*Juniperus* spp.), shrub live oak (*Quercus turbinella*), and Joshua tree (*Yucca brevifolia*) were widespread in the present Arizona Upland subdivision of the Sonoran Desert. ...The isolated chaparral communities in central Arizona, mostly in a northwest-southeast band below the Mogollon Rim, are relicts of ice-age chaparral connections with California. Many species are shared between California and Arizona chaparral, including shrub live oak.” (p. 57)

The current distribution of *Quercus turbinella* exemplifies this East/West chaparral connection. Only one small population of *Quercus turbinella* occurs west of the Newberry Mountains. This is considered rare and endangered community type in California (CNPS, 2012). Another important species defining chaparral/woodland in the Newberry Mountains is *Juniperus californica* which occupies lower elevations along the southern Mojave ecotone relative to other juniper species. The northern distribution of this species along the southern Mojave ecotone has been maintained throughout the Holocene and present day suggesting a physiological restraint to this species. This is unlike the distribution of *Pinus monophylla*, which co-occurs on steeper habitats with

Juniperus californica in the Newberry Mountains, and has expanded distribution north throughout the Holocene.

Vegetation typical of today's Mojave Desert reached northern distribution limits during the warming event, thermal maximum, of the mid Holocene. The thermal maximum was followed by cooler temperatures in the neopluvial period of the late Holocene whereby chaparral/woodlands distribution expanded down-slope an estimated 100-200 meters in elevation (Smith et al., 2000). Subsequent to this cooling event, the climate again warmed and vegetation distributions have since been restrained from further expansion by temperature decreases during the little ice age, around 750-150 ybp (Arundel, 2005). Research by Cole & Webb (1985) in Southern California and Hunter & McAuliffe (1994) in Southern Nevada both report a downward shift of 50-100 m for mid elevation associated *Coleogyne ramosissima* communities within a 360 year time frame during the Little Ice Age. Cole et al. (2008) demonstrates the speed at which vegetation changes occurred in the Holocene, reporting rapid and dramatic increase in winter minimum temperatures of 4° C within 300 years in the Grand Canyon based upon current modeled *Agave utahensis* distribution and its occurrences in lower elevation packrat midden chronosequences.

Post-glacial distributional limits of species are still being formed. Some researchers speculate that species such as the dominant *Larrea tridentata* are currently in a process of advancing northward and upwards in elevation and are slowed only by dispersal limitations (Arundel, 2005). Dominance of creosote/bursage communities in both the Sonoran and Mojave Deserts demonstrates the suitability of arid habitats for this assemblage under a variety of climatic patterns. The upper elevation limit of creosote is

constrained by minimum temperatures as well as maximum precipitation tolerances (Arundel, 2002). It is likely these communities will persist and expand under future climatic scenarios such as the 140 meter elevation gains in creosote distributions reported by Kelly (2008). Few studies document ecologically significant *Larrea tridentata* die-off. Similar to interpretations of the middle Holocene, the distribution of low elevation plant communities are predicted to be less affected by climate change than high elevation communities (Cole & Webb, 1985). For example, desert cedar, *Peucephyllum schottii*, associated with hyperthermic soils in the Colorado Desert was found at relatively high elevations in the McCullough Mountains, next to the Newberry Mountains, during the thermal maximum of the middle Holocene when climate was warmer and more arid than today (Spaulding, 1991). Sonoran species for which minimum summer precipitation was not limiting and winter minimum temperatures are limiting could migrate north due to rising temperatures. In fact, vegetation in these low elevation creosote/bursage communities may resemble future communities further north and in higher elevations under increasing temperatures and aridity. Displacement of unique interior chaparral communities with depauperate low elevation communities should be a great concern for regional biodiversity.

Current Mojave Vegetation Change

Mojave Desert plant communities in all forms are comprised of many long lived shrub species. For example, the dominant *Larrea tridentata* has recorded ages as old as 2,200 years in the Grand Canyon (Bowers et al., 1995; Webb et al., 2009). Re-photography research from the Grand Canyon has given useful insight into the longevity of many common Mojave species (Bowers et al., 1995). This study reports life-spans

greater than 100 years for 14 species. Other traits compatible with long life span for Mojave plant species are slow growth, drought deciduousness and infrequent germination events. These slow processes with little inter-annual change in adult perennial plants allow species to tolerate climatic variation (Rundel & Gibson, 1996). Mojave vegetation dynamics would appear to be unchanged over time; however, recent research from long term monitoring yields insight into Mojave vegetation dynamics by demonstrating the responsiveness of Mojave vegetation to climate.

Mojave vegetation is very responsive to both short and long term climatic fluctuations by observed changes in growth, senescence, mortality and recruitment (Beatley, 1980). Studies which have persisted through long enough intervals and those which were well timed have revealed that extreme drought events promote die-off events of common and dominant species. These pulse processes drive vegetation change (Miriti et al., 2007). For example, in his analysis of a 15 year survey interval in the Mojave National Preserve, Cody, 2000 reports varied canopy cover change and virtually no mortality of individually tagged species. However a 4 year study conducted 6 years later in the Mojave National Preserve documented significant loss in canopy cover across species and high mortality in the dominant bursage, *Ambrosia dumosa*, due to extreme drought in 2002. Similarly, Miriti et al., 2007 reports 50-100% die-off of many common species including the dominant bursage, *Ambrosia dumosa*, and creosote bush *Larrea tridentata* in nearby Joshua Tree National Park in 2002. This study also documented declines in canopy cover preceding die-offs. These well-documented species losses were found to be largely sustained in follow up surveys by Hamerlinck and McAuliffe 2008. Hamerlinck and McAuliffe 2008 found this region-wide die-off event in 2002 to be most

severe along the Sonoran and Mojave Desert ecotone and thus would be expected to have affected communities in the Newberry Mountains.

The well known Beatley plots are the longest running long term vegetation plots in the Mojave region documenting landscape scale changes in numerous plant communities of the northern Mojave and Great Basin transition zone (Webb et al., 2009). These plots were established in 1962 and were last resurveyed in 2000-2002 (Webb et al., 2003). Overall, species were reported to increase in size and abundance throughout the relatively wet periods following the mid-century drought (Webb et al., 2003). Significant mortality was reported for several species, notably an almost complete loss of dominant chenopods, salt bush spp., during the extreme drought of 1989-1991 (Webb et al., 2003). These, drought induced die-offs of dominant plant species are well documented and have altered community structure permanently by resetting ecosystem trajectory and are thus the major mechanism of vegetation change in the Mojave Desert. Salt bush communities highlighted in Beatley's long term research are not represented in the Newberry Mountains where petrocalcic development is uncommon.

Inferences made from results of studies conducted on plant communities or landforms similar to the Newberry Mountains are helpful in predicting potential change and explaining observed change in Newberry Mountains. However, each species in each study cited was affected by drought induced mortality differentially. For most species in these studies juveniles, small statured, short lived, species which show recent canopy loss and species occupying younger, less developed soils are reported most susceptible to die-off severity (Miriti et al., 2007; Hamerlynck & McAuliffe, 2008). Despite similarities, the fact that die-off, severity of die-off and canopy cover were reported different for different

species in each study during the same drought period in the Mojave stresses the need for long term monitoring throughout the region.

In the course of future climate change, temperate woodlands in the southwestern US are expected to change more dramatically while deserts are expected to be less affected (Gonzales, et al., 2010; Williams et al., 2010). Publicly important woodland communities in the southwest are also prone to fires and die-off due to episodic weather events which exacerbate and expedite regime transition. Research shows how woodlands have been altered demographically due to recent droughts that echoed those of the mid-century. A rapid shift is documented for US Southwestern forest/woodland transition due to loss of dominant species during the last mid-century drought (Allen & Breshears, 1998). This ecotone shifted more than 2 km in less than five years and has been maintained for the last 40 years. Warmer temperatures coinciding with prolonged drought promoted ever more extreme die-off events in the southwest US during recent droughts as compared to mid-century drought (Breshears et al., 2005). Williams et al. (2010) estimates an 18% total loss of forests in the southwest since 1985.

Mojave Desert Climate Change

Precipitation events such as cyclic droughts and annual intensity of cool season rains are the most important climatic factors driving Mojave Desert ecosystem dynamics (Miriti et al., 2007). The Mojave Desert is the most arid region in North America and receives about 70% of the annual 137mm average precipitation during the cool season, October to March (Hereford et al., 2006). Mojave Desert vegetation communities are dominated by woody cool season plants which are vegetative and sexually productive in the spring. Recent synthesis of model interpretation predicts the southwestern US

becoming both warmer and drier by increasing minimum temperatures in winter and decreasing cool season precipitation (Seager et al., 2007). Predicted warmer temperatures during cyclic droughts and a loss of cool season moisture, essential for Mojave plants, portend significant vegetation change in the Mojave Desert.

Global temperatures have risen 0.6°C on average over the last century with a marked increase in the last 34 years (Walther et al., 2002; Thomas et al., 2004). While global temperatures are rising steadily, the degree of increase is different within continents and across landscapes (Seager et al., 2007). Increased temperatures further stress vegetation with effects on evapotranspiration rates and soil moisture retention. The EPSCOR lab at the University of Nevada, Las Vegas compared interpolated weather data of the Newberry Mountains survey area generated by PRISM and DAYMET, between the ten years preceding each of the data collection years. Annual average minimum temperatures for the mountain range have risen 1.4°C however in higher elevations, annual minimum temperatures have increased 2.8°C (Guida, 2011). The greater magnitude of warming in higher elevations potentially places greater pressure on the chaparral/woodland communities in the Newberry Mountains.

Emerging precipitation patterns are even less understood and difficult to model. Decadal droughts correlated with Pacific Decadal Oscillation cycles are observed climate patterns in the Mojave Desert. During the last century, these cyclic decadal droughts have occurred three times. The drought at the beginning of the twentieth century lasted until 1904 (Hereford et al., 2006). The mid-century drought and its effects across the entire Southwestern US were well documented and severe. This drought began in the 1950's, ended in the 1970's and preceded a relatively wet period culminating in the wettest

period on record from 1978 to the late 80's (Hereford et al., 2006). Again, the initial vegetation data for the Newberry Mountains was collected in 1979. The most recent of these decadal droughts began in 1999 and arguably continues to the present. Therefore the interval between surveys in the Newberry Mountains spans long term, decadal, wet and dry periods.

Whereas vegetation in the Mojave is known to respond to climatic precipitation patterns with steady increases or decreases of plant size and density, dramatic deviations from average annual precipitation, within one year, fundamentally alter vegetation communities in the Mojave (Beatley, 1980; Hereford et al., 2006; Miriti et al., 2007). These inter-annual weather events are associated with La Nina and El Nino southern oscillation cycles (Hereford et al., 2006). The following list highlights specific single year weather events which have occurred between 1979 and 2008 in the Southeastern Mojave Desert: severe drought of 1989-90, the driest years on record of 2003 and 2007 and the wettest year on record of 2005 (Hereford et al., 2006). Again, the interval between surveys in the Newberry Mountains spans numerous extreme weather events.

The acute effects of these numerous weather events, during the interval between surveys, on community composition in the Newberry Mountains are difficult to ascertain. Rather, results show overall difference between the two survey years and current status of species in relation to 1979.

Other Stochastic Vegetation Change

Recent research concentrates on measurable change in vegetation responses attributable to climatic alteration of species niche space within the landscape; however, innumerable anthropogenic pressures exist which are not in an evolutionary context with

historic vegetation communities. Discerning stochastic causes for change from climatic change is difficult. Rapid urban population increases in the Mojave region result in increased development and recreation pressure on the surrounding landscape (Lovich, 1999; Berry, et al., 2006). Although succession is known to occur in the Mojave, disturbances take centuries to millennia to recover to pre disturbance communities (Vasek, 1983). Due to interceding stochastic events such as continued disturbance and non-native weed invasion as well as climate change, plant communities may never recover to pre disturbance conditions. The Newberry Mountains remain relatively protected from development; nonetheless 5 of the 111 (~4%) of Holland's sites were lost due to development of roads, barrow pits and flood control.

While population increases pressure on the region, the cessation of ranching in the area has released a significant pressure on the Southeastern Mojave Desert ecosystem. The Southeastern Mojave including the Newberry Mountains has been grazed continuously since the establishment of Fort Mojave and Fort Piute along the Mojave trail in the 1850's. Grazing was mainly from cattle, however, a sheep grazing operation was active in the Newberry Mountains as late as the 1970's (Ovary, 2009). Although past grazing intensity certainly altered ecosystem trajectories, studies specifically addressing these changes while they occurred are scarce (Lovich, 1999). Results of grazing impact studies are often contradictory. For example, grazing is theorized to have selected for shrubs over grassland and created nurse plant abundance benefitting current iconic Joshua tree landscapes of the Southeastern Mojave. Conversely, Bowers (1997) reported impacts of grazing on nurse plant shrubs negatively effecting barrel cactus, *Ferocactus cylindraceae*, establishment. In general, Mojave vegetation would be expected to respond

to this stressor with decreased biomass, density and distribution of palatable species as well as compaction of soils (Beever et al., 2006; Milchunas, 2006). Research on the response to removal of grazing suggests long term recovery of species diversity and soil properties (Quengfeng, 2004; Beever et al., 2006; Milchunas, 2006). Historic grazing in semi-arid landscapes created biophysical feedbacks that continue to alter ecosystem trajectory such as continued shrub encroachment long after the cessation of grazing (Neave and Rayburg, 2007). After removal of cattle in a Sonoran Desert study, Quengfeng (2004) found diversity among palatable and herbaceous species continued to rise until equilibrium at 60 years regardless of interceding climatic events.

Documented grazing has occurred in the Newberry Mountains ever since an original feral cattle roundup was documented by Leo Kennedy in 1924, although reports of cattle presence date to the establishment of Fort Mojave in 1870 (Ovary, 2009). Since the 1940's, the entire study area has been an active cattle allotment under numerous leasers. Sheep grazing also occurred as recently as the 1960's. Holland, 1982 describes several transects as heavily grazed. However, it is impossible to quantify the number of head, spatial grazing management or intensity from the data, historical documents and personal contact with ranchers. Grazing intensity was likely disproportionate in topographically accessible areas as opposed to cliff and steep mountainous areas. It is also likely ecosystem properties were altered by grazing long before Holland collected data in 1979. Eventually federal livestock allotments were permanently closed in 1994 due to the federal listing of the Western population of desert tortoise, *Gopherus agassiz agassiz*. This occurred at the midpoint between the two Newberry Mountains surveys,

and subsequent 15 years of plant community recovery has occurred. Unknown grazing impacts add to the mosaic of change across the landscape over 29 years.

Quantifying the extent and timing of numerous small fires occurring over three decades in the Newberry Mountains is also unfeasible. However, four large fires have been documented in the Newberry Mountains within the interval between surveys. These fires largely burned mixed shrub, chaparral and California juniper woodland communities around the base of Spirit Mountain. Boulder strewn cliffs of Spirit Mountain prohibit even burning landscape fires in regions of the mountains with high topographic relief. The Miracle and Spirit fires occurred in 1994 and burned many hectares and the earlier Christmas fire in 1993 burned as many hectares. Several transects fell within these fire extents. Also numerous fire scars are noted by both surveyors in the data. Numerous smaller fires likely continue to be undocumented in the more remote areas of the Newberry Mountains.

Research by Amundsen et al. (1989) determined the variables most responsible for paleo-distributional changes of 38 Sonoran species. This study described how many species now associated with the Mojave were expelled from the Sonoran Desert by increasing summer precipitation and resultant frequent fires. Dominant species of chaparral/woodland such as *Pinus monophylla*, *Juniperus californica*, Joshua trees, and *Coleogyne ramosissima*, are fire intolerant and do not resprout after severe fire damage (Brooks, 2005). Fire frequency is increasing today, ironically, due to the cool season production of fuel by introduced grasses e.g. *Bromus* spp. For example, blackbrush is a community type that has burned extensively throughout the region within the last decade due to introduced grasses (Brooks, 2005). The extreme long-term recovery of *Coleogyne*

ramosissima communities after fire is well documented (Brooks, 2005). This high elevation-associated community type is decreasing in area at an alarming rate relative to other habitats in the Mojave region.

Numerous unknown fires, grazing intensity and other anthropogenic pressure only add to the mosaic of change across the landscape in 29 years. In fact, numerous stochastic events are likely driving quantifiable change in the Newberry Mountains, but the interceding dynamics over these three decades can be inferred from the gradient analysis in this project.

CHAPTER 3

PROJECT PURPOSE AND SPECIFIC AIMS

The purpose of the project is to contribute to the documentation and predictive abilities for vegetation change in the Mojave Desert by resurveying an established network of vegetation plots and analyzing differences over 29 years. Through the establishment of a long term monitoring plan, this project will provide ongoing data collection and analysis of future vegetation change in the Newberry Mountains and Mojave region.

For the purpose of this research, vegetation change is defined by significant differences in the following measures of species abundance within individual species and community composition: density, relative density, relative frequency and relative cover. This project determined if change has occurred within individual species and among vegetation communities at statistically relevant levels over the last 29 years in the Newberry Mountains. Furthermore, the project investigated if detectable change in plant

communities is variable across environmental gradients including solar insolation, elevation, precipitation, aspect, slope, soil type, and plant associations.

In order to achieve the project objectives of investigating vegetation change in the Newberry Mountains over the 29 years between transect sampling and facilitating the establishment of a long term monitoring program, the following measurable objectives are proposed for this project:

- Digitize Jim Holland's hard copy transect data from 1979.
- Relocate transects by digitizing and geo-rectifying 1979 map and assigning coordinates to each transect. Conduct field reconnaissance with Holland's notes to accurately locate transects.
- Photograph and resurvey transects from 1979.
- Archive transects location information, methodology, data and photos with Lake Mead NRA to facilitate the establishment of a long term monitoring program.
- Create environmental variables associated with each transect using multiple sources for GIS layers of the project area.
- Define grouping criteria for transects which share associations of species and other environmental variables in order to compare changes among groups.
- Analyze the data using appropriate multivariate and univariate statistical techniques. Compare 1979 and 2008 data for each individual species and note significant differences.

- Compare the plant community composition between the whole data set as well as subsets of the data from 1979 and 2008 in order to determine differences in degree of change.
- Prepare a report which documents the findings and present the project results with emphasis on management implications to shareholders including the National Park Service, Bureau of Land Management, other Federal agencies and tribal governments.

CHAPTER 4

RESEARCH QUESTIONS

Research questions were developed based on a review of past literature pertaining to long term vegetation change and Mojave Desert ecology. The research questions address possible changes in the vegetation community that would be expected during the 29 years of interceding climate change, which has included warmer and drier conditions. This change in conditions has the potential to alter vegetation communities with multiple and cascading effects on individual species that are dependent on specific temperature and precipitation regimes. For example, diminishing climatic habitat upslope could cause high elevation associated species to decrease in abundance measures across an elevation gradient resulting in an increase in abundance for low elevation associated species which colonize an increasing climatic habitat. Furthermore extreme weather events are known to cause vegetation community change in the Mojave because of regional loss of individual species. Hence, it is hypothesized that:

- Vegetation community composition will be significantly different between 1979 and 2008.
 - Community composition will be more different in high elevation communities.
- Density, frequency and cover of individual species will be significantly different between 1979 and 2008.
 - Species associated with mesic mixed-shrub and woodland communities will decline.

- Species associated with warmer and lower elevation creosote/bursage communities will be more abundant.
- Distribution of individual species (proportion of transects occupied) will be significantly different between 1979 and 2008.

Different environmental variables place physical constraints on the vegetation communities in each transect. Changes in climate would be expected to affect communities in certain topographic locations differently than others. Hence it is hypothesized that:

- Degree of change between transects and within species will be correlated with environmental variables.
 - Change in most species will be positively correlated with elevation.
 - Change in some species will be negatively correlated with change in other species.

CHAPTER 5

METHODS

The Newberry Mountains are a mountain range located entirely within the southern-most tip of Clark County, Nevada, USA. The mountains are distinguished by an exposed granite pluton, belonging to the Spirit Mountain batholith that rises from 183 m in the Colorado River valley to the Spirit Mountain summit at 1,719 m (Walker Jr., 2007). The Newberry Mountains are managed by Lake Mead National Recreation Area, National Park Service and the Bureau of Land Management, Southern Nevada district. The Spirit Mountain Wilderness Area is considered the most important cultural site to Colorado River Native American tribes and is designated a National Heritage Site, Cultural property.

The original, hard copy data were obtained from Lake Mead Park Planner, Jim Holland. Holland collected the data set in the fall of 1979 toward completion of 1982 Masters in Sciences thesis. The thesis was titled “A Vegetative Analysis of the Newberry Mountains, Nevada”. Hard copy data were digitized and all project materials are archived with Lake Mead National Recreation Area, Geographical Information System (GIS) division. Slides of photographs taken by Jim Holland were also digitized and select photos were re-photographed for visual inspection of vegetation differences. Further, Jim Holland was consulted throughout the 2008 survey including on-site reconnaissance.

Jim Holland established 111 belt transects in the fall and winter of 1979. The transect locations were non-randomly selected by Holland in an effort to characterize all major vegetation communities stratified by the entire elevation gradient of the Newberry Mountains. Holland (1982) identified four basic vegetation groups further defined by

elevation and topography. For example, 73 of the 111 sites were located within 610m-1220m in order to represent the variable topography and mixed dominance vegetation communities characteristic of this elevation band (Holland, 1982). These transects were identified, relocated and resurveyed in the winter and spring of 2008. A map of the Newberry Mountains was created by Holland in 1979 which located each transect. This map was digitized and geo-rectified and transects were given coordinates. The vegetation samplers navigated to coordinates and further discerned final transect location with Holland's detailed descriptions of slope, aspect, soil type, and directions based on landmarks. Once each transect was located, a final GPS position was averaged and recorded. A transect heading was established and recorded. A photo was taken and documented from the transect origin towards the transect heading.

Measures of density, cover and frequency were collected for each perennial vascular plant species occurring within transects using the methods of Holland in 1982. Holland (1982) used aerial survey methods, recommended for sparse desert landscapes by Bradley (1965), to construct the 600 m², belt transect. For each transect a 100 m tape was stretched and secured at each end. Orientation of transect was determined in the field using a tossed pencil when topographic limitations allowed. The data was read by only one observer during each of the survey years. Density data were collected using a 3m pole which was walked along each transect with one end fixed at the 100m tape and all perennial species were counted within the poles reach. Perennials whose canopy was within 3m of the center line were counted on the right side of 100m line and on the left only those perennials whose base occurred within 3m of the center line were counted. Density is recorded in whole number increments. Cover data were collected within each

of 100 1x1m quadrats placed along each meter of the 100 m center line. Cover was estimated and recorded to the whole number increment for all perennial species with bases occurring within the quadrat and expressed in analysis as a percentage. Frequency data were collected within each of 100 1x1m quadrats placed along each meter of the 100 m center line. Frequency was recorded as the presence of each perennial species with base within the quadrat. Frequency is recoded as a whole number and expressed in analysis as a percentage of quadrats occupied out of 100 total quadrats. Each of these three variables was further relativized within transect totals of all species measured. Both raw data and relativized data were included in the final data collected.

Created Variables

In order to investigate if the changes detected in the vegetation community are correlated with environmental gradients, we collected environmental data from multiple sources. Environmental data were collected from field measurements and from public access data. The following environmental variables of interest were included for use in modeling species and community data: Easting, Northing, elevation (feet), slope, heat loading capacity (Watt/m^2) during summer maximum, and duration of sunlight (hours) during winter minimum, species associations, and Order 2 soil survey. A 10m Digital Elevation Model projection of the 278,545 acres project area was applied to Nad 83 Conus projection using ArcMAP 9.3. These base layers were used to derive transect specific elevation and geographic coordinates and are necessary for the application of other raster data layers obtained from public access data. The variables, duration of sunlight at winter solstice and heat loading capacity in watts per square meter at summer solstice were calculated using ArcGIS 9.3 Solar Insolation tool (Merkler, 2009). These

are important variables in describing hyperthermic arid soil temperature regimes as well as providing a more ecologically descriptive proxy for aspect (Jenness, 2007). Order 2 county soil survey map layers were obtained from free download at Clark County Maps, <http://gisgate.co.clark.nv.us/gismo/Freedata.HTM>. Soil layer was clipped at project area and spatially joined to provide soil association for each transect. Transect specific temperature and precipitation variables across the topographically complex area were calculated using DAYMET raster layers clipped to project area (DAYMET, 2012). Provisional vegetation associations that closely resembled those types described in California by Sawyer, Keeler- Wolfe, & Evans (2009) were identified from cluster analysis. These groups were further modified and used as a fixed variable grouping criteria.

Measures of density, frequency, and cover were further relativized by within transect totals of all species measured within that plot. A single species' recorded density within each transect was calculated as a percentage of the total density of all recorded species within the same transect. Likewise, a single species' relative cover and frequency measures are expressed as percentages of total transect cover or total transect frequency measures.

Individual species change over time was compared both across and within plots. In order to compare changes in species presence or absence over time as indicated by density and frequency data, five measurements were calculated. These measurements include the number of plots occupied by the species in 1979 (n_1), the number of plots occupied by the species in 2008 (n_2), the number of plots newly colonized by the species

(n_{col}), the number of plots abandoned by the species (n_{ext}), and the number of plots continuously occupied by the species from 1979 to 2008 ($n_{1,2}$).

In order to investigate changes in the community composition over time, we applied Non Metric Multidimensional Scaling (NMS). NMS is a non-parametric analysis of ecological communities which has been used to analyze long term vegetation change (McCune and Medford 1999; Anderson, 2001; Damschen et al., 2010). Using PC-ORD 4.28, we applied NMS in Autopilot thorough mode with Sørensen (Bray-Curtis) dissimilarity measure to all vegetation measures (McCune and Medford 1999). This procedure created ordinations for graphical representation of paired plots and analysis of change (Zimmerman et al. 1985; McCune and Medford 1999). NMS reports dissimilarity measures between ordinated points in a distance metric chosen by the researcher. These dissimilarity measures represent a geometric measure of differences between paired plots from 1979 to 2008 (Zimmerman et al. 1985; Anderson 2001; McCune and Medford 1999). Sørensen (Bray-Curtis) dissimilarity measures between paired (1979 and 2008) plots were obtained from NMS ordinations for all vegetation abundance measures of density, relative density, frequency, relative frequency, cover and relative cover.

Statistical Analysis

In order to investigate changes in the distribution of species over time, tests for proportion including chi squares and likelihood ratio tests were used to compare the proportion of transects occupied by individual species between 1979 and 2008 using SAS 9.3 statistical software (SAS Institute Inc 2011). In order to investigate differences in individual species measures over time, independent samples Student's t-test was applied to all continuous variables associated with each species shared between survey years and

across selected environmental variables. When normality assumptions for the Student's t-test were not met either because of sample size or the non-normal distribution of the continuous data, non-parametric t-test was applied and an exact p-value was calculated using the Monte Carlo method. Again comparisons of means were performed using SAS 9.3 statistical software and assumed a type I error rate of $\alpha=0.05$ (SAS Institute Inc 2011).

Stepwise multiple linear regressions were applied to explore the linear relationship between the predictor variables of both raw and relativized density, cover and frequency, and the criterion environmental variables including Easting, Northing, elevation, slope, temperature, precipitation, duration of sun exposure in hours at winter solstice, heat loading capacity in watts per square meter during summer solstice, vegetation community associations, and soil series associations and to what degree these variables contributed to the observed changes. Prior to the application of stepwise multiple linear regression, tests for multi-collinearity were applied to the data and criterion variables with a correlation coefficient > 0.8 were removed from the analysis and are not represented in the final models.

Analysis of Variance (ANOVA) were applied to these data in order to compare mean changes within paired transects by groups defined by elevation, vegetation association, and soil type. For those variables which did not meet the assumptions of normality, a non-parametric ANOVA on the ranked data were performed. Ad hoc tests included a comparison of ranked mean differences using the Tukey method (SAS Institute Inc 2011). ANOVA, multiple linear regression, and logistic regression were performed using SAS 9.3 and assumed a type I error rate of $\alpha=0.05$.

In order to test if the individual species absolute change and the environmental variables of Easting, Northing, elevation, slope, temperature, precipitation, duration of sun exposure at winter solstice and heat loading capacity during summer solstice were related, calculated Pearson's correlation coefficient for each variable using the SAS 9.3 PROC CORR procedure (SAS Institute Inc 2011). The following 11 species were selected based on sample size, significance in tests between mean densities and potential as ecological indicators: *Acamptopappus sphaerocephalus*, *Achnatherum speciosum*, *Coleogyne ramosissima*, *Cylindropuntia acanthocarpa*, *Eriogonum fasciculatum*, *Ferocactus cylindraceus*, *Galium stellatum*, *Juniperus californica*, *Sphaeralcea ambigua*, *Bahiopsis parishii* and *Yucca schidigera*. Absolute change was calculated by subtracting each species' density in all plots in 1979 from density in all plots in 2008. The absolute value of this number was used for calculation of the correlation coefficient. Zeros in the data were eliminated by adding one to the entire data set. Environmental variables with a correlation coefficient > 0.8 were considered significant.

Non Metric Multidimensional Scaling (NMS) ordination

A Blocked Multiple Response Permutation Procedure (MRBP) was applied for analysis of community compositional changes between 1979 and 2008 paired plots using the software PC-ORD 4.28 (Zimmerman et al., 1985; McCune & Medford, 1999; Mielke & Berry, 2001). Multi response permutation procedures report within-group agreement statistic (A) and statistical significance of the differences in community composition. The A statistic has a maximum value of 1.0 when community composition is identical and a minimum value of -1.0 (McCune and Medford 1999). A significant result assumes a type I error rate of $\alpha=0.05$ and rejects the null hypothesis of no difference between community

composition in 1979 and 2008 (McCune & Medford 1999). In order to ensure results be relevant to the principal species of the vegetation communities we transformed the data for each measure and repeated the analysis. Data were transformed by combining closely related species within genus e.g. *Ephedra nevadensis* is added to *Ephedra viridis* and *Ericameria laricifolia* is added to *Ericameria linearifolia*. Further, species with 3 or less plot occupancies were discarded. The transformation resulted in the loss of 70 out of 144 species

Stepwise multiple linear regression was applied to explore the linear relationship between the predictor variable, NMS dissimilarity measures between paired 1979 and 2008 transects, and the criterion environmental variables including Easting, Northing, elevation, slope, temperature, precipitation, duration of sun exposure at winter solstice and heat loading capacity during summer solstice and to what degree these variables contributed to the observed changes. Analysis of Variance (ANOVA) was applied to these data in order to compare mean changes within paired transects by groups defined by elevation, species association, and soil type. For those variables which did not meet the assumptions of normality, a non-parametric ANOVA on the ranked data were performed. Ad hoc tests included a comparison of ranked mean differences using the Tukey method (SAS Institute Inc., 2011). ANOVA, multiple linear regression, and logistic regression were performed using SAS 9.3 and assumed a type I error rate of $\alpha=0.05$.

CHAPTER 7

RESULTS

Qualitative Description of Re-photography

Photographs obtained from Jim Holland were shot during his 1979-1980 survey season. These same locations were re-photographed using identifiable landmarks and with good representation of vegetation across the landscape. A selection of these paired photographs can be found in Figs. 1-3. Paired photographs are visually, remarkably similar with both shrubs and shrub interspaces in the same positions with minimal growth recognizable. The tree, *Juniperus californica*, is especially recognizable and upon comparison, easy to co-distinguish in the same positions with the same general sizes. One photo taken in 2008 captures many large *Ferocactus cylindraceus*, barrel cactus, unseen in a corresponding 1979 photo (Figure 3). Re-photography suggests minimal visual change to the vegetation community during the last 30 years.



Figure 1 Re-photography shows 1979 view (top) and 2008 view (bottom) toward Spirit Mountain. Red circle exhibits persistence of shrubs and interspaces. Blue circle exhibits evidence of change with dead *Juniperus californica* in 2008. Yellow circle exhibits slow growth in *Yucca schidigera*.



Figure 2 Re-photography shows 1979 view (top) and 2008 view (bottom) of chaparral/woodland. Red circles highlight one prominent *Ferocactus cylindraceus* in 1979 contrasted with many prominent individuals in 2008.



Figure 3 Re-photography close-up shows 1979 view (top) and 2008 view (bottom) of chaparral/woodland. The grass, *Achnatherum speciosum*, is visible in 1979 but not prominent in 2008.

Site Characteristics

Through comparison of basic measurements, certain differences and broad similarities were observed. General characteristics for the 1979 and 2008 surveyed sites are summarized in Table 1: Site Characteristics and Measures of Diversity, 1979 and 2008. A total of 144 species occur in the combined data with 110 species recorded in 1979 and 137 species recorded in 2008. A total of 45,226 individual plants were counted in 1979 with a total cover value of 10,562.55 and a total of 37,723 plants were counted in 2008 with a total cover value of 10,299.14. Species were ranked by their density in each survey year. The four species with the highest ranked overall density in 1979 and 2008 comprised 46 and 49 percent, respectively, of the overall density for each survey year. The following three species with the highest density are in the same rank order from largest to smallest in both 1979 and 2008 data: *Eriogonum fasciculatum*, *Ambrosia dumosa* and *Encelia farinosa*. The fourth highest density species changed from *Coleogyne ramosissima* in 1979 to *Bahiopsis parishii* in 2008. The four species with the largest cover values in 1979 and 2008 comprised 50 and 55 percent, respectively, of the total cover value for all species in each survey year. The following four species, had the largest total cover value in both 1979 and 2008, however the rank order of largest to smallest has changed between survey years: *Larrea tridentata*, *Eriogonum fasciculatum*, *Ambrosia dumosa* and *Encelia farinosa* (Table 2).

Table 14 Site Characteristics and Measures of Diversity, 1979 and 2008.

	Year		p value
	1979	2008	
Plots	103		
Elevation Range	580 m - 5,452 m		
Total Area Surveyed	61.8 sq km		
Total Plants	45,226	37,723	
Species	110	138	
Life form			
Shrub	33,745 (79.7)	27,642 (78.3)	
Herb	2,986 (7.0)	2,657 (7.5)	
Cactus	2,747 (6.5)	2,180 (6.2)	
Tree	1,090 (2.6)	1,024 (2.9)	
Mean species/plot			
Overall	14.58	16.75	0.0336
SE	0.83	0.58	
Elevation			
Low (≤ 548 m)	12.09	13.21	ns
SE	0.79	1.03	
Medium (549 - 1,066 m)	13.81	14.89	ns
SE	0.91	1.13	
High (1,067+ m)	19.12	24.46	0.0052
SE	0.98	1.54	
Simpson's			
Overall	1.69	1.82	ns
SE	0.04	0.06	
Elevation			
Low (≤ 762 m)	1.54	1.63	ns
SE	0.07	0.08	
Medium (762 - 1,067 m)	1.63	1.71	ns
SE	0.08	0.09	
High (1,067+ m)	1.97	2.24	0.0211
SE	0.07	0.09	

Changes in Community Diversity

Several measures of species diversity (alpha: Shannon-Wiener Index (H) and Simpson's Index of Diversity (1-D), beta and gamma) were calculated for vegetation data collected

in 1979 and in 2008 and among elevation groups which loosely correspond to soil temperature regimes (low $\leq 762\text{m}$, medium $>763\text{m} < 1,067\text{m}$, high $\geq 1,067\text{m}$). We used species diversity as a measure of community composition in order to test the hypothesis of significant change between survey years and if those changes were different among elevation groups. Results of community diversity measures are presented in Table 1: Site Characteristics and Measures of Diversity, 1979 and 2008. Data collected in 1979 had a significantly lower mean number of different species per plot than data collected in 2008 (1979: $n=103$, mean=14.6, SE=0.58 vs. 2008: $n=103$, mean=16.8, SE=0.83; $p=0.034$). Differences in mean number of different species were compared by elevation group across survey years. Significant differences in the mean number of different species were only detected at the high elevation sites ($p=0.0052$). No differences in mean number of different species per plot were detected at medium or low elevation sites. The mean number of species per plot among high elevation sites in 2008 was significantly higher than the mean number of species per plot among high elevation sites in 1979 (1979: $n=26$, mean=19.1, SE=0.98 vs. 2008: $n=26$, mean=24.5, SE=1.54; $p=0.0052$).

Other calculated measures of diversity were compared between sites surveyed in 1979 and sites surveyed in 2008. These calculated measures of diversity include the Shannon-Wiener index (H) and Simpson's Index of Diversity (Hill, 1973). There was no significant change in mean Shannon-Wiener diversity index by plot (H) from 1979 to 2008. Higher mean H scores indicate increased species diversity. Differences in H score were only detected at high elevation sites ($p=0.0211$). No differences in species diversity (H) were detected at medium or low elevation sites. Plots at high elevation sites in 2008 had significantly greater mean H than high elevation sites in 1979 (2008: $n=26$,

mean=2.2425, se=0.0911 vs. 1979: n=26, mean=1.9754, se=0.0654; $p=0.0211$). Mean evenness is another measure of diversity. Mean evenness for 2008 data were 0.6734, which indicates moderate evenness. Mean evenness for 1979 data were 0.6494, which also indicates moderate evenness or evenness of community. No significant difference between evenness was observed from 1979 to 2008. Similarly, no significant differences in Simpson's Index of Diversity (1-D) and mean evenness were observed between data collected in 1979 and data collected in 2008 or among different elevation groups (Refer to Table 1).

Table 15 Most Abundant Species by Total Density and Mean Cover per Quadrat, 1979 and 2008.

	Year			
	1979		2008	
	n	%	n	%
Density				
<i>Eriogonum fasciculatum</i>	8,456	18.7	6,360	16.9
<i>Ambrosia dumosa</i>	7,052	15.6	6,021	16.0
<i>Encelia farinosa</i>	3,563	7.9	3,909	10.4
<i>Coleogyne ramosissima</i>	1,906	4.2	1,087	2.4
<i>Achnatherum speciosum</i>	1,885	4.2	1,376	3.7
<i>Larrea tridentata</i>	1,767	3.9	2,028	5.4
<i>Viguera parishii</i>	1,504	3.3	1,623	4.3
<i>Acamptopappus spheracephal</i>	1,150	2.5	738	2.0
<i>Ephedra nevadensis</i>	1,080	2.4	1,081	2.9
Cover				
<i>Ambrosia dumosa</i>	0.18	17.7	0.15	15.4
<i>Larrea tridentata</i>	0.14	13.7	0.20	20.3
<i>Encelia farinosa</i>	0.11	10.4	0.09	9.1
<i>Eriogonum fasciculatum</i>	0.08	8.1	0.10	10.4
<i>Coleogyne ramosissima</i>	0.06	6.1	0.03	2.9
<i>Juniperus californica</i>	0.03	3.2	0.02	2.2
<i>Viguera parishii</i>	0.03	3.0	0.04	3.8
<i>Ephedra nevadensis</i>	0.03	2.9	0.03	3.1
<i>Pinus monophylla</i>	0.03	2.6	0.00	0.5
<i>Hymenoclea salsola</i>	0.02	2.4	0.03	2.7
<i>Quercus turbinella</i>	0.02	2.0	0.03	2.7
<i>Acamptopappus spheracephal</i>	0.02	2.0	0.01	0.8
<i>Achnatherum speciosum</i>	0.01	0.5	0.01	0.7

Plot Occupancy by Density

Density was selected as the most inclusive measure denoting presence or absence of species across plots. Plot occupancy as measured by density was used to test the hypothesis of significant changes to species distribution over time. The following species were prevalent across plots by density measurements in 1979 and the number of plots

occupied (n_1) is reported: *Eriogonum fasciculatum* (78), *Larrea tridentata* (76), *Ambrosia dumosa* (73), *Ephedra nevadensis* (57), and *Krameria grayi* (55). Similarly, the following species were prevalent across plots in 2008 (n_2): *Larrea tridentata* (76), *Eriogonum fasciculatum* (75), *Ambrosia dumosa* (72), *Krameria grayi* (58), *Ephedra nevadensis* (55). The following species colonized the greatest number of plots by density from 1979 to 2008 and number of plots (n_{col}) is included: *Krameria erecta* (25), *Bebbia juncea* (18), *Ferocactus cylindraceous* (15), *Acacia greggi* (14), *Krameria grayi* (13), and *Sphaeralcea ambigua* (13). Species which abandoned the greatest number of plots (n_{ext}) from 1979 to 2008 included: *Cylindropuntia acanthocarpa* (32), *Xylorhiza tortifolia* (23), *Sphaeralcea ambigua* (20), *Acamptopappus sphaerocephalus* (19), *Thamnosia montana* (15), and *Yucca schidigera* (15). The following species report the greatest proportion of plots sampled in 1979 which were continuously occupied in 2008 and the ratio ($n_{1,2}/n_1$) is included: *Galium stellatum* (100%), *Quercus turbinella* (100%), *Coleogyne ramossissima* (95.0%), *Encelia farinosa* (93.5%), and *Larrea tridentata* (92.1%). The following species report the least proportion of plots sampled by density in 1979 which were continuously occupied in 2008 and the ratio ($n_{1,2}/n_1$) is included: *Cylindropuntia acanthocarpa* (39.6%), *Xylorhiza tortifolia* (39.5%), and *Achnatherum speciosum* (37.5%)

Fischer's exact Chi Square test was used to compare the difference in proportion of plots occupied by each species by density from 1979 to 2008. The only species which showed a significant decrease in the proportion of plots occupied from 1979 to 2008 was *Cylindropuntia acanthocarpa* (51.4% versus 32.0%, $X^2=6.776$, $p=0.009$). Only *Galium stellatum* demonstrated a significant increase in proportion of plots occupied by density

from 1979 to 2008 (10.7% versus 18.5%, $X^2=4.189$, $p=0.040$). No difference in the proportion of plots occupied by density was noted for any other species. Table 3 summarizes changes in plot occupancy by density from 1979 to 2008.

Table 16 Plot Occupancy by Density, 1979 and 2008.

Species	n ₁	n ₂	χ^2	p^{**}	n _{col}	n _{ext}	n _{1,2}
<i>Acacia greggi</i>	43	43	0.000	1.000	14	14	29
<i>Acamptopappus sphaerocephalus</i>	39	28	2.212	0.145	8	19	20
<i>Achnatherum speciosum</i>	8	11	0.230	0.633	8	5	3
<i>Ambrosia dumosa</i>	73	72	0.000	1.000	6	7	66
<i>Bebbia juncea</i>	27	36	1.409	0.235	18	9	18
<i>Coleogyne ramosissima</i>	20	21	0.000	1.000	2	1	19
<i>Cylindropuntia acanthocarpa</i>	53	33	6.776	0.009	12	32	21
<i>Echinocereus engelmannii</i>	36	30	0.535	0.465	5	11	25
<i>Encelia farinosa</i>	31	36	0.339	0.560	7	2	29
<i>Encelia virginensis</i>	22	20	0.029	0.864	8	10	12
<i>Ephedra nevadensis</i>	57	55	0.018	0.894	10	12	45
<i>Eriogonum fasciculatum</i>	78	75	0.081	0.776	7	10	68
<i>Eriogonum wrightii</i>	15	19	0.312	0.577	9	5	10
<i>Ferocactus cylindraceus</i>	39	42	0.077	0.782	15	12	27
<i>Galium stellatum</i>	11	19	4.189	0.040	11	3	11
<i>Hymenoclea salsola</i>	25	24	0.000	1.000	11	12	13
<i>Hyptis emoryi</i>	4	10	1.904	0.166	7	1	3
<i>Juniperus californica</i>	25	22	0.107	0.743	0	3	22
<i>Krameria erecta</i>	40	52	2.218	0.136	25	13	27
<i>Krameria grayi</i>	55	58	0.071	0.790	13	10	45
<i>Larrea tridentata</i>	76	76	0.000	1.000	6	6	70
<i>Lotus rigidus</i>	14	18	0.328	0.568	11	7	7
<i>Lycium andersonii</i>	27	25	0.025	0.875	10	12	15
<i>Pinus monophylla</i>	10	11	0.000	1.000	4	3	7
<i>Pleuraphis rigida</i>	13	17	0.346	0.557	10	6	7
<i>Quercus turbinella</i>	13	16	0.158	0.691	3	0	13
<i>Salazaria mexicana</i>	24	26	0.026	0.873	11	9	15
<i>Sphaeralcea ambigua</i>	40	33	0.728	0.393	13	20	20
<i>Thamnosma montana</i>	28	25	0.099	0.754	12	15	13
<i>Bahiopsis parishii</i>	34	38	0.183	0.669	10	6	28
<i>Xylorhiza tortifolia</i>	38	25	3.169	0.075	10	23	15
<i>Yucca schidigera</i>	41	35	0.496	0.482	9	15	26

** Fischer's Exact Test

Plot Occupancy by Frequency

Plot occupancy as measured by frequency was also used to test the hypothesis of significant changes to species distribution over time. Frequency and cover data were recorded within a portion of each belt transect and species represented in the all inclusive density data may not be represented these data. The following species were prevalent across plots by frequency measurements in 1979 and the number of plots occupied (n_1) is reported: *Larrea tridentata* (69), *Eriogonum fasciculatum* (65), *Ambrosia dumosa* (60), *Ephedra nevadensis* (42), and *Yucca schidigera* (41). Similarly, the following species were prevalent across plots in 2008 (n_2): *Larrea tridentata* (73), *Eriogonum fasciculatum* (65), *Ambrosia dumosa* (63), *Ephedra nevadensis* (51), and *Krameria grayi* (43). The following species colonized the greatest number of plots by frequency from 1979 to 2008 and number of plots (n_{col}) is included: *Krameria erecta* (21), *Ephedra nevadensis* (20), *Ferocactus cylindraceous* (17), *Krameria grayi* (17), and *Acacia greggi* (16). Species which abandoned the greatest number of plots (n_{ext}) from 1979 to 2008 included: *Sphaeralcea ambigua* (25), *Xylorhiza tortifolia* (20), *Cylindropuntia acanthocarpa* (19), *Acamptopappus spaherocephalus* (19), and *Yucca schidigera* (14). The following species report the greatest proportion of plots sampled by frequency in 1979 which were continuously occupied in 2008 and the ratio ($n_{1,2}/n_1$) is included: *Larrea tridentata* (94.2%), *Ambrosia dumosa* (93.3%), *Coleogyne ramosissima* (89.5%), *Eriogonum fasciculatum* (89.2%), and *Encelia farinosa* (87.6%). The following species report the least proportion of plots sampled by frequency in 1979 which were continuously

occupied in 2008 and the ratio ($n_{1,2}/n_1$) is included: *Sphaeralcea ambigua* (19.4%), *Thamnosia montana* (20.0%), *Xylorhiza tortifolia* (25.9%), *Galium stellatum* (27.3%) and *Lycium andersoni* (27.9%)

Fischer's exact Chi Square test was used to compare the difference in proportion of plots occupied by each species by frequency from 1979 to 2008. Species which showed a significant decrease in the proportion of plots occupied from 1979 to 2008 included: *Acamptopappus sphaerocephalus* (33.0% versus 20.4%, $X^2=4.061$, $p=0.044$) and *Sphaeralcea ambigua* (30.1% versus 14.6%, $X^2=6.987$, $p=0.008$). Similar to plot occupancy by density results, *Galium stellatum* demonstrated a significant increase in proportion of plots occupied from 1979 to 2008 (10.8% versus 22.2%, $X^2=4.022$, $p=0.048$). No difference in the proportion of plots occupied by frequency was noted for any other species. Table 4 summarizes changes in plot occupancy by frequency from 1979 to 2008.

Table 17 Plot Occupancy by Frequency, 1979 and 2008.

Species	n ₁	n ₂	χ^2	p^{**}	n _{col}	n _{ext}	n _{1,2}
<i>Acacia greggi</i>	27	28	0.024	0.877	16	15	12
<i>Acamptopappus sphaerocephalus</i>	34	21	4.061	0.044	6	19	15
<i>Achnatherum speciosum</i>	21	23	0.113	0.737	6	4	17
<i>Ambrosia dumosa</i>	60	63	0.161	0.689	7	4	56
<i>Bebbia juncea</i>	16	22	1.139	0.286	13	7	9
<i>Coleogyne ramosissima</i>	19	20	0.031	0.860	3	2	17
<i>Cylindropuntia acanthocarpa</i>	25	15	3.038	0.081	9	19	6
<i>Cylindropuntia ramosissima</i>	9	9	0.000	1.000	5	5	4
<i>Echinocereus engelmannii</i>	18	14	0.582	0.445	7	11	7
<i>Encelia farinosa</i>	31	33	0.087	0.768	6	4	27
<i>Encelia virginensis</i>	15	12	0.379	0.538	6	9	6
<i>Ephedra nevadensis</i>	42	51	1.480	0.224	20	11	31
<i>Eriogonum fasciculatum</i>	65	65	0.000	1.000	7	7	58
<i>Eriogonum wrightii</i>	11	16	1.052	0.305	9	4	7
<i>Ferocactus cylindraceus</i>	16	27	3.475	0.062	17	6	10
<i>Galium stellatum</i>	11	23	4.022	0.048	12	6	3
<i>Hymenoclea salsola</i>	14	14	0.000	1.000	9	9	5
<i>Hyptis emoryi</i>	4	5	0.116	0.734	2	1	3
<i>Juniperus californica</i>	23	18	0.745	0.490	1	6	17
<i>Krameria erecta</i>	32	42	2.009	0.156	21	11	21
<i>Krameria grayi</i>	39	43	0.306	0.580	17	13	26
<i>Larrea tridentata</i>	69	73	0.303	0.582	8	4	65
<i>Lotus rigidus</i>	11	14	0.405	0.525	10	7	4
<i>Lycium andersonii</i>	18	11	1.938	0.164	6	13	5
<i>Pinus monophylla</i>	8	8	0.000	1.000	3	3	5
<i>Pleuraphis rigida</i>	14	16	0.154	0.695	9	7	7
<i>Quercus turbinella</i>	11	14	0.405	0.525	5	2	9
<i>Salazaria mexicana</i>	17	19	0.132	0.716	10	8	9
<i>Sphaerolacca ambigua</i>	31	15	6.987	0.008	9	25	6
<i>Thammosma montana</i>	15	14	0.040	0.842	11	12	3
<i>Bahiopsis parishi</i>	36	39	0.180	0.672	11	8	28
<i>Xylorhiza tortifolia</i>	27	17	2.822	0.093	10	20	7
<i>Yucca schidigera</i>	41	35	0.714	0.398	10	16	25

** Fischer's Exact Test

Individual Species Changes across Plots

In order to test the hypothesis of significant change for each species over time, an independent samples Student's t-statistical test was performed across plots for all species shared between 1979 and 2008 data and for each vegetation measurement of density, relative density, frequency, relative frequency, cover and relative cover. Relatively few species are reported with significantly different means for any of the measures. The only species which exhibits a consistent change across multiple vegetation measurements across plots from 1979 to 2008 was *Sphaeralcea ambigua* with significantly lower mean values. *Ferocactus cylindraceus* demonstrated higher mean density, mean relative density and mean relative frequency, however, failed to show a significant change in mean relative cover. *Ericameria laricifolia* and *E. linearifolia* are closely related species which often co-occupy the same plots. Whereas *Ericameria laricifolia* demonstrated a significantly decreased mean density, *E. linearifolia* became more numerous. *Galium stellatum* was shown to have significantly increased plot occupancy in 2008 data and yet results across plots report significantly decreased mean relative frequency and significantly decreased mean relative cover. Of the top ten species with the largest total density and largest total cover, *Larrea tridentata* had a significantly greater mean relative cover in 1979 as compared to 2008. Similarly, *Juniperus californica* had significantly lower mean relative density and lower mean relative frequency in 1979 as compared to 2008.

Results of the comparison of mean density between sampling years are presented in Table 5: Mean Density and Mean Relative Density by Species, 1979 and 2008. Five species were significantly different in mean density between 1979 and 2008. The top ten most numerous species in 1979 and 2008 are not significantly different in mean density

(appendices). Species which demonstrated a significant increase in mean density from 1979 to 2008 include: *Ericameria linearifolia* (10.75 vs. 43.30, $t=2.69$, $p=0.019$), and *Ferocactus cylindraceus* (6.26 vs. 13.24, $t=2.54$, $p=0.016$). Species which demonstrated a significant decrease in mean density from 1979 to 2008 include: *Ericameria laricifolia* (62.5 vs. 13.1, $t=-2.38$, $p=0.035$), *Lepidium fremontii* (8.00 vs. 2.00, $t=-6.57$, $p=0.007$), and *Sphaeralcea ambigua* (11.73 vs. 5.33, $t=-2.76$, $p=0.008$).

Five species were significantly different in mean relative density between 1979 and 2008. The top ten most numerous species are not significantly different in relative density measure (appendices). Species which demonstrated a significant increase in mean relative density from 1979 to 2008 include: *Ericameria linearifolia* (1.34 vs. 3.09, $t=3.09$, $p=0.0096$), *Ferocactus cylindraceus* (1.12 vs. 2.35, $t=3.27$, $p=0.0018$), and *Opuntia chlorotica* (0.10 vs. 0.17, $t=3.44$, $p=0.0264$). Species which demonstrated a significant decrease in mean density from 1979 to 2008 include: *Juniperus californica* (5.82 vs. 1.61, $t=-3.25$, $p=0.0032$) *Lepidium fremontii* (4.00 vs. 0.79, $t=-4.05$, $p=0.0271$).

Table 18 Mean Density and Mean Relative Density by Species, 1979 and 2008.

Species	Mean Density				Mean Relative Density			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>Ericameria laricifolia</i>	62.50	13.13	-2.38	0.0348	6.32	2.11	-1.84	0.0776
<i>Ericameria linearifolia</i>	10.75	43.30	2.69	0.0189	1.34	6.70	3.09	0.0096
<i>Ferocactus cylindraceus</i>	6.26	13.24	2.54	0.0160	1.12	2.35	3.27	0.0018
<i>Juniperus californica</i>	11.48	8.73	-1.53	NS	5.82	1.61	-3.25	0.0032
<i>Lepidium fremontii</i>	8.00	2.00	-6.57	0.0072	4.00	0.79	-4.05	0.0271
<i>Opuntia chlorotica</i>	1.00	1.20	1.00	NS	0.10	0.17	3.44	0.0264
<i>Pinus monophylla</i>	12.50	5.64	-2.03	0.0561	5.84	1.46	-1.62	0.1006
<i>Psoralea fremonti</i>	4.30	7.60	1.36	0.1971	1.88	5.72	2.11	0.0551
<i>Sphaeralcea ambigua</i>	11.73	5.33	-2.76	0.0078	3.58	1.07	-2.07	0.0448
<i>Bahiopsis parishi</i>	36.68	36.89	0.03	0.9793	5.91	8.72	1.96	0.0539

Note: Only species which showed a significant difference ($p \leq 0.05$) in either measurement were included in this table.

Results of the comparison of mean frequency and mean relative frequency between sampling years are presented in Table 6: Mean Frequency and Mean Relative Frequency by Species, 1979 and 2008. Twenty one species were significantly different in mean frequency between 1979 and 2008 as compared to 7 species which were significantly different in mean relative frequency (appendices). Raw frequency measure is not a useful measure of species change. The following species demonstrated a significant increase in mean relative frequency from 1979 to 2008: *Ferocactus cylindraceus* (1.55 vs. 4.09, $t=4.25$, $p=0.0002$), and *Mirabilis laevis* (1.15 vs. 3.48, $t=2.63$, $p=0.017$). The following species demonstrated a significant decrease in mean relative frequency from 1979 to 2008: *Galium stelatum* (4.64 vs. 1.79, $t=-2.70$, $p=0.0145$), *Juniperus californica* (5.80 vs. 3.25, $t=-2.75$, $p=0.009$), *Muhlenburgia porteri*

(5.50 vs. 1.29, $t=-2.31$, $p=0.04$), and *Sphaeralcea ambigua* (4.62 vs. 2.02, $t=-2.55$, $p=0.015$) and *Tetradymia stenolepis* (9.30 vs. 2.95, $t= 2.48$, $p=0.047$).

Table 19 Mean Frequency and Mean Relative Frequency by Species, 1979 and 2008.

Species	Mean Freq				Mean Relative Freq			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>Acacia greggi</i>	6.48	2.44	-4.25	0.0002	4.81	4.12	-0.79	0.4884
<i>Achnatherum speciosum</i>	21.00	10.79	-1.96	0.0597	9.35	8.47	-0.35	NS
<i>Ambrosia dumosa</i>	27.49	17.59	-3.05	0.0028	26.31	29.58	0.96	NS
<i>Aristida purpurea</i>	15.75	4.18	-2.20	0.0469	5.45	3.54	-0.62	NS
<i>Bebbia juncea</i>	7.19	2.50	-2.20	0.0343	9.43	4.11	-1.48	NS
<i>Coleogyne ramosissima</i>	29.58	10.05	-3.13	0.0044	24.01	12.58	-1.96	0.0597
<i>Cylindropuntia acanthocarpa</i>	6.89	2.59	-3.27	0.0027	4.90	3.14	-1.68	0.1007
<i>Cylindropuntia echinocarpa</i>	3.00	1.33	-2.99	0.0305	2.50	2.40	-0.08	NS
<i>Encelia farinosa</i>	29.97	18.88	-2.07	0.0425	28.07	28.99	0.17	NS
<i>Ephedra nevadensis</i>	10.17	4.94	-3.45	0.0009	6.44	5.39	0.34	NS
<i>Eriogonum fasciculatum</i>	29.26	17.43	-3.24	0.0016	17.48	19.33	0.85	NS
<i>Erecaeria laricifolia</i>	32.00	6.43	-2.17	0.0508	11.70	4.43	-2.00	0.0688
<i>Ferocactus cylindraceus</i>	3.06	4.33	1.47	NS	1.55	4.09	4.25	0.0002
<i>Galium stellatum</i>	9.43	2.00	-2.48	0.0467	4.64	1.79	-2.70	0.0145
<i>Gutierrezia sarothrae</i>	13.13	5.21	-2.02	0.0571	7.39	3.71	-1.73	0.0991
<i>Hymenoclea salsola</i>	14.00	7.07	-2.01	0.0546	20.01	21.37	0.17	NS
<i>Juniperus californica</i>	10.65	3.89	-4.26	0.0002	5.80	3.25	-2.75	0.0091
<i>Krameria erecta</i>	7.35	4.69	-2.36	0.0208	5.23	5.46	0.24	NS
<i>Krameria grayi</i>	5.38	3.09	-2.77	0.0075	5.45	6.72	0.88	NS
<i>Larrea tridentata</i>	15.42	6.84	-6.45	0.00	20.55	16.41	-1.44	NS
<i>Lycium andersonii</i>	6.22	2.78	-2.28	0.0325	5.44	3.77	-1.17	NS
<i>Mirabilis bigelovii</i> var. <i>retorsa</i>	2.00	3.29	1.09	NS	1.15	3.48	2.63	0.0168
<i>Muhlenbergia porteri</i>	7.60	1.22	-2.67	0.0206	5.50	1.29	-2.31	0.0396
<i>Sphaeralcea ambigua</i>	6.74	2.00	-3.24	0.0027	4.62	2.02	-2.55	0.0149
<i>Tetradymia stenolepis</i>	10.00	2.00	-2.18	0.0688	9.30	2.95	-2.48	0.0465
<i>Thamnosma montana</i>	5.50	1.71	-3.25	0.005	3.20	2.20	-1.46	NS
<i>Bahiopsis parishi</i>	14.22	8.36	-2.36	0.0221	8.99	10.12	0.64	NS
<i>Yucca schidigera</i>	6.54	3.74	-3.41	0.0012	4.68	4.66	0.03	NS

Note: Only species which showed a significant difference ($p \leq 0.05$) in either measurement were included in this table.

Results of the comparison of mean cover and mean relative cover between sampling years are presented in Table 7: Mean Cover and Mean Relative Cover by Species, 1979 and 2008. Sixteen species were significantly different in mean cover between 1979 and 2008 compared to 7 species which were significantly different for mean relative cover between 1979 and 2008. Comparisons of raw cover measures can detect observer bias in visual estimation data as well as temporal variations in foliar development and are therefore a less useful measure of species change. The top ten species with the largest total cover measures in 1979 and 2008 are not significantly different for mean relative cover (Appendix 3). The following species demonstrated a significant increase in mean relative cover from 1979 to 2008: *Keckiela antirrhinoides* (0.73 vs. 6.28, $t=2.94$, $p=0.035$), *Krameria grayi* (3.89 vs. 6.75, $t=2.33$, $p=0.023$), and *Rhus trilobata* (0.34 vs. 4.86, $t=5.03$, $p=0.0073$). The following species demonstrated a significant decrease in mean relative cover from 1979 to 2008: *Galium stelatum* (5.83 vs. 0.99, $t=-5.00$, $p=0.001$), *Muhlenburgia porteri* (4.07 vs. 0.30, $t=-5.20$, $p=0.0004$), *Pinus monophylla* (33.89 vs. 5.93, $t=-2.95$, $p=0.019$), and *Sphaeralcea ambigua* (2.83 vs. 0.75, $t=-2.29$, $p=0.0305$).

Table 20 Mean Cover and Mean Relative Cover by Species, 1979 and 2008.

Species	Mean % Cover				Mean Relative % Cover			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>Acamptopappus sphaerocephalus</i>	0.31	0.56	1.96	0.0554	6.37	4.16	-1.50	NS
<i>Ambrosia dumosa</i>	1.30	2.86	3.90	0.0002	28.54	24.85	-0.97	NS
<i>Artemesia ludoviciana</i>	0.31	0.04	-10.99	0.0016	1.00	0.24	-3.04	0.0557
<i>Coleogyne ramosissima</i>	2.45	2.54	0.10	0.9195	35.61	14.76	-2.02	0.0507
<i>Encelia farinosa</i>	1.70	3.39	2.34	0.024	39.39	28.26	-1.68	0.0978
<i>Encelia virginensis</i>	0.19	0.50	2.12	0.0528	3.30	4.78	0.88	0.3923
<i>Eriogonum fasciculatum</i>	1.06	2.21	4.42	<0.0001	14.07	16.51	1.06	NS
<i>Eriogonum inflatum</i>	0.05	0.12	2.07	0.045	1.23	2.06	0.97	NS
<i>Ericameria linearifolia</i>	0.29	0.98	2.18	0.047	1.83	5.45	2.07	0.0575
<i>Ferocactus cylindraceus</i>	0.13	0.33	2.98	0.0052	1.43	2.35	1.95	0.0591
<i>Galium stellatum</i>	0.37	0.13	-2.82	0.0115	5.83	0.99	-5.00	0.0012
<i>Keckiella antirrhinoides</i>	0.15	1.07	2.67	0.0417	0.73	6.28	2.94	0.0305
<i>Krameria erecta</i>	0.26	0.59	4.50	<0.0001	4.63	4.78	0.18	0.8581
<i>Krameria grayi</i>	0.16	0.73	5.07	<0.0001	3.89	6.75	2.33	0.0226
<i>Larrea tridentata</i>	0.66	2.80	8.45	<0.0001	21.56	28.20	1.80	0.074
<i>Lycium andersonii</i>	0.27	0.54	2.07	0.049	4.95	3.62	-0.71	NS
<i>Muhlenburgia porteri</i>	0.26	0.04	-4.34	0.0015	4.07	0.30	-5.20	0.0004
<i>Mirabilis laevis</i>	0.03	0.15	2.83	0.0179	0.85	1.25	0.51	0.6832
<i>Pinus monophylla</i>	13.20	1.72	-1.86	0.0839	33.89	5.93	-2.95	0.019
<i>Psoralea fremontii</i>	0.09	0.53	5.44	0.0016	2.78	6.47	2.12	0.0782
<i>Rhus trilobata</i>	0.16	1.62	15.71	<0.0001	0.34	4.86	5.03	0.0073
<i>Sphaeralcea ambigua</i>	0.17	0.10	-0.93	NS	2.83	0.75	-2.29	0.0305
<i>Bahiopsis parishii</i>	0.42	1.22	4.19	0.0001	9.44	10.11	0.26	NS
<i>Yucca schidigera</i>	0.59	1.65	3.29	0.0017	9.32	7.89	-0.86	NS

Note: Only species which showed a significant difference ($p \leq 0.05$) in either measurement were included in this table.

Individual Species Change within Plots

In order to test the hypothesis of significant change for each species over time, plots surveyed in 1979 were paired with the corresponding plots surveyed in 2008. For each of these plots, vegetation measurements including density, relative density, frequency, relative frequency, cover and relative cover were compared by calculating a within plot change equal to the measurement in 1979 minus the measurement in 2008. For each species, the mean change in each of the measurements within plots was

compared using a paired samples Students t-statistical test. Similar to results for across plot measures, relatively few species were reported with significant differences in measures within 1979 and 2008 paired plots. The only species which showed a consistent change across multiple vegetation measurements within paired plots from 1979 to 2008 was *Coleogyne ramosissima* with significantly lower mean values. *Coleogyne ramosissima* is among the top ten species in density and cover and was not reported significantly different for across plot measures. *Juniperus californica*, *Eriogonum fasciculatum* and *Larrea tridentata* were also top ten species which showed significant differences for at least one measure within plots comparisons. Results for *Ferocactus cylindraceus* were identical to across plot measures. *Ferocactus cylindraceus* was reported to have significantly higher mean density, relative density and relative frequency without a significant higher mean relative cover. *Sphaeralcea ambigua* was significantly less dense and less relatively dense.

Results of the comparison of mean density and mean relative density within paired plots are presented in Table 21: Paired Plot Changes in Density and Relative Density, 1979 and 2008. Five species were significantly different in mean density within paired plots. Mean density has increased for *Ferocactus cylindraceus* (mean change=-9.63, N=27, t=-2.76, p=0.01). The following species demonstrated a significant decrease in mean density: *Coleogyne ramosissima* (mean change=43.63, N=19, t=2.28, p=0.035), *Eriogonum fasciculatum* (mean change=33.62, N=68, t=2.45, p=0.017), *Gutierrezia sarothrae* (mean change=66.80, N=15, t=2.76, p=0.0155) and *Sphaeralcea ambigua* (mean change=10.65, N=20, t=2.59, p=0.018). Six species were significantly different in mean relative density within paired plots (Table 9). Only *Bahiopsis parishii* (mean

change=-3.62, N=28, t=-2.87, p=0.007) demonstrated a significant increase in mean relative density. The following species demonstrated a significant decrease in mean relative density: *Coleogyne ramosissima* (mean change=12.97, N=19, t=2.65, p=0.016), *Gutierrezia sarothrae* (mean change=-18.64, N=15, t=-2.21, p=0.044), *Juniperus californica* (mean change=3.39, N=22, t=3.99, p=0.0007) and *Sphaeralcea ambigua* (mean change=1.84, N=20, t=2.32, p=0.031).

Table 8 Paired Plot Changes in Density and Relative Density, 1979 and 2008.

Species	n _{1,2}	Mean Δ Density	t*	p	Mean Δ Relative Density	t*	p
<i>Acacia greggi</i>	29	-5.14	-1.17	NS	-1.81	-1.16	NS
<i>Acamptopappus sphaerocephalus</i>	20	6.30	0.77	NS	0.05	0.02	NS
<i>Achnatherum speciosum</i>	23	18.52	0.96	NS	-2.73	-1.47	NS
<i>Ambrosia dumosa</i>	66	18.91	1.20	NS	1.87	0.69	NS
<i>Bebbia juncea</i>	18	0.78	0.16	NS	2.62	0.75	NS
<i>Coleogyne ramosissima</i>	19	43.63	2.28	0.0349	12.97	2.65	0.0163
<i>Cylindropuntia acanthocarpa</i>	21	2.67	0.83	NS	-0.86	-1.57	NS
<i>Cylindropuntia ramosissima</i>	14	-0.75	-0.20	NS	-4.17	-0.75	NS
<i>Echinocereus englemanni</i>	25	-4.24	-1.22	NS	-0.27	-0.56	NS
<i>Encelia farinosa</i>	29	-12.34	-0.45	NS	-3.25	-0.73	NS
<i>Encelia virginensis</i>	12	-2.08	-0.33	NS	-1.54	-1.15	NS
<i>Ephedra nevadensis</i>	45	-0.44	-0.14	NS	0.05	0.06	NS
<i>Eriogonum fasciculatum</i>	68	33.62	2.45	0.0171	1.04	0.50	NS
<i>Ericameria laricifolia</i>	10	47.90	1.99	0.0774	4.58	1.51	NS
<i>Eriogonum wrightii</i>	10	26.00	0.90	NS	1.14	0.37	NS
<i>Ferocactus cylindraceus</i>	27	-9.63	-2.76	0.0104	-1.79	-3.68	0.0011
<i>Galium stellatum</i>	11	5.82	1.58	NS	0.55	1.00	NS
<i>Gutierrezia sarothrae</i>	15	66.80	2.76	0.0155	-18.64	-2.21	0.0441
<i>Hymenoclea salsola</i>	13	8.08	0.90	NS	-2.84	-0.55	0.5919
<i>Juniperus californica</i>	22	3.45	1.93	0.0668	3.39	3.99	0.0007
<i>Krameria erecta</i>	27	-3.74	-0.70	NS	-1.07	-1.15	NS
<i>Krameria grayi</i>	45	0.62	0.47	NS	-1.26	-1.64	NS
<i>Larrea tridentata</i>	70	-2.57	-0.59	NS	0.51	0.27	NS
<i>Lycium andersonii</i>	15	3.07	1.04	NS	0.52	0.65	NS
<i>Quercus turbinella</i>	13	6.46	0.55	NS	2.42	0.85	NS
<i>Salazaria mexicana</i>	15	16.80	1.00	NS	-1.30	-0.67	NS
<i>Sphaeralcea ambigua</i>	20	10.65	2.59	0.0179	1.84	2.32	0.0314
<i>Thamnosia montana</i>	13	-1.54	-1.04	NS	-0.31	-0.98	NS
<i>Bahiopsis parishii</i>	28	-0.94	-0.15	NS	-3.62	-2.87	0.0072
<i>Xylorhiza tortifolia</i>	15	-1.53	-0.30	NS	-1.15	-0.66	NS
<i>Yucca schidigera</i>	42	2.55	1.45	NS	0.75	1.39	NS

* Pairwise t-test on matching plots

 Δ Density=Density(past)-Density(present)

Results of the comparison of mean frequency and mean relative frequency within paired plots are presented in Table 9: Paired Plot Changes in Frequency and Relative

Frequency, 1979 and 2008. Eleven species demonstrated a significantly different mean frequency within paired plots as compared with only three species with differences in mean relative frequency. Only *Ferocactus cylindraceus* demonstrated a significant increase in mean relative frequency (mean change=-3.53, N=10, t=-3.26, p=0.0098). Among the top ten species, both *Coleogyne ramosissima* (mean change=13.03, N=19, t=2.97, p=0.0091) and *Juniperus californica* (mean change=2.41, N=17, t=2.22, p=0.042) demonstrated a significant decrease in mean relative frequency.

Table 9 Paired Plot Changes in Frequency and Relative Frequency, 1979 and 2008.

Species	n _{1,2}	Mean Δ Frequency	t*	p	Mean Δ Relative Frequency	t*	p
<i>Acacia greggi</i>	12	2.83	2.03	0.0675	-0.54	-0.44	NS
<i>Acamptopappus sphaerocephalus</i>	15	4.80	2.20	0.0450	-0.03	-0.01	NS
<i>Achnatherum speciosum</i>	17	10.41	1.91	0.0746	0.08	0.03	NS
<i>Ambrosia dumosa</i>	56	10.73	3.67	0.0006	-2.71	-0.91	NS
<i>Bebbia juncea</i>	9	4.56	1.00	NS	5.43	0.81	NS
<i>Coleogyne ramosissima</i>	17	21.24	4.08	0.0009	13.03	2.97	0.0091
<i>Cylindropuntia acanthocarpa</i>	6	5.43	3.22	0.0182	2.87	1.63	NS
<i>Cylindropuntia ramosissima</i>	4	-0.75	-0.20	NS	-4.17	-0.75	NS
<i>Echinocereus engelmannii</i>	7	-0.57	-0.37	NS	-1.53	-2.07	0.0844
<i>Encelia farinosa</i>	27	1.83	0.61	NS	-1.08	-0.49	NS
<i>Encelia virginensis</i>	6	9.33	1.95	0.0614	-4.26	-1.03	NS
<i>Ephedra nevadensis</i>	31	4.93	3.28	0.0026	-0.15	-0.11	NS
<i>Eriogonum fasciculatum</i>	58	14.12	5.43	<0.0001	-0.30	-0.18	NS
<i>Eriogonum wrightii</i>	7	5.86	1.24	NS	0.09	0.96	NS
<i>Ferocactus cylindraceus</i>	10	-2.25	-1.89	0.0909	-3.53	-3.26	0.0098
<i>Galium stellatum</i>	3	2.67	3.02	0.0942	0.60	0.51	NS
<i>Hymenoclea salsola</i>	5	8.60	1.84	NS	-18.57	-1.57	NS
<i>Hyptis emoryi</i>	3	-2.33	-0.82	NS	-2.21	-2.03	NS
<i>Juniperus californica</i>	17	7.53	3.80	0.0016	2.41	2.22	0.0416
<i>Krameria erecta</i>	21	1.05	0.87	NS	-2.15	-2.07	0.0513
<i>Krameria grayi</i>	26	2.65	2.74	0.0113	-1.02	-0.81	NS
<i>Larrea tridentata</i>	65	5.55	6.62	<0.0001	3.77	1.38	NS
<i>Lotus rigidus</i>	4	-3.75	-0.77	NS	-4.83	-1.56	NS
<i>Lycium andersonii</i>	5	2.40	0.85	NS	0.93	0.36	NS
<i>Pinus monophylla</i>	5	19.00	1.77	NS	7.41	1.83	NS
<i>Pleuraphis rigida</i>	7	2.13	0.90	NS	-2.09	-0.99	NS
<i>Quercus turbinella</i>	9	11.00	2.01	0.0788	-0.69	-0.22	NS
<i>Salazaria mexicana</i>	9	6.33	0.28	NS	-4.67	-2.51	NS
<i>Sphaeralcea ambigua</i>	6	10.00	2.04	NS	6.79	1.83	NS
<i>Thamnosma montana</i>	3	2.67	1.14	NS	0.96	1.07	NS
<i>Bahiopsis parishii</i>	28	7.39	2.94	0.0066	-1.47	-0.83	NS
<i>Xylorhiza tortifolia</i>	7	1.75	1.59	NS	-0.33	-0.26	NS
<i>Yucca schidigera</i>	25	2.36	2.43	0.0227	-0.28	-0.36	NS

* Pairwise t-test on matching plots

Mean Δ Frequency=Frequency(past)-Frequency(present)

Results of the comparison of mean cover and mean relative cover within paired plots are presented in Table 10: Paired Plot Changes in Cover and Relative Cover, 1979

and 2008. Nine species demonstrated a significantly different mean cover within paired plots as compared with four species with differences in mean relative cover. Among the top ten species, both *Coleogyne ramosissima* and *Larrea tridentata* exhibited significant changes in mean relative cover. The following species demonstrated a significant increase in mean relative cover: *Krameria grayi* (mean change=-3.30, N=25, t=-3.05, p=0.0055) and *Larrea tridentata* (mean change=-8.12, N=62, t=-2.31, p=0.0240). *Coleogyne ramosissima* (mean change=13.03, N=19, t=2.97, p=0.0091) and *Gutierrezia sarothrae* (mean change=2.41, N=17, t=2.22, p=0.0416) demonstrated a significant decrease in mean relative cover.

Table 10 Paired Plot Changes in Cover and Relative Cover, 1979 and 2008.

Species	n _{1,2}	Mean Δ Cover	t*	p	Mean Δ Relative Cover	t*	p
<i>Acacia greggi</i>	12	-0.74	-2.21	0.0489	-4.74	-1.56	NS
<i>Acamptopappus sphaerocephalus</i>	15	-0.28	-1.63	NS	2.52	1.35	NS
<i>Achnatherum speciosum</i>	17	-0.29	-1.74	0.1017	-0.89	-0.74	NS
<i>Ambrosia dumosa</i>	58	-1.64	-4.58	<0.0001	4.80	1.44	NS
<i>Coleogyne ramosissima</i>	17	-0.27	-0.37	NS	11.39	2.39	0.0298
<i>Encelia farinosa</i>	25	-2.41	-3.01	0.0061	5.59	1.00	NS
<i>Ephedra nevadensis</i>	28	-0.61	-1.91	0.0670	1.17	0.57	NS
<i>Ephedra viridus</i>	2	0.30	0.88	NS	0.80	0.83	NS
<i>Eriogonum fasciculatum</i>	52	-1.10	-4.50	<0.0001	-0.55	-0.27	NS
<i>Ferocactus cylindraceus</i>	9	-0.22	-1.86	0.1003	-1.39	-1.58	NS
<i>Gutierrezia sarothrae</i>	10	0.39	2.15	0.0601	5.22	2.76	0.0222
<i>Juniperus californica</i>	17	-0.75	-1.28	NS	0.69	0.21	NS
<i>Krameria erecta</i>	27	-0.48	-4.31	0.0003	-0.95	-0.84	NS
<i>Krameria grayi</i>	25	-0.63	-4.41	0.0002	-3.30	-3.05	0.0055
<i>Larrea tridentata</i>	62	-2.40	-8.68	<0.0001	-8.12	-2.31	0.0240
<i>Quercus turbinella</i>	9	1.28	0.55	NS	0.68	0.15	NS
<i>Bahiopsis parishii</i>	28	-1.03	-4.53	0.0001	-1.76	-0.56	NS
<i>Yucca schidigera</i>	26	-0.50	-2.87	0.0082	2.75	1.63	NS

* Pairwise t-test on matching plots

Mean Δ Cover= Mean Cover(past)- Mean Cover(present)

Correlation Matrix Results

In order to test the hypothesis that changes detected in density of certain species is significantly related to environmental variables, tests for multicollinearity between individual species absolute change and the environmental variables of Easting, Northing, elevation, slope, temperature, precipitation, duration of sun exposure at winter solstice and heat loading capacity during summer solstice yielded no criterion variables at a significant level of multicollinearity for any of the 11 selected species. Results from the correlation matrix are detailed in Appendix 4.

Non-Metric Multidimensional Scaling

Graphical ordination of plots can be helpful in visualizing patterns in paired plot locations (1979 and 2008). NMS analysis was run in Autopilot thorough mode with Sørensen (Bray-Curtis) distance measure using a random starting configuration with 500 iterations. Community composition as measured by relative cover was chosen for graphical representation because this was the only abundance measure that showed a significant difference between community composition between 1979 and 2008. Final stress for the 3 dimensional solution of community composition as measured by relative cover for ordinated paired plots (1979 and 2008) is 15.555 and final instability is 0.002. No obvious directional drift of plot locations were visibly noted in different graphed ordinations including directional vector analysis (Figs. 4-6). Paired plots maintain general regions that correspond to grouping criteria of soil type and vegetation group in NMS ordinations. Computed Sørensen (Bray-Curtis), dissimilarity measures between paired plots were used to further analyze differences between categorical environmental

variables and possible correlations of dissimilarity measures with continuous environmental variables. These dissimilarity measures represent a geometric measure of difference between paired plots from 1979 to 2008.

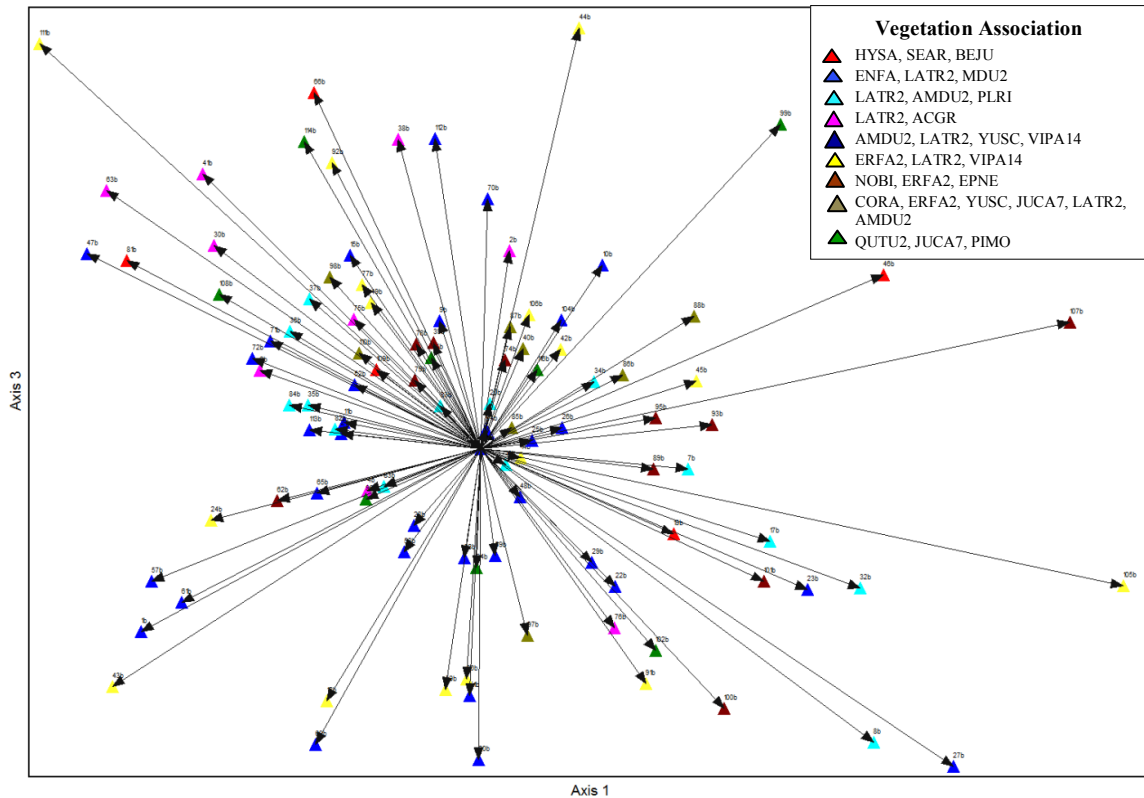


Figure 5 2-dimensional diagram (axis 1 and 3) of successional vectors translated to origin (1979) displaying magnitude and direction of community composition change, as measured by relative cover, of plots between 1979 and 2008 with color coded groups denoting vegetation types. Successional vector diagrams were used to visualize patterns in community composition change between sample years in NMS ordination. Each pair of plots were translated to origin, meaning that all 103 plots sampled in 1979 are located at (0, 0) of the 2-dimensional successional vector diagram (McCune & Mefford, 1999). The corresponding paired 2008 plots were graphed in 2-dimensional space around the origin and connected with vector lines so that direction and magnitude of community composition change as measured by relative cover in ordination space were visualized.

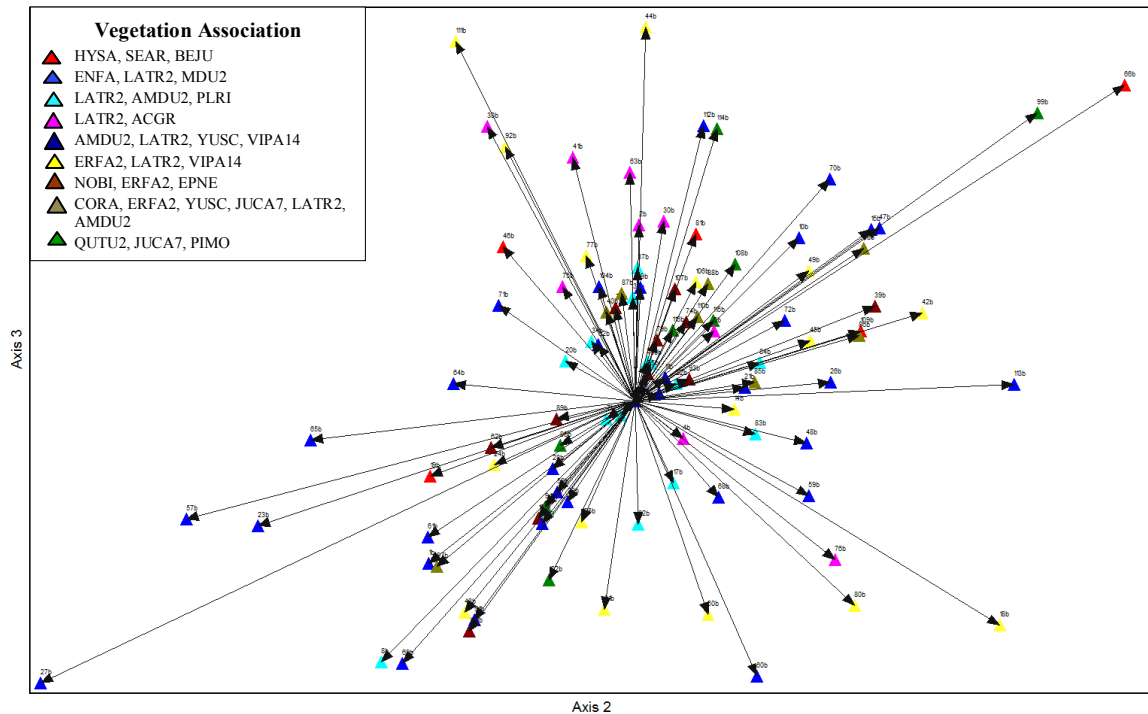


Figure 6 2-dimensional diagram (axis 2 and 3) of successional vectors translated to origin (1979) displaying magnitude and direction of community composition change, as measured by relative cover, of plots between 1979 and 2008 with color coded groups denoting vegetation groups. Successional vector diagrams were used to visualize patterns in community composition change between sample years in NMS ordination. Each pair of plots were translated to origin, meaning that all 103 plots sampled in 1979 are located at (0, 0) of the 2-dimensional successional vector diagram (McCune & Mefford, 1999). The corresponding paired 2008 plots were graphed in 2-dimensional space around the origin and connected with vector lines so that direction and magnitude of community composition change as measured by relative cover in NMS ordination space were visualized.

Multiple Response Permutation Procedure Results

In order to test the hypothesis of significant differences between community compositions among paired plots over time we applied Blocked Multiple Response Permutation Procedure (MRBP). Results of MRBP indicate no significant difference between 1979 and 2008 for the majority of the vegetation measures with the exception of relative cover. The measures which were not significantly different include density, relative density, transformed density, transformed relative density, relative frequency, transformed relative frequency and transformed relative cover. With the exception of the significant difference in relative cover ($A=0.003$, $p=0.04$), the most methodologically observer biased measures are also those measures for which community composition is significantly different. These include frequency ($A=0.012$, $p<0.001$), transformed frequency ($A=0.012$, $p<0.001$), cover ($A=0.025$, $p<0.001$), and transformed cover ($A=0.025$, $p<0.001$). Transformation of data had little effect on MRBP results; however, relative cover is the only measure for which significance varied from raw to transformed data. Although relative cover transformed was approaching significance, the inclusion of species which have low rank order of cover values influenced the significant difference between community composition as measured by relative cover in 1979 and 2008 (See Table 11).

Table 11 Multiple Response Permutation Procedure Results.

Measure	A Statistic	p
Density	0.00045969	0.2843
Density†	0.00035351	0.3108
Relative Density	0.00031149	0.3203
Relative Density†	0.00010369	0.3676
Frequency*	0.01183483	<0.0001
Frequency†*	0.01210383	<0.0001
Relative Frequency	-0.00010246	0.4204
Relative Frequency†	-0.00034251	0.4842
Cover*	0.02519621	<0.0001
Cover†*	0.02455377	<0.0001
Relative Cover*	0.00308564	0.0433
Relative Cover†	0.00293491	0.0520

†Transformed data with combined related species and removal of all species with < 3 occurrences.

*p<0.05

Computed Dissimilarity Measures

In order to test the hypothesis of greater change in community composition for high elevation associated communities, non-parametric ANOVA was performed to evaluate differences in the dissimilarity measures between paired plots as calculated for density, density transformed, relative density, relative density transformed, relative cover and relative cover transformed, within elevation groups, vegetation association groups, and soil types. These distances represent a geometric measure of difference among plots from 1979 to 2008. Pearson's Correlation coefficient was calculated for each dissimilarity measure between paired plots as calculated from density, relative density, relative frequency and relative cover against each environmental variable including

Easting, Northing, elevation (feet), slope, heat loading capacity (Watt/m²), and duration of sunlight (hours). The results were used to exclude variables exhibiting multicollinearity from multiple linear regression analysis. Results of the resultant correlation matrix indicated no significant correlation among variables (Appendix 4).

No significant differences in mean Dissimilarity measures calculated with density, density transformed, relative density, relative density transformed, relative cover and relative cover transformed were observed among different elevation groups. Similarly, no significant differences in mean dissimilarity measures calculated with density, density transformed, relative density, relative density transformed, relative cover and relative cover transformed were observed among different vegetation association groups.

ANOVA test results for differences in dissimilarity measures among soil associations were very similar across all measures. In all measures tested, Kidwell-Tenwell association soils were significantly different than Nolena-Rock outcrop association, Cetrepas-Nolena-Rock outcrop association, and Seanna-Goldroad-Rock outcrop association. Significant difference in mean Dissimilarity measures between Kidwell-Tenwell and Cetrepas-Nolena-Rock outcrop association were reported for all measures except density. ANOVA results for the density measure additionally reports a significant difference between mean Dissimilarity measures of Newera association and Nolena-Rock outcrop association soils groups.

At least one grouping of mean Dissimilarity measures calculated with relative cover transformed was significantly different among soil associations ($p_e=0.03369$). Differences in Dissimilarity measures of relative cover transformed were observed between Kidwell-Tenwell and Nolena-Rock outcrop ($p_e= 0.0068$), Kidwell-Tenwell and

Seanna-Goldroad-Rock outcrop association ($p_e = 0.00057$), and Kidwell-Tenwell and Cetrepas-Nolena-Rock outcrop association soils ($p_e = 0.0196$). For complete comparisons of Dissimilarity measures for relative cover transformed by soil type refer to Table 12. At least one mean Dissimilarity measures calculated with relative cover was significantly different among soil associations ($p_e = 0.045$). Differences in Dissimilarity measures of relative cover were observed between Kidwell-Tenwell and Nolena-Rock outcrop ($p_e = 0.0045$), Kidwell-Tenwell and Seanna-Goldroad-Rock outcrop association ($p_e = 0.048$), and Kidwell-Tenwell and Cetrepas-Nolena-Rock outcrop association soils ($p_e = 0.0385$). For complete comparisons of Dissimilarity measures for relative cover by soil type refer to Table 13. At least one grouping of mean Dissimilarity measures calculated with density transformed was significantly different among soil associations ($p_e = 0.014$). Differences in Dissimilarity measures of transformed relative cover were observed between Kidwell-Tenwell and Nolena-Rock outcrop association ($p_e = 0.023$) and Kidwell-Tenwell and Seanna-Goldroad-Rock outcrop association ($p_e = 0.044$). For complete comparisons of Dissimilarity measures for transformed relative cover by soil type refer to Table 14. At least one mean Dissimilarity measures calculated with relative density transformed was significantly different among soil type ($p_e = 0.024$). Differences in Dissimilarity measures of relative cover transformed were observed between Kidwell-Tenwell and Nolena-Rock outcrop ($p_e = 0.008$), Kidwell-Tenwell and Seanna-Goldroad-Rock outcrop association ($p_e = 0.090$), and Kidwell-Tenwell and Cetrepas-Nolena-Rock outcrop association soils ($p_e = 0.0076$). For complete comparisons of Dissimilarity measures for relative density transformed by soil type refer to Table 15. At least one grouping of mean Dissimilarity measures calculated with density was significantly

different among soil type ($p_e=0.034$). Differences in Dissimilarity measures of density were observed between Newera association and Nolena-Rock outcrop association ($p_e=0.0325$), Kidwell-Tenwell and Nolena-Rock outcrop ($p_e=0.017$), Kidwell-Tenwell and Seanna-Goldroad-Rock outcrop association ($p_e=0.0213$), and Kidwell-Tenwell and Cetrepas-Nolena-Rock outcrop association soils ($p_e=0.0098$). For complete comparisons of Dissimilarity measures for transformed relative cover by soil type refer to Table 16.

Table 12 ANOVA Results for Dissimilarity measures Calculated with Density Values by Elevation and Vegetation Association, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Elevation			0.4121	
Low (<1,800 ft)	24	0.4743 (0.22)		
Medium (1,800 - 3,499)	53	0.5338 (0.19)		
High (>3,500)	25	0.5409 (0.18)		
Low*Medium			0.4371	-10.775 (-27.375, 7.229)
Low*High			0.4633	-10.775 (-30.872, 9.322)
Medium*High			0.9875	-0.702 (-17.764, 16.360)
Vegetation Association			0.1586	
ENFA	22	0.4849 (0.23)		
LATR/AMDU	33	0.4723 (0.18)		
ERFA	26	0.5816 (0.18)		
JUCA	16	0.5298 (0.17)		
ENFA*LATR/AMDU			0.9958	0.939 (-20.058, 21.937)
ENFA*ERFA			0.3264	-15.416 (-37.515, 6.683)
ENFA*JUCA			0.9037	-6.955 (-32.019, 3.649)
LATR/AMDU*ERFA			0.1490	-16.355 (-36.360, 3.649)
LATR/AMDU*JUCA			0.7732	-7.894 (-31.133, 15.346)
ERFA*JUCA			0.8434	8.462 (-15.778, 32.701)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

* $p<0.05$

Table 13 ANOVA Results for Dissimilarity measures Calculated with Relative Cover Transformed Values by Soil Type, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Map Unit Symbol (Soil Type)			0.0369	
100	5	0.4326 (0.14)		
111	8	0.5084 (0.16)		
180	10	0.3496 (0.19)		
470	5	0.5822 (0.27)		
520	10	0.6553 (0.18)		
532	17	0.5581 (0.12)		
610	14	0.4525 (0.23)		
640	19	0.5928 (0.18)		
100*111			0.9957	-10.350 (-52.789, 32.089)
100*180			0.9911	6.100 (-34.674, 46.874)
100*470			0.8940	-17.000 (-64.082, 30.082)
100*520			0.3409	-31.400 (-72.174, 9.374)
100*532			0.8723	-17.718 (-55.590, 20.155)
100*610			1.0000	-5.60 (-44.384, 33.184)
100*640			0.6470	-23.179 (-60.596, 14.238)
111*180			0.5887	16.450 (-18.861, 51.761)
111*470			0.9961	-6.650 (49.089, 35.789)
111*520			0.6807	21.050 (-56.361, 14.261)
111*532			0.9979	-7.368 (-39.285, 24.549)
111*610			0.9967	4.750 (-28.243, 37.743)
180*470			0.2892	-23.100 (-63.874, 17.674)
180*520			0.0068	-37.500 (-70.792, -4.208)*
180*532			0.0057	-23.100 (-63.874, -2.850)*
180*610			0.8682	-11.700 (-42.522, 19.122)
180*640			0.0196	-29.279 (-58.362, -0.196)*
470*520			0.9956	-14.400 (-56.739, 27.939)
470*532			1.0000	-7.368 (-40.510, 25.774)
470*610			0.8676	11.400 (-28.872, 51.672)
470*640			1.0000	-12.829 (-45.408, 19.750)
520*532			0.8806	13.682 (-17.124, 44.488)
520*610			0.1421	25.800 (-6.205, 57.805)
520*640			0.9875	8.221 (-21.978, 38.420)
532*610			0.7390	12.118 (-15.780, 40.015)
532*640			0.9992	-5.461 (-31.268, 20.345)
610*640			0.3678	-17.579 (-44.806, 9.648)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 14 ANOVA Results for Dissimilarity measures Calculated with Relative Cover Values by Elevation and Vegetation Association, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Elevation			0.5263	
Low (<1,800 ft)	24	0.4716 (0.22)		
Medium (1,800 - 3,499)	53	0.5273 (0.19)		
High (>3,500)	25	0.5092 (0.18)		
Low*Medium			0.4899	-9.971 (-24.425, 4.483)
Low*High			0.7837	-6.572 (-23.360, 10.217)
Medium*High			0.9282	3.399 (-10.854, 17.653)
Vegetation Association			0.2067	
ENFA	22	0.4836 (0.23)		
LATR/AMDU	33	0.4676 (0.19)		
ERFA	26	0.5738 (0.18)		
JUCA	16	0.4950 (0.17)		
ENFA*LATR/AMDU			0.9915	0.939 (-20.058, 21.931)
ENFA*ERFA			0.1162	-15.416 (-32.515, 2.683)
ENFA*JUCA			0.9984	-5.955 (-31.019, 6.649)
LATR/AMDU* ERFA			0.1724	-12.355 (-36.360, 3.649)
LATR/AMDU*JUCA			0.9687	-7.894 (-31.133, 15.346)
ERFA*JUCA			0.5860	8.462 (-15.778, 32.701)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 15 ANOVA Results for Dissimilarity measures Calculated with Relative Cover Values by Soil Type, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
100	5	0.4316 (0.17)		
111	8	0.4912 (0.15)		
180	10	0.3291 (0.18)		
470	5	0.5780 (0.28)		
520	10	0.6493 (0.17)		
532	17	0.5567 (0.12)		
610	14	0.4509 (0.23)		
640	19	0.5579 (0.19)		
100*111			0.9989	-9.275 (-51.579, 33.029)
100*180			0.9675	9.200 (-31.445, 49.845)
100*470			0.9076	-16.800 (-63.733, 30.133)
100*520			0.3738	-31.500 (-72.145, 9.145)
100*532			0.8783	-18.871 (-56.623, 18.882)
100*610			1.0000	-5.686 (-44.347, 32.975)
100*640			0.8642	-18.611 (-55.909, 18.688)
111*180			0.5745	18.475 (-16.724, 53.674)
111*470			0.99	-7.525 (-49.829, 34.779)
111*520			0.6047	-22.225 (-57.424, 12.974)
111*532			0.9898	-9.596 (-41.412, 22.220)
111*610			0.9995	3.589 (-29.299, 36.478)
180*470			0.2128	-26.00 (-66.645, 14.645)
180*520			0.0045	-40.700 (-73.886, -7.514)*
180*532			0.0476	-28.071 (-57.644, -1.503)*
180*610			0.7412	-14.886 (-45.610, 15.839)
180*640			0.0385	-27.811 (-56.802, -1.181)*
470*520			0.9957	-14.700 (-55.345, 25.945)
470*532			1.0000	-2.071 (-39.823, 35.682)
470*610			0.8831	11.114 (-27.547, 49.775)
470*640			1.0000	-1.811 (-39.109, 35.488)
520*532			0.9053	12.629 (-16.944, 42.203)
520*610			0.1621	25.814 (-4.910, 56.539)
520*640			0.9026	12.889 (-16.102, 41.881)
532*610			0.7448	13.185 (-13.597, 39.966)
532*640			1	0.260 (-24.514, 25.034)
610*640			0.7092	-12.925 (-39.062, 13.212)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 16 ANOVA Results for Dissimilarity measures Calculated with Density Transformed Values by Elevation and Vegetation Association, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Elevation			0.5324	
Low (<1,800 ft)	24	0.4719 (0.20)		
Medium (1,800 - 3,499)	53	0.5147 (0.19)		
High (>3,500)	25	0.4756 (0.15)		
Low*Medium			0.6095	-7.736 (-25.118, 9.646)
Low*High			0.9972	-2.384 (-22.574, 17.805)
Medium*High			0.6539	5.352 (-11.789, 22.493)
Vegetation Association			0.5034	
ENFA	22	0.4684 (0.19)		
LATR/AMDU	33	0.4735 (0.18)		
ERFA	26	0.5367 (0.19)		
JUCA	16	0.4855 (0.15)		
ENFA*LATR/AMDU			0.9996	-2.030 (-23.071, 19.010)
ENFA*ERFA			0.5575	-15.416 (-37.515, 6.683)
ENFA*JUCA			0.9924	-4.966 (-30.082, 20.151)
LATR/AMDU* ERFA			0.5403	-8.926 (-28.972, 11.120)
LATR/AMDU*JUCA			0.9970	-2.936 (-26.223, 20.352)
ERFA*JUCA			0.8048	5.990 (-18.299, 30.280)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 22 ANOVA Results for Dissimilarity measures Calculated with Density Transformed Values by Soil Type, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Map Unit Symbol (Soil Type)			0.0136	
100	5	0.4232 (0.22)		
111	8	0.5307 (0.13)		
180	10	0.3359 (0.16)		
470	5	0.5703 (0.15)		
520	10	0.5812 (0.17)		
532	17	0.5398 (0.16)		
610	14	0.4564 (0.18)		
640	19	0.5155 (0.16)		
100*111			0.9415	-19.100 (-62.131, 23.931)
100*180			0.9756	9.400 (-31.943, 50.743)
100*470			0.8408	-23.00 (-70.739, 24.739)
100*520			0.6420	-26.00 (-67.343, 15.343)
100*532			0.8509	-19.129 (-57.530, 19.721)
100*610			1.0000	-6.529 (-45.853, 32.796)
100*640			0.9495	-15.916 (-53.855, 22.023)
111*180			0.2020	28.500 (-7.304, 64.304)
111*470			0.9999	-3.900 (-46.931, 39.131)
111*520			0.9979	-6.900 (-42.704, 28.904)
111*532			1.0000	-0.029 (-32.392, 32.333)
111*610			0.9682	12.571 (-20.882, 46.025)
180*470			0.1601	-32.400 (-73.743, 8.943)
180*520			0.0225	-35.400 (-69.156, -1.644)*
180*532			0.0436	-28.529 (-58.611, -1.552)
180*610			0.6316	-15.929 (-47.181, 15.324)
180*640			0.1006	-25.316 (-54.805, 4.173)
470*520			1.0000	-3.000 (-44.343, 38.343)
470*532			1.0000	3.871 (-34.530, 42.271)
470*610			0.8793	16.471 (-22.853, 55.796)
470*640			0.9976	7.084 (-30.855, 45.023)
520*532			0.9982	6.871 (-23.211, 36.952)
520*610			0.5896	19.471 (-11.781, 50.724)
520*640			0.9673	10.084 (-19.405, 39.573)
532*610			0.8449	12.601 (-14.641, 39.842)
532*640			0.9999	3.214 (-21.986, 28.413)
610*640			0.9679	-9.387 (-35.973, 17.199)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 23 ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Elevation and Vegetation Association, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Elevation			0.4121	
Low (<1,800 ft)	24	0.4743 (0.22)		
Medium (1,800 - 3,499)	53	0.5338 (0.19)		
High (>3,500)	25	0.5409 (0.18)		
Low*Medium			0.4371	-10.775 (-27.375, 7.229)
Low*High			0.4633	-10.775 (-30.872, 9.322)
Medium*High			0.9875	-0.702 (-17.764, 16.360)
Vegetation Association			0.1586	
ENFA	22	0.4849 (0.23)		
LATR/AMDU	33	0.4723 (0.18)		
ERFA	26	0.5816 (0.18)		
JUCA	16	0.5298 (0.17)		
ENFA*LATR/AMDU			0.9958	0.939 (-20.058, 21.937)
ENFA*ERFA			0.3264	-15.416 (-37.515, 6.683)
ENFA*JUCA			0.9037	-6.955 (-32.019, 3.649)
LATR/AMDU* ERFA			0.1490	-16.355 (-36.360, 3.649)
LATR/AMDU*JUCA			0.7732	-7.894 (-31.133, 15.346)
ERFA*JUCA			0.8434	8.462 (-15.778, 32.701)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 19 ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Soil Type, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Map Unit Symbol (Soil Type)			0.0242	
100	5	0.4180 (0.23)		
111	8	0.4338 (0.14)		
180	10	0.2828 (0.16)		
470	5	0.5449 (0.18)		
520	10	0.5542 (0.19)		
532	17	0.4680 (0.12)		
610	14	0.4270 (0.19)		
640	19	0.5212 (0.14)		
100*111			1.0000	-7.875 (-50.591, 34.841)
100*180			0.7861	14.200 (-26.840, 55.240)
100*470			0.9156	-33.800 (-74.840, 7.240)
100*520			0.7829	-23.300 (-64.340, 17.740)
100*532			0.9986	-12.529 (-50.649, 25.590)
100*610			1.0000	-6.857 (-45.894, 32.180)
100*640			0.9059	-19.105 (-56.766, 18.556)
111*180			0.4970	22.075 (-13.467, 57.617)
111*470			0.9272	-11.725 (-54.441, 30.991)
111*520			0.7643	-15.425 (-50.967, 20.117)
111*532			0.9997	-4.654 (-36.780, 27.471)
111*610			1.0000	1.018 (-32.191, 34.226)
180*470			0.0736	-33.800 (-74.840, 7.240)
180*520			0.0080	-37.500 (-71.009, -3.991)
180*532			0.0898	-26.729 (-56.590, 3.132)
180*610			0.3779	-21.057 (-52.080, 9.966)
180*640			0.0076	-33.305 (-62.578, -4.032)
470*520			1.0000	-3.700 (-44.740, 37.340)
470*532			0.9808	7.071 (-31.049, 45.190)
470*610			0.8515	12.743 (-26.294, 51.780)
470*640			1.0000	0.495 (-37.166, 38.156)
520*532			0.8772	10.771 (-19.090, 40.632)
520*610			0.5459	16.443 (-14.580, 47.466)
520*640			0.9994	4.195 (-25.078, 33.468)
532*610			0.9963	5.672 (-21.370, 32.714)
532*640			0.9754	-6.576 (-31.591, 18.439)
610*640			0.7137	-12.248 (-387.640, 14.143)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 24 ANOVA Results for Dissimilarity measures Calculated with Density Values by Elevation and Vegetation Association, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Elevation			0.4121	
Low (<1,800 ft)	24	0.4743 (0.22)		
Medium (1,800 - 3,499)	53	0.5338 (0.19)		
High (>3,500)	25	0.5409 (0.18)		
Low*Medium			0.4371	-10.775 (-27.375, 7.229)
Low*High			0.4633	-10.775 (-30.872, 9.322)
Medium*High			0.9875	-0.702 (-17.764, 16.360)
Vegetation Association			0.1586	
ENFA	22	0.4849 (0.23)		
LATR/AMDU	33	0.4723 (0.18)		
ERFA	26	0.5816 (0.18)		
JUCA	16	0.5298 (0.17)		
ENFA*LATR/AMDU			0.9958	0.939 (-20.058, 21.937)
ENFA*ERFA			0.3264	-15.416 (-37.515, 6.683)
ENFA*JUCA			0.9037	-6.955 (-32.019, 3.649)
LATR/AMDU* ERFA			0.1490	-16.355 (-36.360, 3.649)
LATR/AMDU*JUCA			0.7732	-7.894 (-31.133, 15.346)
ERFA*JUCA			0.8434	8.462 (-15.778, 32.701)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Table 25 ANOVA Results for Dissimilarity measures Calculated with Relative Density Transformed Values by Soil Type, 1979 and 2008.

Measure	n	Mean (SD)	p†	Ranked Difference Between Means (95% CI)
Map Unit Symbol (Soil Type)			0.0058	
100	5	0.4234 (0.22)		
111	8	0.5355 (0.13)		
180	10	0.3382 (0.16)		
470	5	0.5907 (0.15)		
520	10	0.5843 (0.17)		
532	17	0.5117 (0.14)		
610	14	0.4589 (0.18)		
640	19	0.5641 (0.16)		
100*111			0.9193	-19.325 (-46.497, 7.847)
100*180			0.9169	8.500 (-17.606, 34.606)
100*470			0.7111	-26.400 (-56.545, 3.745)
100*520			0.0325	-27.200 (-53.306, -1.094)*
100*532			0.9573	-16.024 (-40.272, 8.225)
100*610			0.9999	-7.843 (-32.675, 16.989)
100*640			0.6485	-23.042 (-46.999, 0.915)
111*180			0.0597	27.825 (5.216, 50.434)*
111*470			0.9987	-7.075 (-34.247, 20.097)
111*520			0.9982	-7.875 (-30.484, 14.734)
111*532			1.0000	3.301 (-17.134, 23.737)
111*610			0.9587	11.482 (-9.642, 32.607)
180*470			0.0815	-7.057 (-34.327, 20.947)
180*520			0.0170	-35.700 (-57.016, -14.384)*
180*532			0.0213	-24.524 (-43.519, -5.528)*
180*610			0.5969	-16.343 (-36.077, 3.392)
180*640			0.0098	-31.542 (-50.163, -12.921)*
470*520			1.0000	-0.800 (-26.906, 25.306)
470*532			0.9771	10.376 (-13.872, 34.625)
470*610			0.7546	18.557 (-6.275, 43.389)
470*640			1.0000	3.358 (-20.599, 27.315)
520*532			0.9453	11.176 (-7.189, 30.172)
520*610			0.5481	19.357 (-0.377, 39.092)
520*640			1.0000	4.158 (-14.463, 22.779)
532*610			0.9846	8.181 (-9.021, 25.383)
532*640			0.9755	-7.019 (-22.931, 8.984)
610*640			0.5671	-15.199 (-31.987, 1.589)

Note: Ranked difference between means calculated using Tukey Method

†Permutation p value calculated using the Monte Carlo Method

*p<0.05

Stepwise Multiple Linear Regression Results

In order to test the hypothesis that community composition change over time is significantly correlated with environmental variables, stepwise multiple linear regression was applied to NMS dissimilarity measures which are a geometric measure of difference among plots from 1979 to 2008. Prior to the application of stepwise multiple linear regression, tests for multicollinearity were applied to the data using the SAS 9.3 PROC CORR procedure (SAS Institute Inc 2011) and criterion variables with a correlation coefficient > 0.8 were removed from the analysis and are not represented in the final model. No criterion variables demonstrated a significant level of multicollinearity. Results from the correlation matrix are detailed in Appendix 4. Criterion variables were also tested for the assumption of normality using the SAS 9.3 PROC UNIVARIATE procedure (SAS Institute Inc., 2011), criterion variables with a kurtosis or skew with an absolute value of greater than one were removed from the analysis. After duration of sunlight (hours) was log transformed, all criterion variables met the assumption of normality. For all tests of normality performed on criterion variables refer to Appendix 4.

Multiple linear regression permutations were applied to each predictor variable Easting, Northing, elevation (feet), slope, heat loading capacity (Watt/m²), and duration of sunlight (hours). Only standardized beta coefficients which tested to be statistically significant ($p \leq 0.05$) were included in the final model. No single significant model containing any of the criterion variables was obtained. Since all criterion variables could be statistically rejected from the final models, Easting, Northing, elevation, slope, heat

loading capacity, and duration of sunlight are not useful to describe variance in any of the predictor variables.

CHAPTER 8

DISCUSSION

Similarities between re-photographed sites were remarkable. Small shrubs and sub-shrubs were observed to remain alive and distinguished in 2008 due to concomitant preservation of barren soil inter-space (Figures 1-3). The similarity between survey data in 1979 and 2008 is equally remarkable. When taken as a whole, the results of tests for significant differences between species and community composition in 1979 and 2008 do not support a premise of vegetation community regime shift in the Newberry Mountains. The statistical similarities between surveys supported confidence in accurate plot locations.

Differences in Species Abundance

The numerous measurements and the variety of tests performed were helpful in discerning bias in measures and interpreting results. Certain measures more accurately reflect abundance and status in the community for some species. Analysis of all test results associated with each species aids inference of species dynamics. For example, plot occupancy results describe species dynamics such as site fidelity and immigration. Distribution dynamic is an important context when analyzing species change. Species which are reported significant in numerous tests are considered more indicative of meaningful change. Further, the top ten most abundant species in density and total cover measures represent a large component of the whole community and changes to these species can be a proxy for whole community change (Table 2). Still, changes found in mean abundance measures represent inferred scenarios about each species' current status

based upon life history traits. Density, relative density, relative frequency and relative cover are treated as the least methodologically biased measures for species abundance.

More aspects of the perennial plant community in 1979 and 2008 are the same than are different. A general review of results highlights these similarities. Only two species demonstrated a significant change in plot occupancy. This means that, generally, plant species within the Newberry Mountains exhibited high site fidelity or similar amount of plots occupied over time. This finding is not unusual considering the edaphic environmental conditions in the Newberry Mountains and slow population turnover of Mojave Desert perennials. In addition, relatively few species were significantly less abundant in measures taken in 1979 than those taken in 2008. Similarly, the majority of MRBP tests for difference between community composition in 1979 and 2008 did not report significant difference between survey years.

Those few species in which the data demonstrated a significant change from 1979 to 2008 are representative of either high or low elevations. Whereas tests of differences between abundance measures did not reveal clear distinctions of decreases in abundance of high elevation species and increases in abundance of low elevation species; analysis of changes to rank order of density and total cover measures suggest a shift toward landscape dominance for both low elevation and Sonoran associated species. For example, lower recorded density in 2008 for *Coleogyne ramosissima* and *Achnatherum speciosum*, both species with distinct lower elevation limits, caused a drop in rank order from fourth and fifth most numerous to eighth and sixth most numerous respectively (Table 1). This coincided with the increase in rank order for the low elevation associated species, *Larrea tridentata*, and the Sonoran associated species, *Bahiopsis parishii*, from

sixth and seventh most numerous to fourth and fifth respectively (Table 1.). *Ephedra nevadensis* is another species which out-placed *Coleogyne ramosissima* in 2008 rank order of largest cover. Changes in rank order of total abundance demonstrate changes in the vegetation community.

Several species demonstrated consistent significant change across abundance measures in multiple tests and causal inferences are discussed. The decrease in abundance and significant change within plot comparisons for *Coleogyne* influenced many reported changes including rank order of abundance and relative density. *Coleogyne ramosissima* inhabits specific age-related and shallow soil conditions within several soil associations in the Newberry Mountains. This fact is reflected in the high proportion of plots maintained through survey years (95%) with little colonization or extinction. Furthermore, absolute change in density was not found to be colinear with environmental variables including elevation, slope and Northing. Therefore, the species is declining within a well-defined distribution and not across environmental gradients. We infer that these declines are due to well documented large fires as well as undocumented fires which have occurred within the survey interval and are noted in plot descriptions. Burned stands of *Coleogyne* do not return to previous composition for centuries and the decline in this species is expected to be maintained through any subsequent survey effort (Hunter & McAuliffe, 1994). This species was, however, reported from plots in 2008 that reported no individuals in 1979. Therefore, significant differences reported for all measures observed within plot comparisons were absent in across plot comparisons.

Sphaeralcea ambigua decreased significantly throughout many tests, including a significant decrease in plot occupancy as detected by frequency. Abundance of this

species is known to be positively related to disturbance such as grazing and fires (RMRS, 2012). Hence, a decline in *Sphaeralcea ambigua* in the Newberry Mountains is being reported 14 years after the removal of grazing from the region. *Achnatherum speciosum* and *Gutierrezia sarothrae* are other species for which abundance is known to be positively related to grazing pressure (RMRS, 2012). *Achnatherum* lost a notable proportion of plots occupied in 2008 while *Gutierrezia* decreased significantly in several measures within plot comparisons. The cessation of grazing in 1994 could explain the relative decreases in abundance of these disturbance-related species in plots surveyed from 1979 and 2008; however, absolute difference in density for these species was not colinear with any environmental variables.

In contrast, *Ferocactus cylindraceus* increased significantly from 1979 to 2008 in all comparisons of measures except relative cover within and among plots. Plot occupancy was similar between survey years and absolute change in density was not found to be colinear with any environmental variables. The significant increase in density of individuals without significant increase in relative cover suggests numerous small individuals have recently become established. *Ferocactus* colonies are known to establish during periodic weather events. These establishment events create populations structured by age groups (Bowers 1997). Due to small size class of plants observed during surveys, the historical precipitation events of 2005 likely established this recent tier of the *Ferocactus* population in the Newberry Mountains. Bowers et al. (1995) reported an increase in barrel cactus individuals as the only notable large scale change in any species identified in a Grand Canyon re-photography analysis spanning 100 years. Removal of grazing could potentially affect this species due to an increase in cover for palatable nurse

plants (Bowers 1995). *Krameria grayi* is one of these potential nurse plants. *Krameria grayi* is a highly palatable species for cattle, whose relative cover has significantly increased between survey years. *Krameria* colonized more plots from 1979 to 2008 than any other species. However, after an initial increase in abundance after the removal of grazing, this species is reported to be declining in the Sonoran Desert corresponding with warming temperatures (Munson, 2011). Similar to results for *Ferocactus*, the increase in abundance noted for this species could also be influenced by the removal of grazing in 1994 (RMRS, 2012).

Negligible change in abundance of individual species was observed from 1979 to 2008 and that change was not found to be colinear with environmental variables, including elevation, slope and Northing in 11 selected species. The detection of mechanisms for change, including fire frequency and grazing, is limited at this survey interval. For example, a decade of drought has coincided with the removal of grazing. Further, the species for which meaningful change is evident at this time scale are short-lived species. Short-lived species can fluctuate due to relatively short-term climatic cycles and changes in species abundance may not be indicative of regime shift. For example, *Galium stellatum* occurred in significantly more plots in 2008 but reported decreased mean density, mean relative frequency and significantly decreased mean relative cover. One potential scenario is that the rise in precipitation from the mid 1970's led to an increase in *Galium* distribution and subsequent drought since the 1990's has decreased abundance within the recently established distribution. It is likely that a 29-year survey interval encompasses several of these rise and fall events such as the change from being managed as a grazing allotment. Long survey interval yields minimal

information for causal inference. Shorter interval length reveals the time it takes for this species to colonize and whether decreasing density and cover are short term events or lead to population decline.

Differences in Community Composition

Community composition, as measured by relative cover, was the only measure found to be significantly different between survey years (Table 11). The MRBP was performed between paired plots. The driving force for the difference detected in community composition, was due to significant differences detected in within-plot comparisons of individual species abundance as measured by relative cover. *Larrea tridentata* and *Coleogyne ramosissima* are two of the top ten species with largest cover which were found significant in paired-plot comparisons (Table 9). *Larrea* demonstrated a significant increase in relative cover along with *Krameria grayi*. Although *Krameria* is not among the top ten species with largest cover, this species was influential by occupying the fifth and fourth most plots in both survey years respectively. These two species are representative of low hot deserts and are reported to be in decline, corresponding to diminished winter precipitation, in Sonoran Desert long term research conducted by Munson 2011. Meanwhile *Coleogyne* is within the top ten species with largest total cover and demonstrated significantly decreased relative cover (Table 9). Both *Larrea* and *Coleogyne* did not report significance in across plots comparison of relative cover.

Further, regression analysis and ANOVA results comparing NMS ordination distances reveal that Easting, Northing, elevation, slope, heat loading capacity, duration of sunlight, elevation groups and designated species associations are not useful to

describe variance in NMS ordination distances as measured by relative cover. This is not a surprising result given no significant changes were observed in community composition as measured using density, relative density and relative frequency. However, significant differences in the Sorenson Bray Curtis distance measures were observed by soil association. Significant differences in these NMS ordination distances, which relate to changes in community composition from 1979 to 2008 among soil association groups, were observed. ANOVA results for soil association groups of NMS ordination distances as calculated across each of the six vegetation abundance measures report a significant difference between the Kidwell-Tenwell soil association and each the following three soil associations: Cetrepas-Nolena-Rock outcrop, Seanna-Goldroad-Rock outcrop and Nolena-Rock outcrop. Refer to Table 27 for soil association descriptions.

Kidwell-Tenwell soils had overall lower NMS ordination distances than the other three soil types. The difference between the Kidwell-Tenwell association and the other three soil associations was largely topographic. Kidwell-Tenwell soils are located on the Western bajada of the Newberry Mountains, which gently slopes toward the Paiute valley. This soil is largely occupied by variations of species depauperate communities, dominated by *Larrea tridentata* and *Ambrosia dumosa*. Kidwell-Tenwell soils are relatively deep soils formed of alluvium compared with extreme variation in depth of soils for the other three soil associations, which are derived from colluvium and residuum as well as inclusion of rock outcrops. In contrast, the other three soil types (Cetrepas-Nolena-Rock outcrop, Seanna-Goldroad-Rock outcrop, and Nolena-Rock outcrop) are within species-rich mixed-shrub communities with a highly variable and mixed dominance. *Coleogyne ramosissima* and the other aforementioned species, which showed

a consistent change across measures, are all associated with the other three soil types. These three soil associations can be found across the entire elevation gradient of the Newberry Mountains and include Hyperthermic, Thermic and Mesic soil moisture regimes. The Goldroad-Rock outcrop association (n=14) is also characterized by topographic relief and inclusion of Rock outcrop series but contains solely hyperthermic soil moisture regimes. This association is notable for not being found significantly different from Kidwell-Tenwell soils. Hamerlynck & McAuliffe (2008) have suggested the effects of severe drought events over the last decade were detected on shallow soils with well developed durapan. Restricted root development is thought to adversely affect perennial perserverence through periods of low cool season precipitation (Hamerlynck & McAuliffe, 2008). Similarly, the soils of the other three associations are often in close contact with root restricting bedrock. Thus the vegetation communities associated with these three soil associations could be significantly different in degree of change from deeper Kidwell-Tenwell soils due to the uneven effects of recent drought.

Study Context and Limitations

Plot location accuracy and length of time between surveys were the greatest limitations to interpretation of analysis. Potentially misplaced 100 m plots could have resulted in the survey of different plant communities in topographically variable soil series. This is especially true for the soil specific species such as *Coleogyne*. Although the species occupies each of the aforementioned three soil associations, dense-canopy *Coleogyne* communities only occur in patches on well drained granitic soils. This patchy distribution is shared with *Juniperus californica* and *Pinus monophylla*. Because plots were not randomly located in original surveys, field placement of these plots without bias

to the vegetation community was difficult. Logistical support from the original surveyor, Jim Holland, in the field was invaluable for accurate plot placement.

Furthermore, cover and relative cover are more likely to represent short term variability than other presence and absence based abundance measures like frequency and density. Again, community composition as measured by relative cover was the only measure found significantly different between survey years. Plots were surveyed within four months of late autumn and early winter in 1979, whereas plots were surveyed over an eight month span in 2008. Generally, high elevation sites were surveyed in late spring of 2008 to ensure accurate plant identification. Seasonality of surveys has impact on detection of herbaceous and suffrutescent forbs as well as the canopy cover measure of all perennials which fluctuates according to recent weather events. For example, *Larrea tridentata* is an important species with top-ten highest mean measures. This species had significantly higher mean relative cover, which would be a notable isolated result. However, this species occupied a nearly identical amount of sites and was not significantly different between mean density measures. Density is a good measure for this long-lived species which is seldom found in a seedling stage. Therefore, the increase in mean relative cover for *Larrea*, while significant, does not indicate a major shift in community composition. Similarly, density of individuals can be misleading for certain species due to the inclusion of seedlings which can be established en masse during rare weather events. Cover can, therefore, be a better indicator of dominance for these species, e.g., *Encelia farinosa*.

Caution must be used to ascribe meaningfulness to species and community composition change. Plant species which are early indicators of ecological transition and

each species' response to climatic cues need to be identified for interpretation of vegetation change. Responses of vegetation to a warmer and drier climate can include directional shifts upwards in elevation and toward northern latitudes (Kupfer & Cairns, 1996; Bertin, 2008). However established individuals can persist decades after conditions necessary for population regeneration are gone and therefore are lagging indicators of regime shift (Contamin & Ellison, 2009). This fact is especially true for extremely long-lived Mojave perennials. Further, elevation limits to species distribution could be due to other physiographic constraints such as soil development requirements and changes to species may only indicate changes to a specific habitat and not an entire landscape (Amundsen et al., 1989; Kupfer & Cairns, 1996). Shorter interval length of monitoring lends clarity to these processes.

Implications for Further Research

Cody (2000) stated that the 15 year interval between surveys in his research was not long enough to detect large scale changes in vegetation in the Mojave Desert. Similarly, we conclude that 29 years was not enough time to detect large-scale changes (if they are to occur) in most species and vegetation communities surveyed in the Newberry Mountains. However these long survey intervals miss acute annual events known to cause widespread mortality and recruitment to plant communities in the Mojave as well as short term species abundance dynamics. Understanding short term dynamics aids in interpretation of change at each survey interval and is crucial for identifying those changes that are early indicators of regime shift. This survey work provides baseline information from modeled distributions of plant species and vegetation communities across the Newberry Mountains. Long term monitoring of established plots will produce

prognostic information from the analysis of trending distributions in species and community composition over time. Predictive capabilities are crucial for management intervention in undesirable ecological regime shift.

APPENDICES

**Appendix 1 Comparison of Mean Density and Mean Relative Density by Species, 1979
and 2008.**

Species	Mean Density				Mean Relative Density			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
ACGR	5.60	8.37	0.86	0.3943	2.25	3.35	0.91	0.3676
ACSP	29.49	26.36	-0.38	0.7038	7.76	6.90	-0.46	0.6493
ACSP12	67.32	44.39	-1.14	0.2586	5.49	7.27	0.83	0.4099
ADCO2	1.00	1.80	0.41	0.7040	0.20	0.70	0.76	0.4877
ADPO	8.00	2.00	-6.57	0.0072	4.00	0.79	-4.05	0.0271
AMDU2	96.61	83.63	-0.73	0.4654	28.73	28.34	-0.10	0.9169
AMER	14.00	1.00			1.20	6.22		
ARLU	15.00	4.50	-1.28	0.2575	3.00	0.69	-1.00	0.3623
ARPE2	1.00	12.16	0.67	0.5313	0.10	1.90	0.81	0.4561
ARPU9	42.25	16.88	-1.32	0.2008	2.35	2.85	0.38	0.7106
ASLE8	1.00	5.67	1.32	0.2771	0.15	1.15	2.09	0.1280
ASSU	2.00	1.00	-1.34	0.2722	0.77	0.51	-1.17	0.3723
BAMU	29.80	1.50	-0.65	0.5417	1.06	0.19	-2.01	0.1003
BASE	1.67	2.00	0.50	0.6670	0.60	0.90	0.33	0.7710
BEJU	11.44	8.39	-0.95	0.3478	6.33	2.96	1.48	0.1433
BRAR2	5.00	12.53	0.84	0.4090	0.56	2.40	1.15	0.2615
BRIN	3.00	2.00			3.10	2.05		
CORA	95.30	51.76	-1.61	0.1158	26.51	13.71	-1.88	0.0679
CYAC8	9.23	9.30	0.03	0.9763	1.79	2.24	0.96	0.3387
CYBI9	44.00	15.00	-0.59	0.5952	13.60	3.31	-0.81	0.4786
CYEC3	2.08	3.06	0.79	0.4359	0.86	0.93	0.21	0.8368
CYRA9	6.63	7.46	0.29	0.7757	4.18	3.06	-0.61	0.5494
DUPU	1.00	3.00	1.17	0.4544	0.20	0.39	1.05	0.4835
ECEN	13.19	10.07	-0.39	0.6980	1.38	1.51	0.29	0.7700
ECMO	4.00	4.14	0.06	0.9535	0.40	0.72	0.86	0.4183
ECPO2	1.63	1.20	-0.84	0.4191	0.60	-0.78	-0.78	0.4540
ELEL5	147.00	42.25	-1.02	0.3543	8.80	7.13	-0.34	0.7498
ENFA	114.90	108.60	-0.19	0.8536	29.58	28.87	-0.17	0.0865
ENVI	10.05	15.70	1.14	0.2615	1.95	4.98	1.90	0.0650
EPNE	19.04	18.82	-0.05	0.9596	4.43	3.86	-0.67	0.5029
EPVI	13.00	19.88	0.49	0.6340	1.65	4.46	0.72	0.4903
ERFA2	109.80	84.80	-1.34	0.1811	17.39	18.05	0.25	0.8044
ERHE	17.50	18.60	0.08	0.9366	2.70	4.18	0.63	0.5516
ERIN	29.81	19.45	-1.10	0.2742	5.36	5.53	0.08	0.9377
ERPL3	25.33	3.00	-0.76	0.5043	1.63	1.38	-0.26	0.8367
ERWR	60.67	37.84	-0.85	0.3990	6.60	5.64	-0.30	0.7674
FUHI	3.50	13.67	0.83	0.4678	0.70	6.48	0.85	0.4565
GAST	14.00	7.00	-1.79	0.0820	2.04	1.23	-1.54	0.1330
GRSP	3.67	6.00	0.97	0.4341	0.87	1.06	0.33	0.7708
GUMI	72.77	1.50	-0.94	0.3667	9.32	0.23	-1.03	0.3230
GUSA2	63.80	25.71	-1.79	0.0858	7.38	3.75	-1.19	0.2466
HYEM	9.80	5.25	0.84	0.4156	3.03	3.21	0.11	0.9245
HYS A	21.68	21.58	-0.01	0.9921	10.37	12.63	0.41	0.6840

Appendix 1 Comparison of Mean Density and Mean Relative Density by Species, 1979
and 2008. (Continued).

Species	Mean Density				Mean Relative Density			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>KEAN</i>	5.25	6.88	0.50	0.6292	0.75	1.17	0.77	0.4548
<i>KRER</i>	16.95	16.04	-0.21	0.8377	3.60	3.87	0.35	0.7268
<i>KRGR</i>	10.09	8.77	-0.88	0.3814	3.38	4.13	1.00	0.3174
<i>KRLA2</i>	13.50	2.50	-1.88	0.1096	2.05	0.62	-1.56	0.1695
<i>LATR2</i>	23.56	26.00	0.54	0.5877	13.67	13.32	-0.50	0.8837
<i>LIPU11</i>	87.00	32.00	-0.79	0.5129	6.40	7.32	0.13	0.9077
<i>LORI3</i>	26.14	14.72	-1.16	0.2566	1.51	2.67	1.09	0.2841
<i>LYAN</i>	10.35	6.67	-1.39	0.1702	2.67	2.25	-0.48	0.6349
<i>MAGR9</i>	1.00	1.00			0.40	0.21		
<i>MAPA7</i>	18.50	4.00	-1.08	0.3597	2.60	0.98	-0.92	0.4261
<i>MAPIG</i>	5.00	58.60	1.82	0.1019	1.10	10.57	1.78	0.1089
<i>MATE4</i>	1.00	1.77	0.44	0.6689	1.10	0.40	-1.78	0.1089
<i>MESC</i>	1.00	18.00			0.10	2.08		
<i>MILA6</i>	4.56	6.81	0.92	0.3696	0.78	1.38	1.14	0.2596
<i>MUPO2</i>	7.00	4.38	-1.16	0.2558	1.52	0.93	-1.17	0.2516
<i>NOBI</i>	10.56	11.33	0.19	0.8504	1.87	1.56	0.45	0.6557
<i>OPBA2</i>	4.03	6.19	1.47	0.1462	1.81	2.03	0.28	0.7816
<i>OPPOE</i>	32.14	13.80	-1.29	0.2151	3.33	2.39	-0.56	0.5846
<i>PEEA</i>	4.00	3.67	-0.10	0.9295	1.19	1.49	0.65	0.5802
<i>PESC4</i>	3.33	2.67	-0.71	0.5185	1.47	1.05	-0.60	0.5822
<i>PETH4</i>	1.00	1.00			0.20	0.85		
<i>PHCR4</i>	1.50	1.33	-0.37	0.7246	0.20	0.35	0.93	0.3898
<i>POGR5</i>	6.33	9.17	0.94	0.3497	1.02	1.64	1.52	0.1357
<i>PRFA</i>	6.00	1.50	-1.11	0.3155	1.03	0.43	-0.96	0.3762
<i>PSCO2</i>	14.00	32.50	0.75	0.5308	1.10	3.66	1.07	0.3964
<i>QUTU2</i>	34.08	24.13	-0.69	0.4986	8.61	5.32	-0.76	0.4565
<i>RHIL</i>	7.00	2.00			7.90	0.68		
<i>RHTR</i>	3.80	7.33	0.97	0.3591	1.04	2.06	0.82	0.4327
<i>RIVE</i>	22.00	44.00	0.00	0.0000	1.90	11.36	0.00	0.0000
<i>SADO4</i>	23.50	9.00	-0.62	0.6010	2.45	3.45	0.25	0.2226
<i>SAME</i>	21.00	8.65	-1.23	0.2446	2.96	3.80	0.63	0.5536
<i>SAMO3</i>	8.80	3.67	-1.79	0.0985	1.26	0.78	-1.07	0.3044
<i>SEAR8</i>	102.00	20.14	-2.04	0.0813	25.45	9.05	-1.23	0.2569
<i>STLI3</i>	5.00	12.50			3.30	6.97		
<i>STPA4</i>	6.86	6.51	-0.28	0.7828	1.53	1.55	0.06	0.9480
<i>TEST2</i>	15.00	7.08	-1.50	0.1475	4.36	2.92	-0.88	0.3882
<i>THMO</i>	6.86	5.68	-0.39	0.6999	1.42	1.62	0.39	0.7012
<i>TICA3</i>	4.00	2.00			1.50	0.26		
<i>XYTO</i>	15.58	9.60	-0.66	0.5141	2.53	2.66	0.13	0.8964
<i>YUSC2</i>	9.94	8.48	-0.88	0.3799	2.68	2.18	1.06	0.2895

**Appendix 2 Comparison of Mean Frequency and Mean Relative Frequency by Species,
1979 and 2008.**

Species	Mean % Cover				Mean Relative % Cover			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>ACGR</i>	0.56	0.95	1.70	0.0950	5.78	7.88	1.10	0.2785
<i>ACSP12</i>	0.32	0.56	1.30	0.2011	2.49	3.05	0.54	0.5894
<i>ADPO</i>	0.05	0.14	1.65	0.1247	2.03	1.23	-0.67	0.5155
<i>ARPU9</i>	0.12	0.09	-0.65	0.5288	0.93	0.86	-0.11	0.9133
<i>ASSU</i>	0.07	0.08			1.30	0.85		
<i>BEJU</i>	1.04	0.60	-0.72	0.4748	11.51	5.60	-1.20	0.2370
<i>BRAR2</i>	0.03	0.15	1.14	0.2788	0.20	1.19	0.96	0.3554
<i>CYAC8</i>	0.45	0.45	-0.01	0.9932	5.67	2.78	-1.48	0.1462
<i>CYBI9</i>	0.49	0.15	-0.85	0.4831	10.60	1.22	-1.44	0.2810
<i>CYEC3</i>	0.06	0.07	0.12	0.9055	1.00	0.53	-0.83	0.4422
<i>CYRA9</i>	0.16	0.82	1.59	0.1306	7.31	6.14	-0.26	0.7945
<i>ECEN</i>	0.08	0.14	1.11	0.2779	0.81	1.31	-0.59	0.5586
<i>ECMO</i>	0.09	0.08			0.70	0.32		
<i>ECPO2</i>	0.08	0.15			2.10	1.56		
<i>ELEL5</i>	0.14	0.17	0.21	0.8384	0.80	0.70	-0.16	0.8756
<i>EPNE</i>	0.52	0.73	1.51	0.1353	8.46	5.81	-1.80	0.0760
<i>EPVI</i>	0.32	2.04	0.79	0.4567	1.10	7.14	0.99	0.3547
<i>ERHE</i>	0.29	0.97	0.79	0.4644	2.30	4.52	0.85	0.4344
<i>ERLA12</i>	1.26	0.75	-1.12	0.2842	7.61	4.25	-1.33	0.2093
<i>ERWR</i>	0.61	0.62	0.03	0.9746	4.47	4.33	-0.07	0.9414
<i>FUHI</i>	0.08	0.25			2.10	1.59		
<i>GRSP</i>	0.11	0.06			1.80	0.48		
<i>GUMI</i>	0.70	0.02			6.34	0.15		
<i>GUSA2</i>	0.30	0.27	-0.32	0.7495	3.06	1.55	-1.35	0.1926
<i>HYEM</i>	0.29	1.82	1.58	0.1572	4.65	14.46	1.02	0.3425
<i>HYS A</i>	0.97	2.11	1.66	0.1082	19.16	18.79	-0.05	0.9627
<i>JUCA7</i>	1.89	2.67	1.45	0.1559	14.87	12.61	-0.77	0.4453
<i>KRLA2</i>	0.18	0.17	-0.13	0.9037	3.40	1.08	-1.37	0.2637
<i>LEFR</i>	0.20	0.12			1.30	1.33		
<i>LIPU</i>	1.17	0.29	-1.29	0.4085	9.70	0.90	-1.31	0.4140
<i>LORI3</i>	0.23	0.32	0.59	0.5592	3.51	2.62	-0.48	0.6386
<i>MAPA7</i>	0.04	0.04			0.80	0.17		
<i>MAPIG</i>	0.02	0.24	1.11	0.3307	0.17	4.49	1.12	0.3236
<i>NOBI</i>	1.16	1.58	0.52	0.4226	12.18	9.01	-0.60	0.5605
<i>OPBA2</i>	0.14	0.13	-0.15	0.8777	5.31	1.93	-1.58	0.1222
<i>OPPOE</i>	0.41	0.34	-0.32	0.7560	2.82	1.58	-0.72	0.4927
<i>PESC4</i>	0.04	0.24	2.50	0.2421	1.70	4.29	0.66	0.6291
<i>PLRI3</i>	0.20	0.52	1.77	0.0882	3.10	3.65	0.37	0.7160
<i>POGR5</i>	0.05	0.12	1.86	0.0714	0.99	0.84	-0.43	0.6733
<i>PRFA</i>	5.05	0.05			3.78	0.29		
<i>PSCO4</i>	0.38	0.47			5.90	2.77		
<i>QUTU2</i>	6.87	4.88	-0.65	0.5220	21.39	19.69	-0.27	0.7987

Appendix 2 Comparison of Mean Frequency and Mean Relative Frequency by Species,
1979 and 2008. (continued)

Species	Mean % Cover		<i>t</i>	<i>p</i>	Mean Relative % Cover		<i>t</i>	<i>p</i>
	1979	2008			1979	2008		
<i>RHIL</i>	5.20	1.28			5.60	2.89		
<i>RIVE</i>	0.56	3.11			4.90	9.01		
<i>SADO4</i>	0.18	0.61			1.40	2.89		
<i>SAME</i>	0.32	0.61	1.25	0.2226	3.02	4.64	1.00	0.3274
<i>SAMO3</i>	0.19	0.37	1.36	0.2721	1.17	2.29	0.99	0.3535
<i>SEAR</i>	6.57	4.25	-0.47	0.6717	46.78	30.46	-0.50	0.6535
<i>STLI</i>	0.63	0.73			1.30	7.61		
<i>STPA4</i>	0.11	0.17	1.73	0.0889	2.39	1.89	-0.60	0.5540
<i>TEST2</i>	1.04	0.55	-1.29	0.2294	18.81	4.88	-1.07	0.1205
<i>THMO</i>	0.35	0.19	-1.24	0.2283	4.07	1.51	-1.62	0.1168
<i>XYTO</i>	0.10	0.17	1.06	0.2972	2.00	1.26	-1.11	0.2752

Appendix 3 Comparison of Mean Cover and Mean Relative Cover by Species, 1979 and 2008.

Species	Mean % Cover				Mean Relative % Cover			
	1979	2008	<i>t</i>	<i>p</i>	1979	2008	<i>t</i>	<i>p</i>
<i>ACGR</i>	0.56	0.95	1.70	0.0950	5.78	7.88	1.10	0.2785
<i>ACSP12</i>	0.32	0.56	1.30	0.2011	2.49	3.05	0.54	0.5894
<i>ADPO</i>	0.05	0.14	1.65	0.1247	2.03	1.23	-0.67	0.5155
<i>ARPU9</i>	0.12	0.09	-0.65	0.5288	0.93	0.86	-0.11	0.9133
<i>ASSU</i>	0.07	0.08			1.30	0.85		
<i>BEJU</i>	1.04	0.60	-0.72	0.4748	11.51	5.60	-1.20	0.2370
<i>BRAR2</i>	0.03	0.15	1.14	0.2788	0.20	1.19	0.96	0.3554
<i>CYAC8</i>	0.45	0.45	-0.01	0.9932	5.67	2.78	-1.48	0.1462
<i>CYBI9</i>	0.49	0.15	-0.85	0.4831	10.60	1.22	-1.44	0.2810
<i>CYEC3</i>	0.06	0.07	0.12	0.9055	1.00	0.53	-0.83	0.4422
<i>CYRA9</i>	0.16	0.82	1.59	0.1306	7.31	6.14	-0.26	0.7945
<i>ECEN</i>	0.08	0.14	1.11	0.2779	0.81	1.31	-0.59	0.5586
<i>ECMO</i>	0.09	0.08			0.70	0.32		
<i>ECPO2</i>	0.08	0.15			2.10	1.56		
<i>ELEL5</i>	0.14	0.17	0.21	0.8384	0.80	0.70	-0.16	0.8756
<i>EPNE</i>	0.52	0.73	1.51	0.1353	8.46	5.81	-1.80	0.0760
<i>EPVI</i>	0.32	2.04	0.79	0.4567	1.10	7.14	0.99	0.3547
<i>ERHE</i>	0.29	0.97	0.79	0.4644	2.30	4.52	0.85	0.4344
<i>ERLA12</i>	1.26	0.75	-1.12	0.2842	7.61	4.25	-1.33	0.2093
<i>ERWR</i>	0.61	0.62	0.03	0.9746	4.47	4.33	-0.07	0.9414
<i>FUHI</i>	0.08	0.25			2.10	1.59		
<i>GRSP</i>	0.11	0.06			1.80	0.48		
<i>GUMI</i>	0.70	0.02			6.34	0.15		
<i>GUSA2</i>	0.30	0.27	-0.32	0.7495	3.06	1.55	-1.35	0.1926
<i>HYEM</i>	0.29	1.82	1.58	0.1572	4.65	14.46	1.02	0.3425
<i>HYSA</i>	0.97	2.11	1.66	0.1082	19.16	18.79	-0.05	0.9627
<i>JUCA7</i>	1.89	2.67	1.45	0.1559	14.87	12.61	-0.77	0.4453
<i>KRLA2</i>	0.18	0.17	-0.13	0.9037	3.40	1.08	-1.37	0.2637
<i>LEFR</i>	0.20	0.12			1.30	1.33		
<i>LIPU</i>	1.17	0.29	-1.29	0.4085	9.70	0.90	-1.31	0.4140
<i>LORI3</i>	0.23	0.32	0.59	0.5592	3.51	2.62	-0.48	0.6386
<i>MAPA7</i>	0.04	0.04			0.80	0.17		
<i>MAPIG</i>	0.02	0.24	1.11	0.3307	0.17	4.49	1.12	0.3236
<i>NOBI</i>	1.16	1.58	0.52	0.4226	12.18	9.01	-0.60	0.5605
<i>OPBA2</i>	0.14	0.13	-0.15	0.8777	5.31	1.93	-1.58	0.1222
<i>OPPOE</i>	0.41	0.34	-0.32	0.7560	2.82	1.58	-0.72	0.4927
<i>PESC4</i>	0.04	0.24	2.50	0.2421	1.70	4.29	0.66	0.6291
<i>PLRI3</i>	0.20	0.52	1.77	0.0882	3.10	3.65	0.37	0.7160
<i>POGR5</i>	0.05	0.12	1.86	0.0714	0.99	0.84	-0.43	0.6733
<i>PRFA</i>	5.05	0.05			3.78	0.29		
<i>PSCO4</i>	0.38	0.47			5.90	2.77		
<i>QUTU2</i>	6.87	4.88	-0.65	0.5220	21.39	19.69	-0.27	0.7987

Appendix 3 Comparison of Mean Cover and Mean Relative Cover by Species, 1979 and 2008 (continued).

Species	Mean % Cover		<i>t</i>	p	Mean Relative % Cover		<i>t</i>	p
	1979	2008			1979	2008		
<i>RHIL</i>	5.20	1.28			5.60	2.89		
<i>RIVE</i>	0.56	3.11			4.90	9.01		
<i>SADO4</i>	0.18	0.61			1.40	2.89		
<i>SAME</i>	0.32	0.61	1.25	0.2226	3.02	4.64	1.00	0.3274
<i>SAMO3</i>	0.19	0.37	1.36	0.2721	1.17	2.29	0.99	0.3535
<i>SEAR</i>	6.57	4.25	-0.47	0.6717	46.78	30.46	-0.50	0.6535
<i>STLI</i>	0.63	0.73			1.30	7.61		
<i>STPA4</i>	0.11	0.17	1.73	0.0889	2.39	1.89	-0.60	0.5540
<i>TEST2</i>	1.04	0.55	-1.29	0.2294	18.81	4.88	-1.07	0.1205
<i>THMO</i>	0.35	0.19	-1.24	0.2283	4.07	1.51	-1.62	0.1168
<i>XYTO</i>	0.10	0.17	1.06	0.2972	2.00	1.26	-1.11	0.2752

Appendix 4 Correlation Matrix for Environmental Variables And Selected Species

The CORR Procedure

9 Variables: ACSP E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
ACSP	47	57.23404	29.63929	2690	1.00000	149.00000	ACSP
E	47	3902309	5150	183408543	3893108	3912665	E
N	47	703893	5259	33082953	693849	711808	N
TO	47	6375	156.52032	299645	5767	6560	TO
dur_T2	47	8.69340	0.84674	408.59000	6.34000	9.56000	dur_T2
PT	47	7.86043	0.47075	369.44000	6.24000	8.65000	PT
TA	47	18.56383	0.95198	872.50000	16.70000	21.40000	TA
Slope	47	10.02128	7.61146	471.00000	5.00000	38.00000	Slope
Elevation	47	2995	492.78981	140760	1641	3870	Elevation

Pearson Correlation Coefficients, N = 47

Prob > |r| under H0: Rho=0

	ACSP	E	N	TO	dur_T2
ACSP	1.00000	-0.24745	0.15847	0.02237	-0.13539
ACSP		0.0936	0.2874	0.8814	0.3642
E	-0.24745	1.00000	-0.30209	0.08174	0.03577
E		0.0936	0.0390	0.5849	0.8113
N	0.15847	-0.30209	1.00000	-0.47691	-0.52560
N		0.2874	0.0390	0.0007	0.0001

Pearson Correlation Coefficients, N = 47

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
ACSP	0.34336	-0.30811	0.13527	0.26895
ACSP	0.0181	0.0351	0.3646	0.0675
E	-0.37965	0.10813	-0.05450	0.01487
E	0.0085	0.4694	0.7160	0.9210
N	-0.09218	0.08836	0.46666	-0.24648
N	0.5377	0.5548	0.0009	0.0949

The CORR Procedure

Pearson Correlation Coefficients, N = 47
Prob > |r| under H0: Rho=0

	ACSP	E	N	T0	dur_T2
T0	0.02237	0.08174	-0.47691	1.00000	0.72157
T0	0.8814	0.5849	0.0007		<.0001
dur_T2	-0.13539	0.03577	-0.52560	0.72157	1.00000
dur_T2	0.3642	0.8113	0.0001	<.0001	
PT	0.34336	-0.37965	-0.09218	0.32073	-0.09726
PT	0.0181	0.0085	0.5377	0.0279	0.5155
TA	-0.30811	0.10813	0.08836	-0.32558	0.15169
TA	0.0351	0.4694	0.5548	0.0255	0.3087
Slope	0.13527	-0.05450	0.46666	-0.67194	-0.58578
Slope	0.3646	0.7160	0.0009	<.0001	<.0001
Elevation	0.26895	0.01487	-0.24648	0.42061	-0.05330
Elevation	0.0675	0.9210	0.0949	0.0032	0.7220

Pearson Correlation Coefficients, N = 47
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	0.32073	-0.32558	-0.67194	0.42061
T0	0.0279	0.0255	<.0001	0.0032
dur_T2	-0.09726	0.15169	-0.58578	-0.05330
dur_T2	0.5155	0.3087	<.0001	0.7220
PT	1.00000	-0.95220	-0.01305	0.88955
PT		<.0001	0.9306	<.0001
TA	-0.95220	1.00000	-0.02419	-0.94962
TA	<.0001		0.8718	<.0001
Slope	-0.01305	-0.02419	1.00000	-0.00771
Slope	0.9306	0.8718		0.9590
Elevation	0.88955	-0.94962	-0.00771	1.00000
Elevation	<.0001	<.0001	0.9590	

The CORR Procedure

9 Variables: ACSP12 E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
ACSP12	36	286.86111	77.18925	10327	1.00000	387.00000	ACSP12
E	36	3901770	4279	140463709	3893108	3909917	E
N	36	705584	2981	25401028	696423	711722	N
TO	36	6127	357.73617	220571	5155	6557	TO
dur_T2	36	7.44917	1.70092	268.17000	1.35000	9.23000	dur_T2
PT	36	8.39472	0.53907	302.21000	7.10000	9.41000	PT
TA	36	17.35000	1.32633	624.60000	14.90000	20.40000	TA
Slope	36	19.97222	10.29698	719.00000	5.00000	40.00000	Slope
Elevation	36	3624	743.07421	130455	2137	5452	Elevation

Pearson Correlation Coefficients, N = 36

Prob > |r| under H0: Rho=0

	ACSP12	E	N	TO	dur_T2
ACSP12	1.00000	-0.25953	-0.21970	0.17631	0.38352
ACSP12		0.1264	0.1979	0.3037	0.0209
E	-0.25953	1.00000	0.21566	-0.16661	-0.35071
E		0.1264	0.2065	0.3314	0.0360
N	-0.21970	0.21566	1.00000	-0.10204	-0.07556
N		0.1979	0.2065	0.5537	0.6614

Pearson Correlation Coefficients, N = 36

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
ACSP12	-0.33502	0.38634	-0.17855	-0.25679
ACSP12		0.0458	0.0199	0.1306
E	0.36912	-0.57503	0.10576	0.55319
E		0.0267	0.0002	0.0005
N	-0.06590	-0.03601	0.15258	-0.05629
N		0.7026	0.8349	0.7444

The CORR Procedure

Pearson Correlation Coefficients, N = 36

Prob > |r| under H0: Rho=0

	ACSP12	E	N	T0	dur_T2
T0	0.17631	-0.16661	-0.10204	1.00000	0.77047
T0	0.3037	0.3314	0.5537		<.0001
dur_T2	0.38352	-0.35071	-0.07556	0.77047	1.00000
dur_T2	0.0209	0.0360	0.6614	<.0001	
PT	-0.33502	0.36912	-0.06590	-0.28409	-0.42988
PT	0.0458	0.0267	0.7026	0.0931	0.0089
TA	0.38634	-0.57503	-0.03601	0.28291	0.47224
TA	0.0199	0.0002	0.8349	0.0945	0.0036
Slope	-0.17855	0.10576	0.15258	-0.60052	-0.40144
Slope	0.2974	0.5393	0.3743	0.0001	0.0152
Elevation	-0.25679	0.55319	-0.05629	-0.38258	-0.53721
Elevation	0.1306	0.0005	0.7444	0.0213	0.0007

Pearson Correlation Coefficients, N = 36

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.28409	0.28291	-0.60052	-0.38258
T0	0.0931	0.0945	0.0001	0.0213
dur_T2	-0.42988	0.47224	-0.40144	-0.53721
dur_T2	0.0089	0.0036	0.0152	0.0007
PT	1.00000	-0.96220	0.17508	0.91723
PT		<.0001	0.3071	<.0001
TA	-0.96220	1.00000	-0.17019	-0.93356
TA	<.0001		0.3210	<.0001
Slope	0.17508	-0.17019	1.00000	0.18189
Slope	0.3071	0.3210		0.2884
Elevation	0.91723	-0.93356	0.18189	1.00000
Elevation	<.0001	<.0001	0.2884	

The CORR Procedure

9 Variables: CORA E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
CORA	22	213.77273	79.68685	4703	1.00000	356.00000	CORA
E	22	3903911	2319	85886050	3899209	3909917	E
N	22	704079	2133	15489743	698968	707364	N
TO	22	6362	233.42266	139958	5697	6560	TO
dur_T2	22	7.85591	1.33428	172.83000	5.40000	9.35000	dur_T2
PT	22	8.46909	0.37842	186.32000	7.81000	9.01000	PT
TA	22	17.05000	0.81284	375.10000	16.00000	18.40000	TA
Slope	22	13.95455	9.03684	307.00000	5.00000	35.00000	Slope
Elevation	22	3770	424.35976	82944	3110	4732	Elevation

Pearson Correlation Coefficients, N = 22

Prob > |r| under H0: Rho=0

	CORA	E	N	TO	dur_T2
CORA	1.00000	-0.14948	-0.47259	0.08600	0.00592
CORA		0.5067	0.0263	0.7035	0.9791
E	-0.14948	1.00000	0.05206	0.06586	0.05550
E		0.5067	0.8180	0.7709	0.8062
N	-0.47259	0.05206	1.00000	-0.45882	-0.57394
N		0.0263	0.8180	0.0317	0.0052

Pearson Correlation Coefficients, N = 22

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
CORA	-0.09300	0.22610	-0.34017	0.01523
CORA		0.6806	0.3116	0.9464
E	-0.44081	0.24837	0.06446	-0.21566
E		0.0400	0.2650	0.3351
N	0.64263	-0.81715	0.51396	0.44001
N		0.0013	<.0001	0.0144

The CORR Procedure

Pearson Correlation Coefficients, N = 22

Prob > |r| under H0: Rho=0

	CORA	E	N	T0	dur_T2
T0	0.08600	0.06586	-0.45882	1.00000	0.75393
T0	0.7035	0.7709	0.0317		<.0001
dur_T2	0.00592	0.05550	-0.57394	0.75393	1.00000
dur_T2	0.9791	0.8062	0.0052	<.0001	
PT	-0.09300	-0.44081	0.64263	-0.39403	-0.53623
PT	0.6806	0.0400	0.0013	0.0696	0.0101
TA	0.22610	0.24837	-0.81715	0.45277	0.61168
TA	0.3116	0.2650	<.0001	0.0343	0.0025
Slope	-0.34017	0.06446	0.51396	-0.62557	-0.29862
Slope	0.1214	0.7756	0.0144	0.0018	0.1770
Elevation	0.01523	-0.21566	0.44001	-0.25175	-0.43636
Elevation	0.9464	0.3351	0.0404	0.2584	0.0423

Pearson Correlation Coefficients, N = 22

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.39403	0.45277	-0.62557	-0.25175
T0	0.0696	0.0343	0.0018	0.2584
dur_T2	-0.53623	0.61168	-0.29862	-0.43636
dur_T2	0.0101	0.0025	0.1770	0.0423
PT	1.00000	-0.94296	0.46508	0.85054
PT		<.0001	0.0292	<.0001
TA	-0.94296	1.00000	-0.51440	-0.80709
TA	<.0001		0.0143	<.0001
Slope	0.46508	-0.51440	1.00000	0.43313
Slope	0.0292	0.0143		0.0441
Elevation	0.85054	-0.80709	0.43313	1.00000
Elevation	<.0001	<.0001	0.0441	

The CORR Procedure

9 Variables: CYAC E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
CYAC	65	44.20000	12.79062	2873	1.00000	78.00000	CYAC
E	65	3901965	4415	253627757	3893108	3913213	E
N	65	709062	5806	46089057	697577	720531	N
TO	65	6142	316.04944	399246	5155	6560	TO
dur_T2	65	7.99231	1.27754	519.50000	3.86000	9.41000	dur_T2
PT	65	7.68015	1.02728	499.21000	5.63000	9.41000	PT
TA	65	18.89846	2.20996	1228	14.90000	23.10000	TA
Slope	65	16.67692	11.06106	1084	5.00000	40.00000	Slope
Elevation	65	2736	1184	177850	603.00000	4788	Elevation

Pearson Correlation Coefficients, N = 65

Prob > |r| under H0: Rho=0

	CYAC	E	N	TO	dur_T2
CYAC	1.00000	0.02098	0.08642	-0.05457	0.00647
CYAC		0.8682	0.4936	0.6659	0.9592
E	0.02098	1.00000	0.13489	-0.16207	-0.34274
E	0.8682		0.2840	0.1971	0.0052
N	0.08642	0.13489	1.00000	-0.53526	0.05751
N	0.4936	0.2840		<.0001	0.6491

Pearson Correlation Coefficients, N = 65

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
CYAC	-0.17370	0.18276	-0.17050	-0.16411
CYAC	0.1664	0.1451	0.1745	0.1915
E	-0.17835	0.05448	-0.02658	-0.01151
E	0.1552	0.6664	0.8336	0.9275
N	-0.83089	0.80915	0.19449	-0.85332
N	<.0001	<.0001	0.1206	<.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 65

Prob > |r| under H0: Rho=0

	CYAC	E	N	T0	dur_T2
T0	-0.05457	-0.16207	-0.53526	1.00000	0.50199
T0	0.6659	0.1971	<.0001		<.0001
dur_T2	0.00647	-0.34274	0.05751	0.50199	1.00000
dur_T2	0.9592	0.0052	0.6491	<.0001	
PT	-0.17370	-0.17835	-0.83089	0.40621	-0.19935
PT	0.1664	0.1552	<.0001	0.0008	0.1114
TA	0.18276	0.05448	0.80915	-0.38778	0.25048
TA	0.1451	0.6664	<.0001	0.0014	0.0442
Slope	-0.17050	-0.02658	0.19449	-0.58603	-0.19942
Slope	0.1745	0.8336	0.1206	<.0001	0.1112
Elevation	-0.16411	-0.01151	-0.85332	0.38316	-0.26645
Elevation	0.1915	0.9275	<.0001	0.0016	0.0319

Pearson Correlation Coefficients, N = 65

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	0.40621	-0.38778	-0.58603	0.38316
T0	0.0008	0.0014	<.0001	0.0016
dur_T2	-0.19935	0.25048	-0.19942	-0.26645
dur_T2	0.1114	0.0442	0.1112	0.0319
PT	1.00000	-0.98949	0.04794	0.97429
PT		<.0001	0.7045	<.0001
TA	-0.98949	1.00000	-0.04687	-0.98305
TA	<.0001		0.7108	<.0001
Slope	0.04794	-0.04687	1.00000	0.04528
Slope	0.7045	0.7108		0.7202
Elevation	0.97429	-0.98305	0.04528	1.00000
Elevation	<.0001	<.0001	0.7202	

The CORR Procedure

9 Variables: ERFA E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
ERFA	83	494.74699	104.94271	41064	1.00000	758.00000	ERFA
E	83	3901891	4901	323856927	3893108	3912665	E
N	83	706714	5667	58657281	694031	718589	N
TO	83	6200	314.71608	514636	5155	6560	TO
dur_T2	83	8.05904	1.46475	668.90000	1.35000	9.52000	dur_T2
PT	83	7.81747	0.82306	648.85000	5.63000	9.41000	PT
TA	83	18.62530	1.78598	1546	14.90000	22.80000	TA
Slope	83	16.15663	10.98722	1341	5.00000	47.00000	Slope
Elevation	83	2934	960.37113	243483	754.00000	5096	Elevation

Pearson Correlation Coefficients, N = 83

Prob > |r| under H0: Rho=0

	ERFA	E	N	TO	dur_T2
ERFA	1.00000	0.10947	0.00706	0.14052	0.02965
ERFA		0.3246	0.9495	0.2051	0.7902
E	0.10947	1.00000	0.10929	-0.19749	-0.32528
E	0.3246		0.3253	0.0735	0.0027
N	0.00706	0.10929	1.00000	-0.42370	-0.17641
N	0.9495	0.3253		<.0001	0.1106

Pearson Correlation Coefficients, N = 83

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
ERFA	-0.11555	0.09098	-0.21003	-0.06829
ERFA	0.2982	0.4133	0.0567	0.5396
E	-0.14198	-0.03122	0.13484	0.08174
E	0.2004	0.7794	0.2242	0.4626
N	-0.57669	0.53319	0.29831	-0.60666
N	<.0001	<.0001	0.0062	<.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 83

Prob > |r| under H0: Rho=0

	ERFA	E	N	T0	dur_T2
T0	0.14052	-0.19749	-0.42370	1.00000	0.73204
T0	0.2051	0.0735	<.0001		<.0001
dur_T2	0.02965	-0.32528	-0.17641	0.73204	1.00000
dur_T2	0.7902	0.0027	0.1106	<.0001	
PT	-0.11555	-0.14198	-0.57669	0.21560	-0.17530
PT	0.2982	0.2004	<.0001	0.0503	0.1129
TA	0.09098	-0.03122	0.53319	-0.17539	0.24694
TA	0.4133	0.7794	<.0001	0.1128	0.0244
Slope	-0.21003	0.13484	0.29831	-0.66141	-0.40860
Slope	0.0567	0.2242	0.0062	<.0001	0.0001
Elevation	-0.06829	0.08174	-0.60666	0.14969	-0.27934
Elevation	0.5396	0.4626	<.0001	0.1768	0.0105

Pearson Correlation Coefficients, N = 83

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	0.21560	-0.17539	-0.66141	0.14969
T0	0.0503	0.1128	<.0001	0.1768
dur_T2	-0.17530	0.24694	-0.40860	-0.27934
dur_T2	0.1129	0.0244	0.0001	0.0105
PT	1.00000	-0.98145	0.04336	0.95706
PT		<.0001	0.6971	<.0001
TA	-0.98145	1.00000	-0.07515	-0.97520
TA	<.0001		0.4995	<.0001
Slope	0.04336	-0.07515	1.00000	0.07689
Slope	0.6971	0.4995		0.4896
Elevation	0.95706	-0.97520	0.07689	1.00000
Elevation	<.0001	<.0001	0.4896	

The CORR Procedure

9 Variables: FECY E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
FECY	52	31.11538	15.12647	1618	1.00000	90.00000	FECY
E	52	3901422	4984	202873927	3893108	3911397	E
N	52	709612	5454	36899827	696236	720531	N
TO	52	6073	321.06149	315793	5155	6512	TO
dur_T2	52	7.96596	1.31012	414.23000	3.86000	9.45000	dur_T2
PT	52	7.62500	1.00109	396.50000	5.63000	9.41000	PT
TA	52	19.05962	2.14981	991.10000	14.90000	23.10000	TA
Slope	52	19.84615	11.80127	1032	5.00000	47.00000	Slope
Elevation	52	2632	1125	136879	603.00000	4788	Elevation

Pearson Correlation Coefficients, N = 52

Prob > |r| under H0: Rho=0

	FECY	E	N	TO	dur_T2
FECY	1.00000	-0.06228	-0.19044	0.02114	-0.09115
FECY		0.6609	0.1763	0.8818	0.5204
E	-0.06228	1.00000	0.19999	-0.31128	-0.45898
E		0.6609	0.1552	0.0247	0.0006
N	-0.19044	0.19999	1.00000	-0.41050	0.03199
N		0.1763	0.1552	0.0025	0.8218

Pearson Correlation Coefficients, N = 52

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
FECY	0.25836	-0.24942	0.12675	0.26408
FECY		0.0644	0.0746	0.0585
E	-0.18513	0.03910	0.18318	-0.01575
E		0.1889	0.7832	0.9117
N	-0.83054	0.79907	0.04240	-0.83417
N		<.0001	0.7653	<.0001

The CORR Procedure

Pearson Correlation Coefficients, N = 52
Prob > |r| under H0: Rho=0

	FECY	E	N	T0	dur_T2
T0	0.02114	-0.31128	-0.41050	1.00000	0.59470
T0	0.8818	0.0247	0.0025		<.0001
dur_T2	-0.09115	-0.45898	0.03199	0.59470	1.00000
dur_T2	0.5204	0.0006	0.8218	<.0001	
PT	0.25836	-0.18513	-0.83054	0.35930	-0.10967
PT	0.0644	0.1889	<.0001	0.0089	0.4389
TA	-0.24942	0.03910	0.79907	-0.31974	0.17670
TA	0.0746	0.7832	<.0001	0.0209	0.2102
Slope	0.12675	0.18318	0.04240	-0.52099	-0.19519
Slope	0.3706	0.1936	0.7653	<.0001	0.1655
Elevation	0.26408	-0.01575	-0.83417	0.28554	-0.20991
Elevation	0.0585	0.9117	<.0001	0.0402	0.1353

Pearson Correlation Coefficients, N = 52
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	0.35930	-0.31974	-0.52099	0.28554
T0	0.0089	0.0209	<.0001	0.0402
dur_T2	-0.10967	0.17670	-0.19519	-0.20991
dur_T2	0.4389	0.2102	0.1655	0.1353
PT	1.00000	-0.98684	0.09490	0.97370
PT		<.0001	0.5034	<.0001
TA	-0.98684	1.00000	-0.12437	-0.98455
TA	<.0001		0.3797	<.0001
Slope	0.09490	-0.12437	1.00000	0.15063
Slope	0.5034	0.3797		0.2865
Elevation	0.97370	-0.98455	0.15063	1.00000
Elevation	<.0001	<.0001	0.2865	

The CORR Procedure

9 Variables: GAST E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
GAST	25	41.32000	13.74688	1033	1.00000	68.00000	GAST
E	25	3900384	5287	97509610	3893108	3911397	E
N	25	707842	4514	17696053	696423	718511	N
TO	25	6040	367.78598	150991	5155	6481	TO
dur_T2	25	7.60240	1.81601	190.06000	1.35000	9.45000	dur_T2
PT	25	7.82640	0.73811	195.66000	5.92000	9.10000	PT
TA	25	18.72400	1.60215	468.10000	15.50000	22.60000	TA
Slope	25	23.88000	10.80247	597.00000	5.00000	47.00000	Slope
Elevation	25	2893	847.80840	72315	1003	5096	Elevation

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	GAST	E	N	TO	dur_T2
GAST	1.00000	0.22379	-0.07558	0.08994	-0.05100
GAST		0.2822	0.7195	0.6690	0.8087
E	0.22379	1.00000	0.25264	-0.39205	-0.41225
E	0.2822		0.2231	0.0526	0.0406
N	-0.07558	0.25264	1.00000	0.06898	0.16578
N	0.7195	0.2231		0.7432	0.4284

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
GAST	0.21985	-0.25519	0.00504	0.19064
GAST	0.2910	0.2183	0.9809	0.3613
E	-0.11125	-0.10828	0.48482	0.15972
E	0.5965	0.6064	0.0140	0.4457
N	-0.61212	0.53293	0.16227	-0.56460
N	0.0011	0.0061	0.4383	0.0033

The CORR Procedure

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	GAST	E	N	T0	dur_T2
T0	0.08994	-0.39205	0.06898	1.00000	0.82806
T0	0.6690	0.0526	0.7432		<.0001
dur_T2	-0.05100	-0.41225	0.16578	0.82806	1.00000
dur_T2	0.8087	0.0406	0.4284	<.0001	
PT	0.21985	-0.11125	-0.61212	-0.17863	-0.42729
PT	0.2910	0.5965	0.0011	0.3929	0.0331
TA	-0.25519	-0.10828	0.53293	0.26097	0.52373
TA	0.2183	0.6064	0.0061	0.2077	0.0072
Slope	0.00504	0.48482	0.16227	-0.71336	-0.36860
Slope	0.9809	0.0140	0.4383	<.0001	0.0698
Elevation	0.19064	0.15972	-0.56460	-0.38894	-0.65301
Elevation	0.3613	0.4457	0.0033	0.0547	0.0004

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.17863	0.26097	-0.71336	-0.38894
T0	0.3929	0.2077	<.0001	0.0547
dur_T2	-0.42729	0.52373	-0.36860	-0.65301
dur_T2	0.0331	0.0072	0.0698	0.0004
PT	1.00000	-0.97317	-0.20971	0.93537
PT		<.0001	0.3144	<.0001
TA	-0.97317	1.00000	0.10538	-0.96981
TA	<.0001		0.6161	<.0001
Slope	-0.20971	0.10538	1.00000	-0.03439
Slope	0.3144	0.6161		0.8704
Elevation	0.93537	-0.96981	-0.03439	1.00000
Elevation	<.0001	<.0001	0.8704	

The CORR Procedure

9 Variables: JUCA E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
JUCA	25	12.20000	7.91096	305.00000	1.00000	33.00000	JUCA
E	25	3902899	3060	97572482	3893108	3906074	E
N	25	705886	1612	17647146	702940	708326	N
TO	25	6092	396.13765	152299	5155	6526	TO
dur_T2	25	6.92720	1.73251	173.18000	1.35000	9.10000	dur_T2
PT	25	8.67880	0.34628	216.97000	8.04000	9.41000	PT
TA	25	16.62400	0.88284	415.60000	14.90000	18.70000	TA
Slope	25	19.44000	11.46400	486.00000	5.00000	40.00000	Slope
Elevation	25	3960	623.22415	98988	2934	5452	Elevation

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	JUCA	E	N	TO	dur_T2
JUCA	1.00000	-0.13100	-0.23790	0.21565	0.06692
JUCA		0.5325	0.2522	0.3005	0.7506
E	-0.13100	1.00000	0.55168	-0.24197	-0.29433
E		0.5325	0.0043	0.2439	0.1532
N	-0.23790	0.55168	1.00000	-0.16321	-0.08015
N		0.2522	0.0043	0.4357	0.7033

Pearson Correlation Coefficients, N = 25

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
JUCA	0.16892	-0.07589	-0.20913	0.03260
JUCA		0.4196	0.7185	0.8771
E	0.54895	-0.74986	0.24855	0.57017
E		0.0045	<.0001	0.0029
N	0.07148	-0.26463	0.14900	0.03458
N		0.7342	0.2011	0.8696

The CORR Procedure

Pearson Correlation Coefficients, N = 25
Prob > |r| under H0: Rho=0

	JUCA	E	N	T0	dur_T2
T0	0.21565	-0.24197	-0.16321	1.00000	0.72616
T0	0.3005	0.2439	0.4357		<.0001
dur_T2	0.06692	-0.29433	-0.08015	0.72616	1.00000
dur_T2	0.7506	0.1532	0.7033	<.0001	
PT	0.16892	0.54895	0.07148	-0.32003	-0.40579
PT	0.4196	0.0045	0.7342	0.1189	0.0442
TA	-0.07589	-0.74986	-0.26463	0.31123	0.41161
TA	0.7185	<.0001	0.2011	0.1299	0.0409
Slope	-0.20913	0.24855	0.14900	-0.59096	-0.34105
Slope	0.3157	0.2309	0.4772	0.0019	0.0952
Elevation	0.03260	0.57017	0.03458	-0.42635	-0.46898
Elevation	0.8771	0.0029	0.8696	0.0336	0.0180

Pearson Correlation Coefficients, N = 25
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.32003	0.31123	-0.59096	-0.42635
T0	0.1189	0.1299	0.0019	0.0336
dur_T2	-0.40579	0.41161	-0.34105	-0.46898
dur_T2	0.0442	0.0409	0.0952	0.0180
PT	1.00000	-0.93815	0.29245	0.91574
PT		<.0001	0.1560	<.0001
TA	-0.93815	1.00000	-0.29380	-0.88993
TA	<.0001		0.1540	<.0001
Slope	0.29245	-0.29380	1.00000	0.27454
Slope	0.1560	0.1540		0.1841
Elevation	0.91574	-0.88993	0.27454	1.00000
Elevation	<.0001	<.0001	0.1841	

The CORR Procedure

9 Variables: SPAM E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
SPAM	53	62.47170	14.25402	3311	1.00000	87.00000	SPAM
E	53	3901851	5372	206798078	3893108	3912665	E
N	53	705662	4914	37400083	693849	715990	N
TO	53	6200	316.82531	328600	5155	6560	TO
dur_T2	53	8.06226	1.39295	427.30000	3.86000	9.56000	dur_T2
PT	53	7.92000	0.75364	419.76000	5.63000	9.41000	PT
TA	53	18.44340	1.57022	977.50000	14.90000	22.80000	TA
Slope	53	16.83019	10.56070	892.00000	5.00000	40.00000	Slope
Elevation	53	3073	829.94525	162883	1015	4788	Elevation

Pearson Correlation Coefficients, N = 53

Prob > |r| under H0: Rho=0

	SPAM	E	N	TO	dur_T2
SPAM	1.00000	0.06772	-0.11236	0.00434	-0.16160
SPAM		0.6300	0.4231	0.9754	0.2477
E	0.06772	1.00000	0.03771	-0.09192	-0.24252
E		0.6300	0.7886	0.5127	0.0802
N	-0.11236	0.03771	1.00000	-0.37442	-0.30216
N		0.4231	0.7886	0.0057	0.0279

Pearson Correlation Coefficients, N = 53

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
SPAM	0.21326	-0.22218	0.03721	0.22740
SPAM		0.1098	0.7914	0.1015
E	-0.27944	0.07822	-0.02013	-0.00681
E		0.5777	0.8862	0.9614
N	-0.43041	0.39835	0.29212	-0.45861
N		0.0031	0.0338	0.0006

The CORR Procedure

Pearson Correlation Coefficients, N = 53
Prob > |r| under H0: Rho=0

	SPAM	E	N	T0	dur_T2
T0	0.00434	-0.09192	-0.37442	1.00000	0.79550
T0	0.9754	0.5127	0.0057		<.0001
dur_T2	-0.16160	-0.24252	-0.30216	0.79550	1.00000
dur_T2	0.2477	0.0802	0.0279	<.0001	
PT	0.21326	-0.27944	-0.43041	0.07958	-0.07826
PT	0.1252	0.0427	0.0013	0.5711	0.5775
TA	-0.22218	0.07822	0.39835	-0.04286	0.15279
TA	0.1098	0.5777	0.0031	0.7606	0.2747
Slope	0.03721	-0.02013	0.29212	-0.65685	-0.50456
Slope	0.7914	0.8862	0.0338	<.0001	0.0001
Elevation	0.22740	-0.00681	-0.45861	0.03705	-0.18261
Elevation	0.1015	0.9614	0.0006	0.7922	0.1906

Pearson Correlation Coefficients, N = 53
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	0.07958	-0.04286	-0.65685	0.03705
T0	0.5711	0.7606	<.0001	0.7922
dur_T2	-0.07826	0.15279	-0.50456	-0.18261
dur_T2	0.5775	0.2747	0.0001	0.1906
PT	1.00000	-0.97669	0.26393	0.94393
PT		<.0001	0.0562	<.0001
TA	-0.97669	1.00000	-0.29585	-0.97563
TA	<.0001		0.0315	<.0001
Slope	0.26393	-0.29585	1.00000	0.28821
Slope	0.0562	0.0315		0.0364
Elevation	0.94393	-0.97563	0.28821	1.00000
Elevation	<.0001	<.0001	0.0364	

The CORR Procedure

9 Variables: VIPA E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
VIPA	51	136.33333	33.32787	6953	1.00000	212.00000	VIPA
E	51	3900808	4592	198941220	3893108	3910852	E
N	51	706762	3800	36044869	696423	714600	N
TO	51	6224	284.74507	317436	5155	6550	TO
dur_T2	51	8.07745	1.17663	411.95000	3.96000	9.52000	dur_T2
PT	51	8.03588	0.53171	409.83000	7.01000	9.01000	PT
TA	51	18.19608	1.25283	928.00000	16.00000	20.60000	TA
Slope	51	16.96078	9.95181	865.00000	5.00000	40.00000	Slope
Elevation	51	3114	678.50535	158810	1593	4732	Elevation

Pearson Correlation Coefficients, N = 51

Prob > |r| under H0: Rho=0

	VIPA	E	N	TO	dur_T2
VIPA	1.00000	-0.00015	0.06894	-0.15801	-0.11797
VIPA		0.9992	0.6307	0.2681	0.4097
E	-0.00015	1.00000	0.05245	-0.02696	-0.31203
E		0.9992	0.7147	0.8510	0.0258
N	0.06894	0.05245	1.00000	-0.11219	0.05316
N		0.6307	0.7147	0.4332	0.7110

Pearson Correlation Coefficients, N = 51

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
VIPA	0.05509	-0.03992	-0.02957	0.01909
VIPA		0.7010	0.8368	0.8942
E	0.19521	-0.43922	0.16488	0.43722
E		0.1698	0.0013	0.0013
N	-0.46680	0.36958	0.09837	-0.50219
N		0.0006	0.0076	0.0002

The CORR Procedure

Pearson Correlation Coefficients, N = 51
Prob > |r| under H0: Rho=0

	VIPA	E	N	T0	dur_T2
T0	-0.15801	-0.02696	-0.11219	1.00000	0.65314
T0	0.2681	0.8510	0.4332		<.0001
dur_T2	-0.11797	-0.31203	0.05316	0.65314	1.00000
dur_T2	0.4097	0.0258	0.7110	<.0001	
PT	0.05509	0.19521	-0.46680	-0.03079	-0.31403
PT	0.7010	0.1698	0.0006	0.8302	0.0248
TA	-0.03992	-0.43922	0.36958	0.04248	0.38942
TA	0.7809	0.0013	0.0076	0.7673	0.0047
Slope	-0.02957	0.16488	0.09837	-0.70052	-0.38824
Slope	0.8368	0.2476	0.4922	<.0001	0.0049
Elevation	0.01909	0.43722	-0.50219	-0.06781	-0.40685
Elevation	0.8942	0.0013	0.0002	0.6363	0.0030

Pearson Correlation Coefficients, N = 51
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.03079	0.04248	-0.70052	-0.06781
T0	0.8302	0.7673	<.0001	0.6363
dur_T2	-0.31403	0.38942	-0.38824	-0.40685
dur_T2	0.0248	0.0047	0.0049	0.0030
PT	1.00000	-0.95708	0.09688	0.92619
PT		<.0001	0.4989	<.0001
TA	-0.95708	1.00000	-0.12979	-0.94839
TA	<.0001		0.3640	<.0001
Slope	0.09688	-0.12979	1.00000	0.16656
Slope	0.4989	0.3640		0.2427
Elevation	0.92619	-0.94839	0.16656	1.00000
Elevation	<.0001	<.0001	0.2427	

The CORR Procedure

9 Variables: YUSC E N TO dur_T2 PT TA Slope
Elevation

Simple Statistics

Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
YUSC	61	22.31148	10.81286	1361	-19.00000	42.00000	YUSC
E	61	3901604	4343	237997868	3893108	3910852	E
N	61	705443	3622	43032004	697577	712332	N
TO	61	6278	281.24701	382929	5155	6560	TO
dur_T2	61	8.17508	1.23653	498.68000	3.96000	9.56000	dur_T2
PT	61	8.16525	0.48584	498.08000	7.30000	9.41000	PT
TA	61	17.88689	1.14520	1091	14.90000	19.90000	TA
Slope	61	14.42623	10.08705	880.00000	5.00000	40.00000	Slope
Elevation	61	3305	627.38236	201626	2141	4788	Elevation

Pearson Correlation Coefficients, N = 61

Prob > |r| under H0: Rho=0

	YUSC	E	N	TO	dur_T2
YUSC	1.00000	-0.18133	-0.15081	-0.02575	-0.04361
YUSC		0.1619	0.2460	0.8439	0.7386
E	-0.18133	1.00000	-0.10550	0.02890	-0.19369
E		0.1619	0.4184	0.8250	0.1347
N	-0.15081	-0.10550	1.00000	-0.32957	-0.20019
N		0.2460	0.4184	0.0095	0.1219

Pearson Correlation Coefficients, N = 61

Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
YUSC	-0.05939	0.09280	-0.20447	-0.03304
YUSC		0.6494	0.4769	0.8004
E	0.14389	-0.39708	0.06870	0.41914
E		0.2686	0.0015	0.0008
N	-0.24777	0.19163	0.24101	-0.37296
N		0.0542	0.1390	0.0613

The CORR Procedure

Pearson Correlation Coefficients, N = 61
Prob > |r| under H0: Rho=0

	YUSC	E	N	T0	dur_T2
T0	-0.02575	0.02890	-0.32957	1.00000	0.69168
T0	0.8439	0.8250	0.0095		<.0001
dur_T2	-0.04361	-0.19369	-0.20019	0.69168	1.00000
dur_T2	0.7386	0.1347	0.1219	<.0001	
PT	-0.05939	0.14389	-0.24777	-0.19544	-0.49083
PT	0.6494	0.2686	0.0542	0.1312	<.0001
TA	0.09280	-0.39708	0.19163	0.19696	0.54019
TA	0.4769	0.0015	0.1390	0.1282	<.0001
Slope	-0.20447	0.06870	0.24101	-0.74695	-0.50405
Slope	0.1140	0.5988	0.0613	<.0001	<.0001
Elevation	-0.03304	0.41914	-0.37296	-0.14494	-0.46933
Elevation	0.8004	0.0008	0.0031	0.2651	0.0001

Pearson Correlation Coefficients, N = 61
Prob > |r| under H0: Rho=0

	PT	TA	Slope	Elevation
T0	-0.19544	0.19696	-0.74695	-0.14494
T0	0.1312	0.1282	<.0001	0.2651
dur_T2	-0.49083	0.54019	-0.50405	-0.46933
dur_T2	<.0001	<.0001	<.0001	0.0001
PT	1.00000	-0.95460	0.41002	0.91902
PT		<.0001	0.0010	<.0001
TA	-0.95460	1.00000	-0.41243	-0.94558
TA	<.0001		0.0010	<.0001
Slope	0.41002	-0.41243	1.00000	0.37621
Slope	0.0010	0.0010		0.0028
Elevation	0.91902	-0.94558	0.37621	1.00000
Elevation	<.0001	<.0001	0.0028	

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President's Award, Friends of the Rio Grande Nature Center State Park, 2001.

Publications and Presentations:

Chris L. Roberts, Scott R. Abella, James S. Holland. 29 years of vegetation community change across environmental gradients in a Mojave Desert mountain range. *USGS Natural Resource Needs Related to Climate Change in the Great Basin and Mojave Desert: Research, Adaptation and Mitigation Workshop*, Poster presentation, April 2010.

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