Native Grass Abundance in the Sonoran Desert National Monument and Adjacent Areas

Pacific Biodiversity Institute
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# TABLE OF CONTENTS

## INTRODUCTION ........................................................................................................................ 5

## METHODS AND RESULTS ........................................................................................................ 5

  **ANALYSIS OF NATIVE GRASS ASSOCIATIONS USING TWINSPLAN** ............................................ 5
  **NATIVE GRASS MODEL AND MAP** .......................................................................................... 7
    **Literature Review** ............................................................................................................... 7
    **Data Exploration** ................................................................................................................ 7
      *Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes (PVMCR) and Mountain Upland (MU) Natural Communities* ................................................................. 9
      *Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes (PVMCR) and Mountain Upland (MU) Linear Regression Model* ................................................................. 10
      Mapping the Predicted Abundance of Native Grasses and Refinement of the Model and Map .................................................................................................................. 11

  **NATIVE GRASS RECONNAISSANCE FIELD TRIP** ................................................................... 15
    **October 8, 2004** ................................................................................................................ 15
      Stop 1 - North Bighorn Tank area ..................................................................................... 15
      Stop 2 - North Maricopa area ............................................................................................ 15
    **October 9, 2004** ................................................................................................................ 15
      Stop 2 (continued) - North Maricopa area ....................................................................... 15
      Driving from Stop 2 to Gila Bend ..................................................................................... 15
      Stop 3. Sand Tank Wash – Area A .................................................................................. 18
      Stop 4. Upper bajadas in southwest Vekol Valley ............................................................ 18
      Stop 5. Lower rocky slopes in Area A on the west side of the Vekol Valley ................... 18
    **October 10, 2004** .................................................................................................................. 21
      Stop 6. Rocky slopes above campsite in the eastern Sand Tanks .................................... 21
      Stop 7. Rocky slopes west of campsite in the eastern Sand Tanks ................................... 21
      Stop 8. Rocky slopes along side road toward Bender Spring Canyon ............................. 21
      Stop 9. Pass to Paradise Well ......................................................................................... 28
      Stop 10. *Creosote Bush – Bursage Desert Scrub* east of Paradise Well .......................... 28
      Stop 11. *Creosote Bush – Bursage Desert Scrub* and rocky slopes about 2 miles east of Paradise Well .......................................................... 28
      Stop 12. *Creosote Bush – Bursage Desert Scrub* and rocky slopes about 2 miles east of Paradise Well .......................................................... 30
      Stop 13. Rocky slopes about 3 miles east of Paradise Well as road descends into the upper Vekol Valley .......................................................... 30
      Stop 14. *Creosote Bush – Bursage Desert Scrub* about 5 miles east of Paradise Well in the upper Vekol Valley .................................................. 32
      Stop 15. *Desert Grassland - Creosote Bush – Bursage Desert Scrub* transition zone in the upper Vekol Valley .................................................. 32

  **DISCUSSION** ............................................................................................................................ 37

  **REFERENCES** ......................................................................................................................... 38

  **APPENDIX A. LIST OF NATIVE GRASSES FOUND ON THE SDNM DURING PACIFIC BIODIVERSITY INSTITUTE’S PHASE 2 FIELDWORK** ......................................................... 39

  **APPENDIX B. TWINSPLAN RESULTS** .................................................................................... 40
List of Figures

Figure 1. TWINSPAN results for native grass species using Phase 2 plot data............................ 6
Figure 2. Histogram of number of Phase 2 native community plots by percent cover of native grass (for all natural communities). ........................................................................................................... 8
Figure 3. Histograms, by natural community type, of percent cover of native grasses for Phase 2 natural community plots. ........................................................................................................... 8
Figure 4. Actual versus predicted percent cover of native grasses for Phase 2 plots. ................ 11
Figure 5. Final map of predicted native grass cover.................................................................... 14
Figure 6. A small patch of *Aristida adscencionis*, a non-seasonal annual native grass, growing on north facing rocky slopes in foothills to the North Maricopa Mountains............................ 16
Figure 7. A small patch of *Hilaria rigida*, a warm-season perennial native grass, growing along a small wash in the *Creosote Bush – Bursage Desert Scrub* matrix community near the foothills of the North Maricopa Mountains ................................................................. 17
Figure 8. A healthy patch of *Muhlenbergia porteri*, a summer perennial growing along a very small wash in a *Paloverde Mixed Cacti – Mixed Shrub on Bajadas* natural community of the western portion of the Vekol Valley in Area A. .............................................................................. 19
Figure 9. *Hilaria mutica* stand on the lower rocky slopes on southwest Vekol Valley in Area A. ............................................................................................................................................... 20
Figure 10. Diverse native grass community on north-facing rocky slopes above campsite in East Tactical Area. .............................................................................................................................. 21
Figure 11. Landscape view of diverse native grass community on rocky slopes above campsite in East Tactical Area. Much of the area has over 30% native grass cover. Grass cover is usually lower on the steepest slopes. ........................................................................................................ 22
Figure 12. *Hilaria mutica* native grass community on the lower rocky slopes east of campsite in East Tactical Area. .......................................................................................................................... 23
Figure 13. Native grass community on gentle rocky slopes directly above campsite in East Tactical Area. This community had a diversity of species but was primarily composed of annuals, primarily *Bouteloua aristidoides* and *Bouteloua barbata*. This area had 5 to 20% native grass cover. ................................................................. 24
Figure 14. North-facing rocky slopes west of campsite in East Tactical Area toward the pass to Paradise Well. Native grass cover exceeds 30% in much of this area........................................... 25
Figure 15. East-facing rocky slopes above side road to Bender Spring Canyon. This is west of our campsite in East Tactical Area and north of the pass to Paradise Well. Native grass cover exceeds 40% in much of this area.................................................................................. 26
Figure 16. South-facing rocky slopes across from side road to Bender Spring Canyon. Native grass cover was very low on these rocky, south-facing slopes and did not exceed 2% cover. This was also predicted by our model................................................................. 27
Figure 17. West-facing rocky slopes above the pass to Paradise Well. Native grass cover exceeds 10% in much of this area........................................................................................................ 28
Figure 18. *Creosote Bush – Bursage Desert Scrub* east of Paradise Well. This area has abundant annual native grasses (primarily *Bouteloua* species).................................................................... 29
Figure 19. *Creosote Bush – Bursage Desert Scrub* and low rocky hills about two miles east of Paradise Well. This area has annual native and perennial grass cover exceeding 5% (primarily *Bouteloua* and *Aristida* species) ........................................ 30
Figure 20. Diverse native grasses on rocky slope adjacent to road from Paradise Well as it descends into the Vekol Valley. This area has annual native and perennial grass cover exceeding 25% (primarily *Hilaria mutica* and *Aristida* species)................................. 31
Figure 21. Patches of *Muhlenbergia porteri* in *Creosote Bush – Bursage Desert Scrub* of the upper Vekol Valley at the edge of the Tohono O’odham Nation. Photo taken from the boundary fence.................................................................................................................................................. 32

Figure 22. Adjacent area to that illustrated in Figure 21, but within the SDNM. This area of *Creosote Bush – Bursage Desert Scrub* is in the upper Vekol Valley near the boundary with the Tohono O’odham Nation (TON). There is some stubble and a few small, grazed patches of *Muhlenbergia porteri* in this area, but nothing like what was observed on the TON side of the fence.................................................................................................................................................. 33

Figure 23. Small, disappearing patches of *Hilaria mutica* within the *Creosote Bush – Bursage Desert Scrub* of the upper Vekol Valley west of the main *Desert Grassland* areas. This area was included in a polygon that represents areas with a medium probability of having over 5% cover of native grass. There was ample sign of intense grazing pressure in this area. .. 34

Figure 24. Stubble from *Hilaria mutica* in an area where this grass species is disappearing and giving way to a low diversity *Creosote Bush – Bursage Desert Scrub* community in the upper Vekol Valley west of the main Desert Grassland areas. We have seen the progressive disappearance of *Hilaria mutica* in this area over the last two years. ........................................ 35

Figure 25. Erosion features in an area where *Hilaria mutica* has largely disappeared giving way to sparse cover of creosote bush. .................................................................................................................................................. 36
**Introduction**

In a May 2003 workshop coordinated by The Nature Conservancy (TNC) on conservation elements of the Sonoran Desert National Monument (SDNM), the Native Grass Group was identified as an important conservation element. Native grasses in this group that occur on the SDNM are listed in Appendix A. TNC and others determined that further information was needed on the extent and characteristics of the native grass element.

The purpose of this project was to develop a preliminary biophysical model that could be used as a basis for creating an efficient field sampling design for the Native Grass Group.

The broad parameters of this model development are:

1) Using data from those Phase 2 plots in which native perennial grass cover is 5% or greater, determine whether and for which natural communities a significant correlation exists between native perennial grass cover and various biophysical parameters.

2) Based on those correlations that are significant, develop a spatial model that can be used to predict the occurrences of additional patches (exclusive of the Desert Grassland community or communities for which no significant correlations were observed) at which native perennial grass cover exceeds 5% cover.

3) Using the model, rank resultant patches (high, medium, low) according to their potential to exceed threshold values of 5% native perennial grass cover.

4) Produce polygons and other geospatial data features representing model results.

As a second part of this project, the Conservancy organized a reconnaissance field trip to the SDNM and adjoining portions of the Barry M. Goldwater Range in the early October, 2004 to identify potential sample locations.

**Methods and Results**

Our methods and results are broken into 3 components:

1. A brief analysis to look at associations of individual native grass species using TWINSPAN
2. Development of a native grass model and map
3. A summary of the October 6-8 native grass reconnaissance field trip to the SDNM

**Analysis of Native Grass Associations Using TWINSPAN**

We conducted a very brief analysis of our Phase 2 ecology plot data (Morrison et al 2003) using TWINSPAN (Two Way Indicator Species Analysis). We looked for any natural “groupings” of native grasses (i.e. species of native grass which tend to occur in the same areas). This type of analysis can be useful in advance of modeling groups of species, since many species tend to have independent distributions and do not model well as a group. For example, it does not make sense
to include grass species only occurring in the Desert Grasslands and outlying areas in the same biophysical model as species of the Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes and Mountain Upland communities. Different biophysical factors are driving distribution and percent cover of these species and a model that attempts to combine them is likely to be very poor at providing insight to biophysical factors in either location.

The figure below shows TWINSPAN results. Detailed results are provided in Appendix B. With TWINSPAN, all grass species start off in a single group and step-by-step are divided into two groups based on occurrences and percent cover of species by plots. The figure shows that 2 species (*Pleuraphis mutica* (*Hilaria mutica*) (PLEMUT), and *Muhlenbergia microsperma* (MUHMIC) are the most different from all other species in terms of their distribution and percent cover in plots since they branch off at the highest level, and that they are generally found together. The next greatest difference of the remaining species is *Muhlenbergia porteri* (MUHPOR), which tends to be different in its distribution and does not group with any other species. Next, *Aristida* sp. (ARIXXX), *Poa bigelovii* (POABIG), and *Vulpia octoflora* (VULOCT) are the most different from other species, and tend to group together. Interpretations are similar for the final branch *Aristida purpurea* (ARIPUR), *Bouteloua repens* (BOUREP), *Bouteloua* sp. (BOUXXX), *Elymus elymoides* (ELYELY), *Muhlenbergia* sp. (MUHXXX), and *Pleuraphis rigida* (PLERIG)

Refer to Appendix A for a complete list of grasses found in the Phase 2 sampling. Interpret the grass codes as follows: the first 3 letters of the code are the first 3 letters of the genus name, the last 3 letters of the code are the first 3 letters of the species name. Final 3 letters of XXX in a code mean that those plants were only identified to genus.

**TWINSPAN Results for Native Grass Species**

(Using default cut-off values in PCORD)

![TWINSPAN Results Diagram](image)

**Figure 1.** TWINSPAN results for native grass species using Phase 2 plot data.
Native Grass Model and Map

The process for developing the native grass model involved literature review, extensive data exploration, development of a regression model, and translation of the regression model into a spatial model. Due to budget limitations we were unable to assess reliability of the model through statistical means. Instead, we visually assessed the model results in relation to our knowledge of native grass distribution on the SDNM from previous fieldwork. Based on the model, we characterized areas as having high, medium and low potential for exceeding 5% native grass cover. We made several refinements to the final map based on our field knowledge of the area to create the best representation of areas with 5% or more native grass cover.

Literature Review

First, we conducted a literature review of native grasses and their distributions to find out which variables, if any, other scientists had found to be correlated with native grass cover. Although there were a number of papers that referred to various native grasses, we found only one paper that was available in the ASU library system, and that related cover of some species of native grasses that are found in the SDNM, with biophysical variables.

Mata-Gonzalez et al. (2002) conducted a vegetation study on a low mountain (Mt. Summerford) in the Basin and Range country of southern New Mexico. In their study they found 3 species of native grass that also occur on the SDNM: *Bouteloua curtipendula*, *Muhlenbergia porteri*, and *Aristida ternipes*. They describe their findings as follows:

Grass cover was affected by the interaction of elevation and aspect. On the E aspect grass cover decreased significantly as elevation increased, but on the W aspect, in contrast, grass cover increased significantly as elevation increased. At the lowest elevation, E and N exposures had higher grass cover than S and W exposures. At the intermediate elevations, the N aspect supported higher grass cover than the other 3 aspects and the lowest grass cover was found in the S aspect. The differences between the EN and SW aspects were more marked at the lower parts of the mountain and these differences faded near the top of the mountain.

Data Exploration

We looked at the distribution of native grass cover across all communities and within each community to evaluate whether the 5% threshold for native grass cover suggested by The Nature Conservancy was reasonable in differentiating areas of high grass cover on the Monument. Using the histograms below and a number of other evaluation tools, we decided that 5% was a meaningful breaking point.
Figure 2. Histogram of number of Phase 2 native community plots by percent cover of native grass (for all natural communities).

Figure 3. Histograms, by natural community type, of percent cover of native grasses for Phase 2 natural community plots.
Based on looking at the TWINSPAN results and the native grass cover of plots by community type in detail, we determined the following:

- First, we determined that the desert grassland natural community and associated grass patches on adjacent creosote bush – bursage desert scrub natural communities was a unique ecological occurrence and that it would be treated as a separate element in our native grass abundance model. The plots represented a very limited area that is best delineated by field investigation. We mapped a polygon to represent this area based on our Phase 2 field plots and a brief exploration of the area during our October 10 field trip.
- Second, we determined that the significant native grass presence recorded during our 2003 field sampling in the mesquite woodland community was another unique occurrence and would be treated as a separate element in our native grass abundance model.
- Third, we determined that we had no evidence from prior sampling that significant areas of high native grass abundance occur within the creosote bush – bursage desert scrub, the Paloverde-mixed cacti-mixed scrub on bajadas or rocky outcrop natural communities. Therefore native grass abundance was not modeled in these communities.
- Fourth, our prior sampling revealed that nearly all the areas of high native grass abundance occur in the Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes and Mountain Upland natural communities. Our plot sample size was sufficient in these communities to allow us to conduct a statistical analysis of the prior field data and to develop a linear regression formula that could be used to model the native grass abundance in these areas.
- Fifth, there were no readily observable patterns with the xeroriparian communities in the study area with respect to native grass abundance. We did not include these communities in our native grass model. It is possible that further data exploration and/or fieldwork will reveal some pattern within the xeroriparian community.

**Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes (PVMCR) and Mountain Upland (MU) Natural Communities**

Once we determined that the only natural communities for which we could reasonably develop a statistical model were Mountain Upland and Paloverde-Mixed Cacti on Rocky Slopes, we created scatterplots of variables that we thought might be related to distribution of native grasses within these communities (scatterplots are shown in Appendix C).

The scatterplots show relationships of potential variables with percent cover native grass for the MU and PVMCR natural communities. In the plots, PCNATGR stands for Percent Cover Native Grass and is on the Y-axes, potential model variables are on the X-axes. According to the scatterplots, Northness appears to be a strong variable. Elevation, Eastness, and Curvature also show some relationship to native grass cover. Slope shows no visible relationship. Soil texture was also evaluated, even though this measure was field-derived and as such, cannot be used to create a mapped model. Almost all plots fall within the “rocky” soil class, so at this level of classification the soil variable is not useful. Geology, as recorded in the SDNM database, was also field-derived and was evaluated. It showed promise of being a useful variable. We then checked to see if geology, as mapped in the GIS layer, could be used and incorporated into the
native grass model. We reclassified and overlaid the geology GIS layer with the natural community points, attributed by the points by their GIS geology value. The GIS geology data appeared less useful.

Variables consisting of band values from two different images that were derived from a 21 May 2002 Landsat TM satellite imagery make up the final plots. “PC” variables are band values from a principal components image; “TC” variables are band values from a tasseled-cap image. In the scatterplots, there appear to be weak relationships with some of the PC and TC variables. PC and TC bands 4 and 5 often contain a lot of noise, so the primary bands to consider are bands 1, 2, and 3.

**Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes (PVMCR) and Mountain Upland (MU) Linear Regression Model**

We used an all subsets method for determining the best linear regression model for the following variables: elevation, slope, curvature, eastness, northness, Landsat TM 7 principal component image bands (PC1, PC2, PC3), Landsat TM 7 tasseled cap image bands (TC1, TC2, TC3), field derived geologic units, GIS derived geologic units, and field derived soil texture.

The best two subsets of variables according to Mallow’s CP criteria are:

1. Elevation, northness, and TC3
2. Elevation, northness and PC1 (model Adjusted R-squared = 0.2248)

Adjusted R-squared for both models is 0.22 and both models were highly significant (p<0.0001). There was greater multicollinearity with the PC1 band than the TC3 band, so we chose the first model. Elevation was the strongest variable (p<0.0001), northness was somewhat strong (p = 0.0195), and TC3 was weak (p = 0.0474). TC3 corresponds to canopy and soil moisture in TM satellite images and is referred to as degree of “wetness”.

The regression equation for the model, with % cover native grass as the dependent variable is:

\[ Y = (-11.916) + 2.45*\text{Northness} + 0.016*\text{Elevation} + (-0.115)*\text{TC3} \]

Detailed regression results are provided in Appendix D.

All plots within the communities were used to derive the model except 2 outliers, which had greater than 75% cover of native grasses. There were 98 remaining plots, and since the variation across the plots was so high (see scatterplots in Appendix C), we felt that all plots should be used to derive the best potential model rather than subsetting the data and using part for model derivation and part for accuracy assessment. In the future, the stability of the model could be checked using bootstrap methods.

An informal assessment was made of how well the model predicted % cover of native grasses for the natural community plots (which were also used to derive the model). Summary results are provided in a table and chart below. Detailed results are provided in Appendix E. When looking at the model in terms of % cover classes, the greatest problem area is the number of plots that have 0-4% cover, but are predicted in the 5-10% class.
In the final model, multicollinearity was low. Assumptions of normality and constant variance of error terms were not well met. Several transformations were attempted to improve correspondence with assumptions but these did not prove useful.

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</tr>
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<td>&gt;10%</td>
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Figure 4. Actual versus predicted percent cover of native grasses for Phase 2 plots.

Mapping the Predicted Abundance of Native Grasses and Refinement of the Model and Map

Our map of predicted native grass abundance is based on seven factors:

1. Our analysis of Phase 2 ecology plot data revealed that nearly all the areas of high native grass abundance occur in the Paloverde - Mixed Cacti - Mixed Scrub on Rocky Slopes and Mountain Upland natural communities. We implemented the linear regression formula that we developed to model this distribution in an ArcInfo GRID environment to create an initial predicted native grass abundance map.

2. This GIS model was modified slightly based on results of the Phase 3 field reconnaissance conducted in early October. In areas of predicted high grass abundance, a
slope correction factor was added to downweight areas with steep slopes – as grasses were most abundant on the gentle slope areas (in the zones of high predicted grass abundance).

3. We determined that we had no evidence from prior sampling that significant areas of high native grass abundance occur within the Creosote Bush – Bursage Desert Scrub natural community, the Paloverde-Mixed Cacti-Mixed Scrub On Bajadas or Rocky Outcrop natural communities. Therefore native grass abundance was not modeled in these three communities. It was predicted to be in the low range except for the unique cases presented below (3 and 4). This prediction was incorporated into our final GIS model.

4. We determined that the Desert Grassland natural community and associated grass patches on adjacent Creosote Bush – Bursage Desert Scrub natural communities was a unique ecological occurrence and that it would be treated as a separate element in our native grass abundance model. Polygons for the Desert Grassland community developed from Phase 2 mapping were used as well as a new polygon that represents a small adjacent area where Phase 2 sampling and a brief Phase 3 field reconnaissance indicates that significant patches of Hilaria mutica exist within an area previously mapped as a Creosote Bush – Bursage Desert Scrub natural community in the upper Vekol Valley.

5. During or Phase 3 October 2004 field reconnaissance we identified areas of Creosote Bush – Bursage Desert Scrub and Paloverde-Mixed Cacti-Mixed Scrub On Bajadas in the East Tactical Area of the BMGR east of Paradise Well that had significant abundance of annual and perennial native grasses (primarily Aristida adscensionis, Aristida purpurea var. nealleyi, Aristida ternipes, Bouteloua aristidoides, Bouteloua barbata, Bouteloua curtipendula, and Bouteloua repens). A polygon was digitized to represent this area and it was assigned a medium native grass abundance probability class.

6. We determined that the significant native grass presence recorded during our Phase 2 field sampling in the mesquite woodland community was another unique occurrence and would be treated as a separate element in our native grass abundance model.

7. There were no readily observable patterns with the xeroriparian communities in the study area with respect to native grass abundance. We did not include these communities in our native grass model.

These factors were implemented in the ArcINFO GRID environment with the following commands:

\[
GRASS1 = -11.916 + (2.45 \times \text{NORTHNESS1}) + (0.016 \times \text{DEM}) + (-0.115 \times \text{TC3})
\]

This is the regression formula, implemented in GRID.

GRASS2 = selectmask(GRASS1, ROCKYCOMM3)

This restricts the application of the regression formula to the PVMCR and MU natural communities.

GRASS3 = con(GRASS2 > 6, GRASS2 - (0.2 \times \text{SLOPE}), GRASS2 - 3)

This down weights the high slope areas within the areas of high grass abundance to reflect further analysis of Phase 2 plot data and Phase 3 field work.

GRASS4 = con(NORTHSOUTH == 1, GRASS3 * 0.5, GRASS3)

This down weights areas in the Maricopa Mountains that have lower grass abundance due to geology (granitic rocks) and less precipitation. This also reflects observations from Phase 3 field work.
GRASSPROB1 = reclass(GRASS4,reclass.txt)
   *This transforms the continuous grass abundance prediction numbers into three classes (high, medium and low).*

GRASSPROB2 = con(isnull(GRASSPROB1),1,GRASSPROB1)
   *This converts null values in the grid to 1 (low).*

GRASSPROB3 = merge(MESQUITEGRASS,DESERTGRASSES,PARA-
VEKOL, GRASSPROB2)
   *This merges the predicted abundance classes for the mesquite community, the desert grass community and the somewhat anomalous areas in the upper Vekol valley and Paradise Well areas into the model.*

The resulting predicted abundance class grid was converted into a GIS shapefile and a map (Figure 5). The native grass abundance classes are: high, medium and low.

In the high probability areas we estimate that there is a 50% probability of a native grass cover of over 5% and a 90% probability of there being a native grass cover of at least 1%.

In the moderate probability areas we estimate that there is a 10% probability of a native grass cover of over 5% and a 50% probability of there being a native grass cover of at least 1%.

In the low probability areas we estimate that there is less than 1% probability of a native grass cover of over 5% and less than 10% probability of there being a native grass cover of at least 1%.

These probability estimates are based on a quick examination of how the Phase 2 plot data in relation to the final predicted native grass abundance map and knowledge gained during the Phase 3 October 2004 field trip.
Figure 5. Final map of predicted native grass cover.
Native Grass Reconnaissance Field Trip

John Hall and Dana Backer (of The Nature Conservancy of Arizona) organized a field trip to examine the native grass situation on October 8-10, 2004. Participants in the field trip provided their expert knowledge and advice about the distribution of native grasses in the study area. The participants included: Sue Rutman (Organ Pipe Cactus National Monument) ,Jim Malusa (USGS – NBS), Byron Lambeth (BLM), Karen Kelleher (BLM) , JT Hesse (DOD) , John Anderson (BLM). The field trip was useful to verify and improve the result of the initial native grass abundance model and to explore other issues related to native grass presence in the study area.

A brief description of the sites that were visited on the field trip (including photographs) is presented below.

October 8, 2004

Stop 1 - North Bighorn Tank area
Our first stop was a site at the edge of the South Maricopa Mountains north of I5 that Byron had previously identified as fairly unique in his experience in the presence of native grasses. The site was a valley bottom area crossed by many small washes. There were patches of *Hilaria rigida* growing on the sides of a few of the small washes. But several of us estimated that the overall native grass abundance of this site was only about 1% total cover. Byron stated that this was one of the best sites he had encountered for native grasses. This site is very close to a cluster of Phase 2 plots established by PBI in April 2003. The site was mapped on BLM/NRCS soils maps at a unit 49.

Stop 2 - North Maricopa area
Our second stop was a site in the foothills south of the North Maricopa Mountains that Byron had previously identified as also unique in his experience in the presence of native grasses. This site was a creosote bush – bursage flat with a small wash. There was a patch of *Hilaria rigida* growing on the sides of the small wash. The overall native grass abundance at this site was low – less than 1% total cover. Byron stated again that this was one of the best sites he had encountered for native grasses. This site was also mapped on BLM/NRCS soils maps at a unit 49.

October 9, 2004

Stop 2 (continued) - North Maricopa area
In the morning, we examined the area surrounding the site we visited on October 8th. We explored creosote bush – bursage flats, rocky slopes and xeroriparian areas. We found an absence of native grasses on the flats and very occasional occurrences of small patches of native grasses (primarily *Aristida adscensionis*) on rocky slopes (Figure 6). It appeared that these patches were more prevalent on north and east facing slopes. We also found a few additional patches of *Hilaria rigida* along an extension of the small wash that we visited on October 8 (Figure 7).

Driving from Stop 2 to Gila Bend
As we drove across the desert from Stop 2 to Gila Bend, Peter Morrison examined the flats, lower bajadas and xeroriparian areas that we were traversing. There was a noted lack of native
grass presence in the entire area we traversed. This confirmed our earlier conclusion that native grass abundance is very low in most of the low-lying parts of the study area.

Figure 6. A small patch of *Aristida adscenscionis*, a non-seasonal annual native grass, growing on north facing rocky slopes in foothills to the North Maricopa Mountains.
Figure 7. A small patch of *Hilaria rigida*, a warm-season perennial native grass, growing along a small wash in the *Creosote Bush – Bursage Desert Scrub* matrix community near the foothills of the North Maricopa Mountains.
Stop 3. Sand Tank Wash – Area A
We drove from Gila Bend through creosote bush – bursage flats in the SDNM and into Area A. We stopped briefly to examine one flat and adjacent VXR community in more detail. Very low abundance of native grasses was recorded and observed as we traverse the low-lying desert. We then stopped and walked through an area previously mapped in Phase 2 as a Braided Channel Floodplain community that lies south of the Blue Plateau. This area is on the border of Area A and East Tac. Some Phase 2 plots had been collected in this area. A few small patches of Aristida adscensionis and Muhlenbergia porteri were found in this area, but native grass abundance was less than 1% cover.

Stop 4. Upper bajadas in southwest Vekol Valley
On our way into the Sand Tank Mountains, once we crossed into Area A, we stopped to examine a small wash where a healthy patch of Muhlenbergia porteri, a summer perennial, was growing in a Paloverde Mixed Cacti – Mixed Shrub on Bajadas natural community (Figure 8). Besides occasional patches like this, there were very few native grasses in this area. The area we traversed on the bajada had less than 1% overall cover of native grasses.

Stop 5. Lower rocky slopes in Area A on the west side of the Vekol Valley
We stopped to examine some significant patches of Hilaria mutica mixed with other native grasses as we reached the foothills of the Sand Tank Mountains in the south west side of the Vekol Valley (Figure 9). There were significant areas on these slopes with over 5% cover of native grass.
Figure 8. A healthy patch of *Muhlenbergia porteri*, a summer perennial growing along a very small wash in a *Paloverde Mixed Cacti – Mixed Shrub on Bajadas* natural community of the western portion of the Vekol Valley in Area A.
Figure 9. *Hilaria mutica* stand on the lower rocky slopes on southwest Vekol Valley in Area A.
October 10, 2004

Stop 6. Rocky slopes above campsite in the eastern Sand Tanks
In the morning of October 10, we explored the rocky slopes above our campsite in the eastern slopes of the Sand Tank Mountains. These slopes supported a diverse and abundant native grass community (Figures 10 to 13). Native grass abundance was high and greatly exceeded the 5% cutoff in many places. A complete list of the grass species and other plant species that was found on these slopes is presented in Appendix F. This area was predicted to have relatively high grass cover in our model.

Stop 7. Rocky slopes west of campsite in the eastern Sand Tanks
After exploring the rocky slopes above our campsite, we drove to the west toward the pass to Paradise Well. As we gained elevation the native grass cover increased on the north facing rocky slopes (Figure 14). This was also predicted by the model. Native grass cover exceeded 30% in much of this area.

Stop 8. Rocky slopes along side road toward Bender Spring Canyon
We parked our vehicles a little way up a side road that goes north over a small pass into Bender Spring Canyon. We walked up this road and explored the surrounding country. There were many areas above and below this road were native grass cover exceeded 5% and some places
where it was much more abundant (Figure 15). But native grasses were nearly absent on south-facing slopes (Figure 16). This confirmed predictions from our model.

Figure 11. Landscape view of diverse native grass community on rocky slopes above campsite in East Tactical Area. Much of the area has over 30% native grass cover. Grass cover is usually lower on the steepest slopes.
Figure 12. *Hilaria mutica* native grass community on the lower rocky slopes east of campsite in East Tactical Area.
Figure 13. Native grass community on gentle rocky slopes directly above campsite in East Tactical Area. This community had a diversity of species but was primarily composed of annuals, primarily *Bouteloua aristidoides* and *Bouteloua barbata*. This area had 5 to 20% native grass cover.
Figure 14. North-facing rocky slopes west of campsite in East Tactical Area toward the pass to Paradise Well. Native grass cover exceeds 30% in much of this area.
Figure 15. East-facing rocky slopes above side road to Bender Spring Canyon. This is west of our campsite in East Tactical Area and north of the pass to Paradise Well. Native grass cover exceeds 40% in much of this area.
Figure 16. South-facing rocky slopes across from side road to Bender Spring Canyon. Native grass cover was very low on these rocky, south-facing slopes and did not exceed 2% cover. This was also predicted by our model.
Figure 17. West-facing rocky slopes above the pass to Paradise Well. Native grass cover exceeds 10% in much of this area.

Stop 9. Pass to Paradise Well
We stopped near the pass to Paradise Well and briefly examined the surrounding slopes and a small wash. Native grasses were both very diverse and abundant in this area (Figure 17).

Stop 10. Creosote Bush – Bursage Desert Scrub east of Paradise Well
We stopped just east of Paradise Well and briefly examined an area of Creosote Bush – Bursage Desert Scrub identified during Phase 2 sampling as one of the only areas in this natural community with over 5% native grass cover. This area had abundant cover of mostly annual native grasses (Bouteloua species primarily) and our visit confirmed our observations from the spring of 2003 (Figure 18).

Stop 11. Creosote Bush – Bursage Desert Scrub and rocky slopes about 2 miles east of Paradise Well
We stopped very briefly along the road east from Paradise Well to examine the surrounding flats and a low rocky hill. Native grasses were fairly abundant in this area (Figure 19) and exceeded our 5% cover threshold.
Figure 18. Creosote Bush – Bursage Desert Scrub east of Paradise Well. This area has abundant annual native grasses (primarily Bouteloua species)
Figure 19. Creosote Bush – Bursage Desert Scrub and low rocky hills about two miles east of Paradise Well. This area has annual native and perennial grass cover exceeding 5% (primarily Bouteloua and Aristida species).

Stop 12. Creosote Bush – Bursage Desert Scrub and rocky slopes about 2 miles east of Paradise Well
We stopped very briefly along the road east from Paradise Well to examine the surrounding flats and a low rocky hill. Native grasses were fairly abundant in this area (Figure 19) and exceeded our 5% cover threshold.

Stop 13. Rocky slopes about 3 miles east of Paradise Well as road descends into the upper Vekol Valley.
We stopped very briefly along the very rough road that goes over a low rocky ridge east of Paradise Well and then descends into the upper Vekol Valley. There were abundant and diverse native grasses on this slope (which is within East Tac of the BMGR) (Figure 20). Native grasses were fairly abundant in this area (Figure 19) and exceeded our 15% cover. This is an unusually low elevation site for this amount of native grass cover.
Figure 20. Diverse native grasses on rocky slope adjacent to road from Paradise Well as it descends into the Vekol Valley. This area has annual native and perennial grass cover exceeding 25% (primarily *Hilaria mutica* and *Aristida* species).

We stopped briefly to look at the *Creosote Bush – Bursage Desert Scrub* communities on both sides of the SDNM / TON boundary fence. From the fence, we could see healthy patches of *Muhlenbergia porteri* growing along the very small washes (Figure 21). On the SDNM side we searched for similar patches of grass, but could only find a few patches of grass stubble abundant and diverse native grasses on this slope (which is within East Tac of the BMGR) (Figure 22). Native grasses did not exceeded our 5% cover threshold on either side of the boundary fence.


We stopped briefly to look at the *Desert Grassland - Creosote Bush – Bursage Desert Scrub* transition zone in the upper Vekol Valley. This area had been identified in Phase 2 sampling as the one area where *Hilaria mutica* was often found in patches that sometimes exceed 5% cover. We found several areas where there were patches of *Hilaria mutica* that exceeded 5% cover (Figure 23). But there was also evidence of progressive elimination of the *Hilaria mutica* patches due to high grazing pressure (Figure 24). Near this area we also found fairly extensive
zones where the surface soils had eroded down several feet (Figure 25). The only plant species surviving in this area appeared to be creosote bush.

Figure 22. Adjacent area to that illustrated in Figure 21, but within the SDNM. This area of Creosote Bush – Bursage Desert Scrub is in the upper Vekol Valley near the boundary with the Tohono O'odham Nation (TON). There is some stubble and a few small, grazed patches of *Muhlenbergia porteri* in this area, but nothing like what was observed on the TON side of the fence.
Figure 23. Small, disappearing patches of *Hilaria mutica* within the *Creosote Bush – Bursage Desert Scrub* of the upper Vekol Valley west of the main *Desert Grassland* areas. This area was included in a polygon that represents areas with a medium probability of having over 5% cover of native grass. There was ample sign of intense grazing pressure in this area.
Figure 24. Stubble from *Hilaria mutica* in an area where this grass species is disappearing and giving way to a low diversity *Creosote Bush – Bursage Desert Scrub* community in the upper Vekol Valley west of the main Desert Grassland areas. We have seen the progressive disappearance of *Hilaria mutica* in this area over the last two years.
Figure 25. Erosion features in an area where *Hilaria mutica* has largely disappeared giving way to sparse cover of creosote bush.
Discussion

We believe that our model and map of native grass cover provide a reasonable portrayal of where areas of higher native grass cover are likely to occur on the SDNM, and should be useful in designing a field sampling scheme for further assessing the extent and character of the native grass community. However, we emphasize that this is an initial attempt to map and model the native grass communities of the SDNM and that this work could be greatly improved by having additional data and time with which to develop a model or models (for 1 or more additional natural communities). Thresholds of lower than 5% could be examined and modeled for other natural community types. Accuracy of the model could not be assessed because there was not enough data to both derive a reasonable model and independently check its accuracy.

One confounding factor is that *Bromus rubens* was found to be very abundant during the spring of 2003 on some sites where native grasses are predicted to be high. This non-native grass may be displacing native grasses. If this non-native grass was not present at these sites, native grasses might well have been more abundant. The pervasive influence of the non-native *Schimus arabicus* in much of the study area may also be a negative factor for native grass species.

Although we found little evidence for areas of high native grass abundance in the matrix communities of the study area (*Creosote Bush – Bursage Desert Scrub* and *Paloverde Mixed Cacti – Mixed Shrub on Bajadas* natural communities). It would be possible to model the presence of native grasses at a lower threshold (perhaps greater than or equal to 1% cover). This modeling effort would help identify areas such as those identified by Byron Lambeth at the beginning of our October 2004 field trip. We could use the existing Phase 2 plot data to create this model with supplementation from some additional field sampling. The model would incorporate soil type and perhaps additional information derived from advanced multispectral imagery such as ASTER satellite imagery.

The relatively high abundance of native grasses in the low elevation areas of East Tac east of Paradise Well demonstrates that high native grass cover is possible within the *Creosote Bush – Bursage Desert Scrub* and *Paloverde Mixed Cacti – Mixed Shrub on Bajadas* matrix communities. These areas in East Tac have been excluded from grazing pressure for several decades. The progressive disappearance of native grasses and extensive erosion within the Desert Grassland - Creosote Bush – Bursage Desert Scrub transition zone of the Vekol Valley inside the SDNM is a cause for concern. Reevaluation of current management of this area may be in order.
REFERENCES


APPENDIX A. List of native grasses found on the SDNM during Pacific Biodiversity Institute’s Phase 2 fieldwork.

Aristida adsensionis
Aristida parishii
Aristida purpurea
Aristida ternipes var. ternipes
Aristida
Bouteloua aristidoides
Bouteloua curtipendula
Bouteloua repens
Bouteloua gramma
Digitaria californica
Elymus elymoides
Erioneuron pulchellum
Heptochloa panicea ssp. Brachiata
Heteropogon contortus
Hordeum pusillum
Muhlenbergia microsperma
Muhlenbergia porteri
Muhlenbergia
Pleuraphis mutica
Pleuraphis rigida
Pleuraphis
Poa bigelovii
Triticum aestivum
Trisetum interruptum
Tridens muticus
Vulpia octoflora
Appendix B. TWINSPLAN RESULTS

************* Two-way Indicator Species Analysis (TWINSPLAN) *************
PC-ORD, Version 4.10
29 Sep 2004, 16:25

Twinspan
Number of samples: 111
Number of species: 14
Length of raw data array: 557 non-zero items

SPECIES NAMES
1ARIXXX  2ARIPUR  3BOUXXX  4BOUREP  5ELYELY
6ERIPUL  7MUHXXX  8MUHMIC  9MUHPOR  10PLEMUT
11PLERIG 12POABIG  13TRIMUT  14VULOCT

SAMPLE NAMES
1N44  2N53  3N75  4N76  5N78
6N191  7N77  8N272  9N286 10N215
11N41  12N156 13N182 14N211 15N239
16N287 17N269 18N152 19N147 20N144
21N105 22N311 23N319 24N107 25N109
26N310 27N106 28N111 29N113 30N300
31N282 32N289 33N278 34N112 35N304
36N313 37N318 38N314 39N281 40N279
41N297 42N315 43N115 44N118 45N116
46N317 47N276 48N301 49N306 50N108
51N114 52N117 53N316 54N303 55N119
56N299 57N178 58N179 59N195 60N96
61N188 62N220 63N253 64N222 65N184
66N270 67N250 68N48 69N259 70N169
71N288 72N50 73N181 74N183 75N225
76N243 77N200 78N249 79N98 80N275
81N204 82N260 83N207 84N232 85N263
86N205 87N294 88N194 89N100 90N241
91N255 92N52 93N209 94N248 95N266
96N102 97N265 98N49 99N231 100N201
101N274 102N305 103N268 104N63 105N257
106N245 107N258 108N256 109N51 110N99
111N296

Cut levels:
0.0000 2.0000 5.0000 10.0000 20.0000

Options:
Minimum group size for division = 5
Maximum number of indicators per division = 5
Maximum number of species in final table = 200
Maximum level of divisions = 6

Length of data array after defining pseudospecies: 485
Total number of species and pseudospecies: 41
Number of species: 14
(excluding pseudospecies and ones with no occurrences)

CLASSIFICATION OF SAMPLES
******************************************************************************
DIVISION 1 (N= 111)  i.e. group *
Eigenvalue: 0.5912 at iteration 49
INDICATORS and their signs:
PLEMUT (+)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 2 (N = 102)  i.e. group 0
N44 N53 N75 N76 N78 N191 N77 N272
N286 N215 N41 N156 N182 N211 N239 N287
N269 N105 N311 N319 N107 N109 N310 N106

40
REGION 1 (N = 182)

ITEMS IN POSITIVE GROUP 3 (N = 9) i.e. group *1
N152 N147 N144 N115 N276 N108 N117 N303 N119

ITEMS IN NEGATIVE GROUP 4 (N = 5) i.e. group *0
N222 N183 N200 N204 N231

NEGATIVE PREFERENTIALS
POABIG 1( 46, 2) VULOCT 1( 79, 3) VULOCT 2( 26, 0)

POSITIVE PREFERENTIALS
PLEMUT 1( 3, 9) PLEMUT 2( 1, 9) MUHPOR 3( 11, 2) PLEMUT 3( 0, 9)
PLEMUT 4( 0, 5) PLEMUT 5( 0, 2)

NON-PREFERENTIALS
MUHPOR 1( 44, 4) MUHPOR 2( 30, 4) POABIG 2( 12, 2)

-------- END OF LEVEL 1 --------
DIVISION 3 (N=9)  i.e. group *1
Eigenvalue: 0.3603 at iteration 4
INDICATORS and their signs:
MUHPOR 1(-)
Maximum indicator score for negative group -1
Minimum indicator score for positive group 0

ITEMS IN NEGATIVE GROUP 6 (N=4)  i.e. group *10
N115  N276  N117  N303

BORDERLINE NEGATIVES (N=1)
N115

ITEMS IN POSITIVE GROUP 7 (N=5)  i.e. group *11
N152  N147  N144  N108  N119

NEGATIVE PREFERENTIALS
MUHMIC 1(1,0) MUHPOR 1(4,0) POABIG 1(2,0) VULOCT 1(2,1)
MUHPOR 2(4,0) POABIG 2(2,0) MUHPOR 3(2,0) MUHPOR 4(1,0)
MUHPOR 5(1,0)

POSITIVE PREFERENTIALS

Pلازم 1(4,5) Pلازم 2(4,5) Pلازم 3(4,5) Pلازم 4(2,3)

-------- END OF LEVEL 2 -------

*****************************************************************************

DIVISION 4 (N=5)  i.e. group *00
Eigenvalue: 0.3219 at iteration 1
INDICATORS and their signs:
POABIG 1(++)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 8 (N=3)  i.e. group *000
N222  N183  N200

BORDERLINE NEGATIVES (N=1)
N222

ITEMS IN POSITIVE GROUP 9 (N=2)  i.e. group *001
N204  N231

NEGATIVE PREFERENTIALS

POABIG 1(0,2) VULOCT 1(1,2) VULOCT 2(0,1)

POSITIVE PREFERENTIALS

Pلازم 1(0,2)

NON-PREFERENTIALS

Pلازم 1(4,5) Pلازم 2(4,5) Pلازم 3(4,5) Pلازم 4(2,3)

*****************************************************************************

DIVISION 5 (N=97)  i.e. group *01
Eigenvalue: 0.4348 at iteration 30
INDICATORS and their signs:
VULOCT 1(++) ERIPUL 1(-) POABIG 1(++) MUHPOR 1(-)
Maximum indicator score for negative group -1
Minimum indicator score for positive group 0

ITEMS IN NEGATIVE GROUP 10 (N=13)  i.e. group *010
N269  N319  N106  N111  N118  N116  N181  N243
N275  N263  N305  N258  N256

BORDERLINE NEGATIVES (N=2)
N106  N111

ITEMS IN POSITIVE GROUP 11 (N=84)  i.e. group *011
N44  N53  N75  N76  N78  N191  N77  N272
N286  N215  N41  N156  N182  N211  N239  N287
NEGATIVE PREFERENTIALS
ERIPUL 1(  6,   1) MUHPOR 1(  11,  33) ERIPUL 2(  5,   0)

POSITIVE PREFERENTIALS
POABIG 1(   0,  44) VULOCT 1(   3,  73) VULOCT 2(   1,  24)

NON-PREFERENTIALS
MUHPOR 2(   7,  23)

DIVISION 6 (N=  4) i.e. group *10
Group too small for further division.

DIVISION 7 (N=  5) i.e. group *11
Eigenvalue: 0.2170 at iteration 1
INDICATORS and their signs:
PLEMUT 5(-)
Maximum indicator score for negative group -1
Minimum indicator score for positive group 0

ITEMS IN NEGATIVE GROUP 14 (N =  2) i.e. group *110
N108  N119

ITEMS IN POSITIVE GROUP 15 (N =  3) i.e. group *111
N152  N147  N144

NEGATIVE PREFERENTIALS
VULOCT 1(   1,   0) PLEMUT 4(   2,   1) PLEMUT 5(   2,   0)

POSITIVE PREFERENTIALS

NON-PREFERENTIALS
PLEMUT 1(   2,   3) PLEMUT 2(   2,   3) PLEMUT 3(   2,   3)

-------- END OF LEVEL 3 --------

DIVISION 8 (N=  3) i.e. group *000
Group too small for further division.

DIVISION 9 (N=  2) i.e. group *001
Group too small for further division.

DIVISION 10 (N= 13) i.e. group *010
Eigenvalue: 0.5030 at iteration 3
INDICATORS and their signs:
ERIPUL 1(+) Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 20 (N =  7) i.e. group *0100
N319  N106  N111  N118  N116  N243  N275

ITEMS IN POSITIVE GROUP 21 (N =  6) i.e. group *0101
N269  N181  N263  N305  N258  N256

MISCLASSIFIED POSITIVES (N =  1)
N113

NEGATIVE PREFERENTIALS
ERIPUL 1(  6,  1) MUHPOR 1(  11,  33) ERIPUL 2(  5,  0)
NEGATIVE PREFERENTIALS

POSITIVE PREFERENTIALS
ERIPUL 1 ( 0, 6) VULOCT 1( 0, 3) ERIPUL 2( 0, 5)

NON-PREFERENTIALS
MUHPOR 1 ( 7, 4) MUHPOR 2 ( 4, 3)

********************************************************************************

DIVISION 11 (N= 84) i.e. group *011
Eigenvalue: 0.3878 at iteration 11
INDICATORS and their signs:
TRIMUT 2(+) VULOCT 1(-)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 22 (N = 83) i.e. group *0110
 N44 N53 N75 N76 N78 N191 N77 N272
 N286 N215 N41 N156 N182 N211 N239 N287
 N105 N311 N107 N109 N310 N113 N300 N282
 N289 N278 N112 N304 N313 N318 N314 N281
 N279 N297 N315 N317 N301 N306 N114 N316
 N299 N178 N179 N195 N96 N188 N220 N253
 N184 N270 N250 N48 N259 N169 N288 N50
 N225 N249 N98 N260 N207 N232 N205 N294
 N194 N100 N241 N255 N52 N209 N248 N266
 N265 N49 N201 N274 N268 N63 N297 N245
 N51 N99 N296

BORDERLINE NEGATIVES (N = 1)
 N100

ITEMS IN POSITIVE GROUP 23 (N = 1) i.e. group *0111
 N102

NEGATIVE PREFERENTIALS
MUHPOR 1 ( 33, 0) POABIG 1 ( 44, 0) VULOCT 1( 73, 0) MUHPOR 2( 23, 0)
 VULOCT 2( 24, 0)

POSITIVE PREFERENTIALS
TRIMUT 1( 3, 1) TRIMUT 2( 1, 1)

NON-PREFERENTIALS

********************************************************************************

DIVISION 14 (N= 2) i.e. group *110
Group too small for further division.

********************************************************************************

DIVISION 15 (N= 3) i.e. group *111
Group too small for further division.

-------- END OF LEVEL 4 --------

********************************************************************************

DIVISION 20 (N= 7) i.e. group *0100
Eigenvalue: 0.2694 at iteration1000
RA TROUBLE1000 ITERATIONS, AND RESIDUAL IS STILL 0.00680387
INSTEAD OF 0.00000010 (THE TOLERANCE)
INDICATORS and their signs:
MUHPOR 2(++)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 40 (N = 3) i.e. group *01000
 N319 N243 N275

ITEMS IN POSITIVE GROUP 41 (N = 4) i.e. group *01001
 N106 N111 N118 N116

NEGATIVE PREFERENTIALS
POSITIVE PREFERENTIALS
ELYELY 1( 0, 1) TRIMUT 1( 0, 1) MUHPOR 2( 0, 4)

NON-PREFERENTIALS
MUHPOR 1( 3, 4)

DIVISION 21 (N= 6) i.e. group *0101
Eigenvalue: 0.2051 at iteration 3
INDICATORS and their signs:
MUHPOR 1(++)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 1

ITEMS IN NEGATIVE GROUP 42 (N = 2) i.e. group *01010
N181 N263

ITEMS IN POSITIVE GROUP 43 (N = 4) i.e. group *01011
N269 N305 N258 N256

NEGATIVE PREFERENTIALS
POSITIVE PREFERENTIALS
MUHPOR 1( 0, 4) VULOCT 1( 0, 3) ERIPUL 2( 1, 4) MUHPOR 2( 0, 3)
VULOCT 2( 0, 1)

NON-PREFERENTIALS
ERIPUL 1( 2, 4)

DIVISION 22 (N= 83) i.e. group *0110
Eigenvalue: 0.3591 at iteration 43
INDICATORS and their signs:
MUHPOR 1(-) POABIG 2(-) VULOCT 2(+) PLEMUT 1(-) TRIMUT 1(-)
Maximum indicator score for negative group 0
Minimum indicator score for positive group 0

ITEMS IN NEGATIVE GROUP 44 (N = 29) i.e. group *01100
N287 N107 N113 N300 N282 N289 N112 N304
N313 N318 N314 N281 N279 N297 N315 N317
N301 N306 N114 N316 N299 N249 N294 N100
N241 N248 N266 N99 N296

BORDERLINE NEGATIVES (N = 3)
N107 N315 N249

ITEMS IN POSITIVE GROUP 45 (N = 54) i.e. group *01101
N44 N53 N75 N76 N78 N191 N77 N272
N286 N215 N41 N156 N182 N211 N239 N105
N311 N109 N310 N278 N178 N179 N195 N96
N188 N220 N253 N184 N270 N250 N48 N259
N169 N288 N50 N225 N98 N260 N207 N232
N205 N194 N255 N52 N209 N265 N49 N201
N274 N268 N63 N257 N245 N51

BORDERLINE POSITIVES (N = 1)
N268

NEGATIVE PREFERENTIALS
MUHPOR 1( 28, 5) MUHPOR 2( 21, 2) POABIG 2( 11, 1) MUHPOR 3( 11, 0)
MUHPOR 4( 6, 0)

POSITIVE PREFERENTIALS

NON-PREFERENTIALS
POABIG 1( 18, 26) VULOCT 1( 26, 47) VULOCT 2( 6, 18)

DIVISION 23 (N= 1) i.e. group *0111
Group too small for further division.

-------- E N D   O F   L E V E L   5 --------
DIVISION 40 (N= 3)  i.e. group *01000
Group too small for further division.

DIVISION 41 (N= 4)  i.e. group *01001
Group too small for further division.

DIVISION 42 (N= 2)  i.e. group *01010
Group too small for further division.

DIVISION 43 (N= 4)  i.e. group *01011
Group too small for further division.

DIVISION 44 (N= 29)  i.e. group *01100
Eigenvalue: 0.3187 at iteration 7
INDICATORS and their signs:
ELYELY   1(-)
Maximum indicator score for negative group  -1
Minimum indicator score for positive group   0
ITEMS IN NEGATIVE GROUP 88 (N = 2)  i.e. group *011000
N113    N114
ITEMS IN POSITIVE GROUP 89 (N = 27)  i.e. group *011001
N287    N107    N300    N282    N289    N112    N304    N313
N318    N314    N281    N279    N297    N315    N317    N301
N306    N316    N299    N249    N294    N100    N241    N248
N266    N99     N296
BORDERLINE POSITIVES  (N = 2)
N107    N249
NEGATIVE PREFERENTIALS
ELYELY 1( 2, 0)  ELYELY 2( 2, 0)  ELYELY 3( 1, 0)  ELYELY 4( 1, 0)
POSITIVE PREFERENTIALS
VULOCT 1( 0, 26)  POABIG 2( 0, 11)  VULOCT 2( 0, 6)  MUHPOR 4( 0, 6)
NON-PREFERENTIALS
MUHPOR 1( 2, 26)  POABIG 1( 1, 17)  MUHPOR 2( 1, 20)  MUHPOR 3( 1, 10)

DIVISION 45 (N= 54)  i.e. group *01101
Eigenvalue: 0.4241 at iteration 18
INDICATORS and their signs:
POABIG 1(+)  VULOCT 2(-)
Maximum indicator score for negative group  0
Minimum indicator score for positive group  1
ITEMS IN NEGATIVE GROUP 90 (N = 36)  i.e. group *011010
N44    N76    N191    N272    N41    N182    N239    N311
N278    N178    N179    N195    N220    N253    N184    N270
N250    N259    N288    N50    N225    N207    N232    N194
N255    N52    N209    N265    N49    N201    N274    N268
N63    N257    N245    N51
BORDERLINE NEGATIVES  (N = 4)
N278    N184    N52    N49
ITEMS IN POSITIVE GROUP 91 (N = 18)  i.e. group *011011
N53    N75    N78    N77    N286    N215    N156    N211
N105    N109    N310    N96    N188    N48    N169    N98
N260    N205
NEGATIVE PREFERENTIALS
VULOCT 2( 18, 0)
POSITIVE PREFERENTIALS
POABIG 1( 8, 18)
CLASSIFICATION OF SPECIES

DIVISION 1 (N= 14)  i.e. group *
Eigenvalue: 0.8882  at iteration 9
ITEMS IN NEGATIVE GROUP 2 (N = 12)  i.e. group *0
ARIOXX  ARIPUR  BOUXX  BOUREP  ELYELY  ERIPUL  MUHXXX  MUHPOR
PLERIG  POABIG  TRIMUT  VULOCT
ITEMS IN POSITIVE GROUP 3 (N = 2)  i.e. group *1
MUHMIC  PLEMUT

-------- E N D   O F   L E V E L   1 --------

DIVISION 2 (N= 12)  i.e. group *0
Eigenvalue: 0.2277  at iteration 3
ITEMS IN NEGATIVE GROUP 4 (N = 11)  i.e. group *00
ARIOXX  ARIPUR  BOUXX  BOUREP  ELYELY  ERIPUL  MUHXXX  PLERIG
POABIG  TRIMUT  VULOCT
ITEMS IN POSITIVE GROUP 5 (N = 1)  i.e. group *01
MUHPOR

DIVISION 3 (N= 2)  i.e. group *1
Group too small for further division.

-------- E N D   O F   L E V E L   2 --------

DIVISION 4 (N= 11)  i.e. group *00
Eigenvalue: 0.1285  at iteration 3
ITEMS IN NEGATIVE GROUP 8 (N = 8)  i.e. group *000
ARIOUR  BOUXX  BOUREP  ELYELY  ERIPUL  MUHXXX  PLERIG  TRIMUT
ITEMS IN POSITIVE GROUP 9 (N = 3)  i.e. group *001
ARIOXX  POABIG  VULOCT

DIVISION 5 (N= 1)  i.e. group *01
Group too small for further division.

-------- E N D   O F   L E V E L   3 --------

DIVISION 8 (N= 8)  i.e. group *000
Eigenvalue: 0.1302  at iteration 1
ITEMS IN NEGATIVE GROUP 16 (N = 2)  i.e. group *0000
ERIPUL  TRIMUT
ITEMS IN POSITIVE GROUP 17 (N = 6)  i.e. group *0001
ARIPUR BOUXXX BOUREP ELYELY MUHXXX PLERIG
******************************************************************************
DIVISION 9 (N = 3)  i.e. group *001
Group too small for further division.
******* END OF LEVEL 4 *******
******************************************************************************
DIVISION 16 (N = 2)  i.e. group *0000
Group too small for further division.
******************************************************************************
DIVISION 17 (N = 6)  i.e. group *0001
**************** THIS IS THE END OF THE DIVISIONS REQUESTED ****************
******************************************************************************

ORDER OF SPECIES INCLUDING RARER ONES
6  ERIPUL  |   13  TRIMUT  |    2  ARIPUR  |    3  BOUXXX  |    4  BOUREP
5  ELYELY  |    7  MUHXXX  |   11  PLERIG  |    1  ARIXXX  |   12  POABIG
14  VULOCT  |    9  MUHPOR  |    8  MUHMIC  |   10  PLEMUT  |
ORDER OF SAMPLES
64 N222     |   74 N183     |   77 N200     |   81 N204     |   99 N231
23 N319     |   79 N106     |   28 N111     |   44 N118     |   45 N116
76 N243     |   80 N275     |   17 N269     |   73 N181     |   85 N263
102 N305    | 107 N258      | 108 N256      |   1 N44       |   2 N53
 3 N75      |    4 N76      |    5 N78      |   6 N191      |   7 N77
 8 N727     |    9 N286     |   10 N215     |   11 N41      |   12 N156
 13 N182    |   14 N211     |   15 N239     |   16 N287     |   21 N105
 22 N311    |   24 N107     |   25 N109     |   26 N310     |   29 N113
 30 N300    |   31 N282     |   32 N289     |   33 N278     |   34 N112
 35 N304    |   36 N313     |   37 N314     |   38 N314     |   39 N281
 40 N279    |   41 N297     |   42 N315     |   46 N317     |   48 N301
 49 N306    |   51 N114     |   53 N316     |   56 N299     |   57 N178
 58 N179    |   59 N195     |   60 N96      |   61 N188     |   62 N220
 63 N253    |   65 N184     |   66 N270     |   67 N250     |   68 N48
 69 N259    |   70 N169     |   71 N288     |   72 N50      |   75 N225
 78 N249    |   79 N98      |   82 N260     |   83 N207     |   84 N232
 86 N205    |   87 N194     |   88 N194     |   89 N100     |   90 N241
 91 N255    |   92 N52      |   93 N209     |   94 N248     |   95 N266
 97 N265    |   98 N49      |  100 N201     |  101 N274     |  103 N268
104 N63     |  105 N257     |  106 N245     |  109 N51      |  110 N99
 111 N296   |   96 N102     |   43 N115     |   47 N276     |   52 N117
 54 N303    |   50 N108     |   55 N119     |   18 N152     |   19 N147
 20 N144    |        |

TWO-WAY ORDERED TABLE

   6  ERIPUL  --------  13  TRIMUT  --------  2  ARIPUR  --------  3  BOUXXX  --------  4  BOUREP
   5  ELYELY  --------  7  MUHXXX  --------  11  PLERIG  --------  1  ARIXXX  --------  12  POABIG
  14  VULOCT  --------  9  MUHPOR  --------  8  MUHMIC  --------  10  PLEMUT  --------

--- END OF LEVEL 4 ---
TWO-WAY ORDERED TABLE

1 19445555112
   16372405890

   6  ERIPUL    0000
   13  TRIMUT    0000
   2  ARIPUR    0001
   3 BOUXXK    0001
   4 BOUREP    0001
   5 ELYELY    0001
   7 MHXXXK    0001
   11 PLEGIG    0001
   1  ARIXXX    001
   12 POABIG    001
   14 VULCOT    001
   9 MUHPOR    01
   8 MSHMIC    1
   10 PLEMT    1

00111111111
111000111111
 11 00111
  01

********** TWINSPAN completed **********
Appendix C. Scatterplots of percent cover of native grasses versus potential model variables, based on plot data from Pacific Biodiversity Institute’s Phase 2 field work.
Scatterplot for Natural Community Plots in MU and PVMCR (2 outliers removed)
Appendix D. Detailed linear regression results for modeling percent cover of native grasses for the MU and PVMCR natural communities.

The REG Procedure
Model: Linear_Regression_Model
Dependent Variable: PCNATGR PCNATGR

Analysis of Variance

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Root MSE       7.51020    R-Square 0.2488
Dependent Mean 5.66582    Adj R-Sq 0.2248
Coeff Var      132.55277

Parameter Estimates

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Appendix E. Table of actual versus predicted values of percent cover of native grass for phase 2 natural community plots, which were used to derive the regression model. Plots are for the MU and PVMCR natural communities.

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Appendix F – Checklist of Plants – Sand Tank Mountains, 10 October 2004

Field trip participants: Sue Rutman, John Hall, Peter Morrison, Jim Malusa, Dana Backer, JT Hesse

Plants found on a N-facing slope, ca. 2500-2900 ft elevation, between latitude 32° 39' 44"N, longitude 112° 19' 58"W and latitude 32° 39' 31"N, longitude 112° 20' 01"W

FERN & FERN ALLIES
Astrolepis cochisensis subsp. cochisensis
Astrolepis sinuata subsp. sinuata
Cheilanthes lindheimeri
Pellaea truncata
Selaginella arizonica

GRASSES
Aristida adscensionis (non-seasonal annual)
Aristida purpurea var. nealleyi (summer perennial)
Aristida ternipes var. gentiles (summer perennial)
Aristida ternipes var. ternipes (summer perennial)
Bothriochloa barbinodis (summer perennial)
Bouteloua aristidoides (summer annual)
Bouteloua barbata (summer annual)
Bouteloua curtipendula (summer perennial)
Bouteloua repens (summer perennial)
Bromus rubens (winter annual)
Enneapogon desvauxii (perennial)
Eragrostis ciliaris (summer annual)
Erioneuron pulchellum (summer perennial)
Heteropogon contortus (summer perennial)
Hilaria mutica (warm-season perennial)
Leptochloa mucronata? (summer annual)
Muhlenbergia microsperma (non-seasonal annual)
Muhlenbergia porteri (summer perennial)
Panicum hirticaule (summer annual)
Schismus sp. (winter annuals)
Setaria macrostachya (summer perennial)
Sporobolus cryptandrus (summer perennial)
Tridens muticus (summer perennial)

EVERYTHING ELSE
Boerhavia species (more than one)
Cylindropuntia acanthocarpa
Cylindropuntia fulgida
Cylindropuntia bigelovii
Parkinsonia microphylla
Parkinsonia floridana
Echinocereus engelmannii
Mammillaria grahami
Fouquieria splendens
Ephedra aspera
Opuntia engelmannii var. engelmannii
Calliandra eriophylla var. eriophylla
Lepidium sp.
Trixis californica
Carnegiea gigantea
Ferocactus emoryi
Opuntia chlorotica
Matelea parvifolia
Metastelma arizonicum
Janusia gracilis
Galium stellatum
Allionia incarnate
Krameria grayi
Krameria erecta
Lycium berlandieri
Agave deserti
Marina parryi
Ditaxis neomexicana
Ditaxis lanceolata
Marina parryi
Cassia covesii
Sphaeralcea (?laxa?)
Plantago patagonica
Ayenia microphylla
Ayenia filiformis
Eriogonum fasciculatum
Eriogonum wrightii
Adenophyllum porophyloides
Viguieria parishii
Stephanomeria pauciflora
Aloysia wrightii
Phoradendron californicum
Abutilon sp.
Euphorbia species (more than one)
Machaeranthera sp.
Carlowrightia arizonica
Justicia longii
Prosopis velutina
Nissolia schottii
Celtis pallida
Gymnosperma glutinosum
Ericameria cuneata
Ericameria laricifolia
Gutierrezia sarothrae
Encelia farinosa
Coursetia glandulosa
Lotus ?rigidus?
Stephanomeria pauciflora
Porophyllum gracile
Mirabilis laevis var. villosa
Allionia incarnata
Ziziphus obtusifolia var. canescens
Acourtia wrightii
Cuscuta sp. (growing on Boerhavia)
Anisacanthus thurberi
Maurandya antirrhiniflora subsp. antirrhiniflora
Phaseolus filiformis
Lycium parishii
Evolvulus alsinoides
Amaranthus fimbriatus
Amaranthus *tucsonensis*
*Tidestromia lanuginosa subsp. eliassoniana*

**SEEN ELSEWHERE on Area A:**
*Croton sonorae*
*Meodora scabra*
*Bebbia juncea*
*Jatropha cardiophylla*
*Commicarpus scandens*
*Atriplex canescens*
*Mammillaria thornberi*
*Ipomoea ?hederaceae?*
*Digitaria californica*
*Cynodon dactylon*
*Pectis papposa*
*Hibiscus coulteri*