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

Pacific Biodiversity Institute

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## TABLE OF CONTENTS

**List of Figures**

# 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)**

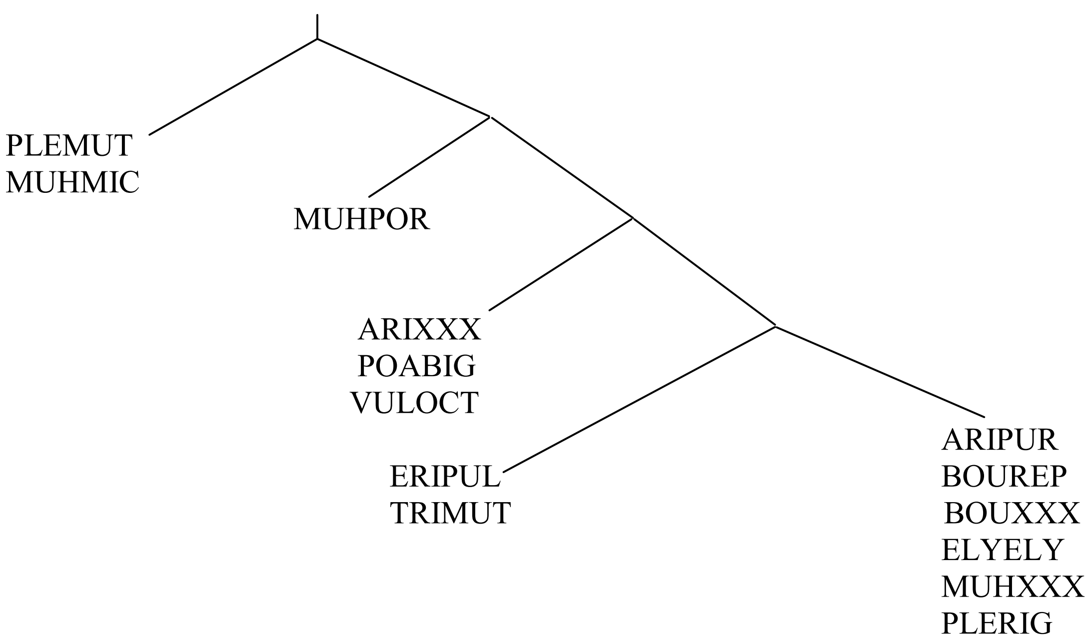


**Figure 1. TWINSPAN results for native grass species using Phase 2 plot data.**

## *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.

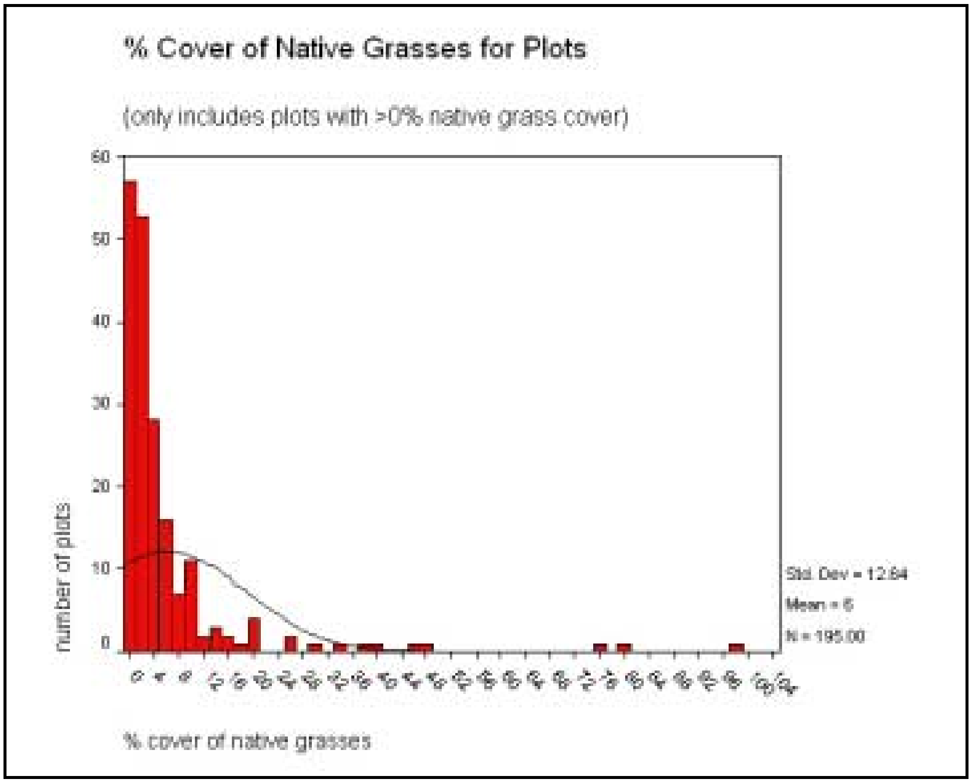


**Figure 2. Histogram of number of Phase 2 native community plots by percent cover of native grass (for all natural communities).**

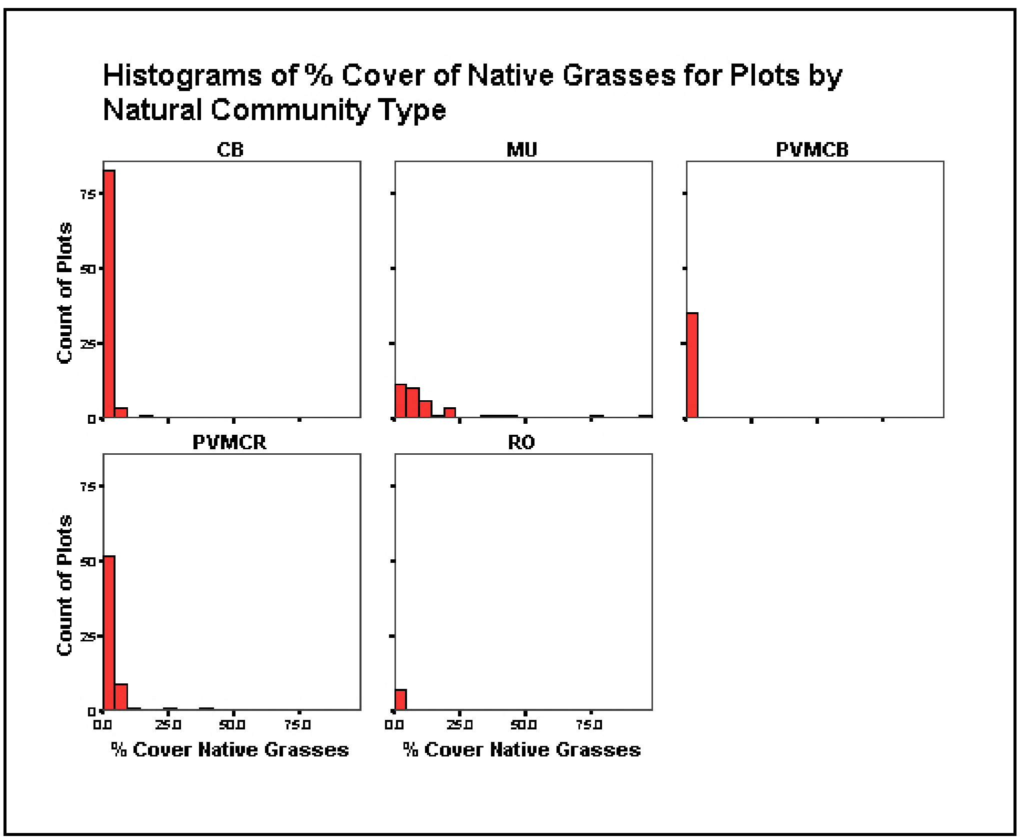


**Figure 3. Histograms, by natural community type, of percent cover of native grasses for Phase 2 natural community plots.**

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.

**Number of plots by actual and predicted % cover values (for plots used to derive model)**

| | | Predicted | | |
|---|---|---|---|---|
| | | 0 to 4% | 5 to 10% | >10% |
| Actual | 0 to 4% | 43 | 24 | 2 |
| | 5 to 10% | 3 | 7 | 7 |
| | >10% | 2 | 3 | 7 |

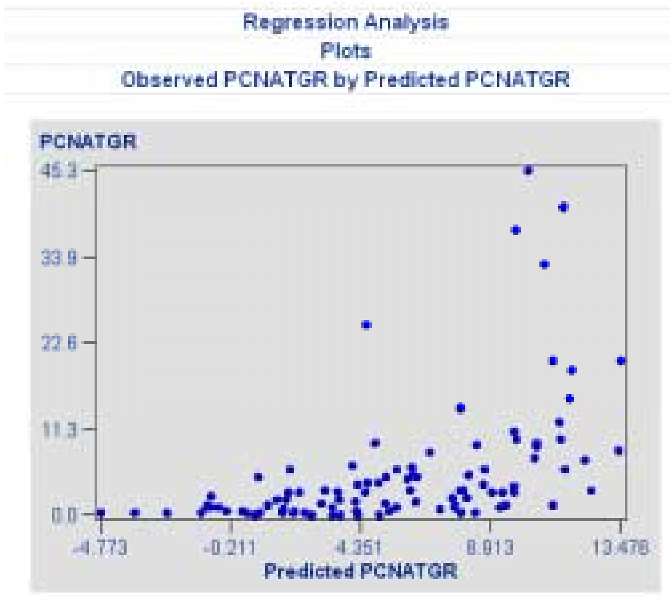


**Figure 4.  Actual versus predicted percent cover of native grasses for Phase 2 plots.**

## 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 adscenscionis, 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 * NORTHNESS1) + (0.016 * DEM) + (-0.115 * 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 * 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.

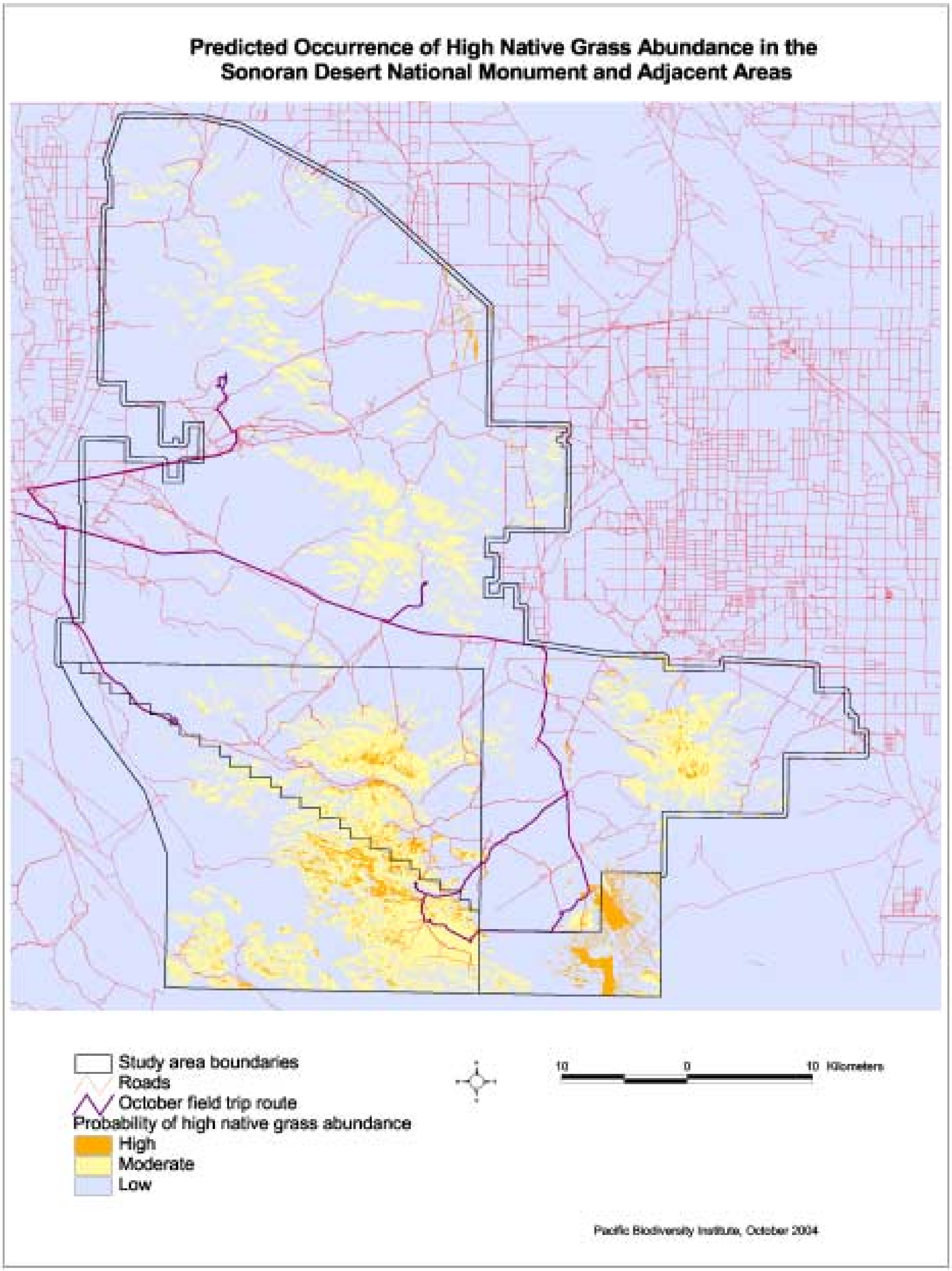


**Figure 5. Final map of predicted native grass cover.**

## *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 8$^{th}$. 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 adscenscionis*) 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 adscenscionis* 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

**Figure 10. Diverse native grass community on north-facing rocky slopes above campsite in East Tactical Area.**

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 an 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).**

**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.**

<u>Stop 14. *Creosote Bush – Bursage Desert Scrub* about 5 miles east of Paradise Well in the upper Vekol Valley.</u>

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.

<u>Stop 15. *Desert Grassland* - *Creosote Bush – Bursage Desert Scrub* transition zone in the upper Vekol Valley.</u>

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

Mata-Gonzales, R., R.D. Pieper, and M.M. Cardenas. 2002. Vegetation patterns as affected by aspect and elevation in small desert mountains. The Southwestern Naturalist 47(3): 440-448.

Morrison, P.H., H.M. Smith IV, S.D. Snetsinger. 2003. *The Natural Communities and Ecological Condition of the Sonoran Desert National Monument and Adjacent Areas.* Pacific Biodiversity Institute, Winthrop, Washington. 113 + xvi p. + Vol. 2 (appendices) 395 p.

**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.  TWINSPAN RESULTS

```
************* Two-way Indicator Species Analysis (TWINSPAN) *************
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
    1 ARIXXX   |    2 ARIPUR   |    3 BOUXXX   |    4 BOUREP   |    5 ELYELY
    6 ERIPUL   |    7 MUHXXX   |    8 MUHMIC   |    9 MUHPOR   |   10 PLEMUT
   11 PLERIG   |   12 POABIG   |   13 TRIMUT   |   14 VULOCT   |

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

 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   3(+)
 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
```

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 N111      N113      N300      N282      N289      N278      N112      N304
 N313      N318      N314      N281      N279      N297      N315      N118
 N116      N317      N301      N306      N114      N316      N299      N178
 N179      N195      N96       N188      N220      N253      N222      N184
 N270      N250      N48       N259      N169      N288      N50       N181
 N183      N225      N243      N200      N249      N98       N275      N204
 N260      N207      N232      N263      N205      N294      N194      N100
 N241      N255      N52       N209      N248      N266      N102      N265
 N49       N231      N201      N274      N305      N268      N63       N257
 N245      N258      N256      N51       N99       N296

 BORDERLINE NEGATIVES    (N =    1)
 N287

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

 BORDERLINE POSITIVES    (N =    2)
 N276      N303

 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)

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


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

 DIVISION    2  (N=   102)         i.e. group *0
 Eigenvalue: 0.4497  at iteration  23
 INDICATORS and their signs:
 ARIXXX   1(-)   MUHPOR   1(+)
 Maximum indicator score for negative group  -1
 Minimum indicator score for positive group   0

 ITEMS IN NEGATIVE GROUP   4  (N =    5)         i.e. group *00
 N222      N183      N200      N204      N231

 BORDERLINE NEGATIVES    (N =    1)
 N231

 ITEMS IN POSITIVE GROUP   5  (N =   97)         i.e. group *01
 N44       N53       N75       N76       N78       N191      N77       N272
 N286      N215      N41       N156      N182      N211      N239      N287
 N269      N105      N311      N319      N107      N109      N310      N106
 N111      N113      N300      N282      N289      N278      N112      N304
 N313      N318      N314      N281      N279      N297      N315      N118
 N116      N317      N301      N306      N114      N316      N299      N178
 N179      N195      N96       N188      N220      N253      N184      N270
 N250      N48       N259      N169      N288      N50       N181      N225
 N243      N249      N98       N275      N260      N207      N232      N263
 N205      N294      N194      N100      N241      N255      N52       N209
 N248      N266      N102      N265      N49       N201      N274      N305
 N268      N63       N257      N245      N258      N256      N51       N99
 N296

 NEGATIVE PREFERENTIALS
ARIXXX  1(   5,   1)

 POSITIVE PREFERENTIALS
MUHPOR  1(   0,  44)  MUHPOR  2(   0,  30)

 NON-PREFERENTIALS
POABIG  1(   2,  44)  VULOCT  1(   3,  76)  VULOCT  2(   1,  25)
****************************************************************************
```

```
 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
PLEMUT  5(   0,   2)

 NON-PREFERENTIALS
PLEMUT  1(   4,   5)  PLEMUT  2(   4,   5)  PLEMUT  3(   4,   5)  PLEMUT  4(   2,   3)

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

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

 NON-PREFERENTIALS
ARIXXX  1(   3,   2)
****************************************************************************

 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
```

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 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
 N102      N265      N49       N201      N274      N268      N63       N257
 N245      N51       N99       N296

 MISCLASSIFIED POSITIVES (N =    1)
 N113

 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)

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

```
 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       N257      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.

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

```
 NON-PREFERENTIALS
VULOCT  1(  36,  11)

               -------- E N D   O F   L E V E L  6 --------


*************** THIS IS THE END OF THE DIVISIONS REQUESTED ***************
***************************************************************************



                         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
 ARIXXX    ARIPUR    BOUXXX    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
 ARIXXX    ARIPUR    BOUXXX    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
 ARIPUR    BOUXXX    BOUREP    ELYELY    ERIPUL    MUHXXX    PLERIG    TRIMUT

 ITEMS IN POSITIVE GROUP   9  (N =    3)         i.e. group *001
 ARIXXX    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.

              --------  E N D   O F   L E V E L   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     |   27 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 N272     |    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 N318     |   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 N294     |   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

```
                            111                                                                         11111111
               677892224478178000       11111111222222333333333344444455555556666666666777777888888889999999900000001
               4471937845607352781234567890123456124569012345678901268913678901235678901258923467890123457801345690

   6  ERIPUL   ------------212222----------------------------------------------1-------------------------------  0000
  13  TRIMUT   ------1-------------------------------------------------1------------------------1--------------4  0000
   2  ARIPUR   ------------------------------------------------2----------------------------------------2-------  0001
   3  BOUXXX   --------------------------------------------------3-------------------------------------------------  0001
   4  BOUREP   ---------------------------------------------------1------------------------------------------------  0001
   5  ELYELY   -------1------------------------------2---------------4---------------------------------------------  0001
   7  MUHXXX   ---------------------------------------------------------------------------------------------2--  0001
  11  PLERIG   ---------------------------------------1------------1---5-------------------------------1--------  0001
   1  ARIXXX   11111---------------------------------------------------------------------------------------1------  001
  12  POABIG   ---11-------------11-1-1-11-1-1--1--11-211221-312212122123---11--1--1-1----11--1-----1---11--1--11-  001
  14  VULOCT   1--12-------1---121--1-111-11-1-11-1111--112111111212122-2111111112211111111112211211222112222233232  001
   9  MUHPOR   -----12222111--222---------------1--1--1-12-223132322444355----------------1-----2-12---221--22-1-13  01
   8  MUHMIC   ------------------------------------------------------------------------------1------1------------  1
  10  PLEMUT   --------------------------------1--------1------2-------------------------------------------------  1

               0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
               0000011111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111111
               0001100000000000000111111111111111111111111111111111111111111111111111111111111111111111111111111111
                    0000000111111000000000000000000000000000000000000000000000000000000000000000000000000000000000
```

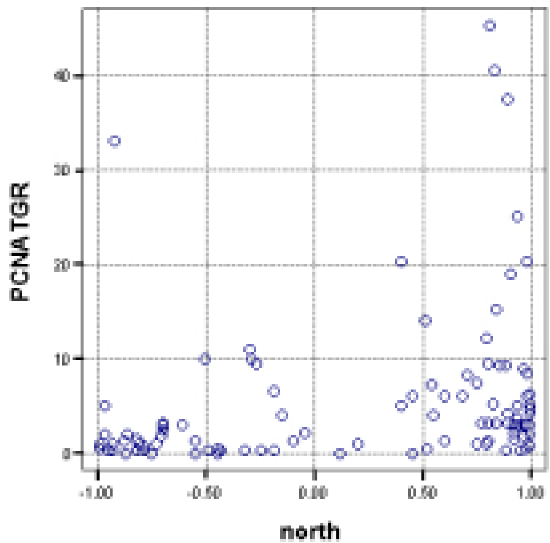
TWO-WAY ORDERED TABLE

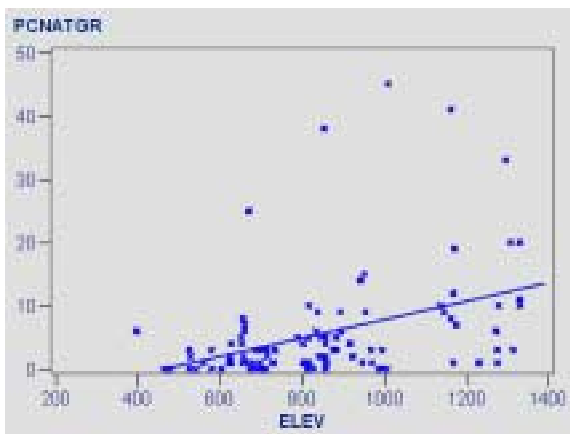
```
                 1
                 19445555112
                 16372405890

   6  ERIPUL     -----------  0000
  13  TRIMUT     -2---------  0000
   2  ARIPUR     -----------  0001
   3  BOUXXX     -----------  0001
   4  BOUREP     -----------  0001
   5  ELYELY     -----------  0001
   7  MUHXXX     -----------  0001
  11  PLERIG     -----------  0001
   1  ARIXXX     -----------  001
  12  POABIG     2--2-2-----  001
  14  VULOCT     1--1-11----  001
   9  MUHPOR     5-2235-----  01
   8  MUHMIC     -----1-----  1
  10  PLEMUT     --334455334  1

                 00111111111
                 11000011111
                 11    00111
                 01
```

********** TWINSPAN completed **********

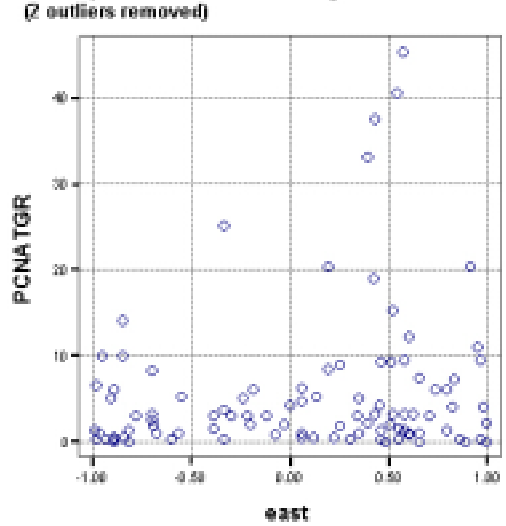
**Appendix C. Scatterplots of percent cover of native grasses versus potential model variables, based on plot data from Pacific Biodiversity Institute's Phase 2 field work.**

Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)

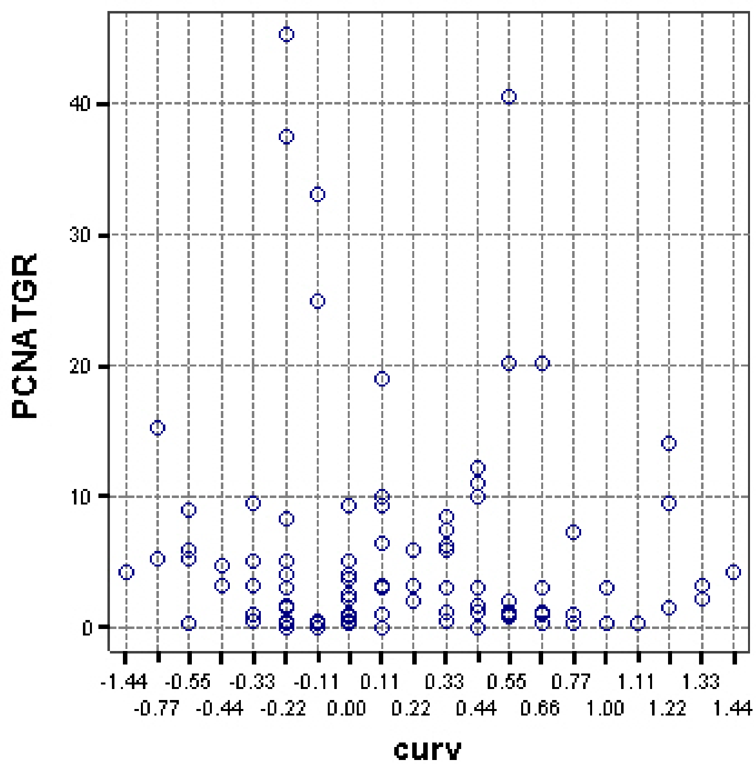


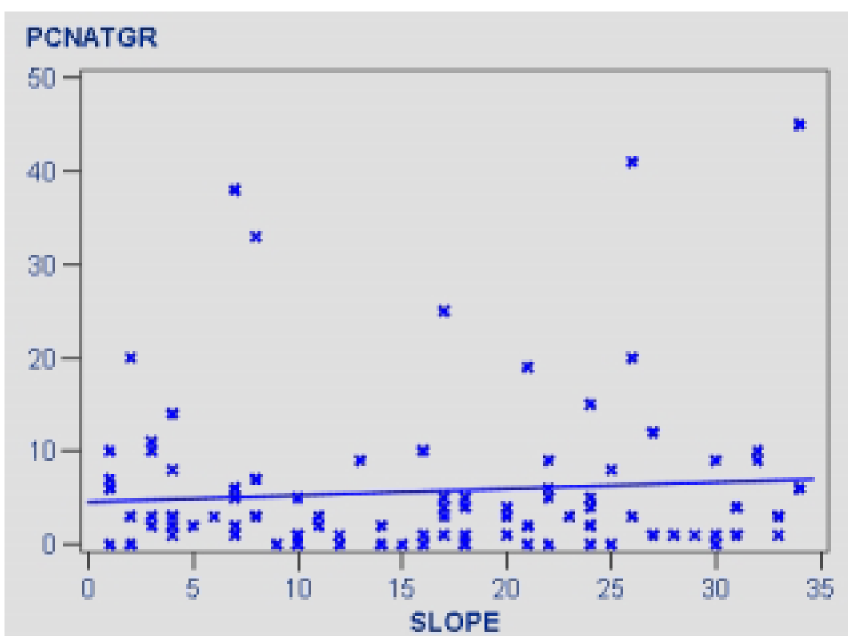




Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)

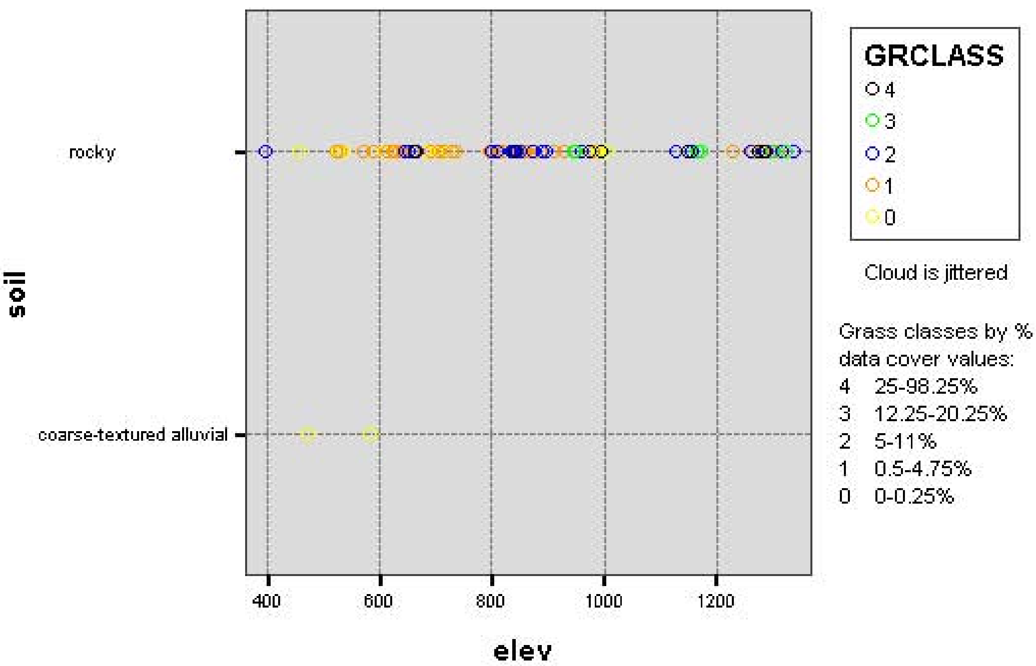


**Scatterplot for Natural Community Plots in MU and PVMCR (2 outliers removed)**

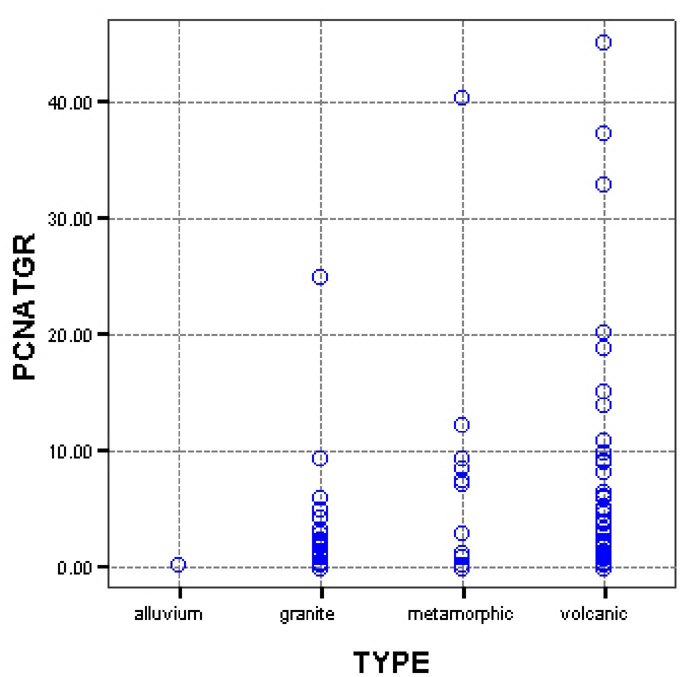


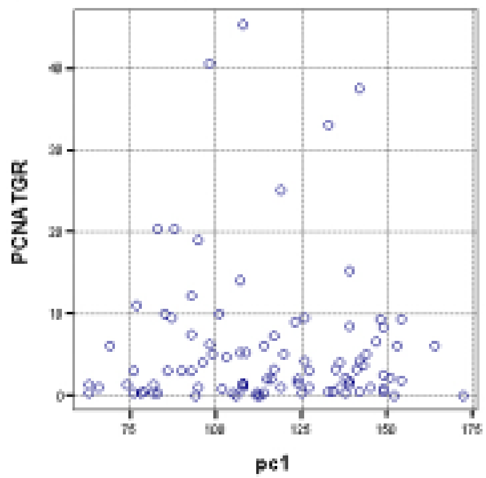
## Scatterplot of Variables for Modeling Native Grass Cover for MU & PVMCR Natural Communities



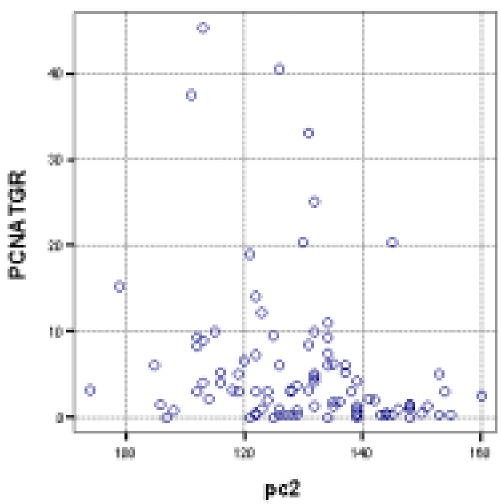

## Geology Variables Derived from GIS Data



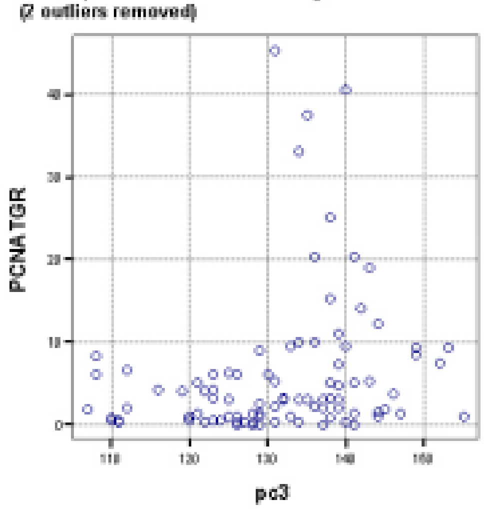
Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)

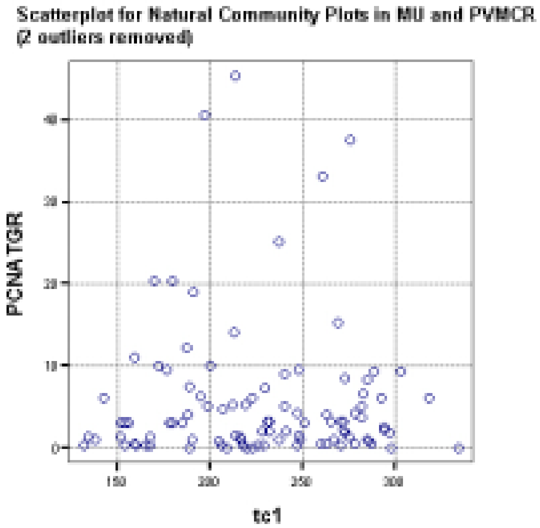


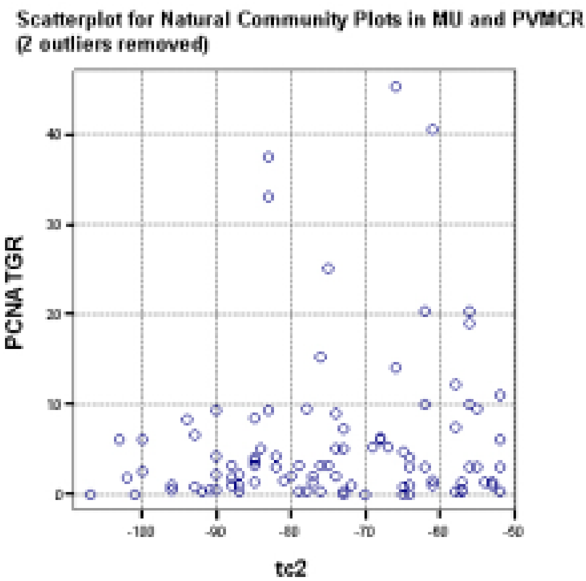

Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)

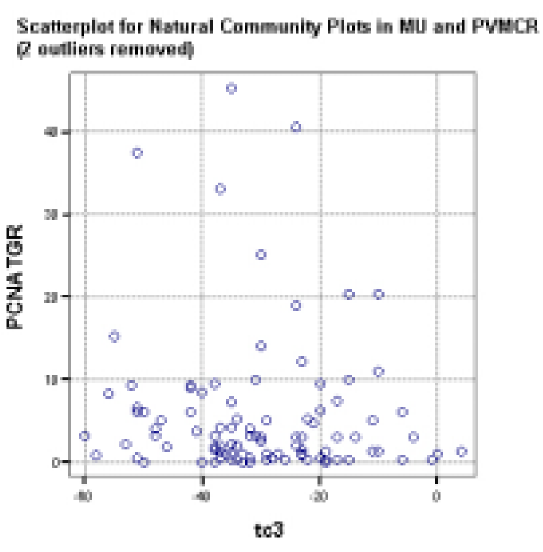



Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)




Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)
PCNATGR
tc1
0
10
20
30
40
150
200
250
300


Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)
PCNATGR
tc2
0
10
20
30
40
-100
-90
-80
-70
-60
-50


Scatterplot for Natural Community Plots in MU and PVMCR
(2 outliers removed)
PCNATGR
tc3
0
10
20
30
40
-60
-40
-20
0

**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

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 1755.60629 | 585.20210 | 10.38 | <.0001 |
| Error | 94 | 5301.88670 | 56.40305 | | |
| Corrected Total | 97 | 7057.49298 | | | |

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

Parameter Estimates

| Variable | Label | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| | 95% Confidence Limits | |
|---|---|---|---|---|---|---|---|---|
| Intercept | Intercept | 1 | -11.91561 | 3.86964 | -3.08 | 0.0027 | -19.59888 | -4.23234 |
| NORTH | NORTH | 1 | 2.45525 | 1.03321 | 2.38 | 0.0195 | 0.40378 | 4.50672 |
| TC3 | TC3 | 1 | -0.11545 | 0.05746 | -2.01 | 0.0474 | -0.22955 | -0.00136 |
| ELEV | ELEV | 1 | 0.01598 | 0.00344 | 4.64 | <.0001 | 0.00915 | 0.02281 |

**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.**

| PLOT | Predicted PCNATGR | NATGR | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| 250 | -4.77 | 0.25 | -9.25 | -0.30 |
| 238 | -3.59 | 0.25 | -7.36 | 0.18 |
| 7 | -2.46 | 0.25 | -5.94 | 1.02 |
| 168 | -1.26 | 0.25 | -4.41 | 1.88 |
| 181 | -1.08 | 1.00 | -4.15 | 1.99 |
| 200 | -1.03 | 1.25 | -4.15 | 2.08 |
| 225 | -0.93 | 1.00 | -4.02 | 2.16 |
| 194 | -0.92 | 2.50 | -3.81 | 1.97 |
| 243 | -0.65 | 1.00 | -4.70 | 3.40 |
| 128 | -0.37 | 0.50 | -3.47 | 2.73 |
| 198 | 0.18 | 0.50 | -2.30 | 2.67 |
| 242 | 0.36 | 0.25 | -3.40 | 4.12 |
| 196 | 0.64 | 0.00 | -2.02 | 3.29 |
| 201 | 0.76 | 5.00 | -2.59 | 4.10 |
| 244 | 0.81 | 0.25 | -1.75 | 3.37 |
| 249 | 1.09 | 1.25 | -3.04 | 5.22 |
| 263 | 1.40 | 2.00 | -1.61 | 4.41 |
| 186 | 1.61 | 0.25 | -0.48 | 3.71 |
| 288 | 1.63 | 0.75 | -0.96 | 4.23 |
| 232 | 1.72 | 2.00 | -1.79 | 5.23 |
| 241 | 1.81 | 3.00 | -2.46 | 6.07 |
| 63 | 1.87 | 6.00 | -1.87 | 5.61 |
| 187 | 1.99 | 0.25 | -0.15 | 4.14 |
| 259 | 2.01 | 0.50 | -1.82 | 5.83 |
| 255 | 2.20 | 3.00 | -1.00 | 5.39 |
| 206 | 2.40 | 0.25 | 0.18 | 4.61 |
| 213 | 2.63 | 0.00 | -0.64 | 5.91 |
| 98 | 2.97 | 1.50 | -0.05 | 5.99 |
| 266 | 3.09 | 3.25 | -0.11 | 6.29 |
| 183 | 3.36 | 1.00 | 1.40 | 5.32 |
| 185 | 3.36 | 0.00 | 1.55 | 5.17 |
| 247 | 3.54 | 3.00 | 0.18 | 6.91 |
| 207 | 3.59 | 2.00 | 0.86 | 6.33 |
| 103 | 3.63 | 0.00 | 1.13 | 6.13 |
| 258 | 4.05 | 6.50 | 1.10 | 7.01 |
| 204 | 4.17 | 1.75 | 1.53 | 6.81 |
| 199 | 4.19 | 0.50 | 2.23 | 6.16 |
| 102 | 4.23 | 4.00 | 2.53 | 5.93 |
| 295 | 4.25 | 0.00 | 1.23 | 7.26 |
| 100 | 4.50 | 3.00 | 1.76 | 7.23 |
| 99 | 4.54 | 25.00 | 1.99 | 7.09 |
| 231 | 4.58 | 4.25 | 1.86 | 7.29 |
| 51 | 4.85 | 9.50 | 2.82 | 6.88 |
| 49 | 4.98 | 4.25 | 2.48 | 7.48 |
| 110 | 5.00 | 0.00 | 2.47 | 7.54 |
| 275 | 5.21 | 1.50 | 2.26 | 8.16 |
| 305 | 5.24 | 5.00 | 1.58 | 8.90 |
| 48 | 5.35 | 0.50 | 2.79 | 7.91 |
| 50 | 5.59 | 1.00 | 3.36 | 7.82 |
| 257 | 5.61 | 6.00 | 2.79 | 8.42 |

| | | | | |
|---|---|---|---|---|
| 289 | 5.98 | 4.75 | 3.39 | 8.57 |
| 52 | 6.09 | 3.25 | 3.95 | 8.24 |
| 245 | 6.15 | 6.25 | 3.53 | 8.77 |
| 278 | 6.16 | 5.25 | 3.90 | 8.41 |
| 260 | 6.27 | 1.75 | 3.43 | 9.10 |
| 274 | 6.32 | 5.00 | 4.10 | 8.55 |
| 256 | 6.77 | 8.25 | 3.45 | 10.08 |
| 169 | 7.13 | 0.75 | 3.43 | 10.84 |
| 294 | 7.57 | 2.25 | 4.46 | 10.67 |
| 319 | 7.65 | 1.00 | 3.93 | 11.37 |
| 107 | 7.66 | 1.25 | 4.09 | 11.23 |
| 209 | 7.83 | 3.25 | 5.78 | 9.89 |
| 276 | 7.85 | 14.00 | 6.13 | 9.57 |
| 104 | 7.86 | 0.25 | 5.13 | 10.59 |
| 248 | 7.95 | 3.25 | 5.96 | 9.94 |
| 205 | 8.08 | 2.25 | 5.95 | 10.21 |
| 268 | 8.14 | 5.25 | 5.92 | 10.35 |
| 105 | 8.37 | 0.25 | 5.80 | 10.93 |
| 279 | 8.41 | 9.25 | 6.09 | 10.73 |
| 265 | 8.66 | 4.00 | 6.09 | 11.22 |
| 304 | 8.69 | 6.00 | 6.51 | 10.87 |
| 106 | 8.96 | 3.00 | 6.56 | 11.35 |
| 311 | 9.24 | 1.00 | 7.20 | 11.27 |
| 111 | 9.33 | 3.00 | 5.36 | 13.29 |
| 310 | 9.45 | 1.25 | 7.29 | 11.62 |
| 113 | 9.73 | 3.00 | 6.06 | 13.40 |
| 282 | 9.74 | 3.75 | 7.31 | 12.17 |
| 116 | 9.74 | 11.00 | 5.88 | 13.60 |
| 296 | 9.79 | 37.50 | 6.78 | 12.80 |
| 118 | 9.82 | 10.00 | 5.93 | 13.71 |
| 303 | 10.24 | 45.25 | 7.97 | 12.51 |
| 318 | 10.46 | 7.50 | 7.58 | 13.33 |
| 297 | 10.52 | 9.25 | 7.37 | 13.67 |
| 315 | 10.53 | 9.50 | 7.81 | 13.24 |
| 281 | 10.54 | 9.00 | 7.93 | 13.14 |
| 117 | 10.81 | 33.00 | 6.24 | 15.38 |
| 109 | 11.10 | 1.25 | 7.55 | 14.65 |
| 108 | 11.11 | 20.25 | 7.49 | 14.72 |
| 317 | 11.33 | 12.25 | 8.56 | 14.09 |
| 115 | 11.37 | 10.00 | 7.82 | 14.93 |
| 316 | 11.46 | 40.50 | 8.70 | 14.22 |
| 112 | 11.51 | 6.00 | 7.50 | 15.51 |
| 301 | 11.69 | 15.25 | 8.16 | 15.22 |
| 306 | 11.76 | 19.00 | 8.90 | 14.62 |
| 313 | 12.23 | 7.25 | 9.36 | 15.09 |
| 300 | 12.44 | 3.25 | 8.41 | 16.48 |
| 314 | 13.41 | 8.50 | 10.21 | 16.60 |
| 114 | 13.48 | 20.25 | 9.65 | 17.30 |

| PLOT | Predicted PCNATGR | NATGR | Lower 95% CI | Upper 95% CI |
|---|---|---|---|---|
| 196 | 0.64 | 0.00 | -2.02 | 3.29 |
| 213 | 2.63 | 0.00 | -0.64 | 5.91 |
| 185 | 3.36 | 0.00 | 1.55 | 5.17 |
| 103 | 3.63 | 0.00 | 1.13 | 6.13 |
| 295 | 4.25 | 0.00 | 1.23 | 7.26 |
| 110 | 5.00 | 0.00 | 2.47 | 7.54 |
| 250 | -4.77 | 0.25 | -9.25 | -0.30 |
| 238 | -3.59 | 0.25 | -7.36 | 0.18 |
| 7 | -2.46 | 0.25 | -5.94 | 1.02 |
| 168 | -1.26 | 0.25 | -4.41 | 1.88 |
| 242 | 0.36 | 0.25 | -3.40 | 4.12 |
| 244 | 0.81 | 0.25 | -1.75 | 3.37 |
| 186 | 1.61 | 0.25 | -0.48 | 3.71 |
| 187 | 1.99 | 0.25 | -0.15 | 4.14 |
| 206 | 2.40 | 0.25 | 0.18 | 4.61 |
| 104 | 7.86 | 0.25 | 5.13 | 10.59 |
| 105 | 8.37 | 0.25 | 5.80 | 10.93 |
| 128 | -0.37 | 0.50 | -3.47 | 2.73 |
| 198 | 0.18 | 0.50 | -2.30 | 2.67 |
| 259 | 2.01 | 0.50 | -1.82 | 5.83 |
| 199 | 4.19 | 0.50 | 2.23 | 6.16 |
| 48 | 5.35 | 0.50 | 2.79 | 7.91 |
| 288 | 1.63 | 0.75 | -0.96 | 4.23 |
| 169 | 7.13 | 0.75 | 3.43 | 10.84 |
| 181 | -1.08 | 1.00 | -4.15 | 1.99 |
| 225 | -0.93 | 1.00 | -4.02 | 2.16 |
| 243 | -0.65 | 1.00 | -4.70 | 3.40 |
| 183 | 3.36 | 1.00 | 1.40 | 5.32 |
| 50 | 5.59 | 1.00 | 3.36 | 7.82 |
| 319 | 7.65 | 1.00 | 3.93 | 11.37 |
| 311 | 9.24 | 1.00 | 7.20 | 11.27 |
| 200 | -1.03 | 1.25 | -4.15 | 2.08 |
| 249 | 1.09 | 1.25 | -3.04 | 5.22 |
| 107 | 7.66 | 1.25 | 4.09 | 11.23 |
| 310 | 9.45 | 1.25 | 7.29 | 11.62 |
| 109 | 11.10 | 1.25 | 7.55 | 14.65 |
| 98 | 2.97 | 1.50 | -0.05 | 5.99 |
| 275 | 5.21 | 1.50 | 2.26 | 8.16 |
| 204 | 4.17 | 1.75 | 1.53 | 6.81 |
| 260 | 6.27 | 1.75 | 3.43 | 9.10 |
| 263 | 1.40 | 2.00 | -1.61 | 4.41 |
| 232 | 1.72 | 2.00 | -1.79 | 5.23 |
| 207 | 3.59 | 2.00 | 0.86 | 6.33 |
| 294 | 7.57 | 2.25 | 4.46 | 10.67 |
| 205 | 8.08 | 2.25 | 5.95 | 10.21 |
| 194 | -0.92 | 2.50 | -3.81 | 1.97 |
| 241 | 1.81 | 3.00 | -2.46 | 6.07 |
| 255 | 2.20 | 3.00 | -1.00 | 5.39 |
| 247 | 3.54 | 3.00 | 0.18 | 6.91 |
| 100 | 4.50 | 3.00 | 1.76 | 7.23 |
| 106 | 8.96 | 3.00 | 6.56 | 11.35 |
| 111 | 9.33 | 3.00 | 5.36 | 13.29 |
| 113 | 9.73 | 3.00 | 6.06 | 13.40 |

| | | | | |
|---|---|---|---|---|
| 266 | 3.09 | 3.25 | -0.11 | 6.29 |
| 52 | 6.09 | 3.25 | 3.95 | 8.24 |
| 209 | 7.83 | 3.25 | 5.78 | 9.89 |
| 248 | 7.95 | 3.25 | 5.96 | 9.94 |
| 300 | 12.44 | 3.25 | 8.41 | 16.48 |
| 282 | 9.74 | 3.75 | 7.31 | 12.17 |
| 102 | 4.23 | 4.00 | 2.53 | 5.93 |
| 265 | 8.66 | 4.00 | 6.09 | 11.22 |
| 231 | 4.58 | 4.25 | 1.86 | 7.29 |
| 49 | 4.98 | 4.25 | 2.48 | 7.48 |
| 289 | 5.98 | 4.75 | 3.39 | 8.57 |
| 201 | 0.76 | 5.00 | -2.59 | 4.10 |
| 305 | 5.24 | 5.00 | 1.58 | 8.90 |
| 274 | 6.32 | 5.00 | 4.10 | 8.55 |
| 278 | 6.16 | 5.25 | 3.90 | 8.41 |
| 268 | 8.14 | 5.25 | 5.92 | 10.35 |
| 63 | 1.87 | 6.00 | -1.87 | 5.61 |
| 257 | 5.61 | 6.00 | 2.79 | 8.42 |
| 304 | 8.69 | 6.00 | 6.51 | 10.87 |
| 112 | 11.51 | 6.00 | 7.50 | 15.51 |
| 245 | 6.15 | 6.25 | 3.53 | 8.77 |
| 258 | 4.05 | 6.50 | 1.10 | 7.01 |
| 313 | 12.23 | 7.25 | 9.36 | 15.09 |
| 318 | 10.46 | 7.50 | 7.58 | 13.33 |
| 256 | 6.77 | 8.25 | 3.45 | 10.08 |
| 314 | 13.41 | 8.50 | 10.21 | 16.60 |
| 281 | 10.54 | 9.00 | 7.93 | 13.14 |
| 279 | 8.41 | 9.25 | 6.09 | 10.73 |
| 297 | 10.52 | 9.25 | 7.37 | 13.67 |
| 51 | 4.85 | 9.50 | 2.82 | 6.88 |
| 315 | 10.53 | 9.50 | 7.81 | 13.24 |
| 118 | 9.82 | 10.00 | 5.93 | 13.71 |
| 115 | 11.37 | 10.00 | 7.82 | 14.93 |
| 116 | 9.74 | 11.00 | 5.88 | 13.60 |
| 317 | 11.33 | 12.25 | 8.56 | 14.09 |
| 276 | 7.85 | 14.00 | 6.13 | 9.57 |
| 301 | 11.69 | 15.25 | 8.16 | 15.22 |
| 306 | 11.76 | 19.00 | 8.90 | 14.62 |
| 108 | 11.11 | 20.25 | 7.49 | 14.72 |
| 114 | 13.48 | 20.25 | 9.65 | 17.30 |
| 99 | 4.54 | 25.00 | 1.99 | 7.09 |
| 117 | 10.81 | 33.00 | 6.24 | 15.38 |
| 296 | 9.79 | 37.50 | 6.78 | 12.80 |
| 316 | 11.46 | 40.50 | 8.70 | 14.22 |
| 303 | 10.24 | 45.25 | 7.97 | 12.51 |

**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

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

GRASSES
*Aristida adscenscionis* (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 cilianensis* (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 porophylloides*
*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 obtusifolira* 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*