Natural Communities Of the Sonoran Desert National Monument and Sand Tank Mountains

Pacific Biodiversity Institute

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Introduction

Pacific Biodiversity Institute (PBI) conducted this project to aid The Nature Conservancy (TNC) in their effort to map, characterize, and assess the condition of the natural communities of the 496,355-acre Sonoran Desert National Monument (SDNM) and adjacent natural communities in the Sand Tank Mountains, which comprise 101,133 acres of the Barry M. Goldwater Range (BMGR) and adjacent Tohono O'odham Reservation (TOR). Our entire study area covers 597,488 acres of the Sonoran Desert. This natural community mapping and characterization builds on and improves the natural community information collected, synthesized, and mapped by TNC for the BMGR (Hall et al 2001), which was extended to the SDNM through GIS modeling

This report presents the results of the first phase of a two-phase project. In the first phase we have mapped the natural communities occurring on the Sonoran Desert National Monument and key extensions of semi-desert grassland and Sand Tank Mountain Uplands natural communities that extend across the monument's boundaries.

We have also provided ecological descriptions for each natural community described in the study area. These descriptions are based on our review of existing literature and our initial fieldwork conducted during November and December 2002. We describe the natural range in variation of natural community composition, structure, and function using biophysical modeling parameters, such as topography, hydrography, soils and surficial geology. We also discuss the applicability of previous modeling parameter assumptions for those natural communities mapped and described in Hall and others (2001) and update these as necessary. Included in this report are representative photographs of each natural community at the local and landscape scales that capture community structural attributes. We discuss the relationship of each natural community to existing plant community classification systems in the Sonoran Desert ecoregion. Finally, in this report we analyze and discuss the relationship between the natural communities we have mapped and described to the existing Bureau of Land Management Ecological Site Inventory data and associated Natural Resource Conservation Service Ecological Site Descriptions.

In the second phase of this project we will assess the condition of the natural communities that are described and mapped in this report. We will also collect additional data that will improve the description of the natural communities in terms of their natural range of variation in composition, structure, and function. In this second phase we will make any needed improvements in delineation of community boundaries and further explore the correlation between natural community boundaries and variations in topography, hydrography, soils and surficial geology. This report should be considered preliminary. It will be revised at the end of the second phase of this project.

Methods

We developed an integrated approach utilizing existing vegetation maps, a wide variety of existing GIS data, Landsat TM7 satellite imagery, digital orthophotography, review of existing literature on natural communities and reconnaissance-level fieldwork that focused on collection of ecological data on composition, structure and function of the natural communities on the SDNM and adjacent areas.

Further discussion of methodology used in this study is included in the description of each of the natural communities.

Data Collection & Processing

We acquired, assembled, processed and reviewed existing GIS data covering the SDNM and adjacent areas (Table 1). We also acquired, reviewed and analyzed existing Landsat satellite imagery and color infrared digital orthophoto quarter quads (DOQQs) covering the study area (Table 2). All data were projected into a common map projection of UTM Zone 12, North American datum 1983, GRS1980 spheroid. It is one of the most robust and up-to-date map projections in use today.

Table 1. Geospatial data used in study.

Data Theme	Geospatial data layer description	Source	Date	Map Scale
Vegetation	Initial natural community map of SDNM extrapolated from the BMGR (Hall et al 2001)	TNC	2002	1:100,000 to 1:250,000
	Arizona GAP vegetation map	(AZ Land Information System (ALRIS)	1998	1:24,000
	Xeroriparian areas (same as streams)	TNC/BLM		
	Biotic Communities (Brown & Lowe (1980))	ALRIS	1993	1:100,000
Soils	NRCS soil layers	NRCS website	2002	1:24,000
	Arizona Soils	ALRIS	Digitized off map dated 1975	1:1,000,000
Geology	Geologic map of Arizona	ALRIS	1992	1:1,000,000
Topography	Digital elevation model data (DEM)	USGS/ARIA		1:24,000
	Digital raster graphics (topographic maps)	USGS/ARIA		1:24,000
	Slope (derived from DEM)	PBI		1:24,000
	Aspect (derived from DEM)	PBI		1:24,000
	Shaded relief image (derived from DEM)	PBI		1:24,000
	5-meter contours	PBI		1:24,000
Hydrography	Streams	USGS		1:100,000
	Tinajas and Springs	TNC		

Water developments	Wells and water development activities (ACTVREV, ACTVNON)	Arizona Dept. of Water Resources		
Land Ownership	Arizona GAP Ownership	Arizona GAP		
	AZLAND	ALRIS	1998	1:100,000
	SDNM Boundary	TNC/BLM	2002	
Transportation	BLM road layer	BLM	2000	1:100,000
	TIGER road layer	US Census Dept.	2000	1:100,000
	Major Roads	ALRIS	1992	1:100,000

Table 2. Imagery used in study.

Image Type	Image layer	Source	Date	Resolution
Digital Orthophotography	Color Infrared Digital Orthophoto Quarter Quads	ARIA	1996	1 meter
	Panchromatic Digital Orthophoto merged 15 minute quads (ENVI compressed format)	BLM	1996	1 meter
Landsat Satellite Imagery	TM7 image for path37 row37	ARIA	May 11, 2002	15 and 30 meter
	TM7 image for path37 row37	ARIA	March 17, 2002	15 and 30 meter
	TM7 image for path37 row37	ARIA	May 20, 2000	15 and 30 meter
	TM7 image for path37 row37	ARIA	Oct. 10, 1999	15 and 30 meter
	TM image for path37 row37	ARIA	July 22, 1985	30 meter

Preliminary Mapping & Classification

First, we reviewed the draft natural community map and GIS model developed by TNC for the BMGR and extrapolated to the SDNM. To aid this review, we acquired Landsat Enhanced Thematic Mapper 7 (TM7) satellite imagery for several dates (Table 2). We processed and examined this imagery to determine its usefulness to this project. We performed an unsupervised spectral classification of the March 2002 image and examined normalized difference vegetation indices (NDVI) for several image dates. We examined the differences between the NDVI images for several dates to determine if vegetation changes were apparent that could aid in mapping the natural communities.

We also acquired 1996 color infrared (CIR) digital orthophoto quarter quads (DOQQs) for nearly the entire study area from the Arizona Regional Image Archive (ARIA). In addition, we examined panchromatic digital orthophotography provided by the BLM for the entire study area. This imagery was merged at a 15-minute quad scale and was highly compressed with the ENVI compression algorithm. The image quality of this later orthoimagery was not as good as the CIR DOQQs, so we used the CIR DOQQs in all areas of the study area, except for a few areas where we could not obtain CIR DOQQ coverage.

During our initial review and evaluation of the natural community mapping we examined other available GIS data on vegetation, geology, soils, topography, hydrography, water developments, roads and land ownership (Table 1). We assembled, read and reviewed pertinent literature on Sonoran Desert vegetation mapping and classification, and made contact with several relevant sources and experts. We briefly reviewed BLM's aerial photo based vegetation/ecological-site mapping, their Ecological Site Inventory data, the Natural Resource Conservation Service (NRCS) Ecological Site Descriptions (ESDs) and associated soil maps and GIS data to determine how it might be of use in mapping the natural communities of the study area.

Based on our initial evaluation of all the above GIS data and imagery it became apparent that significant improvements in TNC's draft natural community map and GIS model for the SDNM were necessary to accurately depict the natural communities. We discussed our initial proposed modifications with TNC for this and subsequent tasks. At this stage, we determined that some of the NRCS soil mapping could be used in improving a natural community map for the SDNM.

We produced a series of maps to guide our fieldwork. The first map of the entire study area at a 1:85,000-scale contained a Landsat TM7 satellite image background and the initial TNC natural community polygon boundaries, hydrography and roads as an overlay. The second set of maps was produced at a 1:12,830-scale with the CIR DOQQs as the background and hydrography, roads and the NRCS soils layer as an overlay.

Fieldwork

Our fieldwork was conducted from November 27 to December 23, 2002. The focus of this work was to closely examine the natural community boundaries depicted in the initial map provided by TNC, to examine the NRCS soil mapping and to gather field ecology data and photographs that could be used to describe and depict the natural communities present in the study area. We also recorded many field notes and map notations about the location of natural community boundaries and locations.

We collected information on the vegetation composition and structure in a representative sample of the natural communities as part of this reconnaissance fieldwork. The percent cover of all plant species within a 30-meter radius sample plot was recorded along with information on ground cover of bedrock, rock, gravel, sand and soil. Information on elevation, aspect and slope was collected as well as pertinent information on landform, geology and soil conditions. The location and description of each plot was recorded, including a GPS waypoint number. Each field plot was located to an accuracy of 5 to 8 meters using a Garmin eTrex GPS receiver. GPS data was downloaded into a notebook computer at the end of each field day. GPS tracks were also downloaded and used to review the area examined during the day's fieldwork.

In addition to the field plots, many other observations of natural community locations and boundaries were noted in field notes and field maps. Often binoculars were used to examine areas that were not readily accessible by foot and notes about the vegetation composition and structure were recorded. Digital photographs were taken at each field plot (usually four photos per plot) and numerous additional photographs were taken of plant species, natural communities and landscape perspectives on the natural communities.

During our fieldwork we used numerous botanical references to aid in the identification and verification of plant species encountered in field ecology plots. These references include Benson and Darrow (1981), Kearney and Peebles (1960), Turner et al (2000), Hickman (1993), Epple and Epple (1995), Earle (1980), Jaeger (1941). Appendix I contains the common names of the plants referred to in this report.

We attempted to sample the significant ecological gradients within each community type, but were limited due to time and budget constraints. During the month of fieldwork, we collected data at 123 specific sites located using GPS. We recorded natural community presence or boundaries at over 200 additional sites in the study area. Over 1000 photographs were taken recording the composition, structure and condition of the natural communities and the SDNM and adjacent lands.

Our fieldwork was conducted during the time of maximum plant dormancy. Most herbaceous plants and grasses were in senescence and annual plants were essentially non-existent. Grazing by livestock had reduced many grass species to short stubble, making identification nearly impossible. Because of these factors, many plants were difficult to identify. Some plant species were recorded as "unknown shrub" or only identified to the genus level. The extended drought experienced by this region accentuated the dormancy of many plants and often made it difficult to find remnants of leaves or seeds. Because of these factors the natural community composition and structure recorded in the reconnaissance field data should be considered as an initial and incomplete description of these natural communities.

During our reconnaissance fieldwork, we visited the only "tinajas" that are mapped on the SDNM. The two "tinajas" are mislabeled or misclassified on the existing maps and GIS data layers. They are "tanks" – or human constructed water developments. We mapped these as developed areas. There are no natural springs known to exist on the SDNM. Because of these factors, we did not include a *Desert Tinaja/Spring* natural community in our map of natural communities. There are two springs known to exist outside the SDNM in the BMGR portion of the Sand Tank Mountains, but constraints on our fieldwork (no access to Area B on the BMGR due to active fire) made it impossible to visit these areas. We will describe the natural communities that exist at these springs if time and budget allow during Phase 2 of this project.

Final Natural Community Mapping, Data Analysis and Interpretation

Field Mapping

Some delineation of natural community boundaries was conducted during the 2002 fieldwork. This included field mapping of some of the *Mountain Upland* community boundaries and some of the boundaries between the *Creosote–Bursage Desert Scrub* community and the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community.

Analysis of Field Data

All field ecology plot data were entered into a Microsoft Access database. Reports on each natural community were generated summarizing the average cover for each plant species and the percent of the plots taken in each community that each plant species occurred in (constancy). This enabled an evaluation of which species were most frequently encountered in each community and which species were dominant in each natural community.

The plot data was also examined to determine which species were limited to specific communities and are likely to be indicator plants for those communities. Variations in tree cover and total vegetative cover were also examined. Evidence of natural variation within natural communities was also examined. This analysis of plot data was used to help classify plots to a single natural community type. In cases where plots were transitional between natural communities a secondary community type was also assigned to the plot.

The plot data and other observational data were then used as a guide for natural community mapping.

Interpretation of Digital Orthophotography

The CIR DOQQs proved to be extremely useful in the delineation of natural communities. Three people worked for nearly one month interpreting this imagery and on-screen digitizing or editing natural community boundaries. This work was checked for accuracy by the authors of this study. In addition to the DOQQs, the photo-interpreters used the plot data, other observation data, digital topographic data (elevation, aspect, slope, contours lines), Landsat TM7 satellite imagery, NRCS soil data, hydrologic data and geologic maps to aid in the interpretation of natural community boundaries.

Modeling of Natural Communities

Two GIS based models were developed for the project. The first model was developed to help separate the *Creosote–Bursage Desert Scrub* community from the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. This distinction was perhaps the most difficult task encountered during the project, since the communities grade into each other. The model that was developed is described in the *Creosote–Bursage Desert Scrub* community description.

The second model was developed to predict the distribution of the *Mountain Upland* community. This model was based on analysis of the field plot data, other field observations and limited field mapping. This model is described in detail in the *Mountain Upland* community description.

Integration

All the above data were integrated to compile the final map of natural communities. This integration process first combined the three matrix communities (*Creosote–Bursage Desert Scrub*, *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* and *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes)* into a base map. Then the small patch communities (*Mountain Uplands, Desert Grasslands, Mesquite Bosques,* and *Rock Outcrops)* were superimposed. The riparian communities (*Valley Bottom Floodplain*, *Valley Xeroriparian Scrub* and *Mountain Xeroriparian Scrub)* were not superimposed, but are considered overlays to the matrix and small patch communities. Lastly, a *Developed/Disturbed Area* GIS layer was developed. This layer depicts small patches of land that have been substantially altered by human activity. Many of these areas retain some of the components of the original natural community present before development. Therefore these communities should be considered an additional overlay to the matrix, small patch and riparian communities.

Community Descriptions

Community descriptions were developed based on review of existing literature, field observations and careful analysis of field ecology plot data. These descriptions should be considered preliminary and will be revised during phase two of this project. They do not include a description of many of the herbaceous, grass and annual species that are present in each community. But these initial descriptions are the best current description of the composition and structure of the natural communities as they are expressed in the SDNM.

Comparison Of Natural Communities And Ecological Sites

A description of the methods used to compare the mapped natural communities to BLM's and NRCS's Ecological Sites is included in the last section of this report along with the results of this analysis.

Map of Natural Communities

Eleven natural communities were mapped and described on the SDNM and adjacent areas in the Sand Tank Mountains and Vekol Valley (Figure 1). These natural communities correspond to similar communities mapped and described on the BMGR (Hall et al 2001) and extrapolated to the SDNM by TNC (Weinstein et al 2002). We did not improve the mapping of the *Desert Tinaja / Springs* community described in this earlier work. No springs appear to exist in the SDNM.

The *Creosote-Bursage Desert Scrub* community is the most extensive community on the SDNM and in the study area as a whole (Table 3). *Paloverde Mixed Cacti – Mixed Scrub* communities on rocky slopes and bajadas cover most of remainder of the study area. Four small patch communities make up the remainder of the area (Table 3).

Table 3. Area Covered by Major Natural Communities in Study Area

	Natural Community	**Sand Tanks** (hectares)	**SDNM** (hectares)	**Total Study Area** (hectares)
Non-Riparian	*Creosote-Bursage Desert Scrub*	19,609	85,773	105,381
	Paloverde Mixed Cacti – Mixed Scrub on Bajadas	6,645	52,455	59,099
	Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes	12,868	59,261	72,129
	Mountain Upland	782	1,283	2,065
	Desert Grassland	774	451	1,225
	Mesquite Bosque	31	1,012	1,043
	Rock Outcrop	167	633	800
	Total Area of Non-Riparian Communities	**40,874**	**200,868**	**241,742**
Riparian				
	Communities			
	Valley Bottom Floodplain	189	5,283	5,472
	Valley Xeroriparian Scrub	471	2,742	3,212
	Mountain Xeroriparian Scrub	121	410	531
	Total Area of Riparian Communities	**781**	**8,435**	**9,215**

We did not subtract the area occupied by the riparian communities from the non-riparian communities in which they occur. Xeroriparian communities are mapped with a 10-meter buffer on either side of the 1:100,000 geospatial hydrography data upon which they are based.

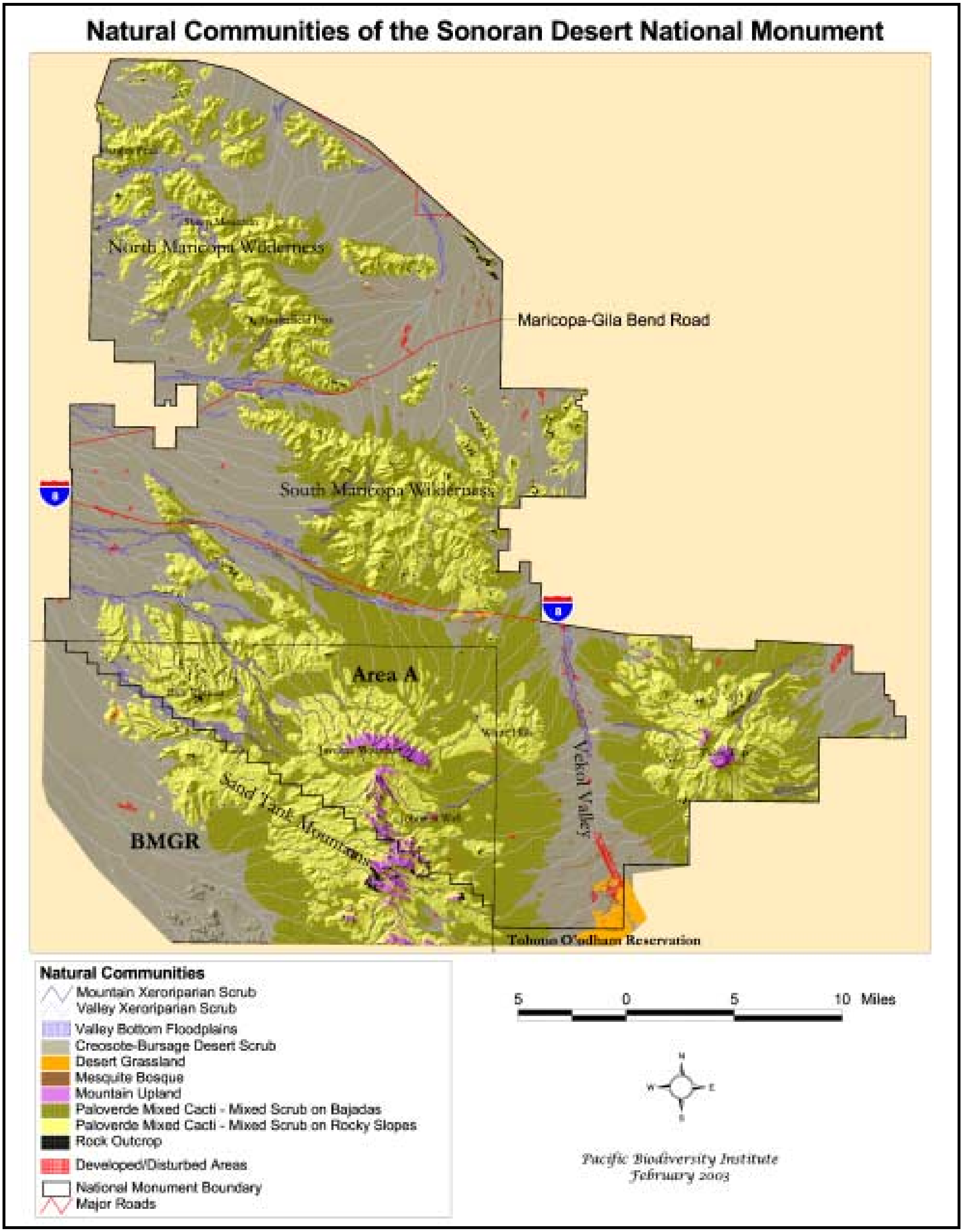

Figure 1. Natural Communities of the Sonoran Desert National Monument and Sand Tank Mountains.

Description of Natural Communities

Creosote-Bursage Desert Scrub

Ecological Characteristics

Description and Composition

The *Creosote–Bursage Desert Scrub* community occupies the lowest elevations on the SDNM covering desert flats, valley bottoms and lower portions of bajadas that extend considerable distances from the desert mountain ranges of the Monument.

Larrea divaricata tridentata is the obvious dominant plant species in this community. It has the highest mean aerial cover (13.5%) and the highest constancy (92%) of any plant species occurring in our initial field ecology plots that were located in this community. *Ambrosia deltoidea* is the second-most common plant species in this community, occurring in 65% of the plots with a mean cover of 3.2% in our field plots. At nearly all sites within this natural community, there is less than 3% cover of leguminous tree species (*Parkinsonia microphylla, Olneya tesota* and/or *Prosopis velutina*). This scarcity of leguminous trees plus the lower abundance of cacti species are the primary factors distinguishing the *Creosote–Bursage Desert Scrub* community from the adjacent *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community.

The *Creosote–Bursage Desert Scrub* community often has low species diversity compared to other natural communities on the SDNM. On some sites less than three perennial species exist. Annual plants and grasses can be an important component of this community, but they were not much in evidence during our early winter fieldwork. Many areas occupied by this community have low overall vegetative cover. The mean overall vegetative cover of all the initial field plots in this community was below 25%.

Larrea divaricata tridentata is perhaps the most ubiquitous plant in the Sonoran Desert. It has a wide ecological amplitude – covering the low elevation desert flats and occurring at the highest elevations in the mountains of the SDNM. It can be found in the driest areas of the monument and it is also found lining the intermittent stream channels as part of the xeroriparian scrub communities. In that light, it makes a very poor indicator plant. *Ambrosia deltoidea* also has a wide ecological amplitude, occurring in nearly all the natural communities in the SDNM. The clear dominance of these two species is a unique feature of the *Creosote–Bursage Desert Scrub* community. The near absence of many other species that characterize other natural communities in the Sonoran Desert is also apparent when examining sites in the *Creosote–Bursage Desert Scrub* community.

Other species that were found during initial field sampling in this community include (in order of constancy in our field plot data): *Chorizanthe rigida, Parkinsonia microphylla, Opuntia acanthocarpa, Carnegiea gigantea, Olneya tesota, Krameria grayi, Fouquieria splendens splendens, Ferocactus* spp.*, Opuntia bigelovii, Opuntia fulgida, Erodium cicutarium, Opuntia engelmannii engelmannii, Lycium* spp.*, Ambrosia dumosa, Encelia farinosa farinosa, Echinocereus engelmannii, Prosopis velutina, Koeberlinia spinosa, Acacia constricta, Opuntia leptocaulis,* and *Mammillaria grahamii grahamii.* None of these species accounted for more than 1% mean cover in the field plots.

Structure

This community is composed of a medium to sparse cover of medium-size to small shrubs (primarily *Larrea divaricata tridentata*). Sometimes there is an extremely sparse overstory of small trees (*Parkinsonia microphylla, Olneya tesota, Prosopis velutina*) and a few large cacti (*Carnegiea gigantea*) – particularly where this community is transitional to the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. The total average tree cover in our field plots within this community was 1.7%. Under and between the small shrubs is a patchy cover of herbs and grasses – often annuals. The dominant ground cover in the community is gravel, sand and soil that form the surface of the lower bajadas and the desert flats. This matrix community covers extensive areas of the SDNM. The *Valley Xeroriparian Scrub* community, occurring along the numerous meandering large and small drainages, dissects this community.

Function and Disturbance Processes

Active geomorphic processes affect this community. These processes include debris flows, gully and surface erosion, and wind erosion. Some of these geomorphic processes are continually active and others are episodic. Episodic high intensity rainstorms and associated erosion processes have a persistent effect on these communities. Sheet wash during rainstorms carries fine soil particles from the soil surface and into small intermittent channels leaving behind the small gravels that characterize the desert pavement that is prevalent in many areas. Gully erosion during these events continually widens and deepens the channels – supporting the very gradual extension and expansion of the *Valley Xeroriparian Scrub* community into the *Creosote–Bursage Desert Scrub* matrix community. Debris flows also may influence some areas within this community if an active bajada is present. On active bajadas, debris flows can deposit new alluvium to the surface of the bajada during peak flow events. Other areas of the bajada can be eroded during these events and the ephemeral streams and associated xeroriparian areas, which dissect the bajada, can change course during storm events. Many bajadas are not subject to active deposition at this time and the streams that once deposited alluvium on their surface are now deeply incised into the bajada. These older bajadas are still subject to gully and surface erosion during storms and to wind erosion. The composition of the *Creosote–Bursage Desert Scrub* community may vary with the age of the surface and the composition of the substrate.

Wildfire is an infrequent event in the Sonoran Desert, but very long return interval fire may periodically visit some sites within the *Creosote–Bursage Desert Scrub* community. Normally, there is insufficient fuel to carry a wildfire, since vegetation often covers less than 24% of the ground surface and there is little vegetation litter on the soil surface.

Landscape Context

The *Creosote–Bursage Desert Scrub* natural community is the most prevalent community on the SDNM occupying nearly 86,000 hectares. It forms the primary matrix community of the Sonoran Desert ecoregion. Areas that are distant from mountain ranges generally have the finest textured soils. These desert flats are often covered with a sparse cover of *Larrea divaricata tridentata* and few other species (Figures 1 and 2). Sites that are closer to the mountains generally have higher species diversity and become transitional to the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community (Figures 3 and 4).

Best Examples on the SDNM

There are many good examples of the *Creosote–Bursage Desert Scrub* community on the Monument. Some of examples are illustrated below (Figures 2-5).

Figure 2. Plot 122. Creosote flat near Mobile, AZ in the northeastern portion of the SDNM. This area is distant from the Maricopa Mountains and has very low species diversity.

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Figure 3. Plot 96. Creosote community and desert pavement south of the Freeman exit on Interstate 8. This plot is in the valley between the Maricopa Mountains and the Sand Tank Mountain. It also has low species diversity.

Figure 4. Plot 121. Bursage dominated desert flat north east of Gila Bend. This plot is closer to the Maricopa Mountains and has higher species diversity than the community illustrated in Figure 1.

Figure 5. Plot 86. *Creosote–Bursage Desert Scrub* community north of Javelina Mountain in an area where it transitions to the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. Most of the cacti and leguminous trees are located in small draws, while the interfluvial areas are covered with desert pavement, creosote, triangle-leaved bursage and other small shrubs and cacti.

Mapping Methods, Biophysical Modeling Parameters and Discussion of Previous Mapping Efforts

The extent of the *Creosote–Bursage Desert Scrub* natural community in our map of natural communities of the SDNM is significantly different from its extent in the map provided to us by TNC at the beginning of the project. In that map, the extent of the *Creosote–Bursage Desert Scrub* community was based on the GAP Analysis statewide vegetation map. Our fieldwork along with interpretation of DOQQs and satellite imagery revealed that there are significant areas of *Creosote–Bursage Desert Scrub* in the Vekol Valley and other areas south of Interstate 8 that were mapped as the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community in the GAP vegetation map and subsequently in TNC's initial map. There are also significant areas delineated in those maps as *Paloverde Mixed Cacti - Mixed Scrub* north of Interstate 8 but these are more appropriately mapped as *Creosote-Bursage Desert Scrub*.

In the northern part of the SDNM and in some other areas of the Monument, there are areas mapped as *Creosote-Bursage Desert Scrub* that have little resemblance to that community and are more appropriately mapped as a *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* or a *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community. We incorporated all these revisions in our map of natural communities of the SDNM.

We developed a GIS model to predict the distribution of the *Creosote–Bursage Desert Scrub* community. This model is based on the spectral characteristics of a Landsat TM7 satellite image and digital elevation data. Several spectral classes from an unsupervised classification of the image corresponded to the *Creosote–Bursage Desert Scrub* community. Its distribution was further confined to areas below 650 meters elevation and to desert flats or bajadas with less than 3 degrees slope. This model predicts the distribution of this community better than the GAP mapping, but its distribution was further refined by careful interpretation of the DOQQs. During this aerial photo interpretation process, we referred to our predictive model and the GAP distribution frequently to facilitate the delineation of the boundaries of this community. The most difficult separation between the *Creosote–Bursage Desert Scrub* community and other communities on the SDNM is where it grades into the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. Fortunately, one can see individuals and clumps of the larger leguminous trees in the digital aerial imagery. We determined the community was *Creosote–Bursage Desert Scrub* if less than 5% cover of leguminous trees is visible in the DOQQ imagery. This is similar to the approach taken by Jim Malusa on the Cabeza Prieta NWR (personal communication).

Many of the revisions that we made in the GAP vegetation map and TNC's initial map are reflected in the boundary between the Lower Colorado Subdivision and Arizona Upland Subdivision of the Sonoran Desestscrub as mapped by Brown and Lowe (1980). Their rough boundaries correspond fairly well to our boundaries between the *Creosote–Bursage Desert Scrub* community and the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community – particularly where we made significant revisions in the Vekol Valley and in the area between Gila Bend and the South Maricopa Mountains. Brown and Lowe's map is very generalized, but it does appear to support some of the modifications in vegetation boundaries that we have made.

Further refinement of the separation between the *Creosote–Bursage Desert Scrub* community and the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community is possible, but not within the time and budget constraints of this project. There is considerable variation in composition and structure within *Creosote–Bursage Desert Scrub* community and many variants exist. There are a few areas on some of the steep, rocky slopes that have a similar composition to the *Creosote–Bursage Desert Scrub* community but these were considered inclusions within the *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community.

Relationship to Plant Community Classification Systems

This community falls within Brown and others' (1979) Creosotebush – Bursage series (154.11). It corresponds with the *Larrea tridentata* Shrubland alliance, Evergreen Shrubland formation of the National Vegetation Classification (TNC 1998).

Paloverde Mixed Cacti - Mixed Scrub on Bajadas

Ecological Characteristics

Description and Composition

This community corresponds to the Arizona Upland Subdivision of the Sonoran Desertscrub (Brown 1994, Brown and Lowe 1980). It occupies the upper bajadas that extend out from the desert mountains in the SDNM and is characterized by a diverse mixture of leguminous trees, large and small cacti, shrubs, herbs and grasses.

This community has some compositional similarities to the adjacent *Creosote–Bursage Desert Scrub* and the adjacent *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities, but it also has significant differences in species presence and abundance. This community is normally found sandwiched in between these two other communities. *Ambrosia deltoidea* is often the dominant plant and has a mean cover of 7.6% and constancy of 79% in our field plots. *Larrea divaricata tridentata* and *Carnegiea gigantea* are found at nearly all sites (86% constancy), however *Larrea* is much more abundant (4.5% mean cover) than *Carnegiea* (1.2% mean cover). *Parkinsonia microphylla* is present at most locations (79% constancy) and has a relatively high mean cover (2.9%). It is one of the most characteristic species of this community. Other species that occurred in over half of our initial field plots include: *Opuntia acanthocarpa, Olneya tesota,* and *Fouquieria splendens splendens.* At most sites within this natural community there is over 5% cover of leguminous tree species (*Parkinsonia microphylla, Olneya tesota* and/or *Prosopis velutina*) along with numerous other shrubs and cacti. *Phoradendron californicum* is a common epiphytic parasite associated with the overstory of leguminous trees.

Some of the other native species that are frequently encountered include: *Krameria grayi*, *Opuntia engelmannii engelmannii*, *Opuntia fulgida*, *Phoradendron californicum*, *Opuntia bigelovii*, *Acacia constricta*, *Echinocereus engelmannii*, *Mammillaria grahamii grahamii*, *Prosopis velutina*, *Rhynchosia texana*, *Koeberlinia spinosa*, *Jatropha cardiophylla*, various grass species, *Ferocactus* spp. *Ephedra* spp., and *Encelia farinosa farinosa*.

A major difference between this community and the similar community found on rocky slopes *(Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes)* is the very infrequent occurrence of *Lycium* species and the low abundance of *Encelia farinosa farinosa,* which are both common on rocky slopes. *Carnegiea gigantea* is considerably more prevalent on the bajadas than on the rocky slopes. On the bajadas, the mean cover of *Parkinsonia microphylla* is less than half that found on the rocky slopes but it is found in both locations with equal constancy.

Structure

This community is composed of a sparse overstory of small trees (*Parkinsonia microphylla, Olneya tesota, Prosopis velutina*) and large cactus (*Carnegiea gigantea*) and a patchy understory of smaller shrubs, herbs and grasses. The total average tree cover in our field plots within this community was 6.5%, significantly more than in the *Creosote–Bursage Desert Scrub community*. The dominant ground cover in the community is gravel and boulders deposited during debris flows, along with sand and soil that form the surface of the bajada. Large patches of this community are found throughout the SDNM.

The *Valley Xeroriparian Scrub* community extends though these large patches along the many sinuous, intermittent drainages.

Function and Disturbance Processes

Active geomorphic processes affect this community. These processes include debris flows, gully and surface erosion, and wind erosion. Some of these geomorphic processes are continually active and others are episodic. Debris flows are the most important geomorphic process that is responsible for forming the bajada. On active bajadas these flows can deposit new alluvium to the surface of the bajada during peak flow events. Other areas of the bajada can be eroded during these events and the ephemeral streams and associated xeroriparian areas, which dissect the bajada, can change course during storm events. Many bajadas are not subject to active deposition at this time and the streams that once deposited alluvium on their surface are now deeply incised into the bajada. These older bajadas may still be subject to gully and surface erosion during storms and to wind erosion. The plant communities that form on the bajada surface vary considerably depending on the age of the bajada, whether it is an active bajada, and the type of material that forms the surface layers of the bajada.

Wildfire is an infrequent event in the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. Like the *Creosote–Bursage Desert Scrub community*, there is usually insufficient fuel to carry a wildfire. On the average, vegetation covers less than 30% of the ground surface and vegetation litter is sparse. However, some variants of this community have relatively high vegetation cover and could support a wildfire.

Landscape Context

The *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* natural community is the third most prevalent community on the SDNM, occupying over 52,000 hectares. It forms the "matrix" of the Arizona Uplands subdivision of the Sonoran Desert ecoregion (Hall et al 2001). This community characterizes the alluvial fans (bajadas) that surround the mountain ranges and larger desert hill complexes. There is usually a very abrupt transition to the *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slope* community at the slope break between the bajada and the rocky slope (usually at 5-6 degrees). The lower transition to the *Creosote–Bursage Desert Scrub* community is often less obvious and these two communities often grade into each other. The *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community is usually found on slightly steeper slopes and at slightly higher elevations than the *Creosote–Bursage Desert Scrub community*. The soils of this community are generally coarse-textured and formed from rocky and gravelly alluvium. There is considerable caliche on or near the surface of the older bajadas.

Best Examples on the SDNM

There are numerous excellent examples of the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community on the SDNM and near the Sand Tank Mountains. Figure 66 illustrates an area that is transitional between *Creosote–Bursage Desert Scrub* and *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* north of the Sand Tank Mountains. An area at the base of the South Maricopa Mountains where this community is more fully developed is illustrated in Figure 7. Figure 8 illustrates an extensive patch of this community occurring on older, dissected bajadas extending north from Javelina Mountain.

Figure 6. West of Plot 86. Excellent example of a fully developed *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* natural community.

Figure 7. Paloverde Mixed Cacti - Mixed Scrub on Bajadas community north of Bighorn Peak.

Figure 8. Extensive old dissected bajada with *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community north of Javelina Mountain. Table Top Mountain in far distance.

Mapping Methods and Biophysical Modeling Parameters

The extent of the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* natural community in our map is significantly different from its extent in the map provided to us by TNC at the beginning of the project. As described in the section above, a significant portion of the area mapped in the GAP vegetation map and TNC's initial map is more accurately mapped as *Creosote–Bursage Desert Scrub*. We also found that there were some areas mapped as *Creosote–Bursage Desert Scrub* that have little resemblance to that community and are more appropriately mapped as a *Paloverde Mixed Cacti - Mixed Scrub on Bajadas*.

Our GIS model that predicts the distribution of the *Creosote–Bursage Desert Scrub* community also predicts the distribution of the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community with slight modifications. Several spectral classes from an unsupervised classification of the Landsat TM image corresponded to the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. Its distribution was further confined to slopes less than 6 degrees but over 2 degrees and areas less than 1200 meters but over 250 meters in elevation. This model predicts the distribution of this community better than the GAP mapping, but we further refined its distribution through careful interpretation of the DOQQs. During this photointerpretation process, we referred to our predictive model and the map provide by TNC frequently to facilitate the delineation of the boundaries of the community. As described in the section above, the most difficult separation between the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community and other communities on the SDNM is where it grades into the *Creosote–Bursage Desert Scrub* community. Fortunately, one can see individuals and clumps of the larger leguminous trees in the digital aerial imagery. We determined the community was *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* if at least 5% cover of leguminous trees are visible in the DOQQ imagery. This is similar to the approach taken by Jim Malusa on the Cabeza Prieta NWR (personal communication).

Further refinement of the mapping of the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community is possible, but not within the time and budget constraints of this project. It is possible to separate the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community into many distinctive variants.

Relationship to Plant Community Classification Systems

This community falls within Brown and others' (1979) Paloverde – mixed cacti series (154.12). It includes many alliances within the Evergreen Shrubland formation of the National Vegetation Classification, including *Ambrosia deltoidea* Shrubland alliance, *Carnegia gigantean* Wooded Shrubland alliance, *Parkinsonia florida* Shrubland alliance, and *Opuntia bigelovii* Shrubland alliance (TNC 1998).

Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes

Ecological Characteristics

Description and Composition

This community has some compositional similarities to *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* but it has significant differences in species presence and abundance. *Parkinsonia microphylla* dominates this community with the highest mean aerial cover (7.67%) and the highest constancy (79%) of any plant species occurring in our initial ecology field plots. While the constancy of *Parkinsonia microphylla* is identical to that found on the bajadas, the average cover of *Parkinsonia microphylla* is over twice as high on the hillslopes as on the bajadas. *Ambrosia deltoidea* dominates the understory in many areas and has a mean cover of 4.64% and constancy of 67% in our field plots. Perhaps the best indicator species for this community is *Encelia farinosa farinosa*, which occurs in relatively high abundance in most areas (mean cover = 3.1%, constancy = 60%). This species rarely occurs on the bajadas as a significant component of the plant community and is not common in the other natural communities on the SDNM. Other species that are common in this community include (in order of constancy in our field plot data): *Carnegiea gigantea, Larrea divaricata tridentata,* various grass species, *Fouquieria splendens splendens, Opuntia acanthocarpa, Lycium* spp.*, Krameria grayi, Olneya tesota, Echinocereus engelmannii, Opuntia engelmannii engelmannii, Ferocactus* spp.*, Notholaena standleyi, Opuntia bigelovii, Calliandra eriophylla, Mammillaria grahamii grahamii, Ephedra* spp*, Encelia frutescens frutescens, Selaginella arizonica,* and *Sphaeralcea ambigua.*

This community has considerable variation that is dependent on aspect, slope, elevation and geologic parent material. One of the most significant variants occurs on northerly facing slopes, primarily in granitic mountains. On these rocky slopes *Selaginella arizonica* is often the dominant plant, covering 20% to 60% of the ground surface (Figure 8). While *Parkinsonia microphylla* is usually present on these north facing rocky slopes, it is often less abundant than elsewhere and *Carnegiea gigantea* is often nearly absent.

Figure 9. Plot 90. Selaginella–paloverde dominated community on rocky slope north of Javelina Mountain.

Structure

This community is composed of a sparse overstory of small trees (*Parkinsonia microphylla* and *Olneya tesota*) and large cactus (*Carnegiea gigantea*) and a patchy understory of smaller shrubs, herbs and grasses. The total average tree cover in our field plots within this community was 9.2%, significantly more than in the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community. The dominant ground cover in the community is the rock (bedrock and colluvium) that forms the rocky slope. Large patches of this community are found throughout the SDNM in all the mountainous regions. The *Mountain Xeroriparian Scrub* community extends though these large patches in the steep and narrow mountain drainages.

Function and Disturbance Processes

Active geomorphic processes affect this community. These processes include rock cracking and spalling, downhill soil and rock creep, gully and surface erosion, wind erosion and possibly occasional landslides during peak storm events. Some of these geomorphic processes are continually active and others are episodic. Water is stored in the cracks between rocks and in the shallow soil. Many of the plants that thrive in this community are adapted to utilize the moisture stored in the cracks in the fractured bedrock and colluvium.

Wildfire is an infrequent event in the *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community. Like other communities in the SDNM, there is usually insufficient fuel to carry a wildfire. On the average, vegetation covers less than 36% of the ground surface and vegetation litter is sparse. However, some variants of this community have quite high vegetation cover (Figure 9) and could easily support a significant wildfire.

Landscape Context
This community forms the core of the SDNM and is the second most extensive natural community on the Monument, covering over 59,000 hectares. It is surrounded by the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* and *Creosote–Bursage Desert Scrub* communities, which cover the lower elevations of the Sonoran Desert. This community occupies nearly all the mountain slope terrain above the bajada / mountain hillslope transition, which usually occurs abruptly at about 5 to 6 degrees slope. Only at the highest elevations in the Monument does this community give way to the *Mountain Upland* community.

Best Examples on the SDNM

There are numerous excellent examples of this community on the SDNM and in the Sand Tank Mountains. Figure 10 illustrates one example in the Sand Tank Mountains where vegetation cover is relatively high. A more typical example of this community where vegetation cover is significantly lower is illustrated in Figure 11 in the North Maricopa Mountains.

Figure 10. Excellent example of densely vegetated *Paloverde Mixed Cacti - Mixed Scrub* community on northeast facing rocky slopes south of Johnson Well in the Sand Tank Mountains.

Figure 11. Plot 1, west of Mobile in North Maricopa Mountains. More sparsely vegetated *Paloverde Mixed Cacti - Mixed Scrub* community on east facing slope, granite bedrock.

Mapping Methods and Biophysical Modeling Parameters

The *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community was initially mapped by TNC on slopes that were greater than 25 degrees. Our analysis of the DOQQs and all our fieldwork indicate that this community extends down to about 5 or 6 degrees and that there is nearly always an abrupt slope break at this point where the bajadas start. The NRCS soil mapping also clearly indicates where this natural community is separated from the *Paloverde Mixed Cacti – Mixed Scrub on Bajadas* community. For most of the SDNM, we used polygons from the NRCS soil GIS layer to delineate the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community with minor adjustments and improvements based on field data and interpretation of the DOQQs. In the Area-A part of the SDNM and in the adjacent Sand Tank Mountains no soil data exists and we delineated this community based on the slope break discussed above and more extensive interpretation of the DOQQs and field data.

It should be noted that small areas with slopes less than 6 degrees are present in the mountains (on summits, plateaus or other relatively flat areas) and were not separated from the rocky slope matrix community. These areas are nearly all very rocky and have similar composition to the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community with few exceptions.

During our fieldwork, we noted very significant differences in the species composition of this community on north and south-facing aspects. The more typical community composition occurs on south, east and west aspects. But on more northerly aspects the species composition shifts significantly. As discussed above, *Selaginella arizonica* becomes one of the dominant plants (often with over 20% ground cover). *Carnegia gigantea* often drops out of the community on north slopes and grass is often much more abundant. Because of these compositional differences, it may be useful to split this community from the other Paloverde communities occurring on rocky slopes. This was not done during the first phase of this project because of time and budget constraints, but could be done based on environmental gradient modeling implemented in a GIS environment. It also may be useful to split out other significant variants within the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community, as this community contains the greatest variation of any community in the SDNM.

Relationship to Plant Community Classification Systems

This community falls within Brown and others' (1979) Paloverde – mixed cacti series (154.12). It includes many alliances within the Evergreen Shrubland formation of the National Vegetation Classification, including *Parkinsonia microphylla* Shrubland alliance, *Ambrosia deltoidea* Shrubland alliance, *Carnegia gigantean* Wooded Shrubland alliance, *Simmondsia chinensis* Shrubland alliance, *Encelia farnosa* Shrubland alliance, and *Opuntia bigelovii* Shrubland alliance (TNC 1998).

Mountain Uplands

Ecological Characteristics

Description and Composition

The *Mountain Uplands* are characterized by the presence of several species that are only found in the cooler and moister habitats of the highest mountains and their north facing slopes. *Canotia holacantha* is probably the best indicator plant of this upland community. It occurred in 75% of our upland field ecology plots and had an average cover of 5.1%, but was absent from all the other communities described in this study. *Ephedra* spp., *Yucca baccata*, and *Agave parryi* are other common plants that are largely confined to the upland plant community. *Vaquelinea californica sonorensis*, *Juniperus coahuilensis* and *Berberis harrisonia* have been reported in the Sand Tank Mountains (Felger et al 1997, Hall et al 2001), but were not observed during our field reconnaissance. These three species appear to be confined to very limited sites within the *Mountain Uplands*.

The *Mountain Uplands* are also characterized by their extensive cover of perennial grasses. On the average, over 14% of the ground surface of our field plots had perennial grass cover. Although positive grass identification was very difficult during our December field reconnaissance, it appears that the primary species that are commonly found in the upland communities include *Muhlenbergia porteri, Setaria leucopila, Tridens muticus, Digitaria californica,* and *Pleuraphis mutica* (Turner et al 2000).

The *Mountain Uplands* are also characterized by unusually high cover (8.5%) and constancy (75%) of *Opuntia engelmannii engelmannii*. *Fouquieria splendens splendens* was also found in 75% of our field plots and had an average cover of 2.6%. *Simmondsia chinensis* was only found in 25% of our *Mountain Upland* field plots (those located in the Bender Spring Canyon area of the Sand Tank Mountains). It was clearly one of the dominant plants in the Bender Spring Canyon area. It may be more common in other *Mountain Upland* areas that we were not able to visit in our initial reconnaissance.

Other species that are common in this community include: *Larrea divaricata tridentata*, *Parkinsonia microphylla*, *Opuntia acanthocarpa*, *Echinocereus* spp., *Rhynchosia texana*, *Yucca elata*, *Carnegiea gigantea*, *Selaginella arizonica*, *Acacia constricta*, *Ferocactus* spp., *Mammillaria grahamii grahamii*, *Lycium* spp., and *Calliandra eriophylla*.

Structure

A unique feature of the *Mountain Uplands* is the very high overall vegetative cover of perennial plants (59.8% mean cover in our field plots). These include small trees, large and small shrubs, perennial herbs and grasses. Tree cover (1.1%) is considerably less than that on the lower rocky slopes, and tree stature is also considerably less. Annuals are present but were not included in the above cover estimate because of the timing of our fieldwork.

Function and Disturbance Processes

Like the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community, active geomorphic processes affect the *Mountain Uplands*. These processes include rock cracking and spalling, downhill soil and rock creep, gully and surface erosion, wind erosion and infrequent landslides during peak storm events. Some of these geomorphic processes are continually active and others are episodic. Water is stored in the cracks between rocks and in the shallow soil. Many of the plants that thrive in this community are adapted to utilize the moisture stored in the cracks in the fractured bedrock and colluvium.

The *Mountain Uplands* are one of the few natural communities on the SDNM that experience regular freezing temperatures in the winter. Infrequent snow also occurs. This community is also subjected to desiccation by regular high winds. Cold temperatures limit plant growth during the late fall, winter and early spring months. Persistent and regular cloud cover appears to affect this community (Figure 12) and may help maintain higher plant moisture levels than in other communities on the SDNM. While this community is not a cloud forest, it appears that some of the same factors that influence the formation of cloud forests may operate in this community as well – at least during the cooler part of the year.

Figure 12. Persistent cloud over Table Top Mountain. Lower elevation limit of cloud is near that of the lower limit of the *Mountain Upland* community. Regular cloud formations at this level may be one factor that influences the development of the mountain upland natural community. The *Mountain Upland* community is enveloped by the cloud. Below the cloud level is the *Paloverde Mixed Cacti - Mixed Scrub* community on rocky slopes and below that (in the foreground) the *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* community.

Wildfire may be an infrequent event in the *Mountain Upland* community, but little is known about the fire return interval. This community is unlike all other non-riparian communities in the SDNM. It has a high level of vegetative cover (nearly 60%), resulting in sufficient fuel to carry and sustain a wildfire. Another factor that may affect the fire return interval is the tendency for mountaintops to attract lightning. This community may have both the necessary fuel and the ignition source to support more frequent fire than other communities in the SDNM.

Landscape Context
The *Mountain Upland* community occupies a small portion of the SDNM (1283 ha). Examples of this community can be found at the higher elevations in the Sand Tank Mountains, on Table Top Mountain and at a few locations on slightly lower mountains to the north of Table Top. It is possible that a few localized areas with similar vegetation composition occur on north facing slopes at the very highest elevations of the Maricopa Mountains, but this has not been confirmed.

The *Mountain Upland* community is surrounded by the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community and grades into this community at its lower boundary. There are many similarities between these two communities and they share many species. In some areas there is a broad ecotone between these two mountain communities.

Best Examples on the SDNM
Excellent examples of this community are illustrated below in the photographs below (Figures 13-18). The best examples of this community are found on the upper north side of Table Top Mountain, the upper north side of Javelina Mountain/Maricopa Peak and at the highest elevations in the Sand Tank Mountains near Bender Spring.

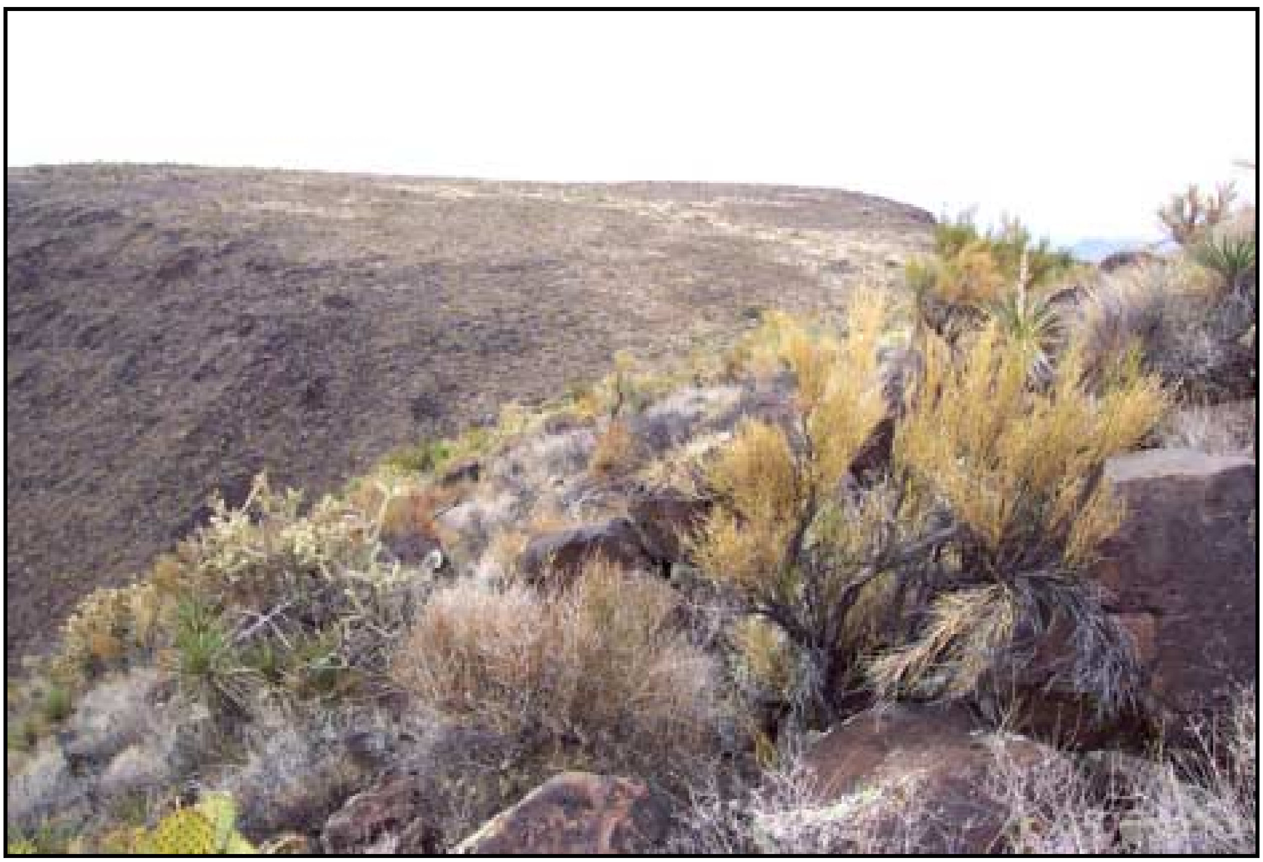

Figure 13. Plot 7. *Mountain Upland* community near summit of Table Top. *Canotia holacantha* on right side, foreground.

Figure 14. Plot 81 north of Bender Springs Canyon in the Sand Tank Mountains. ***Mountain Upland*** **community with abundant** ***Canotia holacantha*** **(the tall yellow-green shrubs occupying the middle portion of the photo).**

Figure 15. ***Mountain Upland*** **community on east side of Maricopa Peak, Javelina Mountain. Note the abundant** ***Canotia holacantha*** **on north facing slope in contrast to south slope dominated by vegetation typical of** ***Paloverde Mixed Cacti - Mixed Scrub*** **communities on rocky slopes.**

Figure 16. Closer look at *Mountain Upland* community on east side of Maricopa Peak.

Figure 17. Details of *Mountain Upland* community on east side of Maricopa Peak. Indicator species include *Canotia holacantha, Yucca baccata, Ephedra aspera and Agave parryi*.

Figure 18. South slope near top of Maricopa Peak. Note the very slight presence of species indicative of *Mountain Upland* community and the abundance of species typical of the *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community. This area is considered transitional to the *Mountain Upland* community.

Mapping Methods and Biophysical Modeling Parameters

We revised the extent of the *Mountain Upland* communities initially mapped by TNC in the Sand Tank Mountains (Hall et al 2001) and Table Top areas based in part on the lower elevation limit of *Canotia holacantha* and *Vaquelinea californica sonorensis* that was documented by Turner and others (1995). In this initial mapping the *Mountain Upland* community extended down to 792 meters in elevation, without regard to aspect.

While occasional occurrences of the indicator species may possibly occur at a few sites down to 792 meters in elevation, this is not a viable elevation limit for the *Mountain Upland* community in the SDNM and Sand Tank Mountains. All of our fieldwork indicates that this elevation limit is too low, particularly on south-facing slopes. We did find one *Canotia holacantha* stand at 848 meters in elevation on a steep, north-facing slope (Plot 66), but our reconnaissance field surveys indicate that the *Mountain Upland* communities are considerably more restricted than initially mapped by TNC.

The most significant biophysical modeling parameters that can be used to predict the occurrence of this community are the combination of aspect and elevation. Neither parameter suffices alone. The *Mountain Upland* community is largely constrained to north-facing slopes above 1000 meters. The community extends much lower in elevation on the most northerly aspects, which are shaded, cooler and retain soil moisture for much longer periods than more southerly aspects. Freezing temperatures are also more common on these north aspect slopes. Based on our field observations, we developed a biophysical model implemented to predict the extent of the Mountain Upland community. Slightly different elevation breaks were used on Table Top Mountain than in the Sand Tank Mountains. The following conditions predict this community's extent with a reasonable degree of accuracy. All these conditions are designed to be implemented simultaneously, with the effect that the upland community wraps around the mountain at lower elevations on more northerly aspects.

Table Top Upland Conditions:

1. If elevation in feet is > 3900 then upland community exists on all aspects
2. If aspect is less than 130 or greater than 210 degrees then upland community extends down to 3800 feet
3. If aspect is less than 110 or greater than 260 degrees then upland community extends down to 3700 feet
4. If aspect is less than 80 or greater than 290 degrees then upland community extends down to 3400 feet
5. If aspect is less than 55 or greater than 330 degrees then upland community extends down to 3200 feet

Sand Tank Upland Conditions:

1. If elevation in feet is > 3800 then upland community exists on all aspects
2. If aspect is less than 130 or greater than 210 degrees then upland community extends down to 3700 feet
3. If aspect is less than 110 or greater than 260 degrees then upland community extends down to 3300 feet
4. If aspect is less than 80 or greater than 290 degrees then upland community extends down to 3000 feet
5. If aspect is less than 55 or greater than 330 degrees then upland community extends down to 2900 feet

The occurrence of the Mountain Upland community in the Sand Tank Mountains at lower elevations than at Table Top is probably due to greater precipitation in the Sand Tanks. This may be related to the large mountain mass that is present. The larger mountain mass may also result in slightly cooler temperatures.

On Table Top Mountain, the *Paloverde Mixed Cacti – Mixed Scrub on Rocky Slopes* community extends nearly to the summit of Table Top Mountain on the south-facing slopes. The same situation was observed on Javelina Mountain and Maricopa Peak in the Sand Tank Mountains. On north-facing slopes, the upland community is more extensive and extends down to about 1000 meters based on the distribution of *Canotia holacantha.* This elevation limit was observed during our fieldwork on Table Top Mountain and areas north of Table Top, on Maricopa Peak and Javelina Mountain, and in the Sand Tank Mountains near Bender Spring.

Some components of the upland community extend lower on the mountain slopes than *Canotia holacantha*. *Yucca baccata*, *Agave parryi*, and *Ephedra spp*. (which are often dominant plant species in the uplands) may occur at significantly lower elevations – but are never a major component of the lower elevation communities. The extent of the *Mountain Upland* community should include areas where these species form a major component of the plant community, even if *Canotia holacantha* and *Vaquelinea californica sonorensis* are absent.

In the southern part of the SDNM and adjacent Sand Tank Mountains, *Simmondsia chinensis* (jojoba) was observed on all aspects in the Bender Spring Canyon. This species was not found in other places on the SDNM during our fieldwork and may be a special component of the upland community in parts of the Sand Tanks. In xeroriparian areas it was found down as low as 835 meters in elevation.

The delineation of the *Mountain Upland* community could be further refined through collection and analysis of additional field data, more comprehensive literature review and consultation with other experts.

Relationship to Plant Community Classification Systems

This community is within the Paloverde – mixed cacti series (154.12) of Brown and others (1979). It is not well described by any associations within that classification, or in the classification work of Warren and others (1981). Within the National Vegetation Classification System (NVCS), it broadly falls under the Evergreen Shrubland formation. It includes a number of alliances, based on dominant plant cover, which have not yet been named or added to the NVCS (TNC 1998).

Desert Grasslands

Ecological Characteristics

Description and Composition

Desert Grasslands are confined to the southeastern corner of the SDNM and adjacent lands in the TOR. The grasslands occupy only 451 hectares on the SDNM. Two species of grass, *Pleuraphis mutica (Hilaria mutica) and Pleuraphis rigida (Hilaria rigida)*, dominate this community to the exclusion of most other species. *Prosopis velutina* appears to be invading the grasslands from adjacent *Mesquite Bosque* communities and is quite common in some areas (Figure 20). The mesquite in the grasslands is often quite young, indicating recent invasion and establishment. Other species observed during our brief field survey of the grasslands include *Koeberlinia spinosa, Larrea divaricata tridentata, Ferocactus* sp. and *Opuntia* spp. Fairly intense grazing of the grasslands on the SDNM prior to our field visit coupled with a prolonged drought and vegetation dormancy made observation and identification of the native vegetation more difficult.

Brown (1994) describes the composition of desert (or semi-desert) grasslands throughout the Southwest in considerable detail. Additional fieldwork is needed in the grasslands of the SDNM to adequately describe their composition and condition.

Structure

The grasslands have a relatively simple structure, with one canopy layer of grasses where they have not been invaded by *Prosopis velutina.* Intensive grazing appears to have broken up this structure, leaving large and small bare areas scattered throughout the community. There are marked differences in structure in the TOR as compared to the SDNM (Figures 19-21).

Function and Disturbance Processes

The most obvious disturbance process that is evident today in the *Desert Grassland* community is livestock grazing. It appears that grazing on the SDNM may have altered the structure and composition of this community. This phenomenon has been documented in many other grassland areas in the Sonoran Desert (Brown 1980). The invasion of the grasslands by mesquite is part of this phenomenon.

Periodic flooding of the grassland area during storms and the saturation of the heavy, clay-rich soils is probably a factor influencing composition and structure of the grasslands. Hydrologic alteration of the drainage system in the Vekol Valley through man-made impoundments appears to have accentuated this phenomenon.

Wildfire may have historically been an important disturbance event as it is in many other grassland ecosystems (Brown 1994).

Landscape Context

The *Desert Grassland* community barely extends into the SDNM and only occupies about 451 hectares. Very small areas of a rocky grassland type exist near the summit of Table Top Mountain and a few places in the Sand Tank Mountains – but these areas are considered inclusions within the *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. The *Desert Grassland* community in the SDNM lies in the upper part of the Vekol Valley in a very flat valley bottom site that receives considerable drainage and moisture from the surrounding mountains. The grasslands are now ringed and sometimes penetrated by mesquite stands, but are primarily a small patch community within the *Creosote–Bursage Desert Scrub* matrix community.

Best Examples on the SDNM

The best example of the Desert Grassland community in the SDNM is at the head of the Vekol Valley, extending southward into the TOR (Figures 19-21).

Figure 19. *Desert Grassland* community and fence line separating the SDNM (left) from the TOR (right). Two different grazing regimes are evident on the two jurisdictions.

Figure 20. Plot 12. ***Desert Grassland*** **on SDNM. Note, the invasion of young** ***Prosopis velutina*** **(green shrubs in the middle and far distance).**

Figure 21. Plot 13. ***Desert Grassland*** **on TOR. Note the strip of young** ***Prosopis velutina*** **(green shrubs in the middle distance).**

Mapping Methods and Biophysical Modeling Parameters

The grasslands were mapped based on a brief field visit and interpretation of color infrared DOQQs. There is one prominent grassland polygon (a very large meadow-like feature) that covers the central portion of the upper Vekol Valley near the boundary between the SDNM and the TOR. This prominent grassland polygon extends into the TOR for over a mile.

Examination of the DOQQs revealed that there appears to be an area to the west of this primary polygon in the center of the valley, which extends west and south on flat to gentle slopes, and has a somewhat similar appearance to the grassland areas. It appears that there are some compositional and structural differences in this area, compared to the main grassland polygon, but the appearance is similar enough that we have tentatively mapped it as grassland. Further field examination is needed to confirm this designation, as the DOQQs have an inadequate resolution and spectral response upon which to reliably map the boundaries of the *Desert Grassland* community.

As mentioned earlier, there are small grassland areas that are inclusions in the *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. In general, these areas are below our minimum mapping unit and vary considerably in composition from the Vekol Valley grasslands. Many of these locations are remote and fairly inaccessible. The composition and structure of these areas is difficult to determine from the DOQQs for the same reasons discussed above. After further field investigation of some of these upland grass areas, we may decide to map these areas as a type of *Desert Grassland* community.

The *Desert Grassland* community is difficult to model with a set of biophysical parameters. The presence of a fine textured, heavy clay soil is one biophysical characteristic of the site. Further investigation of this community may lead to a better understanding of other factors.

Relationship to Plant Community Classification Systems

This community relates to the 143.12 Series (Tobosa-Grass Scrub) of Brown and others (1979). Within the National Vegetation Classification System, the Desert Grassland community relates broadly to the Perennial Graminoid Vegetation formation, but does not appear to fit well into any specific alliance (the most closely related class listed is the *Hilaria mutica* Shrub Herbaceous alliance) (TNC 1998).

Mesquite Bosques

Ecological Characteristics

Description and Composition

Mesquite bosques have been described as "large riparian woodlands, which typically have three vegetational strata (tree overstory, shrub understory, and herbaceous understory)" (Stromberg 2002). The overstory of these stands consists mostly of *Prosopis* spp. with less than 25% of the overstory tree layer composed of other species (Stromberg 2002, Minckley and Clark 1981, 1984; Szaro 1989). But the typical bosques today are very different from those described in historical reports. They are quite small in comparison to historical reports that describe bosques spanning widths of 5 to 10 km and extending for kilometers along some major river systems (Stromberg 2002, Douglas 1938, Neff 1940, Rea 1983).

During our fieldwork and interpretation of the DOQQs, we identified many small patches that either are dominated by *Prosopis velutina* or appear to be dominated by *Proposis* spp. Many of the areas that we identified are near places that have received extensive hydrologic alteration by humans (e.g. watering tanks and ponds for livestock). The combination of the water development and livestock grazing may have influenced the composition and development of these communities. Without historical records or photographs, it is difficult to determine if mesquite bosques existed in these areas before the human alterations. The only mesquite bosque that we were able to sample during our initial fieldwork appeared to have been extensively modified by human use and livestock grazing (Figure 22). The understory was heavily grazed and composed nearly entirely of exotic plants. *Cynodon dactylon, Erodium cicutarium* and other invasive exotic plants dominated this community.

Structure
The classic mesquite bosque is composed of mature or old-growth mesquite which forms a partially closed canopy. None of the mesquite riparian woodlands that we visited during our initial fieldwork had this kind of structure. Most mesquite stands that we visited were very dense and composed of younger trees and saplings. The average vegetative total cover of the mesquite bosques is high, usually exceeding 100% when all canopy layers are added together. This community has by far the highest vegetative cover of any community in the SDNM.

Function and Disturbance Processes
Mesquite bosques are strongly associated with riparian areas and areas where the water table is not very far below the surface. The mesquite stands that we identified on the SDNM were either closely associated with water impoundments, or with *Valley Bottom Floodplain* or *Valley – Xeroriparian Scrub* communities. Regular flooding of mesquite bosques has been documented in the literature (Stromberg 2002, Brown 1994).

Wildfire was an important disturbance event in mesquite bosques (Stromberg 2002, Brown 1994). The mesquite bosques on the SDNM have sufficient vegetation cover and litter to support fire.

Landscape Context
The *Mesquite Bosque* community is a small patch or linear patch community that is strongly associated with riparian areas and floodplains. We have tentatively mapped about 1000 hectares of these patches within the SDNM. These patches occur largely within the *Creosote–Bursage Desert Scrub* matrix community.

Best Examples on the SDNM
The most extensive mesquite stands in the SDNM are located in the Vekol Valley. Most of these stands are very dense, fairly young and associated with water impoundments in the upper valley. But there are some more natural, and somewhat older stands associated with the *Valley Bottom Floodplain* community that we have mapped in the lower Vekol Valley.

An older mesquite bosque is located south of the Freeman Exit off Interstate 8 (Figure 22). Although the understory is composed largely of exotic plants, this stand retains some of the canopy structure of a mature mesquite bosque.

Figure 22. Plot 95. Partially developed mesquite bosque near Interstate 8 in area developed as water tank and pasture. *Prosopis velutina* forms an open overstory canopy and *Cynodon dactylon* covers much of the soil surface at this site.

Mapping Methods and Biophysical Modeling Parameters

Mesquite bosques are somewhat difficult to map from DOQQs or to predict based on biophysical parameters. They are confined to valley bottom locations, near riparian areas or within floodplains. We tentatively mapped many of the most extensive forested areas within the floodplains and in some riparian areas as examples of the *Mesquite Bosque* natural community. It appears that many of these areas may be dominated by mesquite, but are still fairly young. Other areas may possibly have little mesquite in their composition.

The only sure way of accurately identifying and mapping this natural community is to visit each potential site and examine the forest condition and composition at that site. Perhaps more extensive fieldwork will lead to a better understanding of the biophysical parameters that could be used to model the extent of this community.

Relationship to Plant Community Classification Systems

This community relates to the Mesquite series (124.71) of Brown and others (1979) and the *Prospois Velutina* Shrubland alliance, Deciduous Shrubland formation of the National Vegetation Classification System (TNC 1998).

Rock Outcrops

Ecological Characteristics

Description and Composition

Rock cliffs, extensive talus slopes or other rock outcrop areas that are of sufficient size to map characterize the *Rock Outcrop* community. Any other rocky areas that have significant vegetative cover are included in the *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities – only those that are largely devoid of significant vegetation are mapped as rock outcrops. The *Rock*

Outcrop community is a small patch community that normally occurs within the *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. A few rock outcrops border the *Creosote–Bursage Desert Scrub* community. There are many small rock outcrops scattered throughout the *Mountain Upland* and *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities that are too small to map. Both of these communities have considerable surface rock and provide habitat for many of the species that rely on habitat provided by the *Rock Outcrop* community.

The vegetation composition of the *Rock Outcrop* community can be similar to the surrounding *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities – but with significantly less vegetative cover. The rock outcrops are often fairly inaccessible and difficult to sample due to their steepness. The one reconnaissance plot that we were able to establish during our initial fieldwork was in an area with only about 5% total vegetation cover. *Encelia farinosa farinosa* and *Stephanomeria pauciflora pauciflora* were dominant and *Nicotinana obtusifolia* was present at this location.

Structure
The structure of this community is defined by the rock substrate. Some areas are steep cliff faces, some areas are small rocky buttes, some areas are large jumbles of rocks and some areas are extensive talus slopes with a combination of medium and large boulders and talus blocks. The vegetation in all situations is very sparse, with occasional small trees, shrubs and some perennial herbs and grasses. Annual vegetation is largely absent in most circumstances.

Function and Disturbance Processes
The rock outcrop community is exposed to wind erosion and subject to cracking, spalling, rock fall and rock slides. Quarrying, mining, target practice and/or graffiti have impacted some areas that are close to human access points.

Landscape Context
The *Rock Outcrop* community occupies about 633 hectares in the SDNM and adjacent Sand Tank Mountains. This small patch community occurs on steep slopes and rocky summits within the *Mountain Upland* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. Many smaller rock outcrops (not possible to map at the resolution chosen for this project) occur throughout the mountain matrix communities.

Best Examples on the SDNM
The best examples of the *Rock Outcrop* community occur in the Sand Tank Mountains (Figures 23 and 24). But numerous examples occur in the Table Top Mountain area and in the Maricopa Mountains in the central and northern part of the Monument.

Figure 23. Rock outcrops above saguaros rise above Bender Spring Canyon, Sand Tank Mountains.

Figure 24. Plot 67. Top of small rock outcrop, Sand Tank Mountains west of Johnson Well. This rock outcrop was below our minimum map unit and is an inclusion in the *Mountain Upland* community.

Mapping Methods and Biophysical Modeling Parameters

We extensively revised the mapping of rock outcrops provided to us by TNC at the beginning of this project. The initial GIS layer of rock outcrops was based on National Land Cover Data (NLCD) mapping (Vogelmann et al 2001). Close examination of this data layer revealed that it was highly inaccurate. It was based on a classification of Landsat TM satellite imagery. Since most of the land surface of the SDNM is sparsely vegetated, it is not possible to determine rock outcrops using Landsat satellite imagery. Many areas that have no rock were mapped as rock outcrops in the NLCD data but are really bajadas, desert washes or flats. The NLCD data greatly over-predicts the *Rock Outcrop* community in the basalt hills and mountains. The basalt bedrock dominates the spectral response from the land surface in these areas, masking the fact that considerable vegetation exists. After examining the NLCD rock outcrop GIS layer carefully, we rejected this layer and mapped the significant rock outcrops using the much higher resolution DOQQs. We also developed a very steep slope GIS layer (slopes greater than 25 degrees), and a 5-meter interval contour layer to help guide our interpretation of the DOQQs. Using this approach, we were able to map the *Rock Outcrop* community in a much more reliable fashion than was presented in the NLCD data.

Nearly all the rock outcrops exist on or near slopes that exceed 25 degrees. Some of the most significant rock outcrops are vertical, and therefore have no real aerial extent and are difficult to map as a significant rock outcrop polygon. In these cases we often digitized a slightly larger polygon around a vertical cliff rock outcrop to signify its presence. The nature of the rock outcrop community does not lend itself to modeling using biophysical parameters and/or mapping with Landsat satellite imagery.

Relationship to Plant Community Classification Systems

As this community is based on physical features, it's vegetation is not well-captured by most vegetation classifications. Broadly, it corresponds with the Paloverde – mixed cacti series (154.12) of Brown and others (1979), with much sparser vegetation. There are no relevant alliances within the National Vegetation Classification System (TNC 1998).

Valley Xeroriparian Scrub

Ecological Characteristics

Description and Composition

The *Valley Xeroriparian Scrub* community is found along nearly all, low gradient, intermittent streams that flow across the bajadas and desert flats. As we have defined this community, *Valley Xeroriparian Scrub* occurs along the intermittent drainages that cross unconsolidated, alluvial deposits composed of gravels and sands. These drainages are not confined by bedrock outcrops and can change course due to bank cutting, channel migration, channel blockage and reformation during debris flows. It is contrasted with the *Mountain Xeroriparian Scrub* community (discussed later in this paper), which occurs adjacent to steeper gradient streams flowing across rocky slopes and upland communities. The streams of the *Mountain Xeroriparian Scrub* community flow across bedrock and rocky substrates and are largely confined by bedrock where channel migration only occurs on a geologic time scale.

This community occurs as a narrow, linear patch community within the *Creosote–Bursage Desert Scrub* and *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* communities. The vegetation composition is highly variable and depends on the matrix community, the relative size of the drainage system and the very dynamic hydrologic and geomorphic processes that control this community. The community is normally characterized by the overstory dominance of xeromorphic, deciduous trees including *Olneya* *tesota, Parkinsonia florida, and Prosopis velutina* (Hall et al 2001). *Parkinsonia microphylla* is also common in the overstory, but not as abundant and common as *Parkinsonia florida*. *Phoradendron californicum* is a common epiphytic parasite associated with the leguminous trees in the overstory.

In our field plots, *Parkinsonia florida* was the dominant plant (8.6% mean cover) but *Larrea divaricata tridentata* had the highest constancy, occurring in 85% of the plots. *Larrea* was also quite abundant (7.9% mean cover) but it is not an indicator plant of this community. Rather, it is a common component of the surrounding matrix communities. *Ambrosia deltoidea,* another common member of the matrix community, also occurs in most of the plots (69% constancy) but in lower abundance. Other plants with either high constancy or cover include: *Acacia greggii, Acacia constricta, and Ambrosia ambrosioides.*

The plants listed above contribute to a dense understory of shrubs, cacti and herbs. Also included in this understory, according to data from our initial field plots, are: *Lycium* spp*., Celtis pallida pallida, Krameria grayi,* several grass species*, Opuntia acanthocarpa, Carnegiea gigantea, Justicia californica, Hyptis emoryi, Hymenoclea salsola, Opuntia arbuscula, Opuntia fulgida, Erodium cicutarium, Bebbia juncea aspera, Sphaeralcea ambigua,* and *Encelia frutescens frutescens*. This is one of the most diverse natural communities in this region of the Sonoran Desert.

Larger floodplain systems that have multiple braided channels and overland flow between channels are described later in this paper as the *Valley Floodplain* community. Some of the species occurring in that community also occur in the larger washes that lie within the *Valley Xeroriparian Scrub* community.

Structure
The average vegetative cover in the *Valley Xeroriparian Scrub* community measured in our field reconnaissance plots was 52.6%, which is equal to the cover in the other riparian communities and much higher than all the upland communities except for the *Mountain Uplands*. This community typically has three strata: an open overstory of small trees, a dense to sometimes sparse medium to small shrub layer, and a mix of smaller shrubs, grasses and herbs in the understory. Spring annuals often cover some of the bare sand, gravel and soil that is exposed in the wash bottom, but at other times of year the wash itself is devoid of vegetation.

Function and Disturbance Processes
Episodic stream flow along the channels within the *Valley Xeroriparian Scrub* community is the dominant ecological and geomorphic process that controls the composition and structure of this community. Debris flows also occur along the channels during infrequent, high amplitude storms. During the high amplitude flood and debris flow events, some channels can abruptly change course or become more deeply scoured. The frequency, volume and duration of flow events along the channels in this community are a function of catchment area and regional rainfall regime (Warren and Anderson 1985, Hall et al 2001). Geologic substrate, distance from mountain range and stream gradient are also important factors that influence frequency, volume and duration of flow events.

Landscape Context
This community forms long, narrow, sinuous patches within the low gradient bajadas and gentle valley bottoms within the *Creosote-Bursage Desert Scrub* and *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* matrix communities. The stream gradients in this community are nearly always less than 9% (5 degrees) and the community is normally found below 600 meters in elevation. Some valleys and gentle bajadas in which this community is embedded extend over 800 meters in elevation within the Sand Tank Mountains.

Best Examples on the SDNM

There are excellent examples of this community throughout the SDNM and Sand Tank Mountains. Figures 25, 26 and 27 illustrate some of the variation within this community that is present in the area.

Figure 25. Plot 63. ***Valley Xeroriparian Scrub*** **community north of Maricopa Mountains near the northern boundary of the SDNM.**

Figure 26. Plot 35. ***Valley Xeroriparian Scrub*** **community in lower Vekol Valley.**

Figure 27. Plot 118. Desert wash with sparse ***Valley Xeroriparian Scrub*** **community northeast of Gila Bend near the western border of the SDNM. This is one of the driest areas of the Monument and the xeroriparian scrub community is poorly developed despite the fact that the wash has cut down at least 6 meters below the level of the surrounding bajada. This site is over 13-km west of the western edge of the Maricopa Mountains.**

Mapping Methods and Biophysical Modeling Parameters

In the initial mapping provided by TNC, the xeroriparian communities were mapped as linear features along all of the streams delineated on the 1:100,000-scale hydrography data. Unfortunately, the 1:100,000 hydrography data is not an adequate depiction of the hydrography of the SDNM and surrounding area. Most drainages that exist in this area are not shown in this hydrography data. Sometimes even the major channels are not shown, or minor channels were depicted instead. The initial mapping underestimates the extent of the xeroriparian communities on the SDNM by a factor of at least three. Higher resolution hydrography data (at least 1:24,000-scale) is necessary to adequately map these communities based on the approach taken in the initial mapping. However, hydrologic data at this scale has not yet been produced by the USGS for this part of Arizona.

The *Valley Xeroriparian Scrub* community could be accurately mapped by photointerpretation of the DOQQs, but this would require many hours of work and is beyond what is possible within the timeframe and budget for this project.

Relationship to Plant Community Classification Systems

This community has a wide range of vegetation that is not well captured by most vegetation classification systems. Components of the community are included in both the Creoste-Bursage series (154.11) and Paloverde-mixed cacti series (154.1215R) of Brown and others (1979). This community encompasses several alliances in the National Vegetation Classification System (TNC 1998), including the *Parkinsonia florida*, *Prosopis velutina*, and *Olneya testota* alliances. It also shares some characteristics of the *Cercidium floridum-Prosopis glandulsa-Ambrosia ambrosioides* association (154.1215R) of Warren and others (1981).

Mountain Xeroriparian Scrub

Ecological Characteristics

Description and Composition

The *Mountain Xeroriparian Scrub* community is similar to the *Valley Xeroriparian Scrub* community, but it occurs adjacent to the higher gradient streams flowing through the *Mountain Upland* and *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. The intermittent streams that form the basis for the *Mountain Xeroriparian Scrub* community flow across bedrock and rocky substrates and are largely confined by bedrock where channel migration only occurs on a geologic time scale. This community usually occurs where stream gradients equal or exceed 9% (5 degrees slope). Usually, it occurs at elevations above 600 meters.

Like the *Valley Xeroriparian Scrub* community, the *Mountain Xeroriparian Scrub* community has a highly variable composition that is dependent on drainage size and composition of the surrounding matrix community. Aspect and elevation have a pronounced influence on the composition of this community.

The community is normally characterized by the overstory dominance of leguminous, deciduous trees. *Parkinsonia microphylla* is the only species that occurred in all our field plots (100% constancy) and it also has the highest average cover (8.8%). *Olneya tesota* and *Parkinsonia florida* both occur in 75% of the field plots but are less abundant. The lesser importance of *Parkinsonia florida* in this community is one factor that distinguishes it from the *Valley Xeroriparian Scrub* community. *Phoradendron californicum* is a common epiphytic parasite associated with the overstory of leguminous trees.

There is usually a moderately dense to dense understory of shrubs, cacti, herbs and grasses in this community. The most common species encountered in our field plots were (in order of constancy): *Ambrosia deltoidea, Acacia greggii, Lycium* spp., *Prosopis velutina, Ephedra* spp.*, Celtis pallida pallida, Simmondsia chinensis, Larrea divaricata tridentata, Mimosa* sp.*, Justicia californica, Trixis californica californica, Sphaeralcea ambigua, Ambrosia ambrosioides, Opuntia engelmannii engelmannii, Jatropha cardiophylla, Acacia constricta, Atriplex canescens, Brickellia coulteri, Calliandra eriophylla, Encelia farinosa farinosa, Encelia frutescens frutescens,* grass species*, Eriogonum fasciculatum, Fouquieria splendens splendens,* and *Carnegiea gigantea.*

Structure

The average vegetative cover in the *Mountain Xeroriparian Scrub* community measured in our field reconnaissance plots was 52.5% - nearly identical to the average cover in the *Valley Xeroriparian Scrub* community. This community typically has three strata: an open overstory of small trees, a dense to sometimes sparse medium to small shrub layer and a mix of smaller shrubs, grasses and herbs in the understory. The rocky substrate of the intermittent stream bottoms is often very rough. In some places, steep-walled rocky banks are present. In the rockiest areas, the channel and its immediate banks support little vegetation and fewer annuals are present than in the gentle gradient streams that characterize the *Valley Xeroriparian Scrub* community.

Function and Disturbance Processes

Episodic stream flow along the channels within the *Mountain Xeroriparian Scrub* community is the dominant ecological and geomorphic process that controls the composition and structure of this community. Debris flows may also occur along some of these channels during infrequent storm events. Unlike the *Valley Xeroriparian Scrub* community, the channels in this community are more stable and do not change location due to the fact that they are usually carved into bedrock.

Landscape Context

The *Mountain Xeroriparian Scrub* community is a narrow, linear patch community, but the channels and associated scrub communities are often much straighter than the sinuous channels in the *Valley Xeroriparian Scrub* community. These fairly straight channels drain the mountain slopes of the Maricopa Mountains, the Table Top Mountains and the Sand Tank Mountains. The *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community or the *Mountain Upland* community surround this riparian scrub community. The stream gradients are usually equal to or greater than 9% (5 degrees) and the community is normally found above 600 meters in elevation. Some stream channels and associated *Mountain Xeroriparian Scrub* community can extend to over 1100 meters in elevation.

Best Examples on the SDNM

There are excellent examples of the *Mountain Xeroriparian Scrub* community throughout the SDNM and Sand Tank Mountains. Figures 28 and 29 illustrate some of the variation within this community that is present in the area.

Figure 28. Plot 91. ***Mountain Xeroriparian Scrub*** **community on small intermittent stream draining the north slopes of Javelina Mountain.**

Figure 29. Plot 83. *Mountain Xeroriparian Scrub* in Bender Spring Canyon, Sand Tank Mountains.

Mapping Methods and Biophysical Modeling Parameters

As discussed with the *Valley Xeroriparian Scrub* community, there is a need for higher resolution hydrography data to adequately map all of the xeroriparian communities. This is somewhat less of a problem for the *Mountain Xeroriparian Scrub* community as more of the mountain stream channels are captured in the 1:100,000 scale hydrography data, but it still is an issue. Higher resolution hydrologic data is not yet available for this part of Arizona.

The *Mountain Xeroriparian Scrub* community could be mapped through photointerpretation of the DOQQs, but this would require many hours of work and is beyond what is possible within the timeframe and budget for this project.

Relationship to Plant Community Classification Systems

This community has a wide range of vegetation that is not well captured by most vegetation classification systems. Components of the community are included in both the Creosote-Bursage series (154.11) and Paloverde-mixed cacti series (154.1215R) of Brown and others (1979). This community encompasses several alliances in the National Vegetation Classification System (TNC 1998), including the *Parkinsonia microphylla*, *Prosopis velutina*, and *Olneya tesota* alliances. It also shares some characteristics of the *Ambrosia ambrosioides-Olneya tesota-Acacia* spp. association (154.1214R) of Warren and others (1981).

Valley Bottom Floodplains

Ecological Characteristics

Description and Composition

The *Valley Bottom Floodplain* community has many similarities to the *Valley Xeroriparian Scrub* community but differs in regard to width, dominant geomorphic/hydrologic processes and vegetation composition. This community occupies relatively broad floodplain areas within the mountain valleys and along major washes on the bajadas. Multiple, cross-braiding channels characterize the *Valley Bottom Floodplain* community. Significant island areas and adjacent floodplain zones often exist that are inundated by floodwaters during high flow events. These areas are much wider than the typical xeroriparian communities and often bear some resemblance to river floodplains along major perennial rivers throughout the world.

Vegetation composition of the *Valley Bottom Floodplain* community is similar to the *Valley Xeroriparian Scrub* community. Nearly all species that are found in the *Valley Xeroriparian Scrub* community are also found in the floodplain community. But the floodplain community differs considerably from the xeroriparian community in the abundance of some species. *Hymenoclea salsola* is the most abundant plant species in the *Valley Bottom Floodplain* community with an average cover of 11.6% in our field plots. It also occurred in 80% of our plots within this community. In contrast to this, *Hymenoclea salsola* had a mean cover of 0.2% and a constancy of 8% in our plots within the *Valley Xeroriparian Scrub* community. Other species that were largely or solely found within the *Valley Bottom Floodplain* community include: *Bebbia juncea aspera, Hyptis emoryi, Sebastiania bilocularis, Chilopsis linearis arcuata* and *Baccharis sarothroides.*

Parkinsonia florida is the dominant tree in the Valley Bottom Floodplain community (as it is within the Valley Xeroriparian Scrub community). *Parkinsonia microphylla*, *Olneya tesota* and *Prosopis velutina* also contribute to the overstory tree canopy. *Phoradendron californicum* is a common epiphytic parasite associated with the leguminous trees in the overstory. Overall tree cover is less in this community (17%) than it is in the *Valley Xeroriparian Scrub* community (24.6%). This may be due to the more active flooding and scouring within the floodplain which tends to favor shrubs like *Hymenoclea salsola*, *Bebbia juncea aspera*, *Hyptis emoryi*, *Sebastiania bilocularis*, *Chilopsis linearis arcuata* and *Baccharis sarothroides* over tree species that require more stable substrates to become established and survive. All of the above-mentioned shrub species have adaptations such as small flexible, multiple stems and deep roots, which contribute to survival in the floodplain environment.

It is worth noting that many of the examples of the *Mesquite Bosque* community that we have mapped on the SDNM occur as inclusions within the *Valley Bottom Floodplain* community and are controlled by the same geomorphic/hydrologic processes that function in this community.

Other species found in our field plots in this community include: *Acacia greggii*, *Ambrosia ambrosioides*, *Justicia californica*, *Lycium* spp., *Larrea divaricata tridentata*, *Eriogonum fasciculatum*, *Carnegiea gigantea*, *Ambrosia deltoidea* and *Acacia constricta*.

Structure

The structure of this community is unique among the xeroriparian communities in the SDNM. The community is composed of four major elements:

1. Major and minor wash channels that braid through the community
2. Islands that are regularly inundated with floodwaters and have regular deposition and/or erosion

3. Adjacent off channel floodplain areas that are occasionally inundated with floodwaters and subject to deposition and/or erosion
4. Xeroriparian scrub vegetation that lines the banks of many of the wash channels and is above the zone that is subject to regular inundation

Overall vegetation cover is similar to the other xeroriparian communities (51.6%) but tree cover is lower than in those communities. Significant areas of the most frequently inundated areas of the floodplain are covered with small to medium sized shrubs.

Function and Disturbance Processes

The *Valley Bottom Floodplain* community is influenced by episodic stream flow along the main channels and less frequent flood events that inundate islands and off channel areas. The episodic flow volumes in the floodplain areas are generally higher than experienced in channels within the *Valley Xeroriparian Scrub* community. The intermittent stream flows and floods are the dominant ecological and geomorphic processes that control the composition and structure of this community. During high amplitude flood events, many of the wash channels that braid through the floodplain may change course or become more deeply scoured. Due to these factors, this community is probably the most dynamic community in the SDNM.

Landscape Context

The *Valley Bottom Floodplain* community occurs along major wash systems that flow out of mountain ranges within the SDNM. Floodplain areas may be adjacent to *Creosote-Bursage Desert Scrub*, *Paloverde Mixed Cacti - Mixed Scrub on Bajadas,* or *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities. Some of the floodplains occur at the base of mountain slopes on relatively flat canyon bottoms (Figure 30 and 31) while others have formed at the bottom of broad valleys (Figure 32). The *Valley Bottom Floodplain* community is connected to *Valley Xeroriparian Scrub* and *Mountain Xeroriparian Scrub* communities through the intermittent stream network that feeds the channels that flow through the floodplain.

Best Examples on the SDNM

Some of the best examples of the *Valley Bottom Floodplain* community in the SDNM exist in the Sand Tank Mountains along Sand Tank Wash (Figures 30 – 33) and in the Vekol Valley along Vekol Wash (Figure 34). Other good examples occur in the Maricopa Mountains in the northern part of the SDNM and northeast of Table Top Mountain.

Figure 30. Upper portion of Sand Tank Wash valley bottom floodplain community. Note multiple braided channels. During large floods, water flows across most of the valley bottom, including area between major washes.

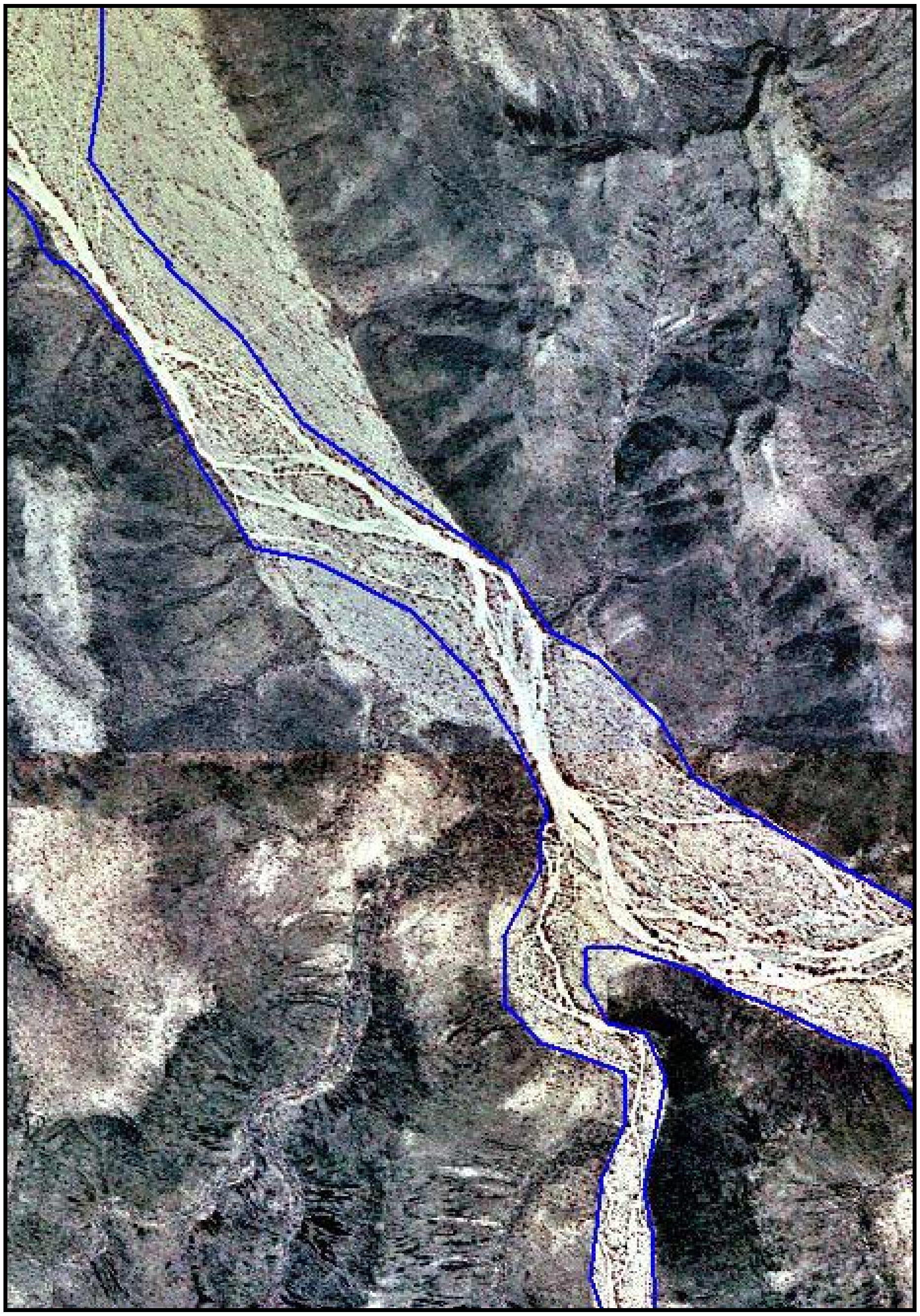

Figure 31. Valley Bottom Floodplain community (outlined in blue) in Sand Tank Wash, background image is a 1996 color infrared digital orthophoto.

Figure 32 (above) and Figure 33 (below): Lower portion of Sand Tank Wash valley bottom floodplain community. Note evidence of recent flooding and flood debris extending throughout area between most active wash channels.

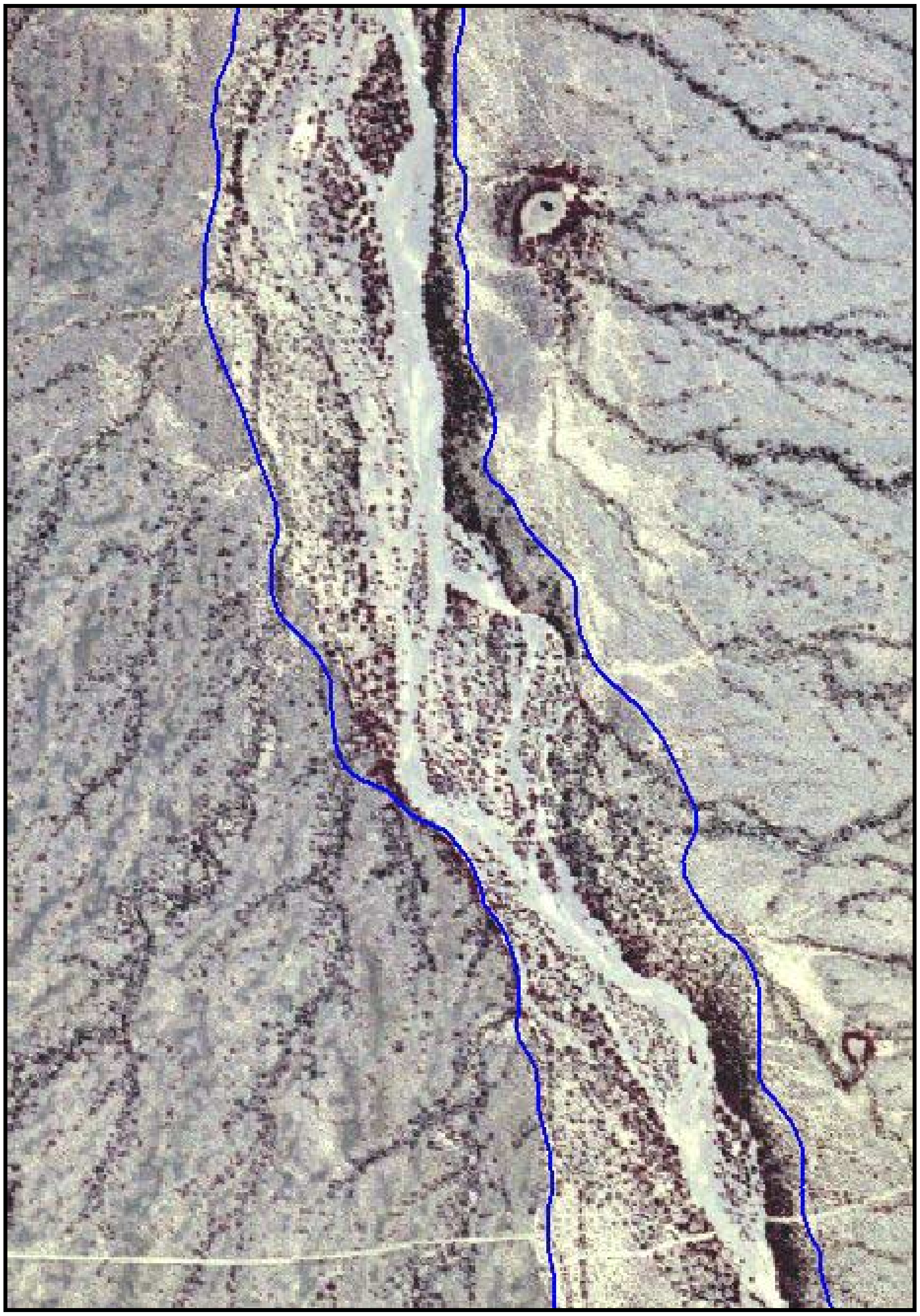

Figure 34. Valley bottom floodplain community in Vekol Valley, background image is a 1996 color infrared digital orthophoto.

Mapping Methods and Biophysical Modeling Parameters

These floodplain communities are distinguished from other xeroriparian communities by their overall width, presence of multiple, braided channels and presence of off channel areas inundated by floods. The xeroriparian communities were mapped as linear features while these floodplain communities were mapped as polygon features. We restricted the floodplain communities that we mapped on the SDNM to areas that generally maintain a width of over 100 meters. They are also only associated with relatively low gradient channels.

The *Valley Bottom Floodplain* community that we mapped should not be confused with the *Valley Bottom Floodplain Complex* community that was mapped in the BMGR (Hall et al 2001). The latter community has a less active channel system, is considerably wider and is largely dominated by infrequent overland flow.

Relationship to Plant Community Classification Systems

This community has a wide range of vegetation that is not well captured by most vegetation classification systems. Components of the community are included in both the Creoste-Bursage series (154.11) and Paloverde-mixed cacti series (154.1215R) of Brown and others (1979). Within the National Vegetation Classification System (TNC 1998), vegetation falls into the Deciduous Shrubland and Evergreen Shrubland formations. The Deciduous Shrubland formation includes a *Hymenoclea monogyra* Shrubland alliance, but not a *Hymenoclea salsola* alliance, which would better describe much of the vegetation in this community.

Comparison Of Natural Communities And Ecological Sites

Introduction

We performed an analysis to describe the relationship of natural community classes to USDA NRCS ecological sites on the Sonoran Desert National Monument (SDNM). Ecological sites, which are used by the BLM in assessing and managing rangelands, are based primarily on soil differences. Natural communities are based on a combination of vegetation and physical factors, and are used by The Nature Conservancy to assess and manage ecosystems. Natural communities are a slightly coarser classification scheme than ecological sites, with seven natural communities mapped for the Sonoran Desert National Monument versus 15 ecological site classes. While the classification systems are based on slightly different criteria, they are complementary. Depending on the specific resource question at hand, one or the other system may prove more useful.

Methods

We used the NRCS Soil survey geographic database (SSURGO) GIS layers to map ecological sites. The SDNM falls within three state soil survey areas. The southwest portion of the Monument, including much of the Sand Tanks and Javelina Mountain, is not mapped (Figure 35).

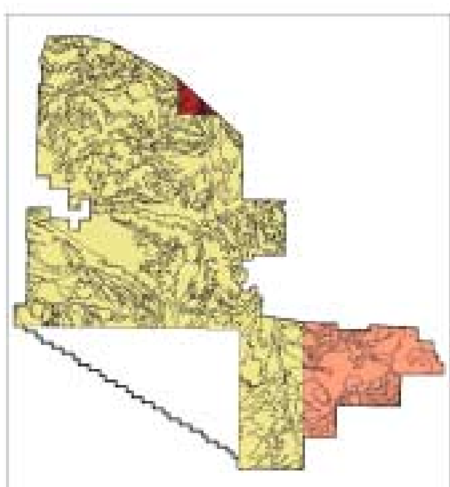

Figure 35. SDNM boundary with three soil survey areas and soil polygon outlines.

A complicating factor in our analysis is that the SSURGO data of the soil survey area covering most of the SDNM is based on a different data/coding structure than the other two areas. While the map line work generally appears continuous across the boundaries, the ecological site classifications often change abruptly (this can easily be seen in Figure 36).

We merged the SSURGO data from three soil areas into a single layer, and cross-walked data codings to arrive at a common list of 15 ecological site classes for the entire SDNM. Each mapped polygon represents a complex of these ecological site classes (e.g. Limy Fan (2-10" p.z.) 65% and Sandy Bottom (2-10" p.z.) 35%). Thus, there are a very large number of unique ecological site complexes. In order to limit the number of classes for analysis, we classified each complex type into one of 15 dominant classes and one of 29 subdominant classes. This reclassification is shown in Table 1. Once the data were reclassed, we intersected the ecological site map with the natural community map, floodplain and developed area overlays, and created summary tables.

Results & Conclusion

Our analysis shows that most of the ecological site classes are comprised of multiple natural community types and visa versa. However, the ecological site classes do tend to be dominated by one or two natural community types, and five of the high elevation/more unique ecological site classes consisted primarily of only one natural community type. These types were basalt hills, granitic hills, and schist hills (mostly *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* communities), loamy bottom and saline loam (pure *Creosote–Bursage Desert Scrub* community). Limy fan, the most abundant ecological site class, is dominated by the *Creosote–Bursage Desert Scrub* community (85%), with *Paloverde Mixed Cacti - Mixed Scrub on Bajadas* making up an additional 14%.

As natural communities are a coarser classification than ecological site classes, each community typically encompassed multiple ecological sites. However, the more unique types corresponded strongly with just one or two ecological site classes each. For example, the *Desert Grassland* community is dominated by limy upland, as well as deep, sandy loam upland. The *Mountain Upland* community is dominated by basalt hills, and the *Rock Outcrop* community corresponds strongly with granitic hills. In addition, the *Valley Bottom Floodplain* community shows a strong correspondence with sandy bottom (77% of the floodplains were in the sandy bottom class).

The relationships among all of the classes can be seen in the tables and maps below (Tables 4, 5 and 6 and Figures 36 and 37). The ecological site dominant and subdominant class codes correspond to those listed in Table 1. Floodplains and developed areas appear on the right side of the tables and do not contribute to totals. These classes were analyzed separately as they are overlays on the natural community map, rather than exclusive community types.

Given the differing purposes and criteria for classification of ecological sites and natural communities, it is not expected or desired that mapped units using the two systems should be the same. However, this analysis has shown a moderate to strong correspondence of the classifications as mapped on the SDNM, depending on community type.

1. Basalt Hills (2-10" p.z.)
    - 1.a. – Basalt Hills (2-10" p.z.) 55% (2)
2. Clay Loam Upland (7-10" p.z.)
    - 2.a. – Clay Loam Upland (7-10" p.z.) 90% (1)
3. Clayey Bottom (7-10" p.z.)
    - 3.a. – Clayey Bottom (7-10" p.z.) 90% (1)
4. Granitic Hills (2-10" p.z.)
    - 4.a. – Granitic Hills (2-10" p.z.) 50-60% (2)
5. Limy Fan (2-10 " p.z.)
    - 5.a. – Limy Fan (2-10" p.z.) 65%-100% (13)
    - 5.b. - Limy Fan (2-10" p.z.) 45-60% and Sandy Bottom (2-10" p.z.) 20-25% (2)
    - 5.c. - Limy Fan (2-10" p.z.) 40%, Limy Upland (2-10" p.z.) 25%, and Sandy Bottom (2-10" p.z.) 15%
    - 5.d. - Limy Fan (2-10" p.z.) 60% and Loamy Bottom (2-10" p.z.) 30% (1)
6. Limy Hills (2-10 " p.z.)
    - 6.a. - Limy Hills (2-10" p.z.) 35%, Shallow Upland (2-10" p.z.) 29%, and Limy Upland, Deep (2-10" p.z.) 15%
7. Limy Slopes (2-10 " p.z.)
    - 7.a. - Limy Slopes (2-10" p.z.) 50% and Limy Upland (2-10" p.z.) 25% (1)
8. Limy Upland (2-10 " p.z.)
    - 8.a. – Limy Upland (2-10" p.z.) 80-90% (4)
    - 8.b. – Limy Upland (2-10" p.z.) 60% and Limy Upland Deep (2-10" p.z.) 15% (1)
    - 8.c. – Limy Upland (2-10" p.z.) 50% and Limy Fan (2-10" p.z.) 30% (1)
9. Limy Upland, Deep (2-10 " p.z.)
    - 9.a. - Limy Upland Deep (2-10" p.z.) 80% (1)
    - 9.b. - Limy Upland Deep (2-10" p.z.) 80% and Sandy Bottom (2-10" p.z.) 15% (1)
    - 9.c. - Limy Upland Deep (2-10" p.z.) 50% and Limy Upland (2-10" p.z.) 25% (2)
    - 9.d. - Limy Upland Deep (2-10" p.z.) 45%, Sandy Bottom (2-10" p.z.) 20%, and Limy Fan (2-10" p.z.) 20% (1)
    - 9.e. - Limy Upland Deep (2-10" p.z.) 40% (1)
10. Sandy Bottom (2-10" p.z.)
    - 10.a. - Sandy Bottom (2-10" p.z.) 75%-100% (3)
    - 10.b. - Sandy Bottom (2-10" p.z.) 65% and Limy Upland Deep (2-10" p.z.) 25% (1)
11. Sandy Loam, Upland (2-10" p.z.)
    - 11.a. - Sandy Loam, Upland (2-10" p.z.) 90% (1)
    - 11.b. - Sandy Loam, Upland (2-10" p.z.) 50-60% and Sandy Bottom (2-10" p.z.) 20-25% (2)
    - 11.c. - Sandy Loam, Upland (2-10" p.z.) 50% and Loamy Bottom (2-10" p.z.) 30% (1)
12. Loamy Bottom (2-10" p.z.)
    - 12.a. - Loamy Bottom (2-10" p.z.) 85% (1)
13. Schist Hills (2-10" p.z.)
    - 13.a. – Schist Hills (2-10" p.z.) 35% and Limy Hills (2-10" p.z.) 20% (1)
14. Saline Loam (7-10" p.z.)
    - 14.a. – Saline Loam (7-10" p.z.) 40% and Limy Fan (2-10" p.z.) 35% (1)
    - 14.b. – Saline Loam (7-10" p.z.) 40% and Limy Upland, Deep (2-10" p.z.) 35% (1)
15. Shallow Upland (2-10" p.z.)
    - 15.a. - Shallow Upland (2-10" p.z.) 55% (1)
    - 15.b. - Shallow Upland (2-10" p.z.) 40%, Sandy Loam, Upland (2-10" p.z.) 20%, and Sandy Bottom (2-10" p.z.) 15% (1)

Table 4. Reclassification of SDNM ecological site complexes into 15 dominant and 29 subdominant classes. Numbers in parentheses following each subdominant class are the number of complexes grouped to create that class. Many classes do not total 100% - this was a problem inherent in the original SSURGO data tables.

Dominant Class	Creosote-Bursage (ha.)	% of Class in Creosote-Bursage	Grassland (ha.)	% of Class in Grassland	Mesquite Bosque (ha.)	% of Class in Mesquite Bosque	Mountain Upland (ha.)	% of Class in Mountain Upland	Paloverde-Mixed Cacti on Bajadas (ha.)	% of Class in PV-MC on Bajadas	Paloverde-Mixed Cacti on Rocky Slopes (ha.)	% of Class in PV-MC on Rocky Slopes	Rock Outcrops (ha.)	% of Class in Rock Outcrops	TOTAL (ha.)	Floodplain (ha.)	% of Class comprising all floodplains	Developed Areas (ha.)	% of Class comprising all Developed
1	27	0	0	0	1	0	177	3	163	3	5791	93	66	1	6225	0	0	10	2
2	0	0	0	0	0	0	0	0	24	83	5	17	0	0	29	0	0	0	0
3	80	29	77	28	120	43	0	0	0	0	0	0	0	0	277	0	0	172	27
4	48	0	0	0	2	0	57	0	548	2	30915	97	425	1	31995	16	0	0	0
5	43052	85	0	0	274	1	0	0	7177	14	142	0	2	0	50647	801	19	146	23
6	0	0	0	0	0	0	0	0	80	49	83	51	0	0	163	0	0	0	0
7	82	6	0	0	0	0	0	0	995	78	193	15	0	0	1270	0	0	1	0
8	6622	33	0	0	18	0	19	0	12193	61	1264	6	4	0	20120	57	1	82	13
9	21955	66	163	0	86	0	0	0	10195	31	720	2	1	0	33120	73	2	108	17
10	3823	65	0	0	267	5	0	0	1781	30	31	1	0	0	5903	3322	77	19	3
11	7415	62	212	2	245	2	0	0	3957	33	177	1	0	0	12005	25	1	105	16
12	1	100	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	2977	100	5	0	2982	0	1	0	0
14	48	100	0	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0
15	700	17	0	0	0	0	0	0	2609	62	891	21	0	0	4200	10	0	1	0
TOTAL	83852		452		1013		253		39720		43190		505		168984	4304	101	644	100

Table 5. Distribution of dominant ecological site class by natural community type.

Sub Class	Creosote-Bursage (ha.)	% of Subclass in Creosote-Bursage	Grassland (ha.)	% of Subclass in Grassland	Mesquite Bosque (ha.)	% of Subclass in Mesquite Bosque	Mountain Upland (ha.)	% of Subclass in Mountain Upland	Paloverde-Mixed Cacti on Bajadas (ha.)	% of Subclass in PV-MC on Bajadas	Paloverde-Mixed Cacti on Rocky Slopes (ha.)	% of Subclass in PV-MC on Rocky Slopes	Rock Outcrops (ha.)	% of Subclass in Rock Outcrops	TOTAL (ha.)	Floodplain (ha.)	% of Subclass comprising all floodplains	Developed Areas (ha.)	% of Subclass comprising all Developed
1a	27	0	0	0	1	0	177	3	163	3	5791	93	66	1	6225	0	0	10	2
2a	0	0	0	0	0	0	0	0	24	83	5	17	0	0	29	0	0	0	0
3a	80	29	77	28	120	43	0	0	0	0	0	0	0	0	277	0	0	172	27
4a	48	0	0	0	2	0	57	0	548	2	30915	97	425	1	31995	16	4	0	0
5a	5169	97	0	0	9	0	0	0	172	3	1	0	0	0	5351	2	0	39	6
5b	1040	39	0	0	21	1	0	0	1555	58	64	2	0	0	2679	342	8	15	2
5c	29399	84	0	0	36	0	0	0	5320	15	75	0	2	0	34833	399	9	56	9
5d	7445	96	0	0	207	3	0	0	130	2	2	0	0	0	7784	58	1	36	6
6a	0	0	0	0	0	0	0	0	80	49	83	51	0	0	163	0	0	0	0
7a	82	6	0	0	0	0	0	0	995	78	193	15	0	0	1270	0	0	1	0
8a	845	14	0	0	4	0	19	0	3925	67	1065	18	0	0	5859	17	0	3	0
8b	3752	40	0	0	9	0	0	0	5583	59	139	1	4	0	9486	21	0	3	0
8c	2026	42	0	0	5	0	0	0	2684	56	61	1	0	0	4775	19	0	75	12
9a	190	6	0	0	0	0	0	0	3071	94	15	0	0	0	3275	11	0	10	2
9b	6019	75	0	0	1	0	0	0	1922	24	37	0	0	0	7978	4	0	2	0
9c	3303	47	0	0	0	0	0	0	3035	43	640	9	1	0	6979	11	0	4	1
9d	3939	86	163	4	78	2	0	0	409	9	0	0	0	0	4588	16	0	48	7
9e	8505	83	0	0	7	0	0	0	1759	17	28	0	0	0	10300	30	1	44	7
10a	35	100	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	2	0
10b	3788	65	0	0	267	5	0	0	1781	30	31	1	0	0	5868	3323	77	18	3
11a	296	97	0	0	6	2	0	0	2	1	0	0	0	0	304	0	0	0	0
11b	4122	50	0	0	8	0	0	0	3955	48	177	2	0	0	8261	25	1	13	2
11c	2998	87	212	6	231	7	0	0	0	0	0	0	0	0	3440	0	0	92	14
12a	1	100	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
13a	0	0	0	0	0	0	0	0	0	0	2977	100	5	0	2982	0	0	0	0
14a	13	100	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0
14b	35	100	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0
15a	32	2	0	0	0	0	0	0	789	52	691	46	0	0	1512	8	0	1	0
15b	668	25	0	0	0	0	0	0	1820	68	200	7	0	0	2688	2	0	0	0
TOTAL	83852		452		1013		253		39720		43190		505		168984	4304	101	644	100

Table 6. Distribution of subdominant ecological site class by natural community type.

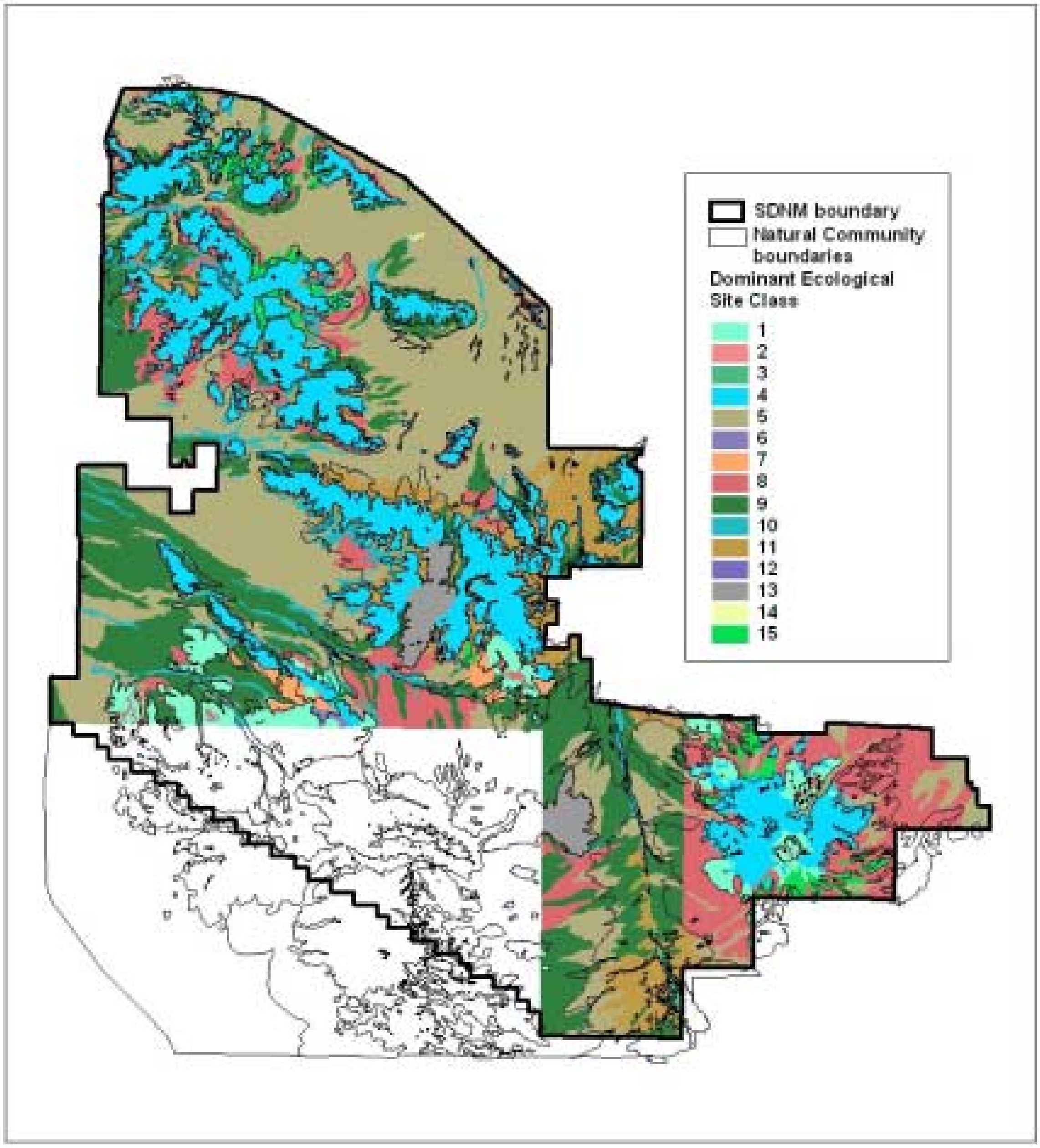

Figure 36. Dominant ecological site classes with natural community boundaries. Map shows generally high correspondence of the higher elevation ecological site classes - granitic hills (class 4), basalt hills (class 1), and schist hills (class 13) - with natural community boundaries overlaid (black lines). Coding differences between soil survey areas can be seen by the strong vertical boundary line in the southeast portion of the map.

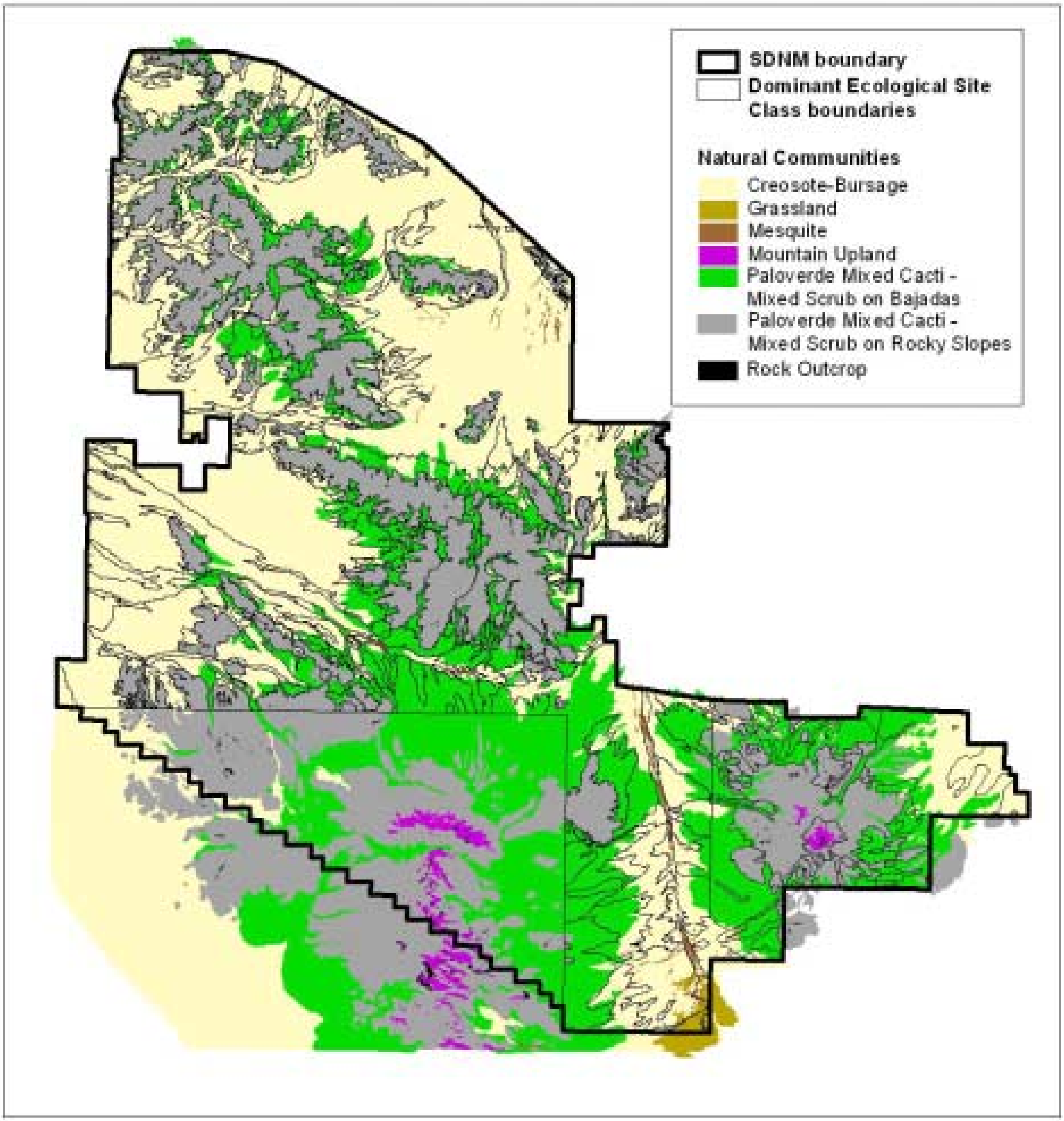

Figure 37. Natural communities with dominant ecological site class boundaries. Map shows generally high correspondence of mapped boundaries for the *Paloverde Mixed Cacti - Mixed Scrub on Rocky Slopes* community.

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Appendix I: Scientific and Common Names of Plants

Scientific Name	*Common Name*
Acacia constricta	whitethorn acacia
Acacia greggii	catclaw acacia
Acourtia nana	desert-holly
Agave deserti simplex	desert agave
Agave parryi	Parry's agave
Amarantha	Wild spinach
Ambrosia ambrosioides	canyon ragweed
Ambrosia deltoidea	triangle-leaved bursage
Ambrosia dumosa	white bursage
Amsyinkia	fiddleneck
Asclepias sublata	rush milkweed
Astrolepis cochisensis	scaly star fern
Astrolepis sinuata sinuata	wavy star fern
Atriplex canescens	four-wing saltbush
Atriplex linearis	thinleaf fourwing saltbush
Atriplex polycarpa	cattle saltbush
Baccharis salicifolia	seep willow
Baccharis sarothroides	desertbroom
Bebbia juncea aspera	sweetbush
Brickellia coulteri	Coulter's brickellbush
Calliandra eriophylla	fairyduster
Canotia holacantha	canotia crucifixion thorn
Carex	sedge
Carnegiea gigantea	saguaro
Celtis pallida pallida	spiny hackberry
Chilopsis linearis arcuata	desert willow
Chorizanthe brevicornu	brittle spine flower
Chorizanthe rigida	rigid spine-flower
Cynodon dactylon	Bermuda grass
Datura wrightii	sacred datura
Echinocereus	hedgehog cactus
Echinocereus engelmannii	Engelmann's hedgehog
Echinocereus fendleri	Boyce Thompson hedgehog
Encelia farinosa farinosa	brittlebush
Encelia frutescens frutescens	button brittlebush
Ephedra	ephedra
Ephedra aspera	boundary ephedra

Ephedra fasciculata	Arizona jointfir
Erigonium fasciculatum	flattop buckwheat
Eriogonum deflexum	skeleton weed
Eriogonum fasciculatum	flat-top buckwheat
Eriogonum maculatum	Eriogonum maculatum
Eriogonum wrightii wrightii	Eriogonum wrightii
Erioneuron pulchellum	fluff-grass
Erodium cicutarium	filaree
Erodium texanum	false filaree
Fagonia laevis	California fagonbush
Ferocactus	barrel cactus
Ferocactus cylindraceus	mountain barrel cactus
Ferocactus cylindraceus	Leconte's barrelcactus
Ferocactus emoryi	barrel cactus
Ferocactus wislizeni	fishhook barrelcactus
Fouquieria splendens	ocotillo
Gutierrezia sarothrae	broom snakeweed
Hymenoclea monogyra	singlewhorl burrobush
Hymenoclea salsola	cheesebush
Hyptis emoryi	desert lavender
Isocoma acradenia	alkali jimmyweed
Janusia gracile	janusia
Jatropha cardiophylla	limberbush
Justicia californica	chuparosa
Koeberlinia spinosa	allthorn
Krameria erecta	range ratany
Krameria grayi	white ratany
Larrea divaricata tridentata	creosotebush
Lycium	desertthorn
Lycium andersonii	desert wolfberry
Lycium berlandieri	Berlandier's wolfberry
Lycium exsertum	Arizona desertthorn
Lycium parishii	Parish's desertthorn
Mammillaria grahamii	pincushion cactus
Mimosa	Mimosa
Nicotiana glauca	tree tobacco
Nicotinana obtusifolia	coyote tobacco
Notholaena standleyi	star cloak-fern
Olneya tesota	desert ironwood
Opuntia	prickly pear cactus
Opuntia acanthocarpa	buckhorn cholla
Opuntia acanthocarpa major	buckhorn cholla
Opuntia acanthocarpa	buckhorn cholla

Opuntia arbuscula	Arizona pencil cholla
Opuntia bigelovii	teddybear cholla
Opuntia chlorotica	pancake prickly-pear
Opuntia engelmannii	Engelmann's prickly pear
Opuntia fulgida	chainfruit cholla
Opuntia fulgida fulgida	chainfruit cholla
Opuntia fulgida mamillata	chainfruit cholla
Opuntia leptocaulis	Christmas cholla
Opuntia macrocentra	shrub-sized prickly-pear
Opuntia phaeacantha	brown-spine prickly pear
Opuntia spinosior	cane cholla
Parkinsonia florida	blue paloverde
Parkinsonia microphylla	yellow or foothill paloverde
Perityle emoryii	Emory's rock daisy
Phoradendron californicum	mistletoe
Pleuraphis mutica	tobosa grass
Pleuraphis rigida	big galleta
Porophyllum gracile	odora
Prosopis velutina	velvet mesquite
Rhynchosia texana	rosary bean
Sebastiania bilocularis	Mexican jumping bean
Selaginella arizonica	arizona spike-moss
Simmondsia chinensis	jojoba
Sphaeralcea ambigua	desert globemallow
Stephanomeria pauciflora	desert straw
Sisymbrium irio	London rocket
Tamarix chinensis	fivestamen tamarisk
Trixis californica californica	California trixis
Yucca baccata	banana yucca
Yucca elata	soap tree yucca
Ziziphus obtusifolia canescens	graythorn