Vegetation Structure and Diversity

Peter Holm

Objectives

From the protocol manual (Lowe et al 1995): "The objective of the ORPI EMP project on vegetation structure and diversity is to provide baseline vegetation data, soil texture data, and slope, aspect, and elevation information for 1 or more vegetation plots (quadrats) at each of the specified sites."

Additional guidance for the objectives can be found in the Sensitive Ecosystems Program plan (Bennett and Kunzmann 1987). Criteria for site selection was to include as diverse vegetation types as possible which are representative of all communities, sensitive habitat and/or characteristic habitats, and communities with relict species. Long-term monitoring at those sites was to provide information on community dynamics including species composition, importance, and distribution.

Introduction

Plants are continuously exposed to environmental conditions and are the most readily observable, measurable, and mappable indicators of climate, soil, biotic interaction, and human disturbance (Lowe 1964). Vegetation can be impacted by herbivory, trampling, fire, cutting, uprooting, climate change, soil disturbance, and invasive species.

Vegetation is also a key component of many species' habitats, providing nourishment, shelter, and structural features needed for communication, surveillance, and other activities. Maps and other information about vegetation communities can be correlated with the composition and distribution of animal communities and used to generate habitat models that predict the occurrence of animal species. Documenting changes in vegetation communities will not only provide indicators of vegetation response to various stressors but also provide insight into ecological processes and long-term trends in other components of the ecosystem.

Methods

Project History

As part of the Sensitive Ecosystems Project, Vegetation Structure and Diversity, 26 permanent plots were established at long-term monitoring sites between 1988 and 1991 (Lowe, Wirt, and Rosen, ca 1994). Soil texture data, and slope, aspect, and elevation information were also provided in the project report. Permanent vegetation plots were selected to be representative of the surrounding EMP site. When the EMP site included different vegetation communities, a separate plot was established in each primary (important) vegetation type. The number of plots per EMP site varies from 1 to 3.

With the exception of the Neolloydia Site (aka Acuña Habitat), all plots were re-inventoried between 1994 and 1997 (Table 4-1.). Also, 3 EMP sites were added and 5 new vegetation plots, bringing the total number of plots to 30 (Figure 4-1). The protocol recommended that an inventory of the plots be performed approximately 5 years after the baseline reading, and after that on a 10-year cycle (Lowe, Wirt, and Rosen, 1995).

Survey and Data Reduction

At each plot, the 2 photopoints were relocated and re-photographed. Each plot measures 20 x 50 m (65 x 164 ft) and is subdivided into ten 10 x 10 m (33 x 33 ft) plots. Non-stretchable measuring tapes were placed around the perimeter, along the 50 m midline, and across the 20 m width at 10 m intervals. The tapes were pulled as tight and straight as possible to ensure the most accurate reading. Data were recorded as follows, from the original protocol (Lowe, Wirt, and Rosen, 1995):

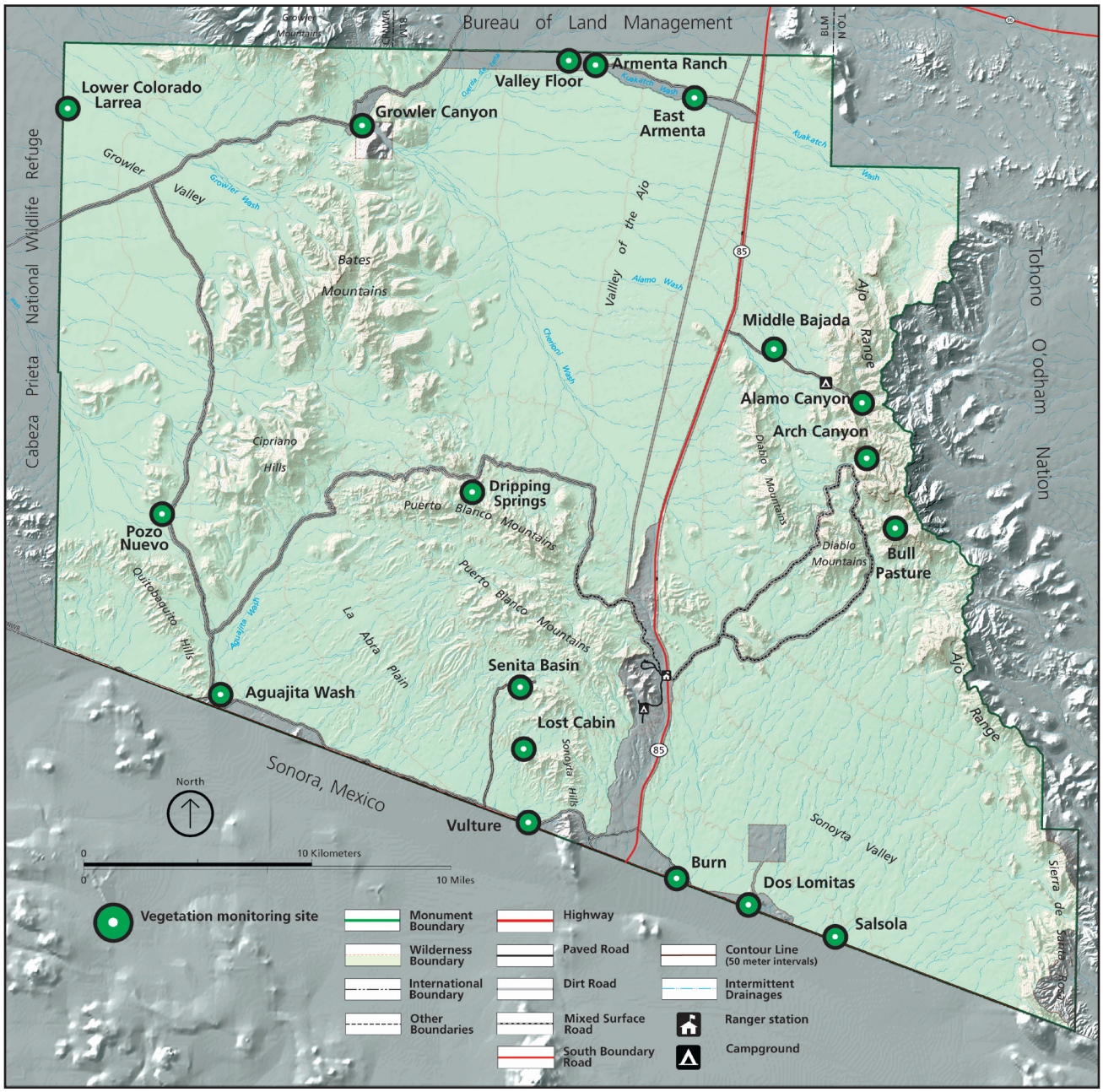

Figure 4-1. Vegetation structure and diversity plots, Organ Pipe Cactus N.M.

Table 4-1. Vegetation structure and diversity plots and years read for Sensitive Ecosystems Project (SEP) and Ecological Monitoring Program (EMP) at Organ Pipe Cactus N.M. (If the inventory of a given plot required multiple visits, spanning 2 calendar years, only the first year is indicated.)

Plot Name	Code	Hydrologic Regime	Soil Gradient Category	Elevation (feet)	SEP	EMP
Aguajita VG01	AGUA1	Xeroriparian	Valley floor	1,140	1989	1994
Aguajita VG02	AGUA2	Upland	Valley floor	1,140	1989	1994
Aguajita VG03	AGUA3	Upland	Valley floor	1,140	1989	1994
Alamo Canyon VG01	ALAM1	Xeroriparian	Rocky slope	2,400	1989	1995
Arch Canyon VG01	ARCH1	Xeroriparian	Rocky slope	3,000	1989	1995
Arch Canyon VG02	ARCH2	Upland	Rocky slope	2,900	1989	1995
Armenta Ranch VG01	ARMR1	Upland	Valley floor	1,565	1990	1996
Armenta Ranch VG02	ARMR2	Degraded xeroriparian	Valley floor	1,565	1990	1996
Bull Pasture VG01	BULL1	Upland	Rocky slope	3,150	1989	1997
Bull Pasture VG02	BULL2	Xeroriparian	Rocky slope	3,150	1989	1997
Burn Site VG01	BURN1	Upland	Valley floor	1,390	1989	1994
Dos Lomitas VG01	DOLO1	Degraded upland	Valley floor	1,400	1989	1994
Dos Lomitas VG02	DOLO2	Degraded upland	Valley floor	1,400	1989	1994
Dripping Springs VG01	DRIP1	Xeroriparian	Rocky slope	2,000	1990	1996
East Armenta VG01	EARM1	Upland	Valley floor	1,720	1989	1994
East Armenta VG02	EARM2	Upland	Valley floor	1,720	1988	1994
Growler Canyon VG01	GROW1	Xeroriparian	Valley floor	1,370	1990	1997
Growler Canyon VG02	GROW2	Wash bed	Valley floor	1,370	1990	1997
Lost Cabin VG01	LOST1	Upland	Rocky slope	1,600	1990	1995
Lower CO Larrea VG01	LOWE1	Upland	Valley floor	1,100		1993
Middle Bajada VG01	MIDB1	Xeroriparian	Bajada	2,110		1995
Middle Bajada VG02	MIDB2	Upland	Bajada	2,110		1995
Neolloydia Site VG01	NEOL1	Upland	Rocky slope	1,600	1989	
Pozo Nuevo VG01	POZO1	Upland	Valley floor	1,240	1989	1994
Salsola Site VG01	SALS1	Xeroriparian	Valley floor	1,480	1990	1997
Senita Basin VG01	SENI1	Upland	Rocky slope	1,665	1990	1995
Senita Basin VG02	SENI2	Xeroriparian	Rocky slope	1,745	1990	1997
Valley Floor VG01	VALL1	Upland	Valley floor	1,540		1995
Valley Floor VG02	VALL2	Xeroriparian	Valley floor	1,540		1995
Vulture Site VG01	VULT1	Upland	Bajada	1,325	1989	1994
Vulture Site VG02	VULT2	Xeroriparian	Bajada	1,325	1989	1994

1. **Presence (P)** was the measure of the number of species present; equivalent to species richness (S), number 4 below. Unknown plants were recorded and a voucher specimen was collected for later identification. In some cases the site had to be revisited to obtain suitable material for identification.

2. **Density (N)** was the number of individuals rooted in a unit area. In this study, the unit area was a 0.1 ha (0.25 a.) plot for perennial plants, and a 1.0 m^2 (10.8 ft^2) plot for ephemerals. Accuracy in making the count for density for a given perennial species in the 0.1 ha (0.25 a.) plot was aided by separate counts for all of the individuals present in each of the ten 10 x 10 m plots (see below), and then summing for the 10. If a single plant had roots/stems in two or more subplots, it was counted only once.

For ephemerals, density counts of abundant taxa (dozens to hundreds of individuals per 1.0 m^2 [10.8 ft^2]) should be summed over conveniently chosen subdivisions (halves, quarters, or other fractions) of the 1.0 m^2 (10.8 ft^2) plot that are used for convenience of counting.

3. **Frequency**, in percentage, for a given species was determined by the number of 10 x 10 m plots occupied by 1 or more individuals of the species rooted in the plot(s). If a species occurs in (is rooted in) 3 of 10 plots, it has a frequency of 30% for that 0.1 ha (0.25 a.) plot. Because the 10 x 10 m plots were contiguous, samples were not independent.

4. **Coverage** of perennial plants was measured by the line intercept method. In line intercept, the distances (lengths) of the plant crowns that intercepted a straight line of meter tape were recorded. The lines of meter tape used for intercept measurements included the plot perimeter of two 50 m (164 ft) tapes and two 20 m (66 ft) tapes, plus the 50 m (164 ft) centerline. The total line length used was 190 m (623 ft).

For a given species, the sum of its crown interception distances (= interception lengths), multiplied by 100, then divided by the total line length yields the percent cover for that species. The sum total meters of distance for all crown interceptions of all species, multiplied by 100, and divided by total line length yields the community coverage percent. Intervals of bare ground (i.e., line segments not intercepted by any plant) can be similarly summed, multiplied by 100, and divided by total line length

5. **Species richness** (S) is the number of species per unit area. The number of species present in a given area provides the species richness values for that area, which area is either a 0.1 ha (0.25 a.) plot (for perennial taxa) or the 1.0 m^2 (10.8 ft^2) plots (for ephemeral taxa). Species richness (S) = species presence (P).

6. **Species diversity** (H') is: $H' = - \sum (p_i * \ln[p_i])$ where p_i is, for each species i, the numerical proportion of that species abundance (N, density) to the total abundance of all plants in the plot or sample, and ln is the natural logarithm. This measure of species diversity, aka the Shannon-Weiner Index, incorporates both species richness (S) and evenness of the abundances of various species. Increasing S will increase H'; conversely, when 1 or a few species tend to overwhelmingly dominate numerically, the value of H' will decrease. These properties make H' a sensitive overall community indicator index.

<u>Additional Criteria</u>

1. Biennials are plants that reproduce during the second year of their life and then die; this also includes plants that may be ephemeral in some years but persist as short-lived perennials in others. Some examples of biennials include trailing four o'clock (*Allionia incarnata*), slimleaf bursage (*Ambrosia confertiflora*), and purple three awn (*Aristida purpurea*). Counts of these plants will fluctuate from year to year. Document the approximate size or height of plants that are counted. For trend analysis, these species must be excluded.

2. Seedlings are plants in their first year of life and have only a slight chance of becoming established. Count established plants and seedlings separately and document the field decisions with photographs and notes. Examples of criteria for judging a plant to be established or not include: presence of a woody stem, presence of branching, overall plant height, and leaf development. Use only established plants in computing density on the plot and for trend analyses.

3. Plants such as creosotebush and big galleta (*Pleuraphis rigidus*) are sometimes difficult to count because of a common base of numerous stems and a continuous crown. Species with overlapping crowns (>15% overlap) can be lumped together as 1 individual. Document decisions.

4. Grasses should be counted as clumps (i.e., bunches, tussocks, or aggregations). Document decisions as necessary. Also count ferns as clumps.

5. Among species which spread via rooting of fragmenting joints, such as jumping cholla (*Cylindropuntia fulgida*), count all plants except when a mass of small plants surrounds the parent plant. Be careful to count only well established joints not part of a parent-based clump.

6. When reading a line-intercept, look down on the line to align the crown margin, then record the beginning and ending of each plant interception along the line. For continuous clumps of 2 or more individuals of a single species, only 1 beginning and ending measurement needs to be taken. However, when 2 species overlap, each must be recorded separately, even though they intercept the same portion of the line. While measuring the length of a line interception of an individual plant crown, the crown is to be visualized as a smooth circle, ellipse, or ellipsoid, and not as a concave polygon, regardless of the degree of openness of the crown. Plants are recorded on the line-intercept regardless of whether they are rooted inside or outside of the plot. Measure line-intercept based on the living part of the plant only.

Only data reductions about percent cover for all woody perennial species combined are reported at this time. A paired t-test was used to evaluate significance of change between first and second surveys for those plots with 2 surveys. Similar data reductions were compiled from the grazing recovery study (Warren and Anderson 1992).

Results

For the 1994-1997 survey, percent cover of perennial vegetation ranged from 3.69 at the Burn Site VG01 to 178.50% at the Alamo Canyon VG01 (Table 4-2). Percent cover, as reported, can exceed 100% because of overlapping canopies among different species. The Alamo Canyon plot actually had 8.2 percent bare ground.

For the 25 plots that were surveyed twice, the mean percent cover increased from 42.99% in 1988-1990 to 52.66% in 1994-1997. This change is significant (t=-4.06, P=0.00045, N=25). A similar comparison can be made with perennial vegetation cover recorded at 20 grazing recover study plots in 1975 and again in 1988 (Warren and Anderson 1992). Percent cover on the grazing recovery plots (Table 4-3) increased from a mean of 18.36% in 1975 to 26.28% in 1988. This increase is significant (t=-5.93, P=0.00001, N=20).

Discussion

Changes in vegetation cover from 1975 to 1988 and from 1988-1990 to 1994-1997 should be interpreted with caution. Annual precipitation during that period, indicated by the 5-year moving average, suggests that both intervals experienced increasing precipitation (Figure 4-2.). A longer series of surveys would be required to determine if the increase truly represents a long-term trend or short-term fluctuation. This lack of a sufficiently long series highlights one of many concerns with the current protocol.

Vegetation monitoring was intended to serve as one of the important integrative links between

Table 4-2. Changes in total perennial vegetation cover at EMP sites, Organ Pipe Cactus National Monument.

Plot	Year 1	Cover (%)	Year 2	Cover (%)	Change Year 1 to Year 2
AGUA1	1989	75.00	1994	83.80	11.7%
AGUA2	1989	62.98	1994	65.83	4.5%
AGUA3	1989	26.88	1994	22.42	-16.6%
ALAM1	1989	152.85	1995	178.50	16.8%
ARCH1	1989	70.65	1995	92.33	30.7%
ARCH2	1989	47.19	1995	87.28	85.0%
ARMR1	1990	8.57	1996	14.57	70.0%
ARMR2	1990	34.66	1996	48.85	40.9%
BULL1	1989	48.96	1997	32.74	-33.1%
BULL2	1989	41.52	1997	51.35	23.7%
BURN1	1989	0.72	1994	3.69	412.5%
DOLO1	1989	11.54	1994	19.19	66.3%
DOLO2	1989	16.64	1994	20.39	22.5%
DRIP1	1990	66.83	1996	77.66	16.2%
EARM1	1989	31.25	1994	27.27	-12.7%
EARM2	1988	31.23	1994	36.77	17.7%
GROW1	1990	52.65	1997	53.16	1.0%
GROW2	1990	41.21	1997	56.94	38.2%
LOWE1			not sampled for perennials		
LOST1	1990	36.83	1995	44.07	19.7%
MIDB1			1995	87.99	
MIDB2			1995	23.11	
NEOL1	1989	28.97			
POZO1	1989	27.97	1994	37.36	33.6%
SALS1	1990	20.74	1997	35.42	70.8%
SENI1	1990	32.76	1995	58.12	77.4%
SENI2	1990	30.65	1997	58.54	91.0%
VALL1			1995	11.22	
VALL2			1995	54.82	
VULT1	1989	19.84	1994	23.17	16.8%
VULT2	1989	84.75	1994	86.99	2.6%

Table 4-3. Changes in total perennial vegetation cover at grazing recovery study sites, Organ Pipe Cactus National Monument. Data from Warren and Anderson (1992).

Plot	Year 1	Cover (%)	Year 2	Cover (%)	Change Year 1 to Year 2
Agua200	1975	3.40	1988	13.50	297.1%
AguaPlot 2E1	1975	10.50	1988	19.70	87.6%
AguaPlot 2E2	1975	16.60	1988	24.00	44.6%
AguaPlot 2E3	1975	9.80	1988	15.50	58.2%
Ajo foothills300	1975	27.60	1988	45.90	66.3%
Ajo foothills3S1	1975	41.40	1988	48.20	16.4%
Ajo foothills3S2	1975	25.30	1988	41.50	64.0%
Ajo foothills3S3	1975	22.50	1988	38.00	68.9%
Ajo foothills3S4	1975	27.40	1988	28.20	2.9%
ArmrControl	1975	10.00	1988	12.70	27.0%
ArmrExclosure	1975	12.30	1988	10.20	-17.1%
DoloControl	1975	7.50	1988	13.20	76.0%
DoloExclosure	1975	16.30	1988	21.00	28.8%
Grow100	1975	10.90	1988	17.80	63.3%
Grow1SE1	1975	15.20	1988	22.20	46.1%
Grow1SE2	1975	7.60	1988	11.30	48.7%
Grow1SE3	1975	20.10	1988	18.60	-7.5%
Seni400	1975	32.70	1988	42.90	31.2%
Seni4W1	1975	21.90	1988	39.40	79.9%
Seni4W2	1975	28.20	1988	41.90	48.6%

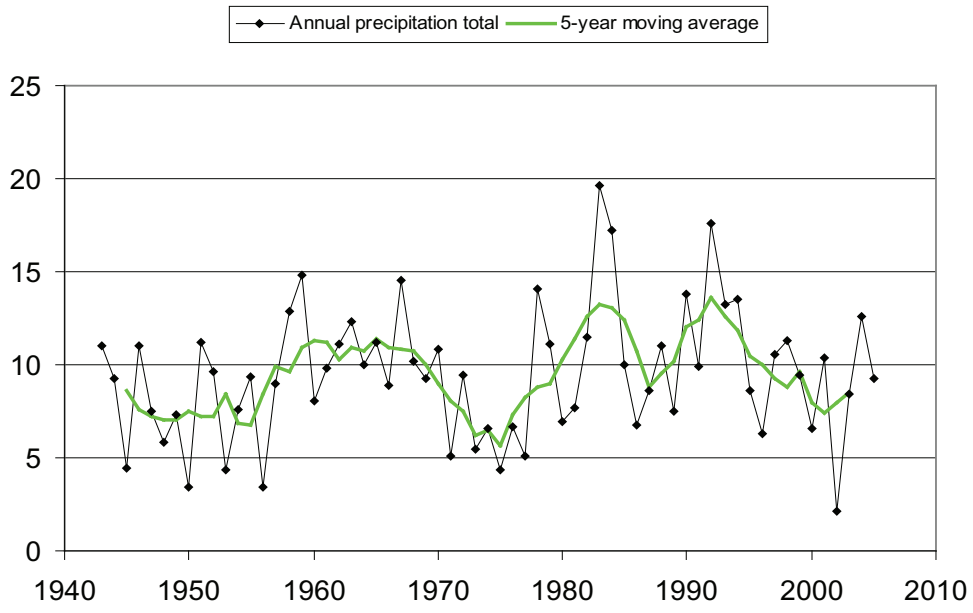

Figure 4-2. Annual precipitation and 5-year moving average recorded at Organ Pipe Cactus National Monument headquarters, 1943-2005.

sub-projects in the EMP at OPCNM (Lowe, Wirt, and Rosen, 1995). There was even a long range vision where vegetation monitoring would provide "(1) intersite variation in composition, structure, and diversity--the community variation in program space, and (2) intrasite change in composition, structure, and diversity--the community change in ecological time."

There are several concerns with the current array of plots and methods for data collection that prevent the protocol from achieving its original goals. Intersecting cover lines and contiguous sub-plots result in non-independence of sub-samples and limit the options for statistical analysis. Some species have zero values in many sub-plots or even whole plots resulting in non-normal distributions. Some plots straddle more than one vegetation community (i.e., they are not homogeneous). Most plots do not overlap animal monitoring plots or transects and some may not even occur in homologous habitat so that direct comparisons cannot be made. Important structural data are not collected such as plant height. The frequency of monitoring is insufficient to measure productivity.

Vegetation monitoring should be a key component in any ecological monitoring program. The Sonoran Desert Network is currently developing new protocols for vegetation monitoring (Mau-Crimmins et al. 2005). Vegetation structure and soil stability (soil aggregate stability and soil compaction) will be monitored on permanent plots every 5 years with all plots being monitored within a park unit in a given year. Vegetation life form abundance, soil quality (soil cover and biological soil crusts), and exotic species status and trends will be monitored together on permanent plots with a rotation that samples some plots every year.

Recommendations

- The original protocol should be abandoned. Improved experimental design and sampling techniques will increase the accuracy and applications of the data collected from each sampling event.
- A committee to develop a new experimental design and sampling techniques should be established and the resulting protocol should be peer-reviewed and amended as necessary.
- While the new protocol is being developed, OPCNM should re-sample some of the cover lines.
- OPCNM should work closely with the Sonoran Desert Network to insure that the new vegetation monitoring protocols and site selection addresses both network and monument needs for resource monitoring and management.

Acknowledgements

Field work was accomplished by Susan Rutman, Ami Pate, Charles Conner, Dennis Casper.

Literature Cited

Bennett, P. S. and M.R. Kunzman. 1987. Organ Pipe Cactus National Monument biosphere reserve sensitive ecosystems program. Special Report Number 7, Cooperative Park Studies Unit, The University of Arizona, Tucson. 82 p.

Lowe, C.H. (ed.) 1964. The vertebrates of Arizona. University of Arizona Press. Tucson. 270 pp.

Lowe, C.H, E.B. Wirt, and P.C. Rosen. 1994. Vegetation structure and diversity in natural communities at Organ Pipe Cactus National Monument, Arizona. Final report submitted to National Park Service at Organ Pipe Cactus National Monument, Arizona. 173pp.

Lowe, C.H, E.B. Wirt, and P.C. Rosen. 1995. Vegetation Structure and Diversity in Natural Communities Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. Organ Pipe Cactus National Monument Ecological Monitoring Program Protocol Manual. Special

Report No. 11, National Biological Service Cooperative Park Studies Unit, The University of Arizona, Tucson. 2:1-61.

Mau-Crimmins, T., A. Hubbard, D. Angell, C. Filippone, and N. Kline. 2005. Sonoran Desert Network Vital Signs Monitoring Plan: Phase III. Sonoran Desert Network. Tucson, Arizona. Technical Report NPS/IMR/SODN-003. 174pp.

Warren, P.L, and L.S. Anderson. 1992. Ecosystem recovery from grazing at Organ Pipe Cactus National Monument: Plant and rodent community changes between 1975-76 and 1987-88. Final report submitted to National Park Service at Organ Pipe Cactus National Monument, Arizona. 59 pp.