

**Organ Pipe Cactus National Monument  
Ecological Monitoring Program  
Monitoring Protocol Manual**

**Special Report No. 11**



**United States Department of the Interior  
National Biological Service  
Cooperative Park Studies Unit  
The University of Arizona**

**and**

**National Park Service  
Organ Pipe Cactus National Monument**



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Ecological Monitoring Program  
Monitoring Protocol Manual**

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National Biological Service  
Cooperative Park Studies Unit  
School of Renewable Natural Resources  
125 Biological Sciences East  
The University of Arizona  
Tucson, Arizona 85721

National Park Service  
Organ Pipe Cactus National Monument  
Route 1, Box 100  
Ajo, Arizona 85321

## Unit Personnel

William L. Halvorson, Unit Leader  
Peter S. Bennett, Research Ecologist  
Cecil R. Schwalbe, Research Ecologist  
Michael R. Kunzmann, Ecologist  
Katherine L. Hiett, Biological Technician  
Joan M. Ford, Research Unit Assistant  
Gloria J. Maender, Editorial Assistant  
James B. Russell, Word Processing Operator  
Mary N. Greene, Secretary

(520) 670-6885  
(520) 621-1174  
FTS (520) 670-6885



## Monument Resources Management Personnel

Harold J. Smith, Superintendent  
James J. Barnett, Chief, Resources Management  
Jonathan F. Arnold, Resources Management Specialist  
Charles W. Conner, Biological Science Technician  
Ami C. Pate, Biological Science Technician  
Thomas N. Potter, Geographer  
Susan Rutman, Plant Ecologist  
Timothy J. Tibbitts, Wildlife Biologist

(520) 387-7662



The Cooperative Park Studies Unit at The University of Arizona (CPSU/UA) was established 16 August 1973 as a unit in the National Park Service (NPS). By action of Secretary of the Interior Bruce Babbitt, the research function of NPS and several other Interior agencies was transferred to a newly created agency, the National Biological Service (NBS), on 12 November 1993. At that time, the CPSU/UA and unit personnel were transferred to the new agency.

The CPSU/UA provides a multidisciplinary approach to studies in natural and cultural sciences. The unit conducts and coordinates research that is funded by various agencies.

Principal Arizona cooperators include the School of Renewable Natural Resources and the Department of Ecology and Evolutionary Biology of The University of Arizona. The Western Archeological and Conservation Center (NPS) and the School of Renewable Natural Resources (UA) provide administrative assistance. Unit scientists hold faculty or research associate appointments at the university.

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## Preface

Organ Pipe Cactus National Monument (ORPI), established in 1937, is located in southwestern Arizona and is geographically near the center of the Sonoran Desert. The monument encompasses 330,689 a. (133,829.8 ha), of which 95% is designated wilderness. On 26 October 1976, the United Nations Education, Scientific, and Cultural Organization (UNESCO) recognized and designated ORPI as a Biosphere Reserve. Although the monument includes only a small portion of the vast Sonoran Desert, it preserves many elements of that ecosystem. Its boundaries encompass not only mountain ranges, but also rich habitats of bajada, valley floor, riparian systems and expanses of arid creosote plains. Although originally conceived as a monument to preserve a unique species of columnar cactus, ORPI now stands as one of the most diverse protected areas of the Sonoran Desert ecosystem in the United States or Mexico.

Like other natural preserves, ORPI is vulnerable to rapidly changing land uses beyond its boundaries. Of special concern is the southern boundary, which borders the neighboring state of Sonora, Mexico. In the late 1960s, the Mexican government encouraged and subsidized agricultural development in the Sonoyta Valley, where previously only subsistence farming had been practiced. Approximately 165 wells were serving 32,000 a. (12,950.4 ha) by 1988. Although a moratorium on the construction of new wells is now in effect, groundwater depletion in the Sonoyta Valley aquifer is a constant threat, as current capacity for water withdrawal exceeds current rates by one-half. Other concerns to ORPI have included the effect of herbicide and pesticide drift on native plants and animals, increased vehicle traffic, and the invasion of nonnative flora and fauna. With the recent passage of the North American Free Trade Agreement, increased urbanization, agricultural development, and manufacturing have become new threats to ORPI desert ecosystems.

### **Sensitive Habitats Project**

In the 1980s, park managers recognized the need to initiate a program to understand the condition of the ecosystem to better protect it from growing outside threats. The first set of projects to meet this goal was known as the Sensitive Habitats Project, first proposed in 1985. This project stemmed from 4 high priority research projects identified in the 1984 Resources Management Plan: (1) Effects of Mexican Agriculture on ORPI, (2) Inventory of ORPI Herpetofauna, (3) Survey of ORPI Insect Fauna, and (4) Climatological Monitoring. These projects were later combined beneath the holistic proposal: "Changes in Sonoran Desert Ecosystems at Organ Pipe Cactus National Monument with Reference to Sensitive Habitats." Monument habitats were considered sensitive because many plant and animal species occur near the edge of their geographical distribution limits, and thus are subject to greater stresses and more rapid changes than elsewhere.

## **Sensitive Ecosystems Program**

In 1986, an international panel of scientists, resource managers and administrators was convened to design a much larger integrative program. The new program was called the Sensitive Ecosystems Program (SEP) and it encompassed numerous projects, including the former Sensitive Habitats Project.

Modelled after the successful Channel Islands Inventory & Monitoring Initiative, the step-down planning technique was used to efficiently organize the management goals and objectives of the program. Step-down planning is a technique requiring a single-purpose primary objective that communicates the identity and nature of the problem to be addressed. After the primary objective is defined, all sequential steps necessary to accomplish this objective, in order from large to small, are identified. In this way, attention is focused on the primary management objective, and only actions needed to attain this objective are considered.

The primary objective for the SEP was to develop a management program to determine (1) the condition of ORPI ecosystems, (2) alternatives available for ecosystem management, and (3) the effectiveness of implemented action programs. Steps that were identified to support this objective included policy review, surveys and investigations of many ecosystem components, long-term monitoring protocols, and the development of an information management system.

By 1988, baseline research associated with 12 studies was underway. By 1991, base funding increases had allowed the monument to bring on a minimal staff to implement recommended long-term monitoring protocols associated with the original research projects. A critical element during the research phase was that resource management staff worked extensively with the principal investigators in the field.

## **Ecological Monitoring Program**

In the spring of 1994, the title of the SEP was changed to the Ecological Monitoring Program (EMP) to reflect a change from the historic focus on “sensitive” monument areas to a broader look at the ecosystem's many components. As a result of the Ecological Monitoring Program, ORPI has the framework for one of the most extensive ecological research and inventorying and monitoring programs in the National Park Service (NPS). The methodologies and tools for long-term monitoring provided by the scientists will provide park managers with the “vital signs” of the monument ecosystem. The protocols herein have been tested and refined as a result of the feedback loop between researchers and field staff.



# Vegetation





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# Special-status Plants Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Ruffner Associates

c/o George Ruffner  
EcoPlan Associates  
1845 South Dobson Road, Suite 111  
Mesa, Arizona 85202

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## Introduction

Conservation and management of populations or species of plants requires understanding population dynamics, including demographic data such as annual growth, age structure, reproductive capacity, establishment, and mortality. Consequently, monitoring is a standard and necessary feature of resource management, as the resulting information facilitates assessing status of a population or species, i.e., whether it is increasing, stable, or decreasing (Pavlik 1987).

Monitoring data should also provide insight into potential problems or threats faced by a species so that efficient and effective management actions can be undertaken. At the very least, these data should identify potential problems as being of natural or anthropogenic origin. Depending on the problem, management actions to enhance the population can be undertaken. Such actions may include artificial pollination to increase seed set, or closing roads and restricting access to sensitive areas impacted by humans to reduce human-induced threats. However, ability of resource managers to address these issues varies with the type and scale of impact. For example, impacts associated with agricultural development in the Sonoyta Valley of Sonora, Mexico, are extremely difficult to mitigate, while impacts such as cactus theft (Bennett et al. 1987) may be moderated by resource management.

The extensive and ongoing acquisition of climatic data from numerous weather stations within Organ Pipe Cactus National Monument (ORPI), Arizona, is highly valuable for monitoring efforts due to the ability to correlate climatic events with plant population dynamics. Climatic data and variation therein provide natural experiments for determining the impact of environmental factors on attributes such as growth, mortality, and establishment of plant species.

This section delineates monitoring protocols for 6 plant species: Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*), senita cactus (*Lophocereus schottii*), organ pipe cactus (*Stenocereus thurberi*), dahlia rooted cactus (*Peniocereus striatus*), desert caper (*Atamisquea emarginata*), and ashy jatropha (*Jatropha cinerea*). The protocol for monitoring Acuña cactus was developed in the late 1970s by Dr. William Buskirk and students from Earlham College, primarily to detect theft of this cactus. This protocol has been upgraded to collect complete demographic data for all individuals that occur within 6 study plots, as well as to detect theft. Protocols for monitoring annual growth of senita cactus and organ pipe cactus were developed by the National Park Service (NPS) in about 1970 and have continued henceforth on an annual basis. Parker (1988) used these data to assess annual growth of both species. This protocol increases the number of sites sampled and the number of individuals measured to provide a data base that encompasses a wider geographic area. Dahlia rooted cactus, desert caper, and ashy jatropha were selected for monitoring because all 3 species are long-lived perennials, with ORPI being at the northern edge of their geographic range. Ashy jatropha also contrasts with the several species of cacti being monitored, in that this species responds quickly to climatic events such as freezing temperatures or rainfall.

## Monitoring Special-status Cactaceae

### Acuña Cactus

Acuña cactus (*Echinomastus erectocentrus* [Coulter] Britton and Rose var. *acunensis* [Marshall] Bravo) is a Candidate—Category 1 species that is being considered for federal status as a threatened plant species. This variety is known from 3 small, isolated populations in Arizona, and from scattered individuals in northern Sonora, Mexico. Numbers in one Arizona population outside ORPI have declined sharply due to theft. Consequently, it would be informative to monitor population dynamics and reproductive status of individuals within the ORPI population to determine if the population is stable, increasing, or decreasing. This protocol is designed to assess population dynamics of Acuña cactus by monitoring growth, mortality, recruitment, and reproductive status of several hundred marked individuals that occur in 6 study plots scattered across Acuña Basin, which encompasses the entire population of this variety within ORPI.

### Species Characteristics

Acuña cactus has an ovoid to cylindrical stem up to 23 cm (9 in.) long and 10 cm (4 in.) in diameter. Young plants are disc-shaped. The tubercles are mammillate, indentations between them are narrow, and their confluence forms about 18 ribs. The dense spines obscure the stem surface. The 3–4 central spines are 2.5–3.5 cm (0.9–1.3 in.) long, with the distal parts being pink or purple, while the basal half may be straw-colored. The upper spines are upwardly convergent. Flowers are 5 cm (2 in.) in diameter and length, with pink petaloids. Fruits are pale green, drying tannish, and about 10 mm (0.3 in.) long. Fruits bear papery scales and open by splitting lengthwise. Each fruit has about 90 black seeds.

The disc-shaped young plants do not have true central spines; all of the spines per areole are similar, with the uppermost one or two being more elongate, converging at the apex of the plant. The 12 pectinate spines per areole are dirty white with maroon tips. Morphologically similar cacti in ORPI are the fishhook cactus (*Mammillaria* spp.), which can be distinguished by hooked central spines, and the hedgehog cactus (*Echinocereus* spp.), which has more elongate stems, with the flowers produced below the apex.

### Study Plots

Six 50- x 20-m (164- x 66-ft)—or 0.1-ha (0.25-a.)—study plots have been established in Acuña Basin. Four of these plots were established by the Field Studies Program of Earlham College in 1977. The 2 remaining plots, one each at the east and west edge of the population range, were added by Ruffner Associates in March 1988, so that monitoring plots would be located throughout the range of this population. Sample Lotus 1-2-3 data spreadsheets, showing individual plant location coordinates and information on size (height and width), are given in Appendix 1-1.

### *Timing of Monitoring*

Monitoring of *Acuña* cactus should be done in mid-March, which is the period of peak flowering.

### *Monitoring*

Monitoring *Acuña* cactus plots is most efficient with 4–6 people. Initially, 2 individuals locate previously marked plants, identify the tag, and collect appropriate data (see following section). One individual measures plants and assesses reproductive status, while the other records data. At the same time, the remaining individuals set up measuring tapes and begin searching 2- x 20-m (7- x 66-ft) subplots for additional *Acuña* cacti. The 2 individuals recording data assist in searching efforts after all previously known plants have been located and measured. If 6 people are available, two should be designated only to move subplot tapes. These 2 people should not enter the plots so as to minimize the impact of monitoring.

### *Location of New Individuals*

Six monitoring plots were systematically and intensively searched for *Acuña* cactus plants during March 1988–1990. All individuals within each plot were mapped, tagged, measured, and assessed for reproductive condition. These same data should be collected annually for at least several more years.

Locating new individuals entails the following steps:

1. Cordon off the entire plot with non-stretchable metric measuring tapes, attaching the ends to corner stakes.
2. Beginning at the 0-m (0-ft) end of the plot, each successive 2- x 20-m (7- x 66-ft) subplot is cordoned off with metric measuring tapes that are placed over the tapes demarcating the plot boundary and then made taut. Tapes should be placed as accurately as possible because plot coordinates of newly located individuals are measured relative to these tapes.
3. Each 2- x 20-m (7- x 66-ft) subplot is then intensively searched for *Acuña* cactus plants, including seedlings that may be < 2 mm (0.07 in.) both in height and diameter.
4. New individuals are mapped, i.e., given an X and Y coordinate relative to the 0- x 0-m (0- x 0-ft) corner point, are assigned a sequential and individually distinct number for that plot (see Appendix 1-1), and are marked using an aluminum tag wired to a small stone. The stone should be placed 10 cm (4 in.) south of the plant, tag down. This facilitates future efforts to relocate plants. Measuring X and Y coordinates for each plant requires determining the 2- x 2-m (7- x 7-ft) area on the metric tapes surrounding the plant. The plant location is then measured to the nearest centimeter relative to the tapes.
5. The tapes are now moved to the next 2- x 20-m (7- x 66-ft) subplot, and steps 2–4 are repeated until the entire 0.1-ha (0.25-a.) plot has been searched.

6. Human impact should be minimized by avoiding all unnecessary walking within the plots. Soft, smooth-soled field boots or tennis shoes should be worn by all individuals.

### *Measurement of Individual Plants*

Measurement of individual plants requires 2 people and entails the following steps:

1. Plant identification numbers consist of a series of 3, 2-digit numbers separated by hyphens. The first number identifies the year in which the plant was first tagged. The second number identifies the plot number (00 through 05), and the third is the plant number within the plot, e.g., year tagged–plot number–plant number. Thus, the tag 89–03–31 indicates the 31st plant in Plot 3, located in 1989. These labels are embossed on aluminum tags using a Dymo tagwriter or similar tagwriter capable of embossing aluminum tags. The tags will occasionally be found overturned, presumably by woodrats.
2. Plant height is measured on the upslope side of each plant from the base to apex of living tissue, excluding spines. Height measurements are taken parallel to the axis of the plant, from a small nail placed upslope of each plant. Nails should be placed similarly for newly located individuals. Height measurements should be made from the upslope side of the plant if the nail is missing or is out of the ground.
3. Two width measurements are taken along perpendicular axes (cardinal directions) at mid-height using calipers.
4. Microhabitat of newly located individuals should be recorded under associates on the data form (Appendix 1-2). This allows quantifying nurse plant or other possible associations related to establishment of Acuña cactus. Associates are coded on data forms as:

1 = open	Individuals occur in open areas, away from the protection of rocks or nurse plants.
2 = rock	Individuals occur within the protection of rocks that may increase shade or moisture received by the plant.
3 = plant	Individuals occur under the canopy of another plant. The first 2 letters of the genus and species of the nurse plant are also recorded, e.g., AMDE for <i>Ambrosia deltoidea</i> (burrobush). These data may also help to relocate individuals.
5. Reproductive status of each plant is quantified by counting buds, flowers, and fruits. Acuña cactus plants may produce additional buds throughout the flowering season. Consequently, accurate determination of number of reproductive structures produced by each plant requires counting these structures about once per week during the remainder of the flowering phenology, i.e., about 2 additional times. The largest of these numbers is the total number of reproductive structures produced in that year.

6. All data should be recorded under appropriate headings on the data form (Appendix 1-2).

### *Data Compilation and Analysis*

Data should be entered into Lotus 1-2-3 files, one per plot:

1. Data entry for each year first requires creation of 4 new columns in the spreadsheet, including 2 columns for plant size (one for height and one for width), and 2 columns for growth over the previous year (one for growth in height and one for growth in width). Width is entered as the average of the 2 width measurements. These columns should be labeled with information as to the appropriate year and heading (see Appendix 1-1). Growth over the previous year can then be calculated as:

$$\text{height in year}_x - \text{height in year}_y$$

where  $\text{year}_x$  is the year in which measurements are currently being taken, and  $\text{year}_y$  is equal to  $\text{year}_x - 1$ .

Similarly, change in width may be calculated:

$$\text{width in year}_x - \text{width in year}_y.$$

Such calculations involve first placing the cursor in the cell in which the data is to be stored. The @SUM function is then invoked, followed by subtracting the 2 appropriate columns. The copy function can be invoked to calculate growth for the remaining individuals.

2. A data column should also be inserted in the spreadsheet, prior to the column used to record height. Record in this column data for newly located individuals. Data should be recorded as "old" for individuals estimated to be > 1 yr old, and "new" for individuals estimated to have germinated since monitoring efforts the previous year (see Appendix 1-1).
3. A column should be inserted to record total number of flowers produced by each individual, with a heading labeled as such.
4. Appropriate graphics include a size-frequency distribution of Acuña cactus plants within each plot and across all plots (Figs. 1-1 through 1-2), a plot of growth during the previous year vs height in the previous year (Fig. 1-3), and a plot of the number of reproductive structures (total number of buds, flowers, and fruits) vs plant height (Fig. 1-4). Graphics are best created using Sigmaplot or comparable scientific graphics software that can import files from Lotus 1-2-3.
5. Data used to graph size-frequency distributions should be manipulated within Lotus 1-2-3. This is accomplished by sorting plants in order of ascending height using the sort command. Number of individuals within each 10-mm increment (i.e., 0-10, 11-20, etc.) are then counted and graphed using Sigmaplot or similar scientific graphics software. Data should be graphed for each plot as well as pooled across all 6 plots (Figs. 1-1 through 1-2).

6. The first step in graphing growth in height over the previous year is to remove character labels and inappropriate columns of data (all but height, width, and growth of each) and save the resulting spreadsheet as a separate file. The entire file is then converted to a DIF format, using the Lotus 1-2-3 Translate program, and then imported into Sigmaplot. Data should be plotted as growth in height over the previous year vs height in the previous year. Insertion of a dashed line across the graph at zero growth aids in interpreting growth data (Fig. 1-3).
7. Graphing the number of reproductive structures vs height involves importing data on flower number and plant height into Sigmaplot, using the same procedure as detailed in step 6. Before importing data, all individuals that did not produce flowers should be deleted from the Lotus 1-2-3 spreadsheet, and the resulting data file should be saved. Data are then graphed in Sigmaplot, with flower number on the Y scale and plant height on the X scale. Statistical analyses are accomplished using the regression procedure, which outputs a goodness of fit measure of the correlation between the 2 parameters and fits a line to the data (see Fig. 1-4).

### *Time Requirements*

The experience of Ruffner Associates indicates that about 15.3 man-hours (range 12–17 hr) are required to intensively search each plot and collect appropriate data. Counting reproductive structures later in the flowering phenology requires about 4 hr per count for an individual familiar with the plots. Data input into Lotus 1-2-3 files, and analyzing and summarizing data on height distribution, growth, and reproductive effort along with producing the corresponding graphics requires about 30 man-hours. However, this effort will progressively increase as additional data are collected and compiled.

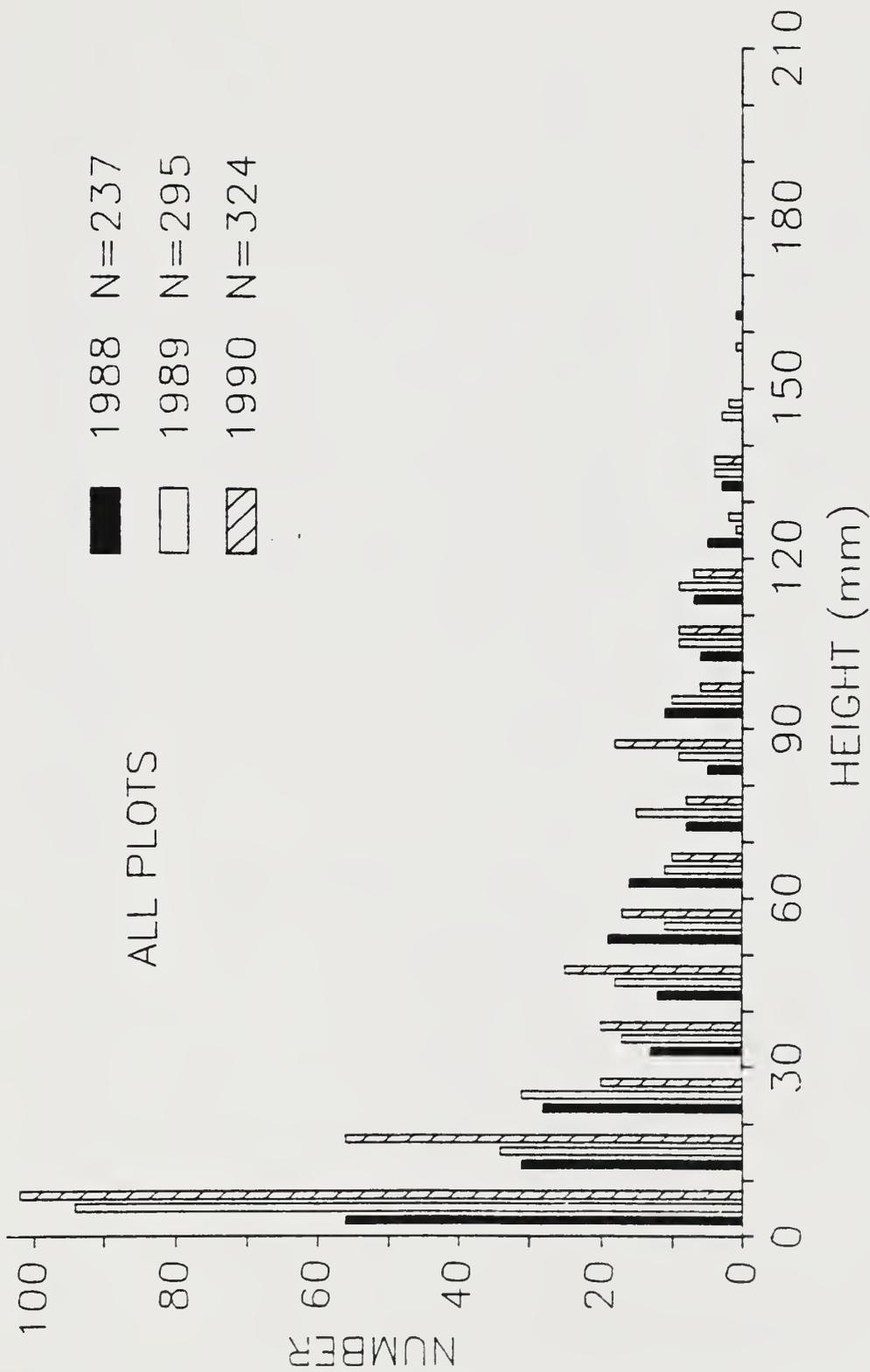


Figure 1-1. Height frequency distribution of Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants located in Acuña Basin, Organ Pipe Cactus National Monument, Arizona. The plants are situated in 6, 0.1-ha (0.25-a.) special-status plants monitoring plots for the Ecological Monitoring Program. Data, pooled across all 6 plots, are for March 1988–1990.

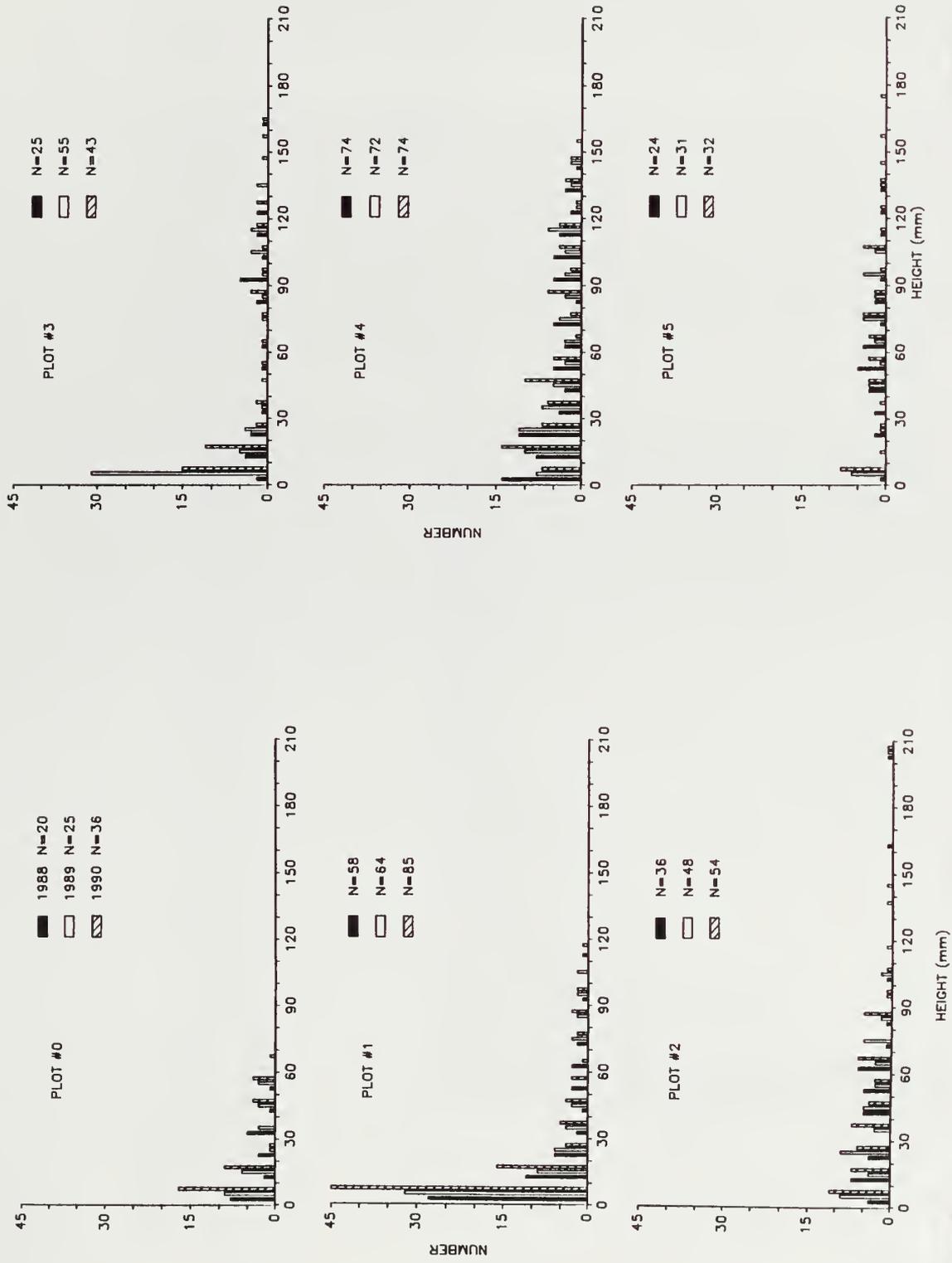


Figure 1-2. Height frequency distribution of Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants located in Acuña Basin, Organ Pipe Cactus National Monument, Arizona. The plants are situated in 6, 0.1-ha (0.25-a.) special-status plants monitoring plots for the Ecological Monitoring Program. Data are for March 1988–1990.

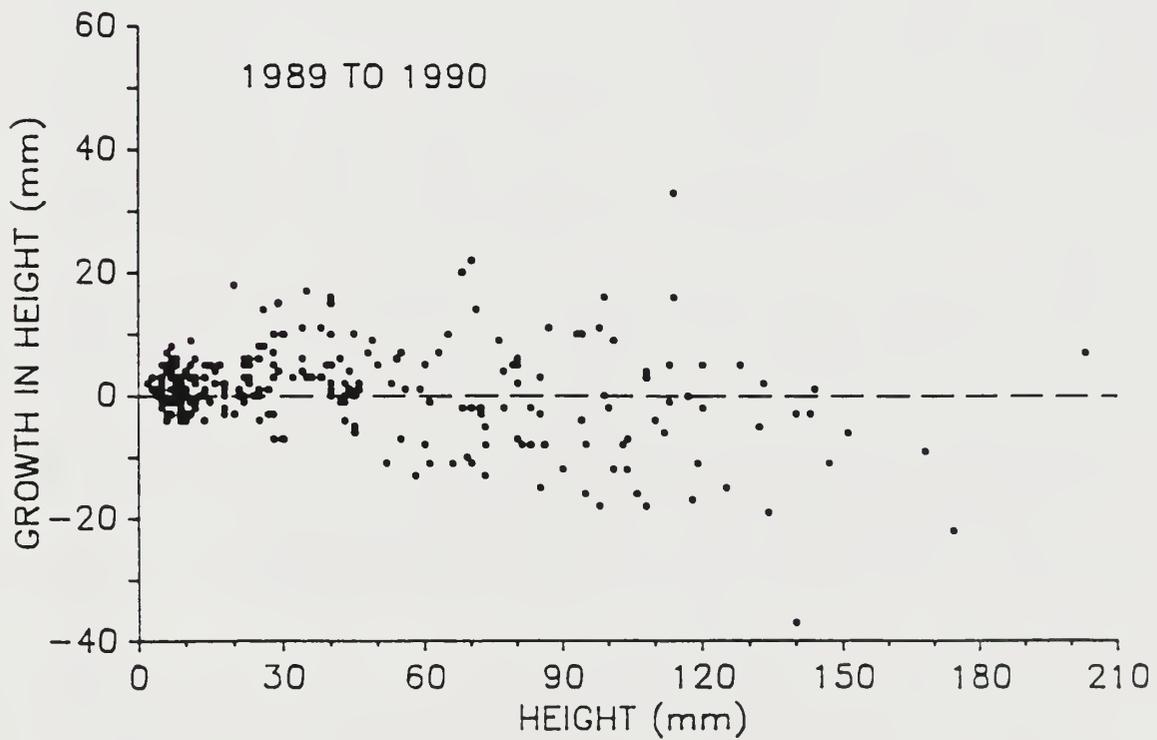
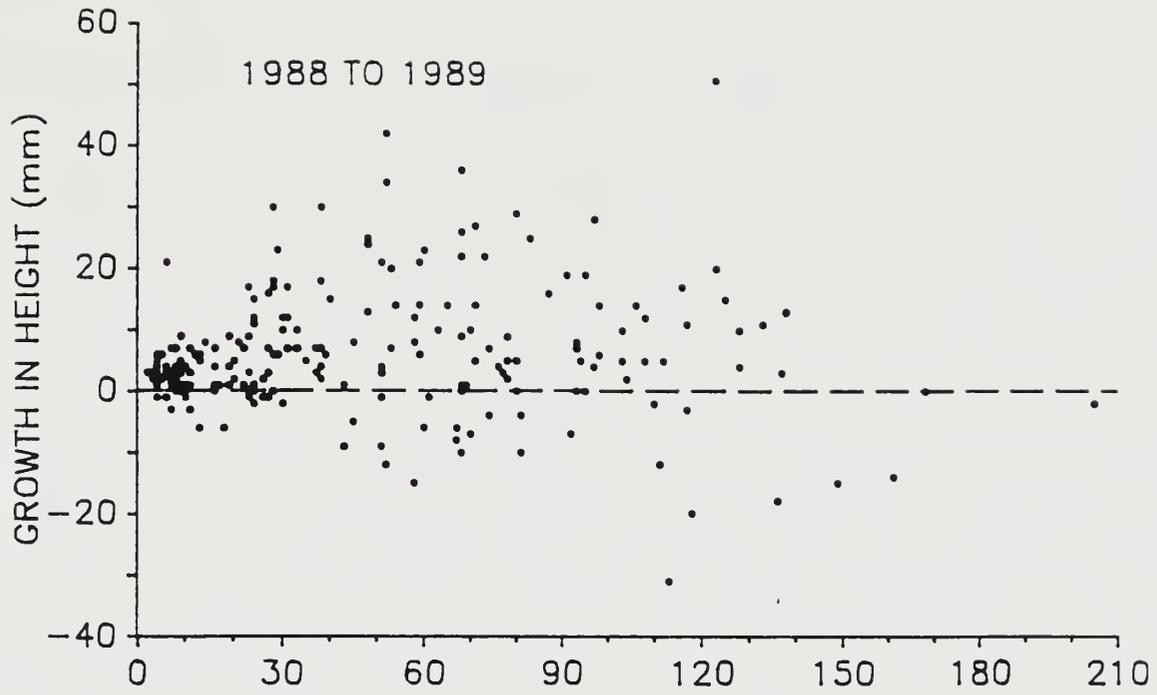


Figure 1-3. Growth in height by Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) individuals located in Acuña Basin, Organ Pipe Cactus National Monument, Arizona. The plants are situated in 6, 0.1-ha (0.25-a.) special-status plants monitoring plots for the Ecological Monitoring Program. Data are presented as growth over the previous year vs height at the start of the year for 1988–1989.

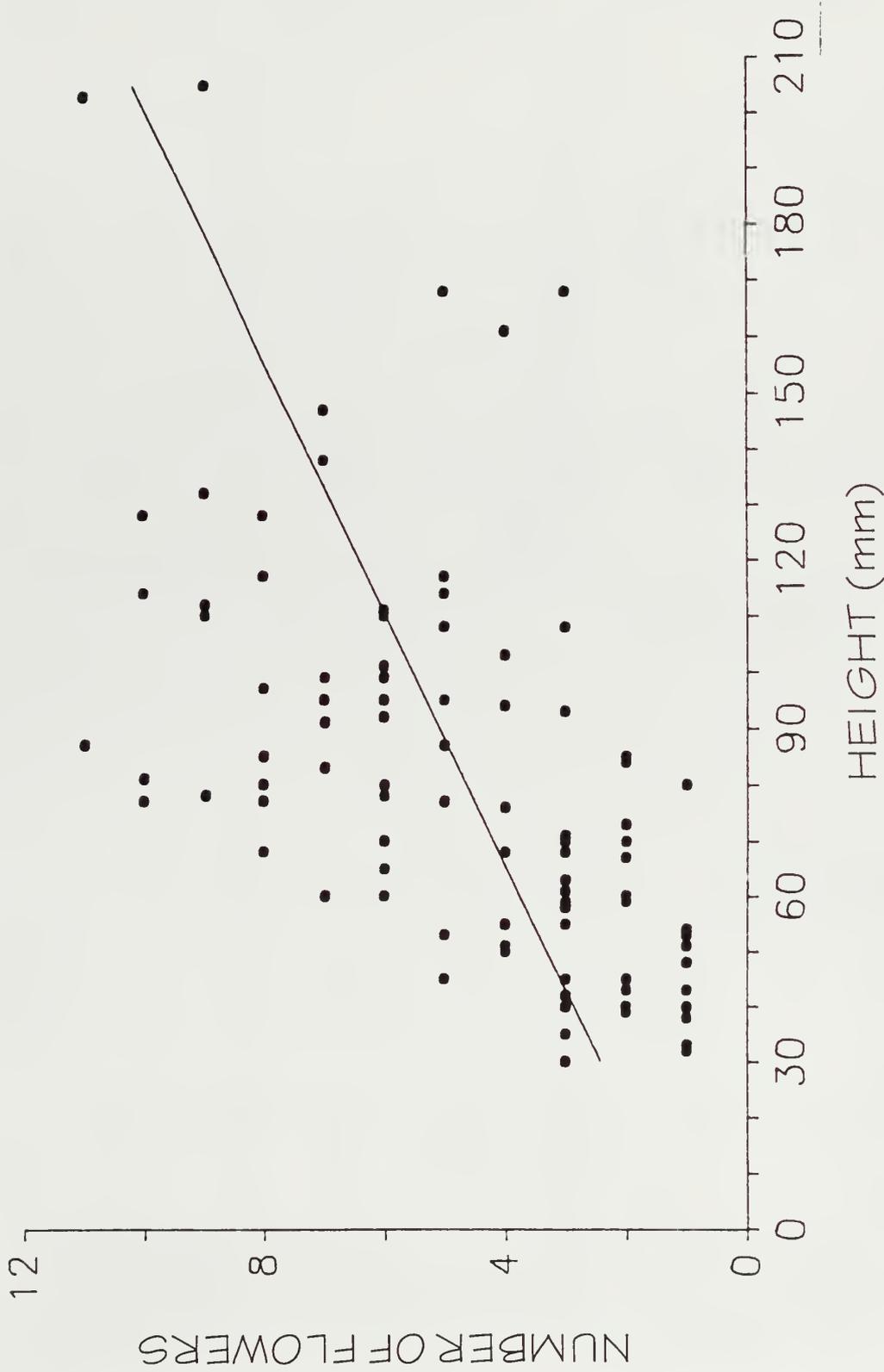


Figure 1-4. Number of flowers produced by flower-bearing Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) individuals, relative to plant height, in the Ecological Monitoring Program at Organ Pipe Cactus National Monument. Data were obtained from plants that occurred in 4, 0.1-ha (0.25-a.) special-status plants monitoring plots during March of 1988 and 1989.

### *Required Materials and Equipment*

Materials required for the successful monitoring of Acuña cactus include:

- (5) 20-m non-stretchable metric measuring tapes
- (2) 50-m non-stretchable metric measuring tapes
- (2) Metric rulers (about 25–30 cm in length) marked in millimeters

Field notebook containing the following:

Directions for locating monitoring plots

Growth and reproduction data forms (Appendix 1-2)

Spreadsheets from previous year(s) to provide information on X-Y coordinates, height, width, and reproductive status

Dymo tagwriter, or similar tagwriter capable of embossing aluminum tags

Aluminum tags for Dymo (or similar) tagwriter

Copper or aluminum 20-gauge wire for attaching tags to plants

Wire cutters

Carpenter's belt (helpful for holding various field equipment)

Calipers for measuring plant width

Small nails for marking upslope location on each newly located individual

### **Senita Cactus and Organ Pipe Cactus**

Senita cactus (*Lophocereus schottii* Britt. and Rose) and organ pipe cactus (*Stenocereus thurberi* Engelm.) are 2 high-profile species of columnar cacti that are at or near their northern range limit in ORPI and, as might be expected, both species are sensitive to prolonged freezing temperatures. Growth patterns of both species reflect climatic events, with growth being correlated with rainfall and prolonged freezing temperatures. Both species are excellent indicators for monitoring growth because of extensive baseline data (20 yr of growth measurements on marked individuals of both species [Parker 1988]), and because both species may be impacted by human or natural events.

### *Species Characteristics*

The senita cactus is a large, arborescent plant with many ascending elongated branches (joints) that arise from ground level. Branches reach 3–7 m (10–23 ft) in height, are 11–13 cm (4–5 in.) in diameter, and usually have 6–7 prominent ribs. The entire plant is 2–5 m (7–16 ft) in diameter. Areoles (small pads from which the spines emerge) on the upper stem are about 6 mm (0.23 in.) apart, and up to 20–25 mm (0.78–0.98 in.) apart on the lower, older stems. The uppermost areoles bear 30 or more long, gray spines that resemble hair from a distance. These spines are 7.5 cm (2.9 in.) long, deflexed, bristly, and twisted. Spines on lower parts of the joint

are very short, stout, and straight. There are 1 central spine and 7–9 radial spines. Flowers are one to several per areole, each being 3.8 cm (1.4 in.) long and about as wide. Flowers open at night and have an unpleasant odor. The outermost petal-like flower parts have pinkish-green midribs and pink margins, while the innermost parts are pink. There are numerous stamens and about 10 stigmas. Fruits are red and fleshy at maturity, globular to ovoid in shape. Fruits fall and burst irregularly.

The organ pipe cactus is a large, arborescent plant that reaches 3–7 m (10–23 ft) in height and 2–6 m (7–20 ft) in width. Numerous columnar branches arise from ground level. Branches are 10–20 cm (4–8 in.) in diameter with 12–19 ribs. Areoles are 6–12 mm (0.23–0.47 in.) apart, each with 11–19 dirty-gray, black, or brown spines that range from 1.2 cm (0.5 in.) to 2.5 cm (0.9 in.) long. Spines are straight and spread in all directions. Plants > 2.0–2.5 m (6.5–8.2 ft) tall produce flowers, usually within 2 m (7 ft) of the stem tips. Flowers have a mild skunk-like odor and are open from just before dark until early the next morning. Flowers are 6.0–7.5 cm (2.5–2.9 in.) long and have obvious scale leaves on the outside of the tube. The outermost petal-like flower parts have reddish mid-ribs and light margins, while the inner parts are lavender with white margins. Anthers are yellowish, while the filaments are white. The numerous stigmas are yellow. Fruits, which mature in late summer or fall, are red and fleshy and contain numerous seeds. Spines on the fruits are dense but deciduous (Benson 1982).

Senita cactus occurs in ORPI only at the southernmost boundary. This species is easily distinguished from organ pipe cactus by fewer ribs, and small, stout spines that do not obscure the view of the stem, as do organ pipe cactus spines. Mature individuals also have hair-like spines on terminal parts of the stems.

### *Study Plots*

In 1970, an ORPI park ranger set up 2 study plots to monitor growth of senita cactus and organ pipe cactus. The original Baker Mine plot, located in the central Puerto Blanco mountains, contained 31 selected organ pipe cacti. Nine senita cactus plants were selected for growth measurements in the Lost Cabin and Senita Basin area. In a 1988 paper, Dr. Kathy Parker generated size-growth models on the 1970–1983 data set for the organ pipe cactus plots (Parker 1988).

In 1990, as a part of the Special-status Plants Ecological Monitoring Program project, additional plots were set up for both species, the purpose being to assess intersite variability in growth rates. An organ pipe cactus plot of 20 individuals was established in the Bates Mountains. Additionally, on the south boundary of these mountains, 3 organ pipe cactus plants and 3 senita cactus plants were selected. Finally, 4 additional senita cacti were selected for monitoring in the Senita Basin area.

In 1994, the Ecological Monitoring Program (EMP) staff and Advisory Committee discussed the merits of selecting new, young plants for growth measurements and discontinuing measurements for older plants that have reached full maturity. A decision was made to monitor these older plants every 5 yr, and to establish photo points for the younger plants. As an additional part of

the organ pipe cactus and senita cactus monitoring protocol, historic photographs of individual plants are to be used for comparison with current condition.

Currently, monitoring plots for senita cactus and organ pipe cactus have been established at Lost Cabin Mine Basin (both species), Senita Basin (both species), Dos Lomitas (both species), Baker Mine (organ pipe cactus), and Bates Well (Organ Pipe cactus). Directions to the study plots and number of individuals within each study plot, as well as previous data on stem length of all monitored plants, are on file at the resources management center at ORPI.

### *Timing of Monitoring*

Monitoring growth of senita cactus and organ pipe cactus should be done in mid-January, as this is the time that growth measurements have been taken over the last 20 yr. In 1995, the first photographs will be taken of plants. This procedure will be repeated every 5 yr.

### *Monitoring*

**Baker Mine Plot.** With the efforts of 4 people (2 teams of 2 individuals), the Baker Mine plot can be easily monitored in 1 dy. Monitoring involves the following steps:

1. Use the map to locate the tagged organ pipe cacti. Each arm of each plant has a tag with the plant number, followed by the arm number. For example, a tag reading "6 12" would indicate plant number 6, arm number 12.
2. Measure each arm and record the data on the field form (Appendix 1-3). With the metal tape, start measuring from the base of the arm, follow the outside curvature to the tip, but do not include the spines. Arms that have pegs are measured from the bottom of the peg. Record the arm length to the nearest 0.25 in. (0.63 cm).
3. When an arm becomes too long to measure easily from the base, place a peg approximately 1 m (3 ft) from the base, or in a solid, fleshy part of the arm. Then, record 2 numbers on the data form: a bottom number recording the measurement from the base to the *bottom* of the peg, and a top number recording the distance from the bottom of the peg to the tip of the arm. In subsequent years, measurements will be made from this peg.
4. Sometimes an arm will become "jointed" near the top. If necessary, record a measurement from the base to the joint, as if it were a peg, and a measurement from the joint to the tip. Make a note of this measurement change on the field observation form.
5. Measure the buds that were observed and measured in previous years, but are still too small for tags. These will be indicated on the field observation form, i.e. "bud on NW side of arm #3 = 4.5 in." If the bud is long enough, it can be tagged. Assign to it the next sequential arm number for that plant and note the number on the field observation form.
6. Look for new buds on the plant. Note their location and measure their length.

7. Examine the plant and record observations about overall condition or appearance, including dead or aborted buds, freeze damage, rot, herbivory, etc. Indicate “healthy” on the field observation form if no problems are observed.
8. Try to minimize any disturbance to the surrounding vegetation or soil during monitoring.
9. In photo-point years, photograph each plant following the directions indicated in the field book.

**Bates Well, Senita Basin, and Dos Lomitas Plots.** Monitoring of these plots only require the efforts of 2 people (one to collect and one to record data). Follow the same procedures as listed above. The Senita Basin and Dos Lomitas measurements can be taken in a single day, but to accurately assess changes within the Bates Well plot requires a separate trip.

### *Data Compilation and Analysis*

Data should be entered into a Lotus 1-2-3 file, one for each species:

1. Data entry requires creation of 2 new columns in the spreadsheet each year. The first column is headed by the year in which data were collected, while the second column is used to store data on growth in the past year. Stem length is recorded in the cell appropriate to each plant and arm number.
2. A new row should be inserted in the spreadsheet when marked individuals produce new stems. The row should be placed as the last line in the spreadsheet for that particular individual. Data are placed in the appropriate column, and the updated file is saved.
3. Appropriate graphics include a plot of growth during the previous year vs height in the previous year (see Parker 1988). Graphics are best done using Sigmaplot or comparable scientific graphics software that can import files from Lotus 1-2-3.
4. Growth of each arm during the past year is calculated as:

$$\text{height in year}_x - \text{height in year}_y$$

where  $\text{year}_x$  is the year in which measurements are currently being taken, and  $\text{year}_y$  is equal to  $\text{year}_x - 1$ . The result is placed in a separate column labeled “Growth from  $\text{year}_y$  to  $\text{year}_x$ .” Similarly, growth of the entire plant over the previous year is calculated as the sum of growth by all arms on a plant.

### *Time Requirements*

The experience of Ruffner Associates indicates that about 80 man-hours are required to measure growth on senita cactus and organ pipe cactus. Data input into Lotus 1-2-3 files, and analyzing and summarizing data should take about 10 additional hours.

## *Required Materials and Equipment*

Materials required for the successful monitoring of senita cactus and organ pipe cactus include:

- (2) 3-ft non-stretchable english measuring tapes, graduated to 0.25 in. or smaller

Field notebook containing the following:

Directions for locating monitoring plots (ORPI files)

Growth data forms (Appendix 1-3)

Spreadsheets from previous year(s) to provide information on plant identification and growth measurements

Dymo tagwriter, or similar tagwriter capable of embossing aluminum tags

Aluminum tags for Dymo (or similar) tagwriter

Copper or aluminum 20-gauge wire for attaching tags to plants

Wire cutters

Extension stick for measuring to the top of cactus stems

Sharpened wooden dowels

Tweezers for cactus spines

Magnetic compass

Camera for photo monitoring

## **Dahlia Rooted Cactus**

Dahlia rooted cactus (*Peniocereus striatus* Brandegee) is an extremely cryptic species of night-blooming cactus that reaches its northern geographic range limit along the southern boundary of ORPI at Dos Lomitas and Blankenship Ranch, apparently due to sensitivity to prolonged freezing temperatures. This species occurs primarily in Sonora, Mexico, and Baja, California (Johnson et al. 1991), but is rare in Arizona, where it is state-listed as S1 (very rare) (Arizona Game and Fish Department 1990). This species may also be impacted by human influences, including population increases of native herbivores caused by agricultural development in the Sonoyta Valley of Sonora, Mexico (Yar Petryszyn, pers. comm.). Consequently, monitoring this species will provide valuable data, due to the combination of possible human influences and the lack of ecological data on this species. This protocol is designed to assess reproduction and mortality as well as damage caused by native herbivores.

## *Species Characteristics*

Dahlia rooted cactus is a very inconspicuous, twig-like plant that often grows entwined in creosotebush (*Larrea divaricata*) or other shrubs. Stems are about 6 mm (0.2 in.) in diameter and gradually enlarge and branch as they grow. Stems have 6–9 broad ribs with narrow intervening grooves. Spines are very small, straight, white or white with black tips, 5–10 or more per areole,

and flattened against the stem. Flowers open diurnally and nocturnally and range from 5.5 cm (2.1 in.) to 7.5 cm (2.9 in.) in diameter and from 7.5 cm (2.9 in.) to 15.0 cm (5.9 in.) in length. The outermost petals have a greenish-purple mid-rib, while the innermost are white to pink or purple. Fruits are scarlet-colored, have deciduous spines, and mature in August to September. The floral tube remains attached to the maturing fruit. The seeds are black.

### *Study Plots*

All monitored individuals occur at Dos Lomitas and Blankenship Ranch. Twenty-two individuals have been tagged and photographs taken to assist relocating these individuals.

### *Timing of Monitoring*

Monitoring of the dahlia rooted cactus should be done in late July. Plants should also be examined 2–3 times from mid-August to late September in order to count buds, flowers, and fruits on each individual.

### *Monitoring*

Monitoring is most efficient with 2 people (one to collect and one to record data) and entails the following steps:

1. Collect appropriate data on each plant, including plant height, number of living basal stems, and number of buds, flowers, and fruits. Record evidence of hedging (clipping of stems by herbivores). Notes should also be taken relative to emergence of new stems or those that have died back (Appendix 1-4).
2. A few marked individuals are small, with 1 or 2 stems and little to no previous hedging. Length of all stems and branches should be measured on these individuals to determine growth rate.
3. Data collection of the number of reproductive structures produced and fruits set requires at least 2–3 additional counts of reproductive structures during August and September. Data are recorded as buds, flowers, and fruits. Consequently, abortion of buds can be assessed relative to rainfall.

### *Data Compilation and Analysis*

All data should be entered into a Lotus 1-2-3 file. Data analyses is directed primarily at monitoring individual survival and determining if bud, flower, and fruit production and abortion of buds are correlated with summer rainfall.

### *Time Requirements*

The experience of Ruffner Associates indicates that about 15 man-hours are required to collect and record data on dahlia rooted cacti during the initial visit each year. For an individual familiar with location of the plants, counting reproductive structures later in the summer requires about 2 hr during each of 2–3 additional visits. Data input into Lotus 1-2-3 and analyzing and summarizing data demands about 15 additional hours.

### *Required Materials and Equipment*

Materials required for the successful monitoring of dahlia rooted cactus include:

3-m non-stretchable metric tape (marked in centimeters) for measuring plants

Photos for locating plants to be monitored

Field notebook containing the following:

    Growth and Reproduction data forms (Appendix 1-4)

    Spreadsheets from previous year(s)

Dymo tagwriter, or similar tagwriter capable of embossing aluminum tags

Aluminum tags for Dymo (or similar) tagwriter

Copper or aluminum 20-gauge wire for attaching tags to plants

Wire cutters

Carpenter's belt (helpful for holding various field equipment)

## Monitoring Special Status Capparidaceae

### Desert Caper

The ORPI population of desert caper (*Atamisquea emarginata* Miers) currently appears stable with a very high reproductive capacity in terms of number of fruits and seeds produced (Ruffner Associates, pers. obs.). However, desert caper is probably the species that is most at risk for future declines or extinction within ORPI due to a combination of low population size, localized distribution, and a large disjunction from other populations. This species may also be impacted by human influences including firewood collection and groundwater drawdown, which has been increasing recently due to agricultural development in the Sonoyta Valley, Sonora, Mexico. Consequently, this monitoring protocol is directed at examining survival and condition of existing individuals.

### *Species Characteristics*

The desert caper is a densely branched shrub to small tree that grows to 4–5 m (13–16 ft) tall in ORPI and to 8 m (26 ft) tall further south. Branching divaricates, is rigid, and the small lateral branches are nearly perpendicular to the main branches. Branches are tawny to silvery. Leaves are simple with entire margins, the apex emarginate, dark green and shiny above, silvery below. The flowers, which have 4 sepals and petals, both in unequal pairs, are solitary or in fascicles. Flowers have 7–9 stamens, one to three of which are reduced and infertile. Fruits are drupe-like, ovoid in shape and contain 1 or 2 seeds that are partly surrounded by a red pulpy aril (Benson and Darrow 1944, 1954).

### *Study Plot*

The study plot is an approximately 5-ha (12-a.) area.

### *Timing of Monitoring*

Monitoring should be done in August when fruit production can be assessed.

### *Monitoring*

Thirty individuals of desert caper were marked with an embossed aluminum tag and mapped on an acetate overlay of a ca. 1:100 scale, color, aerial photograph of the plot during August 1990. This photograph is on file at the resource management center, ORPI, along with an acetate cover sheet that denotes plot boundaries and locations of desert caper individuals to be measured.

Collecting monitoring data on these individuals entails:

1. Locating and identifying these 30 individuals each year in order to collect data on reproductive status, growth, and survival.
2. Reproductive status should be noted as in flower, fruit, or both.

3. Plant size is calculated using 2 perpendicular measures (N-S and E-W) of canopy diameter from which total areal cover is estimated. Width measures include all branches on the individual. Height is measured to the tallest portion of the plant.
4. Comments on vigor or health of individuals should also be noted on the data form (Appendix 1-5).

### *Data Compilation and Analysis*

All data should be entered into a Lotus 1-2-3 file involving the following steps:

1. Data entry requires creation of 3 new columns in the spreadsheet, one for reproductive condition, and two for size measures (one for height and one for width). Width is entered as the average of the 2 measures.
2. Growth rate, size-frequency distribution, and average plant canopy cover can be calculated and summarized by manipulating data within Lotus 1-2-3. Graphics are best done using Sigmaplot or comparable scientific graphics software that can import files from Lotus 1-2-3. Data analyses should be directed primarily at monitoring individual survival and relating mortality events to groundwater levels to determine if there is a correlation between these 2 variables.
3. Growth in height is calculated as:

$$\text{height in year}_x - \text{height in year}_y$$

where  $\text{year}_x$  is the year in which measurements are currently being taken, and  $\text{year}_y$  is equal to  $\text{year}_x - 1$ .

Canopy cover is estimated using the formula:

$$0.25 \times \pi \times \text{diameter}_1 \times \text{diameter}_2$$

Growth in canopy cover is calculated as:

$$\text{canopy cover in year}_x - \text{canopy cover in year}_y$$

where  $\text{year}_x$  is the year in which measurements are currently being taken, and  $\text{year}_y$  is equal to  $\text{year}_x - 1$ .

Average plant canopy cover is the mean value obtained from the 30 individuals.

4. Size-frequency distribution is graphed in Sigmaplot using canopy cover as estimated in step 3. Data are graphed as canopy cover on the X scale and frequency on the Y scale.

### *Time Requirements*

Monitoring of desert caper in the Aguajita Wash plot requires about 25 man-hours. Monitoring efforts are most efficient with 4 people. Data input into Lotus 1-2-3 and data summarization requires approximately 4–5 hr.

### *Required Materials and Equipment*

Materials required for the successful monitoring of desert caper include:

(2) 30-m non-stretchable metric measuring tape

3-m non-stretchable metric measuring tape

Field notebook containing the following:

Aerial photograph of the study plot with acetate overlay that shows locations of marked desert caper individuals (originals on file in the resource management center at ORPI)

Growth and reproduction data forms (Appendix 1-5)

Spreadsheets from previous year(s) to provide information on plant size, fruit presence, and nurse plants

Dymo tagwriter, or similar tagwriter capable of embossing aluminum tags

Aluminum tags for Dymo (or similar) tagwriter

Copper or aluminum 20-gauge wire for attaching tags to plants

Wire cutters

Carpenter's belt (helpful for holding various field equipment)

Small scissors

Height pole marked in decimeter and meter intervals

## Monitoring Special Status Euphorbiaceae

### Ashy Jatropha

Ashy jatropha (*Jatropha cinerea* [Ort.] Muell. Arg.) is a drought-deciduous, perennial shrub that grows to 6 m (20 ft) tall. This species is widely distributed in northern Mexico and Baja, California, but in the United States is restricted to the Tinajas Altas Mountains, and ORPI, near Quitobaquito and in Senita and Lost Cabin Mine basins, where it is a sub-shrub that rarely exceeds 1.5 m (4.9 ft) height. Ashy Jatropha is sensitive to prolonged freezing temperatures and has its northern distribution restricted by low temperatures. Die-back due to low temperatures occurs in ORPI, sometimes causing notable population declines. However, unlike cacti which grow extremely slowly and may survive several years following a fatal frost, these kinds of declines and subsequent population recoveries are quickly manifest in ashly jatropha. Overall, these characters make ashly jatropha excellent for monitoring effects of climatic variation along the southern boundary of ORPI.

### Species Characteristics

Ashy jatropha is a dioecious shrub that grows 1.3–6.0 m (4.2–19.6 ft) tall. Leaves are alternate, kidney to heart-shaped, and covered with fine hairs, at least beneath. Staminate flowers are in terminal cymes on the spur branchlets, and pistillate flowers number from 1 to 3 at spur branch tips. Flower petals of both sexes unite into a 7-mm (0.3-in.) to 9-mm (0.4-in.) long tube. The ovary is 2-chambered, and the fruit is a 2-seeded capsule that is much broader than long and slightly winged on back. This species differs in leaf shape from other jatropha species in ORPI; wedge-shaped jatropha (*Jatropha cuneata*) has a much smaller leaf (5–18 mm [0.2–0.7 in.] long) with a wedge-shaped base, while limberbush (*Jatropha cardiophylla*) has a hairless, heart-shaped, triangular leaf, similar in size to that of ashly jatropha.

### Study Plots

Population dynamics of ashly jatropha are monitored in the 9.75-ha (24.08-a.) plot at Lost Cabin Mine Basin, which was established, mapped, and described in 1987 by Peter Bennett and Michael Kunzmann of The University of Arizona/Cooperative Park Studies Unit in Tucson, Arizona. Each corner is marked with rebar.

### Timing of Monitoring

Ashly jatropha is most easily found when individuals are leafed out. Consequently, monitoring should be done in August or September when such occurrence is most likely. Monitoring should be delayed until individuals bear leaves.

### Monitoring

All ashly jatropha individuals within the 9.75-ha (24.08-a.) plot, except those < 0.5 m (1.6 ft) tall, were labeled with an embossed aluminum tag and mapped on a ca. 1:100 scale, color, aerial photograph during August 1990.

1. Monitoring efforts entail relocating and identifying all individuals on an annual basis to collect data on population size, reproductive status, plant size, and survival. The most effective means of collecting data entails conducting an intensive search of the entire plot to locate immature individuals. New individuals that are > 0.5 m (1.6 ft) in height should be mapped, marked with a sequentially numbered aluminum tag, and all appropriate data collected and recorded on the data form (Appendix 1-6). Smaller plants should only be mapped.
2. While conducting the intensive search for new plants, all previously marked plants should be located and the appropriate data collected. Plant size is estimated using 2 perpendicular measures (N-S and E-W) of canopy diameter from which total areal cover is estimated. Height is measured to the tallest portion of the plant. Size is also assessed by placing individuals into categories of 1–10, 11–20, and > 20 basal stems. Actual number of stems should be recorded when they total < 10.
3. Reproductive status should be recorded as in flower, fruit, or both.
4. Individuals should also be examined for frost damage or die-back, which is indicated by dead basal stems and resprouting of immature basal stems.

### *Data Compilation and Analysis*

All data should be entered into Lotus 1-2-3 and entails the following steps:

1. Data entry for each year first requires creation of 9 new columns in the spreadsheet, including 2 columns for height, 2 columns for number of stems, 4 columns for canopy cover measures, and 1 column for reproductive condition. Data is inserted in the first of each respective new column, while the second new column is used to calculate differences in size and height over 2 successive yr. The 4 columns for canopy cover measures include 2 columns for width, 1 column for total canopy cover, and 1 column for change in cover over the preceding year. Areal cover is estimated from the 2 width measures using the formula:

$$0.25 \times \pi \times diameter_1 \times diameter_2$$

All new columns should be appropriately labeled.

2. For new individuals, data on location should be recorded in addition to the variables in step 1. Data on location should be recorded in 2 appropriately labeled columns: 1 column coded as 0 = wash, 1 = outside of wash, and the other column coded as 0 = growing in the open, 1 = growing under a nurse plant. The first 2 letters of the genus and species should be recorded for those individuals growing under a nurse plant.
3. Size-frequency distribution and location data can be calculated and summarized by manipulating data within Lotus 1-2-3. Graphics are best done using Sigmaplot or

comparable scientific graphics software that can import Lotus 1-2-3 files. Appropriate graphics include a size-frequency distribution using number of basal stems on each plant (Fig. 1-5), percent of individuals in and out of washes, and percent of individuals with and without a nurse plant. Mortality data should be assessed relative to weather data such as freeze frequency or duration of subfreezing temperature using data from the weather station at this site.

### *Time Requirements*

Monitoring ashy jatropha in the Lost Cabin Mine Basin plot requires about 30 man-hours. Monitoring efforts are most efficient with 4 people. Data input into Lotus 1-2-3 and data summarization require about 10 hr.

### *Required Materials and Equipment*

Materials required for the successful monitoring of ashy jatropha include:

- (2) 30-m non-stretchable metric measuring tapes

Field notebook containing the following:

Directions for locating the Lost Cabin Mine plot

Aerial photograph of the study plot with acetate overlay that shows locations of marked ashy jatropha individuals (originals on file in the resource management center at ORPI)

Growth data forms (Appendix 1-6)

Spreadsheets from previous year(s) to provide information on plant size, nurse species, and reproductive condition

Dymo tagwriter, or similar tagwriter capable of embossing aluminum tags

Aluminum tags for Dymo (or similar) tagwriter

Copper or aluminum 20-gauge wire for attaching tags to plants

Wire cutters

Carpenter's belt (helpful for holding various field equipment)

Small scissors



Figure 1-5. Frequency distribution of stem number for ash jatropha (*Jatropha cinerea*) individuals in the special-status plants monitoring plot at Lost Cabin Mine Basin in Organ Pipe Cactus National Monument, Arizona. July 1990.

## Literature Cited

- Arizona Game and Fish Department. 1990. Nongame data management system: special plant list. Phoenix, Arizona.
- Bennett, P. S., R. R. Johnson, and M. R. Kunzman. 1987. Cactus collection factors of interest to resource managers. P. 215–223 in T. S. Elias and J. Nelson, eds. Conservation and management of rare and endangered plants. Proceedings of a California Conference on the Conservation and Management of Rare and Endangered Plants, Sacramento, California.
- Benson, L. 1982. The cacti of the United States and Canada. Stanford University Press, Stanford, California.
- Benson, L., and R. A. Darrow. 1944. A manual of southwestern desert trees and shrubs. The University of Arizona, Biological Science Bulletin No. 6. Tucson, Arizona.
- Benson, L., and R. A. Darrow. 1954. The trees and shrubs of the southwestern deserts. Second edition. University of New Mexico Press, Albuquerque, New Mexico.
- Johnson, R. A., M. A. Baker, D. J. Pinkava, N. Trushell, and G. A. Ruffner. 1991. Special status plants of Organ Pipe Cactus National Monument, Arizona; Sensitive Ecosystems Project. Final report submitted to National Park Service at Organ Pipe Cactus National Monument, Arizona.
- Parker, K. C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. *Botanical Gazette* 149:335–346.
- Pavlik, B. M. 1987. Autecological monitoring of endangered plants. P. 385–390 in T. S. Elias, and J. Nelson, eds. Conservation and management of rare plants. California Native Plant Society, Sacramento, California.

**Appendix 1-1**  
**Special-status Plants Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Sample Data from Monitored**  
**Acuña Cactus (*Echinomastus erectocentrus* var. *acunensis*)**

The following page illustrates a sample Lotus 1-2-3 data spreadsheet, showing individual plant location coordinates and information on size (height and width) for some of the monitored Acuña cactus plants in the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona (ORPI). The complete electronic data are on file at the resources management center at ORPI.

ADUMA PLOT #0

Plant Number	Coordinates		1988 Measure (mm)			1989 Measures (mm)			1990 Measures (mm)			Growth from 1988 to 1989		Growth from 1989 to 1990		1988 Flowers		1989 Flowers		1990 Flowers	
	X	Y	Height	Mean Width	Mean	Height	Mean Width	Mean	Height	Mean Width	Mean	Height	Width	Height	Width	Associate	Total	Total	Total	Total	
1	4.54	5.46	23	28.5	32	22	31	22	31	31	-1	3.5	0	-1		0	0	0	0	0	
2	7.54	10.24	7	9	15	6	15	6	15	15	2	6	-3	0	Amde 3	0	0	0	0	0	
3	7.54	10.12	3	6	8	5	9	5	9	9	2	2	0	1	Amde 3	0	0	0	0	0	
4	8.15	12.83	31	46.5	48	43	56	45	56	56	12	1.5	2	8		0	0	2	2	3	
5	9.93	7.44	24	43.5	45	39	52	44	52	52	15	1.5	5	7		0	0	2	2	3	
6	7.34	17.68	10	18.5	20	10	24	10	24	24	-1	1.5	4	4	Amde 3	0	0	0	0	0	
7	6.36	16.98	16	22	30	16	30	20	31	31	0	8	4	1		0	0	0	0	0	
8	6.59	15.7	29	42	44.5	52	41	45	45	45	23	2.5	-11	0.5	1	0	0	0	0	0	
9	19.54	5.88	7	16.5	20.5	8	20.5	22.5	22.5	22.5	1	4	0	2	1	0	0	0	0	0	
10	22.62	3.29	38	40.5	47	55	46	46	46	46	2	6.5	15	-1	2	0	0	0	0	0	
11	30.91	10.53	40	54	55	55	62	62	62	62	15	1	7	7	1	2	4	7	3	3	
12	24.17	8.35	45	56	55	55	59	55	59	59	8	-0.5	2	3.5	1	0	0	1	1	1	
13	29.43	16.11	4	11	18.5	7	18.5	10	19	19	3	7.5	3	0.5	1	0	0	0	0	0	
14	31.39	17.09	11	21	28.5	12	28.5	18	31	31	1	7.5	6	2.5	1	0	0	0	0	0	
15	29.66	18.95	59	61	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	DEAD	
16	35.19	18.76	33	51	50	40	50	42	57.5	57.5	7	-1	2	7.5	1	0	0	3	3	3	
17	7.8	19.75	31	54.5	54	48	54	55	58	58	17	-0.5	7	4	1	0	1	0	1	0	
18	29.22	14.3	4	11	12	6	12	11	13	13	2	1	5	1	1	0	0	0	0	0	
19	28.89	16.91	7	14	18.5	14	18.5	14	22	22	7	4.5	0	3.5	2	0	0	0	0	0	
20	24.66	9.14	9	20	26	14	26	19	25.5	25.5	5	6	5	-0.5	Amde 3	0	0	0	0	0	
21	9	6	9	20	49	49	49	58	44.5	44.5	5	6	9	-4.5	Caer 3	0	0	0	0	0	
22	35.19	16.76	6	20	18	11	18	10	21	21	1	3	-1	3		0	0	0	0	0	
23	30.89	18.76	33	51	50	40	50	42	57.5	57.5	7	-1	2	7.5	1	0	0	3	3	3	
24	32.69	16.96	4	11	12	6	12	11	13	13	2	1	5	1	1	0	0	0	0	0	
25	28.89	16.91	7	14	18.5	14	18.5	14	22	22	7	4.5	0	3.5	2	0	0	0	0	0	
26	24.66	9.14	9	20	26	14	26	19	25.5	25.5	5	6	5	-0.5	Amde 3	0	0	0	0	0	
27	16	12.7	6	20	18	11	18	10	21	21	1	3	-1	3	Caer 3	0	0	0	0	0	
28	11.95	14.05	7	14	18	8	18	13	18	18	8	0	5	0	0	0	0	0	0	0	
29	10.83	13.85	8	20	20	7	20	15	20	20	8	0	8	0	2	0	0	0	0	0	
30	9.6	15.4	2	10	10	2	10	10	19	19	2	10	-2	-10		0	0	0	0	0	
31	9.95	14.25	8	17	17	8	17	10	19	19	10	2	2	2	1	0	0	0	0	0	
32	10.5	13.15	16	29.5	29.5	16	29.5	18	34.5	34.5	18	34.5	2	5	1	0	0	0	0	0	
33	9.5	10.6	8	17	17	8	17	10	19	19	10	2	2	2	1	0	0	0	0	0	
34	15	19.6	15	19.6	19.6	8	19.6	8	11	11	8	11	8	11	1	0	0	0	0	0	
35	23.5	8.88	3	8	8	3	8	3	8	8	3	8	3	8	2	0	0	0	0	0	
36	24.78	10.17	4	12	12	4	12	4	12	12	4	12	4	12	Jacu 3	0	0	0	0	0	
37	27.43	9.9	3	14	14	3	14	3	14	14	3	14	3	14	1	0	0	0	0	0	
38	29	10	10	20	20	10	20	10	20	20	10	20	10	20	1	0	0	0	0	0	
39	10.75	14.3	3	12	12	3	12	3	12	12	3	12	3	12	1	0	0	0	0	0	

**Appendix 1-2**  
**Special-status Plants Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Growth and Reproduction Data Form for**  
***Acuña Cactus (Echinomastus erectocentrus var. acunensis)***

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



**Appendix 1-3**  
**Special-status Plants Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Growth Data Form for**  
**Senita Cactus (*Lophocereus schottii*)**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



**Appendix 1-4**  
**Special-status Plants Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Growth and Reproduction Data Form for**  
**Dahlia Rooted Cactus (*Peniocereus striatus*)**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



Appendix 1-5

**Special-status Plants Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Growth and Reproduction Data Form for  
Desert Caper (*Atamisquea emarginata*)**

In August 1990, 30 desert caper plants were mapped, marked, and measured. These are indicated on the aerial map overlay of the Aguajita Wash area. The plants are monitored using the following growth and reproduction data form. Reproductive condition should be recorded as in flower, fruit, or both. Nurse plant associations should list the nurse species using the first two letters of the genus and species.

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



Appendix 1-6  
**Special-status Plants Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Growth Data Form for  
Ashy Jatropha (*Jatropha cinerea*)**

Ashy jatropha plants are monitored using the following growth data form. Number of stems should be recorded in categories of 1–10, 11–20, and > 20. Record actual number of stems if < 10. Plant locations relative to a wash and/or a nurse plant should be denoted using 0 or 1, where 0 = away from wash or in the open, and 1 = in/next to a wash or under a nurse plant.

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



Appendix 1-7  
**Special-status Plants Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Plant Species Taxa**

The following index cross-references scientific taxa with common names for the special-status and other plant species named in this report. Special-status species are indicated by the symbol ▲.

**Index**

—A—

ACUÑA CACTUS ▲—*Echinomastus erectocentrus* var. *acunensis*  
*Ambrosia* spp.—BURSAGE  
*Ambrosia deltoidea*—BURROBUSH  
*Atamisquea emarginata* ▲—DESERT CAPER  
*Atriplex* spp.—SALTBUSH

—B—

BURROBUSH—*Ambrosia deltoidea*  
BURSAGE—*Ambrosia* spp.

—C—

CAPER, DESERT ▲—*Atamisquea emarginata*  
*Carnegiea gigantea*—SAGUARO  
*Cercidium* spp.—PALOVERDE  
CREOSOTEBUSH—*Larrea divaricata*

—D—

DAHLIA ROOTED CACTUS ▲—*Peniocereus striatus*  
DESERT IRONWOOD—*Olneya tesota*

—E—

*Echinocereus* spp.—HEDGEHOG CACTUS  
*Echinomastus erectocentrus* var. *acunensis* ▲—ACUÑA CACTUS  
*Ephedra aspera*—JOINT FIR

—F—

FISHHOOK CACTUS—*Mammillaria* spp.  
*Fouquieria splendens*—OCOTILLO

—H—

HEDGEHOG CACTUS—*Echinocereus* spp.

—J—

JATROPHA, ASHY ▲—*Jatropha cinerea*  
JATROPHA, WEDGE-SHAPED—*Jatropha cuneata*  
*Jatropha cardiophylla*—LIMBERBUSH  
*Jatropha cinerea* ▲—JATROPHA, ASHY  
*Jatropha cuneata*—WEDGE-SHAPED JATROPHA  
JOINT FIR—*Ephedra aspera*

—L—

*Larrea divaricata*—CREOSOTEBUSH  
LIMBERBUSH—*Jatropha cardiophylla*  
*Lophocereus schotti* ▲—SENITA CACTUS  
*Lycium* spp.—WOLFBERRY

—M—

*Mammillaria* spp.—FISHHOOK CACTUS  
MESQUITE—*Prosopis* spp.  
MEXICAN-JUMPING-BEAN—*Sapium biloculare*

—O—

OCOTILLO—*Fouquieria splendens*  
*Olneya tesota*—DESERT IRONWOOD  
ORGAN PIPE CACTUS ▲—*Stenocereus thurberi*

—P—

PALOVERDE—*Cercidium* spp.  
*Peniocereus striatus* ▲—DAHLIA ROOTED CACTUS  
*Prosopis* spp.—MESQUITE

—S—

SAGUARO—*Carnegiea gigantea*  
SALTBUSH—*Atriplex* spp.  
*Sapium biloculare*—MEXICAN-JUMPING-BEAN  
SENITA CACTUS ▲—*Lophocereus schotti*  
*Stenocereus thurberi* ▲—ORGAN PIPE CACTUS

—W—

WOLFBERRY—*Lycium* spp.



# Vegetation Structure and Diversity in Natural Communities Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Charles H. Lowe  
Elizabeth B. Wirt  
Philip C. Rosen

Department of Ecology and Evolutionary Biology  
Biological Sciences East, Room 123  
The University of Arizona  
Tucson, Arizona 85721

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## Executive Summary

The datasets obtained in the vegetation project are intended to serve as one of the important integrative links between sub-projects in the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument (ORPI), Arizona. To realize that objective, the research focuses on specific vegetation parameters.

The following parameters—for community composition, structure, and diversity—are measured at the permanent vegetation quadrats established at the EMP sites (below):

1. Presence—species occurrence.
2. Density—number of individuals of each species.
3. Frequency—percent of subquadrats (below) occupied by each species.
4. Coverage—line intercept area occupied by each species.
5. Diversity—species richness and H' species diversity for each quadrat.

At the time of the initial study, in 1988, 15 EMP sites were established. One site, Neolloydia (1 plot), was dropped from long-term monitoring projects because of possible impacts on rare cactus species. In the earlier 1990s, 2 additional sites were added: Pozo Nuevo (1 plot) and Lower Colorado Larrea (1 plot). Then, in 1995, 2 more sites were added to the program: Middle Bajada (2 plots) and Valley Floor (2 plots). In total, there are 18 active EMP sites and 30 plots at the time of this writing:

1. Aguajita Wash	3 plots	10. Growler Canyon	2 plots
2. Alamo Canyon	1 plot	11. Lost Cabin Mine	1 plot
3. Arch Canyon	2 plots	12. Lower Colorado Larrea	1 plot
4. Armenta Ranch	2 plots	13. Middle Bajada	2 plots
5. Bull Pasture	2 plots	14. Pozo Nuevo	1 plot
6. Burn Site	1 plot	15. Salsola Site	1 plot
7. Dos Lomitas	2 plots	16. Senita Basin	2 plots
8. Dripping Springs	1 plot	17. Valley Floor	2 plots
9. East Armenta	2 plots	18. Vulture Site	2 plots

Within these sites, presence, density, frequency, and diversity for the perennial plant species are obtained from subdivided, 0.1-ha (0.25-a.) permanent quadrats, established with 3-4-5 (90°) corners. A minimum of 2 measurement time-points have been obtained for the ephemeral vegetation from 4, 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats within each of the 0.1-ha (0.25-a.) perennial species quadrats. In the initial study, measurements were taken for the late winter-early spring season with regard to winter precipitation, and the summer season with regard to summer precipitation. Precision for successive time-point measurements on the same stand—as in the long-range monitoring program—is made possible by the initial establishment of permanent quadrats.

A plant voucher collection representative of the species found during the initial work on-quadrat has been assembled for storage in the ORPI herbarium. This voucher collection affirms taxa identities for the long-range monitoring program.

Community change across ecological time will be obtained as a natural by-product of the successive time-point recordings for the status of the vegetation stand. The analysis of vegetation change over ecological time will be further assisted by repeat photography at permanent photopoints, also established during the initial study.

For each vegetation quadrat, slope angle was determined by Abney level, directional exposure (aspect) by compass, elevation by topographic quadrangle, and soil texture was determined by mechanical analysis.

Quadrat permanency is assisted by deep (12 in. and 18 in. [30 cm and 46 cm]) rebar corners, with stamped metal identification tags wired to each corner rebar. Quadrat permanency is further ensured by the repeat photography. In 1991, double sets of color transparencies and black and white photographs were obtained, with 1 complete set of each for deposit at ORPI.

During the period of study (1988–1991), 31 plant species new to the known flora of ORPI were collected and deposited in The University of Arizona Herbarium (ARIZ). These new-to-ORPI taxa are documented in the appendices.

In the future long-range monitoring program on site, quantitative data for the set of community parameters given (above) will 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.

## Introduction

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 quadrats (plots) at each of the specified sites. The initial fieldwork was conducted during 1988–1991. The measurements for these physical environmental parameters are relevant to interpretation of vegetation patterns, and to the distribution patterns of other organisms. They are anticipated to play an important role in overall EMP project integration.

### Vegetation Data

The specified vegetation parameters designated and measured for the perennial plant taxa are presence (providing species richness), density, frequency, coverage, and diversity. For ephemeral plant taxa, presence and density are measured within 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats within the 0.1-ha (0.25-a.) quadrats for perennials.

### Soil Texture Data

One soil sample was collected at each 0.1-ha (0.25-a.) vegetation quadrat. Aliquot samples for mechanical analysis of soil texture were obtained from small trenches dug at 5-cm (1.96-in.) intervals to 25.0-cm (9.8-in.) depth on each of the original 26, 0.1-ha (0.25-a.) quadrats represented in the original 16 EMP sites. These samples were taken from along one of the outside 50-m (164-ft) quadrat lines, near the midpoint and directly in front of the photopoint for the cross-plot photograph. The soil-sample trench site is indicated in the photopoint photograph by a short range pole.

Prior to initiating the sample, any superficial veneer of gravel or debris < 1–2 mm (0.04–0.08 in.) thick was lightly brushed away. Trenches were not dug where boulders or very large rocks impinged on the trench; in general, rocks > 6 cm (2.36 in.) were not included in the sample. Mechanical analysis by soil screens sorted each sample into 3 fractions: silt and clay of < 0.2 mm (0.007 in.); coarse sand of 0.2–2.0 mm (0.007–0.07 in.); and rock and gravel of > 2.0 mm (0.07 in.). Data determined from this initial, one-time sampling may be found in Table 2-1.

### Elevation, Aspect, and Slope Information

Elevations given are as read from U.S. Geological Survey (USGS) topographic maps. Aspect was determined with a compass for the direction used to measure slope. Slope was measured as percent gradient along the slope trend direction for each plot, using an Abney level. Data determined from these initial, one-time assessments may be found in Table 2-2.

Table 2-1. Soil texture for soil samples taken from the 26 Vegetation Structure and Diversity monitoring quadrats representing the original 16 Ecological Monitoring Program (EMP) sites in Organ Pipe Cactus National Monument, Arizona. Soil texture is fractioned into the 3 categories (1) rock and gravel, comprised of soil measuring > 2.0 mm (0.07 in.); (2) sand—coarse sand—comprised of soil measuring 0.2–2.0 mm (0.007–0.07 in.); and (3) silt and clay—fine sand, silt, clay, and colloid—comprised of soil measuring < 0.2 mm (0.007 in.).

EMP site and vegetation quadrat		Soil texture		
		Rock and gravel (%)	Sand (%)	Silt and clay (%)
Aguajita Wash	VG01	11.6	83.0	5.4
	VG02	10.0	24.4	65.6
	VG03	18.4	26.0	55.6
Alamo Canyon	VG01	26.5	25.6	47.8
Arch Canyon	VG01	50.0	15.6	34.4
	VG02	60.3	12.7	27.0
Armenta Ranch	VG01	0.9	12.8	86.2
	VG02	13.5	21.2	65.3
Bull Pasture	VG01	58.6	15.7	25.7
	VG02	50.7	13.5	35.8
Burn Site	VG01	20.2	33.0	46.9
Dos Lomitas	VG01	16.7	35.8	47.5
	VG02	17.9	16.9	65.2
Dripping Springs	VG01	66.1	17.9	16.0
East Armenta	VG01	20.2	36.1	43.7
	VG02	12.1	51.1	36.8
Growler Canyon	VG01	5.0	45.8	49.2
	VG02	0.0	5.2	94.8
Lost Cabin Mine	VG01	59.0	17.3	23.9
Middle Bajada	VG01	N/A	N/A	N/A
	VG02	N/A	N/A	N/A
Neolloydia Site (inactive)	VG01	54.5	21.1	24.4
Pozo Nuevo	VG01	7.6	18.8	73.5
Salsola Site	VG01	0.6	5.9	93.5
Senita Basin	VG01	38.4	43.1	18.5
	VG02	75.2	20.7	4.1
Valley Floor	VG01	N/A	N/A	N/A
	VG02	N/A	N/A	N/A
Vulture Site	VG01	29.4	25.8	44.8
	VG02	14.5	24.6	61.0

Table 2-2. Elevation, aspect, and slope information for the 26 Vegetation Structure and Diversity monitoring quadrats representing the original 16 Ecological Monitoring Program (EMP) sites in Organ Pipe Cactus National Monument, Arizona. Elevations given are as read from U.S. Geological Survey (USGS) topographic maps.

EMP site and vegetation quadrat	Elevation	Aspect	Slope (%)	
Aguajita Wash	VG01	348 m (1,142 ft)	ca. level	1.4
	VG02	348 m (1,142 ft)	ca. level	1.8
	VG03	348 m (1,142 ft)	ca. level	1.4
Alamo Canyon	VG01	732 m (2,400 ft)	NW-facing	5.8
Arch Canyon	VG01	915 m (3,000 ft)	N-facing	32.0
	VG02	884 m (2,900 ft)	S-facing	40.0
Armenta Ranch	VG01	477 m (1,565 ft)	ca. level	0.2
	VG02	477 m (1,565 ft)	ca. level	0.1
Bull Pasture	VG01	960 m (3,150 ft)	N-facing	17.0
	VG02	960 m (3,150 ft)	NE-NW-facing	31.0, 36.0
Burn Site	VG01	424 m (1,392 ft)	ca. level	1.4
Dos Lomitas	VG01	427 m (1,400 ft)	ca. level	0.1
	VG02	427 m (1,400 ft)	ca. level	0.5
Dripping Springs	VG01	610 m (2,000 ft)	NW-facing	35.0
East Armenta	VG01	524 m (1,720 ft)	ca. level	1.0
	VG02	524 m (1,720 ft)	ca. level	0.7
Growler Canyon	VG01	418 m (1,370 ft)	ca. level	1.6
	VG02	418 m (1,370 ft)	ca. level	2.0
Lost Cabin Mine	VG01	487 m (1,598 ft)	S-facing	26.0
Middle Bajada	VG01	N/A	N/A	N/A
	VG02	N/A	N/A	N/A
Neolloydia Site (inactive)	VG01	488 m (1,600 ft)	W-facing	6.0
Pozo Nuevo	VG01	378 m (1,240 ft)	ca. level	1.7
Salsola Site	VG01	451 m (1,480 ft)	ca. level	0.2
Senita Basin	VG01	508 m (1,665 ft)	ca. level	1.0
	VG02	532 m (1,745 ft)	NW-facing	49.0
Valley Floor	VG01	N/A	N/A	N/A
	VG02	N/A	N/A	N/A
Vulture Site	VG01	404 m (1,325 ft)	ca. level	1.8
	VG02	404 m (1,325 ft)	ca. level	1.9

## Additional Information

To assist monument personnel in the vegetation monitoring program, here is provided additional information involving floristic aspects of the vegetation project.

There is a large taxonomic burden involved in any vegetation study that has the scope of this one at ORPI. Therefore, for clarity and simplicity, there is also provided an annotated index of plant taxa wherein all perennials and ephemerals are listed that were encountered in various phases of the initial study. In the index, both current and earlier plant names are provided to assist with the overall nomenclatural problem in future monitoring. This additional information is included as:

- Appendix 2-1: Perennial Plant Taxa in Quadrats, Listed by Family
- Appendix 2-2: Ephemeral Plant Taxa in Quadrats, Listed by Family
- Appendix 2-3: Plant Taxa New to the Monument
- Appendix 2-4: Bonus Plants for the Herbarium
- Appendix 2-5: Conspicuous Plant Taxa Off-plot
- Appendix 2-6: Cross-referenced Index of Plant Taxa

## A Few Words of Explanation

In distinguishing between flora and vegetation, the first refers to species, while the latter refers to structure. The flora of a given area is all of the species in that area. The species list for that area therefore represents the flora; that list is referred to as the flora (or a flora) of that area. On the flora species-name list, blue grama (*Bouteloua gracilis*) is a grass. Grass is a vegetation name, not a species name; it refers to the physiognomy (structure) of the individual plant (grass; or shrub, tree, vine, etc.). Grassland is the vegetation (structural) term that refers to the community of grass plants in which the individuals of blue grama and other grasses live. Thus, the grassland flora includes species of grasses that form the grassland vegetation structure—the grassland. For animals, the term fauna is not complimented by a physiognomic term equivalent to vegetation.

Plants are either ephemeral or perennial in life form (growth form; “habit”). Here we use the terms lifeform and growth form interchangeably, rather than restricting “lifeform” to the Raunkiaeran categories.

The term ephemeral refers to taxa with so-called “annual habit.” Ephemeral is used here rather than “annual” for various reasons. While all “annuals” are ephemeral, some “annuals” are not annual. Some are biennial, annual, or both, as with desert senna (*Cassia covesi*). Some are biennial, triennial, or more, as with desert tobacco (*Nicotiana trigonophylla*). Moreover, annual herbaceous growth alone does not guarantee that the plant is an “annual” (i.e., ephemeral) species. For some true perennials as well, have herbaceous annual growth.

Not all perennials are long-lived woody shrubs and subshrubs, trees, vines, and cacti. Several of the perennial taxa are root-perennials, such as desert windflower (*Anemone tuberosa*), bluedicks (*Dichelostemma pulchellum*), and barestem larkspur (*Delphinium scaposum*). Because their growth is herbaceous, root-perennials are also referred to as perennial herbs and herbaceous perennials.

Accordingly, there is commonly some initial confusion on ephemeral vs perennial. In any event, unless plant identification and growthform are already securely known, the root should be obtained with the voucher shoot to assist both taxon identification and correct reference to the perennial or ephemeral list.

In these protocols, ssp. (for subspecies) replaces var. (for variety). Subspecies are races; they are distinct races that are formally described as subspecies in the technical systematic literature. While many of the varieties (vars.) of plants are subspecies, many are not. Those varieties that are not subspecies in nature are artificial “greenhouse and garden” plants that are also called varieties when they receive names given by horticulturists and others.

The endings of species names that are personal names (patronyms) may end with a single -i or a double -i (-ii) when it is the name of a man. It is the intention of the code that a new species name that is formed from a modern personal name of masculine gender should usually end in -i. In the case of double -i (-ii) in this report, the second -i is deleted. All such names are, of course, fully recognizable, whether with an -i or -ii suffix. The principal reason for the procedure here of dropping the second -i, is removal of the spoken confusion in attempting to pronounce the species name, the man’s name. For many workers, this -ii pronunciation adds to the general difficulty of, and discouragement in, learning the plant nomenclature involved in the project.

The majority of the plant names used, all of which are in Appendix 2-6, will be found in Kearney and Peebles (1960), Lehr (1978), and in Bowers (1980, 1982) who followed Lehr (1978). The illustrated volume on desert trees and shrubs by Benson and Darrow (1981) is another helpful reference. In Appendix 2-6, both current and earlier names (synonymy) are provided.

Names for cacti follow Felger (1991). Some recent name changes for plant taxa are given in Rondeau et al. (1991). Pinkava et al. (1992), reporting 52 new plant taxa to the known ORPI flora, was referred to regarding 31 additional taxa in the present study that are new to the ORPI flora (see Appendix 2-3). The binomial for creosotebush, *Larrea divaricata* Cav. (for *Larrea tridentata* [D.C.] Coville), follows Felger and Lowe (1970); for the Ajo oak, *Quercus turbinella* Greene ssp. *ajoensis* C. H. Muell (for *Quercus ajoensis* C. H. Muell), follows Lowe and Felger (unpublished MS).

## Methods for Vegetation and Flora

### Personnel, Materials, and Scheduling Requirements

Successful vegetation monitoring requires attention to personnel, material and equipment, and schedule needs.

#### *Personnel Required for Monitoring*

We recommend that no more than 2 field workers monitor the plots, in respect of ecological impact. The work can be completed more quickly with 3 or 4 workers, however, in such case, field staff must be extremely attentive and careful to walk around the plot to avoid disturbing plants or soil.

#### *Materials Required for Monitoring*

Materials required for, but not limited to, successful monitoring include:

(3) 100-m (328-ft) metric measuring tapes (for laying out 50-m [164-ft] plot boundary and intersect lines)

(6) 30-m (98-ft) metric measuring tapes (for laying out 20-m [66-ft] plot boundary and intersect lines)

(14) Chaining pins (for holding ends of tapes taut)

(4) Range poles (to delineate the corners of the quadrat during rephotographic monitoring)

(1) 35-mm camera (for rephotographic monitoring)

Kodachrome 64 slide film and Pan-X 125 black and white print film (for rephotographic monitoring)

Plant notebooks (for collecting specimens of unknown plants for identification in herbarium)

Field data forms

Field notebooks (for holding data forms, protocols, appendices, and other information)

Copies of completed data forms from past monitoring (for supplying names of species that have occurred on the quadrat)

#### *Perennial Plant Monitoring Schedule*

The Vegetation Structure and Diversity final report recommended that the permanent vegetation monitoring plots should be reread in 1994–1995, approximately 5 yr after the initial readings. Thereafter, the recommended interval for monitoring is every 10 yr. Plots should not be monitored more frequently than in 5-yr intervals because of possible impacts. Monitoring should

be staggered, with 2–3 plots read per year on a 10-yr cycle, or 5–6 plots read per year (in alternate years) on a 10-yr cycle. A staggered schedule will provide continuity in the work.

With these recommendations in mind, the resource management staff devised an appropriate schedule for perennial plant monitoring (Table 2-3). During the first 10-yr cycle, a few plots will necessarily be read at less than a 5-yr interval, in order to achieve optimum monitoring continuity.

### **Data Measurement Parameters**

The following parameters are measured for perennial taxa in the 0.1-ha (0.25-a.) quadrats (Fig. 2-1). In addition, density (N) and species richness (S) are measured for ephemerals (annuals, biennials, et al.) in 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats within the 0.1-ha (0.25-a.) perennial quadrats. The data generated for these parameters constitute the basic data set in the vegetation project.

1. Presence (P) is the measure of species present; equivalent to species richness (S), number 4 below.
2. Density (N) is the number of individuals per unit area. In this study, the unit area is a 0.1-ha (0.25-a.) quadrat for perennial plants, and a 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrat for ephemerals. Accuracy in making the count for density for a given perennial species in the 0.1-ha (0.25-a.) quadrat is aided by separate counts for all of the individuals present in (rooted in, only) each of the 10 subquadrats (see below), and then summing for the 10.

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

3. Frequency, in percentage (10-100%), for a given species is determined by the number of subquadrats occupied by 1 or more individuals of the species rooted in the subquadrat(s). If a species occurs in (is rooted in) 3 of 10 subquadrats, it has a frequency of 30% for that 0.1-ha (0.25-a.) quadrat.

Table 2-3. Perennial plant monitoring schedule for the Vegetation Structure and Diversity monitoring project in the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument, Arizona. Note that Neolloydia Site has been dropped from this original EMP schedule to avoid further ecological impact caused by monitoring.

Monitoring year	EMP monitoring site (number of plots)			
1994	Aguajita Wash	(3)	Dos Lomitas	(2)
	Alamo Canyon	(1)	East Armenta	(2)
	Bull Pasture	(2)	Pozo Nuevo	(1)
	Burn Site	(1)	Vulture Site	(2)
1995	Arch Canyon	(2)	Middle Bajada	(2)
	Armenta Ranch	(2)	Neolloydia Site (inactive)	(0)
	Dripping Springs	(1)	Salsola Site	(1)
	Growler Canyon	(2)	Senita Basin	(2)
	Lost Cabin Mine	(1)	Valley Floor	(2)
1996	East Armenta	(2)		
1997	Burn Site	(1)	Pozo Nuevo	(1)
	Lower Colorado Larrea	(1)		
1998	Dos Lomitas	(2)		
1999	Alamo Canyon	(1)	Bull Pasture	(2)
2000	Aguajita Wash	(3)		
2001	Salsola Site	(1)	Vulture Site	(2)
	Valley Floor	(2)		
2002	Lost Cabin Mine	(1)	Senita Basin	(2)
	Middle Bajada	(2)		
2003	Armenta Ranch	(2)	Salsola Site	(1)
2004	Growler Canyon	(2)		
2005	Arch Canyon	(2)	Dripping Springs	(1)

Following the year 2005, this 10-yr cycle will be repeated for as long as funding and personnel resources are available.

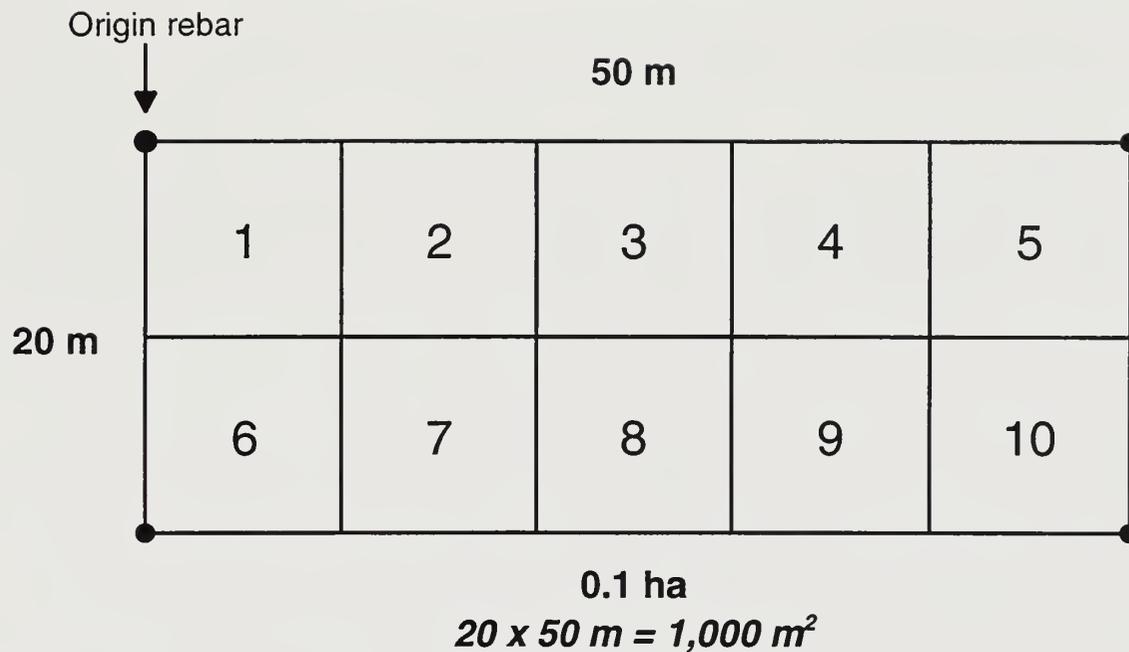


Figure 2-1. The permanent 0.1-ha (0.25-a.) quadrat (plot) with 10, 100-m<sup>2</sup> (1,076-ft<sup>2</sup>) subquadrats and 4 rebar corners, in the Vegetation Structure and Diversity Project in the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument, Arizona. The quadrat origin (rebar) is at a NW or NE corner of each of the 26 quadrats, with the exceptions of a SW origin for Alamo Canyon plot VG01 and a SE origin for Senita Basin plot VG01.

4. Coverage (% Cover) of perennial plants is measured by the line-intercept method (Canfield 1941). In line-intercept, the distances (lengths) of the plant crowns that intercept a straight line of meter tape are recorded. The lines of meter tape used in the line-intercept measurements are the three 50-m (164-ft) tapes and the 2, outside 20-m (66-ft) tapes. These tapes are laid out as the outside boundaries of the 0.1-ha (0.25-a.) quadrat, and as the 50-m (164-ft) tape that bisects the plot along its centerline. The line distance used is thus 190 m (623 ft).

For a given species, the percent calculated from the sum of its crown interception distances (= interception lengths) divided by the total line length (= 190 m [623 ft]) yields the species coverage percent. The sum total meters of distance for all crown interceptions of all species divided by total line length yields the community coverage percent.

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.) quadrat (for perennial taxa) or the 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats (for ephemeral taxa). Species richness (S) = species presence (P).

6. Species diversity ( $H'$ ) is:

$$H' = - \text{SUM} (p_i * \ln[p_i])$$

where  $p_i$  is, for each species  $i$ , the numerical proportion of that species abundance ( $N_i$ , density) to the total abundance of all plants in the quadrat or sample, and  $\ln$  is the natural logarithm. This measure of species diversity 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.

### Instructions for Laying Out the Quadrats and Subquadrats

Quadrat locations were selected to be representative of each EMP site. When an EMP site encompassed important heterogeneous vegetation, two or three 0.1-ha (0.25-a.) quadrats were established there, 1 for each primary vegetation type.

Quadrat and subquadrat boundaries can be accurately laid out in the following steps:

1. Using the directions and diagrammatics, locate the vegetation quadrat rebars. Each 20- x 50-m (66- x 164-ft) plot has an origin rebar at the NW or NE corner. Note: the origin rebar for Alamo Canyon plot VG 01 is on the SW corner, while that for Senita Basin plot VG 01 is on the SE corner. Additionally, each corner rebar is tagged with an EMP site acronym, year the baseline vegetation data was collected, and the quadrat number (01, 02, or 03) within the EMP site.
2. Stretch a 50-m (164-ft) tape straight along the ground from the origin to the parallel, opposite rebar.
3. Similarly delineate the rest of the perimeter by stretching a second 50-m (164-ft) tape straight along the ground from the rebar perpendicularly opposite of the origin to the rebar diagonally opposite. Complete the quadrat boundaries by laying the 2, 20-m (66-m) tapes across adjacent rebars.
4. To establish the interior, subquadrat boundaries, run a 50-m (164-ft) tape from the 10-m (33-ft) mark on 1, 20-m (66-ft) tape across to the 10-m (33-ft) mark on the opposite 20-m (66-ft) tape. Four 20-m (66-ft) tapes can then be run across the rectangle and at 10-m (33-ft) intervals to form the 10 subquadrats (Fig. 2-1). (If not enough tapes are available to form all of the subquadrats at once, simply "leapfrog" the tapes down the plot as each pair of subquadrats are finished being read.) All tapes should be laid straight and as close to the ground as possible.

### Detailed Criteria for Identifying and Counting Perennial Vegetation

In 1994, Rosen prepared the following addendum to the Vegetation Structure and Diversity final report. This addendum states that the guiding principle for deciding which plants to count must be to (1) make clear decisions using common sense and (2) provide a repeatable reading via clear

and precise notes to accompany the data forms and photographs. Therefore, the following criteria must be followed with care in order to assure both the data integrity and value of long-term, continuous monitoring.

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 (*Hilaria rigida*) are sometimes difficult to count because of a common base of numerous stems and a continuous crown. Species with overlapping crowns ( $\geq 15\%$  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 (*Opuntia 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 quadrat. Measure line-intercept based on the living part of the plant only.

7. It is important to look carefully for smaller plants concealed under the crowns of larger species, such as with fishhook cacti (*Mammalaria* spp.) and cenizo (*Atriplex canescens*).
8. If a plant cannot be identified in the field, collect a sample in a plant press notebook and assign it a number (e.g., UNK 1). Until a correct identification is made, this number must then be referred to consistently by all field workers in their counts.
9. Once counting on the quadrat is completed, line-intercept coverages along the perimeter lines and middle bisecting 50 m (190 m total) (164 ft, 623 ft total) are then calculated.
10. At the completion of each quadrat, all field workers' subquadrat counts are transferred from their field notebooks to the data form. Note the location of the origin corner (NE, NW, SW, or SE).

### **Detailed Criteria for Identifying and Counting Ephemeral Vegetation**

Although the Vegetation Structure and Diversity final report recommends annual readings for both summer and winter ephemeral taxa, time constraints and personnel have only allowed monitoring of a few sites in the spring of 1993. If, in future, personnel are available, more ephemeral monitoring can be accomplished.

The following criteria should be considered when monitoring within the ephemeral vegetation subplots:

1. Depending upon rainfall, winter ephemeral readings should be taken in the first half of March, while summer readings should be completed during the month of August.
2. Ephemeral taxa are counted for density in 4, 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats located in each 0.1-ha (0.25-a.) perennial quadrat. The 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrat frames are positioned at 4 points in the 0.1-ha (0.25-a.) quadrat (a) where ephemerals are most abundant, (b) where ephemerals are least abundant, and (c) at 2 intermediate points.

This quadrat layout design for ephemerals was appropriate for the relatively poor showing of ephemeral taxa during the drought period that coincided with the initial fieldwork, and should be the continuing, ongoing monitoring design.

### **Collecting Plant Vouchers**

Plant voucher specimens should be collected and preserved in the field in standard plant presses with newspaper, blotters, and separators. During the initial study, a full set of field vouchers was prepared for the ORPI herbarium. A partial set of vouchers, including those taxa new to the known ORPI flora, was prepared for ARIZ. Only a partial set was deposited there, because the herbarium currently does not have storage space for additional material of the locally common taxa.

## **Locating and Utilizing the Photopoints**

At the time of soil sampling, permanent photopoints were established for rephotography at each 0.1-ha (0.25-a.) quadrat. Each plot contains a pair of permanently marked photopoints for rephotographic monitoring. Rephotography provides direct, visual comparison in the long term of current conditions against historic conditions; especially when compared to baseline photographs taken during the initial study. Such comparative photography complements the direct vegetation measurements read from the quadrats.

Each of the pair of photopoints for each vegetation quadrat is permanently marked with a steel pipe of 2.5-cm (1.0-in.) diameter, which has a circular brass tag labelled "PH 91, sitename." In the baseline photographs, tall range poles mark the plot corners, tape measures show the plot borders, and short range poles indicate the soil sample site. Kodachrome 64 slides and Pan-X 125 black-and-white prints were shot at each photopoint. Duplicate sets of these photographs were processed, one for storage at ORPI, and one for The University of Arizona.

Perform rephotographic monitoring in the following manner:

1. Locate the photopoints, hold range poles up at each quadrat corner, and photograph.

## **Data Management**

Once fieldwork is completed, the following procedures will assure accurate and valuable management of data:

1. Clarify and summarize all notes concerning which plants were counted, as well as the procedures and factors involved in questionable counts. Attach these notes to the data forms. Also attach photographs once they have been developed, if needed.
2. Once developed, label photopoint slides and prints, then place them in photographic sleeves to file with the data forms.
3. For the annual report, calculate density (N), frequency (%), species coverage percent from the line-intercept readings, species richness (S), and species diversity (H'). For more detailed instruction, see the previous section, Data Measurement Parameters.

## Literature Cited

- Benson, L. D. 1977. The cacti of Arizona. The University of Arizona Press, Tucson.
- Benson, L. D., and R. A. Darrow. 1981. Trees and shrubs of the southwestern deserts. The University of Arizona Press, Tucson. 416 p.
- Bowers, J. E. 1980. Flora of Organ Pipe Cactus National Monument. *Journal of the Arizona-Nevada Academy of Sciences*, 15:1-11, 33-47.
- Bowers, J. E. 1982. Checklist of vascular plants of Organ Pipe Cactus National Monument, Arizona. Southwest Parks and Monuments Association, Tucson, Arizona. 45 p.
- Brown, B. T., L. P. Hendrickson, R. R. Johnson, and W. Werrell. 1983. Technical Report no. 10. An inventory of surface water resources at Organ Pipe Cactus National Monument. National Park Service Cooperative Park Studies Unit, The University of Arizona. 97 p.
- Canfield, R. H. 1941. Application of the line intercept method in sampling range vegetation. *Journal of Forestry* 39:288-394.
- Felger, R. S. 1991. Cacti of Organ Pipe Cactus National Monument. Organ Pipe Cactus National Monument, File Report. 4 p.
- Felger, R. S., and C. H. Lowe. 1970. New combinations of plant taxa in northwestern Mexico and southwestern United States. *Journal of Arizona Academy of Sciences* 6:82-84.
- Kearney, T. H., R. H. Peebles, and collaborators. 1960. Arizona flora. University of California Press, Berkeley. 1,085 p.
- Lehr, J. H. 1978. A catalog of the flora of Arizona. Desert Botanical Garden, Phoenix, Arizona. 203 p.
- Pinkava, D. J., M. A. Baker, R. A. Johnson, N. Trushell, G. A. Ruffner, R. S. Felger, and R. K. Van Devender. 1992. Additions, notes and chromosome numbers for the flora of vascular plants of Organ Pipe Cactus National Monument, Arizona. *Journal of Arizona-Nevada Academy of Sciences* 24-25:13-18.
- Rondeau, R., T. R. Van Devender, P. D. Jenkins, R. K. Van Devender, and C. D. Bertelson. 1991. Annotated checklist of vascular plants of the Tucson Mountains, Pima Co., Arizona. Unpublished manuscript.

Appendix 2-1  
**Vegetation Structure and Diversity in Natural Communities  
 Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monumnet, Arizona:  
 Perennial Plant Taxa in Quadrats, Listed by Family**

The following lists perennial plant taxa found in the Ecological Monitoring Program (EMP) vegetation quadrats at Organ Pipe Cactus National Monument, Arizona (ORPI). (Ephemeral [annual/biennial and facultative biennial] plant taxa are listed in Appendix 2-2.)

The common name and taxonomy for each plant are given, and its presence on 1 or more of the monitoring sites is indicated by key abbreviations (see footnote):

**Acanthaceae: Acanthus Family**

*Anisacanthus thurberi*—CHUPAROSA—AC, AY, BP  
*Carlowrightia arizonica*—ARIZONA CARLOWRIGHTIA—AY, DS  
*Justicia californica*—CHUPAROSA—AC, SB  
*Justicia candicans*—CHUPAROSA—AC  
*Siphonaglossa longiflora*—SIPHONAGLOSSA—BP, DS

**Adiantaceae: Fern Family**

*Cheilanthes wootoni*—BEADED LIP FERN—AC  
*Cheilanthes wrightii*—WRIGHT'S LIP FERN—AY, BP  
*Notholaena cochinchinensis*—HELECHILLO—LC  
*Notholaena sinuata*—WAVY CLOAK FERN—AC, AY, BP  
*Notholaena standleyi*—CLOAK FERN—AY, BP, DS, LC, SB  
*Pellaea truncata*—CLIFF BRAKE—AY  
*Pityrogramma triangularis*—GOLD FERN—AC, AY

**Agavaceae: Agave Family**

*Agave deserti*—DESERT AGAVE—BP, DS  
*Agave schottii*—CENTURY PLANT—BP

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*Monitoring site abbreviation key (please note that Neolloydia Site is inactive):*

AC = Alamo Canyon	DL = Dos Lomitas	NS = Neolloydia Site
AR = Armenta Ranch	DS = Dripping Springs	PN = Pozo Nuevo
AW = Aguajita Wash	EA = East Armenta	SB = Senita Basin
AY = Arch Canyon	GC = Growler Canyon	SS = Salsola Site
BP = Bull Pasture	LC = Lost Cabin Mine	VS = Vulture Site
BS = Burn Site	LL = Lower Colorado Larrea	

**Apocynaceae: Dogbane Family**

*Haplophyton crooksi*—COCKROACH PLANT—AY

**Aristolochiaceae: Birthwort Family**

*Aristolochia watsoni*—INDIAN ROOT—AR, AW, DL, GC

**Asclepiadaceae: Milkweed Family**

*Cynanchum arizonicum*—ARIZONA VINE MILKWEED—BP

*Matelea parvifolia*—ANGLE POD—AY, BP

*Sarcostemma crispum*—CLIMBING MILKWEED—DL

*Sarcostemma cynanchoides*—CLIMBING MILKWEED—AW, GC

**Burseraceae: Torchwood Family**

*Bursera microphylla*—ELEPHANT TREE—LC, SB

**Buxaceae: Box Family**

*Simmondsia chinensis*—JOJOBA—AC, AY, BP, DS

**Cactaceae: Cactus Family**

*Carnegiea gigantea*—SAGUARO—AW, BP, BS, DL, DS, EA, NS, SB, VS

*Echinocereus engelmanni*—HEDGEHOG CACTUS—BP, BS, DL, EA, LC, SB, VS

*Echinocereus nicholi*—HEDGEHOG CACTUS—DS

*Echinomastus erectocentrus*—BARREL CACTUS—NS

*Ferocactus emoryi*—BARREL CACTUS—BP, DS

*Ferocactus cylindraceus*—BARREL CACTUS—LC

*Ferocactus wislizeni*—BARREL CACTUS—EA

*Lophocereus schottii*—SENITA CACTUS—SB

*Mammillaria grahami*—FISHHOOK CACTUS—AY, BP, DS, EA, LC, NS, SB

*Mammillaria thornberi*—FISHHOOK CACTUS—DL

*Opuntia acanthocarpa*—BUCKHORN CHOLLA—AW, BP, DL, DS, LC, NS, PN, SB

*Opuntia arbuscula*—PENCIL CHOLLA—EA

*Opuntia bigelovi*—TEDDY BEAR CHOLLA—NS

*Opuntia chlorotica*—PANCAKE PEAR—BP, DS

*Opuntia fulgida*—JUMPING CHOLLA—AW, DL, EA, VS

*Opuntia kunzei*—DEVIL CHOLLA—EA

*Opuntia leptocaulis*—CHRISTMAS CACTUS—AW, DL, EA, PN, VS

*Opuntia phaeacantha*—PRICKLY PEAR—BP, DS

*Opuntia spinosior*—STAGHORN CHOLLA—EA

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*Monitoring site abbreviation key (please note that Neolloydia Site is inactive):*

AC = Alamo Canyon

AR = Armenta Ranch

AW = Aguajita Wash

AY = Arch Canyon

BP = Bull Pasture

BS = Burn Site

DL = Dos Lomitas

DS = Dripping Springs

EA = East Armenta

GC = Growler Canyon

LC = Lost Cabin Mine

LL = Lower Colorado Larrea

NS = Neolloydia Site

PN = Pozo Nuevo

SB = Senita Basin

SS = Salsola Site

VS = Vulture Site

*Peniocereus greggi*—NIGHT-BLOOMING CACTUS—BS, DL  
*Stenocereus thurberi*—ORGAN PIPE CACTUS—DS, LC, SB

**Capparidaceae: Caper Family**

*Atamisquea emarginata*—DESERT CAPER—AW

**Chenopodiaceae: Goosefoot Family**

*Atriplex canescens*—CENIZO—AW, BS, DL, DS  
*Atriplex polycarpa*—ALLSCALE—AW, BS, DL

**Compositae (or Asteraceae): Sunflower Family (or Aster Family)**

*Acourtia wrightii*—BROWNFOOT—BP  
*Ambrosia ambrosioides*—CANYON RAGWEED—AC, AR, AW, AY, GC, SB, VS  
*Ambrosia confertiflora*—SLIMLEAF BURSAGE—AR, AW, DL, GC, SS  
*Ambrosia cordifolia*—RAGWEED—AC, AY  
*Ambrosia deltoidea*—BURROBUSH—AW, AY, BS, DL, DS, EA, LC, NS, PN, SB, VS  
*Ambrosia dumosa*—WHITE BURSAGE—EA, PN  
*Artemisia dracunculus*—WORMWOOD—AC  
*Artemisia ludoviciana*—SAGEBRUSH—AC, AY, BP  
*Baccharis sarothroides*—DESERT BROOM—AC, GC  
*Bebbia juncea*—SWEETBUSH—AW, SB, VS  
*Brickellia californica*—BRICKELLBUSH—AY  
*Brickellia coulteri*—BRICKELLBUSH—AC, AY, BP, DS, SB, VS  
*Dyssodia porophylloides*—SAN FELIPE DOGWEED—LC, SB  
*Encelia farinosa*—BRITTLEBUSH—AC, AW, AY, BP, DS, LC, SB, VS  
*Encelia frutescens*—RAYLESS ENCELIA—GC  
*Ericameria laricifolia*—TURPENTINEBUSH—AY  
*Eupatorium solidaginifolium*—THOROUGHWORT—AY  
*Gutierrezia sarothrae*—BROOM SNAKEWEED—AY, BP, DS  
*Gymnosperma glutinosum*—TATALENCHO—AC, AY, BP  
*Hymenoclea salsola*—CHEESEBUSH—AW, EA, GC, VS  
*Isocoma acradenia*—GOLDENBUSH—AW  
*Machaeranthera pinnatifida*—ASTER—AR, DS, EA, GC  
*Pleurocoronis pluriseta*—ARROW LEAF—DS, LC  
*Porophyllum gracile*—ODORA—DS, LC, NS, SB, VS  
*Stephanomeria pauciflora*—DESERT STRAW—AW  
*Trixis californica*—CALIFORNIA TRIXIS—AC, AY, DS, LC, SB, VS  
*Viguiera parishi*—GOLDENEYE—AY, BP, DS, SB

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**Convolvulaceae: Convolvulus Family**

*Evolvulus alsinoides*—EVOLVULUS—AY, BP  
*Jacquemontia pringlei*—JACQUEMONTIA—AY

**Cruciferae: Mustard Family**

*Arabis perennans*—ROCK CRESS—AY  
*Lyrocarpa coulteri*—COULTER'S LYRE POD—AC, AW, DS, SB, VS

**Cucurbitaceae: Gourd Family**

*Marah gilensis*—WILD CUCUMBER—AY

**Cupressaceae: Cypress Family**

*Juniperus erythrocarpa*—ONE SEED JUNIPER—AY

**Ephedraceae: Joint-fir Family**

*Ephedra nevadensis* ssp. *aspera*—JOINT FIR—BP, DS

**Euphorbiaceae: Spurge Family**

*Acalypha pringlei*—THREE SEED MERCURY—AC, AY, BP, SB  
*Argythamnia lanceolata*—LANCE-LEAVED DITAXIS—AY  
*Argythamnia neomexicana*—DITAXIS—AW, AR, DS, LC, SB, VS  
*Croton sonorae*—SONORAN CROTON—AY  
*Chamaesyce albomarginata*—RATTLESNAKE WEED—AR, GC  
*Chamaesyce arizonica*—ARIZONA SPURGE—AY, DS  
*Chamaesyce pediculifera*—SPURGE—AW, VS  
*Chamaesyce polycarpa*—SMALL SEED SAND MAT—AW, GC, LC, NS, SB, VS  
*Jatropha cardiophylla*—LIMBERBUSH—BP  
*Jatropha cinerea*—ASHY JATROPHA—SB  
*Jatropha cuneata*—WEDGE-SHAPED JATROPHA—DS, LC, NS, SB  
*Poinsettia eriantha*—DESERT POINSETTIA—SB  
*Sapium biloculare*—MEXICAN JUMPING BEAN—AC, SB  
*Tragia nepetaefolia*—NOSEBURN—AC, AY, BP, DS

**Fagaceae: Beech Family**

*Quercus turbinella* ssp. *ajoensis*—AJO OAK—AC

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**Fouquieriaceae: Ocotillo Family**

*Fouquieria splendens*—OCOTILLO—BP, NS, SB

**Gramineae: Grass Family**

*Aristida hamulosa*—THREE-AWN—BP  
*Aristida purpurea*—PURPLE THREE-AWN—AR, BP, DS, EA, LC, SB  
*Aristida ternipes*—SPIDER THREE-AWN—AY, BP  
*Bothriochloa barbinodis*—BLUESTEM, CANE—BP  
*Bouteloua curtipendula*—SIDE OATS GRAMA—BP  
*Bouteloua repens*—SLENDER GRAMA—AY, BP  
*Chloris virgata*—FEATHER FINGERGRASS—DL, SB  
*Digitaria californica*—COTTONTOP—AY, DL  
*Erioneuron pulchellum*—FLUFF GRASS—DL, DS, EA, LC, NS, SB, VS  
*Heteropogon contortus*—TANGLEHEAD—AY, BP  
*Hilaria belangeri*—CURLY MESQUITE GRASS—BP, DS  
*Hilaria rigida*—BIG GALLETA—EA, PN  
*Lycurus setosus*—WOLF TAIL—BP  
*Muhlenbergia porteri*—BUSH MUHLY—AR, AY, EA, GC, LC, SB  
*Setaria macrostachya*—PLAINS BRISTLEGRASS—AY, AR, BP, DS  
*Tridens eragrostoides*—TRIDENS—AY  
*Tridens muticus*—SLIM TRIDENS—SB

**Krameriaceae: Ratany Family**

*Krameria erecta*—SMALL-LEAVED RATANY—SB  
*Krameria grayi*—WHITE RATANY—LC, NS, PN

**Labiatae: Mint Family**

*Hedeoma nanum*—MOCK PENNYROYAL—AC  
*Hyptis emoryi*—DESERT LAVENDER—LC, SB, VS  
*Salvia pinguifolia*—ROCK SAGE—AY

**Leguminosae: Pea Family**

*Acacia angustissima*—ACACIA—BP  
*Acacia constricta*—WHITE THORN—NS, SB  
*Acacia greggi*—CATCLAW—AC, AW, AY, BP, DL, DS, GC, LC, VS  
*Calliandra eriophylla*—FAIRY DUSTER—BP, NS  
*Cercidium floridum*—BLUE PALOVERDE—AR, AW, GC, SS, VS  
*Cercidium microphyllum*—FOOTHILL PALOVERDE—BP, DS, EA, LC, NS, SB, VS  
*Coursetia glandulosa*—COURSETIA—AY, BP, DS

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*Dalea mollis*—SILK DALEA—NS  
*Lotus rigidus*—DESERT ROCK PEA—BP  
*Marina parryi*—PARRY'S DALEA—SB  
*Marina pringlei*—DALEA—VS  
*Nissolia schotti*—NISSOLIA—AY, BP  
*Olneya tesota*—DESERT IRONWOOD—AW, LC, NS, SB, VS  
*Phaseolus acutifolius* ssp. *acutifolius*—WILD BEAN—AY  
*Prosopis velutina*—VELVET MESQUITE—AC, AR, AW, AY, BP, BS, DL, DS, GC, SS, VS  
*Psoralea argophylla*—SMOKE TREE—AW

### **Liliaceae: Lily Family**

*Calochortus kennedyi*—DESERT MARIPOSA—BP  
*Dichelostemma pulchellum*—BLUEDICKS—BP  
*Hesperocallis undulata*—DESERT LILY—PN

### **Malpighiaceae: Malpighia Family**

*Janusia gracilis*—SLENDER JANUSIA—AC, AY, BP, DS, SB

### **Malvaceae: Mallow Family**

*Abutilon abutiloides*—INDIAN MALLOW—DS, VS  
*Abutilon incanum*—INDIAN MALLOW—AY, BP, DS, SB  
*Herissantia crispa*—BLADDER MALLOW—AY, DS, SB  
*Hibiscus coulteri*—DESERT ROSE MALLOW—AY, BP, SB  
*Hibiscus denudatus*—ROCK ROSE MALLOW—NS, SB  
*Horsfordia newberryi*—YELLOW FELT PLANT—LC  
*Malvastrum bicuspidatum*—FORKED MALLOW—AY, BP  
*Sphaeralcea emoryi*—EMORY'S GLOBEMALLOW—AR, AW, AY, DL, GC, SS, VS  
*Sphaeralcea laxa*—CALICHE GLOBEMALLOW—BP, DS

### **Nyctaginaceae: Four-o'clock Family**

*Allionia incarnata*—TRAILING FOUR-O'CLOCK—AR, AW, DL, GC, PN, SS, VS  
*Commicarpus scandens*—COMMICARPUS—AY, VS  
*Mirabilis bigelovi*—BIGELOW'S FOUR-O'CLOCK—AC, AW, AY, BP, DS, SB, VS

### **Oleaceae: Olive Family**

*Forestiera shrevei*—ADELIA—AC, BP  
*Menodora scabra*—MENODORA—AY, SB

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**Onagraceae: Evening-primrose Family**

*Zauschneria californica*—HUMMINGBIRD TRUMPET—AC

**Phytolaccaceae: Pokeberry Family**

*Rivina humilis*—ROUGE PLANT—AY

**Plumbaginaceae: Plumbago Family**

*Plumbago scandens*—PLUMBAGO—AC, VS

**Polygonaceae: Buckwheat Family**

*Eriogonum fasciculatum*—CALIFORNIA BUCKWHEAT—AY

*Eriogonum wrightii*—WRIGHT'S BUCKWHEAT—AY, BP, DS, LC

**Portulacaceae: Portulaca Family**

*Talinum aurantiacum*—FLAME FLOWER—BP

*Talinum paniculatum*—PINK BABY BREATH—AY, BP

**Ranunculaceae: Crowfoot Family**

*Anemone tuberosa*—DESERT WINDFLOWER—AY, BP

*Clematis drummondii*—TEXAS VIRGIN'S BOWER—AC, GC

*Delphinium scaposum*—BARESTEM LARKSPUR—AY, BP

**Rhamnaceae: Buckthorn Family**

*Condalia globosa*—BITTER CONDALIA—AC, AW

*Rhamnus crocea*—RED BERRY BUCKTHORN—AC

*Zizyphus obtusifolia*—GRAY THORN—AC, AR, AW, BP, DS, VS

**Rosaceae: Rose Family**

*Vauquelinia californica*—CALIFORNIA ROSEWOOD—AY

**Rubiaceae: Madder Family**

*Galium stellatum*—BEDSTRAW—AC, AY, SB

**Sapindaceae: Soapberry Family**

*Dodonaea viscosa*—HOPBUSH—AC, AY, BP

*Sapindus saponaria*—SOAPBERRY—AC

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**Scrophulariaceae: Figwort Family**

*Maurandya antirrhiniflora*—BLUE SNAPDRAGON VINE—GC  
*Pennstemon parryi*—PARRY'S BEARDTONGUE—BP, DS

**Selaginellaceae: Selaginella Family**

*Selaginella arizonica*—SPIKE MOSS—BP

**Simaroubaceae: Simarouba Family**

*Castela emoryi*—CRUCIFIXION THORN—AR, GC, SS

**Solanaceae: Potato (Nightshade) Family**

*Lycium andersoni*—WOLFBERRY—AW, BS, EA, SS, VS  
*Lycium berlandieri*—WOLFBERRY—AY, DS, LC, SB  
*Lycium exsertum*—WOLFBERRY—AW  
*Lycium macrodon*—WOLFBERRY—AR  
*Lycium parishii*—WOLFBERRY—AR, AW, DS, GC, VS

**Sterculiaceae: Cacao Family**

*Ayenia compacta*—AYENIA—AY, BP  
*Ayenia microphylla*—SMALL-LEAVED AYENIA—AY

**Ulmaceae: Elm Family**

*Celtis pallida*—DESERT HACKBERRY—AC, AY, BP, DS  
*Celtis reticulata*—NET LEAF HACKBERRY—AC

**Verbenaceae: Vervain Family**

*Aloysia wrightii*—WRIGHT'S LIPPIA—AY  
*Verbena gooddingii*—GOODDING VERVAIN—AY, BP  
*Verbena neomexicana*—HILLSIDE VERVAIN—BP

**Viscaceae: Mistletoe Family**

*Phoradendron californicum*—DESERT MISTLETOE—AR, AW, BP, EA, GC, LC, SS, VS

**Zygophyllaceae: Caltrop Family**

*Fagonia californica*—FAGONIA—LC, NS, SB  
*Larrea divaricata*—CREOSOTEBUSH—AC, AR, AW, AY, BS, DL, DS, EA, GC, LC, NS, PN, SB, SS, VS

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Appendix 2-2  
**Vegetation Structure and Diversity in Natural Communities  
 Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monumnet, Arizona:  
 Ephemeral Plant Taxa in Quadrats, Listed by Family**

The following lists ephemeral (annual/biennial and facultative biennial) plant taxa found in the Ecological Monitoring Program (EMP) vegetation quadrats at Organ Pipe Cactus National Monument, Arizona (ORPI). (Perennial plant taxa are listed in Appendix 2-1.)

The common name and taxonomy for each plant are given, and its presence on 1 or more of the monitoring sites is indicated by key abbreviations (see footnote):

**Aizoaceae: Carpet Weed Family (part)**

*Trianthema portulacastrum*—HORSE PURSLANE—AR, AW, BP, BS, DL, SS

**Amaranthaceae: Amaranth Family**

*Amaranthus* sp. nov.—AMARANTH—BP

*Amaranthus fimbriatus*—FRINGED AMARANTH—BP, DL, DS, GC, SS

*Amaranthus palmeri*—QUELITE—AR, DL, GC, SS

*Tidestromia lanuginosa*—WOOLY TIDESTROMIA—AR, AW, DL, PN

**Boraginaceae: Borage Family**

*Amsinckia intermedia*—COAST FIDDLENECK—VS

*Amsinckia tessellata*—CHECKER FIDDLENECK—AR, VS

*Cryptantha angustifolia*—NARROW-LEAVED CRYPTANTHA—AW, PN, VS

*Cryptantha barbiger*a—BEARDED CRYPTANTHA—AW, BP, DL, EA, VS

*Cryptantha maritima*—WHITE-HAIRED CRYPTANTHA—VS

*Cryptantha pterocarya*—WING NUT CRYPTANTHA—SB

*Harpagonella palmeri*—PALMER'S GRAPPLING HOOK—BP

*Lappula redowski*—STICKSEED—DS, SS

*Pectocarya platycarpa*—BROAD-NUTTED COMB BUR—PN, VS

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*Pectocarya recurvata*—ARCH-NUTTED COMB BUR—AW, DL, EA, GC, VS

**Caryophyllaceae: Pink Family**

*Silene antirrhina*—SLEEPY CATCHFLY—BP

**Chenopodiaceae: Goosefoot Family**

*Monolepis nuttalliana*—POVERTY WEED—AR, DL

**Compositae (or Asteraceae): Sunflower Family (or Aster Family)**

*Chaenactis stevioides*—ESTEVE PINCUSHION—EA

*Dyssodia concinna*—DOGWEED—DL, NS, VS

*Eriophyllum lanosum*—WOOLY SUNFLOWER—SB

*Microseris linearifolia*—SILVER PUFFS—BP

*Pectis papposa*—CHINCHWEED—AR, AW, BP, DL, EA, GC, LC, PN, SB, VS

**Convolvulaceae: Convolvulus Family**

*Cuscuta umbellata*—UMBRELLA DODDER—AR, GC

*Ipomoea costellata*—MORNING GLORY—BP

**Cruciferae: Mustard Family**

*Caulanthus lasiophyllus*—JEWEL FLOWER—BP, SB, VS

*Draba cuneifolia*—WHITLOW GRASS—AY, VS

*Lepidium lasiocarpum*—SAND PEPPERGRASS—AW, BP, BS, DL, VS

*Sisymbrium irio*—LONDON ROCKET—DS

**Euphorbiaceae: Spurge Family**

*Chamaesyce abramsiana*—PROSTRATE SPURGE—AR, AW, BP, DL, GC, SB, SS

*Chamaesyce florida*—FLORIDA SPURGE—AR, AY, BP, VS

*Chamaesyce hyssopifolia*—HYSSOP SPURGE—BP

*Chamaesyce micromera*—SONORAN SAND MAT—AW, BP, EA, GC, PN, SB, VS

*Chamaesyce prostrata*—GROUNDFIG SPURGE—AR

*Chamaesyce setiloba*—BRISTLE-LOBED SAND MAT—AW, SB, VS

**Geraniaceae: Geranium Family**

*Erodium cicutarium*—FILAREE—AR, DS

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### Gramineae: Grass Family

*Aristida adscensionis*—SIX WEEKS THREE-AWN—AY, BP, NS, PN, VS  
*Bouteloua aristidoides*—SIX WEEKS NEEDLE GRAMA—AR, AW, BS, DS, PN  
*Bouteloua barbata*—SIX WEEKS GRAMA—AR, AW, AY, BP, BS, DL, DS, EA, GC, PN, SB, SS, VS  
*Bromus carinatus* ssp. *arizonicus*—ARIZONA BROMEGRASS—AR, DS  
*Bromus rubens*—RED BROMEGRASS—BP, DS  
*Eragrostis cilanensis*—STINKGRASS—SS  
*Leptochloa filiformis*—RED SPRANGLETOP—AY, BP, DS, SS  
*Muhlenbergia microsperma*—LITTLE SEED MUHLY—AW, AY, BS, DS, SS, VS  
*Panicum hirticaule*—PANICGRASS—AR, AY, BP  
*Poa bigelovi*—BIGELOW'S BLUEGRASS—AC, AY, DS  
*Schismus arabicus*—ARABIAN GRASS—AR, AW, BS, DL, EA, GC, LC, PN, SB, SS, VS  
*Vulpia octoflora*—SIX WEEKS FESCUE—BP, DL, DS, SB

### Hydrophyllaceae: Waterleaf Family

*Eucrypta chrysanthemifolia*—TORREY EUCRYPTA—AC, DS  
*Eucrypta micrantha*—SMALL-FLOWERED EUCRYPTA—VS  
*Nama hispidum*—PURPLE MAT—AW, DL, VS  
*Pholistoma auritum*—PHOLISTOMA—AC, AY, DS

### Labiatae: Mint Family

*Salvia columbariae*—CHIA—SB

### Leguminosae: Pea Family

*Astragalus nuttallianus*—NUTTALL LOCOWEED—BP  
*Lotus tomentellus*—HAIRY LOTUS—EA  
*Lupinus concinnus*—ELEGANT LUPINE—EA  
*Vicia ludoviciana*—VETCH—AY, BP

### Malvaceae: Mallow Family

*Sphaeralcea coulteri*—COULTER'S GLOBEMALLOW—AW, AY, BP, BS, DL, GC, SS, VS

### Molluginaceae: Carpet Weed Family (part)

*Mollugo cerviana*—THREAD STEM CARPET WEED—SB, VS

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**Nyctaginaceae: Four-o'clock Family**

*Boerhaavia coulteri*—COULTER'S SPIDERLING—PN, SB, VS

*Boerhaavia erecta*—SPIDERLING—AR, AY, BP, DL, DS, GC, LC, SS

**Onagraceae: Evening-primrose Family**

*Camissonia californica*—CALIFORNIA PRIMROSE—BP

*Camissonia clavaeformis*—PRIMROSE—SB

**Plantaginaceae: Plantain Family**

*Plantago insularis*—WOOLY PLANTAIN—AW, BP, BS, DL, NS, PN, VS

**Polemoniaceae: Phlox Family**

*Eriastrum diffusum*—ERIASTRUM—BP, LC, PN, SB, VS

**Polygonaceae: Buckwheat Family**

*Chorizanthe brevicornu*—BRITTLE SPINEFLOWER—NS, SB

*Chorizanthe rigida*—RIGID SPINEFLOWER—PN

*Eriogonum deflexum*—FLAT-TOPPED BUCKWHEAT—NS, SB

**Portulacaceae: Portulaca Family**

*Montia perfoliata*—MONTIA—AC

*Portulaca umbraticola*—PURSLANE—BP

**Primulaceae: Primrose Family**

*Androsace occidentalis*—ROCK JASMINE—AC, AY

**Ranunculaceae: Crowfoot Family**

*Myosurus aristatus*—MOUSE TAIL—AC

*Myosurus cupulatus*—MOUSE TAIL—AY

**Resedaceae: Mignonette Family**

*Oligomeris linifolia*—LINEAR-LEAVED CAMESS—DL

**Rubiaceae: Madder Family**

*Galium aparine*—GOOSE GRASS—AC

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SS = Salsola Site

VS = Vulture Site

**Solanaceae: Potato (Nightshade) Family**

*Datura discolor*—DESERT THORN APPLE—AC, DS

**Umbelliferae: Parsley Family**

*Bowlesia incana*—HAIRY BOWLESIA—AC, DS, VS

*Daucus pusillus*—AMERICAN CARROT—AC, BP, VS

**Urticaceae: Nettle Family**

*Parietaria hespera*—PELLITORY—AC, AY, DS

**Zygophyllaceae: Caltrop Family**

*Kallstroemia californica*—CALIFORNIA CALTROP—AR, AW, AY, DS, GC, SS

*Kallstroemia grandiflora*—ORANGE CALTROP—AR, BP, GC

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Appendix 2-3  
**Vegetation Structure and Diversity in Natural Communities  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Plant Taxa New to the Monument**

Thirty-one taxa documented as present in the initial, 1988 study were new to the Organ Pipe Cactus National Monument (ORPI) flora. Pinkava et al. (1992), reporting 52 new plant taxa to the known ORPI flora, is the primary reference in regarding these 31 taxa.

**Adiantaceae: Fern Family**

*Cheilanthes parryi* D. C. Eaton.

PARRY'S CLOAK FERN. Kino Peak, 5 December 1990, EBW, CWC, JC.

*Notholaena cochiensis* Goodd.

HELECHILLO. Lost Cabin Mine EMP site, 26 February 1991, 24 November 1990, EBW.

**Amaranthaceae: Amaranth Family**

*Amaranthus* sp nov. (undescribed).

AMARANTH. Bull Pasture EMP site, 5 August 1990, EBW.

**Apiaceae (Umbelliferae): Parsley Family**

*Yabea microcarpa* (Hook. & Arn.) K.-Pol.

CAUCALIS. Estes Canyon, 1 April 1990, EBW.

**Asclepiadaceae: Milkweed Family**

*Asclepias nyctaginifolia* Gray (In Pinkava et al. Supplement).

FOUR-O'CLOCK MILKWEED. Armenta Well, 10 August 1990, EBW.

**Asteraceae (Compositae): Aster Family (or Sunflower Family)**

*Artemisia dracunculus* L.

WORMWOOD. Alamo Canyon EMP site, 14 December 1990, EBW;  
Alamo Canyon, 14 December 1989, EBW.

**Compositae (Asteraceae): Sunflower Family (or Aster Family)**

*Pectis linifolia* L. (In Pinkava, et al. Supplement).

CHINCHWEED. Arch Canyon EMP site, 13 August 1990, 18 November 1990, EBW.

**Convolvulaceae: Morning Glory Family**

*Ipomoea coccinea* L.

SCARLET MORNING GLORY. Arch Canyon EMP site, 13 October 1990, 19 October 1990, EBW.

*Ipomoea costellata* Torr.

MORNING GLORY. Bull Pasture EMP site, 12 August 1990, EBW.

**Cucurbitaceae: Gourd Family**

*Brandegea bigelovi* (Wats.) Cogn.

BRANDEGEA. Aguajita Wash EMP site, 22 April 1989, EBW, PAH;  
Vulture EMP site, 31 March 1989, EBW.

*Echinopepon wrighti* (Gray) Wats.

WILD BALSAM APPLE. Arch Canyon EMP site, 13 October 1990, EBW.

**Cuscutaceae (Convolvulaceae, part): Dodder Family**

*Cuscuta tuberculata* T. S. Brand.

KNOBBY DODDER. Cipriano Hills, 18 September 1988, EBW.

**Euphorbiaceae: Spurge Family**

*Chamaesyce abramsiana* Wheeler. (In Pinkava et al. Supplement).

PROSTRATE SOURGE. Burn EMP site, 25 July 1990, EBW;  
Bull Pasture EMP site, 29 July 1990, EBW.

*Chamaesyce hyssopifolia* (L.).

HYSSOP SPURGE. Alamo Canyon EMP site, Middle Fork Junction, 27 July 1990, EBW;  
Bull Pasture, 13 August 1990, EBW.

*Chamaesyce micromera* Boiss.

SONORAN SAND MAT. Arch Canyon EMP site, 12 August 1990, EBW;  
East Armenta, Ajo Valley, 8 September 1990, EBW.

*Chamaesyce prostrata* Ait.

GROUNDFIG SPURGE. Armenta Ranch EMP site, 30 July 1990, EBW.

*Euphorbia heterophylla* L. ssp. *graminifolia* Michx. Engelm.

PAINTED SPURGE. Bull Pasture EMP site, 13 August 1990, EBW.

**Gramineae: Grass Family**

*Brachiaria arizonica* (Schribn. & Merr) Blake.

BRACHIARIA. Dripping Springs EMP site, 11 August 1990, EBW.

*Enneapogon cenchroides* (Roem & Schulb) Hubbard.

PAPPUS GRASS. Arch Canyon trail, 19 October 1990, EBW.

*Eriochloa aristata* Vasey.

CUP GRASS. Growler Canyon EMP site, 13 October 1988, EBW.

*Sporobolus flexuosus* (Thurb.) Rydb.

MESA DROPSEED. East Armenta EMP site, 8 September 1990, EBW.

**Labiatae: Mint Family**

*Teucrium cubense* Jacq.

GERMANDER. Dos Lomitas EMP site, 12 April 1989, EBW.

**Loasaceae: Stickleleaf Family**

*Eucnide rupestris* (Baill) Thompson and Ernst.

ROCK NETTLE. Kino Peak, 5 December 1990, EBW, CWC, JC.

**Leguminosae: Pea Family**

*Phaseolus acutifolius* ssp. *acutifolius* Gray.

WILD BEAN. Arch Canyon EMP site, 13 October 1990 EBW.

**Malvaceae: Mallow Family**

*Abutilon malacum* Wats.

INDIAN MALLOW. Lava Hills, Puerto Blanco Mts., E. of Route 85, 17 September 1990, EBW;  
Pinckley Peak, Puerto Balnco Mts., 11 September 1988, EBW.

*Anoda pentaschista* Gray.

ANODA. Bull Pasture EMP site, 12 August 1990, EBW.

**Martyniaceae: Unicorn Plant Family**

*Proboscidea parviflora* Woot. (Woot. & Standl.).

DEVIL'S CLAW. Bull Pasture EMP site, 13 August 1990, EBW.

**Molluginaceae: Carpet Weed Family (part)**

*Mollugo cerviana* (L.) Seringe. (In Pinkava et al. Supplement).

THREAD STEM CARPET WEED. Vulture EMP site, 26 July 1990, EBW;  
Senita Basin EMP site, 28 July 1990, EBW.

**Nyctaginaceae: Four-o'clock Family**

*Boerhaavia coulteri* (Hook. f.) Wats.

COULTER'S SPIDERLING. Vulture EMP site, 25 July 1990, EBW.

**Portulacaceae: Portulaca Family**

*Portulaca oleracea* L. (In Pinkava et al. supplement).

PURSLANE. Dripping Springs EMP site, Puerto Blanco Mts., 11 August 1990, EBW;  
Burn EMP site, 25 July 1990, EBW;  
Bull Pasture EMP site, 29 July 1990, EBW.

**Solanaceae: Potato (Nightshade) Family**

*Physalis pubescens* L.

HAIRY GROUNDCHERRY. Bull Pasture EMP site, 13 August 1990, EBW.

Appendix 2-4

**Vegetation Structure and Diversity in Natural Communities  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Bonus Plants for the Herbarium**

The following lists plant taxa not involved in the vegetation project data sets. During various phases of the project work, the vouchers were collected for the Organ Pipe Cactus National Monument (ORPI) herbarium.

<i>Amaranthus graecizans</i>	PROSTRATE PIGWEED
<i>Antirrhinum filipes</i>	TWINING SNAPDRAGON
<i>Boerhaavia wrighti</i>	WRIGHT'S SPIDERLING
<i>Chilopsis linearis</i>	SWEET DESERT-WILLOW
<i>Cirsium neomexicanum</i>	DESERT THISTLE
<i>Crossosoma bigelovi</i>	BIGELOW RAGGED ROCKFLOWER
<i>Descurainia pinnata</i>	YELLOW TANSY MUSTARD
<i>Dicliptera resupinata</i>	DICLIPTERA
<i>Enneapogon desvauxi</i>	NINE-AWNED PAPPUS GRASS
<i>Erigeron divergens</i>	SPREADING FLEABANE
<i>Erodium texanum</i>	LARGE-FLOWERED STORKSBILL
<i>Mimulus rubellus</i>	RED-STEMMED MIMULUS
<i>Muhlenbergia emersleyi</i>	MUHLY
<i>Nicotiana trigonophylla</i>	DESERT TOBACCO
<i>Perityle emoryi</i>	EMORY'S ROCK DAISY
<i>Petalonyx thurberi</i>	THURBER'S SANDPAPER PLANT
<i>Phacelia distans</i>	WILD HELIOTROPE
<i>Phaseolus wrighti</i>	WILD BEAN
<i>Physalis crassifolia</i>	THICK-LEAVED GROUNDCHERRY
<i>Physalis lobata</i>	PURPLE GROUNDCHERRY
<i>Rafinesquia neomexicana</i>	DESERT CHICORY
<i>Solanum douglasi</i>	NIGHTSHADE
<i>Thelypodopsis linearifolia</i>	THELYPODIOPSIS
<i>Trifolium lacerum</i>	CLOVER

Appendix 2-5

**Vegetation Structure and Diversity in Natural Communities  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monumnet, Arizona:  
Conspicuous Plant Taxa Off-plot**

The following is a detail of conspicuous woody-plant taxa directly off-plot (off-quadrat) in the surrounding hectare of each of the 26 Ecological Monitoring Program quadrats in Organ Pipe Cactus National Monument. These taxa include trees, shrubs and subshrubs, vines, and cacti rooted near but outside of the 0.1-ha (0.25-a.) monitoring quadrat (i.e., VG01, VG02, VG03).

**Aguajita Wash**

VG01 *Atriplex elegans*—WHEELSCALE—VG01  
VG01 *Baccharis sarothroides*—DESERT BROOM  
VG01 *Condalia warnocki*—CONDALIA  
VG01 *Hymenoclea salsola*—CHEESEBUSH  
VG01 *Marina parryi*—PARRY’S DALEA

VG02 *Ferocactus emoryi*—BARREL CACTUS  
VG03 *Atamisquea emarginata*—DESERT CAPER  
VG03 *Brandegea bigelovi*—BRANDEGEEA  
VG03 *Suaeda torreyana*—DESERT SEEPWEED

**Alamo Canyon**

VG01 *Carnegiea gigantea*—SAGUARO  
VG01 *Clematis drummondii*—TEXAS VIRGIN’S BOWER  
VG01 *Crossosoma bigelovi*  
—BIGELOW RAGGED ROCKFLOWER  
VG01 *Eriogonum wrightii*—WRIGHT’S BUCKWHEAT

VG01 *Gymnosperma glutinosum*—TATALENCHO  
VG01 *Juniperus erythrocarpa*—ONE SEED JUNIPER  
VG01 *Opuntia phaeocantha*—PRICKLY PEAR  
VG01 *Stenocereus thurberi*—ORGAN PIPE CACTUS

## Arch Canyon

- VG01 *Abutilon californicum*—INDIAN MALLOW  
VG01 *Ayenia compacta*—AYENIA  
VG01 *Berberis harrisoniana*—KOFA BARBERRY  
VG01 *Celtis reticulata*—NET LEAF HACKBERRY  
VG01 *Crossosoma bigelovi*  
—BIGELOW RAGGED ROCKFLOWER  
VG01 *Ditaxis neomexicana*—DITAXIS  
VG01 *Ericameria laricifolia*—TURPENTINEBUSH  
VG01 *Forestiera shrevei*—ADELIA  
VG01 *Juniperus erythrocarpa*—ONE SEED JUNIPER  
VG01 *Justicia californica*—CHUPAROSA  
VG01 *Larrea divaricata*—CREOSOTE BUSH  
VG01 *Lycium exsertum*—WOLFBERRY  
VG01 *Machaeranthera asteroides*—ASTER  
VG01 *Montia perfoliata*—MONTIA  
VG01 *Rhamnus crocea*—RED BERRY BUCKTHORN  
VG01 *Sapium biloculare*—MEXICAN JUMPING BEAN  
VG01 *Sarcostemma cyanchooides*—CLIMBING MILKWEED  
VG01 *Trixis californica*—CALIFORNIA TRIXIS  
VG01 *Verbena neomexicana*—HILLSIDE VERVAIN  
VG02 *Allionia incarnata*—TRAILING FOUR-O' CLOCK  
VG02 *Atriplex canescens*—CENIZO  
VG02 *Atriplex polycarpa*—ALLSCALE  
VG02 *Crossosoma bigelovi*  
—BIGELOW RAGGED ROCKFLOWER  
VG02 *Ferocactus emoryi*—BARREL CACTUS  
VG02 *Jacquemontia pringlei*—JACQUEMONTIA  
VG02 *Sapium biloculare*—MEXICAN JUMPING BEAN  
VG02 *Vauquelinia californica*—CALIFORNIA ROSEWOOD

## Armenta Ranch (VG01 and VG02)

- Allionia incarnata*—TRAILING FOUR-O' CLOCK  
*Ambrosia dumosa*—WHITE BURSAGE  
*Atriplex canescens*—CENIZO  
*Atriplex elegans*—WHEELSCALE  
*Gutierrezia sarothrae*—BROOM SNAKEWEED  
*Machaeranthera pinnatifida*—ASTER  
*Sarcostemma cyanchooides*—CLIMBING MILKWEED

## Bull Pasture

- VG01 *Abutilon incanum*—INDIAN MALLOW  
VG01 *Acourtia wrighti*—BROWNFOOT  
VG01 *Aloysia wrighti*—WRIGHT'S LIPPIA  
VG01 *Ambrosia ambrosioides*—CANYON RAGWEED  
VG01 *Asclepias linaria*—MILKWEED  
VG01 *Atriplex canescens*—CENIZO  
VG01 *Coursetia glandulosa*—COURSE TIA  
VG01 *Dodonaea viscosa*—HOPBUSH  
VG01 *Ericameria laricifolia*—TURPENTINEBUSH  
VG01 *Eriogonum wrighti*—WRIGHT'S BUCKWHEAT  
VG01 *Herissantia crista*—BLADDER MALLOW  
VG01 *Jatropha cardiophylla*—LIMBERBUSH  
VG01 *Machaeranthera arida*—ASTER  
VG01 *Menodora scabra*—MENODORA  
VG01 *Opuntia acanthocarpa*—BUCKHORN CHOLLA  
VG01 *Psilostrophe cooperi*—PAPERFLOWER  
VG01 *Stenocereus thurberi*—ORGAN PIPE CACTUS  
VG02 *Ambrosia ambrosioides*—CANYON RAGWEED  
VG02 *Ambrosia confertiflora*—SLIMELEAF BURSAGE  
VG02 *Anisacanthus thurberi*—CHUPAROSA  
VG02 *Asclepias linaria*—MILKWEED  
VG02 *Baccharis sarothroides*—DESERT BROOM  
VG02 *Celtis reticulata*—NET LEAF HACKBERRY  
VG02 *Ericameria laricifolia*—TURPENTINEBUSH  
VG02 *Forestiera shrevei*—ADELIA  
VG02 *Galium stellatum*—BEDSTRAW  
VG02 *Justicia californica*—CHUPAROSA  
VG02 *Rhamnus crocea*—RED BERRY BUCKTHORN  
VG02 *Vauquelinia californica*—CALIFORNIA ROSEWOOD  
VG02 *Zauschneria californica*—HUMMINGBIRD TRUMPET  
VG02 *Zizyphus obtusifolia*—GRAYTHORN

## Burn Site

VG01 *Ambrosia ambrosioides*—CANYON RAGWEED  
VG01 *Cercidium floridum*—BLUE PALOVERDE  
VG01 *Lycium andersoni*—WOLFBERRY  
VG01 *Lycium fremonti*—WOLFBERRY

VG01 *Prosopis velutina*—VELVET MESQUITE  
VG01 *Sarcostemma cyanchooides*—CLIMBING MILKWEED  
VG01 *Zizyphus obtusifolia*—GRAYTHORN

## Dos Lomas

VG02 *Cercidium floridum*—BLUE PALOVERDE  
VG02 *Lycium andersoni*—WOLFBERRY  
VG02 *Lycium fremonti*—WOLFBERRY

VG02 *Machaeranthera arida*—ASTER  
VG02 *Maurandya antirrhiniflora*—BLUE SNAPDRAGON VINE  
VG02 *Sphaeralcea ambigua*—DESERT MALLOW

## Dripping Springs

VG01 *Abutilon palmeri*—INDIAN MALLOW  
VG01 *Asclepias linaria*—MILKWEED  
VG01 *Crossosoma bigelovi*  
—BIGELOW RAGGED ROCKFLOWER

VG01 *Fagonia californica*—FAGONIA  
VG01 *Fouquieria splendens*—OCOTILLO  
VG01 *Herissantia crispa*—BLADDER MALLOW  
VG01 *Lycium andersoni*—WOLFBERRY

## East Armenta

VG01 *Acacia greggi*—CATCLAW  
VG01 *Ambrosia ambrosioides*—CANYON ARGWEED  
VG01 *Cercidium floridum*—BLUE PALOVERDE  
VG01 *Ephedra trifurca*—LONG-LEAVED JOINT FIR  
VG01 *Lycium parishii*—WOLFBERRY

VG01 *Olneya tesota*—DESERT IRONWOOD  
VG01 *Peniocereus greggi*—NIGHT-BLOOMING CACTUS  
VG01 *Prosopis velutina*—VELVET MESQUITE  
VG01 *Zizyphus obtusifolia*—GRAYTHORN

## Growler Canyon

VG01 *Ambrosia ambrosioides*—CANYON RAGWEED  
VG01 *Ambrosia deltoidea*—BURROBUSH  
VG01 *Camissonia clavaeformis*—PRIMROSE  
VG01 *Celtis pallida*—DESERT HACKBERRY  
VG01 *Cercidium floridum*—BLUE PALOVERDE  
VG01 *Condalia globosa*—BITTER CONDALIA  
VG01 *Condalia warnockii*—CONDALIA  
VG01 *Hymenoclea salsola*—CHEESEBUSH  
VG01 *Lycium andersoni*—WOLFBERRY

VG01 *Monodora scabra*—MENODORA  
VG01 *Zizyphus obtusifolia*—GRAYTHORN  
VG02 *Anisacanthus thurberi*—CHUPAROSA  
VG02 *Celtis pallida*—DESERT HACKBERRY  
VG02 *Chilopsis linearis*—SWEET DESERT WILLOW  
VG02 *Ephedra nevadensis*—JOINT FIR  
VG02 *Krameria grayi*—WHITE RATANY  
VG02 *Maurandya antirrhiniflora*—BLUE SNAPDRAGON VINE  
VG02 *Viguiera deltoidea*—GOLDENEYE

## Lost Cabin Mine

- |  |   |
|--|---|
| VG01 <i>Carnegiea gigantea</i> —SAGUARO          | VG01 <i>Lyrocarpa coulteri</i> —COULTER'S LYRE POD  |
| VG01 <i>Fouquieria splendens</i> —OCOTILLO       | VG01 <i>Opuntia acanthocarpa</i> —BUCKHORN CHOLLA   |
| VG01 <i>Hibiscus denudatus</i> —ROCK ROSE MALLOW | VG01 <i>Sapium biloculare</i> —MEXICAN JUMPING BEAN |
| VG01 <i>Hilaria rigida</i> —BIG GALLETA          | VG01 <i>Trixis californica</i> —CALIFORNIA TRIXIS   |
| VG01 <i>Lophocereus schotti</i> —SENITA CACTUS   |   |

## Neolloydia Site (inactive)

- |   |  |
|---|--|
| VG01 <i>Acacia greggi</i> —CATCLAW                      | VG01 <i>Krameria parvifolia</i> —SMALL-LEAVED RATANY |
| VG01 <i>Brickellia coulteri</i> —BRICKELLBUSH           | VG01 <i>Lycium cf. berlandieri</i> —WOLFBERRY        |
| VG01 <i>Camissonia californica</i> —CALIFORNIA PRIMROSE | VG01 <i>Lyrocarpa coulteri</i> —COULTER'S LYRE POD   |
| VG01 <i>Coursetia glandulosa</i> —COURSEZIA             | VG01 <i>Opuntia fulgida</i> —JUMPING CHOLLA          |
| VG01 <i>Echinocereus engelmanni</i> —HEDGEHOG CACTUS    | VG01 <i>Prosopis velutina</i> —VELVET MESQUITE       |
| VG01 <i>Ferocactus emoryi</i> —BARREL CACTUS            | VG01 <i>Sapium biloculare</i> —MEXICAN JUMPING BEAN  |
| VG01 <i>Gutierrezia sarothrae</i> —BROOM SNAKEWEED      | VG01 <i>Stenocereus thurberi</i> —ORGAN PIPE CACTUS  |
| VG01 <i>Jatropha cardiophylla</i> —LIMBERBUSH           |  |

## Pozo Nuevo

- |  |  |
|--|--|
| VG01 <i>Carnegiea gigantea</i> —SAGUARO                | VG01 <i>Ferocactus emoryi</i> —BARREL CACTUS   |
| VG01 <i>Cercidium microphyllum</i> —FOTTHILL PALOVERDE | VG01 <i>Fouquieria splendens</i> —OCOTILLO     |
| VG01 <i>Dalea mollis</i> —SILK DALEA                   | VG01 <i>Prosopis velutina</i> —VELVET MESQUITE |

## Salsola Site

- |   |   |
|---|---|
| VG01 <i>Atriplex canescens</i> —CENIZO        | VG01 <i>Condalia warnocki</i> —CONDALIA |
| VG01 <i>Condalia globosa</i> —BITTER CONDALIA |   |

## Senita Basin

- |   |   |
|---|---|
| VG01 <i>Encelia frutescens</i> —RAYLESS ENCELIA | VG02 <i>Janusia gracilis</i> —SLENDER JANUSIA   |
| VG01 <i>Hyptis emoryi</i> —DESERT LAVENDER      | VG02 <i>Krameria</i> spp.—RATANY                |
| VG01 <i>Opuntia bigelovi</i> —TEDDY BEAR CHOLLA | VG02 <i>Lophocereus schotti</i> —SENITA CACTUS  |
| VG02 <i>Acacia constricta</i> —WHITE THORN      | VG02 <i>Marina parryi</i> —PARRY'S DALEA        |
| VG02 <i>Dalea mollis</i> —SILK DALEA            | VG02 <i>Menodora scabra</i> —MENODORA           |
| VG02 <i>Ferocactus emoryi</i> —BARREL CACTUS    | VG02 <i>Olneya tesota</i> —DESERT IRONWOOD      |
| VG02 <i>Fouquieria splendens</i> —OCOTILLO      | VG02 <i>Opuntia bigelovi</i> —TEDDY BEAR CHOLLA |
| VG02 <i>Hyptis emoryi</i> —DESERT LAVENDER      |   |

## Vulture Site

VG01 <i>Cercidium microphyllum</i> —FOOTHILL PALOVERDE	VG02 <i>Condalia globosa</i> —BITTER CONDALIA
VG01 <i>Fouquieria splendens</i> —OCOTILLO	VG02 <i>Fagonia californica</i> —FAGONIA
VG01 <i>Mammillaria grahami</i> —FISHHOOK CACTUS	VG02 <i>Fouquieria splendens</i> —OCOTILLO
VG01 <i>Mammillaria thornberi</i> —FISHHOOK CACTUS	VG02 <i>Mammillaria grahami</i> —FISHHOOK CACTUS
VG01 <i>Prosopis velutina</i> —VELVET MESQUITE	VG02 <i>Mammillaria thornberi</i> —FISHHOOK CACTUS
VG01 <i>Stenocereus thurberi</i> —ORGAN PIPE CACTUS	VG02 <i>Opuntia fulgida</i> —JUMPING CHOLLA
VG02 <i>Brandegea bigelovi</i> —BRANDEGEA	VG02 <i>Opuntia acanthocarpa</i> —BUCKHORN CHOLLA
VG02 <i>Camissonia californica</i> —CALIFORNIA PRIMROSE	VG02 <i>Sarcostemma cyanchoides</i> —CLIMBING MILKWEED
VG02 <i>Carlowrightia arizonica</i> —ARIZONA CARLOWRIGHTIA	VG02 <i>Stenocereus thurberi</i> —ORGAN PIPE CACTUS

Appendix 2-6  
**Vegetation Structure and Diversity in Natural Communities  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monumnet, Arizona:  
Cross-referenced Index of Plant Taxa**

**Names in the Index Followed by One or More EMP Site Acronyms**

These plants are primarily those perennials in the 0.1-ha (0.25-a.) quadrats, and ephemerals in the 1.0-m<sup>2</sup> (10.8-ft<sup>2</sup>) quadrats. All are species listed on the quadrat data summary sheets, presently kept at Organ Pipe Cactus National Monument (ORPI). These names are also listed in Appendix 2-1 (Perennial Plant Taxa in Quadrats, Listed by Family) and Appendix 2-2 (Ephemeral Plant Taxa in Quadrats, Listed by Family).

The remainder of taxa having site acronyms are those woody perennials *near, but outside* the 0.1-ha (0.25-a.) quadrats. See also Appendix 2-5 (Conspicuous Plant Taxa Off-Plot). Taxa new to ORPI (Appendix 2-3) that were found on an EMP site, and were off-quadrat, also have a site acronym.

**Names in the Index Followed by an Asterisk (\*)**

These plants are taxa new to the known ORPI flora. They are from both on-site (meaning on an EMP site) and off-site localities. See also Appendix 2-3 (Plant Taxa New to the Monument).

**Names in the Index Followed by a Plus Sign (+)**

These plants (bonus plants) are additional material for the ORPI herbarium. They are vouchers collected at various places on the monument during project work. See also Appendix 2-4 (Bonus Plants for the Herbarium).

**Names in the Index Listed in Boldface**

These are recently-used and familiar names that have been superseded (now synonymous) or are alternates in the taxonomic literature. They are included here for the reader's convenience.

## Index

—A—

*Abutilon abutiloides* [was *A. californicum*]—INDIAN MALLOW—AY, DS, VS  
*Abutilon californicum* [is now *A. abutiloides*]—INDIAN MALLOW—AY, DS, VS  
*Abutilon incanum* [was *A. pringlei*]—INDIAN MALLOW—AY, BP, DS, SB  
*Abutilon malacum* (\*)—INDIAN MALLOW  
*Abutilon palmeri*—INDIAN MALLOW—DS  
*Abutilon pringlei* [is now *A. incanum*]—INDIAN MALLOW—AY, BP, DS, SB  
ACACIA—*Acacia angustissima*—BP  
*Acacia angustissima*—ACACIA—BP  
*Acacia constricta*—WHITE THORN—NS, SB  
*Acacia greggi*—CATCLAW—AC, AR, AY, BP, DL, DS, EA, GC, LC, NS, VS  
*Acalypha pringlei*—THREE SEED MERCURY—AC, AY, BP, SB  
Acanthaceae—*Acanthus* Family  
*Acanthus* Family—Acanthaceae  
*Acourtia wrightii* [was *Perezia wrightii*]—BROWNFOOT—AY, BP  
ADELIA—*Forestiera shrevei*—AC, AY, BP  
Adiantaceae [was **Polypodiaceae**]—Fern Family  
Agavaceae—Agave Family  
AGAVE, DESERT—*Agave deserti*—BP, DS  
*Agave deserti*—AGAVE, DESERT—BP, DS  
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*Agave schottii*—CENTURY PLANT—BP  
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Amaranth Family—Amaranthaceae  
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*Amaranthus fimbriatus*—FRINGED AMARANTH—BP, DL, DS, GC, SS  
*Amaranthus graecizans* (+)—PROSTRATE PIGWEED  
*Amaranthus palmeri*—QUELITE—AR, DL, GC, SS  
*Amaranthus* sp. nov. (\*)—AMARANTH—BP  
*Ambrosia ambrosioides*—CANYON RAGWEED—AC, AR, AW, AY, BP, BS, EA, GC, SB, VS  
*Ambrosia confertiflora*—SLIMLEAF BURSAGE—AR, AW, BP, DL, GC, SS  
*Ambrosia cordifolia*—RAGWEED—AC, AY

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Symbols key: \* Taxa new to ORPI

+ Taxa new to ORPI Herbarium

Synonymous nomenclature

*Ambrosia deltoidea*—BURROBUSH—AW, AY, BS, DL, DS, EA, GC, LC, NS, PN, SB, VS  
*Ambrosia dumosa*—WHITE BURSAGE—AR, EA, PN  
*Amsinckia intermedia*—COAST FIDDLENECK—VS  
*Amsinckia tessellata*—CHECKER FIDDLENECK—AR, VS  
*Androsace occidentalis*—ROCK JASMINE—AC, AY  
*Anemone tuberosa*—DESERT WINDFLOWER—AY, BP  
 ANGLE POD—*Matelea parvifolia*—AY, BP  
*Anisacanthus thurberi*—CHUPAROSA—AC, AY, BP, GC  
 ANODA—*Anoda pentaschista* (\*)—BP  
*Anoda pentaschista* (\*)—ANODA—BP  
*Antirrhinum filipes* (+)—TWINING SNAPDRAGON  
 Apiaceae (or Umbelliferae)—Parsley Family  
 Apocynaceae—Dogbane Family  
 ARABIAN GRASS—*Schismus arabicus* [was *S. barbatus*]  
 —AR, AW, BS, DL, EA, GC, LC, PN, SB, SS, VS  
*Arabis perennans*—ROCK CRESS—AY  
*Argythamnia lanceolata* [was *Ditaxis lanceolata*]  
 —LANCE-LEAVED DITAXIS—AY  
*Argythamnia neomexicana* [was *Ditaxis neomexicana*]  
 —DITAXIS—AR, AW, DS, LC, SB, VS  
*Aristida adscensionis*—SIX WEEKS THREE-AWN—AY, BP, NS, PN, VS  
*Aristida hamulosa*—THREE-AWN—BP  
*Aristida purpurea*—PURPLE THREE-AWN—AR, BP, DS, EA, LC, SB  
*Aristida ternipes*—SPIDER THREE-AWN—AY, BP  
 Aristolochiaceae—Birthwort Family  
*Aristolochia watsoni*—INDIAN ROOT—AR, AW, DL, GC  
 ARROW LEAF—*Pleurocoronis pluriseta* [was *Hoffmeisteria pluriseta*]  
 —DS, LC  
*Artemisia dracunculus* (\*)—WORMWOOD—AC  
*Artemisia ludoviciana*—SAGEBRUSH—AC, AY, BP  
 Asclepiadaceae—Milkweed Family  
*Asclepias linaria*—MILKWEED—BP, DS  
*Asclepias nyctaginifolia* (\*)—FOUR-O’CLOCK MILKWEED—AR  
 ASTER—*Machaeranthera arida*—BP, DL  
 ASTER—*Machaeranthera asteroides*—AY  
 ASTER—*Machaeranthera pinnatifida*—AR, DS, EA, GC  
 Aster Family (or Sunflower Family)—Asteraceae (or Compositae)  
 Asteraceae (or Compositae)—Aster Family (or Sunflower Family)  
*Astragalus nuttallianus*—NUTTALL LOCOWEED—BP  
*Atamisquea emarginata*—DESERT CAPER—AW  
*Atriplex canescens*—CENIZO—AR, AW, AY, BP, BS, DL, DS, SS  
*Atriplex elegans*—WHEELSCALE—AW, AR  
*Atriplex polycarpa*—ALLSCALE—AW, AY, BS, DL  
 AYENIA—*Ayenia compacta*—AY, BP

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*Ayenia compacta*—AYENIA—AY, BP  
*Ayenia microphylla*—SMALL-LEAVED AYENIA—AY  
AYENIA, SMALL-LEAVED—*Ayenia microphylla*—AY

—B—

*Baccharis sarothroides*—DESERT BROOM—AC, AW, BP, GC  
BARBERRY, KOFA—*Berberis harrisoniana*—AY  
BARREL CACTUS—*Echinomastus erectocentrus* [was *Echinocactus erectocentrus*]—NS  
BARREL CACTUS—*Ferocactus cylindraceus* [was *F. acanthodes*]—LC  
BARREL CACTUS—*Ferocactus emoryi* [was *F. covillei*]—AW, AY, BP, DS, NS, PN, SB  
BARREL CACTUS—*Ferocactus wislizeni*—EA  
BEARDTONGUE, PARRY'S—*Penstemon parryi*—BP, DS  
*Bebbia juncea*—SWEETBUSH—AW, SB, VS  
BEDSTRAW—*Galium stellatum*—AC, AY, BP, SB  
Beech Family—Fagaceae  
*Beloperone californica* [is now *Justicia californica*]—CHUPAROSA—AC, AY, BP, SB  
*Berberis harrisoniana*—KOFA BARBERRY—AY  
BIG GALLETA—*Hilaria rigida*—EA, PN  
Birthwort Family—Aristolochiaceae  
BLADDER MALLOW—*Herissantia crispa*—AY, BP, DS, SB  
BLUEDICKS—*Dichelostemma pulchellum*—BP  
BLUEGRASS, BIGELOW'S—*Poa bigelovi*—AC, AY, DS  
BLUESTEM, CANE—*Bothriochloa barbinodis*—BP  
*Boerhaavia coulteri* (\*)—COULTER'S SPIDERLING—PN, SB, VS  
*Boerhaavia erecta*—SPIDERLING—AR, AY, BP, DL, DS, GC, LC, SS  
*Boerhaavia wrightii* (+)—WRIGHT'S SPIDERLING  
Borage Family—Boraginaceae  
Boraginaceae—Borage Family  
*Bothriochloa barbinodis*—CANE BLUESTEM—BP  
*Bouteloua aristoides*—SIX WEEKS NEEDLE GRAMA—AR, AW, BS, DS, PN  
*Bouteloua barbata*—SIX WEEKS GRAMA—AR, AW, AY, BP, BS, DL, DS, EA, GC, PN, SS, SB, VS  
*Bouteloua curtipendula*—SIDE OATS GRAMA—BP, DL  
*Bouteloua filiformis* [is now *B. repens*]—SLENDER GRAMA—AY, BP  
*Bouteloua gracilis*—BLUE GRAMA  
*Bouteloua repens* [was *B. filiformis*]—SLENDER GRAMA—AY, BP  
BOWLESIA, HAIRY—*Bowlesia incana*—AC, DS  
*Bowlesia incana*—HAIRY BOWLESIA—AC, DS  
Box Family—Buxaceae  
BRACHIARIA—*Brachiaria arizonica* (\*) [was *Panicum arizonicum*]—DS  
*Brachiaria arizonica* (\*) [was *Panicum arizonicum*]—BRACHIARIA—DS

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BRANDEGEE—*Brandegea bigelovi* (\*)—AW, VS  
*Brandegea bigelovi* (\*)—BRANDEGEE—AW, VS  
BRICKELLBUSH—*Brickellia californica*—AR, AY, DS  
BRICKELLBUSH—*Brickellia coulteri*—AC, AY, BP, DS, NS, SB, VS  
*Brickellia californica*—BRICKELLBUSH—AR, AY, DS  
*Brickellia coulteri*—BRICKELLBUSH—AC, AY, BP, DS, NS, SB, VS  
BRISTLEGRASS, PLAINS—*Setaria macrostachya*—AR, AY, BP, DS  
BRITTLEBUSH—*Encelia farinosa*—AC, AW, AY, BP, DS, LC, SB, VS  
BROMEGRASS, ARIZONA—*Bromus carinatus* ssp. *arizonicus* [was *B. arizonicus*]—AR, DS  
BROMEGRASS, RED—*Bromus rubens*—BP, DS  
*Bromus arizonicus* [is now *B. carinatus* ssp. *arizonicus*]—ARIZONA BROMEGRASS—AR, DS  
*Bromus carinatus* ssp. *arizonicus* [was *B. arizonicus*]—ARIZONA BROMEGRASS—AR, DS  
*Bromus rubens*—BROMEGRASS, RED—BP, DS  
BROWNFOOT—*Acourtia wrightii* [was *Perezia wrightii*]—AY, BP  
Buckthorn Family—Rhamnaceae  
BUCKTHORN, RED BERRY—*Rhamnus crocea*—AC, AY, BP  
BUCKWHEAT, CALIFORNIA—*Eriogonum fasciculatum*—AY  
Buckwheat Family—Polygonaceae  
BUCKWHEAT, FLAT-TOPPED—*Eriogonum deflexum*—NS, SB  
BUCKWHEAT, WRIGHT'S—*Eriogonum wrightii*—AC, AY, BP, DS, LC  
BURROBUSH—*Ambrosia deltoidea*—AW, AY, BS, DL, DS, EA, GC, LC, NS, PN, SB, VS  
BURSAGE, SLIMLEAF—*Ambrosia confertiflora*—AR, AW, BP, DL, GC, SS  
BURSAGE, WHITE—*Ambrosia dumosa*—AR, EA, PN  
Burseraceae—Torchwood Family  
*Bursera microphylla*—ELEPHANT TREE—LC, SB  
Buxaceae—Box Family

—C—

Cacao Family—Sterculiaceae  
Cactaceae—Cactus Family  
Cactus Family—Cactaceae  
*Calliandra eriophylla*—FAIRY DUSTER—BP, NS  
*Calochortus kennedyi*—DESERT MARIPOSA—BP  
CALTROP, CALIFORNIA—*Kallstroemia californica*—AR, AW, AY, DS, GC, SS  
Caltrop Family—Zygophyllaceae  
CALTROP, ORANGE—*Kallstroemia grandiflora*—AR, BP, GC  
CAMBESS, LINEAR-LEAVED—*Oligomeris linifolia*—DL  
*Camissonia californica*—CALIFORNIA PRIMROSE—BP, NS, VS  
*Camissonia clavaeformis*—PRIMROSE—GC, SB  
CANYON RAGWEED—*Ambrosia ambrosioides*—AC, AR, AW, AY, BP, BS, EA, GC, SB, VS

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CAPER, DESERT—*Atamisquea emarginata*—AW  
 Caper Family—Capparidaceae  
 Capparidaceae—Caper Family  
 CARLOWRIGHTIA, ARIZONA—*Carlowrightia arizonica*—AY, DS, VS  
*Carlowrightia arizonica*—ARIZONA CARLOWRIGHTIA—AY, DS, VS  
*Carnegiea gigantea* [was *Cereus gigantea*]—SAGUARO—AC, AW, BP, BS, DL, DS, EA, LC, NS, PN, SB, VS  
 Carpet Weed Family—Aizoaceae (part), Molluginaceae (part)  
 CARPET WEED, THREAD STEM—*Mollugo cerviana* (\*)—SB, VS  
 CARROT, AMERICAN—*Daucus pusillus*—VS  
 Caryophyllaceae—Pink Family  
*Cassia covesi*—DESERT SENNA  
*Castela emoryi*—CRUCIFIXION THORN—AR, GC, SS  
 CATCHFLY, SLEEPY—*Silene antirrhina*—BP  
 CATCLAW—*Acacia greggi*—AC, AR, AY, BP, DL, DS, EA, GC, LC, NS, VS  
 CAUCALIS—*Yabea microcarpa* [was *Caucalis microcarpa*] (\*)  
*Caucalis microcarpa* [is now *Yabea microcarpa*] (\*)—CAUCALIS  
*Caulanthus lasiophyllus* [was *Thelypodium lasiophyllum*]—JEWEL FLOWER—BP, SB, VS  
*Celtis pallida*—DESERT HACKBERRY—AC, AY, BP, DS, GC  
*Celtis reticulata*—NET LEAF HACKBERRY—AC, AY, BP  
 CENIZO—*Atriplex canescens*—AR, AW, AY, BP, BS, DL, DS, SS  
 CENTURY PLANT—*Agave schottii*—BP  
*Cercidium floridum*—BLUE PALOVERDE—AR, AW, BS, DL, EA, GC, SS, VS  
*Cercidium microphyllum*—FOOTHILL PALOVERDE—BP, DS, EA, LC, NS, PN, SB, VS  
*Cereus gigantea* [is now *Carnegiea gigantea*]—SAGUARO—AC, AW, BP, BS, DL, DS, EA, LC, NS, PN, SB, VS  
*Cereus greggi* [is now *Peniocereus greggi*]—NIGHT-BLOOMING CACTUS—BS, DL, EA  
*Cereus schottii* [is now *Lophocereus schottii*]—SENITA CACTUS—LC, SB  
*Cereus thurberi* [is now *Stenocereus thurberi*]—ORGAN PIPE CACTUS—AC, BP, DS, LC, NS, SB, VS  
*Chaenactis stevioides*—ESTEVE PINCUSHION—EA  
*Chamaesyce* [was *Euphorbia*, part]—SPURGE  
*Chamaesyce abramsiana* (\*)—PROSTRATE SPURGE—AR, AW, BP, BS, DL, GC, SS, SB  
*Chamaesyce albomarginata*—RATTLESNAKE WEED—AR, GC  
*Chamaesyce arizonica*—ARIZONA SPURGE—AY, DS  
*Chamaesyce florida*—FLORIDA SPURGE—AR, AY, BP, VS  
*Chamaesyce hyssopifolia* (\*)—HYSSOP SPURGE—AC, BP  
*Chamaesyce micromera*—SONORAN SAND MAT—AW, AY, BP, EA, GC, PN, SB, VS  
*Chamaesyce pediculifera*—SPURGE—AW, VS  
*Chamaesyce polycarpa*—SMALL SEED SAND MAT—AW, GC, LC, NS, SB, VS  
*Chamaesyce prostrata* (\*)—GROUNDFIG SPURGE—AR  
*Chamaesyce setiloba*—BRISTLE-LOBED SAND MAT—AW, GC, SB, VS  
 CHEESEBUSH—*Hymenoclea salsola*—AW, EA, GC, VS

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Synonomous nomenclature

*Cheilanthes parryi* (\*)—PARRY'S CLOAK FERN  
*Cheilanthes wootoni*—BEADED LIP FERN—AC  
*Cheilanthes wrightii*—WRIGHT'S LIP FERN—AY, BP  
 Chenopodiaceae—Goosefoot Family  
 CHIA—*Salvia columbariae*—GC, SB  
*Chilopsis linearis*—SWEET DESERT WILLOW—GC  
 CHINCHWEED—*Pectis linifolia* (\*)—AY  
 CHINCHWEED—*Pectis papposa*—AR, AW, BP, DL, EA, GC, LC, PN, SB, VS  
*Chloris virgata*—FEATHER FINGERGRASS—DL, SB  
 CHOLLA, BUCKHORN—*Opuntia acanthocarpa*—AC, AW, BP, DL, DS, LC, NS, PN, SB, VS  
 CHOLLA, DEVIL—*Opuntia kunzei* [was *O. stanlyi* ssp. *kunzei*]—EA  
 CHOLLA, JUMPING—*Opuntia fulgida*—AW, DL, EA, NS, VS  
 CHOLLA, PENCIL—*Opuntia arbuscula*—EA  
 CHOLLA, STAGHORN—*Opuntia spinosior*—EA  
 CHOLLA, TEDDY BEAR—*Opuntia bigelovi*—NS, SB  
*Chorizanthe brevicornu*—BRITTLE SPINEFLOWER—NS, SB  
*Chorizanthe rigida*—RIGID SPINEFLOWER—PN  
 CHRISTMAS CACTUS—*Opuntia leptocaulis*—AW, DL, EA, PN, SB, VS  
 CHUPAROSA—*Anisacanthus thurberi*—AC, AY, BP, GC  
 CHUPAROSA—*Justicia californica* [was *Beloperone californica*]—AC, AY, BP, SB  
 CHUPAROSA—*Justicia candidans* [was *Jacobinia ovata*]—AC  
*Cirsium neomexicanum* (+)—DESERT THISTLE  
*Clematis drummondii*—TEXAS VIRGIN'S BOWER—AC, GC  
 CLIFF BRAKE—*Pellaea truncata*—AY  
 CLIMBING MILKWEED—*Sarcostemma crispum* [was *Funastrum crispum*]—DL  
 CLIMBING MILKWEED—*Sarcostemma cynanchoides*—AR, AW, AY, BS, GC, VS  
 CLOAK FERN—*Notholaena standleyi*—AY, BP, DS, LC, SB  
 CLOAK FERN, PARRY'S—*Cheilanthes parryi* (\*)  
 CLOAK FERN, WAVY—*Notholaena sinuata*—AC, AY, BP  
 CLOVER—*Trifolium lacerum* (+)  
 COCKROACH PLANT—*Haplophyton crooksi*—AY  
 COMB BUR, ARCH-NUTTED—*Pectocarya recurvata*—AW, DL, EA, GC, VS  
 COMB BUR, BROAD-NUTTED—*Pectocarya platycarpa*—PN, VS  
 COMMICARPUS—*Commicarpus scandens*—AY, VS  
*Commicarpus scandens*—COMMICARPUS—AY, VS  
 Compositae (or Asteraceae)—Aster Family (or Sunflower Family)  
 CONDALIA—*Condalia warnockii*—AW, GC, SS  
 CONDALIA, BITTER—*Condalia globosa*—AC, AW, GC, SS, VS  
*Condalia globosa*—BITTER CONDALIA—AC, AW, GC, SS, VS  
*Condalia warnockii*—CONDALIA—AW, GC, SS

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Convolvulaceae—Morning Glory Family  
 COTONTOP—*Digitaria californica* [was *Trichachne californica*]  
 COURSETIA—*Coursetia glandulosa* [was *C. microphylla*]  
*Coursetia glandulosa* [was *C. microphylla*]  
***Coursetia microphylla*** [is now *Coursetia glandulosa*]  
 CREOSOTEBUSH—*Larrea divaricata*  
*Crossosoma bigelovi*  
 CROTON, SONORAN—*Croton sonorae*  
 Crowfoot Family—Ranunculaceae  
 Cruciferae—Mustard Family  
 CRUCIFIXION THORN—*Castela emoryi*  
*Cryptantha angustifolia*  
*Cryptantha barbiger*  
 CRYPTANTHA, BEARDED—*Cryptantha barbiger*  
*Cryptantha maritima*  
 CRYPTANTHA, NARROW-LEAVED—*Cryptantha angustifolia*  
*Cryptantha pterocarya*  
 CRYPTANTHA, WHITE-HAIRED—*Cryptantha maritima*  
 CRYPTANTHA, WING NUT—*Cryptantha pterocarya*  
 Cucurbitaceae—Gourd Family  
 CUP GRASS—*Eriochloa aristata* (\*)  
 Cupressaceae—Cypress Family  
 CURLY MESQUITE GRASS—*Hilaria belangeri*  
 Cuscutaceae (Convolvulaceae, part)—Dodder Family  
*Cuscuta tuberculata* (\*)  
*Cuscuta umbellata*  
*Cynanchum arizonicum* [was *Metastelma arizonicum*]  
 Cypress Family—Cupressaceae

—D—

DALEA—*Marina pringlei* [was *Dalea pringlei*]  
*Dalea mollis*  
 DALEA, PARRY'S—*Marina parryi* [was *Dalea parryi*]  
***Dalea parryi*** [is now *Marina parryi*]  
***Dalea pringlei*** [is now *Marina pringlei*]  
 DALEA, SILK—*Dalea mollis*  
***Dalea spinosa*** [is now *Psoralea spinosa*]  
*Datura discolor*  
*Daucus pusillus*

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*Delphinium scaposum*—BARESTEM LARKSPUR—AY, BP  
*Descurainia pinnata* (+)—YELLOW TANSY MUSTARD  
 DESERT BROOM—*Baccharis sarothroides*—AC, AW, BP, GC  
 DESERT CHICORY—*Rafinesquia neomexicana* (+)  
 DESERT IRONWOOD—*Olneya tesota*—AW, EA, LC, NS, SB, VS  
 DESERT LAVENDER—*Hyptis emoryi*—LC, SB, VS  
 DESERT LILY—*Hesperocallis undulata*—PN  
 DESERT MALLOW—*Sphaeralcea ambigua*—DL  
 DESERT STRAW—*Stephanomeria pauciflora*—AW  
 DESERT WILLOW, SWEET—*Chilopsis linearis*—GC  
 DEVIL'S CLAW—*Proboscidea parviflora* (\*)—BP  
*Dichelostemma pulchellum*—BLUEDICKS—BP  
 DICLIPTERA—*Dicliptera resupinata* (+)  
*Dicliptera resupinata* (+)—DICLIPTERA  
*Digitaria californica* [was *Trichachne californica* ]—COTTONTOP—AY, DL  
 DITAXIS—*Argythamnia neomexicana* [was *Ditaxis neomexicana* ]—AR, AW, DS, LC, SB, VS  
*Ditaxis lanceolata* [is now *Argythamnia lanceolata* ]—LANCE-LEAVED DITAXIS—AY  
 DITAXIS, LANCE-LEAVED—*Argythamnia lanceolata* [was *Ditaxis lanceolata* ]—AY  
*Ditaxis neomexicana* [is now *Argythamnia neomexicana* ]—DITAXIS—AR, AW, DS, LC, SB, VS  
 Dodder Family—Cuscutaceae (Convolvulaceae, part)  
 DODDER, KNOBBY—*Cuscuta tuberculata* (\*)  
 DODDER, UMBRELLA—*Cuscuta umbellata*—AR, GC  
*Dodonaea viscosa*—HOPBUSH—AC, AY, BP  
 Dogbane Family—Apocynaceae  
 DOGWEED—*Dyssodia concinna*—DL, NS, VS  
 DOGWEED, SAN FELIPE—*Dyssodia porophylloides*—LC, SB  
*Draba cuneifolia*—WHITLOW GRASS—AY, VS  
 DROPSEED, MESA—*Sporobolus flexuosus* (\*)—EA  
*Dyssodia concinna*—DOGWEED—DL, NS, VS  
*Dyssodia porophylloides*—SAN FELIPE DOGWEED—LC, SB

—E—

*Echinocactus erectocentrus* [is now *Echinomastus erectocentrus* ]—BARREL CACTUS—NS  
*Echinocereus engelmanni*—HEDGEHOG CACTUS—BP, BS, DL, EA, LC, NS, SB, VS  
*Echinocereus nicholi*—HEDGEHOG CACTUS—DS  
*Echinomastus erectocentrus* [was *Echinocactus erectocentrus* ]—BARREL CACTUS—NS  
*Echinopepon wrightii* (\*)—WILD BALSAM APPLE—AY  
 ELEPHANT TREE—*Bursera microphylla*—LC, SB  
 Elm Family—Ulmaceae  
*Encelia farinosa*—BRITTLEBUSH—AC, AW, AY, BP, DS, LC, SB, VS

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Synonymous nomenclature

*Encelia frutescens*—RAYLESS ENCELIA—GC, SB  
 ENCELIA, RAYLESS—*Encelia frutescens*—GC, SB  
*Enneapogon cenchroides* (\*)—PAPPUS GRASS  
*Enneapogon desvauxi* (+)—NINE-AWNED PAPPUS GRASS  
*Ephedra aspera* [is now *E. nevadensis* ssp. *aspera*]—JOINT FIR—BP, DS, EA, GC  
 Ephedraceae—Joint Fir Family  
*Ephedra nevadensis* ssp. *aspera* [was *E. aspera*]—JOINT FIR—BP, DS, EA, GC  
*Ephedra trifurca*—LONG-LEAVED JOINT FIR—EA (off-plot)  
*Eragrostis cilanensis*—STINKGRASS—SS  
 ERIASTRUM—*Eriastrum diffusum*—BP, LC, PN, SB, VS  
*Eriastrum diffusum*—ERIASTRUM—BP, LC, PN, SB, VS  
*Ericameria laricifolia*—TURPENTINEBUSH—AY, BP  
*Erigeron divergens* (+)—FLEABANE, SPREADING  
*Eriochloa aristata* (\*)—CUP GRASS—GC  
*Eriogonum deflexum*—FLAT-TOPPED BUCKWHEAT—NS, SB  
*Eriogonum fasciculatum*—CALIFORNIA BUCKWHEAT—AY  
*Eriogonum wrighti*—WRIGHT'S BUCKWHEAT—AC, AY, BP, DS, LC  
*Erioneuron pulchellum*—FLUFF GRASS—DL, DS, EA, LC, NS, SB, VS  
*Eriophyllum lanosum*—WOOLY SUNFLOWER—SB  
*Erodium cicutarium*—FILAREE—AR, DS  
*Erodium texanum* (+)—LARGE-FLOWERED STORKSBILL  
*Eucnide rupestris* (\*)—ROCK NETTLE  
*Eucrypta chrysanthemifolia*—TORREY EUCRYPTA—AC, DS  
*Eucrypta micrantha*—SMALL-FLOWERED EUCRYPTA—VS  
 EUCRYPTA, SMALL-FLOWERED—*Eucrypta micrantha*—VS  
 EUCRYPTA, TORREY—*Eucrypta chrysanthemifolia*—AC, DS  
*Eupatorium solidaginifolium*—THOROUGHWORT—AY  
 Euphorbiaceae—Spurge Family  
*Euphorbia eriantha* [is now *Poinsettia eriantha*]—DESERT POINSETTIA—SB  
*Euphorbia heterophylla* ssp. *graminifolia* (\*)—PAINTED SPURGE—BP  
*Euphorbia, part* [is now *Chamaesyce*]—SPURGE  
 Evening Primrose Family—Onagraceae  
 EVOLVULUS—*Evolvulus alsinoides*—AY, BP  
*Evolvulus alsinoides*—EVOLVULUS—AY, BP

—F—

Fagaceae—Beech Family  
 FAGONIA—*Fagonia californica*—DS, LC, NS, SB, VS  
*Fagonia californica*—FAGONIA—DS, LC, NS, SB, VS  
 FAIRY DUSTER—*Calliandra eriophylla*—BP, NS

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FELT PLANT, YELLOW—*Horsfordia newberryi*—LC  
 Fern Family—Adiantaceae [was **Polypodiaceae**]  
*Ferocactus acanthodes* [is now *F. cylindraceus*]—BARREL CACTUS—LC  
*Ferocactus covillei* [is now *F. emoryi*]—BARREL CACTUS—AW, AY, BP, DS, NS, PN, SB  
*Ferocactus cylindraceus* [was *F. acanthodes*]—BARREL CACTUS—LC  
*Ferocactus emoryi* [was *F. covillei*]—BARREL CACTUS—AW, AY, BP, DS, NS, PN, SB  
*Ferocactus wislizeni*—BARREL CACTUS—EA  
 FESCUE, SIX WEEKS—*Vulpia octoflora*—BP, DL, DS, SB  
 FIDDLENECK, CHECKER—*Amsinckia tessellata*—AR, VS  
 FIDDLENECK, COAST—*Amsinckia intermedia*—VS  
 Figwort Family—Scrophulariaceae  
 FILAREE—*Erodium cicutarium*—AR, DS  
 FINGERGRASS, FEATHER—*Chloris virgata*—DL, SB  
 FISHHOOK CACTUS—*Mammillaria grahami* [was *M. microcarpa*]—AY, BP, DS, EA, LC, NS, SB, VS  
 FISHHOOK CACTUS—*Mammillaria thornberi*—DL, VS  
 FLAME FLOWER—*Talinum aurantiacum* (incl. *T. angustissimum*)—BP  
 FLEABANE, SPREADING—*Erigeron divergens* (+)  
 FLUFF GRASS—*Erioneuron pulchellum*—DL, DS, EA, LC, NS, SB, VS  
*Forestiera shrevei*—ADELIA—AC, AY, BP  
 Fouquieriaceae—Ocotillo Family  
*Fouquieria splendens*—OCOTILLO—BP, DS, LC, NS, PN, SB, VS  
 FOUR-O’CLOCK, BIGELOW’S—*Mirabilis bigelovi*—AW, AC, AY, BP, DS, SB, VS  
 Four-o’clock Family—Nyctaginaceae  
 FOUR-O’CLOCK, TRAILING—*Allionia incarnata*—AR, AW, AY, DL, GC, PN, SS, VS  
*Funastrum crispum* [is now *Sarcostemma crispum*]—CLIMBING MILKWEED—DL

—G—

*Galium aparine*—GOOSE GRASS—AC  
*Galium stellatum*—BEDSTRAW—AC, AY, BP, SB  
 Geraniaceae—Geranium Family  
 Geranium Family—Geraniaceae  
 GERMANDER—*Teucrium cubense* (\*)—DL  
 GLOBEMALLOW, CALICHE—*Sphaeralcea laxa*—BP, DS  
 GLOBEMALLOW, COULTER’S—*Sphaeralcea coulteri*—AW, AY, BP, BS, DL, GC, SS, VS  
 GLOBEMALLOW, EMORY’S—*Sphaeralcea emoryi*—AR, AW, AY, DL, GC, SS, VS  
 GOLDENBUSH—*Isocoma acradenia*—AW  
 GOLDENEYE—*Viguiera parishi* [was *V. deltoidea*]—AY, BP, DS, GC, SB  
 GOLD FERN—*Pityrogramma triangularis*—AC, AY  
 Goosefoot Family—Chenopodiaceae  
 GOOSE GRASS—*Galium aparine*—AC

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Gourd Family—Cucurbitaceae

GRAMA, BLUE—*Bouteloua gracilis*

GRAMA, SIDE OATS—*Bouteloua curtipendula*—BP, DL

GRAMA, SIX WEEKS—*Bouteloua barbata*—AR, AW, AY, BP, BS, DL, DS, EA, GC, PN, SS, SB, VS

GRAMA, SIX WEEKS NEEDLE—*Bouteloua aristidoides*—AR, AW, BS, DS, PN

GRAMA, SLENDER—*Bouteloua repens* [was *B. filiformis*]—AY, BP

Gramineae—Grass Family

GRAPPLING HOOK, PALMER'S—*Harponella palmeri*—BP

Grass Family—Gramineae

GRAYTHORN—*Zizyphus obtusifolia*—AC, AR, AW, BP, BS, DS, EA, GC, VS

GROUNDCHERRY, HAIRY—*Physalis pubescens* (\*)—BP

GROUNDCHERRY, PURPLE—*Physalis lobata* (+)

GROUNDCHERRY, THICK-LEAVED—*Physalis crassifolia* (+)

*Gutierrezia sarothrae*—BROOM SNAKEWEED—AR, AY, BP, DS, NS

*Gymnosperma glutinosum*—TATALENCHO—AC, AY, BP

—H—

HACKBERRY, DESERT—*Celtis pallida*—AC, AY, BP, DS, GC

HACKBERRY, NET LEAF—*Celtis reticulata*—AC, AY, BP

*Haplophyton crooksi*—COCKROACH PLANT—AY

*Harponella palmeri*—PALMER'S GRAPPLING HOOK—BP

*Hedeoma nanum*—MOCK PENNYROYAL—AC

HEDGEHOG CACTUS—*Echinocereus engelmanni*—BP, BS, DL, EA, LC, NS, SB, VS

HEDGEHOG CACTUS—*Echinocereus nicholi*—DS

HELECHILLO—*Notholaena cochinchinensis* (\*)—LC

*Herissantia crispa*—BLADDER MALLOW—AY, BP, DS, SB

*Hesperocallis undulata*—DESERT LILY—PN

*Heteropogon contortus*—TANGLEHEAD—AY, BP

*Hibiscus coulteri*—DESERT ROSE MALLOW—AY, BP, SB

*Hibiscus denudatus*—ROCK ROSE MALLOW—LC, NS, SB

*Hilaria belangeri*—CURLY MESQUITE GRASS—BP, DS

*Hilaria rigida*—BIG GALLETA—EA, PN

*Hoffmeisteria pluriseta* [is now *Pleurocoronis pluriseta*]—ARROW LEAF—DS, LC

HOPBUSH—*Dodonaea viscosa*—AC, AY, BP

HORSE PURSLANE—*Trianthema portulacastrum*—AR, AW, BP, BS, DL, SS

*Horsfordia newberryi*—YELLOW FELT PLANT—LC

HUMMINGBIRD TRUMPET—*Zauschneria californica*—AC, BP

Hydrophyllaceae—Waterleaf Family

*Hymenoclea salsola*—CHEESEBUSH—AW, EA, GC, VS

*Hyptis emoryi*—DESERT LAVENDER—LC, SB, VS

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—I—

INDIAN MALLOW—*Abutilon abutiloides* [was *A. californicum*]  
INDIAN MALLOW—*Abutilon incanum* [was *A. pringlei*]  
INDIAN MALLOW—*Abutilon malacum* (\*)  
INDIAN MALLOW—*Abutilon palmeri*  
INDIAN ROOT—*Aristolochia watsoni*  
*Ipomoea coccinea* (\*)—SCARLET MORNING GLORY  
*Ipomoea costellata* (\*)—MORNING GLORY  
*Isocoma acradenia*—GOLDENBUSH

—J—

*Jacobinia ovata* [is now *Justicia candicans*]  
JACQUEMONTIA—*Jacquemontia pringlei*  
*Jacquemontia pringlei*  
JANUSIA, SLENDER—*Janusia gracilis*  
*Janusia gracilis*  
JATROPHA, ASHY—*Jatropha cinerea*  
*Jatropha cardiophylla*  
*Jatropha cinerea*  
*Jatropha cuneata*  
JATROPHA, WEDGE-SHAPED—*Jatropha cuneata*  
JEWEL FLOWER—*Caulanthus lasiophyllus* [was *Thelypodium lasiophyllum*]  
JOINT FIR—*Ephedra nevadensis* ssp. *aspera* [was *E. aspera*]  
Joint Fir Family—Ephedraceae  
JOINT FIR, LONG-LEAVED—*Ephedra trifurca*  
JOJOBA—*Simmondsia chinensis*  
*Juniperus erythrocarpa* [was *J. monosperma*]  
JUNIPER, ONE SEED—*Juniperus erythrocarpa* [was *J. monosperma*]  
*Juniperus monosperma* [is now *J. erythrocarpa*]  
*Justicia californica* [was *Beloperone californica*]  
*Justicia candicans* [was *Jacobinia ovata*]

—K—

*Kallstroemia californica*  
*Kallstroemia grandiflora*  
Krameriaceae—Ratany Family  
*Krameria erecta* [was *K. parvifolia*]  
*Krameria grayi*  
*Krameria parvifolia* [is now *K. erecta*]

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—L—

Labiatae—Mint Family

*Lappula redowski*—STICKSEED—DS, SS

LARKSPUR, BARESTEM—*Delphinium scaposum*—AY, BP

*Larrea divaricata*—CREOSOTE BUSH—AC, AR, AW, AY, BS, DL, DS, EA, GC, LC, NS, PN, SB, SS, VS

Leguminosae—Pea Family

*Lepidium lasiocarpum*—SAND PEPPERGRASS—AW, BP, BS, DL, VS

*Leptochloa filiformis*—RED SPRANGLETOP—AY, BP, DS, SS

Liliaceae—Lily Family

Lily Family—Liliaceae

LIMBERBUSH—*Jatropha cardiophylla*—LIMBERBUSH—BP, NS

LIP FERN, BEADED—*Cheilanthes wootoni*—AC

LIP FERN, WRIGHT'S—*Cheilanthes wrightii*—AY, BP

LIPPIA, WRIGHT'S—*Aloysia wrightii*—AY, BP

Loasaceae—Stickleaf Family

LOCOWEED, NUTTALL—*Astragalus nuttallianus*—BP

LONDON ROCKET—*Sisymbrium irio*—DS

*Lophocereus schottii* [was *Cereus schottii*]—SENITA CACTUS—LC, SB

LOTUS, HAIRY—*Lotus tomentellus*—EA

*Lotus rigidus*—DESERT ROCK PEA—BP

*Lotus tomentellus*—HAIRY LOTUS—EA

LUPINE, ELEGANT—*Lupinus concinnus*—EA

*Lupinus concinnus*—ELEGANT LUPINE—EA

*Lycium andersoni*—WOLFBERRY—AW, BS, DL, DS, EA, GC, SS, VS

*Lycium berlandieri*—WOLFBERRY—AY, DS, LC, NS, SB

*Lycium exsertum*—WOLFBERRY—AW, AY

*Lycium fremonti*—WOLFBERRY—BS, DL

*Lycium macrodon*—WOLFBERRY—AR

*Lycium parishii*—WOLFBERRY—AR, AW, DS, EA, GC, VS

*Lycurus phleoides* [is now *L. setosus*]—WOLF TAIL—BP

*Lycurus setosus* [was *L. phleoides*]—WOLF TAIL—BP

LYRE POD, COULTER'S—*Lyrocarpa coulteri*—AC, AW, DS, LC, NS, SB, VS

*Lyrocarpa coulteri*—COULTER'S LYRE POD—AC, AW, DS, LC, NS, SB, VS

—M—

*Machaeranthera arida*—ASTER—BP, DL

*Machaeranthera asteroides*—ASTER—AY

*Machaeranthera pinnatifida*—ASTER—AR, DS, EA, GC

Madder Family—Rubiaceae

Mallow Family—Malvaceae

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MALLOW, FORKED—*Malvastrum bicuspidatum*—AY, BP  
 Malpighiaceae—Malpighia Family  
 Malpighia Family—Malpighiaceae  
 Malvaceae—Mallow Family  
*Malvastrum bicuspidatum*—FORKED MALLOW—AY, BP  
*Mammillaria grahami* [was *M. microcarpa*]—FISHHOOK CACTUS—AY, BP, DS, EA, LC, NS, SB, VS  
*Mammillaria microcarpa* [is now *M. grahami*]—FISHHOOK CACTUS—AY, BP, DS, EA, LC, NS, SB, VS  
*Mammillaria thornberi*—FISHHOOK CACTUS—DL, VS  
*Marah gilensis*—WILD CUCUMBER—AY  
*Marina parryi* [was *Dalea parryi*]—PARRY'S DALEA—AW, SB  
*Marina pringlei* [was *Dalea pringlei*]—DALEA—VS  
 MARIPOSA, DESERT—*Calochortus kennedyi*—BP  
 Martyniaceae—Unicorn-plant Family  
*Matelea parvifolia*—ANGLE POD—AY, BP  
*Maurandya antirrhiniflora*—BLUE SNAPDRAGON VINE—DL, GC  
 MENODORA—*Menodora scabra*—AY, BP, GC, SB  
*Menodora scabra*—MENODORA—AY, BP, GC, SB  
 MERCURY, THREE SEED—*Acalypha pringlei*—AC, AY, BP, SB  
 MESQUITE, VELVET—*Prosopis velutina*—AC, AR, AW, AY, BP, BS, DL, DS, EA, GC, NS, PN, SS, VS  
*Metastelma arizonicum* [is now *Cynanchum arizonicum*]—ARIZONA VINE MILKWEED—BP  
 MEXICAN JUMPING BEAN—*Sapium biloculare*—AC, AY, LC, NS, SB  
*Microseris linearifolia*—SILVER PUFFS—BP  
 Mignonette Family—Resedaceae  
 MILKWEED—*Asclepias linaria*—BP, DS  
 Milkweed Family—Asclepiadaceae  
 MILKWEED, FOUR-O'CLOCK—*Asclepias nyctaginifolia* (\*)—AR  
 MIMULUS, RED-STEMMED—*Mimulus rubellus* (+)  
*Mimulus rubellus* (+)—RED-STEMMED MIMULUS  
 Mint Family—Labiatae  
*Mirabilis bigelovi*—BIGELOW'S FOUR-O'CLOCK—AW, AC, AY, BP, DS, SB, VS  
 MISTLETOE, DESERT—*Phoradendron californicum*—AR, AW, BP, EA, GC, LC, SS, VS  
 Mistletoe Family—Viscaceae  
 MOCK PENNYROYAL—*Hedeoma nanum*—AC  
 Molluginaceae—Carpet Weed Family (part)  
*Mollugo cerviana* (\*)—THREAD STEM CARPET WEED—SB, VS  
*Monolepis nuttalliana*—POVERTY WEED—AR, DL  
 MONTIA—*Montia perfoliata*—AY  
*Montia perfoliata*—MONTIA—AY  
 MORNING GLORY—*Ipomoea costellata* (\*)—BP  
 Morning Glory Family—Convolvulaceae

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MORNING GLORY, SCARLET—*Ipomoea coccinea* (\*)—AY  
 MOUSE TAIL—*Myosurus aristatus*—AC  
 MOUSE TAIL—*Myosurus cupulatus*—AY  
*Muhlenbergia emersleyi* (+)—MUHLY  
*Muhlenbergia microsperma*—LITTLE SEED MUHLY—AW, AY, BS, DS, SS, VS  
*Muhlenbergia porteri*—BUSH MUHLY—AR, AY, EA, GC, LC, SB  
 MUHLY—*Muhlenbergia emersleyi* (+)  
 MUHLY, BUSH—*Muhlenbergia porteri*—AR, AY, EA, GC, LC, SB  
 MUHLY, LITTLE SEED—*Muhlenbergia microsperma*—AW, AY, BS, DS, SS, VS  
 Mustard Family—Cruciferae  
*Myosurus aristatus*—MOUSE TAIL—AC  
*Myosurus cupulatus*—MOUSE TAIL—AY

—N—

*Nama hispidum*—PURPLE MAT—AW, DL, VS  
 Nettle Family—Urticaceae  
*Nicotiana trigonophylla* (+)—DESERT TOBACCO  
 NIGHT-BLOOMING CACTUS—*Peniocereus greggi* [was *Cereus greggi*]—BS, DL, EA  
 NIGHTSHADE—*Solanum douglasi* (+)  
 NISSOLIA—*Nissolia schotti*—AY, BP  
*Nissolia schotti*—NISSOLIA—AY, BP  
 NOSEBURN—*Tragia nepetaefolia*—AC, AY, BP, DS  
*Notholaena cochinchinensis* (\*)—HELECHILLO—LC  
*Notholaena sinuata*—WAVY CLOAK FERN—AC, AY, BP  
*Notholaena standleyi*—CLOAK FERN—AY, BP, DS, LC, SB  
 Nyctaginaceae—Four-o'clock Family

—O—

OAK, AJO—*Quercus turbinella* ssp. *ajoensis* comb. nov. [was *Q. ajoensis*]—AC  
 OCOTILLO—*Fouquieria splendens*—BP, DS, LC, NS, PN, SB, VS  
 Ocotillo Family—Fouquieriaceae  
 ODORA—*Porophyllum gracile*—DS, LC, NS, SB, VS  
 Oleaceae—Olive Family  
*Oligomeris linifolia*—LINEAR-LEAVED CAMBESS—DL  
 Olive Family—Oleaceae  
*Olneya tesota*—DESERT IRONWOOD—AW, EA, LC, NS, SB, VS  
 Onagraceae—Evening Primrose Family  
*Opuntia acanthocarpa*—BUCKHORN CHOLLA—AC, AW, BP, DL, DS, LC, NS, PN, SB, VS  
*Opuntia arbuscula*—PENCIL CHOLLA—EA  
*Opuntia bigelovi*—TEDDY BEAR CHOLLA—NS, SB

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*Opuntia chlorotica*—PANCAKE PEAR—BP, DS  
*Opuntia fulgida*—JUMPING CHOLLA—AW, DL, EA, NS, VS  
*Opuntia kunzei* [was *O. stanleyi* ssp. *kunzei*]—DEVIL CHOLLA—EA  
*Opuntia leptocaulis*—CHRISTMAS CACTUS—AW, DL, EA, PN, SB, VS  
*Opuntia phaeacantha*—PRICKLY PEAR—AC, BP, DS  
*Opuntia spinosior*—STAGHORN CHOLLA—EA  
*Opuntia stanleyi* ssp. *kunzei* [is now *O. kunzei*]—DEVIL CHOLLA—EA  
 ORGAN PIPE CACTUS—*Stenocereus thurberi* [was *Cereus thurberi*]—AC, BP, DS, LC, NS, SB, VS

—P—

PALOVERDE, BLUE—*Cercidium floridum*—AR, AW, BS, DL, EA, GC, SS, VS  
 PALOVERDE, FOOTHILL—*Cercidium microphyllum*—BP, DS, EA, LC, NS, PN, SB, VS  
 PANCAKE PEAR—*Opuntia chlorotica*—BP, DS  
 PANICGRASS—*Panicum hirticaule*—AR, AY, BP  
*Panicum arizonicum* [is now *Brachiaria arizonica*] (\*)—BRACHIARIA—DS  
*Panicum hirticaule*—PANICGRASS—AR, AY, BP  
 PAPERFLOWER—*Psilostrophe cooperi*—BP  
 PAPPUS GRASS—*Enneapogon cenchroides* (\*)  
 PAPPUS GRASS, NINE-AWNED—*Enneapogon desvauxi* (+)  
*Parietaria hespera*—PELLITORY—AC, AY, DS  
 Parsley Family—Apiaceae (or Umbelliferae)  
 PEA, DESERT ROCK—*Lotus rigidus*—BP  
 Pea Family—Leguminosae  
*Pectis linifolia* (\*)—CHINCHWEED—AY  
*Pectis papposa*—CHINCHWEED—AR, AW, BP, DL, EA, GC, LC, PN, SB, VS  
*Pectocarya platycarpa*—BROAD-NUTTED COMB BUR—PN, VS  
*Pectocarya recurvata*—ARCH-NUTTED COMB BUR—AW, DL, EA, GC, VS  
*Pellaea truncata*—CLIFF BRAKE—AY  
 PELLITORY—*Parietaria hespera*—AC, AY, DS  
*Peniocereus greggi* [was *Cereus greggi*]—NIGHT-BLOOMING CACTUS—BS, DL, EA  
*Penstemon parryi*—PARRY'S BEARDTONGUE—BP, DS  
 PEPPERGRASS, SAND—*Lepidium lasiocarpum*—AW, BP, BS, DL, VS  
*Perezia wrightii* [is now *Acourtia wrightii*]—BROWNFOOT—AY, BP  
*Perityle emoryi* (+)—EMORY'S ROCK DAISY  
*Petalonyx thurberi* (+)—THURBER'S SANDPAPER PLANT  
*Phacelia distans* (+)—WILD HELIOTROPE  
*Phaseolus acutifolius* ssp. *acutifolius* (\*)—WILD BEAN—AY  
*Phaseolus wrightii* (+)—WILD BEAN  
 Phlox Family—Polemoniaceae  
 PHOLISTOMA—*Pholistoma auritum*—AC, AY, DS

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Symbols key: \* Taxa new to ORPI

+ Taxa new to ORPI Herbarium

Synonymous nomenclature

*Pholistoma auritum*—PHOLISTOMA—AC, AY, DS  
*Phoradendron californicum*—DESERT MISTLETOE—AR, AW, BP, EA, GC, LC, SS, VS  
*Physalis crassifolia* (+)—THICK-LEAVED GROUNDCHERRY  
*Physalis lobata* (+)—PURPLE GROUNDCHERRY  
*Physalis pubescens* (\*)—HAIRY GROUNDCHERRY—BP  
 Phytolaccaceae—Pokeberry Family  
 PIGWEED, PROSTRATE—*Amaranthus graecizans* (+)  
 PINCUSHION, ESTEVE—*Chaenactis stevioides*—EA  
 PINK BABY BREATH—*Talinum paniculatum*—AY, BP  
 Pink Family—Caryophyllaceae  
*Pityrogramma triangularis*—GOLD FERN—AC, AY  
 Plantaginaceae—Plantain Family  
*Plantago insularis*—WOOLY PLANTAIN—AW, BP, BS, DL, NS, PN, VS  
 Plantain Family—Plantaginaceae  
 PLANTAIN, WOOLY—*Plantago insularis*—AW, BP, BS, DL, NS, PN, VS  
*Pleurocoronis pluriseta* [was *Hoffmeisteria pluriseta*]—ARROW LEAF—DS, LC  
 Plumbaginaceae—Plumbago Family  
 PLUMBAGO—*Plumbago scandens*—AC, VS  
 Plumbago Family—Plumbaginaceae  
*Plumbago scandens*—PLUMBAGO—AC, VS  
*Poa bigelovi*—BIGELOW'S BLUEGRASS—AC, AY, DS  
 POINTSETTIA, DESERT—*Poinsettia eriantha* [was *Euphorbia eriantha*]—SB  
*Poinsettia eriantha* [was *Euphorbia eriantha*]—DESERT POINSETTIA—SB  
 Pokeberry Family—Phytolaccaceae  
 Polemoniaceae—Phlox Family  
 Polygonaceae—Buckwheat Family  
**Polypodiaceae** [is now Adiantaceae]—Fern Family  
*Porophyllum gracile*—ODORA—DS, LC, NS, SB, VS  
 Portulacaceae—Portulaca Family  
 Portulaca Family—Portulacaceae  
*Portulaca oleracea* (\*)—PURSLANE—BP, BS, DS  
*Portulaca umbraticola*—PURSLANE—BP  
 Potato (Nightshade) Family—Solanaceae  
 POVERTY WEED—*Monolepis nuttalliana*—AR, DL  
 PRICKLY PEAR—*Opuntia phaeacantha*—AC, BP, DS  
 PRIMROSE—*Camissonia clavaeformis*—GC, SB  
 PRIMROSE, CALIFORNIA—*Camissonia californica*—BP, NS, VS  
 Primrose Family—Primulaceae  
 Primulaceae—Primrose Family  
*Proboscidea parviflora* (\*)—DEVIL'S CLAW—BP

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Synonomous nomenclature

*Prosopis velutina*—VELVET MESQUITE—AC, AR, AW, AY, BP, BS, DL, DS, EA, GC, NS, PN, SS, VS  
*Psilostrophe cooperi*—PAPERFLOWER—BP  
*Psoralea spinosa* [was *Dalea spinosa*]—SMOKE TREE—AW  
 PURPLE MAT—*Nama hispidum*—AW, DL, VS  
 PURSLANE—*Portulaca oleracea* (\*)—BP, BS, DS  
 PURSLANE—*Portulaca umbraticola*—BP

—Q—

QUELITE—*Amaranthus palmeri*—AR, DL, GC, SS  
*Quercus ajoensis* [is now *Q. turbinella* ssp. *ajoensis* comb. nov.]—OAK, AJO—AC  
*Quercus turbinella* ssp. *ajoensis* comb. nov. [was *Q. ajoensis*]—OAK, AJO—AC

—R—

*Rafinesquia neomexicana* (+)—DESERT CHICORY  
 RAGGED ROCKFLOWER, BIGELOW—*Crossosoma bigelovi*—AC, AY, DS  
 RAGWEED—*Ambrosia cordifolia*—AC, AY  
 Ranunculaceae—Crowfoot Family  
 Ratany Family—Krameriaceae  
 RATANY, SMALL-LEAVED—*Krameria erecta* [was *K. parvifolia*]—NS, SB  
 RATANY, WHITE—*Krameria grayi*—GC, LC, NS, PN  
 RATTLESNAKE WEED—*Chamaesyce albomarginata*—AR, GC  
 Resedaceae—Mignonette Family  
 Rhamnaceae—Buckthorn Family  
*Rhamnus crocea*—RED BERRY BUCKTHORN—AC, AY, BP  
*Rivina humilis*—ROUGE PLANT—AY  
 ROCK CRESS—*Arabis perennans*—AY  
 ROCK DAISY, EMORY'S—*Perityle emoryi* (+)  
 ROCK JASMINE—*Androsace occidentalis*—AC, AY  
 ROCK NETTLE—*Eucnide rupestris* (\*)  
 Rosaceae—Rose Family  
 Rose Family—Rosaceae  
 ROSE MALLOW, DESERT—*Hibiscus coulteri*—AY, BP, SB  
 ROSE MALLOW, ROCK—*Hibiscus denudatus*—LC, NS, SB  
 ROSEWOOD, CALIFORNIA—*Vauquelinia californica*—AY, BP  
 ROUGE PLANT—*Rivina humilis*—AY  
 Rubiaceae—Madder Family

—S—

SAGEBRUSH—*Artemisia ludoviciana*—AC, AY, BP  
 SAGE, ROCK—*Salvia pinguifolia*—AY

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SAGUARO—*Carnegiea gigantea* [was *Cereus gigantea*]—AC, AW, BP, BS, DL, DS, EA, LC, NS, PN, SB, VS  
*Salvia columbariae*—CHIA—GC, SB  
*Salvia pinguifolia*—ROCK SAGE—AY  
SAND MAT, BRISTLE-LOBED—*Chamaesyce setiloba*—AW, GC, SB, VS  
SAND MAT, SMALL SEED—*Chamaesyce polycarpa*—AW, GC, LC, NS, SB, VS  
SAND MAT, SONORAN—*Chamaesyce micromera*—AW, AY, BP, EA, GC, PN, SB, VS  
SANDPAPER PLANT, THURBER'S—*Petalonyx thurberi* (+)  
Sapindaceae—Soapberry Family  
*Sapindus saponaria*—SOAPBERRY—AC  
*Sapium biloculare*—MEXICAN JUMPING BEAN—AC, AY, LC, NS, SB  
*Sarcostemma crispum* [was *Funastrum crispum*]—CLIMBING MILKWEED—DL  
*Sarcostemma cynanchoides*—CLIMBING MILKWEED—AR, AW, AY, BS, GC, VS  
*Schismus arabicus* [was *S. barbatus*]—ARABIAN GRASS—AR, AW, BS, DL, EA, GC, LC, PN, SB, SS, VS  
*Schismus barbatus* [is now *S. arabicus*]—ARABIAN GRASS—AR, AW, BS, DL, EA, GC, LC, PN, SB, SS, VS  
Scrophulariaceae—Figwort Family  
SEEPWEED, DESERT—*Suaeda torreyana*—AW  
*Selaginella arizonica*—SPIKE MOSS—BP  
Selaginellaceae—Selaginella Family  
Selaginella Family—Selaginellaceae  
SENITA CACTUS—*Lophocereus schottii* [was *Cereus schottii*]—LC, SB  
SENNA, DESERT—*Cassia covesi*  
*Setaria macrostachya*—PLAINS BRISTLEGRASS—AR, AY, BP, DS  
*Silene antirrhina*—SLEEPY CATCHFLY—BP  
SILVER PUFFS—*Microseris linearifolia*—BP  
Simaroubaceae—Simarouba Family  
Simarouba Family—Simaroubaceae  
*Simmondsia chinensis*—JOJOBA—AC, AY, BP, DS  
SIPHONGLOSSA—*Siphonoglossa longiflora*—BP, DS  
*Siphonoglossa longiflora*—SIPHONOGLOSSA—BP, DS  
*Sisymbrium irio*—LONDON ROCKET—DS  
SMOKE TREE—*Psoralea spinosa* [was *Dalea spinosa*]—AW  
SNAKEWEED, BROOM—*Gutierrezia sarothrae*—AR, AY, BP, DS, NS  
SNAPDRAGON, TWINING—*Antirrhinum filipes* (+)  
SNAPDRAGON VINE, BLUE—*Maurandya antirrhiniflora*—DL, GC  
SOAPBERRY—*Sapindus saponaria*—AC  
Soapberry Family—Sapindaceae  
Solanaceae—Potato (Nightshade) Family  
*Solanum douglasi* (+)—NIGHTSHADE  
*Sphaeralcea ambigua*—DESERT MALLOW—DL  
*Sphaeralcea coulteri*—COULTER'S GLOBEMALLOW—AW, AY, BP, BS, DL, GC, SS, VS

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*Sphaeralcea emoryi*—EMORY'S GLOBEMALLOW—AR, AW, AY, DL, GC, SS, VS  
*Sphaeralcea laxa*—CALICHE GLOBEMALLOW—BP, DS  
 SPIDERLING—*Boerhaavia erecta*—AR, AY, BP, DL, DS, GC, LC, SS  
 SPIDERLING, COULTER'S—*Boerhaavia coulteri* (\*)—PN, SB, VS  
 SPIDERLING, WRIGHT'S—*Boerhaavia wrightii* (+)  
 SPIKE MOSS—*Selaginella arizonica*—BP  
 SPINEFLOWER, BRITTLE—*Chorizanthe brevicornu*—NS, SB  
 SPINEFLOWER, RIGID—*Chorizanthe rigida*—PN  
*Sporobolus flexuosus* (\*)—MESA DROPSEED—EA  
 SPRANGLETOP, RED—*Leptochloa filiformis*—AY, BP, DS, SS  
 SPURGE—*Chamaesyce* [was *Euphorbia*, part]  
 SPURGE—*Chamaesyce pediculifera*—AW, VS  
 SPURGE, ARIZONA—*Chamaesyce arizonica*—AY, DS  
 Spurge Family—Euphorbiaceae  
 SPURGE, FLORIDA—*Chamaesyce florida*—AR, AY, BP, VS  
 SPURGE, GROUNDFIG—*Chamaesyce prostrata* (\*)—AR  
 SPURGE, HYSSOP—*Chamaesyce hyssopifolia* (\*)—AC, BP  
 SPURGE, PAINTED—*Euphorbia heterophylla* ssp. *graminifolia* (\*)—BP  
 SPURGE, PROSTRATE—*Chamaesyce abramsiana* (\*)—AR, AW, BP, BS, DL, GC, SS, SB  
*Stenocereus thurberi* [was *Cereus thurberi*]—ORGAN PIPE CACTUS—AC, BP, DS, LC, NS, SB, VS  
*Stephanomeria pauciflora*—DESERT STRAW—AW  
 Sterculiaceae—Cacao Family  
 Stickleaf Family—Loasaceae  
 STICKSEED—*Lappula redowski*—DS, SS  
 STINKGRASS—*Eragrostis cilanensis*—SS  
 STORKSBILL, LARGE-FLOWERED—*Erodium texanum* (+)  
*Suaeda torreyana*—DESERT SEEPWEED—AW  
 Sunflower Family (or Aster Family)—Asteraceae (or Compositae)  
 SWEETBUSH—*Bebbia juncea*—AW, SB, VS

—T—

*Talinum aurantiacum* (incl. *T. angustissimum*)—FLAME FLOWER—BP  
*Talinum paniculatum*—PINK BABY BREATH—AY, BP  
 TANGLEHEAD—*Heteropogon contortus*—AY, BP  
 TANSY MUSTARD, YELLOW—*Descurainia pinnata* (+)  
 TATALENCHO—*Gymnosperma glutinosum*—AC, AY, BP  
*Teucrium cubense* (\*)—GERMANDER—DL  
 THELYPODIOPSIS—*Thelypodopsis linearifolia* (+)  
*Thelypodopsis linearifolia* (+)—THELYPODIOPSIS  
*Thelypodium lasiophyllum* [is now *Caulanthus lasiophyllus*]—JEWEL FLOWER—BP, SB, VS

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THISTLE, DESERT—*Cirsium neomexicanum* (+)  
 THORN APPLE, DESERT—*Datura discolor*—AW  
 THOROUGHWORT—*Eupatorium solidaginifolium*—AY  
 THREE-AWN—*Aristida hamulosa*—BP  
 THREE-AWN, PURPLE—*Aristida purpurea*—AR, BP, DS, EA, LC, SB  
 THREE-AWN, SIX WEEKS—*Aristida adscensionis*—AY, BP, NS, PN, VS  
 THREE-AWN, SPIDER—*Aristida ternipes*—AY, BP  
*Tidestromia lanuginosa*—WOOLY TIDESTROMIA—AR, AW, DL, PN  
 TIDESTROMIA, WOOLY—*Tidestromia lanuginosa*—AR, AW, DL, PN  
 TOBACCO, DESERT—*Nicotiana trigonophylla* (+)  
 Torchwood Family—Burseraceae  
*Tragia nepetaefolia*—NOSEBURN—AC, AY, BP, DS  
*Trianthenia portulacastrum*—HORSE PURSLANE—AR, AW, BP, BS, DL, SS  
*Trichachne californica* [is now *Digitaria californica*]—COTTONTOP—AY, DL  
 TRIDENS—*Tridens eragrostoides*—AY  
*Tridens eragrostoides*—TRIDENS—AY  
*Tridens muticus*—SLIM TRIDENS—SB  
 TRIDENS, SLIM—*Tridens muticus*—SB  
*Trifolium lacerum* (+)—CLOVER  
 TRIXIS, CALIFORNIA—*Trixis californica*—AC, AY, DS, LC, SB, VS  
*Trixis californica*—CALIFORNIA TRIXIS—AC, AY, DS, LC, SB, VS  
 TURPENTINEBUSH—*Ericameria laricifolia*—AY, BP

—U—

Ulmaceae—Elm Family  
 Umbelliferae (or Apiaceae)—Parsley Family  
 Unicorn Plant Family—Martyniaceae  
 Urticaceae—Nettle Family

—V—

*Vauquelinia californica*—CALIFORNIA ROSEWOOD—AY, BP  
 Verbenaceae—Vervain Family  
*Verbena gooddingi*—GOODDING VERVAIN—AY, BP  
*Verbena neomexicana*—HILLSIDE VERVAIN—AY, BP  
 Vervain Family—Verbenaceae  
 VERVAIN, GOODDING—*Verbena gooddingi*—AY, BP  
 VERVAIN, HILLSIDE—*Verbena neomexicana*—AY, BP  
 VETCH—*Vicia ludoviciana*—AY, BP  
*Vicia ludoviciana*—VETCH—AY, BP  
*Viguiera deltoidea* [is now *V. parishii*]—GOLDENEYE—AY, BP, DS, GC, SB

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Synonymous nomenclature

*Viguiera parishi* [was *V. deltoidea*]—GOLDENEYE—AY, BP, DS, GC, SB  
 VINE MILKWEED, ARIZONA—*Cynanchum arizonicum* [was *Metastelma arizonicum*]—BP  
 VIRGIN'S BOWER, TEXAS—*Clematis drummondii*—AC, GC  
 Viscaceae—Mistletoe Family  
*Vulpia octoflora*—SIX WEEKS FESCUE—BP, DL, DS, SB

—W—

Waterleaf Family—Hydrophyllaceae  
 WHEELSCALE—*Atriplex elegans*—AW, AR  
 WHITE THORN—*Acacia constricta*—NS, SB  
 WHITLOW GRASS—*Draba cuneifolia*—AY, VS  
 WILD BALSAM APPLE—*Echinopepon wrightii* (\*)—AY  
 WILD BEAN—*Phaseolus acutifolius* ssp. *acutifolius* (\*)—AY  
 WILD BEAN—*Phaseolus wrightii* (+)  
 WILD CUCUMBER—*Marah gilensis*—AY  
 WILD HELIOTROPE—*Phacelia distans* (+)  
 WINDFLOWER, DESERT—*Anemone tuberosa*—AY, BP  
 WOLFBERRY—*Lycium andersoni*—AW, BS, DL, DS, EA, GC, SS, VS  
 WOLFBERRY—*Lycium berlandieri*—AY, DS, LC, NS, SB  
 WOLFBERRY—*Lycium exsertum*—AW, AY  
 WOLFBERRY—*Lycium macrodon*—AR  
 WOLFBERRY—*Lycium fremonti*—BS, DL  
 WOLFBERRY—*Lycium parishi*—AR, AW, DS, EA, GC, VS  
 WOLF TAIL—*Lycurus setosus* [was *L. phleoides*]—BP  
 WOOLY SUNFLOWER—*Eriophyllum lanosum*—SB  
 WORMWOOD—*Artemisia dracuncululus* (\*)—AC

—Y—

*Yabea microcarpa* [was *Caucalis microcarpa*] (\*)—CAUCALIS

—Z—

*Zauschneria californica*—HUMMINGBIRD TRUMPET—AC, BP  
*Zizyphus obtusifolia*—GRAYTHORN—AC, AR, AW, BP, BS, DS, EA, GC, VS  
 Zygophyllaceae—Caltrop Family

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Synonomous nomenclature



# Natural Community Grazing-recovery Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Peter L. Warren  
L. Susan Anderson

The Arizona Nature Conservancy  
300 East University Boulevard, Suite 230  
Tucson, Arizona 85705

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# Sampling the 20- x 50-m Monitoring Plots

## Background

A team of at least 2, preferably 3 or 4, people is needed to sample the 20- x 50-m, 0.1 ha (66- x 164-ft, 0.25 a.) plots. At least one of the team members must be very familiar with the perennial plants that will be encountered on the plots. Before going to the field, visit the herbarium and review all species on the list of plants known from the plots with which participants are not familiar.

## Equipment Needed

The following equipment is required for the monitoring process:

- (2) 50-m tape measures (fiberglass, metric)
- (2) 30-m tape measures (fiberglass, metric)
- (6) steel chaining pins
- hand-held counter
- clipboard
- Density—Subplot Species Count data forms (Appendix 3-1)
- Vegetation Cover—Line-intercept Transect data forms (Appendix 3-2)
- pens or pencils
- list of plant species previously found on plot (Appendix 3-3)

## Location of Plots

The plots are marked at each corner with 1.3-cm (0.5-in.) rebar that extends approximately 15–20 cm (6–8 in.) above ground level. All plots are oriented approximately north-south. All measurements are made beginning from the “origin” corner of the plot. In most cases this is the southeast corner of the plot. (Two exceptions are plots 2S2 and 2S4, both of which are oriented east-west and have the origin corner at the northeast corner.) Each plot corner post has an aluminum tag with the plot I.D. number and the compass direction of the corner. After locating the first corner, the remaining corners can be found by stretching the tape across the appropriate distance (20 or 50 m [66 or 164 ft]) to the location of the other corners.

## Transect and Subplot Sampling Methods

The protocol for sampling the 20- x 50-m plots (Fig. 3-1) entails 5 steps: (1) laying out the plots, (2) counting perennial plants within the subplot, (3) measuring line-intercept transects, (4) moving to the next subplot, and (5) sampling subsequent subplots.

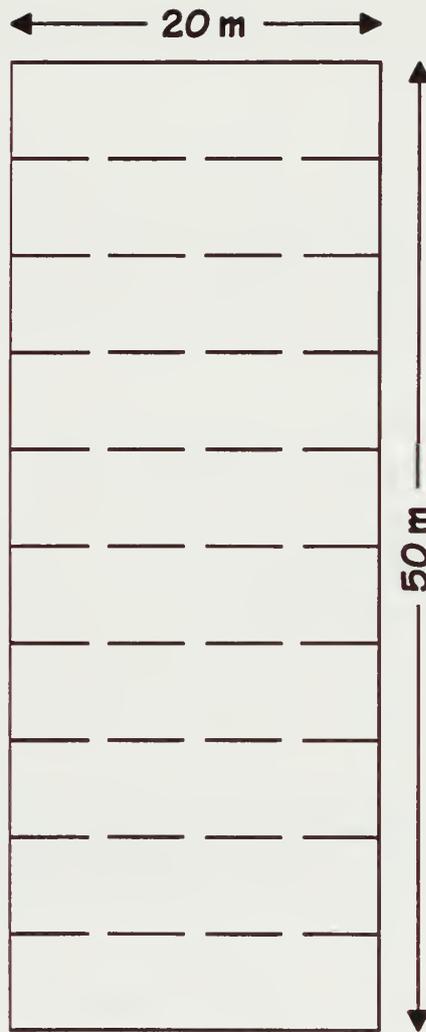


Figure 3-1. Configuration of the 20- x 50-m, 0.1-ha (66- x 164-ft, 0.25 a.) plots in the Natural Community Grazing-recovery study for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. Eleven, 20-m (66-ft) line-intercept transects divide each plot into 10, 5- x 20-m (16- x 66-ft) subplots.

### *Laying out the Plots*

To lay out the 20- x 50-m plots:

1. Find the origin corner (southeast corner for all plots, except 2S2 and 2S4 for which it is the northeast corner).
2. Stretch a 50-m (164-ft) base-line tape along the long east side of the plot (i.e., from the southeast to the northeast corner). Hook the steel end of the tape over the corner post. Keep the tape as low, straight, and tight as possible. (The best way to get a tape straight is to have someone stand on the point for which you are aiming. That person can then direct the tape carrier right or left, in alignment with the anchor point.)
3. Stretch the second 50-m (164-ft) tape along the opposite side of the plot from the southwest corner to the northwest corner, also keeping it low, straight, and tight.
4. Stretch the first 30-m (98-ft) line-intercept cross-tape from the origin (southeast corner) to the southwest corner. Keep the tape as low, straight, and tight as possible. Anchor the tape by hooking it over the first corner post and wrapping it around the second corner post.
5. Stretch the second 30-m (98-ft) line-intercept cross-tape. Move 5 m (16 ft) along the baseline and anchor the end of the tape with a chaining pin. The assistant moves to the 5-m (16-ft) mark along the tape on the opposite side of the plot to serve as a target for stretching the tape.
6. This completes the creation of the first 5- x 20-m (16- x 66-m) subplot extending transversely across the monitoring plot.

### *Counting Perennial Plants within the Subplot*

Once the above has been completed, the next step is to count all of the perennial plants located within the subplot.

1. Prepare a Density—Subplot Species Count data form (Appendix 3-1) with date, plot number, name of sampling team, and so forth. List all species on the data form that have been found on the plot before. One person records while another searches for and counts plants.
2. Carefully inspect the subplot to identify and count *all* plants present. Plants are included in density if they are rooted in the plot, but not if their leaves simply extend over it.
3. Be careful to search around the base of all shrubs, trees, and cacti for small plants that may be growing under the cover of larger plants.
4. List on the data form all species found.

5. As the searcher finds new plants on the plot, he calls out the name and number of individuals for each species and the recorder tallies them on the data form. For common species, the searcher should use the hand-held counter to avoid miscounting.
6. The criterion used to determine whether plants growing close together are different individuals is (1) if the root crowns of neighboring clumps are separated by a distance greater than one-half of the canopy diameter of the smaller of the 2 plants, count them separately; and (2) if the distance between root crowns of neighboring clumps is less than one-half of the canopy diameter, count them as 1 plant.

### *Measuring Line-intercept Transects*

Now record vegetation cover along the line-intercept transect, as follows:

1. Prepare a Vegetation Cover—Line-intercept data form (Appendix 3-2) with date, plot number, name of sampling team, and so forth. One person records data while a second reads the transect.
2. The line-intercept transects are read beginning at the baseline end of the tape measure (zero) and continuing to the opposite side of the plot (20 m [66 ft]). The first 2 transects define the boundaries of the first subplot and are measured now.
3. A plant is recorded if its canopy crosses (or is crossed by) the tape.
4. It is important to look *vertically* down on the tape to determine whether and where the plant canopy crosses the tape. A plumb-bob or equivalent can be helpful for this.
5. Two numbers are recorded for each plant that intercepts the tape, one for each side of the plant's canopy. An "in" value is recorded where the canopy first hits the tape, and an "out" value is recorded where the tape exits the plant canopy. The "in" value should always be smaller than the "out" value.
6. Intercept values are recorded as centimeters and the "in" and "out" points are estimated to the nearest whole centimeter.
7. When the canopies of 2 or more different species overlap, each is scored separately. Theoretically, any number of species could have overlapping canopies at the same point on the line, and all would be recorded. However, in practice it is uncommon to have more than 3 or 4 species overlapping at any one point.
8. Score the "in" and "out" values at the point where the tape actually crosses the foliage of the plant, *not* at the point where it crosses an imaginary canopy edge defined by a line connecting the outer edges of the plant's canopy.

9. Plants are measured along the line-intercept transects even if they are rooted outside the plot.

### *Moving to the Next Subplot*

Once data have been recorded for the subplot, continue to the next subplot as follows:

1. The first transect tape is moved from the first (zero) position, past the second tape, to the third transect position at 10 m (33 ft) along the baseline. Anchor the tape with chaining pins at the 10-m (33-ft) point along the boundary tapes on both sides of the plot.
2. “Leap-frogging” the tapes has created the second 5- x 20-m (16- x 66-ft) subplot and the third line-intercept transect.
3. Repeat line-intercept transect measurements on transect number 3 as described above.
4. Repeat perennial plant density count for the second subplot as described above.

### *Sampling Subsequent Subplots*

Continue as follows:

1. As each transect is measured and each subplot censused, repeat the process of moving the transect tapes in 5-m (16-ft) increments until the entire plot is sampled. A total of 10, 5- x 20-m (16- x 66-ft) subplots are counted and 11, 20-m (66-ft) line-intercept transects are recorded.

### **Data Analysis**

Once data for all plots and subplots have been recorded, they can be analyzed as follows:

1. Plant density counts are simply added for all subplots to provide a total density measurement per 0.1 ha (0.25 a.) for each species.
2. Frequency of distribution can be obtained by dividing by 10 the number of subplots in which a species is found. This proportion is meaningful as an index of clumpedness of distribution for the more common species on the plots—those represented by 10 or more individuals—whose distribution is sufficiently dense to provide an adequate number of individuals in 0.1 ha (0.25 a.).
3. Cover is calculated by subtracting “in” values from “out” values for all plants along the transects to get actual intercept distance for each plant the transect crosses. Add all intercept distances for each species to get total intercept distance along each transect. Cover is calculated as a percentage by dividing the total intercept distance for each species by the length of the transect (20 m = 2,000 cm). Average cover for each species on the plot is calculated by totaling the percent cover value for each species from all transects and dividing the result by 11.

# Sampling the Exclosure/Control Monitoring Plots

## Background

Two livestock exclosures and their paired control plots were sampled as part of this study at Armenta Well and Dos Lomitas. The sampling approach used to monitor these plots is similar to the process used for the 20- x 50-m (66- x 164-ft) plots described above, insofar as it is based on counting density and measuring line-intercept cover of perennial plants. However, the dimensions of the sample are larger in the exclosure and control plots in order to accommodate the size of the exclosures.

## Armenta Well Exclosure

The Armenta Well exclosure encompasses approximately 4.0 ha (9.9 a.) inside a rectangular fence 128 x 315 m (420 x 1,033 ft) in size. Sampling of the Armenta Well exclosure begins at the southeast corner. The area sampled is 100 x 155 m (328 x 509 ft) in size (just over 33% of the exclosure) and is defined on 2 sides by the south and east fence of the exclosure.

## *Equipment Needed*

The following equipment is required for the monitoring process:

- (2) 100-m tape measures (fiberglass, metric)
- (2) 50-m tape measures (fiberglass, metric)
- Density—Subplot Species Count data forms (Appendix 3-1)
- Vegetation Cover—Line-intercept Transect data forms (Appendix 3-2)
- pens or pencils
- list of plant species previously found on plot (Appendix 3-3)

## *Transect and Subplot Sampling Methods*

The protocol for sampling the Armenta Well exclosure monitoring plot entails 4 steps: (1) laying out the first transect, (2) laying out the second transect, (3) sampling transects and subplots, and (4) laying out and sampling subsequent transects.

## **Laying Out the First Transect.**

To lay out the first transect:

1. Begin at the southeast corner of the exclosure and measure 31 m (102 ft) north along the eastern exclosure fence. This point is the beginning of the first transect and is marked with a 0.5-in. (1.3-cm) rebar stake.

2. From the southeast enclosure corner measure 100 m (328 ft) west along the southern enclosure fence. That point is the southwest corner of the sample plot.
3. From the southwest corner of the plot located above, measure north 31 m (102 ft). That point is approximately the west end of the first transect.
4. With someone standing at the west end of the first transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the first transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.
5. When the first transect tape has been extended 100 m (328 ft), bring the tape measuring 31 m (102 ft) to meet the 100-m (328-ft) point, then stretch both tapes tight. A rebar should be found that marks that point.
6. At the 50-m (164-ft) point along the first transect, extend a 50-m (164-ft) tape perpendicular between the fence and the transect tapes. This tape creates the first 2, 31- x 50-m (102- x 164-ft) subplots.

### **Laying Out the Second Transect.**

To lay out the second transect:

1. From the beginning point of the first transect (east end), measure north 31 m (102 ft) along the enclosure east fence to the beginning point of the second transect. This point is marked with 0.5-in. (1.3-cm) rebar.
2. From the end point of the first transect (west end), measure north 31 m (102 ft) to the approximate end point of the second transect. This point is marked with 0.5-in. (1.3 cm) rebar.
3. With someone standing at the west end point of the transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.
4. When the first transect tape has been extended 100 m (328 ft), bring the tape measuring 31 m (102 ft) to meet the 100-m (328-ft) point, then stretch both tapes tight. A rebar should be found that marks that point.
5. After sampling the first 2 subplots, move north the 50-m (164-ft) tape that divides the 2 subplots in order to divide the area between transects 1 and 2 into subplots 3 and 4. The tape should be stretched between the 50-m (164-ft) mark on both transects.

## **Sampling Transects and Subplots.**

Sampling protocol for the Armenta Well enclosure comprises 2 steps:

1. Follow the directions described above for measuring line-intercept transects in the 0.1-ha (0.25-a.) plots in order to read the first transect from east to west.
2. Follow the directions described above for counting all perennial plants in each subplot on the 0.1-ha (0.25-a.) plots, being careful to search around the base of all shrubs, trees, and cacti for small plants that may be growing under the cover of larger plants.

## **Laying Out and Sampling Subsequent Transects.**

The monitoring process continues as follows:

1. From the beginning point of the last transect (east end), measure north 31 m (102 ft) along the enclosure east fence to the beginning point of the next transect. This point is marked with 0.5-in. (1.3-cm) rebar.
2. From the end point of the last transect (west end), measure north 31 m (102 ft) to the approximate end point of the next transect. This point is marked with 0.5-in. (1.3-cm) rebar.
3. “Leap frog” the first tape across the second. With someone standing at the west end point of the transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.
4. When the first transect tape has been extended 100 m (328 ft), bring the tape measuring 31 m (102 ft) to meet the 100-m (328-ft) point, then stretch both tapes tight. A rebar should be found that marks that point.
5. After sampling the next 2 subplots, move north the 50-m (164-ft) tape that divides the 2 subplots in order to divide the area between the next transects into the next 2 subplots. Stretch the tape between the 50-m (164-ft) mark on both transects.
6. Repeat the processes of sampling line-intercept transects and subplots, then “leap frogging” transect tapes, until all 5 transects and all 5 subplots have been sampled.

## **Dos Lomitas Exclosure**

The Dos Lomitas exclosure encompasses approximately 1.3 ha (3.2 a.) inside a rectangular fence 173 x 77 m (568 x 253 ft) in size. Sampling the Dos Lomitas exclosure involves measuring 9 line-intercept transects that subdivide the exclosure into 10 rectangular subplots 17.3 x 77 m (56.7 x 253 ft) in size, and counting all perennial plants on the subplots (i.e., all plants inside the exclosure are counted.)

A control plot equal in size to the enclosure was established 20 m (66 ft) north and offset 40 m (131 ft) west from the enclosure. All 4 corners of the control plot are marked with 0.5-in. (1.3-cm) rebar stakes.

### *Equipment Needed*

The following equipment is required for the monitoring process:

- (2) 100-m tape measures (fiberglass, metric)
- (2) 50-m tape measures (fiberglass, metric)
- Density—Subplot Species Count data forms (Appendix 3-1)
- Vegetation Cover—Line-intercept Transect data forms (Appendix 3-2)
- pens or pencils
- list of plant species previously found on plot (Appendix 3-3)

### *Transect and Subplot Monitoring Methods*

The protocol for sampling the Dos Lomitas enclosure monitoring plot entails 4 steps: (1) laying out the first transect, (2) laying out the second transect, (3) sampling transects and subplots, and (4) laying out and sampling subsequent transects.

### **Laying Out the First Transect.**

To lay out the first transect:

1. Begin at the southwest corner of the enclosure and measure 17.3 m (56.7 ft) east along the south enclosure fence. This point is the beginning of the first transect. The transect end points are not marked.
2. From the northwest corner of the enclosure measure east 17.3 m (56.7 ft). This point is the north end of the first transect.
3. With someone standing at the north end of the first transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the first transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.
4. Each transect is measured beginning at the south end (at the south fence) to the north end (ending at the north fence). The enclosure is wider at the west end than at the east end, so the transects are longest at the west end and are progressively shorter moving east across the enclosure.

### **Laying Out the Second Transect.**

To lay out the second transect:

1. From the beginning point of the first transect (south end), measure east 17.3 m (56.7 ft) along the enclosure fence to the beginning point of the second transect.
2. From the end point of the first transect (north end), measure east 17.3 m (56.7 ft) to the end point of the second transect.
3. With someone standing at the north end point of the transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.

### **Sampling Transects and Subplots.**

Sampling protocol for the Dos Lomas enclosure comprises 2 steps:

1. Follow the directions described above for measuring line-intercept transects in the 0.1-ha (0.25-a.) plots to read the first and second transects from north to south.
2. Count perennial plants in each subplot following the directions described above for counting all perennial plants in each subplot on the 0.1-ha (0.25-a.) plots, being careful to search around the base of all shrubs, trees, and cacti for small plants that may be growing under the cover of larger plants.

### **Laying Out and Sampling Subsequent Transects.**

The monitoring process continues as follows:

1. From the beginning point of the last transect (south end), measure east 17.3 m (56.7 ft) along the enclosure fence to the beginning point of the next transect.
2. From the end point of the last transect (north end), measure east 17.3 m (56.7 ft) to the end point of the next transect.
3. "Leap frog" the first tape across the second. With someone standing at the north end point of the transect (to serve as a target), stretch a 100-m (328-ft) tape from the beginning of the transect. It is best to have someone at both ends of the transect to help guide the person stretching the tape on a true course.
4. Repeat the processes of sampling line-intercept transects and subplots, then "leap frogging" the transect tapes, until all 9 transects and all 10 subplots have been sampled.

## Data Analysis

Once data for all plots and subplots have been recorded, they can be analyzed as follows:

1. Plant density counts are simply added for all subplots to provide a total density measurement per 0.1 ha (0.25 a.) for each species.
2. Frequency of distribution can be obtained by dividing by 10 the number of subplots in which a species is found. This proportion is meaningful as an index of clumpedness of distribution for the more common species on the plots—those represented by 10 or more individuals—whose distribution is sufficiently dense to provide an adequate number of individuals in 0.1 ha (0.25 a.).
3. Cover is calculated by subtracting “in” values from “out” values for all plants along the transects to get actual intercept distance for each plant the transect crosses. Add all intercept distances for each species to get total intercept distance along each transect. Cover is calculated as a percentage by dividing the total intercept distance for each species by the length of the transect. Average cover for each species on the plot is calculated by totaling the percent cover value for each species from all transects and dividing the result by 9 for Dos Lomas, and by 5 for East Armenta.

# Small Mammal Trapping

## Background

At least 1 member of the team should have experience identifying desert rodents in the field. It may be useful to refresh participants' familiarity with identifying characteristics of the rodents by examining specimens at The University of Arizona mammal collection before doing field work.

## Equipment Needed

The following equipment is required for the monitoring process:

- (210) Sherman live traps (medium size)
- rolled oats for bait (2 lbs.)
- heavy duty plastic bags (1 quart size)
- clipboard
- trapping record data forms (Appendix 3-4)
- pens or pencils
- list of small mammal species previously found on the trapping grid (Appendix 3-5)

## Trapping Methods

The protocol for small mammal sampling entails 3 steps: (1) laying out the trapping grid, (2) baiting the traps, and (3) checking the traps.

### *Laying Out the Trapping Grid*

The small-mammal trapping grid is laid out as follows:

1. The traps are laid out in a rectangular grid arrangement of 4 parallel lines with 13 traps in each line that overlays the vegetation monitoring plots. The traps are spaced approximately 5 m (16 ft) apart along each line, and the lines are also 5 m (16 ft) apart.
2. The trapping grid starts at the origin corner (southeast) of the plot and completely overlaps the plot, extending approximately 10 m (33 ft) longer than the plot in the long dimension.
3. The traps are positioned by estimating the distance between them by pacing. The spacing is therefore not exactly repeatable from one trapping period to the next.
4. It is best to lay out a tape measure to calibrate paces before estimating the spacing of traps on the grid by pacing.

5. Traps should be placed at 5-m (16-ft) intervals regardless of the local microhabitat conditions at that spot. There is a tendency to put the trap near “good looking” spots, such as the base of a shrub or near the opening of an active rodent burrow. An effort should be made to keep the traps in a regular array in straight lines to make repeated trapping sessions comparable and to reduce the possibility of losing traps.
6. It is sometimes desirable to smooth and level a site a little with your foot so that the trap will sit firmly and not wobble when a rodent enters it.
7. As many as 4 grids of this size, totalling approximately 200 traps, can be trapped during 1 night if they are close enough together to be within a few minutes travel time of each other. Trying to check more than this many traps in the morning risks letting the sun get high enough to kill animals in the traps before they are all checked and emptied.
8. The traps must be set for 3 consecutive nights to complete 1 session of trapping.
9. It is best not to trap on nights with a full moon, since rodent activity is often somewhat reduced on those nights.

### *Baiting the Traps*

Once the trapping grid is laid, proceed to bait the traps as follows:

1. Use plain rolled oats for bait. Adding an oily bait such as peanut butter for “aroma” does not improve trapping results and makes the traps messy.
2. Use approximately 0.5 tsp of oats to bait each trap. Roughly one-half of this amount is tossed inside the trap and one-half is scattered outside within a few inches of the trap door.
3. When setting the trap door, give each trap a sharp tap on the bottom to check the setting. If the trap door closes when the bottom of the trap is tapped, the tension on the trigger is about right. If the door does not close, or if it is triggered just from the disturbance of picking it up, it is too tight or too loose. Bend the trigger forward or backward to adjust to the proper setting.
4. Traps are baited no more than 1 hr before sunset to insure that no animals are captured when the sun is up high enough to kill them before nightfall.

### *Checking the Traps*

Check traps and record data as follows:

1. Checking of traps should begin at least 1 hr before sun-up. All traps must be checked before the sun has been up for more than 1 hr, or animals will be killed by heat in the traps.

2. At each plot, check all traps and put traps with captures in a shady spot.
3. Shake the animals from the traps one at a time into a heavy plastic bag for inspection and identification. On the data form (Appendix 3-4), record the species, sex, reproductive condition, age (adult or juvenile), and notes about the animal's general condition, if appropriate.
4. Release each animal close to where it was captured.
5. If night-time temperatures are likely to drop to near freezing, all traps should be checked once during the night to avoid mortality due to cold. Animals found in traps should be recorded and released.

### **Small Mammal Trapping at the Enclosures**

The only difference in procedure between trapping on the enclosure/control plots and on the 0.1-ha (0.25-a.) plots is the dimensions of the plots and the number of traps per plot. Otherwise, the protocol follows these steps:

1. On all 4 enclosure and control plots at Armenta Well and Dos Lomitas, traps are laid out in a 10 x 10 grid of 100 traps per plot.
2. At Armenta Well, the trap grids begin at the southeast corner of the enclosure and at the southwest corner of the control plot. Traps are placed at approximately 10-m (33-ft) intervals, estimating the spacing between traps by pacing as described above for the 0.1-ha (0.25-a.) plots, using 100 traps each for both enclosure and control plots.
3. At Dos Lomitas, the trap grids begin at the southwest corner of the enclosure and at the southeast corner of the control plot. Traps are placed at approximately 7-m (23-ft) intervals, estimating the spacing between traps by pacing as described above for the 0.1-ha (0.25-a.) plots, using 100 traps each for both enclosure and control plots.

**Appendix 3-1**  
**Natural Community Grazing-recovery**  
**Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Density—Subplot Species Count Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



**Appendix 3-2**  
**Natural Community Grazing-recovery**  
**Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Vegetation Cover—Line-intercept Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



Appendix 3-3  
**Natural Community Grazing-recovery  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Plant Taxa**

The following index cross-references scientific taxa with common names for the plant species previously recorded on the Ecological Monitoring Program (EMP) Natural Community Grazing-recovery plots at Organ Pipe Cactus National Monument (ORPI).

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*Ambrosia deltoidea*—BURROBUSH  
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*Ayenia pusilla*—AYENIA

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BARREL CACTUS—*Ferocactus wislizeni*  
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*Ditaxis neomexicana*—DITAXIS

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*Erioneuron pulchellum*—FLUFF GRASS  
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HACKBERRY, DESERT—*Celtis pallida*  
HEDGEHOG CACTUS—*Echinocereus engelmanni*  
*Hibiscus coulteri*—DESERT ROSE MALLOW  
*Hilaria rigida*—BIG GALLET  
*Holacantha emoryi*—CRUCIFIXION THORN  
HYMENOTHRIX—*Hymenothrix wislizenii*  
*Hymenothrix wislizenii*—HYMENOTHRIX  
*Hyptis emoryi*—DESERT LAVENDER

—I—

INDIAN MALLOW—*Abutilon* spp.  
INDIAN ROOT—*Aristolochia watsoni*

—J—

JANUSIA, SLENDER—*Janusia gracilis*  
*Janusia gracilis*—SLENDER JANUSIA  
JATROPHA, ASHY—*Jatropha cinerea*  
*Jatropha cardiophylla*—LIMBERBUSH  
*Jatropha cinerea*—ASHY JATROPHA  
JOJOBA—*Simmondsia chinensis*

—K—

*Krameria grayi*—RATANY, WHITE

—L—

*Larrea tridentata*—CREOSOTE BUSH  
*Lemaireocereus thurberi*—ORGAN PIPE CACTUS  
*Leptochloa* spp.—SPRANGLETOP  
LIMBERBUSH—*Jatropha cardiophylla*  
*Lophocereus schottii*—SENITA CACTUS  
*Lycium andersoni*—WOLFBERRY  
*Lycium parishii*—WOLFBERRY  
LYRE POD, COULTER—*Lyrocarpa coulteri*  
*Lyrocarpa coulteri*—COULTER LYRE POD

—M—

MACHAERANTHERA, ARIZONA—*Machaeranthera arizonica*  
*Machaeranthera arizonica*—ARIZONA MACHAERANTHERA  
*Mammillaria microcarpa*—FISHHOOK CACTUS  
*Mammillaria thornberi*—FISHHOOK CACTUS  
MERCURY, THREE-SEED—*Acalypha pringlei*  
MESQUITE, HONEY—*Prosopis glandulosa*  
MEXICAN JUMPING BEAN—*Sapium biloculare*  
MIMOSA—*Mimosa laxiflora*  
*Mimosa laxiflora*—MIMOSA

*Muhlenbergia microsperma*—LITTLE SEED MUHLY  
*Muhlenbergia porteri*—BUSH MUHLY  
MUHLY, BUSH—*Muhlenbergia porteri*  
MUHLY, LITTLE SEED—*Muhlenbergia microsperma*

—N—

*Nicotiana trigonophylla*—DESERT TOBACCO  
NIGHT-BLOOMING CACTUS—*Cereus greggi*

—O—

OCOTILLO—*Fouquieria splendens*  
ODORA—*Porophyllum gracile*  
*Olneya tesota*—DESERT IRONWOOD  
*Opuntia acanthocarpa*—BUCKHORN CHOLLA  
*Opuntia fulgida*—JUMPING CHOLLA  
*Opuntia leptocaulis*—CHRISTMAS CACTUS  
*Opuntia phaeacantha*—PRICKLY PEAR  
*Opuntia spinosior*—STAGHORN CHOLLA  
*Opuntia stanlyi*—DEVIL CHOLLA  
ORGAN PIPE CACTUS—*Lemaireocereus thurberi*

—P—

PALOVERDE, BLUE—*Cercidium floridum*  
PALOVERDE, FOOTHILL—*Cercidium microphyllum*  
PAPERFLOWER—*Psilostrophe cooperi*  
*Porophyllum gracile*—ODORA  
PRICKLY PEAR—*Opuntia phaeacantha*  
*Prosopis glandulosa*—HONEY MESQUITE  
*Psilostrophe cooperi*—PAPERFLOWER

—R—

RATANY, WHITE—*Krameria grayi*  
RATTLESNAKE WEED—*Euphorbia albomarginata*  
ROSE MALLOW, DESERT—*Hibiscus coulteri*

—S—

SAGUARO—*Carnegiea gigantea*  
SANDBUR—*Cenchrus ciliaris*  
*Sapium biloculare*—MEXICAN JUMPING BEAN  
*Sarcostemma crispum*—CLIMBING MILKWEED  
*Sarcostemma cynanchoides*—CLIMBING MILKWEED  
SEEPWEED, DESERT—*Suaeda torreyana*  
SENITA CACTUS—*Lophocereus schotti*  
SENNA, DESERT—*Cassia covesi*  
*Simmondsia chinensis*—JOJOBA  
SIPHONGLOSSA—*Siphonoglossa longiflora*  
*Siphonoglossa longiflora*—SIPHONGLOSSA  
SNAKEWEED, BROOM—*Gutierrezia sarothrae*  
SPRANGLETOP—*Leptochloa* spp.  
*Suaeda torreyana*—DESERT SEEPWEED

—T—

THORN APPLE, DESERT—*Datura discolor*

THREE-AWN, SPIDER—*Aristida ternipes*

TOBACCO, DESERT—*Nicotiana trigonophylla*

TRIXIS, CALIFORNIA—*Trixis californica*

*Trixis californica*—TRIXIS, CALIFORNIA

*Tumamoca macdougali*—TUMAMOC GLOBEBERRY

—W—

WHITE THORN—*Acacia constricta*

WINGSCALE, NARROW-LEAVED—*Atriplex linearis*

WOLFBERRY—*Lycium andersoni*

WOLFBERRY—*Lycium parishii*

—Z—

*Zizyphus obtusifolia*—GRAYTHORN

**Appendix 3-4**  
**Natural Community Grazing-recovery**  
**Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Small Mammal Trapping Record Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

# ORPI Ecological Monitoring Program—Small Mammal Trapping Record Data Form

Date (mm/dd/yy) \_\_\_\_/\_\_\_\_/\_\_\_\_

Page \_\_\_\_ of \_\_\_\_

Location (study site name) \_\_\_\_\_ Observer \_\_\_\_\_

Weather: Temperature (°F) \_\_\_\_\_ Wind speed (mph) \_\_\_\_\_ Cloud cover \_\_\_\_\_

Precipitation \_\_\_\_\_

Moon phase \_\_\_\_\_ Number of traps \_\_\_\_\_

Comments \_\_\_\_\_

Species (*Spp.*)

Sex (*M/F*)

Comments

1			
2			
3			
4			
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20			

*Continued on reverse...*



Appendix 3-5  
**Natural Community Grazing-recovery  
Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Small Mammal Taxa**

The following index cross-references scientific taxa with common names for the small mammal species previously recorded on the Ecological Monitoring Program (EMP) Natural Community Grazing-recovery trapping grid at Organ Pipe Cactus National Monument (ORPI).

**Index**

**—A—**

*Ammospermophilus nelsoni*—SAN JOAQUIN ANTELOPE SQUIRREL  
ANTELOPE SQUIRREL, SAN JOAQUIN—*Ammospermophilus nelsoni*

**—C—**

CACTUS MOUSE—*Peromyscus eremicus*

**—D—**

*Dipodomys deserti*—DESERT KANGAROO RAT  
*Dipodomys merriami*—MERRIAM'S KANGAROO RAT  
*Dipodomys spectabilis*—BANNERTAIL KANGAROO RAT

**—G—**

GRASSHOPPER MOUSE, SOUTHERN—*Onychomys torridus*

**—K—**

KANGAROO RAT, BANNERTAIL—*Dipodomys spectabilis*  
KANGAROO RAT, DESERT—*Dipodomys deserti*  
KANGAROO RAT, MERRIAM'S—*Dipodomys merriami*

**—N—**

*Neotoma albigula*—WHITE-THROATED WOODRAT

**—O—**

*Onychomys torridus*—SOUTHERN GRASSHOPPER MOUSE

—P—

*Perognathus amplus*—ARIZONA POCKET MOUSE

*Perognathus baileyi*—BAILEY'S POCKET MOUSE

*Perognathus intermedius*—ROCK POCKET MOUSE

*Perognathus penicillatus*—DESERT POCKET MOUSE

*Peromyscus eremicus*—CACTUS MOUSE

POCKET MOUSE, ARIZONA—*Perognathus amplus*

POCKET MOUSE, BAILEY'S—*Perognathus baileyi*

POCKET MOUSE, DESERT—*Perognathus penicillatus*

POCKET MOUSE, ROCK—*Perognathus intermedius*

—W—

WOODRAT, WHITE-THROATED—*Neotoma albigula*

# Wildlife





# Lizard Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Philip C. Rosen  
Charles H. Lowe

Department of Ecology and Evolutionary Biology  
Biological Sciences East, Room 123  
The University of Arizona  
Tucson, Arizona 85721

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## Introduction

The objective of the Lizard Monitoring Protocol is to measure population changes in lizards that can be correlated with natural and human-caused environmental changes at ORPI. The lizards and the findings for these ectothermic vertebrates have intrinsic biological importance. They also form one component within the broader Ecological Monitoring Program (EMP) study that is planned to be capable of detecting biotic effects of global climate change, of local human-caused disturbance, and of natural environmental fluctuation. The potential exists to document the immediate effects of environmental fluctuations on lizards, and to use this information to predict and/or illustrate the consequences of human-caused environmental change at ORPI.

This protocol contains a detailed accounting of monitoring methodology. It is presented as an instructional handbook that can be carried afield by National Park Service (NPS) management and research personnel. It also serves as a reference for the field worker and supervising resource manager. A strict adherence to the methods described herein will provide long-term quantitative data on natural lizard communities that will equal or exceed in scope, quality, and duration currently available results (see Turner et al. 1969a, b, 1970; Whitford and Creusere 1977; Gonzales-Romero and Alvarez-Cardenas 1989; Gonzales-Romero et al. 1989).

# Methods

## Overview of Methods

The intensive methodology used for this report consists of standardized lizard line (SLL) transects, and time-standardized sampling (time-constrained search [TCS]). Both methods are detailed later; only summary descriptions are given here.

The lizard lines are permanently located, walk-line transects standardized for recording all observed lizards in a 15-m-wide (49-ft) belt, 7.5 m (24.6 ft) on either side of the walked midline. The line is walked several times during a day beginning at or prior to the emergence of diurnal lizard species. The walks during the course of 1 dy comprise a run. The primary data points generated during a run are the maximum number of lizards observed during any 1 walk, for each species. These species maxima are termed the peak values: they represent the best estimate for abundance of each species on the line at run-time. The sum of peaks over all species is the total estimated lizard abundance. We refer to the maximum peak for a species over a series of runs, over seasons or years, as the maxpeak.

The TCS method is similar to general herpetological field surveying. The investigator walks through the habitat observing lizards and snakes, and investigates potential shelter sites (within vegetation, under rocks, logs, etc.). The observed number for each species is recorded, and, as in the lizard line procedure, size (age) class, sex, and natural history observations are recorded. Like SLL, TCS may be carried out within a single habitat type (e.g., wash xeroriparian, open desertscrub), or it may include an entire canyon or EMP site.

## Statistical Methods

The peak and maxpeak data points obtained for each run or for a series of runs at each site are used to compute species richness ( $S$ , the number of species observed) and species diversity ( $H'$ ,  $H$ -prime):

$$H' = -\text{SUM} (p_i \text{ LOG } p_i)$$

where  $p_i$  is the peak for species  $i$ , divided by the total peak over all species; and LOG is in base 10.

The analytic focus of the monitoring program is to obtain an index of abundance that will document the status of, and the temporal changes in, lizard assemblages. The peak values and diversity indices are compared across sites, macrohabitats, habitat types, and—most importantly—years.

Preliminary data examination has revealed interesting patterns for the different species and among seasons and years. Observation of these patterns served as a guide for the analyses performed. The number of sites studied was too small to permit quantitative tests for normality, so a conservative approach was adopted. Graphical examination of the data distributions showed moderate deviations from the normal distribution, with marked deviations from normality in

side-blotched lizards (*Uta stansburiana*). One-way analysis of variance (ANOVA, with a single classification variable testing for differences in the dependent variable, “peak value”) is not highly sensitive to deviations from assumed normal, homoscedastic data distributions, and could therefore generally be applied to the lizard line data, with the exception of the data from side-blotched lizards.

The second step in analysis proceeded with one-way ANOVA for the following categorical variables: (1) EMP site (= locality), (2) macrohabitat (montane, bajada, valley floor, and floodplain), (3) habitat (upland desertscrub vs xeroriparian desertscrub), (4) season (spring vs summer), and (5) year (1989 vs 1990). These ANOVAs were completed for each species and also for the combined results (= sum of the peak values for each species for a run). Two-way ANOVAs were also run to scan for statistically significant interactions between the classification variables. Each of the 5 categorical variables listed above was found to be highly significant in some, though more usually, most comparisons.

The third step of analysis was to use non-parametric methods to estimate the statistical significance of the several classification variables affecting lizard abundance (peak value).

The strongest categorical variable discovered by ANOVA was EMP site. Therefore, for confirmatory tests, paired-sample t-tests were chosen, and the non-parametric Wilcoxon Signed Rank test and Kruskal-Wallis test (all with pairing within site across years), whenever possible. The sign test was applied to highly skewed data recorded from side-blotched lizards.

Finally, the results of analysis are presented in the format of (1) descriptive statistics (tabular or graphed) and (2) t-tests and non-parametric tests.

## **Guidelines for the Resource Manager**

### *Introduction*

The primary job of the resource manager for lizard monitoring is to assure quality control in the data collection by the field worker. The primary job for the field worker is to develop a full working knowledge of all lizard species at ORPI, and to develop a consistent monitoring technique for running the line transects, as detailed later. The resource manager is further responsible for integrity of data storage, and finally, for proper analytical procedures. In this subsection, we detail these resource manager operations and offer guidelines and examples to assist this oversight role.

### *Handling and Storage of Data*

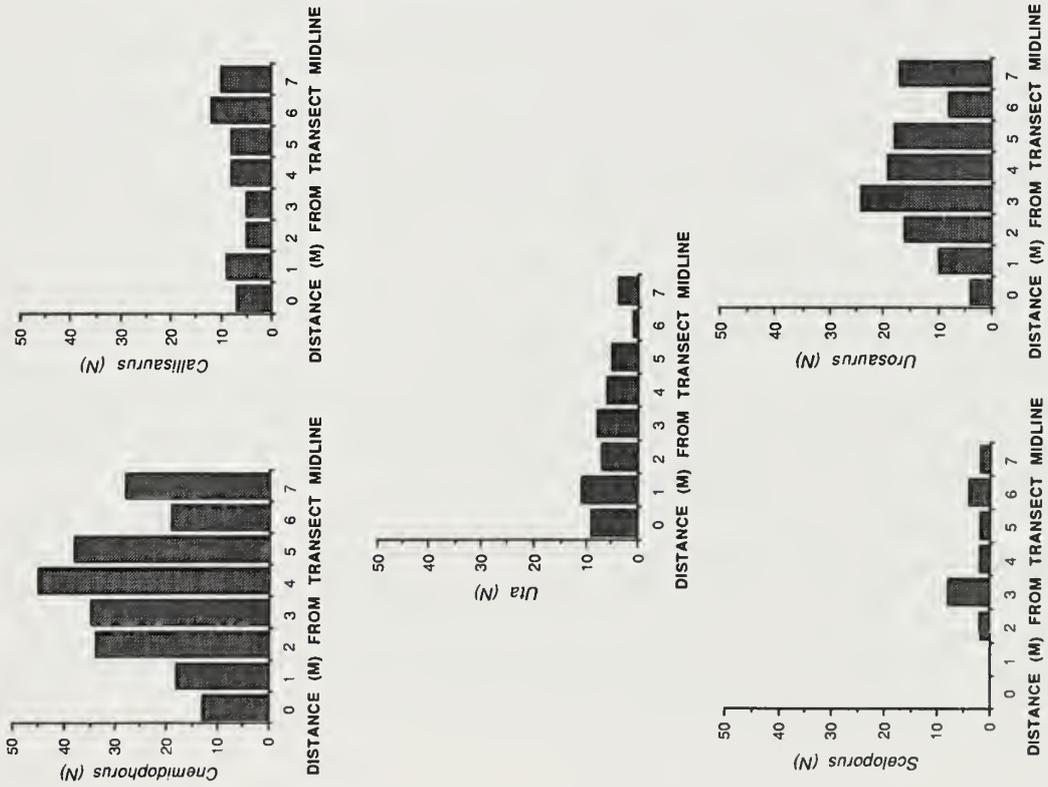
The procedure for handling data coming in from the field is as follows:

1. Following the details provided in the procedural sections of this report, the resource manager should first scan the data forms to confirm proper technique by the field worker, focusing on:
  - (a) proper weather conditions, clear or mostly clear with maximum temperature > 30° C (86° F).

- (b) appropriate start and stop times, in relation to lizard activity for the day of the run. The resource manager should expect to see initially low numbers per walk for the indicator species, followed by a rise to a peak of activity, and finally, a dropoff or, in some cases, a leveling-off that occurs while larger as well as more temperature-tolerant species (such as the desert iguana) become prominently active. There will normally be 4–5 walks of the line per run, ranging from 3 to 6 or more, and depending on terrain and vegetation.
  - (c) proper time spent on the line during individual walks of a run by the field worker, averaging 9–11 min/100 m on the earlier runs when small lizards are active and basking is observed, and 7–9 min/100 m in later runs. Individual field workers may deviate from these averages by up to 2 min as a result of differences in eyesight, hearing and experience. Greater deviations, as at < 10 min/100 m when small lizard species are sought, or regularly  $\geq$  15 min/100 m, indicate altered methodology. Different habitats will require different speeds, with seasonally dense vegetation (as at Armenta Ranch) calling for slower progress, and the resource manager should keep a flexible attitude within average expected walk-rates described here. For example, walks during previous studies ranged from as fast as 4 min/100 m to 18 min/100 m in the extreme.
2. Read the peak values (maximum number observed in any single walk), for each species, directly from the data forms. On the day of the run, note which walks on a run represented maxima for basking and overall activity for the species present; it is generally expected that the peak values will correspond to these.
  3. Indicate on the data form margin which run is taken as the peak for the species, and enter the peak values into the dataset in appropriate format. This dataset can be stored on the computer, as well as in hard copy.
  4. At the end of all lizard line runs for the season, the resource manager should construct histograms of distance from transect midlines, combining all of the season data (Fig. 4-1). These distances can be tabulated from the field data forms. This is a further check for proper technique by the field worker. The resource manager should scan the histograms for:
    - (a) a tendency to consistently under-represent lizards present at > 5 m from the midline.
    - (b) any gross deviation from the baseline patterns that have been provided in Figure 4-1.

We cannot now propose any hard and fast rule for data rejection based on the histograms, but they will minimally provide a guideline for improvement of field worker technique.

DATA from LATDIST.dat89



Data from "LATDIST.DAT90"

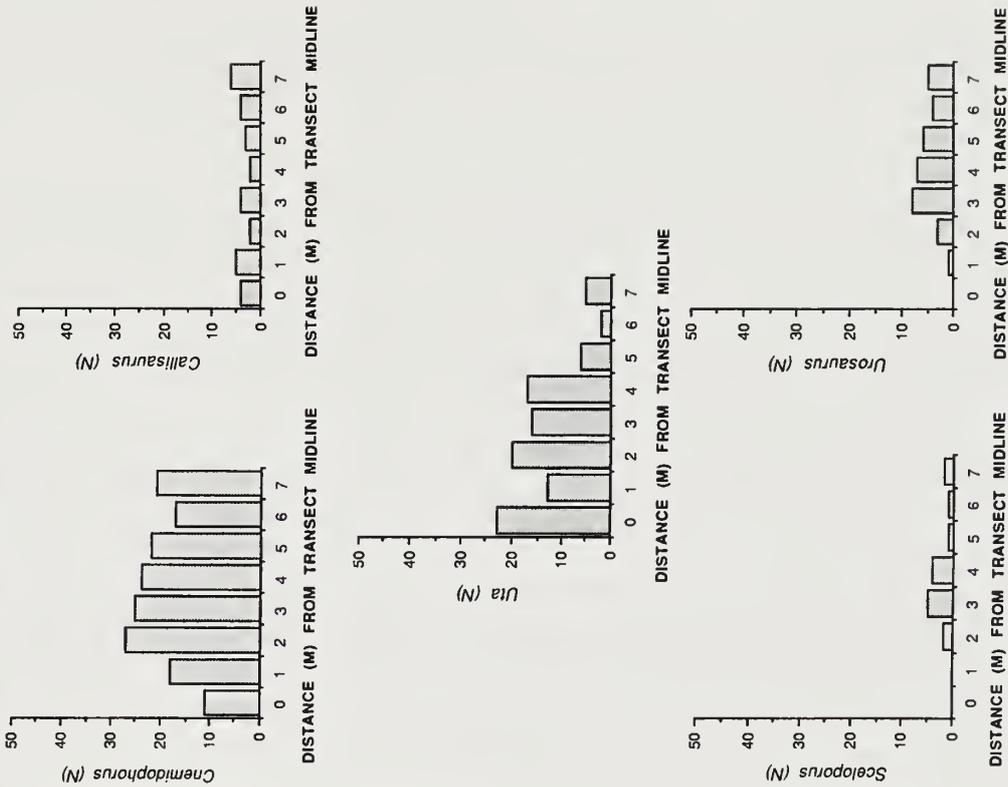


Figure 4-1. Observed distances from lizard line-transect midlines in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona. Darker graphs (left) represent 1989 data, while lighter graphs (right) illustrate data from 1990.

5. If proper technique has not been followed for a run, the data from that run should be excluded from analysis, and not entered into the dataset. This should be noted directly on the field data forms, which should then be stored with the other field data forms. It is to be anticipated with a well-trained field worker, that the only reason to reject data will be a failure of weather conditions—generally when temperatures are too low or dense clouding is present.
6. If the information on distance from midline, or times taken per 100 m, reveal gross failures by the field worker to properly observe lizards, all data from the season are to be excluded from the dataset, and this is to be noted on all of the stored field data forms. If the field worker has made smaller errors, such as improper designation of hatchlings, juveniles, and adults, this should be noted directly on the data forms as well as in the dataset, but the data need not necessarily be excluded from all analyses.

### *Analytical and Statistical Procedures*

**Data.** The peak and maxpeak data points obtained for each run or for a series of runs at each site are used to compute the following:

1. Peak value. For each species, for each run, find the maximum number of individuals seen on the lizard line transect during a single walk.
2. Total peak value. Sum the peak values for all species.
3. Maximum peak value. For each species, find the highest peak value observed over any time span of interest (e.g., year, decade, etc.).
4. Species richness (N). Total the number of species observed or occurring in a given area.
5. Species diversity (H-prime or H'). H' quantifies the degree of evenness in the abundance values for the species on a site or in a sample. High species diversity indicates that many of the species occur in subequal abundances, while low species diversity indicates that a single or a few species are numerically dominant. H' is calculated by the following formula:

$$H' = -\text{SUM} (p_i \text{ LOG } p_i)$$

where  $p_i$  is the peak for species, divided by the total peak over all species, and *LOG* is in base 10. H' may be a sensitive index for population changes occurring within a community (assemblage) of lizards or other organisms.

**Purpose of the Analysis.** The analytic focus of the monitoring program is to obtain an index of abundance that will document the status of, and temporal changes in, lizard assemblages. Peak values and diversity indices are compared across sites, macrohabitats, and habitat types. These comparisons are exploratory undertakings—meant to assist the ultimate objective of ecosystem

monitoring using lizards as indicators. These exploratory analyses are key to developing the baseline with which to compare monitoring results over time.

Exploratory analysis will indicate whether population changes occurred at all sites, or only in certain habitat types or in certain parts of the monument. The project is not designed to determine the underlying mechanisms causing population changes in lizards. Often, however, these mechanisms are obvious to any person willing to think on the job. The field worker and the resource manager are encouraged to think like ecologists, always asking, in effect, “what is happening out there?”

The baseline results indicate that rainfall and soil moisture are of primary importance to population changes in lizards, as well as in snakes and other organisms of all kinds in the desert at ORPI. We expect that cold spring weather might be a factor in certain years, as might severe winter freezes. It is to be expected that marked decreases in food available to lizards will translate to reduced reproduction, with less juveniles, and ultimately to population declines, as demonstrated during the drought at ORPI in the late 1980s.

Remaining aware of the physical environmental and habitat quality changes at ORPI is not here an academic exercise. Lizard populations will fluctuate with varying rainfall, as in the majority of desert organisms. The baseline that is presented in these protocols is not, and cannot be, the full baseline. The complete monitoring baseline will be the relationship between rainfall and population size and change in population size.

When the baseline relationship between lizard population change and climate is established through at least 1 dry and 1 wet period, then will exist a working baseline; the short-term baseline. A 10 yr baseline is regarded as a reasonable first approximation of the long-term baseline. Until the long-term baseline is fully established, only gross changes such as species disappearance or species spread, or grossly reduced abundances in the absence of drought, can be viewed with concern from the resource management perspective. From a broader perspective, of course, especially protracted drought might be of concern as potentially reflective of climate change.

The point here is that lizards may be affected by factors other than climate, such as pollution, collecting, visitor impact, or monument operations. Alternatively, lizards might be more strongly affected by climate change than other ecosystem components. The baseline relationship of lizards and climate will help to evaluate these possibilities.

Thus, the first objective in further analysis will be to define the relationship between climate and lizard population size, using regression and correlation statistics. The question must be asked, does lizard population size correlate with rainfall over the year (or over 2 yr, or a decade)? And, even more directly, does the change in lizard population size correlate with rainfall?

Once results are obtained from the correlation and regression analysis, the data must be examined to see whether the trend over time is for a change in the relationship of lizard populations to

climate. This will determine whether changes in lizard populations reflect climate just as the baseline data predicts, or alternatively, whether lizards are declining from an additional factor or factors. Such information allows us to demonstrate effects of climate change on lizards, should climate change occur, and will also allow to confirm the occurrence of other impacts on lizard populations.

**Statistical Procedures.** Statistical and analytic procedures are the responsibility of the analyst to modify as required by the findings, sampling schedule, and questions being asked. Some of the analyses presented here can be and should be followed, but it is the responsibility of the resource management team to use the proper statistics, and to use common sense to ask the proper questions. It is not possible, at this point in the study, to produce a “canned” analysis that will necessarily apply to all future findings, statistical data distributions, or future questions of importance to the ecology at ORPI. Therefore, this report offers only general guidelines to assist in future analyses.

**Exploratory Analysis.** The first step in analysis should be to examine summary statistics (means and standard errors) and sampling distributions (histograms) for the dataset. The dataset consists of peak values for each species at the individual sites. Years should be studied separately as well as combined, and summary statistics for different habitat types should also be examined. To date, the study has used Cricket Graph on a Macintosh computer to visually examine and compare summary statistics. Any graphics package that conveniently produces bar charts, regressions, scatterplots, and the like should suffice. Likewise, virtually all statistics software will provide the basic analyses outlined here—summary statistics, t-tests and non-parametric two-sample tests, and analysis of variance and multi-sample non-parametric tests.

In past analyses, the preliminary data examination revealed striking patterns for the different species and among seasons and years. Observation of these patterns served as a guide for the analyses performed.

The small number of sites studied precludes quantitative tests for normality (e.g., Kolmogorov-Smirnoff test), so a conservative approach is recommended. Graphical examination of the data distributions will reveal major trends for deviation from normality and equality of variances. A useful test for equality of variances is Levine’s test (Sachs 1982). In past tests, moderate deviations from the normal distribution were found, with marked deviations in the side-blotched lizard species. Variances (as expressed by standard deviations) were not strongly unequal (heterogeneous) for most comparisons sought.

One-way analysis of variance (ANOVA, with a single classification variable testing for differences among sites, years, or habitat types, in the dependent variable, “peak value”) is not highly sensitive to deviations from assumed normal, homoscedastic data distributions. It was possible, in previous testing, to use one-way ANOVA with full confidence to explore the dataset. The assumptions for ANOVA become increasingly stringent as more classification variables are added. For example, a two-way ANOVA would be used to classify results according to both year and habitat type, to search for significant differences in the peak values among years between

habitat types. Such two-way and higher factorial ANOVAs are an efficient exploratory technique, but with the small datasets and likelihood of moderately violated assumptions, they are not properly used to indicate statistical significance. In previous analysis, however, these factorial designs never yielded strongly significant results that were not subsequently verified by non-parametric procedures with less stringent requirements. The ANOVA gives sums of squares as measures of the variance associated with each classification variable, such as year, habitat, season, or site, and hence is recommended as an exploratory procedure for the lizard line data.

Previous analyses examined the following categorical variables: (1) EMP site (= locality), (2) macrohabitat (desert mountain and rockpile, bajada, valley floor and valley floor floodplain), (3) habitat (upland desertscrub vs xeroriparian desertscrub), (4) season (spring vs summer), and (5) year (1989 vs 1990). The ANOVAs were completed for each species and also for the combined results (= sum of the peak values for each species for a run). Also, two-way ANOVAs were calculated to scan for statistically significant interactions between the classification variables.

Interaction terms are another benefit of the use of ANOVA as an exploratory technique. Significant interaction terms in the lizard analysis may show, for example, that habitat types respond differently in the same year. For example: if increases in Year<sub>1</sub> in Habitat<sub>a</sub> were accompanied by decreases in Year<sub>1</sub> in Habitat<sub>b</sub>, and the reverse were found in Year<sub>2</sub>, a strongly significant interaction term would be found in ANOVA, while, for Year or Habitat alone there might be no significant effect. We would know that both year and habitat were probably important, and would infer that different habitats offer different opportunities to the lizard populations in the years studied.

In the analysis, each of the 5 categorical variables enumerated above was significant in some or most comparisons. This indicates that factorial ANOVA designs would be the ideal analytical tool. However, since the assumptions of normality and homoscedasticity cannot be properly evaluated with such small datasets, and because modest deviations from these assumptions in the lizard line data are expected, confirmatory tests cannot be carried out in two-way or higher factorial designs. As more data becomes available it may become possible to use these procedures, but careful testing of assumptions will be required first. On the other hand, for highly significant results, modest violations of assumptions are tolerable.

Previous use of two-way ANOVA revealed few significant interaction terms. It is nonetheless critical to study the two-way (or higher factorial) ANOVAs and to understand the meaning of any interaction terms that do appear. Strong interaction terms between macrohabitat (bajada vs valley floor and valley floor floodplain) and year (1989 vs 1990) were found, indicating that abundances (peak values) were responding very differently in the 2 years in the 2 habitats—as described above.

To reiterate, the data distributions were not sufficiently normal and homoscedastic to validate confirmatory analysis with two-way and higher factorial ANOVAs. At the same time, the several

factors influencing lizard abundance would be ideally analyzed with an ANOVA structure. The solution will be to use non-parametric analogs for the parametric ANOVA procedures.

The third step of analysis recommends non-parametric statistics to estimate the statistical significance of the several classification variables affecting lizard abundance (peak value). This largely eliminates any difficulties that can arise from violating the assumptions of ANOVA.

In previous analyses, the strongest categorical variable discovered by ANOVA was EMP site. Therefore, for confirmatory tests, paired-sample t-tests, and the non-parametric Wilcoxon Signed Rank test, and Kruskal-Wallis test (all with pairing within site across years) were chosen whenever possible. For highly skewed data, such as was found for the side-blotched lizard species, the use of the non-parametric sign test is recommended.

Paired-sample t-tests are powerful and should be used whenever possible. The t-test formula used for lizard line data must be the formulation that accounts for different sample sizes and variances. If data distributions are extremely skewed, t-tests are inappropriate, in which case non-parametric tests should then be used. For the lizard line data, the most useful non-parametric tests will be the Wilcoxon Rank Sum Test (equivalent to paired t- test), the Mann-Whitney U test (unpaired data comparison), and Kruskal-Wallis Test (non-parametric analog for one-way ANOVA).

Useful statistical references that have been followed are Dixon and Massey (1969), Hollander and Wolfe (1973), Sachs (1982), Sokal and Rohlf (1981), and Zar (1984). Various statistics packages on the MacIntosh computer (e.g., Statworks and Statview) are adequate for the simpler, confirmatory statistics. For exploratory analysis, and especially factorial designs, the use of Statistical Analysis Systems (SAS) is recommended, which is available for microcomputers (PCSAS).

### **Statistics for the Baseline Relationship between Climate and Lizard Population.**

Results from exploratory analysis will be the basis for developing the working baseline relationship between lizard population size and climate. The obvious first step in analysis will be to correlate seasonal rainfall with changes in lizard population sizes. Rainfall data may be taken as the monument average, based on automated weather station data. Lizard population size may be taken as peak values from the transects. The first step, as before, will be to examine a graph of rainfall vs population change, and to compute correlation and linear regression statistics.

It is possible, though not likely, that these simple procedures will be all that is required to establish the baseline. More likely, the relationship between rainfall and population size will not be simple, for example, non-linear. Further, there is likely to be a time lag in the influence of rainfall on lizard population size. Here, time series analysis is appropriate to identify proper time lags to employ in the linear or non-linear model that is to be developed to describe the baseline.

Ultimately, a model must be developed to describe predicted or expected lizard population size. Models of this kind are not necessarily simple, and, often, increasing the complexity of the model enhances its portrayal of reality. Will it be necessary to incorporate lizard population size

as a factor in the model of climate and population change? Quite possibly this and other variables will be appropriately included in the model, as data accumulate and an increasingly realistic model can be constructed.

With a model in hand, one can finally proceed to ask the questions that are the objectives of the EMP monitoring study. Is there a long-term trend in lizard population size? Does this long-term trend reflect simply climatic variation, or climatic change? Is there a systematic deviation from the expected relationship between lizard population and climate? These questions are of great interest, and their resolution will require reasoning and statistics we cannot anticipate now.

### **Monitoring Methods Overview**

This section of the protocol presents a full and detailed accounting of the methodology used to obtain the data. The purpose of this manual is to provide field workers necessary and useful information that can be carried afield during lizard monitoring activities to obtain long-term, quantitative data for the EMP project at ORPI. This manual also provides recommendations for scheduling such work.

The objectives of this lizard monitoring program are (1) to use lizards as an indicator of ecosystem health and long-term change, and (2) to document the specifics of long-term change in lizard communities.

The principal methodology to be used here to monitor lizards is the standardized lizard line transect. Additional data are to be obtained using the time-constrained search method. Age structure of the lizard populations is recorded during both transect and search procedures.

#### *Standardized Lizard Line Transects*

The lizard lines are walk-line transects that are standardized for area sampled. The 27 extant lizard lines at ORPI (including the new lines set up on the Middle Bajada, Valley Floor, and Lower Colorado sites) range from 100 m (328 ft) to 300 m (984 ft) in length, and are permanently marked with rebar. They are 15 m (49 ft) wide, 7.5 m (24.6 ft) to each side of the walked centerline (Fig. 4-2). The transects sample principal habitat types at ORPI, and 23 of them are on EMP sites, including the newly established sites of Middle Bajada, Valley Floor, and Lower Colorado Larrea.

Indicator species for the study sites are the western whiptail (*Cnemidophorus tigris*) (bajadas and valley floor) and the red-backed whiptail (*Cnemidophorus burti xanthonotus*) (rockpile). The zebra-tailed lizard (*Callisaurus draconoides*) and the side-blotched lizard are secondary indicator species in addition to the whiptail lizards, at certain sites.

The procedure is to walk along the centerline of the lizard line, recording all lizards within 7.5 m (24.6 ft) of the midline—on each side of the midline (Fig. 4-2). A line is walked several times per day beginning at or prior to the emergence of diurnal lizard species, and continuing until the numbers of individuals of indicator species have peaked and declined. The total of all walks of a line during one day is termed a “run” of the line.

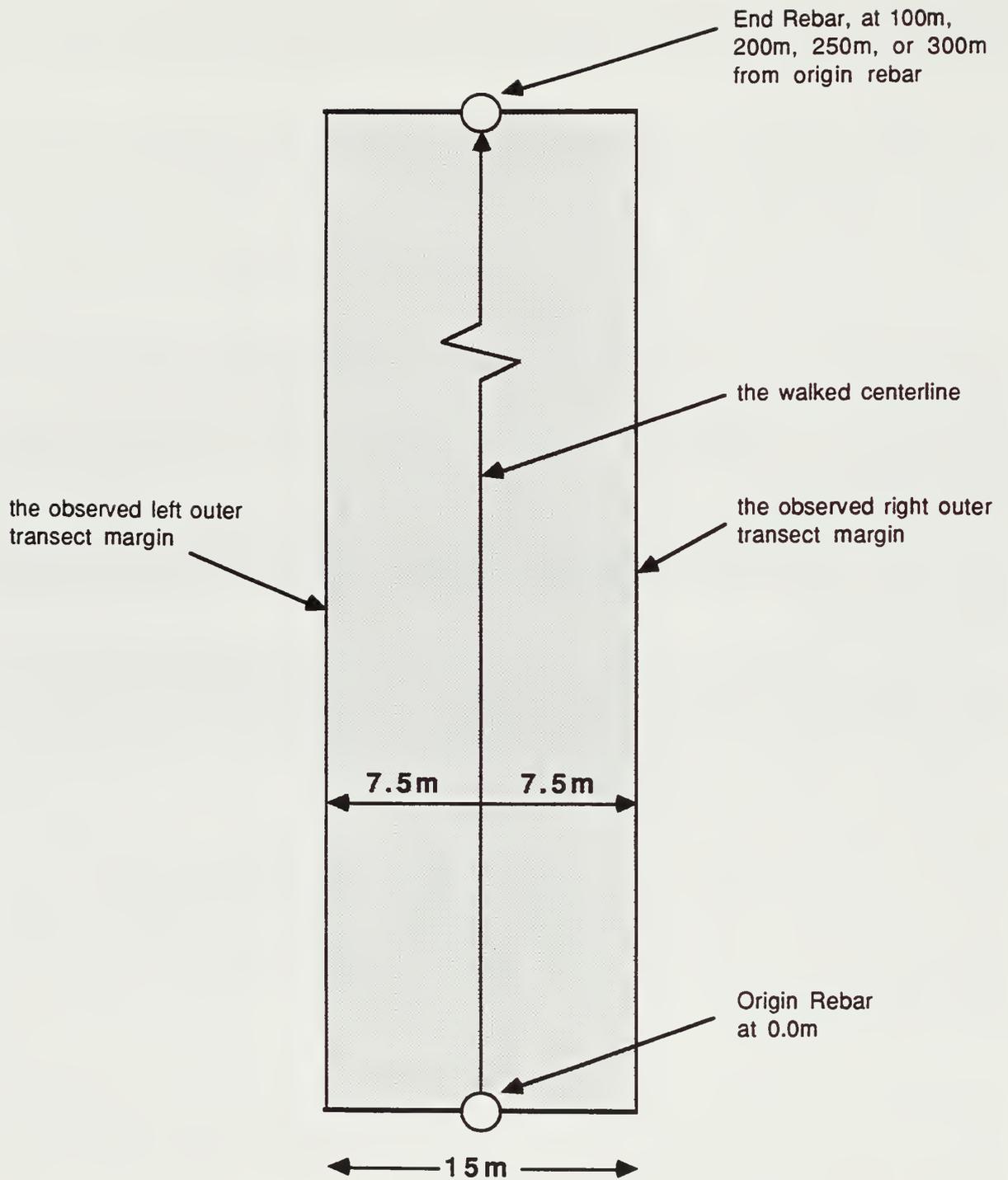


Figure 4-2. Diagram of the 15-m-wide (49-ft) standardized lizard line belt transect in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona. The diagram illustrates a 1,500-m<sup>2</sup> (16,145-ft<sup>2</sup>) observation area within a 15-m (49-ft) belt transect that is 100 m (328 ft) in length.

One lizard line, or a pair of lines on a single site can be run during a single morning. The interval between the initiation of consecutive walks along a line transect during a daily run is 25–60 min. Runs are made in spring (late April to late May) and summer (late July to late August).

The most important data point resulting from a run of a lizard line is the maximum number of whiptails and other site-specific indicator species observed during a single walk of the transect midline. The secondary result is the maximum number of individuals per walk for every other lizard species observed during the daily run. The greatest number observed (for each species) on any walk is termed the “peak value” (for each species) for that daily run.

The following data are recorded separately on each walk: cloud cover, wind, air temperature, substratum temperature, starting time, and ending time. The following are recorded on the standard data form (Appendix 4-1) for each lizard observed on the transect: species, time, distance along transect, distance away from midline, size, sex (if possible), macrohabitat, and behavior.

### *Time-constrained Search*

This method is similar to general herpetological field surveying. For each time-constrained search, starting time, stopping time, weather conditions, and macrohabitats searched are recorded. During each search, the investigator walks through the habitat observing lizards and snakes, and investigates potential shelter sites (within vegetation, under rocks, logs, etc.). The number, size, and sex of each reptile observed are recorded, along with natural history observations as they arise. The time constrained search may cover an entire canyon area or EMP site, or a smaller habitat area.

### *Age-structure*

The age of all lizards observed during line-transect and time-constrained search procedures is recorded in a notebook or on the back of the standard data form. Age is categorized as follows: adult, subadult, juvenile, or hatchling. It is up to the field worker to recognize the distinct age (size) categories present within each species and to record them appropriately. It should not be attempted by those completely unfamiliar with the subject.

It is imperative that lizard line-transect and time-constrained searches be run on warm, clear days during morning times of maximal lizard activity. Otherwise, the data obtained cannot be compared among years or across sites.

### **Procedures for Lizard Line Transects**

Prior to initiating any monitoring work on lizards, the field observer must be thoroughly familiar with all of the lizard species at ORPI, as detailed in this section. Then he (she) should make 2, or more, “dry” runs—following the instructions given in this manual—before actual data runs are made. During or before the dry run attempt, the field worker should be sure to visit each intensive lizard monitoring site to learn the exact location of each lizard line. Ideally, the observer should be able to distinguish juvenile, subadult, and adult age (size) classes for each lizard species, although correct categorization of adults vs juveniles is adequate.

During a year of spring and summer runs, it is useful to use survey flagging (yellow or white) to flag the rebar stakes, and to place a flag on the 3 nearest surrounding shrubs at the origin stake.

### *Knowledge and Equipment Required*

To assure both accurate and consistent data, it is essential that every field worker be properly supplied with both the knowledge and equipment necessary for successful monitoring. Most importantly, the worker must possess, or be willing to acquire with assistance, the following knowledge:

1. Working knowledge of the animals, methodology, and purpose of study. Purpose and methodology, and many details about lizard behavior are covered in the body of this document. An essential working knowledge of the lizards is summarized here, though for a proficiency in species identification the *Field Guide to Western Reptiles and Amphibians* (Stebbins 1985) is recommended.
  - (a) The field worker should be able to distinguish all species of lizards at ORPI at a glance, regardless of the size of the lizard. The single exception to this at ORPI is that careful examination is required to distinguish between the tree lizard (*Urosaurus ornatus*) and long-tailed brush lizard (*Urosaurus graciosus*) in the few areas, such as the Armenta Ranch Site and Bates Well vicinity, where both are known to occur. With some practice, it is possible to distinguish the two species from a distance. Refer to a field guide to memorize the primary characters separating the species, paying particular attention to the long tail and more slender build of the long-tailed brush lizard. The field worker should then work where numerous long-tailed brush lizards can be observed. Carefully observe the overall color pattern and body build, always drawing a contrast with the elsewhere abundant tree lizard. Return to tree lizard populations if necessary, and again to long-tailed brush lizard populations.
  - (b) The distinctive whiptail lizards (genus *Cnemidophorus*) should be easily recognized both close up and at distance. There are two species, western whiptail (*C. tigris*) and red-backed whiptail (*C. burti xanthonotus*). The western whiptail is the principal indicator species in the EMP herpetological program at ORPI. The red-backed whiptail, however, is the indicator species on the Alamo Canyon Site. These indicator species do occur together at some sites, and have both been recorded on the Alamo Canyon Site lizard line. It is quite possible that the red-backed whiptail will be seen on other lizard lines at some point. The field worker should visit Alamo Canyon Site to learn to distinguish the 2 species. The western whiptail will predominate in one end of the site, but with distance will be replaced in prominence by the red-backed whiptail. Note, however, that even in this exercise western whiptails may predominate in other patches of creosotebush-dominated vegetation. The field worker may also consult a field guide to differentiate color between these 2 whiptail species. The nomenclature of the red-backed whiptail is the subspecies *Cnemidophorus burti xanthonotus*. It is quite similar in overall size and shape to the

western whiptail. Be aware, however, that not all red-backed whiptail individuals have the beautiful rusty-red dorsum that is often illustrated or described in field guides: some may be duller, and retain the juvenile striping pattern also seen in the western whiptail. Conversely, some western whiptails may have a slight reddish or orangish overwash to the usual dorsal brown.

- (c) The fully developed red-backed whiptail coloration is unmistakable, but for the above reasons, it is best to learn to rely on additional features for accurate identification. For example, the red-backed whiptail is light-colored below, and almost always a pale, powdery, sky-blue. The western whiptail has black markings below, on a light background color, and often the ventral surfaces are heavily suffused with black. The throat, shoulder, and axilla (armpit) of the western whiptail always have at least some black pigment; this is not seen in the red-backed whiptail. This coloration difference between the 2 species at ORPI is consistent, and should be used for field identification.
- (d) The field worker should know the habitat and microhabitat preferences for all species, and the time and temperature conditions under which they are likely to be most active.
- (e) It should be possible to distinguish several of the species by the sound they make running on the ground or scuttling around a tree trunk. With practice, it is sometimes unnecessary to see the lizard to identify it.
- (f) The field worker ideally should be able to recognize adult, subadult, and juvenile age (size) classes for the diurnal lizard species. This ability is derived only from experience, and only if the field worker remains aware that lizard populations are constantly changing—hatchlings and small juveniles from 1 clutch or 1 yr grow into juveniles or subadults within a year or even a season. However, size/age classes are always obvious when numerous individuals of a species are observed over a short timespan of a few days or weeks. If not obvious, it is because only a single age-class is present.

2. Equipment required for recording data is as follows:

- (2) permanent-ink pens  
or, if necessary, a 2.5-hardness pencil (do not use a soft-lead pencil)
- clipboard
- monitoring handbook (per fieldworker)
- 7.5 m (24.6 ft) or longer metric tape measure
- thermometer
- flagging tape

data forms (Appendix 4-1)

3. Equipment required for laying-out a lizard line transect is as follows:

- 100-m (328-ft) metric measuring tape
- chaining pin
- origin rebar (per transect), 2-ft length
- rebar per 50 m (164 ft) of lizard line, 2-ft lengths
- sledge hammer
- notebook
- magnetic compass
- wire-cutting pliers
- labeled metal tags
- copper wire
- flagging tape

*Preliminaries*

1. Locate the lizard line(s). Be certain to locate the origin, terminus, and midpoint tagged rebar stakes. Note that the origin is a point from which the observer will be walking away from the sun. It may be useful to put flagging tape along the line to avoid wandering off the line accidentally.
2. If there are more than a single line at a site, plan which line to walk first during the daily run. Do not attempt to run more than 2 close lines during a single day.
3. Select routes to go from the end of the line to the next line, or back to the origin. Do not run back and forth on a line: *always start from the origin*. Do *not* pass across or near the line(s) when not actually walking them to collect the standard data.
4. Set up the standard data forms on a clipboard with a pencil or permanent-ink pen. Fill in the date, site, line number, personnel, and start time. See the sample data form (Appendix 4-2).
5. Qualitatively, record the weather on the standard data form (temperature, humidity, wind, sunshine, clouds). Qualitatively, note the weather conditions for the previous day. If it rained within the previous 2 dy, record the exact or approximate amount. Record whether the ground surface is wet, moist, drying, or dry during a run; again, see the sample data form (Appendix 4-2).

6. Mark off 7.5 m (24.6 ft) with a tape measure, on either side of the transect centerline at the origin of the first line walked. Use this to guide decisions in recording lizards as "on the transect," i.e., within 7.5 m (24.6 ft) on either side of the midline. The 7.5 m (24.6 ft) distance may be indicated, at the origin area of the line, with flagging tape or simply with lines drawn on the ground.

### *Walking the Line Transect*

The length of a line transect is walked several times during a complete run. Each walk must conform to the following guidelines:

1. Start at the origin stake.
2. Record the walk number, air temperature at chest height, and the ground surface temperature in the sun. When recording these temperatures, always shade the thermometer bulb by hand or by body. Record air movement and cloudiness. See the sample data form (Appendix 4-2) for examples.
3. Walk down the centerline of the transect, but avoid trampling shrubs. Choose an easy route as the midline, and stick to it each time the transect is walked. The walking pace should be slow and comfortable, but dependent on the observer. The pace should average approximately 10 min/100 m (328 ft) in early walks of a run, when primarily smaller lizards are under observation. Upon nearing the approach of activity peaks for whiptail lizards, the pace should be increased somewhat, or to about 8 min/100 m (328 ft). Be aware that the walking speeds recommended here are only the most general guidelines for what is expected. The pace must correspond to needs imposed by habitat: go slower when vegetation complexity imposes poor visibility, or when wind restricts optimal audibility. Moreover, some field workers may require a slower pace than others, due to differences in experience or eyesight. The field worker should be comfortable with the pace selected. Occasionally, walks will proceed as quickly as 4–5 min/100 m (328 ft), or as slowly as 17–18 min/100 m (328 ft). Overall, however, an individual's walks for a season should average somewhere near the values suggested above.
4. In general, at all times during the walk, the observer should not stop along the line. However, the observer *should stop, if necessary, to confirm identifications* of lizards seen or heard while walking the line at the normal pace, and *may leave the centerline* to confirm identifications.
5. Record each lizard as it is observed on the lizard line, as follows: record the species, time, distance along the transect, distance out from the midline, age(size) class, and sex (if possible). Optionally, record behavior or other notes. See the sample data form (Appendix 4-2). If the lizard is moving when first observed, record its estimated *original* distance from the midline.
6. Record the time when the walk is completed.

7. Prepare to return to the origin to re-walk the line, or to walk the second line. Be sure to stay away from the line when not actually walking for data. Do not disturb the lizards on or near the line when approaching or leaving the line. Always use a circuitous route to go from the end of the line back to the origin.

### *Making a Complete Run*

1. The first walk for a daily run is started just as the habitat begins to warm, usually shortly after sunrise. It should commence when side-blotched lizards and tree lizards are emerging and basking. As an example, the first lizard observed on 3 August 1990 at Burn Site was a juvenile side-blotched lizard at 0623 (although first emergence in summer may be as late as 0732, depending upon temperature and sun exposure). For spring runs, first emergence has been recorded from as early as 0636 to as late as 0836.
2. The first walk is usually taken at a slow pace. Attempt to record all visible side-blotched lizards, including juveniles. This walk may proceed at 9–11 min/100 m (328 ft), or even slower, as necessary. However, do not advance a few feet and then stop to scan for lizards, for such a procedure creates confusion in comparing sites, and should not be used.
3. Rarely, if ever, will it be possible to observe every tree lizard active along a lizard line. Inspect the vegetation along the first 10 m (33 ft) of the line for basking or running tree lizards while waiting for the thermometer to equilibrate at the beginning of a walk. Look for these lizards to be resting on trunks, limbs, and branches, and listen for the sound made when they scuttle around a trunk or limb to hide. Learn to differentiate this sound from the more forceful scuttling sound of similarly-sized spiny lizards (genus *Sceloporus*).
4. Peak values for tree lizards are sometimes obtained late during a run, when the lizards are resting on shaded limbs.
5. A second, slow-paced walk may often be required to record the peak for side-blotched lizards.
6. The second or third walk is at a faster—though still moderate—pace of about 7–9 min/100 m (328 ft), with a focus on the recording of whiptail lizards. Ideally, this walk occurs at the time when the whiptails are basking and moving actively in the sun, and it will often yield the peak number for whiptails. As an example, on 16 April 1989 at Salsola Site, the peak recorded for whiptails occurred at 0855, an hour and 18 min after the first observed species, a side-blotched lizard. During the summer runs, peak values for whiptails have been observed as early as 0735 and, in an unusual case—when the peak number was recorded for shade-active animals—as late as 1030.
7. The fourth, fifth, and any additional walks are also to be taken at a moderate pace. Peak values for numbers of zebra-tailed lizards usually occur during the third or fourth walks, and the whiptail peak may also be recorded then. Zebra-tailed lizard peaks may be recorded at least from 0800 to 1000. When frightened, these lizards will run off of the

transect before being observed, and then not return. Therefore, move slowly, and to avoid frightening the lizard, *leave the midline to circumvent* the lizard, if necessary.

8. At most sites, the final walk will occur just before or while the desert iguana (*Dipsosaurus dorsalis*) begins to become active, usually at relatively high environmental temperatures. On the later walks of a run, when substratum temperatures are high, it is useful to attempt a faster pace of approximately 5–6 min/100 m (328 ft). This may flush out lizards that are concealed in the shade and, occasionally, a peak value may be obtained this way.

### *Timing the Walks During a Daily Run*

Normally, the time between the start-times of sequential walks of a standardized lizard line transect will be 25–60 min. It is the field worker's responsibility to time the walks properly. Before beginning the first walk, the field worker should be ready on the site and aware that lizard activity is beginning. Between walks, the field worker should be active on the site and aware of the progression of lizard activities over the morning.

Each lizard species has a characteristic—though not invariant—cycle of daily behavior and activity: (1) morning emergence, (2) basking, (3) movement activity in the sun, (4) movement activity in sun and shade, (5) activity in the shade, and (6) midday or late afternoon retreat. In general, the first species to emerge at ORPI will be the side-blotched lizard, followed closely by the tree lizard. The next species in sequence is generally a whiptail, followed by the zebra-tailed lizard, or *visa versa* according to juvenile or adult. Spiny lizards are usually conspicuous on the lizard lines slightly later than whiptails, although the former, as a rule, emerge first. The desert iguana is the latest to emerge and becomes active as the heat of the day develops.

On mild or cool days, or during summer rainy periods there can be considerable variation on these cycles. The onset of lizard activity will be delayed on mild or windy, sunny days. On mild to moderately hot days there is frequently a secondary peak of activity during late afternoon.

The objective of the lizard line-transect method is to determine the peak number of lizards observed during the morning phases described above—basking, active movement in the sun, and active movement in the sun-shade mosaic. The field worker achieves this objective by timing walks during a daily run to coincide with the activity peaks of species of interest.

One final, important warning: it is tempting to merely run the lizard lines repeatedly and continuously, without regard to observations of lizard activity. This is not a productive approach, as continuous observer presence on a transect will inhibit lizard activity and frighten lizards away from the transect.

### *Seasonal Timing for Line-transect Operations*

The standard lizard line transects should be run in mid to late spring and in mid summer. Spring runs should commence when the weather first becomes consistently warm, with daily maximum air temperatures of approximately 30–35° C (86–95° F)—daily maximum substratum temperature will be in excess of 50° C (122° F)—generally in mid April or early May. Spring runs should be completed during May. Summer runs should commence at or after the onset of monsoonal rainfall—generally in mid- to late July or early August—and should be completed during August.

All runs of the lizard lines should be conducted on clear or mostly clear, warm or hot mornings. If the ground is wet and remains cool, lizard activity may be reduced or absent, and data obtained on such days are to be rejected. It is imperative that the lines be run on days when normal peak numbers of lizards can be observed basking and active in the morning, as described above. For long-term monitoring, see the seasonal schedule in Table 4-1.

### **Procedures for Time-constrained Search**

The generalized time-constrained search applies to all, or most all, lizard taxa in the habitat. The taxon-specific, time-constrained search refers to a species, genus, or other taxon in the habitat. Prior familiarity with the species involved is clearly necessary. This refers to a comfortable recognition-at-a-glance, which is necessary to obtain accurate results in any field methodology involving counting of individuals by species, be it a time-constrained search, a transect walk, or other.

### *Knowledge and Equipment Required*

For complete, detailed information, refer to this heading in the section titled Procedures for Lizard Line Transects.

### *Habitat Search*

Searching involves thorough herpetological exploration of the habitat. The investigator moves through the habitat, observing lizards and snakes, looking into dense vegetation and crevices, under rocks, logs, and so forth, and looking at distance for perched or moving reptiles.

Table 4-1. Lizard line-transect monitoring in the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument, Arizona. The table shows the recommended schedule for long-term monitoring through 1996. An asterisk (\*) indicates a transect site near, but not on, an EMP site.

Site	1991		1992		1993		1994		1995		1996	
	Spring	Summer										
Aguajita Wash	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Alamo Canyon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Armenta Ranch	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Burn Site	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Creosotebush Site*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dos Lomitas	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
East Armenta	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Growler Canyon	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lizard Grid*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lost Cabin Mine	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lower Colorado Larrea			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Middle Bajada							✓	✓	✓	✓	✓	✓
Pozo Nuevo	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Salsola Site	✓	✓									✓	✓
Senita Basin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Valley Floor							✓	✓	✓	✓	✓	✓
Vulture Site	✓	✓									✓	✓

### *Search Period*

For comparative purposes (for example, between sites, seasons, years, etc.), the actual time involved in search should be comparable for all search periods. A minimum 2-hr period should be used in the generalized time-constrained search. A species-adjusted time period (through experience) should be used in a taxon-specific, time-constrained search.

The time of day in which to locate the 2-hr (or other) period is weather dependent. For example, assuming a dry surface, during a given month, the search period may span 0700 to 1100 on a hot day, 0800 to 1300/1400 on a mild day, or 0900 to 1400/1600 on a fully overcast day. For the generalized time-constrained search involving most lizards, avoid early morning (e.g., before 0700 on most days), mid-day, and early evening. For the taxon-specific search, the time of search should be during peak activity in the daily activity period of the species investigated.

### *Data Recorded*

During either the generalized or taxon-specific time-constrained search, the following data are collected:

1. Location of search
2. Route taken within the searched area
3. Habitat details
4. Weather conditions, today and yesterday, especially if different
5. Search start time and stop time
6. Reptiles by species, sex, size, age, other
7. In addition to the numbers observed, behaviors or other natural history information, as it arises.

## Literature Cited

- Dixon, W. J., and F. J. Massey, Jr. 1969. Introduction to Statistical Analysis, 3rd ed. McGraw-Hill, New York.
- Gonzales-Romero, A., and S. Alvarez-Cardenas. 1989. Herpetofauna de la región del Pinacate, Sonora, Mexico: un inventario. *Southwestern Naturalist* 34:519–526.
- Gonzales-Romero, A., A. Ortega, and R. Barbault. 1989. Habitat partitioning and spatial organization in a lizard community of the Sonoran Desert, Mexico. *Amphibia-Reptilia* 10:1–11.
- Hollander, M., and D. A. Wolfe. 1973. *Nonparametric Statistical Methods*. John Wiley, New York.
- Sachs, L. 1982. *Applied Statistics. A Handbook of Techniques*. Springer-Verlag, New York.
- Sokal, R. R., and F. J. Rohlf. 1981. *Biometry. The principles and practice of statistics in biological research*. W. H. Freeman, New York.
- Stebbins, R. C. 1985. *Field guide to western reptiles and amphibians*. Houghton-Mifflin, Boston.
- Turner, F. B., G. A. Hoddenbach, P. A. Medica, and J. R. Lannom, Jr. 1970. The demography of the lizard, *Uta stansburiana* Baird and Girard, in southern Nevada. *Journal of Animal Ecology* 39:505–519.
- Turner, F. B., J. R. Lannom, Jr., P. A. Medica, and G. A. Hoddenbach. 1969a. Density and composition of fenced populations of leopard lizards (*Crotaphytus wislizenii*) in southern Nevada. *Herpetologica* 25:247–257.
- Turner, F. B., P. A. Medica, J. R. Lannom, Jr., and G. A. Hoddenbach. 1969b. A demographic analysis of fenced populations of the whiptail lizard, *Cnemidophorus tigris*, in southern Nevada. *Southwestern Naturalist* 14:189–202.
- Whitford, W. G., and F. M. Creusere. 1977. Seasonal and yearly fluctuations in Chihuahuan Desert lizard communities. *Herpetologica* 33:54–65.
- Zar, J. H. 1984. *Biostatistical Analysis*. 2nd ed. Prentice Hall, Englewood Cliffs, New Jersey.

**Appendix 4-1**  
**Lizard Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Lizard Line Standard Transect Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork. For an example of proper usage, please see Appendix 4-2.



**Appendix 4-2**  
**Lizard Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Lizard Line Standard Transect Data Form Sample**

The sample data forms on the next 2 pages are from an actual lizard line run, although they have been recopied in neater handwriting than the originals.

This example is to illustrate several points. Some, though not most runs may require 2 or more data forms. Note also that the first observed individuals of indicator species, as well as other species, are noted as they occur over the course of the morning. Any other noteworthy observations are also noted directly onto the data form—these, and the “Habitat/Notes” column are entirely discretionary for the individual field worker. Otherwise, the data forms should be filled out substantially as in the example.

In the past, the back of the data form has often been used to record other lizards observed over the course of the morning, tallied by species and age(size) class. Then, the lizard and other data are summarized in a separate field notebook.

LIZARD LINE STANDARD TRANSECT

Date August 3, 1990 Locality Burn SEP Transect 100 m

Personel Rosen Start time 0615 Stop time 1021

Weather Muggy & warm, clear & mostly still, v. sl. breeze. Yest aft. a storm passed 1/4-1/2 mi E of here. Grd dry here-- rd shows isolated drops fell here.

SPECIES	TIME	DISTANCE FROM: ORIGIN	MIDLINE	AGE/ SIZE	SEX	HABITAT / NOTES
RUN 1	START	0620	Air = 24.3°C	Surface = 24.6°		
* Uta		0623	25	6	ad	♀? basking, saltbush base
	STOP	0636				
(2 <i>Sylvalagus</i> on line 0627 at 47 m, nr wash edge)						
RUN 2	START	0651	Air = 25.9°	Surf = 26.8°		sl. breeze
Uta		0651	1	4	sm juv	— saltbush base, basking
Uta		0658	25	4	ad	♀? " " "
(Spermophilus tereticaudae 0659 at 30 m on line)						
Uta		0702	44	4	lg juv	— saltbush base, sunning
Uta		0704	48	1	ad	♀ wash edge saltbush, " " "
Uta		0710	70	2	sm ad	♀ square base, or hole, " " "
	STOP	0718				
(* * * 1st) <i>U. ornatus</i> (ad ♀ 0724, gravid, sunning on dead trunk)						
RUN 3	START	0728	Air = 27.6°	Surf = 30.8°		sl. breeze
Uta		0728	0	4	lg juv	— active in open
Uta		0735	30	3	juv	— " " " nr burrow
Uta		0735	30	2	ad	♀ " " " " "
(* * 1st) <i>Cnemidactylus tigris</i> 0740 48 0 ad ♂♀ wash edge saltbush, sunning						
Uta		0750	70	3	lg juv	— active - dead snags
Uta		0752	91	0	juv	— sunning under delto. log
Uta		0754	100	7.5	ad	♀ sunning - rockpile
	STOP	0755				
RUN 4	START	0815	Air = 28.8°	Surf = 34.5°		sl. breeze
Uta		0819	30	1	lg juv	— active in open nr burrow
<i>Cnemidactylus tigris</i>		0821	50	3	ad	♀? active wash riparian
<i>magister</i>		0821	50	4	ad	? heard on mesquite, wash
Uta		0823	51	7.5	ad	♂ active, wash, semi-sun
<i>U. ornatus</i>		0824	54	7.5	ad	♂ " " mesq trunk shade
<i>Cnemidactylus tigris</i>		0830	59	0	ad	♂ chasing ♀ in wash bed
Uta		0832	100	0	ad	♂ active in rockpile
	STOP	0834				

\* 1st lizard of day

Uta peak

Cnemidactylus peak

(additional runs - - cont.) →

## LIZARD LINE STANDARD TRANSECT

Date August 3, 1990 Locality Burn SEP Transect 100 m  
 Personel Rosen Start time 0615 Stop time 1015  
 Weather Soil dry to 10 cm at least.

SPECIES	TIME	DISTANCE FROM: ORIGIN MIDLINE	AGE/ SIZE	SEX	HABITAT / NOTES
(0836-0849-Utas active mainly in shade + in burrow entrances)					
Cnemid in shade	RUN 5 START	0849	Air = 29.8°	Surf = 39.9°	v. sl. breeze
			(scorpion! Hadrurus <sup>0854</sup> 70 3 sm ad ?? walking in open sun!)		
	Cnemid tigris	0906	56 2	ad ♀	wash bank, active in Tidstroemia semi-shade
	Uta	0908	75 3	sm juv -	Larrea shade
	Uta	0909	100 0	ad ♂?	rockpile-facing into sun
	STOP	0910			
★★ 1st Callisaurus - - 0911, 2 adults in sun, wash sand)					
(Masticophis flagellum - N end of SEP site, bet. 2 washes, ad ♂ red/pink phase; just out of burrow (head 35.0°, cloacal 29.9°C) under saltbush nr mesquite, graythorn, floridum, saguaro, Larrea. SVL = 1251. Eyes clear but ready to shed. 0916 hrs.)					
★★ 1st Diposaurus ad, lg 0922)					
RUN 6 START	0926	Air = 32.0°	Surf = 43.7°	sl. breeze	
Uta	0929	33 2	lg juv -		Tidstroemia shade, open
Cnemid tigris	0934	44 4	ad ♀		wash riparian edge - salt
" "	0934	44 5	ad ♂		" " ", chasing ♀
U. ornatus	0936	55 4	ad ♀		mesq limb, shade, wash
Callisaurus	0938	68 5	ad ♂		sun-summer annuals
	STOP	0939			
RUN 7 START	1006	Air = 32.9°	Surf = 47.2°	breezy	
Cnemid tigris	1009	50 7.5	ad ♂		wash bank - active mesquite shade
" "	1011	52 0	ad ♀		wash bank - shrub, shade
Uta	1011	51 2	sm juv -		wash bank - sun, shade
	STOP	1015			
(tereticaudus juv at 1016, 95m on line)					
(Cnemid tigris courtship 1018 hrs, in wash bank forb-shrub)					

Appendix 4-3  
**Lizard Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monument, Arizona:  
 Cross-referenced Index of Lizard Taxa**

The following index cross-references scientific taxa with common names for the lizard species named in this report. Names occur in the index followed by one or more Ecological Monitoring Program (EMP) site acronyms, each indicating species presence on that site. Refer to the monitoring site abbreviation key below for site location names.

**Index**

**—B—**

BANDED GECKO, DESERT—*Coleonyx variegatus variegatus*

**—C—**

*Callisaurus draconoides*—ZEBRA-TAILED LIZARD—AC, AR, AW, BS, CS, DL, EA, GC, LC, LG, NS, PN, SB, SS, VS  
 CHUCKWALLA, COMMON—*Sauromalus obesus*—GC, LC

*Cnemidophorus burti xanthonotus*—RED-BACKED WHIPTAIL—AC, AY, BP, GC

*Cnemidophorus tigris*—WESTERN WHIPTAIL—AC, AR, AW, BS, CS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

*Coleonyx variegatus variegatus*—DESERT BANDED GECKO

COLLARED LIZARD, COMMON—*Crotaphytus collaris*—AC, BP, GC, LC

*Crotaphytus collaris*—COMMON COLLARED LIZARD—AC, BP, GC, LC

**—D—**

*Dipsosaurus dorsalis*—DESERT IGUANA—AR, AW, BS, CS, DL, EA, GC, LC, LG, PN, SB, SS, VS

**—G—**

*Gambelia wislizeni*—LONG-NOSED LEOPARD LIZARD—AR, AW, BS, CS, DL, EA, GC, LG, PN, SB, SS, VS

**—H—**

HORNED LIZARD, DESERT—*Phrynosoma platyrhinos*—CS, EA, LG

HORNED LIZARD, REGAL—*Phrynosoma solare*—AR, AW, BS, CS, DL, EA, GC, LC, LG, PN, SB, SS, VS

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*EMP monitoring site / lizard line transect site abbreviation key:*

AC = Alamo Canyon	CS = Creosotebush Site	LG = Lizard Grid Site
AR = Armenta Ranch	DL = Dos Lomitas	NS = Neolloydia Site
AW = Aguajita Wash	DS = Dripping Springs	PN = Pozo Nuevo
AY = Arch Canyon	EA = East Armenta	SB = Senita Basin
BP = Bull Pasture	GC = Growler Canyon	SS = Salsola Site
BS = Burn Site	LC = Lost Cabin Mine	VS = Vulture Site

—I—

IGUANA, DESERT—*Dipsosaurus dorsalis*—AR, AW, BS, CS, DL, EA, GC, LC, LG, PN, SB, SS, VS

—L—

LEOPARD LIZARD, LONG-NOSED—*Gambelia wislizeni*—AR, AW, BS, CS, DL, EA, GC, LG, PN, SB, SS, VS

LIZARD, LONG-TAILED BRUSH—*Urosaurus graciosus*—AR

LIZARD, SIDE-BLOTCHED—*Uta stansburiana*—AC, AR, AW, AY, BS, CS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

LIZARD, TREE—*Urosaurus ornatus*—AC, AR, AW, AY, BP, BS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

LIZARD, ZEBRA-TAILED—*Callisaurus draconoides*—AC, AR, AW, BS, CS, DL, EA, GC, LC, LG, NS, PN, SB, SS, VS

—P—

*Phrynosoma platyrhinos*—DESERT HORNED LIZARD—CS, EA, LG

*Phrynosoma solare*—REGAL HORNED LIZARD—AR, AW, BS, CS, DL, EA, GC, LC, LG, PN, SB, SS, VS

—S—

*Sauromalus obesus*—COMMON CHUCKWALLA—GC, LC

*Sceloporus clarki*—CLARK SPINY LIZARD—AC, AY, BP, DS, GC

*Sceloporus magister*—DESERT SPINY LIZARD—AR, AW, AY, BS, DL, EA, GC, LC, LG, PN, SB, SS, VS

SPINY LIZARD, CLARK—*Sceloporus clarki*—AC, AY, BP, DS, GC

SPINY LIZARD, DESERT—*Sceloporus magister*—AR, AW, AY, BS, DL, EA, GC, LC, LG, PN, SB, SS, VS

—U—

*Urosaurus graciosus*—LONG-TAILED BRUSH LIZARD—AR

*Urosaurus ornatus*—TREE LIZARD—AC, AR, AW, AY, BP, BS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

*Uta stansburiana*—SIDE-BLOTCHED LIZARD—AC, AR, AW, AY, BS, CS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

—W—

WHIPTAIL, RED-BACKED—*Cnemidophorus burti xanthonotus*—AC, AY, BP, GC

WHIPTAIL, WESTERN—*Cnemidophorus tigris*—AC, AR, AW, BS, CS, DL, DS, EA, GC, LC, LG, NS, PN, SB, SS, VS

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*EMP monitoring site / lizard line transect site abbreviation key:*

AC = Alamo Canyon  
AR = Armenta Ranch  
AW = Aguajita Wash  
AY = Arch Canyon  
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DS = Dripping Springs  
EA = East Armenta  
GC = Growler Canyon  
LC = Lost Cabin Mine

LG = Lizard Grid Site  
NS = Neolloydia Site  
PN = Pozo Nuevo  
SB = Senita Basin  
SS = Salsola Site  
VS = Vulture Site

# Small Nocturnal Mammals Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Yar Petryszyn

Department of Ecology and Evolutionary Biology  
Biological Sciences East, Room 123  
The University of Arizona  
Tucson, Arizona 85721

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## Introduction

Monitoring of small mammals by utilizing capture, mark, release, and recapture techniques provides data for long-term assessment of environmental effects such as rainfall, grazing, habitat changes, and people-usage impact. The status of rodent populations has a broad application in that it is indicative of the general health of the environment. Being primary consumers as well as the prey base for many predators (snakes, raptors, and a number of larger mammals), rodent populations rapidly react to changes in available food resources and, in turn, influence population numbers and the health of those animals dependant on them as a food source. Because rodents are found in most habitats, are easily captured and identified, and have a relatively small home range, monitoring is easily implemented, relatively low in cost, and does not require a great number of person hours to accomplish objectives.

Preliminary research for Organ Pipe Cactus National Monument (ORPI) rodent monitoring protocol was conducted by Yar Petryszyn, and summarized in his final report on Special Status Mammals. Nocturnal monitoring was implemented at Core I Ecological Monitoring Program (EMP) sites in 1991. Core II sites, as well as some non-core sites, were later added to this annual monitoring effort. With data collected in this project, total biomass and rodent densities per site are calculated annually.

Efficiency and effectiveness are of primary concern. Time constraints, along with limited personnel seem to be constant companions in any field effort. With this in mind, the following monitoring configurations are proposed.

# Sampling Methods

## Overview

Sampling in ORPI should be conducted annually, in July. This timing enables capture slightly before the period of highest population density for most rodents (Fig. 5-1) but avoids the unpredictable nature of August monsoon weather. For comparability, monitoring should always take place in July. This sampling effort is adequate for documenting general trends in population sizes on an annual basis.

If adequate funding is available, yearly monitoring of the chosen sites is preferred. In any case, no less than biannual sampling of each site is necessary. Many of the rodent populations may react rapidly to environmental changes, reaching peaks and crashing within a 2- or 3-yr period (Fig. 5-2). At a minimum, a 2-yr cycle of monitoring assures that population highs and lows are noted.

If more refined information is desired (such as over-winter loss and reproductive effort), a semiannual monitoring effort may be used. Live trapping should be conducted in late summer or early fall, and again in early spring. Early spring trapping should be conducted sometime in April or, at the latest, the first week in May. This sampling period assures that the smaller rodents have emerged from winter inactivity, and trapping can occur before the above-ground appearance of a large number of the young born that spring.

Two monitoring sessions (spring and late summer) for each site for each year is ideal, providing the best resolution of population activity. This effort exposes minor fluctuations as well as any major changes in small mammal populations. It also assures that any variation in population highs (and lows) between species is documented. The kangaroo rat (*Dipodomys* spp.), for example, generally has higher populations in the spring than in late summer.

## Materials Required

The following equipment is needed to conduct a monitoring session of small nocturnal mammals:

Sherman traps (98)	3.0 x 3.5 x 9.0 in. These traps are capable of capturing the largest and smallest rodents found in the area. Folding traps are preferred to rigid ones to reduce the bulkiness of traps during transportation to the grids.
Compass	For determining grid corners and for trueing grid lines.
100-m tapes (2)	For laying grid lines.

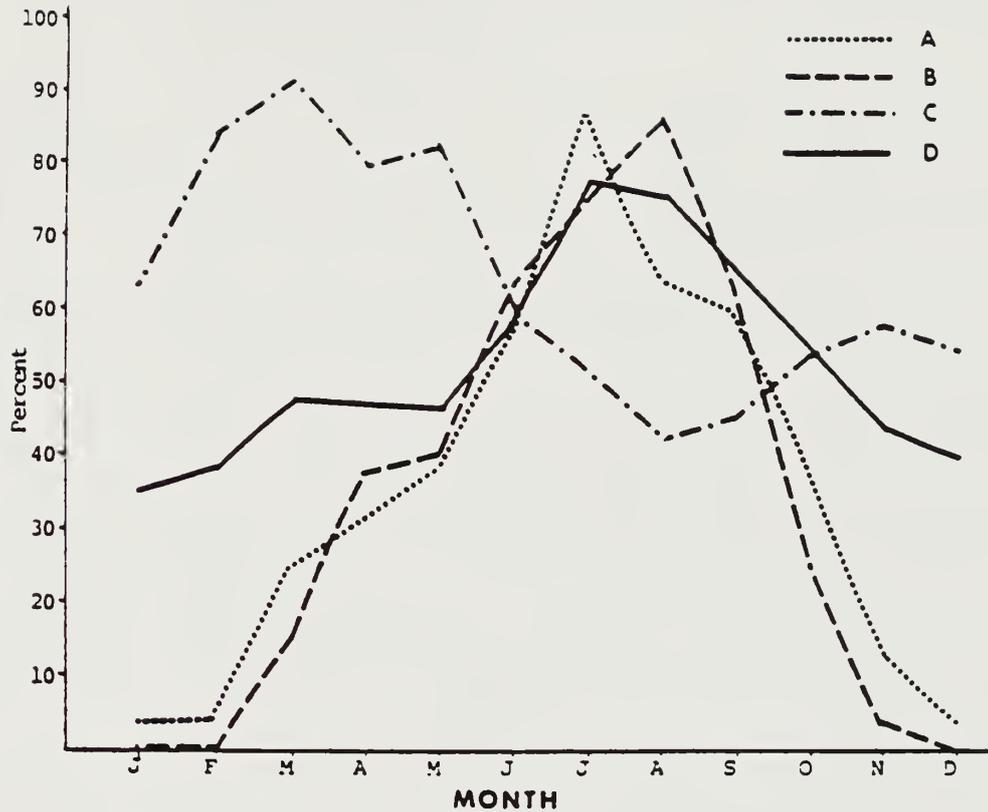


Figure 5-1. Seasonal activity of heteromyid rodents: as an accumulated mean percent over 9 years. Key: A = desert pocket mouse (*Chaetodipus penicillatus*), B = Arizona pocket mouse (*Perognathus amplus*), C = Merriam's kangaroo rat (*Dipodomys merriami*), D = Bailey's pocket mouse (*Chaetodipus baileyi*).

Petryszyn, Y. 1982. Population dynamics of nocturnal desert rodents: a nine-year study. Ph. D. Dissertation. The University of Arizona, Tucson. 108 p.

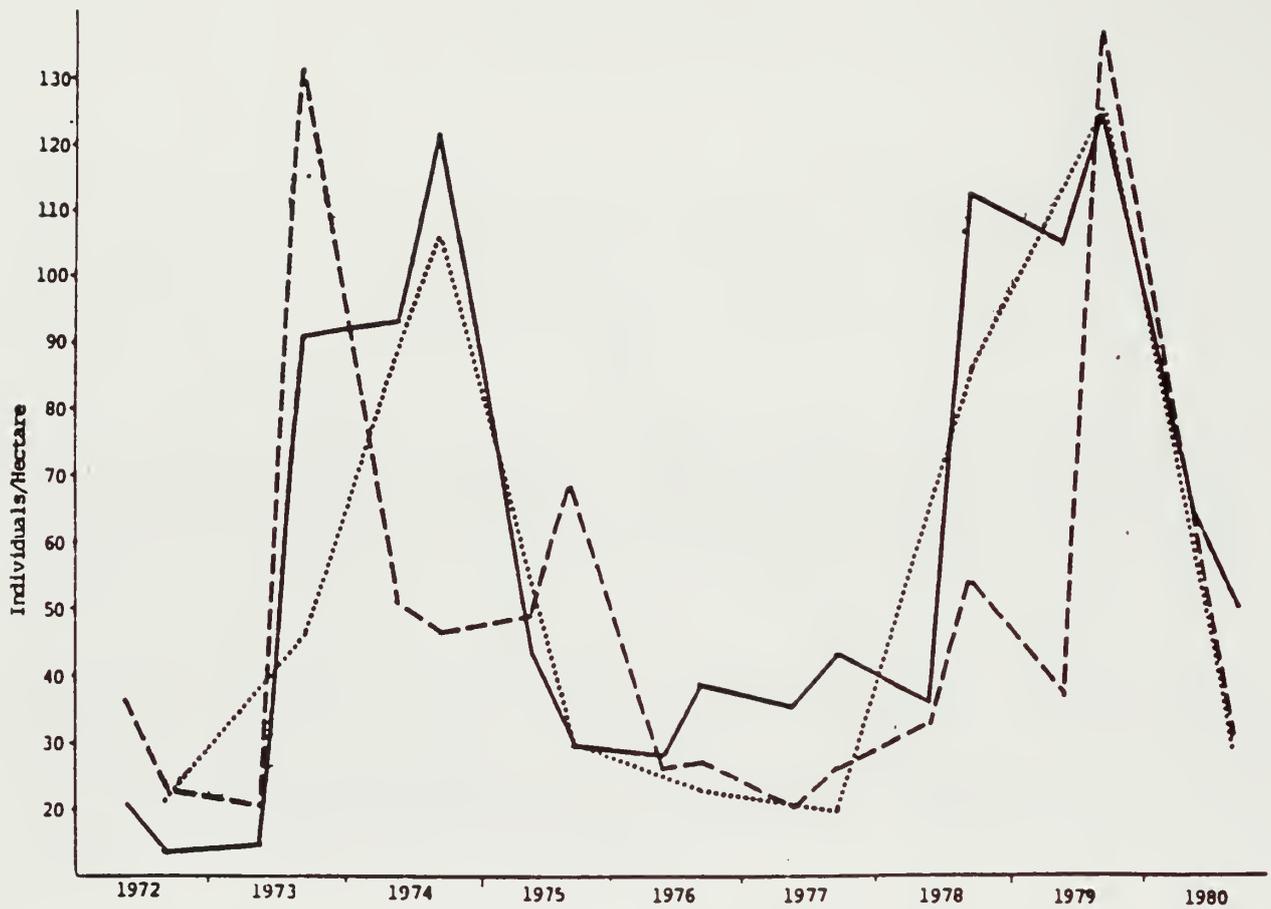


Figure 5-2. Heteromyid numbers on 3 sites sampled from 1972 to 1980, Pima Co., Arizona.

Petryszyn, Y. 1982. Population dynamics of nocturnal desert rodents: a nine-year study. Ph. D. Dissertation. The University of Arizona, Tucson. 108 p.

Bait	Either dry Quaker rolled oats (not the quick type) or mixed bird seed consisting of millet, sunflower seeds, wheat, cracked corn, and milo. (The latter is preferred during rainy weather in order to avoid the gluey effect of wet rolled oats).
Bait pouch	One that can be carried on a belt, if possible.
Cloth bag	Into which rodents, once removed from traps, can be placed during processing.
Lingerie mesh bags (2)	With zippers, for safe handling and processing of packrats ( <i>Neotoma</i> spp.).
Spring-loaded scales (2)	Pesola scales are ideal; one capable of 100-gm weight, the other of 300-gm weight, and both accurate to 1 gm.
Reference	Indicator keys for distinguishing between species (Appendices 5-1 and 5-2).
Data forms	For collecting data (Appendix 5-3).
Clipboard	For carrying data forms.
Pencils or pens (2)	For completing data forms.
Pencil sharpener	If using pencils.
Surgical scissors –or– Indelible marking pen	For identification marking of rodents. If using a marking pen, refillable Pilot Super Color Marker works best, although any brand with very wet ink may be used.
Flagging tape	For marking grid-line ends in difficult terrain. Should be of 2 contrasting colors.

### Setting Up the Trapping Grids

Each site is to be sampled by 1 or 2 grids of 7 rows x 7 stations, with trap stations at 15-m (49-ft) intervals. This configuration conveniently samples 1.4 ha (3.5 a.). Two people can easily set the traps out in 2 grids (total of 98 traps) and check and process the catch without an excessive expenditure of time and effort. Only experienced personnel should attempt to sample a site alone, so that rodent lives are not risked through lack of speed in processing.

The end rows of the 1.4-ha (3.5-a.) monitoring area also sample an area that extends 15 m (49.2 ft), which is the average radius of the home range of most nocturnal rodents. The area confined within the grid proper plus the extended peripheral sample area totals 1.4 ha (3.5 a.) (Fig. 5-3).

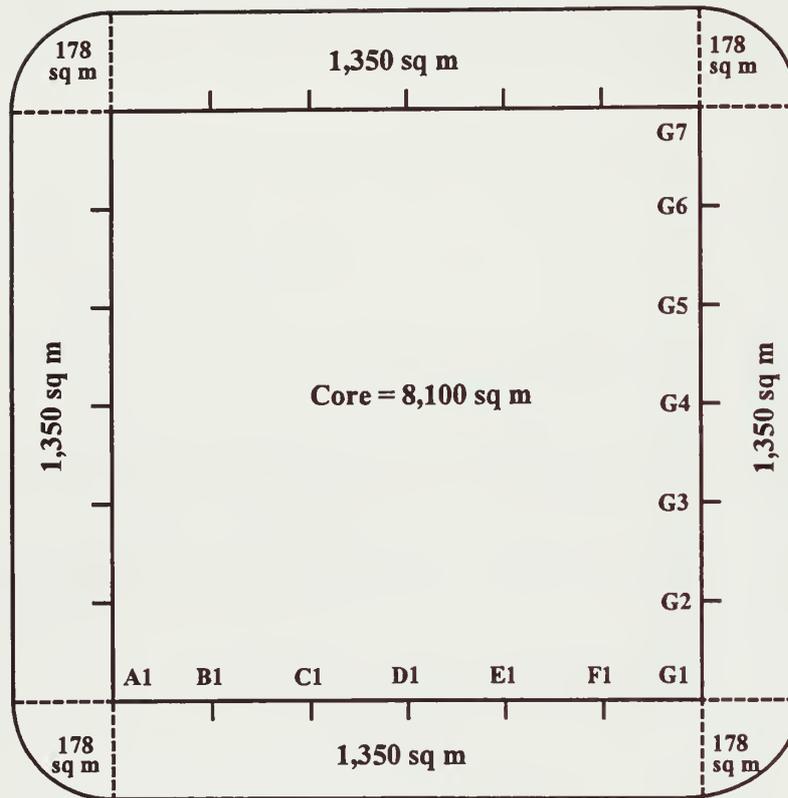


Figure 5-3. Sampling area of trapping grid for small nocturnal mammals in the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. The total area of the grid (including the periphery) is 1.4 ha (3.5 a.).

Find and flag each corner of the grid. Forty-nine traps are placed in a 90 x 90-m (295 x 295-ft) grid, spaced 15 m (49 ft) apart and identified by locations A1 to G7. (Fig. 5-3) Trap placement and identification are made consistent each year in order to track long-term trends in microhabitat selection.

Several methods can be used to accurately set up the trapping grids, depending on terrain and personal preference. The techniques described here can be applied in a variety of ways. If near sunset, the traps may be baited at the same time they are placed in the grid. Otherwise, return to the grid later to bait the traps. If traps are baited too early, there is a chance for diurnal mammals such as roundtail ground squirrels (*Spermophilus tereticaudus*) or Harris' antelope squirrels (*Ammospermophilus harrisi*) to enter the traps.

Sampling grids are activated for a period of 2 consecutive nights. The sequence of sampling activity is (1) the first evening, set up the trapping grids and bait the traps; (2) the following

morning, process the mammals and leave the traps closed on the grids; (3) the following evening, rebait the traps; and (4) on the last morning, process the mammals trapped, then pick up all traps and disassemble the grids.

The fundamental procedures for setting up the trapping grids and laying and baiting the traps are:

1. Lay out a tape on one (or two) of the lines, preferably the baseline (southwest corner to southeast). The tape provides assistance in keeping on the grid lines.
2. Using the compass bearing for that grid, pace 15 m to each trap location. At each location, find the closest spot that will provide shade from the morning sun and prepare by scraping a flat, bare spot to set the trap. Check the tension on the trap and place on the ground. Leave trap door shut until ready to bait.
3. When using the compass, pick a spot on the distant horizon that fits your bearing, if possible. In thick foliage, consult the compass after placing each trap.
4. When large trees or other obstacles are on the line, use the offset method of pacing to stay on line: (a) at the obstacle, turn 90° from the line; (b) move away from the obstacle, counting the number of paces required to clear it; (c) turn 90° again, and now parallel with the line, continue 15-m interval pacing to the next trap-setting location; (d) turning 90° to face the line, return to it by counting the number of offset paces required in step "b" to bypass the obstacle; finally (e) set the next trap and continue 15-m interval pacing on the line.
5. For very difficult terrain, such as is encountered when setting up the Alamo Canyon trapping grids, follow the method described in step 4, with the following addition. Place flagging of 2 alternating, contrasting colors at the ends of each of the lines. These can be labeled with "A1," "A7," "B1," "B7," and so forth. This will help to determine at a distance if traps are being accurately set on line.
6. Along easier terrain, the "perimeter method" of setting grids and traps may be adopted. For this method, a tape may or may not be placed along one line. Initially, the field worker carries 24 traps to place around the perimeter and, by pacing, determines trap locations. This creates a boundary by which the remaining interiors of the lines can be accurately filled in with traps. The remaining 5 traps per line are placed using compass and pacing.
7. In all of the above methods, workers may prefer to delay checking trap tension, as well as placing traps in shade until after the grid has been established. To speed up the grid placement, unfold the traps but merely place them on their "exact" grid location without checking their tension or finding shade. This can also aid in grid alignment accuracy by allowing the worker to see traps on an adjacent line and more precisely judge proper spacing. Later, when the traps are baited, they are also checked for tension and placed in a shady location.

8. Avoid placing traps in proximity to ant colonies. If active ant colonies are present in the area, it is virtually impossible to prevent the loss of bait from the traps.
9. Place traps clear of nearby twigs or branches that, if blown by wind, may possibly cause the trap to spring during the night. Also, place traps on a level surface if at all possible, as wind may rock and consequently spring them.
10. Baiting and setting of the traps should be conducted just before sundown.
11. Adjust the tension on the trap treadle so that a light tap on the top of the trap causes it to spring shut. When set with too much tension, the trap will not spring at the correct time; with not enough, it can be triggered too easily.
12. Toss a two-fingered pinch of oats to the far back, inside of the trap. A few flakes may also be placed in front of the trap opening to attract rodents; however, the animal needs to cross to the back of the treadle in order to spring the trap.
13. Always keep track of your location on the grid. Count to yourself as you lay out or bait traps: “B6,” “B7,” and so forth. This will help avoid any confusion of nonbaited traps. It is especially critical to keep track of your location when processing the rodents in the morning. Missing a trap could mean a horrible death for a rodent.
14. The problems inherent in live trapping through the daylight hours make gathering information on diurnal rodents (such as ground squirrels) exceedingly difficult. If monitoring of diurnal animals is necessary, the traps must be checked every hour. A raised shade-board, placed above the trap, provides shade yet allows air circulation. This is normally required to prevent death due to overheating.

### **Processing Rodents**

Checking traps and rodent processing should begin at first light. Not enough emphasis can be placed upon the need to process the animals very early in the morning. The metal box traps heat up rapidly in sunlight and become little ovens, much to the detriment of the animals inside.

The basic protocols for processing rodents are:

1. Carry a cloth bag, lingerie bag (for packrats), 100- and 300-gm scales, a marking pen (on the first morning only), data forms, and species keys. Make sure the pen is very wet with ink.

2. Wrap the mouth of the cloth bag around the end of the trap, gathering the extra cloth with one hand so that no opening is presented to the rodent. With the other hand, use two fingers to open the trap door (through the cloth of the bag). While doing this, make sure that the rodent is not behind the trap door.
3. Turn the trap upside down and firmly shake the rodent into the bag. When it is at the bottom of the cloth bag, make a ring with your fingers to close around the top of the bag (leaving no openings) and place the trap back in its location.
4. Remove the rodent from the bag with a firm grip on the skin behind its ears. Face away from the sun while handling, so as to minimize the animal's stress from heat and light.
5. Determine species, sex, and weight; record this information on the data form. For more detailed instructions on these procedures, see the following section, Completing Data Forms.
6. Make a wide, thick ink mark on the rodent's belly and release.
7. Close each trap for the day as you progress along the grid.
8. On the second morning of processing, note on the data form if a rodent is recaptured (®), along with its species, but do not weigh or sex.

### **Completing Data Forms**

Record sampling data on forms such as the one provided (Appendix 5-3). Information recorded includes species, individual identification number, trap number, sex, weight, and notes.

#### *Species*

Identify each rodent to species using diagnostics such as nose hair, rump spines, baculum, hind foot length, etc. The most difficult determination of species will be for the Arizona pocket mouse (*Perognathus amplus*), desert pocket mouse (*Chaetodipus penicillatus*), rock pocket mouse (*Chaetodipus intermedius*), and Bailey's pocket mouse (*Chaetodipus baileyi*). Appendix 5-1 summarizes differentiating characteristics to consider.

The mesquite mouse (*Peromyscus merriami*) has only been caught in the monument twice, however, look for this species in heavily wooded mesquite bosques. The mesquite mouse is difficult to distinguish from the cactus mouse (*Peromyscus eremicus*). Appendix 5-2 summarizes differentiating characteristics to consider.

#### *Individual Identification Number*

If a permanent mark is being used, record the 4-digit, unique identification number for each captured sample. To determine this identifier, refer to the following section, Identification Numbering.

### *Trap Number*

The grids are set out in 7 rows with 7 stations per row. Each row is designated as a letter of the alphabet, A through G. Each station in each row is numbered, 1 through 7; thus, the stations are matrixed: A1 to A7 through G1 to G7. The specific location in which individual animals are captured is important to the determination of foraging area, habitat selection, and distribution of each species.

### *Sex*

Record whether the animal is male or female. Generally, sex is determined by comparing the relative distance between the anus and the base of the urethral papilla. In packrat males, for example, this distance is at least twice that found in females. When sexing Arizona pocket mice (*Perognathus amplus*), check carefully, as the male organs are very small.

### *Weight*

The weight of the animal should be taken. This information is used to calculate the biomass of each species present. A hand-held, metric Pesola scale is the easiest and most convenient to use. If the animal is small (up to kangaroo rat size), the clip of the scale can be attached to the base of the animal's tail and the weight read directly as the animal dangles. Determine weight to the nearest 1.0 gm. Be cautious of rodents chewing on or wrapping their tails around the scale, as such behavior may impair accurate weight reading. A cloth bag is needed to weigh larger animals, such as packrats. The animal's weight is computed by subtracting the weight of the bag with the animal included, less the weight of the empty bag.

A 100-gm capacity scale and a 300-gm capacity scale are the most appropriate. The 100-gm scale, with increments of 1 gm, will suffice for most rodents. The 300-gm scale, with 2 gm increments, is needed for larger rodents, such as packrats and ground squirrels (*Spermophilus* spp. and *Ammospermophilus* spp.).

### *Notes*

Include in this section information such as age (adult or juvenile) and reproductive condition (females pregnant or lactating, males testes descendant [TD] or inguinal). Also note any obvious ectoparasites, such as fleas or ticks, that the animal carries.

Additional information included on each data form is (1) date, (2) time traps were checked, (3) information on the weather (wind direction and estimated speed, cloudiness, rain, etc.), and (4) phase of the moon, along with time of moon rise. (The best trapping success usually coincides with no or little moon.)

### **Identification Numbering**

To establish the number of individuals present on the site, a method for marking individuals is needed. The number of animals captured per night does not answer the question of density or biomass per hectare. For example: if, on a grid, 8 kangaroo rats are captured during the first night, and 9 on the second night, it is not known without marking them whether there are actually

9 or possibly 17 kangaroo rats on the grid. The difference in interpretation is almost two-fold. Obviously, a means of marking previously captured individuals is needed.

The use of a permanent-ink pen (such as a wide-tipped magic marker) suffices as just such a marking method. Make a mark on the animal's underside (such as an X or streak). This mark should be placed high on the chest so the animal cannot easily reach it with its mouth. It is suggested that a second mark be made on top of the head, as insurance in the event that the animal removes the initial marking. All animals captured on the first night would be thus marked and readily noticed if recaptured on the second night. Second night recaptures are noted on the data form (Appendix 5-3) with the symbol ®.

The use of permanent ink is of utmost importance when utilizing this system. Any other type of ink will be rapidly removed when the rodent grooms itself and might not be noticeable on the second night of trapping. The permanent ink mark will disappear in a couple of weeks, thereby not interfering in future sampling efforts.

Marking with ink is not adequate if information such as territory, home range, movement, or longevity is desired. A more permanent and individualistic marking system, such as toe clipping, is needed. In this system, each animal has its own unique ID number, created by amputating certain toes. A set of sharp-pointed surgical scissors are used for the amputations. Only 1 toe is removed per foot, and at least 2 toes are removed per animal (though removing as many as four may be necessary). This method of marking the animals has been utilized in field work by numerous researchers over a great number of years and seems to have very little detrimental effect on the animals.

The numbering system, itself, consists of a 4-digit number, each digit referring to a particular foot. The first digit references the right, front foot; the second digit, the left, front foot; the third digit denotes the right, hind foot; and the final digit indicates the left, hind foot. With the proper viewing orientation—the ventral surface of the animal facing the examiner—first the front feet are read (from left to right) and then the rear (also from left to right). The toes on each foot are counted from the midline of the body outward, medial to lateral (Fig. 5-4). If no toes are clipped on a foot, that foot is designated as zero (0). As an example: an individual numbered as 0102 will have no toe missing on the right, front foot; the first toe medially missing on the left front foot; no toe missing on the right hind foot; and the second toe out from the body midline missing on the left hind foot. A copy of the logical numbers available for use with this method is found in Appendix 5-4.

### **Compiling Data**

For the monitoring of small mammals at ORPI, both the actual number of individuals captured as well as an estimate of population size should be collected. This information will be entered into a database, using dBase III. Necessary data should be compiled into 3 major groups: raw data, population estimate, and biomass estimate.

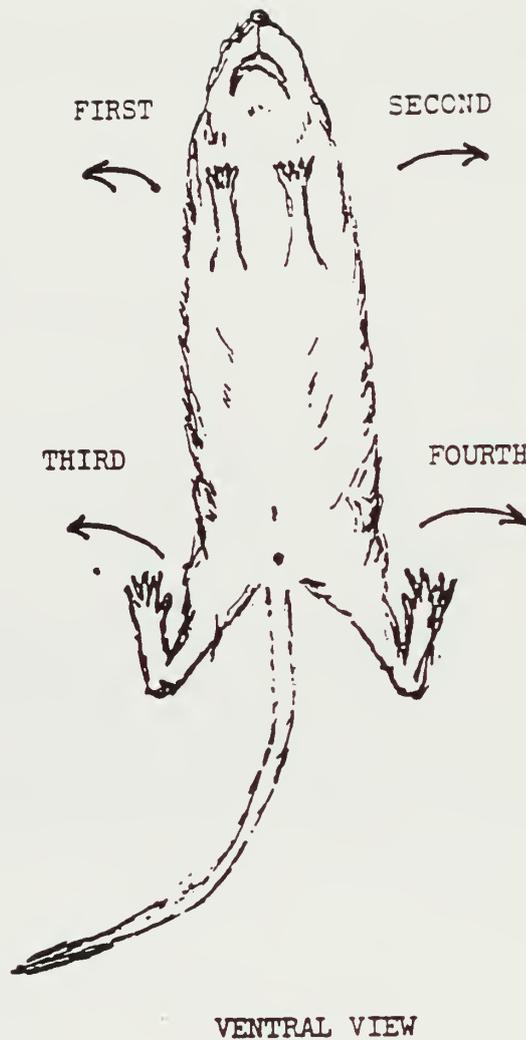


Figure 5-4. Diagrammatic for permanent rodent identification numbering in the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. As an example: to mark individual 2234, clip toe #2 (second from midline of the body) on right, front foot; clip toe #2 on left, front foot; clip toe #3 on the right, hind foot (do not count the thumb, if present); and clip toe #4 on the left, hind foot. Toes are always counted from the midline outward and feet are read like lines on a page.

### *Raw Data*

This is the actual number of individuals captured per grid over a 2-night trapping period. Although it is an underestimate of the actual numbers present in the environment, it is adequate for comparing fluctuations within the system. This data is the actual number of “individuals captured per hectare” per sample period. It is essential that these “raw data” be archived.

### *Population Estimate*

Consistency is the most important factor in estimating rodent population sizes. As long as an estimation system, regardless of type, is used consistently for the duration of the study, a valid comparison between different sites during different periods of time, as well as between other studies, can be made.

The 2 consecutive nights of capture, mark, and release provide a means of estimating the total rodent population at a site during the sampling period. Past long-term research (Petryszyn 1982) has shown that the number of new individuals captured (animals not previously trapped during the monitoring session) declines steadily from night to night. Two nights of trapping typically result in the capture of a certain percentage of the total number of individuals present (Fig. 5-5). Although this value may vary slightly for different species, for the sake of simplicity a standard unit is recommended for all species for use in this project. Two nights of trapping produce a volume of approximately 80% of the animals captured during a 3-night trapping period (Fig. 5-5). Furthermore, captures over a 3-night sampling period total approximately 90% of the animals that are present (Petryszyn 1982). In utilizing these figures as a base, it is assumed that captures over a 2-night trapping period total approximately 72% of the actual number of rodents present:

$$2\text{-night } (N_2) = 0.8 * 0.9 (\text{est. } N) = 0.72 (\text{est. } N)$$

Therefore, to compute an estimated density, increase the number of actual captures by 40% (actual number of individuals captured in 2 nights x 1.4 = estimated number of individuals per ha).

### *Biomass Estimate*

To determine a species' estimated biomass/ha value, following each trapping period multiply the species' population estimate value by the species' mean body weight. Total all species' biomass/ha values to derive the total biomass of nocturnal rodents/ha.

It must be emphasized that the number of *individuals* captured is utilized in these estimates, not the number of captures. Although some animals are caught on both nights, they should be counted only once in calculating population estimates.

The use of these methods in a monitoring system at ORPI should produce consistent, reliable, and comparable estimates of nocturnal rodent populations in varied habitats over both short and long periods of time. Rapid changes in diversity and/or number of small mammals would be noticed by the recommended monitoring schedule. The simplified methods of determining population number and biomass provide a ready means of comparing sites within and between years.

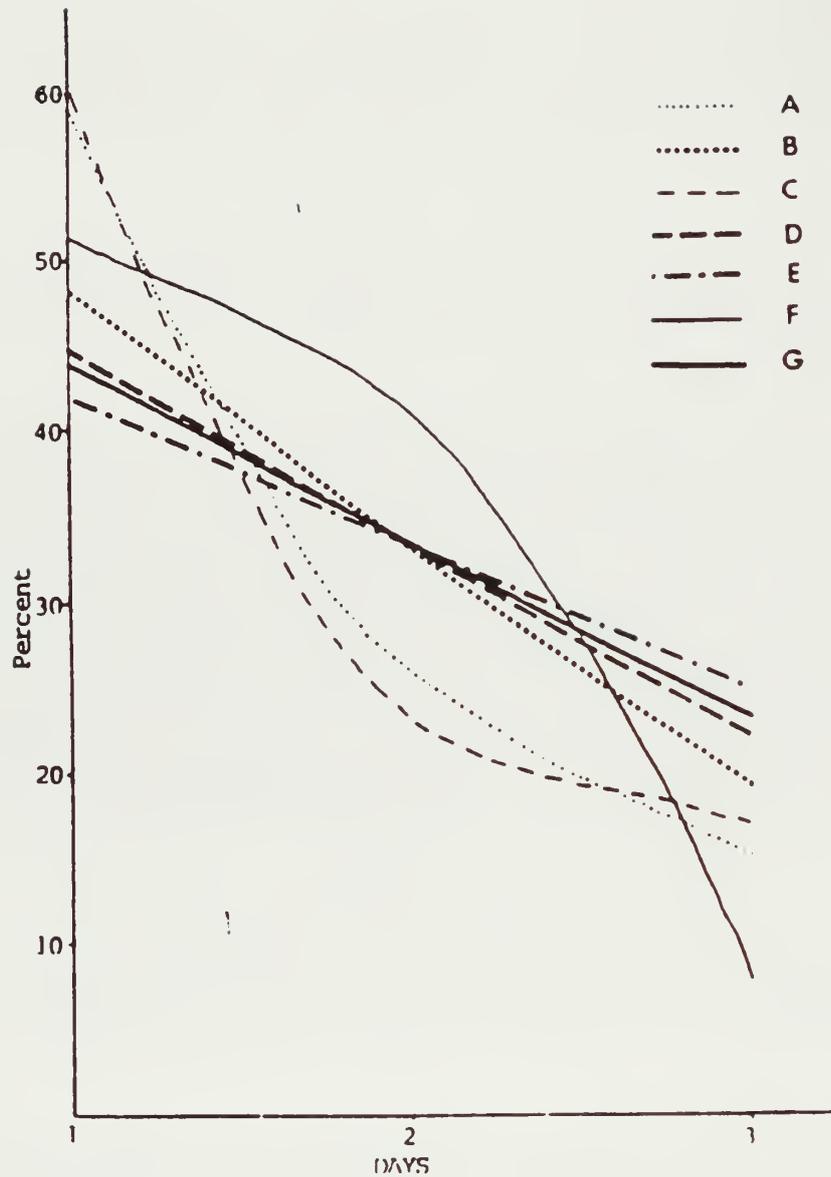


Figure 5-5. Rate of capture of new individuals for 7 species at the Silverbell Site, Pima Co., Arizona. Key: A = rock pocket mouse (*Chaetodipus intermedius*), B = Average for all species, C = Merriam's kangaroo rat (*Dipodomys merriami*), D = desert pocket mouse (*Chaetodipus penicillatus*), E = Arizona pocket mouse (*Perognathus amplus*), F = white-throated woodrat (*Neotoma albigula*), G = Bailey's pocket mouse (*Chaetodipus baileyi*).

Petryszyn, Y. 1982. Population dynamics of nocturnal desert rodents: a nine-year study. Ph. D. Dissertation. The University of Arizona, Tucson. 108 p.

## Literature Cited

Petryszyn, Y. 1982. Population dynamics of nocturnal desert rodents: a nine-year study. Ph.D. Dissertation. The University of Arizona, Tucson. 108 p.

Appendix 5-1

**Small Nocturnal Mammals Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Simplified Key to Select *Chaetodipus* Species of Arizona**

1. Hind foot measures > 26 mm (1 in.) in length, baculum is straight,  
tail is thick and not very bicolored ..... *Chaetodipus baileyi*  
  
Hind foot measures < 26 mm (1 in.) in length, baculum has bend,  
tail is relatively slender and bicolored ..... 2
  
2. Rump spines, hair on very tip of nose is dark,  
dark tubercles on sole of hind foot ..... *Chaetodipus intermedius*  
  
No rump spines, hair on very tip of nose is light-colored,  
light-colored tubercles ..... *Chaetodipus penicillatus*

Appendix 5-2

**Small Nocturnal Mammals Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Simplified Key to Select *Peromyscus* Species of Arizona**

1. Tail is longer than body-head length ..... 2  
Tail is the same length or shorter than body-head length ..... 3
  
2. Hind foot measures > 21 mm (0.83 in.) in length, ear measures  
> 18 mm (0.71 in.) in length, stout body form ..... *Peromyscus eremicus*  
  
Hind foot measures < 21 mm (0.83 in.) in length, ear measures  
< 18 mm (0.71 in.) in length, slender body form ..... *Peromyscus merriami*
  
3. Tail shows white on either side of dark strip when  
viewed from above ..... *Peromyscus maniculatus*  
  
Tail dorsal strip extends to edges with very little  
white showing when viewed from above ..... *Peromyscus leucopus*

**Appendix 5-3**  
**Small Nocturnal Mammals Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Field Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

# ORPI Ecological Monitoring Program—Small Nocturnal Mammals Field Data Form

Plot \_\_\_\_\_ Date (dd/mm/yy) \_\_\_\_\_ Time (2400) \_\_\_\_\_

Weather (cloud cover, wind speed, humidity) \_\_\_\_\_ Temp. \_\_\_\_\_

	Species	ID #	Trap #	Sex	Weight	Notes
	<i>Spp</i>	####	##	♂/♀	gm	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						

Appendix 5-4

**Small Nocturnal Mammals Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Logical Numbering Elimination Form for Individual Marking**

The numbering system for individual marking (by removal of 1 toe per foot) consists of a 4-digit number, each digit referring to a particular foot. With the ventral surface of the animal facing the examiner, the first digit references the right, front foot; the second digit, the left, front foot; the third digit denotes the right, hind foot; and the final digit indicates the left, hind foot. The following page references all of the logical numbers available for use with this method. It is designed to be photocopied and used in the actual monitoring fieldwork.

**ORPI Ecological Monitoring Program—  
Small Nocturnal Mammals Logical Numbering Elimination Form for Individual Marking**

0011	0410	0331	1031	1121	1411	2101	2141	2431	3301	3221	4001	4110	4241
0012	0420	0332	1032	1122	1412	2102	2142	2432	3302	3222	4002	4120	4242
0013	0430	0333	1033	1123	1413	2103	2143	2433	3303	3223	4003	4130	4243
0014	0440	0334	1034	1124	1414	2104	2144	2434	3304	3224	4004	4140	4244
0021	0111	0341	1041	1131	1421	2201	2211	2441	3401	3231	4010	4210	4311
0022	0112	0342	1042	1132	1422	2202	2212	2442	3402	3232	4020	4220	4312
0023	0113	0343	1043	1133	1423	2203	2213	2443	3403	3233	4030	4230	4313
0024	0114	0344	1044	1134	1424	2204	2214	2444	3404	3234	4040	4240	4314
0031	0121	0411	1101	1141	1431	2301	2221	3001	3110	3241	4100	4310	4321
0032	0122	0412	1102	1142	1432	2302	2222	3002	3120	3242	4200	4320	4322
0033	0123	0413	1103	1143	1433	2303	2223	3003	3130	3243	4300	4330	4323
0034	0124	0414	1104	1144	1434	2304	2224	3004	3140	3244	4400	4340	4324
0041	0131	0421	1201	1211	1441	2401	2231	3010	3210	3311	4011	4410	4331
0042	0132	0422	1202	1212	1442	2402	2232	3020	3220	3312	4012	4420	4332
0043	0133	0423	1203	1213	1443	2403	2233	3030	3230	3313	4013	4430	4333
0044	0134	0424	1204	1214	1444	2404	2234	3040	3240	3314	4014	4440	4334
0101	0141	0431	1301	1221	2001	2110	2241	3100	3310	3321	4021	4111	4341
0102	0142	0432	1302	1222	2002	2120	2242	3200	3320	3322	4022	4112	4342
0103	0143	0433	1303	1223	2003	2130	2243	3300	3330	3323	4023	4113	4343
0104	0144	0434	1304	1224	2004	2140	2244	3400	3340	3324	4024	4114	4344
0201	0211	0441	1401	1231	2010	2210	2311	3011	3410	3331	4031	4121	4411
0202	0212	0442	1402	1232	2020	2220	2312	3012	3420	3332	4032	4122	4412
0203	0213	0443	1403	1233	2030	2230	2313	3013	3430	3333	4033	4123	4413
0204	0214	0444	1404	1234	2040	2240	2314	3014	3440	3334	4034	4124	4414
0301	0221	1001	1110	1241	2100	2310	2321	3021	3111	3341	4041	4131	4421
0302	0222	1002	1120	1242	2200	2320	2322	3022	3112	3342	4042	4132	4422
0303	0223	1003	1130	1243	2300	2330	2323	3023	3113	3343	4043	4133	4423
0304	0224	1004	1140	1244	2400	2340	2324	3024	3114	3344	4044	4134	4424
0401	0231	1010	1210	1311	2011	2410	2331	3031	3121	3411	4101	4141	4431
0402	0232	1020	1220	1312	2012	2420	2332	3032	3122	3412	4102	4142	4432
0403	0233	1030	1230	1313	2013	2430	2333	3033	3123	3413	4103	4143	4433
0404	0234	1040	1240	1314	2014	2440	2334	3034	3124	3414	4104	4144	4434
0110	0241	1100	1310	1321	2021	2111	2341	3041	3131	3421	4201	4211	4441
0120	0242	1200	1320	1322	2022	2112	2342	3042	3132	3422	4202	4212	4442
0130	0243	1300	1330	1323	2023	2113	2343	3043	3133	3423	4203	4213	4443
0140	0244	1400	1340	1324	2024	2114	2344	3044	3134	3424	4204	4214	4444
0210	0311	1011	1410	1331	2031	2121	2411	3101	3141	3431	4301	4221	
0220	0312	1012	1420	1332	2032	2122	2412	3102	3142	3432	4302	4222	
0230	0313	1013	1430	1333	2033	2123	2413	3103	3143	3433	4303	4223	
0240	0314	1014	1440	1334	2034	2124	2414	3104	3144	3434	4304	4224	
0310	0321	1021	1111	1341	2041	2131	2421	3201	3211	3441	4401	4231	
0320	0322	1022	1112	1342	2042	2132	2422	3202	3212	3442	4402	4232	
0330	0323	1023	1113	1343	2043	2133	2423	3203	3213	3443	4403	4233	
0340	0324	1024	1114	1344	2044	2134	2424	3204	3214	3444	4404	4234	

Species \_\_\_\_\_

**Small Nocturnal Mammals Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Small Nocturnal Mammals Taxa**

The following index cross-references scientific taxa with common names for the small-nocturnal-mammal species named in this report.

**Index**

**—A—**

*Ammospermophilus harrisi*—HARRIS' ANTELOPE SQUIRREL  
ANTELOPE SQUIRREL, HARRIS'—*Ammospermophilus harrisi*

**—C—**

*Chaetodipus baileyi*—BAILEY'S POCKET MOUSE  
*Chaetodipus intermedius*—ROCK POCKET MOUSE  
*Chaetodipus penicillatus*—DESERT POCKET MOUSE

**—D—**

*Dipodomys merriami*—MERRIAM'S KANGAROO RAT

**—G—**

GROUND SQUIRREL, ROUNDTAIL—*Spermophilus tereticaudus*

**—K—**

KANGAROO RAT, MERRIAM'S—*Dipodomys merriami*

**—M—**

MOUSE, CACTUS—*Peromyscus eremicus*  
MOUSE, DEER—*Peromyscus maniculatus*  
MOUSE, MESQUITE—*Peromyscus merriami*  
MOUSE, WHITE-FOOTED—*Peromyscus leucopus*

**—N—**

*Neotoma albigula*—WHITE-THROATED WOODRAT

**—P—**

*Perognathus amplus*—ARIZONA POCKET MOUSE  
*Peromyscus eremicus*—CACTUS MOUSE  
*Peromyscus leucopus*—WHITE-FOOTED MOUSE  
*Peromyscus maniculatus*—DEER MOUSE  
*Peromyscus merriami*—MESQUITE MOUSE

POCKET MOUSE, ARIZONA—*Perognathus amplus*  
POCKET MOUSE, BAILEY—*Chaetodipus baileyi*  
POCKET MOUSE, DESERT—*Chaetodipus penicillatus*  
POCKET MOUSE, ROCK—*Chaetodipus intermedius*

—S—

*Spermophilus tereticaudus*—ROUNDTAIL GROUND SQUIRREL

—W—

WOODRAT, WHITE-THROATED—*Neotoma albigula*



# Special-status Avian Species Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

R. Roy Johnson

3755 South Hunters Run  
Tucson, Arizona 85730

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## **Introduction**

This monitoring handbook has been compiled to assist the Division of Natural and Cultural Resources Management staff of Organ Pipe Cactus National Monument (ORPI) in assessing changes in relative population levels of birds investigated in the Special-status Avian Species study of the Ecological Monitoring Program (EMP). The primary objective of this monitoring program is to establish (1) avian species, (2) numbers of breeding birds, and (3) sensitive species in the study sites selected in the EMP. Census counts are made to provide information on relative abundances of all breeding birds on each of the sites during breeding and non-breeding periods. With these data, the monument resource managers will be able to detect changes in abundance and/or distribution of birds that may be influenced by, or are the result of, changes in monument resources, adjacent land use, or management practices.

## Monitoring Design Considerations

The degree of resolution necessary to detect potential changes at the population level was a major consideration in establishing a monitoring design for the birds in ORPI. Absolute densities were initially considered necessary to detect any significant changes in population structure in ORPI. However, after working in the monument, it became apparent that determination of relative numbers would suffice. Large sample sizes (number of sightings for each species) are necessary to accurately determine species densities (van Riper et al. 1988). Verner and Ritter (1988) have recently shown that a minimum of 100 detections are necessary to accurately determine bird densities from censusing. There are very few bird species that occur in the monument in sufficient numbers to collect 100 detections within a reasonable time frame.

If 3 consecutive transect counts show a continuing drastic reduction in numbers of any breeding bird species, research scientists need to be consulted.

There are 277 species of birds known to occur, or to have occurred within ORPI. Approximately 63 (Groschupf et al. 1988) of these species breed on at least one of the EMP study sites. Some species cannot be accurately surveyed with standard bird monitoring techniques. Nocturnal species (i.e., owls [Strigidae and Tytonidae] and goatsuckers [Caprimulgidae]), or birds that primarily utilize cliff areas (i.e., turkey vultures [*Cathartes aura*]), or large birds that occur in low numbers would not likely be detected during standard census.

### Species of Special Concern

Several of these avian species that are not included in EMP plot analyses are of concern as indicators of change in the monument (Appendix 6-1). This is especially applicable to several of the larger species (e.g., common raven [*Corvus corax*], greater roadrunner [*Geococcyx californianus*]) and both large and small raptors. Thus, special care must be taken to monitor these species by means other than the standard census techniques described in the manual on monitoring protocols.

Raptors are outstanding barometers of environmental change resulting from either natural or cultural causes. Because raptors are at the top of the food chain, they are ideal indicators of environmental contamination and other types of change associated with human activity. As top carnivores, raptors are affected by environmental effects on lower trophic levels, that is, their food source. Large raptors are good indicators of these changes because of the high numbers of smaller organisms they consume, thus each organism could be considered a potential contamination "site." However, small raptors have certain advantages, even over larger raptors, including (1) smaller territories that are more easily censused, as well as population densities that are often relatively high; and (2) "their relatively large numbers allow statistical treatment of population estimates to determine population trends" (Johnson-Duncan et al. 1988). In addition, since owls are largely nocturnal or crepuscular, the incidence of human contact and direct persecution is lessened, allowing easier detection of population fluctuations resulting from

environmental changes, such as contamination of food chains or other forms of habitat degradation.

Censusing of hawks requires special effort, especially larger raptorial birds, such as turkey vultures, Harris' hawks (*Parabuteo unicinctus*) and red-tailed hawks (*Buteo jamaicensis* ssp.). Road censusing may be instituted by driving a prescribed route and recording the number of vultures, hawks (*Accipiter* spp., *Buteo* spp.), and other larger birds, such as common ravens. Common ravens are very active and have a broad food base, making them one of the most important indicators of change in the monument. Although other large species, such as the greater roadrunner, should be monitored, their ground-dwelling habit makes censusing difficult.

Special censusing techniques need to be applied for raptors. The most specialized censusing techniques apply to nocturnal owls. All owls at ORPI are nocturnal with the exception of the ferruginous pygmy owl (*Glaucidium brasilianum*), a species that is not very useful for the purpose under discussion because it is an extremely rare, local species. Censusing technology and methodology is further discussed in Johnson et al. 1979, Johnson et al. 1981, and Johnson-Duncan et al. 1988.

During the breeding season tape recordings can be used to elicit owl calling. This may be done by walking the same transects that are used for diurnal censusing, using a flashlight, and starting as soon as it is dark enough for owls to answer the tape. Most owls call best for only an hour or two after dark. Experimentation will be needed to further refine the technique for any given area, as different species react differently under given conditions. One to 3 nights before a full moon is usually the most desirable time for elicitation, allowing better visual detection by the observer. Also, most owl species answer better at that time. In addition to moon phase, weather conditions are as important, if not more important, than for diurnal censusing. Censusing of most owls is hampered by inclement weather, such as rain or heavily overcast skies, and high winds.

Some species are limited to certain areas of the monument or certain limited resources scattered throughout the monument. The phainopepla (*Phainopepla nitens*) is a prime example of a species limited by food resources, being limited to areas with sufficient mistletoe and other berries for their strict diets. Thus, although scattered throughout the monument, the phainopepla is more abundant in xeroriparian habitats along washes and at sites like Quitobaquito and Aguajita Springs where berry-producing plants are most plentiful. Among others listed as sensitive species for plots that are restricted to riparian habitats are Bell's vireo (*Vireo bellii*) and bronzed cowbird (*Molothrus aeneus*), with the pyrrhuloxia (*Cardinalis sinuatus*), varied bunting (*Passerina versicolor*), and ferruginous pygmy owl being preferential riparian species.

We have discussed the scattered occurrence of large species (e.g., many of the raptors and ravens). In addition, several species of smaller birds also occur in limited sites and/or numbers. One of the sensitive species, the blue-gray gnatcatcher (*Polioptila caerulea*), occurs in mountain brush found only in limited areas of the Ajo Mountains. The saguaro race of the purple martin (*Progne subis*) also occurs in limited numbers of some, but not all, saguaro stands. Additional work with the avifauna of ORPI will undoubtedly disclose populations of these species or others

that will require the development of special censusing methodology and/or techniques to monitor changes at ORPI.

Field identification of nesting female hummingbirds (Trochilidae) ranges from difficult to impossible. Because male hummingbirds commonly leave the monument shortly after nesting begins, hummingbird activity on EMP plots is often noted; however, species determination is not made.

Field identification of some other species of birds also ranges from difficult to impossible. For example, migrating female warblers can be challenging. Empidonax flycatchers, although not nesting in the monument, are sometimes quite plentiful during migration. Identification to species should not be attempted; leave identification at the generic (*Empidonax*) level (Phillips et al. 1964; Monson and Phillips 1981).

# Monitoring Protocol

## Sampling Methods

The objective of the censusing program is to monitor the number and types of birds in order to detect changes in abundance and distribution that may influence or be influenced by changes in other monument or adjacent land resources. Sampling techniques used to gather information on birds in the study areas include annual counts made during breeding and nonbreeding periods.

## *Materials*

The following are essential to successful monitoring of special-status avian species:

Census data forms (Appendix 6-2)

Monument topographic maps with study-site locations marked

Pencils (No. 2 or HB)

Binoculars

Centigrade thermometer

Bird field-guide

Watch

Camera

## *Personnel*

A single observer who is capable of identifying monument birds by sight and song should be used. An observer unfamiliar with any of the birds should conduct practice sessions (i.e., walk through the count area and identify the birds encountered) before attempting actual surveys.

## *General Rules for Conducting Census*

The following protocols are to be observed during census (modified from van Riper et al. 1988):

1. Wear clothing colored in earth-tones (browns, greens, dark blues, grays), rather than bright colors (red, yellow, whites, etc.)
2. Use a separate tally form for each study plot and total the number of sightings for each species.
3. Walk each belt transect at a moderately slow, steady pace. Consecutive counts of the same belt should take about the same amount of time. Pause only to confirm identification of a bird, or, if plot mapping, to record the specific site for each bird.

4. Record all sighting of breeding species seen or heard within the belt transect. Tally the number of individuals seen for each species. Generally, count only those birds detected in the area directly to the sides or front of the observer. Do not count birds detected behind the observer unless certain that an individual bird was omitted earlier. Beware of “pushing” birds ahead of the oberver, which may result in duplicate counting.
5. Birds should be counted if they are in vegetation, on the ground, or in flight. Flying birds may be counted at any height, as long as they are over the belt transect.
6. Avoid counting the same bird more than once. For example, if a bird is seen flying into a bush ahead of the observer, it should be listed. If a bird of the same species flies out of the bush upon approach, it is reasonable to assume that this is the same bird, unless another of the same species is present. However, unless reasonably certain that a particular individual bird has already been counted, consider it a separate sighting.
7. Birds may be detected by song if call notes or songs are clearly heard and recognized. Visually locate the singing bird or, if it cannot be seen, estimate its position. List it as a sighting only if reasonably certain that it is within the belt transect.
8. Record both nonbreeding and breeding species seen within the plot but outside the transect. Do not spend time tallying the number seen if it interferes with counting breeding species, in which case a rough estimate may be included at the end of the day. Remember, the goal is not to obtain the largest count possible, rather the most accurate count possible. Stick to the methodology outline above. Do not list a bird unless certain of its identification and do not, in fear of inadequate data, include birds outside the plot or transect. An inflated count is as deceptive as a deflated count. The accuracy and integrity of the count can only be maintained by rigorously following the established census procedures, thereby minimizing variations in methodology.

### *Methods*

Censuses for the monument will use all study locations. Standardized techniques for long-term bird monitoring must (1) reduce variables to a minimum, (2) be easily repeatable, (3) produce results usable for comparative analysis, and (4) meet the inherent assumptions of the methodology. The belt transect method is proposed as the best for this study. Belt transects are not restricted to the breeding season and can be used at any time of the year. Also, results from different seasons or separate years can be compared. Even though belt transects are not the most commonly used census method for birds, they are especially suitable for narrow riparian habitats, especially within limited time and budgetary constraints. Transect length was derived by determining the number of bird observations necessary to provide sufficient data for analysis of a given habitat type.

Permanent belt transects were placed in a systematic manner so as to allow for complete sampling of the study plot, while at the same time reducing the probability of censusing the same birds twice. In some cases, topography precluded systematic placement of transect belt lines (e.g., Arch Canyon, Dripping Springs, Alamo Canyon); in these plots, belt lines were laid out in

the best possible manner for each specific plot to enable goal accomplishment. Transect widths vary.

Surveys of breeding birds begins at or before sunrise. In general, on the more open plots, bird activity begins 1 hr or more before sunrise and tapers off within 3 hr after sunrise. On the steeper canyon plots, (e.g., Alamo Canyon, Arch Canyon, Dripping Springs), activity starts later, especially on cool mornings. Study plots conducive to censusing on the same morning by a single individual or a team are: Dos Lomitas and the Burn Site; Dripping Springs, and Armenta Ranch and East Armenta, which have been chosen as comparative plots. These areas can be sampled on the same day, within the 3-hr bird activity time frame.

Census protocols to follow include:

1. Walk at a slow, even rate; recording all species seen or heard and positively identified. If a bird is seen or heard but not identified before it leaves the census belt, it is recorded as an unknown individual.
2. Stop at regular intervals, usually from 50 m (164 ft) to 100 m (328 ft) apart, depending on visibility as influenced by thickness of vegetation or any other conditions (e.g., slope). The only occasions for which to stop other than at these intervals is to identify a species, record nest-building, or for other necessary activities. This regularity helps to reduce variables from one census to another. If such regularity of pace and stopping is followed, censuses for each plot should take approximately the same length of time from one event to another. Additionally, this also helps to maintain a relatively constant length of census time from one plot to another. Usually this amounts to 1–1.5 hr each, although there will be some differences between censusing time required for different plots (based on differences in length, terrain, difficulty of moving through vegetation [for example in riparian plots, e.g., Alamo and Arch Canyons]).
3. Although it is more time consuming, records are more valuable if a map of the census route is made and the actual locality of each bird recorded. If a bird flies or runs from one locality to another within or across the belt, this can be shown with a line and arrow showing direction of movement. Nests are recorded with a cross within a circle at the nest locality.

### *Census Conditions*

Censuses can be conducted only if conditions meet the following criteria:

1. Wind is 6 kph (10 mph) or less.
2. It is not raining.
3. No one has walked the transect or plot within 30 min prior to the census.

4. Only 1 observer conducts each census. No additional persons may accompany the observer unless the census is considered a training session and is so labeled.
5. The avian count must be the only priority of the census. No other business (e.g., collecting plants, transporting materials) should be conducted that (1) affects the pace at which you cover the census route or (2) interferes with your identification of birds.
6. There are no extremely unusual temperatures (e.g., May frosts).

### *Scheduling the Census*

In most years the optimum censusing period is during most of the month of April. There is no time of year when all birds are breeding.

Reconnaissance trips prior to the census should be taken to determine breeding chronology, because this may vary by several weeks from year to year. Migrations may also vary significantly in timing from year to year.

### **Data Management**

Monitoring protocols for avian census data management include (1) data input, (2) data analysis, and (3) reporting.

#### *Data Input*

Belt transect data forms (Appendix 6-2) were designed to allow rapid, accurate tallying of the number of birds detected during censusing. Detailed instructions for using the bird monitoring data forms are included in Appendix 6-2. Census forms are collected immediately following each census and data are entered into the Organ Pipe Cactus database management system using dBase III+ or Fox-Base.

#### *Data Analysis*

After data entry, relative numbers are calculated for each study plot. Conversion factors will then be applied to the data to determine relative densities. Data analysis techniques are still being developed, and this aspect will be added to future revisions of this handbook.

A regression analysis of census data with climatological parameters should be conducted each year to determine how and to what degree abiotic factors impact species distribution and numbers. At the end of each 5-yr period, a trend analysis is conducted for each breeding species that has been censused on each of the plots. A detailed analysis is conducted to determine the occurrence of any changes in one or more of the breeding parameters on any of the indicator species or sensitive species.

#### *Reporting*

Reporting of data is done in 2 ways: (1) with tables and written comments and (2) with graphs. Trend analyses should yield graphs that are suitable for presentation in the park annual report. Data are orally presented to the entire park staff for each year that censusing is conducted. These presentations allow input from all divisions in order to determine their potential impact, in any particular plot(s), upon shifts in species distributions or numbers on a particular plot.

## Literature Cited

- Bennett, P. S., and M. R. Kunzmann. 1987. Memo to Steering Committee, ORPI Sensitive Ecosystems Program. Re: Sensitive Ecosystems Program Study Site Selection and Evaluation. National Park Service, Cooperative Park Studies Unit, The University of Arizona, Tucson. 1 p.
- Bennett, P. S., and M. R. Kunzmann. 1987. Organ Pipe Cactus National Monument Biosphere Reserve Sensitive Ecosystems Program. Special Report No. 7. National Park Service Cooperative Park Studies Unit, The University of Arizona, Tucson. 82 pp.
- Brown, B. T., S. W. Carothers, and R. R. Johnson. 1987. Grand Canyon birds, historical notes, natural history, and ecology. The University of Arizona Press, Tucson, 302 pp.
- Brown, D. E. 1982. Biotic communities of the American Southwest—United States and Mexico. P. 1–342 in D. E. Brown, ed. Desert Plants. Vol. 4:1–4.
- Dawson, D. 1981. Counting birds for a relative measure (index) of density. P. 12–16 in C. J. Ralph, and J. M. Scott, eds. Estimating numbers of terrestrial birds. Proc. International Symposium: Asilomar, California. Studies in avian biology, No. 6. Cooper Ornithological Society. Allen Press, Inc. Lawrence, Kansas. 630 p.
- Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. The birder's handbook. Simon and Schuster, Inc., New York. 785 p.
- Emlen, J. T. 1971. Estimating densities of birds derived from transect counts. *Auk* 88:323–342.
- Franzreb, K. 1977. Inventory techniques for sampling avian populations. BLM Technical Note 307. Bureau of Land Management, Riverside, California. 17 p.
- Franzreb, K. 1981. The determination of avian densities using the variable-strip and fixed-width transect surveying methods. P. 139–149 in C. J. Ralph, and J. M. Scott, eds. Estimating numbers of terrestrial birds. Proc. International Symposium: Asilomar, California. Studies in avian biology, No. 6. Cooper Ornithological Society. Allen Press, Inc. Lawrence, Kansas. 630 p.
- Franzreb, K. 1981. A comparative analysis of territorial mapping and variable-strip transect censusing methods. P. 164–169 in C. J. Ralph, and J. M. Scott, eds. Estimating numbers of terrestrial birds. Proc. International Symposium: Asilomar, California. Studies in avian biology, No. 6. Cooper Ornithological Society. Allen Press, Inc. Lawrence, Kansas. 630 p.

- Groschupf, K., R. R. Johnson, and E. A. McCauley. 1987. The ecology of special status avian species at Organ Pipe Cactus National Monument. Proposal for Research. National Park Service Cooperative Park Studies Unit, The University of Arizona, Tucson. 9 p.
- Groschupf, K. D., Brown, B. T., and R. R. Johnson. 1988. An annotated checklist of the birds of Organ Pipe Cactus National Monument, Arizona. Southwest Parks and Monuments Association. 40 p.
- Hensley, M. M. 1954. Ecological relations of the breeding bird population of the desert biome in Arizona. *Ecological Monogram* 24:185–207.
- Johnson, R. R., L. T. Haight, and J. M. Simpson. 1979. Owl populations and species status in the southwest United States. P. 40–59 in: Proceedings of the symposium on owls of the West—their ecology and conservation. National Audubon Society, Western Education Center, Tiburon, California.
- Johnson, R. R., B. T. Brown, L. T. Haight, and J. M. Simpson. 1981. Playback recordings as a special avian censusing technique. *Studies in Avian Biology* 6:68–75.
- Johnson, R. R., and L. T. Haight. 1985. Avian use of xeroriparian ecosystems in the North American warm deserts. P. 156–160 in R. R. Johnson, et al., Technical Coordinators. Riparian Ecosystems and their management. First North American Riparian Conference, Tucson, Arizona.
- Johnson, R. R., and L. T. Haight. 1988. Avian use of xeroriparian systems in the Big Bend Region, Texas. Contributed papers of the second symposium on resources of the Chihuahuan Desert Region: United States and Mexico, No. 16. Chihuahuan Desert Research Institute, Alpine, Texas. 9 p.
- Johnson-Duncan, E. E., D. K. Duncan, and R. R. Johnson. 1988. Small nesting raptors as indicators of change in the desert southwest. P. 232–236 in: Southwest raptor management symposium and workshop proceedings. National Wildlife Federation, Washington, DC.
- Mayfield, H. 1981. Problems in estimating population size through counts of singing males. P. 220–224 in C. J. Ralph, and J. M. Scott, eds. Estimating numbers of terrestrial birds. Proc. International Symposium: Asilomar, California. *Studies in avian biology*, No. 6. Cooper Ornithological Society. Allen Press, Inc. Lawrence, Kansas. 630 p.
- McCauley, E. A. 1983. Effects of Oklahoma cross timbers riparian vegetation composition on avian community dynamics. M. S. Thesis, Oklahoma State University, Stillwater. 96 p.
- Mikol, S. 1980. Field guidelines for using transects to sample non-game bird populations. U.S. Fish and Wildlife Service/OBS-80-/58. 26 p.

Monson, G., and A. R. Phillips. 1981. Annotated checklist of the birds of Arizona. Second edition. The University of Arizona Press, Tucson. 240 p.

National Geographic Society. Field guide to the birds of North America. Second edition. National Geographic Society, Washington, DC. 464 p.

Phillips, A., J. Marshall, and G. Monson. 1964. The birds of Arizona. The University of Arizona Press, Tucson. 212 p.

Ralph, C. J. and J. M. Scott, eds. 1981. Estimating numbers of terrestrial birds. Proc. International Symposium: Asilomar, California. Studies in avian biology, No. 6. Cooper Ornithological Society. Allen Press, Inc. Lawrence, Kansas. 630 p.

Shreve, F., and I. L. Wiggins. 1964. Vegetation and flora of the Sonoran Desert. Stanford University Press, Palo Alto, California. 2 vols.

van Riper III, C., M. K. Sogge, and C. Drost. Land bird monitoring handbook—Channel Islands National Park, California. National Park Service, Cooperative Park Studies Unit, University of California, Davis.

**Special-status Avian Species Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
ORPI Annotated Checklist of  
Breeding and Special-status Avian Species**

The following key is provided for identifying breeding and sensitive species of birds in Organ Pipe Cactus National Monument. Sensitive species are indicated by the symbol ▲.

**Columbidae: Dove Family**

WHITE-WINGED DOVE (*Zenaida asiatica*)

Common summer, rare winter resident.

*Morphology:* Large white wing patches in flight. When sitting, only a thin white line is visible on wing.

*Behavior:* Nests singly or in colonies. Most common dove in the monument, often flocks with others.

*Habitat:* Found nesting throughout the monument, these doves are abundant after their arrival in April. Numbers decrease in early September, and only a few birds remain through the winter.

*Similar species:* Mourning dove (*Zenaida macroura*). white-winged dove is distinguished by white wing patch and shorter rounded tail.

*Song:* Drawn out cooing call, *who-cooks-for-you* with variations.

**Emberizidae: Warbler Family (in part)**

BLACK-THROATED SPARROW (*Amphispiza bilineata*)

Common permanent resident.

*Morphology:* White eyebrow and whisker stripe with black throat, breast, and lores. Upper body pale brownish-gray, without streaks or wing bars. Juvenile lacks black throat, has grayish head and streaked breast but is distinguished by white eye stripe similar to adult.

*Behavior:* Timing of breeding may be related to rainfall and available food. Requires water to drink in summer and autumn until rains starts. Uses water in green vegetation and insects otherwise. Breeding biology is not well known.

*Habitat:* Found in open areas of creosotebush and desertscrub habitats. Prefers rocky slopes.

*Similar species:* Extent of white on tail is greater than in sage sparrow (*Amphispiza belli*).

*Song:* Highly variable singer. Series of clear notes followed by a trill. Calls are indistinct tinkling notes.

#### ▲ BRONZED COWBIRD (*Molothrus aeneus*)

Common summer resident.

*Morphology:* Male is black with bronze gloss. Wings and tail are blue-black. Thick neck ruff on male gives a hunchback appearance. Female is duller and juveniles are dark brown.

*Behavior:* Brood parasite of at least 77 species, especially orioles. Female pierces host eggs and previously laid cowbird eggs. Gregarious, flocking at all seasons except during breeding (25–30, sometimes up to 500). Male has elaborate courtship display: throws head back, ruffles feathers, quivers wings, and walks stiffly. May also ruffle feathers, spread and bend tail, arch wings, bend head down, and bounce up and down while calling.

*Habitat:* Common in riparian areas and human settlements. Specimen collected from Gray Ranch, 1939.

*Similar species:* This species has larger bill and a wheezier, shorter song version of brown-headed cowbird (*Molothrus ater*).

*Song:* Call is a harsh, guttural *chuck*. Song is a series of gurgling notes.

#### CANYON TOWHEE (*Pipilo fuscus*)

Common permanent resident. Formerly named brown towhee.

*Morphology:* Brown to gray-brown above buffy throat bordered by streaks and rust undertail coverts. Interior populations are paler, with rust crown, and a dark spot in the center of the breast, while pacific coast birds are darker with a dark crown.

*Behavior:* Common in brush, chaparral, wooded canyons, also around picnic areas, buildings and suburban gardens. Feeds on ground using double scratch foraging method. Females are not easily flushed from nest. This species exhibits mouse run behavior like other towhees.

*Habitat:* Found in riparian, desertscrub, and mixed mountain shrub habitats.

*Similar species:* Abert's towhee (*Pipilo aberti*) has black face and is found at lower altitudes than this species.

*Song:* Mellow chipping trill; calls include a sharp *chiup*. Pacific birds' call is a metallic *chink*; their song, an accelerating series of chink notes.

#### LUCY'S WARBLER (*Vermivora luciae*)

Common summer resident.

*Morphology:* Pale gray above, whitish below with a rufous crown patch and rufous rump patch distinct on males.

*Behavior:* Occupies old woodpecker holes, nesting in cavities, banks, and deserted verdin nests. Is only one of 2 northern Arizona hole nesting warblers (the other is the prothonotary (*Protonotaria citrea*)) and is largely insectivorous. Much of their biology is yet unknown.

*Habitat:* More abundant in early, rather than late, summer, this species is found in desertscrub habitat, along desert washes, and near springs and open water. This is the only warbler that breeds at the monument.

*Similar species:* Other warblers lack combination of reddish crown patch and rump.

*Song:* A short, lively trill followed by lower, whistled notes: *weeta weeta weeta che che che*. Call is a sharp *chink*.

#### NORTHERN CARDINAL (*Cardinalis cardinalis*)

Common permanent resident.

*Morphology:* Conspicuous crest; cone-shaped reddish bill. Male is bright red overall with a black face. Female is olive to buffy brown overall with red tinged wings, tail, and crest.

*Behavior:* Both sexes sing year round. Nonmigratory, this species has expanded its southwest range in recent years.

*Habitat:* Seen in riparian and mixed mountain scrub habitats. Specimen collected at Bates Well, 1932.

*Similar species:* Differs from pyrrhuloxia (*Cardinalis sinuatus*) in range, overall red color of body in males. Also, pyrrhuloxia has strong, curved bill to distinguish it from the female and juvenile of this species.

*Song:* A liquid whistling with variations including *cue cue* and *cheer cheer cheer* and *purty purty*. Common call is a sharp *chink*.

▲ PYRRHULOXIA (*Cardinalis sinuatus*)

Uncommon permanent resident.

*Morphology:* Gray overall body with red face, crest, wings, tail, underparts. Both sexes have orange-yellow bills and the female is mostly gray overall with some red.

*Behavior:* Breeds in arid brush, thorn scrub, and thickets (i.e., mesquite) with male feeding female during courtship and incubation. Initially, both sexes actively defend territory but only male maintains ongoing defense. This species forms small flocks during nonbreeding season.

*Habitat:* Found in riparian and mixed mountain scrub habitats.

*Similar species:* Curved orange-yellow bill differs from female and juvenile northern cardinal (*Cardinalis cardinalis*).

*Song:* Call is a sharp *chink*. Song is liquid whistling, thinner and shorter than that of northern cardinal (*Cardinalis cardinalis*).

RUFOUS-CROWNED SPARROW (*Aimophila ruficeps*)

Common permanent resident.

*Morphology:* Gray head with dark reddish crown with distinct white eye ring. This sparrow has a rufous line extending back from eye, and a single black whisker strip on each side of face. Arizona forms are more reddish overall than others.

*Behavior:* Territories are often clumped and female is a close sitter on the nest, often feigning injury to distract predators. Does not flock in winter, but postbreeding family groups often stay together.

*Habitat:* Found on rocky hillsides with mixed mountain shrubs or higher elevation desertscrub.

*Similar species:* Lacks white wing bars of chipping sparrow (*Spizella passerina*) and has a long, rounded tail.

*Song:* Song is a rapid bubbling series of chip notes and its call is a sharp *deer*, usually in a series.

▲ VARIED BUNTING (*Passerina versicolor*)

Rare summer resident.

*Morphology:* Adult male is colorful with blue head and rump, rust nape and breast and dark face, otherwise appears black. Female is gray or buffy brown above; winter male colors edged with brown.

*Behavior:* Winters in northern Mexico, southern Texas to Guatemala. Declining due to habitat lost to conversion of arid brushland for agricultural purposes. Little is known of the ecology of this species.

*Habitat:* Found in riparian, desertscrub, and mixed mountain scrub habitats, this species has been reported from Quitobaquito and Alamo Canyon. Nesting is suspected due to the presence of singing males that have remained for long periods of time at potential breeding sites.

*Similar species:* Culmen is more curved than in both lazuli bunting (*Passerina amoena*) and indigo bunting (*Passerina cyanea*). Field identification of the female is difficult, because of resemblance to the female indigo bunting (*Passerina cyanea*).

*Song:* Song is similar to painted bunting (*Passerina ciris*), that is, a rapid series of various phrases.

## Fringillidae: Finch Family

### HOUSE FINCH (*Carpodacus mexicanus*)

Common permanent resident.

*Morphology:* Brown cap with bib, forehead, rump red to shades of orange and sometimes yellow. Square tail and bib is clear of streaking.

*Behavior:* Occasionally appropriates other species' nests. Uses twigs, grass, debris, leaves, and hair for nests, which are often used for later broods. Feeds predominantly on seeds including food for young. Range in west is expanding. May compete with flocks of house sparrow (*Passer domesticus*) in nonbreeding season.

*Habitat:* Throughout the monument in a variety of habitats, including human settlements. Prefers arid scrub, open woodland, cultivated land and urban areas.

*Similar species:* Lack distinct ear patch and eyebrow of both Cassin's finch (*Carpodacus cassinii*) and purple finch (*Carpodacus purpureus*). Song consists of more strident notes than that of purple finch (*Carpodacus purpureus*).

*Song:* High-pitched of varied 3-note phrases ending with a nasal *wheer*. A whistled *wheet* is its common call note.

## Mimidae: Thrasher Family

### CURVE-BILLED THRASHER (*Toxostoma curvirostre*)

Common permanent resident.

*Morphology:* Mottled breast, large, dark curved bill, breast spots indistinct.

*Behavior:* Builds bulky twig nest most often in spiny shrub or cactus. Becomes an occasional cowbird host. Pair remain throughout year in same area used for nesting. Destroys roosting nests of cactus wren (*Campylorhynchus brunneicapillus*) if found within thrasher's territory. Found often near water source.

*Habitat:* This species is seen and heard in all areas of the monument except at higher mountain elevations. Commonly found in streamside brush, canyons, semiarid brushlands.

*Similar species:* Bill more highly curved than Bendire's thrasher (*Toxostoma bendirei*).

*Song:* Distinctive call of a rapid *whit, wheet*, sometimes 3-noted.

## Muscicapidae: Gnatcatcher Family

### BLACK-TAILED GNATCATCHER (*Polioptila melanura*)

Common permanent resident.

*Morphology:* Blue-gray above, grayish white below, with a black cap on males and mostly black tail.

*Behavior:* Very active bird with tail flicking up and down or side to side. Nest usually in fork of small shrub; compact of plant materials bound with insect and spider silk.

*Habitat:* Occur at lower elevations, where they are seen in riparian, desertscrub, and creosotebush habitats.

*Similar species:* Black-capped gnatcatcher (*Polioptila nigriceps*) has longer bill than this species, and white eye-ring is more distinct. Plumage and vocalizations of coastal California populations differ from inland populations; may be separate species.

*Song:* Rapid series of *jee* notes on one pitch, and a raspy *cheeeh*.

▲ BLUE-GRAY GNATCATCHER (*Polioptila caerulea*)

Rare summer, uncommon winter resident.

*Morphology:* Male is blue-gray above, female grayer; black tail has white outer edges.

*Behavior:* Territorial boundaries shift with available food sources. Tail constantly flicking up and down or side to side. Gnatcatchers are extremely active, small birds.

*Habitat:* Found in the higher elevations of the monument, this bird occurs in riparian and mixed mountain scrub habitats.

*Similar species:* Female is distinguished from female black-capped gnatcatcher (*Polioptila nigriceps*) by bold white eye ring, and voice.

*Song:* A series of melodious but wheezy warbles and the call is a thin, *pwee*.

### Phasianidae: Gallinaceous-fowl Family

GAMBEL'S QUAIL (*Callipepla gambelii*)

Common permanent resident.

*Morphology:* Gray above, with prominent tear-shaped plume. Sides are chestnut and lack scaling on underparts. Male has dark forehead, black throat, black patch on belly. Juvenile is tan and gray with pale mottling and streaking, less scaling.

*Behavior:* Very gregarious, often occurs in large coveys (20–40) in fall and winter and roosts in bushes or low, dense trees. Most frequently feeds and stays at ground level with bimodal pattern of morning and late afternoon foraging separated by a long quiet period.

*Habitat:* Found throughout the monument in areas with good cover, except on the highest mountain peaks, often in riparian and juniper-pine woodland and usually near a permanent water source.

*Similar species:* Chestnut sides and lack of scaling on underparts distinguish this species from California quail (*Callipepla californica*). Occasionally hybridizes with these, as well as with scaled quail (*Callipepla squamata*), where habitat and range overlap.

*Song:* Include grunts and cackles and a plaintive *qua-el*. Also a loud querulous *chi-ca-go-go*, high pitched with 4 notes.

## Picidae: Woodpecker Family

### GILA WOODPECKER (*Melanerpes uropygialis*)

Common permanent resident.

*Morphology:* Black-and-white barred back and rump. Male head has red cap; female has red nape only.

*Behavior:* Nests in excavated saguaro hole made from the previous year. Competes for nest sites with northern flicker (*Colaptes auratus*), starlings, owls, kestrels, and merlins. Young are fed for prolonged period following fledging.

*Habitat:* Found throughout the monument, particularly where there are stands of saguaros. Semidesert, riparian areas, and towns in desert regions.

*Similar species:* Distinguished from the northern flicker (*Colaptes auratus*) by red cap (or nape in females) and lack of moustache, white rump visible in flight, and spotted chest.

*Song:* A rolling *churr* and a loud, sharp, high-pitched *yip*, often in a series.

### NORTHERN FLICKER (*Colaptes auratus*)

Common permanent resident.

*Morphology:* The gilded form of this species is more commonly seen in the monument than is the red-shafted form.

*Behavior:* Most terrestrial of all the northern Arizona woodpeckers, often feeding upon ants on the ground. Prefers snags but will nest in a variety of cavities including cacti, posts, poles, banks, houses, barns, and boxes. Hybridizes with “red-shafted” race.

*Habitat:* There are no summer records of the “red-shafted” form, but in winter it has been found in various parts of the monument including Boundary Road, Quitobaquito, and near the Visitor Center.

*Similar species:* This species comprises 3 races: “yellow-shafted,” “red-shafted,” and “gilded,” all hybridizing in overlapping ranges. The Gila woodpecker (*Melanerpes uropygialis*) lacks the facial moustache, spotted belly, and white rump patch visible in flight of this species.

*Song:* Loud *wik-wik-wik-wik* and *wick-er wick-er wick-er*, or single, loud *klee-yer*.

## Ptilogonatidae: Silky-flycatcher Family

### ▲ PHAINOPEPLA (*Phainopepla nitens*)

Rare summer and common winter resident.

*Morphology:* Solid, shiny black males contrast with the lighter grayish females and juveniles. Crest, red eye, and long tail are distinguishing features.

*Behavior:* Feeds chiefly upon insects on the wing and mistletoe berries. Fluttery flight, often very high. Nests early in desert areas then moves to moister habitats to raise second brood. Breeding is in loose colonies. Territories are often large around a clump of mistletoe berries, but consist of only the nesting tree where food is more scarce.

*Habitat:* Seen throughout the monument, it is most often reported from desert washes or springs with mistletoe-laden mesquites.

*Similar species:* Solid black coloration distinguishes from similar bodyforms of waxwings.

*Song:* Song is rarely heard and call note is a low-pitched, whistled *wurp*.

## Remizidae: Verdin Family

### VERDIN (*Auriparus flaviceps*)

Common permanent resident.

*Morphology:* Dull-gray plumage with chestnut shoulder patches, yellow head and throat. Juvenile is brown-gray overall. Small body with finely pointed bill.

*Behavior:* Feeding style similar to chickadees (Family: Paridae), often hanging upside down in vegetation. Nests are spherical, and this species builds breeding as well as roosting/winter nests. Often forage in family groups in nonbreeding season.

*Habitat:* This species regularly occurs in desertscrub, riparian, and creosotebush habitats.

*Similar species:* The common bushtit (*Psaltriparus minimus*) has a longer tail and lacks yellow head and chestnut wing patches.

*Song:* Call is a series of rapid *chip* notes, while song is a 3-note whistle, the second note higher.

## Strigidae: Typical-owl Family

### ▲ FERRUGINOUS PYGMY OWL (*Glaucidium brasilianum*)

Uncommon permanent resident.

*Morphology:* Long tail, reddish with dark or dusky bars. Crown streaked, upper body parts gray-brown. Eyes are yellow; black nape spots resemble eyes on back of head.

*Behavior:* Diurnal. Late nesting in June and July has been reported for this species. Flies with quick, unmuffled wingbeats. Unknown if it breeds within the monument. Often jerks tail up and down when perched. Nests in cavities, often old woodpecker holes.

*Habitat:* Desert washes, riparian woodland, canyons, and stands of saguaros. Rare in the United States.

*Similar species:* Found at lower elevations than the northern pygmy-owl (*Glaucidium gnoma*). Elf owl (*Micrathene whitneyi*) has shorter tail. Both of these species are also nocturnal.

*Song:* Most common call is a rapid, repeated *took*, most often heard at dawn and dusk.

## Troglodytidae: Wren Family

### CACTUS WREN (*Campylorhynchus brunneicapillus*)

Common permanent resident.

*Morphology:* Dark cap with white eye line and barred wings. A large wren with spotted breast and buff colored belly.

*Behavior:* Builds football-shaped nest most often in cholla cactus. Uses nest for breeding and roosting with pairs resident year round on territories.

*Habitat:* Can be seen or heard in almost any part of the monument, but is particularly abundant in desert and lower canyon areas. Nesting has been reported as early as January.

*Similar species:* Streaked back, barred wings, white eye line, and dark cap distinguish this species from the sage thrasher (*Oreoscoptes montanus*).

*Song:* Low-pitched, harsh, and rapid *cha cha cha cha cha*. Distinctive call heard any time of day or year in desert habitats.

CANYON WREN (*Catherpes mexicanus*)

Common permanent resident.

*Morphology:* Brown wren with white throat and breast and chestnut-colored belly.

*Behavior:* Found in canyons, rock cliffs, near water. Extracts insects in rock crevices with long thin bill.

*Habitat:* Canyons and mountains with cliffs, rock faces, or boulders are the preferred habitat of this species. Occasionally found in suburbs with old stone buildings or other structures having suitable nest sites.

*Similar species:* Differs from other wren species with distinct, white throat and breast and long, straight bill.

*Song:* A descending series of liquid *tees* and *tews*. Call is a sharp *jeet*.

### **Tyrannidae: Tyrant-flycatcher Family**

ASH-THROATED FLYCATCHER (*Myiarchus cinerascens*)

Fairly common summer, uncommon winter resident.

*Morphology:* Grayish-brown above with dark crest. Throat and breast pale gray, belly and undertail coverts pale yellow. Dusky tail shows entirely reddish inner webs and brown tips.

*Behavior:* Cavity-nesting species using old woodpecker holes, fence post holes, and old cactus wren (*Campylorhynchus brunneicapillus*) nests. Will defend territory like kingbird against hawks. A typical flycatcher darts out from a perch and snaps up a flying insect, then often returns to the same perch.

*Habitat:* Regularly seen in the mesquite-lined washes. During summer, it has been reported from Dripping Springs, Arch Canyon, Bull Pasture, and around the campground. Found in deserts, chapparals, and woodlands.

*Similar species:* This species has a thinner bill and generally paler underparts than the brown-crested flycatcher (*Myiarchus tyrannulus*). Also, the species has reddish inner webs of tail, as compared to none in the dusky-capped flycatcher (*Myiarchus tuberculifer*).

*Song:* A burry *ka-brick* or a *ka-wheer*, accented on the second syllable. Song is a series of these sounds.

## Vireonidae: Vireo Family

### ▲ BELL'S VIREO (*Vireo bellii*)

Uncommon transient, common summer resident.

*Morphology:* Plumage is variable depending upon location. Southwestern form is grayish- to greenish-yellow above and grayish-white to yellowish-white below. This vireo has pale white wing bars and indistinct white spectacles.

*Behavior:* Feeds in dense brush and is very nervous and active.

*Habitat:* Found in thickly vegetated areas near open water such as Quitobaquito and Aguajita Spring. Common in moist woodlands, bottomlands, and mesquite.

*Similar species:* Habitat differs from other vireo species.

*Song:* A set of fast, harsh, scolding notes.

Appendix 6-2  
**Special-status Avian Species Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Census Data Form**

The following field data entry form is to be photocopied and used in the actual monitoring fieldwork. The data form is designed to allow rapid, accurate tallying of the number of birds detected during transect monitoring. It is best to use a No. 2 or HB lead pencil. Complete the top portion of the form as follows:

1. **Observer.** Record your name. Only one observer conducts each census. No additional persons may accompany the observer unless the census is considered a training session and is so labeled.
2. **Date.** The date (month, day, year) that the census is conducted.
3. **Time start.** Record the time that you actually begin walking the transect. Use military time (24-hr clock).
4. **Time end.** Record the time that you actually finish walking the transect. Use military time (24-hr clock).
5. **Location.** Write the name of the study site that you are monitoring. Use a separate data form for each study site.
6. **Vegetation type.** Write the association or subassociation of the study site. See the Plots and Transects description section of this report for specific information.
7. **Weather.** Record the following data concurrently with "Time start" (above):
  - (a) **Temperature.** Using the thermometer, measure the atmospheric temperature in degrees centigrade.
  - (b) **Wind speed.** Estimate the average wind speed in miles per hour. If there are gusts, indicate this also. Censusing can only be conducted when wind speed is 10 mph or less.
  - (c) **Cloud cover.** Estimate the percent of cloud cover or, if foggy, the horizontal visibility.

- (d) Precipitation. Indicate precipitation, if any (e.g., heavy dew, mist, drizzle, showers, steady or intermittent, etc.). Censusing can only be conducted when it is not raining.
- 8. Other animal species observed. Record genus and species of any other animal observed on the transect or, if taxonomy is unknown, record the common name.
- 9. Comments. Record any general observations you feel may be relative to the validity of the census (e.g., any loud noise that may frighten birds, passing traffic, etc.).

The remainder of the data form contains areas to record the specifics of birds observed on the transect during the census. The form has been designed to contain up to 50 entries, using both sides. As you walk the transect, record the following information for birds observed:

- 1. Species. Record the genus and species of any bird observed during the census. Use Appendix 6-1 (ORPI Annotated Checklist of Breeding and Special-status Avian Species), as well as the Field Guide to the Birds of North America (National Geographic Society 1987) to help identify taxonomy. If taxonomy is unknown, record the common name.
- 2. Observed. Check only one box in this column. If the bird is observed:
  - (a) on the transect, check the box, "On Tr."
  - (b) off the transect, but on the plot, check the box, "Off Tr."
  - (c) off the plot, check the box, "Off plot."
- 3. Behavior. Record the activity of the bird observed (e.g., foraging, resting, in flight, etc.). If activity includes nesting or courtship display, see step 4, below.
- 4. Number seen. Record the number of birds observed for this species. If you detect a flock, estimate the number of individuals, record this, and circle the number.
- 5. Age/Sex. Record the age of birds **seen**, if known. Valid age categories are adult (A), juvenile (J), nestling (N), and hatchling (H). Also record the sex, if known.
- 6. Nesting? Record "Y" if you observe nesting activity for this species, or "N" if you do not.
- 7. Courtship display? Record "Y" if you observe courtship display for this species, or "N" if you do not. If uncertain, note behavior specifics.

Upon completion of walking the transect, total the number of birds observed for each species and record this in the left margin, next to the species' name. Total only those birds observed on the transect, i.e., "On Tr." checked in second column. (Birds observed off-transect and off-plot are recorded only for documentation and are not included in the actual census data.)



# ORPI Ecological Monitoring Program—Special-status Avian Species Census Data Form

Observer \_\_\_\_\_

Date (mm/dd/yy) \_\_\_\_/\_\_\_\_/\_\_\_\_ Time start (2400) \_\_\_\_\_ Time end (2400) \_\_\_\_\_

Location (study site name) \_\_\_\_\_ Vegetation type \_\_\_\_\_

Weather: Temperature (°C) \_\_\_\_\_ Wind speed (mph) \_\_\_\_\_ Cloud cover \_\_\_\_\_

Precipitation \_\_\_\_\_

Other animal species observed \_\_\_\_\_

Comments \_\_\_\_\_

	Species <i>Spp</i>	Observed			Behavior <i>Describe...</i>	Number seen <i>##</i>	Age Sex <i>A, J, N, H M/F</i>	Nesting? <i>Y/N</i>	Courtship display? <i>Y/N</i>
		<i>On Tr.</i>	<i>Off Tr.</i>	<i>Off Plot</i>					
1		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
2		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
3		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
4		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
5		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
6		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
7		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
8		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
9		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
10		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
11		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
12		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
13		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
14		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
15		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
16		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
17		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
18		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
19		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
20		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					

*Additional space on other side....*

	Species	Observed			Behavior	Number seen	Age Sex	Nesting?	Courtship display?
	<i>Spp</i>	<i>On</i> <i>Tr.</i>	<i>Off</i> <i>Tr.</i>	<i>Off</i> <i>Plot</i>	<i>Describe...</i>	<i>##</i>	<i>A, J, N, H</i> <i>M/F</i>	<i>Y/N</i>	<i>Y/N</i>
21		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
22		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
23		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
24		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
25		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
26		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
27		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
28		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
29		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
30		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
31		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
32		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
33		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
34		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
35		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
36		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
37		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
38		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
39		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
40		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
41		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
42		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
43		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
44		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
45		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
46		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
47		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
48		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
49		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					
50		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>					

*Please make certain that all entries are accurate to the best of your knowledge. Information from these data forms will be compiled and analyzed to determine trends in avian populations at Organ Pipe Cactus National Monument.*

**Special-status Avian Species Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Avian Species Taxa**

The following index cross-references scientific taxa with common names for the special-status and other avian species named in this report. Sensitive species are indicated by the symbol ▲.

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Woodpecker Family—Picidae  
WREN, CACTUS—*Campylorhynchus brunneicapillus*  
WREN, CANYON—*Catherpes mexicanus*  
Wren Family—Troglodytidae

—Z—

*Zenaida asiatica*—WHITE-WINGED DOVE  
*Zenaida macroura*—MOURNING DOVE

# Bat Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Yar Petryszyn

Department of Ecology and Evolutionary Biology  
Biological Sciences East, Room 123  
The University of Arizona  
Tucson, Arizona 85721

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## Introduction

The bat monitoring protocol for Organ Pipe Cactus National Monument (ORPI) was completed in May 1994 by principal investigator, Yar Petryszyn. The initial research for this protocol was conducted with the help of park resources management staff in August and September 1993.

Bats comprise the second largest group of mammals in the world. This is also true for Arizona with 28 species of bats recorded. As a group, only rodents have more species.

All but 2 species of Arizona bats are insect feeders; the other 2 species are nectar/fruit eaters. As consumers of tremendous numbers of insects, bats become good indicators of the health of the food chain. Most insects are primary consumers, thus channeling and possibly concentrating any environmental contaminants. With the great number of insects that bats eat, these contaminants may be further concentrated in bats, much to their detriment. Population declines in some bat populations were noted through the 1950s and 1960s due, at least in part it is thought, to the effect of heavy metals and pesticides (such as DDT) in the environment.

Bats are an intrinsic part of the makeup of ecological systems in the Southwest. Their numbers and diversity as secondary and primary consumers add to the complexity of most food webs.

Due to the mobility of bats, it is often difficult to determine the status of their numbers and diversity. Often, bats are seasonal in their choice of roosts and foraging areas. In addition, local and temporary conditions can effect bat behavior. Wind, moonlight, change in barometric pressure, and rain can all have an effect. These elements must be kept in mind when trying to determine the status of bats in an area.

Counting bats in a day roost or during evening exit flights from a day roost are the best methods of monitoring bat populations. However, for many bat species this is not practical because (1) locations of roosts may not be known, (2) some species do not concentrate in large roosts, (3) some species move to other locations when disturbed, (4) some species move from roost site to roost site on a regular basis, (5) some species have sexually segregated roosts, and (6) often a roost may be used at the same time by several species.

Because all insect-eating bats do need to drink water every day, this allows for a means of sampling bat species diversity and relative abundance. With the use of mist nets as traps, strung at water sources, long-term monitoring of bats may be accomplished. Although mist-netting has its shortfalls, it provides about the only method (other than roost and flight counts) of determining the diversity and relative abundance of bats in a specific area. Over time, any gross changes in bat diversity and numbers should manifest themselves in the database.

Because mist netting has been chosen as the method of monitoring in this study, it is important to realize the shortcomings of such a practice. Some of these are:

1. Not all species of bats have the same propensity to be netted. The echolocation ability of bats varies greatly from species to species, and some are more likely to pick up the presence of a net.
2. The ability to use certain water sources varies among bat species. Some are capable of utilizing the smallest of waterholes, while those with narrow wings need a sizable expanse of water from which to drink.
3. The number of available water sources may change as variation in rainfall from year to year affects how much water is present. Presumably, the dispersion of bats increases with a greater number of water sources.
4. Variation in netting conditions may affect results. For example, changes in temperature, wind, barometric pressure, moonlight, and storms can effect bat foraging. There may be some conditions that cause many bats to remain in their roost. Additionally, even a slight breeze can billow the nets, decreasing their effectiveness.

Although these factors appear to preclude any chance of gathering data that are meaningful, they can be minimized to initiate a viable monitoring program that results in data that is useful. Bats, like most other animals, are creatures of habit. They tend to use the same water sources (if they are available) from year to year. Therefore, the key concept in obtaining meaningful data is consistency, i.e., netting the same water source during the same period of time under the same conditions as much as possible. These tactics, coupled with using the same number and size of nets should provide data that reflect, over time, any trends in bat usage—both in species and numbers.

## Methods

### List of Materials

The following materials are required for mist netting of bats:

Mist nets	5.5-m (18-ft), 9.1-m (30-ft), 18.3-m (60-ft) and 36.6-m (120-ft) (two 18.3-m (60-ft) nets tied together). For Quitobaquito Pond, only the 36.6-m (120-ft) net is needed.
Poles	Two 1.5-m (5-ft) segments joined by a sleeve are needed at each end of the net. Three segments at each end are needed for Quitobaquito Pond.
Anchor cord for poles	Any strong string or cord will do.
Stakes	The type used for tents
Millimeter ruler	Flexible plastic, 150 mm (6 in) is sufficient. Cutting the end off so it is even with the "0" mark makes for easier use.
Scales (2)	100 gm (3.5 oz) (Pesola recommended).
Zip-lock storage bags	For containing bats while weighing. Safe for the short time the bats will spend in them. Quart capacity will suffice for most bats.
Cloth bags	For holding bats after removing from net. Should have string or cloth ties.
Headlamp	This frees both hands for handling bats.
Leather gloves	Light-weight. Deerskin gloves are very good, with the exception of handling large <i>Eumops</i> spp.
Watch	To note the time of capture.
Clipboard	For holding data forms
Data forms	See Appendix 7-1.
Pencils	To complete data forms.
Insect repellent	Use as needed.

“White-out”	If marking bats is a consideration.
References	Description of Bat Species Found in Arizona (Appendix 7-2) <i>Myotis</i> spp. Identification Key (Appendix 7-3) Cross-referenced Index of Bat Taxa (Appendix 7-4) <i>Mammals of Arizona</i> (Hoffmeister 1986) and possibly other references such as <i>The Mammals of North America</i> (Hall 1981).
Camera, film, and flash	For voucher pictures.

### **Procedure for Mist Netting**

Nets should be in place at sunset. To minimize the capture of any birds, keep the nets closed until just before dark. Usually, it is obvious when birds such as doves, thrashers, swallows, etc. stop flying for the evening.

Nets should be set across the middle of small pools, if at all practical. For larger pools, a net set up at the lip of one edge usually proves to be productive.

It is much easier to set up nets with 2 people. One person can hold the pole and net while the other places the panel end-loops over the pole and anchors the pole with cord. The cord may be tied to any nearby object stout enough to hold both the pole and net, or tied to stakes driven into the ground for that purpose.

When anchoring the poles that hold the net, the top 3 panel end-loops should be placed above the anchor cord, and the bottom 2 loops below the anchor cord. Occasionally, the terrain may warrant more net area below the anchor cord (such as across a small ravine, where the poles are on slopes). Under these conditions, 3 panel end-loops are placed below the anchor cord.

The net should be spread taunt enough so that a 2.5-cm (1-in) bag droop occurs in each of the panels. The net itself should be stretched tight. As the evening progresses, the rise in humidity will cause the net to droop, so periodic adjustments should be made to keep the net taunt.

Nets should not be placed more than 30.5 m (100 ft) apart. Any greater distance makes it cumbersome to check nets and time is wasted traveling between them.

The nets should be checked every 5 min. Bats are capable of swiftly chewing holes in nets. If they are left unattended, the nets may become riddled with holes in a short time.

Nets should be maintained until midnight, at which time they should be closed. Much of the bat activity at water sources occurs in the first half of the night. Maintaining nets until midnight provides an adequate representation of bat use.

To close a net, push all the panel end-loops together at the anchor cord on the pole. Take a 30.5-cm (12-in) piece of plastic flagging and tie the end-loops together, using a single knot. (Do not include the anchor cord.) Do this at both ends of the net. (This keeps the loops from getting tangled in the net.) One end of the net can then be taken off the pole and folded toward the other end. When the net is completely folded, place the tied end-loops together and stuff the net into a bag for safe keeping.

### *Recommendations*

For best netting results, it is advisable to consider the following:

1. Sample water sources at different locations; however, whether the water source is small, large, in the open, secluded, or so forth, the same water source should be monitored from year to year.
2. Monitor the sites during the latter part of May or in June. This is the driest time of the year with chance of storms almost nonexistent. In May and June it is warm enough that insects are active, therefore, the bats should be active as well. Also, because the number of available water sources are limited at this time of year, the bats are usually more concentrated.
3. Net during moonless nights. Bats possess good eyesight and they are capable of seeing a moonlit net.

### **Capturing and Handling Bats**

The actual capture and handling of the bats is an effort that requires full concentration and attention. Bats can chew holes in the net if left unattended for any length of time, and can become easily entangled. In the intervals between checking the nets, bat extraction, and data collection, flashlights should be off, and talking kept to a minimum. This helps both to maintain concentration and to avoid scaring off the bats.

When a bat is caught in the net, quickly move to extract it before it can escape or become further entangled. Determine from which side of the net the bat entered. Immobilize the bat with a gloved hand (or give the bat a gloved finger to chew on for distraction) and carefully remove the net strands from head, body, and wings. Be especially careful with the fragile wing membrane and bones.

Place the bat in a cloth bag if it cannot be processed right away.

### *Recommendations*

For best sampling results, it is advisable to consider the following:

1. Do not mark the bats. It can safely be assumed that each bat captured in a net during any given night will not be recaptured in that same net during that same night. Past experience with hundreds of marked bats has proven that only a fraction of a percent are ever

recaptured the same night. Nonetheless, if there is a desire to mark bats in order to periodically check the probability of recaptures during the same night, a spot of “white-out” applied to the back of the bat’s head works well as a temporary mark. The “white-out” is non-toxic and wears off after several days.

## Data Collection

All data are entered into a dBase III database after completion of monitoring, therefore, a data form must be completed for each trapping event at each location. The sample data form (Appendix 7-1) may be modified at your discretion; however, certain information is required to assure that proper data are collected:

1. Location. This is the name of the water source or flyway. Include drainage name, wash or canyon, county, and description of location (miles from..., or Township, Range, Section). Also include elevation, if available.
2. Date. Indicate the day, month, and year that netting occurred.
3. Weather conditions. Include cloud cover, estimated wind speed, humidity (muggy, dry, etc.), and temperature at start and finish.
4. Moon. Indicate the phase of the moon and when moonrise or moonset occurred.
5. Time. Record the time captured for each bat in the net. Occasionally, the time of capture may be approximated when several bats are being removed from the net.
6. Species. Record the species of each bat captured. (See Appendices 7-2 through 7-4.) To speed up the process, abbreviations may be used, e.g., Pip, My.cal, Mac.
7. Sex. Use the symbols ♂ (for male) and ♀ (for female).
8. Forearm. Record forearm length (right or left, length is undifferentiated). Record the measurement in millimeters, however, do not include a “mm” suffix—this measurement is understood to be in millimeters. Not all bats need to be measured; only those for which this measurement may aid in identification. Those species for which forearm measurement may be helpful in identification are: *Myotis* (see Appendix 7-3), *Eumops*, and *Nyctinomops* (see Appendix 7-2).
9. Ear. Record ear length (right or left, length is undifferentiated). Record the measurement in millimeters, however, do not include a “mm” suffix—this measurement is understood to be in millimeters. Not all bats need to be measured; only with some *Myotis* will ear size be helpful in identification. (See Appendix 7-3.)
10. Weight. If possible, each bat should be weighed. The bat may be placed in a plastic Zip-lock storage bag and weighed on a scale (Pesola recommended). Be certain to deduct

the weight of the bag from the total weight when determining the weight of the bat. The use of a 50-gm (1.75-oz) capacity scale would be preferred for all species but *Eumops*, which may require the use of a 100-gm (3.5-oz) capacity scale. The brief span of confinement to the storage bag during weighing is not detrimental to the bat.

11. Individual notes. Indicate breeding status (for females: pregnant, lactating, post-lactating, non-parous; for males: testes descended [TD]); whether adult or juvenile; ectoparasites; any anatomical damage, e.g., hole in wing and so forth for individual samples.
12. Time net opened/Time net closed. Record the time when the net was opened as well as when it was closed.
13. Collective notes. Record comments and other remarks regarding overall observations.

## Literature Cited

- Hall, E. R. 1981. *The Mammals of North America*. John Wiley and Sons, New York. 1,181 p.
- Hoffmeister, D. F. 1986. *Mammals of Arizona*. The University of Arizona Press and the Arizona Game and Fish Department. 602 p.

Appendix 7-1  
**Bat Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Mist Netting Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

**ORPI Ecological Monitoring Program—Bat Monitoring Protocol  
Mist Netting Data Form**

Location \_\_\_\_\_ Date (dd/mm/yy) \_\_\_\_\_ Page \_\_\_\_\_ of \_\_\_\_\_

Weather conditions (cloud cover, wind speed, humidity, temperature at start and finish) \_\_\_\_\_

Moon (phase, time of moonrise or moonset [2400]) \_\_\_\_\_

	Time	Species	Sex	Forearm	Ear	Weight	Individual notes
	2400	<i>Spp</i>	♂/♀	mm	mm	gm	
1							
2							
3							
4							
5							
6							
7							
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23							
24							
25							

Time net opened (2400) \_\_\_\_\_ Time net closed (2400) \_\_\_\_\_

Collective notes: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Appendix 7-2  
**Bat Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Description of Bat Species Found in Arizona**

**Free-tailed Bats (Family: Molossidae)**

*Note:* all of these bats have a “free” tail that protrudes conspicuously beyond the outer edge of the tail membrane.

◆ BIG FREE-TAILED BAT *Nyctinomops macrotis*

The big free-tailed bat is a large bat with narrow wings and a “free” tail. Ears are joined at the midline of the skull. This species is almost twice as large as both the Brazilian free-tailed bat and the pocketed free-tailed bat. Forearm measures 58–64 mm (2.28–2.52 in.) in length.

▲ BRAZILIAN FREE-TAILED BAT *Tadarida brasiliensis*

Sometimes called MEXICAN FREE-TAILED BAT, this species is medium-sized with narrow wings and a “free” tail. Forearm measures 36–46 mm (1.42–1.81 in.) in length. Ears are not joined at the midline of the skull. This species is easily confused with the pocketed free-tailed bat. Seventeen Brazilian free-tailed bats were netted at Quitobaquito during 18–20 April 1994. All but one of these were male. (One or two records of this species’ existence may be found at ORPI, however, no voucher specimen is available.)

▼ POCKETED FREE-TAILED BAT *Nyctinomops femorosaccus* (*Tadarida femorosaccus*)

The pocketed free-tailed bat is medium-sized with narrow wings and a “free” tail. Forearm measures 44–50 mm (1.73–1.97 in.) in length. This species is easily confused with the Brazilian free-tailed bat (*Tadarida brasiliensis*). The pocketed free-tailed bat has ears that join at the midline of the skull. Common at Quitobaquito.

▼ UNDERWOOD’S MASTIFF BAT *Eumops underwoodi*

A “huge” bat that may weigh up to 70 gm (2.47 oz) and display a wing spread of 50.80 cm (20 in.). Underwood’s mastiff bat possesses narrow wings and a “free” tail. Differs from the western mastiff bat in that the forearm measures 65–74 mm (2.56–2.91 in.) in length; ears, 28–32 mm (1.10–1.26 in.); and tragus is small and rounded. Quite common at Quitobaquito.

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*Prominence symbol key:* ■ = not known from the monument; ◆ = not known from the monument, but may be possible; ● = known from the monument; ▲ = occurs at the monument; ▼ = common at the monument.

▲ WESTERN MASTIFF BAT *Eumops perotis*

A “huge” bat that may weigh 80 gm (2.80 oz) and display a wing spread of 53.34 cm (21 in.). The western-mastiff bat possesses narrow wings and a “free” tail. Forearm measures 73–83 mm (2.87–3.27 in.) in length; ears, 36–47 mm (1.42–1.85 in.). Tragus is broad and square. Two of these bats have been captured at Quitobaquito as of May 1994.

### Leaf-chinned Bats (Family: Mormoopidae)

■ GHOST-FACED BAT *Mormoops megalophylla*

The ghost-faced bat is a medium-sized bat having a funny-looking face with flaps of skin. It can be difficult to determine where the mouth is when closed. This species has a reduced uropatagium (tail membrane). The tail partially protrudes from the middle of the tail membrane.

### Leaf-nosed Bats (Family: Phyllostomidae)

● CALIFORNIA LEAF-NOSED BAT *Macrotus californicus*

The California leaf-nosed bat is a medium-sized bat, grey in color. This species has large ears and eyes, a well-developed tail membrane, and a leaf on its nose. It is a relatively docile bat.

● LESSER LONG-NOSED BAT *Leptonycteris curasoae*

The lesser long-nosed bat is a medium-sized bat with a cone-shaped elongated snout and a leaf on the end of its nose. This species has narrow wings and the tail membrane is greatly reduced. These bats feed on the nectar/fruit pulp of saguaro and organ pipe cacti.

● MEXICAN LONG-TONGUED BAT *Choeronycteris mexicana*

The Mexican long-tongued bat is a medium-sized bat with a tube-shaped elongated snout and a leaf on the end of its nose. This species has narrow wings. The tail membrane is greatly reduced, but not so much as in the lesser long-nosed bat (*Leptonycteris curasoae*). The Mexican long-tongued bat still has approximately 8–10 mm (0.31–0.39 in.) of tail membrane. This species feeds on the nectar of saguaros and agaves. This species (1 specimen) has been captured at Alamo Canyon.

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## Plain-nosed Bats (Family: Vespertilionidae)

*Note:* all *Myotis* have a thin, straight, and pointed tragus.

### ■ ALLEN'S BIG-EARED BAT *Idionycteris phyllotis*

Sometimes called ALLEN'S LAPPET-BROWED BAT, this is a medium-sized bat, grey-brown in color. The species displays very large ears, second in size only to the spotted bat. It possesses no leaf on the nose, nor is the nose lumpy. However, it has well developed lappets (fleshy lobes) extending from the anterior parts of the ears. There are no records from the southwest part of Arizona for this species.

### ▼ BIG BROWN BAT *Eptesicus fuscus*

This is a medium-sized bat with brown fur and medium-sized ears. It is a fairly robust bat. The species may often be confused with some of the *Myotis*, but the big brown bat has a tragus with a blunt end.

### ▲ CAVE MYOTIS *Myotis velifer*

The cave myotis is a small bat with medium-sized ears and a large forearm (length > 40 mm [1.57 in.]). Unlike the fringed myotis, no fringe can be found on the edge of the tail membrane; however, a bare patch can be observed between the scapulae.

### ● CALIFORNIA MYOTIS *Myotis californicus*

This is a very small bat with small ears and a very small foot (< 8 mm [0.31 in.] in length). The species displays a keel on the calcar. There is no mask across the face, and the fur is dull. The California myotis may sometimes be confused with the western pipistrelle (*Pipistrellus hesperus*), however, *Myotis* have a thin, straight, and pointed tragus, whereas *Pipistrella* have a rounded tragus that resembles a comma.

### ◆ FRINGED MYOTIS *Myotis thysanodes*

This is a small bat with large ears and a forearm of > 40 mm (1.57 in.) length. A fringe of single hairs can be found on the edge of the tail membrane; however, sometimes these are difficult to see, so the animal must be examined closely.

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▲ HOARY BAT *Lasiurus cinereus*

This is one of the “tree bats.” It is of medium to large size. The animal derives its name from the frosty (hoary, as in hoarfrost) appearance of its brown fur tipped in silver. The species is well furred to the elbow, as well as on the dorsal side of its tail membrane. The hoary bat is usually found at higher elevations. Three were captured at Quitobaquito.

■ LITTLE BROWN MYOTIS *Myotis occultus*

This species is sometimes called *Myotis lucifugus*. It is a small bat with small, dark ears and a forearm of < 40 mm (1.57 in.) length. The braincase is flattened, the fur glossy. Known from the Mogollon Rim area.

■ LONG-EARED MYOTIS *Myotis evotis*

This is a small bat with large (> 18 mm [0.71 in.] in length), black ears. Its forearm is rather short (< 40 mm [1.57 in.] in length). The long-eared myotis may be confused with the southwestern myotis. Known only from the central and northern parts of Arizona.

◆ LONG-LEGGED MYOTIS *Myotis volans*

This species is of small size, with medium- to small-sized ears (length < 18 mm [0.71 in.]) and a forearm of < 40 mm (1.57 in.) in length. The bat is furred to the elbow on the underside of the wing, although the fur may be sparse. Sometimes a keel is found on the calcar.

▲ PALLID BAT *Antrozous pallidus*

The pallid bat is medium-sized with blondish fur and large ears. The species displays no leaf on its nose and no lappets (fleshy lobes). The bat’s muzzle has no lumps, but does truncate abruptly with the nostrils opening forward beneath a horseshoe-shaped ridge.

■ SILVER-HAIRED BAT *Lasionycteris noctivagans*

The silver-haired bat is one of the “tree bats.” It is medium-sized, possessing black fur with silver tips. This species displays fur to the elbow on the underside of each wing, as well as on the dorsal side of the tail membrane. This bat is usually found at higher elevations in Arizona. This species is not on record for the southwestern part of the state.

◆ SOUTHERN YELLOW BAT *Lasiurus ega*

This is one of the “tree bats.” It is medium-sized. Its yellowish fur with silver tips gives it a frosted look, although not as much as the western red bat or the hoary bat. The species is furred to the elbow on the underside of each wing, as well as on the dorsal part of its tail membrane. The southern yellow bat is often found roosting in palms.

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■ SOUTHWESTERN MYOTIS *Myotis auriculus*

The southwestern myotis is a small bat. Its forearm measures < 40 mm (1.57 in.) in length; its dark brown ears, > 18 mm (0.71 in.). This species is generally found in the Mogollon Rim area and the mountains of south-central and southeast Arizona.

◆ SPOTTED BAT *Euderma maculatum*

Immediately recognizable, the spotted bat is medium-sized, having black fur with three white spots and huge ears. The species is found throughout the western United States in elevations of 43–2,743<sup>+</sup> m (142–9,000<sup>+</sup> ft).

▲ TOWNSEND'S BIG-EARED BAT *Plecotus townsendii*

Townsend's big-eared bat is a medium-sized bat, grey-brown in color. It displays big, relatively narrow ears which it curls when at rest. There is no leaf on nose, however, the nose is lumpy due to its muzzle glands.

▼ WESTERN PIPISTRELLE *Pipistrellus hesperus*

This is the smallest bat in North America. It is usually pale in color with dark ears. The species may be confused with the California myotis, but the western pipistrelle has a comma-shaped tragus, whereas all *Myotis* have a thin, straight, and pointed tragus.

■ WESTERN RED BAT *Lasiurus blossevillii*

The western red bat is formally known as *L. borealis*. This is one of the “tree bats.” It is medium-sized, possessing reddish fur with silver tips, giving it a frosted look. The species displays fur to the elbow on the underside of each wing, as well as on the dorsal part of the tail membrane. This bat is not usually found in desert areas.

■ WESTERN SMALL-FOOTED MYOTIS *Myotis ciliolabrum*

This species used to be known as *Myotis subulatus* and *Myotis leibii*. It is a very small bat with small ears and a very small foot (< 8 mm [0.31 in.] in length). The animal displays a keel on the calcar. It also has a dark mask across the face and its fur is glossy. Not known from the southwest portion of Arizona.

◆ YUMA MYOTIS *Myotis yumanensis*

The Yuma myotis is a small bat with small- to medium-sized ears. It displays a large foot (> 8 mm [0.31 in.] in length) and a forearm of 32–36 mm (1.26–1.42 in.) in length; the braincase is abrupt. This bat is “mousey” in color.

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**Prominence symbol key:** ■ = not known from the monument; ◆ = not known from the monument, but may be possible; ● = known from the monument; ▲ = occurs at the monument; ▼ = common at the monument.

Appendix 7-3

**Bat Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument:  
Simplified Key to Select *Myotis* Species of Arizona**

1. Hind foot measures < 8 mm (0.31 in.) ..... 2  
Hind foot measures > 8 mm (0.31 in.) ..... 3
  
2. Keel on calcar, mask, fur glossy ..... *Myotis ciliolabrum*  
Keel on calcar, no mask, fur dull ..... *Myotis californicus*
  
3. Keel on calcar ..... *Myotis volans*  
No keel on calcar ..... 4
  
4. Forearm long (measures > 40 mm [1.5 in.]) ..... 5  
Forearm short (measures < 40 mm [1.5 in.]) ..... 6
  
5. Ears large, fringe of hair on edge of tail membrane ..... *Myotis thysanodes*  
Ears medium, no fringe on tail membrane, bare patch between scapulae ..... *Myotis velifer*
  
6. Ears large (measures > 18 mm [0.71 in.]) ..... 7  
Ears medium or small (measures < 18 mm [0.71 in.]) ..... 8
  
7. Ears black ..... *Myotis evotis*  
Ears brown ..... *Myotis auriculus*
  
8. No keel on calcar, not furred to elbow, braincase flattened,  
fur glossy, forearm measures 36–39 mm (1.42–1.54 in.) ..... *Myotis occultus*  
No keel on calcar, not furred to elbow, braincase abrupt, fur dull  
(mousey-looking), forearm measures 32–36 mm (1.26–1.42 in.) ..... *Myotis yumanensis*

Appendix 7-4  
**Bat Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Bat Taxa**

The following index cross-references scientific taxa with common names for the bat species named in this report. Names occur in the index followed by an indication of the degree of prominence: (1) not known from the monument; (2) not known from the monument, but may be possible; (3) known from the monument; (4) occurs at the monument; and (5) common at the monument.

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# Invertebrate Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Kenneth J. Kingsley

SWCA, Incorporated  
4601 East First Street  
Tucson, Arizona 85711

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## Introduction

The Sensitive Ecosystems Project (SENECPRO)—now the Ecological Monitoring Program (EMP)—invertebrates project began with the idea that monitoring selected invertebrate species might be a useful way to measure changes in environmental conditions. The Request for Proposal stated “An important objective of this project is for scientists to develop methodologies, tools, and step-by-step instructions for long-term monitoring of key ecological parameters. Such protocols are to be suitable for future use by resource managers in spotting problems before serious or irreversible ecosystem deterioration occurs.”

Additional expectations of monument staff have been presented in informal discussions with them. These include the concepts that:

1. Monitoring populations of Howarth’s white (*Ascia howarthi*) might yield useful information on pesticide drift from Mexico or the effect of groundwater draw-down on the butterfly’s food plant.
2. Monitoring populations of the Quitobaquito tryonia (*Tryonia quitobaquiae*) would be useful in understanding effects of groundwater use in Mexico.
3. Monitoring invertebrate populations would be useful in understanding the process of recovery from grazing.
4. Monitoring invertebrate populations or species presence would be useful in understanding and predicting climate change.
5. Monitoring invertebrate populations would be useful for predicting, ascertaining, and reacting to invasion of nonnative species, especially agricultural pests from Mexican agriculture and Africanized honey bees (*Apis mellifera*).

The originators of the RFP believed that invertebrates, being numerous, reproducing quickly, and being sensitive to a wide spectrum of environmental conditions, might be useful as indicators of events and changes in the general environment and in the selected ecosystems or habitat types represented by the study sites.

The author agrees with most of these basic assumptions. However, the data acquired during 3 yr of research, combined with information available in the literature on invertebrate populations, suggest a more complex picture.

A total of 1,024 invertebrate taxa were identified during the 3-year EMP program. The portion of the total fauna this number represents is unknown. Most of the taxa are considered rare, with 439 recorded only once. The diversity of invertebrates and the limited data preclude drawing conclusions about most of the invertebrate fauna. For monitoring purposes, large sample sizes

will be necessary to enable drawing meaningful conclusions. With rare taxa, the effort required to obtain adequate sample sizes is very great and expensive. Even determining adequate sample sizes for rare species that are patchily distributed will be extremely difficult and will require intensive sampling of the area to locate all or most of the species populations before sampling begins.

The 3-year period of observation was marked by less than normal rainfall and higher than normal temperatures. These weather conditions further limit understanding of what might be considered “normal” invertebrate populations, and preclude the determination of accurate baseline population levels that might be useful in meeting the goals of the monitoring concept.

Most of the taxa are poorly known to science. There is no body of literature on population fluctuations and their determinants for native Sonoran Desert invertebrates under a variety of conditions. Currently, we have no idea what population fluctuations mean except in relation to rainfall. The paucity of understanding applies especially to rare species and species that are at the limits of their distribution. Meaningful conclusions might be drawn only if:

1. All factors of concern, such as weather, groundwater levels, pesticide levels, plant community structure and phenology, predator populations, and anthropogenic events were carefully recorded over a reasonably long time (at least 10 to 20 yr); and if
2. Population data on all, or at least many, invertebrate taxa present at each site were accumulated over this same period of time, through sufficient variation in conditions, and in sufficient detail; and if
3. Detailed autecological studies of selected species through a range of conditions were carried out over a sufficiently long time to permit factoring out the effects of each condition that varied.

Given that all of these conditions were met, the best one could reasonably hope for would be observation of correlations between observed relative invertebrate population sizes and some other factors (short of the obvious, such as that the disappearance of water from its habitat results in elimination of the Quitobaquito tryonia, elimination of the desert-caper plant [*Atamisquea emarginata*] results in drastic decline in observed populations of Howarth’s white, etc.).

This document presents concepts, background, and methodology of a monitoring program that might eventually yield worthwhile results. It proposes a 2-tiered monitoring program. Tier 1 is a practical, relatively inexpensive program of field-tested methods that is essentially a continuation of the research program conducted from 1987 to 1990. It might yield useful data over time, but it is unlikely to enable development of predictive models. Tier 2 is much more intensive and expensive, but in my opinion is what would be necessary to be able to address some of the questions posed by the EMP concepts of using invertebrate monitoring for any predictive or deductive purposes. Tier 2 contains methodology that has not been field tested at Organ Pipe Cactus National Monument (ORPI) (or anywhere else, in some cases), and will require continuous development and refinement during the course of the program.

## Background

Most protocols for monitoring invertebrate populations have historically been developed in conjunction with insect pest management (IPM) schemes. The goals of such schemes have been simple, compared to the goals stated and assumed by monument staff. Insect pest management sampling protocols are derived from the results of long-term observation of single species in relatively homogeneous (monoculture or forest) habitats under a variety of conditions by highly-trained professional entomologists. Such protocols are expensive to develop and limited in their predictive ability. The best of these protocols results in an informed decision as to whether or not treatment (insecticide application) would probably be cost-effective. To develop predictively useful data on wild invertebrate populations in heterogeneous habitats would require several times the effort currently being applied to any one species in an IPM situation.

· Currently used population monitoring techniques fall into 2 broad classes: (1) absolute, which attempt to estimate the number of animals per unit area of habitat; and (2) relative, which attempt to measure the population in unknown units and allow only comparisons in space or time (Southwood 1978). As a general rule, absolute techniques tend to be more expensive and intensive than relative techniques, and are not suitable for application in the ORPI monitoring program, with a few exceptions. Therefore, the techniques described below are primarily relative techniques. Relative techniques generally have lower reliability and validity than absolute techniques because they often depend on a number of factors other than population size.

Because so little is known about the species of invertebrates in ORPI, including the validity of assumptions used in any sampling regime, intensive sampling over a period of several years and through a broad range of weather conditions is necessary to enable the development of a simpler approach. The following monitoring program attempts to generate the necessary data that would allow development of a simpler, less costly monitoring program. The time span necessary for application of the techniques described below cannot presently be estimated because it will depend upon a number of unpredictable factors; however, a rough estimate would be 10–20 yr.

There are few well-developed long-term monitoring plans for non-agricultural invertebrate species in heterogeneous habitats. The best with which I am familiar is that for the bay checkerspot (*Euphydryas editha bayensis*) (Murphy and Weiss 1988). This plan is based on 30 yr of detailed intensive study of the species by expert entomologists. In the process of developing a monitoring plan, the investigators experimented with walking transects, mark-recapture techniques, and larval counts. The investigators found that walking transects gave them rough outlines of adult distribution, but gave little information on absolute population numbers, phenology, and microhabitat use. Mark-recapture techniques were found to yield little useful data and to be prohibitively expensive. Studies of larval growth and dispersal demonstrated that several factors were important, including topography, slope orientation, thermal conditions, rainfall, plant phenology, and local microclimates. Other studies on this species (Ehrlich and Murphy 1987) show that a variety of factors is important in determining butterfly population

survival and size. These factors include availability of alternate food sources for larvae; availability of nectar; presence of standing water; and, of course, weather events. Local extinctions were recorded several times during the 30 yr of study, with some local extinctions followed by recolonization in suitable years (Ehrlich and Murphy 1987). Local extinction and recolonization appeared to be most affected by weather patterns, but not in a consistently predictable way. Variations were dramatic from year to year, and rare weather events appeared to be a key factor in dispersal and survival of butterflies (Ehrlich and Murphy 1987).

Less formal and less scientific long-term monitoring of butterflies has been done for several years in Britain and the United States as annual butterfly counts. These follow protocols that would be of very limited value for monitoring within the monument and rely very heavily on observer expertise and weather conditions on the day of sampling.

Two long-term studies of grasshopper populations under more-or-less natural conditions are available in the literature (Joern and Pruess 1986; Capinera and Thompson 1987). Both studies showed variation in densities and relative abundances, with 10-fold density variation over a period of years. Both studies showed changes in species composition from year to year, with some species (especially rare ones) present in some years and absent in others. The 2 studies differed in their conclusions on the relative constancy of assemblages (i.e., the common species were consistently more common than the uncommon species despite fluctuations in the total number of individuals). One study (Joern and Pruess 1986) concluded that assemblages were fairly constant, based on ranks, over time. The other (Capinera and Thompson 1987) showed that assemblages were apparently not constant. The studies differed in field and statistical methods, making comparison of results difficult. For our purposes, the important conclusions, to be drawn from these studies are:

1. We do not really know very much about fluctuations in grasshopper populations, even from long-term studies in prairie ecosystems that are structurally simpler than our desert ecosystems.
2. Grasshopper populations and assemblages are affected by weather and other conditions that we do not understand.
3. Rare or uncommon species may complicate our understanding of the situation.

Mintzer has studied aspects of the ecology and distribution of the Mexican leaf cutter ant (*Atta mexicana*) in the monument for several years (mostly unpublished data). He has located and mapped nests through time. The techniques he originated should continue.

Other long-term studies of invertebrate populations under more-or-less natural conditions are found in a large body of literature associated with forestry and range management. In general, these techniques are based on years of detailed study of specific (primarily pest) species in specific habitats, are IPM based, and have little direct applicability to the situation in the monument.

## Indicator Species

### Concept and Criteria

One of the purposes of the broad approach to sampling used in the 3-year study of invertebrates in ORPI was to obtain enough knowledge of species, roles, and populations so that we might develop a list of indicator species for a monitoring program. Criteria listed in the RFP for selection of indicator species were:

1. Special-status species covered by legislation.
2. Endemics.
3. Species that are harvested by hunting, poaching, and collecting for commercial or domestic purposes.
4. Species that occupy different trophic levels, feeding guilds, etc. so that all levels are represented.
5. Species that are common or dominant.
6. Species that are of special interest to the public, managers, interpreters, and/or scientists, including “heroic” species.
7. Species that occupy sites that are subject to dramatic change such as precipitant loss or alteration of habitat.

To this list, common sense calls for the addition of 2 criteria:

1. Species that are consistently and easily identifiable by monument staff in the context of a larger monitoring program.
2. Species for which population fluctuations meaningfully indicate environmental conditions that cannot be measured in an easier, more efficient, and more consistent way.

### Potential Problems with the Concept and Practice

Only 1 species, the Quitobaquito tryonia, is currently or likely to be covered by legislation as a special-status species. It is currently a Category 2 candidate for listing as an endangered or threatened species. The small size and cryptic nature of this snail make monitoring difficult. A detailed study of the basic biology of this species must be performed before a monitoring program short of a total absolute count can be developed. The Ajo Mountains snail (*Sonorella baboquivariensis cossi*) might conceivably meet criteria for listing as a restricted-habitat endemic. However, current knowledge of this cryptic species is too limited to enable us to

develop even the most rudimentary monitoring program that would have any meaning. Again, an intensive study of the biology of this snail may lead to development of a basis for a useful monitoring plan. No other known invertebrate species found during this study is likely to meet criteria for listing as special-status species.

A few species, for example Howarth's white and the Mexican leaf cutter ant, may be considered "special" in that they are separated by a political boundary from the major concentration of their species. Others, such as *Taeniopoda eques* (no common name), may represent distributional extremes. The value of developing monitoring programs for them is questionable, at best, and may be a waste of time and money, since we have no idea what fluctuations in their populations mean. Intensive studies of the biology of each species are necessary as a foundation for developing a monitoring plan. As a general rule, species at the margins of their distribution are subject to dramatic changes in numbers, including local extinctions, reestablishment, and short-term outbreaks (Wallner 1987; Ehrlich 1984; Murphy et al. 1990). Understanding fluctuations in local populations is not possible without an understanding of the metapopulation that extends beyond local boundaries (Murphy et al. 1990). Meaningful studies of marginal species must expand beyond monument boundaries and include larger portions of the species range.

No invertebrate species known from the monument are likely to be harvested by hunting, poaching, and collecting for commercial or domestic purposes. A few species, such as some of our rare Saturniid moths, and some beetles and butterflies, may be of interest to some collectors, including some commercial collectors. However, most, if not all, collectors are unlikely to risk legal prosecution for collecting species in the protected area of the monument that are obtainable elsewhere with no risk. None of our rare species are truly endemic to the monument (with the exception of those mentioned above), so impact by collectors should not be an important consideration. Some value may come from welcoming collectors and issuing permits for collection of limited numbers of certain rare species as a way of increasing the knowledge of their biology.

Consideration of species that represent different trophic levels and the few species that meet the criteria of being common or dominant encounters other practical problems:

1. Too little is known about even the most common or dominant species to enable us to draw any meaningful conclusion from the observation of fluctuations in their numbers.
2. Fluctuations in numbers of observed individuals may have little or nothing to do with actual population sizes. All species are sensitive to weather conditions and have seasonal and daily activity patterns that make monitoring them difficult. They simply are not visible during periods when weather conditions are not to their liking, or at the wrong season or time of day, even though they may be abundant in cryptic resting stages. Our knowledge is inadequate to enable us to recommend optimal conditions for monitoring any species, or to interpret changes in observed populations.

3. Rainfall patterns are the most important driving force for invertebrate populations in this environment and complicate or cancel out our understanding of any other factors. Fluctuations in invertebrate populations may only tell us, indirectly, the relative amount of rainfall. If we want to measure rainfall, there are easier ways than to monitor invertebrate populations.
4. Many of the most common species are not easily and consistently identifiable under field conditions. For example, *Trimerotropis pallidipennis* (no common name) is quite cryptic in coloration and behavior and closely resembles several other species. Other examples could be given which would eliminate many of the common species. Only a few species are unmistakable, but then we have the other problems mentioned above. Even expert insect taxonomists working under the best laboratory conditions make mistakes in identification of species (Garth 1944 contains several misidentifications). Minimally trained resource management personnel, who are not entomologists and are not familiar with the taxonomic complexities involved, will produce data that is questionable at best.

Among species that are of special interest or that occupy sites that are subject to dramatic change such as precipitant loss or alteration of habitat, the same problems discussed above apply. Knowledge of the biology of the species is insufficient to enable population data to be used as indicators of anything except possibly weather conditions or radical habitat alteration, which are more efficiently measured in other ways.

### Taxa Considered

Species selected for monitoring, in keeping with the above criteria, are:

1. Phylum: Mollusca (mollusks).
  - (a) Family: Hydrobiidae [syn. Truncatellidae] (no common name).
    - (1) *Tryonia quitobaquiae* (Quitobaquito tryonia). A special-status (Category 2 candidate, endemic) species.
  - (b) Family: Helminthoglyptidae (no common name).
    - (1) *Sonorella baboquivariensis cossi* (Ajo Mountains snail). Possibly should be considered officially with the same status as the Quitobaquito tryonia. Although probably not likely to be truly threatened, it is endemic to a very small area.
2. Order: Orthoptera (grasshoppers, crickets, and katydids).
  - (a) Family: Acrididae (short-horned grasshoppers).

- (1) *Trimerotropis pallidipennis* (no common name). A common, fairly conspicuous grasshopper, most prevalent on disturbed, barren soil. Numbers may indicate degree of disturbance of habitat or, inversely, degree of recovery from disturbance. Population size may indicate abundance of rainfall and annual plant growth.
- (2) *Ligurotettix coquilletti* (no common name). An abundant grasshopper, generally distributed and detectable by its calls. Only grasshopper known to defend territories, population levels may be independent of rainfall (Otte and Joern 1975). May indicate habitat quality in some way. Easy to count.

(b) Family: Romaleidae (lubber-grasshoppers).

- (1) *Taeniopoda eques* (no common name). Species of interest because of its isolation, appearance, and behavior (a “heroic” species). Easily detectable and identifiable.

3. Order: Lepidoptera (butterflies and moths).

(a) Family: Papilionidae (swallowtails and parnassian butterflies).

- (1) *Battus philenor* (pipevine swallowtail). A common and conspicuous, easily recognizable species. Population numbers may indicate general environmental conditions. It is a monophagous herbivore as a larva and multiphagous nectar feeder as an adult.

(b) Family: Danaidae (milkweed butterflies).

- (1) *Danaus gilippus* (queen butterfly). A common and conspicuous, easily recognizable species. Population numbers may indicate general environmental conditions. It is a polyphagous herbivore as a larva and multiphagous nectar feeder as an adult.

(c) Family: Lycaenidae (copper, hairstreak, blue, harvester, and metalmark butterflies).

- (1) *Strymon melinus* (melinus hairstreak). A common and conspicuous, easily recognizable species. Population numbers may indicate general environmental conditions. It is a multiphagous herbivore as a larva and multiphagous nectar feeder as an adult.
- (2) *Leptotes marina* (marina blue). A common and conspicuous, easily recognizable species. Population numbers may indicate general environmental conditions. It is a polyphagous herbivore as a larva and multiphagous nectar feeder as an adult.

- (3) *Euphilotes battoides martini* (battoides blue). Selected as a species of special interest. It was recorded in 1942 but not since. It would be an eastern distribution record if it still occurred in the monument.

(d) Family: Pieridae (white, sulphur, and orange-tip butterflies).

- (1) *Eurema nicippe* (nicippe sulphur). A common and conspicuous, easily recognizable species. Population numbers may indicate general environmental conditions. It is a polyphagous herbivore as a larva and multiphagous nectar feeder as an adult.
- (2) *Ascia howarthi* (Howarth's white). Selected as a species of special interest, its distribution in the United States is limited to a small portion of the monument. It is dependent on a special-status plant for its larval food.

4. Order: Hymenoptera (sawflies, parasitic wasps, ants, wasps, and bees).

(a) Family: Apidae (bumble bees, honey bees, and orchid bees).

- (1) *Apis mellifera* (honey bee). Selected because it is introduced, important as a pollinator and potential danger to visitors, is generally abundant, conspicuous, and identifiable. Its population size may indicate general environmental conditions. Scientists from the United States Department of Agriculture (USDA) Bee Research Laboratory have long-term studies ongoing in the monument, and these should be continued.

(b) Family: Formicidae (ants).

- (1) *Pogonomyrmex* spp. (harvester ants). Selected because they are conspicuous, and the genus is easily identifiable (although the species are not easily identifiable). They are seed harvesters, and population size may be indicative of general environmental conditions. There may also be a relationship between populations and degree of recovery from grazing.
- (2) *Aphaenogaster cockerelli* [syn. *Novomessor cockerelli*] (no common name). An abundant, widespread, easily identifiable ant, this species is primarily a predator on insects. Its population size may be indicative of general environmental conditions and the abundance of prey species.
- (3) *Acromyrmex versicolor* (leaf cutter ant). An abundant ant in deep soils, this species was selected because it may be of interest to visitors, because of ease in identifying and counting its colonies, and because it may indicate general environmental conditions.

- (4) *Atta mexicana* (Mexican leaf cutter ant). elected because the only known U.S. population is found in the monument. Dr. Alex Mintzer has long-term studies ongoing in the monument, and these should continue.

5. Order: Araneae (spiders).

- (a) Family: Agelenidae (grass and funnel-web spiders).

- (1) *Agelenopsis* spp. (funnel-web spiders). Selected because they are easily detectable predators and may be indicative of prey population sizes and general environmental conditions.

- (b) Family: Lycosidae (wolf or ground spiders).

- (1) *Lycosa "carolinensis"* (wolf spider). Selected because they are easily detectable predators and may be indicative of prey population sizes and general environmental conditions.

Monitoring these selected species may be of some benefit in increasing understanding of them and (provided that all other potentially important environmental variables are measured simultaneously) may lead to correlative observations with environmental variables. It is possible that, given sufficient time and accuracy of observations, such correlative observations may eventually enable development of useful predictive indicators. However, it must be clearly understood that monitoring just these taxa would be totally inadequate as a monitoring program. Our observations of invertebrates in the monument took place over a short period of time and under unusual weather conditions. To really understand the invertebrates of the monument and what fluctuations in their populations might mean, continuation and intensification of the general sampling begun in the EMP must continue. It is quite possible that some, or most, of the taxa listed above will not be of value in reaching the goals of a management-oriented monitoring program, and that some other taxa may be of greater value.

## Methods

### Tier 1

Tier 1 is a continuation of the research program conducted from 1987 to 1990 and uses essentially the same methodology. It proposes that the same approach be continued over an indefinite period of time, using the same sites and personnel with qualifications similar to those involved in the original project. A rotating schedule of site visits must be developed over time, so that each site can be visited at each season during a 4-year rotation, and high priority sites (to be determined by the EMP Synthesis Committee) can be visited at the same season each year.

At each site visit, the team will conduct a general reconnaissance, noting or collecting representatives of all easily visible macroinvertebrates. Identification by sight will be acceptable only if the observers are sufficiently familiar with the species to make specific determinations in the field. Specimen records afford the most reliable means of making determinations, and specimens should be collected whenever field identification is questionable. Sampling should be done in a minimally disruptive manner, so as to limit environmental impact. A site visit form (Appendix 8-1) will be completed for each site visit.

On each site, the investigators will do a walking reconnaissance, searching for invertebrates present. Special efforts must be made to examine representatives of plants in bloom or in fruit, and all microhabitats evident on the site. Sweep nets and beat sheets should be used on stands of vegetation, as deemed appropriate by the investigators. Where appropriate, rocks and other objects on the ground should be turned over to search for invertebrates. These must be carefully replaced. If standing water is available on the site, the investigators will use dip nets to sample aquatic fauna, and watch the water to observe and collect visiting fauna. When encountered, dead animals and rotting cacti should be observed and probed to capture insects present in them. No major attempt will be made to collect or sample subterranean, wood-inhabiting, litter, or soil invertebrates, and no attempt will be made to sample parasites.

After dark, portable blacklights will be set up at each site to sample insects attracted to them. A standard set-up using a white sheet and 15-watt battery-powered blacklight will be used. Investigators will collect representative specimens of all insects that come to the lights. Blacklighting will continue for at least 2 hr after dark, or until the investigators determine that insect activity has decreased and new taxa are no longer arriving. Visual searches of the ground and plants will also be made after dark. A short-wave ultraviolet light will be used to search for fluorescing scorpions.

Specimens will be killed by use of ethyl acetate killing jars or by plunging them into alcohol, or by pinching as taxonomically appropriate. Specimens will be properly mounted for deposition into the permanent collection. Specimens will be identified by comparison with the permanent collection and by contracting with competent systematists where appropriate.

Notes will be kept for each specimen or observation, recording the location and circumstances, including plant species at which the animal was found, if it can be identified. A record form (Appendix 8-2) will be filled out for each specimen or observation. Record numbers are not necessarily sequential or meaningful except that each specimen shall have a unique number identifying it. Observations all use the record number 9999. Data from these forms will be entered into the dBase-III database provided to the monument as part of the original research program. Appendix 8-3 lists the structure of the database. Annually, the database will be used to compile species accounts and site-taxa lists, similar to those in the report on the original research project. An annual report, summarizing the sites visited, dates, personnel, techniques, and observations, including taxonomic summaries, will be made.

No specific efforts will be made to sample suggested “indicator species” or invertebrates associated with special-status plants. These taxa will be sampled as they are encountered using the above described methods. Special reports for each taxon can be generated from the database, as can lists of invertebrate taxa associated with special-status plants.

## **Tier 2**

The methodology discussed in Tier 2 is that which, in my opinion, is the minimum necessary to allow development of sufficient understanding of invertebrate ecology to permit construction of predictive or determinative models. It includes detailed procedures for the study of suggested “indicator species” and invertebrates associated with special-status plants. If desired, any single project outlined below may be extracted and carried out independently of the others. Many of the techniques in Tier 2 have not been field tested in the monument, and may require modification as the work progresses.

The following techniques must be used simultaneously at all sites to be compared in order to enable accurate comparison of data. Simultaneous timing of sampling, standardization of technique, a high level of expertise of observers (field tested to ensure inter-observer reliability), and standardization of equipment are necessary if data are to be considered comparable between sites. In order to provide environmental data that may be useful in interpreting potential reasons for fluctuation in invertebrate populations, all sites must simultaneously be sampled for temperature, rainfall, humidity, wind, cloud cover; vegetation variables including distribution, abundance, and phenology of plants; presence of or distance from surface and ground water; and environmental contaminants such as insecticides and other air pollutants. By “simultaneous,” I mean at the same time on the same day, at least for most variables. Perceived invertebrate numbers fluctuate hourly, or with an increase in wind speed or the passage of the sun behind a cloud. Accurate comparisons of invertebrate populations between sites cannot be expected if data are acquired under less than simultaneous conditions.

### *General Techniques*

The techniques used by the EMP team should be continued at all sites, with a few modifications to facilitate standardization. To enable comparison of data through the range of seasons and weather conditions, each site should be visited at least once a month, preferably during the dark moon phase. All of these techniques are relative and will yield information on only the presence,

relative abundance, plant and/or microhabitat associations, and activity of taxa. Because the sites vary in size, topography, habitats, and configuration, these techniques must be adapted to each site. For example, it is of little relevance to say “turn over 100 rocks between 6 in. and 1 ft in diameter at each site,” or “examine 100 flowers of each species encountered.” These techniques include:

1. Sample only easily visible macroinvertebrates, in a minimally disruptive manner.
2. On each site, conduct a walking reconnaissance of all invertebrates present. Examine representatives of all plants in bloom and all microhabitats present on the site. Collect or positively identify every invertebrate taxon observed. Record plant associations, microhabitat, and relative abundance. Use sweep nets and beat sheets for sampling vegetation. Turn over rocks and other objects, being careful to replace them. If standing water is available, sample the aquatic fauna by observation and dip nets, and observe the water to collect visiting animals. A site visit form (Appendix 8-1) will be prepared for each site visit.
3. At each site, place a medium-sized dead cottontail rabbit in an open area and observe invertebrates attracted to it over a period of at least 3 days, examining the carcass at least twice during daylight and twice during darkness. Collect specimens of all taxa and record the time after placement of the bait that the collection was made.
4. Wherever and whenever encountered, rotting cacti should be thoroughly examined to obtain specimens of invertebrate inhabitants. Species of cactus, estimated time since death, relative abundance of invertebrates, and position of invertebrates should be recorded.
5. Operate blacklight traps from sunset to sunrise. The same model trap must be used at all sites. Operators must observe the traps and remove specimens at frequent intervals to prevent dying insects from damaging previously collected specimens in the traps.
6. After dark, use short-wave ultraviolet lights to search for fluorescing scorpions.
7. At sites where soil conditions permit, place pitfall traps in all apparent microhabitats. The number of traps to be used will depend upon conditions at each site, but should be sufficient to sample the ground- surface fauna. Traps will be plastic 16-ounce cups, sunk level with the ground surface, covered with wooden shingles placed on small stones, filled with ethylene glycol, and checked periodically during daylight and dark hours to enable release of trapped vertebrates and preservation of invertebrates collected. Traps shall be permanently installed, but closed except during the monthly site visit by the monitoring team.
8. Specimens must be mounted or otherwise processed in the appropriate fashion. A record form (Appendix 8-2) will be prepared for each specimen or observation.

9. Taxonomic determinations must be made by professionals or expert amateurs. Experts on specific taxonomic groups should be contacted, and arrangements made for them to make determinations for difficult groups.
10. Identified specimens will be integrated into the existing collection at the monument. Data for each specimen or observation will be entered into the existing database (Appendix 8-3). Annual reports will be generated for all sites, indicating the taxa observed. Included with each report will be data on environmental variables and taxonomic summaries.
11. This methodology will be continued for at least 10 yr, after which review of all data will determine the potential value or necessity of continuing the program. This review will consider variability of data as the primary determining factor in estimating the length of time this program will continue.

### *Specific Techniques for Indicator Species*

The following techniques are suggested as potentially useful for increasing our understanding of the proposed indicator species.

**Quitobaquito Tryonia.** Because the entire known population of this species is restricted to the aquatic habitats of Quitobaquito, Williams, and Burro Springs, monitoring will be fairly simple and can be carried out by monument staff. Current understanding is that the population is limited to specific sites within these aquatic habitats, but this is based on a limited number of observations. Additional searches must be made of Aguajita Spring to be certain the species does not occur there. To further understand the population biology of this species, a detailed study is proposed, consisting of the following steps:

1. Observers will be trained in the recognition of this species by examining specimens in the monument museum collection.
2. Monthly, for at least 5 yr, the entire population will be counted by carefully examining the available habitat at the above-mentioned springs (including Aguajita Spring). This will require examination of substrate, including submerged soil, leaves, plant stems and other objects *in situ* with hand lenses. Individual snails will be sorted into size classes, which will be presumed to be indicative of age classes. This data will enable estimates of survival and reproduction over time, and yield information on the reproductive biology of the species.
3. Distribution within the habitat will be mapped at each monthly count.
4. Results of monthly counts and distribution mapping will be used after 5 yr to generate a simplified sampling system that will facilitate population estimates in the future.

**Ajo Mountains Snail.** The known distribution of this snail is restricted to canyons in the Ajo Mountains. This species is active only under rare weather conditions. It is not currently protected from handling, marking, or other disturbance. Therefore, a simple monitoring program for this species is:

1. Trained observers will be ready to go immediately whenever appropriate weather conditions occur (during rainfall in the habitat). A sufficient number of observers will be available to survey all areas simultaneously. Seven areas are to be surveyed, and observers will work best in teams of 2 people, for a total of at least 14 trained observers needed to be on hand throughout the rainy season each year. Monitoring this species is sufficiently simple that no great level of training is required for observers.
2. Observers will be trained in the identification of this snail from examination of specimens in the monument museum collection.
3. Observers will walk along consistent routes and trails during each rainfall event affecting the 7 survey areas during the summer rainy season. Routes, once established, will be consistent. Observers will use headlights for observation in darkness. Observers will count all individuals of the species seen within 1 m (3 ft) of both sides of the survey trails.
4. Each snail will be marked on the smooth side of its shell, using indelible non-toxic ink with a number code indicating canyon and sequential number (e.g., ALS235 for the 235th snail recorded in the south fork of Alamo Canyon). Marked snails will be released exactly where they were found. For each snail encountered, observers will record: reference number; precise location in meters from start of route; date and time of observation; substrate; number of other snails within 1-m (3-ft) radius; observer; amount of rainfall at nearest station in the 24 hr preceding the observation; number of days since last observation of that individual snail; apparent food of the snail if feeding is observed; and size of snail measured as greatest diameter of shell, in millimeters. Subsequent records of each marked snail will be tied to the reference number in the snail database. The snail database will be a dBase III database that includes all of the data recorded for each snail.

***Trimerotropis pallidipennis.*** Monitoring this species will be done as part of the monthly general monitoring of each site. The technique to be used is quite simple: count all individuals of this species encountered along 5, 100- x 1-m (328- x 3-ft) transects in each area. Origin of transect lines may differ with each count. This technique is suitable for the relatively open, lowland sites but is not suitable for canyon sites. For canyon sites, the number of individuals of this species encountered along the main trail to and through the site will be sufficient as the only appropriate statistic. For riparian sites, transects should be placed parallel to and at least 5 m (16 ft) away from corridors of dense vegetation. Data from open sites may be compared with each other, provided transects are run simultaneously, and will yield absolute counts (individuals per unit area). For canyon and riparian sites, data will indicate relative trends only and cannot be accurately compared to the other sites. These transects can also be used for monitoring the following other species: *Ligurotettix coquilletti*, pipevine swallowtail, queen butterfly, melinus hairstreak, nicippe sulphur, marina blue, honey bee, funnel-web spiders, and wolf spider.

The primary complicating factor in monitoring this species is that it is often difficult to detect and accurately identify. At least 8 other species (none having common names)—*Conozoa carinata*, *C. sulcifrons*, *C. texana*, *Derotmema delicatulum*, *D. laticinctum*, *Encoptolophus subgracilus*, *Lactista aztecus*, *L. gibbosus*—sufficiently resemble this species that identification may be confused in the field, even by an expert entomologist. Observers must be thoroughly familiar with the target species and the similar nontarget species, and must proceed slowly along transects.

***Ligurotettix coquilletti*.** Use the same transect technique discussed above for *Trimerotropis pallidipennis*, only count the number of individuals of this species that are heard along the transect lines, rather than the number seen. This is a cryptic species that will not often be seen, but can easily be detected by sound. For each individual detected, record the plant species from which it was calling and the number of grasshoppers calling from each individual plant that had any of this species.

***Taeniopoda eques*.** Insofar as is known, based on the limited data collected during the 3-yr EMP program, this grasshopper is limited in distribution to the Ajo Mountains in the monument and is active only in August, September, and October. Repeating the count annually over several years and recording the first (lowest) and last (highest) points at which this species is seen, will more closely define the distribution of the species within available habitat. Measuring the length of trail between first and last points and defining the width of the transect as the average distance from the observer that individuals can be readily detected (these measures must be empirically developed in the field) will enable estimates of number per unit area.

Because this location is a distribution extreme for the species, data on the population in this location will be essentially meaningless without reference to the metapopulation. Therefore, monitoring this species in the monument will only make sense if it is a component of a monitoring program throughout the species range or at least throughout the range in Arizona. The species is distributed primarily in the Chihuahuan Desert from Arizona to Texas and south through Mexico to Costa Rica. In Arizona, isolated populations occur in desert grassland habitats in Sonoran mountain ranges, with abundance apparently increasing eastward (pers. obs.). To enable interpretation of data derived from counts in the monument, counts must also be taken in several other mountain ranges, including at least the Baboquivaris, Santa Ritas, Catalinas, and Chiricahuas, at the same time of year and using the same technique.

**Pipevine Swallowtail.** Adults can be counted along transects as discussed above for *Trimerotropis pallidipennis*. However, observations of adults will yield only a small part of the information needed to understand this species and its distribution in the monument in time and space. Adults are strong fliers and range over large areas that may not be suitable for reproduction. To improve our understanding, counts of larvae will be necessary. Larvae are confined to the indian-root plant (*Aristolochia watsoni*) and are found in summer and fall months. The food plant is generally distributed throughout the monument. Monitoring will consist of locating plants within each site, calculating the number of plants per unit area, and counting and measuring the caterpillars and pupae on each plant. Sample size cannot be predicted

without actually determining the abundance and distribution of the plants and caterpillars on them.

**Queen Butterfly.** Adults can be counted along transects as discussed above for *Trimerotropis pallidipennis*. However, observations of adults will yield only a small part of the information needed to understand this species and its distribution in the monument in time and space. Adults are strong fliers and range over large areas that may not be suitable for reproduction. To improve our understanding, counts of larvae will be necessary. Larvae are confined to milkweed plants (family Asclepiadaceae) and are found in summer and fall months. The food plants are generally distributed throughout the monument. Monitoring will consist of locating plants within each site, calculating the number of plants per unit area, and counting and measuring the caterpillars and pupae on each plant. Sample size cannot be predicted without actually determining the abundance and distribution of the plants and caterpillars on them.

**Melinus Hairstreak.** Adults can be counted along transects as discussed above for *Trimerotropis pallidipennis*. However, observations of adults will yield only a small part of the information needed to understand this species and its distribution in the monument in time and space. Larvae are multiphagous, and their specific food plants within the monument are not known. Understanding this species and the determinants and correlates of its abundance requires an understanding of its food plants, their phenology and abundance, as well as competitors, predators, parasitoids, diseases, and weather conditions that might affect its population. Larvae, especially at early stages of development, are very difficult to detect and distinguish from many other species. An adequate study of this species that would lead to ability to interpret fluctuations in number of adults observed would be much too complex and expensive for NPS to carry out. Therefore, I suggest dropping this species from consideration.

**Nicippe Sulphur.** The same considerations discussed above for the melinus hairstreak apply to this species.

**Marina Blue.** The same considerations discussed above for the melinus hairstreak apply to this species.

**Howarth's White.** The considerations discussed above for *Taeniopoda eques* apply to this species. However, monitoring this species is further complicated by the differences between larvae, pupae, and adults. Larvae are entirely dependent on the rare desert-caper plant. The plant within the United States is limited to a few individuals, which have been located and mapped by the EMP team studying special-status plants.

To understand the biology of the butterfly, a detailed study must begin with careful examination (at least weekly) of every food plant for the presence of eggs, larvae, and pupae. If this is done every week for at least 5 yr in conjunction with measurement of environmental variables, a rudimentary life table for the species can be prepared and our understanding of the species will be increased. In this case, environmental variables should include: temperature, rainfall, humidity, wind, cloud cover; phenology of plants; presence of or distance from surface and

ground water; and environmental contaminants such as insecticides and other air pollutants. Also, the effects of monitoring need to be considered.

To effectively and economically monitor adults, we need to know the optimum times and conditions for adult activity. This can only be done by the inefficient and expensive method of monitoring adults around the clock and around the year. The number of years that this must be done cannot be determined at this time because it depends on variability of data. The simplest way to do this is to station observers at each desert-caper plant from sunrise to sundown every day, each observer recording the number of adults seen each hour. These observations can then be correlated with time, date, and environmental variables to reduce the number of days and hours of observation to a more economic level. Observers do not need to be professional entomologists, but must be trained in distinguishing this species from the other white butterfly species. The same observers could possibly do the weekly immature butterfly counts. Immature counts must be done on a random or rotating schedule so as not to confuse data on adults. (i.e., immature counts done consistently from 1000 to 1200 might disturb adults in such a way that observers might conclude they are not active during those hours, when in fact these might be the optimum hours of adult activity.)

Ehrlich (1984) reports that adult food resources are as important for butterfly populations as are larval food resources. Nectar resources near larval food plants also must be monitored. Adults must be observed feeding and food plants recorded until all plants utilized are known. Plant phenology studies and abundance estimates must be made for all known butterfly feeding plants within 0.8 km (0.5 mi) of each desert-caper plant through the time span of the monitoring program. These data must be considered in any interpretation of observed fluctuations in butterfly numbers.

If conclusions are to be drawn from the results of monitoring this species, it is imperative that similar monitoring be done simultaneously at other sites within the species range. Because this species is primarily located in Mexico, arrangements will need to be made to conduct these studies in that country.

**Battoides Blue.** We do not know whether this species is still part of the monument fauna. Therefore, the first step in monitoring this species is to determine its presence. Unfortunately, subspecies determination is not easy, and must be done by an expert who is familiar with this taxon. This butterfly is active in spring and is most likely to be found near California buckwheat (*Eriogonum fasciculatum*), its food plant in the Ajo Mountains. Alternative approaches for determining its presence would be to:

1. Have monument staff collect all observed spring Lycaenids from California buckwheat plants in the Ajo Mountains and submit them to an expert for identification; or,
2. Hire an expert on a short-term (annually renewable) contract to attempt to find the butterfly during the season when it is most likely to be present.

Either alternative should continue until (1) the butterfly is found, or (2) for at least 10 yr to ascertain that it is not present.

Again, the same problems occur with this taxon that were discussed in the above sections dealing with other marginal taxa. Meaningful data cannot be obtained searching for this taxon in isolation without comparison to other locations at which the taxon is found. If the taxon is found and considered to be worth further study, a program similar to those discussed for the pipevine swallowtail and queen butterfly should be followed.

**Honey Bee.** In addition to current research undertaken by scientists with the USDA Bee Research Lab, monitoring activities for this species should include:

1. Annually locating all honey bee hives on the monument. This will be done by a combination of (1) thoroughly exploring the entire monument on foot, marking and following honey bees at flowers and bee tables, and (2) compiling observations of staff and visitors. Visitors, especially those receiving backcountry use permits, will be encouraged by staff to report the exact locations of all bee hives encountered. These reports will be followed up by a staff member. Locations of all bee hives will be plotted on a map of the monument. The map will be updated annually.
2. Obtain a sample of at least 100 worker bees and a piece of brood comb from each hive annually. Submit these samples to the USDA Bee Research Lab for analysis to determine genetic strain of bees. A cooperative research agreement, and possibly funding, for this must be obtained. As the Africanized strain becomes established, plot its spread through the monument.
3. Working under the direction of USDA researchers, install beehives with pollen traps at all EMP sites or install pollen traps on wild bee hives. Follow the currently used USDA protocol to collect pollen weekly at each site. Concurrently, conduct weekly plant phenology studies to determine abundance and taxa of pollen sources on each site, so that pollen collected by bees can be compared to the available resources.

**Harvester Ants, Leaf cutter Ant, and *Aphaenogaster cockerelli*.** These can be monitored simultaneously, as all are ants that make conspicuous nests. Population fluctuations at the nest level will be monitored. For each EMP site, the monitoring team will annually (in August or September) locate every nest of these ant taxa. Scheduling will depend on ant activity, so that active individuals can be observed at nests. For harvester ants, observers will collect specimens and identify them to species. All nests will be marked in the field by inserting a number-tagged nail in the ground, near the primary nest entrance. Numbers will be sequential for each site. Each nest will be plotted on a map of each site. In subsequent years, previously tagged nests will be examined to determine their viability, and new nests will be plotted. For each nest, record reference number, species, location, date, year first located, active or inactive, living or dead. This must continue over at least 10 yr and environmental variables must be recorded concurrently. To the standard list of environmental variables, density determinations of annual

plants must also be added. With sufficient data, it may be possible to understand determinants of (or at least correlations with) ant population fluctuations.

**Mexican Leaf cutter Ant.** A monitoring program for this species has been begun by Mintzer, and should continue. All existing nests will be identified and mapped annually. This species apparently is found primarily (or only) along washes, and nests (at least mature nests) are fairly conspicuous. Adult ants are unmistakable. Therefore, professional entomologists are not necessary to monitor this species. Training will consist of trainees being led to known nests and shown active adults. Monitoring will consist of observers walking along all washes in the monument at least once every year, searching for nests. Scheduling can be at the convenience of monument staff, but must ensure that all potential habitat is searched annually. Nests will be permanently marked with numbered nails and plotted on a map of the monument. Population data will be compared to data for environmental variables to search for correlations.

The same considerations discussed above for other marginal species must be included in monitoring this species. Study of this isolated population will mean little if it is not compared to similar studies of the species throughout its range. Because this species is located primarily in Mexico, arrangements will need to be made to conduct monitoring studies in that country.

**Funnel-web Spiders and Wolf Spider.** These can be monitored together, as part of the transects used to monitor *Trimerotropis pallidipennis*, discussed above. On transects, active webs and turrets will be counted and recorded.

#### *Invertebrates Associated with Special-status Plants*

Our present understanding of invertebrates associated with special-status plants is inadequate. To develop our understanding, detailed, long-term studies of each plant species must be undertaken. Appropriate techniques will not be the same for each plant species, but will depend upon the form of the plant, its abundance, and its distribution. Essential components of a monitoring program that will apply to all special-status plants are:

1. To locate populations of the plants within the monument. The EMP special-status plants team has mapped the known distribution of these plants within the monument.
2. To select representatives of each plant taxon for detailed study. The number of representatives selected will depend, in part, on the abundance of the plants. The sample must contain plants of all age classes, and, where possible, enough individuals to permit statistical analysis of data. Because invertebrate distribution is likely to be clumped rather than uniform or random, the sample size must be large. Also, adequate examination of plants will be at least partially destructive, so special permits may be required.
3. At least monthly, to examine the selected plants in detail for invertebrates and their signs, including:
  - (a) Eggs, larvae, pupae, and adults.

- (b) Feeding damage to leaves, stems, roots, shoots, flowers, seeds, and fruits.
  - (c) Flower visitors, seed predators and internal consumers, and fruit consumers.
  - (d) Predators and parasitoids affecting all taxa found to feed on or pollinate special-status plants.
4. To submit specimens of invertebrates to taxonomic experts for identification.
  5. To rear out and identify all immature stages found in association with the plants.
  6. To determine what proportion of the sample and population of plants is utilized and affected by each invertebrate taxon and the impacts caused by such utilization. This may involve isolating a sample of plants from invertebrates and comparing plants with and without invertebrate access.
  7. For plants that are at the margins of their known distribution in the monument, it will be necessary to conduct similar studies at other locations within the species ranges.
  8. These studies must continue over a long enough period of time to allow for the possibility of outbreaks of damaging invertebrate populations that might not be apparent under most conditions. A minimum period of 10 yr would be appropriate.

## **General Considerations, Tier 1 and Tier 2**

### *Personnel*

It became evident during the course of the SENECPRO invertebrates project that there was a great deal of difference between observers in their ability and/or propensity to find, identify, collect, and estimate numbers of invertebrates. This difference existed even between professional entomologists, with training at the M.S. or Ph.D. level, many years of field experience, and specific instructions and protocols.

If data gathered in a monitoring program are to be consistent and reliable enough to have any meaning or potential utility, it is imperative that all personnel involved have at least the level of expertise and training of the EMP invertebrates team. An adequate job of monitoring cannot be done on a part-time basis by minimally trained monument staff. Whereas such staff may be able to contribute some useful data on a few taxa, and may be able to provide assistance to professionals, they cannot be expected to generate the kinds of data necessary for effectively monitoring invertebrates. Therefore, successfully carrying out either Tier 1 or Tier 2 depends upon provision of sufficient funding to field enough teams of professional entomologists to carry out the procedures described. Tier 1 procedures can be carried out with 1 or 2 teams. Tier 2 requires several teams to allow comparison of sites, and requires an intensive training period for these personnel to enable them to develop a high level of inter-observer reliability.

Both Tier 1 and Tier 2 methodology requires participation of professional entomologists, with some assistance from nonprofessionals. The primary difference between the tiers is the number

of professionals needed. Tier 1 can be carried out with no more than the number used in the initial research program (4). Indeed, it would be possible to carry out a minimal program with only 1 team of professionals, especially if highly motivated and competent non-professionals were available to conduct field work and specimen preparation. Tier 2 requires an expanded number of professionals.

Both tiers require the involvement of expert systematists for the determination of taxa. These can be remote from the site and hired on a fee-for-specimen basis. The existing collection at ORPI is an excellent reference collection and can be used as a basis for taxonomic determination for those taxa that can easily be identified by sight comparison.

### *Reliability and Comparison Between Sites*

The methodology of Tier 1 does not allow effective comparison between sites, because it precludes simultaneous sampling. However, because it utilizes only a small number of observers, reliability may be fairly good. Tier 2 methodology permits fairly accurate comparison between sites but reduces inter-observer reliability.

### **Nomenclature Authorities**

In this work, invertebrate nomenclature of the higher groups (orders, families, subfamilies and genera) generally follows Arnett (1985) for insects, Roth (1985) for spiders, Borror et al. (1981) for other arthropods, and Bequaert and Miller (1973) for mollusks. Determination and nomenclature at the specific (and in a few cases subspecific) level is based on the use of monographs on the taxa, consultation with experts, and comparison of our specimens to identified specimens in the collection of The University of Arizona Entomology Department.

Butterfly nomenclature follows Bailowitz and Brock (1991), while that of grasshoppers, crickets, and katydids follows Otte (1981, 1984).

Plant order and nomenclature follows the Checklist of Vascular Plants of Organ Pipe Cactus National Monument, Arizona, published by Southwest Parks and Monuments Association, 1985.

Common names appear when either an official common name has been assigned (Stoetzel 1989), or the insect is a butterfly given a common name in Tilden and Smith (1986). Advances are continuously being made in invertebrate taxonomy and identification, so names change with some frequency.

## Conclusions and Management Recommendations

In the opinion of this author, the cost of a meaningful program of monitoring invertebrates will greatly exceed an amount that the National Park Service (NPS) would be willing to pay and will be of questionable value. Present knowledge of the biology of invertebrates is insufficient to permit accurate interpretation of data on population fluctuations or to develop a useful, inexpensive monitoring program. We do not even know enough to develop a complete list of questions for further research that might lead to a knowledge base sufficient for a monitoring program. The period of study of this project was too short and impacted by drought to enable drawing any more useful conclusions. Continued research, including widespread sampling of all invertebrates and concentration on developing basic understanding of some of the species present, is warranted as a way of better understanding all components of our environment. But the utility of data on invertebrate populations in resource management or prediction of environmental changes is not apparent and is not likely, in itself, to justify further work or conclusions regarding environmental variables. It would increase understanding of invertebrates in the monument, and may eventually enable a narrowing of focus to study specific taxa or questions. The monitoring program described here is presented as a foundation for developing a long-term monitoring program.

Tier 1 is a minimalist program of continuing the research conducted from 1987 to 1990. It will yield the same kind of qualitative data and very rough quantitative data obtained in that program, and may be useful in increasing understanding of the role of invertebrates in the monument ecosystems. It may set the stage for additional research that can be more narrowly focused on specific organisms and/or situations. But it is unlikely to enable development of descriptive or predictive models.

The monitoring program presented as Tier 2 may seem overly ambitious and will be extremely expensive and difficult to carry out. However, in the opinion of this author, it is the minimum program necessary to achieve the goals described by NPS staff, formally and informally, for an invertebrates monitoring program. Even if this program is fully executed, it is quite possible that results will be inconclusive and inadequate for the purposes desired by resource management staff. If undertaken, this program will be the most ambitious study of wild invertebrates in wild landscapes ever done and may make an enormous contribution to science.

## Literature Cited

- Arnett, R. H. 1985. American insects: a handbook of the insects of America north of Mexico. Van Nostrand Reinhold Co., New York. 850 p.
- Bailowitz, R. A., and J. P. Brock. 1991. Butterflies of Southeastern Arizona. Sonoran Arthropod Studies, Inc., Tucson, Arizona. 342 p.
- Bequaert J. C., and W. B. Miller. 1973. The mollusks of the arid southwest. The University of Arizona Press, Tucson. 271 p.
- Borror, D. J., D. M. De Long, and C. A. Triplehorn. 1981. An introduction to the study of insects. Saunders College, Philadelphia, Pennsylvania. 827 p.
- Capinera, J. L., and D. C. Thompson. 1987. Dynamics and structure of grasshopper assemblages in shortgrass prairies. *Canadian Entomologist* 119:567–575.
- Ehrlich, P. R. 1984. The structure and dynamics of butterfly populations. P. 25–40 in R. I. Vane Wright and P. R. Ackery, eds. The biology of butterflies. Symposium of the Royal Entomological Society II. Academic Press, London, England.
- Ehrlich, P. R., and D. D. Murphy. 1987. Conservation lessons from long-term studies of checkerspot butterflies. *Conservation Biology* 1:122–131.
- Garth, J. 1944. Butterflies of the Organ Pipe Cactus National Monument, Arizona. *Entomological News* 55:119–124.
- Joern, A., and K. P. Pruess. 1986. Temporal constancy in grasshopper assemblies (Orthoptera: Acrididae). *Ecological Entomology* 11:379–385.
- Murphy, D. D., K. E. Freas, and S. B. Weiss. 1990. An environment-metapopulation approach to population viability analysis for a threatened invertebrate. *Conservation Biology* 4:41–51.
- Murphy, D. D., and S. B. Weiss. 1988. A long-term monitoring plan for a threatened butterfly. *Conservation Biology* 2:367–374.
- Otte, D. 1981. The North American grasshoppers. Vol. 1. Acrididae: Gomphocerinae and Acridinae. Harvard University Press, Cambridge, Massachusetts. 275 p.
- Otte, D. 1984. The North American grasshoppers. Vol. 2. Acrididae: Oedipodinae. Harvard University Press, Cambridge, Massachusetts. 366 p.

- Otte, D., and A. Joern. 1975. Insect territoriality and its evolution: population studies of desert grasshoppers on creosote bushes. *Journal of Animal Ecology* 44:29–54.
- Roth, V. D. 1985. Spider genera of North America. Privately published. n.p.
- Southwest Parks and Monuments Association. 1985. Checklist of vascular plants of Organ Pipe Cactus National Monument, Arizona. 32 p.
- Southwood, T. R. E. 1978. Ecological methods with particular reference to the study of insect populations. Chapman and Hall, London and New York. 524 p.
- Stoetzel, M. B. (Chairman). 1989. Common names of insects and related organisms. Entomological Society of America, Lanham, Maryland. 199 p.
- Tilden, J. W., and A. C. Smith. 1986. A field guide to western butterflies. Houghton Mifflin Co., Boston, Massachusetts. 370 p.
- Wallner, W. E. 1987. Factors affecting insect population dynamics: differences between outbreak and non-outbreak species. *Annual Review of Entomology* 32:317–340.

Appendix 8-1

**Invertebrate Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Site Visit Report Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

**ORPI Ecological Monitoring Program—Invertebrate Monitoring  
Site Visit Report Form**

Date \_\_\_\_\_ Site \_\_\_\_\_

Investigators \_\_\_\_\_

Time arrived \_\_\_\_\_ Time left \_\_\_\_\_ Total hours on site \_\_\_\_\_

Activities of team on site \_\_\_\_\_

General impressions and observations \_\_\_\_\_

Weather: General description \_\_\_\_\_

Temp. range \_\_\_\_\_ Humidity \_\_\_\_\_ Clouds \_\_\_\_\_

Wind: Force \_\_\_\_\_ Direction \_\_\_\_\_ Constancy \_\_\_\_\_

Rain: During trip, amount and duration \_\_\_\_\_

Rain: Days since last \_\_\_\_\_ Evidence of recent \_\_\_\_\_

Plants in bloom \_\_\_\_\_

Plants in fruit \_\_\_\_\_

Unusual conditions (*carrion, rotting cacti, surface water, recent disturbance, surface objects, etc.*) \_\_\_\_\_

**Sight records—no specimen**

Butterflies \_\_\_\_\_

Hymenoptera \_\_\_\_\_

Orthoptera \_\_\_\_\_

Other invertebrates \_\_\_\_\_

**Collections** (*List inclusive record numbers assigned to this visit and any special notes on collections. Use reverse side of this form if necessary.*) \_\_\_\_\_

**Appendix 8-2**  
**Invertebrate Monitoring Protocol for the**  
**Ecological Monitoring Program in**  
**Organ Pipe Cactus National Monument, Arizona:**  
**Specimen or Observation Report Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

**ORPI Ecological Monitoring Program—Invertebrate Monitoring  
Specimen or Observation Report Form**

Record No. \_\_\_\_\_

**Taxonomy**

Class \_\_\_\_\_

Order \_\_\_\_\_

Family \_\_\_\_\_

Subfamily \_\_\_\_\_

Genus \_\_\_\_\_

Species \_\_\_\_\_

Author \_\_\_\_\_

Determined by \_\_\_\_\_

Common name \_\_\_\_\_

**Ecology**

Location \_\_\_\_\_

Date \_\_\_\_\_ Time \_\_\_\_\_

Method (*blacklight, at plant, aquatic, at water, on ground, at nest, other*) \_\_\_\_\_

Plant \_\_\_\_\_

Other observations and notes \_\_\_\_\_

Collector or observer \_\_\_\_\_

**Specimen disposition**

Preparation (*P = pinned, A = alcohol, O = observation, X = other*) \_\_\_\_\_

Collection (*ORPI, UA, other*) \_\_\_\_\_

List name and address if "other" or temporarily out to someone \_\_\_\_\_

Data entered and complete (*yes or no*) \_\_\_\_\_

Appendix 8-3  
**Invertebrate Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monument, Arizona:  
 Database Structure (dBase III)**

<u>Field</u>	<u>Field name</u>	<u>Type</u>	<u>Width</u>	<u>Notes</u>
1	N	Numeric	4	9999 = observation; other numbers = specimen
2	CLS	Character	3	Classification— <i>INS = insecta, ARA = arachnida, etc.</i>
3	ORD	Character	3	Order— <i>first 3 letters</i>
4	FAM	Character	6	Family— <i>first 6 letters</i>
5	SUBFAMILY	Character	15	Subfamily— <i>first 15 letters</i>
6	GENUS	Character	20	Genus— <i>first 20 letters</i>
7	SPECIES	Character	20	Species— <i>first 20 letters</i>
8	AUTHOR	Character	25	Author(s)
9	DET	Character	20	Determined by
10	COMMONNAME	Character	25	Common name
11	LOC	Character	2	Two-letter location code— <i>see catalog</i>
12	DATE	Date	8	Date— <i>mm/dd/yy</i>
13	TIME	Numeric	4	24-hour time
14	COLLECTOR	Character	25	Collector or observer— <i>last name</i>
15	METHOD	Character	10	Method
16	PLANT	Character	25	Plant— <i>if known scientific name</i>
17	PREP	Character	1	Preparation— <i>A = alcohol, O = observation, X = other</i>
18	COLLECTION	Character	3	Collection location

Appendix 8-4

**Invertebrate Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
References on Techniques**

- Arnett, R. H. 1985. American insects: a handbook of the insects of America north of Mexico. Van Nostrand Reinhold Co., New York. 850 p. (Chapter 5, p. 31–52.)
- Borror, D. J., D. M. De Long, and C. A. Triplehorn. 1981 (or later editions). An introduction to the study of insects. Saunders College Press, Philadelphia. 827 p. (Chapter 33, p. 710–753.)

Appendix 8-5

## Invertebrate Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona: Checklist of Supplies for Monitoring and Collecting Invertebrates

The references cited in Appendix 8-4 (References on Techniques) include lists of equipment and supplies and instructions on how to use them. The following list is of equipment and supplies used and recommended by the author. Each worker will eventually develop his or her own personal list, based on experience and judgement.

<u>Field collecting</u>	<u>Laboratory equipment and supplies</u>
Nets— <i>aerial, sweep, dip</i>	Flat, white enamel sorting pan
Beat sheet	Insect pins— <i>assorted</i>
Killing jars— <i>large, medium, pocket</i>	Insect drawers
Ethyl alcohol	“Protom” block
Alcohol	Step block
Vials	Labels— <i>typed and photocopy-reduced to standard size</i>
Aspirator	Number labels
Carrying bag	Glue
Glassine envelopes	Relaxing jar
Plastic sandwich bags	Pinning forceps
Tissues	Minutens
Index cards	Double-mount pinning strips
Pencil	Spreading boards
Shovel	Drying cabinet
Hatchet	Fumigant
Long forceps	Binocular dissecting scope
Small forceps	Dissecting needles
Paintbrush	Eyedropper
Sorting tray	Petri dish
Gloves	Fine jewelers forceps
Ice chest	Dropping bottle— <i>for distilled water</i>
Blacklight	Dropping bottle— <i>for 80% alcohol</i>
Batteries	Scissors
Poles	Miscellaneous jars for rearing larvae
Cord	Computer database
Sheet	Shipping boxes— <i>to send specimens to experts</i>
Site Visit Report Form— <i>Appendix 8-1</i>	Specimen or Observation Report Form— <i>Appendix 8-2</i>

Appendix 8-6  
**Invertebrate Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Cross-referenced Index of Invertebrate Species Taxa**

The following index cross-references scientific taxa with common names for the invertebrate species named in this report.

**Index**

**—A—**

Acrididae (Family)—Short-horned grasshoppers  
*Acromyrex versicolor*—LEAF CUTTER ANT  
Agelenidae (Family)—Grass and funnel-web spiders  
*Agelenopsis* spp.—FUNNEL-WEB SPIDERS  
ANT (NO COMMON NAME)—*Aphaenogaster cockerelli* [syn. *Novomessor cockerelli*]  
ANT, LEAF CUTTER—*Acromyrex versicolor*  
ANTS, HARVESTER—*Pogonomyrmex* spp.  
Ants, sawflies, parasitic wasps, wasps, and bees—Hymenoptera (Order)  
Ants—Formicidae (Family)  
*Aphaenogaster cockerelli* [syn. *Novomessor cockerelli*]  
Apidae (Family)—Bumble bees, honey bees; and orchid bees  
*Apis mellifera*—HONEY BEE  
Araneae (Order)—Spiders  
*Ascia howarthi*—HOWARTH'S WHITE  
*Atta mexicana*—MEXICAN LEAF CUTTER ANT

**—B—**

*Battus philenor*—PIPEVINE SWALLOWTAIL  
BEE, HONEY—*Apis mellifera*  
Bees, bumble; honey bees; and orchid bees—Apidae (Family)  
Bees, honey; bumble bees; and orchid bees—Apidae (Family)  
Bees, orchid; bumble bees; and honey bees—Apidae (Family)  
Bees, sawflies, parasitic wasps, ants, and wasps—Hymenoptera (Order)  
BLUE, BATTOIDES—*Euphilotes battoides martini*  
BLUE, MARINA—*Leptotes marina*  
Blue, copper, hairstreak, harvester, and metalmark butterflies—Lycaenidae (Family)  
Butterflies and moths—Lepidoptera (Order)  
Butterflies, milkweed—Danaiidae (Family)  
Butterflies, orange-tip, white, and sulphur—Pieridae (Family)  
Butterflies, parnassian and swallowtails—Papilionidae (Family)  
Butterflies, sulphur, white, and orange-tip—Pieridae (Family)  
Butterflies, white, sulphur, and orange-tip—Pieridae (Family)  
BUTTERFLY, QUEEN—*Danaus gilippus*

—C—

CHECKERSPOT, BAY—*Euphydryas editha bayensis*

*Conozoa carinata*—NO COMMON NAME

*Conozoa sulcifrons*—NO COMMON NAME

*Conozoa texana*—NO COMMON NAME

Copper, hairstreak, blue, harvester, and metalmark butterflies—Lycaenidae (Family)

Crickets, grasshoppers, and katydids—Orthoptera (Order)

—D—

Danaidae (Family)—Butterflies, milkweed

*Danaus gilippus*—QUEEN BUTTERFLY

*Derotmema delicatulum*—NO COMMON NAME

*Derotmema laticinctum*—NO COMMON NAME

—E—

*Ecoptolophus subgracilus*—NO COMMON NAME

*Euphilotes battoides martini*—BATTOIDES BLUE

*Euphydryas editha bayensis*—BAY CHECKERSPOT

*Eurema nicippe*—NICIPPE SULPHUR

—F—

Formicidae (Family)—Ants

—G—

Grasshoppers, crickets, and katydids—Orthoptera (Order)

Grasshoppers, short-horned—Acrididae (Family)

—H—

HAIRSTREAK, MELINUS—*Strymon melinus*

Hairstreak, copper, blue, harvester, and metalmark butterflies—Lycaenidae (Family)

Harvester, copper, hairstreak, blue, and metalmark butterflies—Lycaenidae (Family)

Helminthoglyptidae (Family)—No common name

Hydrobidae (Family)—No common name

Hymenoptera (Order)—Sawflies, parasitic wasps, ants, wasps, and bees

—K—

Katydids, grasshoppers, and crickets—Orthoptera (Order)

—L—

*Lactista aztecus*—NO COMMON NAME

*Lactista gibbosus*—NO COMMON NAME

LEAF CUTTER ANT, MEXICAN—*Atta mexicana*

Lepidoptera (Order)—Butterflies and moths

*Leptotes marina*—MARINA BLUE

*Ligurotettix coquilletti*—NO COMMON NAME

Lycaenidae (Family)—Copper, hairstreak, blue, harvester, and metalmark butterflies

*Lycosa "carolinensis"*—WOLF SPIDER

Lycosidae (Family)—Wolf or ground spiders

—M—

Metalmark, copper, hairstreak, blue, and harvester butterflies—Lycaenidae (Family)  
Mollusca—Mollusks (phylum)  
Mollusks (phylum)—Mollusca  
Moths and butterflies—Lepidoptera (Order)

—N—

*Novomessor cockerelli* [syn. *Aphaenogaster cockerelli*]  
—ANT (NO COMMON NAME)

—O—

Orthoptera (Order)—Grasshoppers, crickets, and katydids

—P—

Papilionidae (Family)—Swallowtails and parnassian butterflies  
Parasitic wasps, sawflies, ants, wasps, and bees—Hymenoptera (Order)  
Pieridae (Family)—White, sulphur, and orange-tip butterflies  
*Pogonomyrmex* spp.—HARVESTER ANTS

—R—

Romaleidae (Family)—Lubber-grasshoppers

—S—

Sawflies, parasitic wasps, ants, wasps, and bees—Hymenoptera (Order)  
SNAIL, AJO MOUNTAINS—*Sonorella baboquivariensis cossi*  
*Sonorella baboquivariensis cossi*—AJO MOUNTAINS SNAIL  
SPIDER, WOLF—*Lycosa "carolinensis"*  
SPIDERS, FUNNEL-WEB—*Agelenopsis* spp.  
Spiders, funnel-web and grass—Agelenidae (Family)  
Spiders, grass and funnel-web—Agelenidae (Family)  
Spiders, ground or wolf—Lycosidae (Family)  
Spiders, wolf or ground—Lycosidae (Family)  
Spiders—Araneae (Order)  
*Strymon melinus*—MELINUS HAIRSTREAK  
SULPHUR, NICIPPE—*Eurema nicippe*  
SWALLOWTAIL, PIPEVINE—*Battus philenor*  
Swallowtails and parnassian butterflies—Papilionidae (Family)

—T—

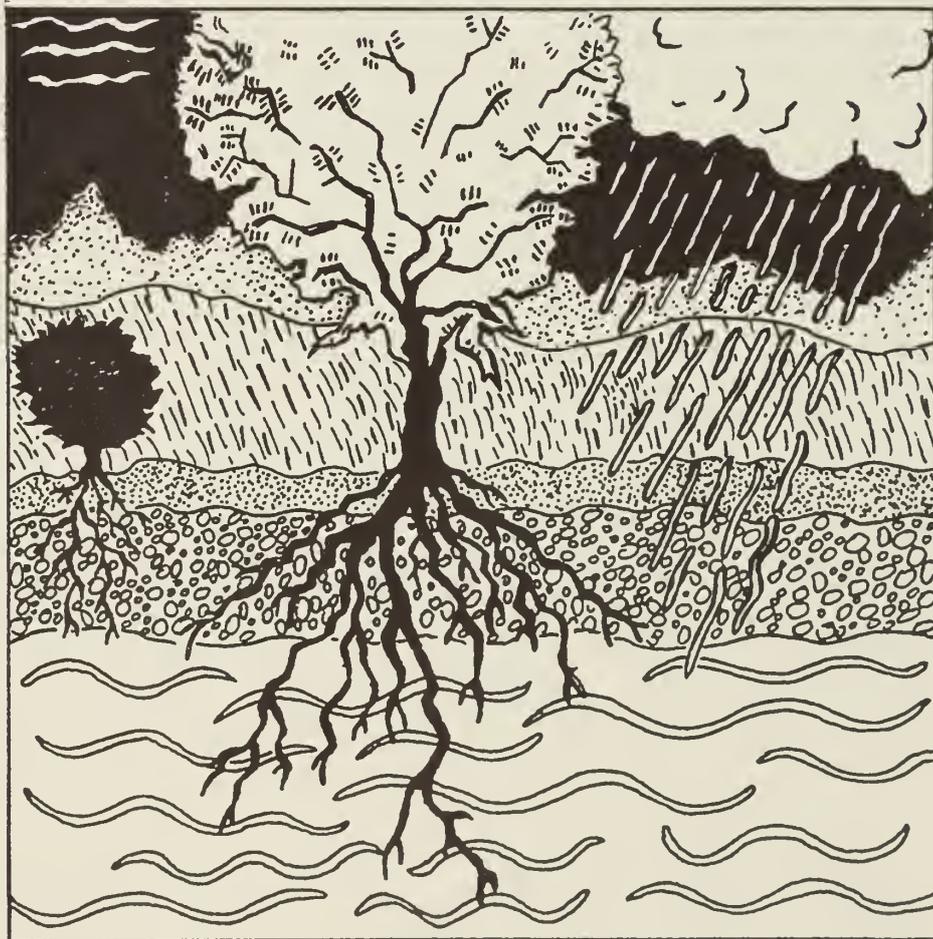
*Taeniopoda eques*—NO COMMON NAME  
*Trimerotropis pallidipennis*—NO COMMON NAME  
TRYONIA, QUITOBAQUITO—*Tryonia quitobaquitae*  
*Tryonia quitobaquitae*—QUITOBAQUITO TRYONIA

—W—

Wasps, sawflies, parasitic wasps, ants, and bees—Hymenoptera (Order)  
WHITE, HOWARTH'S—*Ascia howarthi*



# Climate, Air Quality, and Land-use Trends





# Climate Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Monument Resources Management Personnel

United States Department of the Interior  
National Park Service  
Organ Pipe Cactus National Monument  
Ajo, Arizona 85321

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## Introduction

Scientists and managers recognized early on in monitoring-program planning that climate data are an integral part of any attempt to study or understand environmental changes in an ecosystem. In the Sonoran Desert, plants and animals must adapt to highly variable weather conditions and unpredictable rainfall. Climate data are the primary integrative components of the Ecological Monitoring Program (EMP) at Organ Pipe Cactus National Monument, Arizona (ORPI). Organ Pipe Cactus National Monument has both automated weather stations and rain gauges in place at or near monitoring sites.

### Project History

In 1987, work began on the installation of automated weather stations at or near 9 of the designated EMP sites. The weather stations all came “online” in 1988 and have provided data continuously to the present time. Each station contains Omnidata Datapod data recorders in a protective housing, as well as weather sensors mounted on a suitable structure (e.g., an anchored tripod). Eight Forester rain gauges are also positioned in various locations throughout the monument. Most of these have been in use on a fairly regular basis since 1962 and, since 1982, have been checked regularly at the end of each month. As of this writing, the array of 9 Datapod-based weather stations is being upgraded to an array of 11 stations with newer, more sophisticated and reliable instruments, as well as data loggers based on the Handar model 555A data logger. This change has been necessitated by the obsolescence of the old equipment combined with a growing unavailability of parts and increasing repairs. The expansion from 9 to 11 stations reflects the final designation of 11 Core I sites, 2 of which were added in 1995.

### Current Procedures

The climate-station data loggers record data for each weather parameter on an hourly or bi-hourly basis. Data from each Datapod recorder are stored on an erasable chip. Once information has been stored, these are collected, replaced with erased chips, and brought back to the office. Each chip contains up to 6 wk of hourly data that are downloaded to a chip reader, backed up to diskette, and then erased from the chip. The data are converted to standard units and are imported into a Lotus 1-2-3 spreadsheet from which summaries and intersite comparisons may then be made. The Handar recorders (new in 1995) allow the data to be transferred on-site to a palmtop computer and then be taken back to the office and loaded into a specialized weather software system known as WeaBase. This software permits the generation of site summaries and comparisons, much as before.

Weather stations are optimally serviced once each month, even though the memory capacity of the various loggers may be considerably greater than 1 mo. Monthly site visits are recommended to visually inspect the equipment, especially the sensors and wires, for damage from the elements or from animals (e.g., chewed wires, etc.).

One or 2 field technicians are required to service the datapods and download the data each month.

## Scientific Instruments and Measurements

The Omnidata datapods utilize data storage modules (chips) to store data. Various types of data inputs are recorded in different models of datapods. The current configuration of instruments varies from site to site, with each weather station having between 2 and 4 of the following 4 datapod recorders and associated sensing instruments.

1. DP-211 (solar radiation and soil temperature at 10 cm [4 in.]) at Aguajita, Neolloydia, and Senita Basin sites.
2. DP-214 (wind speed and direction) at all sites but Gachado and Neolloydia.
3. DP-220 (air temperature and relative humidity at 122 cm [48 in.]) at all sites but Neolloydia.
4. DP-230 (air temperature at 15 cm [6 in.] and precipitation) at all sites.

The new Handar data logger handles multiple sensor inputs and records data internally. A palmtop or laptop computer is used in the field to download data from the logger. The primary long-term EMP sites (Aguajita Wash, Alamo Canyon, Bull Pasture, Dos Lomitas, East Armenta, Growler Canyon, Lower Colorado Larrea, Middle Bajada, Pozo Nuevo, Senita Basin, and Valley Floor) will have the new data logging system and sensors at or near the site. Each of the 11 sites will record the following data.

1. Wind speed and direction.
2. Air temperature and relative humidity at 48 in.
3. Solar radiation.
4. Air temperature at 15 cm (6 in.).
5. Precipitation.
6. Soil moisture and temperature at various depths according to site.

In addition, the new stations are powered by an internal, solar-charged, 12-volt battery. The accuracy and longevity of the sensing instruments is greatly improved, and a calibration/replacement schedule is rigorously followed.

As of this writing, Forester rain gauges will be removed from 2 of the original sites, and full climate stations will be installed. Additional rain gauges will be placed at Armenta Ranch, Burn Site, Growler Canyon, Lost Cabin Mine and Vulture Site.

## Methods

### Fieldwork Protocol

This section will refer only to the new stations, as the old ones will have been replaced by late 1995.

### *Equipment Required*

The following materials should be carried to the site:

- (1) HP-200LX palmtop computer and connecting cables
- (1) Digital voltmeter
- (1) Flat blade screwdriver, medium-sized
- (1) Accurate watch
- (1) Pen and small notebook
- (1) Logger enclosure key
- (1) Acid brush for cleaning tipping buckets
- (1) Soft cloth for cleaning pyranometer
- Desiccant packets, charged
- Spare cable ties

### *Weather Station Protocol*

To assure the accuracy of the data, it is necessary to check the sensors. This involves periodic verification of temperature and humidity, as well as calibration of the tipping bucket rain gauge. Most of the sensors have a limited life of 1–3 yr, and may need adjustment/recalibration or replacement periodically.

Before entering the field, the battery-charge level of the palmtop computer should be checked using the setup utility from the main menu. The computer requires 2, size AA, alkaline batteries. Also verify at this time that there is enough available memory to contain the data being collected. Make a note of the date of the previous visit to the site (see file name, step 11, below). Only erase old files from the palmtop after you are sure they have been transferred to the desktop computer, as well as backed up to diskette.

The specific site visit and data collection protocol is as follows:

1. Visually check the climate station for damage.
2. Open the logger enclosure with the key.
3. Connect the palmtop computer to the logger with the connecting cable(s).
4. Open the palmtop computer and turn it on.
5. Terminate all icon functions and bring up the DOS prompt.
6. Change directory to C:\HANDAR.
7. Type 555 and press [Enter].
8. Advance to the "On Line" screen and select "Force Scan."
9. Check various parameters, as desired, to verify sensor function. Also check the battery voltage, which should be > 12 volts.
10. Select "Retrieve Data" from the "On Line" screen.
11. Retrieve data into a binary file, using the file name format:

*??XMMMDD.DAT*

where ?? is the 2-letter site designation,  
X is the last digit of the current year,  
MMM is the first 3 letters of the current month,  
and DD is the current day.

The .DAT extension identifies the file as containing data.

For example, *EA5APR18.DAT* would be the data file collected from the East Armenta weather station on April 18, 1995.

12. Select the period covered as being from the date of the last data collection visit (see previous file name) to the present.
13. When data transfer is completed (this can take several minutes), exit from the program by pressing [Esc] and [Alt]+X to quit.
14. Turn off the palmtop computer and disconnect the cable.

15. Open the logger box, check the color of the desiccant pack against the standard inside, and replace if necessary.
16. Close the logger box and the logger enclosure, being careful not to pinch any wires in the door.
17. Lock the door.

### *Rain Gauge Protocol*

Monthly rainfall data is gathered from the Forester rain gauges by measuring the amount of premeasured transmission fluid (which prevents evaporation of precipitation) and rain water in the bucket and subtracting the known quantity of transmission fluid. Fresh transmission fluid is then measured and placed in the bucket. To accurately reflect the monthly total, rain gauges should be serviced as close to the end of the month as possible. Data from these rain gauges is entered into a Lotus 1-2-3 spreadsheet.

### **Post-fieldwork Protocol**

Upon returning to the office, data should be immediately downloaded from the palmtop computer to the designated weather database desktop computer, then backed up to diskette. Never leave a file uncopied in battery-powered memory.

As of this writing, updated Weabase software has not yet been received. This software will convert raw climate data, create spreadsheets, and generate reports and graphics.



# Air Quality Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

Monument Resources Management Personnel

United States Department of the Interior  
National Park Service  
Organ Pipe Cactus National Monument  
Ajo, Arizona 85321

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## Introduction

Although a visibility-impairing copper smelter 32 km (20 mi) north of Organ Pipe Cactus National Monument (ORPI), Arizona was closed in 1985, new threats to the area air resources are increasing. Agricultural activities on the Mexican border affecting air quality include field burning, pesticide and herbicide use, and truck traffic on dirt roads. New industrial and urban development are planned in Sonoyta, Sonora, as well. The monument is also vulnerable to distant pollution sources such as urban southern California, the industrialized Gulf coasts of Mexico and Texas, and the smelter regions of Arizona and New Mexico. At present, ORPI participates in programs to monitor ambient particulate and radiation levels and to measure acid deposition. The air quality program will be expanded in the future to include visibility monitoring and biological effects of air pollutants monitoring.

To monitor aspects of air quality, ORPI cooperates with 3 different agencies: (1) the National Atmospheric Deposition Program (NADP), (2) the Arizona Department of Environmental Quality (ADEQ), and (3) the Arizona Radiation Regulatory Agency (ARRA). The scientific instruments utilized in these efforts are serviced on a weekly basis by resource management staff. Activities for the 3 agencies are summarized below.

### **Project History**

#### *National Atmospheric Deposition Program*

This program was initiated in 1978 to track geographical patterns and temporal trends in the chemical climate of North America. It is administered by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) Coordination Office at Colorado State University. Various cooperating agencies across the country volunteer personnel and equipment for the program. Organ Pipe Cactus National Monument, 1 of 3 NADP sites in Arizona, initiated sampling in 1980.

In January 1993, ORPI began participation in a special NADP study. The 1-wk/2-wk study was designed to compare the sample chemistry of 1-wk samples with that of 2-wk samples. At that time, another Aerochem Metrics sampler was installed, but the collection bucket on the second sampler was changed every 2 wk instead of every week. At the end of the study, NADP hopes to evaluate the stability of samples under field conditions and the viability of a 2-wk sampling period at some or all of the NADP sites. Lack of funding halted this study in December 1993; however, it was reinstated in April 1994 and completed in 1995.

#### *Arizona Department of Environmental Quality*

The Arizona Department of Environmental Quality (ADEQ) regulates air quality as mandated by the Federal Clean Air Act and Arizona State Statutes. Environmental Protection Agency plans for air quality standards are followed by the department. Among ADEQ projects is the ambient monitoring of airborne particulates with a dichotomous sampler. Sites monitored by ADEQ include areas with urban-related pollution, emissions from industrial facilities, and dust from

agricultural operations. National Park Service sites in the program have the unique objective of monitoring visibility in pristine areas in accordance with federal regulations for visibility protection.

#### *Arizona Radiation Regulatory Agency*

Organ Pipe Cactus National Monument has 1 of 10 statewide continuous air sampling stations monitored by the Environmental Surveillance Program of the Arizona Radiation Regulatory Agency (ARRA). The Statewide Environmental Sampling Program was initiated with the purpose of supplementing baseline data on radiation levels in the environs of the Palo Verde Nuclear Generating Station.

### **Current Procedures**

#### *National Atmospheric Deposition Program*

At present, the ORPI NADP site equipment consists of an Aerochem Metrics wet/dry precipitation collector and a Belfort Universal raingauge with event pen. These are located near the headquarters area. During precipitation events, the wet-side collection bucket is automatically uncovered, then covered when the event has ended. A cumulative weekly sample is collected. The Belfort Universal raingauge records precipitation event times and precipitation weight on chart paper. In the ORPI laboratory, the bucket is weighed to determine precipitation amount. Measurements of pH and specific conductance are then made. The sample is sent to the NADP Central Analytical Lab in Champaign, Illinois, where more extensive measurements are made.

At the Central Analytical Lab, specific conductance is measured, as well as concentrations of hydrogen, ammonium, calcium, magnesium, sodium, potassium, sulfate, nitrate, and chloride. Organ Pipe Cactus National Monument receives monthly, seasonal, and annual data summaries, as well as an annual summary report for all U.S. NADP sites. Additionally, weekly records are kept at the monument. These include copies of the Belfort raingauge chart paper, a unique source of precipitation event data. These charts illustrate the time, duration, and rainfall amount of each precipitation event.

An additional component of the NADP is the U.S. Geological Survey Intersite Comparison Program. Twice a year or more, each NADP site is sent an identical rain sample. The sites perform conductivity and pH measurements. Each site then receives a report on the most probable values for the sample and a determination of achievement at the site of NADP accuracy goals.

#### *Arizona Department of Environmental Quality*

Filters for ambient particulate (PM<sub>10</sub>) are changed weekly and sent to ADEQ.

#### *Arizona Radiation Regulatory Agency*

Filters for radiation monitoring are changed weekly and sent to ARRA.

## Methods

These procedures cover the activities that ORPI resource management staff conduct weekly (every Tuesday morning). Monitoring air quality for the 3 agencies involves 3 stages, each of which maintains a separate set of protocols: (1) pre-fieldwork (preparation) protocol, (2) fieldwork protocol, and (3) post-fieldwork (laboratory) protocol.

### **Pre-fieldwork (Preparation) Protocol**

#### *National Atmosphere Deposition Program*

Raingauge buckets for the NADP study are collected regularly and conductivity and pH measurements are made with samples with sufficient precipitation. The rest of the sample and other field data are sent to the NADP/NTN Coordination Office.

To prepare for NADP fieldwork:

1. Open 1 black mailing box and check to see if there is a bucket inside.
2. Take a snap-on lid from the cupboard and put it with the bucket.
3. Reverse the mailing label.
4. Refasten 2 straps for transport to the site.
5. Check the blue metal notebook case to see if there is blank chart paper for the raingauge chart recorder.

#### *Arizona Department of Environmental Quality*

The dichotomous particulate ( $PM_{10}$ ) sampler at ORPI is located near the NADP sampling equipment. Two filters collect coarse and fine particulate samples for a 24-hr period every 6 dy. The filters are sent to ADEQ for gravimetric and optical density analysis.

To prepare for ADEQ fieldwork:

1. From the cupboard, retrieve clipboard and manila envelope used the previous week. Also retrieve a fresh manila envelope, a field data form, a white cardboard envelope, and the next 2 filters (1 white and 1 yellow, taped together).
2. On the form, write the next run date and the filter numbers. A calendar of run dates is posted on the bulletin board in the lab. If the run date falls on a Tuesday, the filters must be changed ahead of time.

3. Place both the current and previous week envelopes with materials to be taken to the field site.

### *Arizona Radiation Regulatory Agency*

Filters are changed weekly in the continuous air sampler and sent to the Arizona Radiation Regulatory Agency for analysis.

To prepare for ARRA fieldwork:

1. Gather the fieldwork materials. The filter housing and tweezers are kept in a coffee can in the cupboard. A large envelope contains filters, forms, small manila packets, and envelopes addressed to the Arizona Radiation Regulatory Agency.
2. Use the tweezers to place a filter in the housing. Take extreme precaution not to touch the filter. The sides of the filter differ in texture: there is a shiny, random-fiber textured side, and a more even, uniformly textured side. Place the filter in the housing with the even texture on top.
3. Place a small field data form, together with the field form from the previous week, in the blue metal notebook case.

### **Fieldwork Protocol**

#### *All Agencies*

Fieldwork for each of the 3 agencies is performed in a collective, logistically organized manner. Therefore, unlike in the other sections of this report, monitoring protocols for all 3 agencies are combined into a single, organized list. It should be noted that more detailed procedures and training videos for the NADP sampling process are available at ORPI headquarters.

1. It is best to drive to the ARRA radiation sampling site first, to minimize the jostling of rain samples in the NADP buckets. The radiation sampler is located on the west side of the maintenance building.
2. Open the front of the sampler and take an LPM reading by looking at the center of the black bead.
3. Swap the filter housings and take another LPM reading. Finally, fill out the field forms with the appropriate data.

The PM<sub>10</sub> sampler and NADP equipment are located just past the old VIP campground (now a revegetation site) and is reached by following a gravel road beginning about a half-mile up the campground road.

1. Open the black box housing the NADP buckets and undo the twist tie on the plastic bag (around the lid) to get it ready.

2. Turn on the PM<sub>10</sub> sampler by maneuvering the lever next to the wheel clock timer. Allow the sampler to run while changing the NADP buckets. This permits the flow rates to stabilize before taking a reading.

To change the NADP precipitation buckets:

1. Locate the syringe of distilled water kept in the cement block under the NADP stand. Carefully squirt a few drops onto the sensor plate. This should cause the lid to swing smoothly over to the dry-side bucket.
2. If there is precipitation in the wet-side bucket, look for contaminants such as dirt, leaves, or bugs, making note of them in the notebook.
3. Using the plastic bag as a “glove,” snap the plastic lid tightly onto the wet side bucket. Place the bucket in the plastic bag, fasten with a twist-tie, and put it aside.
4. Using the plastic bag as a “glove” again, place a new bucket in the metal holder.

Now return to the ADEQ PM<sub>10</sub> Dichot sampler to gather data there.

1. On the form from the previous run-date, record the “coarse” and “total” rotameter readings.
2. Turn off the machine.
3. Record the “stop time” from the time meter and subtract to calculate “total time.” On the form for the next run-date, record the “start time.” (This will always be the same as the “stop time” from the previous run-date.)
4. Compare the time showing on the wheel-clock timer and “real” time (actual, accurate time, such as on a wristwatch). If these vary by more than half an hour, carefully adjust the wheel-clock timer.
5. Remove the previous run-date filters and replace with new filters. The envelope from the previous run-date can now be sealed and mailed.
6. Finally, restart the sampler and adjust the rotameters to their set points. When this is completed, turn off the machine and close the outside door.

Follow the next steps to change the chart paper in the NADP raingauge.

1. Slide the small door up and pull the pens away from the paper.
2. Remove the cylinder containing the chart by lifting straight up.

3. Wind the raingauge clock about 15 times.
4. If it has rained, open the top of the raingauge and dump any remaining water from the bucket.
5. Carefully remove the chart paper from the cylinder and write in the “bucket off” date and time. Write the “bucket on” date and time on the new chart paper.
6. Place the new chart on the cylinder, making sure that the paper lies tight against the bottom rim, and that the graph lines of the paper are aligned.
7. Replace the cylinder in the sampler housing and position the bottom pen at the correct time on the chart paper.
8. Fill the ink pens if necessary, using a small piece of wire to start the ink flow on the paper.
9. To finish, firmly slide the outside door down

If there is precipitation in the NADP bucket, drive back to the resource center slowly and carefully to prevent any water from sloshing out.

### **Post-fieldwork (Laboratory) Protocol**

#### *National Atmospheric Deposition Program*

More detailed procedures and training videos for the NADP laboratory chemistry procedures are available from ORPI headquarters.

1. If there is no precipitation in the NADP bucket, skip to steps 5–7.
2. Carefully weigh the bucket, follow the instructions for decanting a sample into a wide-mouth nalgene bottle, and fill 4 sample vials for chemistry purposes.
3. Plug in the lab equipment and wait a few hours before performing chemistry measurements.
4. Follow the NADP instructions for replacing the bucket lid and bagging up the quart bottle rain sample.
5. Complete the field observer’s form using, if necessary, preceding records as examples.
6. At the visitor center, photocopy the chart paper, reducing it to fit onto letter size, 8.5- x 11-in. paper.

7. Place the top 2 copies of the field observer form and the original chart paper into the black box with the bucket. Fasten all the straps securely, then place the box with the outgoing mail.

*Arizona Department of Environmental Quality*

Post-fieldwork for the ADEQ involves the following:

1. Place filters and completed data form in envelope provided by ADEQ and mail promptly.

*Arizona Radiation Regulatory Agency*

Post-fieldwork for the ARRA involves the following:

1. Using tweezers, remove the radiation sampler filter from the housing. Be careful not to touch the filter.
2. Carefully insert the filter into the small manila holder.
3. Place the holder containing the filter and the completed field form in an envelope addressed to the Arizona Radiation Regulatory Agency.
4. Place the envelope with the outgoing mail.



# Night-sky Brightness Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona

## Monument Resources Management Personnel

United States Department of the Interior  
National Park Service  
Organ Pipe Cactus National Monument  
Ajo, Arizona 85321

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## Introduction

A major resource of Wilderness areas of the Western United States is the occurrence of clear night skies resulting in excellent opportunities for viewing faint celestial objects not commonly seen near urban centers. Night-sky visibility has been determined to be an “Air Quality Related Value” under the Clean Air Act amendments of 1977 (Peterson et al. 1992), for the visibility of stars and planets at night may be reduced by the scattering effects of air pollutants. The greatest threat to this resource, however, comes from light pollution, or the proliferation of outdoor lighting near wilderness areas causing sky glow that obliterates faint stars, even in the absence of air pollution.

The Wilderness Act of 1964 states that the wilderness character of an area must be preserved, “. . . retaining its primeval character and influence . . .” Dark skies have often been associated with wilderness, and the preservation of this resource is a primary responsibility of the Wilderness area manager.

Threats to the wilderness character of Organ Pipe Cactus National Monument, Arizona (ORPI) are present and increasing. One of these threats is light pollution. A visibly noticeable glow in the southwestern part of the night sky emanating from the border town of Sonoyta, Sonora, Mexico represents a degradation of the wilderness values of the monument. Casual observations indicate that the glow has become more noticeable in recent years, and that in the future this trend can be expected to continue. The recent ratification of the North American Free Trade Agreement is promising to open more doors to urban and commercial expansion in the Sonoyta Valley. This will certainly mean more degradation to the dark, night skies of the monument.

The monitoring of night sky brightness and the reporting of results are important and powerful tools in dark sky protection. In 1987, the Environmental Agency of Japan began a network of observation of night-sky brightness with the purpose of developing an index of air and light pollution throughout the country (Kosai et al. 1993) The network uses photographic and visual observations of the night sky in the collection of monitoring data. For decades, professional astronomers, using photoelectric photometry, have been making more precise measurements of night-sky brightness in the testing and long-term monitoring of the quality of observatory sites. A study at nearby Kitt Peak National Observatory (Pilachowski et al. 1989) revealed that the measured sky brightness near the zenith in 1988 was very close to the predicted natural background at 21.9 magnitudes per square arc-second ( $\text{arcsec}^2$ ). In a National Park Service study site at Bryce Canyon National Park, Utah, photoelectric photometry has also been used to measure sky glow and to verify a model for predicting the amount of sky glow from a point source (Carr et al. 1989).

In winter 1995, an all-sky survey of the night-sky brightness from ORPI was conducted. The objectives of this study were to collect baseline data quantifying the visual appearance of the night sky and to develop a protocol for long-term monitoring.

## Methods

The development of the night-sky brightness survey and monitoring protocol was based on a need for the collection of accurate data while maintaining relatively easy data reduction. It was important that the system employ portable, easy to operate, precision equipment. It was necessary that the resulting monitoring protocol be relatively simple to implement yet yield repeatable, accurate results.

Survey methods included standard astronomical photometry technique. Equipment included a SSP-5 photometer and a 191-mm,  $f/4.8$  refracting telescope. The SSP-5 was selected because it has high accuracy and the photomultiplier tube mimics the response of the industry standard 1P21 photomultiplier. The SSP-5 has a simple, 4-digit LED readout that lends itself to easy data collection in the field. The criteria for telescope selection included (1) portability; (2) a relatively short focal length to allow photometry to be done without a clock-driven, equatorial mounting; (3) the optimum focal ratio for the best SSP-5 response ( $f/5$ ); and (4) the optimum aperture (large enough so as to achieve an acceptable count for suitable extinction stars, yet small enough so as not to overwhelm the photometer with excessive light).

It became clear through test trials that a photographic tripod was not adequate for the system. A small, Dobsonian-style altitude/azimuth mounting was built for the system. This provided a stable mounting that did not require complicated balancing, locking and unlocking of friction clamps (as in a photo tripod), and did not slip when pointed near zenith (as the photo tripod did). The mounting provided smooth motion, and when stopped, held its position. The Dobsonian design with altitude- and azimuth-setting circles facilitated the efficient location of specific sky-glow-survey transect points.

The basic procedures (in order) of protocol implementation are to: (1) conduct calibration procedures by taking readings on extinction stars, (2) conduct the sky-glow survey, (3) perform data reduction, and (4) report results.

### **Preparation of Field Equipment and Other Premonitoring Planning**

Preparation of field equipment should be done at least 1 dy before monitoring is to be conducted. All of the equipment should be gathered and checked to ensure that it is in proper working order. The following checks must be done:

1. Check the battery for a charge; recharge if necessary.
2. With the flip mirror closed, hook-up the photometer (Fig. 11-1) to the battery and turn it on. If the readout stabilizes at around 500 counts, the photometer is operating properly.
3. Check the flashlights to insure that they are working properly. Install new red filters if necessary.

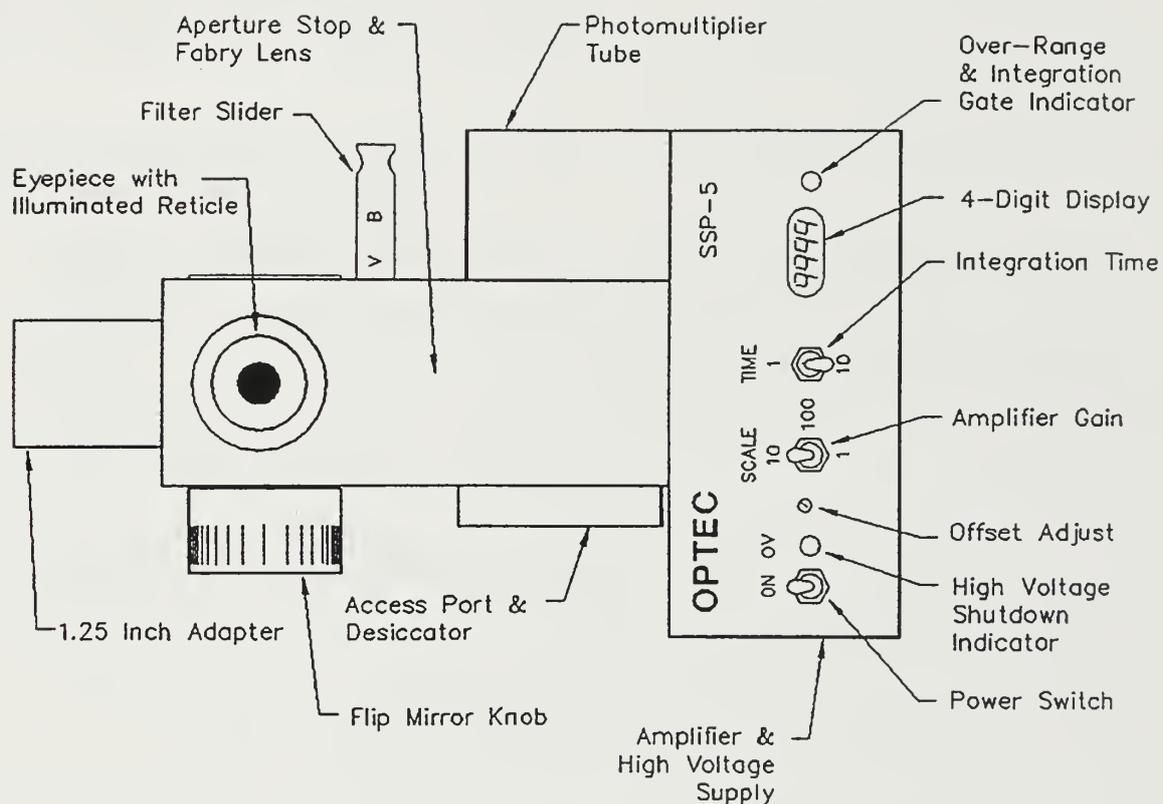


Figure 11-1. Illustration of the Optec Model SSP-5 photoelectric photometer used in night-sky brightness monitoring for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona.

### Materials Required

A complete equipment list follows:

- |                                      |   |
|--------------------------------------|---|
| SSP-5 photometer                     | Includes case, end cap, bag, rubber band, and desiccant packets.    |
| Telescope, 191-mm, f/4.8, refracting | Includes right-angle mounting bracket with 6-mm (0.25-in.), 20 nut. |
| Telrad reflex sight                  | Includes mounting block and hose-clamp.                             |

Dobsonian mount	Includes 16-mm (0.63-in.) 11 hex-nut, leveling block, 11-mm (0.44-in.) hex-head bolts, washers, and 6-mm (0.25-in.) 20 nuts.
Surveyor's tripod	
Battery (12-volt, gel cell with case)	Includes special protection circuitry and fuses, cord with automotive cigarette-lighter adapter.
Two, 11-mm (0.44-in.) wrenches	One is open-end, the other is closed-end.
Allen wrench	Fits knob on flip mirror.
Digital watch with the accurate time	
Circular bubble-level	
Three flashlights	Two are red-filtered, 1 is white.
Star charts	These should be Norton's Atlas, Sky Atlas 2000, or Uranometria 2000.
Monitoring site location map	
Extinction star list	Appendix 11-1.
Field identification charts	Appendix 11-2.
Extinction star data forms	Appendix 11-3.
Sky-glow transect point elimination form	Appendix 11-4.
Sky-glow survey data forms	Appendix 11-5.
Dark sheet of construction paper	With which to construct the dew shield.
Adhesive tape	To secure the dew shield.
Two clipboards and several pens	

### **Arranging for Closure of Ajo Mountain Drive**

Other planning involves arranging for closure of the Ajo Mountain Drive during the monitoring session. Road closure is essential because car headlamps from passing motorists can severely interfere with the sampling results as well as damage the photometer. A 1-mo lead time is recommended so that appropriate interdivisional-management levels can be advised well in advance. At this time, the monitoring date is tentative and completely dependent on weather conditions (see Assessing Conditions, below). As the scheduled sample date approaches and photometric skies are in the forecast, final confirmation for closing the Ajo Mountain Drive should be made. All division chiefs and the Superintendent are to be notified immediately. On the afternoon of the monitoring night, road closure signs should be placed at the entrance to Ajo Mountain Drive. This should allow any cars that are on the loop drive to exit before the field sampling session begins.

## Assessing Conditions

The protocol requires that data be collected only at certain times and under specific conditions. This protocol is to be carried out on clear, winter nights and only under the following conditions.

1. New-moon phase (or near approximate). The moon cannot be present during any part of data collection.
2. Clear, photometric skies. The sky must be totally clear, which condition is known as photometric skies. There must be no high, thin clouds present while collecting data. In determining whether skies are photometric, there should be an assessment of sky conditions before skies are dark. Care must be taken in noting any clouds along the horizon. Such clouds can greatly affect low-altitude transect readings, which are crucial in accessing sky glow from cities. Extremely thin, high clouds may not always be apparent at night, because starlight can shine through them.
3. Low humidity. If conditions are extremely humid (e.g., fog), data collection should be postponed. In conditions of moderate humidity, care must be taken to insure that dew does not condense on the telescope optics. If necessary, a dew shield must be constructed to prevent condensation. This can be accomplished with a sheet of dark construction paper or other lightweight, dark material. Wrap the shield around the objective end of the telescope tube and fasten it securely. It may become necessary to rebalance the telescope after the dew shield is installed. If dew does form on the lens while data is being recorded, remove the dew, install the dew shield, then reacquire all data that may have been affected. Dew can usually be removed by warming the front end of the telescope with a bare hand. With such a method, however, care must be taken not to touch the lens.
4. Settled weather. In unsettled, but otherwise clear, weather, caution should be taken. Sometimes weather can be clear over the Monument, but lightning can be seen around the horizon. Monitoring is not recommended under these conditions. The flashes of lighting can give false readings and may also damage the photomultiplier tube.
5. Low wind. Moderate wind is not a problem as long as it is not strong enough to cause the equipment to vibrate or otherwise be disturbed. During a very windy night, however, the dust and sand particles in the air can noticeably affect visibility and skew data measurements. Such particles can also be blown into the photometer and/or the telescope optics, causing damage. Furthermore, strong wind is a problem on cold winter nights, as it lowers the wind chill factor to intolerable levels.
6. Absence of automobiles near the sample site. Ajo Mountain Drive should be closed, and no traffic present anywhere on the loop during the night of data collection. The dust stirred up by passing automobiles, as well as the intensity of light projected by headlamps, can easily damage the photometer. Intermittent, bright light such as that projected by automobile headlamps can also deter the acquired night vision needed for successful monitoring.

## Equipment Setup

Monitoring is to be conducted on clear, winter nights. As such, temperatures are often quite low. Photometry and data collection require standing in the elements for several hours, therefore, dress warmly. Suggested clothing include thermal underwear, thick wool socks, boots, gloves and or mittens, warm hat, layered shirts and coats, and a scarf. The person collecting data might want a chair and a blanket. Dressing properly can make the difference between an enjoyable and productive night and a miserable and inefficient one.

Plan to arrive at the sampling site just after twilight. Upon arrival, park the field vehicle far enough ahead of the sampling site so that it will not block any of the transect points during monitoring. Set up the monitoring equipment as follows.

1. Position the tripod. Take care to place the tripod in a spot where no nearby vegetation might interfere with the monitoring view. Firmly step on the tripod-leg endpoint cleats to ensure that the tripod legs are securely anchored into the ground. (This lessens the probability of equipment damage should the tripod be bumped during data collection.) Roughly level the tripod.
2. Place the rocker box of the Dobsonian mount (Fig. 11-2) on the tripod head. Using the 16-mm (0.63-in.) 11 hex nut and the knurled tripod bolt, fasten the mount onto the tripod. Level the tripod and mount by placing the circular bubble-level on the inside of the mount. Adjust the tripod by raising and/or lowering the legs until the bubble is centered. Once the rocker box is level, insert the altitude assembly and install the leveling block to the front of the rocker box.
3. Attach the telescope to the mount using the bolt that is present in the slot on the base of the altitude assembly. An 11-mm (0.44-in.) wrench is required to tighten the bolt. Push the telescope mounting bracket up to the guideline marked on the base of the altitude assembly. Fully tighten the telescope mounting bolt. Install and tighten the safety washer and nut on the telescope mounting bolt.
4. Bring the photometer case and the battery over to the tripod. Open the photometer case and carefully remove the photometer. Make certain that the flip-mirror knob (see Fig. 11-1) is in the closed position (the Allen socket is pointing as far as it can toward the 1.25-in. telescope adapter) and take off the end cap. Connect the battery cable to the appropriate plug adapter in the lower right corner of the photometer head. Connect the photometer to the telescope. Make certain that the coupling is completely flush, then completely tighten the knurled set-screw. Plug the other end of the battery cord into the socket in the side of the battery case. Set "Time" to 10 and "Scale" to 10 on the control panel of the photometer. Turn on the photometer. It will read 2221 for approximately 10 sec and then should hover around 500. Let the photometer stay on (stabilize) for at least 30 min before taking the first reading.

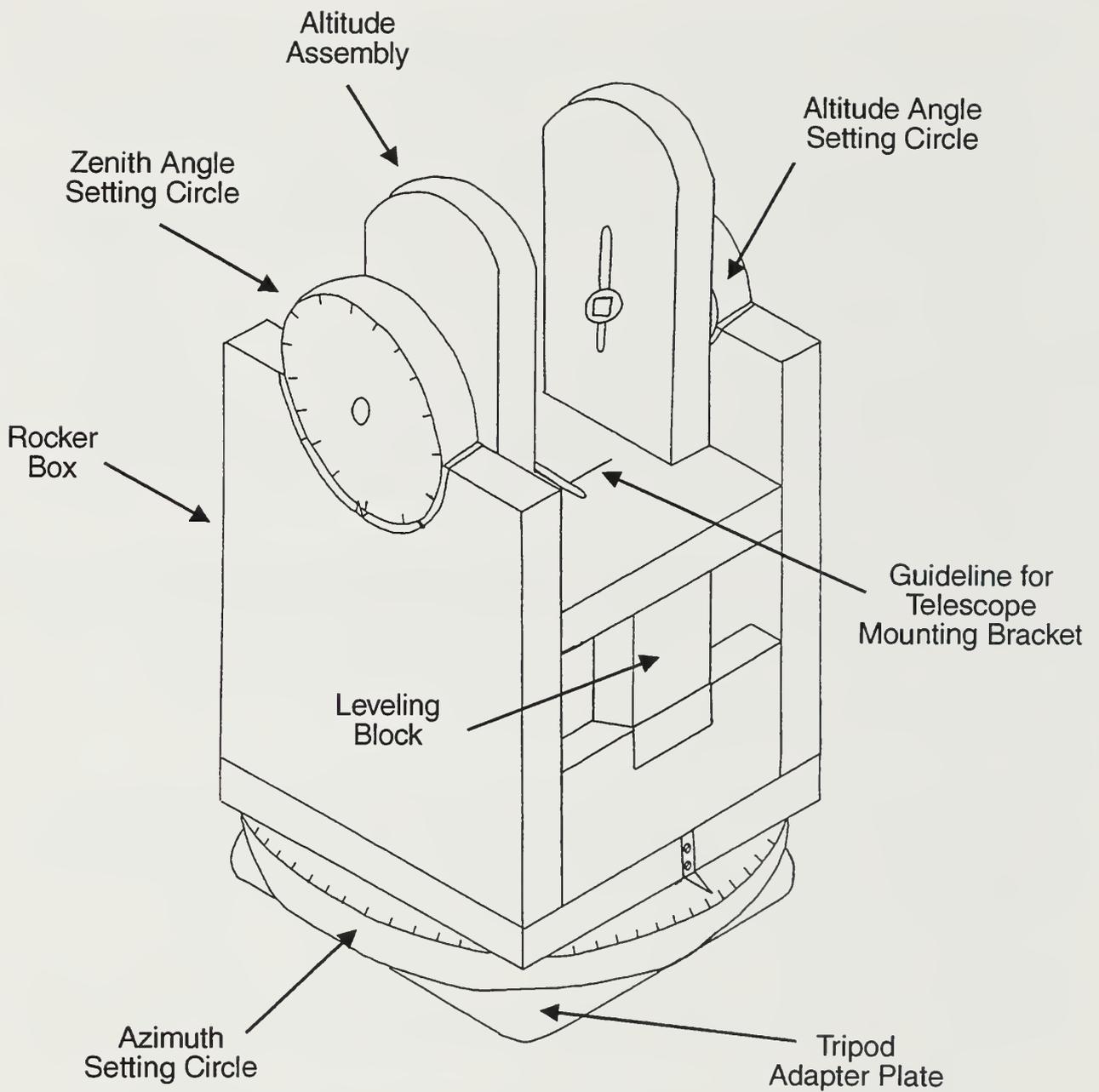


Figure 11-2. Illustration of the Dobsonian mount used in night-sky brightness monitoring for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona.

5. While the photometer is stabilizing, initialize the azimuth-setting circle of the Dobsonian mount. Align the azimuth pointer to  $0^\circ$ . While maintaining this setting, loosen the tripod bolt and move the tripod adapter plate until the telescope is pointing approximately to Polaris. Raise the telescope to approximately  $32^\circ$  altitude (the approximate altitude of Polaris from the sample site). Look through the Telrad and center the view of Polaris in the bull's-eye, using only the tripod adapter plate and the altitude axis. Then look through the photometer eyepiece and center the view of Polaris in the illuminated reticle. If done correctly, the mounting should now be polar-aligned and the setting circles initialized. Make certain that the pointer is still set on  $0^\circ$  and that the view of Polaris is centered, then tighten the tripod bolt to the tripod adapter plate.
6. Accurately align the Telrad. With the view of Polaris centered in the photometer eyepiece, adjust the alignment knobs on the back of the Telrad until the view of Polaris is also centered in the Telrad bull's-eye. Finally, make certain that the telescope was not bumped off of position while adjusting the Telrad. If the telescope has been inadvertently moved, repeat steps 5 and 6.
7. During the remainder of photometric stabilization, the data sheets, extinction star list, field identification charts, and the star charts should be removed from the truck and placed on the truck tailgate work area.
8. Prepare to find the first extinction star.

### **Data Collection of Extinction Stars**

The monitoring procedure requires 2 persons; 1 to take the photometry readings and another to record data. Approximately 10 hr are required for a monitoring session, from equipment setup through the completion of data collection. It is possible to conduct the survey over 2 nights, but completing it in 1 is recommended.

### *Equipment Calibration and Adjustment*

The set of extinction stars listed in Appendix 11-1 is to be used for the period January–March. If this protocol is to be used outside this period, a new list of extinction stars must be generated.

For adequate calibration, the number of extinction stars measured should be 7–10. The goal in extinction star data collection is to measure stars over a wide range of zenith angles. In the baseline dataset collected 26–27 March 1995, 8 extinction stars were measured. The resulting extinction coefficient proved excellent because these 8 stars were distributed over a wide range of air masses (i.e., a wide range of zenith angles) from  $20^\circ$  to  $70^\circ$ .

Measurements made of each of the selected extinction stars include (1) dark count, (2) star + sky + dark, and (3) sky + dark. The procedure for collecting these measurements is as follows:

1. Locate the first extinction star on the list (Appendix 11-1). Using the appropriate charts in the photographic atlas (Sky Atlas 2000 or Norton's) and the field charts (Appendix 11-2), determine the position of the star, then locate it in the sky. On the field chart, the scale will closely match the view seen through the photometer eyepiece.
2. Using the Telrad as a guide, point the telescope at the star. As the telescopic view approaches accuracy, it may become necessary to dim the Telrad bull's-eye until the star is visible. Center the view of the star in the bull's-eye. If the Telrad was carefully aligned, the view of the star should also be centered in the illuminated circle of the photometer eyepiece. Data collection can begin after a quick verification that "Time" is 10, "Scale" is 10, and that the filter is in the "V" position.
  - (a) Measure and record the dark count. The person collecting data begins by reading aloud the zenith angle of the star. The person recording data writes on the Extinction Star Data Form (Appendix 11-3) the zenith angle, and simultaneously records the time (military style, i.e., 2400) to the nearest minute. With the flip mirror still in the closed position, the data collector again makes certain that the view of the extinction star is centered in the photometer eyepiece. Finally, the data collector reads aloud the dark value from the photometer, which the recorder writes under the "Dark" heading.
  - (b) Measure and record star + sky + dark. Using the Allen wrench, the mirror is now flipped forward, taking care not to bump either the telescope or mount, as such may destroy alignment and necessitate repetitious data collection. After flipping the mirror, the first reading is not recorded. The second reading is recorded and, if the third reading is approximately the same as the second, the third is also recorded. If the value of the third reading has decreased significantly, this indicates that the star is drifting out of the field of view, which oftentimes happens. In such cases, the mirror must be closed and the view of the star recentered. Usually, 2 consecutive readings can be recorded before recentering is required to obtain the third. However, this is dependent upon the timing of mirror adjustment, as well as upon the field stars present around the extinction star. Each reading must be judged individually to determine if it makes sense. Repeat this process until 3 readings have been recorded in the "St + S + D" column of the Extinction Star Data Form. Finally, close the flip mirror and prepare to take a sky + dark reading.
  - (c) Measure and record sky + dark. Select an area next to the extinction star that is devoid of any visible stars. The data collector then flips the mirror out of the way and begins to call out the readings after the first one. The data recorder writes these values under the heading "S + D" on the Extinction Star Data Form. Once 3 sky

readings are taken, the data collector flips the mirror back into position. These sky readings can usually be taken consecutively; however, this is dependent upon the richness of the field. Care must always be taken to find a sky field that is devoid of visible field stars.

- (d) Locate and center the next extinction star on the list and repeat all of step 2. Finally, after recording all of the extinction stars, proceed with completion of the sky-glow survey, below.

### **Data Collection of the Sky-glow Survey**

The objective of data collection for the sky-glow survey is to record the brightness of sky patches on certain transect points. The data collection process is similar to that of obtaining the sky value for extinction stars.

The transect consists of 220 points, arranged as shown in Figure 11-3. Table 11-1 describes the relationship between altitudes of transect points and readings taken at degrees azimuth.

It is important to first sample the transect points lying on the Sonoyta and Phoenix sky-glows, during early evening when municipal lights and automobile headlamps are in peak use. These transect points are located on approximately 200–220° azimuths for Sonoyta, and approximately 10–40° azimuths for Phoenix (Fig. 11-4). Take all altitude readings on these azimuths first, following these procedures:

1. The Data Recorder calls aloud the coordinates of the transect point to be sampled, from the Sky-glow Survey Transect Point Elimination Form (Appendix 11-4), and writes down the azimuth and the altitude in the appropriate place on the Sky-glow Survey Data Form (Appendix 11-5).
2. The Data Collector locates the transect point by rotating the rocker box of the Dobsonian mount to the appropriate transect azimuth (using the azimuth-setting circle as shown in Figure 11-2), and by tilting the telescope to the appropriate altitude (using the altitude angle setting circle, also shown in Figure 11-2).
3. The Data Collector looks through the eyepiece to make sure that the sky patch is devoid of visible stars. If there are stars within the illuminated reticle field, the Data Collector must move the telescope to the nearest spot where all stars are absent. In areas of the Milky Way, this may be difficult. In such a case, the Data Collector informs the Data Recorder, who notes on the data form that the field is near the plane of the Milk Way.
4. The Data Collector now calls aloud the dark reading, which the Data Recorder writes on the Sky-glow Survey Data Form (Appendix 11-5), along with the time (2400). Sky readings are then taken by flipping the mirror out of the way and observing (but not recording) the first reading. The Data Collector observes and calls out the next 3 readings, which the Data Recorder also writes on the data form. If any reading is unusually high or

low, it is possible that faint stars are interfering with the photometer. In such a case, the Data Collector must repeat the readings until 3 precise measurements are recorded.

5. The Data Collector flips the mirror back in place to move to the next transect point.
6. The above steps are repeated until all transect points for the Sonoyta and Phoenix sky-glow azimuths have been read and recorded.

Next, beginning with the transect point just beyond the east edge of the Phoenix glow, the remaining transect points may be sampled, proceeding clockwise. The procedure for collecting these measurements is the same as steps 1–5 above. Repeat these steps until all remaining transect points have been read and recorded.

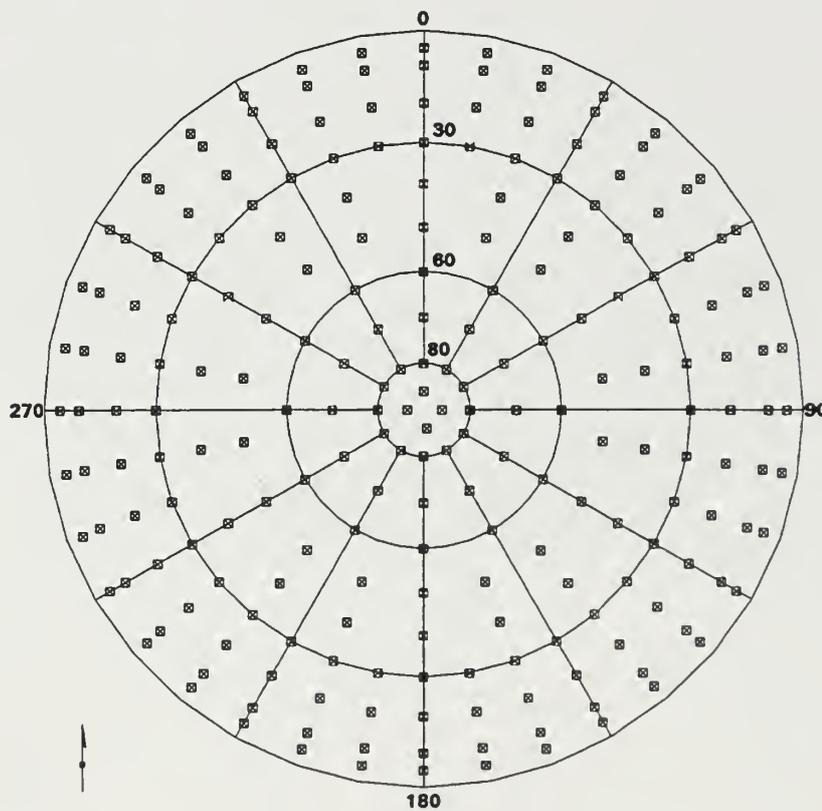


Figure 11-3. Transect sample points for use in the sky-glow survey of the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona. The figure represents a 3-dimensional sky dome—the circles representing horizontal angles (azimuths) and the radii representing vertical angles (altitudes).

Table 11-1. Relationship between altitudes and readings taken for the 220 transect points in sky-glow survey monitoring for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona.

For transect point...	a reading is taken...
5° altitude	every 10° in azimuth
10° altitude	every 10° in azimuth
20° altitude	every 10° in azimuth
30° altitude	every 10° in azimuth
40° altitude	every 20° in azimuth
50° altitude	every 20° in azimuth
60° altitude	every 30° in azimuth
70° altitude	every 30° in azimuth
80° altitude	every 30° in azimuth
Zenith	at each cardinal direction

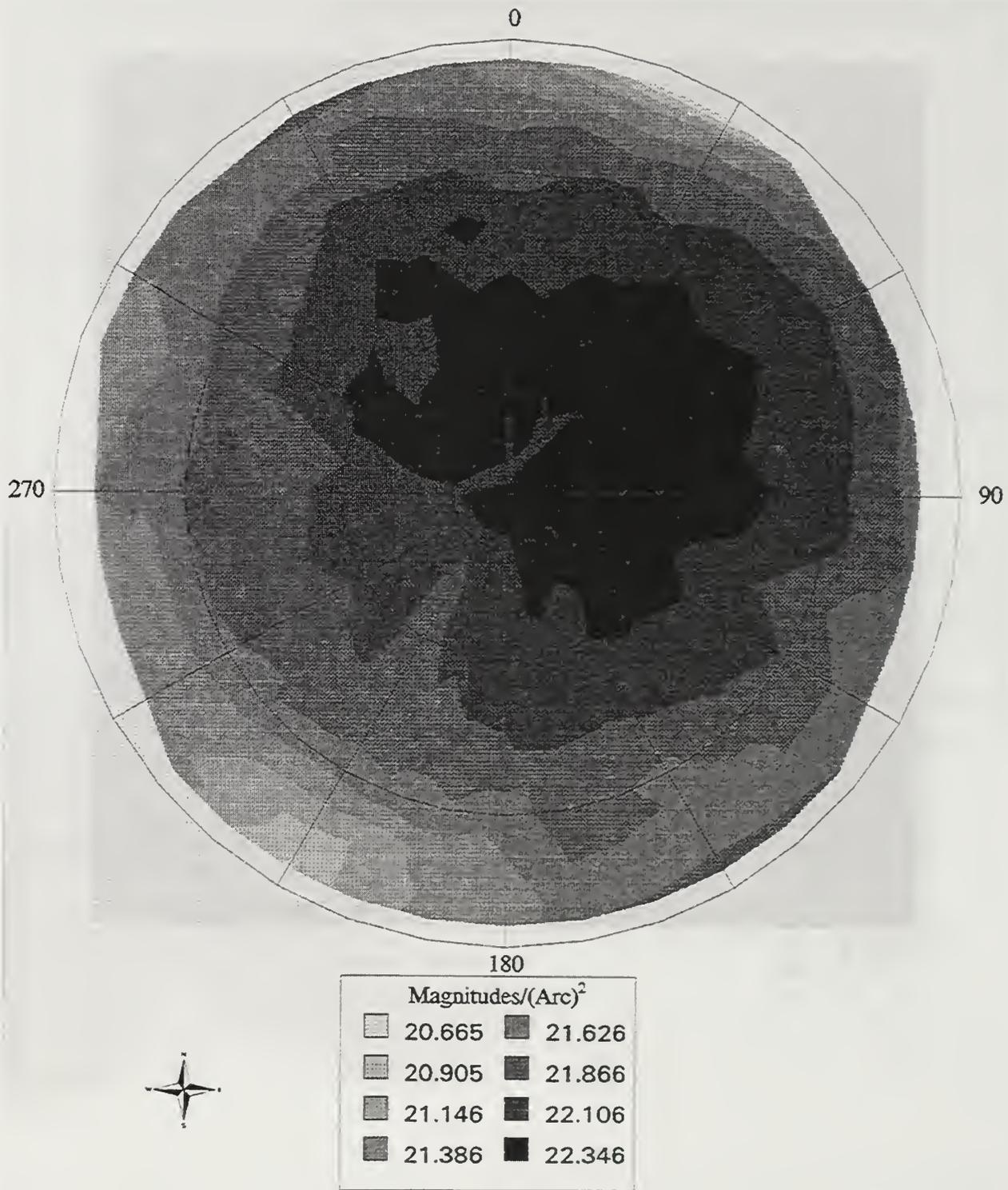


Figure 11-4. Government Information Systems (GIS) computerized plot generated from 26–28 March 1995 dataset of night-sky brightness monitoring values for Organ Pipe Cactus National Monument, Arizona.

5. Proceed clockwise to the next azimuth, and repeat steps 1–4 until all azimuths have been measured and recorded.
6. When the transect is completed and all data is collected, make certain that the mirror is flipped down, blocking all light from entering the photometer.
7. Turn off the photometer. Remove it from the tripod, remove the battery cord, cap the photometer, and put it in the case.
8. Once all of the equipment is dismantled and put away, and before leaving the monitoring site, make certain that nothing is left on the ground.

### **Important Factors to Consider During Monitoring**

Several factors are important to remember during night-sky brightness monitoring. These are as follows:

1. When measuring a sky patch in an area of light pollution, note this on the data form (e.g., in the middle of the Sonoyta glow).
2. Always note if a transect point is blocked by a mountain or vegetation.
3. If the Zodiacal Glow is present, note it on the data sheet.
4. Surveys of the Phoenix and Sonoyta glows should only be gathered when the Milky Way does not interfere. For example, a plane of the galaxy extending through the city glow will produce serious measurement errors. Completion of monitoring in early to mid-winter will avoid this problem.
5. The solar cycle is a major factor affecting the brightness of the night sky. During high solar activity, the sky may brighten significantly. Similarly, during times of little solar activity, the sky can become very dark. The cycle of solar maximum and minimum is 11 yr. As of this writing, the next solar minimum will be 1997. The next solar maximum will follow, 11 yr later, in 2008. It should be noted, however, that the sun is not totally predictable; there is a degree of variation around the predicted cycle.

### **Data Entry and Analysis**

All data are entered into 2 spreadsheets (Lotus 1-2-3). These are the Extinction Star spreadsheet and the Sky-glow Survey spreadsheet.

#### *Extinction Star Spreadsheet*

This spreadsheet (see the example, Appendix 11-6) is used to (1) calculate instrument constant (Q), (2) calculate extinction coefficient (kv), and (3) statistically analyze the linear regression that produces the constants. It requires data entry from the Extinction Star Data Form (Appendix 11-3) and a linear regression on the calculated values for the variables “Airmass” and “ $V - v$ .”

The procedure for completion of the Extinction Star Spreadsheet is as follows:

1. Activate the Lotus 1-2-3 menu and select File, Retrieve to load the template spreadsheet entitled C:\NIGHTSKYNSB\_TEMP.WK3.
2. Enter the following information:
  - (a) Julian date (see Appendix 11-7).
  - (b) Time (military, i.e., 2400) of the observation of each extinction star. Once these are entered, Lotus 1-2-3 will generate a value for zenith angle. This should be a close approximation of measured zenith angle from the field.
  - (c) Count data should be entered into the appropriate cells. Lotus 1-2-3 will then calculate average values for all counts. These values, in turn, will be used by Lotus 1-2-3 to calculate subsequent values.
3. After all field data are entered, right-scroll to the regression analysis section of the spreadsheet, or press the [F5] key ([GOTO]) and enter the spreadsheet:cell address A:AN1.
4. Prepare the data regression as follows:
  - (a) Activate the Lotus 1-2-3 menu and select Data, Regression, X-axis, then range-select the "Airmass" values for the stars that were just entered.
  - (b) Select Y-axis and range-select for the " $V - v$ " values.
  - (c) Select Go to have Lotus 1-2-3 perform the regression. Once complete, the value for instrument constant needs to be recorded for entry into the Sky-glow Survey spreadsheet.
5. Finally, activate the Lotus 1-2-3 menu and select File, Save, [Esc]. Rename the completed spreadsheet using the date of the survey and the unique filename extension for night-sky brightness files, .NSB. (e.g., C:\NIGHTSKY\032695.NSB).

### *Sky-glow Survey Spreadsheet*

This spreadsheet (see the example, Appendix 11-8) requires entry of the data recorded on the Sky-glow Survey Data Form (Appendix 11-5). Sky-brightness values will then be calculated for each transect-point sky patch.

The procedure for completion of the Sky-glow Survey Spreadsheet is as follows:

1. Activate the Lotus 1-2-3 menu and select File, Retrieve to load the template spreadsheet entitled C:\NIGHTSKY\SGS\_TEMP.WK3.
2. Enter the following information:
  - (a) At spreadsheet:cell address A:D2, enter the instrument constant (Q) that was generated by Lotus 1-2-3 in the regression run in the Extinction Star Spreadsheet.
  - (b) Counts recorded on the Sky-glow Survey Data Form (Appendix 11-5).
3. Lotus 1-2-3 calculates average values, using these values with Q to calculate the magnitudes per arcsec<sup>2</sup> under column M.
4. Finally, activate the Lotus 1-2-3 menu and select File, Save, [Esc]. Rename the completed spreadsheet using the date of the survey and the unique filename extension for sky-glow survey files, .SGS. (e.g., C:\NIGHTSKY\032695.SGS).

### **Example Calculations**

The following examples will aid in better understanding how photometer counts are converted into magnitude-per-arcsec<sup>2</sup> values.

#### *Extinction Coefficient/Instrument Constant Calculations*

These calculations are taken from the actual 26 March 1995 dataset for Zeta Aries (see Appendix 11-6).

Formulae input values:

Zenith angle (Z  $\angle$ ) = 70°

Star + sky + dark (St + S + D) (Star) readings: 1,798, 1,797, 1,792

Sky + dark (S + D) (Sky) readings: 1,054, 1,057, 1,021

Dark count reading: 504

Average St + S + D value:

$$(St + S + D) = (1,798 + 1,797 + 1,792) \div 3$$

$$(St + S + D) = 1,795.7$$

Average S + D value:

$$(S + D) = (1,054 + 1,057 + 1,021) \div 3$$

$$(S + D) = 1,044$$

Formula and applied values to determine the star count (St):

$$(St + S + D) - (S + D) = St$$

$$1,795.7 - 1,044 = 751.7$$

The star count must then be converted into instrumental magnitude (v):

$$v = -2.5 \log (St)$$

$$v = -2.5 \log (751.7)$$

$$v = -7.190$$

Instrumental magnitude is then subtracted from the published visible magnitude (V).

$$V \text{ for Zeta Aries} = 4.89$$

$$V - v = 4.89 - (-7.190)$$

$$V - v = 12.08$$

This  $V - v$  value becomes the Y-axis for the linear regression.

Airmass is then calculated:

$$\text{Airmass} = \sec Z \angle$$

$$\text{Airmass} = 1/(\cos Z \angle)$$

$$\text{Airmass} = 1/(\cos 70^\circ)$$

$$\text{Airmass} = 2.92$$

This value becomes the X-axis for the linear regression.

Lotus 1-2-3 would perform the linear regression, giving Zeta Aries the point (2.92, 12.08).

If the above calculations are carried out for several stars over varying values of air mass, the result approximates a line. The slope of this line is the extinction coefficient (kv), and the Y-intercept is the instrument constant (Q). On 26 March 1995, the calculated value for the instrument constant was 12.64613.

### *Sky Patch Brightness Calculations*

These calculations are also taken from the actual 26 March 1995 dataset for Zeta Aries (see Appendix 11-6).

Formulae input values:

$$\text{Instrument constant (Q)} = 12.64613$$

$$\text{Sky + dark (S + D) (Sky) readings: 685, 677, 680}$$

$$\text{Dark count reading: 506}$$

Average S + D value:

$$(S + D) = (685 + 677 + 680) \div 3$$

$$(S + D) = 680.67$$

Formula and applied values to calculate sky patch (S) at 240° Az 70° Alt:

$$S = (S + D) - \text{dark count}$$

$$S = 680.67 - 506$$

$$S = 174.67$$

Formula and applied values to calculate magnitude of sky patch (ms):

$$ms = Q - 2.5 \log (S)$$

$$ms = 12.64613 - 2.5 \log (174.67)$$

$$ms = 7.0406$$

The brightness of the sky patch (7.0406 magnitude) is now known, but the size remains to be determined. In order to obtain an end value of magnitudes per arcsec<sup>2</sup>, it is first necessary to calculate the area of the sky patch in arcsec<sup>2</sup>.

Formula and applied values to determine scale (s):

$$(s) = 206,265 \text{ arcsec per telescopic focal length in millimeters}$$

$$(s) = 206,265 \text{ arcsec per } 191 \text{ mm}$$

$$(s) = 1,079.92 \text{ arcsec per mm}$$

The diaphragm in the photometer is a circle with a diameter of 1 mm, therefore:

$$(s) \times 1 \text{ mm} = \text{diameter in arcsec}$$

$$(1,079.92 \text{ arcsec. per mm}) \times 1 \text{ mm} = 1,079.92 \text{ arcsec diameter}$$

Formula and applied values to determine the area (a) in arcsec<sup>2</sup> of the circular sky patch:

$$(a) = \Pi \times (\text{radius of photometer diaphragm in arcsec})^2$$

$$(a) = 3.14159 \times (1,079.92 \text{ arcsec} \div 2)^2$$

$$(a) = 915,952.7 \text{ arcsec}^2$$

Formula and applied values to determine magnitudes per arcsec<sup>2</sup>:

$$\text{mag per arcsec}^2 = ms + 2.5 \log \text{ area}$$

$$\text{mag per arcsec}^2 = 7.0406 + 2.5 \log (915,952.7 \text{ arcsec}^2)$$

$$\text{mag per arcsec}^2 = 21.945$$

Thus, the brightness of the sky at this sky patch is 21.945 magnitudes per arcsec<sup>2</sup>.

## Literature Cited

- Carr, E. L., T. S. Stocking, M. A. Yocke, and N. Yonkow. 1989. Evaluation of night sky model and human perception of night sky glow. Systems Applications, Inc., San Rafael, California (SYSAPP-89/106).
- Hender, A., and R. H. Kaitchuck. 1982. Astronomical photometry. Van Nostrand Reinhold Company, New York.
- Kosai, K., and S. Isobe. 1992. Night sky brightness over Japan. *Sky and Telescope* 8(5):564–568.
- Pilachowski, C. A., J. L. Africano, B. D. Goodrich, and W. S. Binkert. 1989. Sky brightness at the Kitt Peak National Observatory. *Publications of the Astronomical Society of the Pacific* 101:707–712.

Appendix 11-1  
**Night-sky Brightness Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monument, Arizona:  
 Extinction Star List**

This set of extinction stars is to be used for the period January–March. If the protocol is to be used outside this period, a new list of extinction stars must be generated.

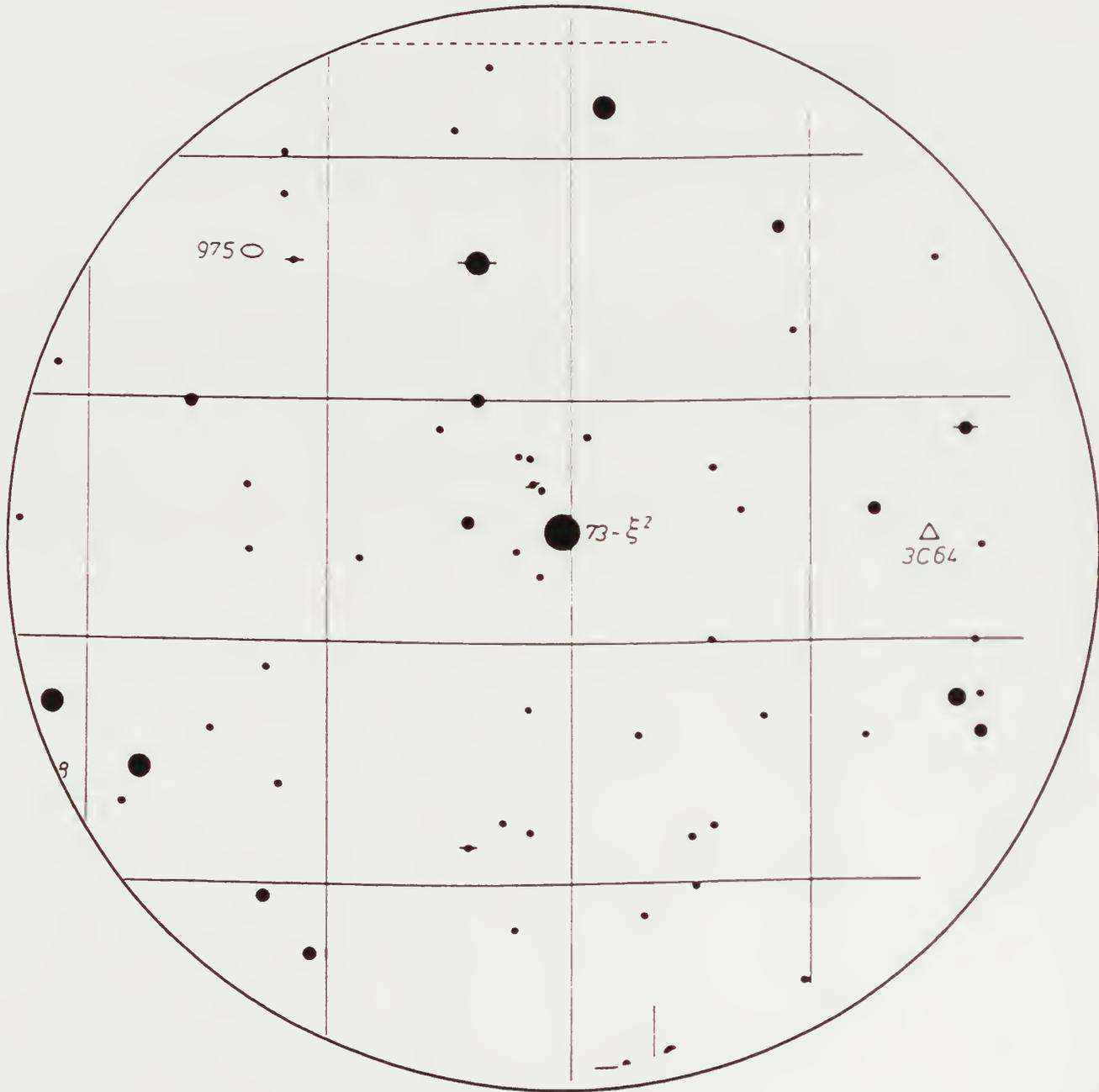
No.	Star name	Published visible magnitude (V)	Reference page no.		
			Norton's Atlas	Sky Atlas 2000	Uranometria 2000
1	Chi (ξ) 2 Cetus	4.28		10	175
2	Rho (ρ) Cetus	4.89		10	265
3	Upsilon (υ) Pisces	4.76		4	127
4	Zeta (ζ) Aries	4.89		4	131
5	Theta (θ) Lepus	4.67		11	271
6	2 Lynx	4.47		1	41
7	26 Ursa Major	4.50		6	45
8	Sigma (σ) Leo	4.06		13	191
9	23 Coma Berenices	4.81		7	149
10	Alpha (α) Sextans	4.49		13	234
11	Beta (β) Crater	4.48		20	326
12	Sigma (σ) Hercules	4.20		8	80
13	Delta (δ) Ursa Minor	4.35		3	2
14	68 Ophiuchus	4.42		16	249

Appendix 11-2

**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Field Identification Charts for 14 Extinction Stars**

The following 14 illustrations represent approximately what the observer will view through the photometer eyepiece upon centering each extinction star. Each star chart is numbered as it appears in the Extinction Star List (Appendix 11-1).

# Chi ( $\xi$ ) 2 Cetus

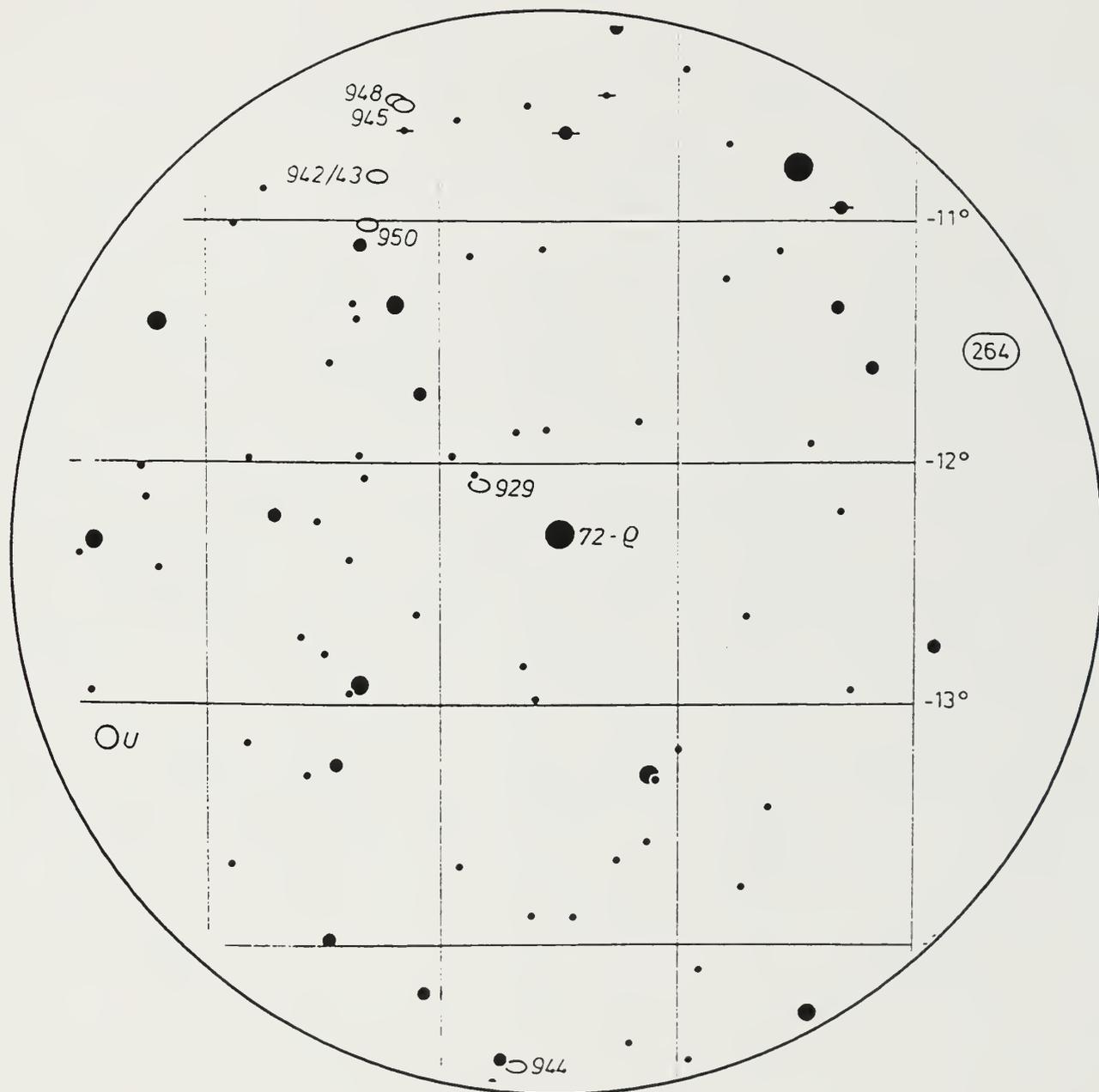


Extinction star list no.:	1
Right ascension:	2° 27' 21"
Declination:	8° 23' 36"
Published visible magnitude (V):	4.28
Photographic magnitude (B - V):	-0.06
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	10
Uranometria 2000 page no.:	175

Location: West star in head.

Notes: Avoid faint stars to the north and east.

# Rho ( $\rho$ ) Cetus

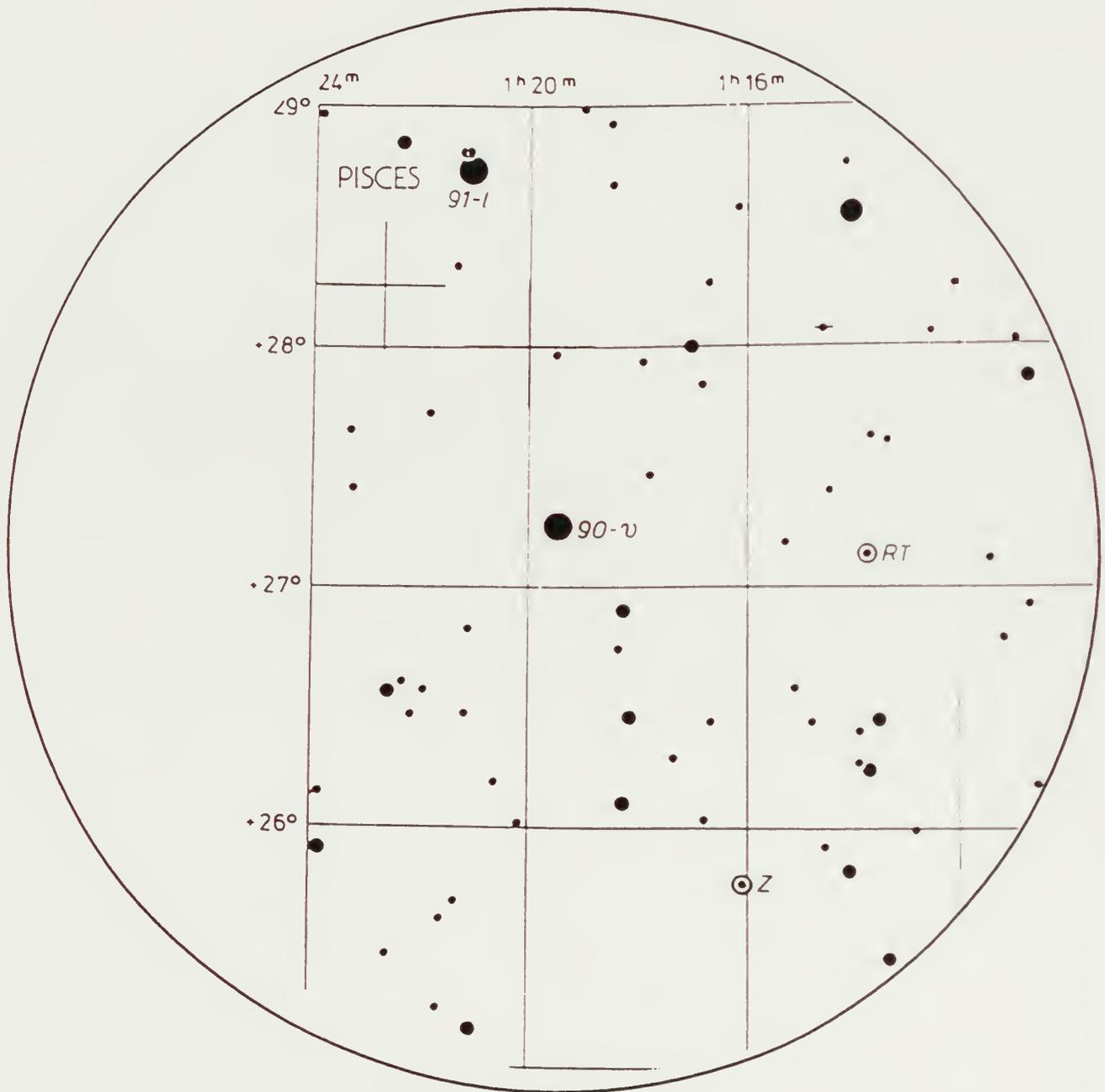


Extinction star list no.: 2  
 Right ascension: 2° 25' 13"  
 Declination: -12° 51' 27"  
 Published visible magnitude (V): 4.89  
 Photographic magnitude (B - V): -0.02  
 Norton's Atlas page no.:  
 Sky Atlas 2000 page no.: 10  
 Uranometria 2000 page no.: 265

Location: Approximately 12° south of Mira.

Notes:

# Upsilon ( $\upsilon$ ) Pisces

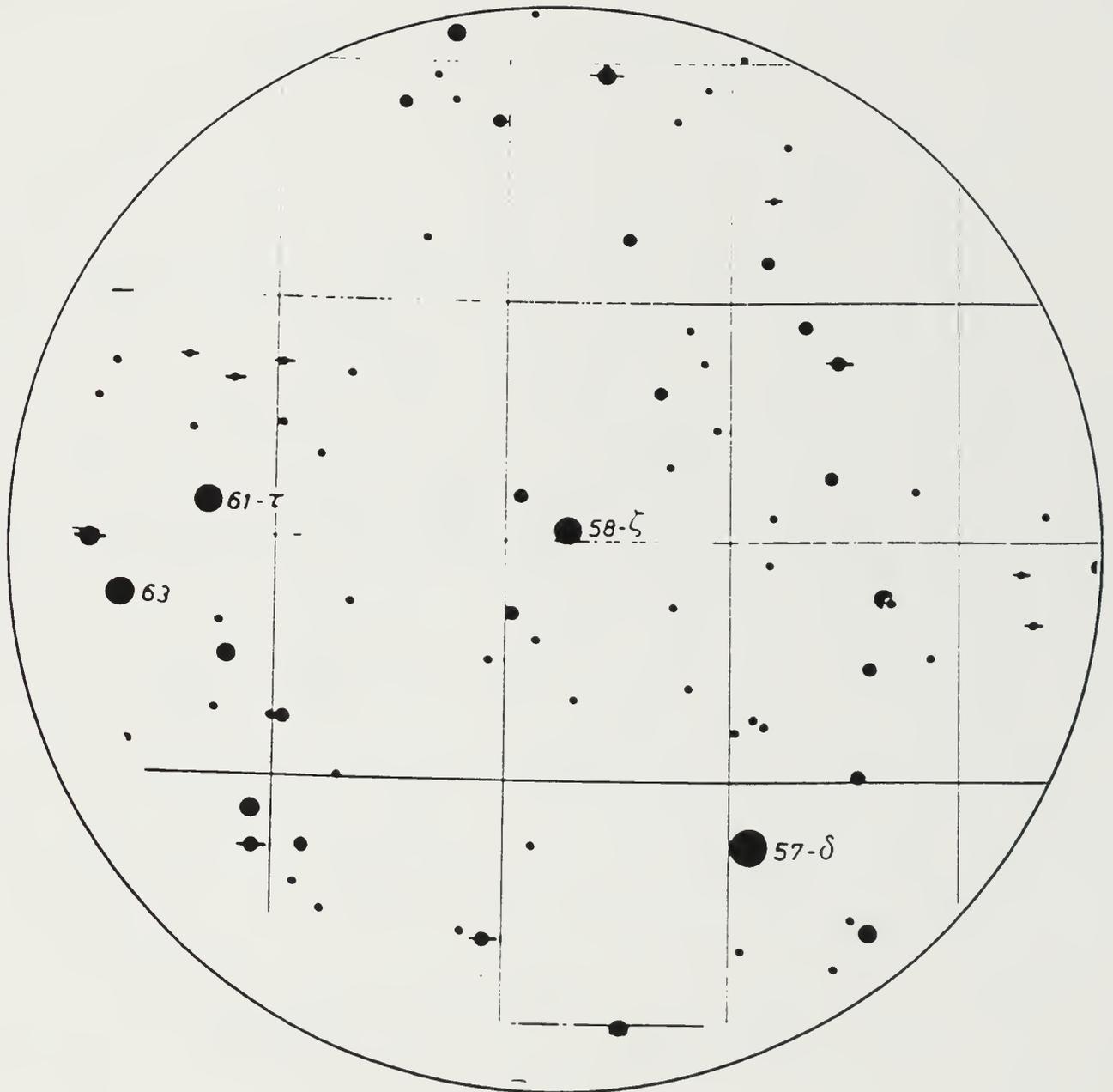


Extinction star list no.:	3
Right ascension:	1° 18' 38"
Declination:	27° 11' 08"
Published visible magnitude (V):	4.76
Photographic magnitude (B - V):	0.03
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	4
Uranometria 2000 page no.:	127

Location: Approximately 9° south of Beta ( $\beta$ ) Andromeda.

Notes:

## Zeta ( $\zeta$ ) Aries

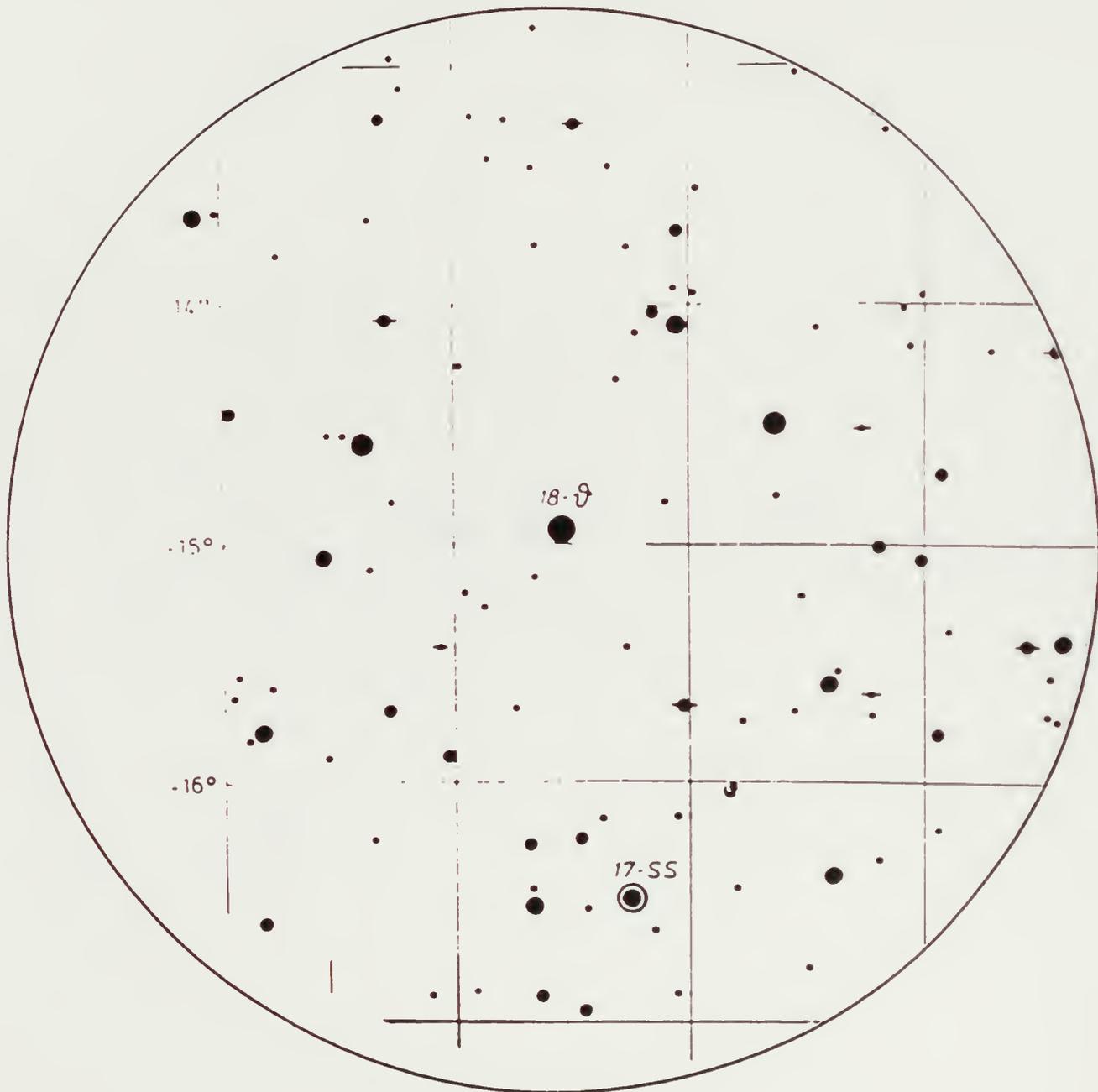


Extinction star list no.:	4
Right ascension:	$3^{\circ} 14' 02''$
Declination:	$20^{\circ} 59' 25''$
Published visible magnitude (V):	4.89
Photographic magnitude (B - V):	-0.02
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	4
Uranometria 2000 page no.:	131

Location: West of the Pleiades.

Notes:

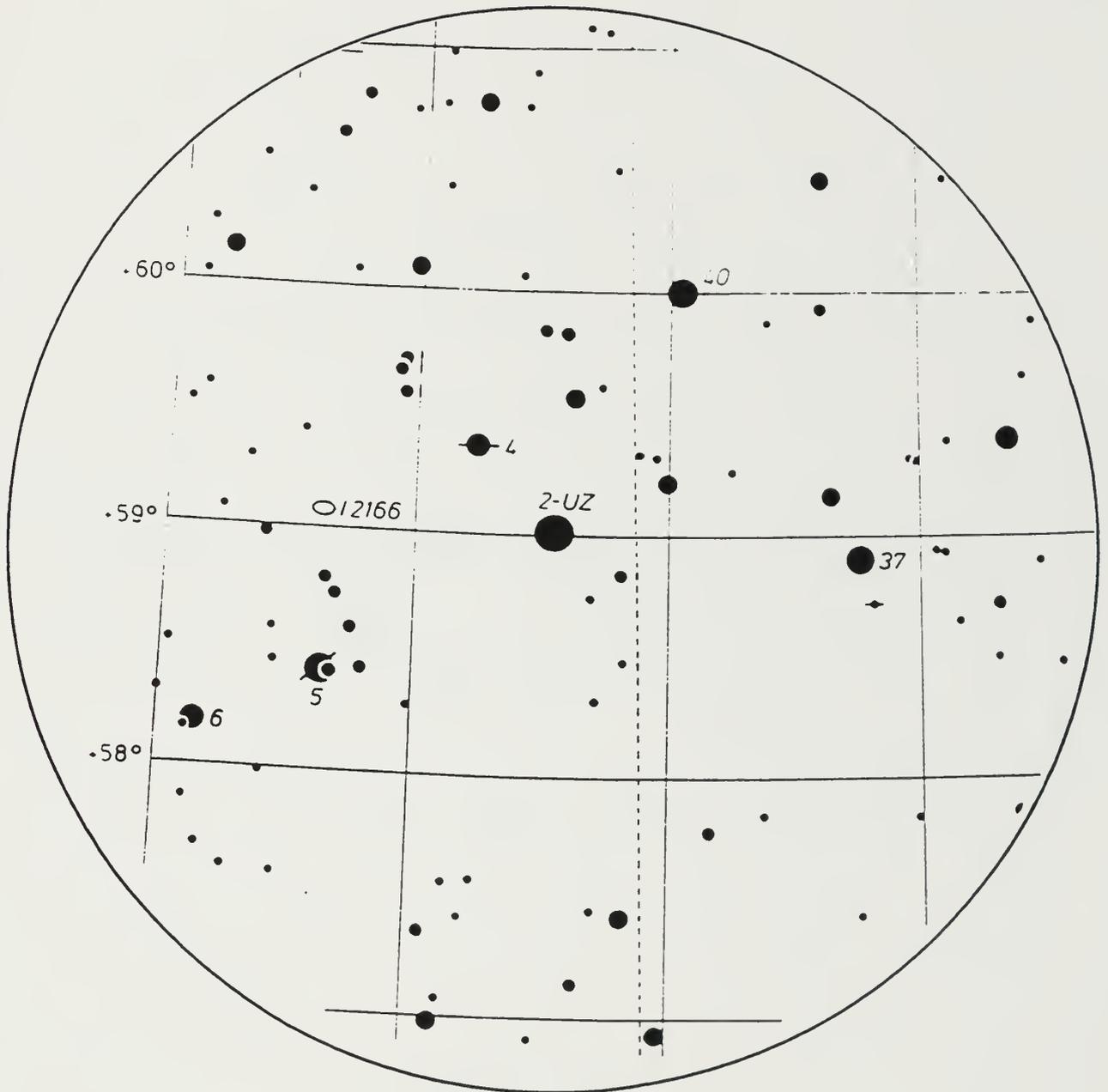
# Theta ( $\vartheta$ ) Lepus



Extinction star list no.: 5  
Right ascension: 6° 05' 28"  
Declination: -14° 55' 59"  
Published visible magnitude (V): 4.67  
Photographic magnitude (B - V): 0.05  
Norton's Atlas page no.:  
Sky Atlas 2000 page no.: 11  
Uranometria 2000 page no.: 271

Location: Southeast of Kappa ( $\kappa$ ) Orion; approximately on the line between M42 and  $\kappa$  Orion.  
Notes:

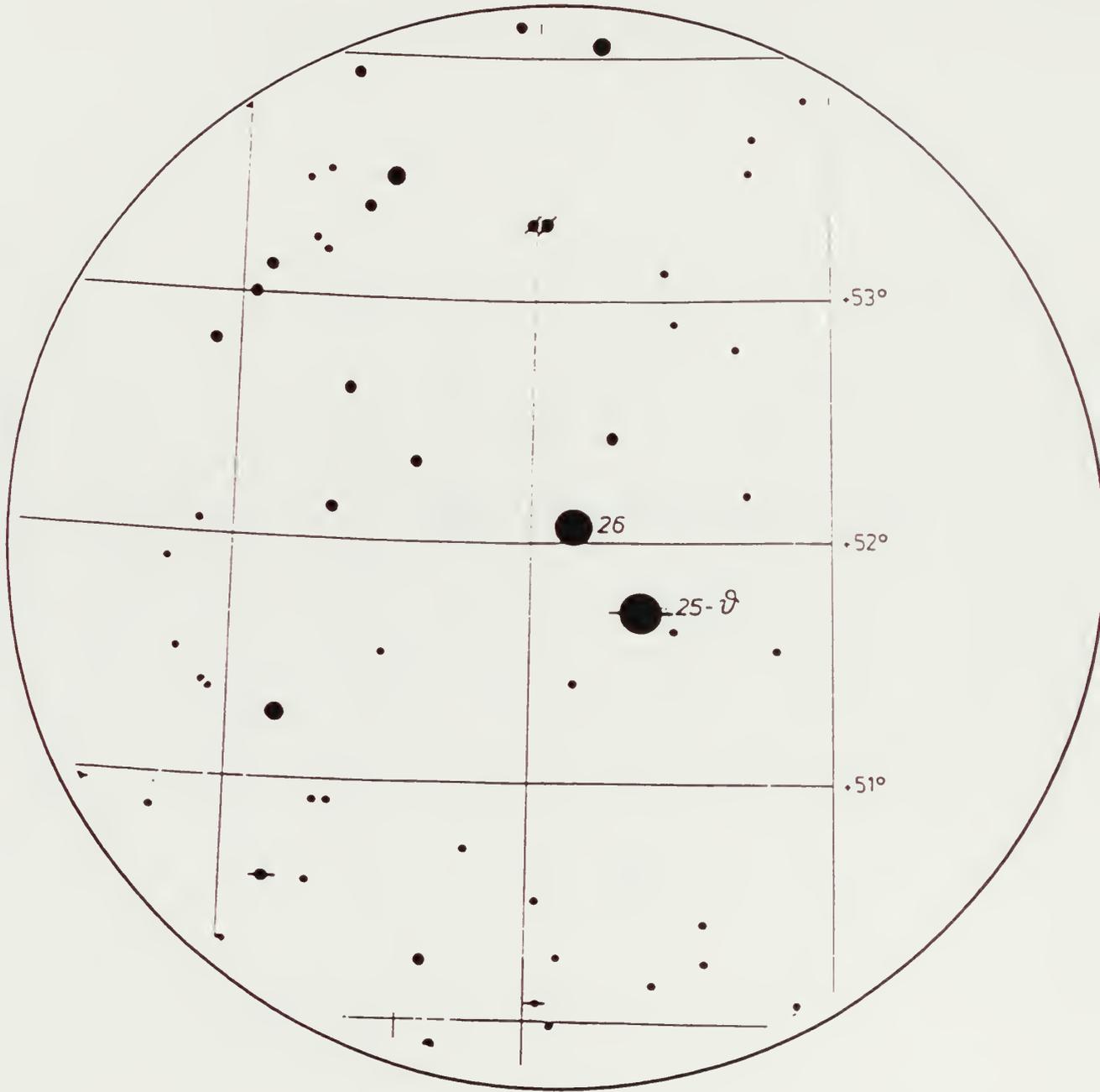
## 2 Lynx



Extinction star list no.:	6
Right ascension:	6° 18' 17"
Declination:	59° 01' 02"
Published visible magnitude (V):	4.47
Photographic magnitude (B - V):	0.01
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	1
Uranometria 2000 page no.:	41

Location: 14° to the north of Beta ( $\beta$ ) Auriga; 2 stars opposite of Capella point toward it.  
 Notes:

## 26 Ursa Major

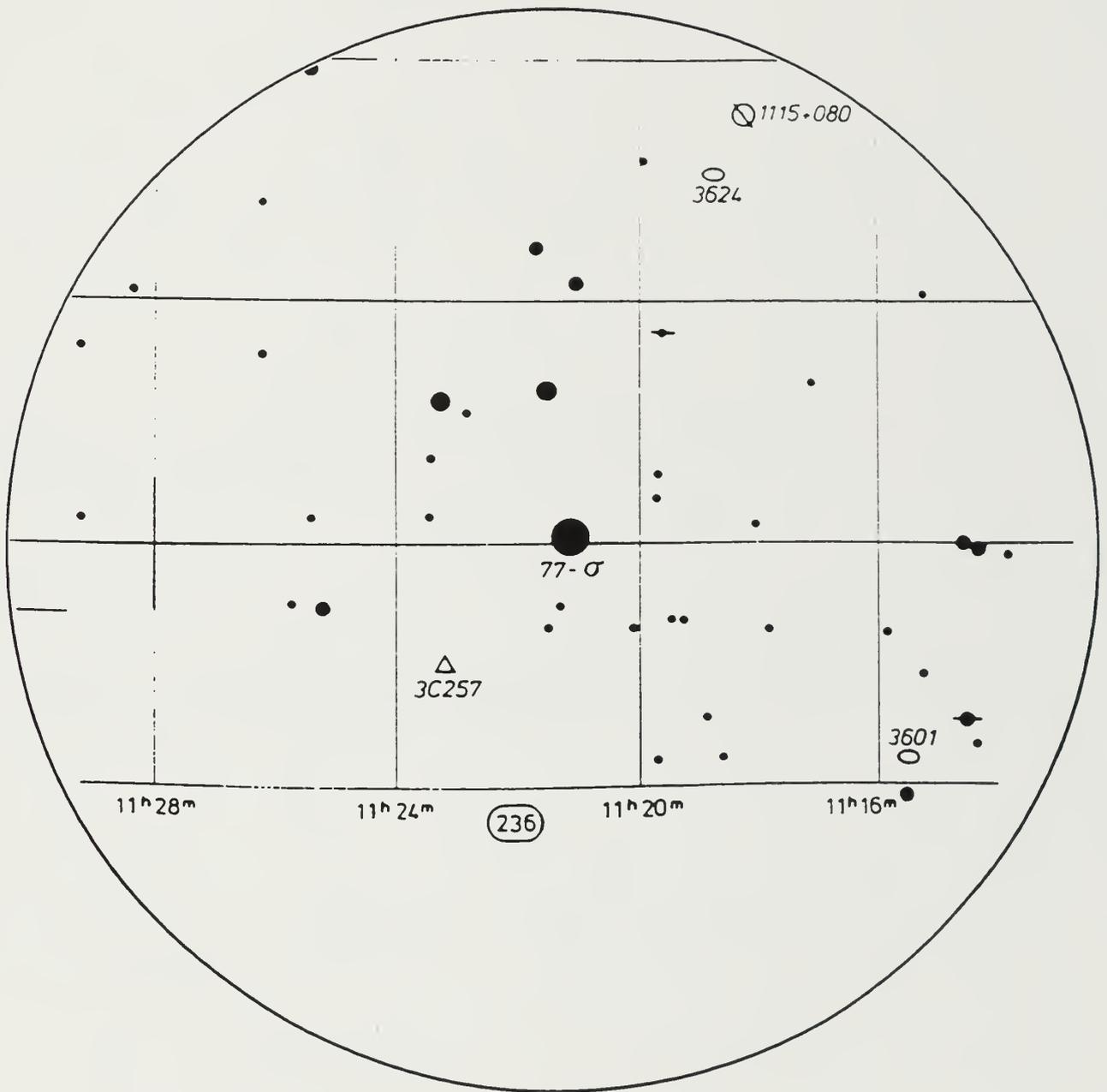


Extinction star list no.: 7  
Right ascension: 9° 33' 48"  
Declination: 52° 07' 08"  
Published visible magnitude (V): 4.50  
Photographic magnitude (B - V): 0.00  
Norton's Atlas page no.:  
Sky Atlas 2000 page no.: 6  
Uranometria 2000 page no.: 45

Location: In the front leg next to Theta ( $\vartheta$ ) Ursa Major.

Notes:

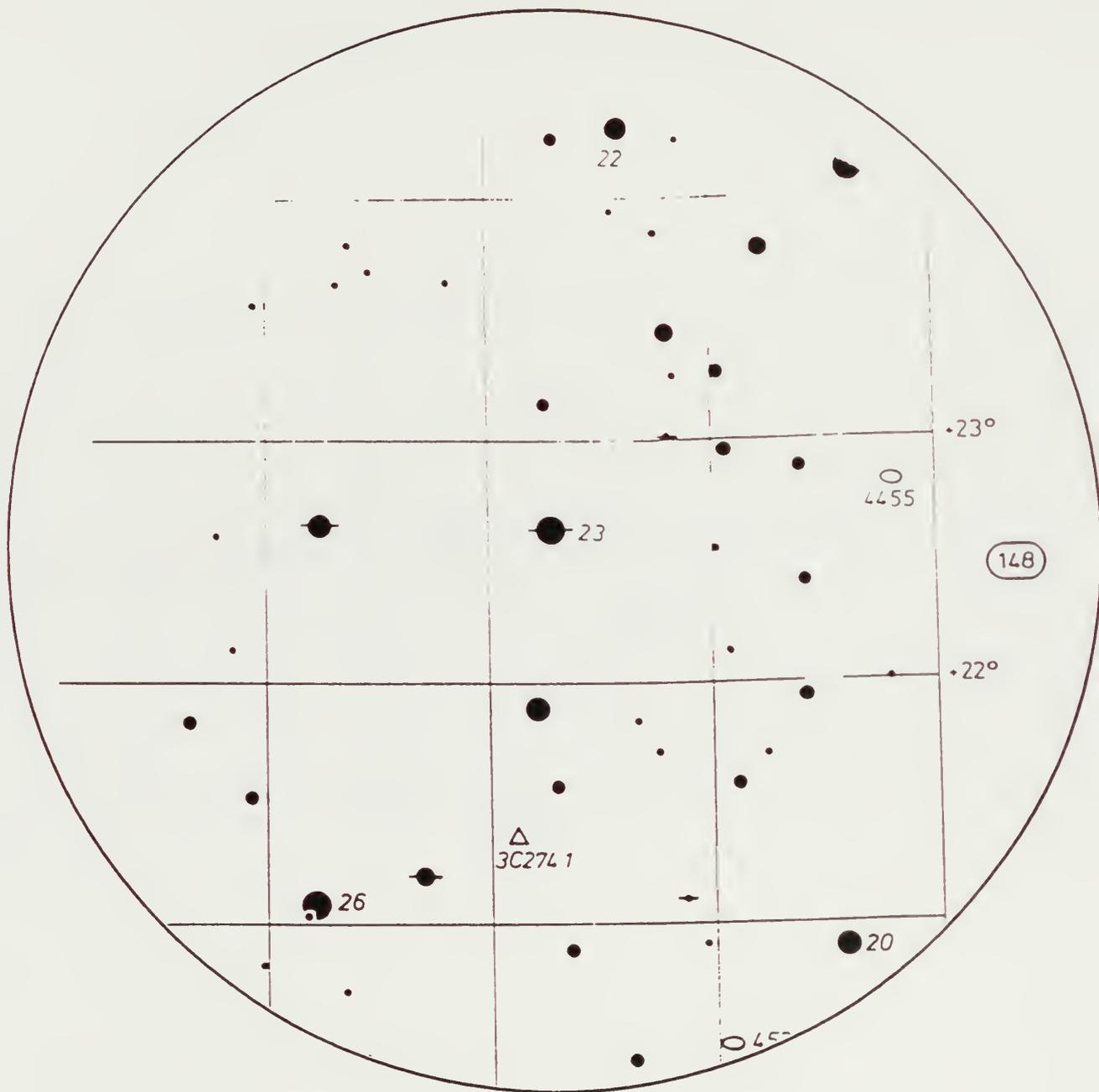
# Sigma ( $\sigma$ ) Leo



Extinction star list no.:	8
Right ascension:	11° 20' 21"
Declination:	6° 06' 42"
Published visible magnitude (V):	4.06
Photographic magnitude (B - V):	-0.07
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	13
Uranometria 2000 page no.:	191

Location: South of Theta ( $\vartheta$ ) Leo and Iota ( $\iota$ ) Leo.  
 Notes:

# 23 Coma Berenices

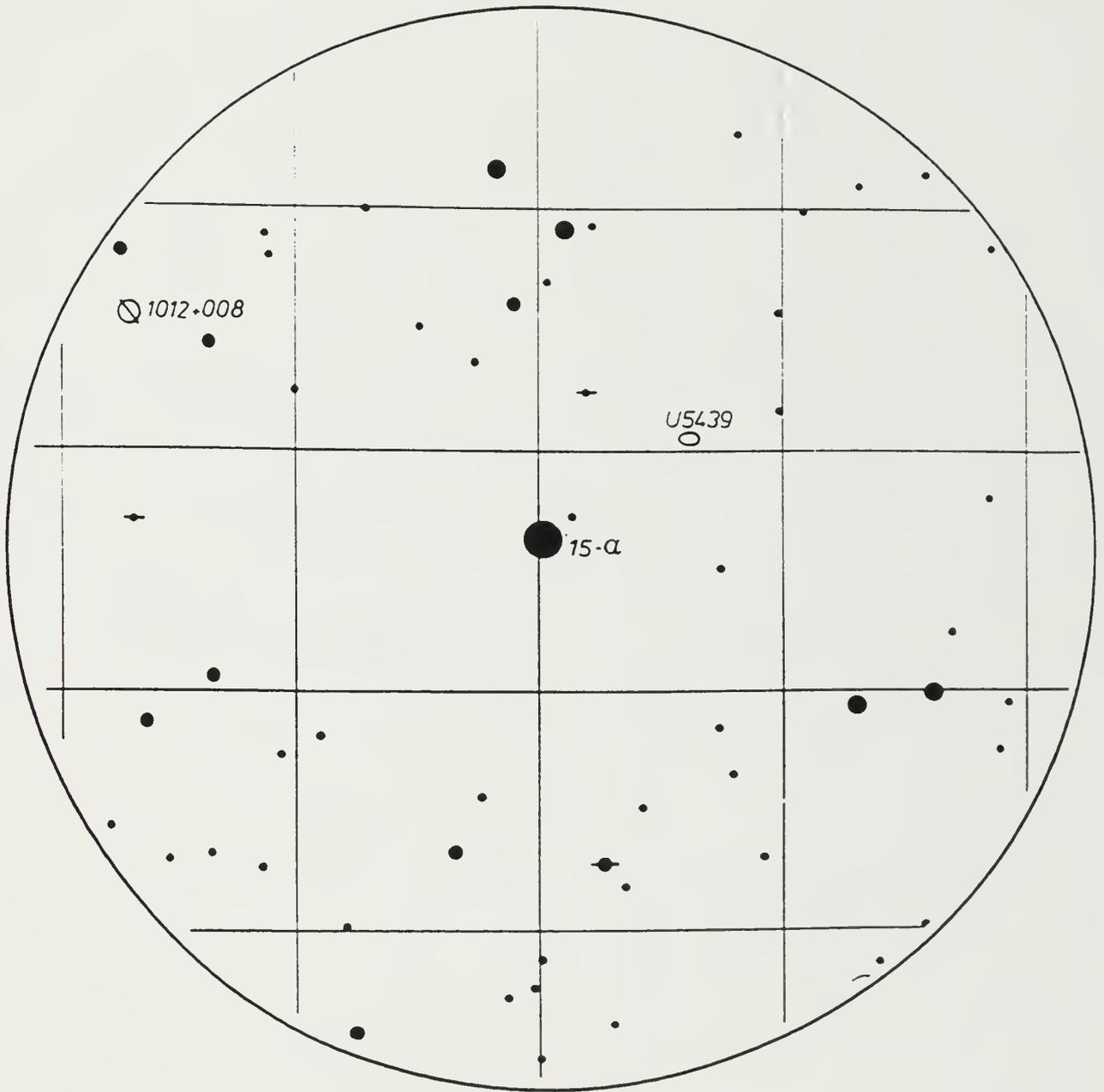


Extinction star list no.:	9
Right ascension:	12° 34' 06"
Declination:	22° 42' 41"
Published visible magnitude (V):	4.81
Photographic magnitude (B - V):	0.00
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	7
Uranometria 2000 page no.:	149

Location: 3.5° south of NGO-4565.

Notes:

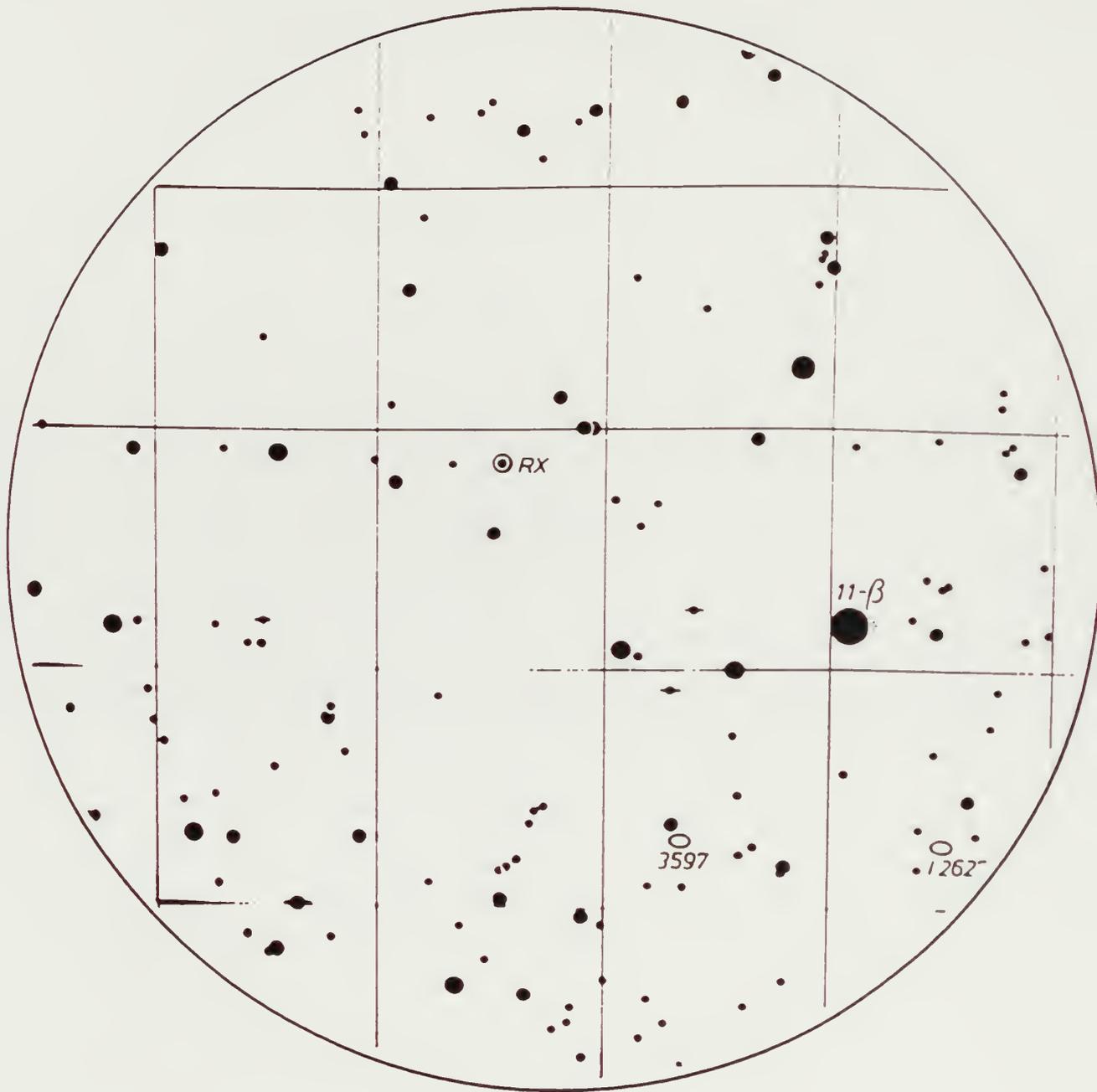
# Alpha ( $\alpha$ ) Sextans



Extinction star list no.: 10  
Right ascension:  $10^{\circ} 07' 10''$   
Declination:  $-0^{\circ} 17' 52''$   
Published visible magnitude (V): 4.49  
Photographic magnitude (B - V): -0.04  
Norton's Atlas page no.:  
Sky Atlas 2000 page no.: 13  
Uranometria 2000 page no.: 234

Location: Northeast of Alpha ( $\alpha$ ) Hydra.  
Notes: Avoid field star to the northwest.

# Beta ( $\beta$ ) Crater

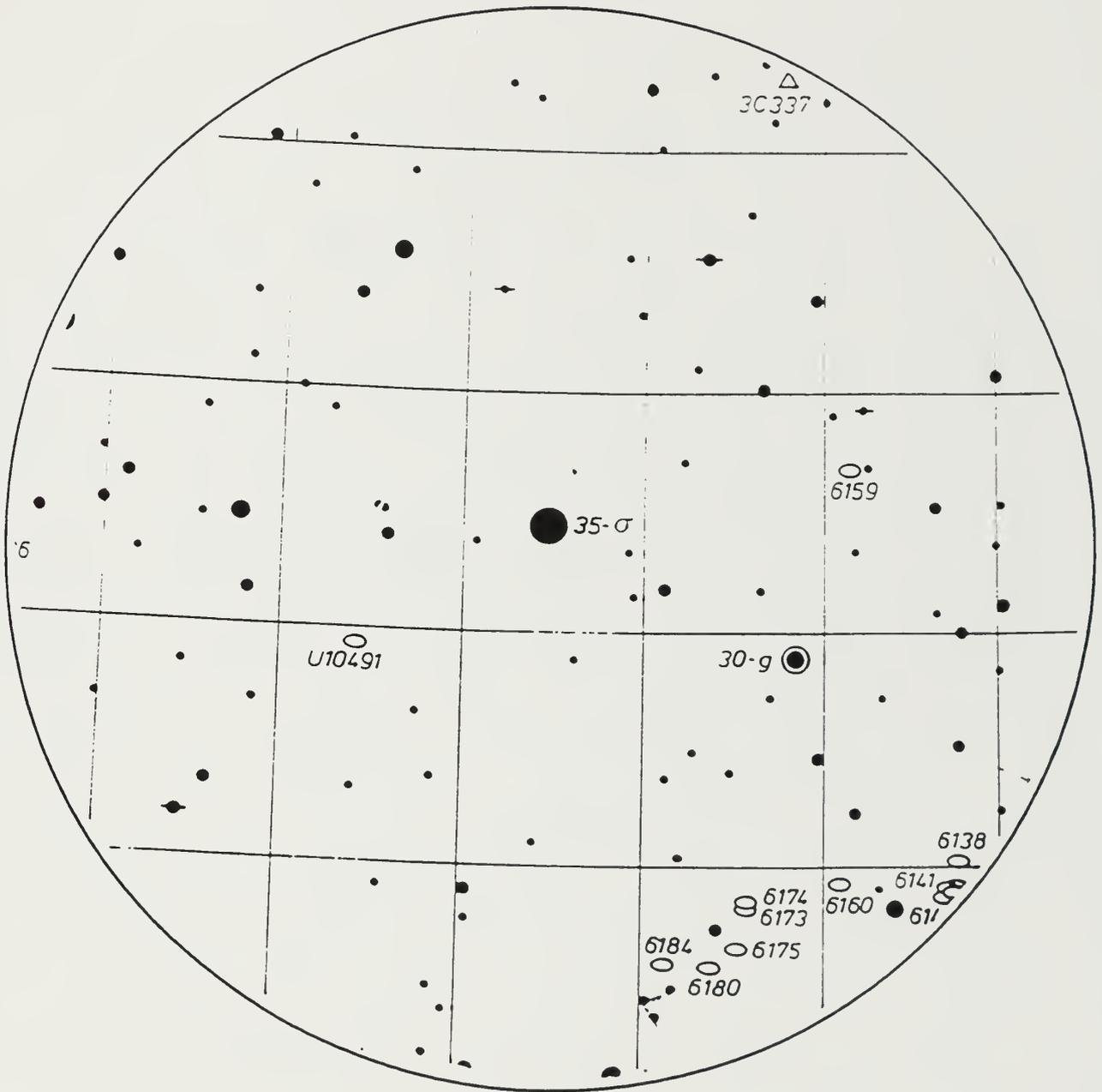


Extinction star list no.: 11  
Right ascension:  $11^{\circ} 10' 55''$   
Declination:  $-22^{\circ} 44' 33''$   
Published visible magnitude (V): 4.48  
Photographic magnitude (B - V): 0.03  
Norton's Atlas page no.:  
Sky Atlas 2000 page no.: 20  
Uranometria 2000 page no.: 326

Location: Most southerly bright star in the crater.

Notes:

# Sigma ( $\sigma$ ) Hercules

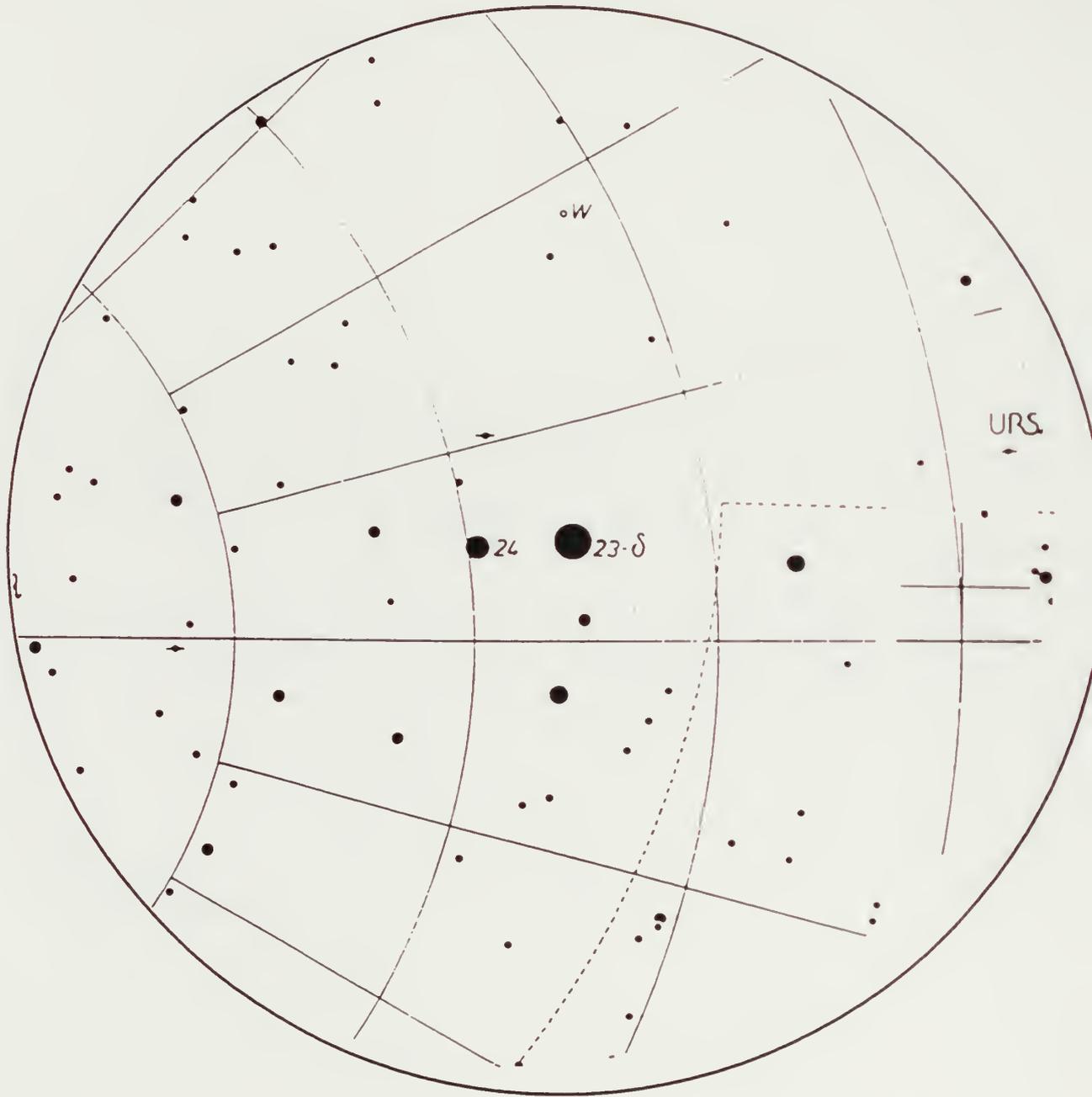


Extinction star list no.:	12
Right ascension:	16° 33' 37"
Declination:	68° 48' 00"
Published visible magnitude (V):	4.20
Photographic magnitude (B - V):	-0.02
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	8
Uranometria 2000 page no.:	80

Location: To the northwest of the northwestern star in the keystone.

Notes:

# Delta ( $\delta$ ) Ursa Minor

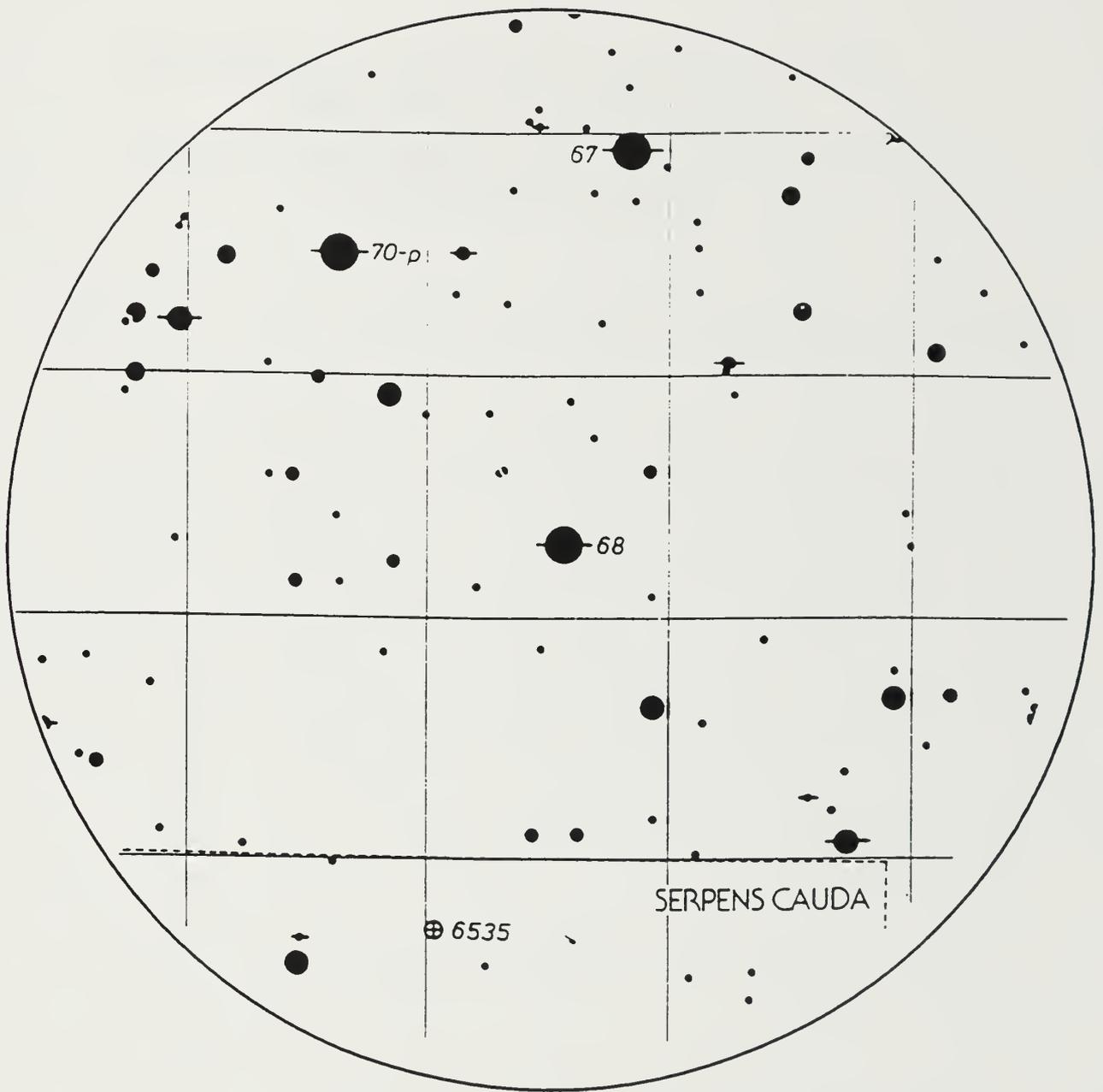


Extinction star list no.:	13
Right ascension:	17° 37' 00"
Declination:	86° 35' 41"
Published visible magnitude (V):	4.35
Photographic magnitude (B - V):	0.01
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	3
Uranometria 2000 page no.:	2

Location: First bright handle star after Polaris.

Notes:

# 68 Ophiuchus



Extinction star list no.:	14
Right ascension:	18° 00' 59"
Declination:	1° 18' 17"
Published visible magnitude (V):	4.42
Photographic magnitude (B - V):	0.04
Norton's Atlas page no.:	
Sky Atlas 2000 page no.:	16
Uranometria 2000 page no.:	249

Location: Most southerly star in the small triangle of stars east of the main part of Ophiuchus.

Notes:

Appendix 11-3  
**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Extinction Star Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.



Appendix 11-4

**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Sky-glow Survey Transect Point Elimination Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

# ORPI Ecological Monitoring Program—Sky-glow Survey Transect Point Elimination Form

Date \_\_\_\_\_ Data Recorder \_\_\_\_\_

Conditions \_\_\_\_\_ Data Collector \_\_\_\_\_

All 220 transect sample points are listed below in clockwise order. Data Recorder: Proceed down the list and check off each point as it is called aloud to the Data Collector.

**Note:** It is important to first sample transect points lying on the Sonoyta and Phoenix sky-glows, during early evening when municipal lights and automobile headlamps are in peak use. These transect points are located on approximately 200–220° azimuths for Sonoyta, and approximately 10–40° azimuths for Phoenix. Once these have been surveyed, continue with the transect point just beyond the east edge of the Phoenix sky-glow. The remaining transect points may then be sampled, proceeding clockwise.

Point	Azimuth	Alt	Point	Azimuth	Alt	Point	Azimuth	Alt
<input type="checkbox"/> 1	0°	5°	<input type="checkbox"/> 34	50°	5°	<input type="checkbox"/> 65	100°	5°
<input type="checkbox"/> 2	0°	10°	<input type="checkbox"/> 35	50°	10°	<input type="checkbox"/> 66	100°	10°
<input type="checkbox"/> 3	0°	20°	<input type="checkbox"/> 36	50°	20°	<input type="checkbox"/> 67	100°	20°
<input type="checkbox"/> 4	0°	30°	<input type="checkbox"/> 37	50°	30°	<input type="checkbox"/> 68	100°	30°
<input type="checkbox"/> 5	0°	40°				<input type="checkbox"/> 69	100°	40°
<input type="checkbox"/> 6	0°	50°	<input type="checkbox"/> 38	60°	5°	<input type="checkbox"/> 70	100°	50°
<input type="checkbox"/> 7	0°	60°	<input type="checkbox"/> 39	60°	10°			
<input type="checkbox"/> 8	0°	70°	<input type="checkbox"/> 40	60°	20°	<input type="checkbox"/> 71	110°	5°
<input type="checkbox"/> 9	0°	80°	<input type="checkbox"/> 41	60°	30°	<input type="checkbox"/> 72	110°	10°
<input type="checkbox"/> 10	0°	Card	<input type="checkbox"/> 42	60°	40°	<input type="checkbox"/> 73	110°	20°
			<input type="checkbox"/> 43	60°	50°	<input type="checkbox"/> 74	110°	30°
<input type="checkbox"/> 11	10°	5°	<input type="checkbox"/> 44	60°	60°			
<input type="checkbox"/> 12	10°	10°	<input type="checkbox"/> 45	60°	70°	<input type="checkbox"/> 75	120°	5°
<input type="checkbox"/> 13	10°	20°	<input type="checkbox"/> 46	60°	80°	<input type="checkbox"/> 76	120°	10°
<input type="checkbox"/> 14	10°	30°				<input type="checkbox"/> 77	120°	20°
			<input type="checkbox"/> 47	70°	5°	<input type="checkbox"/> 78	120°	30°
<input type="checkbox"/> 15	20°	5°	<input type="checkbox"/> 48	70°	10°	<input type="checkbox"/> 79	120°	40°
<input type="checkbox"/> 16	20°	10°	<input type="checkbox"/> 49	70°	20°	<input type="checkbox"/> 80	120°	50°
<input type="checkbox"/> 17	20°	20°	<input type="checkbox"/> 50	70°	30°	<input type="checkbox"/> 81	120°	60°
<input type="checkbox"/> 18	20°	30°				<input type="checkbox"/> 82	120°	70°
<input type="checkbox"/> 19	20°	40°	<input type="checkbox"/> 51	80°	5°	<input type="checkbox"/> 83	120°	80°
<input type="checkbox"/> 20	20°	50°	<input type="checkbox"/> 52	80°	10°			
			<input type="checkbox"/> 53	80°	20°	<input type="checkbox"/> 84	130°	5°
<input type="checkbox"/> 21	30°	5°	<input type="checkbox"/> 54	80°	30°	<input type="checkbox"/> 85	130°	10°
<input type="checkbox"/> 22	30°	10°	<input type="checkbox"/> 55	80°	40°	<input type="checkbox"/> 86	130°	20°
<input type="checkbox"/> 23	30°	20°	<input type="checkbox"/> 56	80°	50°	<input type="checkbox"/> 87	130°	30°
<input type="checkbox"/> 24	30°	30°						
<input type="checkbox"/> 25	30°	60°	<input type="checkbox"/> 57	90°	5°	<input type="checkbox"/> 88	140°	5°
<input type="checkbox"/> 26	30°	70°	<input type="checkbox"/> 58	90°	10°	<input type="checkbox"/> 89	140°	10°
<input type="checkbox"/> 27	30°	80°	<input type="checkbox"/> 59	90°	20°	<input type="checkbox"/> 90	140°	20°
			<input type="checkbox"/> 60	90°	30°	<input type="checkbox"/> 91	140°	30°
<input type="checkbox"/> 28	40°	5°	<input type="checkbox"/> 61	90°	60°	<input type="checkbox"/> 92	140°	40°
<input type="checkbox"/> 29	40°	10°	<input type="checkbox"/> 62	90°	70°	<input type="checkbox"/> 93	140°	50°
<input type="checkbox"/> 30	40°	20°	<input type="checkbox"/> 63	90°	80°			
<input type="checkbox"/> 31	40°	30°	<input type="checkbox"/> 64	90°	Card			
<input type="checkbox"/> 32	40°	40°						
<input type="checkbox"/> 33	40°	50°						

*Continued on reverse...*

Point	Azimuth	Alt
□ 94	150°	5°
□ 95	150°	10°
□ 96	150°	20°
□ 97	150°	30°
□ 98	150°	60°
□ 99	150°	70°
□ 100	150°	80°
□ 101	160°	5°
□ 102	160°	10°
□ 103	160°	20°
□ 104	160°	30°
□ 105	160°	40°
□ 106	160°	50°
□ 107	170°	5°
□ 108	170°	10°
□ 109	170°	20°
□ 110	170°	30°
□ 111	180°	5°
□ 112	180°	10°
□ 113	180°	20°
□ 114	180°	30°
□ 115	180°	40°
□ 116	180°	50°
□ 117	180°	60°
□ 118	180°	70°
□ 119	180°	80°
□ 120	180°	Card
□ 121	190°	5°
□ 122	190°	10°
□ 123	190°	20°
□ 124	190°	30°
□ 125	200°	5°
□ 126	200°	10°
□ 127	200°	20°
□ 128	200°	30°
□ 129	200°	40°
□ 130	200°	50°
□ 131	210°	5°
□ 132	210°	10°
□ 133	210°	20°
□ 134	210°	30°
□ 135	210°	60°
□ 136	210°	70°
□ 137	210°	80°

Point	Azimuth	Alt
□ 138	220°	5°
□ 139	220°	10°
□ 140	220°	20°
□ 141	220°	30°
□ 142	220°	40°
□ 143	220°	50°
□ 144	230°	5°
□ 145	230°	10°
□ 146	230°	20°
□ 147	230°	30°
□ 148	240°	5°
□ 149	240°	10°
□ 150	240°	20°
□ 151	240°	30°
□ 152	240°	40°
□ 153	240°	50°
□ 154	240°	60°
□ 155	240°	70°
□ 156	240°	80°
□ 157	250°	5°
□ 158	250°	10°
□ 159	250°	20°
□ 160	250°	30°
□ 161	260°	5°
□ 162	260°	10°
□ 163	260°	20°
□ 164	260°	30°
□ 165	260°	40°
□ 166	260°	50°
□ 167	270°	5°
□ 168	270°	10°
□ 169	270°	20°
□ 170	270°	30°
□ 171	270°	60°
□ 172	270°	70°
□ 173	270°	80°
□ 174	270°	Card
□ 175	280°	5°
□ 176	280°	10°
□ 177	280°	20°
□ 178	280°	30°
□ 179	280°	40°
□ 180	280°	50°

Point	Azimuth	Alt
□ 181	290°	5°
□ 182	290°	10°
□ 183	290°	20°
□ 184	290°	30°
□ 185	300°	5°
□ 186	300°	10°
□ 187	300°	20°
□ 188	300°	30°
□ 189	300°	40°
□ 190	300°	50°
□ 191	300°	60°
□ 192	300°	70°
□ 193	300°	80°
□ 194	310°	5°
□ 195	310°	10°
□ 196	310°	20°
□ 197	310°	30°
□ 198	320°	5°
□ 199	320°	10°
□ 200	320°	20°
□ 201	320°	30°
□ 202	320°	40°
□ 203	320°	50°
□ 204	330°	5°
□ 205	330°	10°
□ 206	330°	20°
□ 207	330°	30°
□ 208	330°	60°
□ 209	330°	70°
□ 210	330°	80°
□ 211	340°	5°
□ 212	340°	10°
□ 213	340°	20°
□ 214	340°	30°
□ 215	340°	40°
□ 216	340°	50°
□ 217	350°	5°
□ 218	350°	10°
□ 219	350°	20°
□ 220	350°	30°

*Continued on reverse...*

Appendix 11-5  
**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Sky-glow Survey Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

ORPI Ecological Monitoring Program—Sky-glow Survey Data Form

Date \_\_\_\_\_

Data Recorder \_\_\_\_\_

Conditions \_\_\_\_\_

Data Collector \_\_\_\_\_

	Transect Point			Photometer Readings			Notes
	Azimuth	Altitude	Time	Dark	Sky <sub>1</sub>	Sky <sub>2</sub>	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							

	Transect Point		Photometer Readings				Notes
	Azimuth	Altitude	Time	Dark	Sky 1	Sky 2	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							

General Notes:

Appendix 11-6

**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Sample Printout of the Extinction Star Spreadsheet**



## Appendix 11-6, Part B: Spreadsheet Calculation Area

0.556324

	RA	DEC	VMAG	B-V	STARCT	v(inst)	AirMass	V-v	Kv	AMAG	Q	SMAG				
	HR	MIN	DEG	MIN		(d)										
GD=	7															
GST=	-4.78285															
GSTC=	19.21715															
LST=	11.69715	DDR=0.15														
	X12	CET	2	27	8	24	4.28	-0.06	0	ERR	-1.80486	ERR	0.19369	3.930417	ERR	ERR
GD=	7															
GST=	-4.78285															
GSTC=	19.21715															
LST=	11.69715	DDR=-0.2														
	RHO	CET	2	25	-12	-51	4.89	-0.02	0	ERR	-1.34363	ERR	0.19369	4.629752	ERR	ERR
GD=	7															
GST=	-4.78285															
GSTC=	19.21715															
LST=	11.69715	DDR=0.47														
	UPSILON		1	19	27	11	4.76	0.03	0	ERR	-2.23575	ERR	0.19369	4.326958	ERR	ERR
GD=	27.76667															
GST=	16.04068															
GSTC=	16.04068															
LST=	8.520676	DDR=0.37														
	ZETA	ARI	3	14	20	59	4.89	-0.02	751.6667	-7.19006	2.97465	12.08006	0.19369	5.46616	12.65622	20.72988
GD=	28.05															
GST=	16.32478															
GSTC=	16.32478															
LST=	8.804785	DDR=-0.3														
	THETA	LEP	6	5	-14	-56	4.67	0.05	1038.667	-7.54119	2.062508	12.21119	0.19369	5.069487	12.61068	21.4183
GD=	28.28333															
GST=	16.55876															
GSTC=	16.55876															
LST=	9.038757	DDR=1.03														
	2	LYN	6	18	59	1	4.47	0.01	1515.667	-7.95151	1.278376	12.42151	0.19369	4.717609	12.66912	21.79261
GD=	28.36667															
GST=	16.64232															
GSTC=	16.64232															
LST=	9.122319	DDR=0.91														
	26	UMA	9	34	52	7	4.5	0	1488.667	-7.93199	1.069842	12.43199	0.19369	4.707218	12.63921	21.9404
GD=	28.48333															
GST=	16.7593															
GSTC=	16.7593															
LST=	9.239305	DDR=0.11														
	SIGMA	LEO	11	20	6	7	4.06	-0.07	2159.333	-8.3358	1.28717	12.3958	0.19369	4.309312	12.64511	21.73391
GD=	28.58333															
GST=	16.85958															
GSTC=	16.85958															
LST=	9.339579	DDR=0.4														
	23	CMB	12	34	22	43	4.81	0	1069	-7.57244	1.381345	12.38244	0.19369	5.077553	12.65	21.81664

Continued on next page...

```

GD=      28.8
GST=    17.07684
GSTC=   17.07684
LST=    9.556838 DDR=-0.0
        ALPHA SEX 10  7  0 -18  4.49  -0.04  1470 -7.91829 1.194285 12.40829 0.19369 4.721321 12.63961 21.84928
GD=      28.95
GST=    17.22725
GSTC=   17.22725
LST=    9.707249 DDR=-0.4
        BETA CRT 11  11 -22 -45  4.48  0.03 1327.333 -7.80745 1.918741 12.28745 0.19369 4.851641 12.65909 21.66731
GD=      7
GST=    -4.78285
GSTC=   19.21715
LST=    11.69715 DDR= 1.2
        SIGMA HER 16  34  68  48  4.2  -0.02  0  ERR 1.71852  ERR 0.19369 4.53286  ERR  ERR
GD=      7
GST=    -4.78285
GSTC=   19.21715
LST=    11.69715 DDR=1.51
        DELTA UMI 17  37  86  36  4.35  0.01  0  ERR 1.893224  ERR 0.19369 4.716699  ERR  ERR
GD=      7
GST=    -4.78285
GSTC=   19.21715
LST=    11.69715 DDR=0.02
        68 OPH  18  1  1  18  4.47  0.04  0  ERR -16.9625  ERR 0.19369 1.184535  ERR  ERR
10

```

## Appendix 11-6, Part C: Spreadsheet Linear Regression Area

starAIRMASS V-v

```

1 -1.80486  ERR  Regression Output:
2 -1.34363  ERR Instrument Constant 12.64613
3 -2.23575  ERR Std Err of Y Est 0.01898
4 2.97465 12.08006 R Squared 0.980408
5 2.062508 12.21119 No. of Observations 8
6 1.278376 12.42151 Degrees of Freedom 6
7 1.069842 12.43199
8 1.28717 12.3958 Extinction Coef. -0.19369
9 1.381345 12.38244 Std Err of Coef. 0.011178
10 1.194285 12.40829
11 1.918741 12.28745
12 1.71852  ERR
13 1.893224  ERR
14 -16.9625  ERR

```

10

Appendix 11-7

**Night-sky Brightness Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Julian Day Calendar Conversion Table**

The following table is provided for use in converting Gregorian calendar dates to Julian calendar dates. Julian calendar dates are required for entry in the Extinction Star Spreadsheet.

**JULIAN DAY CALENDAR**

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
JAN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
FEB	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60		
MAR	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
APR	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
MAY	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151
JUN	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	
JUL	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212
AUG	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243
SEP	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	
OCT	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304
NOV	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	
DEC	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365

Note: Add 1 to all values 60–365 during leap years.

Appendix 11-8  
**Night-sky Brightness Monitoring Protocol for the  
 Ecological Monitoring Program in  
 Organ Pipe Cactus National Monument, Arizona:  
 Sample Printout of the Sky-glow Survey Spreadsheet**

SYSTEMATIC SKY GLOW SURVEY MARCH 26-27, 1995  
 INSTRUMENT CONSTANT = 12.64613

AZIMUTH	ALTITUDE	SKY 1	SKY 2	SKY 3	S+D (AVG OF 3)	D	M ( $0 - (2.5 * \log((S+D) - D)) + 14.90464$ )	
180	5	838	837	831	835.3333	505	21.25339	
180	10	845	831	839	838.3333	505	21.24357	
180	20	806	795	799	800	505	21.37621	
180	30	773	778	779	776.6667	505	21.46568	
180	40	704	699	699	700.6667	505	21.82198	
180	50	681	692	689	687.3333	505	21.8986	
180	60	691	685	684	686.6667	505	21.90258	
180	70	686	692	683	687	505	21.90059	
180	80	684	687	692	687.6667	505	21.89662	
190	5	844	846	844	844.6667	505	21.22314	
190	10	845	851	864	853.3333	505	21.19578	
190	20	832	831	831	831.3333	505	21.26662	
190	30	746	748	750	748	506	21.59123	
190	40	692	705	707	701.3333	506	21.82383	
190	50	691	692	689	690.6667	505	21.87894	
190	60	696	689	682	689	506	21.89464	
190	70	686	690	688	688	506	21.90059	
190	80	671	677	674	674	505	21.98105	
200	5	909	912	908	909.6667	506	21.03571	EAST EDGE OF SONOYTA GLOW
200	10	929	913	908	916.6667	505	21.01441	IN RICH MILKY WAY FIELD
200	20	918	912	911	913.6667	505	21.02235	
200	30	755	746	745	748.6667	505	21.58378	
200	40	726	734	739	733	506	21.66071	
200	50	700	702	696	699.3333	505	21.8294	
200	60	687	677	678	680.6667	506	21.94524	
200	70	688	685	680	684.3333	506	21.92269	
200	80	678	673	668	673	506	21.99398	

*Continued on next page...*

210	5	1088	1089	1085	1087.333	505	20.63784	MIDDLE OF SONOYTA GLOW
210	10	1067	1055	1056	1059.333	506	20.6933	SOME MILKY WAY PRESENT
210	20	896	898	900	898	505	21.06479	
210	30	783	771	774	776	506	21.47236	
210	40	718	718	714	716.6667	505	21.73664	
210	50	714	707	704	708.3333	506	21.7856	
210	60	721	719	714	718	506	21.73493	
210	70	708	700	704	704	505	21.80364	
210	80	686	685	695	688.6667	506	21.89662	
220	5	950	951	942	947.6667	505	20.93558	
220	10	899	896	895	896.6667	505	21.06848	
220	20	876	881	894	883.6667	506	21.108	
220	30	768	775	776	773	505	21.48043	
220	40	698	699	707	701.3333	505	21.81828	
220	50	688	691	700	693	506	21.87117	
220	60	688	685	694	689	505	21.88873	
220	70	689	691	693	691	506	21.88284	
220	80	668	671	667	668.6667	506	22.02252	
230	5	853	843	841	845.6667	506	21.22314	
230	10	867	873	871	870.3333	505	21.14405	IN MILKY WAY IN CANIS MAJOR
230	20	842	847	844	844.3333	505	21.2242	
230	30	750	758	745	751	505	21.57343	
230	40	726	734	738	732.6667	505	21.65752	
230	50	695	692	694	693.6667	505	21.86153	
230	60	697	684	683	688	506	21.90059	
230	70	680	678	681	679.6667	505	21.94524	
230	80	666	668	669	667.6667	501	21.99615	
240	5	NA	NA	NA	0	NA		ERR BLOCKED BY A MOUNTAIN
240	10	829	830	841	833.3333	505	21.25998	
240	20	832	831	827	830	506	21.27441	IN MILKY WAY
240	30	745	746	758	749.6667	506	21.58378	
240	40	717	713	719	716.3333	506	21.7435	
240	50	707	697	704	702.6667	506	21.81644	
240	60	685	693	691	689.6667	506	21.89069	
240	70	685	677	680	680.6667	506	21.94524	
240	80	670	667	666	667.6667	506	22.02922	
250	5	NA	NA	NA	0	NA		ERR BLOCKED BY A MOUNTAIN
250	10	803	796	799	799.3333	506	21.38237	IN RICH MILKY WAY FIELD
250	20	832	836	822	830	506	21.27441	
250	30	742	740	749	743.6667	506	21.61085	
250	40	726	721	714	720.3333	506	21.72305	
250	50	693	694	699	695.3333	506	21.8577	
250	60	691	688	689	689.3333	506	21.89267	
250	70	688	691	683	687.3333	506	21.90458	
250	80	668	671	670	669.6667	506	22.01587	

Continued on next page...

260	5	NA	NA	NA	0	NA	ERR BLOCKED BY A MOUNTAIN
260	10	832	825	834	830.3333	506	21.27329 RICH AREA
260	20	827	843	822	830.6667	506	21.27218
260	30	748	734	747	743	506	21.6139
260	40	716	715	728	719.6667	507	21.73152
260	50	703	699	700	700.6667	507	21.83313
260	60	683	687	684	684.6667	507	21.92676
260	70	666	667	670	667.6667	506	22.02922
260	80	665	666	662	664.3333	507	22.05872
270	5	NA	NA	NA	0	NA	ERR BLOCKED BY A MOUNTAIN
270	10	794	794	797	795	506	21.39853
270	20	783	783	786	784	507	21.44457
270	30	728	735	741	734.6667	507	21.65752
270	40	715	727	720	720.6667	506	21.72136
270	50	704	709	696	703	505	21.80911
270	60	678	677	678	677.6667	506	21.96406
270	70	671	666	661	666	506	22.04047
270	80	666	660	650	658.6667	505	22.08432
280	5	NA	NA	NA	0	NA	ERR
280	10	817	824	806	815.6667	506	21.32353
280	20	784	781	789	784.6667	507	21.44196
280	30	760	738	743	747	506	21.59573
280	40	713	712	734	719.6667	506	21.72643
280	50	690	701	710	700.3333	506	21.8294
280	60	683	702	699	694.6667	506	21.86153
280	70	658	660	659	659	507	22.09616
280	80	653	655	656	654.6667	506	22.12024
290	5	825	816	810	817	506	21.31887 IN MILKY WAY IN GEMINI
290	10	825	826	816	822.3333	506	21.30041
290	20	803	804	806	804.3333	506	21.36402
290	30	750	745	734	743	506	21.6139
290	40	701	704	721	708.6667	506	21.78381
290	50	686	699	698	694.3333	506	21.86345
290	60	661	660	654	658.3333	506	22.09378
290	70	656	654	653	654.3333	506	22.12267
290	80	650	647	646	647.6667	506	22.1726
300	5	787	787	799	791	506	21.41366
300	10	798	801	805	801.3333	507	21.37867
300	20	780	782	789	783.6667	506	21.44196
300	30	715	717	727	719.6667	507	21.73152
300	40	695	704	706	701.6667	506	21.82198
300	50	667	663	664	664.6667	506	22.04956
300	60	649	652	651	650.6667	507	22.15738
300	70	645	642	644	643.6667	507	22.21161
300	80	644	643	637	641.3333	506	22.22226

*Continued on next page...*

310	5	770	768	771	769.6667	506	21.49813
310	10	786	792	784	787.3333	507	21.43158
310	20	755	761	750	755.3333	507	21.56318
310	30	713	720	725	719.3333	507	21.73322
310	40	690	695	687	690.6667	506	21.8848
310	50	673	668	665	668.6667	507	22.02922
310	60	647	646	657	650	507	22.16243
310	70	652	649	643	648	507	22.17772
310	80	638	635	633	635.3333	506	22.27149
320	5	NA	NA	NA	0	NA	ERR BLOCKED BY VEGETATION
320	10	784	779	776	779.6667	507	21.46169
320	20	747	737	742	742	506	21.61849
320	30	715	716	709	713.3333	507	21.76435
320	40	671	666	667	668	507	22.03371
320	50	663	664	657	661.3333	506	22.07261
320	60	693	693	685	690.3333	506	21.88676
320	70	643	633	636	637.3333	506	22.25483
320	80	637	639	635	637	507	22.26591
330	5	719	724	717	720	506	21.72474
330	10	750	753	752	751.6667	507	21.57933
330	20	742	744	747	744.3333	505	21.60326
330	30	679	686	657	674	504	21.97465
330	40	659	656	657	657.3333	506	22.10093
330	50	643	639	642	641.3333	506	22.22226
330	60	676	679	673	676	505	21.96828
330	70	637	636	627	633.3333	506	22.28841
330	80	625	633	634	630.6667	507	22.32014
340	5	729	731	738	732.6667	506	21.6623
340	10	748	756	747	750.3333	506	21.58081
340	20	713	716	721	716.6667	506	21.74178
340	30	687	688	690	688.3333	506	21.8986
340	40	674	666	662	667.3333	506	22.03146
340	50	640	637	641	639.3333	506	22.23842
340	60	635	632	633	633.3333	506	22.28841
340	70	627	625	629	627	506	22.34381
340	80	636	632	633	633.6667	505	22.2771
350	5	781	781	772	778	506	21.46435
350	10	766	759	761	762	506	21.53017
350	20	729	740	731	733.3333	506	21.65911
350	30	682	689	691	687.3333	506	21.90458
350	40	650	653	645	649.3333	506	22.1599
350	50	668	662	670	666.6667	505	22.02922
350	60	631	633	634	632.6667	506	22.29411
350	70	629	624	627	626.6667	506	22.3468
350	80	636	628	632	632	506	22.29984
ZENITH		636	640	637	637.6667	505	22.24387
ZENITH		629	641	658	642.6667	506	22.21161

# **Agricultural Land-use Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona**

Bruce Brown

EcoPlan Associates  
1845 South Dobson Road, Suite 111  
Mesa, Arizona 85202

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## Introduction

Research associated with the Land-use Trends Surrounding Organ Pipe Cactus National Monument (ORPI) Ecological Monitoring Program (EMP) was concerned with agricultural development in the Sonoyta Valley adjacent to the monument in Sonora, Mexico. Agricultural and urban development in this area has the ability to negatively impact the natural resources of the monument through aquifer depletion, pesticide use, woodcutting, pollution, and livestock trespass.

One of the methods recommended in the Land-use Trends EMP protocol to track agricultural development in the Sonoyta Valley was biannual photopoint photography. Eight photopoints, located on both sides of the international border, were established. Both color slides and black-and-white prints are taken at these points and archived in the monument museum vault. The photos taken at these points comprise exactly the same panoramic views for each photographic session so as to facilitate future comparison. This is accomplished via permanent marks for tripod legs and cross-hair focusing lenses to perfectly align shots with set landmarks.

The purpose of this handbook is to define the protocol for accurate monitoring. The activities set forth in this handbook will generate information that will serve to expand the data series initiated by the EMP study.

## Methods

### Materials Required

Photographic and other equipment requirements include the following:

- (5) rolls of 36-exposure, 35-mm, 125 ASA, black-and-white print film (or equivalent 24-exposure rolls)
- (5) rolls of 36-exposure, 35-mm, Kodachrome 64 color slide film (or equivalent 24-exposure rolls)
- (2) polarizing lens filters
- (2) camera batteries (if needed)
- (2) pencils or pens
- Pentax MX camera with 50-mm lens (contains 35-mm, 125 ASA, black-and-white print film)
- Pentax MX camera with 50-mm lens (contains 35-mm, Kodachrome 64 color slide film)
- graduated cross-hair focusing screen M for camera with color slide film
- focusing screen with vertical center line for camera with black-and-white print film
- lens sun shade
- shutter release cable
- lens cleaning fluid and paper
- Slik U-212 tripod
- Abney level for leveling tripod head (zero adjusted in office)
- flashlight for light pollution sampling
- 2- or 4-wheel drive vehicle
- compass
- Agricultural Land-use Monitoring data forms (Appendix 12-1)
- field notebook with site directions and example photos

## **Location of Photopoints**

Agricultural land use in the Sonoyta Valley is monitored at a series of 8 photopoints. Photographs from each location are compared to previous photographs taken from precisely the same location. The results are then interpreted in an attempt to identify emerging trends.

The field notebook contains directions to each photopoint, as well as black-and-white photographs showing tripod anchor points and photo views to be taken.

Each photopoint is identified with a metal tag attached to a 1-m (3-ft) length of iron rod. The rods have been driven into the ground until only the top 10–15 cm (4–6 in.) are exposed. The general location map should be consulted by monitors who have not previously been to the photopoints.

Monitoring photography is easily accomplished by 1 person. However, since optimal time of day varies from site to site, it is necessary to plan ahead for the daily work. The west and east side photopoints can possibly be covered in a single day, but with difficulty.

## **Photographic Documentation**

Photos are taken at the photopoints semiannually, in April and November. Two or three days should be scheduled to complete the monitoring, and allowances should be made for delays due to sub-optimal weather conditions. Clear or overcast days are best for photo monitoring. Avoid partly cloudy days in which the landscape is full of bright, sunny spots and dark shadows of clouds.

Photographic documentation will be the same for all photopoints. The procedure is to take pictures from each point which results in a 360° panorama of the surrounding landscape. The following procedural protocols should be followed precisely.

Before entering the field:

1. Insert the cross-hairs focusing lens into the designated color slide film camera and the vertical line focusing screen into the camera containing the black-and-white print film.

Once in the field, complete these steps at each photopoint:

2. Do not lose the attachment that connects the camera to the tripod!
3. Fully extend the tripod legs and place each leg on the painted white locator spots.
4. Shorten two of the legs to center the bubble level.
5. Use the camera containing black-and-white print film first.
6. Remove the protective lens filter and replace it with the polarizing lens filter.

7. Aim the camera at the sky and rotate the filter for maximum darkness of the sky.
8. Mount the camera on the tripod.
9. With the Abney level, accurately level the camera/tripod from left to right.
10. Find the north cardinal point with the compass, and position the camera 45° to the right of this point.
11. Using a combination of the graduated cross hairs and the field book example photos, set the elevation angle and line up the shot. Sometimes the vertical line will be aligned with an intersection of ridges or a distant peak. If, due to haze, a distant peak isn't visible through the viewfinder, sight on it visually and pick a closer landmark that is visible through the camera.
12. If glare is present in the viewfinder, attach the sunshade to the camera.
13. Set the exposure. For cameras with automatic settings, it is recommended that the initial exposure speed be set at 1/250th of a second, letting the camera automatically determine the appropriate F-stop. Because the polarizing filter has been adjusted to maximum, the sky will be overexposed. This is expected.
14. Advance the film if necessary, then gently depress the shutter release to expose the shot. If desired, a shutter release cable may be used to insure additional motionless exposure.
15. Record this event on the Agricultural Land-use Monitoring data form (Appendix 12-1) under the section for black-and-white print film. An "x" goes in the blank opposite the 45° number to signify that a picture has been taken from this angle. Then, fill in the information regarding (1) picture number on the roll of film in the camera, (2) filter type, (3) exposure (shutter speed), and (4) F-stop setting.
16. Immediately following this first exposure, change the shutter speed to 1/125th of a second, advance the film 1 frame, and take another picture.
17. Record the information for the second picture in the spaces provided to the right of the data written from the first picture.
18. If desired, after these initial shots, set the red panorama ring on the tripod to initially approximate the other photo angles.
19. Shift the camera 45° to the right.
20. Repeat steps 12–19 until a total of 16 pictures have been taken, 2 at each of the 8 angles spaced 45° apart.

21. As each roll of film becomes completely exposed, rewind it and remove it from the camera, noting the photopoint number(s) on the film label. It is not necessary to remove the camera from the tripod in order to remove and reload film. With careful, slow movements the film can be replaced and readied without losing vertical alignment. However, if there is any doubt as to the shifting of the camera, repeat steps 8–11 above.
22. Remove the camera from the tripod and replace the polarizing lens filter with the protective lens filter.
23. Using the camera containing color slide film, follow steps 6–21 above, completing, in step 15, the lower half of the Agricultural Land-use Monitoring data form (Appendix 12-1).
24. Remove the camera from the tripod and replace the polarizing lens filter with the protective lens filter.
25. Complete the checklist found at the bottom of the Agricultural Land-use Monitoring data form (Appendix 12-1) to insure that all procedures have been followed before moving to the next photopoint.

Finally, after the film has been developed:

26. Label each print, slide, and negative with the appropriate photopoint number and date photographed. Then, file these in the appropriate notebook.

Appendix 12-1  
**Agricultural Land-use Monitoring Protocol for the  
Ecological Monitoring Program in  
Organ Pipe Cactus National Monument, Arizona:  
Agricultural Land-use Monitoring Data Form**

The blank field data entry form on the next page is to be photocopied and used in the actual monitoring fieldwork.

**ORPI Ecological Monitoring Program  
 Agricultural Land-use Monitoring Protocol  
 Agricultural Land-use Monitoring Data Form**

Photo Point \_\_\_\_\_ Date \_\_\_\_\_

**Black & White:** Film: \_\_\_\_\_ ASA \_\_\_\_\_

45°	_____	_____	90°	_____	_____	135°	_____	_____	180°	_____	_____
Number	_____	_____		_____	_____		_____	_____		_____	_____
Filter	_____	_____		_____	_____		_____	_____		_____	_____
Exposure	_____	_____		_____	_____		_____	_____		_____	_____
F-stop	_____	_____		_____	_____		_____	_____		_____	_____
225°	_____	_____	270°	_____	_____	315°	_____	_____	360°	_____	_____
Number	_____	_____		_____	_____		_____	_____		_____	_____
Filter	_____	_____		_____	_____		_____	_____		_____	_____
Exposure	_____	_____		_____	_____		_____	_____		_____	_____
F-stop	_____	_____		_____	_____		_____	_____		_____	_____

**Color Slides:** Film: \_\_\_\_\_ ASA \_\_\_\_\_

45°	_____	_____	90°	_____	_____	135°	_____	_____	180°	_____	_____
Number	_____	_____		_____	_____		_____	_____		_____	_____
Filter	_____	_____		_____	_____		_____	_____		_____	_____
Exposure	_____	_____		_____	_____		_____	_____		_____	_____
F-stop	_____	_____		_____	_____		_____	_____		_____	_____
225°	_____	_____	270°	_____	_____	315°	_____	_____	360°	_____	_____
Number	_____	_____		_____	_____		_____	_____		_____	_____
Filter	_____	_____		_____	_____		_____	_____		_____	_____
Exposure	_____	_____		_____	_____		_____	_____		_____	_____
F-stop	_____	_____		_____	_____		_____	_____		_____	_____

- Checklist:**
- \_\_\_\_\_ Document photo point name.
  - \_\_\_\_\_ Record date.
  - \_\_\_\_\_ Set up tripod.
  - \_\_\_\_\_ Record film type and ASA.
  - \_\_\_\_\_ Mount camera with **black & white film**.
  - \_\_\_\_\_ Take pictures and record on form.
  - \_\_\_\_\_ Mount camera with **color slide film**.
  - \_\_\_\_\_ Take pictures and record on form.
  - \_\_\_\_\_ Sign form.

Monitor \_\_\_\_\_



The cover art was rendered by Ami Pate, a biological technician at Organ Pipe Cactus National Monument.



As the nation's principal conservation agency, the U.S. Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting fish, wildlife and plants, preserving the environmental and cultural values of national parks and historic places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

