Organ Pipe Cactus National Monument Ecological Monitoring Program Annual Report 1993

The Division of Natural and Cultural Resources Management
Organ Pipe Cactus National Monument

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
Annual Report 1993

The Division of Natural and Cultural Resources Managemant
Organ Pipe Cactus National Monument

September 1995

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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.

The Technical Report series allows dissemination of information about high priority resource management questions. The series allows the flexibility of retaining considerable information on study design, methods, results, and applications not afforded in formal scientific publications. Technical reports are given peer review and editing. Documents in this series usually contain information of a preliminary nature and are prepared primarily for use by NBS and NPS personnel and cooperators. Mention of trade names or commercial products does not constitute endorsement or use by NBS.

Reports in this series are produced in limited quantities. As long as the supply lasts, copies may be obtained from the Cooperative Park Studies Unit, NBS–CPSU/UA, 125 Biological Sciences East, The University of Arizona, Tucson, AZ 85721.

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Introduction

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 133,830 ha (330,689 a.), 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 12,950 ha (32,000 a.) 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. Summaries of each of the 12 studies follow. 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. The protocols have been tested and refined as a result of the feedback loop between researchers and field staff.

Land-use Trends Surrounding Organ Pipe Cactus National Monument
In this study the principal investigator, Bruce Brown, determined the current land uses of lands adjacent to the monument with particular emphasis on the Rio Sonoyta Valley in Sonora, Mexico. Acreage in agricultural production, types of crops raised and associated acreage, and annual groundwater pumpage rates were determined during this project.

Inventory and Assessment: Special-status Birds
Principal investigator R. Roy Johnson designed this study to provide information about the distribution and relative abundance of monument birds, with special emphasis on the breeding birds in the vicinity of the permanent study sites.

Inventory and Assessment: Terrestrial Invertebrates
Principal investigator Kenneth J. Kingsley attempted to determine the important invertebrate species in the monument ecosystem and identify indicator species and their relationship to the monument ecosystem. Approximately 4,200 invertebrate specimens were added to the ORPI invertebrate collection.

Inventory and Assessment: Amphibians and Reptiles

This study was designed by Charles H. Lowe to provide information about reptile and amphibian species occurrence, distribution, and relative abundance. Criteria were established, and lizard species were selected to monitor as indication of monument herpetofauna health in the long-term monitoring effort.

Inventory and Assessment: Nonnative Vegetation

Principal investigator Richard Felger identified 62 species of vascular plants, located in or adjacent to the monument, as being possibly nonnative. This represents about 11% of the park flora and may be an over estimation since (1) some "nonnatives" may actually be native, (2) some species are present but not reproducing, and (3) some are in adjacent Sonora but have not been seen in the monument.

Inventory and Assessment: Special-status Mammals

Principal investigator Yar Petryszyn lead the intent of this study, which was to provide information about species distribution and relative abundance of monument mammals. Criteria were established for selection of mammal indicator species, and nocturnal rodents were selected to be monitored.

Inventory and Assessment: Special-status Plants

This project, designed by George Ruffner, made a detailed study of 17 unique or vulnerable plant species to determine regional distribution, abundance, and factors that limit distribution. In addition, the project assessed impacts and threats to the plants and provided recommendations for management. Long-term monitoring protocols were designed for 4 of the 17 plants.

Recovery of Monument Ecosystems Since Termination of Cattle Grazing

Principal investigator: Mr. Peter Warren. In 1977, shortly before the removal of cattle from the monument, vegetation plots and photo points were established to gather baseline data on ecosystem recovery response to the removal of cattle and associated impacts. The purpose of this study was to reread these existing vegetation plots and re-photograph the photo points. In addition, nocturnal rodent populations were re-sampled on the monitoring plots, and relationships between the distribution of rodents and the amount of vegetative cover established.

Climatological Monitoring

Nine automated weather stations were installed near SEP study sites by resource management staff. A combination of the following parameters are measured at the sites: (1) precipitation, (2) relative humidity, (3) wind speed and direction, (4) air temperature at 2 different heights, (5) soil temperature, and (6) solar radiation. This project was designed to provide an important integrative link between all the SEP projects.

Vegetation Community Patterns on the Boundaries of Organ Pipe Cactus National Monument

Principal investigator Peter Warren lead the objectives of this study, which were to examine and document plant community patterns along the park boundary to determine the cross-boundary effects of changes outside the monument on plant communities inside the monument. Patterns of plant community composition and distribution within 2.0 km (1.2 mi) of all boundaries of the monument were examined.

Vegetation Structure and Diversity in Natural Communities

Principal investigator, Charles H. Lowe lead this project, which focused on collecting information on vegetation structure and diversity rather than on plant population dynamics, plant growth, phenology, productivity, plant interactions, and so forth. Presence, density, frequency, coverage, and diversity of perennial plants were measured on 0.1-ha (0.25-a.) permanent quadrats located at each SEP study site. The same parameters were measured for ephemeral plant species on 1.0-m^2 (10.8-ft^2) quadrats. Quantitative data from this study and the resulting long-term monitoring protocols will provide both inter-site variation and intrasite change in composition, structure and diversity of plant species.

Treaties, Agreements, and Accords Affecting Natural Resource Management at Organ Pipe Cactus National Monument

Principal investigator Carlos Nagel compiled the treaties, legal agreements, and memoranda of understanding made between the United States and Mexico that affect the management of natural resources in and around the monument, and provided a mechanism for keeping this information current.

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 components of that ecosystem. 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.

Though still a young program, EMP has already impacted monument management. Development of the ORPI General Management Plan and Resources Management Plan has been influenced by the inventory of resources. Cooperative resource management efforts have been developed with neighboring land management agencies. Contacts have been established with resource counterparts in Sonoyta, Sonora, Mexico, and data is shared on land-use trends, water usage and development, pesticide and herbicide use, as well as other concerns.

Information Management

After 7 yr of baseline data acquired as part of EMP, the integration and synthesis of results have been initiated. Key components in the synthesis of ecological data are Database Management Systems (DBMS) and Geographic Information Systems (GIS). A GIS database is already in place at the monument and new cooperative agreements and proposals will shape the future links between monitoring data and predictions on the status of monument resources. The GIS database is currently being expanded to include detailed information on each monitoring site.

A regional prototype, the proposed Northern Sonoran Desert Ecological Monitoring Model (NSDEMM) will be able to make predictions on resource status and assist resource managers in establishing future monitoring and research sites. In this model, the DBMS will link tabular information to the GIS database and will integrate diverse inventory and monitoring data sources into a single framework.

Ecological Monitoring Program Advisory Committee

In October 1993, the first meeting of the EMP advisory committee was held. The advisory team, a mix of scientists and managers, was convened to provide an ongoing evaluation and assessment of activities associated with the ecological inventorying and monitoring program at ORPI, and to direct progress towards the synthesis of the program. Committee activities include (1) assessing the history of the program and providing guidance for future direction, (2) examining and critiquing completed research and monitoring protocols, (3) providing recommendations for future baseline studies and advanced specialized research, (4) evaluating results of current monitoring and suggesting modifications, if needed, (5) developing strategies for integration and synthesis, and (6) examining alternative methods for data management and linkages with geographic information systems.

Ecological Monitoring Program Study Site Descriptions

The majority of SEP and EMP research was conducted at 16 select study sites (Fig. 1). Sites ranged in size from 2.5 ha (6.1 a.) to 126 ha (311 a.). Site selection was based on the goal of representing the various ecological communities of the monument. In addition, some sites were selected on the south boundary to monitor impacts from agricultural development and urbanization on adjacent Mexican lands. Priority sites for future monitoring were identified by SEP researchers and were divided into 4 groups (Core I, II, III and IV) based on the level of importance for monitoring. Since the original research projects, new sites have been added to the program.

Vegetation associations are taken from Cooperative Park Studies Unit (CPSU) Technical Report No. 8, *Vegetation of Organ Pipe Cactus National Monument* by Peter Warren et. al.

Aguajita

Elevation ca. 335 m (1,099 ft). Located adjacent to Aguajita Wash—a large wash that drains much of the south half of the monument. *Prosopis glandulosa* riparian woodland, *Atriplex polycarpa—Atriplex canescens—P. glandulosa,* and *P. glandulosa—Cercidium floridum* subassociation are the main vegetation types. Sandy soil with scattered cobblestones. The desert caper (*Atamisquea emarginata*) is found here at the limit of its range. Core I site.

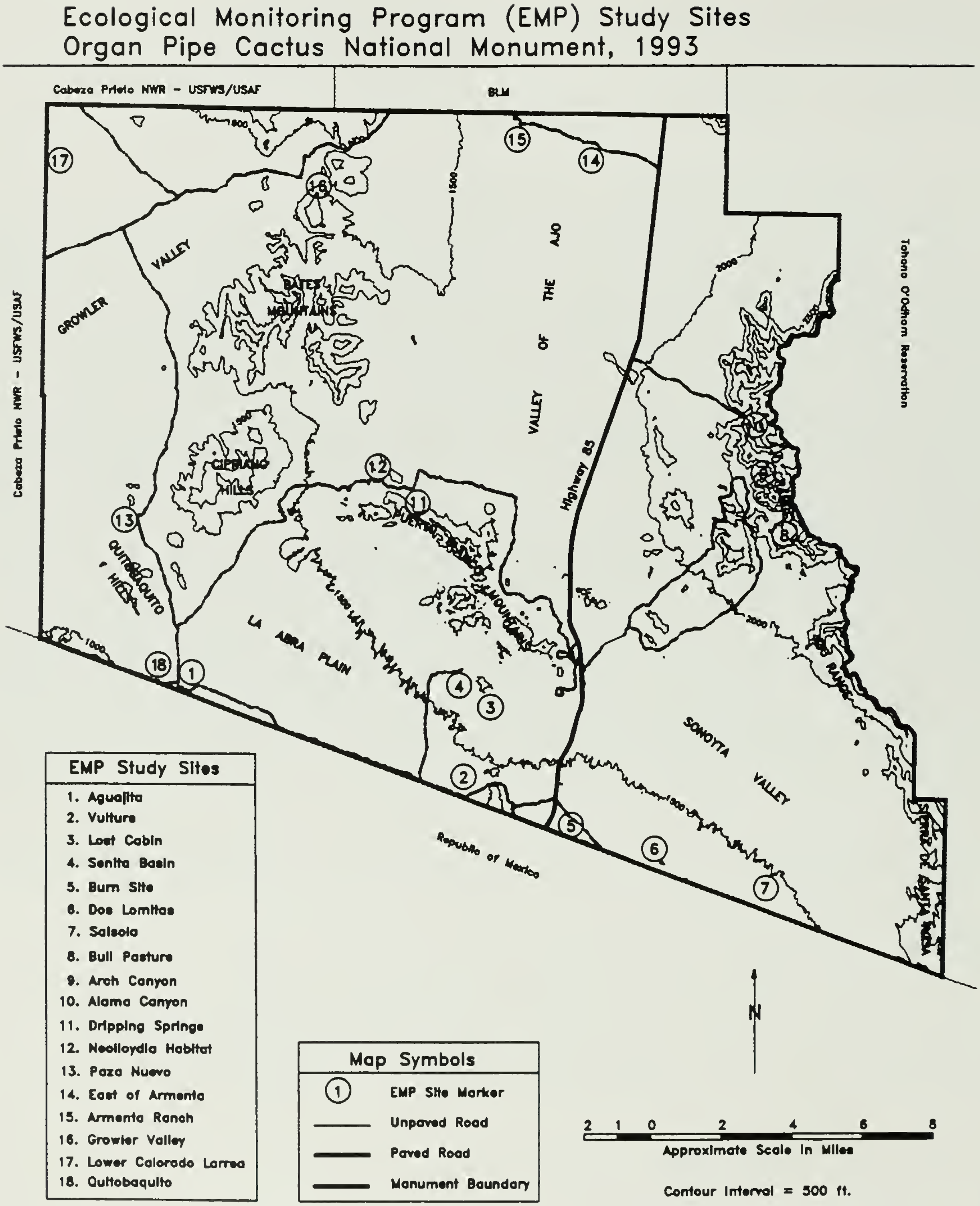


Figure 1. Map of Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, Arizona.

Vulture

Elevation ca. 450 m (1,476 ft). Adjacent to international border on sandy cobbled soil. Lies on the bajada of the Sonoyta Mountains and is transversely dissected by a fourth order wash. The black vulture (*Coragyps atratus*) found roosting in great numbers on the site is at its northern range limit in southern Arizona. Vegetation classification: *Cercidium microphyllum—Ambrosia deltoidea* middle bajada subassociation and *Ambrosia ambrosioides—Olneya tesota—Acacia* spp. subassociation. Core III site.

Lost Cabin

Elevation ca. 500 m (1,640 ft). This site is located on floodplain and upper rocky slope environments. Like nearby Senita Basin SEP site, it is frost-free most of the year. *Cercidium microphyllum—Ambrosia deltoidea—Stenocereus thurberi—Jatropha* spp. vegetation association. Core IV site.

Senita Basin

Elevation ca. 510 m (1,673 ft). This site is situated on a north-facing slope, a south-facing slope, and level ground. Frost-free most of the year, the vegetation types are the 3 most frost-sensitive. Soils vary from deep alluvium to bare rock. *Cercidium microphyllum—Encelia farinosa—Stenocereus thurberi—Jatropha cuneata* hillside subassociation, *Cercidium microphyllum—encelia farinosa—Stenocereus thurberi—Bursera microphylla* subassociation and *Cercidium microphyllum—Ambrosia deltoidea—Stenocereus thurberi* with *Jatropha* spp. subassociation. Core I site.

Burn Site

Elevation ca. 420 m (1,377 ft). Situated near south boundary on 3 different deep floodplain soils, each supporting a different type of vegetation. Portions of all 3 subassociations were burned by a high intensity fire in 1984. Vegetation: *Larrea tridentata—Ambrosia dumosa; Atriplex polycarpa—Atriplex linearis—Prosopis glandulosa;* and *Larrea tridentata—Prosopis glandulosa* floodplain subassociations. Core IV site.

Dos Lomitas

Elevation ca. 430 m (1,410 ft). Adjacent to the international boundary on silty floodplain soil. *Atriplex polycarpa—Atriplex linearis—Prosopis glandulosa* subassociation. Grazing disturbed area in the past; vegetation change has been monitored with a cattle exclosure. Core I site.

Salsola

Elevation ca. 500 m (1,640 ft). Adjacent to international border on silty floodplain soil. *Larrea tridentata—Ambrosia* spp. subassociation and *Larrea tridentata—Prosopis glandulosa* floodplain subassociation. Russian thistle (*Salsola paulsonii*), Palmer's amaranth (*Amaranthus palmeri*), and jumping cholla (*Opuntia fulgida*) are among the significant species. The composition of this community has been profoundly altered by erosion, invasion, and past heavy grazing. Core IV site.

Bull Pasture

Elevation ca. 920 m (3,018 ft). This SEP site is located on mid-elevation bench below the higher peaks of the Ajo Mountains, at the headwaters of Estes Canyon. The area is dissected by 2 drainages, one shallow without permanent water and the other deeper and fed by a spring. Soils are very shallow and rocky. *Simmondsia chinensis—Viguiera deltoidea—Fouquieria splendens* vegetation association. Vegetation is variable depending on slope and exposure. Juniper trees (*Juniperus* spp.) can be found in drainages. Core III site.

Arch Canyon

Elevation ca. 915 m (3,001 ft). The Arch Canyon study site is located in a steep, north-facing drainage in a rocky side canyon. Vegetation is characterized by dense thickets of large sclerophyllous shrubs, 1–2 m (3–7 ft) tall. Several of the dominant species are deciduous. This is the most mesic upland association in the monument, as well as one with the most restricted distribution. Characteristic species: oak belt gooseberry (*Ribes quercetorum*), hoptree (*Ptelea trifoliata*), red berry buck thorn (*Rhamnus crocea*), red barberry (*Berberis haematocarpa*), and jojoba (*Simmondsia chinensis*). Core IV site.

Alamo

Elevation ca. 900 m (2,952 ft). Narrow southward-trending canyon dissecting the Ajo Mountains. Sandy soil with scattered cobbles and large boulders. *Quercus ajoensis* mixed scrub association, with California rosewood (*Vauquelinia californica*), catclaw (*Acacia greggii*), and jojoba as characteristic species. Species diversity is high due to mesic environment, diverse surrounding habitats, and great topographic relief. Core I site.

Dripping Springs

Elevation ca. 650 m (2,132 ft). Steep north-facing mountain slope with thin, rocky soil derived from lava and tuff. Subsurface moisture is abundant locally, especially on tuff deposits. Free water, of low salinity, is found in several caves. Characteristic species: jojoba, goldeneye (*Viguiera deltoidea*), and ocotillo (*Fouquieria splendens*). Core IV site.

Neolloydia Habitat

Elevation ca. 500 m (1,640 ft). This site is located in a habitat area of the rare acuña cactus (*Echinomastus erectocentrus* var. *acunensis* [formerly *Neolloydia erectocentra*]). The habitat lies on level to north- or south-facing slopes of several small hills near the north pediment of the Puerto Blanco mountains. The cactus is confined to a habitat nearly devoid of soil, the plants preferring to grow in cracks in the fractured rhyolite bedrock. Vegetation association: *Ambrosia deltoidea—Cercidium microphyllum* pediment subassociation. Core II. (Most monitoring was halted at this site in order to prevent impact on the sensitive cactus species.)

Pozo Nuevo

Elevation ca. 380 m (1,246 ft). Located near the western boundary of the monument, this study site is situated on fine, sandy loam and cobbled, sandy loam soils. Four different vegetation associations occur here: (1) *Larrea tridentata—Ambrosia dumosa*, (2) *Larrea* *tridentata—Ambrosia* spp., (3) *Ambrosia ambrosioides—Olneya tesota—Acacia* spp., and (4) *Larrea tridentata—Prosopis glandulosa* floodplain. Core I.

East Armenta
Elevation ca. 480 m (1,574 ft). On gravelly to silty soils of a nearly level site. Vegetation is of the *Cercidium microphyllum—Ambrosia deltoidea* and *Larrea tridentata—Prosopis glandulosa* floodplain subassociation. Erosion has cut a few gullies in the vicinity of the site but may not have significantly lowered the water table yet. Core I.

Armenta Ranch
Elevation ca. 480 m (1,574 ft). Previous site of overgrazing, wood cutting, and erosion on the monument north boundary. Fine, silty soils of extreme lower bajadas. Many standing dead mesquites (*Prosopis* spp.) suggesting recent decrease in subsurface water availability. *Larrea tridentata—Prosopis glandulosa* floodplain vegetation subassociation. Core IV.

Growler Canyon
Elevation ca. 420 m (1,377 ft). Wide, east- to west-trending canyon passing through the southern end of the Growler Mountains. Groundwater is near the surface because of confluence of 2 large washes just east of the canyon. Soil is deep, silty, and easily detached. *Prosopis glandulosa* riparian woodland association. Core II.

Lower Colorado Larrea
Elevation ca. 335 m (1,099 ft). Located in the northwest corner of the monument, near the boundary of the Cabeza Prieta National Wildlife Refuge. Fine, silty soils with *Larrea tridentata—Ambrosia dumosa* vegetation association. Added later.

Quitobaquito
Elevation ca. 329 m (1,079 ft). Spring-fed channel and pond with endangered desert pupfish are located here. Study site encompasses the following vegetation associations: (1) *Typha domingensis—Scirpus olneyi*, (2) *Prosopis glandulosa* riparian woodland, and (3) *Cercidium microphyllum—Encelia—Stenocereus—Jatropha*. This is the most recent study site added to the program.

Ecological Monitoring Program Annual Report
Annual reports of ORPI EMP will summarize monitoring activities completed and data collected. They will follow a similar format from year to year to easily provide comparisons. For each monitoring protocol, the following will be provided: (1) introduction, (2) project history, (3) summary of monitoring activities, and (4) methods and results. Simple data summaries in tabular and graphic format will also be provided.

In the 1993 final report that follows here, monitoring activities are divided into 3 sections: (1) vegetation; (2) wildlife; and (3) climate, air quality, land-use trends, and groundwater. Table 1 shows the hours spent in each monitoring activity.

Table 1. Hours spent by Organ Pipe Cactus National Monument staff and volunteers in Ecologocal Monitoring Project activities during 1993.

			Number of hours (includes travel)			
				Office		
EMP monitoring activity	Dates of fieldwork	Number of persons	Field and preparation	Data management	Report	Total
Organ pipe cactus (*Stenocereus thurberi*) Senita cactus (*Lophocereus schottii*)	19–22 January	4	55	34	14	103
Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*)	23–29 March	7	181	41	21	243
Dahlia-rooted cactus (*Peniocereus striatus*)	6 September	1	4	2	2	8
Desert caper (*Atamisquea emarginata*)	23 September	2	8	1	2	11
Ephemeral plants	9–17 March	4	147	11	30	188
Birds	4 April to 28 May	1	138	38	29	205
Lizards	26 April to 24 May 8 August to 10 September	1	190	7	9	206
Nocturnal rodents	28 June to 22 July	3	342	62	44	448
Land-use trends photography	Bi-yearly	1	23	8	2	33
Groundwater measurements	Quarterly	1	21	2	2	25
Weather stations and raingauges data	Monthly	2	340	80	43	463
Lesser long-nosed bat (*Leptonycteris curasoae*)	Monthly	2	47	6	2	55
Quitobaquito desert pupfish (*Cyprinodon macularius eremus*)	1–2 April; 14–15 September	3	94	9	7	110
Air quality (NADP, etc.) data	Weekly	1	127	28	3	158
Program administration	Ongoing	1	0	0	0	109
Total			1,717	329	210	2,365

Vegetation

Acuña Cactus

Introduction

Organ Pipe Cactus National Monument contains 1 of only 4 known populations of acuña cactus. Since 1988, this cactus has been monitored for growth, reproduction, and mortality. Data gathered in this project will aid in gaining an understanding of population dynamics as well as the relationship between rainfall and patterns of mortality and establishment.

Project History

In the late 1970s, William Buskirk and students from Earlham College developed a protocol to monitor acuña cacti at ORPI, primarily to detect theft of the highly valued cactus. Although these monitoring efforts brought a greater knowledge and understanding of the species, much remained unknown concerning its basic biology and population dynamics. Meanwhile, the unexplained serious decline of the other 2 acuña populations in Arizona (the fourth population occurs in Sonora, Mexico) prompted the U.S. Fish and Wildlife Service (USFWS) to declare the cactus a Category 1 candidate species for listing consideration as a threatened plant. In order for USFWS to make sound decisions regarding the implementation of the Endangered Species Act, however, they must have access to sound biological knowledge of taxa being considered for listing, as well as adequate information on demographics.

This knowledge is presently being obtained as a result of the upgraded acuña monitoring protocol developed during the SEP project entitled *Special-status Plants of Organ Pipe Cactus National Monument* (Ruffner Associates 1991). This protocol was designed to collect more complete demographic data for the plant. Monitoring efforts using this protocol began in 1988 and have continued annually. The data collected during this time have already contributed to a paper by the principal investigators: *Seedling Establishment, Mortality and Flower Production of the Acuña Cactus* (Johnson, et al. 1993).

1993 Monitoring Activities

From 23 March through 26 March and again on 29 March, personnel from the Division of Natural and Cultural Resources Management and several volunteers conducted the annual monitoring of acuña cactus. SEP Special-status Plants co-investigators Robert Johnson and Marc Baker assisted during the monitoring effort. This monitoring included measuring all tagged plants, counting flowers and buds, and searching for new seedlings.

On 7 April 1993, a second flower/bud count was made. This day roughly corresponded with the conclusion of flowering phenology for the species. The reproductive condition of the individual plants was assessed for this year using the higher of the 2 counts.

Methods

The field activities consisted of locating, measuring and assessing the reproductive condition (counting flowers and buds) of all previously tagged and mapped individuals on the 6, 0.1-ha (0.25-a.) permanent plots. At the same time, an intensive and systematic search was made within these plots to locate additional plants—plants that, in estimation, had germinated since the last monitoring activity ("new"), or plants that, in estimation, had in fact been alive but had escaped detection during the 1992 monitoring session ("old"). This very intensive search was facilitated by cordoning off the 0.1-ha, 20- x 50-m (0.25-a., 66- x 164-ft) plots into 2- x 20-m (7- x 66-ft) subplots using non-stretchable tape measures. All newly found plants were measured, tagged and given an X and Y coordinate value relative to the 0- x 0-m (0- x 0-ft) corner point of the plot.

Results

A high mortality was observed in acuña individuals in the 1- to 10-mm (0.04- to 0.4-in.) size class in 1993. Of the 109 plants that were entered in this size class last year, 46 had died. In arriving at these mortality figures, it is assumed that the plants not found had, in fact, died. High mortality may be expected among younger and less well-established plants, especially considering the relatively dry summer in 1992 (Fig. 2). The total mortality for all size classes was 123 out of a total of 417 plants (29.5%).

Few new seedlings were found this year. This was probably due to the low 1992 summer precipitation (the principal germination season is after summer monsoon rains.) However, some very small new seedlings were found that probably had germinated from the winter/spring rains of 1993.

An unusual amount of negative growth was observed this year in many plants. Most of this negative growth was only a few millimeters. The same person measured the plants in 1992 and 1993, so variation in technique is probably not a factor.

Data from the 1993 acuña monitoring season is summarized in Tables 2 and 3 and Figures 3–7 on the following pages. Although both width and height measurements are taken in the field, size classes are based upon height only. Table 2 summarizes the number of individuals per size class for 1993 and the number of plants with flowers in those size classes, as well as the mean height growth from 1992 to 1993 and mortality. The frequency figures for growth and mortality are based upon size classes from the previous year, and thus differ from the 1993 absolute frequency figures.

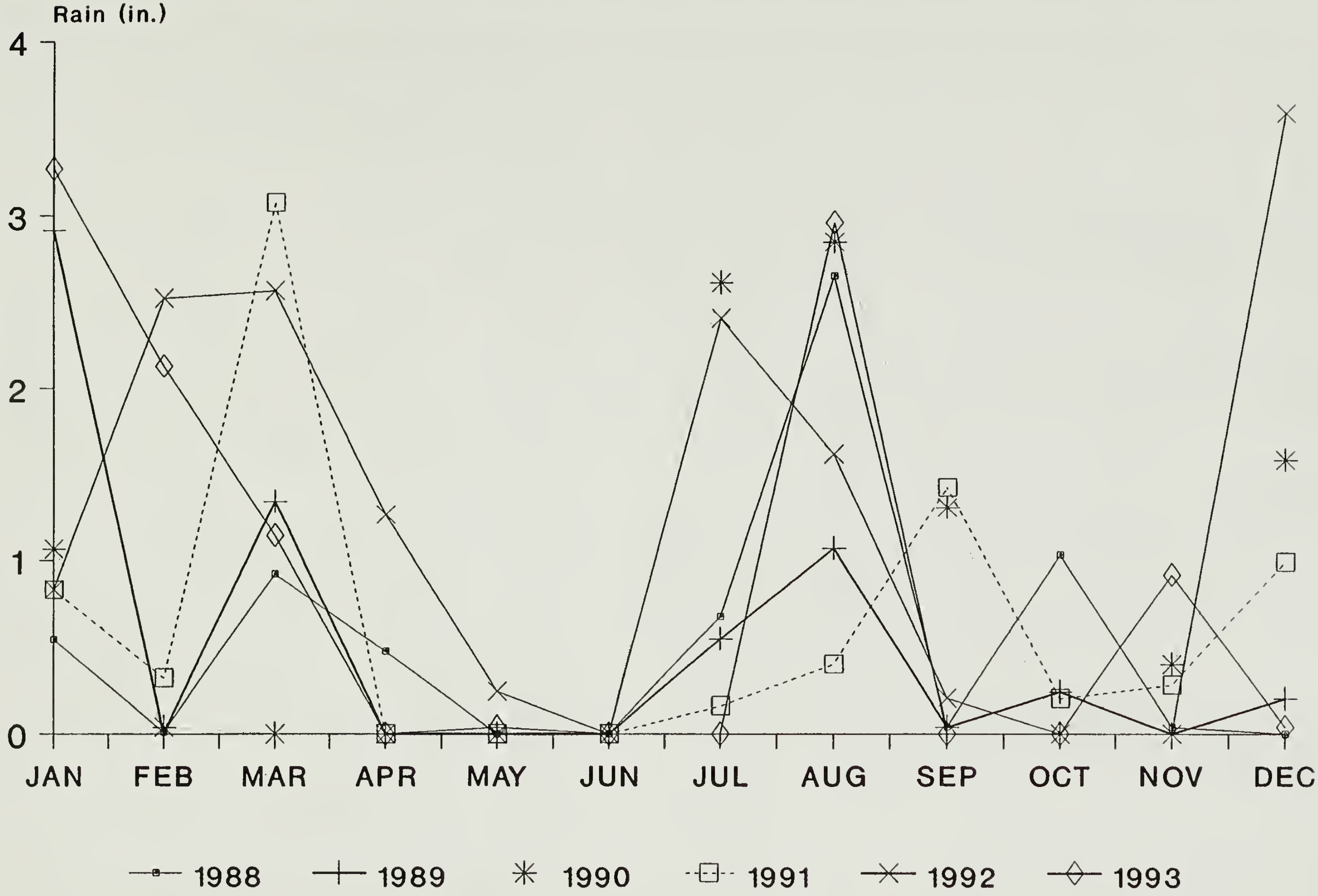


Figure 2. Rainfall data from automated weather station at acuña site, 1988–1993, Ecological Monitoring Program, Organ Pipe Cactus National Monument, Arizona. January–April 1988 and July 1989 data were collected from Dripping Springs site rain gauge.

Table 2. Acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) reproduction, growth, and mortality for 1993 in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona. Mean height growth and mortality figures are based on 1992 size classes.

Size classes (height in mm)	Absolute frequency	Plants with flowers	Mean height growth 1992–1993		Mortality
			Frequency	Growth	
1–10	102	0	109	2.00	46
11–20	50	0	91	2.56	29
21–30	47	0	49	4.26	15
31–40	17	5	17	4.87	2
41–50	16	9	16	6.15	3
51–60	20	14	14	0.77	1
61–70	9	9	20	7.78	2
71–80	17	14	14	3.08	2
81–90	13	12	9	−2.57	2
91–100	8	7	16	2.67	2
101–110	15	13	11	−2.13	2
111–120	5	4	10	10.57	3
121–130	9	9	11	−3.75	3
131–140	6	6	8	0.2	3
141–150	2	2	5	−12.75	1
151–160	4	4	3	1.00	—
161–170	5	5	6	1.33	3
171–180	0	—	4	−4.67	1
181–190	0	—	0	—	—
191–200	1	1	2	10.00	1
201–210	1	1	0	—	—
211–220	0	—	0	—	—
221–230	0	—	2	—	2
231–240	0	—	0	—	—

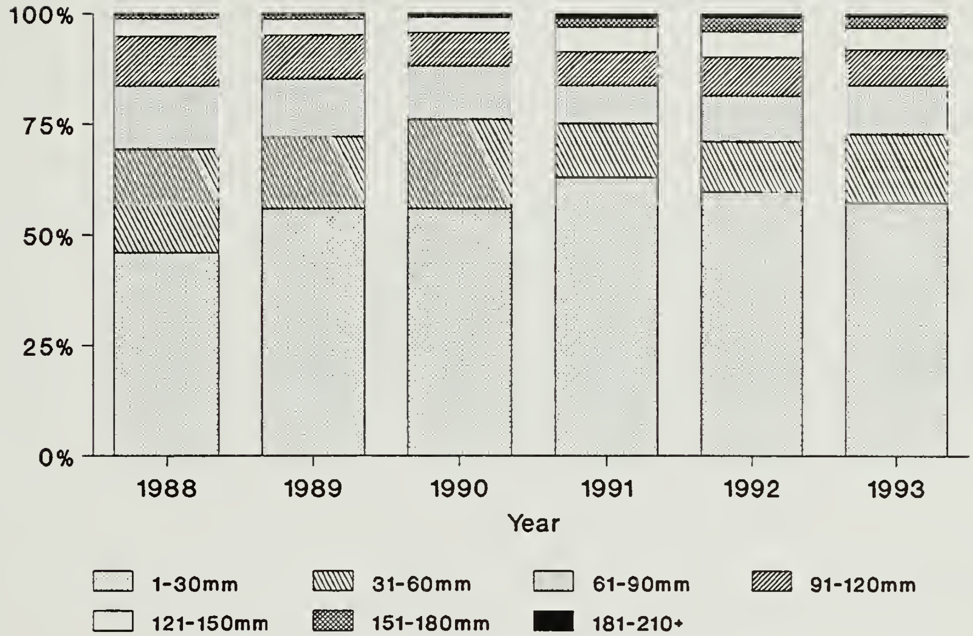


Figure 3. Size (height) distribution percentages of acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants for 1988–1993 in all acuña monitoring plots in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona.

Table 3. Comparison of acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) size distribution for all acuña monitoring plots in the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona, 1988–1993.

Height (mm)	1988	1989	1990	1991	1992	1993
1–30	114	168	181	281	249	198
31–60	58	49	65	54	47	53
61–90	35	39	39	38	43	38
91–120	28	30	25	34	37	28
121–150	10	11	11	25	24	17
151–180	2	3	2	9	13	9
181–210⁺	1	1	1	5	4	2
Total	248	301	324	446	417	345

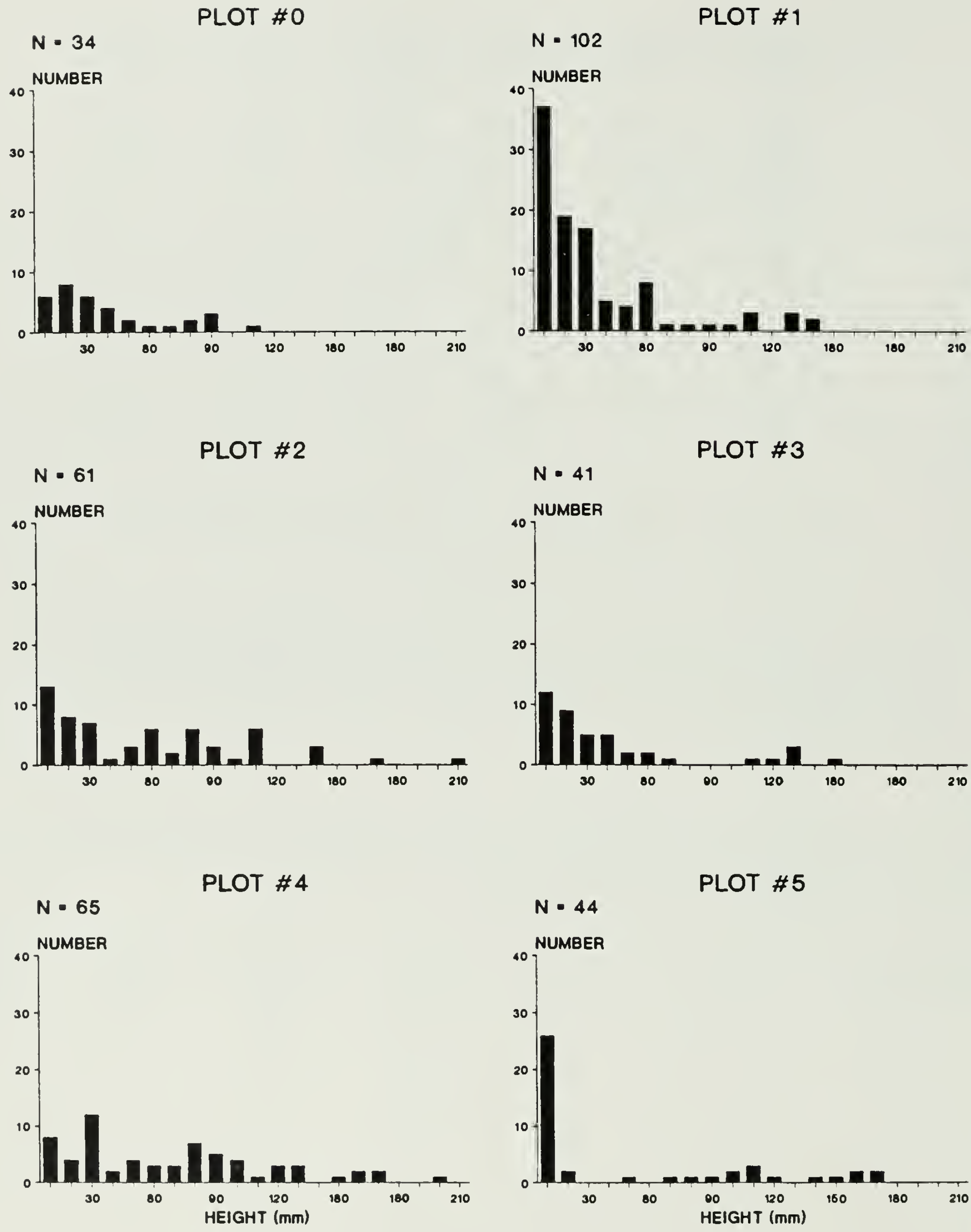


Figure 4. Size (height) distribution of acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants, by acuña monitoring plot, for 1993, Organ Pipe Cactus National Monument, Arizona.

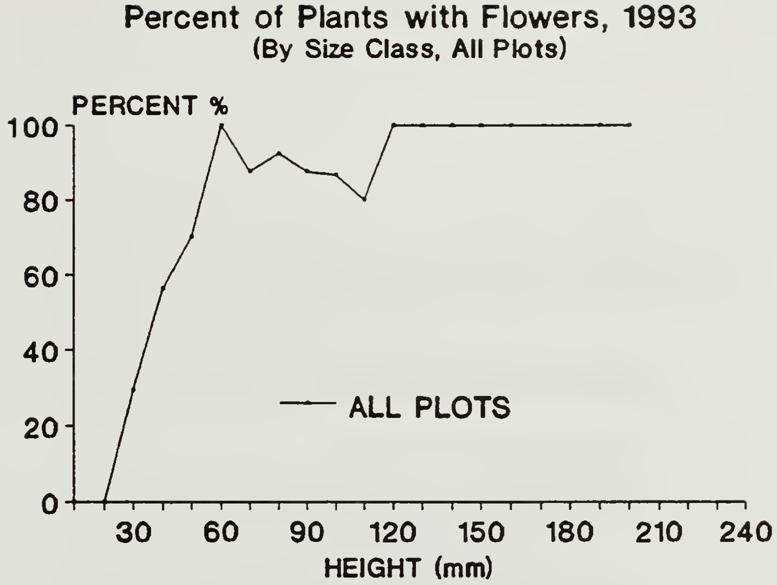


Figure 5. Percentage of acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants with flowers, by size class, for all acuña monitoring plots, 1993, Organ Pipe Cactus National Monument, Arizona.

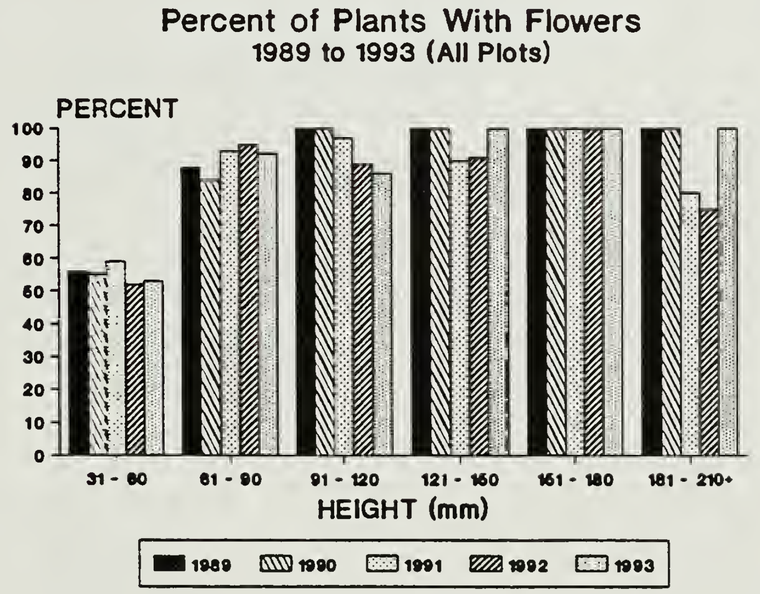


Figure 6. Percentage of acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants with flowers, for all acuña monitoring plots, 1989–1993, Organ Pipe Cactus National Monument, Arizona.

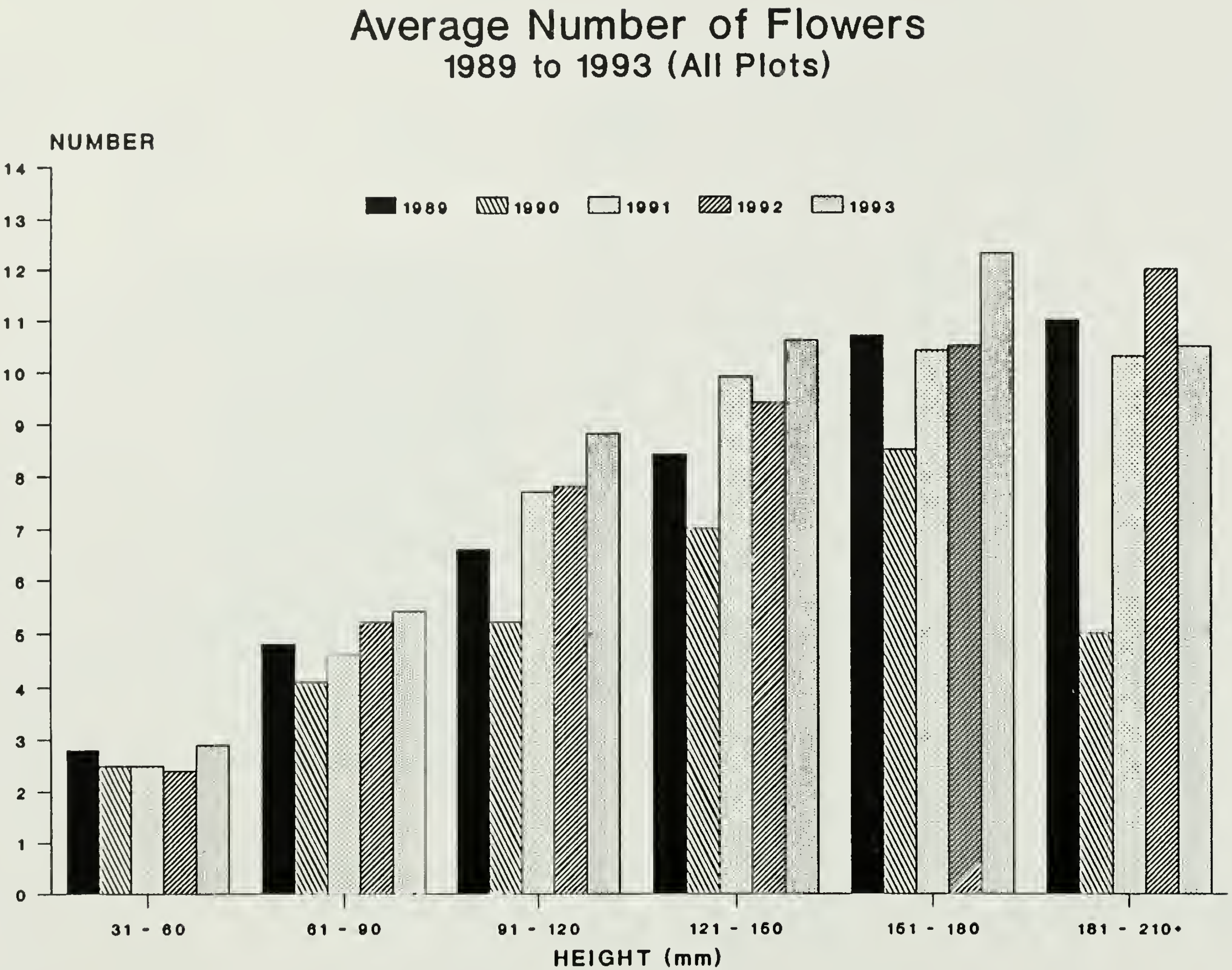


Figure 7. Average number of flowers on acuña cactus (*Echinomastus erectocentrus* var. *acunensis*) plants, for all acuña monitoring plots, 1989–1993, Organ Pipe Cactus National Monument, Arizona.

Dahlia-rooted Cactus

Introduction

The dahlia-rooted cactus (*Peniocereus striatus*) is an extremely cryptic cactus (except when in flower or fruit) that was chosen for monitoring in the Special-status Plants study due to its northern range limit in ORPI, as well as the small size and vulnerability of its population here. Only about 60 of these plants are known to exist in the monument, and these are concentrated on or next to 2 low rocky hill areas on the south boundary. These areas are immediately adjacent to agricultural fields that are subject to aerial spraying of pesticides and are commonly occupied by livestock such as goats and cattle.

Project History

In 1990, 22 plants were located and tagged for future monitoring after a search of the principal habitat areas. Each plant was assigned a number, and a metal identification tag was placed on a short metal pin inserted into the ground near the plant. Yearly monitoring has been conducted since 1990.

1993 Monitoring Activities

In early September 1993, all 22 plants were inspected. This was done later than usual due to the lateness and brevity of the summer rains, to which the flowering of the dahlia-rooted cactus appears to be keyed. The time required to perform this monitoring is about 1 half-day, including transportation.

Methods

All tagged individuals of dahlia-rooted cactus were inspected as to health and general condition during the summer rainy season, when the reproductive status of the plants could be determined. The number of new stems, if any, was recorded along with the number of immature flower buds, mature flowers, and fruits. Also noted was any evidence of herbivory, or hedging. In addition, in 1993, the overall height of the plant was recorded, although this is not necessarily a reliable indicator of plant health. This information was entered into a Lotus 1-2-3 spreadsheet for yearly comparisons, although much of the information is of a qualitative nature.

Results

As mentioned before, the plants were inspected about a month later than usual due to the lateness of the summer rains. While in August there had been little evidence of reproductive activity, by September many of the plants had flowered and some had set fruit. The overall number of flowers and fruit counted (40) was less than in the previous year (52), and there was somewhat greater evidence of herbivory, presumably by rodents or rabbits. The study area, in general, showed a great deal of herbivory, which was especially noticeable on creosote. Again, the explanation could be the lateness and brevity of the summer rains, combined with an expanded small mammal population due to the previous 2 very wet winters. In particular, 1 relatively exposed plant that had been subjected to a great deal of herbivory in the past was gone in 1993. In general, though, the population seemed to be doing well, with many flowers and fruit, and new stem growth on most plants.

Desert Caper

Introduction

A population of the desert caper (*Atamisquea emarginata*) occurs in the Aguajita Wash area near Quitobaquito Springs. This population of approximately 100 individuals is at the northern limit of the range for this species. The nearest population occurs 300 km (186 mi) south in west-central Sonora, Mexico. Desert caper also occurs in Sinaloa and Baja California, Mexico, and in Argentina and Chile as well. Little is known about the ecology and natural history of the species. Flowers are pollinated by Lepidoptera, including Howarth's white (*Ascia howarthii*), a species that requires desert caper as a host plant, and which, in the United States, occurs only in the Aguajita Wash area.

Although this population appears to be stable at the present time, it is considered to be the species most at risk for future declines or extinction within the monument because of its localized distribution, low population size, and large disjunction from other desert caper populations. The population is also at possible risk from human influences, such as groundwater depletion and firewood collection. A long-term monitoring protocol was developed to examine the survival and condition of existing individuals.

Project History

In 1990, 30 individual plants from the Aguajita Wash population were tagged, measured, and mapped on an acetate overlay of a color aerial photograph. Monitoring of these individuals entails locating the plants with the aerial photograph, measuring canopy, and noting reproductive status. Data are entered into a Lotus 1-2-3 spreadsheet. This monitoring has been conducted annually by resource management staff since 1991.

1993 Monitoring Activities

On 23 September 1993, all tagged desert caper plants were inspected by personnel from the Division of Natural and Cultural Resources Management. The monitoring date followed the normal flowering and fruiting period, so assessments of reproductive condition could not be made.

Methods

All 30 tagged desert caper individuals were located and examined in the approximate 5-ha (12-a.) permanent study site. Plant size was calculated using 2 perpendicular measures of canopy diameter, including all live branches on the individual. Height was measured at the tallest live portion of the plant.

Results

Figure 8 shows canopy coverage changes for each of the 30 plants since 1990. Canopy coverage for many of the plants appears to have decreased from the previous year. This could be attributed to the approximate nature of the measurements, as most plants seemed healthy. There was no evidence of wood cutting or gathering in the area.

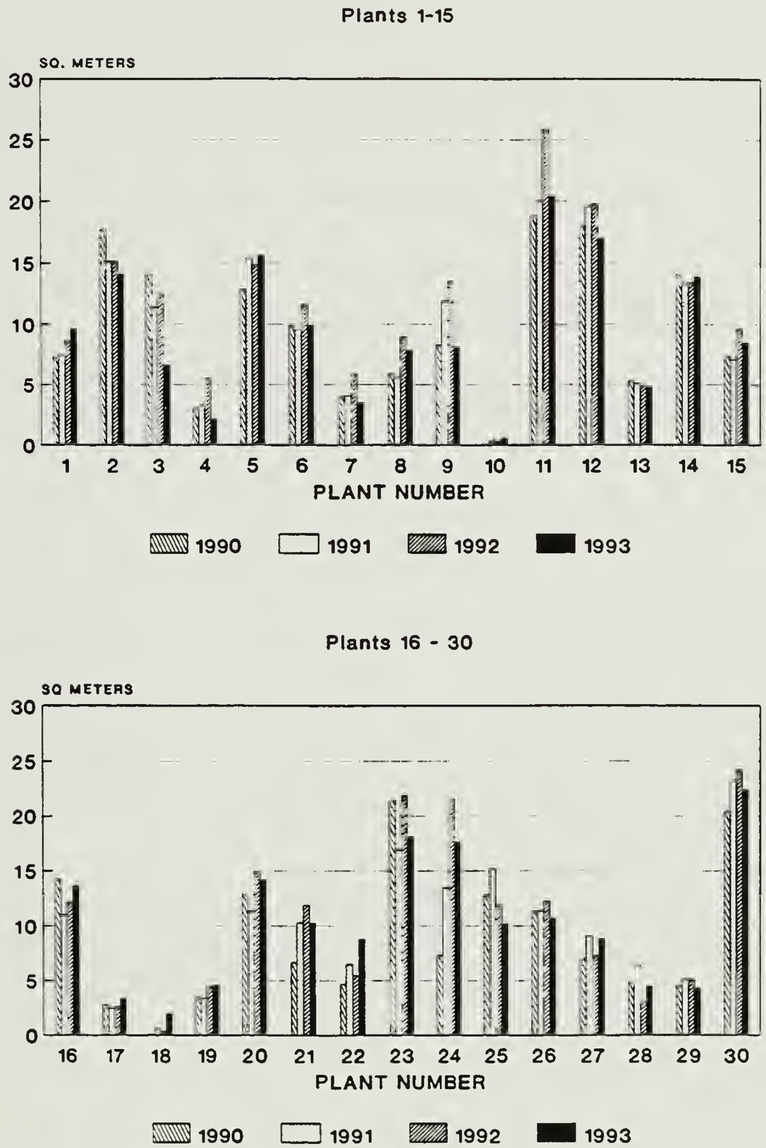


Figure 8. Canopy cover of the 30 desert caper (*Atamisquea emarginata*) plants monitored during 1990–1993 in the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona.

Organ Pipe Cactus and Senita Cactus

Introduction

Organ pipe cactus (*Stenocereus thurberi*) is a columnar cactus species that occurs throughout the monument on south- to southeast-facing rocky slopes. Senita cactus (*Lophocereus schottii*), another columnar cactus, occurs only along the southernmost boundary of the monument, especially in relatively moist habitats along wash banks composed of coarse sediments (Parker 1988). Although they occur extensively throughout northwestern Mexico, and Baja California, both cactus species are near their northern range limit in the monument.

Since 1970, annual growth measurements have been taken from tagged individuals of both species located on study plots in the central and southern Puerto Blanco Mountains of the monument. In 1990, as a part of the SEP project entitled "Special-status Plants," additional plots were set up to monitor the growth of these species.

There are no known significant human-influenced impacts or threats to either organ pipe cactus or Senita cactus populations within the monument. Both will likely maintain healthy and viable populations in the monument over the long-term (Ruffner 1991).

Project History

In 1970, Park Ranger Fred Goodsell selected for long-term growth monitoring 31 organ pipe cacti from a population growing on a steep south- to south-east-facing rocky slope in the central Puerto Blanco Mountains, and 9 Senita cacti growing along a wash on a basin floor in the southern Puerto Blanco Mountains. These individuals represented a wide range of sizes but were sufficiently small to allow access for stem measurements. Annual growth measurements have been made on these individuals by monument staff since 1970. A total of 30 organ pipe cacti and 2 Senita cacti have been monitored the entire 23-yr period. Some of the cacti are no longer monitored due to mortality or severely reduced vigor.

In 1990, as a part of the Special-status Plants project, additional plots were set up for the purpose of assessing intersite variability in growth rates. An organ pipe cactus plot of 20 individuals was established in the Bates Mountains, as well as a plot consisting of 1 additional organ pipe cactus and 3 Senita cacti located in the small hills rising out of the alluvial flats on the south park boundary. In addition, 4 more Senita cacti were selected for monitoring on the original southern Puerto Blanco Mountains.

1993 Monitoring Activities

From 19 to 22 January 1993, stem measurements were made on organ pipe cacti and Senita cacti. This monitoring was conducted by staff from the resource management division following the *Monitoring Protocol Handbook for Plants of Organ Pipe Cactus National Monument, Arizona* (Ruffner).

Methods

Each stem of every study plant has been tagged and labelled. As individual stems grow in length and become more curved, a wooden dowel is inserted 1–2 cm (0.4–0.8 in.) into the tissue between the stem tip and stem base to allow for measurement precision. Measurement of stem tip-peg distances has been repeated annually since 1970 for the original plots, and since 1990 for the new plots.

Results

The complete dataset (1970–1993), for organ pipe cacti only, was tested on size-growth models Parker (1988) had generated using the 1970–1983 dataset. To derive plant size-growth models, Parker related annual plant growth (annual rates of summed stem-growth for all stems on a plant) to both plant size and stem number, with least-squares nonlinear regression analysis. The variables used in the original analysis are detailed in Table 4.

Table 4. Ecological Monitoring Program, Organ Pipe Cactus National Monument, Arizona. Variables used in the least-squares nonlinear regression analysis to derive plant size-growth models for organ pipe cactus (*Stenocereus thurberi*) individuals monitored during 1970–1983. Annual plant growth for each plant in each year constituted the observational unit (N).

Dependent variables		Independent variables	
Annual stem growth	Annual plant growth (Y)	Plant size (X)	Stem number (X)
$(\text{stem length})_t - (\text{stem length})_{t-1}$	$\sum_{i=1}^{n} (\text{annual stem growth})_i$	$\sum_{i=1}^{n} (\text{stem length})_i$	Number of stems

In nonlinear regression models derived from the 1970–1983 dataset, Parker (1988) found that annual plant growth (Y) was significantly related to both plant size and stem number (X). Coefficient of determination values (R^2) were 0.83 and 0.86, respectively. Mean growth rates (± standard deviation) were found to be 0.07 ± 0.06 m/yr for plants < 1 m (3 ft) tall, and 0.62 ± 0.30 m/yr for those > 5 m (16 ft) tall. Although the current dataset (1970–1993) had comparable growth rates (0.06 ± 0.06 m/yr and 0.60 ± 0.33 m/yr for the above size classes), these data did not fit as well when tested on the regression models (Figs. 9 and 10). It is possible that some plants currently being monitored should be deleted from the database because of severely reduced vigor.

The 1990–1993 dataset from the central Puerto Blanco Mountains plot (Baker Mine) was separated and compared with same year data from the recently established Growler Valley plot in an attempt to begin exploring intersite variability in growth rates. Growth rates on the Baker Mine plot were 0.08 ± 0.03 m/yr for plants < 1 m (3 ft) tall, and 0.69 ± 0.38 for those > 5 m (16 ft) tall. Growth rates of plants on the Growler Valley plot were somewhat higher at 0.10 ± 0.05 m/yr and 0.81 ± 0.28 m/yr for the above size classes. Original nonlinear regression models and linear regression models were applied to both datasets (Figs. 11 and 12).

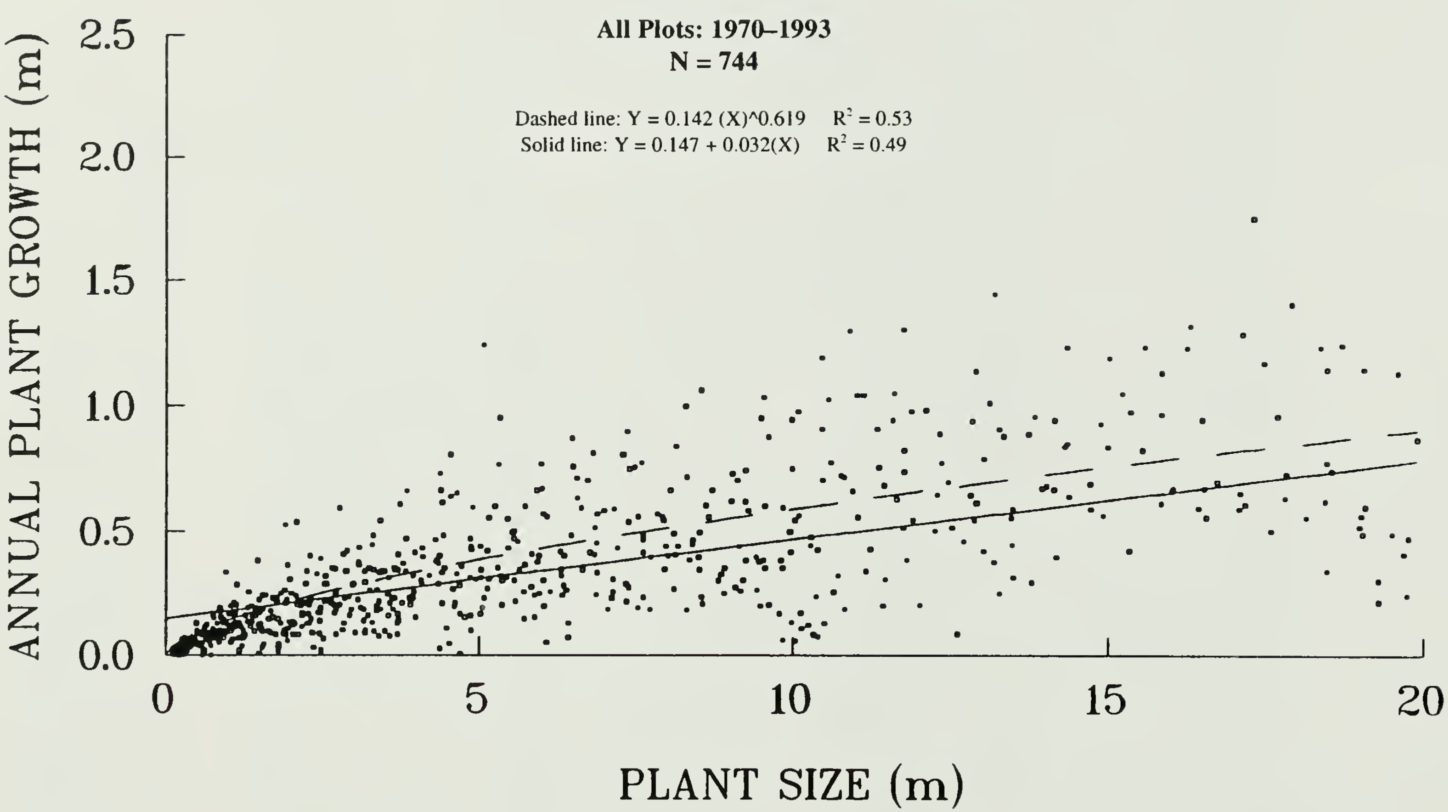


Figure 9. Relationship of annual plant growth (Y) to plant size (X) for organ pipe cacti (*Stenocereus thurberi*) monitored in all plots during 1970–1993 in the Ecological Monitoring Program in Organ Pipe Cactus National Monument. The dashed line represents the original nonlinear regression model applied to the 1970–1983 dataset (Parker, K. C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. Botanical Gazette 149:335–346). The solid line represents a linear regression model.

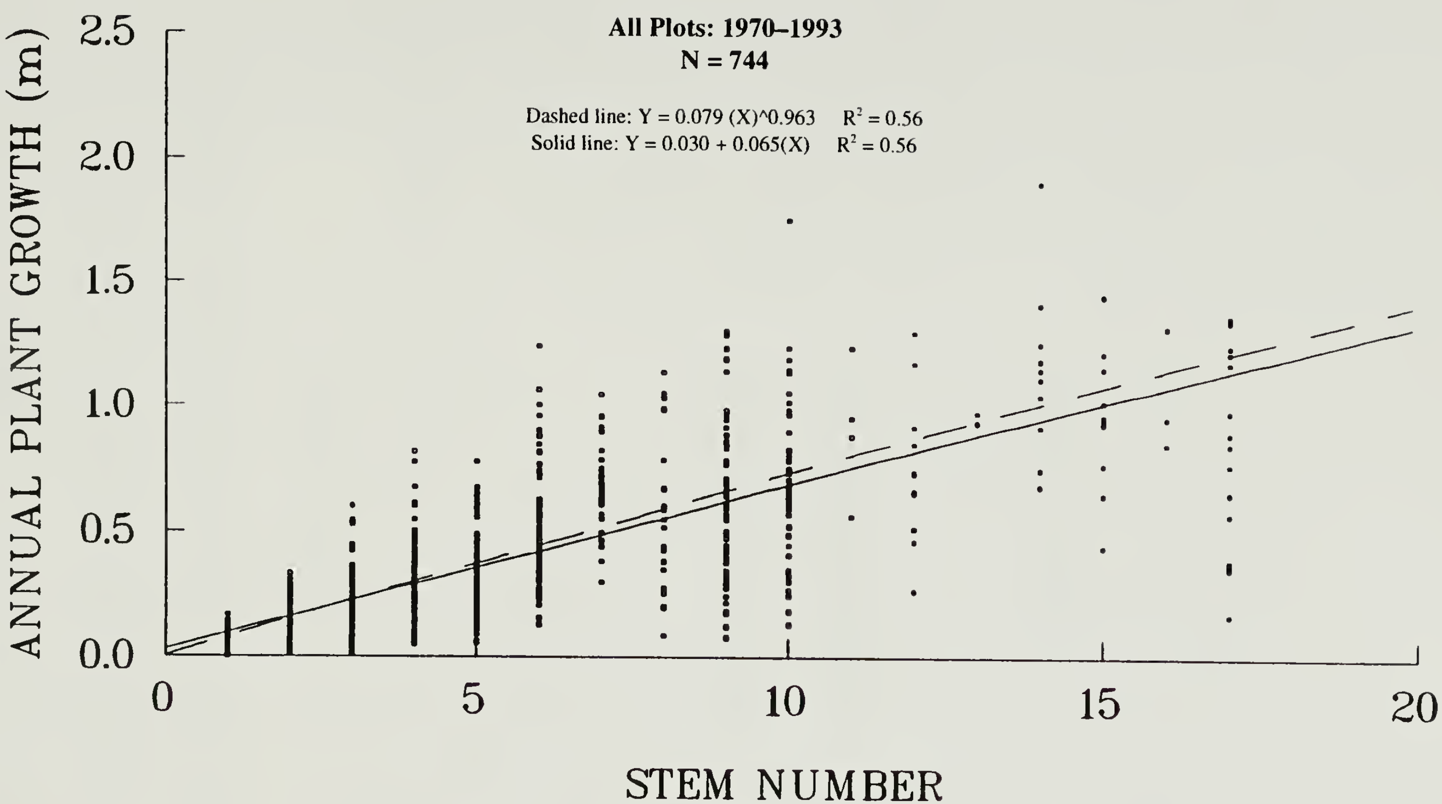
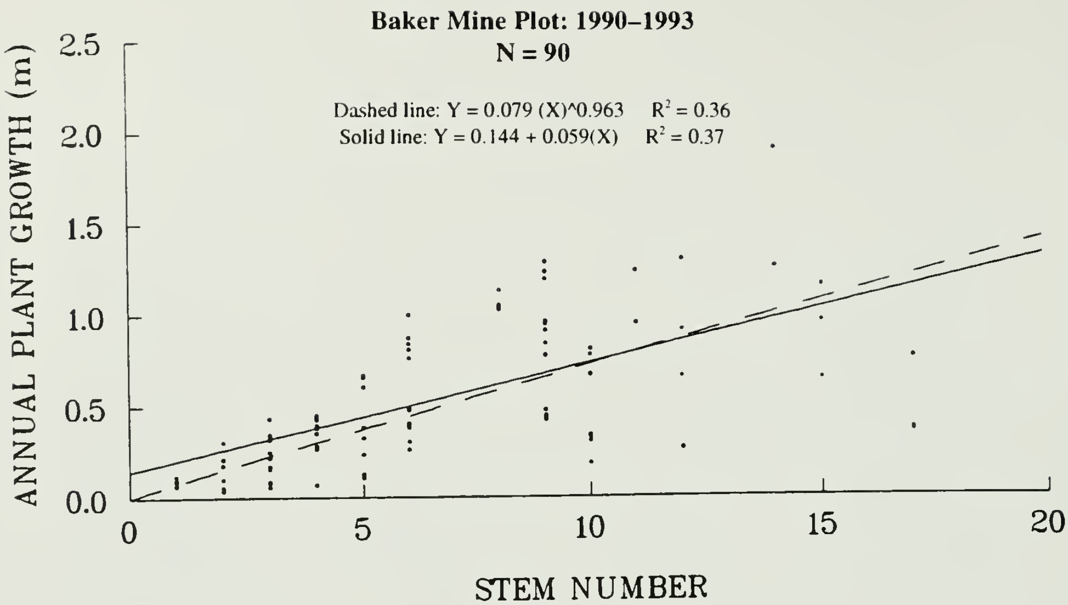


Figure 10. Relationship of annual plant growth (Y) to stem number (X) for organ pipe cacti (*Stenocereus thurberi*) monitored in all plots during 1970–1993 in the Ecological Monitoring Program in Organ Pipe Cactus National Monument. The dashed line represents the original nonlinear regression model applied to the 1970–1983 dataset (Parker, K. C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. Botanical Gazette 149:335–346). The solid line represents a linear regression model.



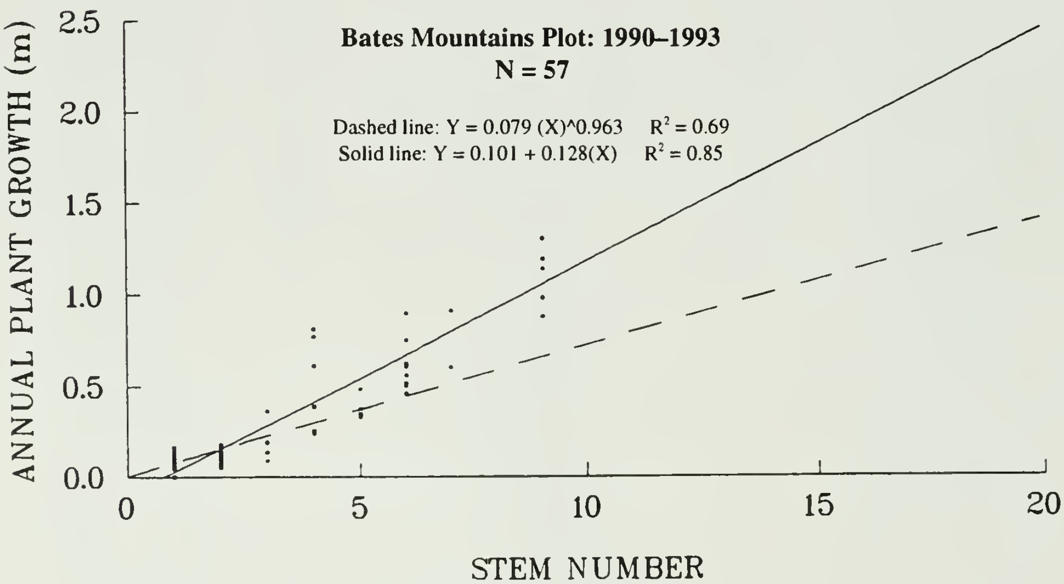
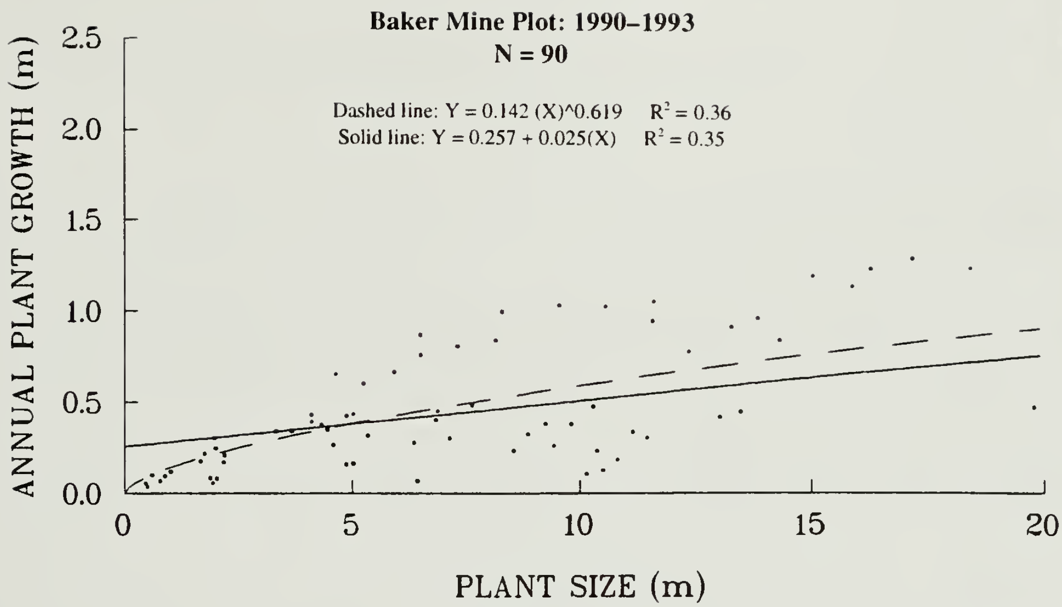


Figure 11. Relationship of annual plant growth (Y) to stem number (X) for organ pipe cacti (*Stenocereus thurberi*) monitored on the Baker Mine plot and the Bates Mountains plot during 1990–1993 in the Ecological Monitoring Program in Organ Pipe Cactus National Monument. The dashed line represents the original nonlinear regression model applied to the 1970–1983 dataset (Parker, K. C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. Botanical Gazette 149:335–346). The solid line represents a linear regression model.



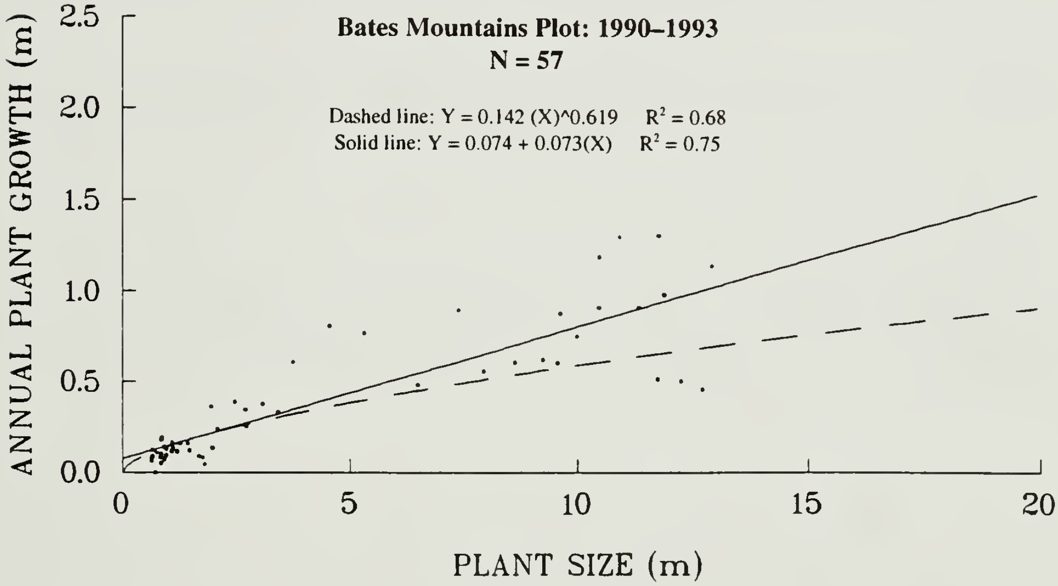


Figure 12. Relationship of annual plant growth (Y) to plant size (X) for organ pipe cacti (*Stenocereus thurberi*) monitored on the Baker Mine plot and the Bates Mountains plot during 1990–1993 in the Ecological Monitoring Program in Organ Pipe Cactus National Monument. The dashed line represents the original nonlinear regression model applied to the 1970–1983 dataset (Parker, K. C. 1988. Growth rates of *Stenocereus thurberi* and *Lophocereus schottii* in southern Arizona. Botanical Gazette 149:335–346). The solid line represents a linear regression model.

Winter Ephemeral Vegetation

Introduction

Long-term monitoring of ephemeral taxa is a part of the Vegetation Structure and Diversity project. One of the original SEP research projects, Vegetation Structure and Diversity in Natural Communities was intended to provide data that would serve as an integrative link between other ecological monitoring projects. Baseline vegetation data, soil texture data and slope, and aspect and elevation information were gathered as part of the final report presented by the principal and co-investigators (Charles Lowe, Elizabeth Wirt, and Philip Rosen). Successive future measurements of the vegetation plots will provide understanding of community change across ecological time.

Project History

Twenty-six permanent quadrants were established for the vegetation measurements at 16 EMP sites. Between 1988 and 1991, these quadrants were measured for perennial, winter ephemeral, and summer ephemeral vegetation. Presence, density, frequency, coverage, and diversity figures were obtained for the perennial species. Presence, density, and diversity of the ephemeral species were also measured.

The Vegetation Structure and Diversity final report recommended that ephemeral monitoring be repeated in periods of optimum rainfall. Ample winter rains in 1992–1993 resulted in a higher than normal density of winter ephemeral plants. This was an ideal opportunity to carry out monitoring at some of the EMP vegetation plots.

1993 Monitoring Activities

On 9–12 March and 15–17 March, personnel from the resource management staff and Elizabeth Wirt (co-investigator) measured winter ephemeral species presence at 7 of the original vegetation quadrants. Plant specimens were collected in plant press notebooks for verification with museum collections.

Methods

The 0.1-ha (0.25-a.) vegetation quadrants were located and delineated with measuring tape. Four different 1.0-m^2 (10.8-ft^2) quadrants were then chosen to fulfill a descending order of vegetation density from "maximum" to "minimum." These were mapped on the field data sheets. A wooden 1.0-m^2 (10.8-ft^2) frame was used to mark the boundaries of each of the 4 areas. Plants were then identified and counted. Unknown specimens were collected in plant press notebooks and were each named "UNK." At a later date, Elizabeth Wirt and Marc Baker used museum specimens to identify some of the UNK species.

Species diversity was determined from the formula:

$$H' = -SUM\ (p_i\ x\ ln(p_i))$$

where H' is diversity; p_i is, for each species i, the numerical proportion of that species abundance (N, density) to the total abundance of all plants in the quadrant or sample; and *ln* is the natural logarithm.

Slides were also taken on the perimeters of the overall 0.1-ha (0.25-a.) vegetation quadrants. These slides will serve as an additional tool to determine species density and diversity.

Results

As expected, an immense number of individuals and species were found on the vegetation plots. The original monitoring in 1988–1991 was conducted during drought conditions, so density and diversity were very low. In Table 5, rainfall data is presented for the fall and winter months before 1993 monitoring. These data were collected from the closest automated weather station or rain gauge to the site. The data collected in 1993 will serve as a good baseline for "wet" conditions.

Often, the 1.0-m^2 (10.8-ft^2) quadrant chosen as representative of "maximum" density had less density than the other chosen quadrants. This can be attributed to the difficulty of making a visual assessment of areas that were jungle-like in ephemeral plant growth. Closer inspection sometimes led to the discovery of greater numbers of species on the quadrants that initially seemed "sparse."

Species summaries are presented in Tables 6–11. Unknown plants (UNKs) have tentative identifications in parentheses if available. Often there was insufficient plant material for identification. Elizabeth Wirt and Dr. Marc Baker used museum specimens to identify some of the UNK species. Many plants could not be identified, and they remain UNK.

Table 5. Ecological Monitoring Program, Organ Pipe Cactus National Monument, Arizona. Precipitation for fall and winter months before 1993 ephemeral vegetation monitoring. Data were compiled from automated weather stations and rain gauges nearest the monitored sites.

	Precipitation (in.)			
Month	Senita Basin	East of Armenta	Growler Valley	Dos Lomitas
October 1992	0.08	0.00	0.00	0.04
November 1992	0.00	0.04	0.00	0.00
December 1992	3.23	3.39	3.90	3.05
January 1993	2.95	2.91	2.44	2.62
February 1993	1.77	1.02	0.59	1.56
March 1993	0.67	0.83	0.59	0.35

able 6. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe actus National Monument, Arizona, 16 March 1993. Ephemeral species summary for East Armenta site, uadrat VG01. Elevation: 524 m (1,720 ft); aspect: approximately level; slope: 1.0%.

ecies presence (P)	Total density in 4, 1.0-m^2 quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m^2 quadrant	Species richness (S)	Species diversity (H')
1 Filago (*Filago* spp.)	747	25	1.856	81	11	1.805
2 Plantain (*Plantago* spp.)	266			77		
3 Arabian grass (*Schismus arabicus*)	216			93		
4 Broad-nutted comb bur (*Pectocarya platycarpa*)	127			96		
5 Purple-rooted cryptantha (*Cryptantha micrantha*)	71			11		
6 Scaled loeflingia (*Loeflingia squarrosa*)	62			0		
7 Nemacaulis (*Nemacaulis* spp.)	50			10		
8 Pincushion cactus (*Chaenactis* spp.)	17			0		
9 Bigelow's linanthus (*Linanthus bigelovii*)	17			12		
10 Jewel flower (*Caulanthus lasiophyllus*)	16			14		
11 Purple mat (*Nama hispidum*)	16			0		
12 Eriastrum (*Eriastrum diffusum*)	8			0		
13 Sand peppergrass (*Lepidium lasiocarpum*)	8			0		
14 UNK # 11 (*Eriogonum* spp.)	6			0		
15 Clubbed primrose (*Camissonia clavaeformis*)	5			0		
16 Bristle hair lotus (*Lotus strigosus* var. *tomentellus*)	5			0		

Table 6—continued.

Species presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
17 Rigid spineflower (*Chorizanthe rigida*)	4			0		
18 Elegant lupine (*Lupinus concinnus*)	4			0		
19 Coulter globemallow (*Sphaeralcea coulteri*)	3			0		
20 Six weeks fescue (*Vulpia octoflora*)	3			1		
21 UNK # 5	3			3		
22 Sand cress (*Calyptridium monandrum*)	2			1		
23 Small-flowered eucrypta (*Eucrypta micrantha*)	2			0		
24 Round tooth phacelia (*Phacelia crenulata*)	1			0		
25 UNK # 3	1			0		
Total	1,660			399		

able 7. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe actus National Monument, Arizona, 11 March 1993. Ephemeral species summary for Growler Canyon site, adrat VG01. Elevation: 418 m (1,370 ft); aspect: approximately level; slope: 1.6%.

ecies presence (P)	Total density in 4, 1.0-m^2 quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m^2 quadrant	Species richness (S)	Species diversity (H')
Arabian grass (*Schismus arabicus*)	4,574	15	1.361	15	7	1.423
UNK # 1 (*Pectocarya* spp. [?])	1,423			0		
Broad-nutted comb bur (*Pectocarya platycarpa*)	1,164			0		
Coast fiddleneck (*Amsinckia intermedia*)	287			278		
Purple-rooted cryptantha (*Cryptantha micrantha*)	215			17		
Wild heliotrope (*Phacelia distans*)	134			119		
Hairy bowlesia (*Bowlesia incana*)	100			86		
Purple mat (*Nama hispidum*)	34			0		
Whitlow grass (*Draba cuneifolia*)	27			0		
Slimleaf bursage (*Ambrosia confertiflora*)	22			22		
UNK # 6	22			22		
UNK # 7	21			0		
Filaree (*Erodium cicutarium*)	16			0		
Coulter globemallow (*Sphaeralcea coulteri*)	10			0		
Woolly plantain (*Plantago insularis*)	5			0		
Total	8,054			559		

Table 8. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona, 12 March 1993. Ephemeral species summary for Growler Canyon site quadrat VG02. Elevation: 418 m (1,370 ft); aspect: approximately level; slope: 2.0%.

Species presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
1 Arabian grass (*Schismus arabicus*)	1,737	35	1.718	11	15	1.414
2 Bigelow bluegrass (*Poa bigelovii*)	952			790		
3 Fiddleneck (*Amsinckia* spp.)	435			358		
4 Hairy bowlesia (*Bowlesia incana*)	244			89		
5 Broad-nutted comb bur (*Pectocarya platycarpa*)	144			83		
6 Western stickseed (*Lappula occidentale*)	136			93		
7 Sisymbrium (*Sisymbrium* spp.)	120			24		
8 Purple-rooted cryptantha (*Cryptantha micrantha*)	58			0		
9 Bearded cryptantha (*Cryptantha barbigera*)	24			0		
10 Arizona bromegrass (*Bromus arizonicas*)	17			9		
11 UNK # 14	10			10		
12 Comb bur (*Pectocarya* spp.)	9			0		
13 UNK # 1	8			0		
14 Chia (*Salvia columbariae*)	6			0		
15 Small-flowered eucrypta (*Eucrypta micrantha*)	4			2		
16 UNK # 11	4			4		
17 UNK # 13	4			3		

ble 8—continued.

ecies presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
American carrot (*Daucus pusillus*)	3			0		
Yellow tansy mustard (*Descurainia pinnata*)	3			0		
Rattlesnake weed (*Euphorbia albomarginata*)	3			0		
Prickly lettuce (*Lactuca serriola*)	3			2		
Pellitory (*Parietaria hesperia*)	3			1		
Phacelia (*Phacelia* spp.)	3			3		
Coulter globemallow (*Sphaeralcea coulteri*)	3			0		
Nuttall locoweed (*Astragalus nuttallianus*)	2			0		
Whitlow grass (*Draba cuneifolia*)	1			0		
Eriastrum (*Eriastrum diffusum*)	1			0		
Large yellow desert primrose (*Oenothera primiveris*)	1			0		
Small-flowered phacelia (*Phacelia micrantha*)	1			0		
UNK # 2	1			0		
UNK # 9	1			0		
UNK # 16 (*Sonchus* spp.)	1			0		
UNK # 18	1			0		
UNK # 19	1			0		
Total	3,944			1,482		

Table 9. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona, 15 March 1993. Ephemeral species summary for Lower Colorado Larrea site. This site was added to the program after measurements were taken in the initial project; therefore, no elevation, aspect, or slope data are available.

Species presence (P)	Total density in 4, 1.0-m^2 quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m^2 quadrant	Species richness (S)	Species diversity (H')
1 Woolly plantain (*Plantago insularis*)	2,563	23	1.883	13	14	1.107
2 Six weeks fescue (*Vulpia octoflora*)	2,235			2,217		
3 Sand peppergrass (*Lepidium lasiocarpum*)	702			27		
4 Arabian grass (*Schismus arabicus*)	618			0		
5 American carrot (*Daucus pusillus*)	593			592		
6 Arch-nutted comb bur (*Pectocarya recurvata*)	523			5		
7 Coulter globemallow (*Sphaeralcea coulteri*)	272			51		
8 Woolly sunflower (*Eriophyllum lanosum*)	168			157		
9 Draba (*Draba* spp.)	82			79		
10 UNK # 9	66			66		
11 Heron bill (*Erodium* spp.)	55			30		
12 Checker fiddleneck (*Amsinckia tessellata*)	18			18		
13 White-haired cryptantha (?) (*Cryptantha maritima* [?])	12			0		
14 Jewel flower (*Caulanthus lasiophyllus*)	11			0		
15 Gordon bladder pod (*Lesquerella gordoni*)	5			1		

able 9—continued.

pecies presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
6 UNK # 4	4			0		
7 Eriastrum (*Eriastrum diffusum*)	3			0		
8 UNK # 6	3			0		
9 UNK # 11	3			3		
0 UNK # 2	2			0		
1 UNK # 5	2			0		
2 Nuttall locoweed (*Astragalus nuttallianus*)	1			1		
3 UNK # 8	1			0		
Total	7,942			3,260		

Table 10. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona, 9 March 1993. Ephemeral species summary for Senita Basin site, quadrat VG01. Elevation: 507 m (1,665 ft); aspect: approximately level; slope: 1.0%.

Species presence (P)	Total density in 4, 1.0-m^2 quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m^2 quadrant	Species richness (S)	Species diversity (H')
1 UNK # 1 (*Calandrinia ciliata* or *Tillaea erecta* [?])	1,386	24	2.030	320	22	1.817
2 Woolly sunflower (*Eriophyllum lanosum*)	1,202			908		
3 Arabian grass (*Schismus arabicus*)	984			959		
4 Eriastrum (*Eriastrum diffusum*)	692			661		
5 Dogweed (*Dyssodia concinna*)	371			0		
6 Brittle spineflower (*Chorizanthe brevicornu*)	332			2		
7 Rigid spineflower (*Chorizanthe rigida*)	276			269		
8 Whitlow grass (*Draba cuneifolia*)	111			111		
9 Arch-nutted comb bur (*Pectocarya recurvata*)	49			27		
10 Chia (*Salvia columbariae*)	47			47		
11 Jewel flower (*Caulanthus lasiophyllus*)	40			40		
12 Plantain (*Plantago* spp.)	18			1		
13 Sand peppergrass (*Lepidium lasiocarpum*)	14			14		
14 Flat-topped buckwheat (*Eriogonum deflexum*)	13			13		
15 Bearded cryptantha (*Cryptantha barbigera*)	10			6		
16 Thread stem carpet weed (*Mollugo cerviana*)	10			9		

able 10—continued.

ecies presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
7 UNK cotyledons	5			0		
8 Spurge (*Euphorbia* spp.)	4			4		
9 Primrose (*Camissonia* spp.)	2			1		
0 Amercan carrot (*Daucus pusillus*)	2			2		
1 Yellow tansy mustard (*Descurainia pinnata*)	2			2		
2 Three-awn (*Aristida* spp.)	1			1		
3 Hairy bowlesia (*Bowlesia incana*)	1			1		
4 UNK # 4	1			1		
Total	5.573			3.399		

Table 11. Winter ephemeral vegetation monitoring in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona, 17 March 1993. Ephemeral species summary for Senita Basin site, quadrat VG02. Elevation: 532 m (1,745 ft); aspect: northwest-facing; slope: 49.0%.

Species presence (P)	Total density in 4, 1.0-m² quadrants	Species richness (S)	Species diversity (H')	Maximum density in 1, 1.0-m² quadrant	Species richness (S)	Species diversity (H')
1 Six weeks fescue (*Vulpia octoflora*)	581	16	1.737	38	12	0.709
2 Woolly sunflower (*Eriophyllum lanosum*)	425			75		
3 Emory rock daisy (*Perityle emoryi*)	148			29		
4 Bigelow's linanthus (*Linanthus bigelovii*)	126			31		
5 Rayed gilia (*Gilia stellata*)	74			26		
6 Long-capsuled primrose (*Camissonia chamaenerioides*)	51			27		
7 Thread plant (*Nemacladus glanduliferus*)	40			17		
8 UNK # 5	34			30		
9 Arabian grass (*Schismus arabicus*)	17			6		
10 Wing nut cryptantha (*Cryptantha pterocarya*)	13			0		
11 Whitlow grass (was UNK # 7) (*Draba cuneifolia*)	4			2		
12 Comb bur (*Pectocarya* spp.)	2			2		
13 Round tooth phacelia (*Phacelia crenulata*)	2			1		
14 Pincushion cactus (*Chaenactis* spp.)	1			0		
15 Yellow tansy mustard (*Descurainia pinnata*)	1			0		
16 Dogweed (*Dyssodia concinna*)	1			0		
Total	1,520			284		

Wildlife

Lizards

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 EMP that is planned to be capable of detecting biotic effects of global climate change, of local human-caused disturbance, and of natural environmental fluctuation. We should be able to document the immediate effects of environmental fluctuations on lizards and use this information to predict and/or illustrate the consequences of human-caused environmental change at ORPI. (From the Introduction to Monitoring Protocol, 19 July 1991)

Project History

Beginning with the end of the initial 4-yr (1987–1991) survey of ORPI herpetofauna, monument staff began implementation of the monitoring protocol, consisting of semiannual (spring and summer) walking of standardized lizard transects. In the beginning, only the Core I sites were visited due to constraints of time and personnel, but by 1993 all sites were visited during both seasons.

1993 Monitoring Activities

From 26 April to 23 May and again from 9 August to 1 October, lizards were monitored at ORPI. The project was carried out by personnel from the Division of Natural and Cultural Resources Management on all 13 of the EMP study sites for which lizard transects had been established, as well as 2 additional sites chosen for this monitoring protocol. Data for peak numbers of lizards observed per walk were compared with similar data for the previous 4 yr, and data on distances from transect midlines were tabulated as a test of proper scope of observation.

Methods

Lizards are monitored using a line-transect method whereby a transect (also called a "lizard line"), varying in length from 100 m (328 ft) to 300 m (984 ft), is walked repeatedly, with all lizards recorded that are seen within 7.5 m (24.6 ft) on either side of the center line. The following data are recorded: (1) distance from the origin, (2) distance from the center line, (3) species, (4) size/age class, and (5) time. Gender is also recorded if it can be determined. Eight sites have just 1 transect each, while 6 sites have 2 transects each that are walked alternately. The Pozo Nuevo EMP site has 4 transects, which require 2 people or 2 days to complete.

Each line is walked beginning at the east end so lizards can easily be seen basking in the morning sun, and all lines are walked beginning with first warmth, shortly after sunrise. A clear, warm, and fairly calm morning is required for good morning lizard activity. The walks are timed to coincide with the peaks of activity of each of the various species of lizards present, with particular attention being given to the "indicator species," usually whiptails

(*Cnemidophorus* spp.), around which the timing and duration of each session are generally determined. Once the number of individuals observed of the indicator species has peaked and is diminishing for 1 or 2 more walks, the session is ended. Each line is run once in the late spring and once again in mid-summer after the onset of the summer rains. The design of the protocol is such that 1 person can walk 2 lines alternately, since one would not want to walk a line so frequently as to frighten the lizards off the line.

Results

Unlike some other animal populations, such as insects or rodents, lizard populations are not tied directly to recent rainfall and vegetative abundance. Although these factors are ultimately the most critical, other factors such as temperature, humidity, soil moisture, and the populations of both reproducing adults (Fig. 13) and predators have a very significant influence that can modify and delay the larger and more obvious effects of rainfall and the resulting growth of vegetation. Thus, some of the results that are seen are not necessarily easily explained in terms of recent weather. Another important factor is the timing of monitoring days in terms of reproductive activity (for which the seasonal timing of the monitoring is designed) and the effects on lizard activity of the weather of the day and of the preceding week. This is especially noticeable in the spring when mornings can be quite cool, and in the summer when there can be effects of the "monsoons" such as clouds on the eastern horizon or a damp soil surface. In fact, some sites have had to be done twice due to unexpectedly and inexplicably low numbers of lizards observed.

Peak values for lizards observed over the years 1988–1993 are illustrated in Figures 14–37. The year 1993 began much as 1992 did, with heavier than usual winter rains, resulting in another profuse bloom of spring annuals. The most notable effect of this extreme vegetative abundance was that the almost 100% cover of annuals seemed to deny many lizards the proper amount of open space for basking and running (Fig. 38). This was noted repeatedly at sites where lizards such as tha western whiptail (*Cnemidophorus tigris*) had difficulty struggling through the grasses and other annuals when attempting to run for cover. At Armenta Ranch, the number of western whiptails seen on the road near the ranch house far exceeded the number seen out in the heavily overgrown flats along the transect. Later on in the summer, however, the situation was reversed, in that lizards were far more abundant out in the flats which were by then only sparsely vegetated. In general, it seemed that many of the lizards that require open running spaces, such as western whiptails and zebra-tailed lizards (*Callisaurus draconoides*), were more abundant than usual along roadsides and far less abundant in open grassy areas of almost complete ground cover.

The summer of 1993 was characterized by a very late start for the summer "monsoon" rains. The few lizard lines that were completed in August yielded poor results compared to the lines that were completed after the onset of the rains in late August. The summer rains were fairly well limited to one brief burst of rain at the end of August, with July being abnormally dry, and September being drier still. The results for the summer monitoring were fairly good, however, since the monitoring was properly delayed for the rainy season. Some sites still had inexplicably poor results, as they had also yielded in 1992. These included Aguajita Wash (Figs. 14 and 15) and Alamo Canyon (Fig. 16). The factors mentioned previously (weather, populations of predators, and reproducing adults) are the only ones that come to mind in trying to explain the poor results at these sites. It is clear that there is much yet to be learned about the dynamics of lizard behavior and activity, and that proper timing of the monitoring effort is crucial.

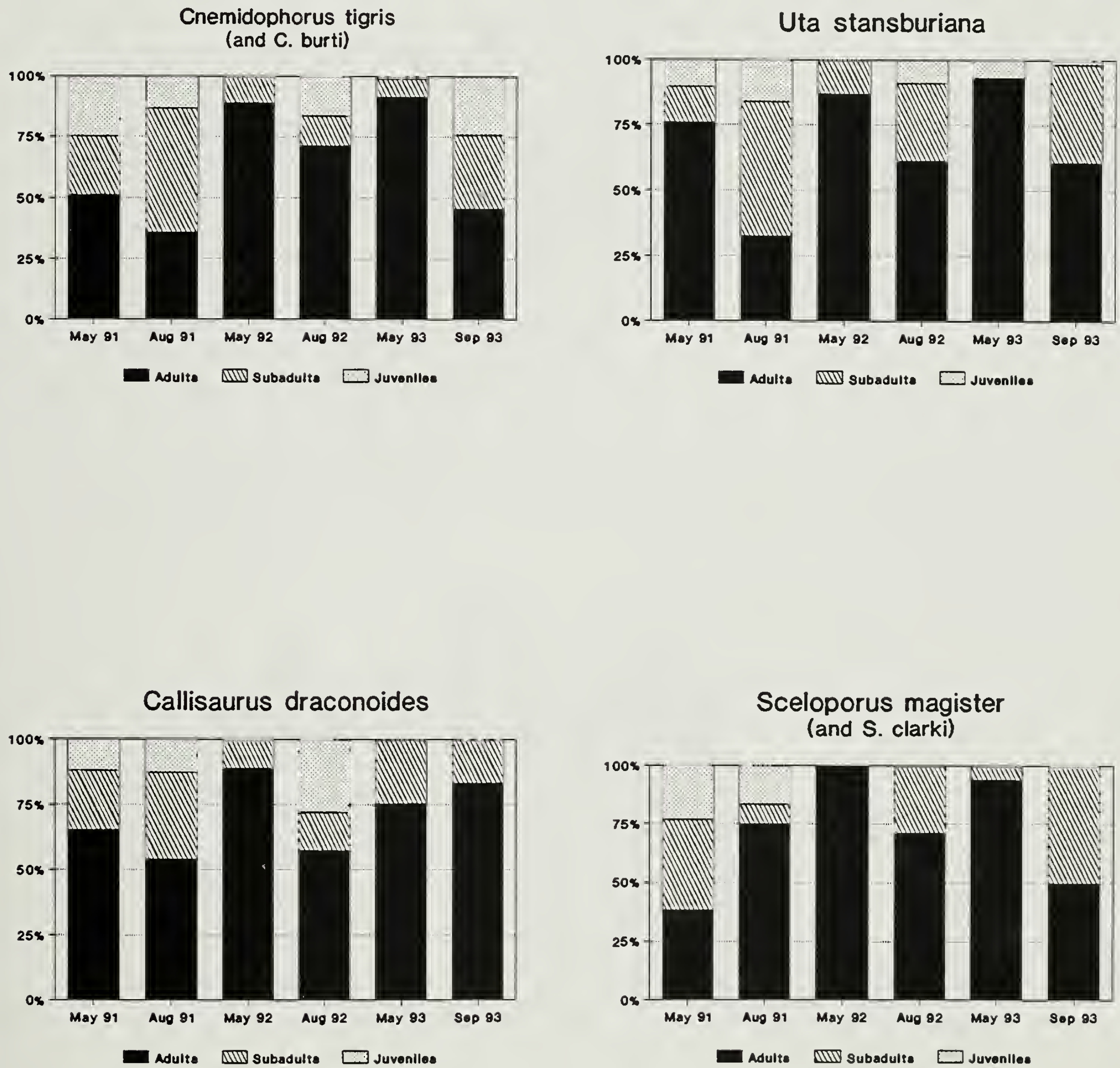
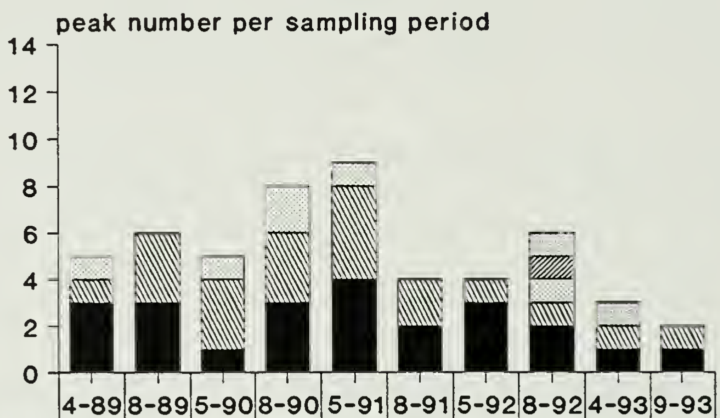


Figure 13. Age structure of lizard species monitored during 1991–1993 at all Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, Arizona. Data are shown for (1) western whiptail (*Cnemidophorus tigris*) and red-backed whiptail (*Cnemidophorus burti*), (2) side-blotched lizard (*Uta stansburiana*), (3) zebra-tailed lizard (*Callisaurus draconoides*), and (4) desert spiny lizard (*Sceloporus magister*) and Clark spiny lizard (*Sceloporus clarki*).

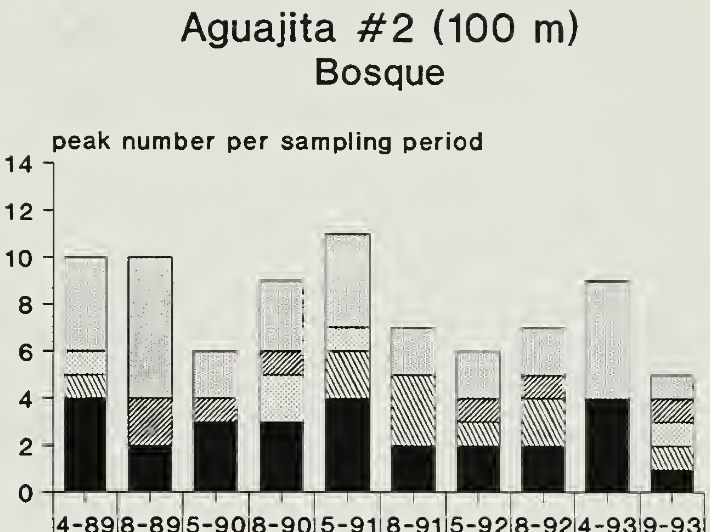
Note—Figures 14–37 chart peak values of lizard species observed on the Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, Arizona. The following species abbreviations and taxons are used: **Callisaurus** = zebra-tailed lizard (*Callisaurus draconoides*); **Cnemi burti** = red-backed whiptail (*Cnemidophorus burti*); **Cnemidophorus**, **Cnemi tigris**, and **Cnemidophoris tigris** = western whiptail; **Crotaphytus** and **Crotaphytus collaris** = common collared-lizard; **Dipsosaurus** = desert iguana (*Dipsosaurus dorsallis*); **Gambelia** = long-nosed leopard lizard (*Gambelia wislizeni*); **Heloderma** = Gila monster (*Heloderma suspectum*); **Phrysonoma solare** = regal horned-lizard **Sceloporus** = desert spiny lizard (*Sceloporus magister*) for all sites except Alamo Canyon (Fig. 16), in which case the species is Clark spiny lizard (*Sceloporus clarki*); **Urosaurus** and **Urosaurus ornatus** = tree lizard, except where specified as **Urosaurus graciosus** (long-tailed brush lizard); **Uta** and **Uta stansburiana** = side-blotched lizard.

Aguajita #1 (100 m)
Saltbush



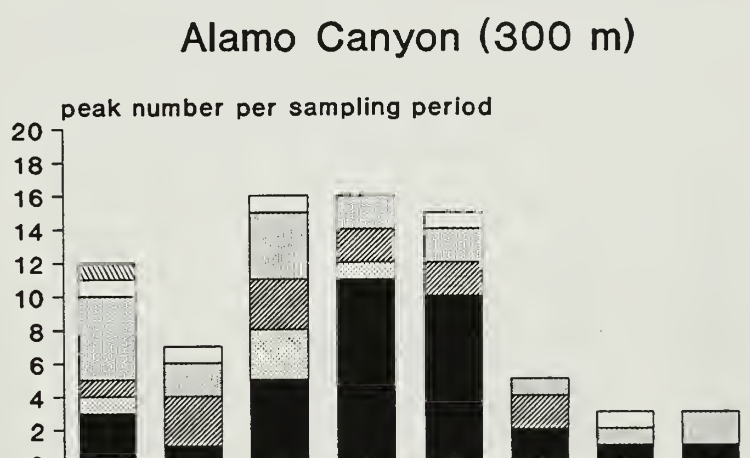
	4-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93
Urosaurus	0	0	0	0	0	0	0	1	1	0
Sceloporus	0	0	0	0	0	0	0	1	0	0
Callisaurus	1	0	1	2	1	0	0	1	0	0
Uta	1	3	3	3	4	2	1	1	1	1
Cnemidophorus	3	3	1	3	4	2	3	2	1	1

Figure 14. Peak values of lizard species monitored from April 1989 through September 1993 at Aguajita #1 (Saltbush) site.



	4-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93
Urosaurus	4	6	2	3	4	2	2	2	5	1
Sceloporus	0	2	1	1	0	0	1	1	0	1
Callisaurus	1	0	0	2	1	0	0	0	0	1
Uta	1	0	0	0	2	3	1	2	0	1
Cnemidophorus	4	2	3	3	4	2	2	2	4	1

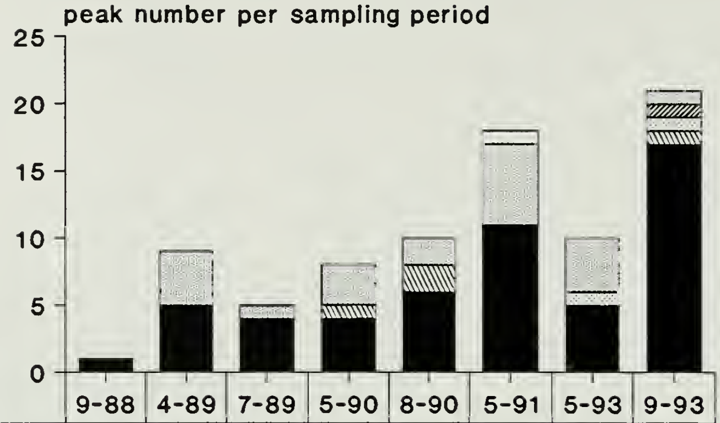
Figure 15. Peak values of lizard species monitored from April 1989 through September 1993 at Aguajita #2 (Bosque) site.



	8-89	5-90	5-91	8-91	5-92	8-92	4-93	8-93
Cnemi tigris	1	0	0	0	0	0	0	0
Crotaphytus	1	1	1	0	1	0	1	0
Urosaurus	5	2	4	2	2	1	1	2
Sceloporus	1	3	3	2	2	2	0	0
Callisaurus	1	0	3	1	0	0	0	0
Cnemi burti	3	1	5	11	10	2	1	1

Figure 16. Peak values of lizard species monitored from August 1989 through August 1993 at Alamo Canyon site.

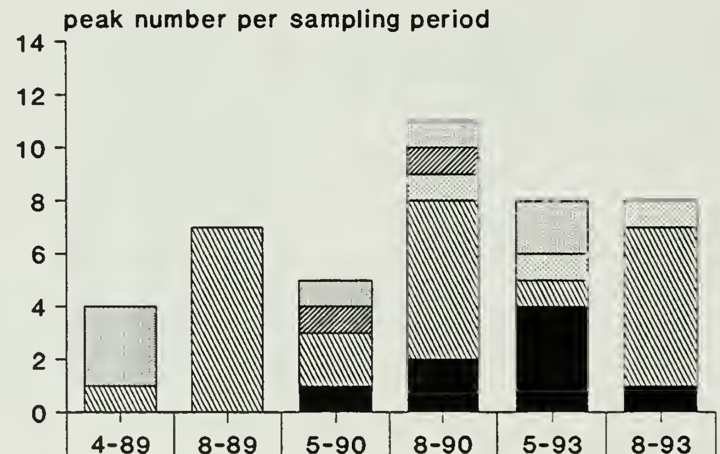
Armenta Ranch (200 m)



		9-88	4-89	7-89	5-90	8-90	5-91	5-93	9-93
Dipsosaurus	□	0	0	0	0	0	1	0	0
Urosaurus	▒	0	4	1	3	2	6	4	1
Sceloporus	▨	0	0	0	0	0	0	0	1
Callisaurus	░	0	0	0	0	0	0	1	1
Uta	▧	0	0	0	1	2	0	0	1
Cnemidophorus	■	1	5	4	4	6	11	5	17

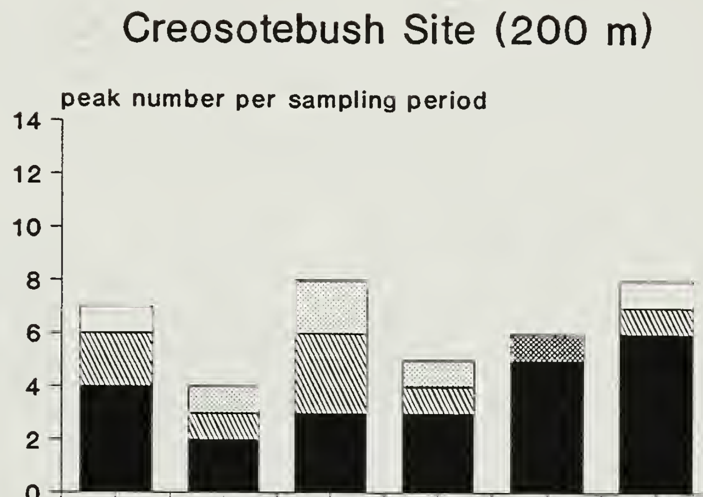
Figure 17. Peak values of lizard species monitored from September 1988 through September 1993 at Armenta Ranch site.

Burn Site (100 m)



		4-89	8-89	5-90	8-90	5-93	8-93
Urosaurus	▒	3	0	1	1	2	0
Sceloporus	▨	0	0	1	1	0	0
Callisaurus	░	0	0	0	1	1	1
Uta	▧	1	7	2	6	1	6
Cnemidophorus	■	0	0	1	2	4	1

Figure 18. Peak values of lizard species monitored from April 1989 through August 1993 at Burn site.



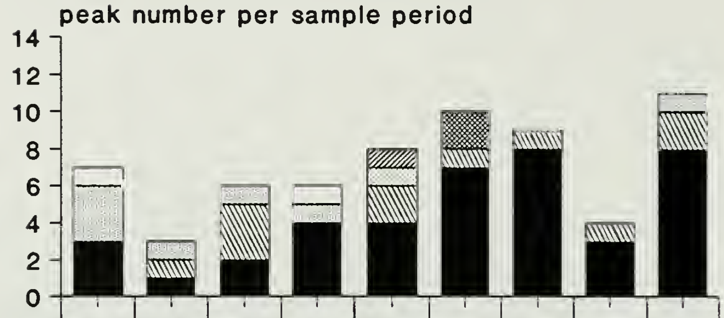
	8-89	5-90	8-90	5-91	5-93	9-93
Gambelia	0	0	0	0	1	0
Dipsosaurus	1	0	0	0	0	1
Callisaurus	0	1	2	1	0	0
Uta	2	1	3	1	0	1
Cnemidophorus	4	2	3	3	5	6

Figure 19. Peak values of lizard species monitored from April 1989 through September 1993 at Creosotebush site.

	4-89	8-89	8-90	5-91	8-91	4-92	8-92	5-93	9-93
Gambelia	0	0	0	0	0	0	1	0	0
Urosaurus	1	0	1	1	1	0	1	0	1
Sceloporus	1	0	0	0	0	0	0	0	0
Callisaurus	0	1	1	0	1	0	0	0	0
Uta	1	0	1	1	0	0	1	1	3
Cnemidophorus	4	1	3	4	6	8	8	1	10

Figure 20. Peak values of lizard species monitored from April 1989 through September 1993 at Dos Lomitas #1 (Inside Exclosure) site.

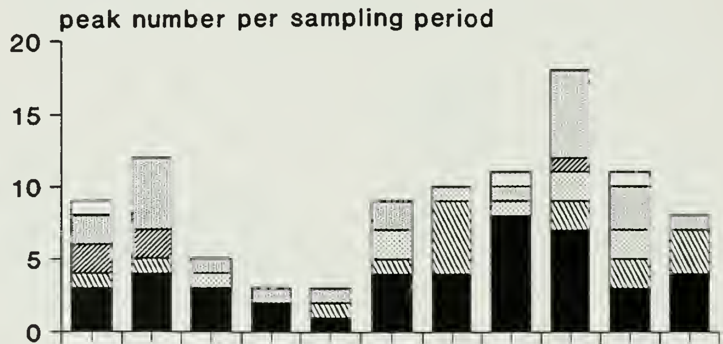
Dos Lomitas #2 (100 m)
Outside Exclosure



	4-89	8-89	8-90	5-91	8-91	4-92	8-92	5-93	9-93
Gambelia	0	0	0	0	0	2	0	0	0
Dipsosaurus	1	0	0	1	0	0	0	0	0
Urosaurus	3	1	1	1	0	0	0	0	1
Sceloporus	0	0	0	0	1	0	0	0	0
Callisaurus	0	0	0	0	1	0	0	0	0
Uta	0	1	3	0	2	1	1	1	2
Cnemidophorus	3	1	2	4	4	7	8	3	8

Figure 21. Peak values of lizard species monitored from April 1989 through September 1993 at Dos Lomitas #2 (Outside Exclosure) site.

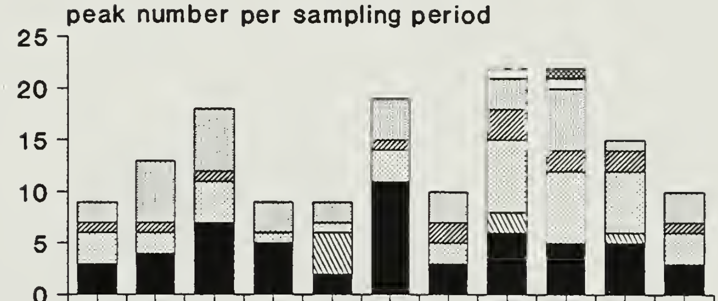
East Armenta #1 (200 m)
Desertscrub



	8-88	4-89	7-89	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93
Dipsosaurus	1	0	0	0	0	0	0	1	0	1	0
Urosaurus	2	5	1	1	1	2	0	1	6	3	1
Sceloporus	2	2	0	0	0	0	0	0	1	0	0
Callisaurus	0	0	1	0	0	2	1	1	2	2	0
Uta	1	1	0	0	1	1	5	0	2	2	3
Cnemidophorus	3	4	3	2	1	4	4	8	7	3	4

Figure 22. Peak values of lizard species monitored from August 1988 through August 1993 at East Armenta #1 (Desertscrub) site.

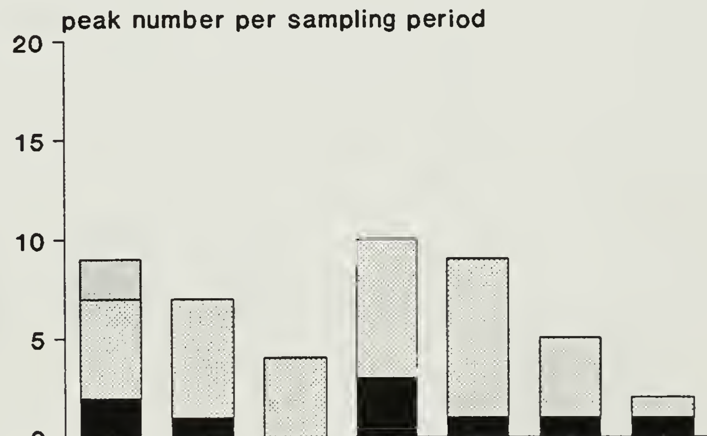
East Armenta #2 (200 m)
Kuakatch Wash



	8-88	4-89	7-89	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93
Gambelia	0	0	0	0	0	0	0	0	1	0	0
Dipsosaurus	0	0	0	0	0	0	0	1	1	0	0
Urosaurus	2	6	6	3	2	4	3	3	6	1	3
Sceloporus	1	1	1	0	0	1	2	3	2	2	1
Callisaurus	3	2	4	1	1	3	2	7	7	6	3
Uta	0	0	0	0	4	0	0	2	0	1	0
Cnemidophorus	3	4	7	5	2	11	3	6	5	5	3

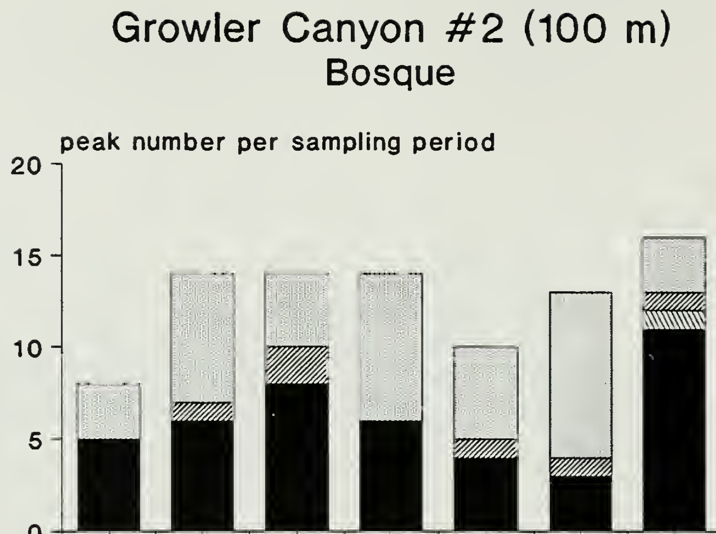
Figure 23. Peak values of lizard species monitored from August 1988 through August 1993 at East Armenta #2 (Kuakatch Wash) site.

Growler Canyon #1 (100 m)
Wash Bed



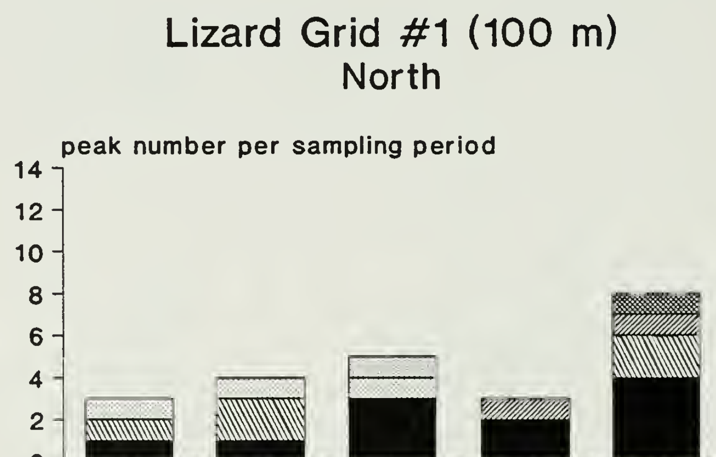
	4-89	5-91	8-91	5-92	8-92	5-93	9-93
Urosaurus	2	0	0	0	0	0	0
Callisaurus	5	6	4	7	8	4	1
Cnemidophorus	2	1	0	3	1	1	1

Figure 24. Peak values of lizard species monitored from April 1988 through September 1993 at Growler Canyon #1 (Wash Bed) site.



		4-89	5-91	8-91	5-92	8-92	5-93	9-93
Urosaurus		3	7	4	8	5	9	3
Sceloporus		0	1	2	0	1	1	1
Uta		0	0	0	0	0	0	1
Cnemidophorus		5	6	8	6	4	3	11

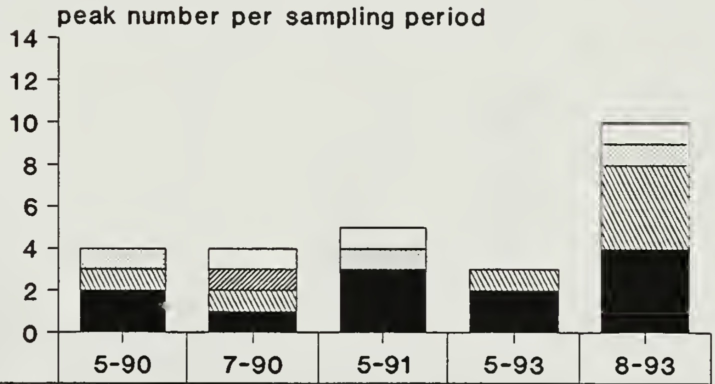
Figure 25. Peak values of lizard species monitored from April 1988 through September 1993 at Growler Canyon #2 (Bosque) site.



		5-90	7-90	5-91	5-93	8-93
Gambelia		0	0	0	0	1
Urosaurus		0	0	1	0	0
Sceloporus		0	0	0	1	1
Callisaurus		1	1	1	0	0
Uta		1	2	0	0	2
Cnemidophorus		1	1	3	2	4

Figure 26. Peak values of lizard species monitored from May 1990 through August 1993 at Lizard Grid #1 (North) site.

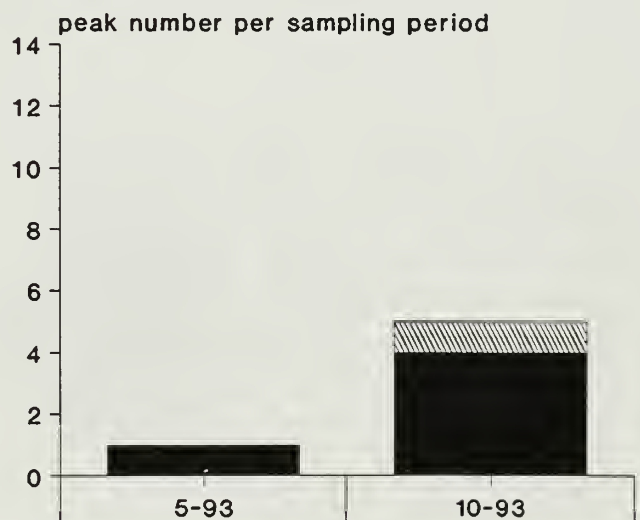
Lizard Grid #2 (100 m)
South



	5-90	7-90	5-91	5-93	8-93
Dipsosaurus	0	1	1	0	1
Urosaurus	0	0	1	0	0
Sceloporus	0	1	0	0	0
Callisaurus	1	0	0	0	1
Uta	1	1	0	1	4
Cnemidophorus	2	1	3	2	4

Figure 27. Peak values of lizard species monitored from May 1990 through August 1993 at Lizard Grid #2 (South) site.

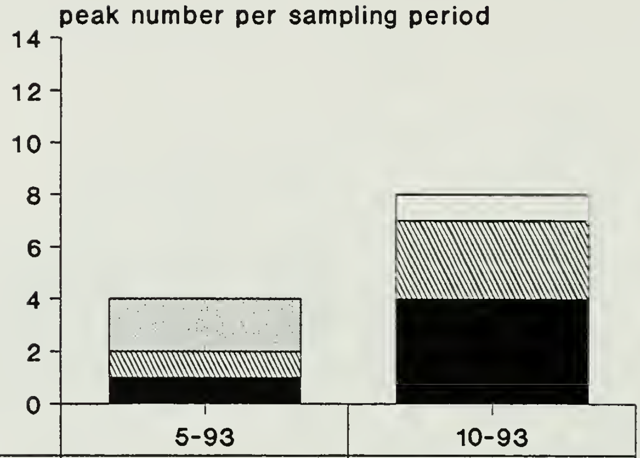
Lost Cabin #1 (100 m)
Wash Flats



	5-93	10-93
Uta stansburiana	0	1
Cnemidophorus tigris	1	4

Figure 28. Peak values of lizard species monitored from May 1993 through October 1993 at Lost Cabin #1 (Wash Flats) site.

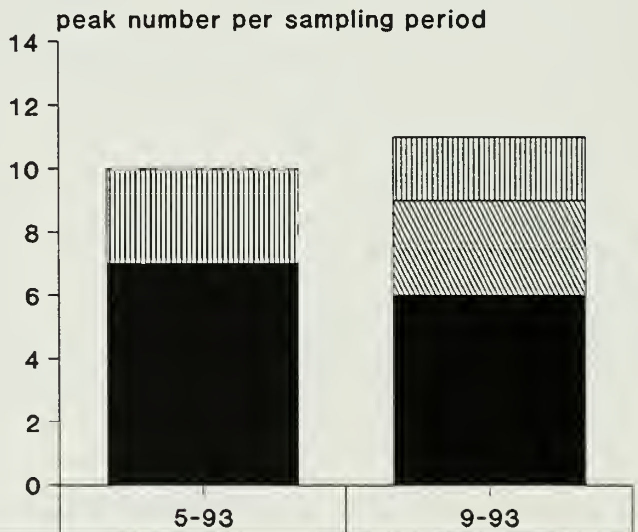
Lost Cabin #2 (100 m)
Rocky Draw



	5-93	10-93
Crotaphytus collaris	0	1
Urosaurus ornatus	2	0
Uta stansburiana	1	3
Cnemidophorus tigris	1	4

Figure 29. Peak values of lizard species monitored from May 1993 through October 1993 at Lost Cabin #2 (Rocky Draw) site.

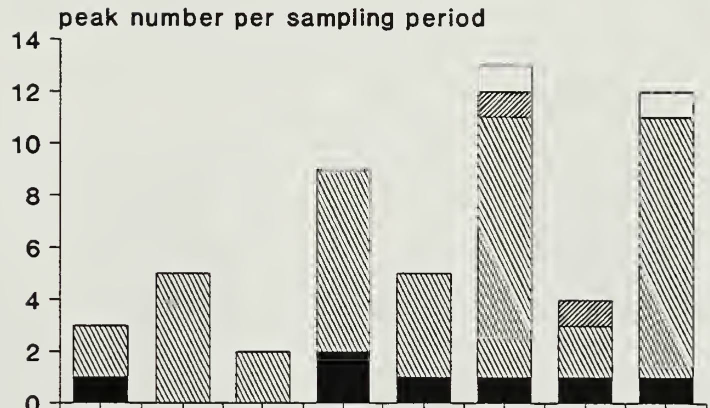
Lower Colorado Larrea (200 m)



	5-93	9-93
Urosaurus graciosus	3	2
Uta stansburiana	0	3
Cnemidophorus tigris	7	6

Figure 30. Peak values of lizard species monitored from May 1993 through September 1993 at Lower Colorado Larrea site.

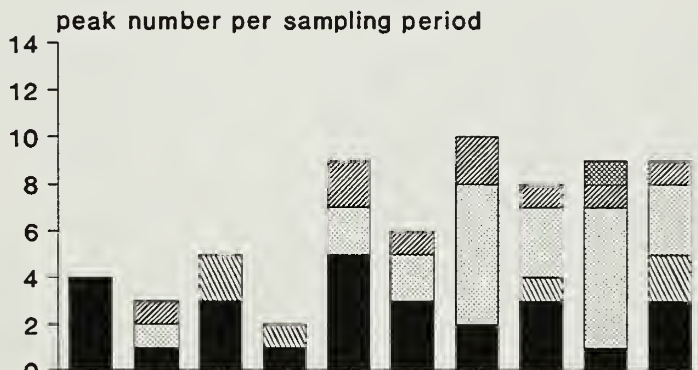
Pozo Nuevo #1 (100 m)
Hill Base



	5-89	8-89	5-91	8-91	5-92	8-92	4-93	9-93
Crotaphytus	0	0	0	0	0	1	0	1
Sceloporus	0	0	0	0	0	1	1	0
Uta	2	5	2	7	4	10	2	10
Cnemidophorus	1	0	0	2	1	1	1	1

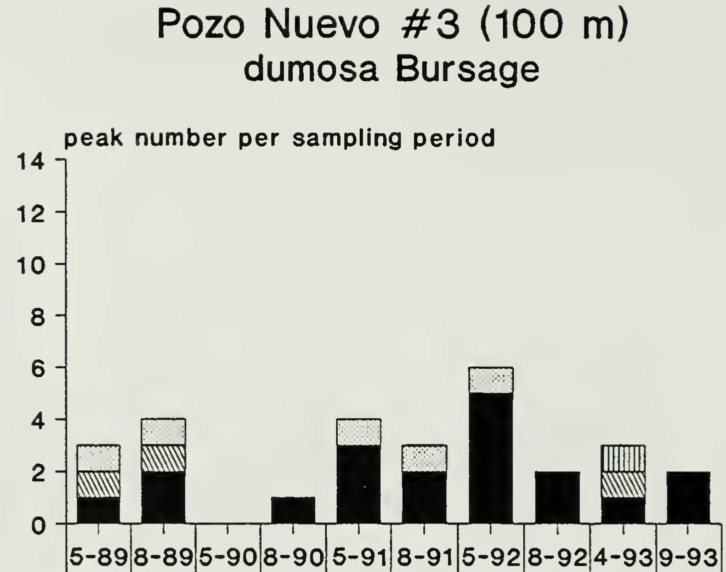
Figure 31. Peak values of lizard species monitored from May 1989 through September 1993 at Pozo Nuevo #1 (Hill Base) site.

Pozo Nuevo #2 (100 m)
Wash



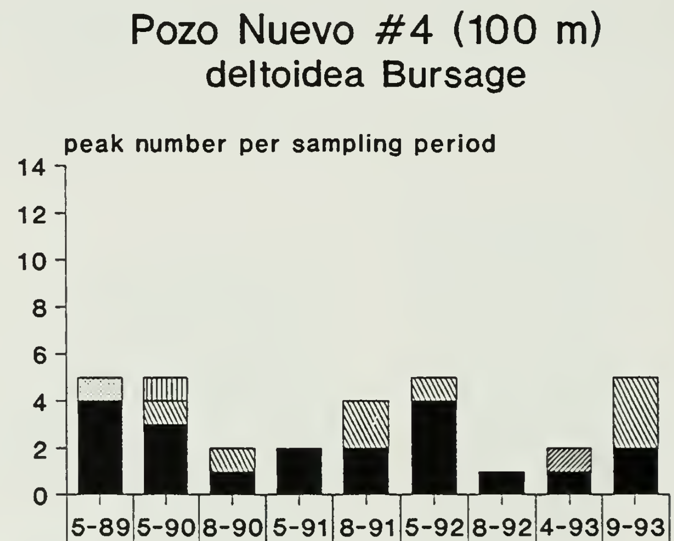
	5-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93
U. graciosus	0	0	0	0	0	0	0	0	1	0
Sceloporus	0	1	0	0	2	1	2	1	1	1
Callisaurus	0	1	0	0	2	2	6	3	6	3
Uta	0	0	2	1	0	0	0	1	0	2
Cnemidophorus	4	1	3	1	5	3	2	3	1	3

Figure 32. Peak values of lizard species monitored from May 1989 through September 1993 at Pozo Nuevo #2 (Wash) site.



	5-89	8-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93
Heloderma	0	0	0	0	0	0	0	0	1	0
Callisaurus	1	1	0	0	1	1	1	0	0	0
Uta	1	1	0	0	0	0	0	0	1	0
Cnemidophorus	1	2	0	1	3	2	5	2	1	2

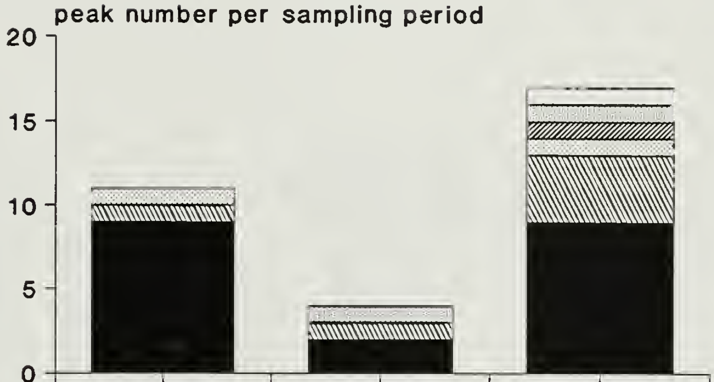
Figure 33. Peak values of lizard species monitored from May 1989 through September 1993 at Pozo Nuevo #3 (*dumosa* Bursage) site.



	5-89	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93
Phrynosoma solare	0	1	0	0	0	0	0	0	0
Sceloporus	0	0	0	0	0	0	0	1	0
Callisaurus	1	0	0	0	0	0	0	0	0
Uta	0	1	1	0	2	1	0	0	3
Cnemidophorus	4	3	1	2	2	4	1	1	2

Figure 34. Peak values of lizard species monitored from May 1989 through September 1993 at Pozo Nuevo #4 (*deltoidea* Bursage) site.

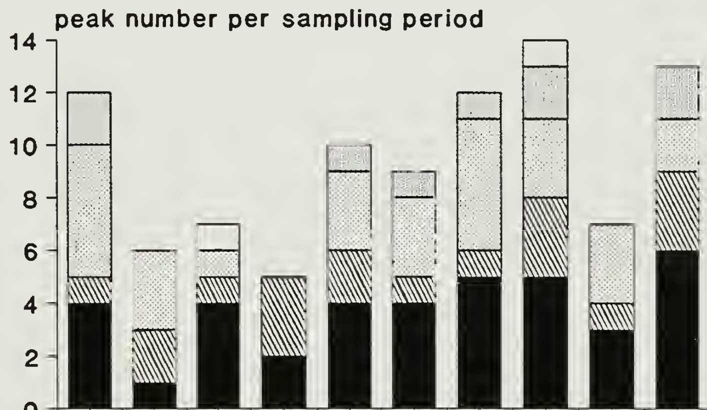
Salsola Site (200 m)



	4-89	5-93	9-93
Dipsosaurus	0	0	1
Urosaurus	0	1	1
Sceloporus	0	0	1
Callisaurus	1	0	1
Uta	1	1	4
Cnemidophorus	9	2	9

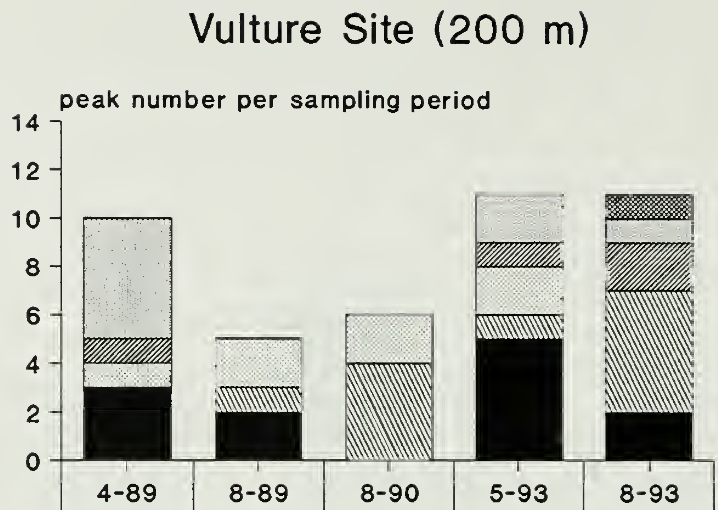
Figure 35. Peak values of lizard species monitored from April 1989 through September 1993 at Salsola site.

Senita Basin (250 m)



	5-89	8-89	5-90	8-90	5-91	8-91	4-92	8-92	4-93	9-93
Dipsosaurus	0	0	1	0	0	0	0	1	0	0
Urosaurus	2	0	0	0	1	1	1	2	0	2
Callisaurus	5	3	1	0	3	3	5	3	3	2
Uta	1	2	1	3	2	1	1	3	1	3
Cnemidophorus	4	1	4	2	4	4	5	5	3	6

Figure 36. Peak values of lizard species monitored from May 1989 through September 1993 at Senita Basin site.



	4-89	8-89	8-90	5-93	8-93
Gambelia	0	0	0	0	1
Urosaurus	5	0	0	2	1
Sceloporus	1	0	0	1	2
Callisaurus	1	2	2	2	0
Uta	0	1	4	1	5
Cnemidophorus	3	2	0	5	2

Figure 37. Peak values of lizard species monitored from April 1989 through August 1993 at Vulture site.

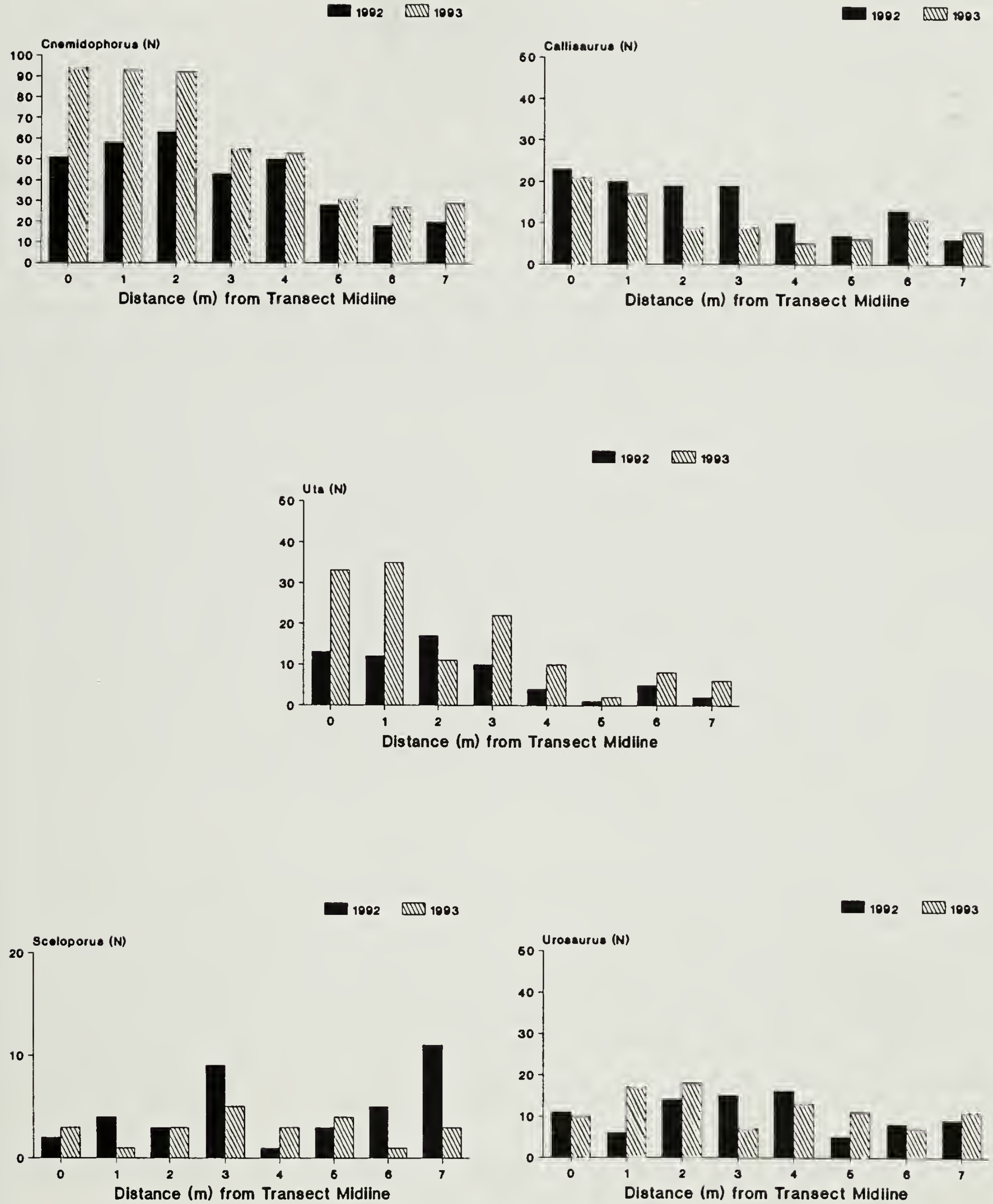


Figure 38. Observed distances from lizard line-transect midlines in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona. Species observed are whiptails (*Cnemidophorus* spp.), zebra-tailed lizards (*Callisaurus* spp.), side-blotched lizards (*Uta* spp.), spiny lizards (*Sceloporus* spp.), and tree lizards (*Urosaurus* spp.).

Nocturnal Rodents

Introduction

Nocturnal rodent population assessment and monitoring has been proven to be an efficient way to document and monitor overall habitat conditions in the Sonoran Desert. By serving as a major prey base for bird, reptile, and mammal predators, nocturnal rodents and their known population dynamics can serve as a tool for making assessments of general ecosystem health. Nocturnal rodents are particularly efficient to study because they (1) are found in most habitats, (2) respond quickly to changes in the primary production of plants, (3) can have several litters in a year, (4) are easily captured, (5) have a relatively small home range, (6) can be captured repeatedly in the same area, and (7) are easily identified (Petryszyn and Russ 1991).

Project History

The SEP project Special Status Mammals of Organ Pipe Cactus National Monument, contracted to Yar Petryszyn of The University of Arizona, collected baseline information on nocturnal rodent densities and distributions over a diverse array of macro- and microhabitats within the monument. Although several inventories of mammals existed for the monument before this study (Mearns 1907; Cockrum 1981; Cockrum and Petryszyn 1986), this was the first effort to make population assessments of nocturnal rodents over wide-ranging habitats in the monument.

Field work began in 1987 and consisted of establishing and sampling permanent rodent grids located on each of 16 (at that time) study sites. Additionally, at most sites, pitfall traps were placed to capture desert shrews. Large Havahart traps were set for the capture of larger animals such as fox, badger, skunk, and ringtail.

Two families of nocturnal rodents are present in the monument: (1) mice, rats, lemmings, and voles (Family: Cricetidae) and (2) pocket mice, kangaroo mice, and kangaroo rats (Family: Heteromyidae). Results from this study showed that the heteromyids, consisting of pocket mice (*Chaetodipus* spp. and *Perognathus* spp.) and kangaroo rats (*Dipodomys* spp.) strongly dominated bajada and valley fill macrohabitats. The cricetids, represented by the white-throated woodrat (*Neotoma albigula*), and the cactus mouse (*Peromyscus eremicus*), were the main constituents of the mountain canyon macrohabitats. During the course of this study, one mammalian species new to the monument—the Arizona cotton rat (*Sigmodon arizonae*)—was recorded.

As a final part of the study, monitoring protocols were developed so that monument resource management staff could continue monitoring nocturnal rodent populations.

1993 Monitoring Activities

For a 5-wk period from 29 June through 23 July, nocturnal rodents were monitored at ORPI. Staff from the Division of Natural and Cultural Resources Management conducted this activity on 7 of the 8 Core I and Core II EMP study sites. Five non-core EMP sites were also sampled this year. One of the 5 non-core sites, the newly established Lower Colorado Larrea site, was sampled by project co-investigator, Steven Russ. Rodent density and biomass were estimated for each site. At the Core I and II sites where monitoring has been implemented since 1991, 3-yr comparisons were made for rodent density and biomass (Fig. 39).

Methods

Nocturnal rodents were monitored using capture, mark, release, and recapture methods described in the *Monitoring Protocol for Small Nocturnal Mammals* (Petryszyn and Russ, 1991). Forty-nine 7.6- x 8.9- x 22.9-cm (3.0- x 3.5- x 9.0-in.) Sherman live-traps were baited and set on each of the 2 mammal grids (Bull Pasture has only 1 grid) located at each study site. Trap stations on each grid were given permanent alphanumeric designations of A1–G7 (A1 = southwest grid corner; G7 = northeast grid corner). This designation is useful in tracking species microhabitat selection and species distribution over time. Trapping was conducted during 2 consecutive nights with rodent processing, i.e., weighing, sexing, and marking, beginning near dawn. Biomass and densities were estimated using the assumption that 72% of the rodent population existing on the sampling grid (effective sampling area = 1.4 ha [3.5 a.]) is captured during the 2-night trapping period. The field techniques and population modelling methods followed are covered in detail in the monitoring handbook.

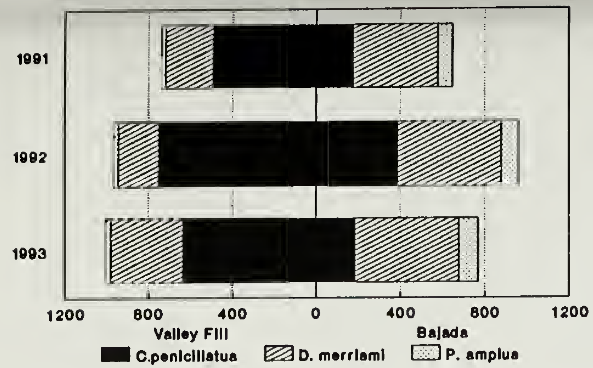
Well before the monitoring work began, Petryszyn was consulted to determine if the usual 1-trap-per-station setup would sufficiently sample the probable very high densities of heteromyids resulting from high rainfall (and hence high primary plant production) occurring in 1992 and early 1993. He suggested incorporating a 2-trap-per-station setup to serve as an index to relate the difference in results between the 2 sampling methods (1 trap vs 2 traps per station). Temporary grids were established using 2 traps per station (98 traps per grid) near one of the 2 permanent grids at the East of Armenta, Armenta Ranch, and Pozo Nuevo study sites. These paired plots were very similar in habitat characteristics and were located at least 50 m (164 ft) apart.

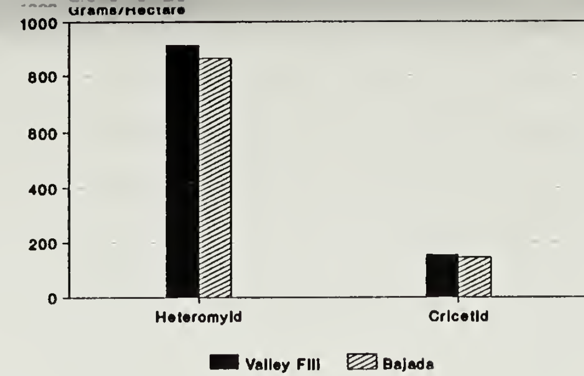
Results

During this 5-wk trapping period, which translated to 2,450 trap nights (49 traps per grid per night), 1,413 individual rodents (excluding recaptures and the few individuals that escaped before being processed) were captured, representing 9 different species. Two spotted skunks were also captured at the Alamo Canyon site. This year an unusually high number of the southern grasshopper mouse (*Onychomys torridus*) was captured. The estimated total biomass (cricetids and heteromyids) ranged from 555.85 gm/ha (48.05 oz/a.) at Senita Basin to 3,642.10 gm/ha (314.86 oz/a.) at Alamo Canyon. See Figures 39–52 for a summary of monitoring results.

Six of the Core I and II study site areas were grouped according to macrohabitat (valley fill and bajada—Lowe 1992) and evaluated by family and by dominate species for the 3-yr monitoring period. Although biomass by family was very similar for the 2 macrohabitats, species composition was very different (Fig. 39).

On the 3 paired-sample plots, paired-sample T-tests suggested there was a significant difference ($P \geq 0.95$) in the numbers of Merriam's kangaroo rat (*D. merriami*) and the desert pocket mouse (*Chaetodipus. penicillatus*) that were captured using the 1-trap-per-station setup vs using the 2-traps-per-station setup (Table 12). The issue, however, of whether to switch to a 2-traps-per-station setup in years of high rodent density has been further discussed during recent EMP Advisory Committee meetings. It has been agreed that monitoring staff will stick to a 1-trap-per-station configuration since relative, not absolute, rodent abundance is the parameter intended for monitoring via this protocol.





Valley Fill Macrohabitat—Growler, Aguajita, and Dos Lomitas EMP Sites

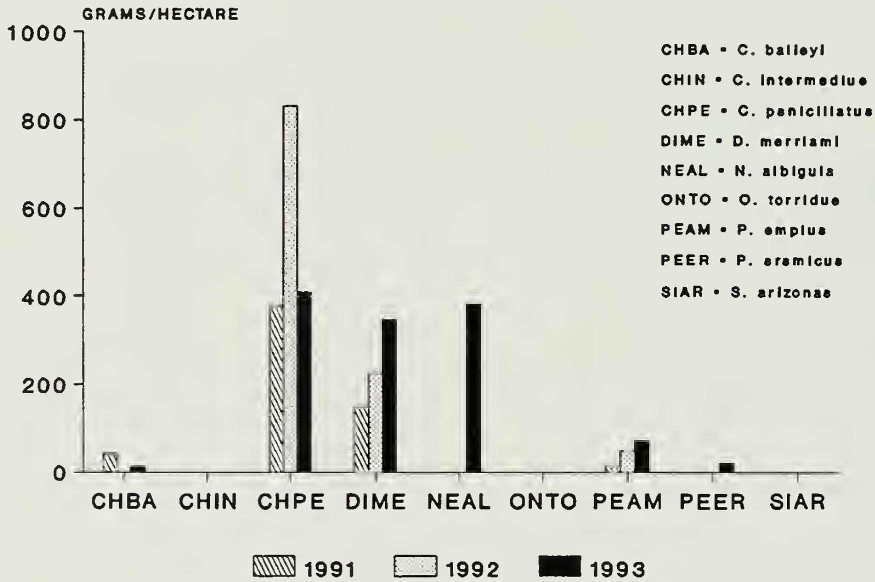
Species	1991 (N = 3)	1992 (N = 3)	1993 (N = 3)	1991–1993 (N = 9)
All Heteromyids	762.70 ± 111.62	964.97 ± 70.73	1,008.33 ± 100.55	912.00 ± 61.08
All Cricetids	109.37 ± 55.73	130.67 ± 74.66	222.17 ± 91.43	154.07 ± 41.47
Desert pocket mouse	491.90 ± 200.42	747.72 ± 78.87	632.35 ± 156.13	623.99 ± 85.24
Merriam's kangaroo rat	226.20 ± 111.87	196.40 ± 72.84	345.88 ± 167.58	256.16 ± 65.93
Arizona pocket mouse	17.47 ± 6.95	20.80 ± 14.87	25.52 ± 23.35	21.26 ± 8.32

Bajada Macrohabitat—East of Armenta, Senita Basin, and Pozo Nuevo EMP Sites

Species	1991 (N = 3)	1992 (N = 3)	1993 (N = 3)	1991–1993 (N = 9)
All Heteromyids	648.50 ± 231.87	1,155.20 ± 74.86	789.55 ± 220.04	864.42 ± 121.17
All Cricetids	193.28 ± 188.60	89.37 ± 69.67	154.35 ± 67.48	145.67 ± 63.07
Desert pocket mouse	175.50 ± 50.26	386.88 ± 16.71	184.68 ± 66.12	249.02 ± 42.28
Merriam's kangaroo rat	401.87 ± 151.46	490.88 ± 92.31	493.28 ± 190.78	462.01 ± 76.69
Arizona pocket mouse	71.13 ± 33.31	81.70 ± 16.21	90.28 ± 26.55	81.04 ± 13.45

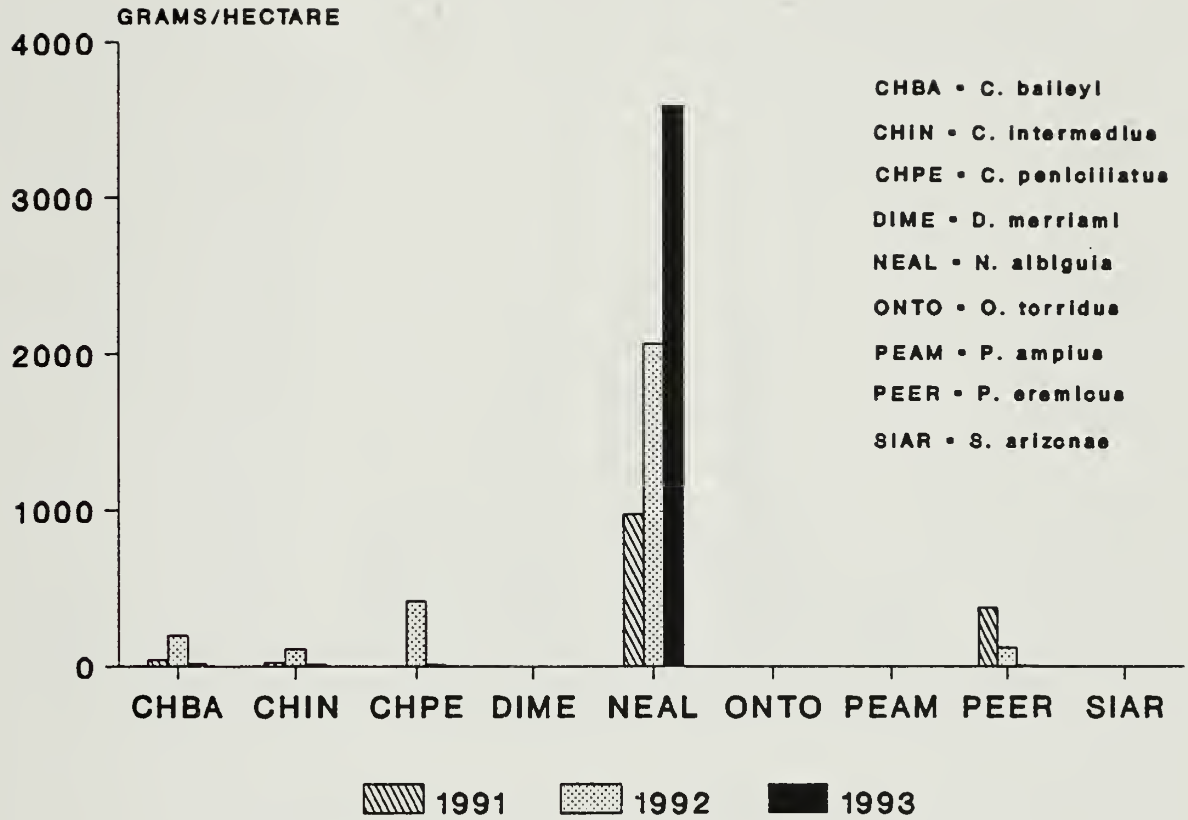
Figure 39. Comparison of mean biomass estimates for small nocturnal mammals, by macrohabitat, 1991–1993, Ecological Monitoring Program, Organ Pipe Cactus National Monument, Arizona. Estimates are given for the total heteromyids, total cricetids, and for the desert pocket mouse (*Chaetodipus penicillatus*), Merriam's kangaroo rat (*Dipodomys merriami*), and Arizona pocket mouse (*Perognathus amplus*). Values shown in the table are mean biomass in gm/ha, followed by 1 standard error. Means only are shown in graphs.

Note—Figures 40–52 display density and biomass estimates for small nocturnal mammals observed on the Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, Arizona. The following species abbreviations are used: **CHIBA** = *Chaetodipus baileyi* (Bailey's pocket mouse), **CHIN** = *Chaetodipus intermedius* (rock pocket mouse), **CHPE** = *Chaetodipus penicillatus* (desert pocket mouse), **DIME** = *Dipodomys merriami* (Merriam's kangaroo rat), **NEAL** = *Neotoma albigula* (white-throated woodrat), **ONTO** = *Onychomys torridus* (southern grasshopper mouse), **PEAM** = *Perognathus amplus* (Arizona pocket mouse), **PEER** = *Peromyscus eremicus* (cactus mouse), and **SIAR** = *Sigmodon arizonae* (Arizona cotton rat).



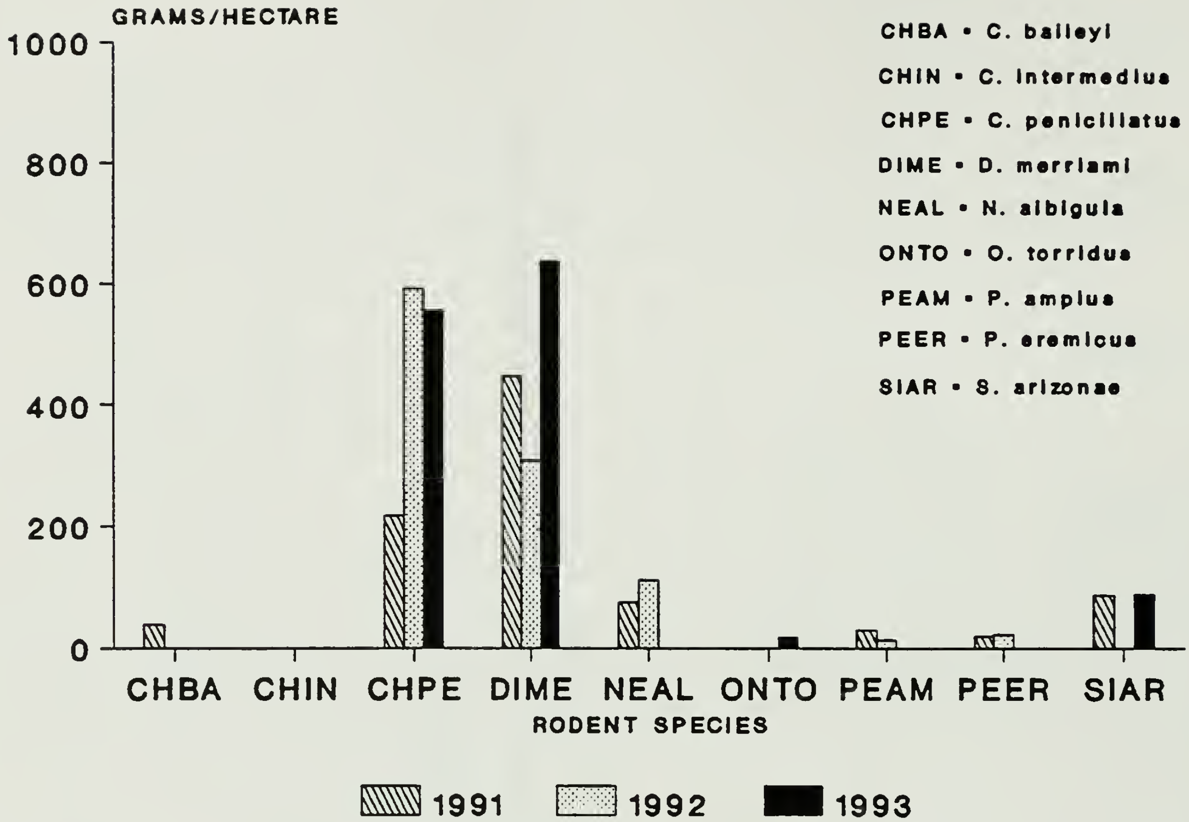
	1991	1992	1993
Total Heteromyid			
Density (n/ha)	34.5	61.0	43.0
Biomass (g/ha)	586.8	1,105.4	842.5
Total Cricetid			
Density (n/ha)	0.0	0.0	4.0
Biomass (g/ha)	0.0	0.0	402.8
Diversity (H')	0.743	0.577	0.413
Capture success (night 1)	29.6%	67.3%	52.0%
Capture success (night 2)	63.3%	82.7%	63.3%
Recapture	35.5%	31.1%	30.6%

Figure 40. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Aguajita sites.



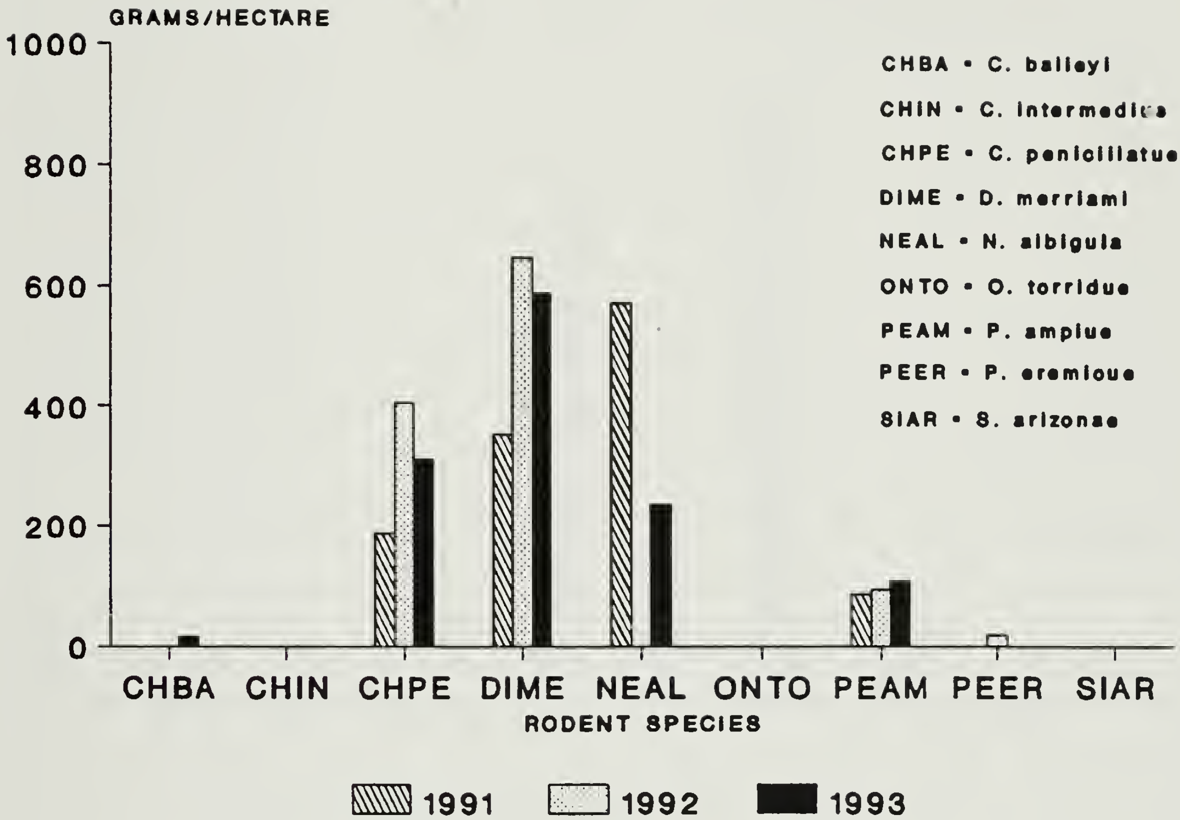
	1991	1992	1993
Total Heteromyid			
Density (n/ha)	3.5	34.0	2.0
Biomass (g/ha)	64.8	725.2	39.3
Total Cricetid			
Density (n/ha)	28.5	25.0	26.0
Biomass (g/ha)	1,353.3	2,189.0	3,602.8
Diversity (H')	0.963	1.458	0.420
Capture success (night 1)	33.7%	64.3%	33.7%
Capture success (night 2)	49.0%	76.5%	40.8%
Recapture	31.2%	25.4%	40.9%

Figure 41. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Alamo Canyon site.



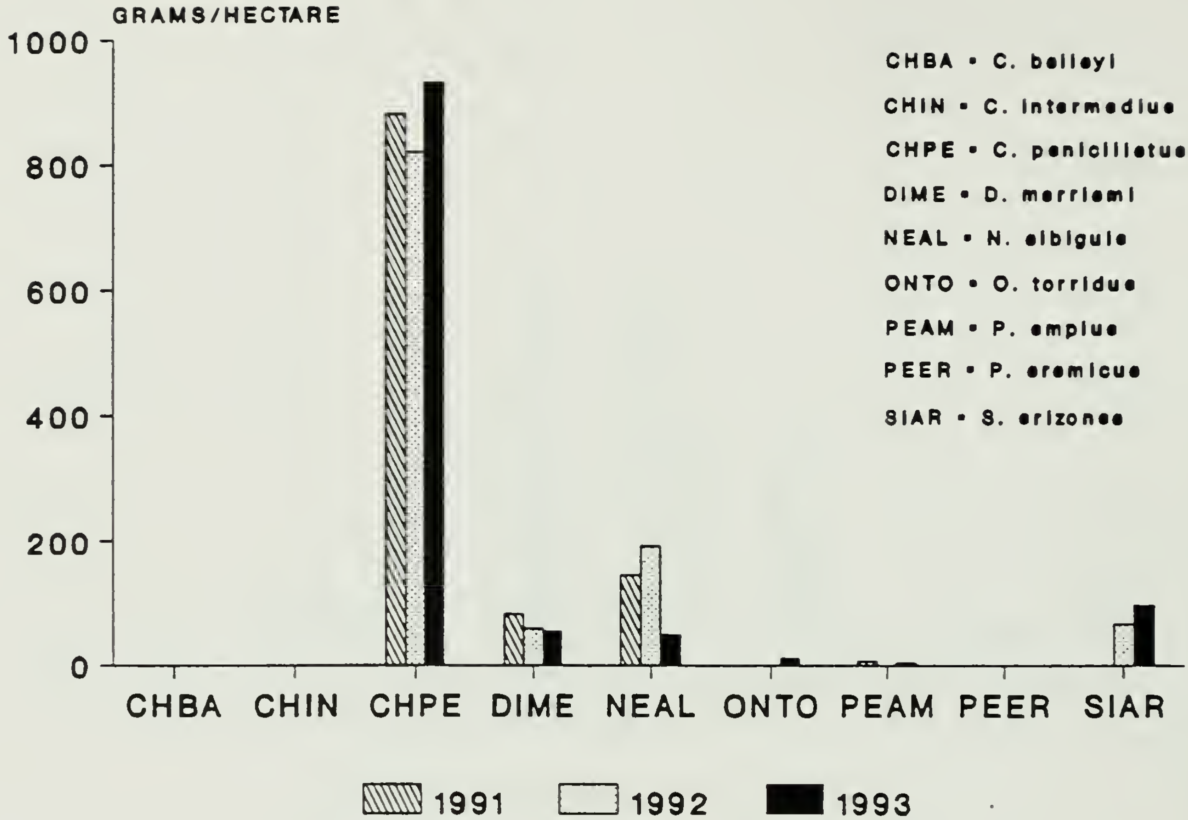
	1991	1992	1993
Total Heteromyid			
Density (n/ha)	31.0	45.5	51.0
Biomass (g/ha)	731.6	909.5	1,189.7
Total Cricetid			
Density (n/ha)	2.5	2.0	2.5
Biomass (g/ha)	182.7	133.4	107.2
Diversity (H')	1.275	0.762	0.827
Capture success (night 1)	32.7%	45.9%	69.4%
Capture success (night 2)	52.0%	71.4%	69.4%
Recapture	30.3%	29.0%	42.5%

Figure 42. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Dos Lomitas sites.



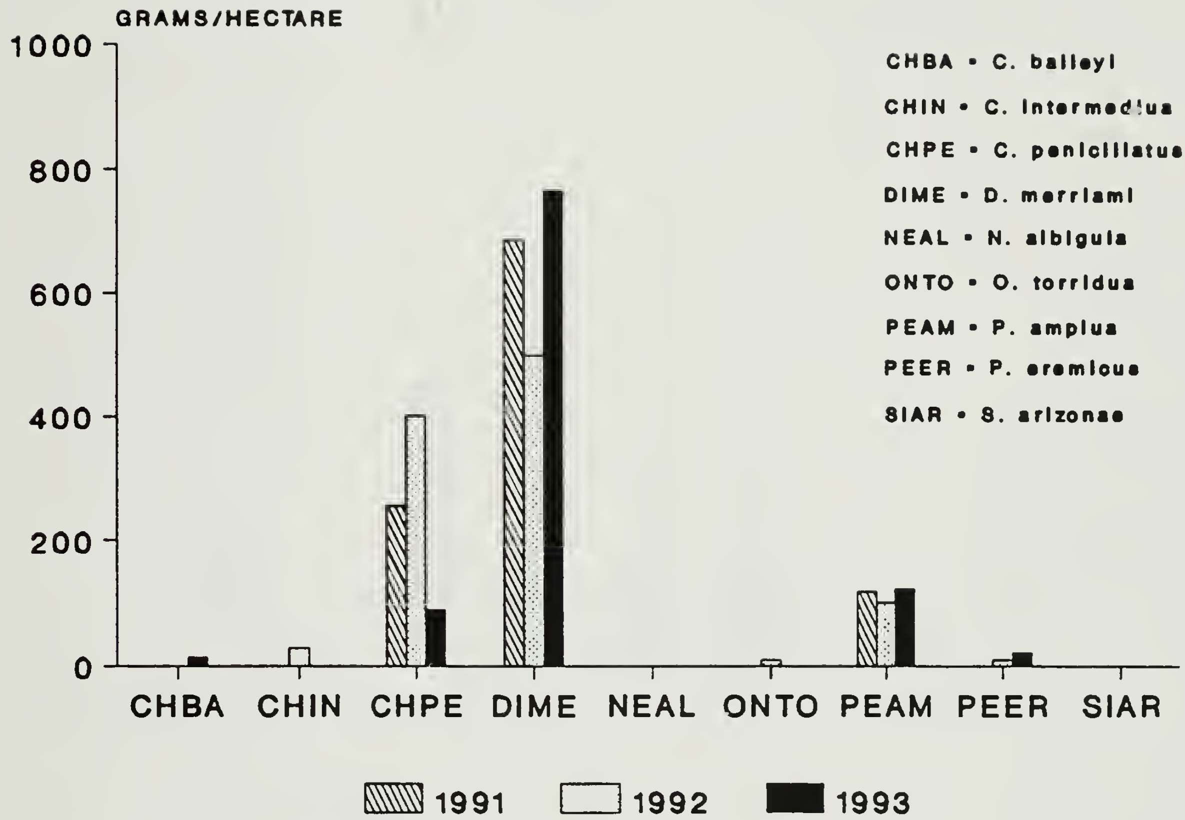
	1991	1992	1993
Total Heteromyid			
Density (n/ha)	30.0	53.5	45.0
Biomass (g/ha)	626.2	1,146.7	1,025.1
Total Cricetid			
Density (n/ha)	4.0	1.0	2.0
Biomass (g/ha)	570.5	19.9	236.5
Diversity (H')	1.309	1.080	1.231
Capture success (night 1)	42.8%	73.5%	58.2%
Capture success (night 2)	46.9%	73.5%	62.2%
Recapture	43.5%	48.6%	38.7%

Figure 43. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the East Armenta sites.



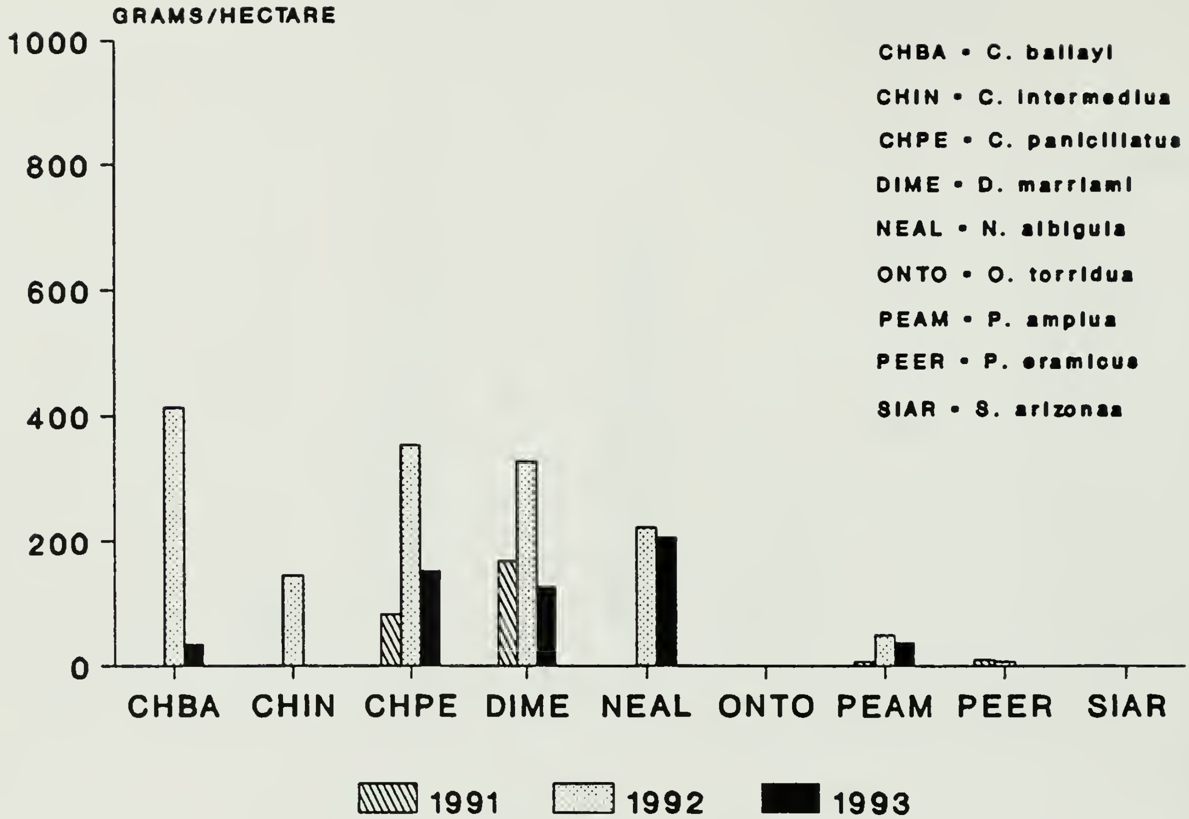
	1991	1992	1993
Total Heteromyid			
Density (n/ha)	56.0	53.0	61.5
Biomass (g/ha)	969.7	880.0	992.6
Total Cricetid			
Density (n/ha)	1.0	1.5	3.0
Biomass (g/ha)	145.4	258.6	156.5
Diversity (H')	0.317	0.269	0.410
Capture success (night 1)	62.2%	55.1%	81.6%
Capture success (night 2)	67.3%	80.6%	73.5%
Recapture	12.8%	30.5%	31.6%

Figure 44. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Growler Canyon sites.



	1991	1992	1993
Total Heteromyid			
Density (n/ha)	48.0	52.5	39.0
Biomass (g/ha)	1,060.8	1,030.0	993.6
Total Cricetid			
Density (n/ha)	0.0	1.0	1.0
Biomass (g/ha)	0.0	19.5	20.6
Diversity (H')	1.063	1.204	1.102
Capture success (night 1)	60.2%	76.5%	48.0%
Capture success (night 2)	67.3%	55.1%	58.2%
Recapture	40.3%	40.5%	42.1%

Figure 45. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Pozo Nuevo sites.



	1991	1992	1993
Total Heteromyid			
Density (n/ha)	10.0	63.5	15.5
Biomass (g/ha)	258.5	1,288.9	349.9
Total Cricetid			
Density (n/ha)	0.5	2.0	1.5
Biomass (g/ha)	9.4	228.7	206.0
Diversity (H')	1.006	1.575	1.367
Capture success (night 1)	8.2%	73.5%	17.3%
Capture success (night 2)	17.3%	86.7%	20.4%
Recapture	16.7%	30.0%	10.1%

Figure 46. Density and biomass estimates, 1991–1993, for small nocturnal mammals observed on the Senita Basin site.

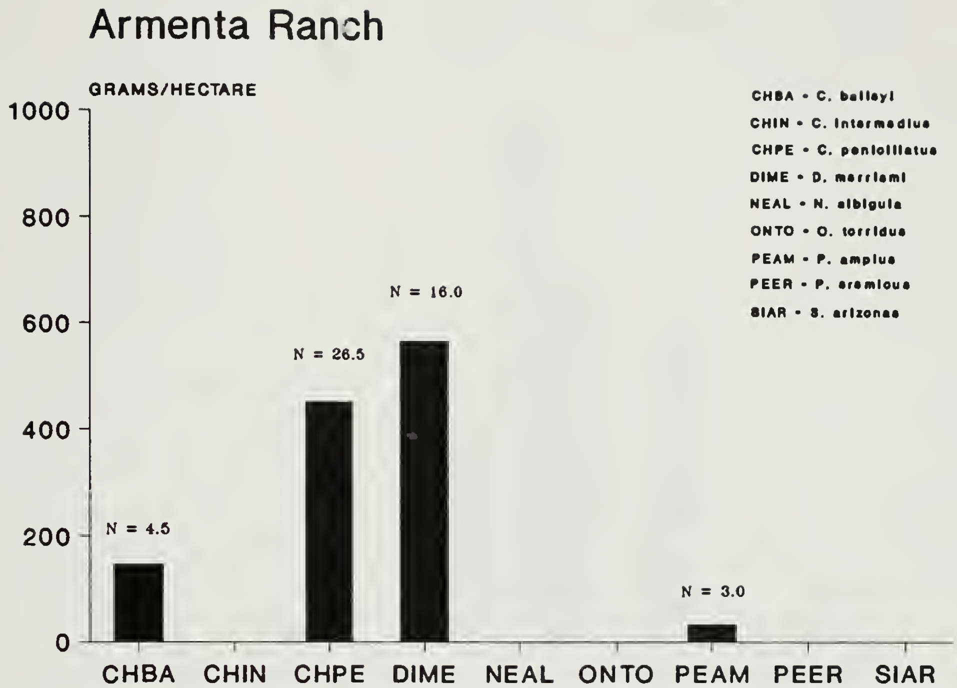


Figure 47. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Armenta Ranch site (non-core).

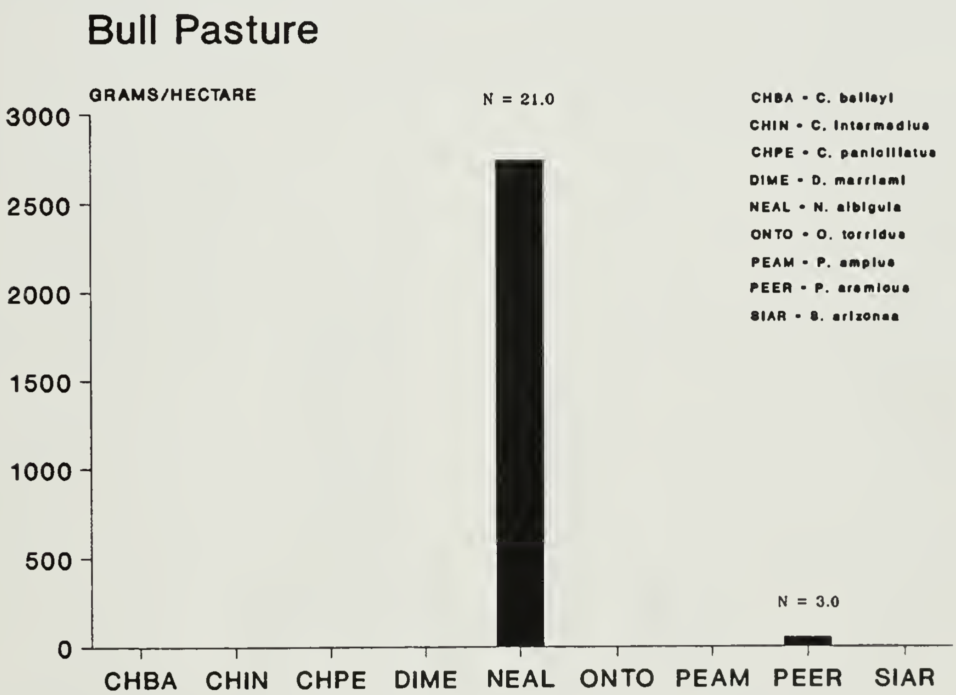


Figure 48. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Bull Pasture site (non-core).

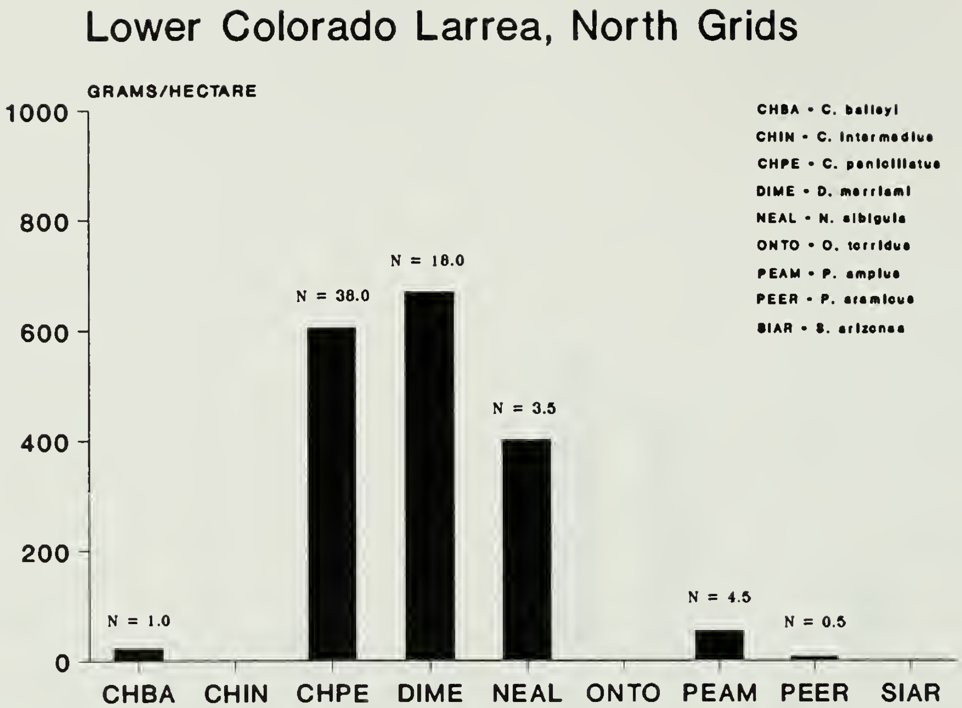


Figure 49. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Lower Colorado Larrea (North Grids) site (non-core).

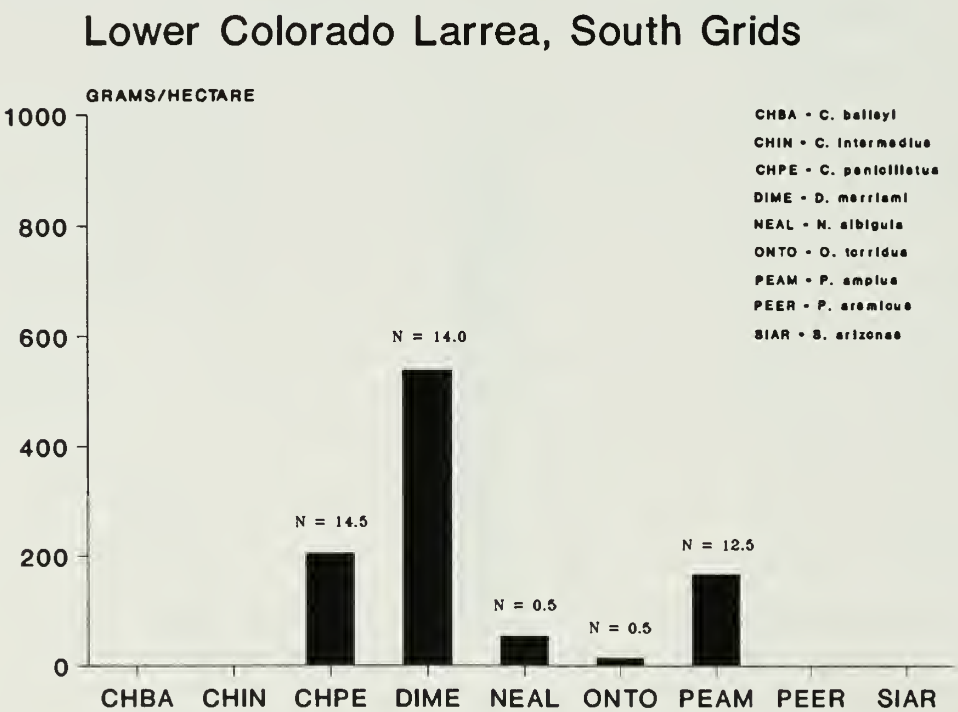


Figure 50. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Lower Colorado Larrea (South Grids) site (non-core).

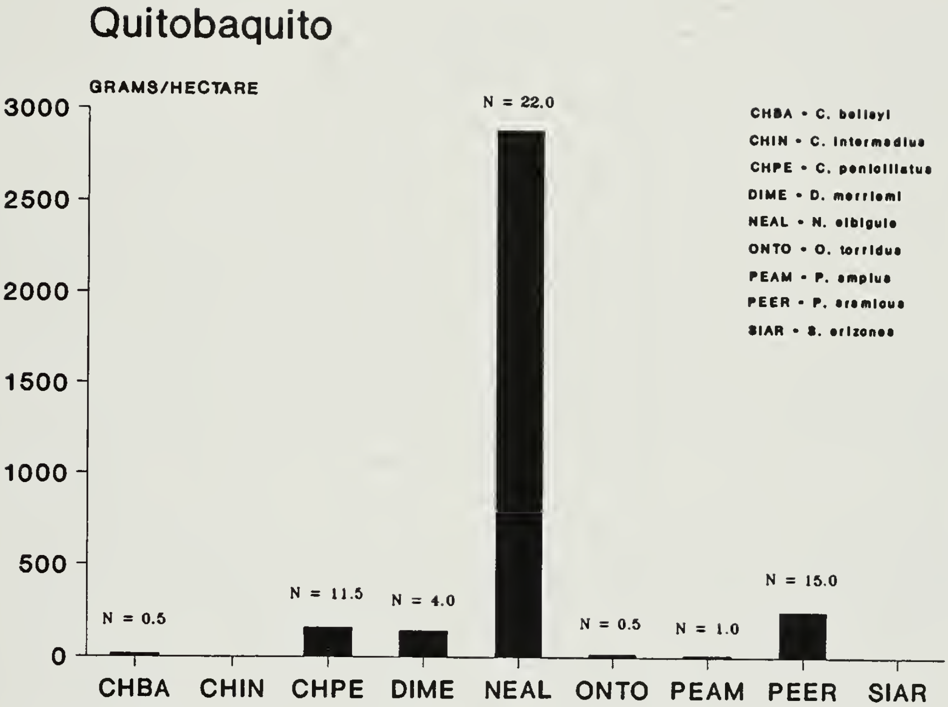


Figure 51. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Quitobaquito site (non-core).

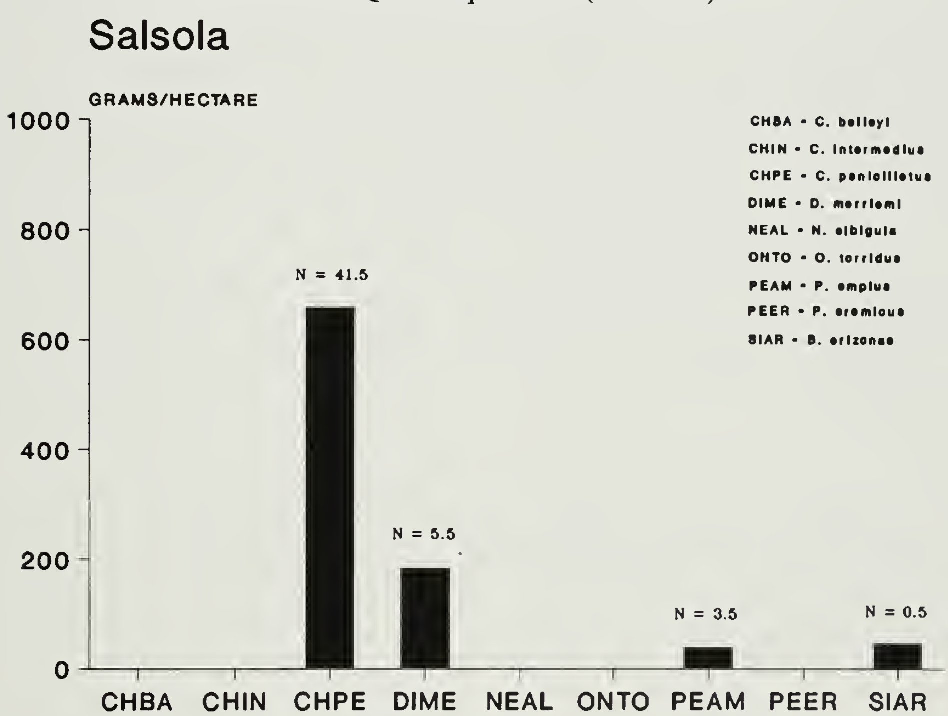


Figure 52. Density and biomass estimates, 1993, for small nocturnal mammals observed on the Salsola site (non-core).

Table 12. Results of paired-sample t-test comparing 1 trap per station to 2 traps per station in the capture of nocturnal mammals for the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona. Values in table are rodent densities. Trapping period was 2 consecutive nights. Recaptures were not counted. Ho: $\mu d \leq 0$; Ha: $\mu_d > 0$.

	All Heteromyids		All Cricetids		Merriam's kangaroo rat (*Dipodomys merriami*)		Desert pocket mouse (*Chaetodipus penicillatus*)		Arizona pocket mouse (*Perognathus amplus*)	
Site	1 trap	2 traps	1 trap	2 traps	1 trap	2 traps	1 trap	2 traps	1 trap	2 traps
Armenta Ranch	40	85	0	0	9	19	23	52	3	6
East Armenta	36	104	1	3	14	29	12	54	10	21
Pozo Nuevo	44	75	0	2	16	20	12	38	16	17
Probability ($\mu d \leq 0$)	$P \leq 0.024$		$P \leq 0.092$		$P \leq 0.047$		$P \leq 0.011$		$P \leq 0.122$	

Birds

Introduction

There are 277 species of birds known to occur, or to have occurred, within ORPI (Groschupf 1988). Of these, 63 are known to breed here. Bird studies in the monument date back to 1941, when Huey (1942) wrote an annotated checklist of 150 bird species. Other studies completed a little later reported on ecology and general habitat relationships of breeding birds within the monument (Philips and Pulich 1948; Hensley 1959). Studies focusing on the ecology and distribution of selected species or populations continued through the early 1980s (Cole and Whiteside 1965; Beck et al. 1973; Inouye et al. 1981).

It is now thought that baseline assessment and long-term monitoring of bird populations can provide a good tool for measuring ecological change over time. The research project Ecology of Special Status Avian Species, conducted by R. Roy Johnson, CPSU/UA, was initiated in 1987 to provide this kind of baseline information on bird population parameters. As a part of this investigation, monitoring protocols were designed for use by monument resource management staff.

Project History

One of the 12 original SEP research projects, Ecology of Special Status Avian Species, made baseline assessments of bird population structure, relative abundances, and species richness at the EMP study sites. In addition, this investigation attempted to examine the factors that account for variation in bird communities of specific habitats over time, and to design monitoring protocols to measure these changes. The initial research phase of the project investigated various means of sampling bird populations on the study sites. By the end of the 1987 field season, an appropriate censusing methodology, a comparable database, and an outline for future censuses had been produced. Monitoring protocols were further refined and tested by the principal investigator through the 1989 census. A preliminary project closeout meeting was held with Johnson in April 1992. A training session in monitoring methodology was provided to the resource management monitoring staff at that time.

Although the draft monitoring protocols were partially implemented and tested by resource management staff at the 7 Core I and II EMP sites in 1991, and again in 1992 during the training session with Johnson, neither of these outings are to be considered "valid" censuses, since certain monitoring protocol rules were violated. The 1993 monitoring session, however, is considered the first "valid" census, as it was conducted in full accordance with protocol requirements.

1993 Monitoring Activities

From 4 April through 29 May, birds were censused at ORPI. Monitoring staff from the Division of Natural and Cultural Resources Management conducted this activity on a total of 14 EMP study sites.

Methods

Ecology of Special Status Avian Species monitoring protocol is designed to obtain information on relative abundances of all breeding birds on EMP study sites during breeding periods (Johnson and Hiett). This is done by censusing birds within belt transects, with the belt width varying and dependent on the particular study site. Most transects are 40 m (131 ft) in width. In the narrow, thickly vegetated riparian areas (Growler Canyon, Aguajita Wash, and Alamo Canyon), transect widths are approximately 20 m (66 ft). Almost all transects are 1,000 m (3,281 ft) in length.

Censusing began at close to sunrise on all sites. Direct counts were made on all birds heard or seen within the transect while walking down the transect line. Observations on behavior, and if possible, age and sex, were recorded on the field forms. Birds occurring off the transects were recorded as well.

Three censuses (each census was considered a sample replicate) were made at each study site. According to the monitoring protocol, a minimum of 3 censuses is needed to statistically estimate data reliability. The sample replicates were spaced at approximately 3-wk intervals. One observer conducted all censuses at all sites, except for 1 census in which a new biological technician accompanied the observer. The methods followed during this monitoring period are detailed in the draft monitoring handbook (Johnson and Hiett 1992).

Special effort was made to avoid duplicating counts. Some bird species, such as the verdin (*Auriparus flaviceps*), black-tailed gnatcatcher (*Polioptila melamura*), curve-billed thrasher (*Toxostoma curvirostre*), and Lucy's warbler (*Vermivora luciae*) tend to stay in a fairly small area, thus allowing individuals to be tracked relatively easily. Those species, however, that tend to be wider-ranging—like the Gila woodpecker (*Melanerpes uropygialis*), *Myiarchus* flycatchers (*Myarchus* spp.), orioles (*Icterus* spp.), and flickers (*Colaptes* spp.)—demand that a censuser pay close attention to the movement of these birds around the study site area to minimize duplicate counts. House finches (*Carpodacus mexicanus*) and mourning doves (*Zenaida macroura*) that flocked to Dripping Springs were counted only as they departed the water pool. If there were questions as to a bird species identity, it was listed as an "unknown."

Two species of *Myiarchus* flycatchers occur in the monument: ash-throated flycatcher (*Myiarchus cinerascens*) and brown-crested flycatcher (*Myiarchus tyrannulus*). Because of similarities in physical and behavioral characteristics between the two species, identification was sometimes a problem. For this reason, sightings were lumped into *Myiarchus* spp.

All cowbird sightings were tabulated as "unknown cowbird." Although the bronzed cowbird (*Molothrus aeneus*) does occur in the monument (primarily near the south boundary, close to Mexican agricultural fields), brown-headed cowbirds (*Molothrus ater*) are probably far more abundant monument-wide.

"Unknowns" were counted as individual species in richness and diversity tabulations only if it was certain that the bird species was different from all others observed during that particular census. For example, during a census that recorded both white-winged doves (*Zenaida asiatica*) and mourning doves, a field recording of "unknown dove" would be tallied with either white-winged or mourning dove for the above tabulations, since only these two species of doves could reasonably be expected to occur on the plot.

Results

The number of birds censused on the 14 study sites over 3 replicates averaged 1,259 individuals. More than 65 different bird species were recorded. Of these, 42 are known to breed on the monument.

Gambel's quail (*Callipepla gambelii*) numbers on many sites were probably underestimated, as this species typically remains on the ground as the censuser passes. Whereas a quail covey could be quite large, many individuals likely escaped detection during counts.

Species richness, as well as diversity, was consistently higher at the study sites located in riparian areas, as may be expected (Table 13). Diversity values for Dripping Springs are highly skewed because of the flocking behavior of house finches and mourning doves. Of the 5 basic habitat types (Groschupf 1988) that are available to birds in ORPI, 4 are represented in these 14 study sites. The results from this census are organized by study site and are presented in Table 13.

Table 13. Summary of Special-status Avian Species Monitoring Program on 14 Ecological Monitoring Program study sites. Values displayed in table are mean density per census (n = 3 censuses) followed by 1 standard error.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Turkey vulture	1.0		0.3						1.3	1.0				
Cathartes aura	± 0.5		± 0.3						± 0.3	± 0.8				
Black vulture										0.3				4.7
Coragyps atratus										± 0.3				± 3.0
Black-shouldered kite												1.0		
Elanus caeruleus												± 0.5		
Red-tailed hawk									0.3					
Buteo jamaicensis									± 0.3					
Harris' hawk	0.3													
Parabuteo uncintus	± 0.3													
American kestrel	0.3					0.3								
Falco sparverius	± 0.3					± 0.3								
Unknown raptor												0.3		
												± 0.3		
Gambel's quail	15.7	0.7	5.7		0.7	7.7	1.7	4.0	8.0	2.7	0.3	1.7		3.7
Callipepla gambellii	± 7.7	± 0.5	± 2.7		± 0.5	± 5.0	± 0.3	± 1.7	± 0.5	± 1.1	± 0.3	± 0.7		± 1.0
White-winged dove	12.0	3.7	7.3	1.0	7.3	6.0	1.7	3.7	8.7	6.7	5.7	5.0	4.3	5.0
Zenaida asiatica	± 5.2	± 1.5	± 3.0	± 0.5	± 5.6	± 3.7	± 0.7	± 2.2	± 3.3	± 3.3	± 3.8	± 2.4	± 1.8	± 2.0
Mourning dove	5.7	8.3	24.7	1.0	7.7	13.0	61.7	13.3	20.3		5.7	40.3	5.7	3.7
Zenaida macroura	± 2.4	± 3.1	± 7.7	± 0.8	± 1.9	± 2.0	± 14.2	± 4.7	± 10.1		± 0.3	± 15.5	± 2.0	± 0.3
Unknown dove		0.7		0.3					0.3			0.7	1.3	
		± 0.5		± 0.3					± 0.3			± 0.5	± 0.7	

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Lesser nighthawk *Chordeiles acutipennis*			1.0 ± 0.5					0.7 ± 0.5						
Unknown swift					0.7 ± 0.5									
Unknown hummingbird	3.3 ± 1.1	15.3 ± 5.4	0.3 ± 0.3	4.0 ± 1.2			2.0 ± 0.5	0.3 ± 0.3	4.3 ± 0.3	4.0 ± 0.9			4.7 ± 1.9	1.0 ± 0.5
Gila woodpecker *Melanerpes uropygialis*	5.3 ± 1.0		0.7 ± 0.5				2.3 ± 0.3	3.3 ± 1.0	4.7 ± 0.7	4.7 ± 0.7	0.3 ± 0.3	1.3 ± 0.3	5.0 ± 1.6	6.3 ± 1.4
Ladder-backed woodpecker *Picoides scalaris*		0.3 ± 0.3		0.3 ± 0.3						0.3 ± 0.3		0.3 ± 0.3	0.3 ± 0.3	
Unknown woodpecker								0.3 ± 0.3						
Northern flicker *Colaptes auratus*	1.7 ± 0.7			0.7 ± 0.5	1.0 ± 0.5	0.7 ± 0.3		1.7 ± 1.0		0.7 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	1.0 ± 0.5	0.7 0.3
"Empidonax" flycatcher *Empidonax* spp.	0.7 ± 0.3	5.7 ± 1.9		0.3 ± 0.3			0.7 ± 0.5		1.0 ± 0.5				0.3 ± 0.3	
"Myiarchus" flycatcher *Myiarchus* spp.	6.3 ± 2.4	2.3 ± 1.0	4.0 ± 1.2	2.7 ± 1.4	1.0 ± 0.5	1.3 ± 0.5	4.3 ± 0.7	2.0 ± 0.5	4.3 ± 1.2	4.3 ± 1.0	3.0 ± 0.8	4.3 ± 0.7	5.3 ± 1.9	3.7 ± 1.9
Brown-crested flycatcher *Myiarchus tyranulus*									0.7 ± 0.5					0.7 ± 0.5
Vermilion flycatcher *Pyrocephalus rubinus*			0.7 ± 0.5									0.3 ± 0.3		

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Western Kingbird *Tyrannus verticalis*						0.3 ± 0.3						1.0 ± 0.5		
Say's phoebe *Sayornis saya*											0.3 ± 0.3			
Lark sparrow *Chondestes grammacus*					3.0 ± 2.4									
Purple martin *Progne subis*											0.3 ± 0.3			0.3 ± 0.3
Violet-green swallow *Tachycineta thalassina*	2.0 ± 1.6			0.7 ± 0.5										0.7 ± 0.3
Unknown swallow	3.7 ± 1.9					0.7 ± 0.5								
Common raven *Corvus corax*		1.3 ± 0.3			0.7 ± 0.3		1.3 ± 0.5	0.7 ± 0.3	0.3 ± 0.3			1.7 ± 1.0		0.3 ± 0.3
Verdin *Auriparus flaviceps*	8.0 ± 0.5	4.7 ± 1.0	4.0 ± 1.4		2.0 ± 0.5	1.7 ± 0.7	0.3 ± 0.3	3.0 ± 1.4	9.7 ± 1.2	4.0 ± 0.5		3.0 ± 0.8	6.0 ± 0.8	3.0 ± 0.9
Cactus wren *Campylorhynchus brunneicappillus*	1.0 ± 0.5	1.3 ± 0.5	0.7 ± 0.5	2.7 ± 1.4	0.7 ± 0.3	1.0 ± 0.5	4.0 ± 0.8	1.7 ± 1.0	0.3 ± 0.3	2.3 ± 0.3			5.0 ± 0.9	6.0 ± 1.7
Canyon wren *Catherpes mexicanus*		1.0 ± 0.5					0.7 ± 0.3			0.3 ± 0.3				
Rock wren *Salpinctes obsoletus*		1.7 ± 0.7												

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Black-tailed gnatcatcher	7.0	2.7	4.0	2.3	0.7	1.0	2.3	2.3	5.7	6.0		1.7	5.0	6.3
Polioptila macroura	± 1.2	± 1.0	± 2.9	± 0.5	± 0.3	± 0.0	± 1.0	± 0.5	± 1.5	± 2.6		± 1.0	± 0.8	± 2.7
Hermit thrush		0.7												
Catharus guttatus		± 0.5												
Northern mockingbird	9.7	0.7	5.3	1.3	2.0	2.0	0.3	1.0	5.0	0.7		1.0	0.3	
Mimus polyglottos	± 1.0	± 0.5	± 2.2	± 0.7	± 1.2	± 0.9	± 0.3	± 0.5	± 1.2	± 0.3		± 0.8	± 0.3	
Curve-billed thrasher	2.7	2.7	1.0	0.3		1.3	1.0	2.3	3.0	1.7	0.3	0.7	4.3	3.7
Toxostoma curvirostre	± 1.2	± 1.2	± 0.5	± 0.3		± 0.7	± 0.5	± 1.5	± 1.4	± 0.7	± 0.3	± 0.5	± 1.5	± 0.7
Phainopepla	24.3	28.7	7.0	7.3	7.3	2.7	2.3	5.0	35.0	12.3		5.7	2.7	22.3
Phainopepla nitens	± 8.5	± 5.2	± 2.9	± 4.4	± 1.0	± 0.5	± 1.5	± 1.4	± 14.7	± 2.3		± 3.1	± 1.8	± 11.0
Loggerhead shrike							1.0	0.3			0.3	0.3		
Lanius ludovicianus							± 0.8	± 0.3			± 0.3	± 0.3		
Bell's vireo	4.7		0.7						1.3			0.3		
Vireo bellii	± 0.5		± 0.5						± 0.5			± 0.3		
Unknown vireo?			0.3											
			± 0.3											
Yellow-rumped warbler										0.7				
Dendroica coronato										± 0.5				
Black-throated gray warbler		1.3							0.3					
Dendroica nigrescens		± 1.1							± 0.3					
Hermit warbler		1.0							0.7					
Dendroica occidentalis		± 0.8							± 0.5					

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Townsend's warbler *Dendroica townsendi*		5.3 ± 3.6	0.3 ± 0.3	0.3 ± 0.3			0.3 ± 0.3	1.7 ± 1.0	0.3 ± 0.3					
Lucy's warbler *Vermivora luciae*	6.7 ± 0.3		5.0 ± 1.4			0.3 ± 0.3		0.3 ± 0.3	5.3 ± 1.5			1.7 ± 0.7		1.0 ± 0.5
Wilson's warbler *Wilsonia pusilla*	1.0 ± 0.8	1.7 ± 1.0							1.0 ± 0.8					
Unknown warbler?	1.0 ± 0.8						0.3 ± 0.3					0.3 ± 0.3	1.7 ± 1.0	
Unknown yellow warbler?	1.0 ± 0.8								0.3 ± 0.3			0.7 ± 0.5		
Western tanager *Piranga ludoviciana*		0.7 ± 0.5												
Northern cardinal *Cardinalis cardinalis*	1.0 ± 0.5	4.3 ± 1.7							1.0 ± 0.5	1.0 ± 0.8	0.3 ± 0.3		1.0 ± 0.5	
Pyrrhuloxia *Cardinalis sinuatus*							0.3 ± 0.3		3.0 ± 1.4					
Blue grosbeak *Guiraca caerula*	0.3 ± 0.3													
Black-headed grosbeak *Pheucticus melanocephalus*		0.3 ± 0.3							0.3 ± 0.3					
Lazuli bunting *Passerina amoena*	0.7 ± 0.5	1.7 1.0							2.0 ± 1.2	1.7 ± 0.7		0.3 ± 0.3		

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Green-tail towhee *Pipilo chlorurus*		0.3 ± 0.3												
Canyon towhee *Pipilo fuscus*	0.7 ± 0.5	3.3 ± 0.5	0.7 ± 0.5	3.0 ± 0.5			1.3 ± 0.5		4.3 ± 2.0	0.7 ± 0.3			0.3 ± 0.3	0.7 ± 0.5
Rufous-crowned sparrow *Aimophila ruficeps*				1.3 ± 0.7										
Brewers sparrow *Spizella breweri*			4.0 ± 1.7		1.7 ± 1.4	2.0 ± 1.6		3.0 ± 2.4	0.3 ± 0.3	0.7 ± 0.5	1.0 ± 0.8	2.3 ± 1.9		4.0 ± 3.2
Black-throated sparrow *Amphispiza bilineata*			4.0 ± 2.2	1.3 ± 0.7				0.7 ± 0.3			3.7 ± 0.7			
White-crowned sparrow *Zonotrichia leucophrys*	2.7 ± 2.2	0.3 ± 0.3	2.3 ± 1.9		0.3 ± 0.3	2.0 ± 1.6		0.3 ± 0.3	1.0 ± 0.8	0.7 ± 0.5		0.3 ± 0.3		0.7 ± 0.5
Unknown sparrow			0.3 ± 0.3		0.7 ± 0.5	0.3 ± 0.3			0.3 ± 0.3					
Yellow-headed blackbird *Xanthocephalus xanthocephalus*						1.0 ± 0.8								
Unknown blackbird	9.7 ± 7.9					2.3 ± 1.9								
Great-tailed grackle *Quiscalus mexicanus*	2.0 ± 1.6					1.7 ± 0.7					1.0 ± 0.5	1.0 ± 0.8		
Unknown cowbird *Molothrus* spp.	8.0 ± 3.3	9.7 ± 4.1	1.7 ± 0.7		1.0 ± 0.8	2.3 ± 1.2	1.3 ± 0.7	0.3 ± 0.3	6.3 ± 2.9	4.0 ± 2.2	0.7 ± 0.5	10.7 ± 6.4	3.0 ± 2.0	3.7 ± 2.2

Table 13—continued.

Species	Aguajita Wash	Alamo Canyon	Armenta Ranch	Bull Pasture	Burn Site	Dos Lomitas	Dripping Springs	East of Armenta	Growler Valley	Lost Cabin	Pozo Nuevo	Salsola Site	Senita Basin	Vulture Site
Hooded oriole *Icterus cucullatus*	0.7 ± 0.5	2.3 ± 0.7	1.0 ± 0.5	0.3 ± 0.3				0.3 ± 0.3	5.0 ± 0.5					0.7 ± 0.5
Scott's oriole *Icterus parisorum*		1.3 ± 0.7		0.3 ± 0.3			3.0 ± 0.9	0.3 ± 0.3		0.3 ± 0.3	0.7 ± 0.5		1.7 ± 0.5	
Unknown oriole									0.3 ± 0.3					
House finch *Carpodacus mexicanus*	15.7 ± 3.9	36.0 ± 11.3	0.7 ± 0.3	5.3 ± 1.7			56.7 ± 22.9	7.0 ± 2.6	2.0 ± 1.2	13.3 ± 3.5	0.3 ± 0.3	1.7 ± 1.0	14.0 ± 3.7	8.3 ± 2.8
Lesser goldfinch *Carduelis psaltria*	8.3 ± 5.3	3.3 ± 2.0					2.3 ± 1.5		1.3 ± 0.7					
Average Species Richness Value	23.67	22.33	16.33	12.00	10.00	13.00	16.33	16.00	24.33	16.00	8.33	15.33	16.00	16.00
Average Number of Individuals	174.67	155.33	87.67	37.00	38.33	51.67	153.33	59.67	149.00	75.00	24.33	90.00	73.00	90.33
Average Diversity Value (H')	2.747	2.469	2.328	2.161	1.871	2.102	1.719	2.310	2.584	2.429	1.827	1.894	2.471	2.379

Desert Pupfish

Introduction

Quitobaquito pond and springs are located in the southwestern portion of ORPI, adjacent to the U.S./Mexico international border. An endemic subspecies of the endangered desert pupfish (*Cyprinodon macularius eremus*) inhabits the spring outflows and the pond at Quitobaquito. The water for the pond is provided by 2 springs north of the pond.

The goals of NPS are to ensure the continued survival and well being of the endangered desert pupfish, to provide shallow water habitat for young Sonoran mud turtles (*Kinosternon sonoriense longifemorale*), and to provide a varied habitat for aquatic crustaceans and microorganisms. To these ends, the pond, channel, springs, and the associated riparian and xeroriparian habitat of the area are inspected weekly. In addition, a census of the pupfish is performed each year.

There are 2 primary objectives of the annual census. The first objective is to provide information on the status of the desert pupfish population present in Quitobaquito Pond and Channel. This information includes an estimate of the population size and the distribution of size classes. The second objective is to thoroughly inspect the pond and channel for the presence of nonnative fish that may detrimentally affect the pupfish population. Accomplishment of both objectives provides a preliminary basis for the evaluation of the health of the pupfish population at Quitobaquito. Further research, monitoring, or management actions are recommended based on census results.

Project History

Pupfish Census

Pupfish census work began at Quitobaquito with research conducted by Boyd E. Kynard in 1975 and continued almost yearly through 1981. Population estimates ranged from a high of 7,294 individuals in 1975 to a low of 1,800 in 1981, with intervening years showing a range of 3,000 to 6,700 individuals. The reliability of these figures has always been in question and resulted in contract research with The University of Arizona in 1985 to determine the most suitable method for sampling this species.

Census work up to 1985 used a mark-recapture technique that identified markable (≥ 22 mm [0.86 in.] length) and submarkable (< 22 mm [0.86 in.] length) fish. Left pectoral fins were clipped on markable-size fish, which involved considerable handling of each individual. In 1985, Bill Matter assisted the park in implementing a census technique that bases the population estimates on depletion of the population from several successive trapping efforts. Fish from each trapping effort were temporarily held in a screened holding tank maintained in the pond. The total catch per "trapping run" was plotted against the accumulated catch to arrive at an estimate of the total population. This method has been of limited success in that there has not been consistent depletion, partially due to the limited number of trapping runs. Based on observations during each census, this and other methods provided estimates of the population that were too low.

Quitobaquito Habitat Project

In November 1989, a project entitled the Quitobaquito Habitat Project, developed in consultation with USFWS, was initiated. The project was designed to provide a natural-appearing shallow water habitat for desert pupfish, young Sonoran mud turtles, associated crustaceans, and microorganisms. The goal of the Quitobaquito Habitat Project was to enhance the present habitat of the desert pupfish and associated fauna, particularly the Sonoran mud turtle, and to reduce or eliminate catastrophic events such as have occurred twice in recent history, when the pond water level fell significantly enough to threaten pupfish habitat in the pond. Because of rapid vegetation growth in the open earthen ditches and pools associated with the 2 springs feeding the pond, the system designed to hold and transport water was designed to be as maintenance-free as possible.

The project consisted of constructing an open, concrete-lined stream channel from the springs to the pond, with an underground pipeline backup. The channel is the primary means of water transport from the springs to the pond. The stream channel was designed to duplicate the approximate width and depth historically used when the area was farmed, and incorporates areas of both slower and faster moving water. The use of pools, overhangs, and islands within the stream channel provide protection and necessary habitat for both desert pupfish and Sonoran mud turtles.

The project was completed in December 1989. Four full years of monitoring of the pond and channel have revealed encouraging data. Within 1 week after the channel to the pond was opened, pupfish were found at the southwest spring, indicating that they had moved up the entire length of the 213-m (700-ft) channel. As of the writing of this report, desert pupfish have now fully colonized the entire length of the new channel, and are found primarily in the shallow pools.

1993 Monitoring Activities

Weekly Inspections of Quitobaquito

The Quitobaquito area was inspected once a week throughout 1993 by monument resource management staff. Inspections involved visually inspecting the channel, the southwest and northeast springs, pond perimeter, pond outflow, trails, and the historic fig and pomegranate orchard. Emphasis on observations of desert pupfish included visually monitoring for presence along the stream channel, springs, and pond perimeter. Notes were made of habitat use, areas of concentration, and age classes. Observation for the presence of nonnative fish such as mosquitofish (*Gambusia affinis*) is also of primary importance.

Annual Quitobaquito Desert Pupfish Census

It had been decided that, beginning in 1993, there would be an additional spring census during the breeding season, so on 1–2 April 1993 and again on 14–15 September 1993, ORPI staff conducted pupfish censuses at Quitobaquito Pond and Channel under USFWS Endangered Species Subpermit PRT-676811.

Methods for the Pupfish Census

Quitobaquito Pond

Both the spring and summer 1993 censuses of Quitobaquito Pond were conducted using a total of 47 traps placed around the perimeter of the pond. The traps contained no bait, and a trapping run consisted of a 2-hr period after which the trap was emptied into an ice chest in the boat and placed back in the pond, except at the end of the day. Three runs were done each day for a total of 6 runs over the 2-dy period. The fish from each run were counted, and approximately 65 fish from each run were measured for length, to determine size distribution. The fish were then placed in 1 of 3 holding tanks situated in the water at the northwest end of the pond. Once trapped, the fish were held until the end of the census, for a total of about 28 hr for the fish trapped during the first run.

Quitobaquito Channel

The 1993 censuses of Quitobaquito Channel and Springs were done using 10 traps placed in the spring channel and 2 traps placed at the southwest spring. One run of approximately 4 hr was done each day of the census. The fish from the runs in the channel and spring were counted and released, with 15 fish being measured for length from each trap that held at least 15 fish. All fish were measured from each trap that held 15 or fewer fish. A total of 15 fish were measured from the 2 traps at the southwest spring. Fish that were trapped in the channel and springs were not held, due to the potential for harm in the transport of the fish to the holding tanks.

Results

Pupfish Census

A total of 2,305 fish was trapped in the pond in the spring of 1993. A much larger number of 4,299 fish was caught in the summer. The channel yielded similar numbers of 1,128 fish in the spring and 1,160 in the summer. As previously indicated, these numbers for the channel would be expected to include recaptures from the first day (the fish trapped the first day were released). The number of captures was not consistently declining. No nonnative fish were captured or observed in either the pond or channel.

Total mortality for the 2 dy was 12 individuals for the spring census and 34 for the summer census. This last number included 15 fish that were found dead in the holding tanks at the very end of the census when the fish were being released. This higher than usual mortality was probably due to the unusually large number of fish caught and the subsequent crowding in the tanks. Larger holding tanks will be used for the next census.

The total number of fish captured in Quitobaquito Pond during the spring census was comparable to the 2,470 captured during the 1992 summer census. The large increase of captures that occurred during the summer 1993 census came almost entirely from the first day of trapping. The one obvious difference for this census was that the runs for the first day started about an hour later than usual, with the last (and most productive) run lasting an extra hour, thus ending at about 1800. This was the result of increased set-up time due to the condition of the traps and tanks, as well as the time required to process the fish in the channel. The numbers for the channel stayed much the same as in the previous yr (1,136 fish in 1992). The vegetation in the channel seems to have grown to its maximum and is now fairly stable, although still subject to seasonal variation and maintenance by park staff. This vegetation provides cover and habitat for both fish and turtles, and is cleared minimally to maintain an open channel and unimpaired water flow. Pupfish exist in large numbers in both pond and channel habitats, even though the channel has become thickly vegetated with both aquatic and terrestrial vegetation.

Based on visual observations during the census, the fish that were caught were but a fraction of the total pupfish population in the pond and channel. There appears to be a healthy grouping of age/size classes and no nonnative fish species or other nonnative competitors were observed. All indications are that the present population of desert pupfish is in good condition.

In 1994, the spring census will be dropped due to unnecessary impact. Larger holding tanks will be used in the fall census, and a minimum of 3 people will be on hand to properly perform all of the work involved in the annual census.

Quitobaquito Inspections

The weekly inspection and maintenance of the pond and channel went without any major incidents, with the main task being frequent clearing of various parts of the channel of aquatic vegetation and root masses. This clearing was done in a gradual and minimal way so as to reduce impact while keeping the water flowing. Once again it was observed that pupfish appeared in large numbers in all parts of pools where aquatic vegetation (usually root masses) had been cleared back to the pool edges. This was true throughout the length of the channel, from the southwest spring to the channel mouth. In the future, the pools will be better maintained in a partially cleared state, while not disturbing the pool perimeters or substrate.

On 1 August 1993, a 25-cm (10-in.) catfish (*Ictalurus melas*) was caught and removed from the southwest spring by researchers conducting a census of the Sonoran mud turtle. There were no other nonnative fish found during the census, and the origin of the fish could not be determined. After consultation with the appropriate scientific and governmental authorities, it was decided to attempt to trap with hoop traps (generally used for turtles) any other catfish, and to search the pond and channel at night using high-powered flashlights. Other methods of trapping were considered, but were rejected due to potential harm to turtles. The methods used appeared to work well, although no further nonnative fish were encountered. In the future, occasional visual searches by night will be conducted, in addition to the usual weekly daytime observations.

Lesser Long-nosed Bat

Introduction

The lesser long-nosed bat (*Leptonycteris curasoae*) is a nectar, pollen, and fruit-eating bat that migrates seasonally from Mexico to southern Arizona and southwestern New Mexico. This species was declared federally endangered by USFWS in 1988, because surveys in Arizona and Mexico conducted from the 1970s to 1985 failed to reveal large numbers of this bat. A draft recovery plan has been issued by USFWS. This plan provides for the de-listing of the lesser long-nosed bat as a federally endangered species after 5 yr if maternity roosts in Arizona and Mexico show no decline in numbers.

Organ Pipe Cactus National Monument is home to one of the largest maternity colonies of lesser long-nosed bat in Arizona. Between April and November, Copper Mountain (an abandoned adit in the northeast portion of the monument) houses 10,000–20,000 female bats with young. During their stay, the bats play an important role in pollination of the agave (Family: Agavaceae), organ pipe cactus, senita cactus, and saguaro cactus (*Carnegiea gigantea*), as well as in seed dispersal. Since many aspects of lesser long-nosed bat ecology are still unknown, the monument plays an important role in the protection of a vital maternal roost, as well as with coordination of research and monitoring efforts. The principal function of the resource management staff has been to assist researchers in conducting specific lesser long-nosed bat projects and to help with census events, field observations of behavior, and remote-sensing equipment maintenance.

Project History

The Copper Mountain maternity colony was discovered in 1989. During the spring, summer and fall of 1989 through 1993, exit counts were conducted at the mine. Four methods (or combinations thereof) were used including live monitoring with dim white or red light, night-vision live viewing, night vision videotaping, and walk-through checks. In early spring and early fall, the mine was checked to see when the bats arrived and left for the season. Temperature and humidity were continually recorded at various locations within the mine at hourly intervals throughout the year, beginning in March 1990 through the present date.

An NPS funded research project was conducted in 1993 to evaluate the status of bat populations in ORPI. One component of this study was to evaluate and assess the status of the Copper Mountain lesser long-nosed bat maternity colony. The research was conducted by bat biologists Virginia and David Dalton. The Daltons were responsible for the establishment of the current environmental monitoring program, as well as past population estimates. They were also the principal investigators in the evaluation of the impacts of low-level military aircraft on the colony in 1992.

1993 Monitoring Activities

Monitoring efforts in 1993 included maintenance of a remote monitoring system to gather baseline data on roost temperature, humidity, and sound levels. Two census counts were conducted, one in July and the other in August. Additionally, guano samples were collected regularly, both during and after primary food sources were in bloom or bearing fruit.

Methods

The Copper Mountain remote sensing system is comprised of a series of temperature and humidity probes located throughout the mine tunnel and linked to a computer. Recording is continuous and data are downloaded monthly to computers located at monument headquarters.

Census counts of the maternity colony were conducted with night vision devices assisted by supplementary infrared illumination. Counts commenced at dusk and concluded when the number of bats emerging dropped significantly and/or when the number of bats returning to the mine roughly equaled the number emerging. At the end of each count, the tunnel was entered and an estimate of bats remaining in the roost was made.

Guano splatter sheets were placed in the mine tunnel and were replaced every other week. Samples were analyzed by Peter VanderWater for pollen type identification.

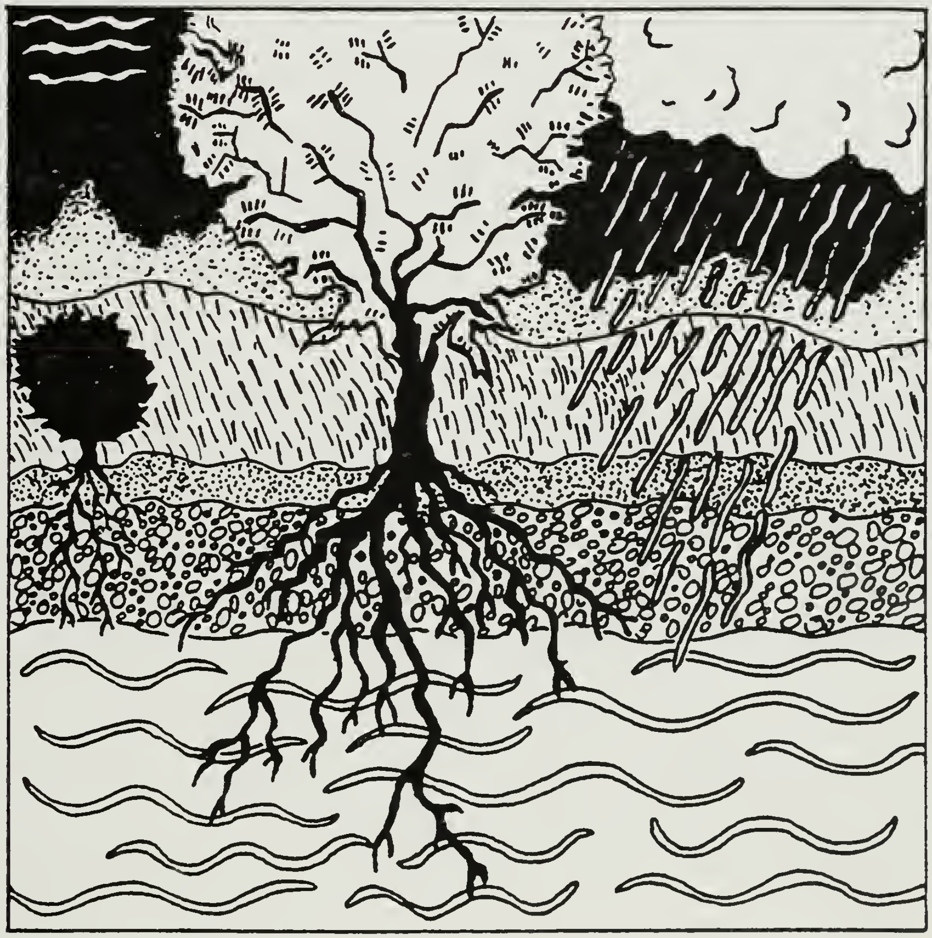
Results

Lesser long-nosed bats appear to begin arriving at Copper Mountain Mine in small numbers in mid- to late April. They do not appear to arrive simultaneously. There are only some hundreds of animals early and late in the season rather than the thousands one usually observes mid-season. A live count made on 14 May 1993 yielded 13,540 exiting bats, with 5,000 more counted inside the mine during a walk-through. Simultaneous live counts and video counts were performed later in the summer. On 16 July, the numbers counted were 12,774 (live) and 17,909 (video). On 7 August, the count was 16,235 (live) and 15,166 (video).

The environmental recording system, installed in 1990, generally performed well during 1993. Wires chewed by rodents and malfunctioning probes contributed to some lost data. The temperature rises gradually deep inside the mine, correlating with the arrival of bats for the season. Other temperatures in the main passage do not correlate with these events, rather they fluctuate directly with the ambient outside temperatures. It appears that the bats can alter the roost temperature with their own body heat by as much as 1.7–2.2° C (3.0–4.0° F) daily.

Results from the guano analysis made by VanderWater will be used in future foraging ecology studies.

Climate, Air Quality, and Land-use Trends



Climate

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 component of EMP. Organ Pipe Cactus National Monument has both automated weather stations and rain gauges in place near monitoring sites.

Project History

In 1987, work began on the installation of automated weather stations at or near 9 of the designated ecological monitoring sites. The weather stations all came "on-line" in 1988 and have been providing data ever since. Eight Forester rain gauges are also located in various locations throughout the monument. Most of these have been in use since the early 1960s, though not consistently until 1982.

1993 Monitoring Activities

Resource management division personnel serviced all 9 automated weather stations monthly in 1993. Servicing consisted of changing data storage modules, replacing batteries when necessary, and checking for damaged or malfunctioning equipment. Data were downloaded and entered into Lotus 1-2-3 spreadsheets. Rain gauges were checked at the end of each month to determine the total monthly rainfall.

Methods

The 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.
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.

All recorders record data at 1-hr intervals, except for the DP-230, which records at 2-hr intervals. A description of the data is given in Table 14. Accuracy of the sensor/recorder combinations (as advertised) is described in Table 15.

Table 14. Data provided by the datapod climate recorders used in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona.

Weather parameter	Sampling interval	Type of sample
Air temperature at 48 in. (122 in.)	10 min	Instantaneous
Air temperature at 15 cm (6 in.)	5 min	Average
Soil temperature at 10 cm (4 in.)	5 min	Average
Relative humidity at 48 in. (122 in.)	10 min	Instantaneous
Wind speed and direction	3 min	Average
Solar radiation	5 min	Average
Precipitation	Cumulative	Count

Table 15. Accuracy parameters of the sensor/recorder combinations (as advertised) for the datapod climate recorders used in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona.

Combination	Accuracy parameter
Temperature	± 0.5° C (0.3° F)
Relative humidity	± 5.0%
Wind speed	± 1.6 kph (1.0 mph)
Wind direction	± 3.0°
Solar radiation	± 5.0%
Precipitation	± 0.5% at 1.3 cm (0.5 in.) per hour ± 4.0% at 3–15 cm (1–6 in.) per hour

To maintain the accuracy of the data, it is necessary to check the sensors, which involves periodic verification of temperature and humidity, as well as calibration of the tipping bucket rain gauges. Most of these sensors have a limited life of 1–3 yr, and some will need to be replaced or recalibrated at the factory within the near future. The relative humidity sensors were all replaced at the end of 1991, with a significant improvement in accuracy, but will need to be replaced again in 1994. The solar radiation sensors are known to have deteriorated and lost accuracy, and will be replaced in 1994. The wind speed sensors are beginning to show an increased threshold of starting speed, and some of the wind direction sensors are giving intermittent erroneous readings. These will be checked again and replaced as needed. The temperature sensors are still operating well.

After data are downloaded, summary spreadsheets are created in Lotus 1-2-3. The summaries give daily means, maximums, minimums, and totals of all measured parameters at each site. Intersite comparisons give daily comparisons between all sites where a given parameter is measured. These summaries, comparisons, and the raw hourly data are available for all 9 weather stations and are stored on floppy disks in the vault of the Sonoran Desert Biosphere Reserve Center, as well as in the office of the Chief of Resources Management.

Monthly rainfall data are gathered from the Forester rain gauges by measuring the amount of pre-measured transmission fluid (which prevents evaporation of precipitation) and rain water in the bucket and subtracting the known quantity of transmission fluid. Then fresh transmission fluid is measured and placed in the bucket. Data from these rain gauges are entered into a Lotus 1-2-3 spreadsheet.

Results

Climate data were collected on schedule in 1993, although some minor technical and environmental difficulties were encountered. This is to be expected in a system that is subject to the harsh conditions of constant exposure to the elements. The wires at East Armenta were encased in a flexible metal conduit, which solved the problem of chewing by animals. The tipping bucket at Neolloydia Site broke internally when a spot weld failed. This was repaired, but not before some rain went unrecorded. The other sites had somewhat less than the usual number of failures, and the problems with rodents and/or rabbits were less troublesome than before, probably because an increasing amount of conduit has been installed at the sites.

Easily the most serious problem is still the age and wear and tear on the sensing instruments. Temperature readings continue to be quite accurate. Humidity figures are probably low by up to 5% in the middle range and as much as 15% in the low range. Wind speed and direction data are suspect at many of the sites. Solar radiation numbers are high. Rainfall data are accurate, although some question exists as to the basic design of the rain gauge in that the screen on top that keeps debris out of the small funnel may cause a significant amount of deflection of the rain, especially during a downpour. This last question needs to be resolved in light of the fact that the average rainfall for the Forester rain gauges consistently exceeds that for the tipping buckets, even with a similar site comparison.

Six different reports are available summarizing the hourly data on a daily basis, with daily maximums, minimums, means, and standard deviations. All but one of these reports are intersite comparisons for all sites where the parameters are monitored. The reports available are:

1. Site report with all parameters monitored at that site.
2. Intersite comparison of rainfall.
3. Intersite comparison of air temperature at 122 cm (48 in.).
4. Intersite comparison of freezing temperatures.
5. Intersite comparison of air temperature at 15 cm (6 in.).
6. Intersite comparison of relative humidity.

Each report covers a period of 28 dy, except at year's end. A sample of each type of report for the same period of 1–28 January 1993 is included in this report. See Figures 53–58.

DATE	TOTAL SOLAR RADIATION kWh/m^2	MAX 1 HOUR SOLAR RADIATION kWh/m^2	MEAN SOIL TEMP @ 10cm deg C	STD DEV SOIL TEMP @ 10cm deg C	MAX 1 HOUR SOIL TEMP @ 10cm deg C	MIN 1 HOUR SOIL TEMP @ 10cm deg C	MEAN WIND SPEED mph	STD DEV WIND SPEED	WIND MOVEMENT miles	MAX 1 HOUR WIND SPEED mph	WIND DIRECTION 1 hr avg @ 4:XX pm degrees	MEAN AIR TEMP @ 48" deg C	STD DEV AIR TEMP @ 48" deg C	MAX 1 HOUR AIR TEMP @ 48" deg C	MIN 1 HOUR AIR TEMP @ 48" deg C	HOURS TEMP BELOW FREEZING #	MEAN RH @ 48" %	STD DEV RH @ 48" %	MAX 1 HOUR RH @ 48" %	MIN 1 HOUR RH @ 48" %	PRECIP mm	MAX 2 HOUR PRECIP mm	MEAN AIR TEMP @ 15cm deg C	STD DEV AIR TEMP @ 15cm deg C	MAX 2 HOUR AIR TEMP @ 15cm deg C	MIN 2 HOUR AIR TEMP @ 15cm deg C	DATE
01-Jan-93	19.3	3.5	11.3	2.19	15.0	8.5	0.7	1.10	17.6	3.3	208	11.6	4.18	18.5	6.5	0	79.5	13.29	92.0	57.0	0	0	11.5	4.86	19.5	5.0	01-Jan-93
02-Jan-93	10.5	2.2	10.9	1.33	13.0	9.0	1.3	1.43	30.8	4.5	191	12.1	3.02	17.5	6.5	0	73.1	14.31	90.0	45.0	0	0	11.7	3.62	17.0	6.0	02-Jan-93
03-Jan-93	18.6	3.6	11.1	1.59	14.0	8.0	1.6	1.64	37.8	5.5	253	8.5	3.00	12.0	1.5	0	65.5	22.68	91.0	34.0	4	3	8.9	3.62	13.5	1.0	03-Jan-93
04-Jan-93	16.9	3.2	8.1	2.30	11.5	5.0	1.3	1.01	31.6	3.0	281	7.7	4.00	14.0	1.0	0	51.4	13.34	86.0	35.0	0	0	7.8	4.58	15.0	1.5	04-Jan-93
05-Jan-93	12.2	2.4	9.7	1.67	12.0	7.5	0.7	0.78	16.6	2.8	118	10.1	3.02	15.0	5.0	0	71.3	12.99	90.0	52.0	0	0	10.1	3.32	15.0	5.5	05-Jan-93
06-Jan-93	3.5	1.0	11.6	1.02	13.0	10.5	2.0	1.20	47.2	4.2	112	13.1	1.44	15.0	10.5	0	88.9	1.61	92.0	83.0	19	7	13.0	1.41	15.0	11.0	06-Jan-93
07-Jan-93	2.6	0.7	13.0	0.44	13.5	12.5	2.9	1.52	20.4	6.3	118	14.8	0.47	15.5	14.0	0	88.8	0.41	89.0	88.0	4	2	14.8	0.48	15.5	14.0	07-Jan-93
08-Jan-93	17.6	3.2	13.7	1.14	16.0	12.0	3.6	2.71	86.0	7.9	236	13.6	3.14	17.0	8.0	0	77.4	16.13	91.0	43.0	9	6	14.0	3.18	17.5	8.0	08-Jan-93
09-Jan-93	17.8	3.3	12.2	1.58	15.0	10.0	0.7	1.02	17.0	3.8	140	11.8	2.95	16.5	7.0	0	77.0	14.33	92.0	50.0	0	0	11.9	3.37	17.0	7.0	09-Jan-93
10-Jan-93	1.8	0.6	11.7	0.54	12.5	11.0	4.1	2.28	97.3	9.4	135	11.9	1.47	14.0	9.5	0	89.2	3.14	92.0	82.0	17	6	12.0	1.33	13.5	10.0	10-Jan-93
11-Jan-93	17.5	3.5	13.1	1.40	16.0	11.5	1.0	0.84	24.1	2.8	196	13.0	2.52	17.5	8.5	0	80.9	10.99	91.0	56.0	0	0	13.4	2.67	18.0	8.5	11-Jan-93
12-Jan-93	15.7	3.3	11.7	1.80	14.5	9.0	0.4	0.60	10.7	2.4	101	11.8	2.58	16.5	8.0	0	72.2	11.52	91.0	56.0	0	0	12.0	3.04	16.5	8.0	12-Jan-93
13-Jan-93	8.6	1.8	13.0	1.04	15.0	12.0	0.6	0.21	14.4	2.5	140	13.7	1.88	18.0	11.5	0	88.0	5.18	92.0	28.0	16	9	13.3	1.80	17.0	11.0	13-Jan-93
14-Jan-93	13.4	2.4	12.9	1.34	15.5	11.0	0.5	0.52	12.2	1.5	123	13.6	2.09	12.5	10.5	0	82.5	6.54	90.0	68.0	0	0	13.5	2.30	17.5	10.5	14-Jan-93
Mean	12.6	2.5	11.2		14.0	9.8	1.5		36.2	4.3		12.0		16.0	7.2		72.9		91.0	59.1			12.0		16.3	7.6	Mean
Maximum	19.3	3.6	13.7		16.0		4.1		97.3	9.4		14.8		18.5			89.2		97.0		19	9	14.8		19.5		Maximum
Minimum			8.1			5.0	0.4		10.7			7.7			1.0		51.4			34.0			7.8			1.0	Minimum
Total						\			513.7							0					69						Total

DATE	TOTAL SOLAR RADIATION kWh/m^2	MAX 1 HOUR SOLAR RADIATION kWh/m^2	MEAN SOIL TEMP @ 10cm deg C	STD DEV SOIL TEMP @ 10cm deg C	MAX 1 HOUR SOIL TEMP @ 10cm deg C	MIN 1 HOUR SOIL TEMP @ 70cm deg C	MEAN WIND SPEED mph	STD DEV WIND SPEED	WIND MOVEMENT miles	MAX 1 HOUR WIND SPEED mph	WIND DIRECTION 1 hr avg @ 4:XX pm degrees	MEAN AIR TEMP @ 48" deg C	STD DEV AIR TEMP @ 48" deg C	MAX 1 HOUR AIR TEMP @ 48" deg C	MIN 1 HOUR AIR TEMP @ 48" deg C	HOURS TEMP BELOW FREEZING #	MEAN RH @ 48" %	STD DEV RH @ 48" %	MAX 1 HOUR RH @ 48" %	MIN 1 HOUR RH @ 48" %	PRECIP mm	MAX 2 HOUR PRECIP mm	MEAN AIR TEMP @ 15cm deg C	STD DEV AIR TEMP @ 15cm deg C	MAX 2 HOUR AIR TEMP @ 15cm deg C	MIN 2 HOUR AIR TEMP @ 15cm deg C	DATE
15-Jan-93	9.6	2.1	12.9	1.27	15.0	11.5	0.4	0.44	8.8	1.5	151	13.9	1.95	18.0	11.5	0	82.3	5.62	89.0	20.0	0	0	13.8	2.27	18.0	11.0	15-Jan-93
16-Jan-93	17.4	3.5	14.3	1.69	17.0	12.0	1.3	0.91	30.2	2.9	140	15.6	2.55	20.0	11.5	0	79.3	9.53	90.0	63.0	1	1	15.7	2.91	20.5	11.5	16-Jan-93
17-Jan-93	5.9	1.3	14.4	0.46	15.5	14.0	2.4	1.44	57.1	5.2	151	15.5	0.92	17.5	14.5	0	86.2	1.72	88.0	82.0	0	0	15.5	0.89	17.0	14.5	17-Jan-93
18-Jan-93	14.3	3.6	14.0	0.93	16.0	12.5	2.6	2.90	63.0	9.3	185	13.3	2.30	17.5	9.5	0	85.3	6.05	90.0	67.0	5	3	13.8	2.19	18.0	10.0	18-Jan-93
19-Jan-93	21.8	3.8	13.0	2.03	16.5	10.5	0.6	0.69	13.2	2.9	208	11.7	3.07	16.5	7.0	0	78.1	12.49	91.0	56.0	0	0	12.0	3.50	17.5	8.0	19-Jan-93
20-Jan-93	21.9	3.6	12.3	2.23	16.0	9.5	0.9	0.75	21.1	3.0	264	12.0	3.71	18.0	7.0	0	71.9	14.31	91.0	47.0	0	0	12.3	4.00	19.0	7.5	20-Jan-93
21-Jan-93	22.8	3.8	12.2	2.42	16.0	9.0	1.3	1.33	31.3	4.6	292	12.3	4.79	19.0	4.5	0	66.8	17.80	92.0	40.0	0	0	12.3	5.43	20.0	4.5	21-Jan-93
22-Jan-93	22.6	3.5	12.5	2.48	16.5	9.5	1.1	1.20	27.1	4.2	230	13.8	5.10	23.5	6.5	0	70.0	18.37	91.0	35.0	0	0	13.7	5.76	23.0	6.0	22-Jan-93
23-Jan-93	23.9	3.9	12.9	2.24	17.0	10.0	2.1	1.44	51.1	4.8	286	13.6	3.25	19.5	9.5	0	52.0	19.08	87.0	32.0	0	0	13.7	3.94	20.5	9.0	23-Jan-93
24-Jan-93	23.6	3.8	12.2	2.58	16.5	8.5	1.3	1.07	31.2	3.7	303	12.5	5.60	20.5	2.5	0	45.8	20.30	89.0	27.0	0	0	12.4	6.33	22.0	2.0	24-Jan-93
25-Jan-93	23.0	3.9	12.9	2.42	17.0	10.0	2.5	1.50	61.0	4.5	348	14.8	4.47	21.5	6.0	0	25.3	16.03	67.0	10.0	0	0	15.0	4.78	22.5	5.5	25-Jan-93
26-Jan-93	15.4	2.5	11.9	1.78	15.0	9.0	0.5	0.76	11.4	2.9	230	12.4	4.84	20.0	3.5	0	49.5	18.64	81.0	26.0	0	0	11.8	5.43	20.5	2.5	26-Jan-93
27-Jan-93	13.5	3.8	13.0	2.09	16.0	10.5	0.8	1.10	18.4	4.0	185	14.1	4.52	22.5	8.0	0	58.8	19.44	84.0	33.0	0	0	13.9	5.02	23.0	7.5	27-Jan-93
28-Jan-93	24.0	3.9	14.5	2.32	18.5	11.5	0.7	0.98	16.7	2.8	180	13.5	4.76	20.5	7.0	0	71.3	19.10	92.0	43.0	0	0	13.9	5.31	27.0	7.5	28-Jan-93
Mean	18.6	3.4	13.1		16.3	10.6	1.3		31.5	4.0		13.5		19.6	7.8		66.3		87.3	45.1			13.6		20.3	7.6	Mean
Maximum	24.0	3.9	14.5		18.5		2.6		63.0	9.3		15.6		23.5			86.2		92.0		5	3	15.7		23.0		Maximum
Minimum			11.9			8.5	0.4		8.8			11.7			2.5		25.3			10.0			11.8			2.0	Minimum
Total									441.6							0					6						Total

Data File: S8_93_01

Figure 53. Sample automated weather station report, 1–28 January 1993, for the Senita Basin site in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona.

RAINFALL SITE COMPARISON REPORTING PERIODS 1 & 2, 1993

	Armenta East		Aguajita Wash		Bull Pasture		Bates Well		Gachado Well		Headquarters		Neolloydia		Senita Basin		Salsola		
	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	
01/01/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/01/93
01/02/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/02/93
01/03/93	4	3	2	2	5	4	3	2	4	3	5	4	2	2	4	3	5	3	01/03/93
01/04/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/04/93
01/05/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/05/93
01/06/93	13	6	16	7	35	13	12	7	10	5	20	9	17	9	19	7	12	8	01/06/93
01/07/93	20	8	3	2	22	7	14	8	3	2	5	2	7	3	4	2	7	3	01/07/93
01/08/93	5	5	8	5	33	30	8	7	6	3	15	14	13	9	9	6	8	4	01/08/93
01/09/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/09/93
01/10/93	21	8	9	3	60	11	18	4	13	3	28	8	27	8	17	6	13	3	01/10/93
01/11/93	3	1	3	1	3	2	0	0	8	6	4	4	8	5	0	0	1	1	01/11/93
01/12/93	1	1	0	0	2	1	1	1	0	0	0	0	1	1	0	0	0	0	01/12/93
01/13/93	4	2	6	3	22	10	6	3	21	7	18	10	5	3	16	9	17	5	01/13/93
01/14/93	0	0	3	3	0	0	0	0	0	0	1	1	0	0	0	0	1	1	01/14/93
Maximum	21	8	16	7	60	30	18	8	21	7	28	14	27	9	19	9	17	8	Maximum
Total	71		50		182		62		65		96		80		69		64		Total

	Armenta East		Aguajita Wash		Bull Pasture		Bates Well		Gachado Well		Headquarters		Neolloydia		Senita Basin		Salsola		
	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	PRECIP mm	MAX 2 HOUR PRECIP mm	
01/15/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/15/93
01/16/93	0	0	1	1	2	1	0	0	5	3	1	1	1	1	1	1	8	7	01/16/93
01/17/93	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	01/17/93
01/18/93	3	2	2	1	17	7	0	0	9	4	13	3	2	1	5	3	4	2	01/18/93
01/19/93	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	01/19/93
01/20/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/20/93
01/21/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/21/93
01/22/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/22/93
01/23/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/23/93
01/24/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/24/93
01/25/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/25/93
01/26/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/26/93
01/27/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/27/93
01/28/93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01/28/93
Maximum	3	2	2	1	17	7	0	0	9	4	13	3	2	1	5	3	9	7	Maximum
Total	3		3		21		0		14		15		3		6		12		Total

Figure 54. Sample intersite rainfall comparison report, 1–28 January 1993, for weather-monitored sites in the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona.

AIR TEMPERATURE AT 48 INCHES, SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East Air Temperature at 48 inches degrees C			Aguajita Wash Air Temperature at 48 inches degrees C			Bull Pasture Air Temperature at 48 inches degrees C			Bates Well Air Temperature at 48 inches degrees C			Gachado Well Air Temperature at 48 inches degrees C			Headquarters Air Temperature at 48 inches degrees C			Senita Basin Air Temperature at 48 inches degrees C			Salsola Air Temperature at 48 inches degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	10	19	3	13	24	4	16	20	15	11	18	6	10	21	3	11	20	3	12	19	7	10	21	4	01/01/93
01/02/93	11	16	4	13	23	5	16	17	15	11	17	7	11	20	3	11	18	5	12	18	7	11	19	3	01/02/93
01/03/93	7	12	-2	11	19	2	13	16	11	7	12	-1	9	14	0	9	12	4	8	12	2	8	14	-2	01/03/93
01/04/93	6	14	-3	8	17	-2	14	17	12	5	12	-2	6	15	-3	7	15	-3	8	14	1	5	14	-4	01/04/93
01/05/93	10	15	4	14	21	7	14	16	13	10	16	5	10	17	5	10	16	5	10	15	5	10	16	4	01/05/93
01/06/93	13	16	10	17	20	15	16	19	14	14	16	11	13	17	11	13	15	10	13	15	11	13	16	10	01/06/93
01/07/93	15	16	14	20	24	18	20	21	19	16	17	15	16	18	14	15	16	14	15	16	14	15	17	14	01/07/93
01/08/93	13	16	7	19	25	10	20	22	16	14	18	7	15	19	9	15	18	10	14	17	8	14	18	9	01/08/93
01/09/93	11	16	6	15	22	8	16	18	15	12	18	6	12	18	7	12	17	6	12	17	7	12	18	7	01/09/93
01/10/93	12	14	10	16	19	14	17	20	15	13	15	11	12	16	10	12	15	10	12	14	10	12	15	10	01/10/93
01/11/93	12	16	6	17	21	10	19	21	16	12	17	7	13	18	7	14	18	8	13	18	9	13	18	7	01/11/93
01/12/93	10	17	3	15	22	7	16	19	15	12	18	6	11	18	6	11	17	5	12	17	8	11	17	5	01/12/93
01/13/93	13	17	10	18	25	12	18	19	16	14	19	12	13	18	9	13	18	10	14	18	12	13	19	10	01/13/93
01/14/93	12	16	9	17	23	12	19	20	17	14	18	11	13	19	9	14	19	10	14	18	11	13	18	10	01/14/93
Mean	11	16	6	15	22	8	17	19	15	12	16	7	12	17	6	12	16	7	12	16	8	11	17	6	Mean
Maximum	15	19		20	25		20	22		16	19		16	21		15	20		15	19		15	21		Maximum
Minimum	6		-3	8		-2	13		11	5		-2	6		-3	7		-3	8		1	5		-4	Minimum

	Armenta East Air Temperature at 48 inches degrees C			Aguajita Wash Air Temperature at 48 inches degrees C			Bull Pasture Air Temperature at 48 inches degrees C			Bates Well Air Temperature at 48 inches degrees C			Gachado Well Air Temperature at 48 inches degrees C			Headquarters Air Temperature at 48 inches degrees C			Senita Basin Air Temperature at 48 inches degrees C			Salsola Air Temperature at 48 inches degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	13	19	9	19	37	13	18	19	17	14	20	11	13	20	9	14	19	10	14	18	12	13	19	8	01/15/93
01/16/93	15	20	11	19	25	15	18	20	16	16	21	12	16	22	11	16	21	11	16	20	12	15	20	11	01/16/93
01/17/93	15	18	15	20	22	18	19	20	18	17	19	16	16	19	15	16	18	15	15	18	15	16	18	15	01/17/93
01/18/93	13	17	9	17	22	14	19	21	18	14	19	8	14	18	10	14	18	9	13	18	10	14	18	10	01/18/93
01/19/93	11	16	7	14	20	9	19	22	18	12	17	7	11	18	6	12	18	8	12	17	7	11	17	5	01/19/93
01/20/93	10	19	4	13	21	5	19	22	18	11	18	6	11	21	3	11	19	4	12	18	7	10	19	3	01/20/93
01/21/93	11	19	5	15	22	7	19	22	18	12	21	7	12	21	3	13	20	7	12	19	5	11	22	2	01/21/93
01/22/93	12	23	6	15	25	6	20	24	18	13	23	7	13	25	6	14	23	4	14	24	7	12	24	4	01/22/93
01/23/93	11	18	6	15	23	7	19	22	17	12	20	6	12	21	6	13	19	10	14	20	10	11	22	3	01/23/93
01/24/93	11	19	5	14	23	6	16	20	13	9	20	-1	12	23	-1	13	20	8	13	21	3	10	23	-1	01/24/93
01/25/93	12	21	5	17	25	10	14	17	10	13	22	2	15	24	6	15	23	9	15	22	6	16	21	9	01/25/93
01/26/93	13	21	5	14	22	7	16	19	14	11	21	4	10	20	4	11	20	3	12	20	4	10	19	5	01/26/93
01/27/93	13	22	7	16	25	8	14	18	13	14	24	10	13	23	7	13	22	7	14	23	8	13	22	7	01/27/93
01/28/93	14	22	8	16	24	9	13	19	10	14	22	9	14	23	7	14	22	8	13	21	7	14	22	7	01/28/93
Mean	13	19	7	16	24	9	17	20	15	13	20	7	13	21	6	13	20	8	14	20	8	13	20	6	Mean
Maximum	15	23		20	37		20	24		17	24		16	25		16	23		16	24		16	24		Maximum
Minimum	10		4	13		5	13		10	9		-1	10		-1	11		3	12		3	10		-1	Minimum

Figure 55. Sample intersite air temperature (at 122 cm [48 in.]) comparison report, 1–28 January 1993, for weather-monitored sites in the Ecological Monitoring Program at Organ Pipe Cactus National Monument.

ORGAN PIPE CACTUS NATIONAL MONUMENT — 1993 FREEZING TEMPERATURES BY SITE	Armenta East # of Hours < 0	Min Temp deg C	degree hours	Aguajita Wash # of Hours < 0	Min Temp deg C	degree hours	Bull Pasture # of Hours < 0	Min Temp deg C	degree hours	Bates Well # of Hours < 0	Min Temp deg C	degree hours	Gachado Well # of Hours < 0	Min Temp deg C	degree hours	Headquarters # of Hours < 0	Min Temp deg C	degree hours	Senita Basin # of Hours < 0	Min Temp deg C	degree hours	Salsola # of Hours < 0	Min Temp deg C	degree hours
12/31 noon to 01/01 noon	0	3	0	0	4	0	0	10	0	0	5.5	0	0	3	0	0	3	0	0	6.5	0	0	3	0
01/01 noon to 01/02 noon	0	4	0	0	4.5	0	0	14	0	0	6.5	0	0	3	0	0	5	0	0	6.5	0	0	3	0
01/02 noon to 01/03 noon	0	7	0	0	9.5	0	0	12	0	0	8	0	0	8.5	0	0	7.5	0	0	8	0	0	8.5	0
01/03 noon to 01/04 noon	9	-3	17	5	-2	6	0	11	0	8	-1	4	7	-2	11	2	-2	3	0	1	0	11	-3	23
01/04 noon to 01/05 noon	0	4	0	0	7	0	0	12	0	0	5	0	0	4.5	0	0	4.5	0	0	5	0	0	3.5	0
01/05 noon to 01/06 noon	0	10	0	0	14	0	0	14	0	0	10	0	0	10	0	0	10	0	0	10	0	0	10	0
01/06 noon to 01/07 noon	0	13	0	0	17	0	0	15	0	0	14	0	0	12	0	0	13	0	0	13	0	0	13	0
01/07 noon to 01/08 noon	0	14	0	0	20	0	0	20	0	0	15	0	0	15	0	0	14	0	0	14	0	0	14	0
01/08 noon to 01/09 noon	0	5.5	0	0	7.5	0	0	14	0	0	6	0	0	6.5	0	0	5.5	0	0	7	0	0	7	0
01/09 noon to 01/10 noon	0	9.5	0	0	13	0	0	14	0	0	11	0	0	10	0	0	9.5	0	0	9.5	0	0	9.5	0
01/10 noon to 01/11 noon	0	10	0	0	13	0	0	16	0	0	11	0	0	12	0	0	11	0	0	11	0	0	11	0
01/11 noon to 01/12 noon	0	3	0	0	7	0	0	15	0	0	6	0	0	5.5	0	0	5	0	0	8	0	0	5	0
01/12 noon to 01/13 noon	0	10	0	0	15	0	0	15	0	0	11	0	0	12	0	0	11	0	0	11	0	0	11	0
01/13 noon to 01/14 noon	0	9	0	0	12	0	0	18	0	0	12	0	0	9	0	0	9.5	0	0	11	0	0	10	0
MAX	9		17	5		6	0		0	8		4	7		11	2		3	0		0	11		23
MIN		-3			-2			10			-1			-2			-2			1			-3	
TOTAL	9		17	5		6	0		0	8		4	7		11	2		3	0		0	11		23

	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours	# of Hours < 0	Min Temp deg C	degree hours
01/14 noon to 01/15 noon	0	8.5	0	0	12	0	0	16	0	0	10	0	0	8.5	0	0	9.5	0	0	10	0	0	8	0
01/15 noon to 01/16 noon	0	11	0	0	14	0	0	16	0	0	11	0	0	11	0	0	11	0	0	11	0	0	11	0
01/16 noon to 01/17 noon	0	14	0	0	18	0	0	17	0	0	15	0	0	14	0	0	14	0	0	14	0	0	14	0
01/17 noon to 01/18 noon	0	13	0	0	17	0	0	19	0	0	14	0	0	14	0	0	13	0	0	14	0	0	14	0
01/18 noon to 01/19 noon	0	8	0	0	9	0	0	18	0	0	8	0	0	6.5	0	0	7.5	0	0	7	0	0	5.5	0
01/19 noon to 01/20 noon	0	3.5	0	0	5	0	0	17	0	0	6	0	0	2.5	0	0	4	0	0	7.5	0	0	3	0
01/20 noon to 01/21 noon	0	4.5	0	0	7	0	0	18	0	0	0	0	0	3	0	0	6.5	0	0	4.5	0	0	2	0
01/21 noon to 01/22 noon	0	5.5	0	0	5.5	0	0	17	0	0	7	0	0	5.5	0	0	4	0	0	6.5	0	0	3.5	0
01/22 noon to 01/23 noon	0	5.5	0	0	7	0	0	18	0	0	6.5	0	0	5.5	0	0	9.5	0	0	9.5	0	0	3	0
01/23 noon to 01/24 noon	0	4.5	0	0	6	0	0	15	0	1	0	0	1	-1	1	0	7.5	0	0	2.5	0	2	0	0
01/24 noon to 01/25 noon	0	5	0	0	9.5	0	0	10	0	0	2	0	0	9	0	0	9.5	0	0	11	0	0	5.5	0
01/25 noon to 01/26 noon	0	5	0	0	7	0	0	14	0	0	3.5	0	0	3.5	0	0	3	0	0	3.5	0	0	4.5	0
01/26 noon to 01/27 noon	0	6.5	0	0	8	0	0	12	0	0	9.5	0	0	7	0	0	7	0	0	8	0	0	7	0
01/27 noon to 01/28 noon	0	8	0	0	9	0	0	10	0	0	8.5	0	0	8	0	0	8	0	0	9	0	0	8	0
MAX	0		0	0		0	0		0	1		0	1		1	0		0	0		0	2		0
MIN		3.5			5			10			0			-1			3			2.5			0	
TOTAL	0		0	0		0	0		0	1		0	1		1	0		0	0		0	2		0

Figure 56. Sample intersite freezing temperatures comparison report, 1–28 January 1993, for weather-monitored sites in the Ecological Monitoring Program at Organ Pipe Cactus National Monument.

AIR TEMPERATURE AT 15 CENTIMETERS, SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Neolloydia			Senita Basin			Salsola			
	Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	10	19	2	10	19	3	12	18	8	11	19	4	10	20	3	11	19	4	11	19	6	12	20	5	10	20	3	01/01/93
01/02/93	10	16	3	10	17	3	11	14	8	11	17	6	10	18	2	11	17	5	12	16	6	12	17	6	11	18	4	01/02/93
01/03/93	6	12	-4	8	13	1	5	9	-1	7	13	-2	8	14	-2	9	12	4	8	14	2	9	14	1	8	13	-3	01/03/93
01/04/93	6	14	-5	5	13	-4	7	11	4	5	12	-3	5	15	-4	7	14	-2	7	13	2	8	15	2	5	14	-4	01/04/93
01/05/93	10	15	4	10	16	5	9	12	6	11	16	6	10	15	5	10	15	5	10	15	6	10	15	6	10	16	5	01/05/93
01/06/93	13	15	10	13	15	11	11	13	9	14	16	11	13	16	11	13	15	11	13	15	11	13	15	11	13	16	11	01/06/93
01/07/93	15	16	14	15	16	14	13	13	12	16	17	15	15	17	13	15	16	14	15	15	14	15	16	14	15	17	14	01/07/93
01/08/93	13	16	6	14	18	8	11	13	8	14	18	8	15	18	9	14	17	10	13	18	8	14	18	8	14	18	10	01/08/93
01/09/93	11	16	5	12	18	6	9	12	5	12	18	6	12	17	7	12	16	6	12	17	6	12	17	7	12	17	8	01/09/93
01/10/93	12	14	10	12	15	10	9	12	7	13	15	12	12	15	10	12	14	10	12	14	10	12	14	10	13	15	11	01/10/93
01/11/93	11	16	5	13	18	8	10	13	4	12	17	7	13	18	7	13	17	8	12	17	7	13	18	9	13	18	6	01/11/93
01/12/93	11	16	4	12	18	6	9	13	4	12	18	6	11	16	5	11	16	5	11	17	6	12	17	8	11	16	6	01/12/93
01/13/93	13	17	9	13	18	10	11	12	10	14	19	11	13	18	9	13	16	9	13	17	11	13	17	11	13	18	10	01/13/93
01/14/93	12	16	8	13	18	9	10	12	9	14	18	11	13	18	9	12	17	9	14	17	12	13	18	11	13	17	11	01/14/93
Mean	11	15	5	11	16	6	10	12	6	12	17	7	11	17	6	12	16	7	12	16	8	12	16	8	12	16	6	Mean
Maximum	15	19		15	19		13	18		16	19		15	20		15	19		15	19		15	20		15	20		Maximum
Minimum	6		-5	5		-4	5		-1	5		-3	5		-4	7		-2	7		2	8		1	5		-4	Minimum

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Neolloydia			Senita Basin			Salsola			
	Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			Air Temperature at 15 cm degrees C			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	13	18	9	14	19	10	11	14	8	14	20	10	13	18	9	13	18	9	14	18	11	14	18	11	13	19	9	01/15/93
01/16/93	15	20	11	16	21	12	13	16	10	16	21	12	15	21	11	15	20	11	16	20	12	16	21	12	16	21	12	01/16/93
01/17/93	15	17	14	16	19	15	12	13	11	17	19	16	16	18	15	15	17	15	15	17	14	16	17	15	16	18	15	01/17/93
01/18/93	13	17	9	14	19	11	10	12	7	15	19	9	14	18	10	13	17	9	13	17	11	14	18	10	14	18	11	01/18/93
01/19/93	10	17	6	12	18	7	8	13	5	11	18	7	11	17	7	11	16	7	11	17	7	12	18	8	11	16	5	01/19/93
01/20/93	10	17	3	11	19	4	10	15	5	11	18	6	10	19	2	11	18	4	11	17	6	12	19	8	10	18	3	01/20/93
01/21/93	10	19	3	12	19	6	12	17	8	12	20	7	11	20	3	12	19	6	13	19	10	12	20	5	10	21	2	01/21/93
01/22/93	11	21	4	12	23	4	13	21	7	12	22	7	12	23	5	13	21	4	14	21	10	14	23	6	12	23	4	01/22/93
01/23/93	10	18	4	13	20	6	14	17	12	12	20	5	12	20	5	13	19	10	13	19	9	14	21	9	11	22	3	01/23/93
01/24/93	10	18	4	11	19	5	14	19	12	9	20	-1	11	21	-1	12	20	8	13	20	8	12	22	2	10	22	-1	01/24/93
01/25/93	12	21	4	15	22	9	14	17	10	13	22	3	14	22	5	14	22	9	15	21	12	15	23	6	15	22	7	01/25/93
01/26/93	13	21	5	11	19	6	15	19	13	11	19	6	10	19	3	11	18	3	14	20	11	12	21	3	10	19	5	01/26/93
01/27/93	13	22	6	13	22	7	14	18	11	14	23	9	13	22	8	13	21	7	14	22	9	14	23	8	14	22	8	01/27/93
01/28/93	13	21	7	13	22	8	13	19	9	13	23	8	14	22	7	14	21	8	14	22	9	14	22	8	14	22	7	01/28/93
Mean	12	19	6	13	20	8	12	16	9	13	20	7	12	20	6	13	19	8	14	19	10	14	20	8	12	20	6	Mean
Maximum	15	22		16	23		15	21		17	23		16	23		15	22		16	22		16	23		16	23		Maximum
Minimum	10		3	11		4	8		5	9		-1	10		-1	11		3	11		6	12		2	10		-1	Minimum

Figure 57. Sample intersite air temperature (at 15 cm [6 in.]) comparison report, 1–28 January 1993, for weather-monitored sites in the Ecological Monitoring Program at Organ Pipe Cactus National Monument.

RELATIVE HUMIDITY SITE COMPARISON: REPORTING PERIODS 1 & 2, 1993

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/01/93	81	92	54	83	95	56	66	67	65	77	87	59	79	90	52	76	90	51	79	92	57	79	91	52	01/01/93
01/02/93	77	92	50	82	95	49	64	65	63	76	86	53	72	89	40	72	87	44	73	90	45	71	90	36	01/02/93
01/03/93	71	92	33	66	94	29	64	69	61	68	87	31	70	90	28	62	88	30	65	91	34	68	93	24	01/03/93
01/04/93	66	92	37	70	97	40	60	61	59	69	89	50	71	93	36	50	78	33	51	86	35	73	93	36	01/04/93
01/05/93	73	92	52	75	94	47	62	68	59	72	87	46	74	91	50	71	88	50	71	90	52	74	91	52	01/05/93
01/06/93	89	92	84	91	92	86	69	71	67	85	88	82	87	91	80	85	89	83	89	92	83	88	91	86	01/06/93
01/07/93	89	91	88	89	91	86	59	70	69	84	86	83	86	88	82	85	86	83	89	89	88	87	89	85	01/07/93
01/08/93	79	91	47	76	93	39	69	70	67	75	89	43	77	90	42	72	87	41	77	91	43	76	90	43	01/08/93
01/09/93	78	93	53	77	94	46	68	70	67	74	89	47	76	90	48	74	88	48	77	92	50	76	92	48	01/09/93
01/10/93	89	93	79	89	93	77	69	70	69	85	88	77	88	91	84	85	89	83	89	92	82	88	90	82	01/10/93
01/11/93	85	92	66	79	92	58	69	70	67	77	89	58	78	91	52	77	88	48	81	91	56	79	92	51	01/11/93
01/12/93	77	93	48	78	95	54	69	70	67	75	88	44	77	90	53	77	89	54	78	91	56	77	90	52	01/12/93
01/13/93	89	92	80	88	92	78	69	70	59	84	87	78	86	89	76	84	87	78	88	97	78	85	90	70	01/13/93
01/14/93	84	91	74	85	92	68	69	70	68	81	87	72	80	88	62	79	86	64	83	90	68	81	88	64	01/14/93
Mean	81	92	60	81	94	58	67	69	66	77	88	59	79	90	56	75	87	56	78	91	59	79	91	56	Mean
Maximum	89	93		91	97		69	71		85	89		88	93		85	90		89	97		88	93		Maximum
Minimum	66		33	66		29	60		59	68		31	70		28	50		30	51		34	68		24	Minimum

	Armenta East			Aguajita Wash			Bull Pasture			Bates Well			Gachado Well			Headquarters			Senita Basin			Salsola			
	% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			% Relative Humidity			
	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	
01/15/93	84	91	65	83	92	65	69	69	68	80	87	65	82	88	64	80	86	66	82	89	70	82	91	65	01/15/93
01/16/93	80	91	61	80	92	58	68	69	67	77	87	60	77	88	56	77	87	59	79	90	63	79	90	60	01/16/93
01/17/93	86	91	78	87	91	82	69	69	68	83	86	76	83	87	74	83	86	79	86	88	82	85	89	75	01/17/93
01/18/93	85	92	65	84	91	59	69	70	68	80	89	62	83	90	70	83	89	66	85	90	67	85	91	69	01/18/93
01/19/93	81	92	58	78	93	50	68	69	66	76	88	51	78	90	54	76	87	53	78	91	56	79	92	52	01/19/93
01/20/93	77	93	50	74	94	44	67	69	65	73	88	46	73	90	39	71	90	45	72	91	47	75	91	43	01/20/93
01/21/93	74	93	47	72	94	45	64	65	63	70	89	39	69	91	41	68	88	44	67	92	40	71	91	35	01/21/93
01/22/93	74	93	36	73	95	38	61	63	60	74	88	43	73	90	36	69	91	38	70	91	35	73	91	36	01/22/93
01/23/93	69	92	37	59	93	30	55	59	47	60	88	28	61	89	32	60	85	34	57	87	32	64	91	18	01/23/93
01/24/93	51	79	30	45	71	27	32	46	22	56	90	24	51	92	25	41	52	31	46	89	27	61	92	24	01/24/93
01/25/93	35	64	10	26	45	8	20	26	14	35	87	10	27	75	7	23	43	5	25	67	10	16	40	9	01/25/93
01/26/93	34	61	15	58	90	34	11	25	6	57	84	30	63	85	30	56	86	29	50	81	26	59	86	29	01/26/93
01/27/93	57	76	34	68	93	34	38	58	10	55	83	27	67	86	35	64	86	33	59	84	33	67	88	33	01/27/93
01/28/93	68	91	36	74	93	38	58	65	46	69	87	35	69	90	33	66	90	37	71	92	43	69	91	31	01/28/93
Mean	68	86	44	69	88	44	53	59	48	67	87	43	68	88	43	66	82	44	66	87	45	69	87	41	Mean
Maximum	86	93		87	95		69	70		83	90		83	92		83	91		86	92		85	92		Maximum
Minimum	34		10	26		8	11		6	35		10	27		7	23		5	25		10	16		9	Minimum

Figure 58. Sample intersite relative humidity comparison report, 1–28 January 1993, for weather-monitored sites in the Ecological Monitoring Program at Organ Pipe Cactus National Monument.

Air Quality

Introduction

Although a visibility-impairing copper smelter 32 km (20 mi) north of the monument was closed in 1985, new threats to 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. Organ Pipe Cactus National 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, the monument participates in programs to monitor ambient particulate and radiation levels and 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) National Atmospheric Deposition Program, (2) Arizona Department of Environmental Quality, and (3) Arizona Radiation Regulatory Agency. The instruments 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, one 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. 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 the study in December 1993, but it was restarted in April 1994.

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 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 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.

1993 Monitoring Activities

Buckets for the NADP study were collected weekly. Conductivity and pH measurements were made with samples with sufficient precipitation. The rest of the sample and other field data were sent to the NADP/NTN Coordination Office.

Filters for ambient particulate (PM_{10}) and radiation monitoring were changed and sent to ADEQ and ARRA, respectively.

Methods

National Atmospheric Deposition Program

The NADP site equipment consists of an Aerochem Metrics wet/dry precipitation collector and a Belfort Universal rain gauge 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 rain gauge records precipitation event times and precipitation weight on chart paper. In the ORPI lab, 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 a yearly summary report for all U.S. NADP sites. Additionally, weekly records are kept at the monument. These include copies of the Belfort Universal rain gauge 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 United States 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 of NADP accuracy goals at the site.

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.

Arizona Radiation Regulatory Agency

Filters are changed weekly in the continuous air sampler and sent to the Arizona Radiation Regulatory Agency for analysis.

Results

National Atmospheric Deposition Program

Organ Pipe Cactus National Monument was 1 of 162 NADP sites that met the "completeness criteria" for 1993. The data from these sites were included in national summary maps of weighted mean concentrations and deposition estimates for various ions. These national summary maps along with annual, seasonal, and weekly data summaries for each site in the NADP network are included in the *NADP/NTN Annual Data Summary, Precipitation Chemistry in the United States, 1993*. Since 1991, precipitation chemistry results for ORPI have not changed significantly. Weighted mean concentrations of sulfates (SO_4) and nitrates (NO_3), important components of acid deposition, have decreased a small amount. The summaries for ORPI are presented in Figures 59 and 60.

Arizona Department of Environmental Quality

Results of PM_{10} monitoring are summarized in annual Air Quality Data for Arizona reports. Table 16 presents PM_{10} data from 1987 to 1992 (1993 annual report has not yet been released) for both ORPI and Ajo sampling sites. The sudden decrease in numbers in 1991 reflects an equipment switch from Sierra Anderson high volume samplers to dichotomous samplers, which measure lower PM_{10} concentrations. The new equipment was chosen in order to determine particle size fractions and chemical components.

Arizona Radiation Regulatory Agency

The report for 1993 on background radiation levels has not yet been received. No increase in environmental background radiation levels was reported in previous reports.

National Atmospheric Deposition Program/National Trends Network

1993 ANNUAL & SEASONAL DATA SUMMARY
(Printed 06/07/94)

SITE IDENTIFICATION

Site	Organ Pipe Cactus Nat'l Mon.
State	AZ
County	Pima
Operation	NPS
Funding	NPS
Site No.	030620
CAL Code	AZ06
Latitude	31:57:02
Longitude	112:48:00
Elevation	506 m

SAMPLE VALIDITY FOR ANNUAL PERIOD

Sampling Intervals		53
Valid Samples		51
with precipitation		22
with full chemistry#	(19)	
without chemistry	(3)	
without precipitation		29
Invalid Samples		2
with precipitation		2
missing precipitation data		0

SUMMARY PERIOD INFORMATION	Annual	Winter	Spring	Summer	Fall
First summary day (yrmoda)	921229	921201	930302	930601	930831
Last summary day (yrmoda)	940104	930302	930601	930831	931130
Summary period (days)	371	91	91	91	91
Sampling intervals	53	13	13	13	13
Measured precipitation (cm)	30.3	21.9	1.2	9.8	5.1
Valid samples with full chemistry#	19	10	2	3	4
Valid samples with full chemistry & valid field pH	12	9	1	1	1

NADP/NTN COMPLETENESS CRITERIA	Annual	Winter	Spring	Summer	Fall
1. Summary period with valid samples (%)	98.1	100.0	92.3	92.3	100.0
2. Summary period with precipitation coverage (%)	100.0	100.0	100.0	100.0	100.0
3. Measured precipitation with valid samples (%)	99.6	100.0	93.9	99.5	100.0
4. Collector efficiency (%)	106.4	104.2	106.7	102.0	107.2
Measured precip. with full chem. & valid field pH (%)	96.9	75.3	91.9	96.0	92.0

STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES

PRECIPITATION-WEIGHTED MEAN CONCENTRATIONS	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH (lab)	pH (fld)
						mg/L						
Annual	0.06	0.041	0.030	0.329	0.09	0.28	0.56	0.37	3.17e-3	5.37e-3	5.50	5.27
Winter	0.04	0.021	0.010	0.172	0.05	0.19	0.28	0.33	4.69e-3	7.24e-3	5.33	5.14
Spring	0.16	0.075	0.032	0.555	0.07	0.36	0.94	0.51	2.46e-3	5.37e-3	5.61	5.27
Summer	0.03	0.006	0.038	0.053	0.16	0.29	0.06	0.27	1.86e-3	4.07e-3	5.73	5.39
Fall	0.13	0.130	0.060	1.049	0.12	0.50	1.92	0.61	3.27e-3	5.01e-3	5.49	5.30
DEPOSITION						kg/ha						
Annual	0.18	0.124	0.091	0.997	0.28	0.84	1.71	1.11	9.60e-3	1.63e-2	--	--
Winter	0.08	0.046	0.022	0.377	0.11	0.43	0.61	0.71	1.03e-2	1.59e-2	--	--
Spring	0.02	0.009	0.004	0.069	0.01	0.04	0.12	0.06	3.06e-4	6.68e-4	--	--
Summer	0.03	0.006	0.037	0.052	0.16	0.28	0.06	0.26	1.82e-3	3.98e-3	--	--
Fall	0.06	0.066	0.031	0.536	0.06	0.25	0.98	0.31	1.67e-3	2.56e-3	--	--
WEEKLY SAMPLE CONCENTRATIONS						mg/L						
Minimum value	0.01	0.004	0.003	0.042	0.02	0.08	0.05	0.19	9.77e-5	3.89e-3	4.71	4.61
Percentile 10	0.02	0.007	0.003	0.042	0.02	0.08	0.07	0.22	1.86e-4	3.95e-3	4.82	4.68
Percentile 25	0.07	0.010	0.013	0.109	0.06	0.32	0.10	0.39	7.41e-4	5.10e-3	5.38	4.96
Percentile 50	0.13	0.039	0.036	0.302	0.10	0.62	0.42	0.71	2.29e-3	8.97e-3	5.64	5.05
Percentile 75	0.32	0.074	0.071	0.627	0.23	1.69	0.76	1.37	4.17e-3	1.09e-2	6.13	5.29
Percentile 90	0.74	0.185	0.145	1.090	1.06	3.56	2.04	2.76	1.51e-2	2.13e-2	6.73	5.40
Maximum value	1.57	0.186	0.151	1.660	1.29	3.63	2.80	3.03	1.95e-2	2.45e-2	7.01	5.41
Arithmetic mean	0.28	0.059	0.049	0.461	0.26	1.11	0.65	0.96	4.19e-3	9.35e-3	5.38	5.03
Arith. std. dev.	0.38	0.057	0.046	0.433	0.37	1.15	0.72	0.82	5.45e-3	5.76e-3	--	--
Below detection	0	0	2	0	2	0	0	0	0	0	0	0

OTHER PARAMETERS	Measured Precipitation** cm	Conductivity uS/cm	Equivalence Ratios SO4/NO3	Equivalence Ratios SO4+NO3/H(lab)	Equivalence Ratios Cation/Anion
Minimum value	0.03	3.1	0.56	1.41	0.62
Percentile 10	0.03	3.3	0.81	1.49	0.67
Percentile 25	0.13	4.8	0.98	4.37	0.93
Percentile 50	0.28	9.4	1.18	5.68	0.98
Percentile 75	1.19	15.7	2.11	78.08	1.19
Percentile 90	6.81	22.0	3.55	223.36	1.42
Maximum value	9.37	40.1	3.87	1233.45	1.56

OTHER ANNUAL & SEASONAL DEPOSITION VALUES

	Total N from NO3 & NH4 (kg/ha)	Equivalence Ratios SO4/NO3	Equivalence Ratios SO4+NO3/H(lab)	Equivalence Ratios Cation/Anion
Annual	0.41	1.70	3.82	1.06
Winter	0.18	2.16	2.12	1.05
Spring	0.02	1.85	6.72	1.06
Summer	0.18	1.22	5.52	1.33
Fall	0.10	1.59	6.35	0.99

Valid samples for which all laboratory chemical measurements were made (the **only** samples described by the percentile distributions in the STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES).

** Measured precipitation for sample periods during which precipitation occurred **and** for which complete valid laboratory chemistry data are available.

Figure 59. National Atmospheric Deposition Program 1993 annual and seasonal data summary for Organ Pipe Cactus National Monument, Arizona.

NADP/NTN WEEKLY PRECIPITATION CHEMISTRY DATA FOR 1993
(Printed 06/06/94)

Site: **Organ Pipe Cactus Nat'l Mon.** State: Arizona Site No.: 030620 CAL Code: AZ06

Date On modayr	Date Off modayr	Lab Type	pH Lab	pH Field	Conductivity Lab uS/cm	Conductivity Field uS/cm	Ca (mg/L)	Mg	K	Na	NH4	NO3	Cl	SO4	H	Eq. Ra. c/a	Ppt cm	Coll. Eff. c/rg	Notes	Inval-code	Obs
#122992	010593	w	5.67	4.96	4.1	7.0	0.07	0.008	<0.003	0.075	0.10	0.62	0.10	0.39	2.14e-3	0.72	0.33	1.22			bl1
#010593	011293	w	5.38	5.41	3.3	4.1	0.02	0.024	0.009	0.203	<0.02	0.08	0.32	0.22	4.17e-3	1.12	6.81	1.04			bl1
#011293	011993	w	5.64	5.25	3.9	4.7	0.07	0.039	0.013	0.302	<0.02	0.08	0.51	0.24	2.29e-3	1.11	3.71	1.04			bl1
011993	012693	t	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--			bl1
012693	020293	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
#020293	020993	w	5.24	4.99	6.3	9.1	0.07	0.023	0.022	0.159	0.20	0.42	0.25	0.80	5.75e-3	0.97	1.07	1.11			bl1
#020993	021693	w	4.71	4.61	9.8	12.9	0.03	0.007	0.009	0.042	0.11	0.89	0.07	0.71	1.95e-2	0.96	0.48	1.12			bl1
#021693	022393	w	5.90	4.97	5.4	6.4	0.07	0.010	<0.003	0.109	0.04	0.54	0.10	0.35	1.26e-3	0.67	0.13	1.43			bl1
#022393	030293	w	5.53	5.10	5.3	7.1	0.05	0.035	0.014	0.266	0.11	0.32	0.42	0.54	2.95e-3	0.93	1.19	1.05			bl1
030293	030993	t	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--			bl1
030993	031693	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
031693	032393	w	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.08	1.24	ns	c	bl1
#032393	033093	w	5.60	5.27	7.0	7.0	0.13	0.073	0.030	0.545	0.05	0.29	0.93	0.46	2.51e-3	1.04	1.14	1.08			cwc
033093	040693	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		cwc
040693	041393	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
041393	042093	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
042093	042793	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
042793	050493	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
050493	051193	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
#051193	051893	wa	7.01	--	40.1	--	1.57	0.185	0.145	1.003	1.06	3.56	1.45	3.03	9.77e-5	1.24	0.03	0.53			acp
051893	052593	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
052593	060193	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
060193	060893	wa	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.05	0.85	ns	c	jfa
060893	061593	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	ns		bl1
061593	062293	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
062293	062993	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
062993	070693	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
#070693	071393	wa	6.13	--	16.2	--	0.32	0.068	0.071	0.852	0.30	1.69	0.76	1.47	7.41e-4	0.98	0.05	0.98			cwc
071393	072093	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
072093	072793	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		cwc
072793	080393	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
#080393	081093	w	4.90	--	22.0	--	0.67	0.074	0.112	0.264	0.81	3.63	0.38	2.76	1.26e-2	0.88	0.28	1.03			cwc
081093	081793	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
081793	082493	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01	--	na		acp
#082493	083193	w	5.81	5.39	3.1	2.8	0.01	0.004	0.036	0.042	0.14	0.18	0.05	0.19	1.55e-3	1.56	9.37	--			acp
#083193	090793	w	6.14	--	17.3	--	0.20	0.045	0.091	0.507	1.29	3.18	0.35	1.37	7.24e-4	1.23	0.23	1.33			
090793	091493	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		bl1
091493	092193	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
092193	092893	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
092893	100593	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
#100593	101293	w	4.82	--	15.7	--	0.46	0.066	0.047	0.585	0.07	1.70	0.49	1.86	1.51e-2	0.93	0.13	1.20			acp
#101293	101993	wa	6.73	--	14.1	--	0.74	0.106	0.038	0.627	0.10	1.30	0.51	0.99	1.86e-4	1.42	0.03	1.49			acp
101993	102693	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
102693	110293	t	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01	--			acp
110293	111093	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01	--	na		jfa
#111093	111693	w	5.51	5.30	10.9	13.7	0.11	0.136	0.059	1.090	0.06	0.33	2.04	0.54	3.09e-3	0.97	4.70	1.05			jfa
111693	112393	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	ns		jfa
112393	113093	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
113093	120793	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp
#120793	121493	w	5.85	4.86	14.7	20.7	0.21	0.186	0.068	1.660	0.23	0.63	2.80	0.83	1.41e-3	1.07	0.20	1.27			acp
#121493	122193	w	5.51	5.00	4.8	6.1	0.24	0.010	0.018	0.069	0.07	0.49	0.10	0.42	3.09e-3	1.19	0.23	1.16			acp
#122193	122893	wa	6.31	--	9.4	--	0.22	0.024	0.151	0.364	0.09	1.14	0.76	1.04	4.90e-4	0.62	0.03	1.10			acp
122893	010494	da	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.	--	na		acp

Valid samples with complete laboratory chemistry data. Only these samples are included in the mean concentrations, depositions and percentile distributions on the previous page.

NOTE: DATA IN THE NADP/NTN DATA BASE ARE OCCASIONALLY REVISED TO REFLECT NEW INFORMATION. CURRENT DATA, INCLUDING VALUES FOR PARAMETERS NOT PRINTED ON THIS PAGE, ARE AVAILABLE IN DISKETTE, ELECTRONIC OR PRINTED FORM FROM THE NADP/NTN COORDINATION OFFICE (see inside cover for address).

Figure 60. National Atmospheric Deposition Program weekly precipitation chemistry data for 1993, Organ Pipe Cactus National Monument, Arizona.

Table 16. Ambient particulate (PM_{10}) concentrations for Organ Pipe Cactus National Monument (ORPI) and Ajo sampling sites. PM_{10} is measured in $\mu g/m^3$. State and federal regulations set a standard of 150 $\mu g/m^3$, not to be exceeded more than once per year over a 3-yr period.

PM_{10} concentrations ($\mu g/m^3$)						
	ORPI			Ajo		
	Annual arithmetic mean	24-hr average		Annual arithmetic mean	24-hr average	
Year		Max	2nd High		Max	2nd High
1987	17	105	36	39[a]	253[b]	102
1988	16	53	46	42[a]	102	71
1989	19	65	50	41[a]	12	86
1990	23	108	108	44[a]	121	112
1991	11	36	26	31[a]	80	74
1992	11	30	24	23[a]	47	42

[a] Based on a limited number of samples.
[b] Exceeded state and federal standards.

Land-use Trends

Introduction

The Land-use Trends Surrounding Organ Pipe Cactus National Monument project conducted from 1987 to 1988 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 depletion of the aquifer that is shared by the monument and Mexico in the Rio Sonoyta watershed. In addition, other aspects of agricultural development are of concern. The aerial application of agricultural pesticides is a threat due to wind drift. Increased human habitation causes impact from pollution, habitat degradation, woodcutting, livestock trespass, and so forth.

The Mexican portion of the Sonoyta Valley is a prime site for agricultural development. At the conclusion of the research phase of the Land-use Trends project in 1988, more than 12,141 ha (30,000 a.) had been developed for irrigated agriculture. Total water withdrawal from the approximately 165 agricultural wells in 1987–1988 was estimated to be 83,152 a-ft, more than 2.5 times the annual groundwater recharge rate of 28,135 a-ft. Although moratoriums are currently in effect to (1) prohibit development of new wells for irrigation and (2) limit the land developed for irrigated agriculture to the present 12,950 ha (32,000 a.), this is of little reassurance when one realizes that the total current annual pumping *capacity* in the Sonoyta Valley is estimated to be 191,000 a-ft, or more than 600% of the estimated annual groundwater recharge rate.

Four different methods were recommended in the monitoring protocol to track agricultural development in the Sonoyta Valley:

1. Bi-annual photopoint photography of the agricultural area to detect changes through time.
2. Periodic aerial photography of the same area.
3. Collection of data from Mexican agricultural officials on crops, acreage, and chemical use.
4. Computation based on well depths and electrical use of the amount of water being pumped for agriculture.

Program History

Resource management staff has conducted the agricultural photopoint monitoring protocol since 1988. These photopoints are located adjacent to the international border, both in Mexico and the United States, and offer long-term visual information on changes in land use.

As recommended in the Land-use Trends final report, a good working relationship has been maintained with Mexican agricultural officials from the Secretaría de Agricultura y Recursos Hidráulicos (SARH) located in Sonoyta, Sonora. Resource management personnel at ORPI have regularly provided depth-to-water data from monument wells and agricultural photopoint photos to these officials. In return, the monument receives annual data on depth-to-water and electricity use at Mexican agricultural wells and information on crops and pesticide use.

1993 Monitoring Activities

Photos were taken in April and November at 8 border photopoints. Information from SARH on well depths, electricity use, and crops was not received until early 1994 due to delays inherent in the centralization of agricultural data in Caborca, Sonora, which is almost 100 mi (160 km) south of the monument. Upon receipt of the necessary figures from SARH and the Comisión Federal de Electricidad (CFE), the Lotus 1-2-3 spreadsheets were completed. A summary of the well use for 1993 is provided here (Fig. 61), along with a summary of crop acreage for the last 12 yr (Fig. 62).

Methods

Agricultural Photopoints

Twice each year, in April and November, a sequence of photos is taken from each of the 8 established photopoints along the border. Four of these points are on the Mexican side of the border, while 4 are on the U.S. side. Each photopoint consists of a tagged rebar and 3 painted spots indicating the placement of the tripod. The head of the tripod is leveled by shortening 2 of the legs, and thus the photos are taken from exactly repeatable locations. Each individual photo in each panoramic sequence is located by means of comparison to existing black-and-white photos that are contained in the monitoring field book. Each photo sequence is shot using both color slide and black-and-white print film. Once processed, the slides, prints, and negatives are labelled and archived. One duplicate set of black-and-white prints is provided to SARH.

Mexican Agricultural Data

Soon after the beginning of each year, electrical and well-depth data are retrieved from Mexican agriculture and utility officials. These data are entered into a complex Lotus 1-2-3 spreadsheet that calculates—using assumed pump efficiencies—the amount of water being drawn from each well. A copy of this spreadsheet, when completed, is provided to SARH.

Results

All 8 boundary photo points were visited and photos taken without incident in 1993. Slides and prints showing Mexican agricultural development on the monument boundary were processed and archived in the Sonoran Desert Biosphere Reserve Center museum vault.

Well depth and electrical data from Mexico for 1992 and 1993 were not received until early 1994. These figures were processed and entered into the appropriate Lotus 1-2-3 spreadsheets. Information was also obtained on the general distribution of crop acreage and the use of pesticides, herbicides, and fertilizers in the Sonoyta Valley. A vexing problem is the incomplete nature of the well data due to difficulties encountered by Mexican officials in measuring wells. This is due either to blockage of the access hole or excessive oil (from leaky electric pumps) in the well. In addition, the calculations involved in the spreadsheet are based on 2 different ways of considering well depths. One is to use the static level, meaning the water level when no water is being pumped. (This figure is currently the only one available, and is obtained each year in

WELL	EJIDO 1993	VOLUME AT STATIC LEVEL (m3)	VOLUME AT DYNAMIC LEVEL (m3)	STATIC LEVEL (m)	DYNAMIC LEVEL (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL ENERGY (kW)
						ASSUMED LEVEL OF PUMP EFFICIENCY = 45 %												
						<------ MONTHLY VOLUME (m3) EXTRACTED BASED ON DYNAMIC LEVEL ------>												
4 11	Ejido Cerro Colorado	1,491,862	458,894	5.41	17.47	0	0	0	0	0	0	196,296	227,068	35,530	0	0	0	48,511
5 05	Figueroa Uribe Aurelio	152,094	69,335	11.26	24.70	0	0	0	0	0	0	29,987	22,079	8,290	4,951	4,023	0	10,363
5 08	Figueroa Uribe Aurelio	0	0	8.67	24.70	0	0	0	0	0	0	0	0	0	0	0	0	0
5 24	Jaime Sierra Loreto	412,359	160,373	15.30	39.34	0	6,431	13,808	38,101	17,866	36,664	26,654	16,757	2,336	920	936	0	18,177
5 29	Flores Altamirano Rafael	2,728,328	674,148	7.86	31.81	1,927	2,598	7,029	65,657	115,941	115,172	149,403	148,536	8,660	57,500	1,725	0	129,764
5 31	Ejido Morelia	0	0	15.32	40.00	0	0	0	0	0	0	0	0	0	0	0	0	0
6 01	Ejido Morelia	1,000,068	640,544	25.62	40.00	0	0	0	30,242	66,434	157,161	219,133	166,085	0	0	[illegible]	0	155,040
6 02	Ejido Papago	964,553	857,060	29.74	30.00	275	0	0	90,457	191,337	134,190	60,061	331,173	47,044	2,523	3	0	155,585
6 09	Ejido Morelia	1,170,397	791,656	16.91	25.00	0	3,173	77,738	120,573	96,776	138,024	188,792	164,994	1,586	0	0	0	119,760
6 20	Ejido Hombres Blancos, No 3																	61,826
6 35	Ejido Hombres Blancos, No.1																	205,344
6 36	Ejido Hombres Blancos, No.2	0	0	16.38	15.47	0	0	0	0	0	0	0	0	0	0		0	0
6 40	L. Internacional Pozo #2																	4,604
6 42	Ejido Sonoyta Papagos No 2																	129,143
6 43	Ejido Sonoyta Papagos No 3																	162,530
7 01	San Martin	1,063,030	775,203	22.32	30.78	0	10,137	146,247	143,896	72,874	156,336	134,135	92,224	19,001	177	177	0	134,384
7 05	SPR de R I San Pedro	1,264,564	737,230	21.32	36.57	352	99	41,633	114,574	39,035	124,669	98,699	99,042	54,124	91,256	75,745	0	163,141
7 09	SPR de R I. Los Angeles	1,757,742	1,076,978	16.01	26.13	0	0	117,838	216,298	200,999	67,944	179,856	242,930	49,736	980	398	0	170,287
7 10	Col Emiliano Zapata	27,405	17,831	19.52	30.00	0	0	1,383	6,572	5,107	1,829	1,432	925	231	226	127	0	3,237
7 12	Julio/Rafael Mun	1,459,249	697,353	19.88	41.60	12,450	112,928	135,310	135,504	62,357	79,694	78,724	78,724	671	938	151	0	175,542
7 15	Col E. Obregonista	185,383	186,984	16.35	16.21	2,192	2,773	2,834	3,905	11,174	16,240	11,061	26,466	58,794	4,486	47,060	0	18,341
7 15	Const / Cap Molina	121,548	59,217	13.69	28.10	218	606	1,212	1,359	1,136	16,126	13,785	8,645	1,223	333	[illegible]	0	10,069
7 19	Lopez Mateos	419,411	309,871	20.00	27.07	0	0	0	11,477	19,688	36,080	66,085	113,654	48,137	14,745		0	50,758
7 21	Julio/Rafael Mun	932,155	561,759	25.51	42.33	0	25,712	260,206	246,733	29,109	0	0	0	0	0	0	0	143,891
7 23	Ejido Desierto de Sonora	362,091	334,563	34.88	37.75	8,182	4,365	9,088	38,865	33,463	56,494	75,424	67,347	16,119	14,166	11,049	0	76,424
7 24	B. de Las Americas	0	0	34.98	40.00	0	0	0	0	0	0	0	0	0	0	0	0	0
7 25	Ejido Desierto de Sonora	404,411	340,638	34.88	41.41	0	0	9,187	30,901	17,392	69,368	102,687	107,732	3,372	0	0	0	85,356
7 26	Ejido Desierto de Sonora	466,647	467,050	46.35	46.31	0	856	43,679	71,942	104,201	85,645	117,904	38,255	0	4,568	0	0	130,860
7.27	Lopez Mateos	819,204	655,130	16.85	21.07	0	52,064	128,301	125,046	67,939	71,437	80,253	85,249	44,840	0	0	0	83,527
7 28	SPR Guadalupe	0	0	33.19	39.93	0	0	0	0	0	0	0	0	0	0	0	0	0
7 31	SPR de R I. Los Angeles	2,020,964	825,963	22.18	54.27	0	0	68,725	175,953	203,305	34,392	150,380	119,783	73,116	134	174	0	271,241
8 01	SPR Los Nanos	3,213,325	1,864,301	26.05	44.90	32,360	70,211	172,561	225,179	265,143	221,351	228,352	261,606	155,266	142,623	89,648	0	506,521
8 02	SPR Los Mesquites	1,039,582	1,046,935	41.29	41.00	0	148,007	273,524	294,564	187,911	0	41,355	52,238	24,668	24,668	0	0	259,740
8 03	SPR Los Mesquites	1,010,153	753,941	41.05	55.00	0	0	0	150,896	186,051	164,418	115,200	78,423	58,952	0	3	0	250,920
8 04	SPR Los Mesquites	862,454	465,323	34.46	63.87	1,449	3,933	28,151	38,501	27,944	1,035	42,020	37,880	45,953	31,463	206,954	0	179,840
8 09	SPR Los Nanos	14,799	34,739	31.00	39.97	0	0	0	0	0	0	0	0	0	0	34,739	0	8,402
8 23	Francisco I. Madero	118,512	86,431	30.12	41.30	0	0	3,201	26,890	37,133	15,686	3,521	0	0	0	0	0	21,600
8 24	Francisco I. Madero	2,344,952	1,740,182	30.27	40.79	20,743	44,728	154,279	209,703	233,040	254,107	213,269	207,110	161,086	220,723	21,392	0	429,520
8 29	Col Sonoyta	909,041	519,836	42.54	74.39	0	16,884	88,150	113,209	118,540	45,852	38,210	40,165	42,475	16,350	0	0	234,000
8 30	Col Sonoyta	1,914,160	918,945	49.76	103.65	0	17,793	145,600	147,131	115,370	35,013	12,054	16,071	180,039	154,401	95,412	0	576,360
8 32	Col Sonoyta	1,744,623	916,273	40.33	76.79	0	0	154,434	179,054	118,107	74,204	52,855	28,408	175,094	109,843	24,276	0	425,760
8 37	Ejido Tetabiate No 2	62,018	62,343	40.29	40.08	0	0	0	0	40,078	21,771	495	0	0	0	0	0	15,120
8 38	Col. Francisco I. Madero	373,357	209,879	33.91	60.00	28,755	8,924	84,282	71,722	6,610	6,280	3,305	0	0	0	0	0	76,200
8 40	Capitan Molina No.8	3,795,534	2,225,490	42.68	72.79	18,163	181,628	234,845	234,845	272,987	215,956	220,678	534,532	115,879	195,977	0	0	980,240
9 04	Ejido Desierto de Sonora	208,356	178,893	65.94	76.80	0	0	0	0	50,496	36,994	35,879	55,523	0	0	0	0	83,136
10.02	S.P.R. Pericales de R.I	254,782	237,797	70.00	75.00	0	0	0	881	27,323	62,578	30,320	45,479	61,873	9,343	0	0	107,920
10.03	S.P.R. de R I. Pericales	699,753	653,103	70.00	75.00	0	0	0	0	58,700	186,148	65,310	153,096	137,231	52,618	0	0	296,400
11.09	S P.R. El Cumplimiento																	15,680
11 10	Col. Cuauhtemoc	0	0	56.24	80.00	0	0	0	0	0	0	0	0	0	0	0	0	0
11 11	Col Cuauhtemoc	165,925	129,565	57.05	73.06	0	0	0	0	1,267	47,592	30,582	18,458	16,829	14,658	131	0	57,280
12 02	Col. A Obregon	249,681	205,431	94.94	115.39	0	0	229	10,885	36,893	40,788	68,630	38,841	8,249	687	229	0	143,440
20 05	Col. Sonoyta	0	0	41.52	60.00	0	0	0	0	0	0	0	0	0	0	0	0	0
21 01	S P R.I Reforma	1,036,975	984,734	55.23	58.16	0	0	0	36,598	186,399	133,207	152,757	170,714	100,019	205,039	0	0	346,560
21 03	Col CNCI Fracso	1,388,704	1,078,968	75.00	96.53	0	1,917	55,606	169,282	193,661	136,138	149,560	106,829	124,633	88,476	52,866	0	630,240
21 06	Col CNCI Fracso	317,499	215,442	57.63	84.93	0	0	0	0	130,604	64,913	19,925	0	0	0	0	0	110,720
21.07	S P.R. Las Delicias	374,795	250,863	80.32	120.00	0	0	7,602	50,734	39,827	37,844	26,441	37,018	17,022	22,640	11,733	0	182,160
21 09	Col America	789,464	597,695	101.45	134.00	0	0	6,314	43,609	120,762	102,609	122,144	51,896	42,622	48,147	59,592	0	484,640
21 10	Col America	1,406,246	1,105,795	89.84	114.25	0	453	23,375	79,151	228,658	208,291	238,609	65,959	101,368	88,971	71,050	0	764,480
21 13	Col CNCI Fracso	479,098	362,585	71.14	94.00	0	141	22,644	55,133	83,262	47,398	68,495	56,399	26,019	2,954	141	0	206,240
21 14	Col CNCI Fracso	1,558,353	1,513,721	69.39	76.02	0	3,478	74,782	86,955	263,649	290,779	119,651	134,607	266,779	219,823	53,217	0	696,320

Figure 61. Water usage for the Sonoyta agricultural district, 1993.

Figure 61—continued.

1993

ASSUMED LEVEL OF PUMP EFFICIENCY = 45 %

WELL	EJIDO	VOLUME AT STATIC LEVEL (m3)	VOLUME AT DYNAMIC LEVEL (m3)	STATIC LEVEL (m)	DYNAMIC LEVEL (m)	MONTHLY VOLUME (m3) EXTRACTED BASED ON DYNAMIC LEVEL: JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL ENERGY (kW)
21 15	Col CNCl Fracso	5,690	5,378	69.70	73.75	0	359	359	359	717	0	717	717	1,434	359	359	0	2,400
21 16	S.P.R Las Delicias	1,359,918	1,199,055	82.44	93.50	26,300	58,822	88,798	121,319	173,071	164,587	184,666	104,352	117,643	108,311	51,186	0	678,400
21.18	Col. CNCl Fracso	1,508,392	1,115,383	72.03	97.41	0	0	121,641	158,668	122,023	138,564	133,474	93,139	154,596	155,232	38,045	0	657,450
21 19	Col. America	0	0	87.87	102.74	0	0	0	0	0	0	0	0	0	0	0	0	0
22 04	Col. Grupo Valdez	722,706	587,881	73.21	90.00	0	0	0	1,469	170,107	0	130,444	160,705	117,517	7,639	0	0	320,160
22.07	S.P.R. Jose L. Portillo	1,077,612	647,815	57.11	95.00	0	0	417	70,418	85,448	9,185	169,921	175,905	121,631	14,891	0	0	372,400
22.09	S.P.R. Cuatro Cerros	0	0	90.00	90.00	0	0	0	0	0	0	0	0	0	0	0	0	0
22 10	Col. 21 de Marzo II Frac	737,102	670,479	99.33	109.20	908	86,443	129,493	189,231	90,802	51,575	66,648	54,844	545	0	0	0	443,040
22 11	Col. 21 de Marzo II Frac	368,178	343,002	94.96	101.93	195	23,930	56,032	86,383	47,861	37,938	58,561	17,510	14,592	0	0	0	211,560
22.12	Col. 21 de Marzo I Frac	410,591	402,053	97.95	100.03	0	0	0	397	64,498	60,929	118,554	58,815	91,724	7,137	0	0	243,360
22 13	S P R Jose L Portillo	351,789	216,159	67.59	110.00	3,065	0	49,037	56,969	65,983	0	15,865	14,423	10,637	180	0	0	143,880
22.14	Ejido La Nariz	786,263	711,431	75.01	82.90	1,914	5,622	80,377	119,728	105,973	120,804	127,024	36,514	65,545	40,667	5,263	0	356,880
23 08	S.P R El Cumplimiento	6,796	5,267	72.95	94.13	0	0	211	421	421	632	632	421	211	2,317	0	0	3,000
23 09	SPR Tomas Urbina	1,406	1,328	84.61	89.57	0	0	0	0	0	0	0	886	443	0	0	0	720
23.10	SPR Tomas Urbina	2,545	1,784	88.32	126.00	0	0	0	0	0	0	0	0	0	0	1,784	0	1,360
23.11	Col Direccion del Norte	37,047	29,294	92.07	116.44	0	0	0	0	0	2,044	0	0	0	20,948	6,302	0	20,640
23 12	Col Direccion del Norte	0	0	76.54	138.00	0	0	0	0	0	0	0	0	0	0	0	0	0
23 13	Col. Cuauhtemoc	0	0	75.00	100.00	0	0	0	0	0	0	0	0	0	0	0	0	0
23 16	S.P R. de R.I. Los Huicos	509,438	416,813	90.00	110.00	0	361	60,575	91,944	112,496	39,482	54,085	13,701	18,930	17,127	3,113	0	277,440
23.18	SPR Emiliano Zapata	549,069	431,939	73.68	93.66	141	0	0	97,821	32,466	97,680	70,578	91,611	28,796	12,845	0	0	244,800
24 01	Col. Jalisco	332,468	309,860	111.94	120.00	0	0	0	0	70,648	68,582	58,584	56,271	54,370	1,405	0	0	225,000
24 03	Col. 21 de Marzo III Frac	315,968	296,320	109.04	116.27	0	14,327	87,327	102,791	91,534	114	114	114	0	0	0	0	208,480
24 04	SPR R.I Maria Elena	472,376	410,762	100.00	115.00	0	0	0	0	0	0	0	0	168,650	242,111	0	0	285,840
24 05	Mejia Hernandez Felipe	53,467	53,609	124.87	124.54	0	0	10,509	11,253	9,979	7,112	14,543	212	0	0	0	0	40,400
24 08	SPR Leyes de Reforma Cajeme	221,929	220,886	97.4	97.86	0	0	0	0	0	0	0	0	124,020	96,965	0	0	130,800
24 09	Col 21 de Marzo III Frac	1,429	1,426	101.79	102.00	0	0	518	130	130	130	130	130	130	130	0	0	880
24 10	Com.Ind. San Francisomito	5,565	5,236	95.02	101.00	654	262	131	654	785	1,047	654	393	262	0	393	0	3,200
24.13	SPR de R I. Avilez Nunez	152,049	138,425	91.95	101.00	0	0	0	29,452	40,055	62,242	6,087	589	0	0	0	0	84,600
24 14	SPR Jacinto Lopez	559,975	501,640	103.02	115.00	0	0	0	17,417	122,953	54,147	105,708	85,877	115,538	0	0	0	349,080
24 15	Col. Jalisco	607,416	515,992	97.64	114.94	0	115	0	0	141,248	90,983	86,842	42,558	142,628	11,617	0	0	358,880
24 18	SPR Heroes del 47	308,223	224,230	77.98	107.19	0	0	1,480	48,842	34,967	53,467	82,144	0	0	0	3,330	0	145,440
24 19	SPR Heroes del 47	29,119	21,680	79.68	107.02	0	0	0	0	19,642	927	1,112	0	0	0	0	0	14,040
24.20	Col. 21 de Marzo III Frac	0	0	125.80	134.83	0	0	0	0	0	0	0	0	0	0	0	0	0
24.23	SPR Heroes del 47	0	0	76.82	101.63	0	0	0	0	0	0	0	0	0	0	0	0	0
24 99	SPR Jacinto Lopez	872,567	793,243	100.00	110.00	0	26,321	63,099	187,494	166,220	101,319	99,336	66,885	82,209	361	0	0	528,000
27 07	Escobar Magdaleno H	21,819	17,346	99.37	125.00	0	11,370	0	5,976	0	0	0	0	0	0	0	0	13,120
33 01	CJN Juarez No 24	29,041	26,457	114.76	125.97	645	287	2,125	3,698	4,542	7,291	823	1,430	1,482	2,954	[illegible]	0	20,167
34.06	S P R. Jose Maria Morelos	540,160	521,721	128.46	133.00	0	41,302	74,404	155,070	114,811	30,418	46,521	47,117	10,736	746	596	0	419,880
34 07	S.P R. Jose Maria Morelos	260,087	215,110	110.00	133.00	0	0	0	199	65,805	33,400	64,016	50,696	0	0	394	0	173,120
34.08	S.P R. Jose Maria Morelos	224	215	117.98	123.00	0	0	215	0	0	0	0	0	0	0	0	0	160
34.09	S P.R. de R.I. Los Olivos	304,117	274,638	135.46	150.00	0	0	0	176,276	71,216	18,156	6,522	353	0	0	2,115	0	249,280
36.01	Ejido El Ejemplo	335,346	279,012	119.81	144.00	0	0	0	28,920	63,212	88,138	60,595	35,118	0	0	3,030	0	243,120
36 04	Ejido El Ejemplo	4,875	4,402	130.16	144.15	0	0	0	0	4,127	0	0	138	138	0	0	0	3,840
36.05	Ejido El Ejemplo	389,140	353,203	119.81	132.00	13,221	7,512	11,418	54,836	65,052	41,916	51,531	15,474	34,103	35,305	22,836	0	282,120
36.07	Ejido El Ejemplo	4,860	4,673	147.29	153.20	286	0	0	698	611	1,002	705	553	408	0	410	0	4,332
36 99	Ejido El Ejemplo	9,916	7,602	115.00	150.00	0	0	0	0	0	0	0	0	0	4,453	3,149	0	6,900
38 04	Ejido Nueva Creacion Cajeme																	258,960
TOTALS		59,846,286 m3	41,039,738 m3 = 33,257 acre-feet			174,396	996,882	3,431,953	5,711,809	6,545,990	5,232,230	5,897,506	5,578,371	3,813,786	2,631,204	1,025,612	0	18,864,293

Jan.1994 electrical figures are not yet available,
so Dec.1993 use cannot yet be calculated.
(December use is generally quite low compared to other months.)

The following wells were included because of electricity usage,
even though well depths are not available :

6.20 Ejido Hombres Blancos Pozo #3
6.35 Ejido Hombres Blancos Pozo #1
6.40 L. Internacional Pozo #2
6.42 Ejido Sonoyta Papagos Pozo #2
6.43 Ejido Sonoyta Papagos Pozo #3
11.09 S.P.R. El Cumplimiento
38.04 Ejido Nueva Creacion Cajeme

SECRETARIA DE AGRICULTURA Y RECURSOS HIDRAULICOS (S.A.R.H.)

RURAL DEVELOPMENT DISTRICT No.139 CABORCA, SONORA

CENTER FOR RURAL DEVELOPMENT ASSISTANCE No.01 SONOYTA, SONORA

"AREAS CULTIVATED THROUGH 1993"

Crops	1982 Area (ha.)	%	1983 Area (ha.)	%	1984 Area (ha.)	%	1985 Area (ha.)	%	1986 Area (ha.)	%	1987 Area (ha.)	%	1988 Area (ha.)	%	1989 Area (ha.)	%	1990 Area (ha.)	%	1991 Area (ha.)	%	1992 Area (ha.)	%	1993 Area (ha.)	%
Corn	26:	2.6	16	0.2	69	0.7	78	0.8	106	1.0	182	1.6	51	0.5	79	0.7	19	0.2	53	0.5	149	1.4	115	1.0
Beans	118	1.2	17	0.2	25	0.2	189	1.9	917	9.0	39	0.4	—	—	25	0.2	100	0.9	111	1.0	4	0.0	10	0.1
Wheat	2,220	21.8	2,128	20.9	213	2.1	2,247	22.0	4,171	40.9	4,289	38.9	3,270	29.6	2,860	25.9	1,663	15.1	955	8.7	733	6.6	895	8.1
Sesame	51	0.5	346	3.4	319	3.1	117	1.1	174	1.7	549	5.0	124	1.1	90	0.8	234	2.1	30	0.3	51	0.5	—	—
Cotton	3,525	34.6	3,481	34.2	5,118	50.2	2,918	28.6	430	4.2	837	7.6	1,812	16.4	1,197	10.9	1,686	15.3	2,560	23.2	951	8.6	1,021	9.3
Vegetables	106	1.0	49	0.5	19	0.2	107	1.0	88	0.9	70	0.6	43	0.4	14	0.1	28	0.3	286	2.6	658	6.0	519	4.7
Fruits	639	6.3	1,035	10.2	1,190	11.7	959	9.4	722	7.1	644	5.8	357	3.2	232	2.1	232	2.1	170	1.5	91	0.8	86	0.8
Alfalfa	1,136	11.1	993	9.7	1,052	10.3	704	6.9	552	5.4	686	6.2	579	5.2	390	3.5	998	9.0	908	8.2	517	4.7	541	4.9
Feed	15	0.1	—	—	16	0.2	26	0.3	296	2.9	585	5.3	684	6.2	156	1.4	336	3.0	66	0.6	30	0.3	—	—
Sorghum	—	—	2	0.0	—	—	33	0.3	52	0.5	136	1.2	80	0.7	13	0.1	242	2.2	—	—	—	—	—	—
Barley	—	—	20	0.2	—	—	—	—	—	—	10	0.1	163	1.5	—	—	—	—	—	—	—	—	—	—
Safflower	—	—	—	—	—	—	—	—	—	—	—	—	13	0.1	178	1.6	—	—	—	—	—	—	10	0.1
TOTALS	8,071	79.2	8,087	79.4	8,021	78.7	7,378	72.4	7,508	73.7	8,027	72.8	7,176	65.1	5,234	47.4	5,538	50.2	5,139	46.6	3,184	28.9	3,197	29.0

The percentages refer to the area under cultivation in relation to the total irrigable area.

Irrigable Area	1982 - 1986	10,191 hectares
	1987 - 1993	11,031 hectares

Figure 62. Crop acreages in the Sonoyta agricultural district, 1982–1993.

November when all wells in the district are shut down for a period of 3 dy, after which the water levels are measured.) The other measure is the dynamic level, taken while the pumps are active. This measure provides a more realistic basis for calculations of water withdrawal based upon energy usage. Unfortunately, these figures have not been available since the original work on this project was done. Thus, the dynamic water level figures given are either old numbers, estimates, or duplications of the static levels. All of these above-stated difficulties and omissions are a continuing problem with this protocol, although the final figures continue to give a reasonable estimate of water withdrawal in the area. Table 17 gives comparisons of total energy usage, total water withdrawals—based on both sets of well depths—and total crop acreage.

Table 17. Comparative water usage and crop acreage totals for Sonoyta agricultural district, 1989–1993. (Totals for 1993 do not include December figures.)

			Water withdrawal		
Year	Crop acreage (ha)	Energy usage (kwh x 10^6)	Based on static levels (m^3 x 10^6)	Based on dynamic levels (m^3 x 10^6)	Based on dynamic levels (a-ft)
1989	5,234	42.0	111.6	87.6	71,002
1990	5,538	39.2	115.7	87.6	70,962
1991	5,139	32.8	108.0	75.2	60,910
1992	3,184	18.9	65.4	42.9	34,796
1993	3,197	18.9	59.8	41.0	33,257

One conclusion that is indicated in every category above is that agriculture has been going through a period of decline in the Sonoyta area in the last few years. From discussions with officials at SARH, it would appear that the reason is primarily the combination of low crop prices and increased production costs such as fertilizers, other chemicals, and the energy to run the pumps at the wells. In going through the electricity meter books provided by the CFE, it is clear that an increasing number of wells have had the electricity turned off due to lack of payment. Recent discussions have indicated, however, that cotton prices have climbed due to crop failures elsewhere in the world, and that the Mexican government is providing greater assistance to agricultural development in the Sonoyta area. So, although the future of agriculture in the area is uncertain, it is probably improving relative to the last few years. An additional note needs to be made that this protocol does not include data for the wells (there are now 2) used for the municipal water supply (water used for drinking, washing, industrial use, etc.). Even though agricultural water use may fluctuate, the urban population is growing, along with small industry. This trend, which will no doubt be affected by the North American Free Trade Agreement (NAFTA), will need to be addressed in future attempts to gauge water withdrawals in the Sonoyta area.

Groundwater

Introduction

In the early days of mining and ranching in ORPI, wells were drilled or dug by hand and reached depths of nearly 61 m (200 ft). Most of these wells are now dry, caved in, or sealed off from access by humans or wildlife. Some well depths were checked intermittently by park rangers, but no monitoring program existed.

In the 1960s, the Mexican government promoted irrigated agriculture on land adjacent to the ORPI border. This prompted concern over possible impacts, including (1) disruption of the flow at Quitobaquito Springs, (2) lowering of water levels in the Lukeville area, and (3) long-term effects on the water supply at monument headquarters. Because of the threat to the Organ Pipe aquifer, research and monitoring programs were initiated to measure well depths and to study the geology of Quitobaquito Springs. Resource management staff continues to contribute to this effort by measuring depth-to-water levels in monument wells 4 times per year.

Program History

In response to groundwater concerns, NPS Water Resources Division conducted a well and spring inventory at ORPI in the early 1970s and began a program of measuring water levels at selected wells to establish seasonal and long-term trends. In 1981, a program of regular monitoring of groundwater depth in wells was initiated. Fourteen wells are monitored by the U.S. Geological Survey (USGS), under contract to NPS, and/or by park staff; 6 wells are monitored by both NPS and USGS. Three observation wells were drilled by USGS in October 1988 to augment the data provided by existing historic wells on the border.

1993 Monitoring Activities

Depth-to-water measurements were made at 13 wells in January, April, July, and October.

Methods

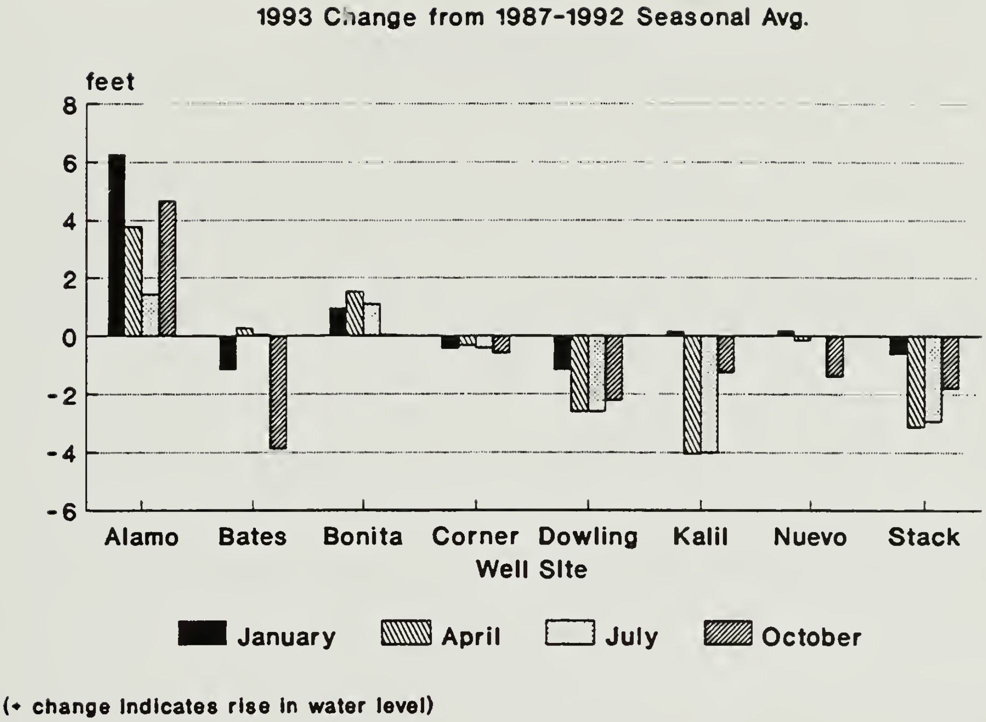
Depth-to-water is measured from a fixed reference point using a steel tape. The measurements are recorded in a field book and later entered into a Lotus 1-2-3 spreadsheet.

Results

All the wells were checked, on schedule, in 1993. Monitoring of the Pozo Salado well was discontinued at the end of 1993 because it had collapsed. In January, all of the wells (except for the USGS test wells) were measured for depth to the well bottom. These measurements confirmed that Pozo Salado had indeed collapsed, with the current bottom level 3 m (10 ft) above the historic average water level. Table 18 shows depth-to-water measurements for all but the USGS test wells. Figure 63 illustrates ORPI well depths (for non-dry wells) and graphs standard deviations from average seasonal water levels for all but the USGS test wells.

Table 18. Depth-to-water measurements (ft) at Organ Pipe Cactus National Monument wells, 1993. Approximate depth of hole is also included.

Well	1993 Depth-to-water (ft)				Approximate Depth of Hole (ft)
	January	April	July	October	
Alamo	1.70	3.66	7.70	4.75	17
Bates	31.95	31.12	32.51	34.02	67
Bonita	26.33	25.70	26.44	26.97	36
Corner	59.94	59.75	60.08	60.30	97
Dowling	83.47	86.33	86.94	85.86	137
Hocker	16.19	16.44	Dry	Dry	18
Kalil	78.59	86.35	86.87	81.91	187
Nuevo	42.53	42.46	43.14	43.67	134
Stack	99.89	104.59	105.02	102.51	206



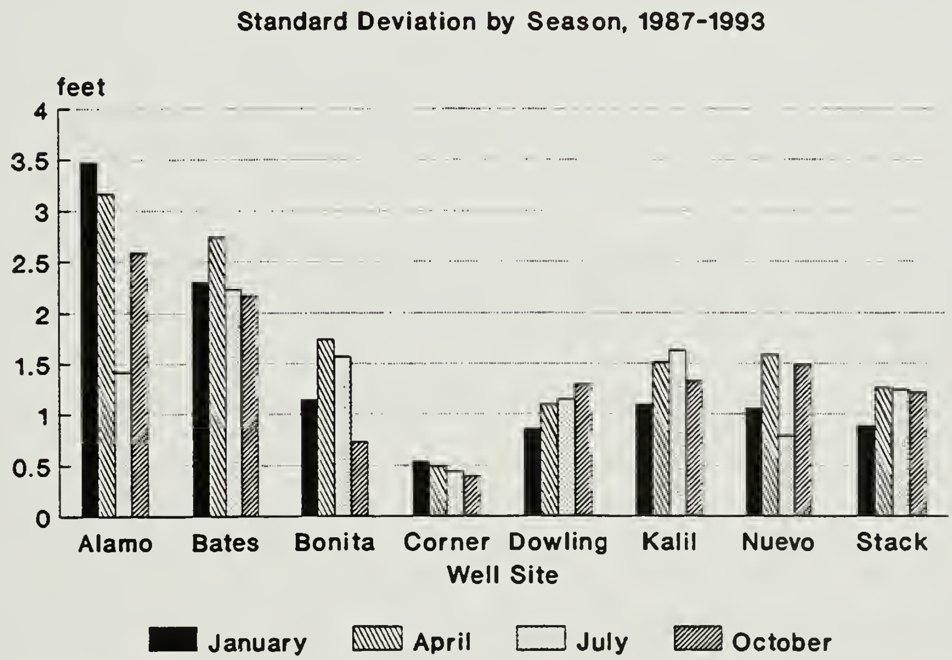


Figure 63. Organ Pipe Cactus National Monument well depths (for non-dry wells) and standard deviations from average seasonal water levels for all but the U.S. Geographical Survey test wells.

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