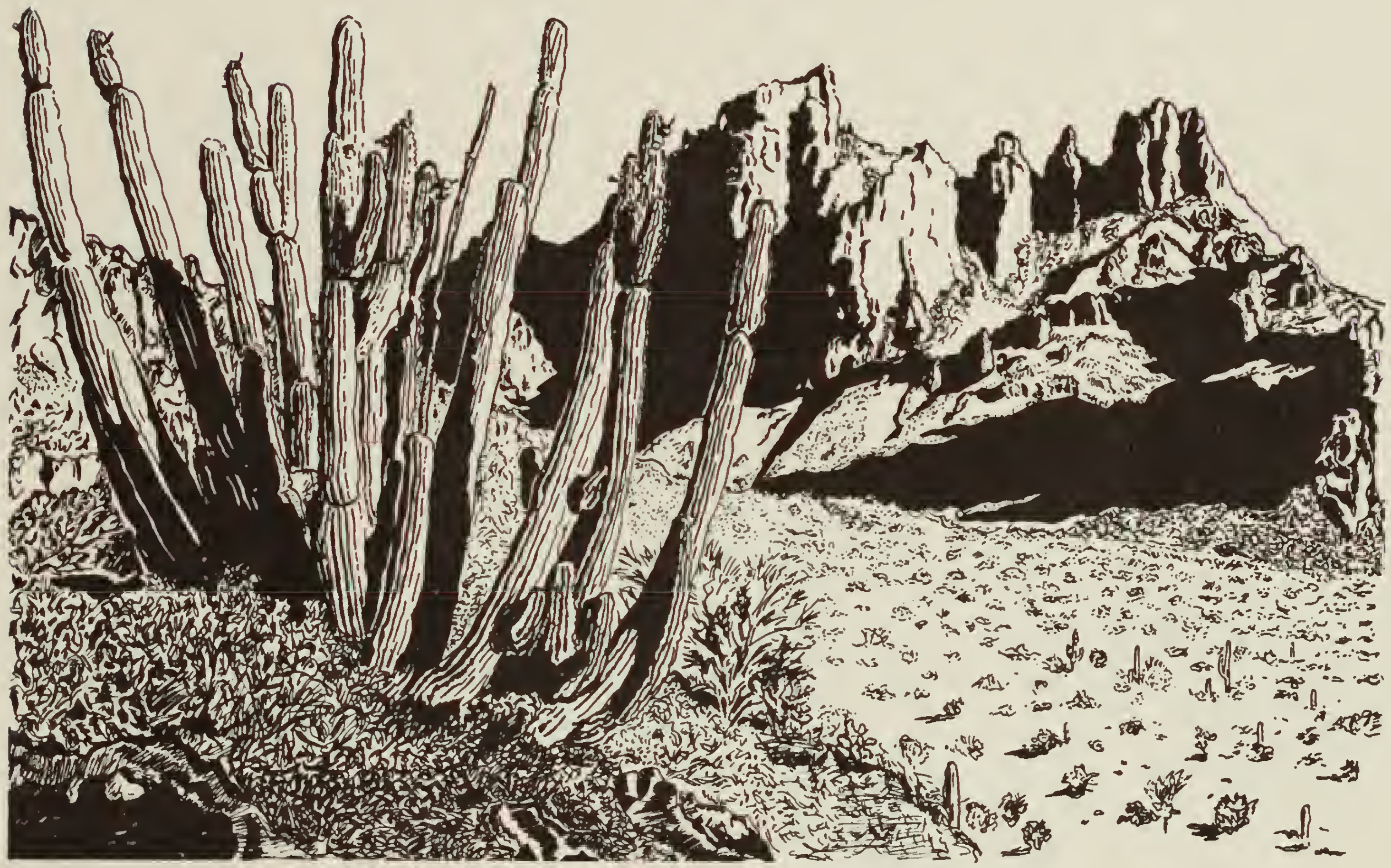
Organ Pipe Cactus National Monument Ecological Monitoring Program Annual Report 1995

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



United States Department of the Interior
United States Geological Survey
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 1995

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June 1998

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The Cooperative Park Studies Unit at the University of Arizona (CPSU/UA) was established 16 August 1993 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. On 1 October 1996, NBS became the Biological Resources Division of the U.S. Geological Survey.

As the nation's largest water, earth, and biological science and civilian mapping agency, the USGS works in cooperation with more than 2,000 organizations across the country to provide reliable, impartial, scientific information to resource managers, planners, and other customers. This information is gathered in every state by USGS scientists to minimize the loss of life and property from natural disasters, contribute to sound economic and physical development of the nation's natural resources, and enhance the quality of life by monitoring water, biological, energy, and mineral resources.

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 of 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 USGS personnel and cooperators. Mention of trade names or commercial products does not constitute endorsement or use by USGS.

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, USGS–CPSU/UA, 125 Biological Sciences East. The University of Arizona, Tucson, AZ 85721.

*This list does not include personnel who contributed to the Ecological Monitoring Program in 1995 but no longer work at Organ Pipe Cactus National Monument: Harold J. Smith (Superintendent), James J. Barnett (Chief, Resources Management), Jonathan F. Arnold (Ecologist), and Dennis Casper (Biological Science Technician).

This report was printed on recycled paper.

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Introduction

Organ Pipe Cactus National Monument (OPCNM), established in 1937, is located in southwestern Arizona and is geographically near the center of the Sonoran Desert. The monument encompasses 133,830 ha, of which 95% is designated wilderness. On 26 October 1976, the United Nations Education, Scientific, and Cultural Organization (UNESCO) recognized and designated OPCNM 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 bush plains. Although originally conceived as a monument to preserve a unique species of columnar cactus, OPCNM 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, OPCNM 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 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 is twice the rate of recharge (Great Western Research 1988). Other concerns to OPCNM 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 desert ecosystems in the monument.

Sensitive Habitats Project

With growing outside threats to the monument in the 1980s, park managers recognized the need to initiate a program that could provide insight about the condition of the ecosystem at OPCNM. The first set of projects to meet this goal was known as the Sensitive Habitats Project, 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 OPCNM Ecosystems, (2) Inventory of OPCNM Herpetofauna, (3) Survey of OPCNM 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 occurring there were near the edge of their geographical distribution limits, thus 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.

Modeled after the successful Channel Islands Inventory and Monitoring Initiative, step-down planning was used to efficiently organize the management goals and objectives of the program. Step-down planning requires 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 OPCNM ecosystems, (2) alternatives available for ecosystem management, and (3) the effectiveness of implemented action programs. Steps 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 these 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 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
R. Roy Johnson designed this study to provide information about the distribution and relative abundance of the monument's birds, with special emphasis on the breeding birds in the vicinity of the permanent study sites.

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

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 indicators of herpetofaunal health in the long-term monitoring effort.

Inventory and Assessment: Nonnative Vegetation

Richard Felger identified 62 species of vascular plants, located in or adjacent to the monument, as possibly nonnative. This represents about 11% of the park flora, which may be an over-estimation because (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

The intent of Yar Petryszyn's study 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

In this project, designed by George Ruffner, a detailed study was made 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

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. Peter Warren reread these existing vegetation plots and rephotographed the photo points. In addition, nocturnal rodent populations were resampled 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 OPCNM resource management staff. Combinations of the following parameters are measured at the sites: precipitation, relative humidity, wind speed and direction, air temperature at 2 heights, soil temperature, and 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

Peter Warren examined and documented plant community patterns along the park boundary to determine the cross-boundary effects of changes outside the monument on plant communities within the monument. Patterns of plant community composition and distribution within 2 km of all boundaries were examined.

Vegetation Structure and Diversity in Natural Communities

In this project, Charles H. Lowe 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 permanent quadrats located at each SEP study site. The same parameters were measured for ephemeral plant species on 1.0-m^2 quadrats. Quantitative data from this study and the resulting long-term monitoring protocols will provide both intersite 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

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 spring 1994, the title SEP was changed to the Ecological Monitoring Program (EMP) to reflect a change from the historic focus on "sensitive" areas to a broader look at the ecosystem's many components. As a result of the EMP, OPCNM 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, the EMP has already affected monument management. Development of the OPCNM 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 are shared on land use trends, water usage and development, pesticide and herbicide use, and other concerns.

Information Management

After 9 years of baseline data acquired as part of the 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, 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 the status of resources 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 Assistance Committee (EMPAC)

In October 1993, the first EMPAC meeting 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 OPCNM, and to direct progress toward the synthesis of the program. Committee activities include assessing the history of the program and providing guidance for future direction, examining and critiquing completed research and monitoring protocols, providing recommendations for future baseline studies and advanced specialized research, evaluating results of current monitoring (and suggesting modifications, if needed), developing strategies for integration and synthesis, and examining alternative methods for data management and linkages with GIS.

In 1995, the committee assisted with the selection of 2 new Core I EMP sites and placement of nocturnal rodent and vegetation quadrats and lizard transects at these sites. Also in 1995, the committee met with resources management staff to discuss issues related to vegetation monitoring protocols, weather station placement, and the logistics of installing soil moisture and soil temperature probes at weather stations.

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 to 126 ha. Sites were selected to meet the goal of representing the various ecological communities of the monument. In addition, some sites on the south boundary were selected 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 (cores), based on the level of importance for monitoring. Since the original research projects, new sites have been added to the program.

At a 1994 EMPAC meeting, the sites were evaluated in terms of habitat representation, redundancy, logistics, and monitoring data collected to date. The committee decided that 2 habitat types lacked representation: middle bajada and valley bottom. Two new study sites in those habitats were chosen and in 1995 added to the monitoring program. The following study site descriptions are broken into the current core designations. At Core I sites, the full monitoring program is carried out. These sites contain bird and lizard transects, vegetation quadrats, nocturnal rodent grids, and have an automated climate station either on site or nearby. Non-Core I sites have second priority in the monitoring program and only rainfall data are collected at most of these sites.

Core I Sites

Aguajita

Elevation ca. 735 m. This site incorporates Aguajita Wash and adjacent uplands. Aguajita Wash is a large wash that drains much of the south half of the monument. *Prosopis velutina* riparian woodland and *P. velutina—Cercidium floridum* subassociation are the 2 main vegetation types. *Atamisquea emarginata* reaches its northern geographic limits here. The upland sites are dominated by an *Atriplex polycarpa—Atriplex linearis—Prosopis velutina* subassociation.

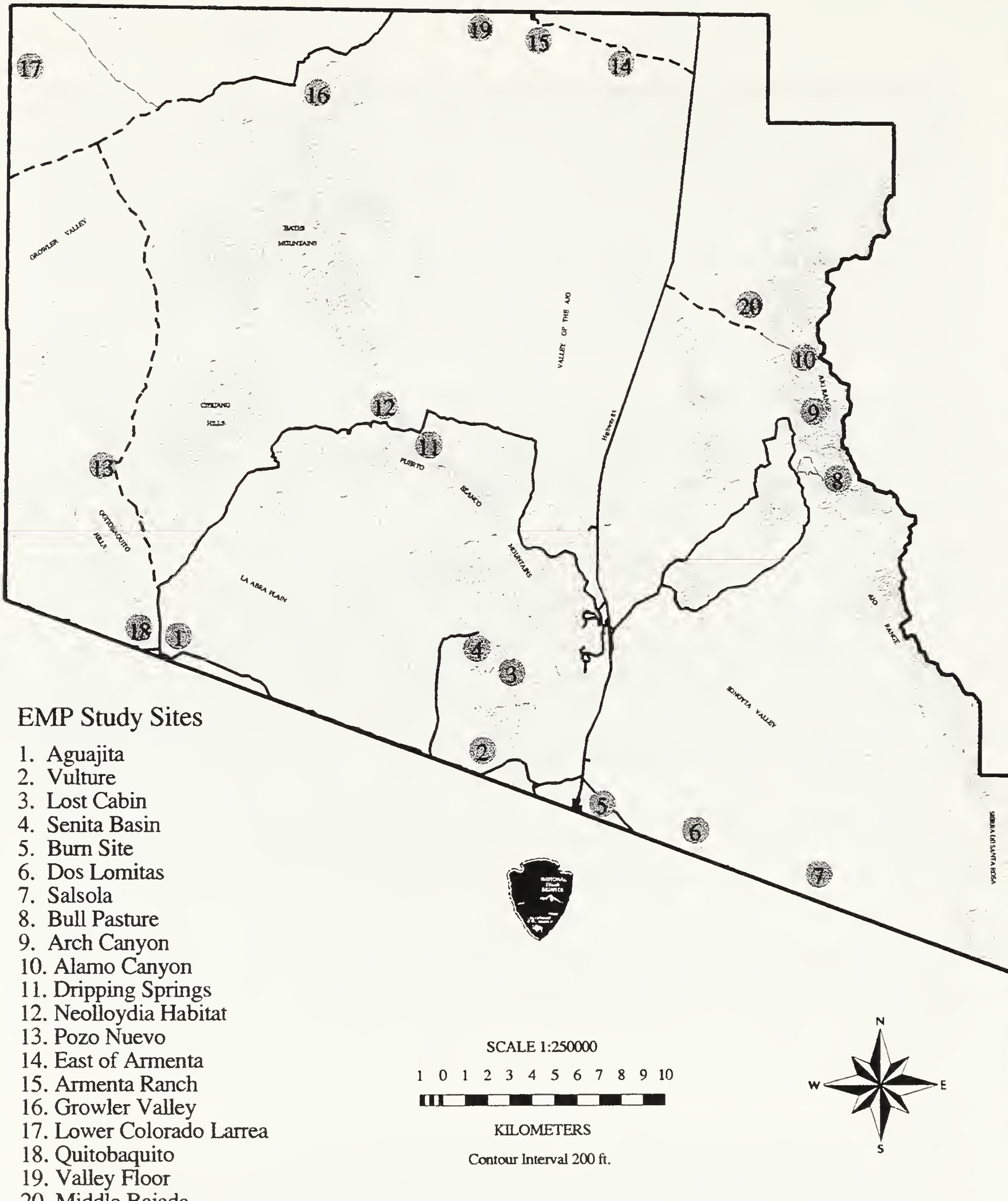


Figure 1. Map of Ecological Monitoring Program study sites in Organ Pipe Cactus National Monument.

Alamo Canyon

Elevation ca. 900 m. This site is located in a steep, narrow canyon dissecting the Ajo Mountains. Soil is sandy with scattered cobbles and large boulders. *Quercus turbinella* var. *ajoensis* (= *Q. ajoensis*) mixed scrub subassociation, with *Vauquelinia californica, Acacia greggii*, and *Simmondsia chinensis* are characteristic species in the riparian zone. Upland species diversity is high due to the relatively mesic environment, diverse surrounding habitats, and topographic relief.

Dos Lomitas

Elevation ca. 487 m. This site is adjacent to the International Boundary, east of Lukeville. Livestock grazing and other environmental disturbances have occurred at this site in the past, causing plant community collapse and severe soil erosion. The vegetation association prior to this degradation is unknown, but probably included *Atriplex polycarpa, Atriplex linearis, Larrea tridentata,* and *Prosopis velutina*. These species are currently colonizing the area.

East Armenta

Elevation 480 m. This nearly level site supports a *Larrea tridentata—Pleuraphis rigida—Prosopis velutina* floodplain subassociation on a sandy loam. Erosion has cut a few gullies in the vicinity of the site, but may not yet have significantly lowered the water table.

Growler Canyon

Elevation ca. 420 m. This site is located in a wide canyon that trends east to west in the northern end of the Bates Mountains. Groundwater is near the surface because of the confluence of 2 large washes just east of the canyon. Soil is deep, silty, and easily detached. The vegetation is *Prosopis velutina* riparian woodland subassociation. The area has one of the longest-documented histories of overuse by livestock anywhere in the monument.

Lower Colorado Larrea

Elevation ca. 335 m. This site is located in the northwest corner of the monument, near the boundary of the Cabeza Prieta National Wildlife Refuge. It contains fine, silty soils with a *Larrea tridentata—Ambrosia dumosa* vegetation subassociation.

Middle Bajada

Elevation ca. 630 m. This new Core I site is located on the middle bajada of the western-facing slope of the Ajo Mountains, to the north of the Alamo Canyon Road. The vegetation on the slopes is an *Ambrosia deltoidea—Cercidium microphyllum*—mixed cactus association. The bajada is deeply dissected by drainages, which are lined with xeroriparian zones dominated by *Acacia constricta, Cercidium microphyllum, Simmondsia chinensis, Lycium berlandieri*, and *Brickellia coulteri.* The site is nearly level, sloping slightly to the northwest. The soil is in the Cipriano Series, a very gravelly loam underlain by a duripan.

Pozo Nuevo

Elevation ca. 380 m. This site is located near the western boundary of the monument, and is situated on fine sandy loam and cobbley sandy loam soils. The vegetation classification is *Larrea tridentata—Ambrosia dumosa* association.

Senita Basin

Elevation ca. 510 m. This site includes a north-facing slope, a south-facing slope, and level ground. It remains frost-free most of the year. The vegetation types are the 3 most-frost-sensitive ones: *Cercidium microphyllum—Encelia farinosa—Stenocereus thurberi—Jatropha cuneata* hillside subassociation, *Cercidium microphyllum—Encelia farinosa—Stenocereus thurberi—Bursera microphylla* subassociation, and *Cercidium microphyllum—Ambrosia deltoidea—Cereus thurberi* with *Jatropha* spp. subassociation. Soils vary from deep alluvium to bare rock.

Valley Floor

Elevation ca. 450 m. This new Core I site is located in the Valley of the Ajo and encloses one channel of Kuakatch Wash. This and other drainages in the area are shallow and during the summer floodwaters often breach channels. The soil at the site is a deep and well-drained, very–fine sandy loam in the Gilman Series. The vegetation along the channels is dominated by *Prosopis velutina, Olneya tesota*, and *Cercidium microphyllum* with a prominent vine component *(Clematis drummondii, Sarcostemma cynanchoides, Aristolochia watsonii).* Areas between drainages are dominated by *Larrea tridentata, Muhlenbergia porteri,* and annuals. *Dipodomys deserti* (desert kangaroo rat) plays an important role in patterning the latter plant association.

Non-Core I Sites

Arch Canyon

Elevation ca. 915 m. Arch Canyon is a west-facing canyon located in the Ajo Mountains. One perennial vegetation quadrat is located on a steep, north-facing drainage in a rocky side canyon below the arch. Vegetation is characterized by dense thickets of large, sclerophyllous shrubs, 1–2 meters in height. The dominant shrub is *Simmondsia chinensis.* The other vegetation quadrat is located across the canyon on a steep slope with a southern exposure. The dominants on this quadrat were various grass species, *Simmondsia chinensis, Ambrosia deltoidea, A. cordifolia,* and *Encelia farinosa.*

Armenta Ranch

Elevation ca. 480 m. This site is located on a severely degraded site acquired by NPS in the 1970s. Prior to its incorporation in the monument, the area was overgrazed for decades, vegetation was cleared for housing and farming, and fuelwood was harvested. These uses led to the severe erosion that continues today. The water table is presumed to have dropped dramatically due to gullying, resulting in the widespread death of deep-rooted plants. The soil is classified as a Gilman Series sandy loam. The vegetation subassociation is *Larrea tridentata—Prosopis velutina* floodplain.

Bull Pasture

Elevation ca. 920 m. This site is located on a mid-elevation bench below the higher peaks of the Ajo Mountains, at the headwaters of Estes Canyon. The area is dissected by 2 drainages, 1 shallow without permanent water and the other deeper and fed by a spring. Soils are very shallow and rocky. The vegetation subassociation is *Simmondsia chinensis—Viguiera deltoidea—Fouquieria splendens.* Subassociations vary depending on the slope and exposure. *Juniperus coahuilensis* is found in drainages.

Burn Site

Elevation ca. 420 m. This severely disturbed site is situated near the International Boundary east of Lukeville. The area was severely overgrazed until 1979, and various soil erosion control structures were built in the 1950s to 1960s. The recovering vegetation burned in 1983. The potential plant association throughout most of the site was probably dominated by *Larrea tridentata, Ambrosia deltoidea, Atriplex polycarpa,* and *Atriplex linearis.*

Dripping Springs

Elevation ca. 650 m. This site is located in a steep, north-facing slope in the Puerto Blanco Mountains 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 include *Simmondsia chinensis, Coursetia glandulosa, Viguiera deltoidea*, and *Fouquieria splendens.*

Lost Cabin

Elevation ca. 500 m. This site incorporates floodplain and upper rocky slope habitats. Like the nearby Senita Basin EMP site, it is frost-free most of the year. The vegetation association is *Cercidium microphyllum—Ambrosia deltoidea—Stenocereus thurberi—Jatropha* spp.

Neolloydia Habitat

Elevation ca. 500 m. This site includes habitat for the rare cactus *Echinomastus erectocentrus* var. *acunensis*. The plants occur on level, 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, and the plants prefer to grow in cracks in the fractured granite bedrock. The vegetation association is *Ambrosia deltoidea—Cercidium microphyllum* pediment subassociation.

Quitobaquito

Elevation ca. 330 m. This site incorporates a spring-fed channel and pond surrounded by a mesquite bosque with a dense shrub layer consisting mostly of *Lycium fremontii*. The littoral zone around the perimeter of the pond is occupied by *Scirpus americanus.* Surrounding the mesquite bosque is a plant association dominated by *Atriplex polycarpa, Atriplex linearis*, and *Suaeda moquinii (=S. torreyana). Pluchea sericea* dominates the spring heads and *Distichlis spicata* carpets the salty, wet, open areas. This diverse system continues to recover from past human occupation and livestock grazing.

Salsola

Elevation ca. 500 m. This site is located adjacent to the International Boundary on silty floodplain soil. *Larrea tridentata—Ambrosia* spp. subassociation and *Larrea tridentata—Prosopis velutina* floodplain subassociation. The understory in the floodplain is dominated by the weedy nonnative plants *Salsola australis* and *Amaranthus palmeri.* The composition of this community has been profoundly altered by erosion, fire, nonnative plants, and past overgrazing and woodcutting.

Vulture

Elevation ca. 450 m. This site is located adjacent to the International Border on sandy cobbley soil. It lies on the bajada of the Sonoyta Mountains and is transversely dissected by a fourth-order wash. The site was named after a colony of roosting black vultures *(Corahyps atratus)*, a species that is at its northern range limit in southern Arizona. Along the shallow wash channels, the xeroriparian plant community is dominated by *Cercidium microphyllum, Olneya tesota,* and a diversity of shrubs and sub-shrubs. Outside the narrow riparian corridor, the vegetation is dominated by *Larrea tridentata* and *Ambrosia deltoidea.*

Ecological Monitoring Program Annual Report

Annual reports of Organ Pipe Cactus National Monument's EMP will summarize monitoring activities completed and data collected. They will follow a similar format from year to year. For each monitoring protocol the following will be provided: introduction, project history, summary of monitoring activities, methods, and results. Simple data summaries in tabular and graphic format will also be provided.

In the 1995 final report that follows here, monitoring activities are divided into 3 sections: (1) vegetation, (2) wildlife, and (3) physical environment. Table 1 shows the hours spent in each monitoring activity.

Results from 1995 monitoring of Vegetation Structure and Diversity perennial vegetation plots will be summarized in a future separate report.

Table 1. Hours spent by Organ Pipe Cactus National Monument staff and volunteers in Ecological Monitoring Program activities during 1995. "Office hours" include administration, data management and report writing.

1995 EMP activity	Field hours	Office hours	Total
Climate	333.0	190.5	523.5
Vegetation structure & diversity	363.0	53.0	416.0
Nocturnal rodents	352.5	26.5	379.0
Acuña cactus *(Echinomastus eretocentrus* var. *acunensis)*	209.0	37.0	246.0
Lizards	194.5	16.0	210.5
EMP report editing	--	160.0	160.0
Birds	96.5	49.0	145.5
Air quality	115.0	29.0	144.0
Organ pipe cactus *(Stenocereus thurberi)* and Senita cactus *(Lophocereus schotti)*	72.5	47.5	120.0
Bats	103.0	12.5	115.5
EMP technical report publication administration	--	96.0	96.0
Ecological Monitoring Program Assistance Committee meetings	--	90.0	90.0
Desert pupfish *(Cyprinodon macularius eremus)*	58.0	6.0	64.0
Groundwater	51.0	4.0	55.0
EMP administration	--	45.5	45.5
Lesser long-nosed bat *(Leptonycteris curasoae)*	33.0	8.0	41.0
Land use trends	21.5	9.0	30.5
EMP integrated database development	--	24.0	24.0
Dahlia-rooted cactus *(Peniocereus striatus)*	5.0	0.0	5.0
Total	2,007.5	903.5	2,911.0

Acuña Cactus

Introduction

Organ Pipe Cactus National Monument (OPCNM) contains 1 of only 5 known populations of acuña cactus *(Echinomastus erectocentrus* var. *acunensis).* Four populations are known from Arizona and a fifth occurs in nearby Sonora, Mexico. Of the 4 populations in Arizona, 1 occurs on private land, 2 occur on Federal land, and 1 occurs on a mixture of state, federal, and private lands. Since 1988, the population of acuña cactus on the monument has been monitored for growth, reproduction, and mortality. Data gathered in this project will aid in gaining an understanding of population dynamics and the relationship between rainfall and patterns of mortality and establishment.

Project History

In the late 1970s, William Buskirk and students from Earlham College, Indiana, developed a protocol to monitor acuña cacti at OPCNM, primarily to detect theft of the highly valued cactus. They established 4 permanent plots, 2 plots very close to the Puerto Blanco Loop Drive and 2 plots farther away from the road.

Although the monitoring efforts of Earlham College brought a greater knowledge and understanding of the species, its basic biology and population dynamics remained poorly understood. Meanwhile, the decline of the other 3 acuña populations in the United States prompted the U.S. Fish and Wildlife Service (USFWS) to identify the cactus as a category 1 candidate species, a category that includes species under consideration for listing as threatened or endangered under the Endangered Species Act (ESA). Good biological and ecological information will help the USFWS decide whether or not the species should be protected under the ESA.

This knowledge is presently being obtained as a result of the upgraded acuña monitoring protocol titled "Special-status Plants Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument," developed during the SEP project (Ruffner Associates 1995). The protocol was designed to collect more complete autecological and demographic data for the species. Two additional permanent plots were added during this phase. By collecting long-term demographic information, the monument should be able to monitor the stability of the population. By comparing the demographic statistics of the 3 plots near the road to the 3 plots farther away from the road, the monument may be able to determine if illegal collection is harming the population.

Monitoring efforts using the established protocol began in 1988 and have continued annually. Based on the first few years of data, the principal investigators have produced a paper titled "Seedling Establishment, Mortality, and Flower Production of the Acuña Cactus" (Johnson et al. 1993).

1995 Monitoring Activities

From 4–6 March, OPCNM staff carried out the acuña monitoring protocol. Kathy Hiett, biological science technician with the Biological Resources Division of the U.S. Geological Survey, also assisted in the monitoring effort. This monitoring included measuring all tagged plants, counting flowers and buds, and searching for new seedlings.

Methods

As in previous years, the March 1995 field activities consisted of locating and measuring all previously tagged and mapped individuals on the 6 0.1-ha (20 x 50 m) permanent plots. At the same time, an intensive and systematic search was made within half of the area of each plot to locate seedlings—plants that probably had germinated since the last monitoring activity ("new recruits"), or young pre-reproductive plants that had been alive during the previous census but had escaped detection ("newly discovered juveniles"). (In previous years, this seedling search covered the entire area of the 6 0.1-ha plots.) The plots were cordoned off into 2 x 20-m 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 corner point ("origin") of the plot.

Reproductive condition of the plants was assessed later, at the peak of flowering. Flower/bud counts were made during the March monitoring session and again on 4 April, and the higher of the 2 counts for the individual plants was used to assess reproductive effort.

Results

Table 2 summarizes 1995 reproduction, growth, and mortality for all 6 acuña cactus plots. Table 3 and Figures 2–3 show size frequency distribution. Figures 4–5 summarize 1989–1995 acuña reproductive activity. Table 4 presents recruitment data for all plots.

The data collected since 1988 indicate that during most years acuña cactus has low frequency recruitment punctuated by episodes of good or abundant recruitment years (Table 3). Species with such "episodic" recruitment have frequency distributions showing 1 or more pulses, each pulse representing a good recruitment year (cohort). This monitoring project documented the establishment of a large cohort of acuña cactus in 1990 and 1991, 2 years with abundant late-summer rainfall. The primary germination period is during the summer monsoon. The 1990 and 1991 pulses of recruitment should be visible in the frequency distributions of the 6 plots, assuming that environmental conditions did not cause unusually high mortality of either cohort.

The frequency distributions of acuña cactus in all 6 monitoring plots combined (Fig. 2) were not consistent with the finding of episodic recruitment in the species (Table 4). The cohorts should have been in the 1- to 10-mm or possibly the 11- to 20-mm size class in 1995. Plots 1 and 5 and possibly plot 3 showed peaks in these size classes, but the 1990 and 1991 cohorts were not obvious in the frequency distributions for plots 0, 2, and 4. Plot 1 had a "J-shaped" frequency distribution, which is typical of species having nearly constant recruitment.

Table 2. Acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* reproduction, growth, and mortality for the Ecological Monitoring Program at Organ Pipe Cactus National Monument, Arizona, 1995. Mean height, growth, and mortality figures are based on 1994 size classes.

	Number of plants, all plots combined				
Size class (height in mm)	Total plants, 1994	Mortalities, 1994–1995	Total plants, 1995	Plants with flowers, 1995	Mean growth (mm), 1994–1995
1–10	100	26	108	0	2.72
11–20	51	3	54	0	5.00
21–30	29	0	33	0	8.72
31–40	21	0	20	0	9.57
41–50	17	0	19	8	8.59
51–60	17	2	21	14	8.53
61–70	15	0	12	11	7.67
71–80	20	2	18	18	11.44
81–90	11	1	11	10	14.20
91–100	14	2	8	8	13.83
101–110	4	1	10	9	18.67
111–120	5	0	10	9	18.20
121–130	9	1	6	6	9.38
131–140	5	1	11	10	8.75
141–150	7	2	4	4	-2.80
151–160	3	0	1	1	10.00
161–170	3	0	2	2	28.67
171–180	1	0	1	1	12.00
181–190	2	0	5	5	-6.00
191–200+	0	--	2	2	--
Total	334	41	356	118	--

Table 3. Comparison of acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* size distribution for all acuña monitoring plots in Organ Pipe Cactus National Monument, Arizona, 1988–1995.

Height Class (mm)	Census Year							
	1988	1989	1990	1991	1992	1993	1994	1995
1–30	114	168	181	281	249	198	180	195
31–60	58	49	65	54	47	53	55	60
61–90	35	39	39	38	43	38	46	41
91–120	28	30	25	34	37	28	23	28
121–150	10	11	11	25	24	17	21	21
151–180	2	3	2	9	13	9	7	4
181–210+	1	1	1	5	4	2	2	7
Total	248	301	324	446	417	345	334	356

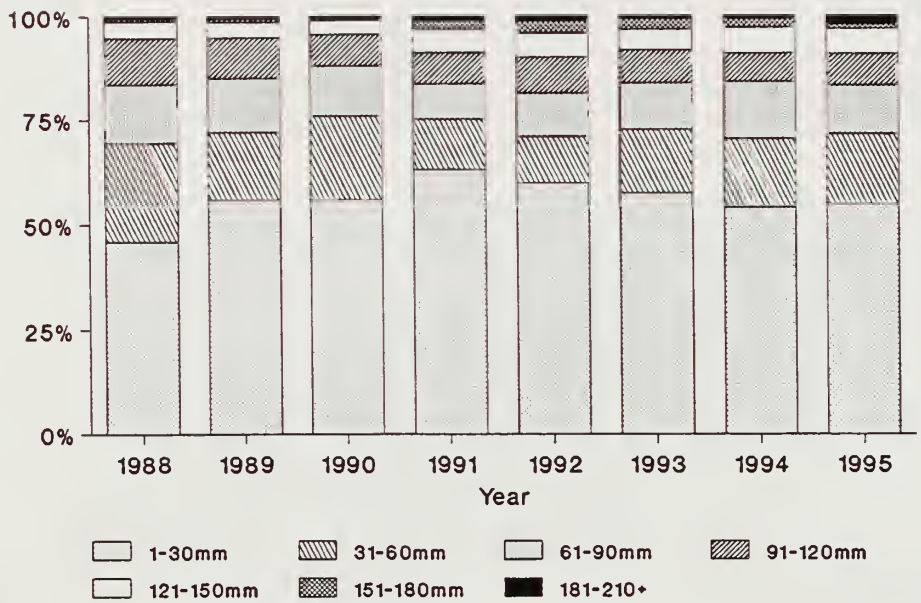


Figure 2. Size (height) distribution percentages of acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* plants for all acuña cactus monitoring plots at Organ Pipe Cactus National Monument, Arizona, 1988–1995.

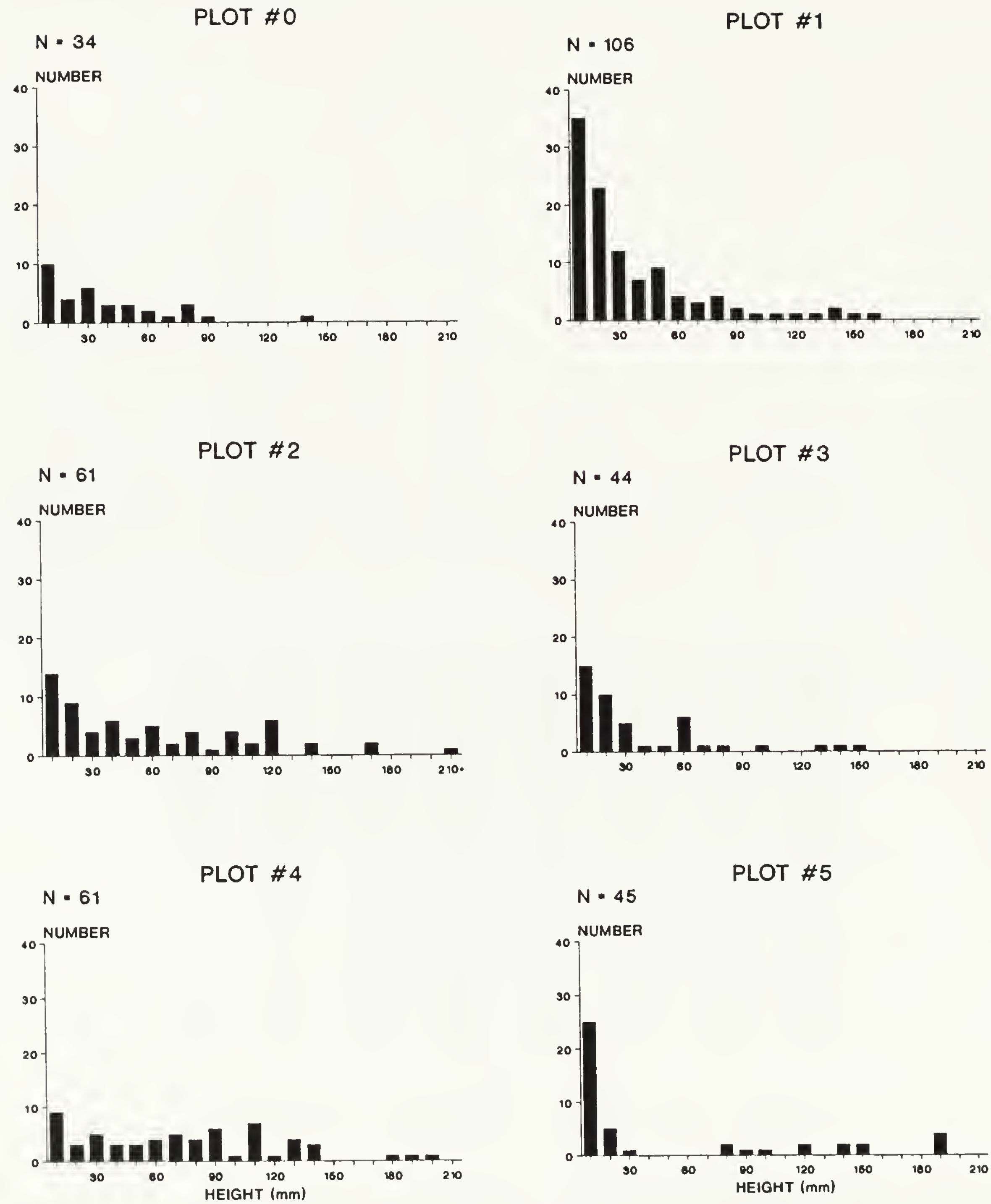


Figure 3. Size (height) frequency distribution of acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* plants, by acuña cactus monitoring plot at Organ Pipe Cactus National Monument, Arizona, 1995.

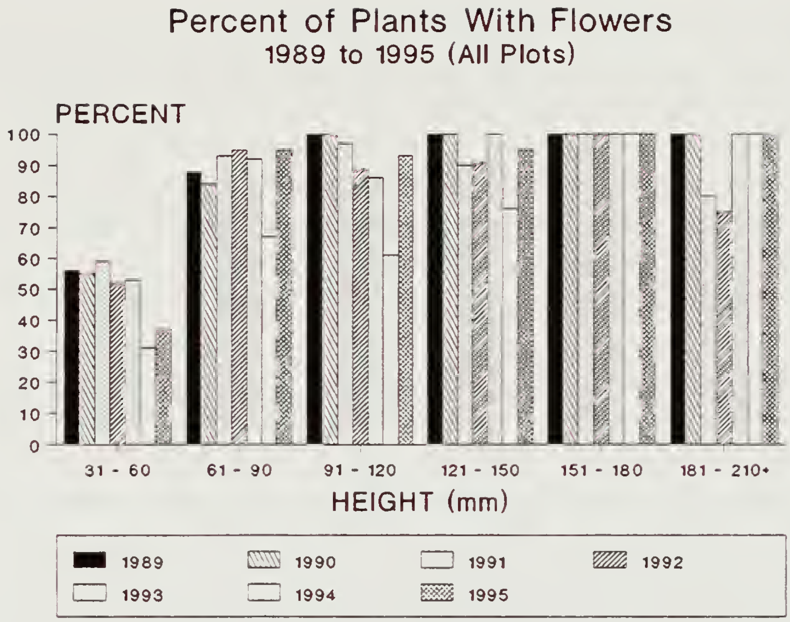


Figure 4. Percentage of acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* plants with flowers, by size class, for all acuña cactus monitoring plots at Organ Pipe Cactus National Monument, Arizona, 1989–1995.

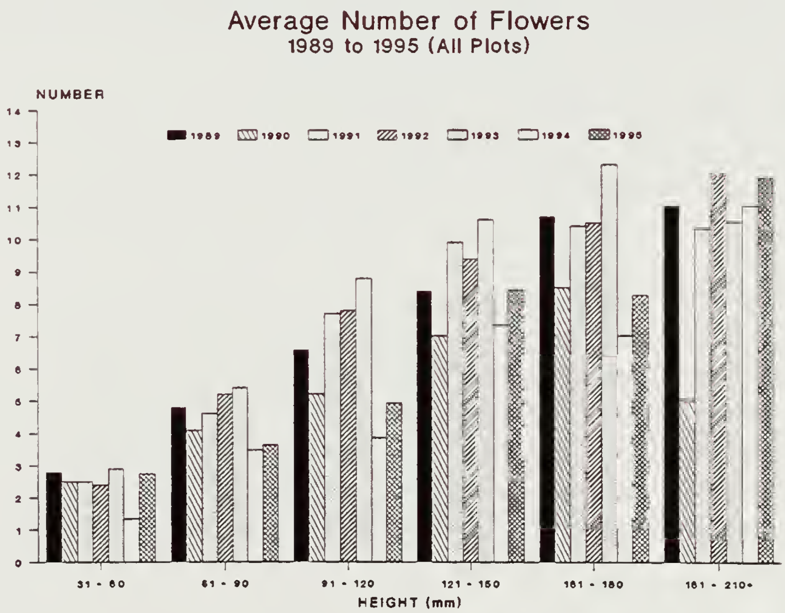


Figure 5. Average number of flowers on acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* plants, for all acuña monitoring plots at Organ Pipe Cactus National Monument, Arizona, 1989–1995.

Table 4. The number of new recruits and newly discovered juveniles found in each acuña cactus *(Echinomastus erectocentrus* var. *acunensis)* monitoring plot during each year of census at Organ Pipe Cactus National Monument, Arizona, 1989–1995. New recruits were small plants that are less than 5- to 6-mm wide and less than 5- to 6-mm tall. Newly discovered plants were generally greater than 5- to 6-mm wide and greater than 5- to 6-mm tall. Most newly discovered plants were those which had germinated in the previous year, but escaped detection. Total area surveyed was 600 m^2.

Plot number	Number of new recruits / number of newly discovered juveniles						
	1989	1990	1991	1992	1993	1994	1995
0	1/11	0/7	1/8	0/5	0/2	0/0	4/3
1	3/5	0/6	18/33	0/6	5/6	3/2	8/7
2	1/0	0/0	2/1	0/1	4/0	5/2	2/6
3	17/15	6/2	2/10	0/9	0/5	1/4	0/5
4	3/5	0/8	8/6	1/2	4/3	2/1	2/1
5	4/3	2/2	21/9	2/13	15/3	12/9	12/9
Total	29/39	8/25	52/67	3/36	28/19	23/18	28/31

The "disappearance" of the cohorts was puzzling. It could be explained by the relatively small number of plants sampled or by above-average mortality in the smallest size class. The passage of time and the collection of more years of data may help us understand these results.

Each plot had a different height frequency distribution. Between-plot differences in demographics are not uncommon in plant populations. Subpopulations in local areas may increase and decline, while the population as a whole is stable. Another explanation for the between-plot differences in the frequency distributions could be the effect of illegal collecting.

Illegal collection of acuña cactus plants continues to occur. At least 3 plants were illegally taken from the plots in 1995. The threat of illegal collection has been difficult to quantify because it has been difficult to confidently determine that collecting was the cause of mortality, particularly if the plant was collected several months before a spring census. Clear signs that a plant had been stolen were a shallow hole in the ground and the individually numbered tag left at or near the plotted location of the plant. Animal herbivory does not leave the same type of evidence. Often no sign of the plant or its tag remained; in these cases the cause of mortality was impossible to determine. Collectors appeared to target plants larger than 40 mm, probably because these plants are reproductive (flowers make the plants easily visible) and they have an attractive height-to-width ratio.

The future of the population will rely on plants that are 41- to 110-mm tall because these plants produce the majority of all seeds produced in the population in a given year (Table 2, Figs. 4 and 5) and will continue to reproduce for many additional years. Plants 30- to 41-mm tall can reproduce (Fig. 4), but they generally produce few flowers (Fig. 5). Plants larger than 110 mm produce a large number of flowers (Fig. 5), but these plants are uncommon (Fig. 3). The frequency distribution of plot 1 illustrates the positive relationship between the number of plants in the 41- to 110-mm size class and the number of recruits. Plot 1 contains the largest number of plants in the 41- to 110-mm size class and also has the largest number of seedlings and juveniles. If illegal collecting continues to occur and continues to target plants that are critical to population stability, population decline is likely to occur.

The data from plots 0 and 3 (Fig. 3) may illustrate a local decline in plant density caused by illegal collecting or other cause of mortality that was size-specific. These two plots had the lowest density of all plots, despite being located near the core of the population. They also had very few plants greater than 100 mm, indicating that either large plants were selectively collected or smaller plants in their reproductive prime were taken in the past. Plots 0 and 3 were located within the core of the population and were near the road where the cacti can be easily seen by passing visitors. Plot 0 was next to a pullout that was closed nearly a decade ago to control collecting. Plot 3 is immediately adjacent to the road.

The frequency distribution for plot 5 (Fig. 3) might also be interpreted as a population in decline because it showed a near lack of plants in the prime reproductive size classes of 40- to 70-mm tall. However, no collecting has ever been recorded in this plot, which was located on the western fringe of the population at some distance from the road. Its frequency distribution more likely illustrates the effects of marginal habitat or location on survival and reproduction than of illegal collecting.

The frequency distribution for plot 2 (Fig. 3) was difficult to interpret. Like plots 0 and 3, plot 2 was located near the population core, but it received heavier visitation and presumably illegal collecting because it was immediately adjacent to an interpretive pullout (since closed) that bore the acuña name. The frequency distribution of plot 2 most closely resembled that of plot 4, which is located on the eastern fringe of the population. The less-than-expected number of plants in the smallest size class may be caused by the degraded condition of the site causing a high mortality of new germinants and seedlings or by some other unfavorable biotic or abiotic factor.

If a demographic model of this population is created in the future, between-plot comparisons of size-class survivorship should be made. Experimental models should be developed that will test the effect of various levels of illegal collecting pressure on different size-classes of plants.

There were 28 new seedlings found in 1995 (Table 4). This number was unexceptional and was not considered to be an "episodic" year.

Almost all plants that were of reproductive size (height) in 1995 flowered (Fig. 4). Reproductive plants produced a conservative number of flowers (Fig. 5), however, indicating that environmental conditions were less than optimal.

Dahlia-rooted Cactus

Introduction

The dahlia-rooted cactus *(Peniocereus striatus)* is a cryptic, slender-stemmed cactus with 1 or more stems arising from an underground tuber. The small population in OPCNM represents the northern limit of the species' range in North America. Due to the relative rarity of the plants and the vulnerability of the population, the monument began monitoring the species in 1990. About 60 plants have been found in the monument; these are concentrated on or near 2 low, rocky hills close to the International Boundary between the United States and Mexico. The habitat is immediately adjacent to agricultural fields, which are subject to aerial spraying of pesticides and 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 tag was placed on a short metal pin that was put into the ground near the plant.

Summary of 1995 Monitoring Activities

On 19 September 1995, the 22 tagged plants were inspected. The time required to perform this monitoring is about 1 half day, including transportation.

Methods

P. striatus plants are inspected as to general health and condition during the summer rainy season when the reproductive status of plants can be determined. The number of new stems, if any, is recorded along with the number of immature flower buds, mature flowers and fruits. Also noted is any evidence of herbivory, or hedging. Beginning in 1994 the overall height of the plant was recorded, although this is not necessarily a reliable indicator of plant health. All of this information is entered into a Lotus spreadsheet for yearly comparisons, although much of the information is of a qualitative nature.

Results

The monitoring in 1995 was done in mid-September so that the number of mature fruit could be accurately counted. There were more fruits in 1995 than in 1994 (Table 5). The greater success in fruit set was possibly due not only to the timing of the monitoring, but also to the heavy summer rains all along the southeast boundary. Above-average rainfall was recorded at the Dos Lomitas rain gauge for the summer of 1995 (Table 6). Seven plants that looked dead in 1994 had resprouted in 1995.

The monitoring protocol for this species is currently under review. An improved protocol that will more accurately measure population status and reproductive success will be developed and implemented during 1996–1997.

Table 5. Number of developed fruits on individual dahlia-rooted cactus *(Peniocereus striatus)* plants, Organ Pipe Cactus National Monument, Arizona. Monitoring dates: 13 August 1992; plant numbers 1–7 on 8 August 1993 and plant numbers 8–22 on 3 September 1993; 18 August 1994; 19 September 1995.

Plant identification number	Number of developed fruits			
	1992	1993	1994	1995
1	0	0	0	0
2	0	0	0	0
3	11	0	0	1
4	2	0	0	0
5	0	0	0	0
6	3	0	0	2
7	0	0	0	0
8	0	0	0	4
9	2	0	0	4
10	4	10	4	6
11	1	3	1	0
12	1	0	2	9
13	0	0	0	0
14	0	0	0	0
15	3	0	0	0
16	2	0	1	2
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	2	0	0	0
21	--	0	0	0
22NE	--	0	0	0
22SW	--	0	0	0
Total	31	13	8	28

-- = plants not monitored in 1992.

Table 6. Summer and winter precipitation, in millimeters, near the dahlia-rooted cactus *(Peniocereus striatus)* population, Organ Pipe Cactus National Monument, Arizona, 1990-1995. Winter precipitation is the sum of rainfall amounts from October through May preceding the fruit count/monitoring period. Summer precipitation is the sum of rainfall amounts from June through September. Precipitation data are from the Dos Lomitas rain gage.

Year	Winter precipitation (mm) (October–May)	Summer precipitation (mm) (June–September)
1990	65	149
1991	175	80
1992	218	128
1993	194	65
1994	114	66
1995	232	137
Mean ± standard deviation	167 ± 59	104 ± 35

Organ Pipe Cactus and Senita Cactus

Introduction

Organ pipe cactus *(Stenocereus thurberi)* is a columnar cactus species that occurs throughout the monument primarily on south- to southeast-facing rocky slopes. Senita cactus *(Lophocereus schottii)*, another columnar cactus, occurs only within the southern portion of the monument, especially in relatively moist habitats along wash banks composed of coarse sediments (Parker 1988). Although they occur 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 titled Special Status Plants, additional plots were set up to monitor the growth of these species.

Human-influenced impacts or threats to either *S. thurberi* or *L. schottii* populations within the monument, though not presently obvious, might occur from illegal collecting, pesticide drift from Mexican agriculture, past overgrazing, and possibly from global climate change.

Project History

In 1970, Park Ranger Fred Goodsell selected for long-term growth monitoring 31 *S. thurberi* from a population growing on a steep, south-southeast-facing rocky slope in the central Puerto Blanco Mountains, and 9 *L. schottii* plants 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. The individuals were permanently tagged.

Monument staff have measured the annual growth of these individuals since 1970. A total of 30 *S. thurberi* and 2 *L. schottii* have been monitored the entire 26-year period. Some individuals in the original study are no longer measured 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. A plot of 20 individuals was established in the Bates Mountains, as well as a plot consisting of 1 additional *S. thurberi* and 3 *L. schottii* plants located in the small hills rising out of the alluvial flats on the south park boundary. In addition, 4 more *L. schottii* were selected for monitoring on the original southern Puerto Blanco Mountains plot.

1995 Monitoring Activities

S. thurberi plants on the Baker Mine plot were measured on 6 January, on the Dos Lomitas plot on 10 January, and on the Bates Well plot on 4 January. *L. schottii* plants on the Lost Cabin/Senita Basin plot were measured on 5 January and plants on the Dos Lomitas plot were measured on 10 January. This monitoring was conducted by resource management staff following the "Special-status Plants Monitoring Protocol for the Ecological Monitoring Program in Organ Pipe Cactus National Monument, Arizona" (Ruffner Associates 1995). To increase the sample size of small organ pipe cacti in the Baker Mine plot, 8 single-stemmed plants under 1-m tall were added to the monitoring program in 1995.

Methods

Each stem of every study plant was numbered and tagged, with the exception of newly budding stems. As individual stems grew in length and became more curved, a wooden dowel was inserted 1–2 cm into the tissue between the stem tip and stem base to assist in measurement precision. Measurement of stem tip to dowel distances was repeated annually since 1970 for the original plots, and since 1990 for the new plots. Distances were measured to the nearest 0.25 in. [0.64 cm] with a steel tape measure.

Using the 1970–1983 data sets for both cactus species, Parker (1988) developed mathematical models relating plant growth rates to plant size, age, and meteorological conditions with analysis of variance and regression analysis. In previous EMP reports, the complete data set (1970–1994) for *S. thurberi* was tested on the size-growth models relating annual plant growth to both plant size and stem number, with least-squares nonlinear regression analysis, and mean plant growth to winter precipitation and freeze frequency, with multivariate regression analysis. Beginning with this report, only the data for the variables used in the regression analyses will be presented, while the regression analyses will be omitted.

Variables were defined by Parker (1988) and in this and other annual EMP reports as follows:

Annual plant growth = $\sum_{i=1}^{n}$ (annual stem growth increment)$_i$

Plant size = $\sum_{i=1}^{n}$ (total stem length)$_i$

Stem number = Number of stems

Meteorological factors:

Freeze frequency: Number of days November$_{t-1}$ – April$_t$ with minimum temperature $\leq 0°$ C

Summer precipitation: Precipitation for June$_t$ – September$_t$

Winter precipitation: Precipitation for November$_{t-1}$ – April$_t$

where t = year; i = the ith stem; and n = the number of stems on a plant.

Results

The measurement data collected in 1995 for plant growth are presented in Tables 7 and 8. The climate data for the meteorological variables used in the model developed by Parker (1988) is presented in Table 9. There were no freezes as defined by Parker (1988) at the monitoring sites during the winter of 1994–1995.

For the original plants in this study, growth measurements have been collected for 26 years, nearly twice the number of years studied by Parker (1988). Given the amount of new information, it is appropriate that the relationships between dependent, independent, and meteorological factors be reevaluated. In the coming year, the monument staff will evaluate this monitoring protocol to determine if the objectives of the study are being met.

Table 7. Growth increments of organ pipe cactus *(Stenocereus thurberi)* plants at the Baker Mine, Dos Lomitas, and Bates Well sites, Organ Pipe Cactus National Monument, Arizona, 1994–1995. Variables are defined in the text.

Plot location	Plant identification number	Number of stems, 1995	Annual plant growth 1995 (inches)	Plant size 1995 (inches)
Baker Mine	4	6	21.25	360.25
Baker Mine	5	10	14.00	954.75
Baker Mine	6	18	52.50	1,258.75
Baker Mine	7	11	28.00	799.50
Baker Mine	8	6	26.75	382.00
Baker Mine	9	4	9.25	209.50
Baker Mine	10	19	67.25	1,436.63
Baker Mine	11	7	16.00	258.50
Baker Mine	12	8	27.00	428.00
Baker Mine	13	18	18.75	1,181.00
Baker Mine	14	6	8.25	423.25
Baker Mine	15	1	1.25	43.50
Baker Mine	16	5	6.25	286.75
Baker Mine	17	10	18.75	529.00
Baker Mine	18	11	16.50	872.50
Baker Mine	19	4	1.25	100.50
Baker Mine	20	11	2.75	457.00
Baker Mine	21	6	8.25	478.25
Baker Mine	23	9	14.25	598.50
Baker Mine	24	3	6.00	178.50
Baker Mine	25	6	6.25	316.75
Baker Mine	26	12	15.50	1,093.00
Baker Mine	27	6	10.25	261.26
Baker Mine	28	4	6.75	215.75

Table 7—continued.

Plot location	Plant identification number	Number of stems, 1995	Annual plant growth 1995 (inches)	Plant size 1995 (inches)
Baker Mine	30	10	24.00	572.88
Baker Mine	31	3	4.25	98.25
Baker Mine	33a	2	4.00	97.00
Baker Mine	33	14	35.25	707.75
Baker Mine	34	12	32.50	1,134.50
Baker Mine	37	1	1.00	23.00
Dos Lomitas	1	1	0.25	14.25
Dos Lomitas	2	1	1.25	22.25
Dos Lomitas	3	5	15.00	134.00
Bates Well	1	4	4.00	43.25
Bates Well	2	3	3.00	45.50
Bates Well	3	3	4.75	63.00
Bates Well	4	4	16.00	254.63
Bates Well	5	2	2.75	50.75
Bates Well	6	2	1.25	37.00
Bates Well	7	13	35.50	575.16
Bates Well	8	11	23.75	549.76
Bates Well	9	8	20.25	479.88
Bates Well	10	2	3.75	51.25
Bates Well	11	4	0	21.00
Bates Well	12	3	4.75	86.51
Bates Well	13	4	2.50	119.51
Bates Well	14	7	9.00	438.76
Bates Well	15	2	1.00	51.75
Bates Well	16	6	7.00	348.00

Table 7—continued.

Plot location	Plant identification number	Number of stems, 1995	Annual plant growth 1995 (inches)	Plant size 1995 (inches)
Bates Well	17	6	12.00	527.25
Bates Well	18	1	0	42.75
Bates Well	19	2	3.50	87.75
Bates Well	20	5	9.00	158.25

Table 8. Growth increments of senita cactus *(Lophocereus schottii)* plants at the Dos Lomitas, Senita Basin and Lost Cabin Mine sites, Organ Pipe Cactus National Monument, Arizona, 1994–1995. Variables are defined in the text.

Plot location	Plant identification number	Number of stems 1995	Annual plant growth 1995 (inches)	Plant size 1995 (inches)
Dos Lomitas	1	6	29.25	245.38
Dos Lomitas	2	2	2.75	33.50
Dos Lomitas	3	6	15.75	178.50
Lost Cabin Mine	3	20	70.25	1,486.15
Lost Cabin Mine	5	27	102.75	1,515.75
Lost Cabin Mine	8	4	4.25	54.75
Senita Basin	10	10	22.00	205.38
Senita Basin	11	6	15.25	336.00
Lost Cabin Mine	12	11	76.00	684.50
Lost Cabin Mine	13	3	19.75	46.00

Table 9. Winter and summer precipitation as measured by the Senita Basin rain gauge (nearest to the Lost Cabin Mine *Stenocereus thurberi* plot) and the Growler Valley weather station (nearest to the Bates Well *Stenocereus thurberi* plot), Organ Pipe Cactus National Monument, Arizona.

	Precipitation (mm)	
Month and year	Senita Basin	Growler Valley
June 1994	1	1
July 1994	0	0
August 1994	73	6
September 1994	23	15
October 1994	18	4
November 1994	16	14
December 1994	113	89
January 1995	12	28
February 1995	23	48
March 1995	13	19
April 1995	15	18
Total	307	242

Perennial Vegetation Structure and Diversity

As part of the SEP project Vegetation Structure and Diversity, 26 permanent quadrats were established at long-term monitoring sites between 1988–1991. Presence, density, frequency, coverage, and diversity were measured at all quadrats during this phase. The protocol recommended that an inventory of the quadrats be performed approximately 5 years after the baseline reading, and after that on a 10-year cycle (Lowe et al. 1995).

In 1994, monument staff began re-inventorying the perennial vegetation quadrats, and continued this work in 1995. Twelve quadrats were inventoried in 1994, and 9 were sampled in 1995. The remaining plots will be inventoried in 1996. Because this project has required extensive protocol documentation and detailed data management, results of the 1994–1996 repeat inventory will be analyzed in a future separate report.

Lizards

Introduction

The objectives of the lizard monitoring protocol are to estimate population size and track population dynamics in lizards, which may aid in understanding natural and human-caused environmental changes at OPCNM. Additionally, data on these ectothermic vertebrates have intrinsic biological importance. Lizard monitoring is an important component of 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. Documented effects of environmental fluctuations on lizards could be used to predict or illustrate the consequences of human-caused environmental change at OPCNM (Rosen and Lowe 1996).

Project History

Beginning with the end of the initial 4-year (1987–1991) survey of OPCNM herpetofauna, monument staff initiated the monitoring protocol, consisting of twice-yearly (spring and summer) sampling along standardized lizard transects. Initially, only the Core I sites were visited due to constraints of time and personnel, but by 1993 all sites were visited during both activity seasons.

Summary of 1995 Activities

Lizards were censused at OPCNM from 12 April to 23 June and again from 23 August to 5 October. The project was conducted by resource management personnel on all 16 of the standard EMP study sites for which lizard transects had been previously established, as well as 2 additional sites used only for lizard monitoring. In addition, lizard transects were established at Quitobaquito and at the 2 new EMP study sites that were added in 1995. Data for peak numbers of lizards observed per sampling session are compared with similar data for the previous 5 years, and data on distances from transect midlines were presented graphically for future reference regarding technique.

Methods

The methods follow the monitoring protocols set forth in Rosen and Lowe (1995). Lizards were censused using a belt transect that varied in length from 100 m to 300 m. Eight sites possessed just 1 transect, with lengths ranging from 100–300 m, while 9 sites had 2 100-m transects each, and 1 site had 4 100-m transects. On those sites with 2 transects, each transect was sampled alternately throughout the morning by the same observer. The EMP site containing 4 transects required 2 observers working in tandem during 1 day or 1 observer working 2 days to complete. The center line of each transect was traversed repeatedly during the morning, beginning at the easternmost end of the transect with the sun at the observer's back. This orientation aided lizard detection since they could be more readily seen basking in the morning sun. Sampling of the transects was timed during a morning so that they were not traversed too frequently, which may frighten the lizards off the line. In general, a transect was sampled every 30–40 min, resulting in 4–8 samples per transect during a morning. Since a clear, warm, and fairly calm morning was required for good morning lizard activity, sampling was only conducted under those conditions, and all transects were begun with the arrival of first warmth, shortly after sunrise. The sampling was timed to include the peaks of activity for each of the various species of lizards present, with particular attention being given to the "indicator species," usually whiptail lizards *(Cnemidophorus* spp.*)*. This was accomplished partially through continuous awareness of lizard activity in the immediate vicinity of the transects, with the activity of the indicator species helping to determine duration of the sampling period. Once the number of individuals observed of the indicator species had peaked and was diminishing for 1 or 2 more walks, the session was ended. Each transect was run once in the late spring and once again in mid-summer after the onset of the summer rains.

Detections of all lizards seen within a 7.5-m perpendicular distance to either side of the center line were recorded. If a definitive identification could be made from aural cues, it was noted also. Each lizard detection included data for distance from the origin of the transect, perpendicular distance from the center line, species, size/age class, and time. Gender was recorded if it could be determined. Peak values for each species were tabulated for each transect by selecting the sample with the highest total for that species during the morning. Activity patterns usually varied by species, so that peak values tended to occur at different times in the morning for different species. For a given transect, 2 peak values were generated for each species and each year, corresponding to the spring and summer monitoring periods.

Results

Unlike some animal populations, such as insects or rodents, lizard populations are not tied directly to recent rainfall and vegetative abundance (Rosen and Lowe 1996). Although these specific parameters may be the ultimate causes of population changes, other factors such as temperature, humidity, soil moisture, and the numbers of reproducing adult lizards and lizard predators may have a very significant influence. Those factors can modify and delay the effects of rainfall and the resulting growth of vegetation. Thus, some of the population results that are observed are not necessarily easily explained in terms of recent weather phenomena. Another important factor is the timing of the 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.

The year 1995 began much as did 1994, with somewhat sparse winter rains. Even though there were good rains in February, the following months were warm and dry, with a light production of spring annuals. The previous summer had been relatively dry as well, so the herbaceous ground cover of annuals was patchy, with little new growth. Numbers for all lizard species were not much changed from the previous year.

Paucity of rainfall also characterized the summer of 1995. A brief monsoon season began in late August, and resulted in a poor yield of summer annuals. The 2 sites in the southeast portion of the monument (Dos Lomitas and Salsola) received very good summer rains, although these did not begin until late-August. Ground cover over most of the monument by this time consisted only of perennial vegetation, with few, if any, annuals. There was 1 more burst of rain in early September, although many sites seemed to have missed significant precipitation altogether. The result was a near absence of green vegetation throughout much of the monument.

Since the lizard monitoring protocol calls for waiting to begin the summer field work until after the start of the monsoons, lizards were observed despite the scarcity of green vegetation. A general trend that continued overall in 1995, was that summer peaks were higher than spring peaks for most species. This was to be expected since the summer monitoring would detect new recruits following reproductive activity in the spring (Table 10, Fig. 6). Some sites, especially those that received a good portion of rain in August, yielded high numbers of western whiptails *(Cnemidophorus tigris)* (6–10) per transect. Overall, numbers were higher for sideblotched lizards *(Uta stansburiana)* and low for zebra-tailed lizards *(Callisaurus draconoides)*, an indicator species at a few sites. Tree lizards *(Urosaurus ornatus)* were seen in slightly greater numbers than in 1994, especially in the spring, though not up to levels of previous years. Alamo Canyon continued to yield few lizards, even though vegetative conditions were good and the weather was entirely appropriate for monitoring. The Alamo transect was run once in the spring, with a yield of 3 *U. ornatus*, 1 Clark spiny lizard *(Sceloporus clarki)*, 1 red-backed whiptail *(Cnemidophorus burti xanthonotus)*, and 1 Gila monster *(Heloderma suspectum)* (seen crawling into a hollow log). The summer monitoring detected only 3 *U. ornatus* at Alamo Canyon.

Observed perpendicular distances from lizard transect midlines are summarized in Figure 7. Peak lizard data for each Core I site are summarized in Figures 8–26, and for each non-Core I site in Figures 27–37 (Creosotebush and Lizard Grid transects are lizard monitoring sites only).

Table 10. Age class structure for 4 lizard genera monitored at Organ Pipe Cactus National Monument, Arizona, 1991–1995. ("Sp"= spring season, "Su"= summer season)

Sideblotched lizard *(Uta stansburiana)*

	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94	Sp 95	Su 95
Adults	22	14	20	27	28	71	28	77	37	185
Sub-adults	4	22	3	13	0	44	1	31	8	32
Juveniles	3	7	0	4	2	2	7	3	13	1
Total	29	43	23	44	30	117	36	111	58	218

Zebra-tailed lizard *(Callisaurus draconoides)*

	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94	Sp 95	Su 95
Adults	49	13	57	35	52	30	24	30	32	26
Sub-adults	17	8	7	9	17	6	14	1	11	1
Juveniles	9	3	0	17	0	0	0	0	0	0
Total	75	24	64	61	69	36	38	31	43	27

Desert spiny lizard *(Sceloporus magister)* and Clark spiny lizard *(Sceloporus clarki)*

	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94	Sp 95	Su 95
Adults	5	9	18	15	16	9	9	5	10	5
Sub-adults	5	1	0	6	1	9	2	4	1	6
Juveniles	3	2	0	0	0	0	0	0	0	1
Total	13	12	18	21	17	18	11	9	11	12

Western whiptail *(Cnemidophorus tigris)* and red-backed whiptail *(Cnemidophorus burti xanthonotus)*

	Sp 91	Su 91	Sp 92	Su 92	Sp 93	Su 93	Sp 94	Su 94	Sp 95	Su 95
Adults	103	43	167	107	169	138	103	135	111	111
Sub-adults	48	61	21	18	14	91	38	54	22	71
Juveniles	50	16	0	25	2	74	7	32	8	61
Total	201	120	188	150	185	303	148	221	141	243

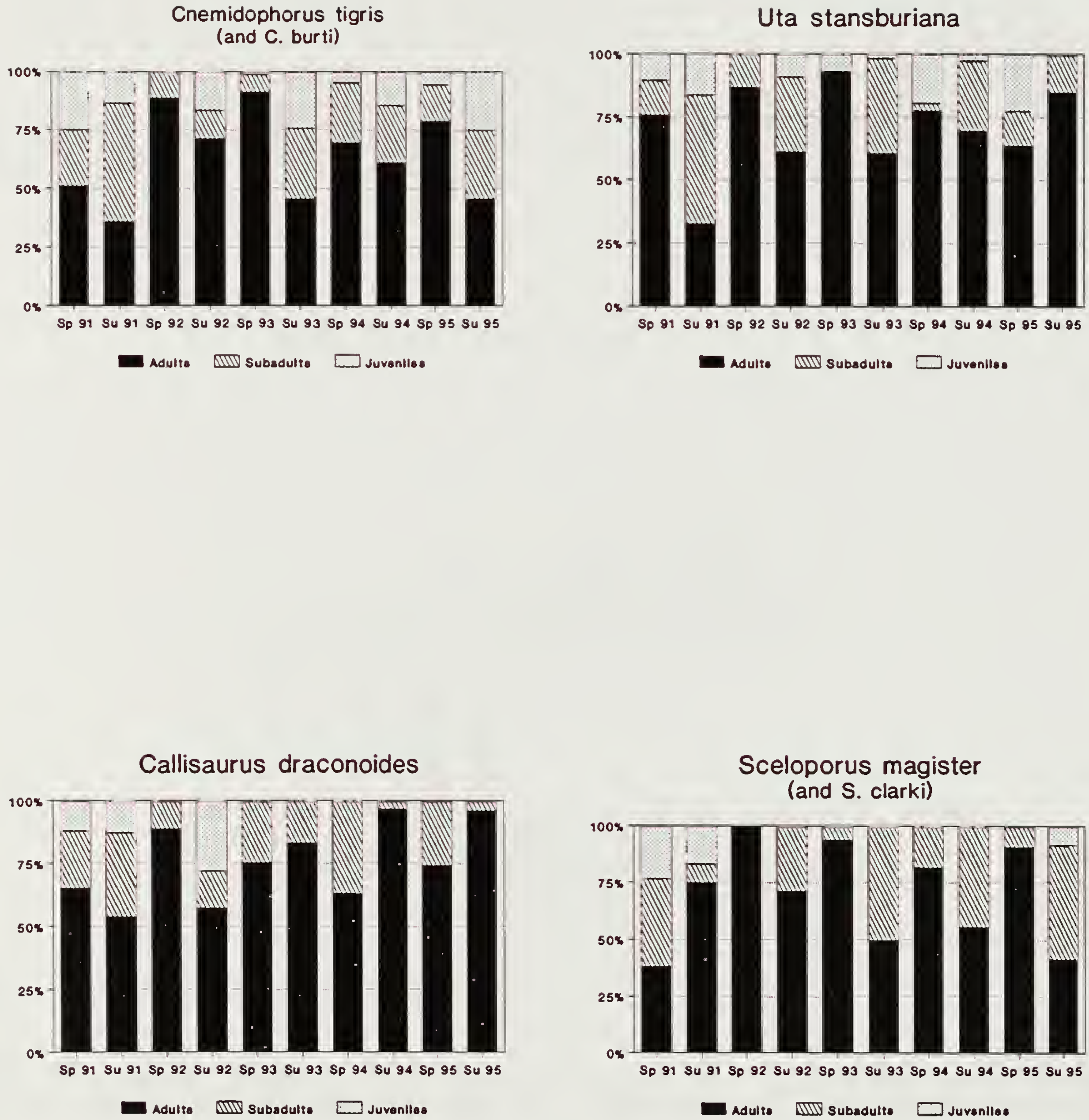


Figure 6. Age class structure of lizards monitored at Organ Pipe Cactus National Monument, Arizona, 1991–1995.

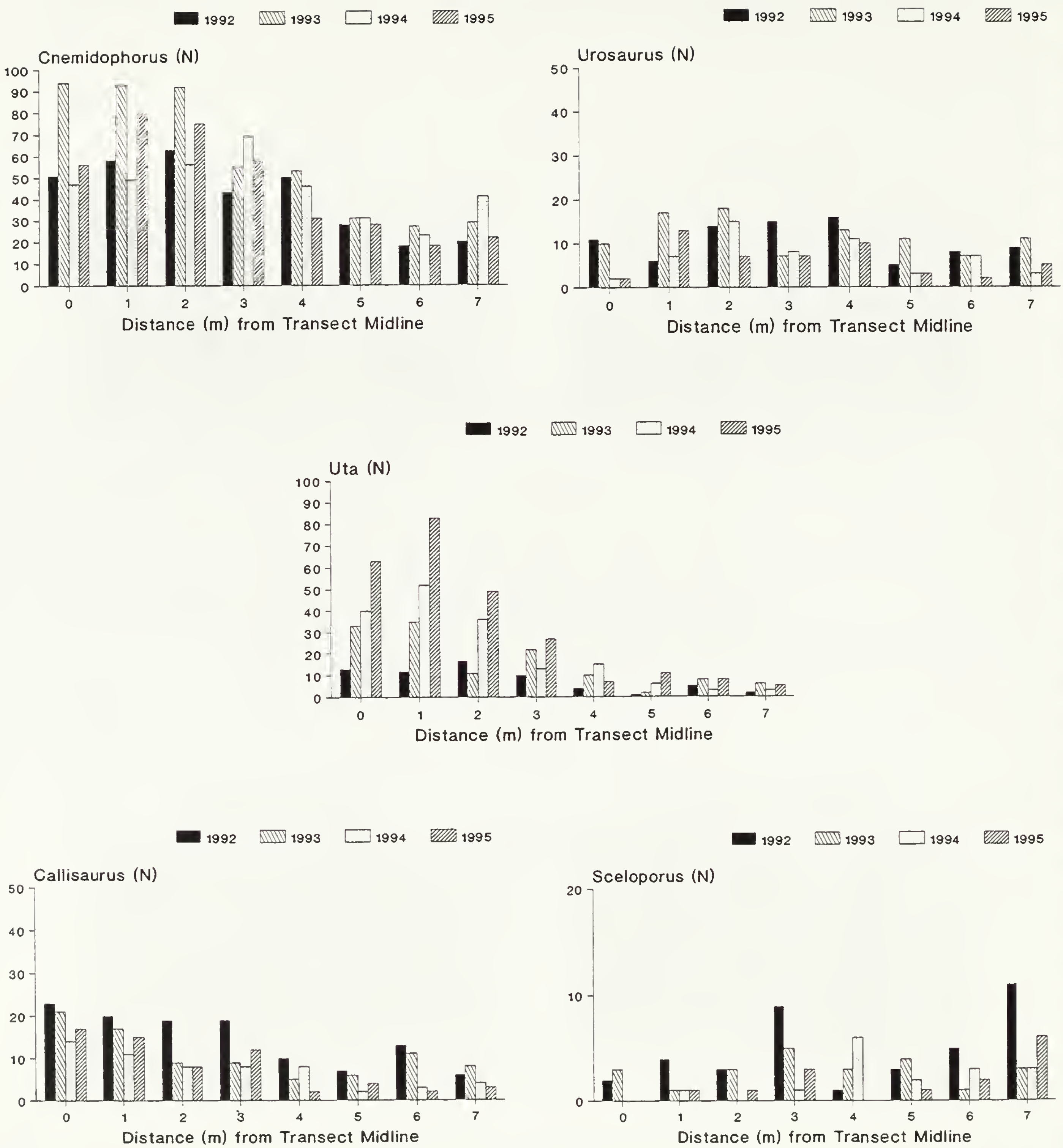
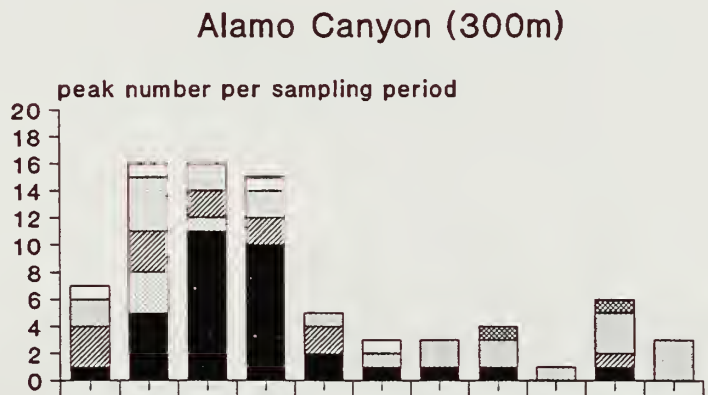


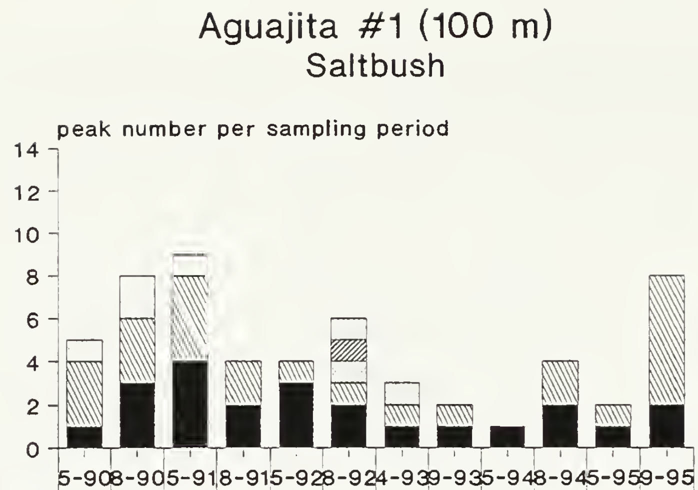
Figure 7. Observed distances from lizard transect midlines, Organ Pipe Cactus National Monument, Arizona, 1992–1995. **Cnemidophorus** = *Cnemidophorus* spp., **Urosaurus** = *Urosaurus ornatus*, **Uta** = *Uta stansburiana*, **Callisaurus** = *Callisaurus draconoides*, **Sceloporus** = *Sceloporus* spp.

Note: Figures 8–37 display peak numbers of lizards observed for each sampling period per transect. The following species abbreviations and taxons are used within charts: **Callisaurus** = zebra-tailed lizard *(Callisaurus draconoides);* **Cnemi burti** = red-backed whiptail *(Cnemidophorus burti xanthonotus)*; **Cnemi tigris** = western whiptail *(Cnemidophorus tigris)*; **Crotaphytus** = common collared-lizard *(Crotaphytus collaris)*; **Dipsosaurus** = desert iguana *(Dipsosaurus dorsalis)*; **Gambelia** = long-nosed leopard lizard *(Gambelia wislizenii)*; **Heloderma** = Gila monster *(Heloderma suspectum)*; **Phrynosoma solare** = regal horned-lizard *(Phrynosoma solare)*; **S. magister** = desert spiny lizard *(Sceloporus magister)*; **S. clarki** = Clark spiny lizard *(Sceloporus clarki)*; **U. ornatus** = tree lizard *(Urosaurus ornatus)*; **U. graciosus** = longtailed brush lizard *(Urosaurus graciosus)*; **Uta** = side-blotched lizard *(Uta stansburiana).*



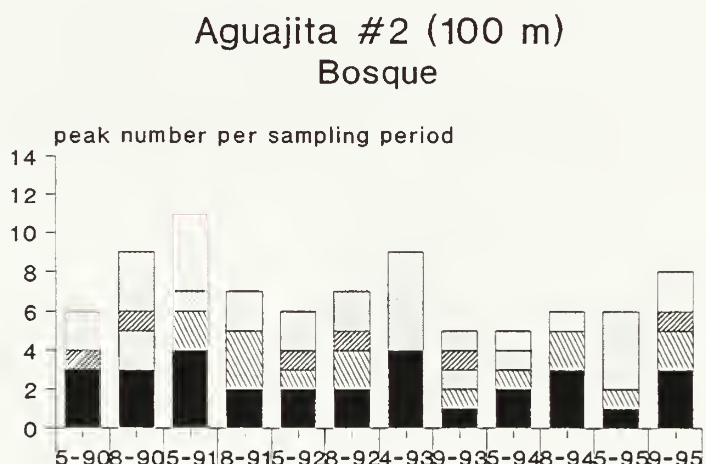
	5-90	5-91	8-91	5-92	8-92	4-93	8-93	5-94	9-94	5-95	9-95
Heloderma								1		1	
Crotaphytus	1	1		1		1					
U. ornatus	2	4	2	2	1	1	2	2	1	3	3
S. clarki	3	3	2	2	2					1	
Callisaurus		3	1								
Cnemi burti	1	5	11	10	2	1	1	1		1	

Figure 8. Peak values for lizard species at Alamo Canyon, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	8-94	5-95	9-95
U. ornatus						1	1					
S. magister						1						
Callisaurus	1	2	1			1.						
Uta	3	3	4	2	1	1	1	1		2	1	6
Cnemi tigris	1	3	4	2	3	2	1	1	1	2	1	2

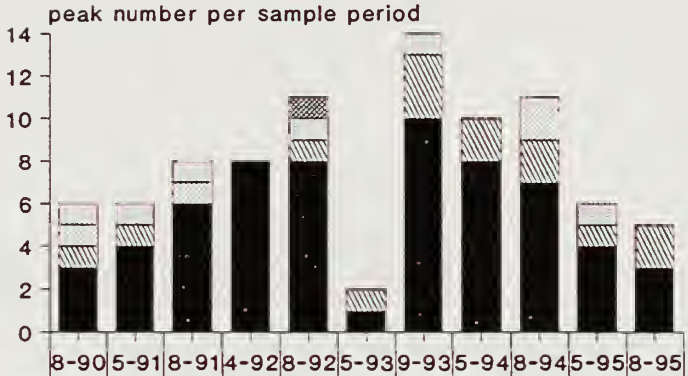
Figure 9. Peak values of lizard species monitored at Aguajita #1 (Saltbush) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	8-94	5-95	9-95
Heloderma									1			
U. ornatus	2	3	4	2	2	2	5	1	1		4	2
S. magister	1	1			1	1		1				1
Callisaurus		2	1					1		1		
Uta			2	3	1	2		1	1	2	1	2
Cnemi tigris	3	3	4	2	2	2	4	1	2	3	1	3

Figure 10. Peak values of lizard species monitored at Aguajita #2 (Bosque) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

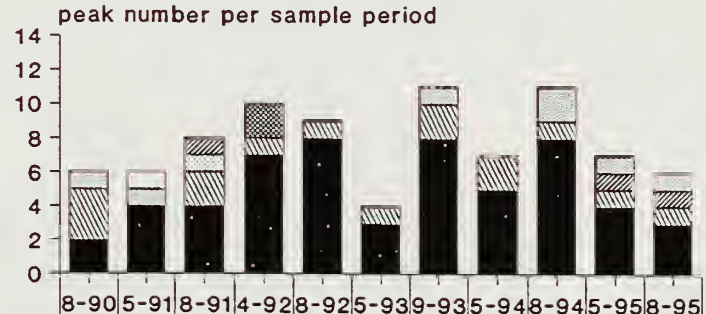
Dos Lomitas #1 (100 m)
Inside Exclosure



	8-90	5-91	8-91	4-92	8-92	5-93	9-93	5-94	8-94	5-95	8-95
Gambelia					1						
U. ornatus	1	1	1		1		1			1	
Callisaurus	1		1						2		
Uta	1	1			1	1	3	2	2	1	2
Cnemi tigris	3	4	6	8	8	1	10	8	7	4	3

Figure 11. Peak values of lizard species monitored at Dos Lomitas #1 (Inside Exclosure) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

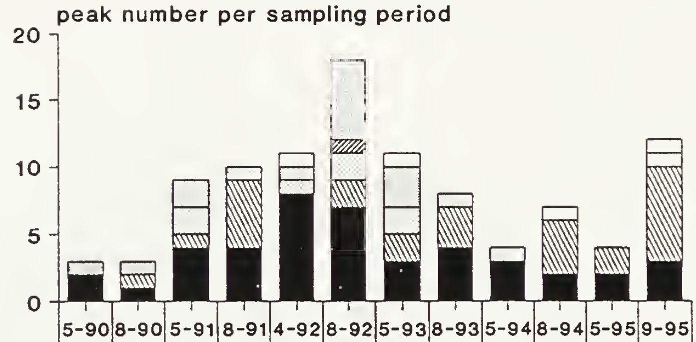
Dos Lomitas #2 (100 m)
Outside Exclosure



	8-90	5-91	8-91	4-92	8-92	5-93	9-93	5-94	8-94	5-95	8-95
Gambelia				2							
Dipsosaurus		1									
U. ornatus	1	1					1		2	1	1
S. magister			1							1	1
Callisaurus			1								
Uta	3		2	1	1	1	2	2	1	1	1
Cnemi tigris	2	4	4	7	8	3	8	5	8	4	3

Figure 12. Peak values of lizard species monitored at Dos Lomitas #2 (Outside Exclosure) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

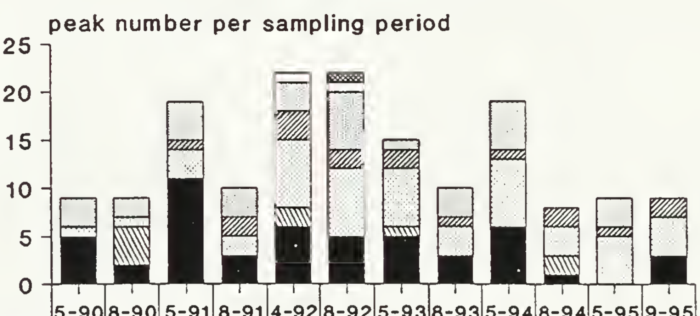
East Armenta #1 (200 m)
Desertscrub



	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93	5-94	8-94	5-95	9-95
Dipsosaurus					1		1			1		1
U. ornatus	1	1	2		1	6	3	1				
S. magister						1						
Callisaurus			2	1	1	2	2		1			1
Uta		1	1	5		2	2	3		4	2	7
Cnemi tigris	2	1	4	4	8	7	3	4	3	2	2	3

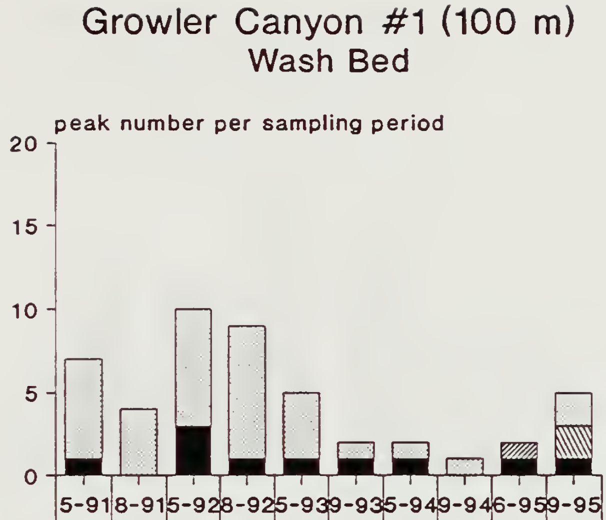
Figure 13. Peak values of lizard species monitored at East Armenta #1 (Desertscrub) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

East Armenta #2 (200 m)
Kuakatch Wash



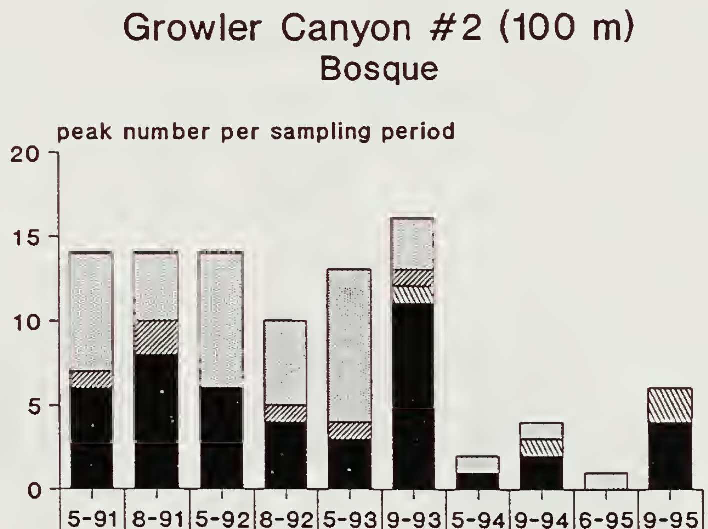
	5-90	8-90	5-91	8-91	4-92	8-92	5-93	8-93	5-94	8-94	5-95	9-95
Gambelia						1						
Dipsosaurus					1	1						
U. ornatus	3	2	4	3	3	6	1	3	5		3	
S. magister			1	2	3	2	2	1	1	2	1	2
Callisaurus	1	1	3	2	7	7	6	3	7	3	5	4
Uta		4			2		1			2		
Cnemi tigris	5	2	11	3	6	5	5	3	6	1		3

Figure 14. Peak values of lizard species monitored at East Armenta #2 (Kuakatch Wash) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



	5-91	8-91	5-92	8-92	5-93	9-93	5-94	9-94	6-95	9-95
Phrynosoma solare									1	
Callisaurus	6	4	7	8	4	1	1	1		2
Uta										2
Cnemi tigris	1		3	1	1	1	1		1	1

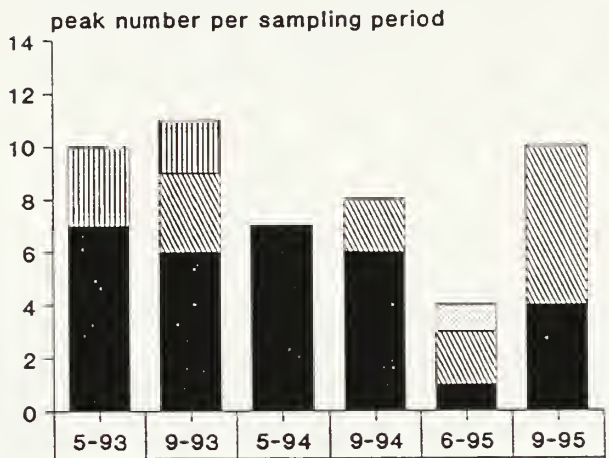
Figure 15. Peak values of lizard species monitored at Growler Canyon #1 (Wash Bed) transect, Organ Pipe Cactus National Monument, Arizona, 1991–1995.



	5-91	8-91	5-92	8-92	5-93	9-93	5-94	9-94	6-95	9-95
U. ornatus	7	4	8	5	9	3	1	1	1	
S. magister	1	2		1	1	1				
Uta						1		1		2
Cnemi tigris	6	8	6	4	3	11	1	2		4

Figure 16. Peak values of lizard species monitored at Growler Canyon #2 (Bosque) transect, Organ Pipe Cactus National Monument, Arizona, 1991–1995.

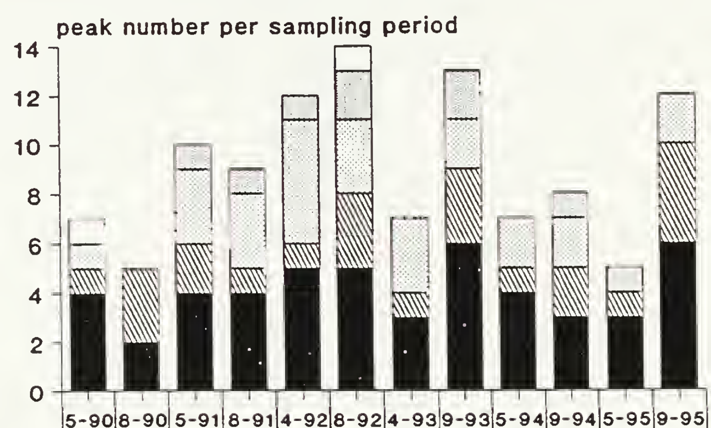
Lower Colorado Larrea (200 m)



		5-93	9-93	5-94	9-94	6-95	9-95
U. graciosus	(vertical lines)	3	2				
Phrynosoma solare	(dotted)					1	
Uta	(hatched)		3		2	2	6
Cnemi tigris	(solid)	7	6	7	6	1	4

Figure 17. Peak values of lizard species monitored at Lower Colorado Larrea transect, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

Senita Basin (250 m)



	5-90	8-90	5-91	8-91	4-92	8-92	4-93	9-93	5-94	9-94	5-95	9-95
Dipsosaurus	1					1						
U. ornatus			1	1	1	2		2		1	1	
Callisaurus	1		3	3	5	3	3	2	2	2		2
Uta	1	3	2	1	1	3	1	3	1	2	1	4
Cnemi tigris	4	2	4	4	5	5	3	6	4	3	3	6

Figure 18. Peak values of lizard species monitored at Senita Basin transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

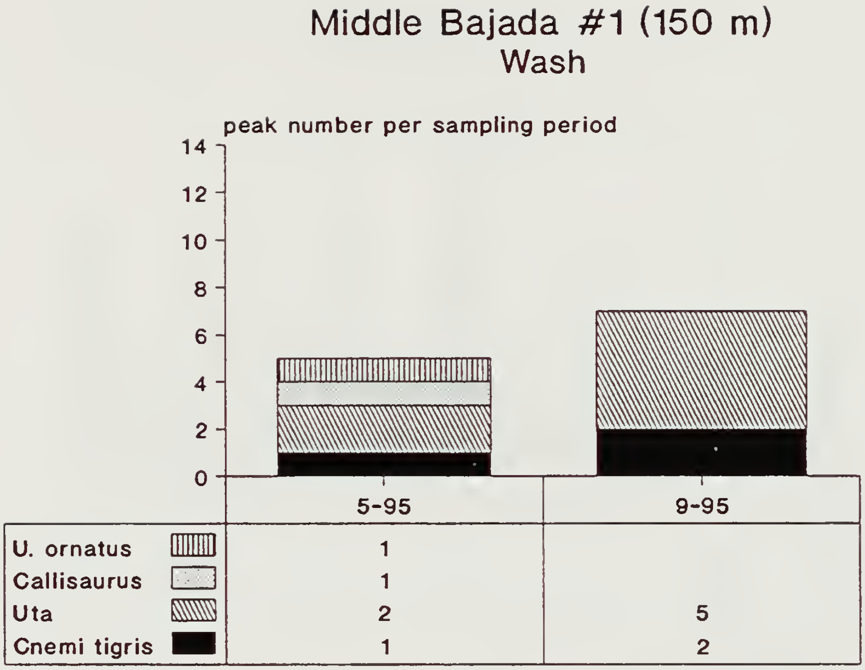


Figure 19. Peak values of lizard species monitored at Middle Bajada #1 (Wash) transect, Organ Pipe Cactus National Monument, Arizona, 1995.

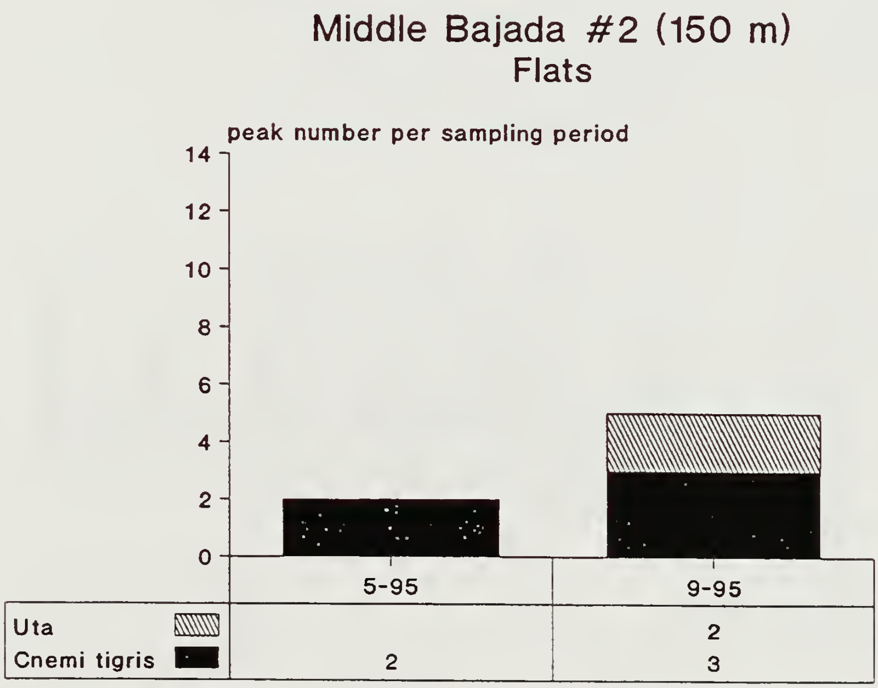
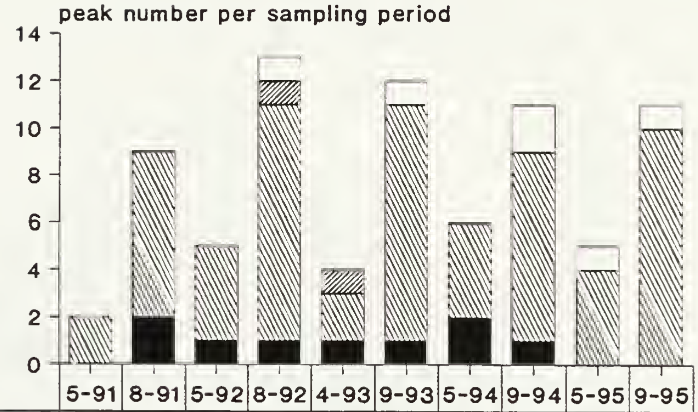


Figure 20. Peak values of lizard species monitored at Middle Bajada #2 (Flats) transect, Organ Pipe Cactus National Monument, Arizona, 1995.

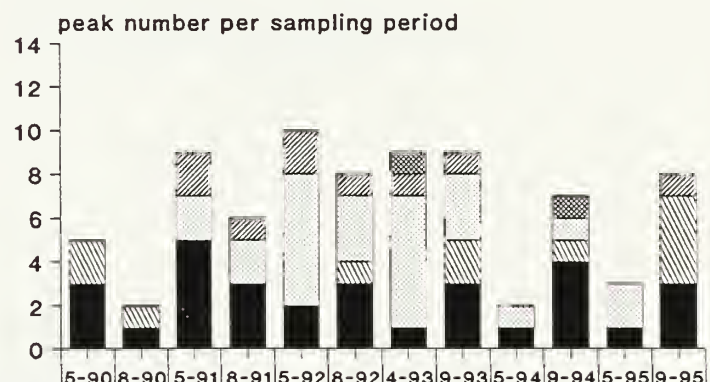
Pozo Nuevo #1 (100 m)
Hill Base



	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94	5-95	9-95
Crotaphytus				1		1		2	1	1
S. magister				1	1					
Uta	2	7	4	10	2	10	4	8	4	10
Cnemi tigris		2	1	1	1	1	2	1		

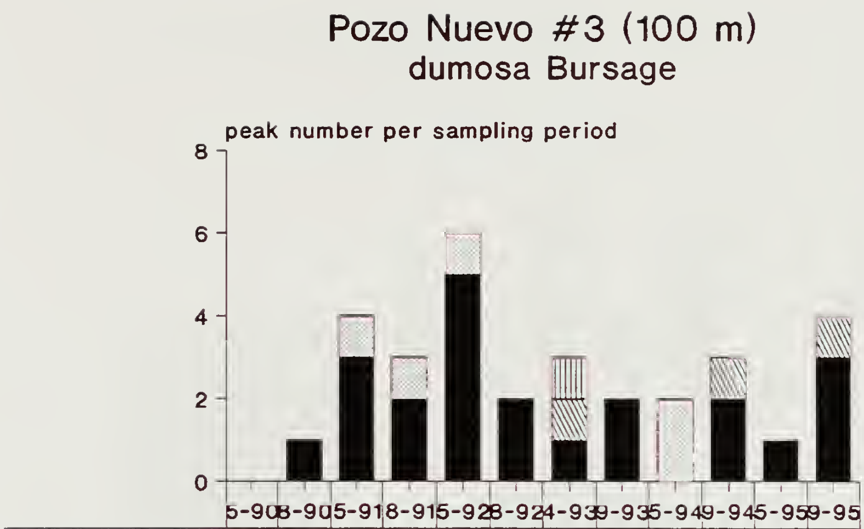
Figure 21. Peak values of lizard species monitored at Pozo Nuevo #1 (Hill Base) transect, Organ Pipe Cactus National Monument, Arizona, 1991–1995.

Pozo Nuevo #2 (100 m)
Wash



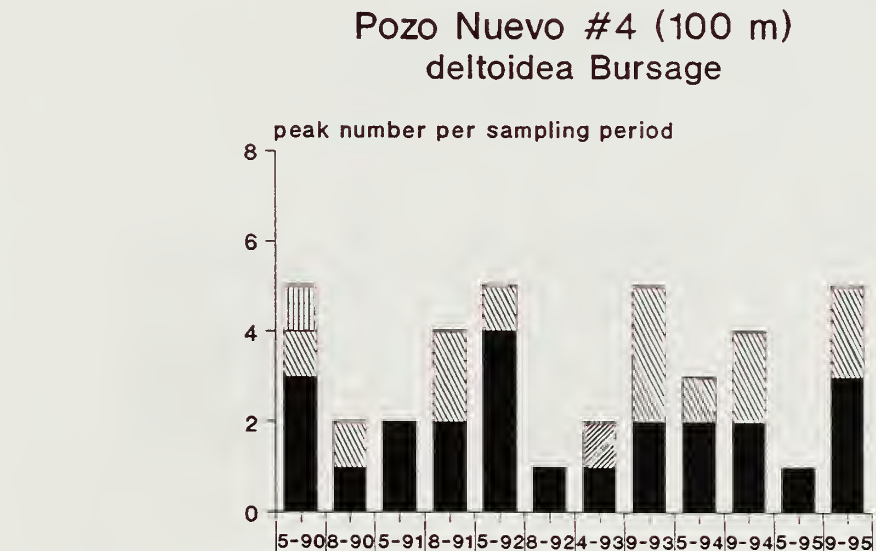
	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94	5-95	9-95
U. graciosus							1			1		
S. magister			2	1	2	1	1	1				1
Callisaurus			2	2	6	3	6	3	1	1	2	
Uta	2	1				1		2		1		4
Cnemi tigris	3	1	5	3	2	3	1	3	1	4	1	3

Figure 22. Peak values of lizard species monitored at Pozo Nuevo #2 (Wash) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



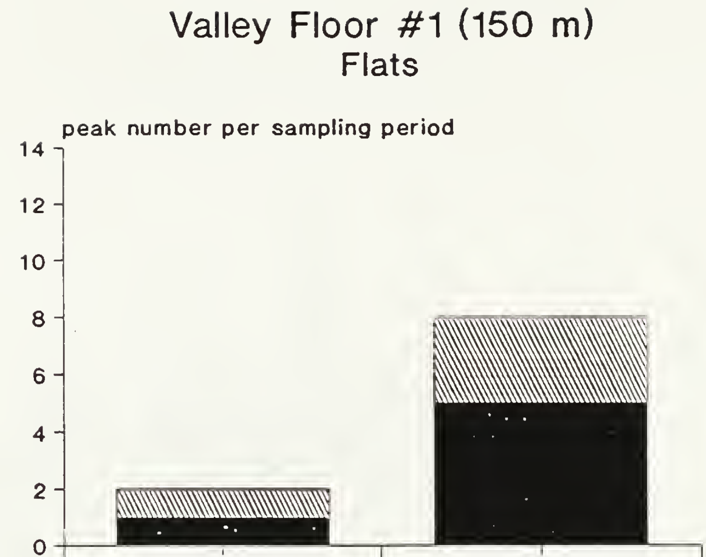
	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94	5-95	9-95
Heloderma							1					
Callisaurus			1	1	1				2			
Uta							1			1		1
Cnemi tigris		1	3	2	5	2	1	2		2	1	3

Figure 23. Peak values of lizard species monitored at Pozo Nuevo #3 (*dumosa* Bursage) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



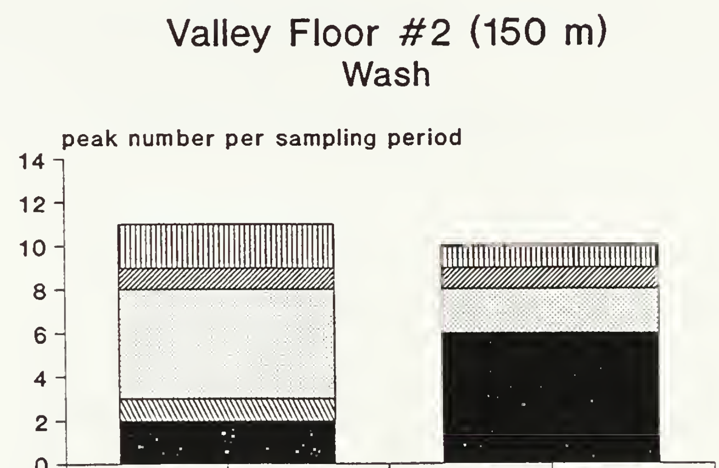
	5-90	8-90	5-91	8-91	5-92	8-92	4-93	9-93	5-94	9-94	5-95	9-95
Phrynosoma solare	1											
S. magister							1					
Uta	1	1		2	1			3	1	2		2
Cnemi tigris	3	1	2	2	4	1	1	2	2	2	1	3

Figure 24. Peak values of lizard species monitored at Pozo Nuevo #4 (*deltoidea* Bursage) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



	5-95	9-95
Uta	1	3
Cnemi tigris	1	5

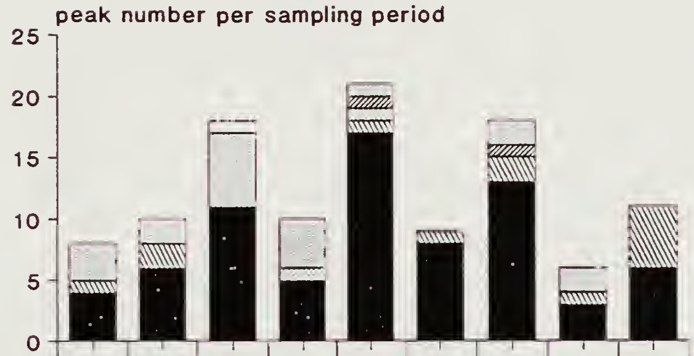
Figure 25. Peak values of lizard species monitored at Valley Floor #1 (Flats) transect, Organ Pipe Cactus National Monument, Arizona, 1995.



	5-95	9-95
U. ornatus	2	1
S. magister	1	1
Callisaurus	5	2
Uta	1	
Cnemi tigris	2	6

Figure 26. Peak values of lizard species monitored at Valley Floor #2 (Wash) transect, Organ Pipe Cactus National Monument, Arizona, 1995.

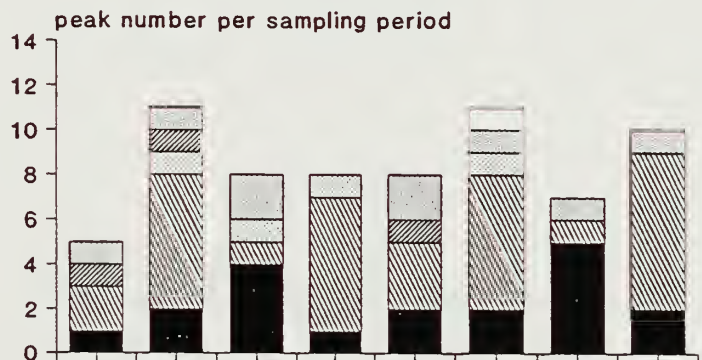
Armenta Ranch (200 m)



	5-90	8-90	5-91	5-93	9-93	5-94	9-94	5-95	9-95
Dipsosaurus			1						
U. ornatus	3	2	6	4	1		2	2	
S. magister					1		1		
Callisaurus				1	1				
Uta	1	2			1	1	2	1	5
Cnemi tigris	4	6	11	5	17	8	13	3	6

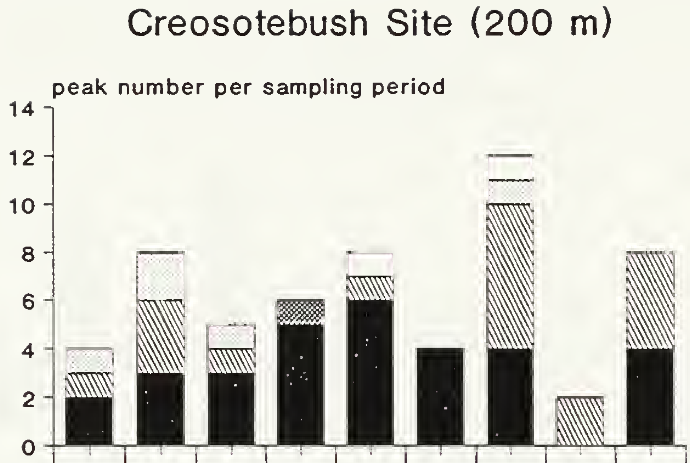
Figure 27. Peak values of lizard species monitored at Armenta Ranch transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

Burn Site (100 m)



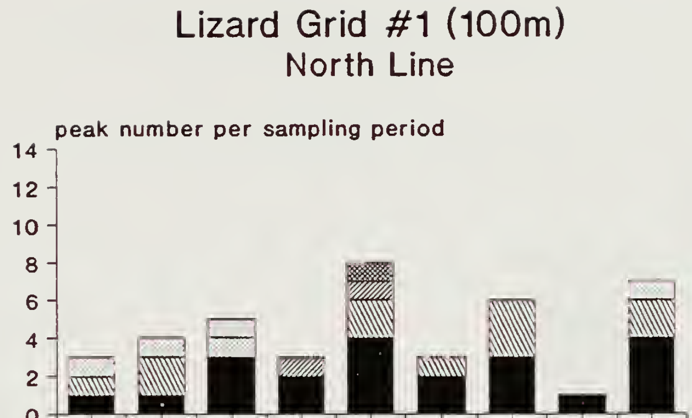
	5-90	8-90	5-93	8-93	6-94	8-94	4-95	9-95
Dipsosaurus						1		
U. ornatus	1	1	2		2	1	1	1
S. magister	1	1			1			
Callisaurus		1	1	1		1		
Uta	2	6	1	6	3	6	1	7
Cnemi tigris	1	2	4	1	2	2	5	2

Figure 28. Peak values of lizard species monitored at Burn Site transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



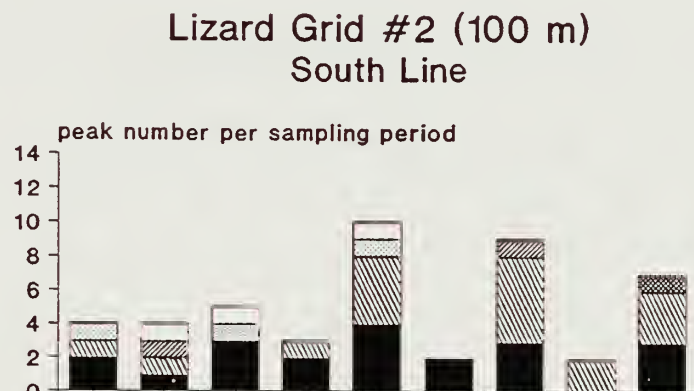
		5-90	8-90	5-91	5-93	9-93	5-94	8-94	6-95	9-95
Gambelia					1					
Dipsosaurus						1		1		
Callisaurus		1	2	1				1		
Uta		1	3	1		1		6	2	4
Cnemi tigris		2	3	3	5	6	4	4		4

Figure 29. Peak values of lizard species monitored at Creosotebush Site transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



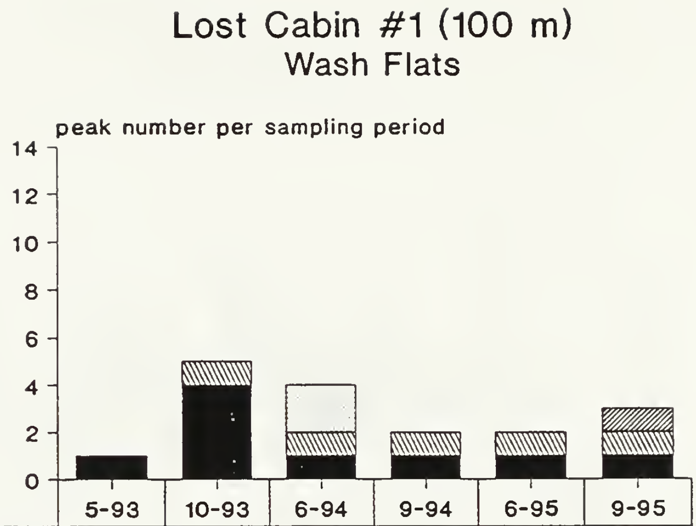
	5-90	7-90	5-91	5-93	8-93	5-94	8-94	5-95	8-95
Gambelia					1				
U. ornatus			1						
S. magister				1	1				
Callisaurus	1	1	1						1
Uta	1	2			2	1	3		2
Cnemi tigris	1	1	3	2	4	2	3	1	4

Figure 30. Peak values of lizard species monitored at Lizard Grid #1 (North) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



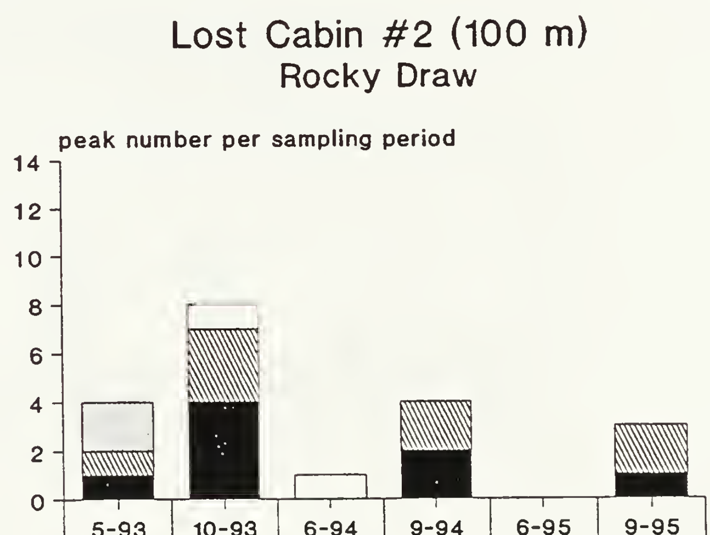
	5-90	7-90	5-91	5-93	8-93	5-94	8-94	5-95	8-95
Gambelia									1
Dipsosaurus		1	1		1				
U. ornatus			1						
S. magister		1					1		
Callisaurus	1				1				
Uta	1	1		1	4		5	2	3
Cnemi tigris	2	1	3	2	4	2	3		3

Figure 31. Peak values of lizard species monitored at Lizard Grid #2 (South) transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.



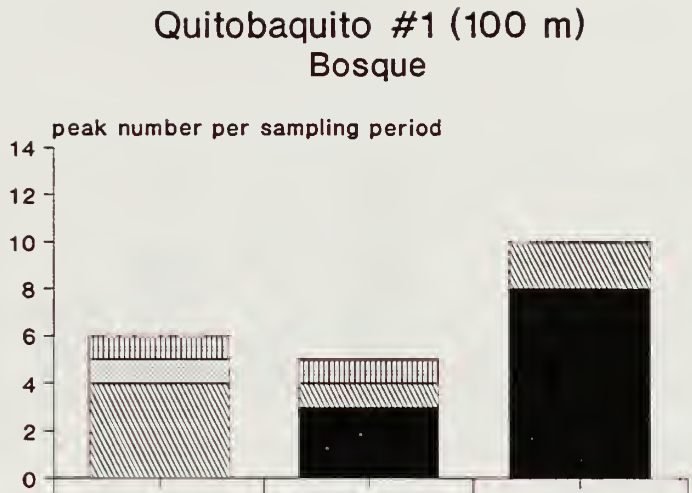
	5-93	10-93	6-94	9-94	6-95	9-95
Callisaurus						1
U. ornatus			2			
Uta		1	1	1	1	1
Cnemi tigris	1	4	1	1	1	1

Figure 32. Peak values of lizard species monitored at Lost Cabin #1 (Wash Flats) transect, Organ Pipe Cactus National Monument, Arizona, 1993–1995.



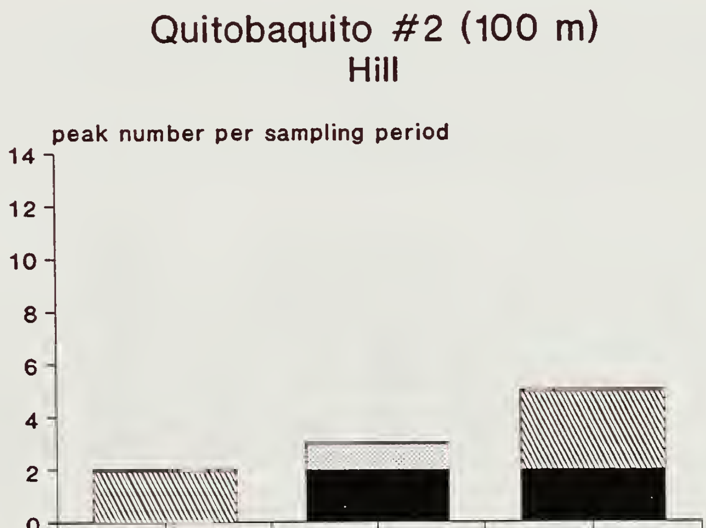
	5-93	10-93	6-94	9-94	6-95	9-95
Crotaphytus		1	1			
U. ornatus	2					
Uta	1	3		2		2
Cnemi tigris	1	4		2		1

Figure 33. Peak values of lizard species monitored at Lost Cabin #2 (Rocky Draw) transect, Organ Pipe Cactus National Monument, Arizona, 1993–1995.



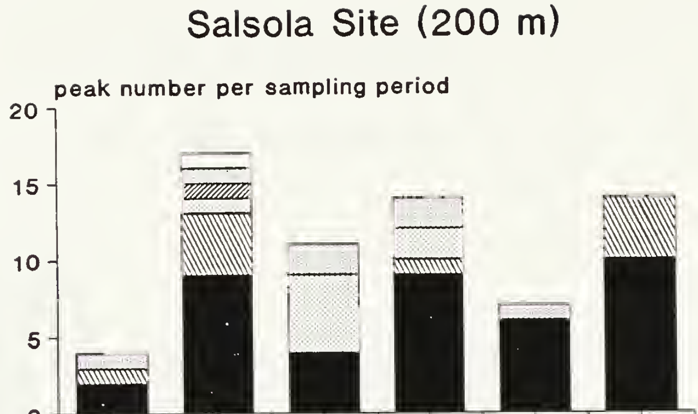
	8-94	6-95	9-95
U. ornatus	1	1	
Callisaurus	1		
Uta	4	1	2
Cnemi tigris		3	8

Figure 34. Peak values of lizard species monitored at Quitobaquito #1 (Bosque) transect, at Organ Pipe Cactus National Monument, Arizona, 1994–1995.



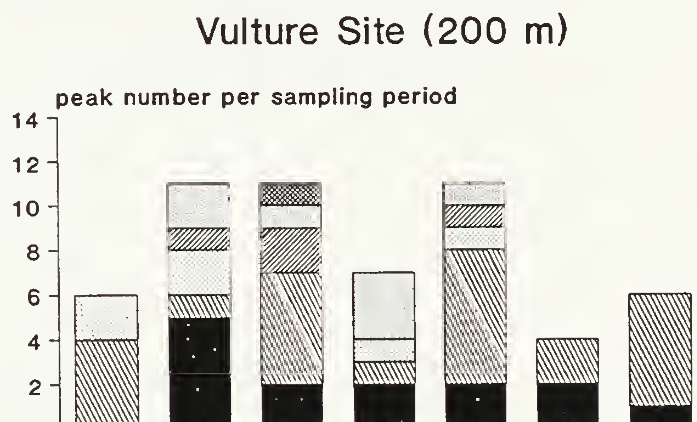
	8-94	6-95	9-95
Callisaurus		1	
Uta	2		3
Cnemi tigris		2	2

Figure 35. Peak values of lizard species monitored at Quitobaquito #2 (Hill) transect, Organ Pipe Cactus National Monument, Arizona, 1994–1995.



	5-93	9-93	5-94	8-94	5-95	10-95
Dipsosaurus		1				
U. ornatus	1	1	2	2	1	
S. magister		1				
Callisaurus		1	5	2		
Uta	1	4		1		4
Cnemi tigris	2	9	4	9	6	10

Figure 36. Peak values of lizard species monitored at Salsola Site transect, Organ Pipe Cactus National Monument, Arizona, 1993–1995.



	8-90	5-93	8-93	5-94	9-94	4-95	9-95
Gambelia			1				
U. ornatus		2	1	3	1		
S. magister		1	2		1		
Callisaurus	2	2		1	1		
Uta	4	1	5	1	6	2	5
Cnemi tigris		5	2	2	2	2	1

Figure 37. Peak values of lizard species monitored at Vulture Site transect, Organ Pipe Cactus National Monument, Arizona, 1990–1995.

Nocturnal Rodents

Introduction

By serving as a major prey base for bird, reptile, and mammalian predators, and contributing to soil aeration and seed dispersal, nocturnal rodents occupy a key trophic level in terrestrial ecosystems. Population fluctuations of nocturnal rodents are often pronounced, and have many implications for other trophic levels. Understanding how rodent populations vary is important for gaining insight into how other trophic levels respond to those changes and to better understand the functioning of desert ecosystems. Nocturnal rodents are particularly suitable for study because they (1) are found in most habitats, (2) respond quickly to changes in the primary productivity of plants, (3) have high fecundity with several litters in a year possible, (4) are easily captured and recaptured, (5) have a relatively small home range, and (6) are relatively easy to identify (Petryszyn and Russ 1996).

Project History

The SEP project, Special Status Mammals of Organ Pipe Cactus National Monument, contracted to Yar Petryszyn (The University of Arizona) to collect 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, 1 or 2 pitfall traps (3-lb coffee cans) were placed to capture desert shrews *(Notiosorex crawfordi)*. Large Havahart traps were set for the possible capture of larger animals such as badger *(Taxidea taxus)*, ringtail *(Bassariscus astutus)*, foxes, and skunks.

The study confirmed the presence of 2 families of nocturnal rodents as being present in the monument: Cricetidae and Heteromyidae. Study results showed that the heteromyids, 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 small mammal constituents of mountain canyon macrohabitats. During the course of this study, the Arizona cotton rat *(Sigmodon arizonae)*, a cricetid, was confirmed on the monument for the first time in December 1988.

As a final part of the study, monitoring protocols were developed to guide monument resource management staff in monitoring nocturnal rodent populations through time. Institutionalized nocturnal rodent monitoring began by monument staff in 1992 and has continued since.

1995 Monitoring Activities
During a 4-week period from 27 June through 30 July, nocturnal rodents were monitored by resources management staff on 18 EMP study sites.

Methods
Nocturnal rodents were monitored using capture, mark, release, and recapture methods (Petryszyn 1995). Forty-nine Sherman live-traps (measuring 3 x 3.5 x 9-in.) were placed on a 7 x 7 grid, with 15-m spacing between stations. Two grids were located at each study site, with the exception of 1 grid each at Bull Pasture and Dripping Springs. Trap stations on each grid were given permanent alphanumeric designations of A1 through G7 (A1 = southwest grid corner; G7 = northeast grid corner). This designation is useful in tracking species microhabitat selection and species distribution over time. Traps were baited with rolled oats and opened at dusk for 2 consecutive nights at each site. Rodent processing (weighing, sexing, and marking) was begun near dawn on the following morning and finished before the sun had risen high enough to heat the traps appreciably.

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) was captured during the 2-night trapping period (Petryszyn 1995). Species diversity was determined from the formula:

$$\mathbf{H' = - SUM\ (p_i\ x\ ln(p_i))},$$

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 rodents on the quadrant or sample and ln is the natural logarithm. Field techniques and population modeling methods are explained in detail in the EMP monitoring protocol manual (Petryszyn 1995).

Results
Tables 11–20 contain summaries of monitoring results at Core I sites and Tables 21–28 at non-Core I sites. For statistical summaries, numbers from the 2 grids at each site are combined. Figures 38–55 display biomass estimates for each small nocturnal rodent species observed on the Ecological Monitoring Program sites in Organ Pipe Cactus National Monument, 1991–1995. (Fewer years for some sites.) During the 4-week trapping period, 921 individual rodents (excluding recaptures and the few individuals that escaped before being processed) were captured in 3,332 trap nights (49 traps/grid/night), representing 9 species. Estimated total biomass (cricetids and heteromyids combined) ranged from 193.2 g/ha at Armenta Ranch (Table 21, Fig. 48) to 3,058.1 g/ha at Bull Pasture (Table 22, Fig. 49).

Many sites demonstrated a decline in heteromyid density from 1994 to 1995, including Aguajita Wash (Table 11, Fig. 38), Dos Lomitas (Table 13, Fig. 40), East Armenta (Table 14, Fig. 41), Lower Colorado Larrea (Table 16, Fig. 43), Pozo Nuevo (Table 18, Fig. 45), and Salsola (Table 27, Fig. 54). Armenta Ranch showed the most striking decline, from 61 n/ha in 1994 to 7 n/ha in 1995 (Table 21, Fig. 48). Heteromyid numbers at Growler Canyon (Table 15, Fig. 42) and

Quitobaquito (Table 26, Fig. 53), sites with a dense bosque component, remained constant over the 2 years. At the Bull Pasture quadrat, heteromyids were captured after 2 years of only cricetid activity (Table 22, Fig. 49). *N. albigula* biomass at Alamo Canyon decreased annually from 1993 to 1995 (Fig. 39), while heteromyid biomass increased substantially (Table 12).

In 1995, 2 new Core I EMP study sites were sampled. High diversity was found at the Middle Bajada site, with 8 species caught (Fig. 44) and a total combined cricetid and heteromyid estimated biomass of 920.1 g/ha (Table 17). The Valley Floor site produced low biomass, yet 6 species were found (Table 20, Fig. 47).

Three non-core study sites were sampled in 1995 as well. The Burn Site quadrats yielded very low density, diversity, and biomass, with an estimated 253.8 g/ha heteromyid biomass (Table 23), and only 2 species captured (Fig. 50). The Dripping Springs site was notable for its high numbers of Bailey's pocket mouse *(Chaetodipus baileyi)* (Fig. 51). Six species of nocturnal rodents were caught at the Vulture Site quadrats (Fig. 55).

Out of the 3,332 trap nights in 1995, 252 traps were found cleaned out of bait (usually by ants), with substantial "clean-outs" at Lower Colorado Larrea, Bull Pasture, and Aguajita sites. Also, 110 traps were found sprung but empty, which could have been the result of wind, uneven ground, animals bumping traps, or entry by arthropods. Only Bull Pasture and Alamo Canyon sites experienced large numbers of sprung traps. Three tail injuries from traps were recorded in 1995, compared to 16 (a combination of leg and tail injuries) in 1994. In 1995, 6 rodents died during processing, while in 1994, 9 mortalities occurred during the monitoring session, 4 of which were killed by ants.

Table 11. Results from small nocturnal rodent monitoring at the Aguajita Wash site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	61.0	43.0	31.0	18.5
Biomass (g/ha)	1,105.4	842.5	753.95	310.65
Total Cricetid				
Density (n/ha)	0.0	4.0	3.5	6.0
Biomass (g/ha)	0.0	402.8	404.95	321.85
Diversity (H')	0.577	1.226	1.347	1.458
Capture success, night 1	67%	52%	40%	29%
Capture success, night 2	83%	63%	49%	35%
Recapture	31%	31%	38%	39%

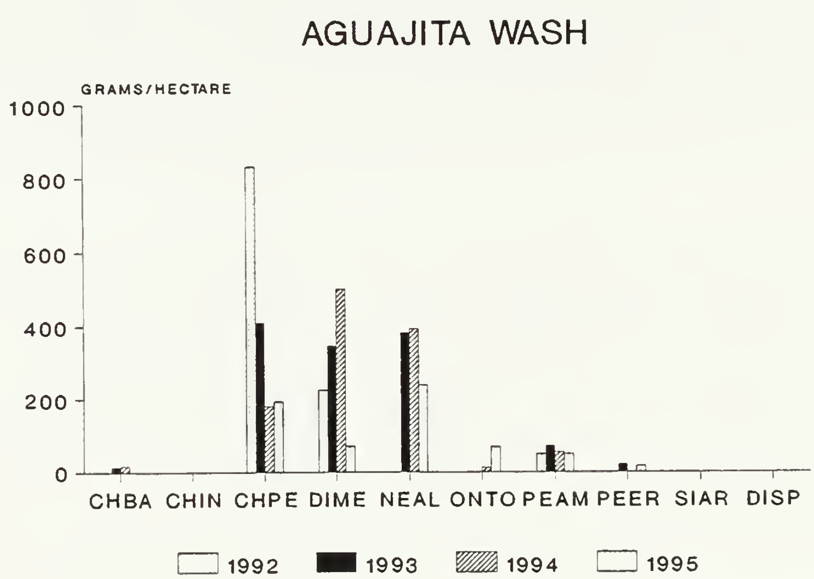


Figure 38. Biomass estimates for small nocturnal rodents observed at the Aguajita Wash site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 12. Results from small nocturnal rodent monitoring at the Alamo Canyon site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	3.5	2.0	4.0	19.0
Biomass (g/ha)	64.8	39.3	57.5	318.25
Total Cricetid				
Density (n/ha)	28.5	26.0	20.5	16.0
Biomass (g/ha)	1353.3	3602.8	2677.2	1844.85
Diversity (H')	0.963	0.420	0.855	1.457
Capture success, night 1	34%	34%	27%	34%
Capture success, night 2	49%	41%	39%	54%
Recapture	31%	41%	38%	28%

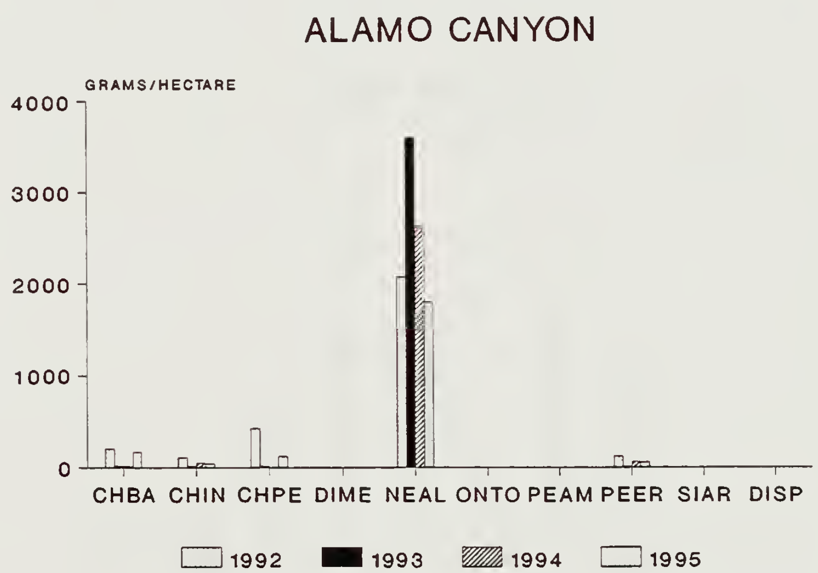


Figure 39. Biomass estimates for small nocturnal rodents observed at the Alamo Canyon site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 13. Results from small nocturnal rodent monitoring at the Dos Lomitas site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	45.5	51.0	48.0	23.0
Biomass (g/ha)	909.5	1189.7	1391.2	524.65
Total Cricetid				
Density (n/ha)	2.0	2.5	3.5	1.5
Biomass (g/ha)	133.4	107.2	363.7	203.5
Diversity (H')	0.762	0.827	1.011	0.926
Capture success, night 1	46%	69%	56%	29%
Capture success, night 2	71%	69%	71%	37%
Recapture	29%	43%	31%	41%

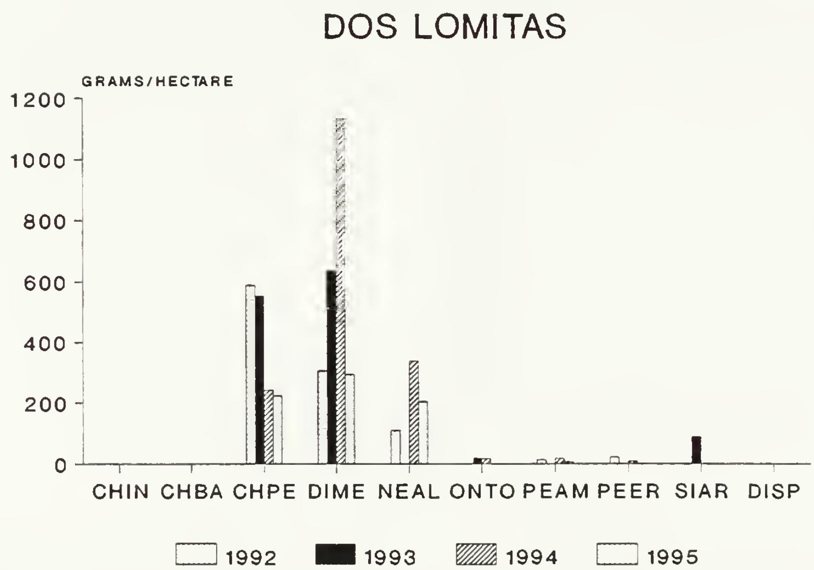


Figure 40. Biomass estimates for small nocturnal rodents observed at the Dos Lomitas site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 14. Results from small nocturnal rodent monitoring at the East Armenta site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	53.5	45.0	48.5	33.5
Biomass (g/ha)	1146.7	1025.1	1228.35	592.6
Total Cricetid				
Density (n/ha)	1.0	2.0	2.5	6.5
Biomass (g/ha)	19.9	236.5	371.0	792.5
Diversity (H')	1.080	1.231	1.186	1.313
Capture success, night 1	74%	58%	69%	42%
Capture success, night 2	74%	62%	63%	57%
Recapture	49%	39%	45%	30%

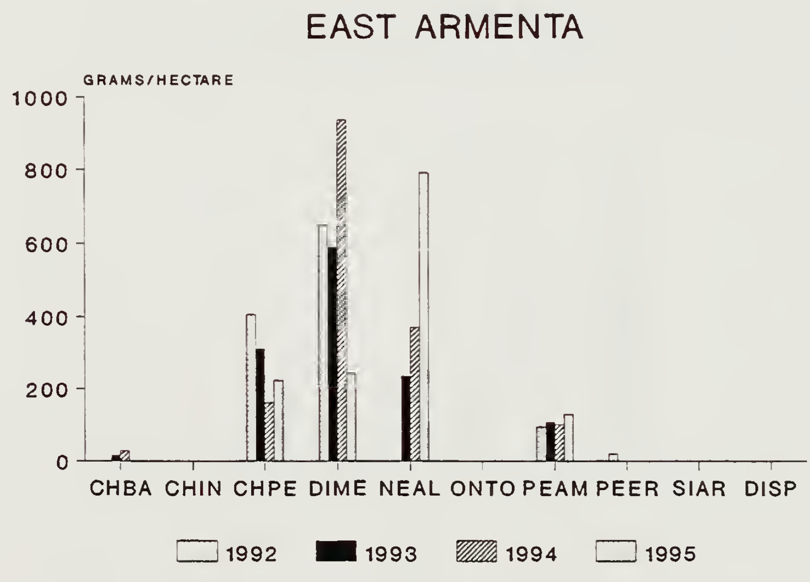


Figure 41. Biomass estimates for small nocturnal rodents observed at the East Armenta site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 15. Results from small nocturnal rodent monitoring at the Growler Canyon site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	53.0	61.5	44.0	45.0
Biomass (g/ha)	880.0	992.6	963.3	739.75
Total Cricetid				
Density (n/ha)	1.5	3.0	1.0	2.5
Biomass (g/ha)	258.6	156.5	180.5	308.7
Diversity (H')	0.269	0.410	0.783	0.436
Capture success, night 1	55%	82%	54%	59%
Capture success, night 2	81%	74%	56%	57%
Recapture	31%	32%	30%	34%

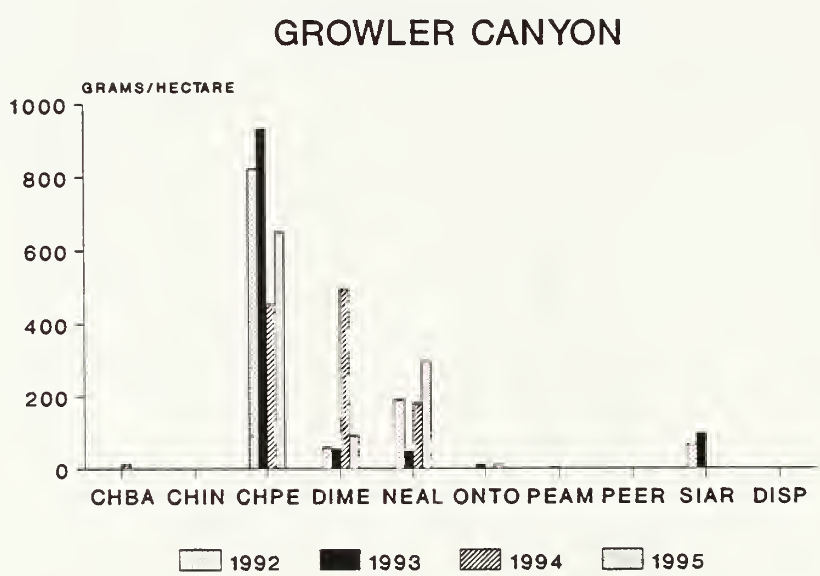


Figure 42. Biomass estimates for small nocturnal rodents observed at the Growler Canyon site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 16. Results from small nocturnal rodent monitoring at the Lower Colorado Larrea site (south grids), Organ Pipe Cactus National Monument, Arizona, 1993–1995.

	1993	1994	1995
Total Heteromyid			
Density (n/ha)	41.0	51.5	17.5
Biomass (g/ha)	910.0	1632.3	507.2
Total Cricetid			
Density (n/ha)	1.0	1.0	0.0
Biomass (g/ha)	65.5	22.9	0.0
Diversity (H')	1.200	0.719	0.586
Capture success, night 1	43%	63%	17%
Capture success, night 2	54%	67%	23%
Recapture	20%	35%	20%

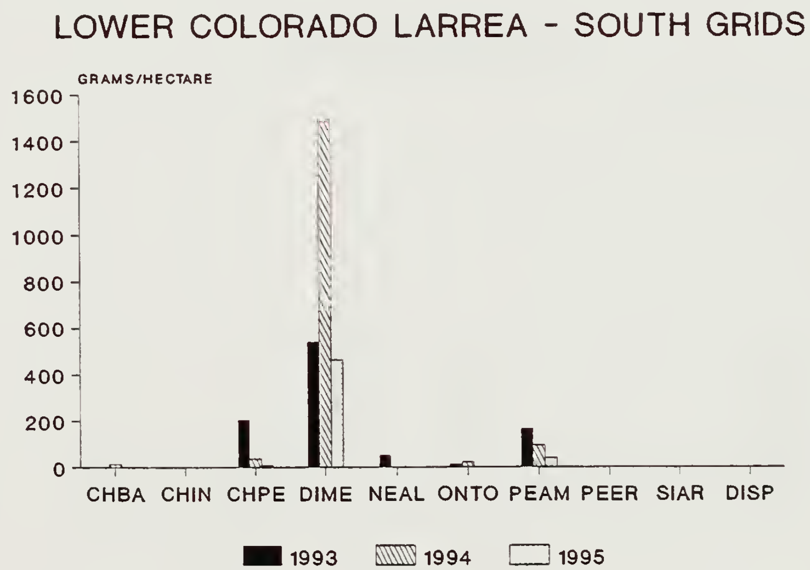


Figure 43. Biomass estimates for small nocturnal rodents observed at the Lower Colorado Larrea site (south grids), Organ Pipe Cactus National Monument, Arizona, 1993–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 17. Results from small nocturnal rodent monitoring at the Middle Bajada site, Organ Pipe Cactus National Monument, Arizona, 1995.

	1995
Total Heteromyid	
Density (n/ha)	27.5
Biomass (g/ha)	570.4
Total Cricetid	
Density (n/ha)	3.5
Biomass (g/ha)	349.7
Diversity (H')	1.479
Capture success, night 1	32%
Capture success, night 2	47%
Recapture	33%

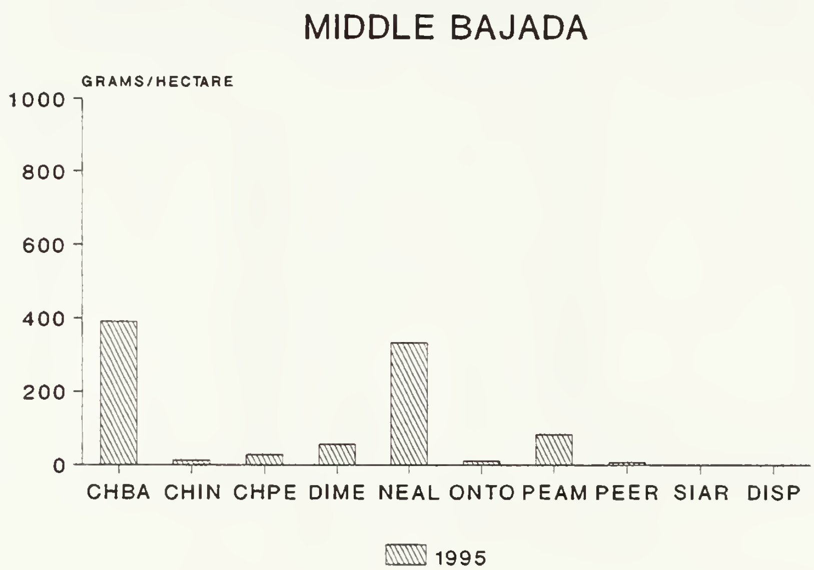


Figure 44. Biomass estimates for small nocturnal rodents observed at the Middle Bajada site, Organ Pipe Cactus National Monument, Arizona, 1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae.*

Table 18. Results from small nocturnal rodent monitoring at the Pozo Nuevo site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	52.5	39.0	37.0	21.0
Biomass (g/ha)	1030.0	993.6	1069.1	606.9
Total Cricetid				
Density (n/ha)	1.0	1.0	0.5	0.0
Biomass (g/ha)	19.5	20.6	9.3	0.0
Diversity (H')	1.204	1.102	0.726	0.780
Capture success, night 1	77%	48%	59%	27%
Capture success, night 2	55%	58%	51%	24%
Recapture	41%	42%	68%	34%

Figure 45. Biomass estimates for small nocturnal rodents observed at the Pozo Nuevo site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae.*

Table 19. Results from small nocturnal rodent monitoring at the Senita Basin site, Organ Pipe Cactus National Monument, Arizona, 1992–1995.

	1992	1993	1994	1995
Total Heteromyid				
Density (n/ha)	63.5	15.5	18.0	24.0
Biomass (g/ha)	1288.9	349.9	357.7	431.2
Total Cricetid				
Density (n/ha)	2.0	1.5	0.0	0.5
Biomass (g/ha)	228.7	206.0	0.0	48.5
Diversity (H')	1.575	1.367	1.386	1.463
Capture success, night 1	74%	17%	15%	24%
Capture success, night 2	87%	20%	23%	31%
Recapture	30%	10%	1%	28%

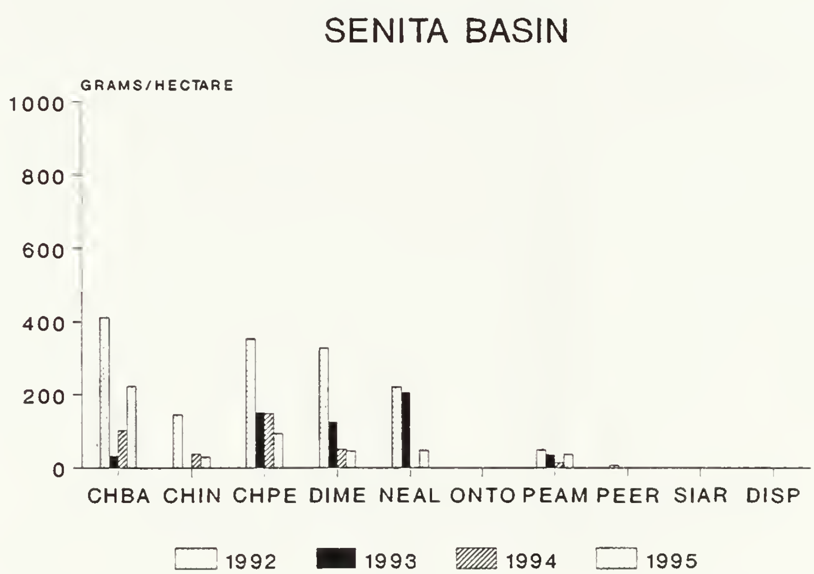


Figure 46. Biomass estimates for small nocturnal rodents observed at the Senita Basin site, Organ Pipe Cactus National Monument, Arizona, 1992–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 20. Results from small nocturnal rodent monitoring at the Valley Floor site, Organ Pipe Cactus National Monument, Arizona, 1995.

	1995
Total Heteromyid	
Density (n/ha)	6.0
Biomass (g/ha)	151.8
Total Cricetid	
Density (n/ha)	2.5
Biomass (g/ha)	241.4
Diversity (H')	1.712
Capture success, night 1	5%
Capture success, night 2	15%
Recapture	19%

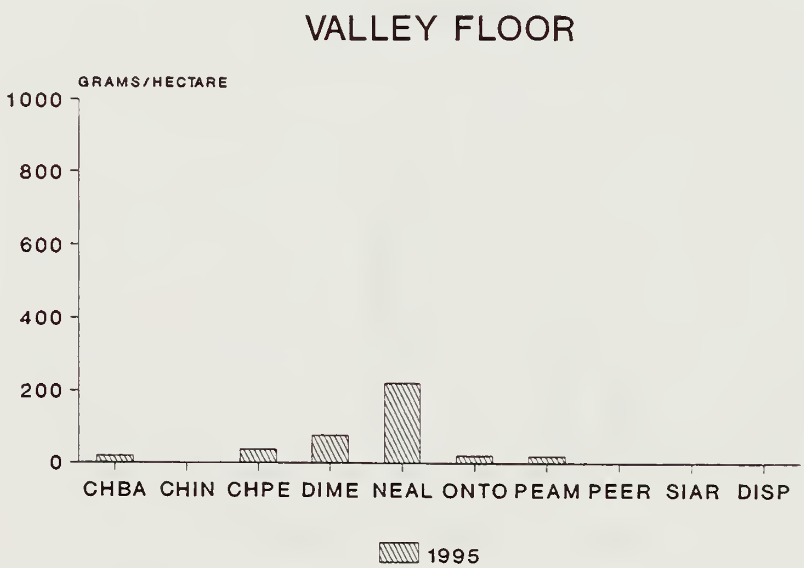


Figure 47. Biomass estimates for small nocturnal rodents observed at the Valley Floor site, Organ Pipe Cactus National Monument, Arizona, 1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 21. Results from small nocturnal rodent monitoring at the Armenta Ranch site, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

	1993	1994	1995
Total Heteromyid			
Density (n/ha)	50.0	61.0	7.0
Biomass (g/ha)	1193.6	1854.9	164.9
Total Cricetid			
Density (n/ha)	0.0	1.0	1.5
Biomass (g/ha)	0.0	115.5	28.3
Diversity (H')	1.087	1.076	1.650
Capture success, night 1	54%	78%	11%
Capture success, night 2	59%	79%	9%
Recapture	19%	38%	35%

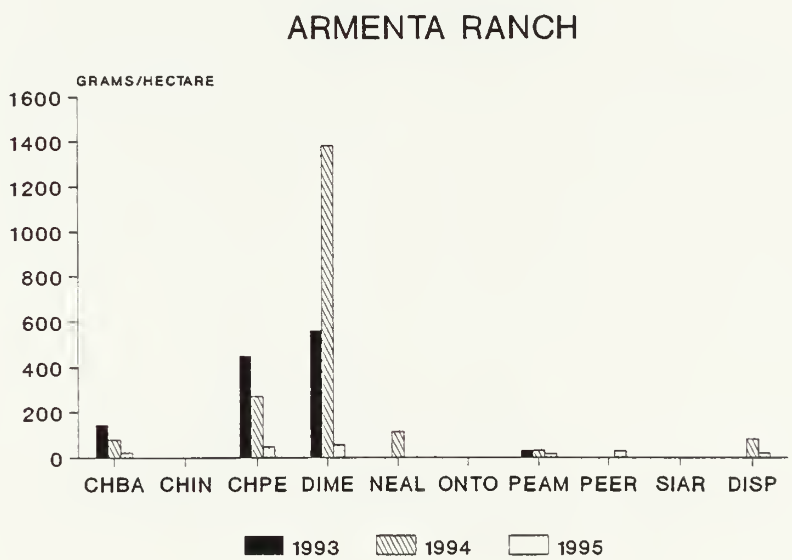


Figure 48. Biomass estimates for small nocturnal rodents observed at the Armenta Ranch site, Organ Pipe Cactus National Monument, Arizona, 1993–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 22. Results from small nocturnal rodent monitoring at the Bull Pasture site, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

	1993	1994	1995
Total Heteromyid			
Density (n/ha)	0.0	0.0	2.0
Biomass (g/ha)	0.0	0.0	38.9
Total Cricetid			
Density (n/ha)	24.0	31.0	28.0
Biomass (g/ha)	2795.9	3514.6	3019.2
Diversity (H')	0.377	0.491	0.683
Capture success, night 1	33%	35%	22%
Capture success, night 2	31%	47%	45%
Recapture	47%	39%	14%

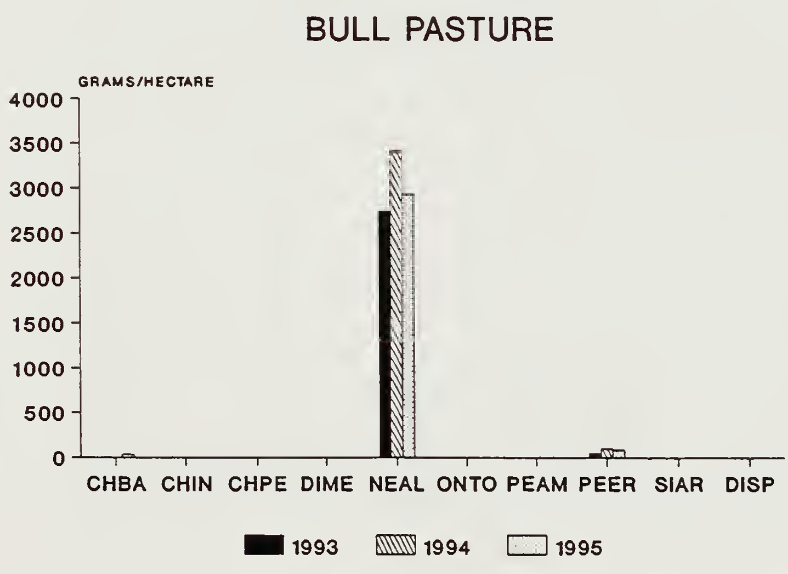


Figure 49. Biomass estimates for small nocturnal rodents observed at the Bull Pasture site, Organ Pipe Cactus National Monument, 1993–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 23. Results from small nocturnal rodent monitoring at the Burn Site, Organ Pipe Cactus National Monument, Arizona, 1995.

	1995
Total Heteromyid	
Density (n/ha)	12.5
Biomass (g/ha)	253.8
Total Cricetid	
Density (n/ha)	0.0
Biomass (g/ha)	0.0
Diversity (H')	0.627
Capture success, night 1	12%
Capture success, night 2	17%
Recapture	22%

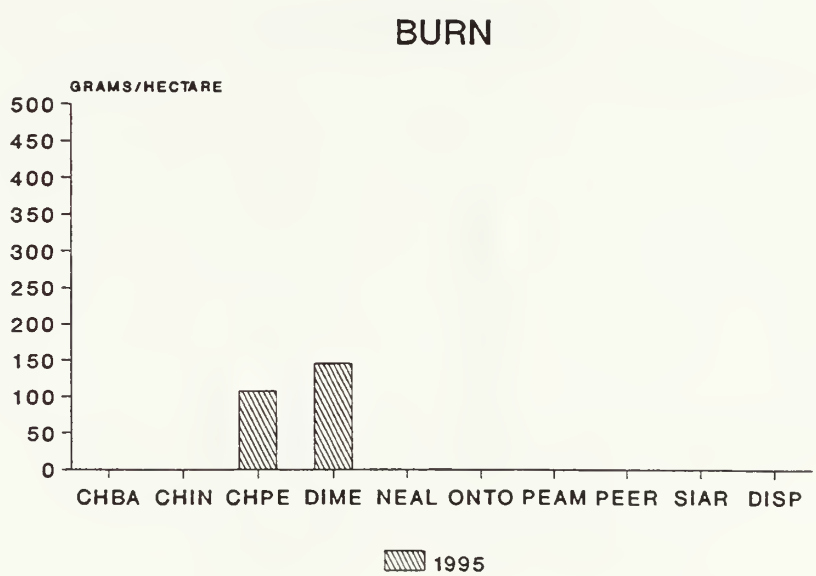


Figure 50. Biomass estimates for small nocturnal rodents observed at the Burn Site, Organ Pipe Cactus National Monument, 1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*

Table 24. Results from small nocturnal rodent monitoring at the Dripping Springs site, Organ Pipe Cactus National Monument, Arizona, 1995.

	1995
Total Heteromyid	
Density (n/ha)	31.0
Biomass (g/ha)	702.5
Total Cricetid	
Density (n/ha)	8.0
Biomass (g/ha)	897.6
Diversity (H')	0.876
Capture success, night 1	47%
Capture success, night 2	53%
Recapture	38%

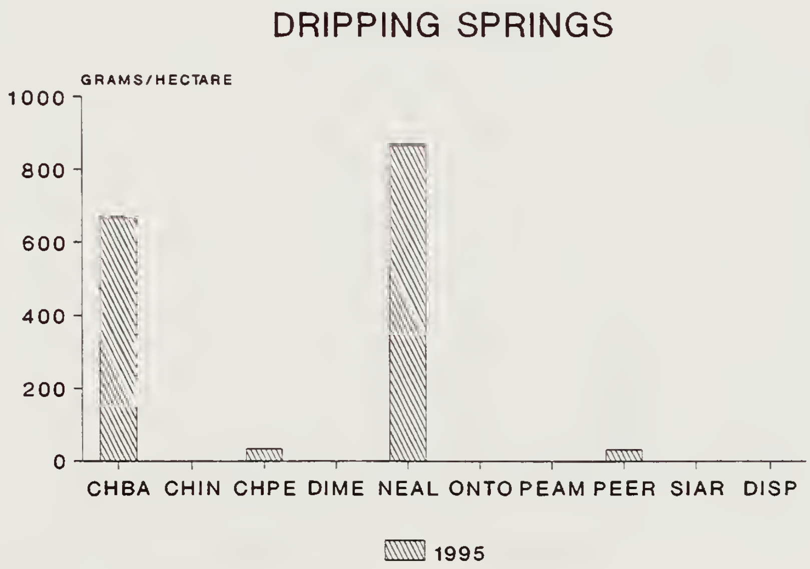


Figure 51. Biomass estimates for small nocturnal rodents observed at the Dripping Springs site, Organ Pipe Cactus National Monument, Arizona, 1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 25. Results from small nocturnal rodent monitoring at the Lost Cabin site, Organ Pipe Cactus National Monument, Arizona, 1994–1995.

	1994	1995
Total Heteromyid		
Density (n/ha)	29.5	29.5
Biomass (g/ha)	473.7	494.15
Total Cricetid		
Density (n/ha)	0.0	3.0
Biomass (g/ha)	0.0	441.5
Diversity (H')	0.497	1.062
Capture success, night 1	30%	31%
Capture success, night 2	38%	43%
Recapture	19%	18%

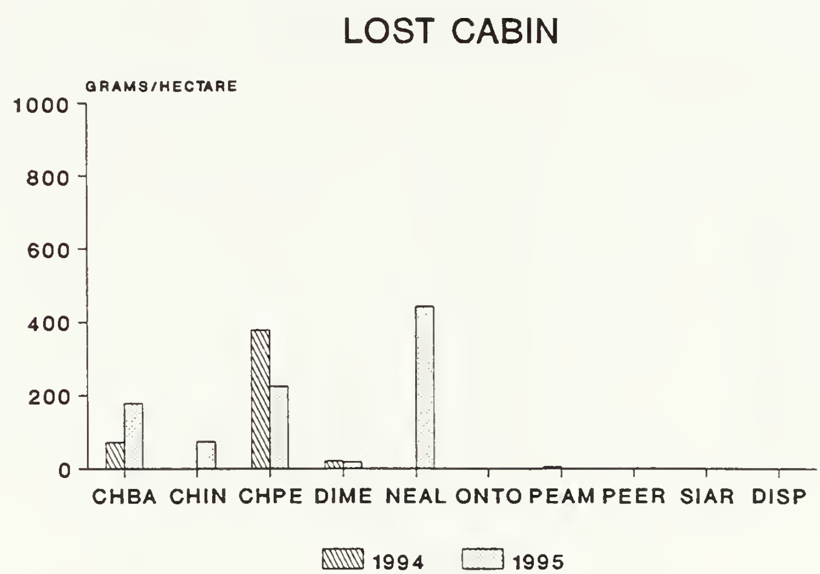


Figure 52. Biomass estimates for small nocturnal rodents observed at the Lost Cabin site, Organ Pipe Cactus National Monument, Arizona, 1994–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 26. Results from small nocturnal rodent monitoring at the Quitobaquito site, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

	1993	1994	1995
Total Heteromyid			
Density (n/ha)	17.0	18.5	23.0
Biomass (g/ha)	327.9	355.1	316.75
Total Cricetid			
Density (n/ha)	52.5	18.0	17.5
Biomass (g/ha)	3157.9	2159.1	2088.2
Diversity (H')	1.401	1.373	1.091
Capture success, night 1	69%	46%	49%
Capture success, night 2	77%	46%	56%
Recapture	45%	40%	41%

Figure 53. Biomass estimates for small nocturnal rodents observed at the Quitobaquito site, Organ Pipe Cactus National Monument, 1993–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae.*

Table 27. Results from small nocturnal rodent monitoring at the Salsola site, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

	1993	1994	1995
Total Heteromyid			
Density (n/ha)	50.5	48.5	23.5
Biomass (g/ha)	881.9	1259.2	483.05
Total Cricetid			
Density (n/ha)	0.5	0.5	3.5
Biomass (g/ha)	45.5	11.5	252.2
Diversity (H')	0.637	0.793	1.069
Capture success, night 1	54%	62%	29%
Capture success, night 2	73%	66%	42%
Recapture	31%	45%	11%

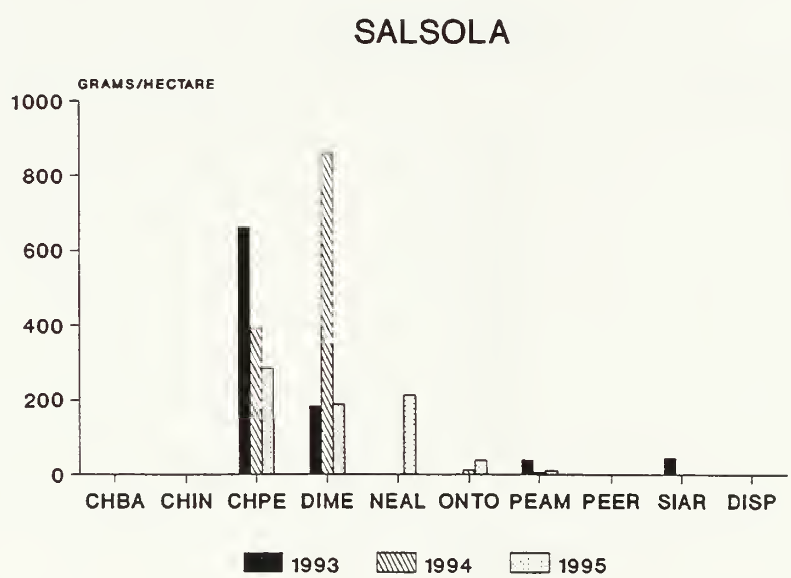


Figure 54. Biomass estimates for small nocturnal rodents observed at the Salsola site, Organ Pipe Cactus National Monument, Arizona, 1993–1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Table 28. Results from small nocturnal rodent monitoring at the Vulture Site, Organ Pipe Cactus National Monument, Arizona, 1995.

	1995
Total Heteromyid	
Density (n/ha)	27.5
Biomass (g/ha)	468.0
Total Cricetid	
Density (n/ha)	4.0
Biomass (g/ha)	518.5
Diversity (H')	1.218
Capture success, night 1	28%
Capture success, night 2	42%
Recapture	11%

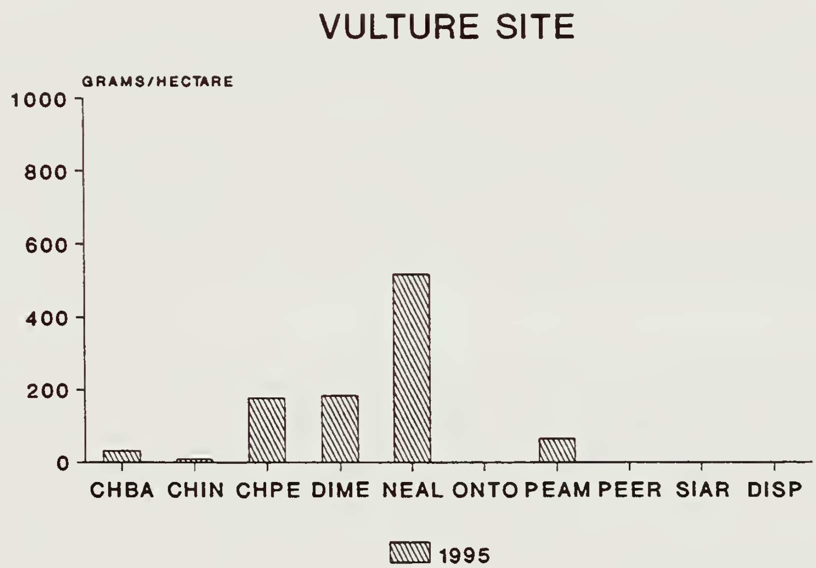


Figure 55. Biomass estimates for small nocturnal rodents observed at the Vulture Site, Organ Pipe Cactus National Monument, Arizona, 1995. The following species abbreviations are used: **CHBA** = *Chaetodipus baileyi*, **CHIN** = *Chaetodipus intermedius*, **CHPE** = *Chaetodipus penicillatus*, **DIME** = *Dipodomys merriami*, **DISP** = *Dipodomys spectabilis*, **NEAL** = *Neotoma albigula*, **ONTO** = *Onychomys torridus*, **PEAM** = *Perognathus amplus*, **PEER** = *Peromyscus eremicus*, and **SIAR** = *Sigmodon arizonae*.

Birds

Introduction

Within Organ Pipe Cactus National Monument, 277 species of birds are known to occur, or to have occurred historically (Groschupf et al. 1988). Of these, 63 are known to breed currently. Bird studies in the monument date to 1941, when Huey (1942) wrote an annotated checklist for 150 species. Later studies 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).

Ecologists generally agree that baseline assessment and long-term monitoring of bird populations may provide a means for measuring ecological change over time. A project conducted by Roy R. Johnson, CPSU/UA, Ecology of Special Status Avian Species, was initiated in 1987 to provide baseline information on bird population parameters. As part of this investigation, monitoring protocols were designed for use by monument resource management staff.

Project History

As 1 of the 12 original SEP research projects, Ecology of Special Status Avian Species made baseline assessments of bird community composition, 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 examined 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.

Following the training session with Johnson, the draft monitoring protocols were partially implemented and tested by resource management staff at 7 EMP sites in 1991 and 1992. However, neither of these attempts were considered valid censuses, because certain monitoring protocol rules were violated. The 1993 monitoring session, however, was considered the first valid census, as it was conducted in full accordance with protocol requirements.

1995 Monitoring Activities

Birds were censused by resource management monitoring staff in April and May on 7 EMP study sites: Aguajita Wash, Alamo Canyon, Dos Lomitas, East Armenta, Growler Canyon, Pozo Nuevo, and Senita Basin.

Methods

The methods followed are detailed in the monitoring handbook (Johnson 1995). The protocol is designed to obtain information on relative abundances of all breeding and migrant birds on EMP study sites during breeding periods. 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 wide, but in the narrow, thickly vegetated riparian areas (Growler Canyon, Aguajita Wash, and Alamo Canyon) transect widths are approximately 20 m. Almost all transects are 1,000 m in length.

Standard pre-census preparation included conducting practice censuses in mixed Sonoran Desert scrub and xeroriparian habitats. Bird vocalization audio-tapes were extensively used both before and during the census so that the observer could maintain a familiarity with calls and songs from breeding birds, winter residents, and transients.

Censusing began as close as possible 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 data sheets. Birds occurring off the transects were recorded but were not used in relative abundance and species richness estimates.

Three censuses, with each census considered a sample replicate, were made at each study site. According to the monitoring protocol, a minimum of 3 censuses are needed to reliably make statistically significant estimates from the data. The sample replicates were spaced at approximately 3-week intervals. One observer conducted all censuses at all sites.

In all censuses, special effort was made to avoid duplicating counts. Some bird species such as the verdin *(Auriparus flaviceps)*, black-tailed gnatcatcher *(Polioptila melanura)*, 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 Gila woodpecker *(Melanerpes uropygialis)*, Myiarchus flycatchers *(Myiarchus* spp.*)*, orioles (*Icterus* spp), and northern flicker *(Colaptes auratus)* demand that an observer pay close attention to the movement of these birds around the study site area so that duplicate counts are minimized.

If there was doubt as to a bird species identity, it was listed as "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 2 species, identification was sometimes difficult. Because of this, sightings were lumped into *Myiarchus* spp. "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 *(Zenaida macroura)*, a field recording of "unknown dove" would be tallied with either white-winged or mourning dove for the above tabulations, since only these 2 species of doves could reasonably be expected to occur on the plot.

Results

The number of birds censused on the 7 study sites over 3 replicates averaged 81.75 individuals. Sixty-one bird species were recorded (Table 29). Of these, 39 are known to breed in the monument. Species diversity was determined from the formula:

$$\mathbf{H' = - SUM\ (p_i\ x\ ln(p_i))},$$

where H' is diversity, p_i is, for each bird species i, the numerical proportion of that species abundance (N, density) to the total abundance of all bird species on the transect, and ln is the natural logarithm.

Species richness and diversity values are presented in Figure 56. The results from this census are organized by study site and are presented in Table 29.

Table 29. Summary of avian species monitoring on 7 EMP study sites, Organ Pipe Cactus National Monument, Arizona, 1995. Values in table are mean abundance per census (n=3 censuses) followed by 1 standard error.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Turkey vulture *Cathartes aura*	2.0 ± 0.8	-	-	-	4.0 ± 1.7	-	0.7 ± 0.5
American kestrel *Falco sparverius*	-	-	-	-	-	-	0.3 ± 0.3
Red-tailed hawk *Buteo jamaicensis*	-	-	-	-	-	-	0.3 ± 0.3
Unknown accipiter	0.3 ± 0.3	-	-	-	-	-	-
Gambel's quail *Callipepla gambellii*	10.3 ± 3.5	0.7 ± 0.5	5.7 ± 3.0	2.0 ± 1.2	10.3 ± 4.0	-	0.3 ± 0.3
White-winged dove *Zenaida asiatica*	13.7 ± 1.4	7.0 ± 0.5	5.0 ± 2.3	4.7 ± 2.1	11.7 ± 1.1	2.0 ± 0.8	3.0 ± 1.4
Mourning dove *Zenaida macroura*	4.7 ± 0.7	8.7 ± 1.8	10.7 ± 1.4	11.0 ± 4.0	15.3 ± 5.8	6.3 ± 1.8	2.7 ± 0.7
Western screech-owl *Otus kennicottii*	-	-	-	-	0.3 ± 0.3	-	-
Unknown hummingbird	1.3 ± 0.7	10.7 ± 0.5	-	0.3 ± 0.3	2.0 ± 0.5	1.0 ± 0.5	4.7 ± 1.9
Gila woodpecker *Melanerpes uropygialis*	6.0 ± 0.5	0.3 ± 0.3	1.3 ± 0.5	3.0 ± 0.0	3.0 ± 0.8	0.3 ± 0.3	4.0 ± 0.5
Ladder-backed woodpecker *Picoides scalaris*	0.7 ± 0.3	0.7 ± 0.3	-	-	-	-	-
Northern flicker *Colaptes auratus*	0.3 ± 0.3	1.3 ± 0.5	2.3 ± 0.7	1.0 ± 0.5	1.7 ± 0.5	0.3 ± 0.3	3.7 ± 0.7
Western wood-peewee *Contopus sordidulus*	-	0.3 ± 0.3	-	-	-	-	-

Table 29—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
"Empidonax" flycatcher *Empidonax* spp.	1.3 ± 0.7	6.3 ± 0.7	-	-	0.7 ± 0.5	-	-
Vermilion flycatcher *Pyrocephalus rubinus*	-	-	-	-	0.3 ± 0.3	-	-
"Myiarchus" flycatcher *Myiarchus spp.*	4.7 ± 0.5	2.7 ± 0.7	1.7 ± 0.7	1.3 ± 0.5	5.3 ± 1.0	1.3 ± 1.1	3.3 ± 0.7
Violet-green swallow *Tachycineta thalassina*	1.7 ± 0.7	0.3 ± 0.3	0.7 ± 0.5	-	-	-	-
Unknown swallow	0.7 ± 0.5	0.7 ± 0.5	0.3 ± 0.3	0.3 ± 0.3	-	-	-
Common raven *Corvus corax*	0.3 ± 0.3	-	-	0.3 ± 0.3	-	-	-
Verdin *Auriparus flaviceps*	10 ± 1.4	5.0 ± 0.5	1.0 ± 0.0	3.3 ± 0.7	4.0 ± 1.2	1.3 ± 1.1	6.7 ± 1.5
Cactus wren *Campylorhynchus brunneicappillus*	0.3 ± 0.3	1.3 ± 0.5	2.0 ± 0.5	1.3 ± 0.7	0.3 ± 0.3	0.7 ± 0.3	8.3 ± 1.5
Canyon wren *Catherpes mexicanus*	-	4.0 ± 1.7	-	-	0.7 ± 0.5	-	-
Black-tailed gnatcatcher *Polioptila melanura*	3.7 ± 1.0	2.7 ± 0.5	0.7 ± 0.5	-	5.7 ± 1.1	0.7 ± 0.5	2.7 ± 0.5
Hermit thrush *Catharus guttatus*	-	0.3 ± 0.3	-	-	-	-	-
Northern mockingbird *Mimus polyglottos*	5.3 ± 0.7	0.7 ± 0.3	2.0 ± 1.6	2.0 ± 1.6	4.0 ± 2.5	0.7 ± 0.5	1.0 ± 0.5
Curve-billed thrasher *Toxostoma curvirostre*	2.3 ± 1.0	4.0 ± 0.9	0.3 ± 0.3	1.3 ± 0.3	6.0 ± 0.0	-	2.0 ± 0.9

Table 29—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Crissal thrasher *Toxostoma dorsale*	0.3 ± 0.3	-	-	-	-	-	-
Phainopepla *Phainopepla nitens*	26.3 ± 12.7	22.7 ± 4.4	1.7 ± 0.7	1.7 ± 1.0	11.7 ± 3.5	-	4.0 ± 1.7
Loggerhead shrike *Lanius ludovicianus*	-	-	-	1.7 ± 1.0	-	-	-
Bell's vireo *Vireo bellii*	4.3 ± 0.3	-	-	-	3.0 ± 0.5	-	-
Warbling Vireo *Vireo gilvus*	-	-	-	-	-	-	-
Unknown Vireo	0.3 ± 0.3	-	-	-	-	-	-
Yellow-rumped warbler *Dendroica coronata*	0.3 ± 0.3	-	-	-	-	-	-
Black-throated gray warbler *Dendroica nigrescens*	0.3 ± 0.3	-	-	-	0.3 ± 0.3	-	0.7 ± 0.5
Hermit warbler *Dendroica occidentalis*	-	-	-	-	-	-	-
Townsend's warbler *Dendroica townsendi*	0.7 ± 0.5	0.7 ± 0.5	-	-	-	-	0.3 ± 0.3
Lucy's warbler *Vermivora luciae*	6.3 ± 1.0	-	0.3 ± 0.3	-	1.3 ± 0.3	-	-
Macgillivray's warbler *Oporornis tolmiei*	-	-	-	-	0.3 ± 0.3	-	-
Wilson's warbler *Wilsonia pusilla*	2.3 ± 1.0	6.3 ± 2.7	-	-	3.0 ± 1.2	0.3 ± 0.3	1.0 ± 0.8
Unknown "warbler" 1	0.7 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	-	-	-	0.7 ± 0.5

Table 29—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
Unknown "warbler" 2	-	0.7 ± 0.5	-	-	-	-	-
Yellow-breasted chat *Icteria virens*	-	-	-	-	0.3 ± 0.3	-	-
Western tanager *Piranga ludoviciana*	0.7 ± 0.5	0.3 ± 0.3	-	-	0.3 ± 0.3	-	-
Northern cardinal *Cardinalis cardinalis*	-	4.3 ± 1.1	-	-	2.3 ± 1.0	-	0.3 ± 0.3
Pyrrhuloxia *Cardinalis sinuatus*	-	-	-	-	1.0 ± 0.8	-	-
Black-headed grosbeak *Pheucticus melanocephalus*	-	0.3 ± 0.3	0.3 ± 0.3	-	0.3 ± 0.3	-	-
Lazuli bunting *Passerina amoena*	0.3 ± 0.3	0.7 ± 0.5	-	-	0.7 ± 0.5	-	-
Varied bunting *Passerina versicolor*	-	1.0 ± 0.8	-	-	0.3 ± 0.3	-	-
Green-tailed towhee *Pipilo chlorurus*	0.3 ± 0.3	1.3 ± 0.7	-	-	0.3 ± 0.3	-	-
Canyon towhee *Pipilo fuscus*	0.3 ± 0.3	3.7 ± 0.7	-	-	4.3 ± 1.0	-	1.0 ± 0.8
Brewers sparrow *Spizella breweri*	-	-	1.3 ± 1.1	-	-	2.7 ± 2.2	-
Black-throated sparrow *Amphispiza bilineata*	-	-	-	0.3 ± 0.3	0.3 ± 0.3	2.3 ± 0.5	0.3 ± 0.3
Lark bunting *Calamospiza melanocorys*	-	-	40.7 ± 33.2	-	-	-	-

Table 29—continued.

Species	Aguajita Wash	Alamo Canyon	Dos Lomitas	East Armenta	Growler Canyon	Pozo Nuevo	Senita Basin
White-crowned sparrow *Zonotrichia leucophrys*	-	0.7 ± 0.5	1.0 ± 0.8	-	-	-	-
Red-winged blackbird *Agelaius phoeniceus*	0.7 ± 0.5	-	-	-	-	-	-
Great-tailed grackle *Quiscalus mexicanus*	-	-	0.7 ± 0.5	-	-	-	-
Brown-headed cowbird *Molothrus ater*	5.0 ± 0.9	11.7 ± 1.4	1.0 ± 0.8	1.0 ± 0.5	5.3 ± 0.5	0.7 ± 0.3	2.3 ± 0.5
Hooded oriole *Icterus cucullatus*	0.7 ± 0.5	2.3 ± 0.3	-	1.0 ± 0.5	4.3 ± 0.3	-	-
Scott's oriole *Icterus parisorum*	-	-	-	1.3 ± 0.5	-	0.7 ± 0.5	0.3 ± 0.3
House finch *Carpodacus mexicanus*	11.7 ± 0.7	21.0 ± 3.6	0.3 ± 0.3	4.0 ± 1.0	1.7 ± 0.7	0.7 ± 0.3	6.0 ± 0.9
Lesser goldfinch *Carduelis psaltria*	-	1.0 ± 0.8	-	-	-	-	-
Average Species Richness Value	23.67	24.00	12.67	13.33	24.67	8.33	17.00
Average Number of Individuals	131.33	137.00	81.33	43.00	116.67	22.00	61.00
Average Diversity Value (H')	2.707	2.757	1.844	2.284	2.851	1.865	2.589

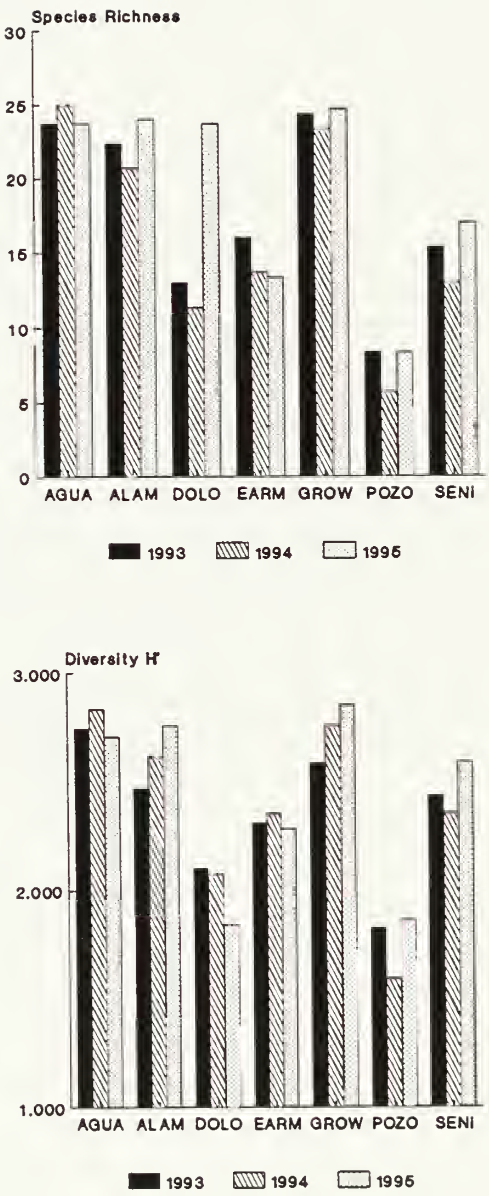


Figure 56. Bird species richness and diversity values recorded on 7 study sites in Organ Pipe Cactus National Monument, Arizona, 1993–1995. The following abbreviations are used: **AGUA** = Aguajita Wash, **ALAM** = Alamo Canyon, **DOLO** = Dos Lomitas, **EARM** = East Armenta, **GROW** = Growler Canyon, **POZO** = Pozo Nuevo, **SENI** = Senita Basin.

Bats

Introduction

Bats comprise the second most diverse group of mammals in the world but their mobility, nocturnal habits, and secretive or inaccessible roost sites make it difficult to study their numbers and diversity. Fourteen species of bats are known to occur in Organ Pipe Cactus National Monument (OPCNM), including a large maternal colony of the endangered lesser long-nosed bat *(Leptonycteris curasoae)* and the following: the western pipistrelle *(Pipistrellus hesperus)*, the cave myotis *(Myotis velifer)*, the California myotis *(Myotis californicus)*, the big brown bat *(Eptesicus fuscus)*, the pallid bat *(Antrozous pallidus)*, the California leaf-nosed bat *(Macrotus californicus)*, Underwood's mastiff bat *(Eumops underwoodi)*, the western mastiff bat *(Eumops perotis californicus)*, the pocketed free-tailed bat *(Nyctinimops femorosaccus)*, and the Brazilian free-tailed bat *(Tadarida brasiliensis)*. In a 1981 CPSU/UA technical report, E. Lendell Cockrum summarized bat populations, life histories, and habitats at OPCNM (Cockrum 1981). Since that time, elimination of cattle grazing and closing abandoned mines may have affected historic water sources and roost sites. In 1993, Yar Petryszyn was contracted to assess the current abundance and diversity of bats in the monument and to develop a long-term monitoring protocol.

While the desired technique to monitor bat populations involves censusing of roost sites, locating day roosts and performing exit counts, this is problematic because of difficult access and widely spaced distribution. Because all insect-eating bats must drink water regularly, mist-netting at water sources during the summer months can provide an indication of bat activity, relative abundance, and overall distribution. Although mist-netting has shortcomings, including influence of weather and varying propensities for capture among bat species, it provides the most accurate technique for determining diversity and relative abundance of bats in a specific area. With sufficient intensity and duration of monitoring activities, gross changes in diversity and numbers may become apparent.

Project History

Beginning in 1993, principal investigator Petryszyn visited the monument to gather baseline information on bat diversity and develop a long-term monitoring protocol. Tinajas, springs, and Quitobaquito pond were chosen for mist-net sampling. Because bats are creatures of habit, tinajas with the greatest capacity for retaining water in the hottest part of the year were chosen to capture the highest concentration of bats. In addition, Quitobaquito pond was mist-netted bimonthly in 1993, 1994, and 1995 by Petryszyn for a study on *E. underwoodi*. (Results of this study are not yet published.)

1995 Monitoring Activities

Resource management staff conducted bat monitoring at Wild Horse Tank on 26 May 1995. Unseasonably cold temperatures reduced the number of captures and caused rescheduling to June. Five sites were netted 19–23 June, and 1 site was netted 28 August after summer rains had filled the tinaja.

Methods

Standard mist-net techniques deploying 2.6-m tall, black nylon, 4-shelf, 38-mm mesh nets were used at study sites. Nets 5.5 m or 9.1 m in length were placed at the edge of water or in a flyway near water at tinajas and pools. At Quitobaquito, a boat was used to set up a 36.6-m net across the middle of the pond. Nets were opened at dusk and closed at midnight and checked regularly for captured bats every 15–20 min. Bats were removed from the net and released on site after species identification, sex, age, weight, forearm length, and reproductive condition were recorded.

Results

Overall bat captures for 1993–1995 are presented in Tables 30–35. During the first year of protocol testing (1993), some sites were sampled 2 nights in a row. A Mexican long-tongued bat *(Choeronycteris mexicana)* was caught in 1994, the first reported capture since 1979 of this species, which is primarily found in southeastern Arizona in the summer months.

Scheduling of the 1995 bat monitoring session was complicated by weather conditions. Few winter rains occurred from October 1994 to April 1995, so tinajas were dry or contained little water by spring of 1995. Unseasonably cold May weather caused bat monitoring to be postponed until June, when the tinajas were even drier. Two of the sites, North Alamo Canyon and the Bates Valley tinajas, were dry in June and not netted. South Alamo Canyon was chosen to replace North Alamo in June. After monsoon rains had replenished water levels, North Alamo was netted in August.

Two unusual species were caught in 1995. A Townsend's big-eared bat *(Corynorhinus townsendii)* was captured at Wild Horse Tank in May (Table 31). This species is uncommon in low desert environments and infrequently captured in the monument. In August, a hoary bat *(Lasiurus cinereus)* was caught at North Alamo Canyon (Table 30). The only other recorded capture for this species was in 1979 at Quitobaquito (Cockrum 1981). This tree-roosting bat is usually found at higher elevations in conifer forests, but is encountered during migration in lowland areas (Cockrum 1981).

Detailed site descriptions and results are summarized in the following narrative and in Tables 36–40. Female reproductive status is indicated by these labels: gravid, lactating, post-lactating, or no reproductive status noted.

Alamo Canyon (Table 36)

The site of the "Paisley tinajas" is approximately 0.8 km upstream of the confluence of the North and South forks of Alamo Canyon in the Ajo Mountains. One 5.5-m net was set across a small pool and a 9.1-m net was set slightly downstream over a flyway in the canyon that sometimes holds water but was dry in 1995. The unusual capture of a *L. cinereus* occurred at 2113 hr.
The South Fork site was netted for the first time in 1995 because the traditional North Alamo Canyon monitoring site was dry. Located approximately 2.4 km upstream in the rugged South Alamo drainage, these tinajas are well sheltered and hold water when other similar sized tinajas are dry.

Wild Horse Tank (Table 37)

This Diablo Mountains water source is a semi-permanent pool below a cliff with an artificial dam built in historic ranching days. Both bat diversity and abundance are usually high here. One 9.1-m net was placed at the edge of the pool. Unusually low numbers were caught in May, due probably to cold temperatures; the site was revisited in June. During the June monitoring, an overwhelming number of bats caught in the net caused field workers to close the net for half an hour in order to process the bats. Most of these were male *P. hesperus* and female *M. velifer*.

Bull Pasture (Table 38)

Several deep tinajas are found in this lush middle elevation area of the Ajo Mountains. Sampling was conducted at tinajas in a drainage that empties into Estes Canyon. In 1995, a 5.5-m net was placed between 1 large and 1 ephemeral pool and a 9.1-m net was placed downstream over a flyway that did not contain water.

Bates Valley

The Bates Mountain Range in the northwestern corner of the monument contains 2 principal tinaja sites, Tinajas Estufas and Hidden Gorge Tinajas. In 1993, Tinajas Estufas were sampled for 2 nights with 2 5.5-m nets next to pools. Bat diversity was high at this site although density was low. In June 1994, the Tinajas Estufas were completely dry. The nearby Hidden Gorge plunge pool tinajas were mostly dry as well, except for 1 small pool below a steep cliff. A 5.5-m net was placed in the flyway above this pool. Many bats were observed, but very few were caught. In late spring 1995, the entire Bates Mountain Range was dry and monitoring was not conducted.

Dripping Springs (Table 39)

This permanent water pool under a rock overhang on a mountainous slope in the Puerto Blanco Mountains is difficult to sample because of the dense shrubby vegetation growth around the pool. One 5.5-m net was oriented diagonally across the overhang opening, with 1 pole set uphill on top of a small cliff face. Field workers heard and observed numerous bats visiting the water source although many avoided or bounced off of the mist net.

Quitobaquito Pond (Table 40)

A 36.6-m net was set up and checked by boat at this spring-fed pond approximately 0.22 ha in size. Quitobaquito is the main water source in the monument where bats of the Molossidae family are captured. Characteristics of this family, narrow wings and a "free" tail, cause its relative lack of mobility and need for water sources with a large surface area. *N. femorosaccus* and one of the largest bats in North America, *E. underwoodi*, were caught here in 1993 and 1994. The first confirmed record of another species of free-tailed bat, *T. brasiliensis*, was made here in 1993. This species passes through the monument during its spring and fall migrations, yet is occasionally caught at other times of the year. A highlight of the 1995 Quitobaquito bat monitoring was the first recapture of an *E. underwoodi* banded during Petryszyn's 1993–1994 study.

Note: Tables 30–35 contain the following species abbreviations: PIHE = *Pipestrellus hesperus*, MYCA = *Myotis californicus*, MYVE = *Myotis velifer*, EPFU = *Eptesicus fuscus*, MACA = *Macrotus californicus*, ANPA = *Antrozous pallidus*, LECU = *Leptonycteris curasoae*, COTO = *Corynorhinus townsendii*, LACI = *Lasiurus cinereus*, CHME = *Choeronycteris mexicana*, EUUN = *Eumops underwoodi*, EUPE = *Eumops perotis*, NYFE = *Nyctinomops femorosaccus*, TABR = *Tadarida brasiliensis*.

Table 30. Bat monitoring results at North Alamo Canyon, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
6 Aug. 1993	27	0	2	2	3	2	4	0	0	0	0	0	0	0	40
7 Aug. 1993	37	1	0	2	3	6	9	0	0	0	0	0	0	0	58
5 Jun. 1994	5	1	0	1	0	2	8	0	0	1	0	0	0	0	18
20 Jun. 1995 (S. Alamo)	3	0	7	2	2	0	1	0	0	0	0	0	0	0	15
28 Aug. 1995	16	1	0	0	1	4	1	0	1	0	0	0	0	0	24
Total	88	3	9	7	9	14	23	0	1	1	0	0	0	0	155

Table 31. Bat monitoring results at Wild Horse Tank, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
9 Aug. 1993	56	2	5	2	4	4	12	0	0	0	0	0	0	0	85
9 Sep. 1993	20	0	0	3	0	6	0	1	0	0	0	0	0	0	30
4 Jun. 1994	35	4	14	1	2	0	3	0	0	0	0	0	0	0	59
26 May 1995	4	5	8	13	0	1	3	1	0	0	0	0	0	0	35
19 Jun. 1995	36	2	27	2	7	3	2	0	0	0	0	0	0	0	79
Total	151	13	54	21	13	14	20	2	0	0	0	0	0	0	288

Table 32. Bat monitoring results at Bull Pasture, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
8 Aug. 1993	20	0	11	1	0	2	18	0	0	0	0	0	0	0	52
6 Jun. 1994	1	0	2	0	0	0	18	0	0	0	0	0	0	0	21
23 Jun. 1995	21	2	5	3	0	4	4	0	0	0	0	0	0	0	39
Total	42	2	18	4	0	6	40	0	0	0	0	0	0	0	112

Table 33. Bat monitoring results at Bates Valley, Organ Pipe Cactus National Monument, Arizona 1993–1994. (This site was not netted in 1995 because of dry conditions.)

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
6 Sep. 1993 (Estufa)	6	2	1	3	1	0	1	0	0	0	0	0	0	0	14
7 Sep. 1993 (Estufa)	11	0	0	6	4	3	1	0	0	0	0	0	0	0	25
8 Jun. 1994 (Gorge)	0	0	0	0	4	1	1	0	0	0	0	0	0	0	6
Total	17	2	1	9	9	4	3	0	0	0	0	0	0	0	45

Table 34. Bat monitoring results at Dripping Springs, Organ Pipe Cactus National Monument, Arizona, 1993–1995.

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
9 Sep. 1993	4	0	1	2	0	5	0	0	0	0	0	0	0	0	12
7 Jun. 1994	10	0	2	7	0	1	2	0	0	0	0	0	0	0	22
22 Jun. 1995	10	0	2	2	1	2	0	0	0	0	0	0	0	0	17
Total	24	0	5	11	1	8	2	0	0	0	0	0	0	0	51

Table 35. Bat monitoring results at Quitobaquito Pond, Organ Pipe Cactus National Monument, Arizona, 1993–1995. (* Nets were left open until dawn for 1994 monitoring.)

Date Monitored	PIHE	MYCA	MYVE	EPFU	MACA	ANPA	LECU	COTO	LACI	CHME	EUUN	EUPE	NYFE	TABR	Total
22 Sep. 1993	1	0	0	0	0	0	0	0	0	0	0	0	9	1	11
23 Sep. 1993	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
2 Jun. 1994*	2	0	0	1	0	0	0	0	0	0	12	0	55	0	70
3 Jun. 1994*	0	0	0	2	0	0	0	0	0	0	6	0	30	0	38
21 Jun. 1995	3	0	0	1	0	0	0	0	0	0	4	0	29	1	38
Total	6	0	0	4	0	0	0	0	0	0	22	0	124	2	158

Table 36. Bat monitoring results at Alamo Canyon, Organ Pipe Cactus National Monument 1995.

South Alamo Canyon, 20 June 1995 (Net hours = 4.1)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	2	0	1	0	0	0	0	3
Myotis velifer	2	0	0	0	5	0	0	7
Eptesicus fuscus	1	0	1	0	0	0	0	2
Macrotus californicus	1	0	1	0	0	0	0	2
Leptonycteris curasoae	0	0	0	0	0	1	0	1
Total	6	0	3	0	5	1	0	15

North Alamo Canyon, 28 August 1995 (Net hours = 7.4)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	4	0	0	4	8	0	0	16
Myotis californicus	0	0	0	0	1	0	0	1
Macrotus californicus	0	0	0	0	1	0	0	1
Lasiurus cinereus	0	0	0	0	1	0	0	1
Antrozous pallidus	0	0	0	0	4	0	0	4
Leptonycteris curasoae	0	0	0	0	1	0	0	1
Total	4	0	0	4	16	0	0	24

Table 37. Bat monitoring results at Wild Horse Tank, Organ Pipe Cactus National Monument, Arizona, 1995.

Wild Horse Tank, 26 May 1995 (Net hours = 4.3)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	3	0	0	0	1	0	0	4
Myotis californicus	1	0	0	2	2	0	0	5
Myotis velifer	2	0	0	0	6	0	0	8
Eptesicus fuscus	12	0	0	0	1	0	0	13
Antrozous pallidus	0	0	0	0	1	0	0	1
Corynorhinus townsendii	1	0	0	0	0	0	0	1
Leptonycteris curasoae	0	1	1	0	1	0	0	3
Total	19	1	1	2	12	0	0	35

Wild Horse Tank, 19 June 1995 (Net hours = 3.4)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	27	0	4	1	4	0	0	36
Myotis velifer	1	0	0	0	26	0	0	27
Myotis californicus	1	0	0	0	1	0	0	2
Eptesicus fuscus	1	0	0	0	1	0	0	2
Macrotus californicus	2	0	4	0	1	0	0	7
Antrozous pallidus	3	0	0	0	0	0	0	3
Leptonycteris curasoae	0	0	1	0	1	0	0	2
Total	35	0	9	1	34	0	0	79

Table 38. Bat monitoring results at Bull Pasture, Organ Pipe Cactus National Monument, Arizona, 1995.

Bull Pasture, 23 June 1995 (Net hours = 8.2)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	19	0	1	0	1	0	0	21
Myotis californicus	1	0	1	0	0	0	0	2
Myotis velifer	3	0	0	0	2	0	0	5
Eptesicus fuscus	3	0	0	0	0	0	0	3
Antrozous pallidus	4	0	0	0	0	0	0	4
Leptonycteris curasoae	0	0	0	0	3	1	0	4
Total	30	0	2	0	6	1	0	39

Table 39. Bat monitoring results at Dripping Springs, 1995, Organ Pipe Cactus National Monument, Arizona.

Dripping Springs, 22 June 1995 (Net hours = 4.0)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	3	0	7	0	0	0	0	10
Myotis velifer	0	0	0	0	2	0	0	2
Eptesicus fuscus	1	0	0	0	1	0	0	2
Macrotus californicus	1	0	0	0	0	0	0	1
Antrozous pallidus	1	0	0	0	0	1	0	2
Total	6	0	7	0	3	1	0	17

Table 40. Bat monitoring results at Quitobaquito Pond, Organ Pipe Cactus National Monument, Arizona, 1995.

Quitobaquito Pond, 21 June 1995 (Net hours = 4.2)

Species	Adult male	Gravid female	Lactating female	Post-lact. female	Female, no repro.	Juvenile male	Juvenile female	Total
Pipistrellus hesperus	0	0	3	0	0	0	0	3
Eptesicus fuscus	1	0	0	0	0	0	0	1
Nyctinomops femorosaccus	18	1	1	0	9	0	0	29
Tadarida brasiliensis	1	0	0	0	0	0	0	1
Eumops underwoodi	4	0	0	0	0	0	0	4
Total	24	1	4	0	9	0	0	38

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 designated federally endangered by the U.S. Fish and Wildlife Service (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 the USFWS. This plan provides for the delisting of *L. curasoae* as a federally endangered species after 5 years if maternity roosts in Arizona and Mexico show no decline in numbers.

Organ Pipe Cactus National Monument is home to the largest maternity colony of *L. curasoae* in the United States. Copper Mountain, an abandoned adit in the northeast portion of the monument, houses 10,000–20,000 female bats with young between April and November. During their stay, the bats play an important role in the pollination of agaves *(Agave* spp.*)* and organ pipe *(Stenocereus thurberi)*, senita *(Lophocereus schotti)*, and saguaro cacti *(Carnegiea gigantea)*, as well as seed dispersal. Since many aspects of *L. curasoae* 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 continuously recorded at various locations within the mine at hourly intervals throughout the year, beginning in March 1990 through 1994. In summer 1994, the recording system became nonoperational and the computer was removed.

A OPCNM NPS-funded research project was conducted in 1993 to evaluate the status of bat populations. The component of this study to evaluate and assess the status of the Copper Mountain *L. curasoae* maternity colony was conducted by Virginia and David Dalton. The Daltons conducted past population estimates and established the remote sensing program. They were also the principal investigators in the evaluation of the effects of low-level military aircraft on the colony in 1992.

A component of a U.S. Air Force Legacy Fund study on the foraging ecology of *L. curasoae* in the Sand Tank Mountains (Barry M. Goldwater Gunnery Range) took place in the monument in 1994. On 29 May 1994, 100 bats were captured at Copper Mountain and fitted with light tags. Observers were then stationed on high points in the monument and Sand Tank Mountains to observe for light-tagged bats. Principal investigators for this project were the Daltons; results were summarized in a supplement to their 1994 Investigator's Annual Report, *Foraging Territory of the Long-Nosed Bat at Organ Pipe Cactus National Monument.*

1995 Monitoring Activities

Monitoring efforts in 1995 included 2 emergence counts; on 16 June with infra-red and video techniques, and on 19 August without special equipment. Guano samples were collected regularly throughout the period of use by bats, both during and after the primary food sources were in bloom or bearing fruit. Guano splatter sheets were placed in the mine tunnel and were replaced approximately every other week. These sheets were placed in plastic bags and frozen for later analysis.

Methods

Guano splatter sheets were placed in the mine tunnel and were replaced approximately every other week. To minimize disturbance, the guano sheet replacement was conducted at mid-morning to coincide with the bats' low point of activity. Sheets with samples were then frozen and will be stored until analysis can be performed.

Resource management staff and the Daltons conducted 1 emergence count using infra-red sensitive equipment and video camera. The video was viewed at a later date to estimate total number of *L. curasoae* that exited the roost. The second count was performed visually on site.

Results

L. curasoae appear to begin arriving at Copper Mountain Mine in small numbers in mid- to late-April. They do not appear to arrive simultaneously. The 16 June emergence count yielded an estimate of 10,900 bats; while 13,960 bats were counted during the 19 August flight.

During the regular visits of May and June, monument staff became aware that barn owls *(Tyto alba)* were venturing farther into the Copper Mountain tunnel than previously known. On 26 May, a barn owl was found perched on the framework above one of the main maternity chambers. Abundant whitewash in the tunnel indicated the owl(s) was spending significant time within the tunnel. On 13 June, monument staff found large numbers of bats flying in the tunnel during midday, including many just inside the north entrance in strong light. Because these bats seemed agitated, monument staff crawled along the floor beneath them to investigate possible disturbance. A barn owl was seen ahead in the tunnel standing on a rock and possibly feeding. Monument staff noted numerous owl castings ("pellets") along the floor which were not evident on previous visits. Several were collected. These were taken outside the tunnel, examined, and found to be comprised almost entirely of bat bones and fur.

After the 16 June 1995 emergence videotaping, the Daltons and monument staff entered the tunnel and proceeded to the maternity chambers. A barn owl was flushed off a nest scrape located immediately outside the northern chamber. The nest contained six eggs, and a seventh broken egg lay nearby. The nest was surrounded by owl castings, all of which appeared to be comprised entirely of bat remains.

After consultation with the USFWS, Arizona Game and Fish Department (AGFD), and other mammalogists and authorities, it was decided the barn owls could exert significant predation pressure and harassment, and should be removed. On 22 July, 4 nestling owls were removed by monument and AGFD staff (under USFWS depredation permit PRT-804857) and fostered to a captive adult female by AGFD. Subsequent regular inspections suggested that the adult barn owls spent little or no time in the tunnel after the nestlings were removed. However, 3 or more barn owls were seen or heard in the immediate vicinity on all visits. The monument is now evaluating options for physically excluding barn owls from the main tunnel without inhibiting bat movements.

Desert Pupfish

Introduction

Quitobaquito pond and springs are located in the southwestern portion of OPCNM, adjacent to the United States/Mexico 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 the National Park Service are to ensure the continued survival and well-being of the endangered desert pupfish, to provide shallow water habitat for Sonoran mud turtles *(Kinosternon sonoriense longifemorale)* and to provide a varied habitat for aquatic crustaceans and microorganisms. To this end, 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 *C. macularius eremus* population present in the 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 (The University of Arizona) 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.

Prior to 1985, left pectoral fins were clipped on fish ≥22 mm long, and population size was estimated using mark-recapture. This involved considerable handling of each individual. In 1985, Bill Matter (The University of Arizona) assisted the park in developing 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 that was 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 probably low.

Quitobaquito Habitat Project

In November 1989, 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, and 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 that holds and transports water was designed to be as maintenance-free as possible. Although wetland vegetation still proliferates quickly in the channel and must be periodically removed, the new system is physically more stable than the old ditches and guarantees constant water delivery to the pond and habitat for aquatic vertebrates and invertebrates.

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 of the channel used when the area was farmed, and incorporates areas of both slower- and faster-moving water. The construction 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. Six years of monitoring the pond and channel have provided 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 channel, where they are now found primarily in the shallow pools.

1995 Monitoring Activities

Weekly Inspections of Quitobaquito

The Quitobaquito area was inspected approximately once a week throughout 1995 by OPCNM 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 *C. macularius eremus* 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)* and catfish *(Ictalurus melas)* was also of primary importance.

Annual Quitobaquito Desert Pupfish Census

On 31 August and 1 September 1995, monument staff conducted the pupfish census at Quitobaquito pond and channel under USFWS Endangered Species Subpermit PRT-676811. Although in 1993 a spring census was also conducted, it was dropped in 1994 to avoid unnecessary impact.

Methods for the Pupfish Census

Quitobaquito Pond

The 1995 census of Quitobaquito pond was conducted using 47 unbaited minnow traps placed around the perimeter of the pond. A trapping run consisted of a 2-hour period after which the trap was emptied into an ice chest filled with pond water in the boat and then placed back in the pond, except at day's end. The fish from each run were counted, and approximately 65 randomly selected fish from each run were measured for length, to determine size distribution. The fish were then placed in holding tanks in the pond. The original protocol called for 3 runs each day for a total of 6 runs over the 2 day period, however in 1995, only 5 runs were completed due to holding tank limitations. Once trapped, the fish were held until the end of the census, for a total of about 23 hours of captivity for the fish trapped during the first run.

Quitobaquito Channel

The 1995 census of the Quitobaquito channel and springs was done using 9 unbaited minnow traps placed in the spring channel and 2 traps placed at the southwest spring. One run of approximately 4 hours 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 spring 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 6,644 pupfish were trapped in 1995. Of these, 1,602 were trapped in the channel, while 5,042 were trapped in the pond (Table 41). This was considerably greater than any previous catches, and the census was ended after 2 of the scheduled 3 runs on the second day. The available capacity in the holding tanks was insufficient for the unprecedented numbers of fish that were being caught. The very first run on the first day yielded 2,053 fish, with 3,618 being held in the tanks by day's end. The effects of crowding manifested themselves early on the second day with dead and chewed fish seen floating in the tanks, and so the census was ended. For comparison, the number of pupfish trapped in the pond in 1994 was 1,162. The 1992 summer census trapped 2,470 pupfish, and the 1993 spring and summer censuses trapped 2,305 and 4,299, respectively (Fig. 57, Table 41). No nonnative fish were captured or observed in either the pond or channel. Total mortality for the 2-day trapping period was approximately 70 pupfish. Pupfish size distribution for 1995 is summarized in Figure 58.

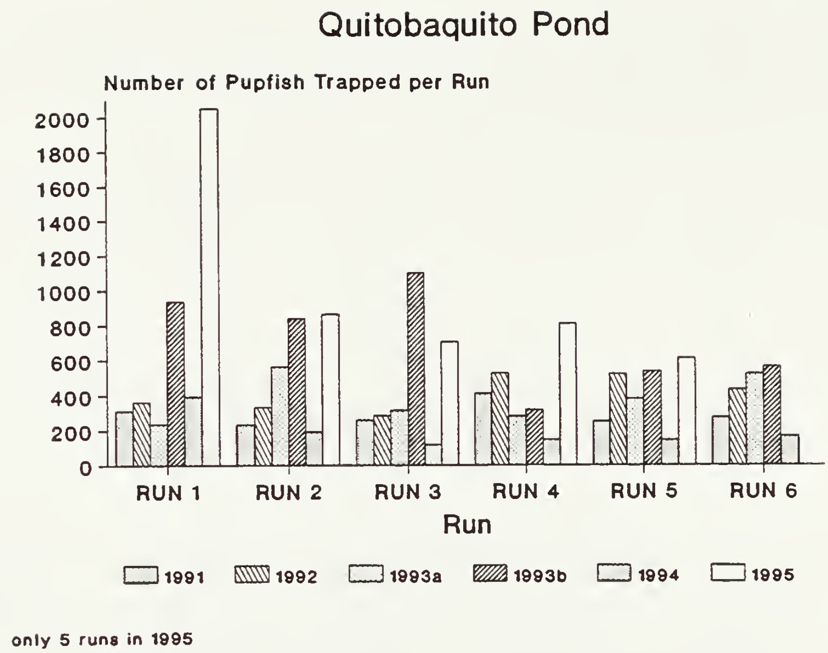
Table 41. Number of pupfish trapped per run in Quitobaquito pond and channel, at Organ Pipe Cactus National Monument, Arizona, 1991–1995. In 1995, the pond census was stopped after Run 5 due to holding capacity being exceeded.

Pond	1991	1992	1993A	1993B	1994	1995
Run 1	311	362	238	936	392	2,053
Run 2	233	335	563	840	191	861
Run 3	260	284	316	1,101	119	704
Run 4	411	528	283	320	149	811
Run 5	250	525	381	538	143	613
Run 6	273	436	524	564	168	--
Total	1,738	2,470	2,305	4,299	1,162	5,042
Channel	**1991**	**1992**	**1993A**	**1993B**	**1994**	**1995**
Run 1	522	667	690	743	701	829
Run 2	357	469	438	417	464	773
Total	879	1,136	1,128	1,160	1,165	1,602

A = Spring
B = Summer

The fairly consistent number of pupfish trapped in the channel in recent censuses may be a positive indication of the stability of the population. However, because the number trapped in the channel would be expected to include recaptures from the first day (the fish trapped the first day were released), these numbers are difficult to interpret. The fact that so many more pupfish were trapped in the pond in 1995 than in any previous year cannot be readily explained. In 1996, the census methodology will be reevaluated with an eye towards increasing holding capacity or setting a catch limit to try to avoid any future mortality from excessive crowding.

The vegetation in and alongside the channel seems to have grown to its maximum and is now fairly stable, although still subject to seasonal variation and maintenance by resources management staff. This vegetation provides cover and habitat for both fish and turtles, and the aquatic vegetation, and bullrush root masses are cleared minimally to maintain an open channel and unimpaired water flow. Pupfish exist in large numbers in both pond and channel habitats, even when pools become thickly vegetated with both aquatic and terrestrial vegetation.



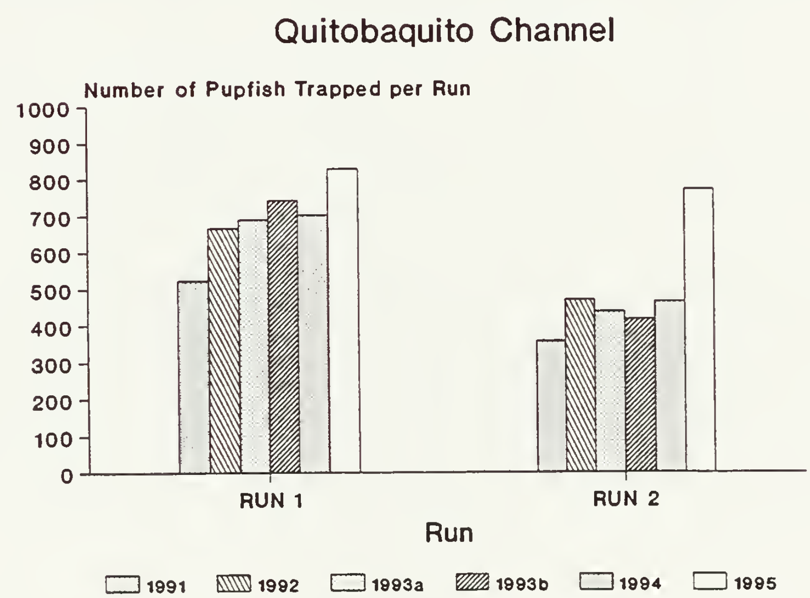
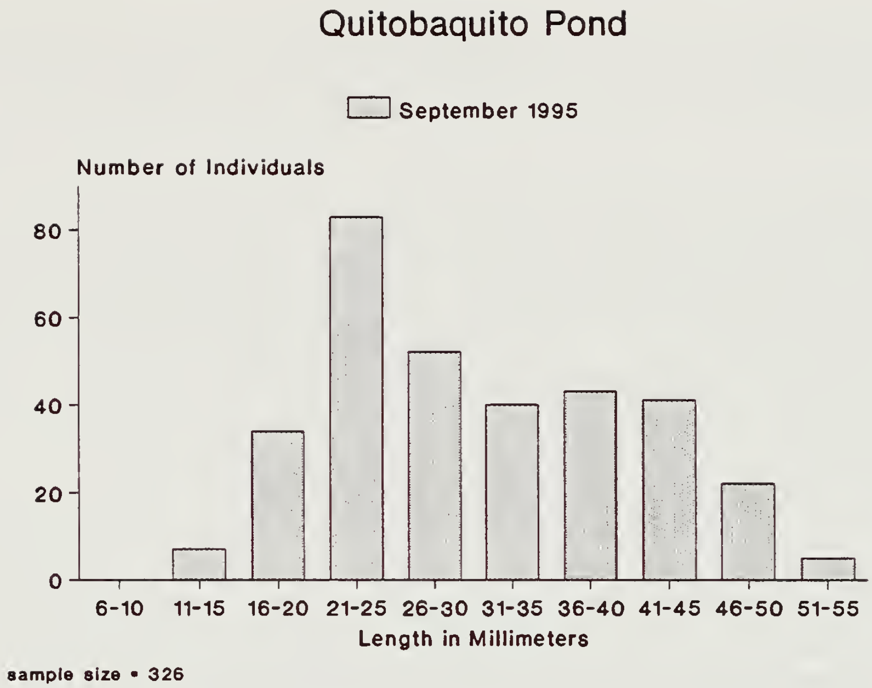


Figure 57. Number of pupfish *(Cyprinodon macularius eremus)* trapped per run in Quitobaquito pond and channel, Organ Pipe Cactus National Monument, Arizona, 1991–1995.



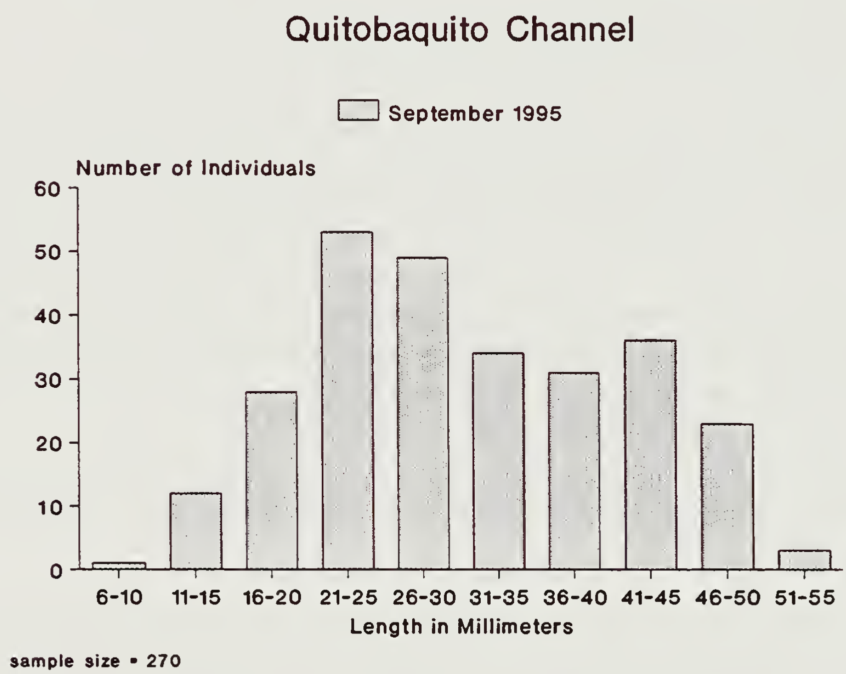


Figure 58. Size distribution of pupfish *(Cyprinodon macularius eremus)* caught in Quitobaquito pond and channel, Organ Pipe Cactus National Monument, Arizona, during the 1995 census.

Based on measurements and on visual observations during the census, there appears to be a healthy distribution of age/size classes. No nonnative fish species or other exotic competitors were observed. All indications are that the present population of *C. macularius eremus* is in good condition.

In May 1995, a visitor reported seeing "several dozen" fish in the range of 10–15 cm in Quitobaquito pond. Monument staff immediately engaged in an intensive examination of Quitobaquito, with assistance from the Arizona Game & Fish Department and USFWS. This effort included 5 nights of sampling with seine nets, hoop traps and angling. No nonnative fish were confirmed. Periodic sampling for nonnative fish continues.

Quitobaquito Inspections

The 1995 weekly inspections and maintenance of the pond and channel went without any major incidents, with the main task consisting of clearing 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 to congregate 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 by keeping them partially cleared, while not disturbing the pool perimeters or substrate. No nonnative fish were observed during inspections.

Another aspect of the Quitobaquito inspection process is natural history observations. Plants in bloom, wildlife, and other noteworthy observations were recorded. In 1995, 15 *K. sonoriense* were observed in the channel and pond. In August, roots clogged the southwest spring inlet-pipe, causing water to back up and flood the area. Monument staff encountered Mexican national visitors several times during the year, including a mother and daughter from a nearby settlement filling numerous jugs with water. Staff removed 4 plants of the exotic species tamarisk *(Tamarix chinensis)* during the year. Another noteworthy observation was a common kingsnake *(Lampropeltis getulus)* swimming in the channel in May.

Climate

Introduction

Scientists and managers recognized early in planning for the EMP that climate data are an integral part of any attempt to study or to understand environmental changes in an ecosystem. In the Sonoran Desert, plants and animals must adapt to highly variable weather conditions and unpredictable rainfall, and their populations are directly and indirectly influenced by climatic events. Indeed, climate, and especially precipitation, seems to be a powerful "forcing function" in the ecology of the desert. Thus, climate data are the primary integrative component of the Ecological Monitoring Program. Organ Pipe Cactus National Monument has both automated weather stations and rain gauges in place near monitoring sites and at other locations.

Project History

Work began in 1987 on the installation of 9 automated weather stations at sites in the monument designated as ecological monitoring sites. These stations all came "on line" in 1988. Eight Forester rain gauges are also located throughout the monument in various locations. Most of these have been in use since the early 1960s, though not consistently until 1982.

In 1995, the array and composition of the 9 automated weather stations was upgraded. The new array consisted of 11 stations (at or near the 10 Core I sites, and at Bull Pasture), 7 of which were at existing sites, 4 of which were at new station sites. The instruments and recorders were all replaced with new late-generation equipment, and all stations were set up with a full array of meteorological instruments. The data at each station were recorded on one logger, the Handar 555A, and power was supplied by a solar panel and internal battery.

1995 Monitoring Activities

Resource management personnel serviced all 9 automated weather stations monthly in 1995, while gradually upgrading 7 existing stations, removing 2 existing stations and installing 4 new stations. Servicing consisted of downloading data onto a palmtop computer and checking for damaged or malfunctioning equipment. Data were downloaded from the palmtop to a PC at the office and entered into a new weather database with enhanced reporting capabilities. Forester rain gauges were checked at the end of each month to determine the monthly total rainfall.

Methods

The configuration of instruments was made identical from site to site, with each weather station recording hourly data for the following parameters: wind speed and direction at 3-m above ground surface, air temperature and humidity at 122-cm above ground surface, solar radiation, air temperature at 30.5-cm above ground surface, and precipitation. In addition, sensors for soil moisture and temperature awaited installation as soon as proper techniques could be established for installation and calibration.

After data were downloaded, summary spreadsheets were created in a specialized weather database called WeaBase. The summaries gave daily means, maximums, minimums, and totals of all measured parameters of each site. Intersite comparisons give daily comparisons between all sites where a given parameter is measured. These summaries, comparisons, and the raw hourly data will be available for all 11 weather stations once all the bugs (there have been many) have been worked out. As with any latest generation software, there are problem areas, and the vendors have been most cooperative in helping to iron them out. The data are backed up on disks that are kept in a fire-proof vault.

Monthly rainfall data were 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 was measured and placed in the bucket. Water was filtered out of the used transmission fluid so the fluid could be used again. Data from these rain gauges were entered into a Lotus spreadsheet.

Results

The year 1995 saw the replacement and reconfiguration of the weather stations and so marked a new beginning in climate monitoring at OPCNM. The new instruments are more accurate and longer lasting than the ones replaced, and the field handling of the data has been simplified and augmented with expanded on-site data viewing capabilities. There have been unexpected problems with both the logger software and the weather database, but these are well on the way to being solved.

Several 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. New features not available previously include wind data presented in a windrose histogram format and evaporation rates calculated from other measured parameters. Data summaries for 1995 will include 2 different database formats (Lotus and Excel) because of the changes in each weather station configuration. Table 42 compares Datapod and Handar weather station configurations.

Table 42. Comparison of weather data parameters measured for Datapod and Handar weather station configurations at Organ Pipe Cactus National Monument, Arizona.

	Sample interval		Type of sample		Database storage format	
Weather Parameter	Datapod	Handar	Datapod	Handar	Datapod	Handar
Air temperature at 122 cm	10 minutes	1 minute	Instantaneous	Instantaneous	Hourly average	Hourly maximum, minimum, and average
Air temp temperature at 15 cm	5 minutes	1 minute	Instantaneous	Instantaneous	2 hour average	Hourly maximum, minimum, and average
Relative humidity at 122 cm	10 minutes	1 minute	Instantaneous	Instantaneous	Hourly average	Hourly maximum, minimum, and average
Precipitation	2 hours	1 hour	Accumulation	Accumulation	2 Hour total	Hourly total
Wind speed	3 minutes	5 seconds	Instantaneous	Instantaneous	Hourly average	Hourly average and maximum
Wind direction	3 minutes	5 seconds	Instantaneous	Instantaneous	Hourly average	Hourly average
Solar radiation	5 minutes	1 hour	Accumulation	Instantaneous	1 hour energy accumulation	Hourly value of power
Soil temperature	5 minutes (at 10 cm only)	1 minute (at various depths)	Instantaneous	Instantaneous	Hourly average	Hourly maximum, minimum, and average
Soil moisture	not measured	1 minute	not measured	Instantaneous	not measured	Hourly average

Air Quality

Introduction

Federal land management areas are classified as Class I, II, or III areas to facilitate implementation of the Clean Air Act. Mandatory Class I areas, the most protected from increases in air pollution, were designated by Congress in 1977. Class I areas consist primarily of national parks and national forest lands with designated wilderness. Since OPCNM became a wilderness area in 1978, the monument falls under Class II status and is not afforded the same protection from air pollutants as Class I lands. However, the monument contains outstanding scenic features and ecological resources that are vulnerable to the air environment.

Although a visibility-impairing copper smelter 24 km north of the monument was closed in 1983, new threats to air resources are increasing. Agricultural activities on the Mexican border affecting air quality include field burning, garbage burning, pesticide and herbicide use, and truck traffic on dirt roads. New industrial and urban developments are planned in the Sonoyta, Sonora, area, and increasing tourist and truck traffic through the monument has the potential to dramatically increase air pollutants. Organ Pipe Cactus National Monument is also affected by regional haze 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, OPCNM cooperates with 3 agencies, the National Atmospheric Deposition Program, Arizona Department of Environmental Quality, and the Arizona Radiation Regulatory Agency, to monitor aspects of air quality. The air quality program will be expanded in the future to include visibility monitoring and ozone monitoring.

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. Rain samples are collected weekly at sites throughout the country, and chemistry measurements are performed both in the field and at a Central Analytical Laboratory. The program 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 provide personnel and equipment for the program. Organ Pipe Cactus National Monument, 1 of 3 current NADP sites in Arizona, initiated sampling in 1980.

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 (dichot) 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. A dichot sampler, measuring coarse and fine particulates less than 10 microns in diameter (PM_{10}), has been in place since 1991. Before that, a high volume air sampler measured particulates with less resolution than the dichot method.

Arizona Radiation Regulatory Agency

Organ Pipe Cactus National Monument has 1 of 10 statewide continuous air sampling stations monitored by the Environmental Surveillance Program of the Arizona Radiation Regulatory Agency (ARRA). The Statewide Environmental Sampling Program was initiated with the purpose of supplementing baseline data on radiation levels in the vicinity of the Palo Verde Nuclear Generating Station.

1995 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 NAPD/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 OPCNM NADP site equipment consists of an Aerochem Metrics wet/dry precipitation collector and a Belfort Universal rain gauge with event pen, 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 was collected. The Belfort Universal rain gauge recorded precipitation event times and precipitation weight on chart paper. In the lab at OPCNM, the bucket was weighed to determine precipitation amount. If rainfall was of sufficient volume, measurements of pH and specific conductance were made. The sample was then sent to the NADP Central Analytical Lab in Champaign, Illinois, where more extensive chemistry measurements were performed.

At the Central Analytical Lab, specific conductance and pH was measured, as well as concentrations of hydrogen, ammonium, calcium, magnesium, sodium, potassium, sulfate, nitrate and chloride. The monument received monthly, seasonal, and annual data summaries as well as a yearly summary report for all U.S. NADP sites. Additionally, weekly records were kept at the monument. These included copies of the Belfort rain gauge chart paper, a unique source of precipitation event data. These charts illustrated the time, duration, and rainfall amount of each precipitation event.

An additional component of the NADP is the U.S. Geological Survey Intersite Comparison Program. Twice a year or more, each NADP site was sent an identical rain sample. The sites performed conductivity and pH measurements. Each site then received a report on the most probable values for the sample and a determination of the site's achievement of NADP accuracy goals.

Arizona Department of Environmental Quality

The dichotomous particulate (PM_{10}) sampler at OPCNM is located near the NADP sampling equipment. Two filters collected coarse and fine particulate samples for a 24-hour period every 6 days. The filters were sent to ADEQ for gravimetric and optical density analysis.

Arizona Radiation Regulatory Agency

Filters were changed weekly in the continuous air sampler and sent to ARRA for analysis.

Results

National Atmospheric Deposition Program

Organ Pipe Cactus National Monument was one of 162 NADP sites that met the "completeness criteria" for 1994. 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 were included in *NADP/NTN Annual Data Summary, Precipitation Chemistry in the United States, 1994* (NADP 1994). (The annual report for 1995 was not yet completed.) Since 1991, precipitation chemistry results for OPCNM have not changed appreciably. Weighted mean concentrations of sulfates (SO_4) and nitrates (NO_3), important components of acid deposition, increased in summer and fall 1994 and the weighted mean pH of 5.00 in fall 1994 was very low. The 1994 summary from the annual report is presented in Figure 59, and Table 43 presents pH and weighted mean concentrations of SO_4 and NO_3 from 1990 to 1994.

Arizona Department of Environmental Quality

Results of PM_{10} monitoring are summarized in annual *Air Quality Data for Arizona* reports (ADEQ 1996). Table 44 presents PM_{10} data from 1987–95 for both the Organ Pipe and Ajo samplers. The Ajo site is located within city limits (approximately 17 miles north of the monument's north boundary). The sudden decrease in numbers in 1991 reflected 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. In 1995, the annual mean remained stable at OPCNM and increased at the Ajo site.

Arizona Radiation Regulatory Agency

The 1994 report from the Radiation Measurements Laboratory reported no increase in environmental background radiation levels.

National Atmospheric Deposition Program/National Trends Network

1994 ANNUAL & SEASONAL DATA SUMMARY
(Printed 02/11/96)

SITE IDENTIFICATION

Site	Organ Pipe Cactus Nat'l Mon.
State	AZ
County	Pima
Operation	NPS
Funding	NPS
Site No.	30620
CAL Code	AZ06
Latitude	31:57:02
Longitude	112:48:00
Elevation	506 m

SAMPLE VALIDITY FOR ANNUAL PERIOD

Sampling Intervals	52
Valid Samples	49
with precipitation	24
with full chemistry*	(16)
without chemistry	(8)
without precipitation	25
Invalid Samples	3
with precipitation	3
missing precipitation data	0

SUMMARY PERIOD INFORMATION	Annual	Winter	Spring	Summer	Fall
First summary day (yrmoda)	940104	931130	940301	940531	940830
Last summary day (yrmoda)	950103	940301	940531	940830	941129
Summary period (days)	364	91	91	91	91
Sampling intervals	52	13	13	13	13
Measured precipitation (cm)	30.0	3.9	1.8	8.6	6.2
Valid samples with full chemistry*	16	5	3	3	6
Valid samples with full chemistry & valid field pH	12	4	3	2	3

NADP/NTN COMPLETENESS CRITERIA	Annual	Winter	Spring	Summer	Fall
1. Summary period with valid samples (%)	98.1	92.3	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 (%)	99.3	99.4	98.6	98.2	100.0
4. Collector efficiency (%)	102.0	108.4	98.7	100.9	102.0
Measured precip. with full chem. & valid field pH (%)	98.4	98.4	95.9	97.3	97.8

STATISTICAL SUMMARY OF PRECIPITATION CHEMISTRY FOR VALID SAMPLES

PRECIPITATION-WEIGHTED MEAN CONCENTRATIONS (mg/L)	Ca	Mg	K	Na	NH4	NO3	Cl	SO4	H(lab)	H(fld)	pH (lab)	pH (fld)
Annual	0.25	0.049	0.032	0.279	0.11	0.51	0.48	0.57	5.07e-3	5.48e-3	5.30	5.26
Winter	0.05	0.028	0.014	0.248	0.03	0.17	0.41	0.22	4.80e-3	8.95e-3	5.32	5.05
Spring	0.22	0.052	0.022	0.324	0.08	0.34	0.53	0.43	3.54e-3	8.00e-3	5.45	5.10
Summer	0.66	0.052	0.070	0.104	0.21	0.92	0.15	0.97	1.12e-3	1.85e-3	5.95	5.73
Fall	0.23	0.134	0.043	0.970	0.13	0.79	1.72	0.90	9.95e-3	5.94e-3	5.00	5.23
DEPOSITION (kg/ha)												
Annual	0.75	0.147	0.096	0.836	0.32	1.52	1.44	1.71	1.52e-2	1.64e-2	--	--
Winter	0.02	0.011	0.005	0.097	0.01	0.07	0.16	0.09	1.88e-3	3.51e-3	--	--
Spring	0.04	0.010	0.004	0.059	0.01	0.06	0.10	0.08	6.47e-4	1.46e-3	--	--
Summer	0.56	0.045	0.060	0.089	0.18	0.79	0.13	0.83	9.56e-4	1.58e-3	--	--
Fall	0.14	0.083	0.027	0.602	0.08	0.49	1.07	0.56	6.18e-3	3.69e-3	--	--
WEEKLY SAMPLE CONCENTRATIONS (mg/L)												
Minimum value	0.01	0.003	0.003	0.023	0.02	0.10	0.04	0.05	4.17e-4	4.57e-4	4.42	4.29
Percentile 10	0.01	0.003	0.003	0.023	0.02	0.11	0.04	0.11	5.88e-4	5.58e-4	4.54	4.51
Percentile 25	0.03	0.015	0.006	0.090	0.03	0.13	0.13	0.21	1.79e-3	4.22e-3	4.84	5.03
Percentile 50	0.29	0.050	0.024	0.266	0.11	0.54	0.42	0.81	4.90e-3	5.50e-3	5.32	5.26
Percentile 75	0.73	0.110	0.089	0.624	0.25	1.19	0.94	2.20	1.53e-2	9.24e-3	5.76	5.38
Percentile 90	1.94	1.035	0.654	7.756	1.33	5.88	13.96	7.07	2.94e-2	3.88e-2	6.24	6.27
Maximum value	3.53	2.530	0.793	21.000	3.18	10.84	37.70	9.84	3.80e-2	5.13e-2	6.38	6.34
Arithmetic mean	0.57	0.237	0.118	1.730	0.34	1.44	3.03	1.77	9.13e-3	9.42e-3	5.04	5.03
Arith. std. dev.	0.88	0.621	0.230	5.168	0.78	2.69	9.29	2.62	1.06e-2	1.35e-2	--	--
Below detection	2	0	2	0	3	0	0	0	0	0	0	0

OTHER PARAMETERS	Measured Precipitation** cm	Conductivity uS/cm	Equivalence Ratios SO4/NO3	SO4+NO3/H(lab)	Cation/Anion
Minimum value	0.03	2.1	0.65	0.64	0.74
Percentile 10	0.03	2.4	0.87	0.83	0.80
Percentile 25	0.09	4.8	1.18	1.39	1.02
Percentile 50	1.36	7.7	1.41	3.94	1.13
Percentile 75	2.81	20.6	2.19	15.58	1.36
Percentile 90	5.74	93.8	9.25	79.71	1.82
Maximum value	6.15	166.4	11.78	95.11	1.95

OTHER ANNUAL & SEASONAL DEPOSITION VALUES

	Total N from NO3 & NH4 (kg/ha)	Equivalence Ratios SO4/NO3	SO4+NO3/H(lab)	Cation/Anion
Annual	0.59	1.45	3.95	1.21
Winter	0.03	1.73	1.53	1.20
Spring	0.03	1.66	4.09	1.28
Summer	0.32	1.36	31.36	1.43
Fall	0.17	1.48	3.17	1.03

* 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 1994 annual and seasonal data summary for Organ Pipe Cactus National Monument, Arizona.

Table 43. Weighted mean concentrations of NO_3, SO_4, and pH for National Atmospheric Deposition Program (NADP) rainfall samples at Organ Pipe Cactus National Monument, Arizona, 1990–1994. NO_3 and SO_4 values in mg/L. The spring 1990 sampling period did not meet the NADP sample validity criteria.

	Annual			Winter			Spring			Summer			Fall		
Year	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH	NO_3	SO_4	pH
1990	0.98	0.81	5.34	0.24	0.78	5.76	0.97	20.36	7.71	1.29	0.85	5.32	0.76	0.89	5.24
1991	0.72	0.81	5.24	0.40	0.43	5.21	0.16	0.31	5.98	1.50	1.43	5.06	0.75	0.97	5.15
1992	0.58	0.52	5.27	0.23	0.35	5.45	0.21	0.27	5.45	1.34	0.91	5.11	0.87	0.95	5.15
1993	0.28	0.37	5.50	0.19	0.33	5.33	0.36	0.51	5.61	0.29	0.27	5.73	0.50	0.61	5.49
1994	0.51	0.57	5.30	0.17	0.22	5.32	0.34	0.43	5.45	0.92	0.97	5.95	0.79	0.90	5.00

Table 44. PM_{10} concentrations for Organ Pipe Cactus and Ajo sampling sites, Arizona, 1987–1995. 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-year period.

	Organ Pipe Cactus N.M.			Ajo		
	Annual Arithmetic	24-hour Average		Annual Arithmetic	24-hour Average	
Year	Mean	Max	2nd Hi	Mean	Max	2nd Hi
1987	17	105	36	39[1]	253[2]	102
1988	16	53	46	42[1]	102	71
1989	19	65	50	41[1]	123	86
1990	23	108	108	44[1]	121	112
1991	11	36	26	31[1]	80	74
1992	11	30	24	23[1]	47	42
1993	10	23	19	23[1]	51	45
1994	9	22	17	19[1]	38	30
1995	9	26	19	24	54	54

[1] Based on a limited number of samples. [2] Exceeded State and Federal standards.

Land Use Trends

Introduction

In the "Land Use Trends Surrounding Organ Pipe Cactus National Monument" (OPCNM) project, conducted from 1987–1988, researchers examined agricultural development in the Sonoyta Valley adjacent to the monument in Sonora, Mexico (Great Western Research 1988). Agricultural (and urban) development in this area has the potential to negatively impact the natural resources of the monument through depletion of the aquifer in the Rio Sonoyta watershed that is shared by the monument and Mexico. 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, nonnative plants and animals, and altered wildfire frequency.

The Mexican portion of the Sonoyta Valley is a prime site for agricultural development. At the conclusion of the research phase of the project in 1988, over 12,140 ha had been developed for irrigated agriculture. Total water withdrawal from the approximately 165 agricultural wells in 1987–88 was estimated to be 83,152 acre-feet (1.026×10^8 m^3), more than 2.5 times the annual groundwater recharge rate of 28,135 acre-feet (3.472×10^7 m^3). 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, 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 acre-feet (2.357×10^8 m^3), or more than 6 times the estimated annual groundwater recharge rate.

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

1. Biannual photo-point 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. Estimation of the amount of water being pumped for agriculture based on computations of well depths and electrical use.

Project History

Monument resource management staff has conducted the agricultural photo-point monitoring protocol since 1988. These photo-points 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 Secretaria de Agricultura y Recursos Hidráulicos (SARH) located in Sonoyta, Sonora. Organ Pipe Cactus National Monument resource management staff has regularly provided depth-to-water data from monument wells and agricultural photo-point 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.

1995 Monitoring Activities

Photos were taken in April and November at 8 border photo-points. Information from SARH on well depths was not available for 1994 and 1995 due to the lack of money to conduct the survey. It is hoped, but not anticipated, that the wells will be sounded again sometime in the near future. Consequently, the calculations used in the estimates for water pumpage in 1994 and 1995 were based on well depths from 1993. It is expected that this does not have as great an effect on the estimates as does electricity use, which is by far the major variable in the calculations. These figures for electricity usage continue to be available.

Methods

Agricultural Photo-points

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

Mexican Agricultural Data

Soon after the beginning of each year, electrical and well-depth data were retrieved from Mexican agriculture and utility officials. These data were entered into a complex Lotus spreadsheet which calculated, using assumed pump efficiencies, the amount of water being drawn from each well. A copy of this spreadsheet, when completed, was provided to SARH.

Results

All 8 boundary photo-points were visited and photos taken without incident in 1995. Slides and prints showing Mexican agricultural development on the monument boundary were processed and archived in the monument museum vault.

Electrical data from Mexico for 1994 and 1995 were received in late 1995. Data for December 1995 were not yet available, although this month is one of generally light water usage. As mentioned before, well depths were not taken in 1994 or 1995, and so 1993 depths were used. These figures were processed and entered into the appropriate Lotus spreadsheets. Table 45 presents water usage and crop acreage data for 1989–1995.

Table 45. Comparative water usage and crop acreage totals for Sonoyta Agricultural District, 1989–1995.

Year	Crop Acreage (ha.)	Energy Usage (kWh x 10^6)	Water Withdrawal Based on Static Levels (m^3 x 10^6)	Water Withdrawal Based on Dynamic Levels (m^3 x 10^6)	Water Withdrawal Based on Dynamic Levels (acre-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	19.6	62.8	43.3	35,083
1994	--	30.0	95.0	66.4	53,772
1995*	--	29.9	89.3	65.2	52,873

* No data for December.

Groundwater

Introduction

The development of groundwater resources was very important in the early days of mining and ranching in OPCNM, since surface water is scarce and largely ephemeral in the area. Wells were drilled or dug by hand, and reached depths of nearly 60 m. Some attempts to reach water were unsuccessful, including NPS test wells in the Valley of the Ajo. Most of these wells are now dry, caved in, or sealed off from access by humans or wildlife. Historically, 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 OPCNM 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. Other possible impacts related to groundwater levels include land subsidence and loss of riparian habitats. Because of these possible problems, inventory and monitoring were conducted in the 1970s and 1980s by NPS and the U.S. Geological Survey (USGS). Resource management staff continue to contribute to this effort by measuring depth-to-water levels in monument wells 4 times a year.

Project History

In response to groundwater concerns, the NPS Water Resources Division conducted a well and spring inventory at OPCNM in the early 1970s and began a program of measuring water levels at selected wells to establish seasonal and long-term trends. A control structure was installed at Quitobaquito springs, and monument personnel were trained to collect flow data.

In 1981, a program of regular monitoring of groundwater depth in wells was initiated. Fourteen wells were monitored by the USGS, under contract to the NPS, or by park staff (6 wells are monitored by both NPS and USGS). Three observation wells were drilled by the USGS in October 1988 to augment the data provided by existing historic wells on the border.

1995 Monitoring Activities

Depth-to-water measurements were made at 11 wells in January, April, July, and October. Monitoring at 2 wells, Salado and Dowling, was discontinued due to their collapse.

Methods

Depth-to-water was measured from a fixed reference point using a steel tape. The measurements were recorded in a field book and later entered into a Lotus spreadsheet.

Results

All the wells were checked on schedule in 1995. Table 46 presents 1995 depth-to-water measurements at monitoring wells. Figure 60 compares 1995 well depths with 1987–1994

Table 46. Well depth-to-water measurements, in feet, Organ Pipe Cactus National Monument, Arizona, 1995. Approximate depth-of-hole also included.

	Depth-to-water				
Well	January	April	July	October	Approximate Depth-of-hole
Alamo	2.38	3.22	7.35	8.64	17
Bates	38.15	38.32	38.96	38.59	67
Bonita	26.70	26.89	28.03	26.76	36
Corner	60.77	60.59	60.80	60.93	97
Hocker	17.09	16.37	dry	dry	18
Kalil	81.69	86.42	87.99	84.99	187
Nuevo	41.05	40.71	42.65	42.86	134
Stack	102.66	105.23	106.37	105.30	206

averages. Figure 61 summarizes standard deviation by season for well depths for all but the USGS test wells. Figures 62 and 63 present 1987–1995 well depth data for Alamo Well and Bates Well, respectively. Figure 64 shows well depths for the southwest portion of the monument, 1987–1995, and Figure 65 presents depth-to-water for wells on the southeastern monument boundary, 1987–1995.

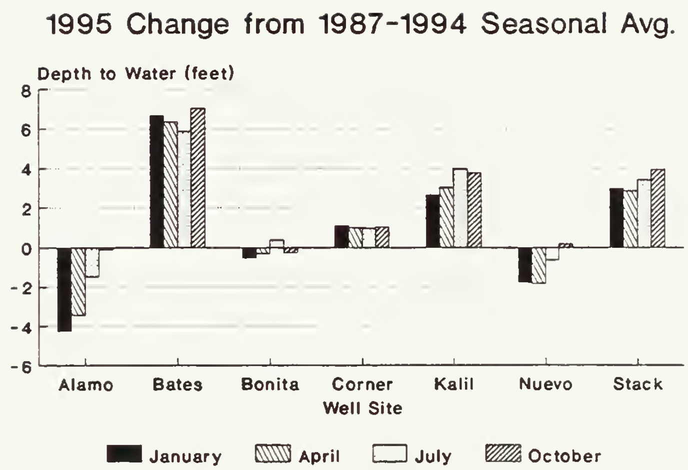


Figure 60. Comparison of 1995 seasonal well depths with well depth averages at Organ Pipe Cactus National Monument, Arizona from 1987–1994.

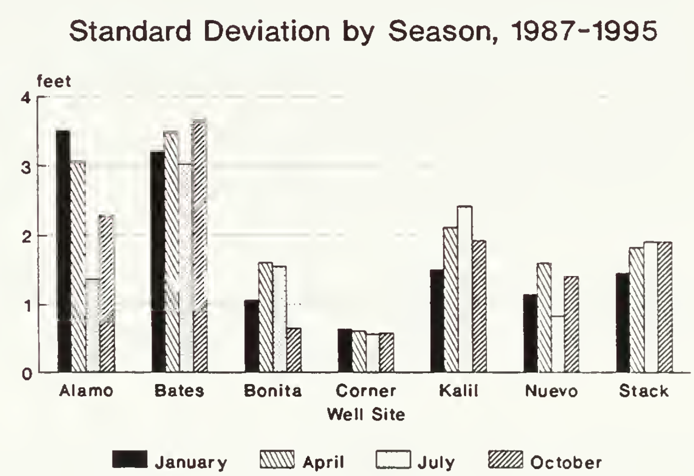


Figure 61. Yearly variability of well depths by season, Organ Pipe Cactus National Monument, Arizona, 1987–1995.

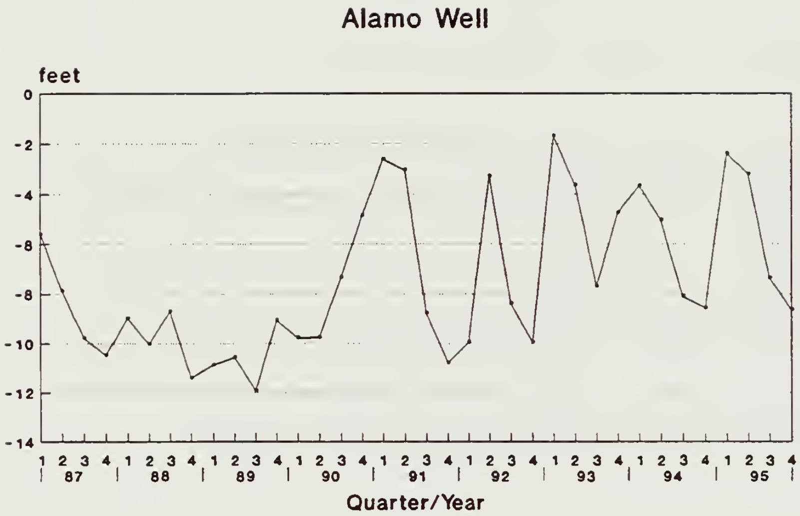


Figure 62. Depth-to-water (in feet) at Alamo Well, Organ Pipe Cactus National Monument, Arizona, 1987–1995. (quarter 1 = January, quarter 2 = April, quarter 3 = July, quarter 4 = October.)

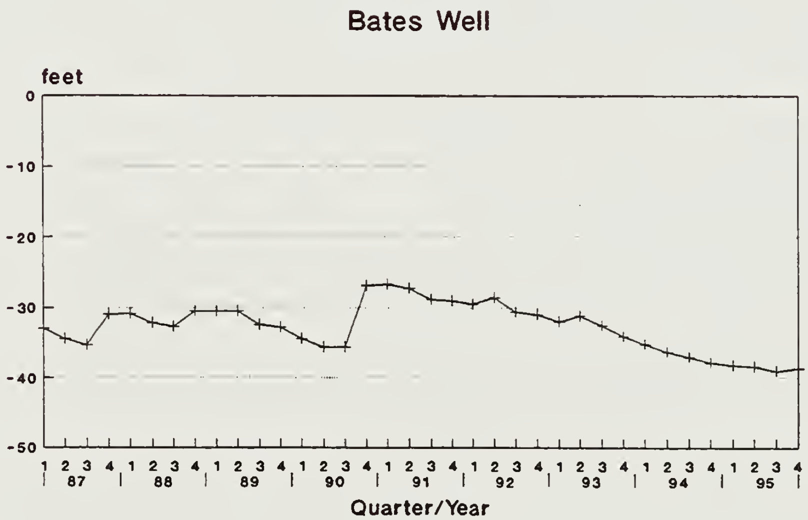


Figure 63. Depth-to-water (in feet) at Bates Well, Organ Pipe Cactus National Monument, Arizona, 1987–1995. (quarter 1 = January, quarter 2 = April, quarter 3 = July, quarter 4 = October.)

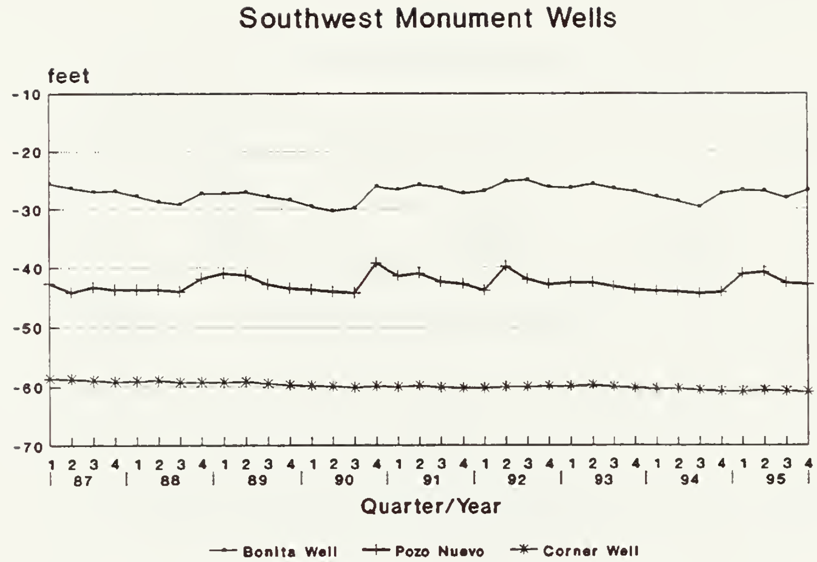


Figure 64. Depth-to-water (in feet) at Bonita Well, Pozo Nuevo, and Corner Well, Organ Pipe Cactus National Monument, Arizona, 1987–1995. (quarter 1 = January, quarter 2 = April, quarter 3 = July, quarter 4 = October.)

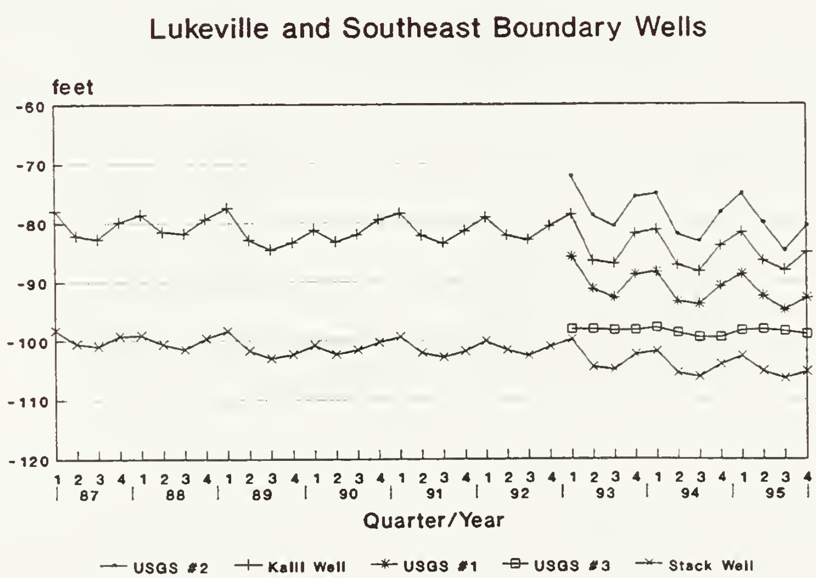


Figure 65. Depth-to-water at USGS #2 (Lukeville), Kalil Well, USGS #1 (Camino Dos Republicas), USGS #3 (Salsola), and Stack Well, Organ Pipe Cactus National Monument, Arizona, 1987–1995. (quarter 1 = January, quarter 2 = April, quarter 3 = July, quarter 4 = October.)

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The cover art was rendered by Ami Pate, a biological technician at Organ Pipe Cactus National Monument.

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