NPS GLOBAL CLIMATE CHANGE PROGRAM

A SUMMARY OF RESEARCH INTERESTS

FOR THE

PROPOSED SONORAN DESERT BIOGEOGRAPHIC PROVINCE STUDY SITE

TO BE LOCATED AT

ORGAN PIPE CACTUS AND SAGUARO NATIONAL MONUMENTS

ORPI and SAGU. Study how climate affects species distribution and vegetation structure. ESD (P, o).

ORPI and SAGU. Monitor selected sensitive plant species such as senita cactus and organ pipe cactus. ESD (U, o).

ORPI and SAGU. Integrate the diverse data base into a workable GIS for ORPI and SAGU. ESD (D). *

ORPI. Study hydrologic characteristics and relationships. CHS (P).

ORPI and SAGU. Monitor soil moistures and temperatures as they affect selected sensitive animal species such as the desert tortoise. ESD (U, p).

ORPI. Study, in the ORPI and Pinacate areas, the past effects of sea level change on geomorphology and land form factors in an effort to develop predictive capabilities for future global change events. SEP (P, d).

ORPI and SAGU. Compare remote ORPI and urban impacted SAGU for differences in ecosystem response to climatic change events in an effort to factor out anthropogenic factors affecting vegetation dynamics in the Sonoran Desert. ESD (P, u, o). *

ORPI and SAGU. Examine cultural and archeological resources for information about past cultural responses to climatic change in the Sonoran Desert, as well as to provide an assessment of the potential effects of global climate change on cultural resource preservation in the parks. HI (P, o). *

ORPI. Experimentally test various hypotheses relative to potential ecological effects of global climate change in the Sonoran Desert, particularly as change relates to amount and seasonal distribution of rainfall. ESD (P, d).

April 23, 1990
3:00 p.m. Version

CAPABILITIES AND INTEREST STATEMENT

FOR

GLOBAL CLIMATE CHANGE RESEARCH AND MONITORING
IN THE SONORAN DESERT BIOGEOGRAPHIC REGION

AT

ORGAN PIPE CACTUS NATIONAL MONUMENT AND
INTERNATIONAL BIOSPHERE RESERVE
(CORE RESEARCH AREA)

AND

SAGUARO NATIONAL MONUMENT
(CONTRIBUTING PARK)

THROUGH

THE COOPERATIVE PARK STUDIES UNIT
UNIVERSITY OF ARIZONA

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ABSTRACT

This proposal is for the inclusion of a Sonoran Desert Biogeographic Province study site in the NPS Global Climate Change Program. Organ Pipe Cactus National Monument and International Biosphere Reserve (ORPI) would be the core research area. Saguaro National Monument (SAGU) would serve as a the primary contributing area. The Cooperative Park Studies Unit at the University of Arizona (CPSU/UA) would provide the research and coordinating services for this undertaking. Both parks have a long and proven history of active research and resource monitoring. Furthermore, the Sonoran Desert is one of the most intact and biologically diverse arid land regions on Earth. Therefore, these two parks, and the cooperating sites and agencies associated with this proposal, make ORPI-SAGU the logical locations to center one component of the NPS Global Climate Change Program.

The proposed work will focus on nine main lines of investigation that should yield good information on the effects of global climate change on Sonoran Desert ecosystem components. These nine foci are (1) study how climate affects species distribution and vegetation structure; (2) monitor selected sensitive plant species such as senita cactus and organ pipe cactus; (3) integrate the diverse data base into a workable GIS for ORPI and SAGU; (4) study hydrologic characteristics and relationships; (5) monitor soil moistures and temperatures as they affect selected sensitive animal species such as the desert tortoise; (6) study, in the ORPI and Pinacate areas, the past effects of sea level change on geomorphology and land form factors in an effort to develop predictive capabilities for future global change events; (7) compare remote ORPI and urban impacted SAGU for differences in ecosystem response to climatic change events in an effort to factor out anthropogenic factors affecting vegetation dynamics in the Sonoran Desert; (8) examine cultural and archeological resources for information about past cultural responses to climatic change in the Sonoran Desert, as well as to provide an assessment of the potential effects of global climate change on cultural resource preservation in the parks; and (9) experimentally test various hypotheses relative to potential ecological effects of global climate change in the Sonoran Desert, particularly as change relates to amount and seasonal distribution of rainfall.

INTRODUCTION

Understanding the effects of global climate change on natural systems requires mobilizing an extensive and complex research program: scientists with relevant expertise must be identified; significant variables and interrelationships between variables must be identified and measured; and research methodologies must be designed, evaluated, and implemented. Particularly important is the selection of long-term research sites. To develop the models necessary to predict responses of biotic systems to climatic changes, research locations must be sought that (1) are representative of a significant portion of the United States and the world; (2) contain ecosystems and constituent biological elements that are sensitive to climatic perturbations; (3) have a long record of systematic data collection so that past climatic effects can be calibrated for future predictions; (4) are, and have been, protected from development or other site-specific disturbances so that site integrity is ensured; and (5) currently have the facilities and institutional partnerships necessary to implement a complex research program.

This proposal discusses the advantages of including the Sonoran Desert Biogeographic Province in the NPS Global Climate Change Program (GCCP). We regard the inclusion of at least one desert study area in this initiative to be imperative because nearly 25% of the total land base of the continental United States, and almost 20% of the Earth, is classified as arid or semi-arid. Additionally, desert plants live in an extreme environment, and are thus very sensitive to changes in climate. Accordingly, using the Sonoran Desert Biogeographic Province as a

study area satisfies both criterion one (representativeness) and criterion two (sensitivity) stated above.

We specifically propose that Organ Pipe Cactus National Monument (ORPI), an International Biosphere Reserve (IBR), serve as the core research area for the Sonoran Desert Biogeographic Province study site. Saguaro National Monument (SAGU) will serve as the primary contributing area to provide data for high elevation vegetation communities and other resources not found in ORPI. The Cooperative Park Studies Unit at the University of Arizona (CPSU/UA) will provide research, coordination, and administrative support for this effort. The combination of sensitive natural and cultural resources, past and present research, ongoing long-term monitoring activities, and research support facilities provided by this tri-partnership fulfill the remaining criteria stated above and make this Sonoran Desert Biogeographic Province study site an extremely strong candidate for participation in this program. A brief description of each of the three NPS partners in this proposal is given below.

Organ Pipe Cactus National Monument

ORPI, established in 1937 and designated as an IBR in 1976, contains 330,690 acres of prime Sonoran Desert habitat and is located in the extreme southwestern portion of Pima County, Arizona, adjacent to the Mexican border. As an IBR it institutionally provides "a standard against which can be measured the effect of Man's impact on his environment." Approximately 95% (i.e., 312,600 acres) of the monument is designated wilderness. Elevation in ORPI ranges from 1044 feet west of Quitobaquito Springs to 4808 feet in the Ajo Mountains. Annual rainfall averages 9.25 inches at monument headquarters.

Daily high/low temperatures average 67/19 F in January and 103/69 F in July.

Saguaro National Monument

SAGU will provide opportunities for GCCP research not available in ORPI. A primary emphasis of research at SAGU will be on high elevation areas of the Sonoran Desert Biogeographic Province. SAGU, established in 1933, contains a total of 83,574 acres, separated into the 62,836 acre Rincon Mountain District (RMD) and the 20,738 acre Tucson Mountain District (TMD). The monument is located in northeastern Pima County, Arizona and defines the eastern and western extremes of the Tucson Basin. Almost 85% (i.e., 71,400 acres) of the monument is designated wilderness. Elevation in SAGU ranges from 2200 feet in the Avra Valley in TMD to 8660 feet on Mica Mountain in RMD. Annual rainfall averages 11 inches near the monument headquarters in RMD. Daily high temperatures for RMD average 93 F in July and daily low temperatures average 38 F in January.

Cooperative Park Studies Unit, University of Arizona

The CPSU/UA, with an extensive and longstanding record of cooperation with both ORPI and SAGU, will provide the scientific and administrative support necessary to carry out this program. It will also provide coordinating services for involving other agencies and research interests from the Sonoran Desert.

POTENTIAL RESOURCE SENSITIVITY

Several varied factors make ORPI and SAGU outstanding areas with regard to this sensitivity criterion. The Organ Pipe Cactus region of southwestern Arizona and northwestern Mexico is probably the largest area of relatively intact desert in North America, and it remains one of the larger desert areas in the world that is relatively uninfluenced by human activities. The

Colorado River Lowland and Arizona Upland subdivisions of the Sonoran Desert meet in ORPI (Shreve 1951; Brown et al. 1979, 1980). Additionally, a relict pocket of a third subdivision, Central Gulf Coast vegetation (Shreve 1951, Brown and Lowe 1980), occurs in Senita Basin at ORPI. SAGU includes the Rincon Mountains, the divide between the Sonoran and the Chihuahuan deserts (Shreve 1951, Benson and Darrow 1981). Ecotones are associated with the junctions of these different desert types, with the classic edge effect characteristics of increased biological diversity and population density.

Accordingly, the Sonoran Desert region features a diversity of plant and animal life from which to judge the effects of global climate change. Vegetation is particularly important as a sensitive yardstick for measuring changes in precipitation and soil moisture patterns. Unlike animals, plants cannot move to another location to escape climatic changes from day to day or season to season. They respond to changes in temperature, soil, moisture, slope, aspect and the multitude of climatic, edaphic, and other conditions of their environment. In turn, vegetation serves as a nutritional substratum for animal life --including humans-- where it prehistorically served a critical subsistence function. Thus, vegetation is probably the best component for assessing the health of the desert ecosystems of the core research area. By correctly interpreting changes over time, we can evaluate the past and present "health" of the ecosystem and postulate what is to come.

Another important feature of the Sonoran Desert Biogeographic Province that lends itself well to climatic studies is the presence of numerous plant and animal species existing on the periphery of their natural ranges. Long-term changes in

climatic conditions can be highly significant to these organisms, particularly those dependent upon specific weather patterns. Small changes in climate can have dramatic effects on their health and long-term survivability (Turner 1990). Exceptional research on this topic has been conducted by Parker (1977, 1985, 1987) with organ pipe cactus (Lemaireocereus thurberi) and senita cactus (Lophocereus schottii) in ORPI and by Steenbergh and Lowe (1976, 1977, 1983) with saguaros (Carnegiea gigantea) at both ORPI and SAGU. Other sensitive plant species have also been studied at the two monuments, where numerous arid-adapted plant species are found that occur nowhere else in the United States. Other organisms, including certain insect species, are in turn unique associates of some of these plant species.

Shifts in climatic conditions also result in shifts in plant and animal distributions in the Sonoran Desert. Such distributions are influenced by global shifts and local weather patterns generated from several distinct sources--El Nino (Andrade and Sellers 1988, Swetnam and Betancourt 1990)), the Pacific coast of the western U.S., Gulf of Mexico, Polar jet stream, Rocky Mountains, and Gulf of California. Some species of amphibians, for example, remain burrowed in the ground, emerging only when local rain events are sufficient for reproduction. Several localized insect species may be equally indicative of local climatic changes.

AVAILABILITY OF RELEVANT BASIC DATA

As noted previously, both ORPI and SAGU have a long history of systematic ecological study. They also have substantial ongoing and planned monitoring programs. This section describes current monitoring and research programs, and the availability of data from past research efforts.

Sensitive Ecosystems Program

The ORPI Sensitive Ecosystems Program (SEP) is an extensive inventory and monitoring program that was initiated in 1986. It has become a vital and integral part of the overall research and resource management program in the monument. Research and monitoring efforts, although parkwide in many cases, are concentrated at 16 identified study sites, ranging in size from 2.1 - 160 hectares, each reflecting specific components of the overall ORPI resource. Through this program, long-term monitoring protocols have been established and baseline inventory data has been acquired on park reptiles, amphibians, small mammal populations, avifauna, terrestrial invertebrates, special status plants, non-native vegetation, land-use trends on property adjacent to the monument, and vegetation structure and diversity in natural communities.

The SEP can serve as a base on which to build global climate change studies, particularly to provide baseline data for predictive modeling and monitoring activities.

Climatological Monitoring. As part of SEP, nine automated weather stations have been established throughout the monument near existing SEP study sites. Variables recorded include air and soil temperature, solar radiation, wind speed and direction, relative humidity and precipitation. Data is recorded hourly on data storage modules and is summarized monthly.

Inventory and Assessment: Special Status Plants. A total of six sensitive plant species have been identified for long-term monitoring under SEP. The U.S. populations for most of these species are limited to the boundaries of ORPI. All of the plant species are very sensitive to climatic fluctuations. Monitoring is currently being conducted on three of the species: organ pipe

cactus (Lemaireocereus thurberi) and senita cactus (Lophocereus schottii) (twenty years of growth data already exists for both of these species); and acuna cactus (Neolloydia erectocentra var. acunensis). In FY91 the monitoring of the remaining three species (Jatropha cinerea, Peniocereus striatus and Atamesquia emarginata) will be initiated.

Future Sensitive Ecosystems Program Monitoring. In FY91 long-term monitoring protocols will be implemented for several other completed SEP studies. These protocols will involve intensively monitoring, at least annually, populations of small mammals, birds, reptiles, amphibians and terrestrial invertebrates at the 16 identified study site locations throughout the monument. In addition, vegetation structure and diversity will continue to be evaluated at each of the study sites. Currently, three years of data exist for the majority of these subjects.

Air Quality Monitoring

National Atmospheric Deposition Program. ORPI is part of the National Atmospheric Deposition Program (NADP) network of sites which monitor wet and dry deposition. Variables recorded include daily precipitation, pH, and conductivity.

Particulate Monitoring. In cooperation with ORPI, the Arizona Department of Environmental Quality has established a PM-10 hi-vol sampler in the monument. Fine particulates have been monitored at SAGU since 1985 as part of the Western Fine Particulate Network.

Radiation Monitoring. The Arizona Radiation Regulatory Agency, as part of the Statewide Environmental Radiation Monitoring Program, has installed an air-sampling station in ORPI to provide data on background environmental radiation.

Gaseous Pollutants. At SAGU, ozone levels have been monitored since 1983 and sulfur dioxide levels since 1986. Field studies on ponderosa pine have revealed ozone injury (Duriscoe and Selph 1985, Duriscoe 1987). Wetmore (1987) surveyed lichens throughout SAGU to complete a flora and to sample for air pollution sensitivity. Ongoing research on air pollutant sensitivities of saguaro cactus will provide valuable information on changes in plant tissue (physiological, histochemical and histological), gross morphology, soils, and nutrient cycling due to pollution. Work is underway on the physiology of cryptogamic crusts which act as stabilizers of desert soils and which show sensitivities to air pollutants and microclimate changes. Native species are grown for inclusion in a biomonitoring garden where pollutant sensitivities can be evaluated.

Water Resources Monitoring

Groundwater. In ORPI, 10 wells are currently monitored for depth-to-water on a quarterly basis. The U.S. Geological Survey (USGS) monitors well depths in ORPI on a semi-annual basis at nine locations. In 1989, USGS dug three new wells in ORPI to monitor groundwater depth in the Sonoyta Valley. An ongoing SEP study is gathering data on groundwater usage as it relates to agricultural development and urbanization on Mexican lands bordering the monument. At Quitobaquito, USGS continuously monitors spring flows. These monitoring programs all lend themselves well to incorporation into GCCP research. Potential effects of climate change on groundwater supplies is a critical question in the Sonoran Desert Biogeographical Province.

Precipitation. Rainfall is recorded at 17 locations throughout ORPI. Seven sites have rain gauges, nine have

automated datapods, and a recorder is located at the NADP station.

Fire and Meteorological Monitoring

The earliest historical data in the SAGU archives are the Individual Fire Reports which record wildfire occurrences beginning in the year 1937. Fire weather records for the desert areas and the coniferous forest are available from the 1950's. In 1986 an automated weather station was installed in the cactus forest and an automated station was established in the coniferous forest in 1989. Baisan (1988, in press) has produced an excellent fire history of Mica Mountain and tree-ring samples collected during this study have the potential to extend climatic data collection back to the late 15th century for SAGU.

Natural History and Cultural Resource Collections

Over 370 different plant species have been recorded in ORPI and 1000 in SAGU. Specimens of the majority of plants occurring in the core research area are available at the Sonoran Desert Biosphere Reserve Center (SDBRC) at ORPI, as well as at the University of Arizona herbarium. Information on the flora of both ORPI and SAGU is available at the University of Arizona and the Arizona-Sonora Desert Museum.

ORPI also maintains an extensive collection of vertebrate and invertebrate specimens from the monument. Collection dates extend from the 1930's to the present. As part of the SEP, the monument's invertebrate collection will be enlarged by approximately 5,000 specimens by the end of FY90.

Observation records of ORPI fauna, beginning in the 1930's, are available at the SDBRC. Over 6,000 records are kept on file. Most of the observations can be accessed electronically by specific information fields such as "species," "location," or

"date." Similar information exists for SAGU dating from the 1960's. In addition, a Man and the Biosphere abstract database of all research conducted in or related to ORPI is on file and can be electronically accessed.

Cultural artifact collections from both ORPI and SAGU are stored at the Western Archeological Center (WACC). ORPI historical files are kept in a fire-proof archives room in the SDBRC. The SAGU Civilian Conservation Corps records, as well as older park files of historical values are stored at WACC.

Archeological Resources

The archeological database within ORPI and SAGU, coupled with recent data acquired from cultural resource management activities in surrounding areas, provides a detailed background on human adaptation and settlement dating back to at least 7000 B.C. Approximately 4000 acres of ORPI have been surveyed, (slightly more than 1% of the monument), in an ongoing archeological survey. With additional surveying there is a high potential for further discovery of sites that can be used to trace adaptive change, as well as glean environmental data such as dates for relict land forms and the location of extinct water sources. In ORPI, the high visibility of sites on the desert surface allows for easy location, plotting, analysis and recording of information by which adaptive changes may be traced without disruptive excavation. Twenty-eight percent of SAGU has been surveyed; the 335 recorded sites comprise a representative sample for use in ecological studies.

Research

The database of past and present research and results at both the core research area and contributing park is extensive. In 1989, there were 32 distinct research activities associated

with ORPI and 12 with SAGU, including research on climate, paleoecology, and external land-use impacts. These are briefly described below.

Climate. At ORPI, a meteorological tower will be constructed in 1990 by USGS to collect data on (a) the chemistry of airborne particles, which can then be related to source by mesoscale meteorology, and (b) quantitative relations between meteorological fluxes and fluxes important to soil development. Existing and future data collected as part of the NADP will be used to determine the chemistry of wetfall inputs.

Paleoecology. Paleoecological studies on packrat middens have generated valuable information about ORPI's past (Van Devender 1985, 1989). These studies can serve as a baseline for investigating climate change effects over the past 32,000 years at ORPI. Significant findings include evidence that (a) ice age pinyon-juniper-oak woodlands were well developed 32,000 to 12,500 years ago in the Ajo Mountains, (b) Larrea divaricata and Encelia farinosa have been dominant in continuously varying desertscrub communities in the Hornaday Mountains in adjacent Mexico for the last 10,000 years, and (c) the Arizona alligator lizard (Gerrhonotus kingii) and chipmunks (Tamias sp.) were in the Ajo Mountains during the last glacial period. Similar studies from the Puerto Blanco Mountains in ORPI provided a detailed history of the vegetation for the last 14,000 years at the lower edge of the Arizona Upland subdivision of the Sonoran Desert. Further studies on packrat middens in ORPI will be carried out to expand the information base on the past fauna and flora of the region.

External Land Use Impacts. The effects of urban development on SAGU have been a management concern for years. A study initiated by Shaw et al. (1987) will provide valuable data when

completed in 1991. The initial focus of this research was the identification of critical habitats for SAGU's fauna, and the characterization of land ownership and zoning patterns along the monument's boundaries. Detailed and related research included within this study are (a) movements and habitat use by desert mule deer and javalina in an urban environment; (b) impacts of exotic cavity-nesting birds on native avifauna (Mannan and Bibles, 1990); (c) populations of desert tortoise and gila monsters; (d) impacts of house cats on wildlife; and (e) densities of cats and dogs in different types of residential developments. Another segment of this research, entitled "Wildlife Relationships: Synthesis and Analysis-SAGU" will result in an integration of all the data into a format that facilitates simultaneous analyses of two or more factors and the development of map-based presentations of the results. The final phase of the boundary effects study will be a survey of wildlife-related attitudes, perceptions, and behavior of people residing within one mile of SAGU's boundaries.

SUPPORT CAPABILITIES

ORPI, SAGU, CPSU/UA, the University of Arizona, and the greater Tucson metropolitan area have the support capabilities necessary to accomplish this research initiative.

Sonoran Desert Biosphere Reserve Center. As described earlier, ORPI contains a dedicated research facility known as the Sonoran Desert Biosphere Reserve Center. This facility houses a collection of several thousand natural history specimens dating from the 1930s. At least one specimen of each vascular plant and vertebrate species known to occur in the monument, as well as a large selection of invertebrates, have been catalogued and are being curated in compliance with NPS standards. In addition to

providing office space for permanent and seasonal employees and volunteers, there is a computer room, laboratory, and equipment for laboratory and field work. The center also houses a research library, species observation records, climatic data, over 1000 maps, and a fire-resistant vault for archival records.

Community Center. This support facility in ORPI provides basic subsistence amenities (cooking and sleeping), as well as additional work space, a conference room, and a field specimen preparation area.

High Elevation Wildland Research Station. At SAGU, Manning Camp, located in the Rincon Mountains, provides a high elevation (8600 feet) wildland research station (with bunks, kitchen, desks, corral, storage area) where research programs relevant to transition and Canadian life zones can be carried out.

Universities, Archeological and Conservation Center, and Museums. The University of Arizona, a major academic institution, is centrally located within the Sonoran Desert Biogeographic Province, at Tucson, Arizona. Additionally, Arizona State University is also conveniently located in Tempe, Arizona. The NPS Western Archeological and Conservation Center is also located in Tucson, Arizona.

Onsite Museums. Both ORPI and SAGU offer heavily utilized visitor centers containing educational exhibits on immediate resources, for information dissemination, and interpretive programs.

SCOPE OF EXISTING SCIENCE PROGRAM

Over the past several years, both ORPI and SAGU have built research and resources management programs (and successfully integrated them into all aspects of park planning, management, and operations) which meet or exceed the capabilities of any

comparably sized units in the National Park System. In combination with research programs administered through CPSU/UA, they rival the scope and complexity of any unit in the NPS.

ORPI's SEP plan documents 34 research projects, of which 14 have now been funded and are underway. This program utilizes the research services of several agencies, institutions, and organizations coordinated through the shared oversight of park management and CPSU/UA. A key feature of the program is a "step-down" plan which documents how science programs will be transferred into long-term monitoring, management actions, and interpretive programming. In addition, ORPI will soon have a revised General Management Plan (GMP) and it will be the first GMP in the Service to include a MAB (Biosphere Reserve) element as a primary section of the plan.

SAGU's resource protection program is fully documented in its Natural and Cultural Resources Management Plan - one of the first such plans in the Western Region to be rewritten and approved in the new NPS format. Current NPS sponsored research includes a four-year investigation of the relationships between the wildlife resources of the monument and adjacent land development and use; a multi- faceted research program to identify possible impacts of pollutants upon saguaro vitality; and a study of saguaro mortality and vegetative succession in response to a major fire event. All three projects emphasize collaborative components, and translation of management concerns and research findings into public interpretive programs and media.

Both ORPI and SAGU have long been identified as supportive locations for appropriate independent research. At the present time these areas host a total of some 44 independent research

efforts conducted by scientists from throughout the United States and several foreign countries.

CPSU/UA plays an integral role in providing administrative support and technical guidance for research programs at both ORPI and SAGU. It also shares information with other members of the scientific community and enhances park-based research programs through providing information and suggesting management applications. Such information and strategies are gained from cooperating with a variety of prestigious research facilities. These facilities include the USGS Research Project Office at Tumamoc Hill; the Tree-Ring Laboratory, the Office of Arid Lands Studies, the School of Renewable Natural Resources, and the Department of Ecology and Evolutionary Biology at the University of Arizona; the Desert Botanical Garden in Phoenix; the Boyce Thompson Arboretum; the Santa Rita Experimental Range; and the National Audubon Society's Appleton-Whittell Research Ranch near Elgin, AZ.

EXISTENCE OF SCIENTIFIC, MANAGEMENT AND EDUCATIONAL LINKAGES

CPSU/UA, ORPI, and SAGU have established traditions of initiating, facilitating, and maintaining linkages within the NPS, the scientific community, the interagency and interjurisdictional community, and with the public at large.

During the past two years alone, these units played key roles in sharing local science, management, and educational concerns at locally hosted forums such as the International Seminar on Arid Lands, the biennial Conference of the George Wright Society, the Desert Parks Workshop, and the annual Sensitive Ecosystems Program integration meetings.

Together, ORPI, SAGU, and CPSU/UA maintain overlapping networks which link scientists, managers, educators, elected

officials, and public interest groups at the local, state, regional, national, and international levels. ORPI has developed particularly close working relationships with the University of Sonora, Friends of Pronatura (a conservation organization), and the Tohono O'odham Nation, to name a few. SAGU is a founding participant in the Tucson Basin Land Manager's Forum, comprised of representatives from the USFS, NPS, BLM, USF&WS, Arizona Game & Fish and State Lands Departments, Pima County, City of Tucson, and Arizona-Sonora Desert Museum. This group meets monthly to share information and cooperatively address issues of mutual concern. CPSU/UA is a frequently used focal point for linking the scientific community with both park areas.

Besides providing professional contacts, these networks are used to share information on science programs and management concerns with the public through interpretive programs (both on- and off-site). They also help maintain very close and constructive ties with the Southwest Parks & Monuments Association, and with local offices of organizations such as the Nature Conservancy, Audubon Society, and Sierra Club.

Perhaps the best testimony to the strength of NPS linkages in the Sonoran Desert Biogeographic Province is the fact that several park research projects have received substantial supplemental funding from other Federal agencies (e.g., USFS, USGS, BOR), local governments (e.g., City of Tucson, Pima County), and other jurisdictions (e.g., Southwest Parks and Monuments Association, Pima Association of Governments). Such contributions attest to the strong bonds that are in place and to broadly held expectations for their perpetuation.

RELEVANCE OF PROPOSED SCOPE OF WORK

The primary purpose of this project will be to provide an arid lands component to the larger United States global climate change initiative thus enhancing man's understanding of the impacts and consequences of the anthropogenic greenhouse effect on life in all its forms and functions. A Sonoran Desert study site would be particularly relevant to the GCCP because, in such arid and semi-arid lands, the effects of climatic variability on vegetation is greatly magnified, compared to such effects in humid temperate ecosystems. Much could be learned from study of the ecological effects of past and current climatic change in the Sonoran Desert Biogeographic Province. This potential gain in knowledge is reflected below in the nine foci of our proposal.

The first focus of our program will address the basic question of how climate affects species distribution and vegetation structure. Addressing this question will involve compiling complete floras and plant collections for ORPI and portions of SAGU. Production of detailed, georeferenced vegetation maps for selected portions of both monuments will also be necessary. We will also cooperate with the USGS (Tumamoc Hill) and the Tree-Ring Laboratory to develop and field test a working model of the relationships of climate to vegetation distribution in the Sonoran Desert. Much of the basic data for such modeling (e.g., climatic records, species distribution records, soils maps, topographic maps, ocean surface temperature data, atmospheric circulation patterns, atmospheric CO_2 concentrations) already exist. Much work is needed to refine the model and develop its predictive capabilities. This climate-vegetation model will be designed to interact with both physically and statistically-based mesoscale climate models

currently under development. The University of Arizona may soon be deeply involved with developing such a mesoscale model for the Sonoran Desert that we will be able to interact with.

The second focus of this effort will be the monitoring of selected plant species such as the senita cactus and the organ pipe cactus. These species are on the edge of their range and thus should be particularly sensitive to climate change. The purpose of this focus will be to develop these and numerous other species as "indicators of climate change."

The third focus of this project will be to integrate the broad array of primary data sets (e.g., fire history records, climate records, tree ring data, vegetation and flora, land use data, historic and prehistoric human occupation records) into a workable Geographic Information System (GIS) for, first, the core research area, and, then, the contributing park. The GIS will become the data management system for this project.

The fourth focus of this effort will be the study of hydrologic characteristics and relationships (e.g., frequency and volume of surface runoff, spring flow, groundwater levels) in selected watersheds of the core research area. These baseline data will be used in long-term monitoring programs to compare current and future statistics with past statistics to identify changes that might be occurring.

The fifth focus of this investigation will be to monitor soil moistures and temperatures in association with weather station data being collected at selected sites. These measurements may allow detection of faunal elements associated with certain desert habitats that might prove to be more sensitive indicators of microclimatological conditions than perennial plant species. In particular, it is hypothesized that

the absence of the desert tortoise from the Lower Colorado River subdivision of the Sonoran Desert in Arizona may be due to low soil moisture levels at critical times of the year rather than to minimum winter temperatures.

The sixth area of focus of this research will be a cooperative effort with the USGS in the proposed Organ Pipe Cactus-Pinacate International Biosphere Reserve to integrate regional coastal geochronology with geomorphology, landform analysis, and stream terrace downcutting history to assess long-term variations in sea-level fluctuations. These results will then be used to refine the predictive capabilities of models of potential global change effects in the region.

The seventh focus of this research will be the investigation of differences between remote and undisturbed ORPI and urban encroached SAGU. This focus will attempt to factor-out global change effects from other natural or anthropogenic factors affecting the dynamics of vegetation in the Sonoran Desert. Accordingly, this research will provide a model to be used in other settings for controlling variables irrelevant to the study of global climate change. Permanent plots and transects in comparable areas of ORPI and SAGU, as well as some general park surveys of selected components, will be studied and monitored over time. These study areas will be compared with monitoring efforts at Tumamoc Hill, the Santa Rita Experimental Range, and other study sites.

The eighth focus of this project will be to examine cultural and archeological resources, primarily in the core research area. Archeological survey data in ORPI will be expanded to provide a better understanding of man's early association with the flora and fauna of the Sonoran Desert. Dr. Gary Nabhan of the Desert

Botanical Garden has undertaken an evaluation of traditional ethnographic utilization of vegetation at ORPI under a MAB funded study that will be completed in 1990. By extending this study to allow long-term monitoring of utilization of ethnobotanical resources, scientists could track changes in availability of these resources.

The ninth focus of this effort will be to test various hypotheses relative to potential ecological effects of global climate change in the Sonoran Desert. In cooperation with other neighboring land managing agencies such as the U.S. Air Force, tests using either rainout shelters or supplemental watering will yield an understanding of potential widespread vegetation effects should global climate change result in an increase or decrease in quantity of rainfall, or a shift in seasonal distribution of rainfall.

This proposed program of research and monitoring in the Sonoran Desert is an ambitious effort that will combine biological, physical, cultural, and modeling components into an integrated assessment of the impacts of global climate change on arid lands resources and human inhabitants. Undoubtedly, the results of this effort will provide many benefits to the global change scientific community and to management in the two monuments.

APPENDIX I

SELECTED REFERENCES

Anderson, K.M. 1990. Archeology and global warming proposal. Unpublished notes prepared for meeting with Organ Pipe Cactus National Monument, Saguaro National Monument, and the Cooperative Park Studies Unit-University of Arizona.

Andrade, E.R. and W.D.Sellers. 1988. El Nino and its effect on precipitation in Arizona and western New Mexico. J. of Climatology 8: 403-410.

Baisan, C.B. 1988. Fire history of the Rincon Mountain Wilderness-Saguaro National Monument. Unpublished report to the National Park Service, Saguaro National Monument, Tucson, Arizona.

Bennett, P.S. and M.R. Kunzmann. 1987. Organ Pipe Cactus National Monument and Biosphere Reserve, Sensitive Ecosystems Program. Special Report No. 7. National Park Service, Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

Benson, L. and R.A. Darrow. 1981. The trees and shrubs of the Southwestern deserts. 3rd. Ed. University of Arizona Press, Tucson, Arizona.

Bowers, J.E. 1985. Annotated checklist of vascular plants, Rincon Mountains, Pima County, Arizona. Unpublished report to the National Park Service, Saguaro National Monument, Tucson, Arizona.

Bowers, J.E. 1980. Annotated checklist of vascular plants of Organ Pipe Cactus National Monument. University of Arizona, Applied Remote Sensing Program, Office of Arid Lands Studies, Tucson, Arizona.

Bowers, J.E. and S.P. McLaughlin. 1988. Flora and vegetation of the Rincon Mountains, Pima County, Arizona. Desert Plants 8(2): 50-95.

Brown, D.E., and C.H. Lowe. 1980. Biotic communities of the Southwest. USDA For. Serv. Gen. Tech. Rep. RM-78. Rocky Mountain Forest and Range Experiment Station. Ft. Collins, CO.

Brown, D.E., C.H. Lowe, and C.P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. J. AZ-NV Acad. Sci. 14:(suppl. 1) 1-16.

Brown, D.E., C.H. Lowe, and C.P. Pase. 1980. A digitized systematic classification for ecosystems, with an illustrated Summary of the natural vegetation of North America. USDA For. Serv. Gen. Tech. Rep. RM-73. Rocky Mountain Forest and Range Experiment Station. Ft. Collins, CO.

Brown, B.T. and R.R. Johnson. 1982. An inventory of the surface water resources of Organ Pipe Cactus National Monument, Arizona. Technical Report No. 10. National Park Service, Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

Bryan, K. 1925. The Papago Country, Arizona - a geographic, geologic, and hydrologic reconnaissance with a guide to desert watering places. U.S.G.S., Water Supply Paper 499.

Claassen, H.C. and A. Riggs. 1989. Unpublished Investigators Annual Report to the National Park Service, Organ Pipe Cactus National Monument, Lukeville, Arizona.

Duriscoe, D.M. 1987. Evaluation of Ozone injury to selected tree species in the Rincon Mountains of Arizona. Unpublished report to the National Park Service, Air Quality Division, Denver, Colorado under Contract No. CX-0001-4-0058.

Duriscoe, D. and M. Selph. 1985. Geographic extent and severity of air pollution in Saguaro National Monument (Rincon Unit). Unpublished report to the National Park Service, Air Quality Division, Denver, Colorado.

Esserlieu, M.K. and R.J. Olson. 1986. Biological vulnerabilities of National Park Service Class I areas to atmospheric pollutants. Oak Ridge National Laboratories Environmental Sciences Division Publ. No. 2646.

Great Western Research. 1988. Land use trends surrounding Organ Pipe Cactus National Monument. Unpublished report to the National Park Service, Western Region, San Francisco, California under Contract No. CX 8000-7-0031.

Mannan, R.W. and B. Bibles. 1990. Impacts of exotic cavity-nesting birds on native cavity-nesting birds in Saguaro National Monument. Unpublished report to the National Park Service, Saguaro National Monument, Tucson, Arizona under Cooperative Agreement Order No. CA 8014-1-0002.

Martin, S.C. and R.M. Turner. 1977. Vegetation change in the Sonoran Desert Region, Arizona and Sonora. J. of AZ Acad. of Sci. 12(2): 59-69.

Parker, K.C. 1977. Site preferences, reproductive characteristics, and population dynamics of Organ Pipe Cactus (Lemaireocereus thurberi) in Souther Arizona. University of Wisconsin, M.S. thesis.

Parker, K.C. 1985. Demographic patterns of organ pipe cactus populations in southern Arizona. Dept. of Geography, University of Georgia.

Parker, K.C. 1987. Ecological relationships of saguaro, organ pipe and senita in Organ Pipe Cactus National Monument. Dept. of Geography, University of Georgia, PhD Dissertation.

Parker, K.C. 1988. Growth rates of Stenocereus thurberi and Lophocereus schottii in southern Arizona. Bot. Gaz. 149.

Rankin, A. 1989. Archeological survey at Organ Pipe Cactus National Monument. Unpublished progress report to the National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.

Shaw, W.W., A. Goldsmith, P.R. Krausman, and R.W. Mannan. 1987. Relationship between adjacent land uses and the wildlife resources of Saguaro National Monument. Research proposal submitted to the National Park Service, Saguaro National Monument, Tucson, Arizona.

Shreve, F. 1951. Vegetation and flora of the Sonoran Desert: vol. 1, vegetation. Carnegie Institute, Washington, D.C. Publ. No. 591: 1-192.

Simpson, K. and S.J. Wells. 1983a. Archeological survey in the eastern Tucson basin: Saguaro National Monument, Rincon Mountain Unit, Cactus Forest Area. Publ. in Anthro. No. 22. National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.

Simpson, K. and S.J. Wells. 1983b. Archeological survey in the eastern Tucson Basin: II. Saguaro National Monument, Rincon Mountain Unit, Cactus Forest Area. Publ. in Anthro. No. 22. National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.

Simpson, K. and S.J. Wells. 1984a. Archeological survey in the eastern Tucson Basin: III. Saguaro National Monument, Rincon Mountain Unit, Tanque Verde Ridge, Rincon Creek, Mica mountain Areas. Publ. in Anthro. No.22. National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.

Simpson, K. and S.J. Wells. 1984b. Archeological survey in the eastern Tucson Basin: IV. Saguaro National Monument, Rincon Mountain Unit, Tanque Verde Ridge, Rincon Creek, Mica Mountain Areas. Publ. in Anthro. No. 22. National Park Service, Western Archeological and Conservation Center, Tucson, Arizona.

Stacey, V.K. Pheriba, and J. Hayden. 1975. Saguaro National Monument: an archeological overview. Unpublished report to the National Park Service, Western Archeological Center, Tucson, Arizona.

Steenbergh, W.F. and C.H. Lowe. 1976. Ecology of the Saguaro: I. the role of freezing weather in a warm-desert plant population. pp. 49-92. In: Research in the National Parks, National Park Centennial Symposium. U.S. Department of the Interior, National Park Service Symposium Series 1. Washington, D.C.

Steenbergh, W.F. and C.H. Lowe. 1977. Ecology of the Saguaro: II. Reproduction, Germination, Establishment, Growth, and Survival of the Young Plant. U.S. Department of the Interior, National Park Service Scientific Monograph Series, No. 8. Washington, D.C.

Steenbergh, W.F. and C.H. Lowe. 1983. Ecology of the Saguaro: III. Growth, and Demography. U.S. Department of the Interior, National Park Service Scientific Monograph Series, No. 17. Washington, D.C.

Steenbergh, W.F. and P.L. Warren. March 1977. Preliminary ecological investigations of natural community status at Organ Pipe Cactus National Monument. Technical Report No. 3, National Park Service, Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

Swetnam, T.W. and J.L. Betancourt. 1990. El Nino-Southern oscillation phenomena and forest fires in the Southwestern United States. In J.L. Betancourt and A.M. MacKay, Editors, 1990. Proceedings of the Sixth Annual Pacific Climate (PACLIM) Workshop, March 5-8, 1989. California Department of Water Resources, Interagency Ecological Studies Program Technical Report No. 23: 129-134.

Turner, R.M. 1990. Long-term vegetation change at a fully protected Sonoran Desert site. Ecology (in press).

Van Devender, T.R. 1985. History of vegetation and climate in the Puerto Blanco Mountains, Organ Pipe Cactus National Monument, southwestern, Arizona. Unpublished report submitted to Southwestern Parks & Monuments Association and Organ Pipe Cactus National Monument.

Van Devender, T.R. 1989. Further packrat midden studies in Organ Pipe Cactus National Monument. Unpublished report submitted to Southwestern Parks & Monuments Association and Organ Pipe Cactus National Monument, Arizona.

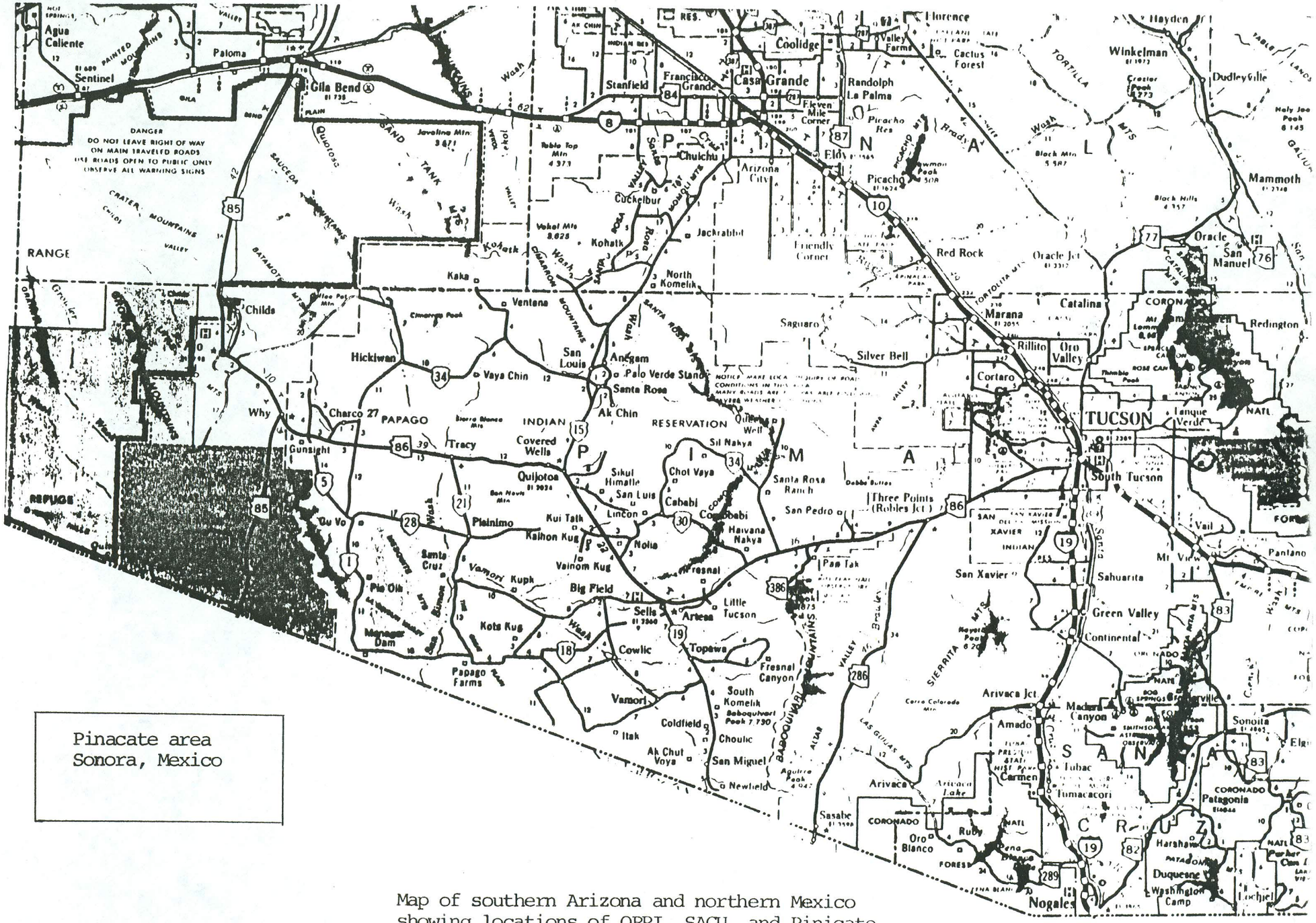
Van Devender, T.R. and M.A. Dimmit. 1989. Unpublished Investigators Annual Report to the National Park Service, Saguaro National Monument, Tucson, Arizona.

Warren, P.L., J.E.Bowers, B.K. Mortensen, B.D. Treadwell, and K.L. Reichhardt. 1980. Vegetation of Organ Pipe Cactus National Monument. Technical Report No. 8, National Park Service, Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

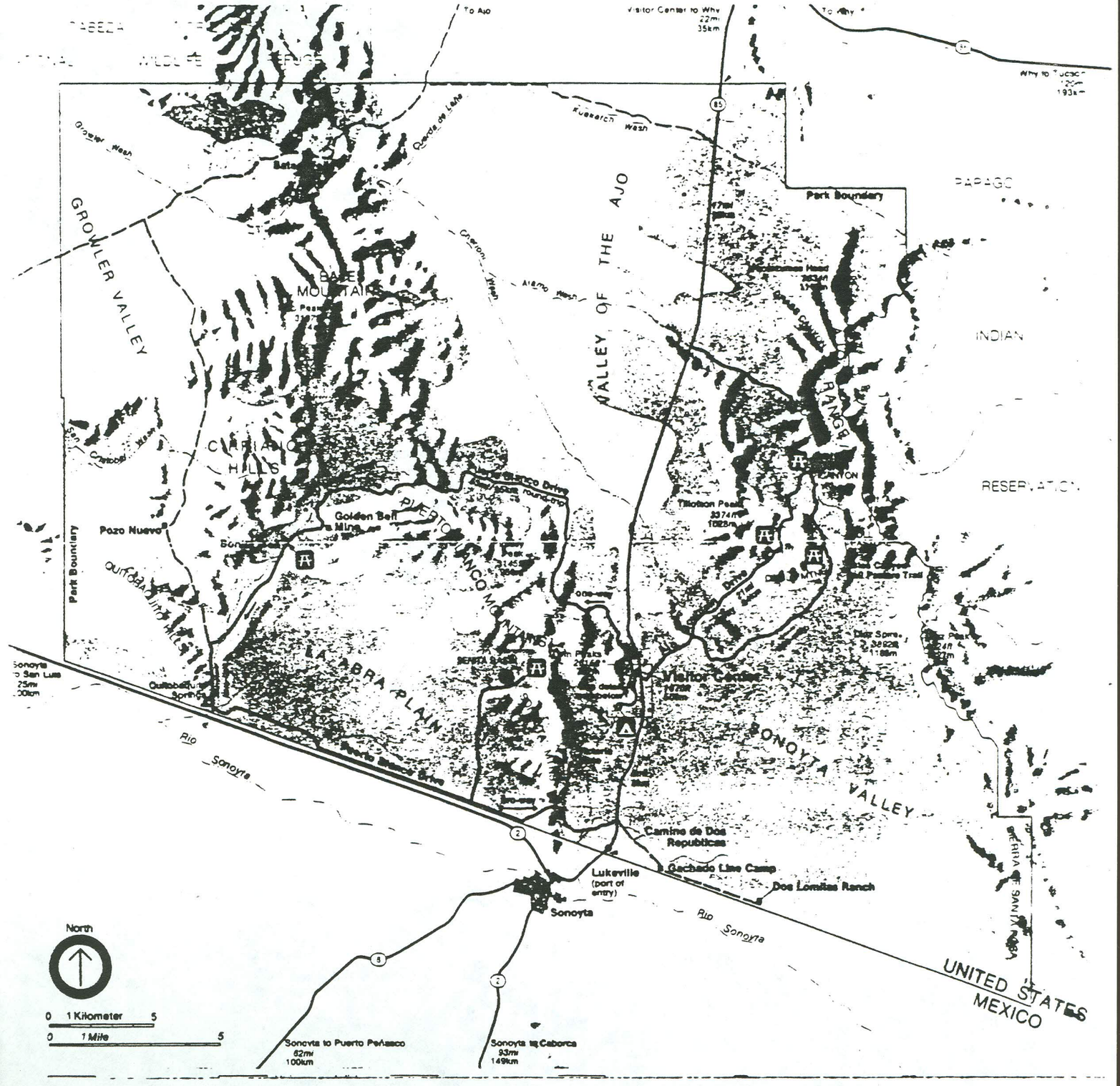
Wetmore, C.M. 1987. Lichens and air quality in Saguaro National Monument with chemical analysis of Chiricahua lichens. Unpublished report to the National Park Service, Air Quality Division, Denver, Colorado under Contract CX-0001-2-0034.

APPENDIX II

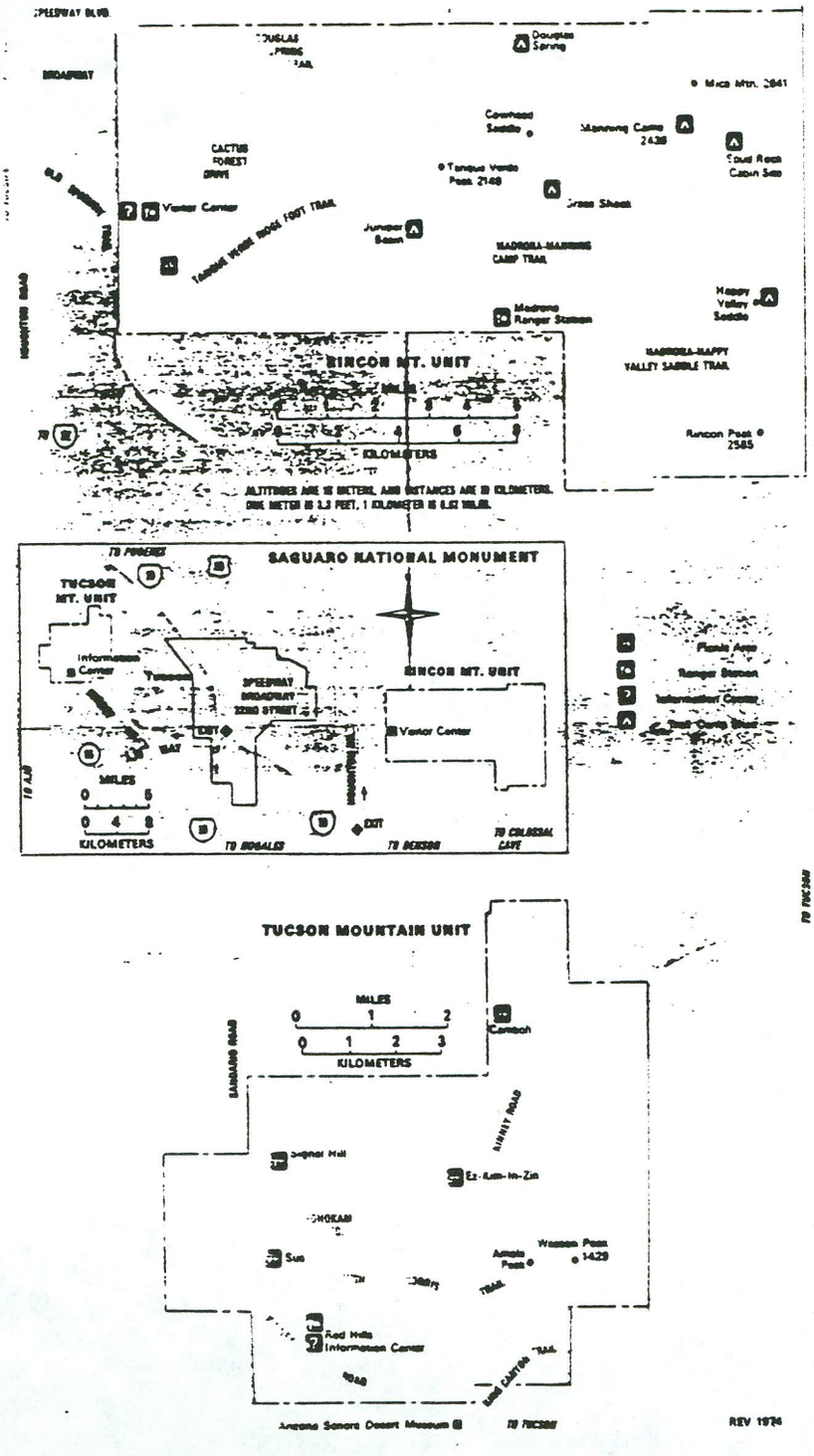
MAPS OF SOUTHERN ARIZONA, ORPI, AND SAGU



Map of southern Arizona and northern Mexico showing locations of ORPI, SAGU, and Pinicate area of Sonora, Mexico.



Map of ORPI area.



Map of SAGU area showing Rincon Mountain Unit and Tucson Mountain Unit.

APPENDIX III

LIST OF THOSE WHO HELPED WITH PROPOSAL

The preparation of this Statement of Capabilities and Interest generated a great deal of excitement within the scientific community and among other agencies in the Southern Arizona area. Many people gave very freely of their time and expertise in a two-day scoping session in March 1990. Others very graciously offered useful review comments and ideas for inclusion in this statement. We are grateful to each one for their assistance and support.

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