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P.O. Box 905
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Author: Betty Alex

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Mapping and Modeling Sensitive Plants in Big Bend National Park

BETTY ALEX

*Division of Science and Resource Management, Big Bend National Park, P.O. Box 129,
Big Bend National Park, TX 79834*

Correspondent: *betty_l_alex@nps.gov*

ABSTRACT—Because of its geographic location, its broad range in elevation, and its wide variety of substrates—including a variety of limestones, clays, lavas, intrusive igneous rocks, and alluvial gravels—Big Bend National Park is an area of high floral diversity. A project is underway to relocate populations of the approximately 200 plant species that occur in the park that are ranked as rare in the state of Texas. Populations are relocated and mapped using GPS; individuals are counted, the extent of the population is mapped or otherwise noted, and both plants and habitats are photographed. It has become apparent that many of these rare plants co-occur, and that often their required habitats are strongly based on substrate or parent material. Geologic formations as well as soils often appear to be the controlling factor for appropriate habitat. A Geographic Information System (GIS) is being used to define the habitats of many of these plants, and models are being created to attempt to predict other locations of plant populations.

INTRODUCTION—*Geographic Setting*—Big Bend National Park is located near the geographic center of the Chihuahuan Desert, in the southern-most portion of that desert in the United States. The park is a highly diverse area with a wide variety of habitats, mainly due to three factors: a wide range in elevation, geographic location, and geologic diversity. The elevation of the park ranges from 488 m along the Rio Grande in Boquillas Canyon to over 2,379 m at the top of Emory Peak in the Chisos Mountains. Habitats within the park range from subtropical riverine along the Rio Grande to Arizona pine/Arizona cypress/Douglas fir forest in the protected canyons of the highest mountains. A wide gradient of grassland, desert shrubland, and badland lies in between. The temperature gradient is similarly diverse with summer temperatures along the Rio Grande routinely exceeding 43.3 °C while the Chisos Mountains remain 11 degrees cooler; winter temperatures are generally mild park wide, but snow and hard frost events occur most years in the mountains.

Occupying a geographic location in the center of the Chihuahuan Desert, the park is a focal point for typical Chihuahuan Desert vegetation, and has been targeted as an area of special conservation concern by organizations such as the World Wildlife Fund which describes the Chihuahuan Desert as “one of the three most biologically rich and

diverse desert ecoregions in the world.” Approximately 3,500 plant species, estimates of up to 1000 endemic species, at least 16 endemic plant genera, and around one-fifth of all the world’s cacti species occur in the Chihuahuan Desert. This diversity is the result of the isolating effects of basin and range physiography coupled with dynamic climate changes over the last 10,000 years, and colonization of multiple inhospitable habitats by specialist species with restricted ranges. The easternmost region of the desert, including Coahuila which bounds the park, “once constituted a refuge from severe climatic changes that occurred in the past” and facilitated speciation in many animals and plants. (World Wildlife Fund 2001).

The biota of the area is also influenced to varying degrees by surrounding ecological areas. According to the World Wildlife Fund Terrestrial Ecoregions of the World (World Wildlife Fund 2001) ecoregions within 483 km of Big Bend include: Edwards Plateau savanna, Tamaulipan mezquital, Tamaulipan matorral, Sierra Madre Oriental pine-oak forests, Sierra Madre Occidental pine-oak forests, Meseta Central matorral, Colorado Plateau shrublands, Arizona Mountains forests, Sinaloan dry forests, Sonoran-Sinaloan transition subtropical dry forest, Sonoran desert, Western short grasslands, and the Central and Southern mixed grasslands. Migrating birds are potential transporters of seeds from any of these areas.

The Chihuahuan Desert is relatively young in geologic time, and the higher elevations contain relic flora and fauna retained from a pre-desert era. The flora of the Chisos Mountains retains species such as Arizona cypress (*Cupressus arizonica*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), Arizona pine (*Pinus arizonica* var. *stormiae*), and quaking aspen (*Populus tremuloide*s). Several species have become isolated in the mesic island of the Chisos Mountains, some possibly for long enough to have undergone speciation.

The sedimentary geology within the park ranges from Cretaceous limestones and clays, to Miocene sandstones and siltstones, to Tertiary alluvial and colluvial gravels. Tertiary igneous intrusions and lavas and the attendant fracturing and faulting, punctuate, intrude and overlie the sedimentary structures, often metamorphosing or contorting those formations. The igneous geology of Big Bend National Park is relatively unique in that the composition of the rock is generally peralkaline, creating a chemical habitat that differs substantially from most igneous mountains in the United States and México (Robert Scott, 2004, pers. comm., USGS).

These diverse factors create an environment in which desert species adapted to highly xeric conditions thrive only feet from more mesic-dependent species common to the Rocky Mountains, Edwards Plateau, or Central México. This varied flora makes Big Bend a repository of numerous species rare in the U.S. or even in the world.

Project Background—For many years, Big Bend National Park resource staff have made efforts to track plant species that are rare, listed Endangered or Threatened, or subject to illegal collecting. U.S. Fish and Wildlife Service (USFWS) have been tracking rare plants since the late 1970s. The Texas Natural Heritage Program (now called the Wildlife Diversity program) began tracking rare plants statewide in 1984. During the 1980s, several monitoring plots for endangered species were established in Big Bend National Park, and other species were informally censused or sporadically mapped in attempts to record their locations in order to better protect them and to better understand their habitat requirements.

More formal tracking of rare and sensitive plants in Big Bend National Park began when Louie (1996) wrote “The Rare and Threatened Plant Species of Big Bend National Park, Texas.” Louie defined her rare and sensitive plants as “all federally ranked plants (Endangered, Threatened, and Candidate species) and other plants suspected to be threatened” in Big Bend National Park. She compiled maps of reported locations. While this began a concerted effort to relocate reported rare plant populations, many of the locations were very general. Attempts to relocate species were sporadic depending on staff availability and on limited funding for projects relating to specific plants.

During the late 1990s, the park, NPS, USFWS, Texas Parks and Wildlife Department (TPWD), and the Desert Botanical Garden, Phoenix, Arizona, established several more monitoring sites. In 1999, a seasonal employee was hired to research and organize the existing locational information on Louie’s list of 32 species and create a database populated with that information. The task proved to be larger than expected and over the six-month duration of that project only about half the existing information was compiled into the database, but it was a very good beginning at understanding the magnitude of the project and the dearth of information available about some of the less studied rare plants occurring in the park.

The Sensitive Plant List and database was revitalized in 2003 when the U.S. Geological Survey, National Biological Infrastructure Inventory (NBII) provided funding to hire a seasonal employee to relocate the sensitive plants.

Composing the Sensitive Plant List—As originally conceived and proposed, this project dealt with the original list of 32 species composed by Louie (1996). She stated: “Future biological scrutiny of plant species coined ‘rare’ may determine that some taxa are not at all rare, while others may be in greater peril than initially understood.” Those changes in information had occurred in the intervening years since her study, giving reason for numerous changes to the original list. Because of USFWS attention, far more is now known about the three Federally-listed cacti on the original Louie list. There were

two Federal ‘Candidate Species’ in Louie’s report. The taxonomic distinctiveness of the first—*Castilleja elongata*—is currently in question and this species may be stripped of its specific taxonomy and subsumed into the widespread, common, but variable species, *Castilleja integra*. The second—*Festuca ligulata*—has received considerable research attention and the park populations are well-studied. One of Louie’s “Species of Concern” (*Erigeron mimegletes*) was dropped from the list because it was ‘lumped’ into a larger and more cosmopolitan species. Two other “Species of Concern” (*Aquilegia longissima* and *Ostrya chisosensis*) have been investigated to the extent that park management is assured that the populations are stable and widespread within the park, even though individual populations remain small. Others of Louie’s high-priority species, while still rare, are now much better understood (such as *Echinocereus chisoensis* var. *chisoensis*), thanks in part to the investigations precipitated by their rarity and vulnerability.

There are factors other than strict ‘rarity’ that are important to assist the National Park Service in properly managing park resources. A plant may be reasonably common worldwide or statewide but be rare in Big Bend National Park. Those plants may be on the edge of their range and therefore susceptible to local extirpation, or they may be undergoing speciation which makes them potentially important to science. Plants that occur in other places are often not protected in those areas, but are protected within the park; Big Bend National Park may be the only public land where the plants are found, making it important to preserve them for future research. Some plants that occur within the park may be more common in México, but Big Bend National Park is the only United States area in which they are found. Other plants may be locally common within the park, but occur almost nowhere else. A few species are known only from within the boundaries of the park. Charismatic taxa, like cacti and orchids, are highly subject to both commercial poaching and casual poaching by visitors. Several cacti species often targeted by poachers are infrequent enough to cause concern even though they are not technically ‘rare’, and most orchids occurring in the park are not common at any location within or outside the park. Many plants recently added to the park’s Sensitive Plant list are poorly understood and, in fact, some have not been located for decades. In addition, some of the original TPWD records and other herbarium records may have been based on misidentification or confusion over place names. These records need to be either verified or marked as possibly spurious.

Because of these complex factors, numerous species have been added to the sensitive plants list, based heavily, but not exclusively, on *An Annotated List of the G3/T3 and Rarer Plant Taxa of Texas* (W.R. Carr, 2003, unpubl. report, Texas Conservation Data Center, The Nature Conservancy, Austin, Texas) with additional information

from the NatureServe website (NatureServe 2003). Louie's list of 32 species has now grown to about 170 'target species' (available upon request from BIBE staff). This list is under constant review and is revised at the end of each year's field season.

Prioritizing the Sensitive Plant List—Using a Geographic Information System (GIS), the park's natural resource staff developed a ranking system intended to direct efforts toward documenting the locations and populations of species to facilitate better resource management within the park.

Priority 1 – **These** species are rare within the park and to properly manage them park staff needs specific locational information.

1a – Reasonably good locations for these species exist and if searched for at those locations during the proper season, relocating them in years of average to high rainfall should be possible.

1b – While there is good documentation that these plants occurred within the park in the past, there are no specific locations. These plants are high priority, but will not be actively searched for until there is unambiguous information from herbarium or other records that define such locations. If this information is discovered, these plants will be elevated to 1a status. In addition, good photos or drawings of the plants will be sought to facilitate field identification.

Priority 2 – These plants are moderately rare or highly poachable. Plants in this category will be relocated, mapped, and photographed at appropriate seasons after Priority 1 plant work is completed or when field workers are in the area of Priority 2 species.

Priority 3 – These species have a Texas State Rank of at least an S3 (see Appendix I and II for Global and State Rankings). They may be more common outside the park and not subject to poaching pressure or habitat destruction. Few or no exact locations exist for these plants within the park; to manage them properly we should know their habitat and educate employees in their identification. They will be less actively sought, but relocated and recorded when appropriate.

Priority 4 – Priority 4 species are locally common in the Big Bend area or within the park and are rated S3 in Texas. Plants are recorded when encountered to better understand their range, habitat and frequency, but not actively searched out. Some of these plants may be very rare in Texas, but are well-documented and reasonably well-understood within the park.

Species ranked as S1 or S2 on the Carr (2004, in litt.) list are obviously the most rare but S1/S2 species may not necessarily be high priority for park resource management.

Several S1 species, such as *Juniperus flaccida*, *Pinus arizonica* var. *stormiae*, and *Salvia regia*, all found nowhere else in the US, are so common within the park, that mapping them would be a huge project in itself. Other rare species are low priority because the park has already been intensively surveyed to find populations of those plants (*Echinocereus chisoensis* var. *chisoensis*, *Ostrya chisosensis*). *Cupressus arizonica* and *Sambucus nigra* ssp. *cerulea* are rare in Texas and uncommon in the Chisos Mountains, but are far more common throughout the western U.S. Other species (*Potamogeton chystocarpus*, *Senna wislizeni*, *Chamaecrista greggii*) known from elsewhere in the Trans-Pecos but not reported from the park are on the list for the sole purpose of reminding researchers to watch for them in appropriate habitats.

Most efforts under this project are focused on plants about which little is known or understood, rather than on the high profile species with which USFWS is concerned. Other projects are already expending considerable time and effort toward recording, tracking, and better understanding those species.

This list is dynamic, and prioritization can and has changed throughout the course of the project. For example, *Brongniartia minutifolia* was originally Priority 1a, but after finding large populations across wide areas (>1100 plants) during the 2003 field season, it was lowered in priority to category 4, and will be recorded when encountered. Other changes to the list occur as more information is gathered from both within and outside the park.

METHODS—The first step in relocating a plant species is to search herbarium records and other references for specific locations within the park for each species. Because Big Bend National Park is remote, only the park herbarium, Sul Ross State University herbarium, University of Texas herbarium, and some other herbarium records and references that are on the Internet have been searched. Locational information from various reference books, from personal knowledge of park employees and others conversant with rare plants has also been incorporated. The collection dates and bloom dates from references and herbarium records are also incorporated. With this information, locations are prioritized both by areas and by seasons, increasing the effectiveness and efficiency of fieldwork.

Field—Using the locations gathered, areas are prioritized to be searched based on reported bloom dates. When species are located in the field, locations are recorded using a Global Positioning System (GPS). Other data, including plant species, UTM coordinates, date, time, number of plants, recorder, species information (such as whether a plant is in bud, in flower, or in fruit), whether a specimen was collected, and

records of photos taken are recorded with any additional comments on a Compaq iPAQ 3850 using ArcPad 6.x software.

To record plants for future identification, an Olympus C5050 digital camera is used. Photo documentation includes close-up photos of flowers, fruit, leaves, and other key morphological characteristics as well as the entire plant and the habitat, if appropriate. Photos are organized by family, species, recorder, and location, and are being entered in a photo database as time allows.

Specimens are generally collected if: (1) identification is tentative or ambiguous, and (2) there is enough plant material that collecting a specimen is unlikely to damage the population (no more than 0.05% of a single plant or population); or (3) there is no specimen available from the Big Bend or Sul Ross State University herbaria, and identification and documentation are specifically needed. The project focuses primarily on species location and data gathering. Specimen collection appropriates time and funding from those activities. Multiple trips to sites are often made to get appropriate photos and specimens.

Lab—Data is downloaded to the computer, collated, and manipulated in ArcView 3.3 and Excel prior to reforming the data into an ArcView shapefile format. The original Access database developed at the beginning of the project has proven to be too complex to organize the field data appropriately. The database will be reconfigured to accommodate the field data and make it a more user-friendly tool. Most data compilation will occur over the winter months when plants are dormant.

All photos are archived to an external hard drive and backed up to the park's server. Since digital media is not considered adequately archiveable due to rapid technological changes rendering media inaccessible, three to six of the best photos of each species will be printed, stored in archival-quality sleeves, and placed in the Science and Resource Management Research Library. To date just over 12 GB of photos have been organized, most of which are already identified and organized in a phylogenetic/locational format. At the end of the project, the digital files will be made available to park employees and researchers.

SYNOPSIS OF FIELD WORK—Field work focused on (1) relocating the species, (2) recording the location using GPS to facilitate future relocation and understanding of requisite habitat, (3) photographing plants in flower and fruit to aid in subsequent identification by park employees and researchers, and (4) documenting the population size and extent at those locations.

For most of the decade of the 1990s, the Big Bend area experienced one of the worst droughts on record with rainfall averaging 20 to 30% below normal over that

period and some years falling below 50% of normal. Anecdotal information from long-time residents, indicated that this drought was worse than either the drought of the 1930s or the 1950s. It was certainly a 10-year period of poor plant production. Fortunately, the rains began earlier than usual in 2003, with substantial rainstorms falling area-wide in April and May and continuing into the autumn. Fieldwork in the 2004 season benefited from moderate spring rains that increased into torrential downpours in the late summer and autumn. Some locations became inaccessible due to impassible and closed roads at exactly the time of year that some species would most likely be blooming, so there are several high priority locations, especially along the River Road, that need to be covered during future fieldwork.

SUCCESSES OF THE YEAR—During the 2004 field season, staff relocated 245 populations of sensitive plants for a total of almost 8,900 individual plants. Fig. 1 depicts the areas where species were found. Four species of plants that were not on the park's list of vascular plants (National Park Service 1996) have been documented and a fifth species, *Stevia ovata* var. *texana*, which is listed as an S1 in Texas, was discovered in the park's herbarium collection, but was not on the park's plant list. It too will be added to the Sensitive Plant list after consultation with Dr. A. Michael Powell of Sul Ross State University and Jackie Poole of the TPWD Wildlife Diversity Program.

A few of the more significant finds:

- Park staff relocated a second *Batesimalva violacea* population. This is a G2/S1 species known only from two park locations and four locations in México.
- Park staff relocated two populations of *Brickellia veronicifolia* var. *petrophila* (G5/S1) and found a third new population, totaling 48 plants. This is an S1 species known only from the Chisos Mountains in the U.S.
- Three of the eight *Perityle* taxa were located. The ecology of this group of plants is poorly understood and many of the varieties may be undergoing speciation and inter-sectional hybridization (Dr. A.M. Powell, 2003, pers. comm., Sul Ross State University, Alpine, Texas), making it important to the understanding of the ecological changes naturally occurring within the Chihuahuan Desert. Fifteen *Perityle bisetosa* var. *scalaris* plants were located while searching in the Dead Horse Mountains for other species reported there. This variety (G2T1/S1) has only been documented from four other locations just outside the park and one just within the park boundary. A large population of another rare relative, *Perityle aglossa* (G3S3) was found in the same area. Two *Perityle rupestris* var. *albiflora* (G4T3S3) plants were found in the Chisos Mountains.

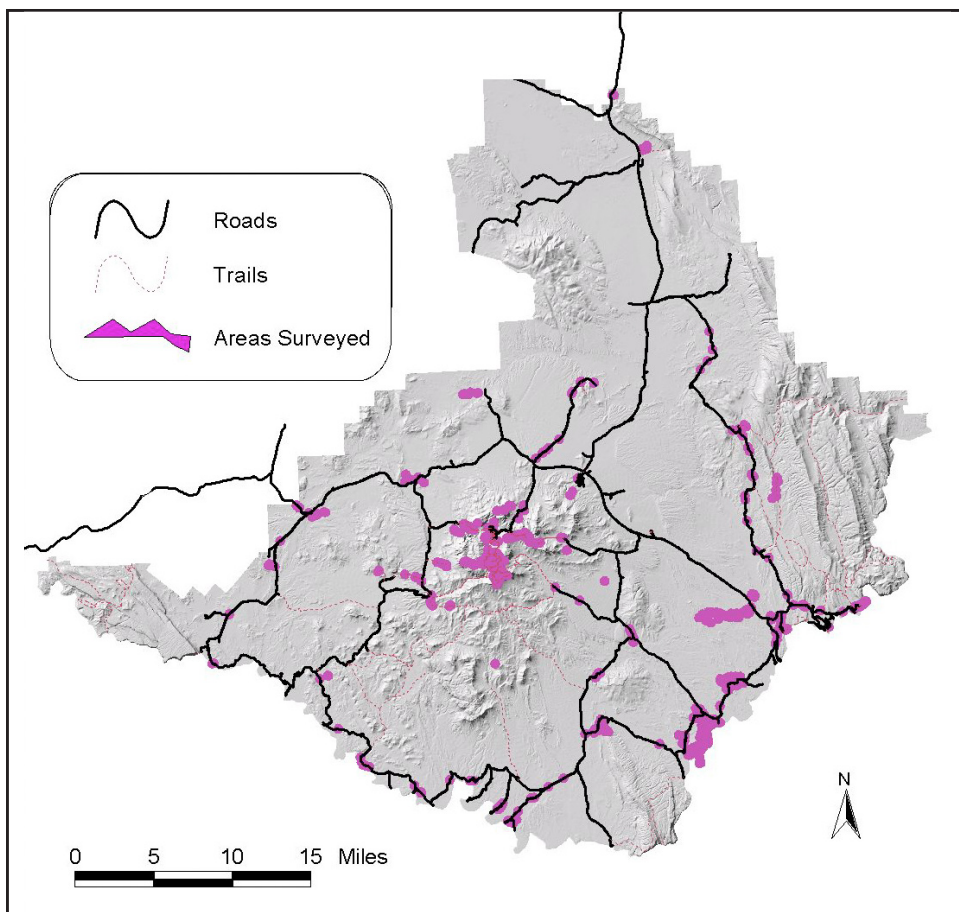


FIG. 1—Areas surveyed during the 2004 field season.

- *Fendlera linearis* (syn=*F. rigida*) was reported within the U.S. only from three park locations, two Solitario locations (now within Big Bend Ranch State Park), and two other Brewster County locations. Two large, stable populations of *Fendlera linearis* were documented, one of which was previously unreported.
- A new location for *Festuca ligulata*, (G1S1) known only from the Chisos and Guadalupe mountains in the U.S. and the Sierra del Carmen in Coahuila, México, was documented.
- *Heterosperma pinnatum*, a G5/S1 species, was found at a previously unreported site.
- With only one obscure locational reference inside the park for *Bonamia repens*, a G3/S2 species endemic to the Trans-Pecos, two new populations were found in a different habitat than previously reported.

- A large and apparently healthy and stable population (at least 135 individuals) of *Gaura boquillensis*, a G2/S2 species, was documented.
- *Justicia warnockii* (G3/S3) was relocated at one of the previously reported sites and found at two additional new sites.

Orchids in 2004—During the 2003 field season both *Malaxis wendtii* and *Stenorrhynchos michuacanus* populations were relocated and recorded, and several *Dichromanthus cinnabarinus* populations were documented, but no *Hexalectris* orchids were located during 2003. Because of the unknown status of the *Hexalectris* orchids, extra significance was placed on relocating those populations during 2004, especially since the rains of late 2003 and early 2004 made it more likely that we could find those species this year.

Allison Freeman, seasonal Biological Technician, was responsible for most of the work done in relocating and recording orchids this year. She targeted several previously reported locations for *Hexalectris* species for thorough monitoring, and she located the first plants on 1 June 2004. Over the next 2½ months, she found at least one population of every *Hexalectris* species known to occur in Big Bend; 130 *Hexalectris* plants were located at 19 sites; seven of the sites were previously unreported locations discovered while searching for other species.

Hexalectris revoluta is the rarest of the *Hexalectris* species occurring within the park (G1G2/S1). Known from three Trans-Pecos mountain ranges, two sites in Arizona, and a few sites in México, one of its common names, Chisos Coral Root, reflects the fact that the Chisos Mountains are the best-known location for this species. Allison found one area where there was a population of eight plants and another area where there was a single plant. Both areas will be monitored in future years to determine the population stability.

Hexalectris warnockii, ranked G2G3/S2, has a very spotty distribution from the Dallas, Texas, area to southern Arizona and with wide areas of no occurrence between sites. Twenty-five plants were found at six locations, with one large population of 17 plants.

Hexalectris grandiflora, ranked G4/S2, is known only from the Chisos and Davis mountains of Trans-Pecos, Texas, and a few sites in the Chihuahuan Desert of México. There is only one herbarium record of *H. grandiflora* from the park, and the single population found this year was at that recorded location. Only two plants were located even after several trips to the area throughout the blooming season. This species appears to favor a somewhat different habitat than the other *Hexalectris* species.

Hexalectris nitida, ranked G3/S3 was previously recorded from only two locations within the park. This year a total of 18 plants of this species were found in five localities.

Hexalectris spicata (G5) occurs infrequently across the southern U.S. It is tracked because *H. spicata* is rare within the park and can be threatened by forest management practices. Both varieties were found: *H. spicata* var. *spicata* was located at one site in large numbers (31 individuals), and *H. spicata* var. *arizonica* at four other sites in somewhat lower numbers (40 individuals total).

Other orchid species also responded to the increased rainfall. *Malaxis wendtii* and *Dichromanthus cinnabarinus* populations located last year were recorded again in 2004, and a new location for *Stenorrhynchos michuacanus* was documented.

Deiregyne confusa was last found in the park and in the United States in 1931. Though it had been searched for through the years, no other records of it existed. Over 15 years ago, Dr. Barton Warnock told the author that he had seen it in the Chisos Mountains years before that, but gave no exact location. This orchid was akin to the Holy Grail for those working on this project: while certain it had at one time existed within the park, workers held little hope of ever finding it. However, two blooming specimens were found and several orchid plants that did not bloom in 2004 are suspected to be *D. confusa* and will be monitored over the next few blooming seasons.

Applied modeling—A rare plant's habitat—For many years, *Bonamia ovalifolia*, a G1/S1 plant, was reported from only two locations within Big Bend National Park. The original collection location was a 19th century record from “below San Carlos along the Rio Grande.” During the 2003 field season, a new population of *Bonamia ovalifolia* was discovered by local photographer Roy E. Morey. The habitat is significantly different from the two previously known locations (Alex, 2003, unpubl. report, National Park Service, Big Bend National Park, Texas).

Because the actual areal extent of that site was larger than the other known areas, a GIS model could be constructed that might help define other areas where the species occurs. I created a model based on the Morey site location using a 1990 Landsat7 image and a very general digital geology map. The model defined several high probability areas to search.

Soils have long been considered one of the dominate factors in defining habitat. However, had the *Bonamia* model used soils, none of the locations subsequently located would have been defined by the model. *B. ovalifolia* and several other species appear to be obligate to specific geologic strata or to substrata derived from those strata.

Spring fieldwork did not allow time for checking the model, but I gave a program on the project to educate and enlist assistance from park personnel. A park employee subsequently reported two additional locations for *B. ovalifolia*. I visited and documented those populations, and found that both locations were high probability areas according to the untested model. The model also indicated that another area near one of the new sites

was a high probability area. I visited that locality and found 132 *B. ovalifolia* plants. Two other areas of high probability have been inaccessible due to torrential rains. When the roads are again reasonably passable, those areas will be searched.

CONTINUING WORK—*Rare Plants or Rare Habitats?*—This project began as an attempt to relocate individual species, accurately map their location, and gather basic information about plant numbers. Until there is adequate information on all the target species, that will continue to be the focus of funded fieldwork. However, as the two field seasons have progressed, it has become apparent that when searching for one species several others that are on the list are usually found. Generally, the associated species grow together in a narrow habitat type. Moving away from the concentration of species, one or two species will persist to the very edge of what might be termed marginal habitat. At that point no ‘sensitive’ species occur, although there may be no particularly obvious major change in the area, but rather a gradational variation in the habitat. Many of these changes are so subtle that they are difficult to define or describe in qualitative terms. After two seasons of data collection, several basic species associations have become evident.

For example, when mapping the two newest *B. ovalifolia* (S1) habitats, *Selinocarpus parvifolius* (S3) and *Mimosa turneri* (S3) were found to be two of the dominant species in the habitat. When the *B. ovalifolia* disappears, *S. parvifolius* and *M. turneri* are still present, but as one moves away from the concentration of *B. ovalifolia*, first the *S. parvifolius* and then the *M. turneri* disappear as well. When searching a reported area for *Chamaesyce chaetocalyx* var. *triligulata* (S1), and *C. golondrina* (S2), *B. ovalifolia* (S1), *Gaura boquillensis* (S2), *Croton pottsii* var. *thermophilus* (S1), and the locally abundant species *Catbestecum erectum* (S1), *Psathyrotes scaposa* (S3), and *Hechtia texensis* (S3) were also documented. This type of association has prompted workers to occasionally visit locations of lower priority species in hope of finding the higher priority plants. Sometimes this approach has worked.

Target species that occur together in the Chisos Mountains usually occupy small habitat niches that do not lend themselves to landscape-level modeling. Those species occupy narrow canyons, watercourses, steep cliffs, or other small, limited areas. However, as noted above concerning *B. ovalifolia*, several species groupings occur in the desert areas that may be specific enough to create GIS models of their habitat. As these associations become better defined, additional models of high-priority species will be developed.

Employee Field Guide—An effort to compile a new version of the park field guide to sensitive plants began last winter. Descriptive information in lay language on each species was compiled to assist employees such as trail crew, fire crews, and road crews to identify sensitive plants. Maps will be included as appropriate. The guide will also be available to other employees for information and education, but will not be available to the public, since it will include locations for some sensitive plants.

Plans for Future Fieldwork—Field work will concentrate on species for which we have specific locations but have not yet found.

CONCLUSION—Since the inception of this current survey, at least one location of 110 of the 210 species on the Big Bend National Park Sensitive Plant list has been documented. The habitat requirements and plant associations related to many of the rare species are better understood, and information has been developed that will assist in creating GIS models of some species habitats, and thereby possibly help locate additional populations. A strong relationship with a specific geologic substrate appears to control several of the species habitats, and this relationship will be instrumental in understanding habitat requirements. Several species that had not been seen in the park for 20 or more years have been located, most notably *Deiregyne confusa*, Confused Ladies' Tresses—an orchid that had not been reported in the U.S. since 1931.

The project is gathering information that is invaluable to the management of a large and diverse area like Big Bend National Park, and to the conservation of rare species. Park resource managers are not only gaining insights into the habitats for rare species, but are also coming to better understand the relationships of common species to rare and the multiplicity of diverse habitats of the Chihuahuan Desert.

The persons most responsible for the tremendous success of this field work are Seasonal Biological Technician Allison Leavitt, a highly observant and profoundly tenacious field botanist who did most of the field work, and Dr. Joe Sirotnak, Park Botanist, Big Bend National Park. Dr. Sirotnak has worked closely with both Allison and me to assist with numerous facets of the project; Joe's advice, assistance, and support has been invaluable. Sincere appreciation must also go to Dr. A. Michael Powell, of Sul Ross State University, Alpine, Texas, who has assisted immensely throughout the project, and identified difficult specimens. Without his assistance, many specimens would have been unidentified and we would not have known that we had found several rare species. Dr. Billie Turner, of Sul Ross State University and The University of Texas at Austin, has also greatly assisted with some particularly difficult plant identifications. We look forward to working with these two professionals as we complete the final project report. Jackie Poole of Texas Parks and Wildlife Department, Wildlife Diversity Program, has been instrumental in every phase of the project, from planting the first seed of inquiry many years ago, to answering the innumerable questions of a non-botanist, to giving sustained encouragement of the value and importance of the information being gathered, and sharing specific information on numerous species. Last but distinctly not least, the project would not have been possible were it not for the substantial financial support of the U.S. Geological Survey, National Biological Infrastructure Inventory Program and the personal support of Dan Phillips, Node Coordinator at the USGS Center for Biological Informatics, Reston, VA.

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APPENDIX I: Global Rank

Rank	Meaning
G1	Critically imperiled globally, extremely rare, five or fewer occurrences. (Critically endangered throughout range.)
G2	Imperiled globally, very rare, 6 to 20 occurrences. (Endangered throughout range.)
G3	Very rare and local throughout range or found locally in restricted range, 21 to 100 occurrences. (Threatened throughout range.)
G4	Apparently secure globally.
G5	Demonstrably secure globally.
G?	Not ranked to date.
G#?	Rank uncertain.
G#G#	Ranked within a range as status uncertain.
G#NA	Accidental in North America.
G#NE	An exotic species established in North America.
G#T#	“G” = species rank; “T”=rank of variety or subspecies
GH	Of historical occurrence throughout its range; may be rediscovered.
GU	Possibly in peril rangewide, but status uncertain; need more information.
GX	Believed to be extinct throughout range; little or no expectation of rediscovery.
Q	Qualifier Denoting questionable taxonomic status.
C	Captive population exists.

APPENDIX II: State Rank

Rank	Meaning
S1	Critically imperiled in state, extremely rare, very vulnerable to extirpation, five or fewer occurrences.
S2	Imperiled in state, very rare, vulnerable to extirpation, 6 to 20 occurrences.
S3	Rare or uncommon in state, 21 to 100 occurrences.
S4	Apparently secure in state.
S5	Demonstrably secure in state.
SA	Accidental in state.
SE	An exotic species established in state.
SH	Of historical occurrence in state; may be rediscovered.
SN	Regularly occurring, non-breeding status.
SP	Potential occurrence in state.
SR	Reported, but without conclusive evidence to accept or reject report.
SRF	Reported in error, but error persists in literature.
SU	Possibly in peril in state, but status uncertain.
SX	Apparently extirpated from state.
SZ	Migratory/transient in state to irregular/dispersed locations.
S#?	Rank uncertain.
S?	Not ranked to date or denoting uncertain rank.
C	Captive population exists.
