Status Assessment Report for *Sclerocactus mesae-verdae* (Mesa Verde cactus)

Prepared for:

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PREAMBLE FOR THE RECOVERY OF SCLEROCACTUS MESAE-VERDAE.

Excerpt of the 1984 US Fish and Wildlife Recovery Plan (Heil 1984):

"The primary objective of this recovery plan is to restore the Mesa Verde cactus to non-threatened status by:

1) Securing the five known populations from present and future human threats.

2) Ensuring that the Mesa Verde cacti are maintained as vigorous and self-sustaining populations throughout their natural habitat.

As this objective is met, delisting will be initiated when the following criteria have been met:

I.) Establishment of at least two restricted use areas for selected portions of Mesa Verde cactus habitat on the Navajo Indian Reservation and on BLM administered land.

II.) Provision of Mesa Verde cactus stock to trade outlets to help relieve the black market demand through the addition of 10,000 plants per year into the commercial pipeline for 5 years.

These goals are to be evaluated for adequacy upon attainment and prior to delisting."

STATUS ASSESSMENT REPORT

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SUMMARY

Sclerocactus mesae-verdae is a rare cactus species. Its global range is restricted to scattered colonies in the Four Corners area of Colorado and New Mexico in the United States. Although shale badlands habitat occurs throughout the Four Corners region, the cactus occupies only a small fraction of that habitat. The majority, approximately 70 percent, of the known populations is within the Navajo Nation. In response to observations suggesting a decline in the abundance of this species an evaluation of the status of *S. mesae-verdae* has been undertaken by the Navajo Nation.

More than 56 areas, which covered more than 7 sections (approximately 4,723 acres), within Navajo Nation lands were surveyed in 2004. Several of these sites were reported to have had 1,500 or more individuals prior to 2002. However, the 2004 survey found that few sites supported more than 20 individuals. The total number of plants counted at all sites surveyed was 948 (68 percent) live cacti, 428 (31 percent) dead cacti, and 20 damaged cacti, which may well die within a few years. This represents a precipitous decline in population size that is consistent with observations on populations growing on Ute Mountain Ute land in Colorado and land managed by the Bureau of Land Management in New Mexico. Most of the living plants are small and are not yet reproductively mature. Therefore, because *Sclerocactus mesae-verdae* is a slow-growing species, recovery will be a slow process.

The primary threat that can be directly mitigated by land management is to limit continuing habitat loss. The primary causes of habitat loss are off-road vehicle use, disturbance caused by activities associated with energy development, urban development, and overgrazing. Another threat, which has been significant in the past, is illegal collection. The impact of illegal collection in the future cannot be surmised. However, the relatively few number of reproductively mature plants suggests that the populations cannot support any collection pressure at the present time.

Biological threats, such as arthropod infestations, and environmental stochasticities, particularly drought, are exacerbated by anthropogenic activities that result in habitat loss. Environmental and biological impacts can be alleviated by providing sufficient habitat throughout its range for small populations to remain viable during periods of natural attrition. The recent drought and outbreaks of various arthropod infestations emphasize the importance of conserving multiple and spatially separated populations. Spatially separated populations are more likely to experience different environmental, biological, and anthropogenic-based stresses. They are also likely to exhibit a larger degree of genetic diversity, which may be lacking within single populations.

As a consequence of the documented population decline, a primary conservation objective for *Sclerocactus mesae-verdae* must be to maintain all current populations. Progress can be assessed through population monitoring. The selected populations should be as widely separated across the landscape as possible. The goal should be to achieve stable populations composed of multiple-sized individuals. Population sizes should be at least comparable to those reported within the last 20 years. Sites dedicated to the

conservation of the cactus would be very valuable in safeguarding the taxon for future generations.

INTRODUCTION

Conservation assessments of rare plant taxa provide the foundation for sound decisions in guiding the application of appropriate management practices. Using the best available information is important in all planning processes. Therefore assessments help to set the ecological context for conservation priorities and land stewardship. The appropriate scale for assessments, strategies, and agreements is determined by the ecological context in which the management decisions are being made. Anywhere in the range of a site-specific to global scale may be appropriate depending upon the taxon and specific objectives. The Navajo Nation manages the majority of the land on which *Sclerocactus mesae-verdae* occurs. Therefore any management decisions made by the Navajo Nation have considerable effects on the global population of *S. mesae-verdae*. Considerations in any management plan must include abiotic and social factors that influence sustainability as well as the biological factors that are specific to the taxon.

Sclerocactus mesae-verdae is a rare cactus species. Its global range is restricted to scattered colonies in the Four Corners area of Colorado and New Mexico in the United States (Figure 1). The majority of its known range is within the Navajo Nation. Although shale badlands habitat occurs throughout the region, the cactus occupies only a small fraction of that habitat. Because *S. mesae-verdae* was listed as Threatened (LT) by the US Fish and Wildlife Service (50 CFR Part 17), a Recovery Plan was written in 1984 (Heil 1984). The Recovery Plan suggested that populations should be monitored to determine their stability. From 1986 until the year 2000, populations appeared to be stable and periodically new populations were found (Coles 2003, Bureau of Land Management 2003, Roth personal communication 2004). However, since 2000 declines have been observed range wide. In some regions all plants seemed to have been eliminated. This event has prompted concern that the current conservation practices may be inadequate. In response to this concern the Navajo Natural Heritage Program initiated a status assessment of the populations on Navajo Nation lands, which culminated in this conservation assessment.

This conservation assessment describes the biology, ecology and potential threats to this taxon. It also summarizes monitoring results on populations in both New Mexico and Colorado. Finally it summarizes the findings of the field surveys made in 2004 on Navajo Nation lands and identifies some areas that may be potential conservation sites.

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MANAGEMENT STATUS AND NATURAL HISTORY

Management status

U.S. Fish & Wildlife Service:	Listed Threatened (LT) under the U.S. Endangered Species Act (30 October 1979)	
Lead Region:	U.S. Fish & Wildlife Service R2 - Southwest	
Navajo Nation:	Endangered species - GROUP 3 (G3) category.	
State of New Mexico:	Endangered	
Bureau of Land Management:	Special Status plant species	
NatureServe Network Status:	Global rank:	Imperiled, G2 (12 September 2003)
	Subnation rank:	Colorado Imperiled (S2), Navajo Nation Vulnerable (S3), New Mexico Imperiled (S2)
IUCN World status:	Vulnerable (Walter and Gillett 1998)	

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Sclerocactus mesae-verdae is listed as Threatened (LT) by the US Fish and Wildlife Service (50 CFR Part 17; U.S. Fish and Wildlife Service 1979) under the U.S. Endangered Species Act of 1973. The Endangered Species Act of 1973, as amended, prohibits the removal and reduction to possession from Federal lands of any plant listed under the provisions of the Act. For any listed plant, it is also prohibited for any person subject to the jurisdiction of the United States to import or export, deliver, receive, carry, transport, or ship in interstate or foreign commerce in the course of a commercial activity; or sell or offer to sell any listed plant. The Act also provides for the issuance of permits to carry out otherwise prohibited activities involving listed species under certain circumstances.

Sclerocactus mesae-verdae is designated a Group 3 (G3) Endangered species by the Navajo Nation. A Group 3 species is any species or subspecies whose prospects of survival or recruitment within the Navajo Nation are likely to be in jeopardy in the foreseeable future (Navajo Nation Division of Natural Resources 2001). The Navajo Nation Department of Fish and Wildlife determines the appropriate group for listing a species according to any of the following factors: 1) The present or threatened destruction, modification, or curtailment of its habitat; 2) Over-utilization for commercial, sporting or scientific purposes; 3) The effect of disease or predation; 4). Other natural or man-made factors affecting its prospects of survival or recruitment within the Navajo Nation; or 5) Any combination of the foregoing factors (Navajo Nation Division of Natural Resources

2001). Tribal laws protect species in Groups 2 and 3. Title 17 § 507 of the Navajo Tribal Code makes it unlawful for any person to "take, possess, transport, export, process, sell or offer for sale or ship any species or subspecies" on the Navajo Endangered Species List.

A designation of Endangered by the State of New Mexico (rule filed as 19 NMAC 21.2; FRCD 91-1) means that the taking of endangered species is prohibited, with the exception of permitted scientific collections or propagation and transplantation activities that enhance the survival of endangered species (Sivinski and Lightfoot 1992, Sivinski and Lightfoot 1995). "Taking" means "the removal, with the intent to possess, transport, export, sell or offer for sale *Sclerocactus mesae-verdae* from the places in the state of New Mexico where they naturally grow" (Sivinski and Lightfoot 1995).

The Bureau of Land Management (BLM) designates *Sclerocactus mesae-verdae* as a Special Status plant species because the U.S. Fish and Wildlife Service lists it as Threatened. "It is BLM policy to manage for the conservation of special status plants and their associated habitats and to ensure that actions authorized, funded, or carried out do not contribute to the need to list any species as threatened or endangered" (BLM Manual Supplement H-6840-1).

The NatureServe and the Heritage Programs Ranking system designated *Sclerocactus mesae-verdae* as G2, which indicates it is "Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction or elimination. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000) or acres (2,000 to 10,000) or linear miles (10 to 50)." The Heritage Programs in the states of Colorado and New Mexico both give the taxon an S2 designation, which indicates it is "Imperiled in the subnation [state] because of rarity or because of some factor(s) making it very vulnerable to extirpation from the subnation". The Navajo nation designates it as S3, which denotes it is "Vulnerable in the subnation, either because it is rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals".

According to The International Union for Conservation of Nature and Natural Resources (IUCN -The World Conservation Union[1]) Red Data Book Categories, a Vulnerable (V) designation is awarded to taxa that are believed likely to move into the Endangered category in the near future if the causal factors continue operating. Included are taxa of which most or all the populations are decreasing because of over-exploitation, extensive destruction of habitat or other environmental disturbance; taxa with populations that have been seriously depleted and whose ultimate security is not yet assured; and taxa with populations that are still abundant but are under threat from serious adverse factors throughout their range

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Recommendations that were made in the *Sclerocactus mesae-verdae* Recovery Plan (Heil 1984, US Fish and Wildlife Service 1996) included the establishment of monitoring plots and the surveying and mapping of populations in New Mexico. Monitoring programs of between 5 and 18 years have been undertaken in New Mexico (Cully et al. 1992, Bureau of Land Management 2003) and Colorado (Coles and Naumann 2000, Coles 2003). Other suggestions in the Recovery Plan included protecting the known populations through management and enforcement of existing regulations and establishing at least two restricted use areas for selected portions of Mesa Verde cactus habitat on the Navajo Indian Reservation and on Bureau of Land Management (BLM) administered land (Heil 1984, US Fish and Wildlife Service 1996). Transplanting *S. mesae-verdae* individuals that were to be unavoidably impacted by road improvements and surveying for cacti prior to oil and gas exploration and other development projects are both examples of management and regulation enforcement that have occurred since the taxon was listed as Threatened (for example Roth 2004a and 2004b).

Several *S. mesae-verdae* colonies are in a restricted use area, the Hogback Area of Critical Environmental Concern (ACEC), managed by the Bureau of Land Management, Farmington Resource District. *Sclerocactus mesae-verdae* populations within the ACEC are periodically monitored (Bureau of Land Management 2003). At the current time "restricted use" has been interpreted quite liberally and livestock grazing, which disturbs soil structure and may trample plants, is still permitted on the part of the ACEC that overlaps the Waterflow grazing allotment (Stern 2004). A final recommendation of the Recovery Plan was to encourage introduction of large numbers of *S. mesae-verdae* plants into the commercial cactus trade to deter collection from wild populations (Heil 1984, US Fish and Wildlife Service 1996). Cultivation of *Sclerocactus mesae-verdae* remains very difficult (Brack personal communication 2004) and few plants are available on the open market at the current time.

Classification and description

Systematics and synonymy

Class	Dicotyledoneae
Order:	Caryophyllales
Family:	Cactaceae
Genus:	*Sclerocactus*
Scientific name:	*Sclerocactus mesae-verdae* (Boissevain ex Boissevain & C. Davids.) L. Benson
USDA NRCS Plant Code:	SCME4
Common name:	Mesa Verde fishhook cactus or Mesa Verde cactus

Synonyms: *Coloradoa mesae-verdae* Boissevain ex Boissevain & C.Davids.; *Echinocactus mesae-verdae* (Boissevain ex Boissevain & C. Davids.) L. Benson; *Pediocactus mesae-verdae* (Boissevain ex Boissevain & C. Davids.) Arp

History of species

Sclerocactus mesae-verdae has always been treated as a distinctive species. Unlike may other members of the Cactaceae, its unique taxonomic status has never been questioned although several authors have considered it belonging to different associations at the generic level. *Sclerocactus mesae-verdae* was first discovered at its type locality near Cortez, Colorado by Charles H. Boissevain and described as *Coloradoa mesae-verdae* (Boissevain and Davidson 1940).

The type specimen of *Sclerocactus mesae-verdae* was collected from Colorado (Boissevain s.n.) and reportedly deposited at the Dudley Herbarium at Stanford University (Heil and Porter 1994). However, Benson when reviewing the genus *Sclerocactus* in 1965 did not find the original specimen and he therefore designated a neotype, L.E. & R. Benson # 16155 (Heil and Porter 1994), and deposited it at Pomona College herbarium (POM), which has since been moved to and combined with the Rancho Santa Ana Botanical Garden Herbarium (RSA). Details of the neotype specimen collection data (POM-306837) from RSA_POM herbarium are: "Cactaceae; *Sclerocactus mesae-verdae*; Lyman Benson #16155, 11 April 1962; Montezuma; Southwest side of southern attenuation of Mesa Verde; near base of the prominent butte; bare hills. San Juan River. South slope. Alt. 5,800ft. Desert. Alkaline soil."

After the initial description as *Coloradoa mesae-verdae* (Boissevain and Davidson 1940), Benson (1951) placed the cactus in the genus *Echinocactus*. Later, in 1966, he transferred it to the genus *Sclerocactus* (Benson 1966). Del Weniger (1970) does not recognize the genus *Sclerocactus* and supports the concept that it belongs in the genus *Echinocactus*. Arp (1972) placed the species in the genus *Pediocactus*. He believed it to be most closely related to *P. bradyi* and *P. glaucus* (synonym: *S. glaucus*). In 1982, Benson reported that he concurs that *S. mesae-verdae* is related to the genus *Pediocactus*, especially *P. bradyi*, in its spines and flowers, but it is most appropriately assigned to *Sclerocactus* because the fruit dehisces in a manner typical of the latter. *Sclerocactus mesae-verdae* is also closely related to *S. wrightiae* (Heil and Porter 1994) and Benson (1966) believes that *S. wrightiae* is the connecting link between *S. mesae-verdae* and *S. whipplei*.

Biology and Ecology

Description

Sclerocactus mesae-verdae is a small perennial plant. It has a much-branched taproot. The stems are depressed-globose to ovoid. Most commonly the stems are less than 5 cm in diameter, but it is not unusual to find stems up to 11 cm tall and up to 8 cm in diameter. Rarely, stems of 19 cm diameter have been recorded (Cully et al. 1993). Stems are typically a pale green color. Each stem has 13 to 17 ribs. The tubercules are inconspicuous. The areoles are woolly with 7 to 13 straw- or gray-colored, spreading radial spines that are 6 to 13 mm long. There are generally no central spines but occasionally there may be one (up to four in atypical cases), 7 to 15 mm long, that is straight or, rarely, hooked. The conspicuous flowers are 1 to 3 cm wide and 1 to 3.5 cm long. The outer tepals, with purple mid-stripes and cream-gold margins, are oblanceolate in shape, 1 to 2.5 cm long and 5 to 8 mm wide. The inner tepals are typically yellow-creamy colored, although some may be pink, also oblanceolate in shape but 1.5 to 3 cm long and approximately 5 mm wide. The filaments are pale yellow to white and the anthers yellow. The style is light green, densely papillate and the 7 to 9 lobed stigma is green. The fruit is green but becomes tan at maturity. It is short, 8 to 10 mm long, cylindrical in shape and indehiscent (Benson 1982, Heil and Porter 1994). The seeds are black and 2.5 to 3 mm long and 3 to 4 mm wide, with tubercles on the seed coat. Apparently the tubercles of the seed coat of *S. mesae-verdae* are unusual having a polygonal base (Hochstätter 1995).

Examples of plants observed during the 2004 survey are shown in photographs in Figures 2 through 6. Sizes ranged from approximately 5 mm to approximately 15 cm in diameter. Individuals with multiple stems were very common, which is in contrast to past years when the author tended to see a majority of single stemmed individuals. Multiple stems may be a result of mechanical or biological damage to the original single stem. Mechanical damage may come from trampling. Infestation by the cactus borer, or longhorn, beetle (*Moneilema semipunctatum*) causes damage that, when not fatal, can cause multiple stem production, commonly termed sprouting (Coles 2003). Photographs in Figures 7, 8, and 9 illustrate the phenomenon.

Sclerocactus parviflorus ssp. *intermedius* (eagle-claw cactus) frequently grows within the same general area as *S. mesae-verdae*. However, it tends to grow on more sandy soils, often with a higher vegetation cover. *Sclerocactus parviflorus* ssp. *intermedius* is easily distinguished from *S. mesae-verdae* by its strongly hooked central spines and pinkish-purple flowers (Figure 10).

References to descriptions, photographs, line drawings and herbarium specimens

Descriptions and a photograph of *Sclerocactus mesae-verdae* are in Heil (1994), Heil and Porter (1994), Earle (1980), Weniger (1970), and Innes and Glass (1991). Descriptions are also in Boissevain and Davidson (1940), Arp (1972), Benson (1982), Weber (1987), Weber and Wittmann (2001), and Martin and Hutchins (1980). Descriptions and photographs are also published on the internet and include: The New Mexico Rare Plant Technical Council, and the CRC websites (see reference section for internet addresses).

Habitat

Sclerocactus mesae-verdae occurs on dry, low, exposed hills and mesas of Mancos or Fruitland clays at about 1,200-2000 m in elevation. Annual precipitation varies from approximately 8 to 20 cm. Average temperatures in the town of Shiprock range from a high/low in January (coldest month) of 44.4^{o}F/17^{o}F to a high/low in July (hottest month) of 95^{o}F/58^{o}F (City-data.com 2004).

Soils that support *Sclerocactus mesae-verdae* are typically sodic, high in selenium, and alkaline. These clay soils also have severe shrink-swell properties and poor permeability (Potter et al. 1985). Mancos and Fruitland clay formations erode easily, forming low rolling hills, commonly known as "badlands," which tend to provide harsh conditions for vascular plants. The *S. mesae-verdae* population at Sheep Springs, New Mexico, appears to grow in the Menefee Formation on the tops of hills and mesa slopes. Actually, the roots are anchored in the Mancos Shale Formation while the base of the plant rests on the Menefee Formation, which comprises a very thin surface layer (Heil 1984). It is not known if this situation applies to occurrences on other formations, such as those just east of Feather Hill. The formation east of Feather Hill belongs to the Mesa Verde Group, and is primarily Gallup Sandstone (New Mexico Bureau of Geology and Mineral Resources 2003). *Sclerocactus mesae-verdae* has been described as a gypsophile (Heil 1984) but the exact geologic strata occupied by the species, and its edaphic requirements are not known. The lithography and chemistry of the Mancos shale soils are locally variable (Potter et al. 1985). This variability is likely to contribute to the patchy distribution of plant species on the landscape. Further investigation is needed to provide an understanding of the factors restricting its distribution.

The shale slopes have a variable cover of surface gravels, from 0 to 100 percent (see Figures 11 and 12). In the 2004 survey, many small plants, especially at the site near Sanostee, were observed actually growing out from under gravels (see examples in Figure 13). These gravels may provide a slightly moister microhabitat, which benefits seed germination and seedling establishment.

Sclerocactus mesae-verdae typically grows in open conditions with high light exposure. Plants grow with variable aspects. In the 2004 survey, plants were often observed in the canopy of live or in the remains of dead shrubs and grasses (Figures 14, 15, 16, 17). These may provide suitable microhabitat conditions or provide refugia from the impacts of grazing and other disturbance. *Sclerocactus mesae-verdae* individuals have been found on slopes with gentle to steep inclines and also on flat areas. Many plants that appeared to have initially colonized a flat area were growing on a slope because of soil erosion (Figure 18).

Vegetation cover is generally very low, from less than 5 percent to 15 percent of the ground cover. Principal vegetation types are those of the Great Basin Desert scrub and Desert Grassland communities (Dick-Peddie 1993) and include the mat saltbush faciation and a shortgrass subclimax (Cannon and Weiss 1957). The most common shrub associates include mat saltbush (*Atriplex corrugata*) and Gardner's saltbush (*Atriplex gardneri*). Other shrub associates include *Atriplex confertifolia, Tetradymia spinescens, Zuckia brandegei*, and *Frankenia jamesii*. In Colorado bud (spiney) sage (*Picrothamnus desertorum*, synonym *Artemisia spinescens*) has been reported to be a common associate (Coles 3003). This is in contrast to observations made in New Mexico that "the absence of *Sclerocactus mesae-verdae* seems to be coincidental with the appearance of *Artemisia spinescens"* (Navajo Natural Heritage Program element occurrence records received in 2004). Associated perennial grasses commonly include alkali sacaton (*Sporobolus airoides*), galleta grass (*Hilaria jamesii*), and purple threeawn (*Aristida purpurea*). Cheatgrass (*Bromus tectorum*) and *Eremopyrum triticeum* (synonym *Agropyron triticeum*) are common non-native grass associates. *Eremopyrum triticeum* was particularly common at the sites surveyed during the 2004 survey. The abundance and species of associated forbs tend to be dependent upon the year and include scorpion weed (*Phacelia* sp., *Phacelia splendens*), globemallow (*Sphaeralcea* sp., *Sphaeralcea coccinea*), prince's plume (*Stanleya pinnata*), buckwheat (*Eriogonum salsuginosum*), *Eriastrum diffusum, Gila lappula*, and *Cryptantha* species. Russian thistle (*Salsola kali*) is a frequent non-native associate.

At the current time, potential habitat is best defined as habitat that from casual observation seems suitable for the species, but which is not occupied by it. This ignorance of true potential habitat is an important consideration when estimating how much habitat exists that can support this species in the future. An example of the difficulty in predicting potential habitat is illustrated in the region of Red Wash where a relatively large population was found on a small hill. There were several other small hills on an otherwise flat landscape in this area. Even though all these other small hills were searched no plants were found. This seemed surprising because all the little hills in the vicinity looked to have very similar habitat. However, it was noted that *Suaeda* (seepweed) shrubs were also only found where the *Sclerocactus mesae-verdae* plants were found, which suggests that there are likely to be some edaphic differences amongst the hills.

Reproduction and Autecology

Sclerocactus mesae-verdae is a long-lived perennial that grows slowly. The largest plant measured in Colorado was 10.9 cm in diameter the year before it died, and was approximately 43 years old (Coles 2003). In Colorado populations, the annual increase in stem diameter is approximately 2.6 mm in years of normal precipitation, (Coles 2003). This rate is higher than that observed among populations in New Mexico. Cacti in plots monitored by the Navajo Natural Heritage Program increased by an average of 0.85 cm over 6 years (1995 to 2001), which indicates an average growth rate of only 1.4 mm per year (Roth 2004a). In the same plots, transplanted cacti grew much more slowly and only increased in diameter by an average of 0.4 cm during the same time period (Roth 2004a).

The flowers are hermaphroditic, possessing both male and female organs. *Sclerocactus mesae-verdae* has been reported to be self-incompatible, as are many members of the Cactaceae family (Cully et al. 1993, Benson 1982). For example, *S. glaucus*, with which it is closely related, is self-incompatible (Tepedino 1998). However, *S. mesae-verdae* is apparently partially self-compatible (Tepedino 1998). Notwithstanding that *S. mesae-verdae* is partially self-compatible, it relies on a single or an assemblage of suitable pollinator species for abundant seed set. Principal, or perhaps sole, pollinators are members of the Halictidae family (Tepedino 1998). A principal pollinator of *S. mesae-verdae* is reported to be a Halictidaen metallic green sweat bee (Knight 1981 in Heil 1984). Various other arthropods, including fungus beetles (*Tritoma* sp.), blister beetles (*Epicauta* sp.) and several members of the Coleoptera (beetles) and Hymenoptera (wasps, ants, bees, and sawflies) have been captured in the flowers but it is not known if any are effective pollinators (Cully et al 1993). Research by Tepedino (1998) suggests that, unlike *S. glaucus*, there is no evidence to suggest fruit or seed set is being limited by inadequate pollination. This is might be a reflection of the fact *S. mesae-verdae* is partially self-compatible. Coles (2003) reported that *S. mesae-verdae* stems begin producing flowers when they reach approximately 2.0 cm in diameter (range 1.6 to 2.4 cm). The number of reproductive structures (buds, flowers, fruits) produced by individual stems is positively correlated with stem diameter (Coles 2003).

Pollen viability of individuals in several *Sclerocactus mesae-verdae* populations was estimated by the ability to stain pollen grains with cotton blue dye (Cully et al 1993). This stain does not indicate physiological viability, only that the pollen grain membranes are intact and the grains are filled with cytoplasm. Of two hundred pollen grains collected at each site, 89.5 percent of grains collected in New Mexico and 93 percent of grains collected in Colorado stained positive and were thus believed to be viable and reproductively robust (Cully et al 1993).

Running water is likely a major causal agent in seed dispersal (Heil 1984). The seeds may be carried away from the parent plant by running water and then fall into cracks as the clay soils dry. The leaping movement of sand or soil particles as they are transported in water over an uneven surface, or saltation, is probably also an important factor, particularly on hilltops (Heil 1984). A dry period might be required for anchoring the seeds in the cracks of the soil, especially in areas where associated vegetation is sparse (Knight 1981 in Heil 1984). Wind, specifically dust devils, and ants are also likely to contribute to seed dispersal (Knight personal communication 2004). Ant colonies are often observed near cacti (for example see Figure 19). These modes of seed dispersal are consistent with the patchy spatial distribution of the cactus. Although wind can occasionally cause long distance seed dispersal, in general wind-dispersed seeds move only short distances (Silvertown 1987).

Seeds ripen in late May to early June, and these fresh seeds will not sprout in the first year because the seed coat needs to be scarified (Brack personal communication 2004). In nature, seeds need to over winter and be exposed to many freeze thaw cycles, which contribute to cracking the seed coat over time (Brack personal communication 2004). A cool moist spring promotes germination (Brack personal communication 2004). Germination mainly occurs after it warms up and the rains have come (Brack personal communication 2004). There may be an extended germination period depending upon the year. Coles (personal communication 2004) has been monitoring plots in Colorado since 1986 and believes that most seeds germinate in the late summer and early fall after the monsoon rains. Cracks in the clay soil, where the seeds fall and may germinate, are likely an important part of the plant's microhabitat.

Demography

By far the most demographic data has been collected on populations in Colorado (Coles 2003). In Colorado, growth and reproductive parameters have been measured annually on more than one thousand *Sclerocactus mesae-verdae* stems since 1986 (Coles 2003). The term "recruitment" in the Colorado study included both the young individuals (seedlings) from seeds and the sprouts that grow from the bases of plants that have had their upper stems both partially or totally removed either from arthropod infestation or mechanical damage (Coles 2003). Periods of significant recruitment, are termed "recruitment events" by Coles (2003). In this context "recruitment events" means single-year population increases that are more than 25 percent higher than the long-term average. Years in which sprout recruitment was high tended to be years with average precipitation following beetle outbreaks. Recruitment events were separated both temporally and spatially. There were only three recruitment events in the Colorado plots over eighteen years and each tended to be concentrated within a single plot in any given year, and several years passed without substantial recruitment in any plot (Coles 2003). Seedling survivorship was 53 percent (290/549) over the 18 years of the study (Coles 2003). Survivorship among sprouts was 50 percent (77/154) over the same period. This number is surprisingly high and possibly reflects the fact that small seedlings go unnoticed and the true mortality rate is higher. Coles (2003) suspects that most seedlings emerge in the early fall after the summer monsoon season and that the seedlings observed each spring have already survived their first winter (Coles 2003).

Over the eighteen years of Coles (2003) study, sixty-four seedlings and eighty sprouts survived to produce fruits and flowers. Each individual that grew from seed took an average of 7.95 ± 2.25 years to reach reproductive maturity whereas the sprouts only took an average of 2.2 ± 1.8 years to do so. The production of flowers and fruit was positively correlated with stem diameter (Coles 2003). Therefore, because sprouts grew more quickly than seedlings, the sprouts made a greater proportional contribution to the total reproductive effort of the population (Coles 2003). However, it is important to note that they made no contribution to the genetic diversity of the population. The seedlings, having been the result of sexual reproduction, are likely to have made a greater contribution to the overall fitness of the population. A simple diagram, principally using data from Coles' eighteen-year study (Coles 2003), is constructed in Figure 20 to outline the life cycle of *Sclerocactus mesae-verdae.*

Average mortality rates in the Colorado plots varied from 5 to 10 percent in most years, with rare die-offs of up to 25 percent averaged over the study population (Coles 2003). A small but consistent cause of mortality was the desiccation of stems less than 1.0 cm in diameter. Other minor causes included mechanical damage, from trampling by cattle to burial by ground squirrels. Similar losses have been observed in the New Mexico populations (Cully et al. 1993). Most of the mortality observed in Colorado *Sclerocactus mesae-verdae* populations was caused by the periodic arthropod infestations (Coles 2003). The considerable impact of periodic arthropod infestations also seems similar to the observations made in New Mexico (Bureau of Land Management 2003, Roth personal communication 2004). However, unlike the 25 percent mortality in the Colorado plots many of the populations in New Mexico experienced a more dramatic toll of an 80 percent or more mortality rate (Bureau of Land Management 2003). Figure 21 shows the remains of dead *S. mesae-verdae* individuals.

In summary, Coles (2003) data indicate that the cactus populations experience both significant mortality and recruitment events at infrequent (typically greater than 10 year) intervals. These events stand out against a background of low recruitment and mortality levels in most years. Because periods in which high levels of germination occur are rare, a short-term study would have either missed them or, if encountered, arrived at the erroneous conclusion that a high level of germination and recruitment is typical for the taxon.

Community Ecology

Shrub and grass canopies are likely to provide a suitable microclimate for seed germination and seedling establishment (Figures 14, 15, 16 and 17). In addition, they may be refugia from disturbance, such as off road vehicle wheels and livestock trampling.

There may be a critical relationship between the soil microbial community and *Sclerocactus mesae-verdae*. Steven Brack (personal communication 2004) considers that research is warranted to determine if *S. mesae-verdae* requires an association with specific soil microbes for nutrient absorption. Mycorrhizal associations have been reported for other cactus species, including *Opuntia* sp. (Estrada-Luna and Davies 2001) and the related *Pediocactus bradyi* (Arizona Game and Fish Department 2001).

Sclerocactus mesae-verdae individuals may fall prey to pocket gophers (*Thomoys battae*) that have been observed within its habitat (Cully et al. 1993, Coles 2003). This interaction is unlikely to pose a significant threat unless environmental perturbation or reduction in pocket gopher predators causes the populations of the interacting species to become unbalanced.

Predation by the longhorn beetle, also called the cactus borer beetle, *Moneilema semipunctatum* (Cerambycidae) causes significant fluctuations in the size of *Sclerocactus mesae-verdae* populations. This cerambycid beetle is typically a specialist on cacti of the *Opuntia* genus but may expand its range to other species, such as *S. glaucus* as well as *S.*

mesae-verdae, at times when the beetle population overwhelms the available *Opuntia* cacti (Kass 2001). The beetle's larvae are the principal agents of cactus mortality. Adult beetles lay eggs at the base of large cactus stems; when the larvae hatch they enter the stem and eat it out from the inside, usually killing it. Significant *S. mesae-verdae* mortality caused by the beetle has been recorded three times, 1987-88, 1993-1994, and 1999-2000, during a long-term monitoring study in Colorado (Coles 2003). The infestations were localized; one Colorado plot experienced two outbreaks, while one remained un-infested (Coles 2003). During the outbreaks, most stems greater than 2 cm in diameter were killed but victims ranged in size from 0.6 to 10.4 cm (Coles 2003). Response to the infestations differed between the plots but typically some plants, approximately 15 percent, sprouted and thus recovered from the beetle larvae attack (Coles 2003). Such beetle outbreaks likely result in a significant and long-lasting reduction in reproductive output because flower and fruit production is positively correlated with stem diameter (Coles 2003). However, the drop in reproductive output caused by a loss of larger plants may be mitigated to some extent by the sprouts on the damaged stems (Coles 2003). Sprouts grow relatively rapidly and may start producing seeds within three years (Coles 2003).

Another organism that has been associated with predation of *Sclerocactus mesae-verdae* is the army cutworm (*Euxoa* sp.; Bureau of Land Management 2003). This is a caterpillar that typically kills seedling plants by cutting into them around the soil line (Cranshaw 1998). In 2003, many of the diseased-looking cacti on the Farmington Resource District had small to large openings in the tubercles and the plants were hollowed out (Bureau of Land Management 2003). Apparently there was an infestation of army cutworms (*Euxoa* sp.) that were using the cactus as a source of food. In some cases the cutworms were even attacking the roots (Bureau of Land Management 2003). Whether the cutworms were actually responsible for the cacti's demise or were opportunistic after the significant drought had severely impacted the plants is not entirely clear. Cutworms commonly exploit plants weakened by environmental stress (Cranshaw 1998). The lack of alternative vegetation due to the drought was also likely to have also contributed to the cutworm's infestation on *S. mesae-verdae*.

Damage caused by a third arthropod species, which has not yet been identified, was observed on plants in the monitoring plots in Colorado (Coles 2003). The "new" insect predator is a particular cause for concern, since it appears to target medium-sized stems that would also have a significant effect on reproductive output. Many of the stems that survived the drought were badly damaged by the new insect (Coles 2003). The fate of these stems needs to be monitored in the future to determine the impacts of this insect on the Colorado populations. The combination of this "new" predator and the *Moneilema* beetle appears to put all stems larger than 1 cm at risk and many stems may never reach the size needed to produce flowers and seeds (Coles 2003). This potential threat is also a concern for *Sclerocactus mesae-verdae* populations in New Mexico. During the recent drought, the small diameter size classes (< 3.00cm) of cacti fared best among the *S. mesae-verdae* population near Shiprock, which has been monitored by the Navajo Natural Heritage Program (Roth 2004b). However, if this additional pest that attacks smaller-stemmed individuals, migrates south from Colorado these populations will be particularly vulnerable to decimation.

Climate has also significant impact on both short-term physiology and on more far-reaching demographic parameters. Plants withdraw into the soil during dry periods and small plants may be completely hidden by a thin covering of soil. This is especially common after a rainstorm where the soil washes over, and gets caught in, the top of the retracted cactus top. The numbers of reproductive structures per individual are also likely affected by climate variables (Coles 2003). Low numbers of fruits and flowers per stem in 1990, 1999, and 2002 in monitoring plots in Colorado were attributed to extremely dry conditions in the preceding winter and spring (Coles 2003). In contrast, a similar drop in reproduction in 1996 was attributed to a hard freeze occurring in April 1996 (Coles 2003). However, even though it is clear that annual variations in climate affect cactus survival and reproduction, the specific relationships among climate variables and recruitment remain undefined (Coles 2003).

Propagation and cultivation

The 1984 Recovery Plan (Heil 1984) recommended that a program be developed for the commercial artificial propagation of *Sclerocactus mesae-verdae*. The specific recommendations included: a) developing improved artificial propagation techniques; b) providing stock to outlets for commercial use; and c) developing a program for salvage of individual Mesa Verde cactus that are unavoidably threatened with destruction (Heil 1984).

It has been noted that, "*Sclerocactus mesae-verdae* appears in nature to be one of the most resistant [to environmental stress], while in cultivation it belongs to the most difficult cacti to grow" (Editor, Kaktusy 1972). Apparently *S. mesae-verdae* is very difficult to cultivate, even as grafted specimens (Editor, Kaktusy 1972, US Fish and Wildlife undated, Mathew 1994, Brack personal communication 2004).

As many as 90 percent of the plants collected may rot and die within the first year (Heil 1984). Mesa Gardens is a commercial horticultural concern that has enjoyed notable success in propagating a wide variety of cactus and succulent species. Mesa Gardens has been experimenting with *Sclerocactus mesae-verdae* for many years and has found it to need very exacting cultural conditions (Brack personal communication 2004). Steve Brack at Mesa Gardens sows seeds outdoors in the coldest part of the winter, putting the pots in a wooden frame covered with window screen so that the only moisture is from snow or winter rain. In the spring, approximately from mid March, the pots are watered every day and germination occurs at various times later in the spring and early summer (Brack personal communication 2004). Plants repotted in the spring one year will flower during spring of the following year (Brack personal communication 2004). However, even once established the plants are still easy to lose (Brack personal communication 2004). Water-logged soils either from over-watering or too much natural precipitation results in death. *Sclerocactus mesae-verdae* is especially difficult to cultivate in areas of high humidity because it rots so easily (Brack personal communication 2004). Although Mesa Gardens have grown several individuals from seed to flowering size that have been sold in the past, at the present time all established plants are being retained for seed production (Brack personal communication 2004).

Sclerocactus mesae-verdae plants are rarely for sale, presumably because they are so difficult to cultivate. However, there are several sources of seed from cultivated plants. For example, seed can be purchased on the Internet (see Appendix B) as well as at specialized nurseries, such as Mesa Gardens in New Mexico.

Sclerocactus mesae-verdae plants have been transplanted at least two sites on Navajo nation land; one in the Shiprock Gallup Oilfield and the other along the Cudei Road (N57). Thirty-five individuals were transplanted within the Shiprock-Gallup oil field in the spring of 1989. In August of the same year the site was revisited and apparently only a few individuals had survived transplantation (Navajo Natural Heritage Program element occurrence # 41). No live plants were found at this site in 2004. In 1995, cacti were transplanted near Cudei due to the improvement of road N57 (Navajo Natural Heritage Program element occurrence # 27). The information on the exact numbers of plants transplanted is unavailable for this report. However, in 1997, 27 of the transplants had survived. The area around this monitoring plot was surveyed in 2004 and only two live plants were found.

CONSERVATION

<u>Distribution</u>

The terms "population" and "occurrence" are interchangeable in this report. A population can be defined as "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). A less restrictive definition of population and one that is used in this report since the species genetics is unknown is that it is "a group of individuals of the same species that occurs in a given area" (Guralnik 1982). Occurrences, or populations, include plants in large areas of land where there are contiguous stretches of apparently suitable, or potential, habitat.

It is unknown at the present time to what extent *Sclerocactus mesae-verdae* individuals interact either within or between patches. Although seed dispersal influences the distribution of genes within and among populations, long distance exchange of genetic material frequently depends upon pollinator activity. Spatially disjunct groups of bee-pollinated species can have high levels of pollen dispersal and thus gene flow between them (see Reproductive biology and Autecology section). For example, Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70-631 m) from the nest to forage even when plentiful food was available. Honeybees apparently have even greater range and can regularly forage 2 km away from their hive (Ramsey et al. 1999). However, even though interaction is expected between many occurrences it is not known to what extent some patches are genetically isolated. Long distance exchange of genetic material frequently depends upon pollinator behavior as well as their flight range. One element of bee behavior that may be critical to *S. mesae-verdae* cross-pollination is that bees are density dependent foragers (Geer and Tepedino 1993). Bee visits may therefore be fairly few especially in conditions of low flower production, for example during drought or under high levels of arthropod herbivory. In addition, it is likely that there are other species of flowering plants in greater abundance between occurrences, which are likely to provide higher reward for the bee's effort. Therefore, because *S. mesae-verdae* is partially self-compatible and individuals are isolated, it is unclear how much genetic exchange is between, rather than within, small patches of plants. Therefore, although genetic isolation might tend to encourage considerable genetic variation between populations, there might be little variation within populations. This situation is likely to increase their vulnerability to genetic stochasticity (Frankel et al. 1995). Loss of heterozygosity is strongly correlated with a substantial decrease in population fitness (Reed and Frankham 2003).

Global overview

Sclerocactus mesae-verdae is restricted to an area of approximately 365 square km in the Four Corners area of Montezuma County, Colorado and San Juan County, New Mexico. It has been found on land managed by the Bureau of Land Management, on private land, and on the lands of the Ute Mountain Ute and the Navajo Nation (Figure 1). At least 70 percent of the entire populations of *S. mesae-verdae* lies within the Navajo Nation and another 20 percent within Ute Mountain Ute land (Heil 1984).

In 1984, the total population of *Sclerocactus mesae-verdae* was estimated to be approximately 5,000 to 10,000 plants over its total known range within Colorado and New Mexico (Heil 1984). Within the last two years the cactus population has undergone a precipitous decline. Arthropod infestations and an extended period of drought are thought to be the primary causes (see Community Ecology section; Coles 2003, Bureau of Land Management 2003, Muldavin et al. 2003). Periodic arthropod infestations and droughts are likely natural occurrences from which the cactus has recovered many times in the past. However, recovery is a current concern because much of its habitat has become significantly degraded through widespread land use practices, which include off-road vehicle recreation, activities associated with resource extraction, urban development, and livestock grazing. Subsequent invasions by non-native species have also contributed to habitat loss.

Navajo Nation lands

Sclerocactus mesae-verdae populations are centered in the north-central San Juan County, New Mexico. The majority of plants can be found within a 20-mile radius around the town of Shiprock. An additional, disjunct population is in the Sheep Springs area.

Sclerocactus mesae-verdae does not have an even distribution throughout its range but tends to form major populations within certain favorable habitats (Heil 1984). The number of individuals of *S. mesae-verdae* per unit area also varies substantially. Several hundred individual plants have been observed within approximately 50 square meters to as few as a single specimen with no other *S. mesae-verdae* cacti within several hundred meters of it.

Abundance and Population Trends

From 2002 to 2003, *Sclerocactus mesae-verdae* populations declined by 80 percent in New Mexico (Muldavin et al. 2003). A similar decline in population size was observed on the Navajo Nation in 2003 (Roth personal communication 2004). Between April 2002 and April 2003, the monitoring plots on Colorado experienced an average 20.4 percent decline in population size (Coles 2003). In addition, 96 of the 535 living stems in the Colorado plots were judged to be in poor condition in 2003 and therefore if these plants die, as expected they will, before April 2004, the total mortality over the two-year period will be nearly 36% (Coles 2003).

Navajo Nation lands - 2004 survey

Prior to 2004, there were approximately 45 known element occurrences distributed from the Colorado-New Mexico border to a few miles south of Sheep Springs. In 2004, a systematic survey was undertaken to determine the current status of the plants at each of these known sites on Navajo Nation lands. The known element occurrence (EO) sites on Navajo Nation land were re-surveyed between April 20 and May 9, 2004. This time was chosen because flowering is typically at a peak during this period of time. Surveys were most intensive in the area within 20 miles around the town of Shiprock. Surveys around many of the known EO locations, such as that in the area of Malpais Arroyo, Many Devils Wash, and southwest of the town of Cudei, were extended to include more than the area described in the original EO if the habitat looked suitable. In addition, seven "new" sites where suitable habitat seemed to exist were also surveyed.

At each location two to five biologists surveyed the area by methodically walking over the area searching for cacti. When cacti were found they were marked on a tally sheet. Examples of the tally sheets are in Appendix C. Dead and live cacti were differentiated and both types were recorded. Many of the cacti were multi-stemmed but the cactus was classed by the size of its largest stem. At 17 of the sites, 100 m long transect-lines were laid out using a tape measure and surveyed for cacti using a 1 m x 0.5 m rectangular quadrat frame. The objective was to obtain a quantitative description of the spatial pattern of *Sclerocactus mesae-verdae* distribution. Dead cacti were also recorded along the transect line.

Unlike past reports, at no site were thousands, or even hundreds, of individuals found. At some sites only one or two cacti were observed in 2004 even though hundreds, and in some cases thousands, had been reported in prior years. Declines were most notable where the original element occurrence indicated counts of greater than 10 plants. Details of each site visited, including appropriate maps, have been submitted to the Navajo Natural Heritage Program (Ladyman 2004). The results are summarized in Table 1. One of the problems with historic data is that quantitative information is often missing. Plants were reported but the actual numbers were not described. Therefore, a decline was noted when plants were absent from a site. It was conservatively regarded as a site experiencing “no change” when even one plant was found at a known occurrence in the 2004 survey. Declines were observed at 34 sites (Table 1).

In the area that comprised the original EO #001, east of Many Devils Wash, the 2004 survey teams found 27 individuals; of which 23 were dead and only four were alive. This represents a 99.7 percent drop from the 1,500 or more individuals reported in 1989 (Navajo Natural Heritage Program element occurrences records received in 2004). More area, within two additional map sections near to that of the original EO #001 location description, was also surveyed in order to increase the likelihood of finding more cacti. One hundred and ninety-four more cacti were found; 122 of which were dead but <u>only 72 of which were alive</u>. Therefore, although considerably more than double the area was surveyed only 76 live cacti were found. This indicates a precipitous decline in this population that had previously numbered in the thousands.

A site west-northwest of the N36/US491 (formerly US 666) intersection and south of Shiprock had been surveyed prior to a proposed housing development as recently as in 2000. During that survey approximately 1,125 individuals were found and mapped (Navajo Natural Heritage Program element occurrences records received in 2004). In 2004, four botanists surveyed this site. There were many vehicle tracks and unmapped roads in this area but the habitat appeared to be suitable for *Sclerocactus mesae-verdae*. After an intensive search the botanists realized it was likely that *S. mesae-verdae* cacti had previously been marked by an assortment of rolled plastic tape, pin flags and wood stakes because they found at least 36 such markers that had no cacti beside them. In addition, approximately 50 percent of the 55 cacti that were found in the area had some type of marking (plastic, wire from a pin flag, piece of wood). However 35 of those 55 cacti were dead, one was very damaged and yellow, and only 19 were alive. An additional comment can be made about a small portion of the site. In 1999, at the north end of the site between the power lines and the highway just south of the ruins of the Talk family's (great) grandmother’s house there were at least seven *S. mesae-verdae* cacti as well as at least an additional three cacti just north of the same ruins (Ladyman report to The IHS/Navajo Natural Heritage Program 1999). None of these ten *S. mesae-verdae* cacti could be relocated in 2004. This area had more exotic weeds in 2004 than in 1999 and seemed to be even more disturbed.

A third area that has suffered an obvious reduction in *Sclerocactus mesae-verdae* population size was around the Malpais Arroyo. This area is within the region covered by Navajo Natural Heritage Program EO #33. In 1990, the botanist for the Navajo Natural Heritage Program estimated that several hundred cacti, ranging from 1.5 to 10 cm in diameter, were located alongside the Malpais Arroyo north and south of the Hogback Canal (Navajo Natural Heritage Program element occurrence records received in 2004). The locations that were mentioned in the original element occurrence report were visited in 2004. One solitary cactus that was marked by the wire of a pin-flag was found near transmission lines. No doubt this was one of the cacti recorded in a previous survey at EO #33. However, few others were found in the areas described in the original observation records. Live *S. mesae-verdae* plants were most numerous on the upper slopes and the edge of the ridges within the arroyo complex. A total of one hundred and sixteen live individuals were counted within about an area of greater than 300 acres.

There were also many sites where no plants or only the remains of dead plants (see Figure 21) were found were found in 2004. Briefly these included: EO #039*NN which is approximately three miles due west of Yellow Hill; EO #040*NN which is near Dead Mans Wash; EO #041*NN which is within the Shiprock/Gallup old oil field; EO #028*NN which is now a housing subdivision; EO #016*NN which has now been converted to housing and agricultural land south of the Hogback Canal road; EO #018*NN which is approximately 3 miles north of intersection of roads 491 and 64 just north of Salt Creek Wash; An unnumbered element occurrence at the south end of Cudei; EO #042*NN which is an area west of Shiprock on Route 64 (Hwy 504); within EO #20*NN south of Skinney Rock and at the cross roads south east of Blue Mountain; EO #010*NN which is approximately 0.5 miles south of the CO-NM state line; EO 026*NN which is across from Littlewater; and part of EO # 033*NN that is within ~0.25 miles east and west of Highway 491 (formerly US 666).

In addition, no plants were found at the known occurrence sites in the Sheep Springs area that are disjunct from the populations centered round Shiprock. A brief survey was made at the known locations, including an old monitoring site, in the Sheep Springs region on May 7, 2004. The areas visited are described on hardcopies of the 7.5' topographic maps (Sheep Springs and Nashiti quadrangles) that have been submitted to the Navajo Natural Heritage Program (Ladyman 2004). All three locations within EO # 005 appeared to have suitable habitat but no cacti were observed. Sheep and cattle disturbance was very heavy at two of the locations. The third site was adjacent to a house and, because it was fenced off with electric fencing, it was only observed from the fence line. However, the habitat appeared degraded and snakeweed (*Gutierrezia sarothrae*) was abundant. Similarly, EO #004, EO #006, and EO #014 also appeared to have suitable habitat but no plants were found. However, at these sites there was extensive livestock disturbance to the point that there were patches of up to 20 square meters that were churned up by multiple hoof prints. Habitat at the UTM coordinates associated with EO #048 did not appear to be appropriate for *S. mesae-verdae*, the soil being loose sand along a shallow wash. No plants were found there. However, the status of the population in Sheep Springs is not clear. Although plants were not found at the sites described in the original element occurrence records, plants were observed in a right-of-way survey in 2004 (Knight personal communication 2004). This particular area needs further surveys and precise counts of the numbers of plants in the area.

All sites that had suitable habitat but where no plants were found in 2004 should be re-surveyed in the future. Plants can be expected to re-colonize some areas from seed stored in the seed bank in the soil. Also, small stems, less than 1 cm diameter may have been missed or were obscured by gravels and vegetation canopy. The photograph in Figure 22 illustrates the cryptic nature of even well developed small stems.

Sclerocactus mesae-verdae plants are reportedly on the Uranium Mill Tailings Remedial Action (UMTRA) site near Shiprock (U.S. Department of Energy 2002). The former uranium mine is located on a 230-acre (93-hectare) tract south of the San Juan River and near to the town of Shiprock. Two piles of tailings covered approximately 29 hectares (72 acres) before the site underwent remediation. Biological surveys prior to 2002 confirmed the presence of "several populations containing from one to more than 100 per group present" (U.S. Department of Energy 2002). This area was not surveyed in 2004 and the current condition of these populations is unknown.

Transect data

The patchy distribution of *Sclerocactus mesae-verdae* is likely to make estimates of population size very difficult. Estimates of population size over large areas are often made after making direct counts of individuals in small areas and then multiplying the mean per given area by the total area of apparently suitable habitat. However, *S. mesae-verdae* grows in patches or as solitary individuals and trying to extrapolate population size by only considering the species density in a small plot may be misleading (Elzinger et al 1998, Goldsmith 1991). A limited study was undertaken in 2004 in order to see if survey results from small plots could be used to estimate the total population size.

At eighteen element occurrence sites, transect lines were established and contiguous quadrats frames (1m x 0.5m) were surveyed after the first live plant was found. The first live plant was designated to be within the first rectangular quadrat frame (Figure 23). A 100 m transect line was then run across habitat that appeared suitable for *Sclerocactus mesae-verdae* (for example in Figure 24). Because the transect line was laid out to run over *S. mesae-verdae* habitat as much as possible, the direction of the line was not randomly chosen. Contiguous habitat would usually extend 100 m in only one direction from the initial cactus and this direction was always chosen.

The sample mean and its standard deviation over a number of small plots (quadrat frames) can be used to estimate the sample size needed to obtain an estimate of the true population size, within some level of precision (Elzinger et al. 1998; see also Appendix A). A higher level of precision for an estimate of population size requires a larger number of samples. The equation [A] to determine this sample size is:

$$N = \frac{[Z\alpha]^2\,[s]^2}{[B]^2} \qquad [A]$$

where:

- N = uncorrected sample size estimate
- $Z\alpha$ = the tabulated standard normal coefficient for a given confidence level (for example, for a confidence level of 80% $Z\alpha = 1.28$ and for a confidence level of 90% $Z\alpha = 1.64$; Elzinger et al. 1998).
- s = the standard deviation.
- B = the desired level of precision expressed as half of the maximum acceptable confidence interval width.

The transect data are reported in Table 2. The number of individuals per quadrat is indicated in each cell. These data can be examined in several different ways but one of the simplest is to consider that each quadrat is independent of the others and is in representative habitat on a population wide basis. No level of replication is invoked. Therefore there were a total of 1,800 readings that equaled a mean of 0.026, rounded up to 0.03, individuals per frame (0.5m x 1m) with a standard deviation of 0.6.

Using equation [A], a sample size of 79,570 1m x 0.5 m quadrats are needed to obtain an estimate of population size with a 90 percent confidence level and a level of precision of 5 percent (see Appendix A). This means that every inch and thus every plant on approximately 40,000 square m (approximately 10 acres) of suitable habitat would need to be counted in order to get an estimate of the population size at these levels of confidence and precision. If the confidence level were dropped to 80 percent with a 20 percent precision level the sample size (number of 1m x 0.5 m quads) would be reduced to just over 3,000 quadrat frames (see Appendix A). Although this is a very low level of precision and confidence it appears to be a more manageable undertaking.

However, there are at least four very important points that must be appreciated when considering these estimates of sample size. The first and most important is that this estimate assumes that the data are normally distributed. This is also the assumption when estimates of population size are made after observing 10 cacti within 1 acre and a casual estimation is made that there must be at least 100 in 10 acres of similar habitat. Current evidence suggests that the distribution of *Sclerocactus mesae-verdae* is unlikely to be a statistically normal one. That is, the data are unlikely to fit a bell shaped curve (Steele and Torrie 1960). This absence of a normal distribution considerably complicates the issue but is unlikely to reduce the acreage that must be surveyed to arrive at a reliable estimate of population size (Ludwig and Reynolds 1988, Steele and Torrie 1960).

Secondly, it should be noted that “N” is the uncorrected sample size estimate and, even if the data are normally distributed, can only be applied if the population is very large compared to the proportion of the population being sampled (Elzinger et al. 1998). If the sampled population is 5 percent or more of the total population then the sample size needs correction, which always results in a larger sample size being needed for the same levels of confidence and precision (Elzinger et al. 1998). This point is likely to apply if each transect is used to uniquely represent the area in which it was surveyed. For example at EOs #70, #23, #24, #36, #22 and #56 the average number of individuals were 0.01 per frame and the standard deviation 0.1 (Table 2). Therefore, 107,584 rectangular (0.5x1m) quads would be the minimum sample size to achieve an estimate of the population size with a 90 percent confidence level and a level of precision of 5 percent. In contrast at EO #35 the average number of individuals were 0.16 per frame and the standard deviation 0.598 (Table 2). In this case 15,044 rectangular (0.5x1m) quads would be the minimum sample size to achieve an estimate of the population size with a 90 percent confidence level and a level of precision of 5 percent.

A third point to consider is the impact of non-random choice of sampling direction. Plant density may be expected to be higher through contiguous habitat than in fragmented habitat. The fourth point, that is directly associated with the last, or third point, is that the microhabitat conditions and precise edaphic requirements are unknown. Therefore, there is the possibility that plants will not grow in areas that appear to be potential habitat along a transect line. Thus the zero readings that contribute to the standard deviation are actually in error because they do not represent habitat that could be occupied.

Monitoring Activities

The Recovery Plan recommended the establishment of monitoring plots and the surveying and mapping of populations in both New Mexico and Colorado (Heil 1984, U.S. Fish and Wildlife Service 1996). Such activities have been executed within the last 20 years. However, although unpublished reports such as in the form of intra-agency updates and memos seem to have been consistently prepared, formal publications of the results have been sporadic. This makes definitive conclusions difficult to reach on a rangewide basis but the decline suffered in the last four years is undeniable.

Monitoring studies by the Navajo Natural Heritage Program

In the spring of 1995, the Navajo Natural Heritage Program transplanted 29 *Sclerocactus mesae-verdae* from the BIA Route N57 right-of-way into 4 monitoring plots just outside the right-of-way and in close proximity to their original location (Roth 2004a). In addition to the transplanted cacti there were a total of 22 naturally occurring cacti, which would function as controls within the plots (Roth 2004a). All naturally occurring and transplanted cacti were mapped and tagged. Annual measurements that included height (cm), diameter (cm), and the number of reproductive structures (flowers, buds, aborted flower/buds, immature/mature fruits), as well as the vigor of each plant were made between 1995 and 2004 (Roth 2004a).

Between 1995 and 2002, 69 percent of the transplanted plants survived and 55 percent of the naturally occurring plants remained. Therefore the transplantation effort appeared to be effective. However, a precipitous decline was observed at these monitoring plots between 2002 and 2004. The number of surviving transplanted plants dropped from 20, in 2002, to 4 individuals, in 2004, and the number of naturally occurring plants dropped from 12 to 2 individuals in the same period (Roth 2004a). This is a loss of 80 percent of the population in 2 years. The population structure also changed. The average stem diameter for all stems in the monitoring plots declined from approximately 4 cm throughout 1995 to 2003 to less than 1.5 cm in 2004 (Roth 2004a). Drought and arthropod infestation appeared largely responsible for the observed decline (Roth 2004a).

In 2001, the Navajo Natural Heritage Program (Department of Fish & Wildlife) initiated another transplantation and monitoring study. On April 9 2001, five *Sclerocactus mesae-verdae* monitoring plots were established within the designated non-development zone of the future Northern Navajo Fairgrounds site located south of Shiprock, New Mexico, east of US HWY 666, and north of Navajo Route 36 (Roth 2004b). On April 10 2001, Navajo Natural Heritage Program staff transplanted 54 *S. mesae-verdae,* which had been excavated from the south-central portion of the proposed Northern Navajo Fairgrounds site, into the monitoring plots (Roth 2004b). Cacti that naturally occurred within the plots served as a control population to determine the success of the transplanting effort (Roth 2004b).

Monitoring the plots in the future Northern Navajo Fairgrounds has taken place annually between 2001 and 2004. Very little recruitment, and a substantial decline in the total number of both transplanted and naturally occurring individuals, has been observed during this time (Roth 2004b). Sixty-five percent of the 54 transplanted cacti have died since 2001, the greatest decline being observed between 2002 and 2003 (Roth 2004b). Seventy-six percent of the naturally occurring cacti died between 2002 and 2004 (Roth 2004b). Reproduction rates were extremely low for naturally occurring as well as transplanted cacti. In 2003, only 2 of the naturally occurring plants and none of the transplanted cacti were reproductive (Roth 2004b). In 2004 the situation was reversed, 2 of the 19 transplanted cacti had reproductive structures, while none of the 12 naturally occurring cacti were reproductive (Roth 2004b).

Disproportionate loss of large diameter cacti in the naturally occurring population of *Sclerocactus mesae-verdae* in the monitoring plots resulted in an overall smaller average diameter stem class than among the transplanted cacti during 2004 (Roth 2004b). Originally, transplanted cacti had a larger proportion of juvenile, small diameter plants (<1.99cm) and a lower proportion of large diameter, mature plants (> 5.00cm) than the naturally occurring cacti (Roth 2004b). This trend continued into 2002, although there was a shift in diameter size classes from larger diameters towards smaller size classes. In 2003, 90 percent of the large diameter naturally occurring cacti (> 4.00cm) were gone and none of the large diameter transplanted cacti had survived (Roth 2004b). The very low levels of reproduction observed during 2003 and 2004 were likely a reflection of the increased numbers of individuals with small diameter stems in the population (see Reproduction and Autecology section).

Three *Sclerocactus mesae-verdae* monitoring plots were established in June 1993 at the Navajo Engineering and Construction Authority (NECA) gravel extraction site near Shiprock, New Mexico (Roth 1998). The plots were monitored annually until 1998. The population size fluctuated somewhat during this time (Roth 1998). The period of the highest mortality rate was between 1993 and 1994, when the cacti population decreased from 67 to 54 plants (Roth 1998). Trampling of cacti by livestock in the plots was a primary cause of the mortality (Roth 1998). After 1994, the plant population increased steadily with a substantial recruitment of new plants recorded in 1997 and 1998, which may be attributed to increased rainfall during those years (Roth 1998). Reproductive effort fluctuated between all plots, but was consistently higher in plots 1 and 2 than in plot 3 (Roth 1998). This lower reproductive capacity was correlated to the smaller average stem diameter of plants in plot 3 over the other two plots (Roth 1998). The total number of plants in the three plots increased from the 67 in 1993 to 99 plants in 1998 (Roth 1998). The precise status of the plants in these three monitoring plots is not known because the boundaries of the plots were obscured when the area was surveyed in 2004. However, the whole general area (EO # 35), including the monitoring plots, was surveyed and only 30 live individuals were found in 2004 (Table 1).

Monitoring activities other than by the Navajo Natural Heritage Program

In April 1986 a study plot was established near Waterflow in San Juan County, New Mexico and, as part of the same Program, an additional plot was established at Sheep Springs on Navajo Nation lands in 1988 (Cully et al. 1993). The study plots were each a 100 m x 200 m rectangle. The Waterflow site was monitored annually until 1991 (Cully et al. 1993) and the Sheep Springs site until 1995 (Navajo Natural Heritage Program element occurrence records received in 2004).

The population at the Waterflow site grew from 65 individuals in 1986 to 142 individuals in 1991, which was the last published report of population size. The number of juveniles that appeared annually was low except for in 1991 when a total of 24 small (young) plants were found. These juveniles are likely to have germinated at the same time but a year or probably more previously. Seedlings that are recently germinated are easily overlooked due to their small size and inconspicuous color. Over the 5-year monitoring period nine plants died and 21 plants were "missing" from the Waterflow site. Some of the "missing plants" are likely to have been illegally collected because torn-up tags were recovered at the site, while others may have been lost to pocket gophers (Cully et al. 1993).

Approximately 50 plants were counted at the Sheep Springs site in 1988 (Cully et al. 1993). However this was an under count as large plants were found in the plot in later years that must have been overlooked initially. Results published in 1992 indicated that the population of the site rose to 122 with 8 dead and eight missing (Cully et al. 1993). Young individuals (that is less than or equal to 1 cm in diameter) totaled 15 between 1988 and 1991; 4 in 1989, 10 in 1990 and 1 in 1991 (Cully et al. 1992). A brief visit to the approximate vicinity of the site in 2004 failed to find any plants and the site should be re-surveyed by a Navajo Natural Heritage Program botanist in 2005.

For approximately the last 16 years, the New Mexico Bureau of Land Management has monitored *Sclerocactus mesae-verdae* populations on the Farmington Resource area, particularly in the Hogback Area of Critical Environmental Concern (ACEC), in New Mexico. Four sites in the Hogback ACEC have been selected for yearly monitoring. Monitoring typically occurs each April. The population densities within this area have fluctuated over the years but appeared to show a generally stable population between 1987 and 2002 (Bureau of Land management 2003). However, in March 2003 the "vast majority of the cactus population was dead or dying" (Bureau of Land Management 2003). Mortality of the cacti was estimated at over 80 percent. Many of the diseased cacti had small to large openings in the tubercules and the plants were hollowed out. Apparently there was an infestation of army cutworms (*Euxoa* sp.) that were using the cactus as a source of food (Bureau of Land Management 2003). In some cases the cutworms were attacking the roots (Bureau of Land Management 2003). This is a concern because if the roots are destroyed there is no chance that the plants can re-sprout. Cutworms commonly attack plants that have been weakened by other stresses (Cranshaw 1998).

Three 100 m x 200 m permanent plots in Colorado have been monitored every year from 1986 through 2003, with the exception of 1993 (Coles 2003). The plots, each about three miles apart, were established in Montezuma County, Colorado in 1986 at the same time as the Waterflow plot in New Mexico. The sampling sites were non-randomly located in the densest colonies that could be found (Coles 2003). Except for in 1993 when the study area could not be accessed, every stem in each plot has been relocated and measured each spring as close as possible to May 1, which is the average date of peak anthesis in southwestern Colorado. Stem diameter, relative vigor (on a subjective scale of 1, excellent, to 5, dead), and numbers of flowers and fruits on each stem have been recorded (Coles 2003). The cause of death is also noted. New stems are recorded as they are found and a determination made as to whether they are new seedlings, or sprouts, or older plants discovered for the first time (Coles 2003).

Through the 18 years of this Colorado study, 1,394 cactus stems were tracked (Coles 2003). Between 1986 and 2002, the population of cacti within the three Colorado plots grew substantially, from 160 stems in 1986 to a maximum of 360 in 2000 (Coles 2003). Depending upon the plot, the populations have been stable (one plot) or declining (two plots) since 2000. In the eighteen years of this study, annual recruitment rates in all plots were generally low. However there were three times when a plot experienced a single-year population increase of more than 25 percent higher than the long-term average (Coles 2003). This increase was due to recruitment of new seedlings and/or sprouts into the population. These times of high recruitment tend to be concentrated within a single plot in any given year, and several years passed without substantial recruitment in any of the monitoring plots. This episodic pattern is likely related to local climate conditions (Coles 2003). Years in which sprout recruitment was high tended to be years with average precipitation but following an infestation of the longhorn beetle (*Moneilema semipunctatum*) outbreaks (Coles 2003; see Community Ecology section). Average mortality rates ranged from 5 to 10 percent, with rare die-offs of up to 25 percent (Coles 2003). The episodic nature of both recruitment and mortality emphasizes the importance of truly long-term and annual studies. Short-term studies would likely have either under- or over-estimated both the potential recruitment and mortality rates of the taxon.

Threats

Habitat modification and destruction is the major threat to *Sclerocactus mesae-verdae*. Specific threats include urbanization and agricultural conversion of habitat, livestock grazing, off-road vehicle traffic, road building, and activities related to resource extraction (Heil 1984, U.S. Fish and Wildlife Service undated). The threats associated with environmental stochasticities, such as drought and arthropod infestations, weaken a plant and increases mortality. Unfortunately, many anthropogenic factors exacerbate a plant's damaged condition and thus compromise weakened plants.

Off road vehicle traffic, especially hard-driven recreational vehicles such as dirt bikes and ATVs, and livestock grazing degrade habitat and modify fragile soil structure and chemistry (see Figures 25 and 26). Such disturbance will also affect the soil microbial composition, which may be important to *Sclerocactus mesae-verdae* (see Community Ecology section). As well as causing disturbance, off-road vehicles and livestock grazing compacts soil, which prevents water from being absorbed and seeds from taking root. Increased soil erosion by water (precipitation) and wind is another consequence of disturbance.

Livestock grazing also has subtle effects on the ecology of an area, modifying the assemblage of plant species in favor of unpalatable and often invasive species (Strasia 1970). Domestic sheep can also have indirect effects on insect-pollinated plant species. Sugden (1985) reported that sheep grazing in the habitat of *Astragalus monoensis* endangered sustainable populations of pollinator bee species by destroying potential and existing nest sites and removing food resources.

Development of energy resources in the Four Corners area continues unabated (Energy, Minerals and Natural Resources Department. 2003). The Fruitland Coal formation of the San Juan Basin is the largest coal bed methane (CBM) producer in the United States (Energy, Minerals and Natural Resources Department. 2003). Although CBM production from the New Mexico portion of the San Juan Basin apparently peaked in 1999, the production is still significant as the play matures (Energy, Minerals and Natural Resources Department. 2003). Higher energy prices will encourage further exploration and development of marginal reserves as the play runs out. Humates are an additional extractable resource of the Fruitland and Menefee formations and their extraction may be a threat to *Sclerocactus mesae-verdae* habitat in the future. Humate is used as a soil conditioner and as an additive to drilling muds (Energy, Minerals and Natural Resources Department 2003). Approximately 12.1 billion short tons of humate resources are within the San Juan Basin (McLemore and Hoffman 2003).

Activities related to resource extraction by the energy industry leads to degraded habitat. The well sites and discrete mine sites *per se* may appear to impact a relatively small area. However, the myriad of unofficial roads, random turn-outs and turn-around points, multiple pipelines, and small but enduring piles of waste, leads to large scale habitat degradation.

In addition to direct disturbance and modification of soil properties, traffic associated with the extraction industries, recreational off-road vehicles, and livestock all contribute to the spread of invasive weedy species that can become established in disturbed conditions given adequate precipitation. *Sclerocactus mesae-verdae* is unlikely to be competitive against weed species. Tall weed species will shade the stems and are likely to use water more aggressively, thereby depleting available soil water at a faster rate. At the present time, relatively few vascular plants grow within its habitat but within the last decade weeds such as cheatgrass (*Bromus tectorum*) have become much more abundant (author's personal observation).

Environmental conditions have significant impacts to the life history of *Sclerocactus mesae-verdae* (see also Community Ecology section). Drought was believed to be primarily responsible for the extremely high mortality rate observed in the last couple of years. It is also noteworthy that its' most common shrub associate, *Atriplex corrugata*, was also badly impacted by the drought and that the two diverse taxa appeared to be equally susceptible to the dearth of water.

Global climate change is a threat to many species but the impacts to *S. mesae-verdae* are difficult to predict. Although there has been a significant drought recently, precipitation in New Mexico could increase over the next century (Environmental Protection Agency 1998). Additional changes to the climate may also occur. For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by 2100 temperatures in New Mexico could increase by 3°F in spring (with a range of 1 to 5°F), 4°F in fall (with a range of 2 to 7°F), and 5°F in winter and summer (with a range of 2 to 9°F). Although precipitation is estimated to decrease slightly (with a range of 0 to 10 percent) in summer, it is predicted to increase slightly in fall (with a range of 0 to 10 percent), to increase by approximately 15 percent in spring, and increase by approximately 30 percent in winter (Environmental Protection Agency 1998). This may mean that some invasive weedy species could grow in areas presently too dry for colonization. The warming temperatures may lead to an increase in the frequency and the intensity of pest outbreaks (Environmental Protection Agency 1998). The effect of warmer temperatures *per se* may not be detrimental to *S. mesae-verdae,* as long as the high temperatures are restricted to daytime periods. However, *S. mesae-verdae* cacti need cool nights and individuals are stressed by continuous hot humid weather in the summer (Brack personal communication 2004). A long heat wave with hot nights results in a high mortality rate (Brack personal communication 2004). The impacts from climate change may also be exacerbated by anthropogenic activities. The threats and resources of *S. mesae-verdae* are outlined in the diagram in Figure 27.

Predation by the cactus borer beetle *Moneilema semipunctatum* causes significant population fluctuations (Coles 2003). Populations have been observed to recover from such outbreaks and, under historic conditions, *M. semipunctatum* infestations do not appear to be a significant threat. In fact, arthropod predation is not necessarily bad at levels under which the species has evolved and may even be important to long term species sustainability. Arthropod predation has had an important influence on population dynamics and diversity within some genera (Green and Palmbald 1975, Mancuso and Moseley 1993). However, interactions between pests and climate conditions, along with a shrinking amount of available habitat are causes for concern. The observation that cutworms (*Euoxa* sp.) were eliminating populations of *Sclerocactus mesae-verdae* particularly warrants more research. Cutworms are not typical pests of *Sclerocactus* species and may have been opportunistic in their attack. The cause for concern in the case of the cutworm attack comes from the nature of cutworm activity. Fifteen percent of *Moneilema semipunctatum*-attacked cacti re-sprout to become reproductively active individuals. This did not appear to be the case for the recent cutworm infestation, where even the roots were attacked (Bureau of Land Management 2003). A third type of arthropod infestation was observed in the Colorado monitoring plots in 2003 (Coles 2003; see Community Ecology section). The identity of the organism was not determined but it appears to be complimentary in its action to the cactus borer beetle. The synergy between these two pest species is another cause for concern (see Community Ecology section).

Repeated collection by commercial and private collectors has been cited as a major threat to sustainable populations of *Sclerocactus mesae-verdae* (NatureServe 2004, US Fish and Wildlife Service 1979). In the past, evidence of significant collection existed (Cully et al. 1994, Knight personal communication 2004). However, the amount of illegal collection at the current time is difficult to gauge. *Sclerocactus mesae-verdae* plants are seldom offered in retail markets, probably because they are difficult to cultivate (see Propagation and Cultivation section).

Potential Conservation sites

Conservation sites were classified using four primary characteristics: (1) size of the current population, (2) condition of the population, such as multiple age classes and evidence of flowering and fruiting, (3) current condition of the site and surrounding area, such as the extent of exotic weed cover and land use or the area, and (4) prospect for maintaining or improving the condition of the site. These factors are part of the standard guidelines used by NatureServe for ranking conservation sites.

Several of the areas surveyed on Navajo lands in 2004 can be considered as conservation areas. Four general areas are suggested in this report. However, further surveys and consideration of goals presently unknown to the author of this report may indicate that other areas are more suitable. The four areas identified as potential conservation areas are: Monument Rocks and Palmer Mesa region, Many Devils Wash region, Malpais Arroyo region, and the region northwest of Sanostee. The numbers of live, dead and reproductive individuals found at each site are tabulated in Table 3 and graphically described in Figure 28. Each site is discussed in the following paragraphs.

Monument Rocks and Palmer Mesa region (includes EO # 045NN)
Evaluation: Good to Excellent Viability
Size (based on 2004 actual counts): More than 100 individuals
Condition: This occurrence has an excellent likelihood of long-term viability as evidenced by the presence of multiple age classes and evidence of flowering and fruiting, which indicates that the reproductive mechanisms are intact (Figure 29). Several large relatively healthy individuals were found (Figures 30 and 31). It is unknown why these individuals are flourishing. One could speculate superior genetic composition and/or ideal microhabitat conditions. Isolation may have also protected them from arthropod infestation. This occurrence appears to be a high-quality site with less than 1 percent cover of exotic plant species in much of the *Sclerocactus mesae-verdae* habitat. There is significant anthropogenic disturbance in the valley bottoms but some areas at the base of the mesas are in a relatively undisturbed condition. Plants were found in two main areas

separated by approximately 1.5 miles. Cacti were not found in the intervening area, which has areas of unsuitable habitat as well as localized areas of intense soil disturbance due to gas development. However, surveys in future years may find isolated individuals or patches of individuals. Conservation of the relatively undisturbed shale slopes near the cliff bottoms should be emphasized.

Landscape Context: This occurrence has stretches of habitat that are unfragmented and includes the ecological features needed to sustain this species. These include the presence of the appropriate, very specific edaphic requirements of this species, such as barren Mancos shale or Fruitland clay badlands and low vegetative cover.

East of Many Devils Wash (EO #001NN)

Evaluation: Good Viability

Size (based on 2004 actual counts): 76 individuals.

Condition: This occurrence should have a good likelihood of long-term viability. The area has supported large populations of *Sclerocactus mesae-verdae* in recent times and there should be a substantial seed bank. Even though the population size has significantly declined, the presence of multiple age classes and evidence of flowering and fruiting, which indicates that the reproductive mechanisms are intact, are encouraging signs that this population can recover, albeit slowly (Figure 32). Anthropogenic disturbance within the occurrence is relatively low. Exotic species are present, but appear to comprise less than 5 percent of the total ground cover in *S. mesae-verdae* habitat. Another advantage of the area is that in addition to the plants that were found in at least 4 main areas within the occurrence, solitary individuals were found between the larger population centers. This implies there are likely to be additional individuals within the area.

Landscape Context: The surrounding landscape has large stretches of unfragmented habitat that contains the ecological features needed to sustain the occurrence, such as barren Mancos shale or Fruitland clay badlands and low vegetative cover.

Malpais Arroyo region (EO #033NN)

Evaluation: Good to Fair

Size (based on 2004 actual counts): 115 live individuals

Condition: Plants were found in three main areas within this occurrence that covered approximately 1 square mile. Isolated cacti were found in areas between or surrounding the main areas. The population had multiple age classes and several plants were in flower and/or fruit, indicating that there is reproduction and potential sustainability (Figure 33). The occupied habitat is somewhat degraded (Figure 34). However, exotic plant species were observed primarily in the arroyo bottoms and made up less than 1 percent of the ground cover in *Sclerocactus mesae-verdae* habitat. There is a moderate level of anthropogenic disturbance, such as vehicle tracks. The Evaluation viability rating was reduced from Good to Fair because of the potential for further anthropogenic degradation of habitat. On biological and ecological criteria the viability of the occurrence may be increased from Good to Excellent. There were many large-sized plants that were reproducing

Landscape Context: There is evidence of disturbance from human activities, but the ecological processes needed to sustain the species are still intact.

Region northwest of Sanostee (near EO #038NN).

Evaluation: Excellent to Good

Size: Greater than 100 individuals.

Condition: Individuals were only found in a relatively small area but the area warrants further surveys. Even though the plants that were found were in a localized area, this region was included as a potential Conservation Site because this occurrence appears to have an excellent likelihood of long-term viability. One hundred and seventy five individuals were found, some of which had already started to flower and fruit, which indicated reproduction is occurring and that there is the potential for further population replacement and growth (Figure 35). Anthropogenic disturbance within the occurrence is minimal. However the Evaluation viability rating was reduced from Excellent to Good because there seems to be the potential for habitat degradation from encroaching urbanization in the future. Exotic species comprised less than 1 percent total ground cover in suitable *Sclerocactus mesae-verdae* habitat.

Landscape Context: The surrounding landscape contains the ecological processes needed to sustain the occurrence but habitat areas are fragmented and many are impacted by human activities.

Considerations and information needs

As a consequence of the observed population decline, a primary conservation objective for *Sclerocactus mesae-verdae* must be to maintain all current populations. Most of the living plants are small and are not yet reproductively mature (Figure 36). Therefore, because *S. mesae-verdae* is a slow-growing species, recovery will be a slow process. Progress in achieving and maintaining stable population numbers can be measured by monitoring selected sites. In selected occupied areas, the fate of each cactus should be observed each spring. Surveys over potential habitat at bi- or tri-yearly intervals would determine the trends in cactus population recovery. Direct counts of its abundance are likely the most reliable way to measure population size. The patchy spatial distribution of the plants indicates that estimates of population size made from extrapolating densities in small areas to larger areas are subject to significant error (see Transect section). As suggested by Heil (1984), additional surveys of potential habitat in Arizona, Utah, and in areas between the Shiprock region and the disjunct population at Sheep Springs in New Mexico may still yield unknown populations.

Sclerocactus mesae-verdae habitat surrounding urban areas, such as Shiprock, Cudei and Sanostee is under considerable pressure due to urban expansion, associated recreational land use, and, to a lesser extent, agricultural development. Areas cleared for housing and agriculture are not the only impacts associated with human population growth. Increased recreation, such as using ATVs and dirt bikes, contribute to the larger sphere of urbanization influence.

Development of energy resources in the Four Corners area will continue for the foreseeable future (Energy, Minerals and Natural Resources Department. 2003). Higher energy prices are likely to encourage further exploration and development of marginal reserves as the play runs out. Therefore, all potential *Sclerocactus mesae-verdae* habitat, especially in the Fruitland and Menefee formations should be surveyed to determine the actual and potential impacts from resource extraction. Humates are an additional extractable resource of the Fruitland and Menefee formations and their extraction may be a threat to *S. mesae-verdae* habitat in the future (see Threats section). Approximately 12.1 billion short tons of humate resources are within the San Juan Basin (McLemore and Hoffman 2003). The impacts from activities of the extractive industries must be minimized if suitable habitat for *S. mesae-verdae* is to remain after the energy resources of the region have become depleted.

Progress on the Star Lake and Navajo Railroads should continue to be monitored (Heil 1984, US Fish and Wildlife Service 1996). At the current time it appears to be unlikely that a railroad will go through *Sclerocactus mesae-verdae* habitat (Mathers et al. 1998).

The present-day impacts from collecting need to be clarified. Because of the severe decline in numbers, the extant native populations could not withstand collection. The fragility of individuals in cultivation indicates that collected plants are not long-lived and therefore may be re-collected by determined cactophiles. However, while in the past over-collection has posed a threat, the present-day pressures are not known.

Potential habitat has not been critically defined. *Sclerocactus mesae-verdae* microhabitat requirements, particularly its edaphic requirements, need to be examined in detail. Further investigation is needed to provide an understanding of the factors restricting its distribution. Estimates of "potential" habitat are subject to error if the specific conditions for colonization and growth are unknown.

Ecological studies of *Sclerocactus mesae-verdae*, particularly mechanisms of pollination, seed dispersal, seed dormancy, seed germination rates, and non-human mortality factors need to be undertaken. Given the recent arthropod predation pressures, the interactions between the various predatory species and their combined, as well as specific, impacts should be studied.

The arguments in support of the ecological importance of a single species are often difficult to convey. However, public appreciation and support for the preservation of *Sclerocactus mesae-verdae* continues to be needed throughout its range.

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FIGURES, TABLES, APPENDICES

Figure 1. Map of United States of America indicating the global range of *Sclerocactus mesae-verdae.*

Figure 2. Example of live *Sclerocactus mesae-verdae* plants observed during the 2004. It was sometimes difficult to determine if stems arose from independent germination events or were sprouts from a large dead buried individual. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 3. Example of live *Sclerocactus mesae-verdae* plants observed during the 2004. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 4. Example of a live *Sclerocactus mesae-verdae* plant observed during the 2004. The parent plant was likely ravaged by drought and an arthropod infestation. These stems appear to be surviving. ©Photograph taken by Juanita A. R. Ladyman, 2004.

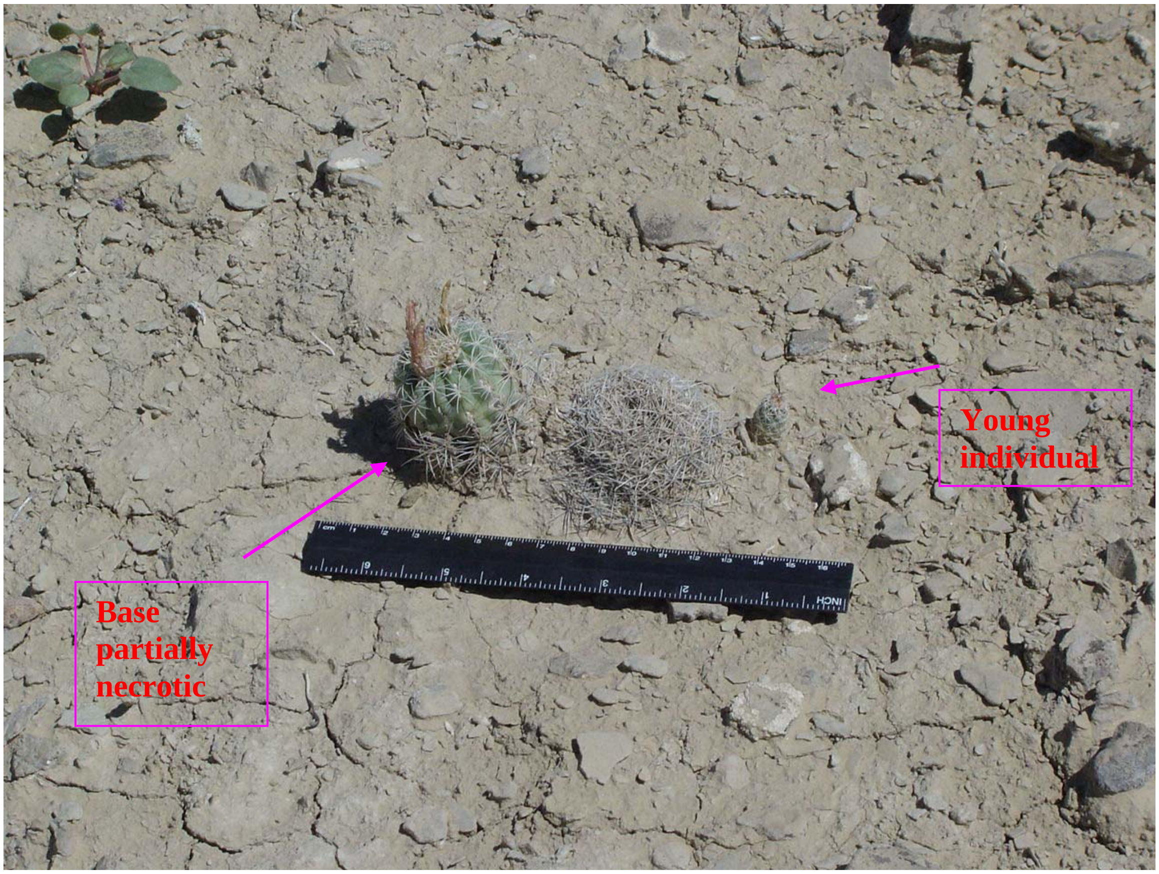

Figure 5. Examples of live and dead *Sclerocactus mesae-verdae* stems observed during 2004. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 6. Photograph of a large *Sclerocactus mesae-verdae* plant in the Malpais Arroyo area. Note the high reproductive potential of this individual and also the small sprout on the main stem. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 7. The photograph demonstrates the sprouting phenomenon on a *Sclerocactus mesae-verdae* stem. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 8. The photographs demonstrate the sprouting phenomenon from necrotic base of a large *Sclerocactus mesae-verdae* stem. ©Photograph taken by Juanita A. R. Ladyman, 2004.

A

B

Figure 9. The photographs demonstrate the sprouting phenomenon from dead *Sclerocactus mesae-verdae* stems. In (A) the white soil crust is composed primarily of lichen. Note the fruit production on the damaged stem in (B). ©Photograph taken by Juanita A. R. Ladyman, 2004.

A.

B.

Figure 10. A and B. *Sclerocactus parviflorus* ssp. *intermedius*. ©Photographs taken by Juanita A. R. Ladyman, 2004.

Figure 11. This *Sclerocactus mesae-verdae* plant grows among a high cover of surface gravels. ©Photograph taken by Juanita A. R. Ladyman, 2004.

Figure 12. This *Sclerocactus mesae-verdae* plant grows on barren shale mostly devoid of gravels. ©Photograph taken by Juanita A. R. Ladyman, 2004.

A.

B.

Figure 13. A and B. In the 2004 survey, many small *Sclerocactus mesae-verdae* plants, especially at the site near Sanostee, were observed (red circles) actually growing out from under gravels. The blue circle indicates two sprout-stems growing from the damaged base. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 14. *Sclerocactus mesae-verdae* plant growing out from under a saltbush shrub. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 15. *Sclerocactus mesae-verdae* plant growing out from under a dead shrub. The size of the cactus plant suggests that the shrub was alive for most of the cactus' life. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 16. *Sclerocactus mesae-verdae* plant growing in a clump of grass. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 17. *Sclerocactus mesae-verdae* plant growing in a clump of grass. Photograph© taken by Juanita A. R. Ladyman, 2004.

18. This photograph of a *Sclerocactus mesae-verdae* plant on the shale edge of a shallow drainage demonstrates the potential for active soil erosion within its habitat. Note that even though its stem looks slightly necrotic it is likely to reproduce this year. Photograph© taken by Juanita A. R. Ladyman, 2004.

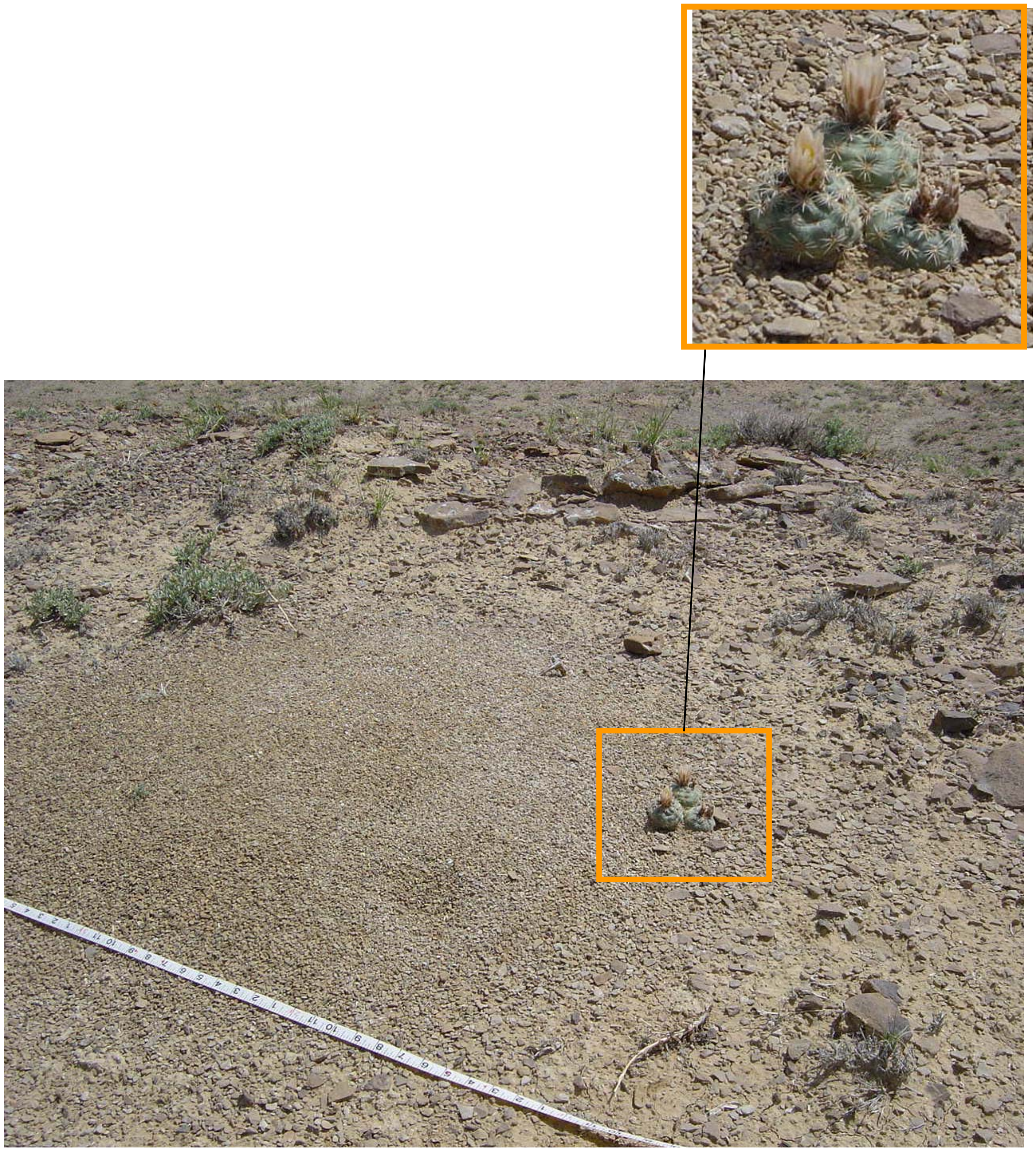

Figure 19. Ant colonies are often observed near *Sclerocactus mesae-verdae* individuals. Photograph© taken by Juanita A. R. Ladyman, 2004.

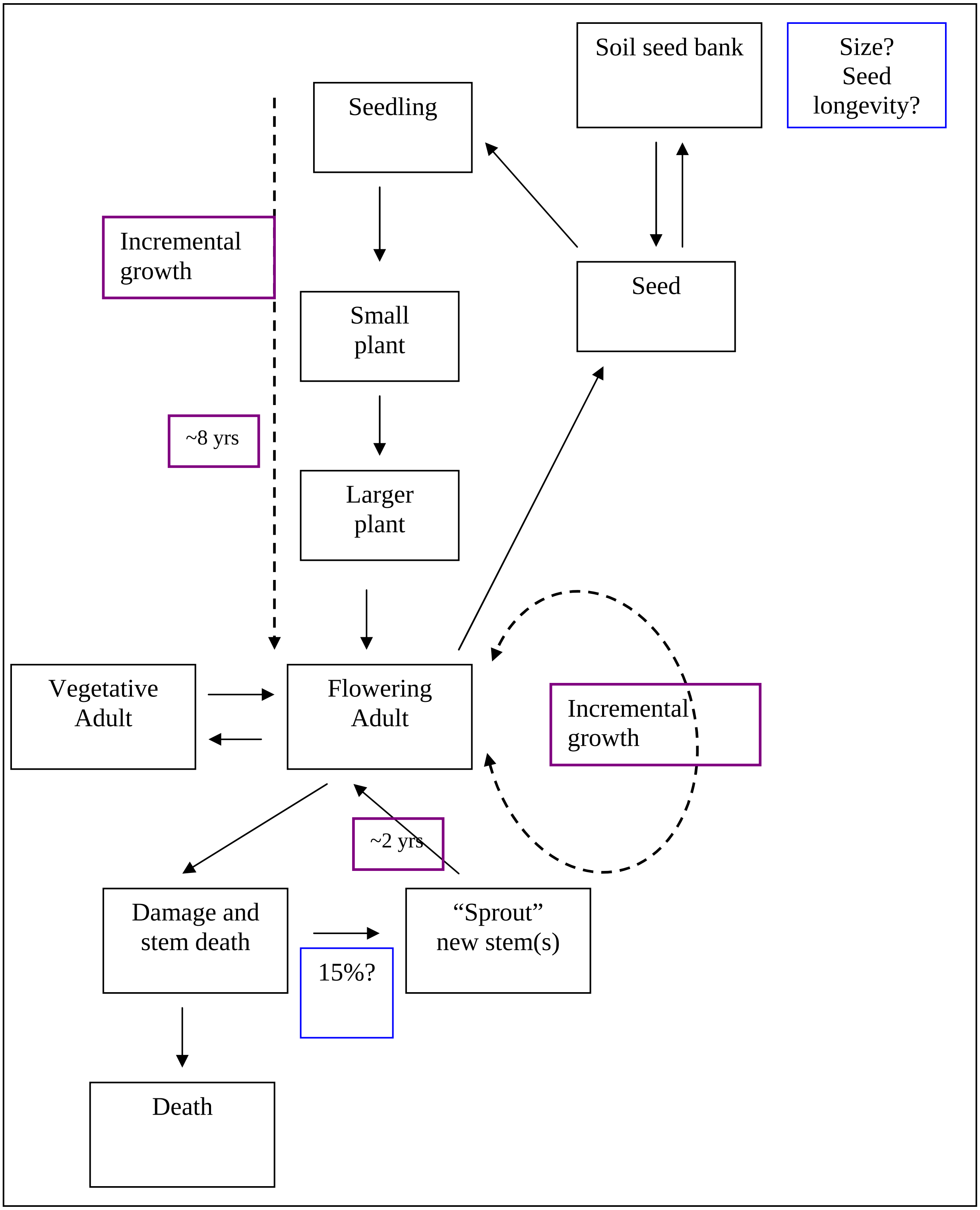

Figure 20. Life cycle diagram of *Sclerocactus mesae-verdae* constructed principally using the demographic data collected on Colorado populations by Coles (2003). More study is required to confirm that this sequence of events is applicable to individuals in New Mexico populations.

Figure 21. Examples of dead *Sclerocactus mesae-verdae* individuals. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 22. The photograph illustrates a small *Sclerocactus mesae-verdae* individual. The color and relatively larger size of this specimen makes it relatively easy to spot. However, smaller individuals or those that have a layer of mud adhering to the stem are very difficult to see. Photograph© taken by Juanita A. R. Ladyman, 2004.

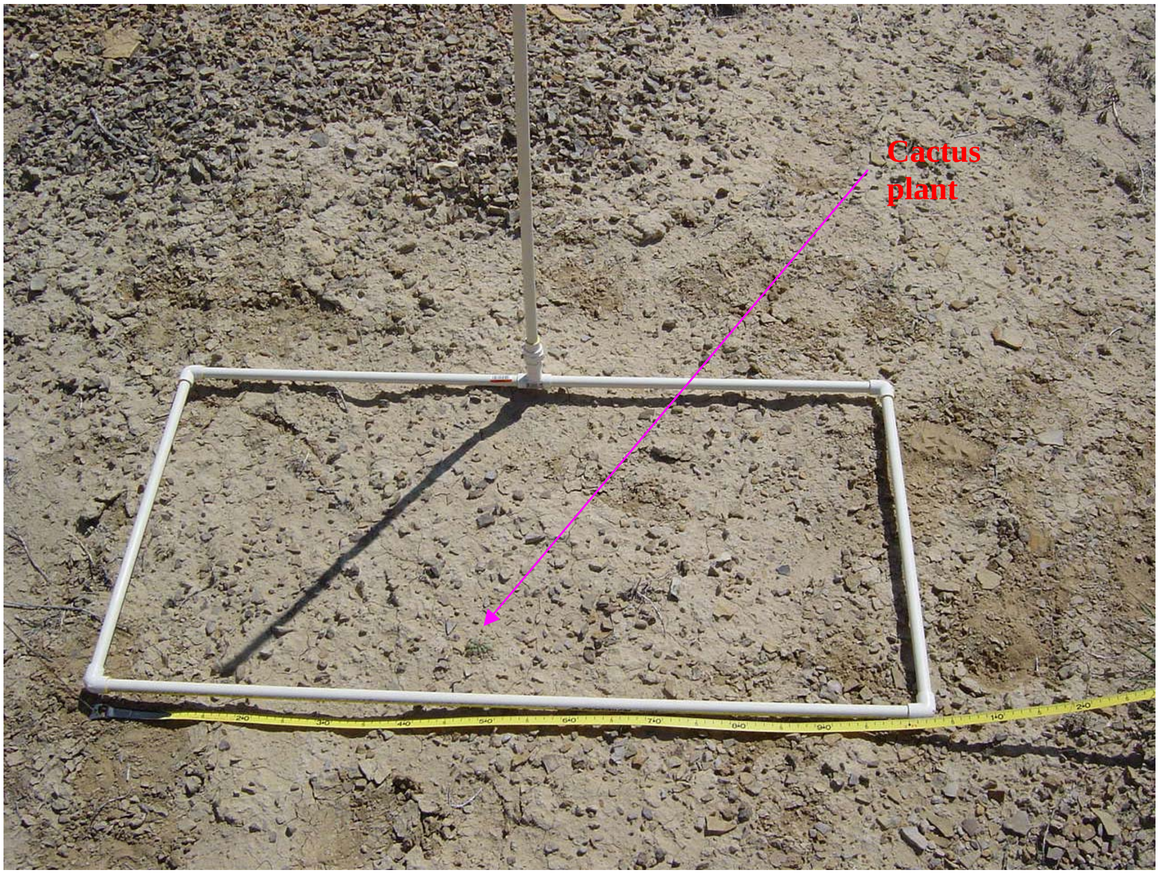

Figure 23. The first live plant was chosen to be within the first rectangular quadrat frame shown in the photograph. Photograph© taken by Juanita A. R. Ladyman, 2004.

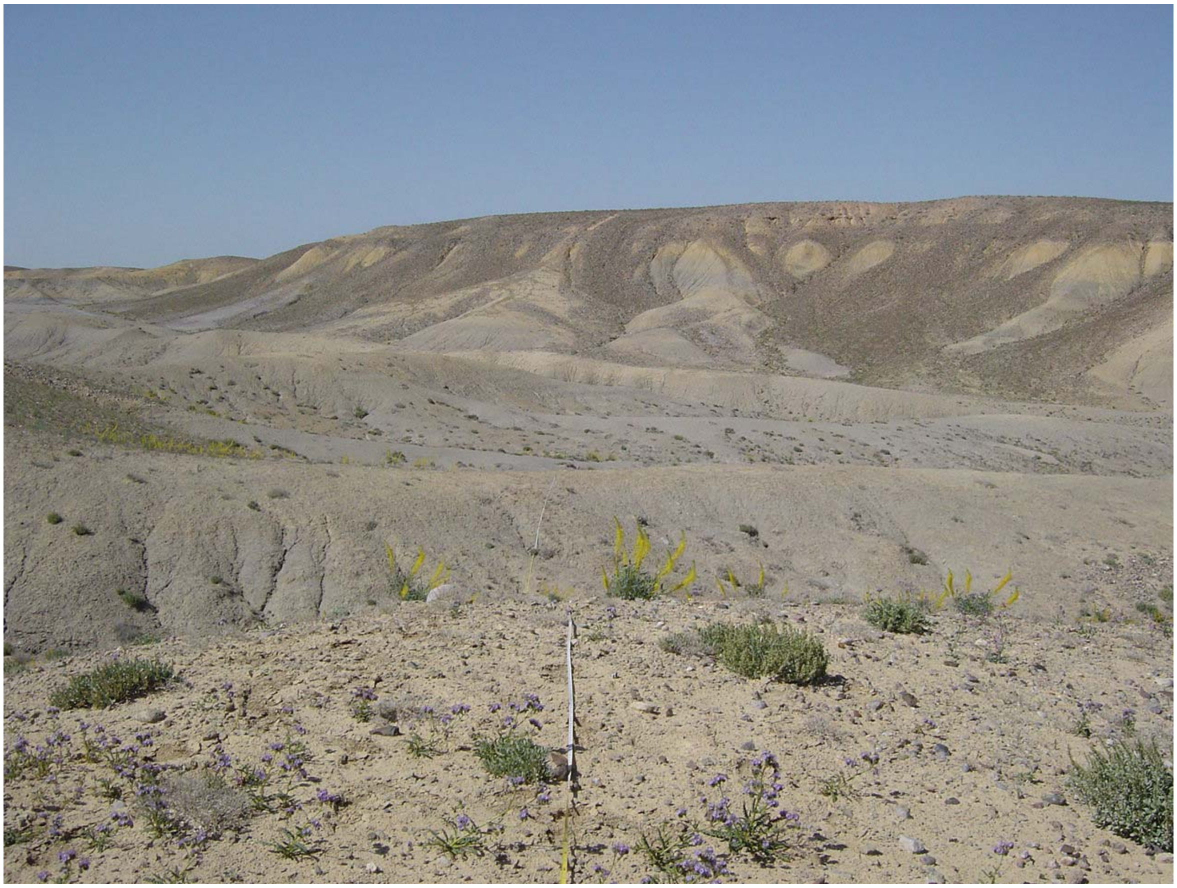

Figure 24. A 100m transect line was run across habitat that appeared suitable for *S. mesae-verdae*. Transect line data are reported in Tables 1 and 2. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 25. Off-road vehicle traffic, especially hard-driven recreational vehicles such as dirt bikes and ATVs, degrade habitat by increasing soil compaction, soil erosion and modifying fragile soil structure and chemistry. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 26. Off road vehicle traffic degrade habitat by increasing soil compaction, soil erosion and modifying fragile soil structure and chemistry. Photograph© taken by Juanita A. R. Ladyman, 2004.

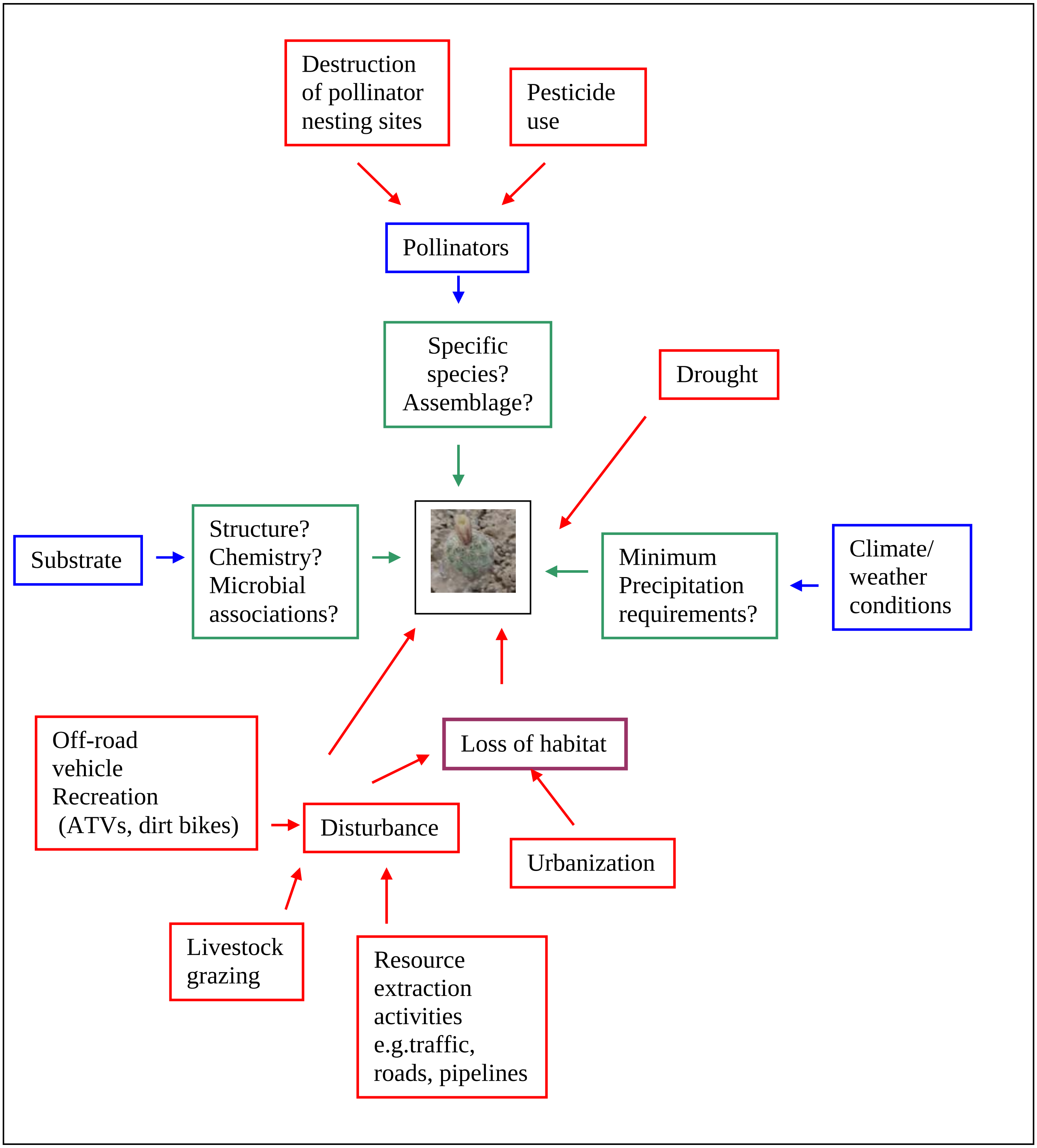

Figure 27. A diagram outlining some of the resources and threats to *Sclerocactus mesae-verdae.*

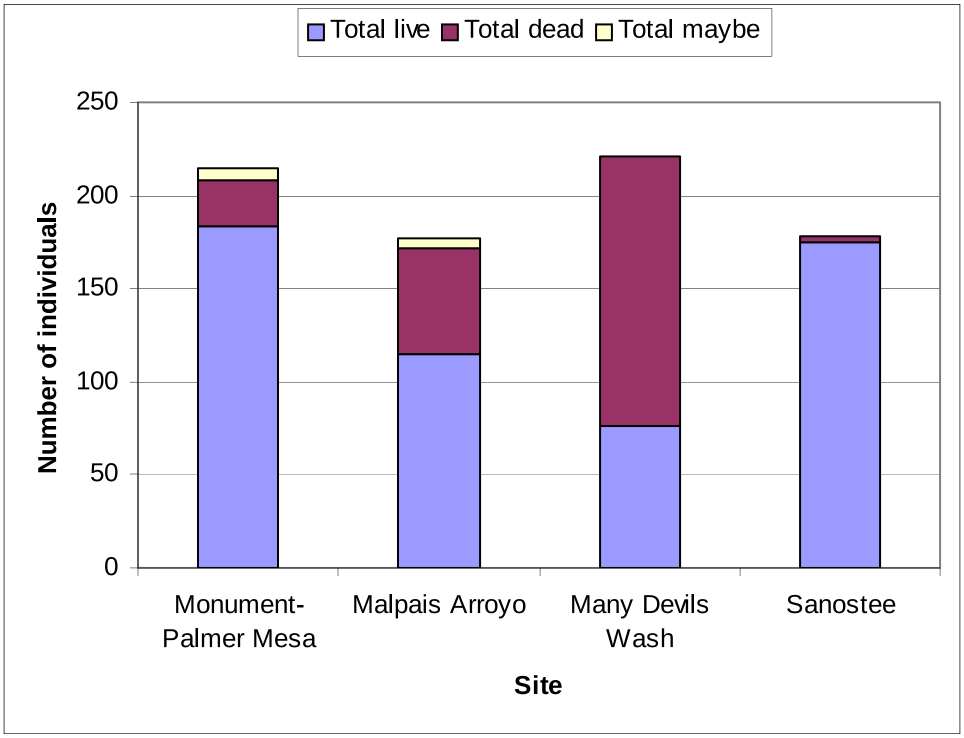

Figure 28. The numbers of live versus dead individuals found at selected sites during 2004 (see text for further details). “Maybe” refers to plants that were in poor condition and appeared likely to die.

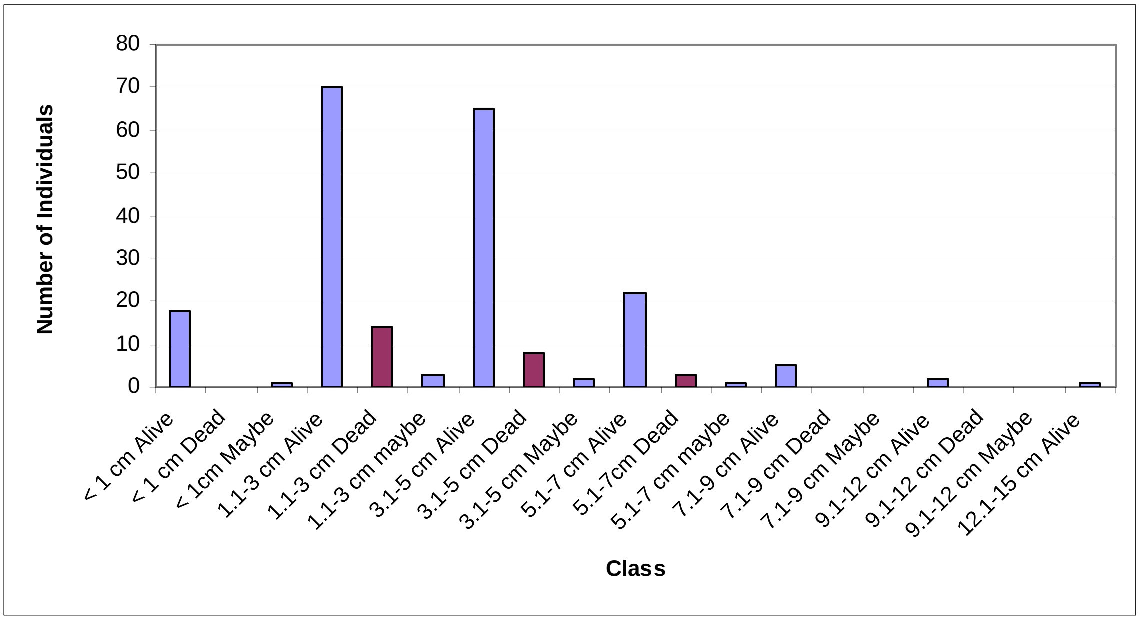

Figure 29. Classes of live and dead plants in the Monument Rocks and Palmer Mesa region. “Maybe” refers to plants that were in poor condition and appeared likely to die.

Figure 30. *Sclerocactus mesae-verdae* in region of Monument Rocks and Palmer Mesa. Photograph© taken by Juanita A. R. Ladyman, 2004.

Figure 31. *Sclerocactus mesae-verdae* in region of Monument Rocks and Palmer Mesa. Photograph© taken by Juanita A. R. Ladyman, 2004.

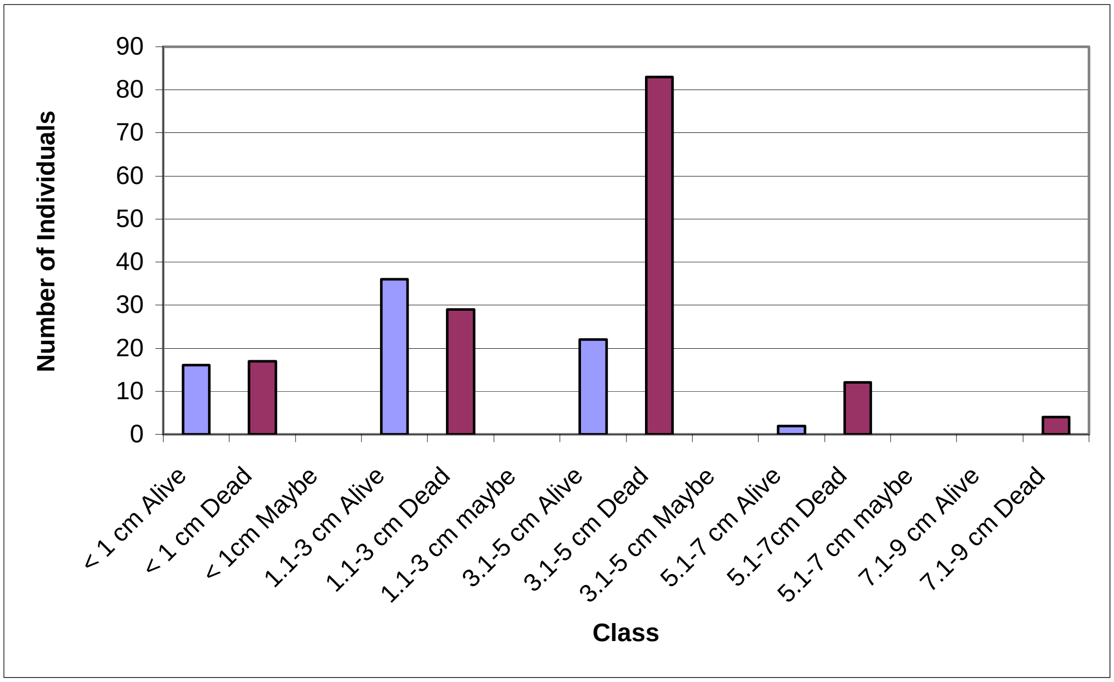

Figure 32. Classes of live and dead plants in East of Many Devils Wash. "Maybe" refers to plants that were in poor condition and appeared likely to die.

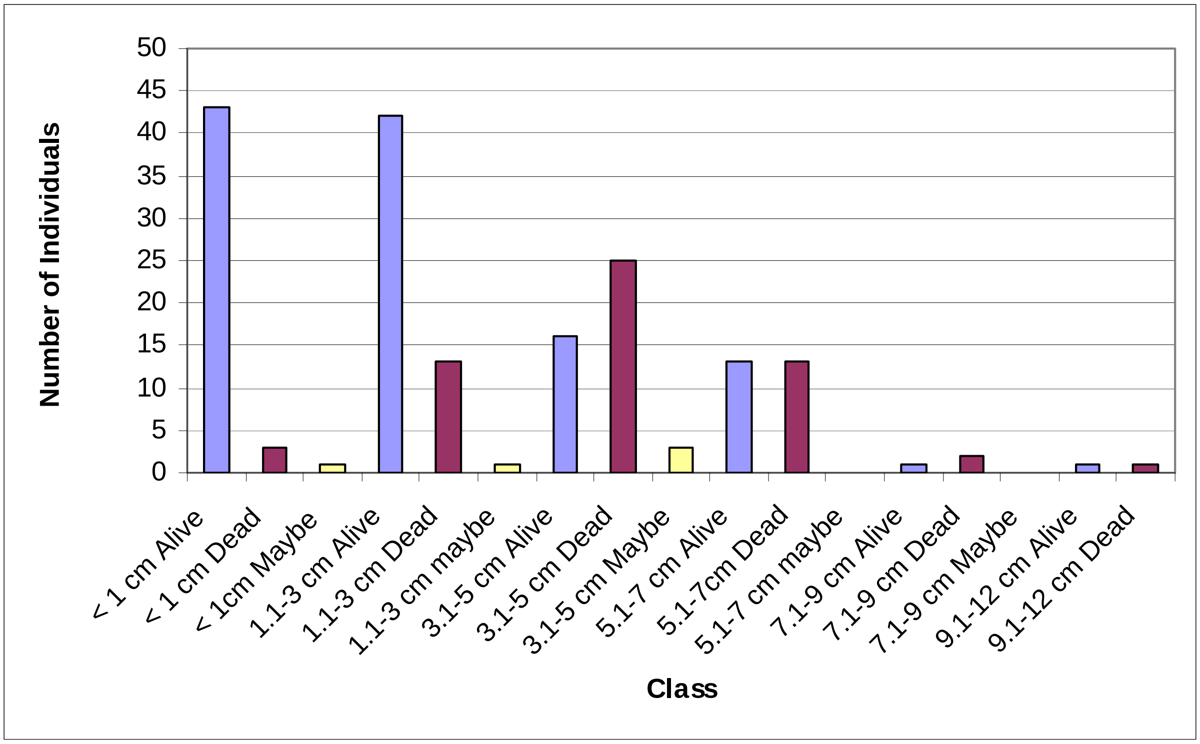

Figure 33. Classes of live and dead plants in the Malpais Arroyo region. "Maybe" refers to plants that were in poor condition and appeared likely to die.

Figure 34. Photograph illustrating that the weeds are largely restricted to the arroyo bottoms soil disturbance is localized to certain areas in the Malpais Arroyo region. Photograph© taken by Juanita A. R. Ladyman, 2004.

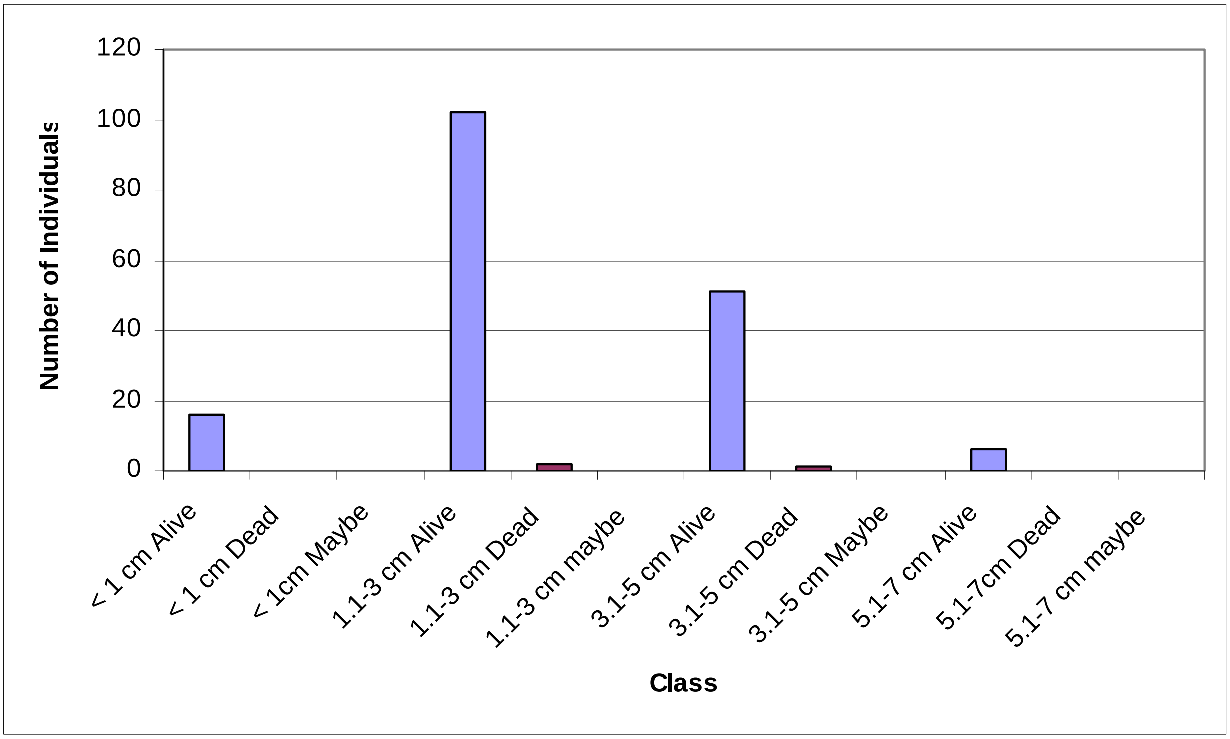

Figure 35. Classes of live and dead plants Region west of Sanostee.

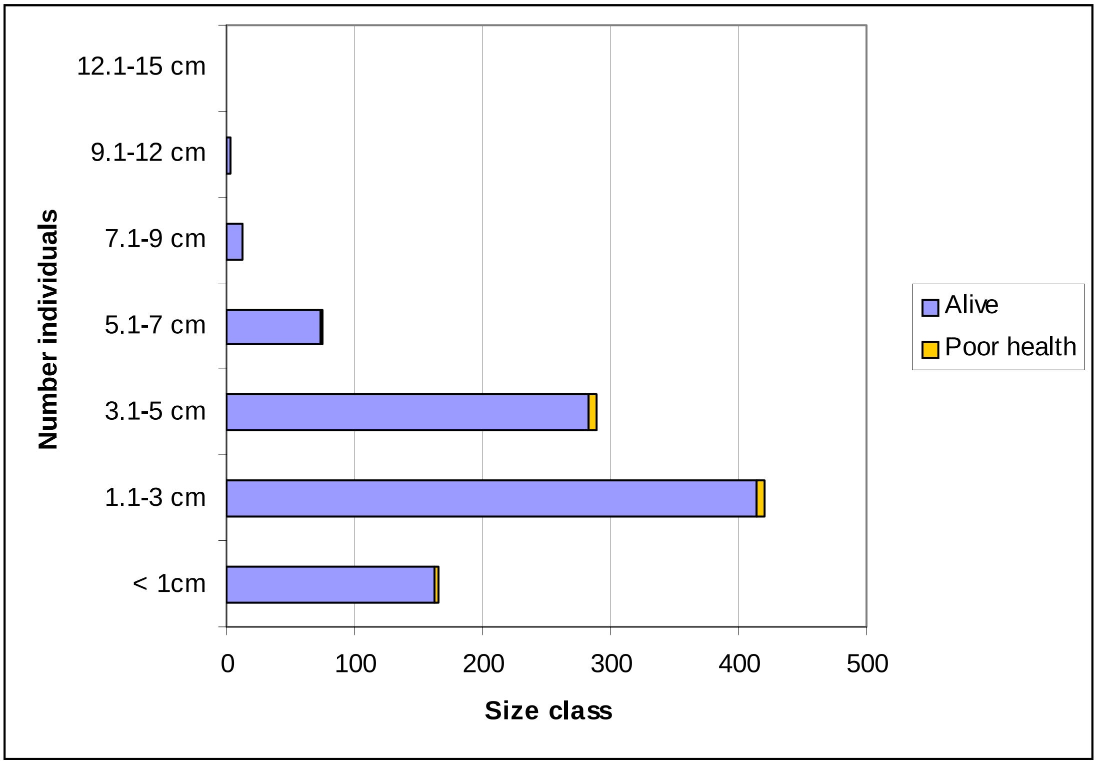

Figure 36. Frequency distribution based on stem-diameter size of *Sclerocactus mesae-verdae* individuals that were observed in 2004. Plants were placed in a size class according to the diameter of largest stem (cm). These cacti may have single or multiple stems. The stems may have arisen from sprouts on an older damaged stem or may be due to stems directly grown from seed.

Table 1. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
056*NN	Sanostee East	28-Apr	6	6	0	0	2	1997: 4 individuals	"+"
023*NN	Sanostee West	28-Apr	7	3	4	0	1	1989-4: Site 1: 13 cacti total. Site 2: 3 cacti. Did not search entire area; the 2 sites are probably part of the same population as the habitat is continuous. *1989-6: 6 cacti at Site 1 & 4 at Site 2.	"-"
022*NN	Sanostee East	28-Apr	16	15	1	0	6	1989-5-1: 4 plants.	"+"
039*NN	Yellow Hill	29-Apr	0	0	0	0	0	1990: 7 cacti ;1 was smashed by a hoof.	"-"
038*NN	Sanostee West	29-Apr 30-Apr	178	175	3	0	63	1989: 11 cacti found on low hills at base of mesa	"+"
017*NN	Sanostee West	30-Apr	16	15	1	0	7	1989: No quantitative data – only that plants were present	No quantitative data prior to 2004; plants present in 2004
037*NN	Sanostee West	30-Apr	0	0	0	0	0	Before 1991: No quantitative data – only that plants were present	"-"
036*NN	Sanostee West	27-Apr	2	2	0	0	2	1989: 3 cacti.	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
024*NN	Sanostee East	29-Apr	4	4	0	0	1	1989-5-1: 8 cacti total, 5 in fruit. 1989-6-2: 3 cacti.	"-"
040*NN	Mitten Rock	29-Apr	0	0	0	0	0	1989: 9 cacti.	"-"
001*NN (including sites marked 72 & 72b in 2004)	Shiprock/ Sulphur Springs	28-Apr 4-May	221	76	145	0	3	Circa 1989: The DOE identified approximately 1,500 individuals 1.5 mi along Many Devils Wash.	"-"
028*NN	Shiprock	23-Apr	0	0	0	0	0	1900: No quantitative data – only that plants were present	"-"
035*NN	Shiprock	23-Apr	58	30	26	2	1	1991-10-11&12: 99 individuals at 7 sites; includes 47 adults, 1 mature, 33 juveniles & 18 seedlings. 1993-1997: BSSP-NNHP personnel conducted annual monitoring on 4 small populations/plots.	"-"
EO 59 (from hardcopy)	Shiprock	25-Apr	9	3	6	0	0	2000: Estimate from a small scale hardcopy map created in 2000: between 500 to 1,500	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
041*NN	Ship Rock	27-Apr 4-May	1	0	1	0	0	1989: The BIA transplanted approximately 35 cacti from EOR #001to this location. Few transplanted cacti were alive in the summer of 1989. 1989-8-21: 12 cacti (not transplanted) within the oil field	"-"
EO 57 (from hardcopy)	Sulphur Springs	3-May	55	19	35	1	0	2000: Estimate from a small scale hardcopy map created in 2000: between 500 to 1,500	"-"
New Site - Cactus Peak	Shiprock	30-Apr	0	0	0	0	0	New site - no prior information available.	Not applicable
052*NN, 053*NN	Chimney Rock	21-Apr	9	1	8	0	0	1991: 10 plants in one area and 8 in another	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004. "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
032*NN, 050*NN	Chimney Rock	22-Apr	7	6	0	0	3	1984: 33 cacti (EO 032). 1991: 57 cacti adjacent to the roadway, scattered over about 0.25 mi. Based on previous studies, the author estimated that as many as 200 cacti could occur in the area (EO 050).	"-"
016*NN	Shiprock	24-Apr	0	0	0	0	0	1963: No quantitative data – only that plants were present	"-"
002*NN	Shiprock	24-Apr	5	4	1	0	1	Before 1981: No quantitative data – only that plants were present	No quantitative data prior to 2004; plants present in 2004
018*NN	Shiprock	24-Apr	0	0	0	0	0	1970: No quantitative data – only that plants were present	"-"
011*NN	Shiprock	23-Apr	0	0	0	0	0	1964: No quantitative data – only that plants were present	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
027*NN	Rattlesnake	23-Apr	3	2	1	0	0	1995-Spring: Cacti were transplanted to this site. 1997: Observed 19 non-transplants & 27 transplanted cacti within the monitoring plots. A number of cacti were also outside the plots, but no attempt was made to count them.	"-"
013*NN	Shiprock	23-Apr	5	4	1	0	1	1985: 4 individuals	No change
015*NN	Shiprock	24-Apr	10	8	0	1	6	1959: No details	No quantitative data prior to 2004; plants present in 2004
New Site-SW Cudei	Rattlesnake	5-May	89	61	28	0	16	New site – no prior information available.	Not applicable
100 (EO number given by 2004 survey team)	Rattlesnake	25-Apr	0	0	0	0	0	Estimate from a small scale hardcopy map created in 2000: between 500 to 1,500	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
101 (EO number given by 2004 survey team)	Rattlesnake	25-Apr	1	1	0	0	0	2000: Estimate from a small scale hardcopy map created in 2000: between 500 to 1,500	"-"
042*NN	Rattlesnake	25-Apr	0	0	0	0	0	1990: 7 at the south base of the hill. 4 plants were found on the rim of this hill.	"-"
055*NN	Chimney Rock	22-Apr	32	2	30	0	0	1998: 33 plants – all reproductive	"-"
New site- Monument Rocks	Palmer Mesa	4-May	65	46	17	2	21	New site – no prior information available.	Not applicable
045*NN	Palmer Mesa	23-Apr 2-May	150	137	8	5	69	1989: 6 dead and 7 live plants, one of which looked unhealthy.	"+"
020*NN	Skinny Rock	23-Apr	51	35	16	0	15	1990-1-9: Several cacti at southwest base of Blue Hill. "..Population probably stretches east through the Horseshoe Gallup Oil Field & is connected with those plants in EOR #45. 1990: a 100' corridor was surveyed along a proposed pipeline. 18 sites with a total of 213 plants were located.	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
New Site	Canal Creek	2-May	10	8	2	0	4	New site – no prior information available.	Not applicable
047*NN	Canal Creek	2-May	26	22	4	0	21	1990: 30 plants	"-"
043*NN (70)	Rocky Point	1-May	82	71	11	0	28	1990: 6 plants found; 1 large plant appeared diseased; 1mortality (EO 43).	"+"
70b	Rocky Point	1-May	4	4	0	0	3	New site – no prior information available.	Not applicable
New Area – FH	Rattlesnake and Rocky Point	26-Apr	11	10	0	1	4	New site – no prior information available.	Not applicable
044*NN	Rocky Point	26-Apr	55	52	3	0	13	1990: 17 plants, 1 large plant had been smashed on top of the hill by a tire. Others were noted growing between the tire tracks. Another plant was run over but was not damaged.	"+"
44 b – new site	Rocky Point	5-May	0	0	0	0	0	New site – no prior information available.	Not applicable
010*NN	Skinny Rock	23-Apr	0	0	0	0	0	1977 & "Pre-1981:" No quantitative data	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
046*NN (combine with 71)	Canal Creek	2-May	1	0	1	0	0	1990: at least 4 plants	"-"
014*NN	Skinny Rock	24-Apr	28	11	17	0	3	199: 3 cacti just west of access road	"+"
046*NN	Canal Creek	25-Apr	1	0	1	0	0	1990: 4 plants were found at Site 1	"-"
026*NN	Littlewater	27-Apr	0	0	0	0	0	1993: 3 cacti on Mancos sand/shale.	"-"
033*NN - near Black Cone	Skinny Rock	24-Apr	0	0	0	0	0	1990-3-24 (Pop 13): Along a dirt road west from US666 to Black Cone made 4 stops and found cacti at 3 locations. 2 large cacti were at the edge of the road.	"-"

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
033*NN – Malpais Arroyo region	Canal Creek/ Skinney Rock	25-Apr 1-May	178	115	57	5	27	1994: 12 populations & 3 isolated individuals, totaling 123 cacti. 1991: (Pops 17-19): 33 cacti. Likely that cactus is scattered throughout the Malpais Arroyo area. 1990 (Pops 14-16): Estimated several hundred cacti were located alongside the Malpais Arroyo N & S of the Hogback Canal.	"-"
New Site – S. Dead Mans Wash	Mitten Rock	30-Apr	0	0	0	0	0	New site – no prior information available.	Not applicable

Table 1 continued. Results of the 2004 survey for *Sclerocactus mesae-verdae* cacti and a comparison with their prior abundance.

Original EOR/ New site	Quad name	2004 Visit Date	Number of individuals 2004					Prior abundance information at site from NNHP database (data received from Roth 2004)	Difference between last observation and observation in 2004 "-" signifies decline; "+" signifies increase
			Total	Live	Dead	In poor health	Reproductive (fruits &/or flowers) individuals in 2004		
005*NN	Sheep Springs	8-May	0	0	0	0	0	1985 Site 1: estimated >25 individuals. A monitoring plot was set up in 1985. Total # of plants exceeded 200. NNHP monitored the plot from 1989-1995. Site 2: Discovered 91. 34 cacti in ROW plus additional uncounted cacti outside ROW. Site 3:1993 Small cluster of plants.	"-"
004*NN	Sheep Springs	8-May	0	0	0	0	0	1985: 7 individuals. Pre-1981: Approximately 20-25 individuals.	"-"
006*NN	Naschiti	8-May	0	0	0	0	0	1965-5-2: 10 individuals, in flower, flowers pale yellow.	"-"
019*NN	Naschiti	8-May	0	0	0	0	0	1988: Approximately 25 individuals.	"-"
048*NN	Naschiti	8-May	0	0	0	0	0	1989: 20 plants	"-"

Table 2. A. Number of *Sclerocactus mesae-verdae* individuals per quadrant (0.5x1m) per transect at each of 18 element occurrences (Eos). **B.** The mean number and the standard deviation (stdev) of individuals per quadrant frame.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
1	1	1	3	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2
2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2 A. continued.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. A continued.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B.

Quadrat frame	EO /52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
Average	0.010	0.050	0.030	0.020	0.010	0.040	0.040	0.010	0.010	0.010	0.020	0.010	0.010	0.010	0.010	0.030	0.090	0.050
Std dev	0.100	0.330	0.300	0.141	0.100	0.243	0.197	0.100	0.100	0.100	0.141	0.100	0.100	0.100	0.100	0.223	0.805	0.261

Total 1,800 quadrat frames

Average 0.026 individuals/quad

Std dev 0.258

Table 3. The demographics of the populations at each of the proposed conservation sites.

Original EOR/New site	Number of individuals					Stem diameter size class (diameter of the largest live stem if multiple stems)																		
	Total[1]	Total live	Number with fruit or flowers	Total dead	Total Unk[2]	< 1 cm			1.1 – 3 cm			3.1 – 5 cm			5.1-7cm			7.1-9 cm			9.1-12 cm			12.1-15 cm
						Alive	Dead	Unk	Alive	Dead	Unk	Alive	Dead	Unk	Alive	Dead	Unk	Alive	Dead	Unk	Alive	Dead	Unk	Alive
Monument Rocks – Palmer Mesa - 045*NN	215	183	90	25	7	18	0	1	70	14	3	65	8	2	22	3	1	5	0	0	2	0	0	1
Malpais Arroyo – 033*NN	178	115	30	57	5	43	3	1	42	13	1	16	25	3	13	13	0	1	2	0	1	1	0	0
Many Devils Wash – 001*NN	221	76	3	145	0	16	17	0	36	29	0	22	83	0	2	12	0	0	4	0	0	0	0	0
Sanostee – 038*NN	178	175	63	3	0	16	0	0	102	2	0	51	1	0	6	0	0	0	0	0	0	0	0	0

[1] Total number of individuals
[2] Unk = Unhealthy individuals

Table 4. A. Number of *Sclerocactus mesae-verdae* individuals per expanded quadrant (1.5x1m) per transect at each of 18 element occurrences; see Appendix A. B. The mean number and the standard deviation (stdev) of individuals per quadrant frame.

A.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
1	1	1	3	1	1	2	1	1	1	1	1	1	1	1	1	1	1	2
2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. A. continued.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4. A. continued.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
87	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

B.

Quadrat frame	EO 51/52	EO 35	EO 13	EO 2	EO 15	EO 17	EO 70	EO 23	EO 71	EO 14	EO 45	EO 24	EO 36	EO 22	EO 56	EO 33	Feather Hill	EO 44
Average	0.01	0.16	0.03	0.03	0.01	0.04	0.10	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.09	0.05
St.dev.	0.10	0.60	0.30	0.17	0.10	0.24	0.30	0.10	0.10	0.14	0.14	0.10	0.10	0.10	0.10	0.22	0.81	0.26

Total 1,800 quadrat frames
Average 0.03611
St. dev. 0.2913

Appendix A. Sample sizes - Determining the necessary sample size for estimating a single population mean or a population total with a specified level of precision (see Elzinger et al. 1998).

An estimate of the uncorrected sample size can be calculated from the equation:

$$N = \frac{[Z\alpha]^2 [s]^2}{[B]^2}$$

where:	N	=	uncorrected sample size estimate
	Zα	=	the standard normal coefficient for a given confidence level (for example for a confidence level of 80 % Zα = 1.28 and for a confidence level of 90 % Zα = 1.64; Elzinger et al. 1998).
	s	=	the standard deviation
	B	=	the desired level of precision expressed as half of the maximum acceptable confidence interval width

The number of individuals in each quadrat frame is reported in Table 2. This data can be examined in several different ways but one of the most straightforward is to consider that each quadrat is independent of the others and is in representative habitat on a population wide basis. No level of replication is invoked. Therefore there were a total of 1,800 readings that equaled a mean of 0.026, rounded up to 0.03, individuals per frame (0.5m x 1m) with a standard deviation of 0.258.

From Table 2:

Mean = 0.03 individuals/quad of a total of 1800 quads.
Std dev = 0.258

Z Standard normal coefficient for Cl of 90% = 1.64 (Elzinger et al. 1998).
B desired precision level for a 5% desired error of a mean of 0.03 = 0.0015

N = (2.6896x0.066564)/ 0.00000225 = 79,569 quads of 0.5m x 1m equivalent to approximately 10 acres

Z Standard normal coefficient for Cl of 90% = 1.64 (Elzinger et al. 1998).
B desired precision level for a 20 % desired error of a mean of 0.03 = 0.006

N = (2.6896 x 0.066564)/ 0.000036 = 4,973 quads of 0.5m x 1m

Z standard normal coefficient for l of 80% = 1.28 (Elzinger et al. 1998).
B desired precision level for a 20 % desired error of a mean of 0.03 = 0.006

N = (1.6384 x 0.066564) / 0.000036 = 3,029 quads of 0.5m x 1m

Because of the paucity of plants, individuals were also noted when they were outside, but within 1m of the edge of the frame. This resulted in essentially counting the numbers of individuals in quadrats of 1.5 m x 1m (Table 4). Although the larger quadrat frames tended to reduce the number of frames that needed to be surveyed the difference in size was not significant and actually resulted in a larger area (for example 52, 505 square m versus 40,000 square m) needing to be surveyed for a given level of precision. This can be interpreted to support the fact that the cacti are sparsely and widely distributed across the landscape.

From Table 4:

Mean = 0.036 individuals/quad of a total of 1800 quads.
Std dev = 0.291

Z Standard normal coefficient for Cl of 90% = 1.64 (Elzinger et al. 1998).
B desired precision level for a 5% desired error of a mean of 0.036 = 0.0018

N = (2.6896 x 0.084854)/ 0.0000033 = 70,007 quads of 1.5m x 1m
equivalent to approximately 26 acres

Z Standard normal coefficient for Cl of 90% = 1.64 (Elzinger et al. 1998).
B desired precision level for a 20 % desired error of a mean of 0.036 = 0.0072

N = (2.6896 x 0.066564)/ 0.000036 = 4,973 quads of 1.5 m x 1m

Z standard normal coefficient for Confidence interval e.g. 80% = 1.28
B desired precision level for a 20 % desired error of a mean of 0.036 = 0.0072

N = (1.6384 x 0.084854)/ 0.00005184 = 2,682 quads of 1.5m x 1m

As written in the text, there are at least four very important points that must be appreciated when considering these estimates of sample size. The first and most important is that this estimate assumes that the data are normally distributed. This is also the assumption when estimates of population size are made after observing 10 cacti within 1 acre and a casual estimation is made that there must be at least 100 in 10 acres of similar habitat. Current evidence suggests that the distribution of *Sclerocactus mesae-verdae* is unlikely to be a statistically normal one. That is the data are unlikely to fit a bell shaped curve (Steele and Torrie 1960). This absence of a normal distribution considerably complicates the issue but is unlikely to reduce the acreage that must be surveyed to arrive at a reliable estimate of population size (Ludwig and Reynolds 1988, Steele and Torrie 1960).

Secondly, it should be noted that “N” is the uncorrected sample size estimate and, even if the data are normally distributed, can only be applied if the population is very large compared to the proportion of the population being sampled (Elzinger et al. 1998). If the sampled population is 5 percent or more of the total population then the sample size needs correction, which always results in a larger sample size being needed for the same levels of confidence and precision (Elzinger et al. 1998). This may be true if each transect is used to uniquely represent the area in which it was surveyed. For example at EOs #70, #23, #24, #36, #22 and #56 the average number of individuals were 0.01 per frame and the standard deviation 0.1 (Table 2). Therefore, 107,584 rectangular (0.5x1m) quads would be the minimum sample size to achieve an estimate of the population size with a 90 percent confidence level and a level of precision of 5 percent. In contrast at EO # 35 the average number of individuals were 0.16 per frame and the standard deviation 0.598 (Table 2). In this case 15,044 rectangular (0.5x1m) quads would be the minimum sample size to achieve an estimate of the population size with a 90 percent confidence level and a level of precision of 5 percent.

A third point to consider is the impact of non-random choice of sampling direction. Plant density may be expected to be higher through contiguous habitat than in fragmented habitat. The fourth point, that is directly associated with the last, or third point, is that the microhabitat conditions and precise edaphic requirements are unknown. Therefore, there is the possibility that plants will not grow in areas that appear to be potential habitat along a transect line. Thus the zero readings that contribute to the standard deviation are actually in error because they do not represent habitat that could be occupied.

Appendix B. Commercial suppliers of *Sclerocactus mesae-verdae* seed

Cactus Heaven,
33 St Anne's Junction,
MALTA, MST 08, Europe
No plants although many other *Sclerocactus* species; seeds from cultivated *Sclerocactus mesae-verdae* plants are available
http://cactus-heaven.com/index.phtml

Mesa Garden
P.O. Box 72
Belen, NM 87002
No plants although many other *Sclerocactus* species; seeds from cultivated *Sclerocactus mesae-verdae* plants are available
http://www.mesagarden.com/

Navajo Country - since 1979
P.O. Box 510201, D-68242 Mannheim, Germany
No plants although many other *Sclerocactus* species; seeds from cultivated *Sclerocactus mesae-verdae* plants are available
http://www.fhnavajo.com/terms.html

Appendix C. Tally sheets used in field survey, 2004.

Navajo Nation SMV - Inventory. Date: ______________ Biologists: _________________ p__/__
SITE:_______________ T:______ R: _________ Sec:__________ Position in sec:____________________
UTM: Easting: _________________ Northing_____________________ (Log #:________ _____)
Quad:_________________________ Boundary UTM log # ______________ Photo#_____________
Location: ____

____

____

☐______________________________ ☐______________________________
% gravels_______________________ % cryptogamic crust______________________________
Habitat/Associates (note dominant) ____

____

____
Disturbance/activities (e.g. tire tracks)____

____
Aspect: ____________ Slope: _____________ % canopy cover: __________________________
Topographic position: ____
UTMS: at each corner: Easting: ____________ Northing_______________ (Log #:_______ _____)
Easting: ____________ Northing_______________ (Log #:_______ _____)
Easting: ____________ Northing_______________ (Log #:_______ _____)
Easting: ____________ Northing_______________ (Log #:_______ _____)

Sclerocactus mesae-verdae

Area size of the cluster/distance between individuals/ No. Flowering, w/ fruit/comments /**arthropod infestations**	< 1 cm	1.1-3 cm	3.1-5 cm	5.1-7 cm	7.1-9 cm	9.1-12 cm	12.1-15 cm	.5 cm

Navajo Nation SMV - Inventory **Date:**______________________ **Site:**___________________ **TRS:**_________________________ *D=dead; A= Alive; M = maybe alive but looks likely dead - comment (y) yellow (h) holes etc.* CODE: F=Flowering. FR = fruit

< 1 cm			1.1-3			3.1-5			5.1-7			7.1-9			9.1-12			12.1-15			>15 cm		
D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M

Navajo Nation SMV - Inventory. Date: ______________ Biologists: __________________________
SITE:______________ T:______ R: ________Sec:_________ Position in sec:__________________
UTM: Easting: _________________ Northing_____________________ (Log #:_______ _____)
Quad:__________________________ Boundary UTM logs #
____
____

Location: ____
____
____

Notes/Sketch of site:
____
____
____
____
____
____
____

TRANSECT: ___________ SITE: _________________ T;______ R:_____ S:_____ Date:__________
Quad 1 : UTM EAST_______________________ North _______________________ |Compass direction traveled
Quad 100 UTM EAST_______________________ North _______________________ | from Quad 1:____________

D=dead; A= Alive; M = maybe alive but looks likely dead - comment (y) yellow (h) holes etc. CODE: F=Flowering. FR = fruit

	< 1 cm			1.1-3			3.1-5			5.1-7			7.1-9			9.1-12			12.1-15			>15 cm		
Quad	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M
1																								
2																								
3																								
4																								
5																								
6																								
7																								
8																								
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11																								
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37																								
38																								
39																								
40																								

TRANSECT: _______________ Site:___________________ Transect orientation:________________________________
Date___________________

D=dead; A= Alive; M = maybe alive but looks likely dead - comment (y) yellow (h) holes etc. CODE: F=Flowering. FR = fruit

	< 1 cm			1.1-3			3.1-5			5.1-7			7.1-9			9.1-12			12.1-15			>15 cm		
Quad	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M
41																								
42																								
43																								
44																								
45																								
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TRANSCECT: ________________ Site:____________________ Transect orientation:__________________________________
Date____________

D=dead; A= Alive; M = maybe alive but looks likely dead - *comment (y) yellow (h) holes etc.* CODE: F=Flowering. FR = fruit

	< 1 cm			1.1-3			3.1-5			5.1-7			7.1-9			9.1-12			12.1-15			>15 cm		
Quad	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M	D	A	M
81																								
82																								
83																								
84																								
85																								
86																								
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96																								
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98																								
99																								
100																								

Comments/sketch/other

<u>Instructions for activities at each location.</u>

Confirm and define the area to be surveyed on the map.

Define the area on the ground – for example use arroyos, electric lines etc to keep track of where you are. If you use flagging tape you must take it down at the end of the survey.

Take UTMs at each corner of the survey area. Use a consistent numbering system (see below). Use the GPS to take UTMs of the boundary of the survey site.

For the first one or two areas try to get a sense of consistency between biologists. [On Day One we will all need to all walk over the same area and see how similar the readings are – one day will hopefully be adequate to standardize data collection].

For each survey area:
One person starts at one of the defined sides of the site and the second person at the other side of the site and they start counting cacti throughout the site – see forms. Hopefully the people will meet in the middle having effectively covered the area. Stick in pin flags so you know where you have been while searching the site so individuals are not counted twice! They can then be removed after searching the area.

Take a photograph of the area the first cacti were found.

To try to obtain an objective measure of spatial distribution one or more transects will be run. The transect will start with the first cactus found. The transect direction will then point to SUITABLE habitat to eliminate walking in areas the cactus has no chance of occurring.

Transect line: 100 m long number of cacti in every 1 m quad (1mx0.5m). Separate form to inventory form. After the transect line is read, survey the rest of the site.

NB - the disturbance/rubbish/other impacts.

Make sure the area you surveyed is well marked and the site designation on data collection sheets agree with that marked on the map.

Make sure all necessary photos for descriptive purposes are taken.

Habitat:
Note cover by gravels
Note cryptogamic crust
If any soil other than the powdery Mancos shale
Species: Associates = within 1 foot. Otherwise community.