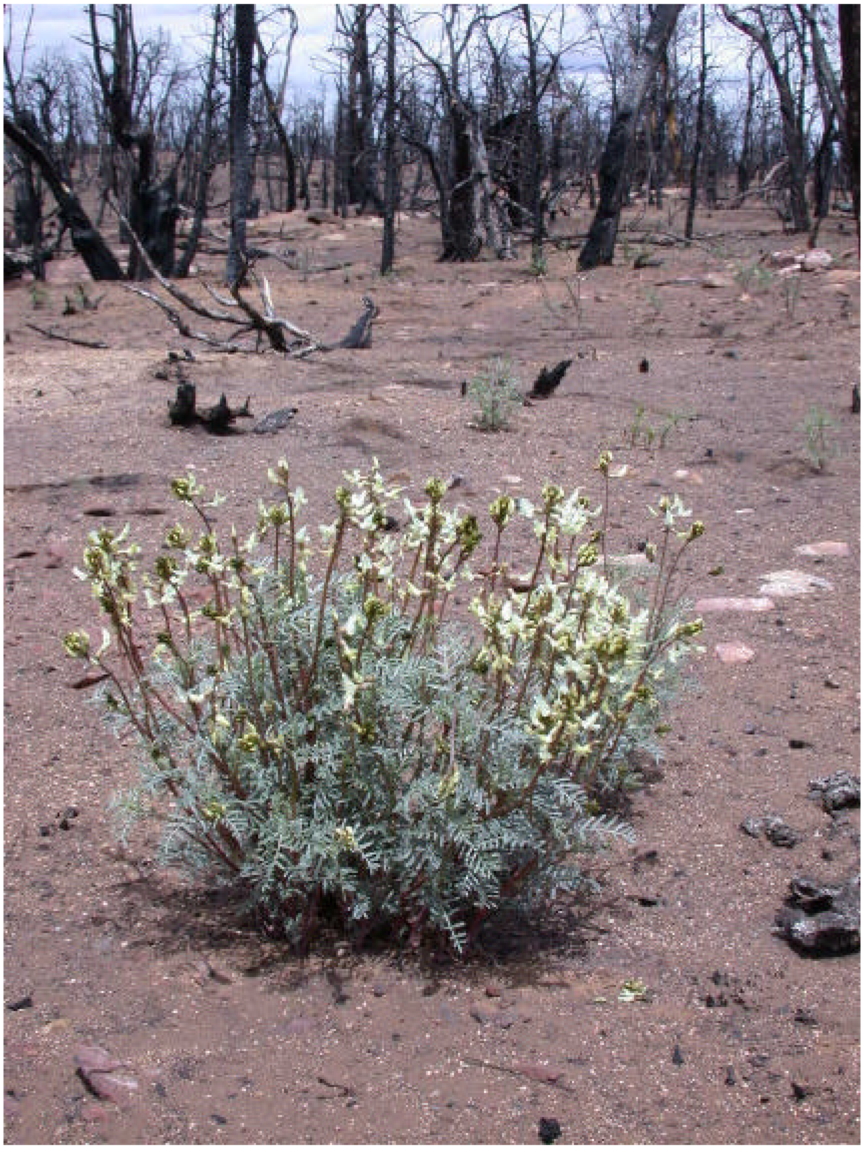
Population Status Survey of Schmoll's Milkvetch (*Astragalus schmolliae* C.L. Porter)



Final Report

June 30, 2004

Prepared For:

National Park Service
Mesa Verde National Park

Prepared By:

David G. Anderson

Colorado Natural Heritage Program
College of Natural Resources, CSU
8002 Campus Delivery
254 General Services Building
Fort Collins, CO 80523
http://www.cnhp.colostate.edu

ACKNOWLEDGEMENTS

This project was made possible by the assistance of many people. The need for the project was initially recognized by Laura Hudson, George San Miguel, Marilyn Colyer, and Anne Cully, who subsequently secured funding and human resources within the park to support the project. George San Miguel functioned as the primary contact in the park and he ensured that Natural Resource personnel were available to support the fieldwork requirements of the project. George was instrumental in project and study design development and in orienting and providing guidance to field biologists. Marilyn Colyer's long experience in the park and botanical expertise also were invaluable to the project. Her observations and monitoring efforts have added valuable insight into the natural history of Schmoll's milkvetch. Allan Loy provided the necessary technical assistance and was extremely generous with his time. His advice and expertise with GPS systems were indispensable. This project would not have been possible without the field assistance of (in alphabetical order) Jane Ashdown, Anne Black, Maureen DeCoursey, Cheri Dorshak, Jennifer Jones, David Marion, Allen Nabors, Charlotte Thompson, and Kathrine Uziel. Their dedication, hard work, and good company were incredibly valuable. Pat Oppelt offered crucial assistance with resampling permanent plots for Schmoll's milkvetch. Lisa Floyd-Hanna provided guidance on locations of *Astragalus schmolliae* on Park Mesa. Liz Bauer provided the opportunity to look at specimens in the NPS Herbarium at Mesa Verde. Thanks also are due to the Mesa Verde Park Dispatchers for their oversight of the fieldwork activities. Special thanks are due to Ron Heibert, director of the National Park Service's Colorado Plateau Cooperative Ecosystems Studies Unit at Northern Arizona University. It was Ron's decision to release the CPCESU funding that made this project possible. Dr. William A. Weber and Tim Hogan of the CU Herbarium generously offered their expertise regarding eponymy. Special thanks go to Amy Lavender for her immense contribution through her expertise with GIS. Renée Rondeau and Mike Wunder assisted with the development of sampling methodology. Georgia Doyle, Boyce Drummond, and Phyllis Pineda assisted with insect identification. Thanks also are due to Karin Decker and Susan Spackman Panjabi for their careful review of the draft manuscript.

ABSTRACT

Schmoll's milkvetch (*Astragalus schmolliae*) is among the rarest of Colorado's endemic plant species. Its global distribution is constrained almost entirely to Chapin Mesa in Mesa Verde National Park and the Ute Mountain Ute Tribal Park. Outlying patches are also known from neighboring Park Mesa, east of Chapin Mesa in Mesa Verde National Park, and from the West Chapin Spur. It is found primarily growing in red loess on mesa tops in old growth pinyon-juniper woodlands between 6,500 and 7,500 feet in elevation. It is considered critically globally imperiled (G1) by the Colorado Natural Heritage Program, a rank used for species with a restricted range, a global distribution consisting of less than five occurrences, a limited population size, or significant threats. It was formerly considered a species of concern by the U.S. Fish and Wildlife Service. In Mesa Verde National Park it is threatened by habitat change, rapid development, noxious weed invasion, and herbivory. Off-highway vehicle use and livestock grazing may threaten portions of the population outside Mesa Verde National Park, but there has been no research to determine the impacts of grazing on this species. Its limited global distribution renders it vulnerable to impacts to individuals and their habitat. Although some important research has been done on this species, the plant remains poorly understood. To facilitate its appropriate management and conservation its complete range, density, defining ecological parameters, and threats must be known. Acquiring this baseline data enables managers to act wisely on behalf of this species and will facilitate the development of long-term monitoring protocols and management plans.

In 2001 the Colorado Natural Heritage Program was contracted by Mesa Verde National Park to conduct a population status survey of Schmoll's milkvetch. Field work was conducted in 2001 and in 2003 during which the population in Mesa Verde National Park was mapped, transects were sampled to determine density and other environmental variables, natural history observations were made, permanent plots were established to monitor demographic variables, and some basic autecological research was conducted. In 2002, it was decided to postpone fieldwork on this project until 2003 because severe drought had caused most Schmoll's milkvetch individuals to remain dormant. Then, from July 29 to August 4 2002, the Long Mesa Fire burned 2,601 acres on Chapin and Park Mesas, which included 37.9% percent of the known distribution of Schmoll's milkvetch in Mesa Verde National Park. This resulted in additional concern for the viability of Schmoll's milkvetch and created new management challenges. It also provided a valuable opportunity to investigate the effects of fire on this species, which was addressed in 2003 using quantitative and qualitative methods. This project provides Mesa Verde National Park and Ute Mountain Ute Tribal Park managers with information needed to manage Schmoll's milkvetch.

All project goals were completed in 2003 except those pertaining to work on the Ute Mountain Ute Tribal Park Portion of Chapin Mesa. Population edges of all known stands were mapped. Belt transects were used to determine density in large stands. Permanent plots were established in 2003 for population monitoring and to compare demographic variables between burned and unburned areas. Seed viability and germinability was assessed. Soil nutrients, pH, conductivity, and organic matter were measured at three permanent plot sites. Other rare plant occurrences were documented as they were found, and natural history observations were made throughout the study area that were pertinent to Schmoll's milkvetch.

Schmoll's milkvetch occupies 806.1 hectares in Mesa Verde National Park on Chapin Mesa, the West Chapin Spur, and Park Mesa. Of this, 306 hectares burned in the 2002 Long Mesa Fire. Population density was determined throughout the known extent of Schmoll's milkvetch in Mesa Verde National Park. The average density of Schmoll's milkvetch in Mesa Verde National Park was estimated to be 0.060 plants per square meter in 2001, and 0.037 plants per square meter in 2003. Transects that were resampled in 2003 suggest that population density decreased 39% from 2001 to 2003. The difference in population density between burned and unburned areas in 2003 was statistically insignificant, suggesting that fire is not responsible for the population decline. However, the sample size was small, and more rigorous sampling is needed. Drought or prolonged dormancy are the most likely causes of the observed population decline. Seedlings were observed throughout the range of Schmoll's milkvetch in Mesa Verde National Park except at the population on northern Park Mesa that was burned in 1996 by the Chapin 5 Fire. There were no clear differences in seedling success between burned and unburned areas, but sites were not observed in mid- and late summer when differences might better be observed. Viability of seeds collected in 2003 is very high (between 94 and 100%). The patterns of seed germination are suggestive of a species that maintains a persistent seed bank. Recruitment appears to be highly episodic and is probably greatest in years that are moist in March through May. Plants in areas burned in 2002 displayed higher reproductive effort and vigor, and produced approximately 241 times more seeds per plant than did plants in unburned areas. It is likely that this resulted in part from depletion of pollinator resources in unburned areas. Plants in areas burned in 1996 on Park Mesa had very high vigor (possibly due to high soil nitrate levels) but did not set fruit although flowers were produced and insect visitation was observed. The implications of post fire management, and management needs that follow from the results of this study, are discussed.

TABLE OF CONTENTS

INTRODUCTION

This report presents the findings of a two-year effort to identify key ecological parameters and threats to Schmoll's milkvetch (*Astragalus schmolliae* C.L. Porter) to support management decisions that ensure the continued viability of this species. The need for this project was identified by natural resources personnel in Mesa Verde National Park who recognized the need to better understand the current status of this species in order to properly manage for its persistence. Development (e.g., construction of buildings and roads and fiber optic cable installation), fire, mechanical fuels reduction activities, weed invasion, and visitor impacts are some of the factors that have had significant effects on Schmoll's milkvetch and its habitat. However, very little is known about the response of this species to these impacts, which creates a difficult situation for land managers who wish to ensure the health of this species and avoid or mitigate possible negative impacts. This project was initiated in 2001 when the Colorado Natural Heritage Program was contracted by Mesa Verde National Park to conduct this study. Fieldwork was conducted from May 16 to June 30, 2001, and from April 28 to May 27, 2003.

Global Distribution and Management Status

The distribution pattern of Schmoll's milkvetch is typical of a narrow endemic, which are often common within their narrow range on a specific habitat type (Rabinowitz 1981). However, Schmoll's milkvetch is unusual since its habitat is apparently much more widespread. Thus the causes of its rarity are unknown. It may be the product of a recent speciation event that has not had time to spread throughout its available habitat, or its distribution may be limited by habitat variables that are not yet understood.

The global distribution of Schmoll's milkvetch consists of one large stand and a few other smaller peripheral stands on Mesa Verde (Figure 1). The majority of the population occurs in one vast, nearly continuous stand of perhaps 2,500 hectares on southern Chapin Mesa from the area south of Farview in Mesa Verde National Park (MVNP) to somewhere near the southern tip of the mesa just north of the Mancos River in the Ute Mountain Ute Tribal Park (Figure 2) (Hudson et al. 2001, pers. comm. Colyer 2001). Schmoll's milkvetch was documented on the West Chapin Spur by Friedlander (1980), where it is separated from the large stand on Chapin Mesa by the upper reaches of Spruce Canyon. Schmoll's milkvetch was found on the western rim of Park Mesa in 1997 in an area burned by the Chapin 5 Fire in 1996 (Floyd-Hanna et al. 1997, 1998, Mesa Verde National Park 2001). Subsequent survey work revealed the presence of another population on Park Mesa to the south in an unburned area (Floyd-Hanna et al. 1999), and six other small patches were found in 2003. A nearly continuous belt of red loess links the disjunct stands on Park Mesa with the large stand on Chapin Mesa. There are several specimens and observations that were taken on canyon bottoms around Chapin Mesa where seeds probably washed down from the mesa top. In 2001 *A. schmolliae* was found below the Cliff House Sandstone Formation on the steep sides of Chapin Mesa along the Spruce Canyon trail, Pictograph Point trail, and in other areas where seeds and red loess soil may have washed down from above. There are probably many such areas at the cliff bases bordering Chapin Mesa, many of which are difficult to access due to the steep cliffs characteristic of the Cliff House Sandstone Formation throughout the park. Very little is known about the distribution of *A. schmolliae* in the Ute Mountain Ute Tribal Park, where it is likely that a large proportion of the population occurs. It is known that the stand is dense on most of Chapin Mesa south of MVNP, and density of *A. schmolliae* is second only to mutton grass (*Poa fendleriana*) as a dominant understory plant

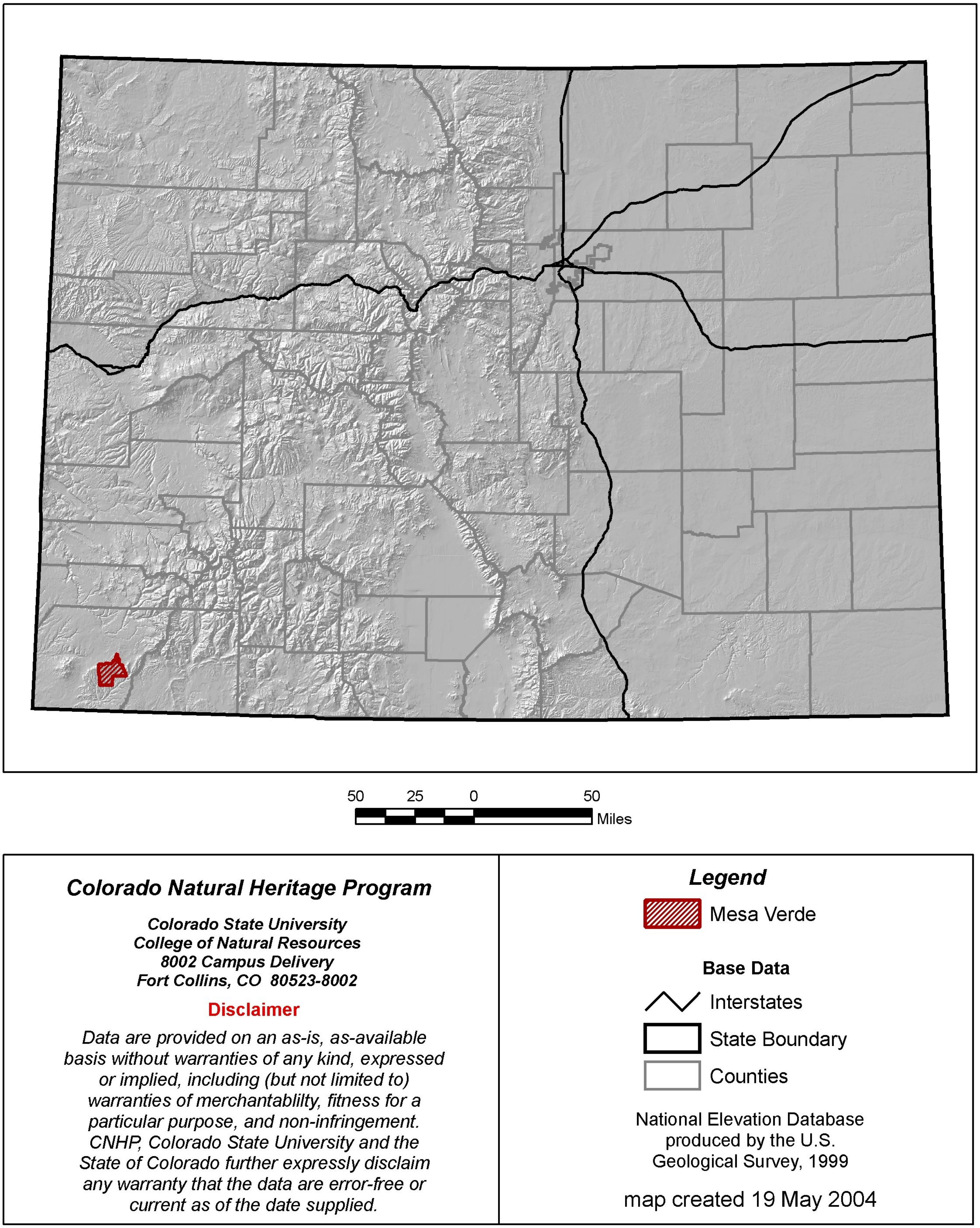
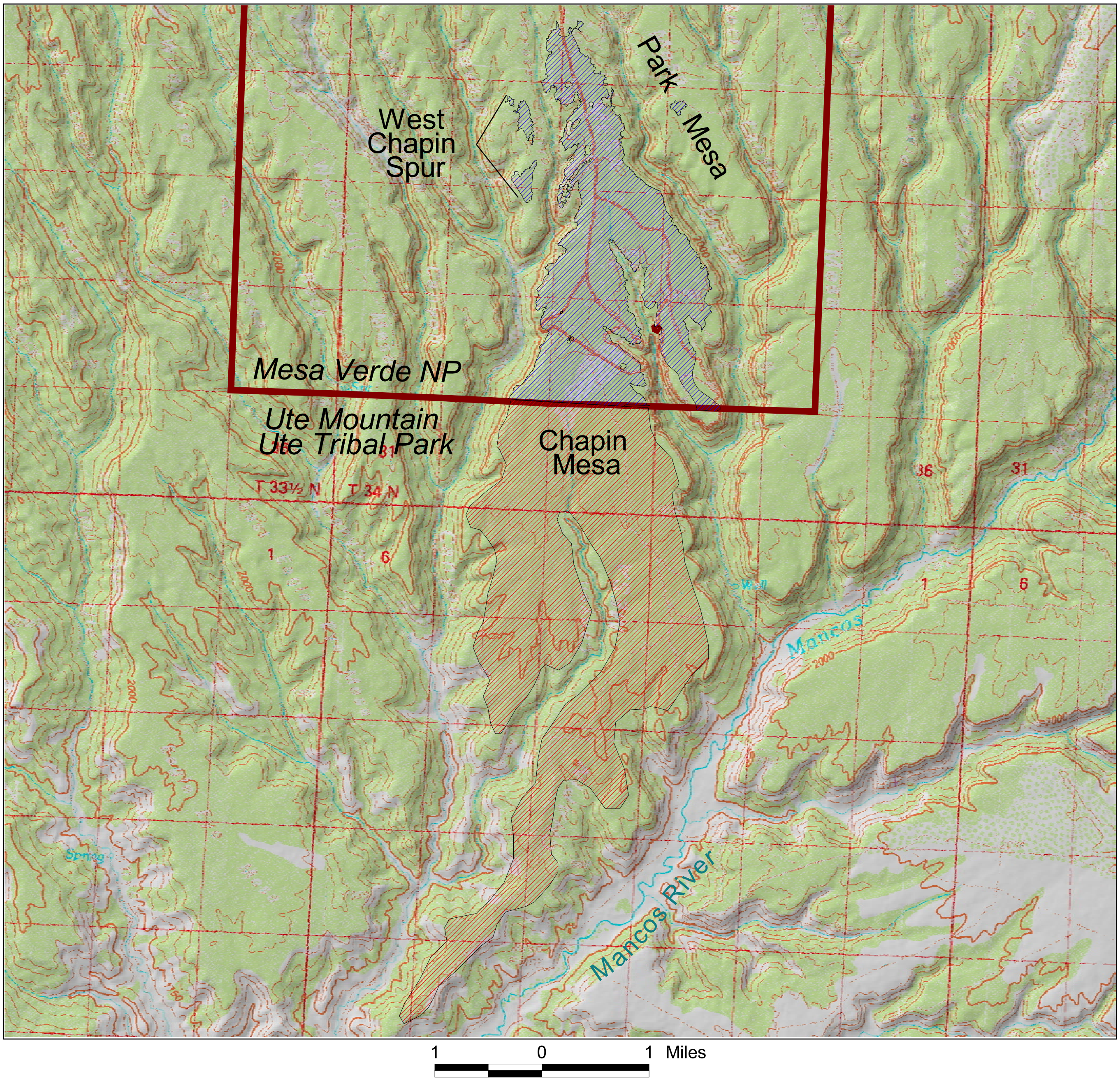


Figure 1. Location of Mesa Verde National Park in Colorado.



Colorado Natural Heritage Program

Colorado State University
College of Natural Resources
8002 Campus Delivery
Fort Collins, CO 80523-8002

map created 15 June 2004

Disclaimer

Data are provided on an as-is, as-available basis without warranties of any kind, expressed or implied, including (but not limited to) warranties of merchantability, fitness for a particular purpose, and non-infringement. CNHP, Colorado State University and the State of Colorado further expressly disclaim any warranty that the data are error-free or current as of the date supplied.

Legend

Schmoll's Milkvetch Global Range

- Known Distribution
- Probable Distribution

Base Data

- Interstates
- NPS Property Line
- State Boundary
- Counties

National Elevation Database and Digital Raster Graphics produced by the U.S. Geological Survey, 1999

Figure 2. The known distribution of Schmoll's milkvetch in Mesa Verde National Park, and the probable distribution in the Ute Mountain Ute Tribal Park, relative to major landscape features and jurisdictional boundaries.

(pers. comm. Colyer 2002). It is likely that other stands remain to be discovered within MVNP, particularly on Park Mesa.

Because its global range is highly restricted, Schmoll's milkvetch is currently considered critically globally imperiled (with a natural heritage imperilment rank of G1) by the Colorado Natural Heritage Program (Colorado Natural Heritage Program 2004). Typically, plants ranked as G1 have a global distribution consisting of less than five occurrences, have a small total population size, or have significant threats to their long-term viability. Schmoll's milkvetch is not federally listed as threatened or endangered. It was formerly listed as a Category 3 species by the US Fish and Wildlife Service following the recommendations of Peterson (1981). This listing was later amended to C2, but these designations were later dropped by the US Fish and Wildlife Service. It is listed by the Center for Plant Conservation among their National Collection of Endangered Plants (Center for Plant Conservation 2001).

Despite its global rarity, Schmoll's milkvetch is quite common within its extremely localized range. Within its occupied area there are few areas larger than 0.25 hectares where plants are not present and the current study estimates that within MVNP alone there are more than a quarter of a million individuals, although density declined approximately 39% between 2001 and 2003 (please see the Results section of this report for details). Schmoll's milkvetch is arguably among the more common plants in the pinyon-juniper woodlands of southern Chapin Mesa.

History of Knowledge

Schmoll's milkvetch was first collected in 1890 by Alice Eastwood, but because the specimen was no longer in flower it was misidentified as a relative of *Astragalus coltonii* (Peterson 1981). It was not formally recognized as a separate species until 1945 when C.L.

Porter described it (Porter 1945). It was named after Dr. Hazel Marquerite Schmoll, who was a curator of botany at the Colorado State Museum. She collected the type specimen in 1925 that Porter used to describe the species. Rupert Barneby included Schmoll's milkvetch in his two volume Atlas of the North American *Astragalus* (1964). Weber and Wittmann (2001) speculate that this species is the result of a hybridization event between *Astragalus scopulorum* and *A. lonchocarpus*. The first thorough field assessment of Schmoll's milkvetch was done in 1979 and 1980 by Joseph Friedlander, then a graduate student at Colorado State University, as a part of his masters thesis research. Along with Schmoll's milkvetch, Friedlander also studied the Cliff Palace milkvetch (*Astragalus deterior*) and the Mesa Verde stickseed (*Hackelia gracilenta*), also globally rare plants endemic to Mesa Verde. Friedlander was the first to thoroughly map the occurrences of these species in MVNP and his maps were the only source of information on the overall distribution of these species in MVNP prior to this study. Another field investigation was done in 1980 by William Harmon to assess the suitability for federal listing of Schmoll's milkvetch. The report following from this work recommended that the species be federally listed as "sensitive" (category C3) (Peterson 1981). This recommendation was later amended to C2 (Hessl and Spackman 1995). Natural resource staff at MVNP have continuously monitored the three permanent plots established in 1980 by Friedlander (Colyer 1980-2000). Following the Chapin 5 fire in 1996, two isolated patches of Schmoll's milkvetch were found on Park Mesa (Floyd-Hanna et al. 1997, 1998). Plants in burned areas were observed to resprout and produce seeds the year after the fire at this site, and seedlings were observed (Floyd-Hanna et al. 1997, 1998). Floyd-Hanna (1999) also observed a strong positive correlation between total annual precipitation and density of Schmoll's milkvetch and documented competitive interactions with musk thistle (*Carduus nutans*).

Overall there has been very little research on Schmoll's milkvetch and detailed studies are warranted. Information is lacking regarding the autecology and life history of Schmoll's milkvetch and such knowledge would make a significant contribution to the conservation and management of the species.

Eponymy

Two spellings of the specific epithet for Schmoll's milkvetch are found in the literature. The original spelling used by Porter (1945) and by Barneby (1964) is "*schmollae*." To remain consistent with recommendations in the International Code of Botanical Nomenclature, the ending of the epithet was changed to "*schmolliae*" sometime in the 1970's or 1980's (the first usage found of the new spelling was in Peterson (1981)). Chapter 6, article 75(D) of the International Code of Botanical Nomenclature (International Association of Plant Taxonomy 2000) offers recommendations for correct endings of epithets based on a personal name. When an incorrect gender ending is originally applied by the author, as in the case of Schmoll's milkvetch, the correct ending (in this case "*iae*" instead of "*ae*") can be applied without changing the original authorship. Thus, although Porter's original spelling of the epithet was technically incorrect, he remains cited as the original author of the species ("*Astragalus schmolliae* Porter"). However, at least one author (Isely 1998) has recently used the spelling "*schmollae*," and because the code offers only recommendations in cases such as this, this too is an acceptable spelling in the literature. The "*schmolliae*" spelling is used here to remain consistent with the International Code of Botanical Nomenclature recommendations and with most treatments of this taxon (Peterson 1981, Floyd-Hanna et al. 1999, Kartez 1999, Weber and Wittmann 2001, Hartman and Nelson 2001, International Legume Database and Information Service 2002, Missouri Botanic Garden 2002, USDA, ARS, National Genetic Resources Program 2002, NatureServe 2004, USDA, NRCS 2004, and other authors).

Classification and Description

Schmoll's milkvetch is a member of the family Fabaceae (legume family). As such it has leaves typical of many of the legumes, with numerous small leaflets borne on a central rachis. The foliage and stems of Schmoll's milkvetch are cinereous (ash-colored due to a covering of short hairs). This is a useful diagnostic characteristic in telling it apart from *Astragalus scopulorum,* which also occurs throughout Chapin Mesa. *A. scopulorum* has leaves that are sparsely hairy to glabrous, giving it a very green appearance. Schmoll's milkvetch is a plant of modest stature, typically 30 to 60 cm tall with one to several stems branching from an underground root crown. The flowers are creamy white and borne on a terminal raceme. The fruit, a pod, is 3 to 4 cm long, pendulous, and usually slightly decurved (curving downward). This is another useful diagnostic characteristic in distinguishing it from *Astragalus scopulorum*, which has recurved fruits with a deep sulcus (groove) on the abaxial surface. *Astragalus wingatanus* can also be readily distinguished from Schmoll's milkvetch when in flower or in fruit, since it has purple and white flowers and smaller, flattened fruits. It also does not have the upright habit of Schmoll's milkvetch. For Barneby's complete technical description of Schmoll's milkvetch see Appendix 1.

Schmoll's milkvetch has a deep taproot that can exceed 40 cm in length and is probably much longer, which enables the plant to exploit water resources deep in the soil (Friedlander 1980, pers. comm. George San Miguel 2001). From the low success rate of transplantation efforts it appears that it cannot survive if the taproot is severed (pers. comm. San Miguel 2001).

Habitat Summary

The habitat for Schmoll’s milkvetch is dense piñon-juniper woodland of mesa tops in the Mesa Verde area (Friedlander 1980). Schmoll’s milkvetch is found in both sunny and shaded locations (Peterson 1981). It prefers deep, reddish loess soils and is generally less common near cliff edges and in ravines where the soil is shallower. The loess soils have been deposited on the mesa tops over the past one million years and are still being deposited today (Griffitts 1990).

Phenology and Life History

Schmoll’s milkvetch plants emerge in early spring and usually begin flowering in later April or early May. Flowering continues into early or mid-June (Barneby 1964, Friedlander 1980, Peterson 1981, Spackman et. al. 1997). Fruit set begins in late May and occurs through June, and by late June most fruits have dehisced and released their seeds. The fruits dehisce while still attached to the plant. The typical lifespan of Schmoll’s milkvetch is not known. Colyer (pers. comm. 2002 speculates that individuals may live up to 20 years. During very dry years, as observed in 2002, Schmoll’s milkvetch can remain dormant with no above ground biomass production (pers. comm. Marilyn Colyer 2003). The species appears to flourish in growing seasons that follow wet winters, when most plants produce above ground shoots and produce numerous flowers.

Pollination Ecology

As in many legumes with papillionaceous (butterfly shaped) flowers, Schmoll’s milkvetch flowers require a strong insect for pollination, such as a bee, because the floral morphology is such that the insect must force itself between the petals to pollinate the flower. Schmoll’s milkvetch appears to be an obligate entomophile, requiring pollination by insects to set fruit (Friedlander 1980). Thus, any management actions on behalf of Schmoll's milkvetch will need to take into consideration the pollinators of the species.

Human Impacts

Many activities within and around the park have resulted in considerable localized impacts to Schmoll's milkvetch, and such impacts are ongoing. Some anthropogenic impacts within the occupied habitat of Schmoll's milkvetch include construction (roads, pathways, buildings, and buried cables and pipelines), visitor impacts, and mechanical reduction of hazardous woodland fuels accumulations. Indirect human impacts that may also affect Schmoll's milkvetch include weed infestations, erosion, and possibly post-fire management practices. Use of pesticides (including insecticides, herbicides, and algacides) throughout MVNP for weed or other pest control may also have impacts on Schmoll's milkvetch or its pollinators. Decreasing air quality throughout the Four Corners Area is probably having a large biological impact on MVNP. Over the last 10 years the pH of rainfall in the area has dropped from 5.5 to 4.9, which may be affecting numerous biological processes including seed and seedling survival of Schmoll's milkvetch (pers. comm. Marilyn Colyer 2002).

Fire History

Two recent fires have impacted a large portion of the known population of Schmoll's milkvetch in MVNP. The Chapin 5 Fire burned the northernmost populations known on Park Mesa in 1996. Preliminary studies of the impacts of fire on Schmoll's milkvetch were initiated shortly after the discovery of these populations (Floyd-Hanna et al. 1999). In 2002 the Long Mesa Fire burned much of the MVNP portion of Chapin Mesa and impacted a large portion (37.9 %) of the known population of Schmoll's milkvetch in MVNP.

GOALS OF THE PROJECT

The goals of this project were intended to provide an autecological overview of this species that can support efforts to provide appropriate management and stewardship throughout the range of Schmoll's milkvetch. Unfortunately, it was not possible to visit the portion of the population that resides on the Ute Mountain Ute Tribal Park, but the results of this study are relevant for the management of this portion of the population as well. Specific goals for this project included the following:

- Map the entire distribution of Schmoll's milkvetch in Mesa Verde National Park
- Measure population densities throughout the range of the species, emphasizing heavily-used areas
- Determine defining ecological parameters that control the temporal and spatial variation in population density and health
- Provide information relative to Schmoll's milkvetch that will be useful in planning activities to enable land managers to reduce impacts on this species resulting from human activities, weeds, and other factors
- Recommend additional research to further assist with the management of Schmoll's milkvetch

METHODS

The entire population (with the exception of a few small outlying stands) is found on Chapin Mesa in one vast stand of perhaps 2,500 hectares. Within this patch, Schmoll's milkvetch is present almost continuously with few voids exceeding 0.25 hectares. Thus, assessing the range-wide status and density of this species requires atypical sampling methods for rare plant population assessment. To assess the density of Schmoll's milkvetch, a sampling regime was developed that was rapid, repeatable, and that could be used to extrapolate density estimates for the entire area surveyed. Selected environmental variables were also quantified to investigate species-environment relationships, and census information was documented to assess the density and specific local impacts to the population. See the following sections for detailed descriptions of the methods employed.

Mapping Schmoll's milkvetch

One of the primary goals of this project was to generate accurate geographical data on location and density of population to permit managers to mitigate future impacts on Schmoll's milkvetch. An accurate determination of the population density throughout the occupied area required the use of GPS/GIS and quantitative sampling. The detailed data generated by this project in 2001 will be a useful resource for land managers for planning activities in MVNP.

Four types of geographical data were gathered in the field in 2001 and 2003: polygons, lines, points, and transects. These are discussed in detail below. A Trimble GPS datalogger was used in the field in 2001, and a Trimble Geoexplorer III in 2003, to generate these features (points, lines, polygons, and transects). The GPS units were set to record a point every five seconds. When mapping line, polygon, or transect features, the points were connected to create the feature. To create a point feature, 60 points were taken in series at a location and the average of the points was used to generate a final point. During times of poor GPS satellite geometry (PDOP greater than 6.0) data could not be collected. Each feature was attributed in the field using a data dictionary that was custom-made for this project. Items that were qualified or quantified in the data dictionary were associated weed species, estimated canopy cover, disturbance, number of individuals, buffer direction and width, association with bitterbrush or yucca, and overall quality of the occurrence of Schmoll's milkvetch (excellent, good, fair, poor). Additional data and comments were also documented for each feature in a field notebook. These included general observations regarding Schmoll's milkvetch or other species and technical notes (recording datalogger files and dates).

All GPS data were post-processed and differentially corrected to create highly accurate map features. The estimated locational accuracy was recorded in the attribute table of each feature in the ArcView shapefiles, which are one of the final products of this research. All data were reprojected to UTM zone 13 NAD 27 for work done at CNHP. Data supplied to MVNP are projected in UTM zone 12 NAD 83. The estimated occupied area within MVNP (see Table 3) was determined in ArcView 3.2a (ESRI 1992-2000), using the Xtools extension, version of June 1, 2001.

Polygons

Discrete, bounded patches of Schmoll's milkvetch were mapped using polygons. The boundaries of these polygons often followed roads, trails, building edges, or natural features such as cliffs. Polygons were used to map Schmoll's milkvetch in highly-developed areas (research, maintenance, and headquarters loops). All plants within 10 meters of the polygon edge were counted to allow for extrapolation of the population size within the polygon. All plants were counted in polygons 20 meters in diameter or less.

Lines

Lines were used to map the edges of the population of Schmoll's milkvetch. Edges may be along the cliffs of Chapin Mesa or they may be in the vicinity of developed areas. Lines were used where the boundaries of occupied areas were too large to use polygons. 10-meter buffers were applied to lines on the side occupied by Schmoll's milkvetch and all plants within the buffer were counted to allow for extrapolation of population density. This work was begun in

2001 and completed in 2003. Composite polygons were created from the line features denoting population edges to create features that portray the extent of most of the population in Mesa Verde National Park. Some minor editing was required to join lines together to form a cohesive boundary.

Points

Points were used to map very small occurrences. A buffer size was entered into the data dictionary equal to the radius of the occurrence. All plants were counted within these occurrences. Points were occasionally used to mark where a line began or ended, or to mark other features of interest. Occurrences of *Astragalus deterior* also were marked with points when they were encountered.

Belt Transects

Belt transects were used to assess the density of Schmoll's milkvetch throughout its occupied habitat in MVNP on Chapin Mesa in 2001. As with Friedlander's transects sampled in 1979 and 1980, their function was to determine the population density and extrapolate a population size estimate. However, the 2001 sample design also permitted the interpolation of a population density surface throughout the area sampled in 2001.

The belt transects were oriented in an east-west direction and extended across the mesa from edge to edge (see Figure 3). They were 10 meters wide and spaced 500 meters apart following UTM northing lines projected in NAD 27 Datum, Zone 12T. On the West Chapin Spur, the same methodology was used but UTM northing lines projected in NAD 83 Zone 12T were used instead. Each belt transect was broken into 100-meter segments within which a census of the observed plants was taken and tallied. Thus, coarse variation in population density

Figure 3 is not available.

could be measured in two dimensions throughout the study area. In 2001, 17,236 linear meters of belt transects were sampled on Chapin Mesa, for a total sampled area of 172,360 square meters. In 2003 an additional 3,446 linear meters of belt transects were sampled on the West Chapin Spur, adding 34,460 square meters to the sampled area. In 2001, transects were walked using a compass for orientation, a small recreation-grade GPS (Garmin model 12 CX) to follow the UTM northing lines, and a Trimble datalogging GPS to record the position of the transect. Because the accuracy of the hardware used for orienting transects was somewhat limited, the transect lines strayed up to 15 meters north or south of the UTM northing lines in 2001. However, the use of the datalogger to record the precise position of the transect line and the post-hoc differential correction of the data will allow transects to be repeated at a future date using a real-time GPS. In 2003, a Trimble Geoexplorer 3 GPS unit was used that displayed UTM coordinates while a line feature was being created, so reliance on the Garmin GPS for navigation was obviated and transects could more closely follow UTM northing lines, with deviations rarely exceeding 10 meters.

A point shapefile was generated from the centroids of 100-meter belt transect segments using Arc View 3.2a (ESRI 1992-1999), resulting in 197 attributed points for generating the density grid on Chapin Mesa. From these points, a density grid was interpolated using the splining algorithm in Spatial Analyst 2.0 (ESRI 1992-2000). The density grid was clipped using the mapped population boundary, which was not possible in preliminary analyses included in Anderson (2001). Density of populations on West Chapin Spur and Park Mesa was determined based on 2003 transect data for the two southernmost populations on West Chapin Spur. For the northernmost population on West Chapin Spur and for Park Mesa populations, density was determined by extrapolation from the number of individuals counted within 10 meters of the population edge. These data were also used to estimate total abundance for these populations. At the north Park Mesa population that had been monitored by Floyd-Hanna et al. (1999), a complete census and the mapped population boundary were used to calculate density in 2003.

All apparent impacts on Schmoll's milkvetch were documented as they were observed during all mapping activities. These impacts are summarized in the Results section. Two impacts, browsing and caterpillar damage, were quantified along belt transects by counting the number of affected individuals in 2001. In 2003, browsing impacts were documented and burned and unburned areas were noted.

Quantifying Density Change by Resampling Transects

In 2003 transects were selected for resampling in burned and unburned areas. 38 belt transect segments were resampled, for a total resampled area of 38,100 square meters (or 3,810 linear meters). Transects were resampled to test two null hypotheses regarding effects of fire and year on plant density. Thus, abundance, evidence of browsing, and whether an area was burned or unburned was documented in the resampled transect segments. Two transect segments included both burned and unburned areas and were thus excluded from the statistical analyses. The first null hypothesis is that there were no differences in density in burned and unburned transect segments in 2003. An unpaired Student's *t*-Test was used to compare density in burned and unburned transect segments in 2003 for testing this hypothesis. The second null hypothesis was that there was no difference in density between belt transect segments sampled in 2001 and resampled in 2003. A paired Student's *t*-Test was used to compare resampled density in 2003 with density sampled in 2001. Please see Figure 3 for the locations of the resampled transects.

Population Monitoring

Three permanent plots were established in 2003 to investigate population structure, life history, recruitment success, reproductive effort, and vigor (Figure 3). Two plots were established at sites that were burned in 2002, and one was established in an unburned site (Table 1). Each plot is 10 x 10 meters and is divided into four quadrants, each 5 x 5 meters (Figure 4). The plot corners were permanently marked with metal stakes. The UTM coordinates of the northwest corner of each plot were determined to facilitate future monitoring (Table 1). A 50 meter tape was used to delineate each plot and quadrant during sampling.

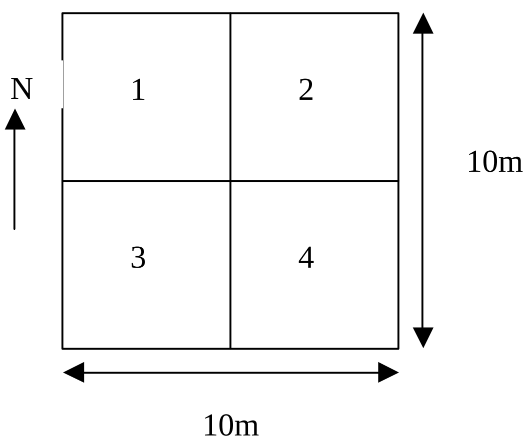
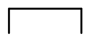


Figure 4. Basic layout of permanent plots at Sun Temple, Sun Point, and West Chapin Spur.

Within each quadrat, all Schmoll's milkvetch seedlings were marked using a nail with flagging that were placed one inch to the north of each plant. In subsequent visits some of these markers were replaced with numbered plastic plant tags. At West Chapin Spur and Sun Temple, all plants in quadrant 1 were marked as seedlings, juveniles (plants at least one season old without reproductive structures) and adults (plants bearing reproductive structures). At Sun Point, juveniles and adults were marked in all four quadrants because there were very few representatives of these stages at this plot. Each age/stage class was marked by tags on which the tops were cut as follows:

Seedling: 

Juvenile: 

Adult: 

Each plot was visited two or more times in 2003 to assess demographic parameters (Table 2). Baseline data were gathered at the first visit to each plot (number of seedlings, juveniles, and adults) and plants were marked. During revisits, new seedlings were documented and marked, and mortality was documented.

Two congeners, *Astragalus scopulorum* and *A. wingatanus*, were present within two of the monitoring plots. *Astragalus scopulorum* was present in the West Chapin Spur plot, and *A. wingatanus* was found in the Sun Temple plot. In both cases the seedlings were readily distinguished from those of Schmoll's milkvetch by their vesture, color, and leaflet size and shape.

Reproductive effort (RE) and vigor (V) were assessed nondestructively using the methods of Floyd-Hanna et al. (1999) on marked adults at Sun Point and Sun Temple. It was also determined at Park Mesa although individuals were not marked at this plot. RE was assessed by counting flowers, fruits, and aborted flowers on each marked adult. At Sun Temple, there were enough adults in Quadrant 1 to provide an estimates of RE, but at Sun Point all four quadrants were sampled. V was assessed by counting the number of stems per plant. Destructive methods in which biomass is measured directly would provide much better measures of relative biomass allocation, but these methods are labor intensive and inappropriate for use within the monitoring plots.

Table 1. Summary descriptions of the three permanent plots and Park Mesa. Data were gathered for reproductive effort and vigor only at Park Mesa during a single visit from a 5x5 meter area equivalent to one quadrant of the permanent plots. Coordinates are in NAD 83 Zone 12, and mark the northwest corner of each plot.

Plot Name	UTM Coordinates	Burned/ Unburned	Seedlings Marked	RE/V determined
Sun Point	N4115000 E723000	Unburned	Yes	Yes
Sun Temple	N4116000 E723000	Burned 2002	Yes	Yes
West Chapin Spur	N4119000 E721000	Burned 2002	Yes	No
Park Mesa	N4122000 E723000	Burned 1996	No	Yes

Table 2. Calendar of visitation to the three permanent plots and to Park Mesa in 2003.

Plot Name	Visit 1	Visit 2
Sun Point	5/5	5/24
Sun Temple	5/5	5/21, 5/26
West Chapin Spur	5/4	5/23
Park Mesa	5/25	--

Seed Viability, Seed Germination, and Fecundity

Seed viability and seed germination was assessed by Annette Miller at the National Center for Genetic Resources Conservation using seed collected by Marilyn Colyer on June 23, 2003 from two burned sites north of Fewkes Canyon, near the Sun Temple permanent plot. Insufficient seed was available from unburned sites to obtain samples for seed viability and germination assessment. Seeds were prepared for testing by removing them from the fruits and cleaning them using standard techniques (utilizing sieves and blown air). Of the approximately 6,000 seeds collected by Colyer, 100 were randomly selected for viability and germination testing from each of two sites for a total of 200 seeds. Seed viability was tested by exposing the embryos of 50 seeds from each site to a solution of 2,3,5-triphenyltetrazolium chloride (the TZ test). Seed germination was tested by planting 50 seeds from each site in moist towels in a 15-25 degree C incubation chamber.

To estimate fecundity, the number of seeds per fruit were counted from fruits collected at Cedar Tree House (burned in 2002) and from the Headquarters Loop (unburned) on May 27 2003. At each location, five fruits were collected from each of three different plants. After drying, the fruits, which were not yet ripe, were dissected and the number of large (presumably viable) and small (presumably not viable) seeds were counted from each.

Soil Analysis

Soil samples were collected from three plot locations in 2003 (Sun Point, Sun Temple, and Park Mesa) to provide preliminary data on soil texture, pH, salinity, and nutrients. The samples were taken using a trowel to collect the upper five centimeters of soil. Soil near the surface was tested to characterize the seedling germination environment in burned and unburned areas. The samples were analyzed by the Colorado State University Soil, Water, and Plant Testing Laboratory.

Long-Term Monitoring

As a part of his masters thesis research, Joseph Friedlander established three permanent plots in 1980 to enable the park to monitor the population of Schmoll's milkvetch. Census data were gathered from two of the three permanent plots in 2001. Permanent plot #1 was not resampled because the boundaries could not be discerned. All three plots were resampled in 2003. GPS points were obtained at each plot to facilitate future relocation. Number of individuals, age class (mature, immature, dead), species richness, and percent canopy cover were noted at each plot. MVNP Park staff have data from these plots from 1980 to 2000. In 2003, permanent monumentation was installed at these plots to enhance their ability to withstand fire, reduce uncertainty, and facilitate their continued monitoring in perpetuity. Field notes and raw data from the monumentation and resampling were provided to Natural Resources Staff at MVNP but these data were not analyzed.

Natural History Observations

Extensive notes were taken to document natural history observations pertinent to Schmoll's milkvetch. These are distilled and included in this report where relevant.

RESULTS AND DISCUSSION

Population Distribution

Figure 5 shows the known extent of Schmoll's milkvetch in MVNP as mapped in 2001 and 2003. Six new small populations were found on Park Mesa in 2003 (shown on the map as points). It is likely that other small isolated populations exist on Park Mesa.

Three stands were identified on the West Chapin Spur in 2003. This was surprising, because Friedlander (1980) had included most of the West Chapin Spur within the distribution of Schmoll's milkvetch in his thesis. This area was surveyed in 2003 after the Long Mesa Fire, so it is possible that portions of the population were extirpated by the fire. Some areas of West Chapin Spur were apparently burned severely, and there are many areas where no plants or seeds of any species appeared to have survived. However, Schmoll's milkvetch was also not found in a few patches of unburned forest where it had been reported by Friedlander (1980) on West Chapin Spur. This suggests that the range may have contracted due to environmental change, drought, or natural metapopulation dynamics over the last 24 years. There is some evidence suggesting that incomplete documentation is the most likely reason for the differences between Friedlander's map and the distribution observed in 2003. After the fieldwork on West Chapin Spur was completed in 2003, a copy of Friedlander's thesis was provided to the Colorado Natural Heritage Program by The Nature Conservancy. It includes a large topographic map,

Figure 5 is not available.

hand-drawn by Friedlander, entitled “Known Ranges of Rare Plant Species in Mesa Verde National Park, Colorado, December 1979.” This map is not included in the copy of his thesis deposited at the CSU library. For West Chapin Spur, this map includes only a small mark directly west of the Research Loop, where Schmoll’s milkvetch was also documented in 2003. However, the map included in his thesis includes a large polygon that circumscribes most of the southern portion of West Chapin Spur. From these maps it appears that Friedlander may have only observed Schmoll’s milkvetch west of the Research Loop but assumed that it was more widespread on West Chapin Spur than it actually is for unknown reasons. Attempts were made in 2003 to find Joseph Friedlander through internet searches to enquire about the disparities observed on West Chapin Spur, but these attempts were not successful.

Much of the habitat on the southern portion of West Chapin Spur appears to be of poor quality for Schmoll’s milkvetch. The soil is thin, and the topography is irregular and rocky. Such sites do not often support large numbers of individuals on Chapin Mesa.

Some recurring patterns of distribution were consistently observed in 2001 and 2003. Generally, plants were not found on the distal portions of points and promontories, such as the Balcony House overlook area, where a side canyon causes a narrowing of the mesa top. Soils tend to be thin in these areas and they may not contain the water resources necessary to sustain Schmoll’s milkvetch due to better drainage. These areas also have higher exposure to wind. Near the edges of the mesa top, density usually declined among patches of exposed bedrock. Plant distribution tends to follow ravines and pouroffs far downslope, and Schmoll’s milkvetch may continue well into the canyons in some cases. This distribution pattern is well illustrated near Cedar Tree House where Schmoll’s milkvetch is scattered along a pouroff far into a side canyon.

The distribution of Schmoll's milkvetch relative to the Long Mesa Fire of 2002 is shown in Figure 6. Of the 806.1 hectares of Mesa Verde National Park occupied by Schmoll's milkvetch, 306 (37.9%) hectares were burned in 2002.

No plants were observed on the canyon bottoms in 2001 and 2003, although historical reports have noted plants on the side canyon bottoms where red loess has collected (Colorado Natural Heritage Program 2004). The Cliff House Sandstone Formation is a formidable barrier to searching the slopes of the mesas. In some areas where the mesa slopes below the Cliff House Sandstone could be accessed, scattered plants and clumps were found. These areas included the Pictograph Point trail, Spruce Canyon below the Headquarters Loop, and the old Tourist Trail to Park Mesa. It is likely that many of the inaccessible slopes below Chapin Mesa also are populated by occasional patches or individuals of Schmoll's milkvetch.

Population Density and Size

Population size, density, and occupied area were determined for the entire portion of the population known in MVNP in 2001 and 2003 (Table 3, Figure 7). These parameters are all significantly lower than those estimated by other researchers for Chapin Mesa (including West Chapin Spur (Friedlander 1980) and Park Mesa (Floyd-Hanna et al. 1999). Resampled transects on Chapin Mesa showed a 39% population decline from 2001 to 2003 (please see the discussion under the Resampling Transects in 2003 in Burned and Unburned Areas section of this report.

In the present study, the total population of Schmoll's milkvetch in MVNP is estimated at 294,499 individuals in 806.12 occupied hectares, with an average density of .037 plants per meter (Table 3). In 1980, Friedlander observed an average density of 0.2 plants per square meter in his study plots, which is almost twice as dense as the densest stands observed in the present study, and five times denser than the average density estimated for MVNP in 2003. Friedlander

Figure 6 is not available.

Figure 7 is not available.

Table 3. Density and population size estimates of Schmoll's milkvetch in Mesa Verde National Park extrapolated from 2001 and 2003 data. These data were gathered in different years during which population size apparently declined 39%. Thus, to summarize these data they are transformed here based on the observed 39% decline. The transformed data are included here in italics; figures determined based on untransformed data are not in italics. Occupied area was assumed to have remained unchanged for the purposes of these calculations.

	2001	**2003**
Estimated population size on Chapin Mesa:	454733	*277387*
Estimated population size on Park Mesa:	*3605*	2199
Estimated population size on West Chapin Spur:	*24448*	14913
Estimated total population size of Schmoll's milkvetch **in MVNP:**	**482786 plants**	**294499 plants**
Area occupied on Chapin Mesa:	781.88 hectares	
Area occupied on Park Mesa:	3.29 hectares	
Area occupied on West Chapin Spur:	20.95 hectares	
Total occupied area in MVNP:	**806.12 hectares**	
2001 density of Schmoll's milkvetch on Chapin Mesa:	.058 plants / m^2	*.035 plants / m^2*
2003 density of Schmoll's milkvetch on Park Mesa:	*.110 plants / m^2*	.067 plants / m^2
2003 density of Schmoll's milkvetch on West Chapin Spur:	*.117 plants / m^2*	.071 plants / m^2
Density of Schmoll's milkvetch **in MVNP (determined using belt transect data):**	**.060 plants / m^2**	**.037 plants / m^2**

extrapolated a total population size estimate of 2,100,000 plants, using 1,050 hectares as the "total habitat size" for Schmoll's milkvetch. It is assumed here that this population size estimate is for MVNP only. Floyd-Hanna et al. (1999) measured densities of .80 to .91 on Park Mesa, and .41 to 1.4 in the Glades area of Chapin Mesa.

Several factors may account for the differences between the density observations. The methods employed in the various studies may account for some of the differences. The use of transects in the present study to interpolate density is not subjective and covered a large portion of the population of Schmoll's milkvetch. Friedlander (1980) probably selected study sites nonrandomly for his research where density may have been locally higher. On Park Mesa, The methodology employed by Floyd-Hanna et al. (1999) was not described in great detail and thus could not be replicated to resample the plots at this site. Density was determined at this site in 2003 by mapping the population edge and counting all plants seen within the patch.

Environmental and autecological factors may also explain some of the observed differences in density. Aboveground growth is reduced in dry years (such as 2000 and 2001), and enhanced in summers after wet winters (Colyer 1980-2000, pers. comm. Marilyn Colyer 2002). Because Schmoll's milkvetch can remain dormant in dry years, comparing average number of plants with aboveground parts per unit area between years does not necessarily equate to measuring changes in the true density or population size. Alternatively, the observed difference may reflect an actual decrease in the population size due to climate change, acid rain, increased impacts from herbivory, lack of pollinators, or other factors. On Park Mesa it is possible that the decline resulted from competition with grasses (please see the Implications of Fire and Management for Population Viability section of this report for a detailed discussion).

Densities of Schmoll's milkvetch in the belt transect segments sampled in 2001 were used to estimate mean local densities throughout the occupied area in MVNP, shown in Figure 7. 2003 data were used to estimate density in the outlying populations on West Chapin Spur and Park Mesa, as described in the Methods section of this report. Figure 7 best illustrates the course-scale (100 to 500 meters) spatial variation in density of Schmoll's milkvetch throughout its occupied area in MVNP. Density of Schmoll's milkvetch was consistently high approaching the western rim of Cliff Canyon in the area east of the Mesa Top Loop Road. Pockets of high density also were found west of The Glades and elsewhere around the Mesa Top Loop area. Although it is not reflected in the transect data, the north rim of Fewkes Canyon (where the Sun Temple permanent plot was established) also has a high density of Schmoll's milkvetch.

The splining interpolation algorithm used to generate the density map makes assumptions that may or may not be valid for Schmoll's milkvetch. The result shown in Figure 7 is a gently varying surface based on the assumption that distance from a sample point does not decrease potential density. If distance from a sample point does decrease the potential density, then another algorithm would be more appropriate for creating the density surface.

Fine-scale (10 to 100 meters) variation in density also was observed. Scattered Schmoll's milkvetch individuals are broadly distributed, but most of the observed individuals were found in clumps containing 10 to 100 or more individuals (Figure 8). The clumps varied in size but are generally 4 to 15 m^2 in size. The clumped distribution of Schmoll's milkvetch was a major

Figure 8. An example of the clumped distribution typical of Schmoll's milkvetch. This clump is along the access road that connects to the Ute Mountain Ute Tribal Park, south of the Mesa Top Loop. This is a particularly large clump; most are approximately ¼ this size.

complicating factor in identifying an appropriate sampling protocol for determining relative density throughout the population. Although no quantitative data were routinely gathered regarding the association of the clumping pattern with environmental variables, many informal observations were recorded in an attempt to elucidate the underlying causes of the pattern.

General Natural History Observations

Although no soil moisture measurements were taken, some clumps of Schmoll's milkvetch appeared to be associated with slightly more mesic microsites, based on the patterns of drainage and topography observed in their vicinity. The clumps often were associated with flat, mostly bare patches of soil that were observed throughout Chapin Mesa. Many of these features appeared to be slightly depressed areas where water might pool briefly during heavy rainfall events or perhaps where meltwater may linger in the winter and springtime. The reason for the lack of duff and litter on these features is not known. However, it is possible that ants are clearing detritus in these areas. Some of these features had ant mounds within them. Colyer (pers. comm. 2002) speculates that ants may be the cause of the clumped distribution, since ants can create areas with friable soil, reduced bulk density, enhanced precipitation penetration, and enhanced soil nutrient levels. Plants often were found in small drainages and erosional features, although not consistently. It is possible that although these areas are more moist, they are not suitable microsites for Schmoll's milkvetch because the soil is shallower in them and Schmoll's milkvetch prefers deep soils.

Schmoll's milkvetch plants sometimes were observed in high numbers rooted under the canopy of bitterbrush (Figure 9). In some locations this association seemed very strong and had all the appearances of a nurse plant relationship such as those observed often in desert ecosystems (Niering et al. 1963, Barbour et al. 1987). It is possible that plants growing beneath

Figure 9. Schmoll's milkvetch (just below center of frame) rooted under the canopy of bitterbrush (*Purshia tridentata*).

the canopy of bitterbrush were protected from browsing, and percent soil moisture may have been higher as well in these microsites due to reduced insolation. It also appeared that plants growing under bitterbrush were less likely to be attacked by butterfly larvae (see discussion of insect larvae impacts on the following page). Interestingly, Friedlander (1980, p. 55) noted that Schmoll's milkvetch was not found in forest openings dominated by bitterbrush. The Sun Point permanent plot contains large amounts of bitterbrush, but seedlings were most abundant in open portions of this plot in 2003. More research is needed to determine the degree of spatial autocorrelation of Schmoll's milkvetch and bitterbrush and the ecological importance of this relationship.

In April and May of 2003, numerous plant taxa were observed in burned areas on West Chapin Spur and Chapin Mesa, some of which are not commonly seen in unburned areas. These include *Androsace septentrionalis, Collinsia parviflora, Corydalis aurea, Delphinium nuttallianus,* and *Gilia ophthalmoides*. *Amelanchier utahensis* and *Quercus gambelii* were resprouting vigorously on canyon sides, and *Yucca baccata* was resprouting in less intensely burned areas on the mesa tops. Surface soils in burned areas were hydrophobic and appeared likely to prevent absorption of rainwater to some extent. However, gentle soaking rains occurred periodically through May that resulted in moist soils, although the surface rapidly dried afterward. Abundant evidence of animal activity was apparent from deer, hare, lizard, and beetle tracks in the fine soil.

Evidence of the drought was apparent in the vegetation of Chapin Mesa. Along some unburned transects, dead bitterbrush (*Purshia tridentata*) was observed that may have died during the 2002 drought. The permanent plot at Sun Point contains several dead *P. tridentata* individuals that dominate nearly half the plot. Some individuals appeared to be sprouting at the base after the canopy died in the Mesa Top Loop area. Some *Yucca baccata* individuals were observed to have many dead leaves in 2003 that may also have resulted from drought stress.

The total annual precipitation measured at Mesa Verde National Park in 2002 was 11.0 inches (Western Regional Climate Center 2004). This is well below the average between 1948 and 2003 (17.5 inches). However, five years (1948, 1950, 1956, 1977, and 1989) were drier, and there is much variation in precipitation (Figure 10). While this appears to have had observable effects on vegetation, it seems likely that drought is common enough that affected species, included Schmoll’s milkvetch, will recover from its effects.

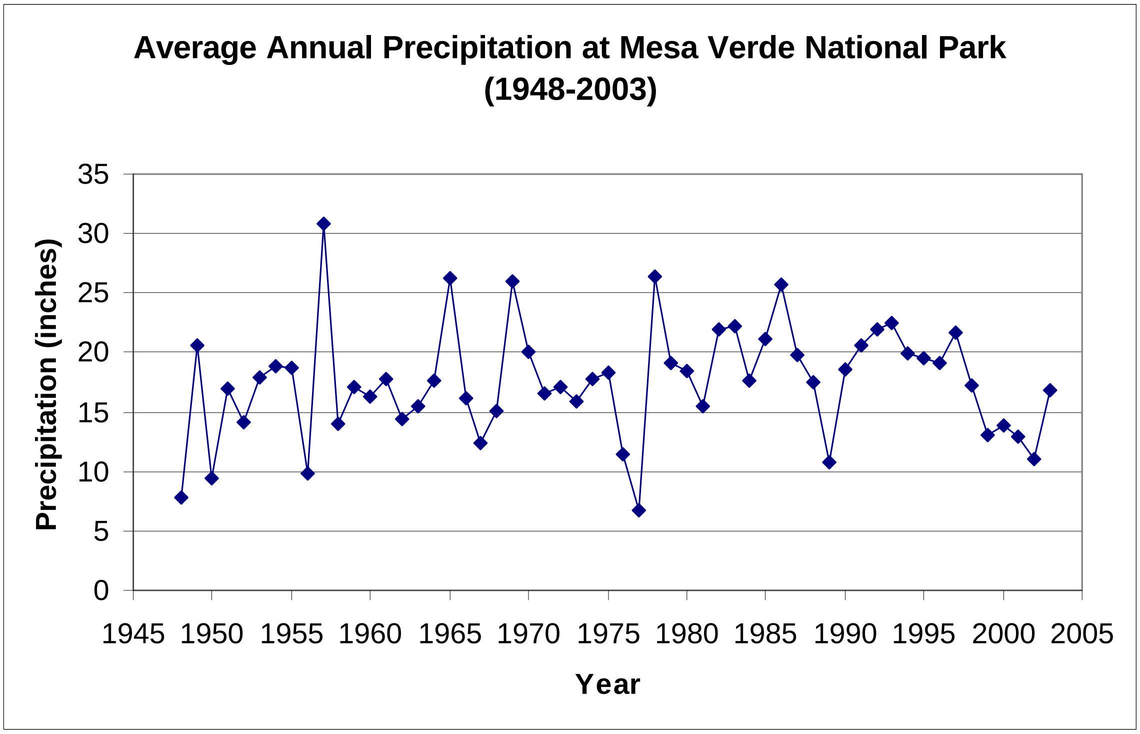


Figure 10. Average Annual Precipitation at Mesa Verde National Park from 1948 through 2003. Data obtained from the Western Regional Climate Center (2004).

Other Rare Plant Occurrences

The Cliff Palace Milkvetch (*Astragalus deterior*) was encountered in several locations in 2001 and 2003. Four previously documented occurrences were updated and two small previously unknown patches were identified in 2001, and two other occurrences were revisited in 2003. Element occurrence data gathered regarding this species have been entered into the Colorado Natural Heritage Program's Biodiversity Tracking and Conservation System (Colorado Natural Heritage Program 2004).

Density Comparisons in Resampled Transects

Resampling of transects in 2003 permitted the use of statistical methods for examining the effects of burning and drought on population density. The mean density of all transect segments was similar in 2001 prior to burning (an average of 0.074 plants/m^2 in transect segments that subsequently burned, and 0.070 plants/m^2 in transect segments that did not burn). Density declined in both burned and unburned transect segments between 2001 and 2003. The decline in density was slightly lower in burned transect segments than in unburned, but the difference in density in 2003 between burned and unburned transect segments was not statistically significant (Table 4), suggesting that burning did not significantly impact plant mortality. It is important to note, however, that this is based on a small sample size, and other patterns may emerge with a more robust sample. Mean density for the resampled transects went from 0.070 plants/m^2 in 2001 to 0.043 plants/m^2 in 2003. These data suggest that the total population of Schmoll's milkvetch decreased by 39% between 2001 and 2003. From these data there is no evidence that Schmoll's milkvetch benefits from fire.

Because the unpaired Student's *t*-Tests determined no significant difference between density in burned and unburned transect segments, these populations were lumped to compare density in 2001 and 2003 using a paired Student's *t*-Test. The decline in density from 2001 to 2003 is highly statistically significant (Table 5). Thus, whatever caused this decline had a much greater effect on density (and thus population size) than did fire. Several factors may be responsible for the density decline. It is possible that plants may remain dormant for more than one year, and that some plants in both burned and unburned areas remained dormant in 2003. However, the availability of spring moisture suggests that most plants probably did not remain dormant in 2003. Therefore, mortality due to drought in 2002 is the most parsimonious explanation for the density decline. It is interesting that fire did not seem to exacerbate the impact of drought. Perhaps removal of competitors caused by fire increases soil water availability for Schmoll's milkvetch in burned areas, even though the heat of the fire and increased insolation probably reduces water availability near the surface. Thus removal of competitors may compensate for greater water loss in burned areas, while in unburned areas insolation and evaporative water loss is probably not as great but competition for water and transporative water loss are probably much greater. This may also account to some extent for the greater reproductive effort and vigor observed in burned areas. If density is lower in unburned areas than in burned areas, it is possible that mortality after the Long Mesa Fire (August 4, 2003) was greater in unburned areas than in burned areas. In the scenario described above, continued use of limited soil water resources by non-dormant competitors in late summer in unburned areas may have resulted in lower soil water potential which may have increased mortality of dormant Schmoll's milkvetch individuals.

Table 4. Summary of unpaired Student's *t*-Test results comparing density in burned and unburned transect segments in 2003.

	Burned	**Unburned**	**Result**
N (transect segments)	15	23	--
Mean	0.056	0.036	--
SD	0.052	0.028	--
t	--	--	1.55
P	--	--	0.13

Table 5. Summary of paired Student's *t*-Test results comparing density in 2001 and 2003 in resampled transect segments.

	Result
N (transect segment pairs)	38
2001 Mean	0.072
2003 Mean	0.045
P	0.0004

Analyses of Soil from Burned and Unburned Sites

Soil analysis data showed some interesting correlations with fire history and vigor of Schmoll's milkvetch (Table 6). Soil organic matter and soil nitrate appear related to the time elapsed since fire. Soil organic matter was lowest at Sun Temple (burned in 2002), intermediate at Park Mesa (burned in 1996) and highest at Sun Point (unburned). Conversely, nitrate was highest in burned plots, and very low at Sun Point. It is not known if these variables control the ability of Schmoll's milkvetch to reproduce. Plant vigor appears to be related to soil nitrate levels, although reproductive effort and fecundity do not, since soil nitrate was highest at Park Mesa and lowest at Sun Point. Phosphorus was very high at Sun Temple, suggesting that fire in 2002 greatly increased the level of this nutrient. It is not known if this affects the fecundity of plants at this site. These results should be interpreted cautiously due to small sample sizes.

Table 6. Summary of edaphic variables determined in the upper 5 cm of soil at three sites in 2003.

	----------paste-----------		Lime	%	Texture
Location	**pH**	**EC mmhos/cm**	**Estimate**	**OM**	**Estimate**
Park Mesa	7.2	0.8	Low	4.3	Loam
Sun Temple	7.8	0.7	High	2.8	Sandy Loam
Sun Point	7.7	0.9	High	6.0	Loam

	AB-DTPA Extract (ppm)						
Location	**NO_3-N**	**P**	**K**	**Zn**	**Fe**	**Mn**	**Cu**
Park Mesa	19.5	7.1	365	0.9	22.3	10.0	1.1
Sun Temple	11.3	19.6	252	1.4	27.2	13.7	1.0
Sun Point	3.3	8.4	328	1.1	30.8	5.1	1.4

Demography

Seedlings of Schmoll's milkvetch have not been observed often, and they are not seen at all in most years (pers. comm. Colyer 2002). No seedlings were observed in 2001, but they were abundant in both burned and unburned areas in 2003 throughout Chapin Mesa and the West Chapin Spur, suggesting that recruitment is highly episodic. While seedlings were observed in many locations, their distribution was patchy and they were not observed in some areas, including populations on Park Mesa that burned in 1996. Seed germination is probably greatest after moist springs such as that of 2003. It has been hypothesized that fire promotes seed germination (Floyd-Hanna et al. 1999) but data and observations made during this study in 2003 do not support this hypothesis.

Numerous seedlings were present in permanent plots at Sun Temple, Sun Point, and West Chapin Spur (Tables 7-9). Because these locations were chosen subjectively based on the

Table 7. Summary of demographic data from the Sun Temple permanent plot. “Present” are all plants seen on the first visit, and plants seen again on the second visit, alive or dead. “Total live” are all living plants in the quadrant on the second visit. “New” are seedlings that emerged after previous visit, or were unnoticed before; juveniles and adults in this category were not noticed previously due to concealment by logs or dense vegetation. “Missing” are plants that were previously marked; a marker was found but no plant was next to it. These plants were probably consumed by herbivores. “Browsed” seedlings are dead, but browsed juveniles and adults are not. “Desiccated” seedlings are dead.

		5/5/2003	**5/21/2003 (seedling data gathered on 5/26/03)**					
		total	total live	present	new	missing	browsed	desiccated
Quadrant 1	Seedlings	24	31	24	8	0	1	
	Juvenile	46	46	46				
	Adult	21	22	22				
Quadrant 2	Seedlings	18	17	16	4	2		3
	Juvenile	18	22	22				
	Adult	6	6	6				
Quadrant 3	Seedlings	4	6	4	2	0		
	Juvenile	12	16	16				
	Adult	9	9	9				
Quadrant 4	Seedlings	26	31	22	10	4		1
	Juvenile	32	37	37				
	Adult	8	8	8				
Total	**Seedlings**	**72**	**85**	**66**	**24**	**6**	**1**	**4**
	Juvenile	**108**	**121**	**121**	**0**	**0**	**0**	**0**
	Adult	**44**	**45**	**45**	**0**	**0**	**0**	**0**
	Seedling attrition	**11**						
	Seedling Delta N	**13**						

Table 8. Summary of demographic data from the Sun Point permanent plot. "Present" are all plants seen on the first visit, and plants seen again on the second visit, alive or dead. "Total live" are all living plants in the quadrant on the second visit. "New" are seedlings that emerged after previous visit, or were unnoticed before; juveniles and adults in this category were not noticed previously due to concealment by logs or dense vegetation. "Missing" are plants that were previously marked; a marker was found but no plant was next to it. These plants were probably consumed by herbivores. "Browsed" seedlings are dead, but browsed juveniles and adults are not. "Desiccated" seedlings are dead.

		5/5/2003	**5/24/2003**					
		total	total live	present	new	missing	browsed	desiccated
Quadrant 1	Seedlings	33	39	33	11	0	2	3
	Juvenile	5	7	5	2	0	0	0
	Adult	7	6	7	0	0	1	0
Quadrant 2	Seedlings	65	60	59	10	3	2	4
	Juvenile	4	7	4	3	0	0	0
	Adult	5	5	5	0	0	0	0
Quadrant 3	Seedlings	13	13	12	2	0	1	0
	Juvenile	0	2	0	2	0	0	0
	Adult	0	1	0	1	0	0	0
Quadrant 4	Seedlings	9	11	8	4	0	1	0
	Juvenile	3	2	2	0	0	0	0
	Adult	3	2	3	0	0	1	0
Total	**Seedlings**	**120**	**123**	**112**	**27**	**3**	**6**	**7**
	Juvenile	**12**	**18**	**11**	**7**	**0**	**0**	**0**
	Adult	**15**	**14**	**15**	**1**	**0**	**2**	**0**
Seedling Attrition		**16**						
Seedling Delta N		**3**						

Table 9. Summary of demographic data from the West Chapin Spur permanent plot. "Present" are all plants seen on the first visit, and plants seen again on the second visit, alive or dead. "Total live" are all living plants in the quadrant on the second visit. "New" are seedlings that emerged after previous visit, or were unnoticed before; juveniles and adults in this category were not noticed previously due to concealment by logs or dense vegetation. "Missing" are plants that were previously marked; a marker was found but no plant was next to it. These plants were probably consumed by herbivores. "Browsed" seedlings are dead, but browsed juveniles and adults are not. "Desiccated" seedlings are dead.

		5/4/2003	**5/23/2003**					
		present	total live	present	new	desiccated	browsed	missing
Quadrant 1	Seedlings	51	39	40	3		4	11
	Juvenile	5	7					
	Adult	0	0					
Quadrant 2	Seedlings	7	8	5	3			2
	Juvenile	1	1					
	Adult	1	1					
Quadrant 3	Seedlings	1	0	1		1		
	Juvenile	1	1					
	Adult	0	0					
Quadrant 4	Seedlings	15	16	15	4		3	
	Juvenile	1	1					
	Adult	2	2					
Total	**Seedlings**	**74**	**63**	**61**	**10**	**1**	**7**	**13**
	Juvenile	**8**	**10**	**0**	**0**	**0**	**0**	**0**
	Adult	**3**	**3**	**0**	**0**	**0**	**0**	**0**
	Seedling Attrition	**21**						
	Seedling Delta N	**-11**						

presence of numerous plants and seedlings (to facilitate population monitoring), the numbers of seedlings in each plot cannot be used to compare germination rate between burned and unburned sites. However, valid comparisons can be made between seedling survivorship in the plots.

Seedling survivorship was monitored in April and May of 2003 at the three permanent population monitoring plots. Seedlings were still emerging when the plots were established in early May and newly emerged seedlings were documented at all three plots during the second visit. During May the net change in the number of seedlings increased at Sun Point and Sun Temple but decreased at West Chapin Spur.

Seedlings grew vigorously through May at Sun Point, Sun Temple, and West Chapin Spur. In late April and early May they typically had one or two leaves (Figure 11), and by late May many had begun to branch and had between 2 and 7 leaves (Figure 12).

There was no change observed in the populations of juveniles and adults. The differences observed between the first and second visits are due to individuals that were missed on the first visit due to concealment by dense vegetation or by logs.

The causes of seedling mortality were documented when they could be observed, and they differed between the three plots. In order of their respective impacts, the two sources of seedling mortality observed in May 2003 were browsing and desiccation. Many seedlings were missing when the plots were revisited (a marker was found but there was no seedling next to it). These seedlings were probably lost to herbivory. Occasionally evidence of browsing was observed where the seedling stem was found but no leaves remained (Figure 13). However, it is possible that seedlings eaten by mammals were pulled out of the ground, which would leave little evidence given the small size of the seedlings in May. The missing seedlings from each plot are thus assumed to have also been lost to herbivory. Lagomorphs (either the desert cottontail or black tail jackrabbit) and mule deer are the most likely herbivores to have eaten the seedlings. Tracks of a rabbit were seen in the West Chapin Spur plot (Figure 14), as well as mule deer tracks (Figure 15). Browsing was responsible for much of the seedling attrition at this location.

Mortality attributed to desiccation was 36% at Sun Temple, 25% at Sun Point, and 5% at West Chapin Spur (Figure 16). Since desiccation was already observed to be a significant

Figure 11. Seedling of Schmoll's milkvetch at Sun Point on 5/5/03.

Figure 12. Seedling seedling of Schmoll's milkvetch at Sun Temple on 5/26/03.

Figure 13. Browsed seedling of Schmoll's milkvetch at West Chapin Spur on 5/23/03.

Figure 14. Rabbit tracks in the permanent plot on West Chapin Spur (where browsing was heavy) on 5/23/03.

Figure 15. Mule deer tracks in the West Chapin Spur permanent plot on 5/23/03.

Figure 16. Desiccated seedling of Schmoll's milkvetch at Sun Temple on 5/21/03. This plant is still green but is completely dried and brittle.

source of mortality in May, it is possible that it also results in considerable mortality in June (before the onset of monsoonal rains) and later summer months as well. However, seedlings of Schmoll's milkvetch are known to allocate much of their biomass production to root growth (Friedlander 1980), so it is possible that seedlings that survive long enough to reach deeper soil layers by midsummer may not succumb easily to desiccation.

Numerous seedlings were seen at the southernmost population known from Park Mesa on May 1, 2003 where there has been no fire in hundreds of years (Floyd et al. 2000). Despite a concerted effort to find them, no seedlings were observed in areas burned on Park Mesa in 1996. Floyd-Hanna et al. (1999) had reported finding abundant seedlings at these locations in 1997 after the fire, when the area was in an early successional stage. There was also no seed production observed at these locations in 2003. No seedlings or plants were found in areas burned in 2002 on Park Mesa, but they had not previously been documented in this area.

Seed Germination and Relationship with Fire

The viability of Schmoll's milkvetch seeds collected in the burned area near Sun Temple in 2003 was very high, approaching 100% (Table 10). Mechanical scarification (clipping) was required to promote the germination of most seeds, as is common among legumes including *Astragalus* (Baskin and Baskin 2001). Subsequent "coaxing" (removal of seed coats) was also required for many seeds. The germination pattern exhibited by Schmoll's milkvetch is suggestive of a species that maintains a persistent seed bank of long-lived seeds (pers. comm. Miller 2003). That the seeds, though viable, required much effort to germinate suggests that even in good years some seeds may remain dormant. This pattern would be adaptive if summer conditions are likely to cause high seedling mortality even when abundant spring moisture is available.

It is not known if dormancy is broken by heat, which would suggest that Schmoll's milkvetch is adapted to fire. However, the fact that it has persisted in the absence of fire through most of the last millennium is strong evidence that fire is not a requirement for germination. A robust crop of seedlings was observed in 2003 in both burned and unburned areas, which also demonstrates that fire is not required. However, seedling survivorship may differ in burned and unburned areas. Permanent plots established in this study were not resampled at the end of summer in 2003, so survivorship of seedlings through their first summer could not be determined. Determining this important demographic variable is a high research priority for Schmoll's milkvetch.

The longevity of seeds of Schmoll's milkvetch is not known, but many legumes, including members of *Astragalus*, have long-lived seeds. Bowles et al. (1993) germinated seeds of *A. neglectus* from herbarium specimens that were 97 years old.

Table 10. Results of viability tests of the seeds of *Astragalus schmolliae*. Seeds were collected by Marilyn Colyer on June 23, 2003. Sample 1 was collected between Fewkes Canyon and Cliff Canyon. Sample 2 was collected in the same general area but on the west side of the Mesa Top Loop Road. Both samples were collected in areas burned in 2002. Data provided by Annette Miller.

TZ Test (50 seeds per sample)

	Sample 1	**Sample 2**
live from hard	46	47
live from swollen	1	3
dead swollen	2	0
abnormal	1	0
total live by TZ	**94%** of 50 seeds	**100%** of 50 seeds

Sample 1: Germination (50 seeds): Planted 11/18/2003

	Normal		Dead	Comments
Date	from swollen	from clipped		
11/18				planted in towels, 15-25 deg.
11/24			2	46 hard clipped (1 swollen)
12/1	1			Moved from towel to top of blotter in box
12/5		8		
12/11		18		
12/16		9		Removed seed coats from clipped ungerminated seeds
12/19		11		
12/22		1		
Total	**1**	**47**	**2**	
Germination		**96%**		

Sample 2: Germination (50 seeds): Planted 11/18/2003

	Normal		Dead	
Date	from swollen	from clipped		
11/18				planted in towels, 15-25 deg.
11/24			1	44 hard clipped (5 swollen)
12/1	1	2		Moved from towel to top of blotter in box
12/5		6		
12/11		9		Removed seed coats from clipped ungerminated seeds
12/16		16		
12/19		8		
12/22		2		
1/5				Removed seed coats from 4 swollen ungerminated seeds
1/14	4	1		
Total	**5**	**44**	**1**	
Germination		**98%**		

Pollinator Observations and Hypotheses

Several insect visitors were observed visiting the flowers of Schmoll's milkvetch in 2003 (Table 11). Flower visitation was recorded in areas burned in 1996 on Park Mesa and in areas burned in 2002 on Chapin Mesa, but not in unburned areas at Park or Chapin Mesas. Insect visitors included a butterfly (Figure 17), a long horned beetle, a syrphid fly, anthophorid bees (Figures 18), and a megachilid bee (Figure 19) (pers. comm. Drummond 2004). Bees were the most active visitors, and appeared to be effective pollinators of Schmoll's milkvetch. Anthophorid bees (Figure 18) observed on April 28 and May 20, 2003 were very active visitors and pushed themselves into the flowers. The papillionaceous flowers of Schmoll's milkvetch require such visitors for their pollination because the flowers must be "tripped" to expose the anthers and stigma. Honeybees (*Apis melifera*) were not observed visiting Schmoll's milkvetch. Insect visitors were observed by Friedlander (1980), who noted visitations most commonly by bumble bees (*Bombus* sp.) and also by beeflies (*Bombylius* sp.), and butterflies.

Although flower production occurred on Park Mesa in areas burned in 1996, no fruitset was observed in these populations. This suggests that reproduction might be pollinator limited, although visits by megachilid bees were observed on Park Mesa on May 25, 2003 (Figure 19).

Table 11. Insect visitors observed in 2003 on the flowers of *Astragalus schmolliae*.

Date	**Taxonomic I.D.**	**Common Name**	**Location**
4/28	Syrphidae	Syrphid Fly	North of head of Cliff Canyon
4/28	Anthophoridae spp.	Digger Bee	North of head of Cliff Canyon
5/21	*Colias eurytheme* Boisduval	Orange Sulphur	CCC Loop
5/25	*Strictoleptura canadensis cribripennis* LeConte	Long Horned Beetle	Northern Park Mesa
5/25	Megachilidae	Leaf Cutting Bee	Northern Park Mesa

Figure 17. An adult orange sulphur butterfly (*Colias eurytheme*) captured and released on Chapin Mesa in the CCC loop on May 21, 2003.

Figure 18. Anthophorid bee visiting the flowers of Schmoll's milkvetch. Photo taken April 28, 2003 north of the head of Cliff Canyon on Chapin Mesa.

Figure 19. Megachilid bee visiting the flowers of Schmoll's milkvetch. Photo taken May 25, 2003 at a small population burned in the 1996 Chapin 5 Fire.

Reproductive Effort and Fecundity

Large differences in reproductive effort and fecundity were observed between Sun Point, Sun Temple, and Park Mesa. Fruit production was very high at Sun Temple (burned) (Table 12), where 31% of reproductive structures at Sun Temple were fruits by May 22. However, fruit production was almost non-existent at Sun Point (unburned) (Table 13), and was not observed at the northern Park Mesa population (burned in 1996) (Table 14). Plants in areas burned in 2002 were often observed to be heavily laden with fruits (Figure 20), while very little fruit production was observed in unburned areas (Figure 21). It is possible that the flush of nitrate made available by the fire provided the nutrients needed for individuals to produce large numbers of fruits. However, soil nitrate appears to be highest at Park Mesa (Table 6) where there was no fruit production at all.

Fruit production was extremely limited in unburned areas in 2003. Considerable effort was required to find any legumes on plants in unburned areas in 2003. This was also observed by Colyer (pers. comm. 2003) when she attempted to collect seeds from unburned areas in June of 2003 for viability tests. Fruits made up only 0.43% of reproductive structures at Sun Point by May 24, where only three fruits were observed out of 684 reproductive structures in the plot.

Fruit production in unburned areas was not quantified in 2001, but it was observed regularly as evinced by Figure 22. It is possible that pollinators were drawn to the burned area in 2003, leaving plants in unburned areas without sufficient pollinator resources.

Table 12. Reproductive effort and vigor of adults in Quadrant 1 at Sun Temple on May 22, 2003.

plant id	vigor (# of stems)	total reproductive structures	flowers	aborted	fruits
1	2	4	1	3	0
2	4	106	7	68	31
3	4	133	54	34	45
4	4	84	38	8	38
5	2	37	1	35	1
6	--	9	0	9	0
7	4	179	56	75	48
8	2	70	28	32	10
9	20	420	56	201	163
10	4	151	39	86	26
11	2	25	5	20	0
12	2	21	5	16	0
13	4	132	65	35	32
14	2	17	0	4	13
15	2	201	34	77	90
16	4	114	29	40	45
17	1	39	22	1	16
18	2	110	46	21	43
19	4	52	20	26	6
20	1	60	13	23	24
21	5	86	40	29	17
22	2	16	3	13	0
TOTAL		**2066.00**	**562.00**	**856.00**	**648.00**
PERCENT			**27.20**	**41.43**	**31.36**
MEAN	**3.67**	**93.91**	**25.55**	**38.91**	**29.45**
FECUNDITY					**402.64**

Table 13. Reproductive effort and vigor of adults in all quadrants at Sun Point on May 22, 2003.

Quadrant	plant id	vigor (# of stems)	total reproductive structures	flowers	aborted	fruits
1	1	3	0	0	0	0
1	2	1	18	0	18	0
1	3	2	16	14	2	0
1	4	3	20	11	9	0
1	5	3	83	51	32	0
1	6	3	60	9	51	0
1	7	1	10	0	10	0
1	8	1	40	0	40	0
2	1	2	101	27	73	1
2	2	1	50	21	27	2
2	3	4	24	24	0	0
2	4	1	34	30	4	0
2	5	2	55	56	9	0
3	1	4	*	3	0	0
4	1	5	11	11	0	0
4	2	3	12	11	1	0
4	3	3	91	82	9	0
4	4	1	59	41	18	0
TOTAL			**684**	**391**	**303**	**3**
PERCENT				**57.16**	**44.30**	**0.44**
MEAN		**2.39**	**40.24**	**21.72**	**16.83**	**0.17**
FECUNDITY						**1.67**

*Plant is strangely stunted with many unexpanded buds.

Table 14. Reproductive effort and vigor of adults at Park Mesa on May 25, 2003.

plant id	vigor (# of stems)	total reproductive structures	flowers	aborted	fruits
1	3	18	18	0	0
2	5	37	37	0	0
3	23	396	359	37	0
4	9	170	164	6	0
5	19	122	122	0	0
6	4	41	38	3	0
7	14	65	63	2	0
TOTAL		**849**	**801**	**48**	**0**
PERCENT			**94.35**	**5.65**	**0.00**
MEAN	**11.00**	**121.29**	**114.43**	**6.86**	**0.00**
FECUNDITY					**0.00**

Figure 20. Typical adult Schmoll's milkvetch at Sun Temple with copious fruit production on 5/26/03.

Figure 21. Typical adult Schmoll's milkvetch in the unburned area of Chapin Mesa in 2003. This plant, photographed on 5/26/03 along the road south from the Mesa Top Loop, has not produced any fruits, and the flowers are drying and abscising from the plant. Note scars on the stem where flowers have fallen.

Figure 22. Schmoll's milkvetch in fruit in the Mesa Top Loop area in 2001. Very few fruits were observed in this area in 2003.

Many remaining flowers at Sun Temple appeared likely to produce fruits as they had somewhat enlarged ovaries, while those at Sun Point did not appear likely to produce fruits. Most flowers on plants in unburned areas were drying and abscising from the plant without producing fruits (Figure 21). These were documented at the permanent plots as "aborted." The phenology of plants at Sun Point appeared somewhat retarded, possibly because most flowers had not yet been pollinated by May 24. This was more pronounced at Park Mesa where 94% of reproductive structures on adults were flowers on May 25.

The small dataset comparing the number of seeds per fruit in plants from burned and unburned areas suggests that pollinator visitation is greater at recently burned sites. The number of large seeds per fruit appears to be greater in the plants from burned (Cedar Tree House) than in those from unburned (Headquarters Loop) areas (Table 15). The plants from the Headquarters Loop also tended to have more poorly developed seeds per fruit. Because these seeds were collected before the fruits were fully ripened they were not tested for viability. The fruits also tended to be smaller in unburned areas when they were found, although this was not quantified in 2003. Fecundity (total reproductive output per plant, i.e., number of seeds) was estimated for the Sun Point and Sun Temple plots based on the number of seeds per legume determined for Cedar Tree House and the Headquarters Loop. These estimates of seeds per fruit, combined with estimates of fruitset per plant presented in Tables 12-14, suggest that plants in burned areas produced an average of 241 times more seeds per plant than did plants in unburned areas in 2003.

While nutrient deficiency may be responsible for poor fruitset in unburned areas in 2003, the common observation of fruits on Chapin Mesa in 2001 prior to the Long Mesa Fire suggests that availability of pollinators better explains the 2003 observations. As an obligate entomophile, reproductive output is highly dependent on the availability of pollinators.

Table 15. Seeds per legume determined from two sites on Chapin Mesa on May 26, 2003.

Cedar Tree House (Burned)				**Museum Loop (Unburned)**			
plant	**legume**	**large seeds**	**small seeds**	**plant**	**legume**	**large seeds**	**small seeds**
1	1	16		1	1	8	4
1	2	14	1	1	2	8	7
1	3	16		1	3	9	5
1	4	9		1	4	6	3
1	5	14	1	1	5	6	7
2	1	15		2	1	15	
2	2	12		2	2	14	5
2	3	16	2	2	3	12	1
2	4	12	2	2	4	18	
2	5	12	4	2	5	18	
3	1	12		3	1	6	
3	2	16		3	2	5	1
3	3	9	3	3	3	8	
3	4	16		3	4	7	1
3	5	16		3	5	10	3
Mean seeds per legume		**13.67**	**2.17**			**10**	**3.7**

Vigor

Marked variation in plant vigor was observed between the three sites (Sun Point, Sun Temple, and Park Mesa) where it was measured. Vigor was highest at Park Mesa in both adults (Table 14) and juveniles (Table 16). At all three sites vigor of adults was higher than that of juveniles. However, vigor of juveniles at Park Mesa was much higher than at Sun Point and Sun Temple. Because Park Mesa adults had very low reproductive effort, while Sun Temple adults had lower vigor but extremely high reproductive effort, vigor is not a good predictor of reproductive effort or life history stage. Vigor appears to be related to soil nitrate concentration (see Table 6). However, it is not known why vigor is so high on Park Mesa while other demographic variables (fruitset, seedling recruitment) are low. Some speculation is offered in the following section.

Table 16. Summary of vigor (number of stems per plant) for juvenile (non-reproductive) plants at three plots. See tables 12-14 for data on vigor for adults.

	Sample size	Mean Vigor
Sun Point	20	1.3
Sun Temple	45	1.96
Park Mesa	72	10.06

Implications of Fire and Management for Population Viability

Data and observations made in 2003 suggest that more information is needed before fire can be considered beneficial to Schmoll's milkvetch. The biggest data gap is knowledge of recruitment success in post-fire Schmoll's milkvetch populations. Seedlings that germinated in late April and early May were observed to flourish in 2003, but observations were not made to document their survivorship later in the summer when soil water potential is likely to increase. Additional demographic data are needed to assess the relative viability of plants in burned and unburned areas.

Observations made in 2003 corroborate with earlier observations (Floyd-Hanna et al. 1999) suggesting that Schmoll's milkvetch is adapted to, or at least tolerant of, a natural fire regime. The habit of Schmoll's milkvetch suggests that it is tolerant of fire, with its deep taproot and shallowly buried root crown, to which the plant dies back during winter months. Plants can resprout following a low intensity fire if the root crown is not damaged (Floyd-Hanna et al. 1997, 1998). Reproductive effort and fecundity were clearly higher in areas burned in 2002, and vigor also appears to be greater. Thus these data from this study support to some degree the statement by Floyd-Hanna et al. (1999, pg. 9) that "conditions created by fire in the piñon-juniper woodlands actually promote the health of *A. schmolliae*." Their conclusions were based on comparisons of three years of observations from a small population found on Park Mesa in the area burned by the Chapin 5 fire with plots on Chapin Mesa. As seen in 2003 on Chapin Mesa, the plants monitored by Floyd-Hanna et al. (1999) on Park Mesa flourished in the year following fire.

The profuse show of sexual reproduction observed in 1997 on Park Mesa (Floyd-Hanna 1999) appears to be an ephemeral phenomenon. No fruit production whatsoever was observed anywhere in the area burned in 1996. This might be explained by low population levels of pollinators, although insects were observed visiting flowers at this location (Figure 19). While portions of this population were dense as reported by Floyd-Hanna et al. (1999), most plants were non-reproductive.

It appears that prolific fruiting in burned areas of Chapin Mesa may have come at the expense of fruit production in unburned areas. Thus it is possible that the net impact of burning on fecundity is less than would be suggested by the fecundity estimates determined at the Sun Temple plot. Colyer (pers. comm. 2003) has observed that pollinators seem to favor burned areas. It is possible that this behavior resulted in the depletion of pollinators in unburned areas, which would explain the near absence of fecundity observed at the Sun Point plot.

Seedlings were observed on Park Mesa in 2003 at the southern population that has not burned, but no seedlings were observed in the populations that burned in 1996 despite rigorous attempts to find them. Thus, northern Park Mesa was the only place where no seedlings were seen in 2003 within the known population boundaries of Schmoll's milkvetch. It is possible that competition with other species is precluding seedling establishment at this site, or that the seed bank has been depleted.

More research is needed to determine why no reproduction appears to be occurring at the northern Park Mesa population. Most of the area burned in 1996 on Park Mesa was observed to have very high grass cover, thus it seems likely that competition with grass species may be involved. The removal of woody vegetation appears to result in competitive release of grasses on Mesa Verde. In sites where no seeding has been done, removal of woody vegetation appears to favor *Poa fendleriana*, the most common grass species on Mesa Verde. This is seen in mechanical fuels reduction areas and in the clear zone on Chapin Mesa, where cover of *P. fendleriana* can approach 75%. Density of Schmoll's milkvetch appears low in these areas, although there are few quantitative data with which to compare density since these sites are narrow where they were traversed by transects. Casual observations in these areas suggest that plants have low reproductive effort and vigor in these sites. This is probably due to competition for water and nutrients with *P. fendleriana*. On Park Mesa, other unknown grass species (which could not be identified in May due to lack of inflorescences) have become dominant in the area burned in 1996. These species are likely to be those that were seeded onto the burned area by helicopter following the fire. Cheatgrass (*Bromus tectorum*) also comprises approximately 1/3 of the grass cover of this area (Figure 23). Given the phenological overlap of Schmoll's milkvetch seedling growth with the peak growth of *Bromus tectorum*, it is likely that the presence of *B. tectorum* in populations of Schmoll's milkvetch compromises its viability.

Invasion of weeds into burned areas is a well-known problem in MVNP. Musk thistle (*Carduus nutans*) is particularly invasive in burned areas in southern MVNP and has been observed aggressively invading areas occupied by Schmoll's milkvetch (Figures 24 and 25) (Floyd-Hanna et al. 1999, Romme et al. 2003). This species poses a significant threat to plants in burned areas. As observed by San Miguel (pers. comm. 2003), the threat of *C. nutans* is exacerbated in burned areas where there is little topographic heterogeneity to trap seeds. In 2003, the canopies of Schmoll's milkvetch individuals were probably among the best seed traps in burned areas (Figure 26). Thus, some Schmoll's milkvetch individuals have probably had the misfortune of serving as a nurse plant for a weed that might result in their eventual demise. It is not known if Schmoll's milkvetch can survive such an intensely competitive scenario, but this situation invokes the story of the strangler fig, which establishes as an epiphyte on its host tree before slowly stifling it into extirpation.

It is not known if natural succession will eventually lead to the regeneration of piñon-juniper forests similar to those that remain unburned on Mesa Verde in areas burned in 1996 and 2002. Certainly it will take hundreds of years for the forest that burned in 2002 to regenerate even under ideal conditions (Floyd et al. 2003). The presence of exotic species suggests that succession may follow a different trajectory, or may be arrested or slowed due to the

Figure 23. Invasion of Park Mesa by cheatgrass where it was burned in 1996 by the Chapin 5 fire. Photo taken 5/25/03.

Figure 24. Musk thistle invading the burned area of northeastern Chapin Mesa on 5/23/03.

Figure 25. Invasion of Chapin Mesa by Musk Thistle Photo taken on May 22, 2003 south of the Research Loop.

Figure 26. Musk thistle rosette that established under the canopy of Schmoll's milkvetch. Photo provided by George San Miguel.

dominance of these species. This has obvious implications for the future of Schmoll's milkvetch in a post-fire setting mediated by human activities.

While competition with grass may threaten Schmoll's milkvetch in burned areas, the alternatives may also be equally deleterious. Romme et al. (2003) observed that invasion of non-native plants was much reduced where grass seed was used following the Chapin 5 fire. Floyd-Hanna et al. (1999) observed a negative correlation between density of Schmoll's milkvetch and musk thistle, suggesting that the presence of musk thistle is deleterious to Schmoll's milkvetch. Clearly, post-fire management decisions are likely to have considerable effects on population viability of Schmoll's milkvetch. Nonetheless, it appears that caution is needed in future decisions regarding the use of grass seeding for post-fire revegetation within populations of Schmoll's milkvetch. Comparison of demographic parameters is needed in coming years between populations in burned and unseeded areas with populations in burned and seeded areas of Chapin Mesa to determine the impacts of the use of grass seed for post-fire revegetation on Schmoll's milkvetch.

The observations made in 2003 on Park Mesa strongly suggest that while fire may confer some short-term benefits to plants in burned areas (possibly at the expense of reproductive success in unburned areas if depletion of pollinator resources is responsible for poor fecundity), it may have long-term detrimental impacts.

Other Apparent Impacts to Schmoll's Milkvetch

Apparent impacts to individuals or populations that were observed in 2001 and 2003 not resulting from fire and post-fire management are summarized below.

Drought

The results of this study suggest that drought is deleterious to Schmoll's milkvetch and may cause population decline. Although mitigation of this threat falls beyond the ability of managers to control, it has implications for the viability of Schmoll's milkvetch. If we are, as some climatological data suggest, beginning a period of persistent drought, then drought may continue to cause population decline for Schmoll's milkvetch.

Early Senescence

Throughout the distribution of Schmoll's milkvetch, plants were observed with dead above ground parts (Figure 27). On affected plants, the entire aboveground portion of the plant was dried and withered, having apparently grown in the spring but subsequently senesced. Disease or attack of the roots by an insect are the probable causes. No plants were excavated to explore the latter hypothesis. It is not known if these plants were killed or were merely injured.

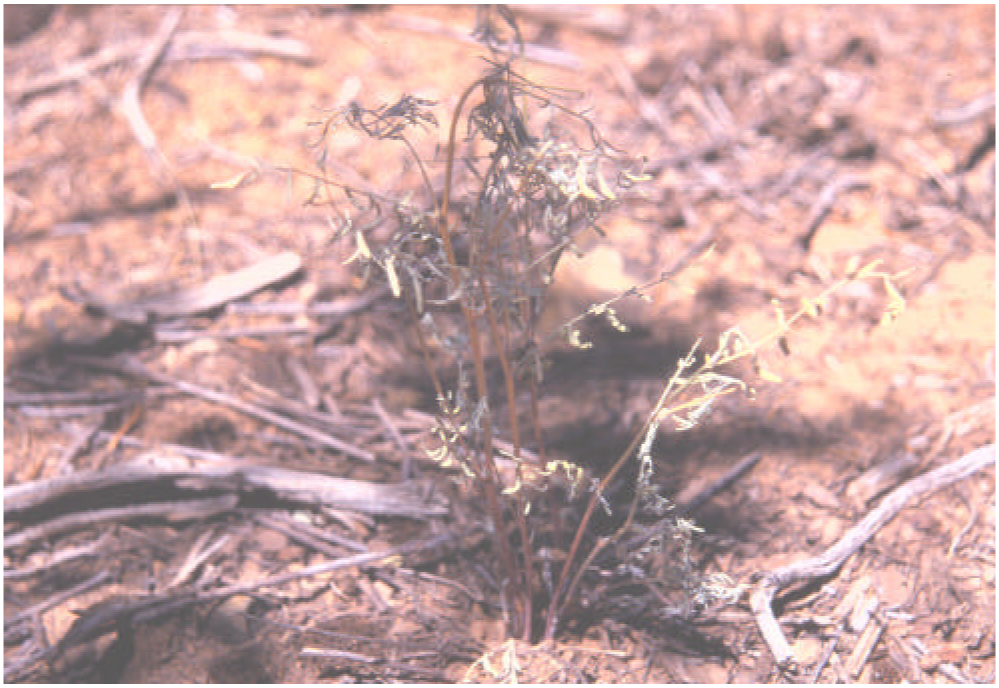


Figure 25. Senescent Schmoll's milkvetch individuals such as this were frequently observed in 2001. The cause of the senescence is unknown, but it appears to have occurred suddenly.

Aphids

Numerous plants were observed on which portions of the plant, usually the flower stalk and upper stems, were almost completely encrusted with black aphids (Figure 28). No plant mortality resulting from aphid attack was observed in 2001. However, most plants that had been attacked by aphids appeared to have failed to produce seeds in 2001. Stunted flowers and fruits were seen on these plants. Aphids were not observed on Schmoll's milkvetch outside of the Mesa Top Loop area, with the most pronounced infestations observed on plants at the comfort station. Aphids were not observed on Schmoll's milkvetch in 2003.

Figure 28. Black aphids encrusted on the terminal raceme of Schmoll's milkvetch at the Mesa Top Loop comfort station. All flowers have fallen off and the stem is abnormally twisted.

Insect Larvae

The most significant insect impacts observed for Schmoll's milkvetch in 2001 resulted from butterfly larvae. Of the 10,026 plants counted along belt transects in 2001, 712 (7.1% of the sample population) had been attacked by caterpillars. The impact of the butterfly larvae on the Schmoll's milkvetch was first noted on June 6, 2001 along a belt transect in the Mesa Top Loop area (Zone 12 N4117000 E723769). Observations were made of up to three larvae per Schmoll's milkvetch individual in 2001 (Figure 29). It appeared from our observations that a single butterfly larva was capable of completely defoliating a plant, leaving only the stems and some of the leaf midveins. Because plants in this condition were extremely difficult to see in the field, it is possible that some of these individuals were missed during the census of affected plants. By mid-June no more larvae were observed and some plants were seen that had been defoliated but were beginning to sprout new leaves. No impact from caterpillars was observed in 2003. It is likely that Schmoll's milkvetch individuals can survive intense periodic insect herbivory if it does not occur every year.

The species that attacked Schmoll's milkvetch in 2001 is the clouded sulphur butterfly (*Colias philodice* Goddart 1819) (pers. comm. Doyle 2001, pers. comm. Pineda 2001). This species is common throughout North America in both natural and cultural vegetation (Wright 1993, NatureServe 2004). They subsist on a diet of legumes and they are an occasional agricultural pest of clover and alfalfa fields. Because Friedlander made no note of this species in 1980, it is possible that it is a newcomer to MVNP, or that its populations in the area fluctuate greatly depending on climatic variation or other factors. Impacts from this species were not observed in 2003, although the orange sulphur (*Colias eurytheme*), a close relative, was observed visiting flowers of Schmoll's milkvetch in 2003. The larvae of this species also feed on a broad range of leguminous species. This species sometimes hybridizes with the clouded sulphur (Brock and Kaufman 2003).

Figure 29. Larvae of the clouded sulphur butterfly devouring a Schmoll's milkvetch in the Mesa Top Loop area. Note the lack of any remaining leaflets on the plant.

Seed Predation

Low levels of seed predation were observed on Schmoll's milkvetch in 2001. These impacts were also noted by Friedlander (1980) and they were attributed to the larvae of weevils or snout beetles. The larvae eat the seeds while they are still inside the pod and then exit through a small bore hole. The bore hole is the only outward manifestation of the predation but when the pods are opened there are no seeds inside. These impacts were not quantified in 2001. Seed predation was not observed in 2003, but it is more easily observed when fruits have ripened which occurs in June after the fieldwork was completed in 2003.

Browsing

A small number of plants were observed in 2001 that had been browsed (24 of 10,026 along belt transects). Browsed plants were also observed in 2003 on the West Chapin Spur and on Park Mesa, although the latter appears to have resulted from horse grazing (see the Grazing section below). In most cases the flower stalk was the target of the browser and the vegetative portions of the plants were mostly left alone. However, there were some instances in which most or all of the plant had been browsed, leaving only the bases of the stems. No direct observations of browsing were made in 2001. Several species are potential browsers of Schmoll's milkvetch including mule deer, jackrabbits, cottontails, and mice.

Browsing appears to have significant impacts on recruitment of Schmoll's milkvetch (please see the demography section of this report for details). Mule deer and lagomorphs (desert cottontail or black tail jackrabbit) appeared to have caused most seedling mortality observed in 2003. Thus, wildlife management policies of MVNP and the Ute Mountain Ute Tribal Park may affect the viability of Schmoll's milkvetch.

Infrastructure and Construction

A considerable portion of Chapin Mesa has been developed to enable visitors to access selected areas and to provide facilities that permit the operation of the park. These areas are limited almost entirely to the research, maintenance, and headquarters loops, roads, and the viewing areas for the ruins. The vast majority of the area occupied by Schmoll's milkvetch is not directly impacted by construction activities. Historically these activities have resulted in considerable loss of plants and some attrition from large construction activities is continuing. The construction of the large parking lot southeast of the old CCC complex in 2000 undoubtedly resulted in considerable mortality of Schmoll's milkvetch plants, as the population surrounding this lot is rather dense. The removal of the island of vegetation at the three-way intersection (junction of the Mesa Top Loop road and the Cliff Palace Loop road) in 2001 also resulted in an unquantified loss of Schmoll's milkvetch plants. Perhaps the greatest recent impact has been the installation of thousands of meters of underground fiber optic cables throughout the developed areas of the park, although observations suggest that Schmoll's milkvetch may respond favorably to this kind of disturbance if it is not constantly repeated or followed up with additional disturbances (Colorado Native Plant Society 1997).

Secondary effects of construction also are issues that may impact Schmoll's milkvetch in the surrounding areas. Construction areas are excellent corridors for weed invasion and close monitoring of them in coming years may help identify new weed invasions and avoid costly eradication efforts later. Bur buttercup (*Ceratocephala orthoceras*) was frequently observed in areas disturbed by fiber optic cables and construction. Localized erosion impacts to Schmoll's milkvetch also may result from construction activities, but such impacts were not observed in 2001.

Weed Invasion

Numerous non-native plant species have been found in or near populations of Schmoll's milkvetch (Table 17). Invasion of burned areas by weeds represents a significant threat to Schmoll's milkvetch, especially following the Long Mesa Fire. Two weed species, *Carduus nutans* (Figures 24 and 25) and *Bromus tectorum* (Figure 23), are especially invasive in burned areas of MVNP. *Carduus nutans* appears to outcompete Schmoll's milkvetch (Floyd-Hanna et al. 1999). The canopy of Schmoll's milkvetch can act as a seed trap for this species (Figure 26), which greatly increases the likelihood of negative impacts to Schmoll's milkvetch from

Table 17. Noxious weeds and weedy exotic species observed with Schmoll's milkvetch in MVNP in 2001 and 2003. Nomenclature follows Kartesz (1999).

Weed Scientific Name	**Weed Common Name**	**Comments**
Alyssum alyssoides	Hairy Allyssum	Common but patchily distributed; impacts to Schmoll's milkvetch are unknown.
Agropyron cristatum	Crested Wheatgrass	Found in many roadside locations. Though not widespread, this species presents a threat to Schmoll's milkvetch because it is allelopathic and it is a strong competitor.
Bromopsis inermis	Smooth Brome	Common in the vicinity of roads and structures; forms dense stands in some sites. Co-occurs with Schmoll's milkvetch more commonly than any other weed species.
Bromus tectorum	Cheat Grass	This species is widespread but uncommon in unaltered habitat. It is absent in unburned piñon-juniper woodland on Chapin Mesa, but common in thin soils near canyon rims and pouroffs. It appears to proliferate aggressively following fire, and represents a large portion of total plant cover on portions of Park Mesa burned in 1996. It is likely to spread throughout the area burned by the Long Mesa Fire as well. It has great potential to competitively exclude Schmoll's milkvetch and represents a significant threat in burned areas. It is not known if its spread was augmented by accidental introduction as a contaminant in seed mix.
Carduus nutans	Musk Thistle	As Mesa Verde's greatest noxious weed threat, this species should be eradicated wherever found in MVNP. It already co-occurs with Schmoll's milkvetch in many locations, particularly in the headquarters, maintenance, and research loop areas. It has proliferated vigorously following fire, and numerous founder populations were observed in 2003 following the Long Mesa Fire. This species is known to compete with Schmoll's milkvetch on Park Mesa (Floyd-Hanna et al. 1999). This species is not a problem in the backcountry of lower Chapin Mesa at present, but it seems to follow in the footsteps of human activities such as mechanical fuels reduction and with fire. At lower elevations on Chapin Mesa, the Ute Mountain Ute Tribal Park may be too hot and dry for this species.
Ceratocephala orthoceras	Bur Buttercup	Common and sometimes dense, but apparently it has not yet spread throughout occupied habitat of Schmoll's milkvetch. It is more prevalent in wet years (pers. comm. Marilyn Colyer 2002). Commonly co-occurs with Schmoll's milkvetch; impacts to Schmoll's milkvetch are unknown but it is allelopathic. Because it is a spring annual it may have negative effects on Schmoll's milkvetch seedling establishment in heavily-infested areas.
Cirsium arvense	Canada Thistle	Specific to wetter sites; can form extremely dense and pernicious stands; competitively excludes Schmoll's milkvetch completely where they occur together.
Erodium cicutarium	Red-Stemmed Filaree	An occasional weed that is widely distributed in anthropogenically disturbed sites. It is most common at the rock quarry on Chapin Mesa.
Melilotus officinale	Yellow Sweet Clover	This species occurs along roadsides and at the rock quarry on Chapin Mesa. It is not known to co-occur with Schmoll's milkvetch. However, this species threatens other rare plant species in Colorado and has invaded natural or quasi-natural landscapes throughout the west. It is worthy of close scrutiny by land managers.
Salsola tragus	Russian Thistle	Known from Park Mesa (Floyd-Hanna et al. 1999) and Chapin Mesa. This species may spread in burned areas.

competition (discussed in the Implications of Fire on Management for Population Viability section of this report).

Salsola tragus and other annual weeds are also a concern in burned areas of MVNP. Because *Salsola* matures in late summer it was not possible to assess its extent in 2003, although young plants were seen on May 27, 2003 at Cedar Tree Tower.

In many anthropogenically disturbed areas weeds co-occur with Schmoll's milkvetch. Numerous weed species are present at the old rock quarry site on the eastern rim of Chapin Mesa. These include *Erodium cicutarium, Carduus nutans, Bromus tectorum*, and *Melilotus officinale*. In heavily-infested areas, overspray during weed management and eradication efforts may represent an additional threat to Schmoll's milkvetch. Careful application and selection of herbicides will help to reduce impacts to Schmoll's milkvetch.

Visitor Impacts

Because backcountry travel is prohibited in the park, visitor impacts to Schmoll's milkvetch are extremely localized. All observed human impacts were in the vicinity of trails, roads, parking lots, buildings, and developed archaeological sites. Due to the close attention paid by the park to limiting visitor impacts to designated areas, visitors have a very minor impact to Schmoll's milkvetch compared to other impacts. The only impact observed in this category was trampling damage to plants growing adjacent to pathways and trails. Plants that had been stepped on were observed on the Pictograph Point trail at several locations. Plants grow extremely close to the trail along much of its mesa top stretch. Several plants crushed by car wheels on the edges of gravel roads in the Research Loop and Picnic Area also were observed.

Mechanical Fuels Reduction

Strategic removal of live trees and woody debris is ongoing in MVNP to reduce the danger and potential impact of a catastrophic fire on lower Chapin Mesa. Fuels reduction activities have applied two kinds of treatments resulting in areas where there are no trees or woody debris and in other areas where the trees have merely been thinned and the woody debris removed.

In both treatments the ecological conditions for Schmoll's milkvetch are very different from those of the pinyon-juniper woodland habitat. In locations that were thinned in 2000, there appears to have been a proliferation of muttongrass (*Poa fendleriana*), probably in response to increased insolation or competitive release from the overstory species. Schmoll's milkvetch individuals found in these areas were growing among large, crowded bunches of muttongrass and appeared small and unhealthy. In these situations it appeared as though the muttongrass had become much more of a dominant species and was potentially outcompeting other understory species such as Schmoll's milkvetch.

Mechanical fuels reduction activities result in a low to moderate level of surface disturbance. Musk thistle (*Carduus nutans*) appears to be capitalizing on this disturbance regime because numerous plants were found in all areas visited where mechanical fuels reduction activities were taking place. The most significant problem area noted was the fuels reduction zone adjacent to the main road east of the Research Loop. The area surrounding the "million gallon water tank" north of the Research Loop also was heavily infested although control measures were underway during the 2001 fieldwork. This area has been disturbed periodically since 1948 and has had no revegetation work (pers. comm. Colyer 2002). Periodic water releases also encourage the proliferation of weeds at this site.

Currently there are not enough data available to make a definitive statement regarding the effects of mechanical fuels reduction on Schmoll's milkvetch. However, given the qualitative observations cited above it appears likely that significant negative impacts are occurring. Monitoring the effects of the mechanical fuels reduction treatments may allow managers to mitigate some of the negative impacts to Schmoll's milkvetch in the future. Lisa Floyd-Hanna established Schmoll's milkvetch monitoring plots in a large fuel break cut along the MVNP/ Ute Mountain Ute Tribal Park boundary line in 2001 (pers. comm. Floyd-Hanna 2002). These plots may provide valuable data needed to support the appropriate management of mechanical fuels reduction areas in MVNP.

Grazing

No grazing impacts were observed on Schmoll's milkvetch inside Mesa Verde National Park. Light grazing by horses that have trespassed from the Ute Mountain Ute Tribal Park is the only grazing pressure on Schmoll's milkvetch on the northern portion of Chapin Mesa. There is the potential for grazing impacts on the Ute Mountain Ute Tribal Park due to the presence of cattle and horses there. The effects of grazing on Schmoll's milkvetch have not been documented. Heavy browsing of Schmoll's milkvetch was observed at the southern population on Park Mesa in 2003. At this site there was evidence of horses (fresh hoofprints and feces) suggesting that it was consumed by horses.

Off-Highway Vehicle Use

Impacts of off-highway vehicle use (OHV) activity are non-existent at MVNP. However, there is some potential for impacts from OHV activity outside of MVNP. The amount of current

OHV vehicle use on Chapin Mesa is not known but may warrant the scrutiny of land managers in the Ute Mountain Ute Tribal Park.

APPARENT MANAGEMENT NEEDS

Maintain a strong noxious weed management and eradication program in the park. Management of noxious weeds, particularly musk thistle (*Carduus nutans)* and cheat grass (*Bromus tectorum*), is a necessary part of conservation management of Schmoll's milkvetch. The post-fire behavior of these species on Mesa Verde gives cause for concern with respect to the long-term viability of Schmoll's milkvetch (Floyd-Hanna et al. 1999). Management of other species may also be needed if they become problematic. Awareness and timely eradication of other encroaching species that could become serious weed problems will prevent more costly control measures later. Examples of species that could become serious problems include Russian knapweed, purple and yellow starthistle, medusahead, camelthorn, and African rue.

Keep human impacts to a minimum. Current park management with regard to visitors appears favorable to the persistence of Schmoll's milkvetch. Maintain current park policies controlling backcountry travel. Minimize human activities in areas of high Schmoll's milkvetch density and plan future park development with respect to these areas. Limit development sprawl in headquarters, maintenance, and research loop areas. Reducing the footprint size of development on Chapin Mesa will leave more habitat available for Schmoll's milkvetch.

Continue to monitor Schmoll's milkvetch. Continued monitoring of permanent plots would provide valuable information for land managers. This includes plots established for this project, those of Floyd-Hanna in the Mechanical Fuels Reduction area along the southern park border on Chapin Mesa, and those of Friedlander (1980). Monitoring burned and unburned areas using plots and a robust sampling protocol to compare demography and survivorship in burned and unburned areas Comparing vegetation composition and structure will provide valuable insight into observed demographic trends. Observations made in 2003 strongly suggest that there may be concern for the viability of *Astragalus schmolliae* in burned areas due to natural and human mediated alteration of vegetation. These impacts may not become apparent for five to ten years.

Continue to fund research on Schmoll's milkvetch. There is much to be learned regarding the autecology of Schmoll's milkvetch, as with many other rare plant species. Gaining an understanding of its fire ecology, pollination ecology, physiological ecology, and population ecology would allow the wise management of this species and would make valuable scientific contributions. Because it is abundant within its range, it is an ideal species for ecological studies, in that a small amount of destructive sampling would not serve to further imperil the species. Although it cannot reasonably be excavated from the wild for greenhouse studies, it can be grown from seed, as evinced by the success of the Denver Botanical Garden in growing it in a demonstration garden. Thus it also may be suitable for greenhouse experiments to measure its competitive ability, nutrient needs, and other autecological studies. Research is needed to investigate the reasons for poor fruitset observed in unburned areas in 2003, and in areas burned in 1996. The monitoring plots discussed above will yield valuable information on demographic bottlenecks that will assist with managing for the viability of Schmoll's milkvetch. Genetic and cytological studies are needed to determine the genetic diversity and degree of heterozygosity in Schmoll's milkvetch. This research would help determine the importance of the maintenance of genetic diversity for maintaining population viability. This research could also investigate the ancestry of Schmoll's milkvetch and determine whether it is, as hypothesized by Weber and Wittmann (2001), the result of a hybridization event between *A. scopulorum* and *A. lonchocarpus*. A possible hybrid origin involving *A. scopulorum* and *A. wingatanus* as parents should also be investigated, since these species are both known to be sympatric with Schmoll's milkvetch.

Promote Schmoll's milkvetch as a valuable part of the natural heritage of the Mesa Verde area. As one of Colorado's rarest endemic plants, it is part of what makes this area unique and could help foster an interest in rare plant conservation and conservation in general among the general public. Along with other natural and cultural resources, it lends global significance to MVNP and the Ute Mountain Ute Tribal Park. Increasing awareness and educating the local public about Schmoll's milkvetch could help actualize management goals by building public support for its conservation.

REFERENCES

Anderson, D.G. 2001. Population Status Survey of Schmoll's Milkvetch (*Astragalus schmolliae* C.L. Porter). Summary of Year 1 Results. Prepared for the National Park Service, Mesa Verde National Park by the Colorado Natural Heritage Program.

Barbour, M.G., J.H. Burk, W.D. Pitts. 1987. Terrestrial Plant Ecology. Second Edition. Benjamin/ Cummings Publishing Company, Inc. Menlo Park, CA.

Baskin, C. C. and J. M. Baskin. 2001. Seeds- Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press. San Diego, CA.

Barneby, R.C. 1964. Atlas of North American *Astragalus*. Memoirs of New York Botanical Garden, Vol. 13. Bronx, NY.

Bowles, M.L., R.F. Betz, and M.M. DeMauro. 1993. Propagation of rare plants from historic seed collections: implications for species restoration and herbarium management. Restoration Ecology 1:101-106.

Brock, J.P. and K. Kaufman. 2003. Butterflies of North America. Houghton Mifflin Company. Singapore.

Center for Plant Conservation. 2001. National Collection of Endangered Plants. Accessed online at http://www.mobot.org/CPC/ on November 10, 2001.

Colorado Native Plant Society. 1997. Rare Plants of Colorado, Second Edition. Falcon Press Publishing Company Inc. Helena, MT.

Colorado Natural Heritage Program. 2004. Biodiversity Tracking and Conservation System. Colorado State University, Fort Collins, Colorado, U.S.A.

Colyer, M. 1980-2000. Unpublished data from resampling permanent plots established by J. Friedlander in 1980.

Colyer, M. 2000. Floral Species of Concern- Mesa Verde National Park. Unpublished Annotated Plant Species List.

Colyer, M. 2001-2003. Personal communications with Mesa Verde National Park Botanist regarding *Astragalus schmolliae*.

Doyle, G. 2001. Personal communication with Colorado Natural Heritage Program Ecologist regarding insect identification.

Drummond, B. 2004. Personal communication with Colorado State University Entomologist regarding identification of insect visitors to *Astragalus schmolliae*.

Environmental Systems Research Institute, Inc. (ESRI). 1992-2000. ArcView 3.2a and Spatial Analyst 2.0. GIS software programs.

Floyd, L.M., W.H. Romme, and D.D. Hanna. 2000. Fire history and vegetation pattern in Mesa Verde National Park, Colorado, USA. Ecological Applications 10(6): 1666-1680.

Floyd, M.L., M. Colyer, D.D. Hanna, and W.H. Romme. 2003. Gnarly Old Trees: Canopy Characteristics of Old-Growth Piñon-Juniper Woodlands. Pages 11-29 in: (M.L. Floyd, Ed.) Ancient Piñon-Juniper Woodlands- a Natural History of Mesa Verde County.

Floyd-Hanna, L. 2002 and 2003. Personal communications with Prescott College Professor and Botanist regarding *Astragalus schmolliae*.

Floyd-Hanna, A. DaVega, D. Hanna, W. H. Romme. 1997 and 1998. Chapin 5 Fire Vegetation Monitoring and Mitigation, 1st and 2nd Year Reports. Unpublished reports produced for Mesa Verde National Park.

Floyd-Hanna, L., D. Hanna, C. Funicelli, M. Colyer, G. San Miguel. 1999. The Role of Fire and Noxious Weed Infestations on Rare Plants at Mesa Verde National Park. Colorado Natural History 1999 Small Grants Program Report.

Friedlander, J. D. 1980. The Status of Rare and Endangered Plant Species in Mesa Verde National Park, Colorado. M.S. Thesis, Colorado State University, Fort Collins, CO.

Griffitts, M.O. 1990. Guide to the Geology of Mesa Verde National Park. Lorraine Press, UT.

Hartman, R.L. and B.E. Nelson. 2001. A Checklist of the Vascular Plants of Colorado. Unpublished list accessed at http://www.rmh.uwyo.edu/colorado/colcklist.pdf. Rocky Mountain Herbarium, Laramie, WY.

Hessl, A. and S. Spackman. 1995. Effects of Fire on Threatened and Endangered Plants: an Annotated Bibliography. Information and Technology Report 2. National Technical Information Service. Springfield, VA.

Hudson, L, G. San Miguel, M. Colyer, A. Cully. 2001. Proposal for Biological Survey-Population Status Survey for Schmoll Milkvetch (*Astragalus schmollae* C.L. Porter) at Mesa Verde National Park and Ute Mountain Ute Tribal Park. Unpublished.

International Association for Plant Taxonomy. 2000. International Code of Botanical Nomenclature (Saint Louis Code). Adopted by the Sixteenth International Botanical Congress St. Louis, Missouri, July - August 1999. Koeltz Scientific Books, Königstein.

International Legume Database and Information Service. 2002. Report generated by LegumeWeb from the ILDIS World Database of Legumes, version 5.00 at http://biodiversity.soton.ac.uk/. Accessed on January 30, 2002.

Isely, D. 1998. Native and naturalized Leguminosae (Fabaceae) of the United States (exclusive of Alaska and Hawaii). Monte L. Bean Life Science Museum, Brigham Young University; MLBM Press, Provo, Utah. 1007 pp.

Kartesz, J. T. 1999. A Synonymized Checklist and Atlas with Biological Attributes for the Vascular Flora of the United States, Canada, and Greenland. First Edition. In: Kartesz, JT and CA Meacham. Synthesis of the North American Flora [computer program]. Version 1.0. Chapel Hill, NC: North Carolina Botanical Garden.

Mesa Verde National Park. 2001. Chapin #5 Fire Rehabilitation Accomplishment Report. Executive Summary. Unpublished report accessed on November 1, 2001 at http://www.nps.gov/meve/mvnp/pages/baer2.htm.

Miller, A. 2004. Personal communication with National Center for Genetic Resource Preservation Seed Analyst regarding *Astragalus schmolliae*.

Missouri Botanical Garden. 2002. W^3Tropicos Nomenclatural Data Base. Accessed January 30, 2002 at http://mobot.mobot.org/.

NatureServe. 2004. NatureServe Explorer- an online encyclopedia of life. Version 1.5. Arlington, VA: Association for Biodiversity Information. Available: http://www.natureserve.org/explorer/.

Niering, W.A., R.H. Whittaker, C.H. Lowe. 1963. The Saguaro: a Population in Relation to its Environment. Science 142:15-23.

O'Kane, S.L. 1988. Colorado's Rare Flora. Great Basin Naturalist 48(4): 434-484.

Peterson, J.S. 1981. Status report on *Astragalus schmolliae*. Unpublished report prepared for the Colorado Natural Areas Program, Denver, CO.

Pineda, P. 2001. Personal communication with Colorado Natural Heritage Program Ecologist regarding insect identification.

Porter, C.L. 1945. Two Tioid *Astragalus* novelties from the Rocky Mountain Region. Madroño 8:99-102.

Rabinowitz, D. 1981. The Seven Forms of Rarity. Pages 205- 218 in: H. Synge, Ed. The Biological Aspects of Rare Plant Conservation. John Wiley and Sons. New York, NY.

Romme, W.H., S. Oliva, and M.L. Floyd. 2003. Threats to the Piñon-Juniper Woodland. Pages 339-360 in: (M.L. Floyd, Ed.) Ancient Piñon-Juniper Woodlands- a Natural History of Mesa Verde County.

San Miguel, G. 2001. Personal communications with Director of Natural Resources at Mesa Verde National Park regarding *Astragalus schmolliae*.

Spackman, S., B. Jennings, J. Coles, C. Dawson, M. Minton, A. Kratz, and C. Spurrier. 1997. Colorado Rare Plant Field Guide. Prepared for the Bureau of Land Management, the U.S. Forest Service, and the U.S. Fish and Wildlife Service by the Colorado Natural Heritage Program.

USDA, ARS, National Genetic Resources Program. 2002. Germplasm Resources Information Network – (GRIN). [Online Database} National Germplasm Resources Laboratory, Beltsville, Maryland. Accessed via the internet at http://www.ars-grin.gov/var/apache/cgi-bin/npgs/html/taxon.pl?316313 (30 January 2002).

USDA, NRCS. 2004. The PLANTS Database. Accessed via the internet at www.plants.usda.gov. Baton Rouge, LA 70874-4490 USA.

Weber, W.A. and R.C. Wittmann. 2001. Colorado Flora- Western Slope. Third edition. University Press, Boulder, CO.

Western Regional Climate Center. 2004. Colorado Climate Summaries. Accessed via the internet at http://www.wrcc.dri.edu/summary/climsmco.html.

Wright, A.B. 1993. Caterpillars- the Concise Field Guide to 120 Common Caterpillars of North America. Houghton Mifflin, New York, NY.

APPENDIX 1

Technical Description (From Barneby 1964)

Tall and robust, strigulose throughout with fine, appressed hairs up to 0.4-0.55 mm. long, the stems green or purplish at base, the herbage cinereous, the leaflets pubescent on both sides, the inflorescence ± black-hairy; stems few, erect and ascending from the shallowly buried root-crown, 3-6 dm. long, ribbed and fistular below, shortly branched at 1-4 nodes preceding the first peduncle, the internodes below the first branch mostly short and lacking developed leaves, the upper ones much longer, flexuous; stipules 2-7 mm. long, dimorphic, the lowest papery, castaneous or purplish brown, adnate to the vestigial petiole to form an obtuse or bidentate sheath, decurrent around ½ to nearly the whole stem's circumference, the median and upper ones herbaceous, obscurely adnate, with deltoid-acuminate, triangular, or lanceolate, mostly deflexed blades; leaves 4-10 cm. long, shortly petioled or the uppermost subsessile, with (7) 11-21 opposite or scattered, linear, linear-oblong, or –elliptic, obtuse or retruse, flat leaflets 6-25 (30) mm. long, all articulate; peduncles erect, 9-21 cm. long, the first 1 or 2 usually very stout and long, the inflorescence mostly projected well beyond the main stem-axis; racemes loosely (7) 10-28 flowered, ultimately second, the axis (2.5) 4.5-20 cm. long in fruit; bracts membranous, lanceolate or lance-ovate, 1.5-3 mm. long; pedicels at anthesis 1-1.3 mm. long, in fruit widely spreading, arcuately recurved, or deflexed, a trifle thickened, 2-2.5 mm. long; bracteoles 0-2, minute when present; calyx 6-705 mm. long, rather densely and loosely black –strigulose, the slightly oblique disc 1-1.2 mm. deep, the cylindric or cylindro-campanulate tube (5) 5.5-6 mm. long, 2.6-3.2 mm. in diameter, the triangular-subulate teeth 1-1.7 mm. long, all crowded toward the dosal side of the calyx, the ventral sinus wide and deeply cut back; petals ochroleucous, concolorous; banner recurved through ± 45°, rhombic-elliptic, deeply notched, 14.5-18 mm. long, ± 7-8 mm. wide, incurved through 95° to the broadly triangular, obtuse, obscurely porrect apex; anthers 0.6-6.5 mm. long; pod pendulous, stipitate, the straight, slender stipe 5-10 (12)mm. long, the body linear-oblanceolate in profile, (2.5) 3-4 cm. long, 3.5-5 mm. in diameter, nearly straight to gently decurved, tapering gradually downward into the stipe, shortly acuminate or cuneately acute and cuspidate at apex, obcompressed-triquetrous, with low-convex lateral and shallowly but narrowly grooved dorsal faces, carinata ventrally by the prominent, thick suture, the thinly fleshy, green, strigulose valves becoming stiffly paper, stramineous, cross-reticulate; ovules 18-20; seeds (not seen quite ripe) ± 3 mm. long.