U.S. Fish & Wildlife Service

Sentry Milk-vetch

(Astragalus cremnophylax var. cremnophlax)

Recovery Plan

September 2006

SENTRY MILK-VETCH

(*Astragalus cremnophylax* Barneby var. *cremnophylax* Barneby)

RECOVERY PLAN

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for Regional Director, Southwest Region
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Literature citation of this document should read as follows:

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The original plan was prepared by Dr. Joyce Maschinski in 1993, but was not finalized by the Fish and Wildlife Service. Since then, new information has been gathered and several authors have worked on revisions to the original plan. The following individuals have contributed to earlier versions and the final plan: Sue Rutman, Bruce Palmer, William Austin, Mima Falk, Nancy Brian, and Julie Crawford. This plan benefited greatly from review and suggestions from Dr. Loreen Allphin and Dr. Tina Ayers.

The cover photograph is used with the kind permission of the photographer, Julie Crawford. Pam Lunge created Figure 1 for the Fish and Wildlife Service. Marty Tuegel, Fish and Wildlife Service, created Figure 2.

EXECUTIVE SUMMARY

Current Status: Sentry milk-vetch is listed as endangered and is known from three locations on the South Rim of Grand Canyon National Park (Park). As of 2006, the original population at Maricopa Point contained approximately 332 individuals. The Maricopa Point population supported 685 plants in 2000. This population was in severe decline until 1990 when a protective fence was erected. Following protection, plant numbers began to stabilize, and, by 1994, the population began to exhibit a modest upward trend. The primary cause of population decline prior to protection was trampling by Park visitors. Despite the construction of a barrier fence, trampling of sentry milk-vetch and habitat degradation still occur at Maricopa Point, although this type of activity is very much reduced. The Maricopa Point population is currently declining, most likely due to drought conditions. Upon its discovery in 1991, a smaller population on the South Rim east of Grandview Point consisted of three plants. That population consisted of two plants in 2001 and three plants in 2006. In 1994, a third population of approximately 1,000 plants was discovered on the North Rim of the Grand Canyon and identified as the listed variety based on morphological characteristics. Recent genetic research suggests that this population is genetically distinct from the South Rim populations and may be worthy of varietal or other taxonomic distinction (Allphin *et al.* 2005). For the purposes of this recovery plan, we are considering the populations on the North Rim to be distinct genetic and taxonomic units. In 2002, additional populations were discovered on the South Rim of the Canyon at "Lollipop Point". In 2006, there were an estimated 220 individuals scattered along several different locations in the vicinity of "Lollipop Point". In total, there are less than 600 sentry milk-vetch plants on the South Rim of the Grand Canyon.

Habitat Requirements and Limiting Factors: Sentry milk-vetch is known primarily from areas where Kaibab limestone forms large flat platforms with shallow soils near pinyon-juniper woodlands. The Kaibab limestone at Maricopa Point may have high porosity and perhaps high water retention that aids plant growth. The species' habitat specificity, reduced number and vigor of plants, and small habitat size make it vulnerable to extinction. The major threats to the species include habitat destruction and modification, decreased population numbers, stochastic environmental or demographic events, extreme rarity, and low reproduction.

Recovery Goal: The ultimate objective of this recovery plan is to delist sentry milk-vetch. Recovery actions in the recovery plan will ensure the species' survival and promote recovery.

Recovery Criteria and Objectives: In order to **downlist** the species, achieve, maintain, and provide long-term protection for at least four viable sentry milk-vetch populations of at least 1,000 individuals each, for a total of at least 4,000 individuals in the wild. Each natural population must be stable or increasing over a ten-year period. Each artificially established population must be stable or increasing over a thirty-year period. Protect each population

from threats in perpetuity. **Recovery** (delisting) will be attained when there are eight viable sentry milk-vetch populations of 1,000 individuals each, with long-term protection. Each natural population must be stable or increasing over a ten-year period and each artificially established population must be stable or increasing over a thirty-year period. Protect each population from threats in perpetuity. Assess the species' status and threats by monitoring populations and the effects of the threats.

Major Actions Needed:

1. Protect populations from habitat destruction, environmental and demographic stochastic events, and ensure adequate regulatory protection.
2. Survey potential habitat to determine if other populations exist.
3. Maintain and manage natural populations to their maximum potential.
4. Maintain the yearly monitoring on the Maricopa Point population, according to established monitoring methods.
5. Conduct and coordinate research on biology and ecology to determine the species' requirements.
6. Establish and maintain a botanical garden/greenhouse population program.
7. Establish new populations as necessary to meet recovery criteria.
8. Develop public awareness and support for preservation of the species.
9. Exchange information among partners.

These actions are not necessarily listed in order of priority. Prioritized stepped-down actions are provided in the Implementation Schedule. The **Major Actions Needed** are discussed in more detail in the Step-down Outline of Recovery Actions and the Narrative Outline of Recovery Actions.

Total Cost of Downlisting (minimum for first five years): $963,000
The estimated cost of each recovery task is provided in the Implementation Schedule of this recovery plan.

Costs:	Year	Minimum Costs:
	2007	$ 226,000
	2008	$ 216,000
	2009	$ 141,000
	2010	$ 190,000
	2011	$ 190,000
	2012+	To be determined

Date of Recovery: Time to achieve recovery is unknown. Time to reclassification will be based on the time it will take to survey existing habitat, accomplish priority research needs, establish a botanical garden population, establish new wild populations, and implement

management to protect the species. Time estimates for these actions are presented in the Implementation Schedule. Estimated time to delisting is contingent upon results obtained during the downlisting recovery period. Success in protection and establishment of populations will help determine the remaining effort necessary to reach recovery.

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PART I – INTRODUCTION

Brief Overview

Sentry milk-vetch (*Astragalus cremnophylax* Barneby var. *cremnophylax* Barneby) was listed as an endangered species on December 5, 1990 (55 FR 50184-50187) pursuant to the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.). It is a rare endemic known only from three locations on the South Rim of the Grand Canyon, Coconino County, Arizona, within Grand Canyon National Park (Park). Marcus E. Jones first discovered the species in 1903, but he mistakenly identified it as *A. humillimus* and reported it as "apparently common at the Grand Canyon . . . on sandy ledges." In 1947, Ripley and Barneby made a second collection of the species 3.2 kilometers (2 miles) west of El Tovar, a hotel on the South Rim. Their collection was taken at Maricopa Point, where the largest known population on the South Rim exists. Barneby (1964) described the population of perhaps 100 individuals as being confined to a strip of Kaibab limestone pavement not over 46 meters (50 yards) in length. Additional surveys for the species did not locate any other populations until 1991, when three plants were discovered near Grandview Point by Therean Taylor of the Park. In 2002, plants identified as sentry milk-vetch by Therean Taylor were located at “Lollipop Point”. He estimated that there were approximately 341 plants scattered among six new sites. It should be noted that in a 1947 letter from Barneby to Dr. Kearney, Barneby says, “The canyon Astragalus, far from being, in the words of Jones, “apparently common”, is unquestionably a great rarity.”

The main threats to this species are habitat destruction and modification within its very limited distribution, low density, low reproductive potential, stochastic events such as the on-going drought, and its reduced genetic variability. All of these concerns will affect this species’ ability to persist in the future. The implementation of the actions outlined in this recovery plan is crucial for the survival and recovery of this species.

Sentry milk-vetch has a U.S. Fish and Wildlife Service (Service) recovery priority of 6. Recovery priorities assigned to listed species range from 1 to 18, with species ranking 1 having the highest Service recovery priority. A recovery priority of 6 denotes a subspecies with a high degree of threat and low recovery potential.

This plan outlines the steps necessary to achieve, maintain, and document long-term stability of sentry milk-vetch by removing threats, enhancing existing populations, and creating new populations if needed. Attainment of these objectives will lead to the recovery of the species.

Taxonomy and Description

Although Jones made the first collection of *Astragalus cremnophylax* in 1903, the species was not described until 45 years later (Barneby 1948). With typical style, Barneby

assigned a specific epithet that describes the dramatic site occupied by the species. The English translation of the Latin word *cremnophylax* means "watchman of the gorge." In 1979, Barneby described a new variety, *A. cremnophylax* var. *myriorrhaphis* (cliff milk-vetch), from plants discovered by Ralph Gierisch, Bureau of Land Management (BLM), and associates in 1978, on Buckskin Mountain, Coconino County, Arizona (Barneby 1979). A third variety, *A. cremnophylax* var. *hevronii* (Marble Canyon milk-vetch), was also described by Barneby (1992). The Marble Canyon milk-vetch was discovered in 1991 by Bill Hevron of the Navajo Natural Heritage Program, on the east rim of Marble Canyon, Coconino County, Arizona. After the discovery of variety *myriorrhaphis*, the group of plants containing the type-specimen of the species was automatically assigned the name *A. cremnophylax* var. *cremnophylax*.

A. cremnophylax and three other species are in the subsection *Humillimi* of the genus *Astragalus*, family Fabaceae (pea family). Plants in this subsection have silvery-haired leaves and stems. Flowers have short, campanulate calyxes with pale, purplish-pink petals and white-tipped wings. The cushion-shaped *Humillimi* appear to be derived from *A. gilensis* or from a similar and recent common ancestor and have retained nearly all the basic features of flower, fruit, stipule, and hair-attachment, but are reduced in size or in numbers of nearly all organs (Barneby 1964).

Astragalus cremnophylax is distinguished from other species in the subsection *Humillimi* by its compact, 3 to 12 millimeter (0.1 to 0.5 inch) long, pinnately compound leaves that bear 5 to 9 minute leaflets, and small white to pale-purple flowers with banners 5 to 6 millimeters (0.2 inch) and keels not over 4.5 millimeters (0.2 inch) long (Figure 1). Pistils have 4 to 6 ovules. The pods are 3.0 to 4.5 millimeters (0.1 to 0.2 inch) long, obliquely egg-shaped and densely hairy (Barneby 1964).

Several characteristics distinguish sentry milk-vetch from the Marble Canyon and cliff milk-vetches. The Marble Canyon and cliff milk-vetches are somewhat larger and coarser than variety *cremnophylax*. The cliff milk-vetch has leaves that are 13 to 35 millimeters (0.5 to 1.4 inches) long, which is three to four times the length of mature sentry milk-vetch leaves. It also has leaves that are dimorphic within a growing season; early season leaves are short and soft and late season leaves are stiffly erect and leaf stalks harden and become prickly after the leaflets fall (Barneby 1979, Cronquist *et al.* 1989). The Marble Canyon milk-vetch is rather similar to the cliff milk-vetch in foliage, but has larger flowers of brighter color. There is another species of milk-vetch (*A. calycosus*) that grows sympatrically with sentry milk-vetch. In its diminutive form, it can be confused with sentry milk-vetch. The fruits of sentry milk-vetch are unilocular; the fruits of *A. calycosus* are bilocular. Barneby (1992) assigned names to all three varieties based on minor morphological differences and geographical isolation. It is unlikely there is gene flow between the populations of the different varieties due to their geographic isolation (Allphin *et al.* 2005). The cliff milk-vetch is known from several sites along the north Kaibab Plateau,

Marble Canyon milk-vetch is known from two sites on the rim of Marble Canyon (Navajo Nation), and the distribution of sentry milk-vetch is described below.

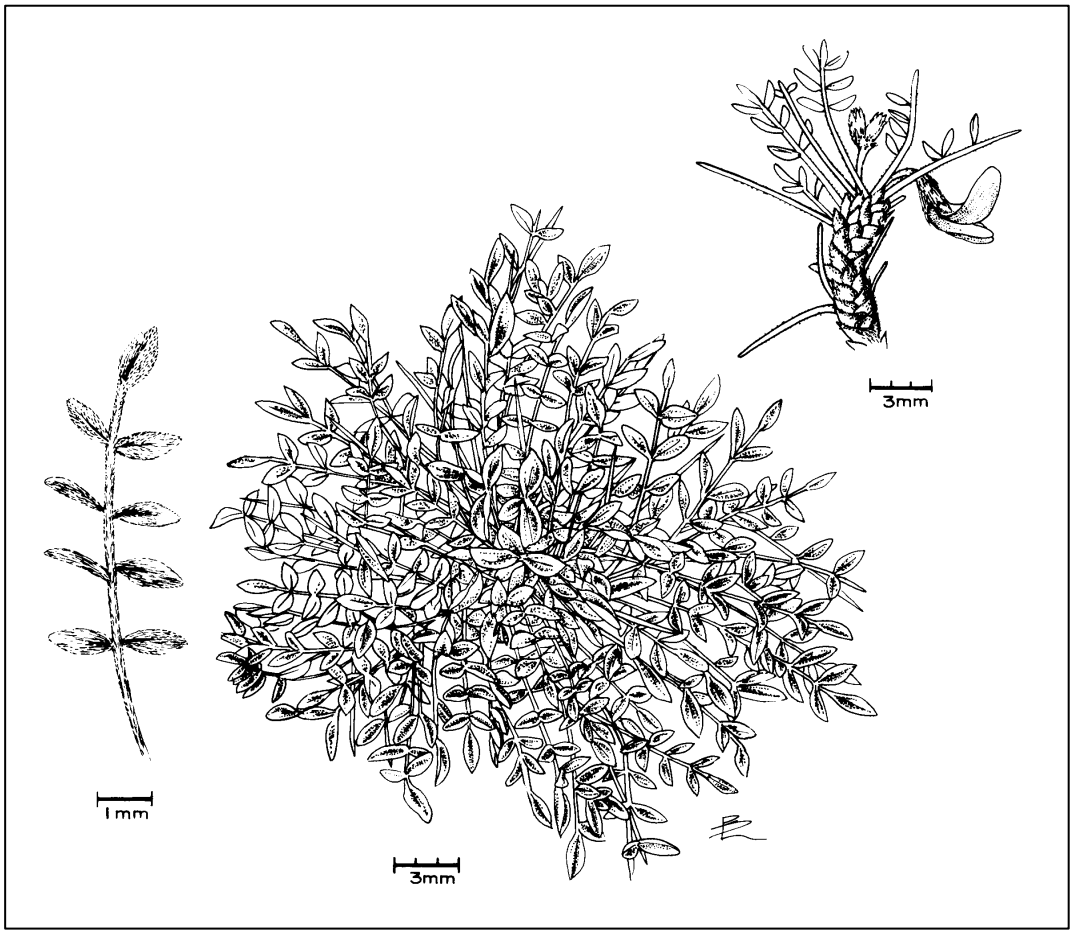

Figure 1. The growth habit, leaf, and flower of sentry milk-vetch (Pam Lunge).

Distribution

Sentry milk-vetch is currently known from three locations on the South Rim (Figure 2). The largest population on the South Rim, of approximately 332 individuals in 2006, occurs at Maricopa Point and has been known since 1947, when Ripley and Barneby collected there. The population has decreased by approximately 49 percent since 2000, when 683 plants were located. Surveys for the plant have been conducted for many miles in each direction from this population (U.S. Fish and Wildlife Service 1990, Maschinski 1992, Warren 1993, Taylor 2002, Crawford 2006). No new populations were discovered until 1991, when three plants were found at a site east of Grandview Point (Warren 1993), a straight-line distance of approximately 20 kilometers (12.5 miles) from Maricopa Point.

Further surveys at Grandview Point in 1993 resulted in the discovery of a total of six plants in a localized area (K. Warren 1993). As of 2006, three plants existed at the Grandview Point site (Crawford 2006).

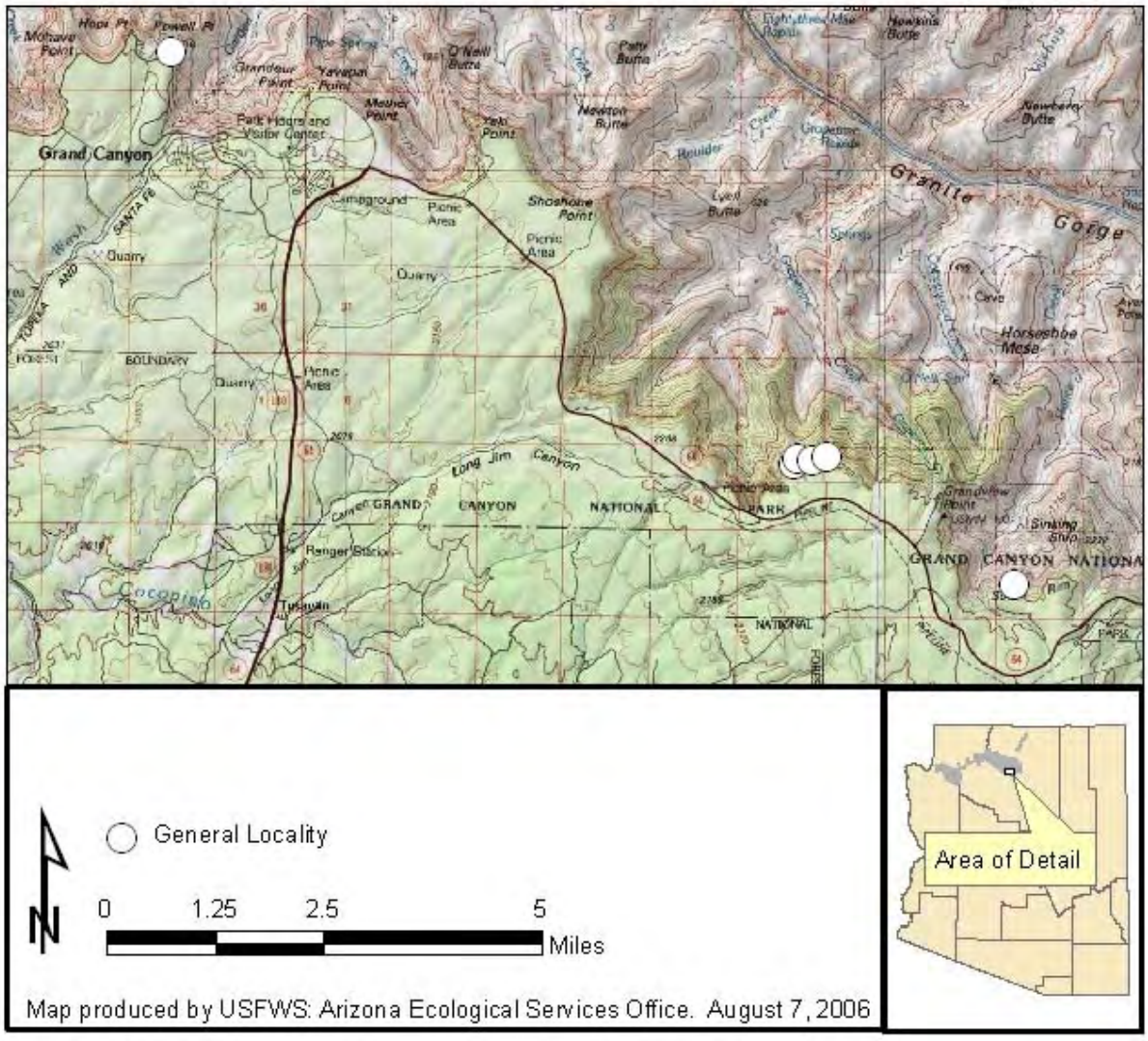

Figure 2. Location of sentry milk-vetch populations on the South Rim, Grand Canyon National Park (Marty Tuegel).

In 2002, as a result of surveys conducted for construction projects in the Park, Therean Taylor discovered an additional population of the species on the South Rim. What has been referred to as the "Lollipop Point" population occurs between Maricopa Point and Grandview Point. At the time of discovery, the population was estimated to contain

approximately 250 individuals in three subpopulations. Other sites were identified further east (east of Zuni Point), but Julie Crawford and Mima Falk, plant ecologists with the Park and the Service, visited these sites in 2006 and found no areas that supported sentry-milk vetch (Crawford 2006). In 2006, an estimated 220 sentry milk-vetch plants were scattered among four locations at "Lollipop Point" (Crawford 2006).

In 1994, what has been identified as another population of the species was discovered on the North Rim (Cape Final) of the Grand Canyon (Brian 2001). This population (which consists of up to five subpopulations) was identified as variety *cremnophylax* based on morphology, by Dr. Stanley Welsh, an *Astragalus* expert (Allphin *et al*. 2005). There are differences between sentry milk-vetch on the South Rim and the plants found at Cape Final. First, they are separated by the canyon itself, suggesting that gene flow between the populations is unlikely. Second, South Rim sentry milk-vetch plants produce orange seeds in contrast to the black seeds produced by the Cape Final plants.

Allphin *et al*. (2005) completed a genetic and reproductive analysis of the varieties of *A. cremnophylax*. Their results demonstrate that plants from the South Rim had low reproductive success (> 30 percent seed set) due to high rates of mortality of developing embryos. By comparison, the Cape Final plants showed higher reproductive success (approximately 80 percent seed set). The South and North Rim populations also differ in breeding system; the South Rim plants are obligate outcrossers (need pollen from a different plant to produce viable seed) and the Cape Final plants are inbreeders, or self-compatible. Although they found few significant differences among populations and taxa for most reproductive and morphological characteristics, statistically significant differences ($P \leq 0.05$) were observed among taxa for fruit/flower and seed/ovule ratios. Plants from Maricopa Point had the lowest seed/ovule ratio in the species complex. These data were constant despite fluctuations in precipitation patterns across years of monitoring. The plants from Maricopa Point and Cape Final produced significantly fewer fruits to flowers than the cliff and Marble Canyon milk-vetch. The Maricopa Point plants grow on the least fertile site among all the taxa; Maricopa Point had the highest percent sand content and the lowest levels of macronutrients. The site also had the lowest amount of live plant cover (four percent) compared to 23 percent at Cape Final.

The results of the genetic analysis indicate that most taxa had very little genetic variation within populations or among taxa. The Maricopa and Grandview plants had the lowest genetic variability, as measured by polymorphic index (0.167). By contrast, the Cape Final plants (0.500) and the Redwall population of the Marble Canyon milk-vetch (0.389) had the highest observed levels of heterozygosity. The largest number of private alleles, not shared with the other taxa, was found in the Cape Final plants (10). The South Rim populations (Maricopa and Grandview) had two private alleles each.

Based on all the different factors measured for all the varieties and related taxa, the authors conclude that the Cape Final plants are distinct from the Maricopa plants and may

deserve varietal or species level status. All three varieties of *A. cremnophylax*, and the Cape Final plants, are historically isolated and genetically differentiated. All of the varieties are rare and need to be managed separately. Further work is required in order to determine the level at which the Cape Final plants should be recognized and to resolve the phylogenetic relationships among the varieties. The Service agrees with the conclusions of the Allphin *et al*. work. As such, the Cape Final plants are considered to be distinct and not part of *A. cremnophylax* var. *cremnophylax*.

Permanent study plots for annual population monitoring were established in 1988 at Maricopa Point (Brian 2000 and 2001). At that time, there were 361 individual plants within the monitoring plots (about 75 percent of the estimated total population). Of those, 58 percent were severely damaged, apparently due to trampling by Park visitors at this popular canyon overlook. Trampling resulted in plant loss and habitat degradation. By the time a protective fence was erected in 1990, the number of plants within the monitoring plots had declined to 285. The effects of trampling persisted after fencing, and the number of plants within the plots continued to decline to 278 in 1991. The number of plants then stabilized, and by 1994, a modest upward trend was evident with 337 individuals in the 1994 monitoring plots (U.S. Fish and Wildlife Service 1992, Maschinski and Rutman 1993, Warren 1993, Maschinski *et al.* 1994, Warren 1994). Monitoring conducted in 2000 resulted in detection of a total of 685 plants at Maricopa Point and two plants at the site near Grandview Point (Brian 2000). Monitoring conducted in 2001 indicated that a total of 665 plants existed at Maricopa Point and the two remained at the site near Grandview Point (Brian 2001). The most recent monitoring completed (2006) has shown a marked decline in plants at Maricopa Point, with only 332 plants detected, a decrease of 49 percent since 2000. The Grandview population still has three plants (2006) and there are approximately 220 individuals along the South Rim in the vicinity of "Lollipop Point" (Crawford 2006).).

It should be noted that the number of sentry milk-vetch plants reported from previous years are not necessarily comparable. We believe that some of the numbers represent plants that were present only in the monitoring plots, as compared with numbers that may represent a census of the entire area. Unfortunately, it is not always clear from the data sheets which approach was taken. There has been inconsistency in the application of the monitoring protocol due to changes in personnel. Therefore, we present the numbers that we recovered from various reports and are using them to present a snapshot of the general trend for the species since monitoring was initiated in 1988. A direct comparison can be made between the numbers from 2001, 2002, and 2006 because complete inventories were conducted in those years (Brian 2001, Crawford 2006).

Park staff initiated a perimeter tracing method for long-term monitoring of basal cover changes in sentry milk-vetch in the 1990's (Rowlands and Brian 1996). This method is more accurate than the measurements that had been used previously. Originally, 112 plants were tagged and traced, but since then only a sub-set of the plants have been traced, with a few new plants having been added. To date, no comparisons of the tracings have been

made, although all of the mylar tracings are at Grand Canyon NP. The Park is seeking funds to analyze the data and to determine if this type of monitoring will continue in the future.

At one time, the potential habitat for sentry milk-vetch was thought to include all layers of the Kaibab Formation, which forms hundreds of miles of both rims of the Grand Canyon, and at bedrock outcrops away from the canyon rims. However, several observers have hypothesized that the potential habitat may be far more restricted. Populations occur on a specific, pure white layer of highly porous Kaibab limestone. The original population on the South Rim occurs where large open platforms are formed near pinyon-juniper woodlands where soils are shallow, and where there are cracks in Kaibab limestone slabs. The Grandview plants occur on small, cracked slab. Such areas along the South Rim are a small subset of the total extent of the Kaibab limestone. The "Lollipop Point" population on the South Rim generally follows the same pattern, but a portion of the population also occurs in what has been referred to as a "predominance of small (2-5 cm) broken limestone rocks within a fine limestone sand matrix" (Taylor 2002).

Habitat and Site Description

Sentry milk-vetch forms mats or shallow mounds in scarcely visible cracks on Kaibab limestone bedrock, in sand-filled hollows of rock (Barneby 1964), or on shallow gravelly soils. The species appears to occur on one specific, pure white layer of Kaibab limestone where the bedrock forms an unshaded platform. It has not been found on small, shaded ledges or cliffs. The Grandview Point plants occur in a large crack in a small isolated ledge. The habitat is characterized by shallow soils or bedrock on the limestone platforms (55 FR 50184-50187).

Prevost (1991) investigated soils at Maricopa Point and found them to be extremely shallow at less than 7 centimeters (2.8 inches) deep. Textures ranged from very gravelly, very fine sandy loam to extremely gravelly loamy fine sand. Clay content ranged from about 8 to 14 percent. Soils were mildly alkaline, with a pH value of 7.8, and were only slightly effervescent. The first 2 centimeters (0.8 inch) of the soil profile was characterized by subangular to subrounded fragments of mixed mineralogy, predominantly comprised of limestone, chert, and basalt less than 2 centimeters (0.8 inch) in diameter. The soil profile from 2 to 6 centimeters (0.8 to 2.4 inches) was very gravelly, very fine sandy loam with a weak thick platy structure, which was soft, very friable, slightly sticky, and nonplastic with fine irregular and tubular pores. Below 6 centimeters (2.4 inches) lies the Kaibab limestone bedrock (Prevost 1991).

In comparison with other sites along the South Rim of Grand Canyon, soils at Maricopa Point have less lime content, slightly greater magnesium content, mixed mineral gravels present, and less residual soils of limestone origin. The subrounded gravels and concave landform at Maricopa Point may indicate an alluvial parent material, probably transported from nearby sources (Prevost 1991).

The low lime content and slightly higher magnesium content of soils at Maricopa Point suggest that the underlying bedrock may be more porous than at other sites on the South Rim. According to Levine *et al.* (1989), the porosity of the bedrock limestone influences the surface soil formation. Highly porous bedrock may contribute to calcium carbonate removal and dolomite crystal-lattice formation. As dolomite dissolves, magnesium is released in solution and incorporated into soils. Thus, there is some preliminary evidence that soil, bedrock chemistry, and hydrology at Maricopa Point are distinctive. Because soil moisture is less than 0.6 percent at Maricopa Point, bedrock may play a role in providing moisture to plants. Whether the presence of sentry milk-vetch is tied directly to these conditions is unknown.

Soils at Grandview Point and "Lollipop Point" have not been analyzed, but cursory investigation indicates that the Kaibab limestone there forms a flat, white platform, similar to the one at Maricopa Point.

Maricopa Point is 1860 meters (m) (6102 feet (ft)) in elevation. Grandview and "Lollipop Point" are at similar elevations along the South Rim. The Maricopa Point population is found within a fenced enclosure, in an area that is approximately 2,520 m^2 (27,125 ft^2). The areas occupied by sentry milk-vetch at Grandview and "Lollipop Point" have not been calculated, but they are very small. At Grandview, the plants are found on one small rock outcrop, and at "Lollipop Point" the plants are restricted to the small areas with the limestone bedrock. Within the enclosure, plants only occupy about 10 percent of the site (Brian 2001). The climate of the South Rim is semiarid and precipitation patterns fluctuate greatly. Based on a 58-year record (Green and Sellers 1964), the South Rim received annual average rainfall of 40.6 cm (16 inches). The spring months (April, May, and June) are relatively dry; average precipitation was 2.54 cm (1 inch). Summer (July, August) precipitation was 10.67 cm (4.2 inches). Average temperature for January is -3.3º C (26º F); for July it is 16.7º C (62º F). Temperatures during August can be over 32º C (90º F). The average growing season is 148 days. The first freeze can occur as early as October and as late as May (Brian 1997).

Associated plants in the vicinity of the species include rock mat (*Petrophytum caespitosum*), pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), little-leaf mountain mahogany (*Cercocarpus intricatus*), cliffrose (*Purshia stansburiana*), Hartweg evening primrose *(Calyophus hartweggi)*, wheatgrass (*Agropyron smithii*), and bluegrass (*Poa pratensis*) (Phillips *et al.* 1982). These plants are typical in pinyon-juniper woodland. A complete list of species found at Maricopa Point, including non-native species, can be found in Appendix A of the Sentry Milk-Vetch Survey Handbook (Brian 2001). *Astragalus calycosus* is a common milk-vetch in the surrounding area, but its larger size, upright growth form, and purple-pink flowers that fade to blue on stalks that extend above the leaves make it easily distinguishable from *A. cremnophylax*.

Life History and Ecology

Sentry milk-vetch exhibits two episodes of flowering from March through April and from September through November. Spring is the most common flowering time and usually results in successful fruit and seed set (Maschinski 1990a). Fall flowering plants set fruit, but seeds may not germinate until the next year (Maschinski 1991). This bi-seasonal flowering pattern has also been observed in plants cultivated at The Arboretum at Flagstaff (Maschinski 1990a). Plants in cultivation produced flowers after one year of vegetative growth. Age of first reproduction in the wild population is known to occur as early as one year from germination in individuals that have not been stressed by external factors (e.g., damage to foliage, lack of moisture) (Warren 1993).

Plants bearing the greatest number of mature fruits and seeds in May and June are generally the largest plants in the population. These large plants produced an average of 200 fruits in spring 1992 (Warren 1993). Smaller sized individuals produced disproportionately fewer fruits than projected based on the size of the plant (Warren 1993). The average number of seeds per fruit is 3.02, but the number can vary from one to six seeds (Maschinski 1990a, 1991).

Dispersal of seeds is very limited. Because the soft, pliable pods do not forcefully expel seeds as they split, seeds may remain within the pod attached to the parent plant for months (Maschinski *et al.* 1994). Seeds often fall into the foliage of the parent plant. Ants have been seen visiting the plants, but their influence on sentry milk-vetch is unknown. Ants may act as dispersal agents, but some species of ants eat seeds, flowers, or flower parts. Wind and water likely play an important role in seed dispersal (Maschinski 1990b). Because the fruits and tiny orange seeds are inconspicuous and do not seem to attract birds and mammals, the seeds are probably not dispersed or eaten by them.

Further evidence for limited seed dispersal comes from natural seed germination. Seed germination occurs in the fall, as early as September. Seedlings often germinate within 10 centimeters (4 inches) of an adult plant, but occasionally seedlings become established more than 30 centimeters (12 inches) from a parent plant. Seedlings that attempt to grow within the mat of the parent plant, or less than 5 millimeters (0.2 inch) from the edge of the mat have a decreased probability of survival (Maschinski *et al.* 1994). Establishment may occur within the foliage of the parent plant or other species such as rock mat, or at the base of species such as cliffrose or snakeweed (*Gutierrezia sarothrae*). Seedlings become established in soils between 2.5 to 5 centimeters (1 to 2 inches) in depth, suggesting that shallower soils do not have enough moisture retention for survival of seedlings (Maschinski 1990b). Maschinski *et al.* (1994) believe that persistence of seeds in a seed bank is minimal due to the shallow soils, large areas of exposed bedrock, and exposure of the site to high winds.

Data indicate seed germination varies from year to year. In cultivation, 49 percent of seeds collected in 1989 germinated readily without any special treatment (Maschinski 1990a). Only 31 percent of seeds collected in 1991 germinated (Maschinski 1991). Coincident with the decline in the seed germination rate is a decline in the numbers of individuals present at Maricopa Point. Several factors, including environmental factors, may be responsible for the year-to year differences in seed germination.

Seedling survival in cultivation was closely correlated with the substrate in which seeds were planted. Seedlings did not survive in well-aerated soil, but required limestone substrates for survival (Maschinski 1990a). These results suggest that the high water retention of heavy limestone soils was required for seedling growth and development.

Sentry milk-vetch plants at Maricopa Point did not set seed under pollinator enclosures, indicating that the plants are probably obligate outcrossers (Allphin *et al.* 2005). Plants at Grandview Point have set seed, despite the low numbers of individuals present at the site. It is not known if those plants are self-compatible or if seedlings produced at this site are from seeds stored in the seed bank. There is no information on the longevity of seeds in the soil.

An *ex situ* population of sentry milk-vetch was established at the Arboretum in Flagstaff. In 1996, there were 28 plants, but there are none remaining. The plants were very difficult to keep under greenhouse conditions because of the watering requirements (Maschinski pers. comm. 2006). Greenhouse plants did not resemble plants in the wild; they were leggy (up to 15 cm (5.9 in)) in length and produced flowers in the spring and fall.

Reasons for Listing / Threats

The Fish and Wildlife Service carefully assessed the best scientific and commercial information available regarding the past, present, and future threats faced by *Astragalus cremnophylax* var. *cremnophylax* as part of the evaluation to list this species as endangered (55 FR 50184-50187). The pertinent listing factors (per section 4(b) of the Endangered Species Act) identified in the rule listing the species were: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) the inadequacy of existing regulatory mechanisms; and (4) other natural or manmade factors affecting its continued existence.

The Present or Threatened Destruction, Modification, or Curtailment of its Habitat or Range

Because the largest known confirmed population has sustained severe declines, the species remains in danger of extinction (55 FR 50184-50187, Maschinski and Rutman 1993). Trampling does not appear to be a threat to the very small population at Grandview and “Lollipop Point”.

For decades, Maricopa Point has been a popular viewing point for visitors to the South Rim of the Grand Canyon. It is one of the first opportunities along the Hermit Road to view the canyon, and a large parking lot near the point makes visitation safe and convenient. Visitors arrive at Maricopa Point by shuttle bus, personal vehicles, or by walking along the West Rim Trail from Grand Canyon Village. The Park keeps the parking lot open to private vehicles from December 1 through February 28. From March 1 through November 30, Hermit Road is closed to private vehicles, but shuttle buses transport people from Grand Canyon Village to points along the Hermit Road, including Maricopa Point. Paved trails and dirt trails formed by casual, repeated use ("social trails") fragmented the population of sentry milk-vetch before the area was fenced.

Prior to fencing of the sentry milk-vetch population in 1990, many thousands of visitors per year walked over the population. Prior to protection, about 100 visitors per hour visited Maricopa Point during the peak visitor season of May and June (Warren 1993). Trampling of plants can cause mechanical injury to plant parts and alter habitat conditions through soil compaction, erosion, and physical disturbance (Hamilton and Lassoie 1986, Kuss 1986, Thomas and Wilson 1992). These impacts to plants can reduce photosynthetic activity, increase water loss, create increased energy costs for regrowth, and reduce reproductive output (Kuss 1986, Thomas and Wilson 1992). Early studies conducted on sentry milk-vetch by O'Brien (1984) reported that, out of 410 plants located and measured, 227 (65 percent of all mature plants recorded) were unhealthy and declining from trampling. In July 1986, the Park erected wooden fencing along portions of the paths at Maricopa Point to guide visitors away from the population. These efforts had limited success. The demographic monitoring data collected beginning in 1988 demonstrated that the number of sentry milk-vetch plants was in decline, soil was disturbed, and many plants were low in vigor (Rutman 1988). Trampling may have resulted in a decline in occupied habitat (apparently suitable habitat occurs at Maricopa Point that is currently unoccupied). In May 1990, the Park built a fence that directed visitor foot traffic completely around the population to a canyon overlook adjacent to Maricopa Point. In 1995, wire mesh was added to the wooden fence to improve restriction of human access. Paved trails within the area were removed and signs were placed on the fence to restrict access. The fence deters the vast majority of visitors from walking through the population of sentry milk-vetch, although some visitors violate the enclosure. In 1993, the Park estimated that one visitor per day intruded into the enclosure (Warren 1993).

The extent and effects of trampling and other threats to sentry milk-vetch at Maricopa Point have been documented in demographic monitoring plots (O'Brien 1984, Rutman 1988, Maschinski and Rutman 1993, Maschinski *et al.* 1994). In 1988, the first year of a long-term study, 356 plants were included within the monitoring plots (Table 1). Sixty-five percent of all plants in the monitoring plots showed some degree of trampling, and more than half of all plants (58 percent) showed severe trampling (Rutman 1988, Maschinski *et al.* 1994). Within one year, about 10 percent of the adult population had been lost (Warren

1993). Between May 1989 and May 1990, subpopulations experienced 19 to 63 percent mortality, depending upon the amount and severity of human traffic (U.S. Fish and Wildlife Service 1992, Maschinski and Rutman 1993). The population continued to decline between 1990 and 1992, even after the enclosure fence was built. Below-average rainfall in 1989 compounded the effects of trampling, which may have increased plant mortality (55 FR 50184-50187, Maschinski and Rutman 1993).

Trampled sentry milk-vetch plants lost leaf and branch biomass to varying degrees, depending on their position near heavy foot traffic areas. By 1990, many plants that had been monitored for three years had lost 95 percent of their aboveground biomass. Though some degree of this loss may be attributed to various factors (e.g., low precipitation), trampling is considered the primary cause. However, by 1992 and after two years of protecting the site, many of these plants had not begun to recover and many had died. Plants that received the most severe damage were those immediately adjacent to the rim. The loss of photosynthetic material on mature plants probably adversely affected plant vigor, the ability to withstand environmental stress, and flower and fruit production. The long-term effect of trampling is manifested in the current distribution of sentry milk-vetch plants. Plants in the formerly heavily visited areas normally occur where some surface irregularity in the rock, such as a deep crack or bump, protected the plant, or where some moderate to large sized obstruction diverted visitor traffic flow.

It is likely that trampling adversely affected sentry milk-vetch seedling recruitment and survival. Prior to protection, uprooted seedlings were observed in the monitoring plots and only those seedlings in sites relatively safe from human traffic survived (55 FR 50184-50187). Since construction of the fence in 1990, the number of established seedlings growing to reproductive maturity has been increasing (Maschinski *et al.* 1994).

Foot traffic compacts or otherwise disturbs the soil or bedrock surface and may adversely affect the plant/soil relationship (Kuss 1986). This effect may make germination less successful, seedling mortality higher, and reduce the vigor of mature plants (Hamilton and Lassoie 1986). Sentry milk-vetch distribution was markedly affected by trampling. Where the soil in occupied habitat is deepest, 2.5 to 5 centimeters (1 to 2 inches), foot traffic caused the greatest disturbance when the soil was wet and muddy. Plants in these areas were generally found where foot traffic was diverted by some small obstruction such as a shrub, tree, or dead tree branch. On the bedrock-dominated habitat, foot traffic has polished the limestone pavement, which may have adversely affected the porosity of the substrate (U.S. Fish and Wildlife Service 1990).

Table 1. Estimates and numbers of individual sentry milk-vetch plants detected in monitoring plots from 1988 through 2006, at Maricopa Point, Grand Canyon National Park. Data from Barneby (1964), Phillips *et al*. (1982), Warren (1988-1994), Brian (2000 and 2001), Juarez-Cummings and Crawford (2004) and Crawford (2006).

Year	Seedlings	Adults	Total
circa 1964	no data	no data	approximately 100
1982	no data	no data	approximately 150
1983	no data	no data	489
1988	46	314	360
1989	16	333	349
1990	10	275	285
1991	31	247	278
1992	24	249	273
1993	55	264	319
1994	69	268	337
1995	no data	no data	no data
1996	no data	no data	450
1997	no data	no data	no data
1998	no data	no data	no data
1999	no data	no data	no data
2000	143	540	683
2001	108	557	665
2002	no data	no data	no data
2003	no data	no data	no data
2004	272	60	332
2005	36	374	410
2006	10	317	327

Human traffic indirectly affects the sentry milk-vetch population through habitat degradation. Over time, trampling has resulted in the loss of plant cover, which has resulted in erosion of the thin soil. Foot traffic can also displace what little soil builds on the limestone surface, thus reducing the number of microsites available for germination. Most seedlings establish near plants or other obstructions that stop the sheet flow. The loss of plant cover due to trampling can reduce the microsites available for seedling establishment.

Sentry milk-vetch habitat and plants were probably lost when the Park constructed the West Rim Trail at Maricopa Point, in the early 1900s. This trail, which was paved in 1962, passed within a few feet of the rim and fragmented the sentry milk-vetch population. The paved trail was removed in May 1990 when the site was fenced to exclude human foot traffic.

The demographic data from 1988 through 1994 were further analyzed and interpreted by Maschinski *et al.* (1996). Their analyses confirmed that the size of the Maricopa Point population fluctuated even with protection. However, their population viability analysis indicated that removal of trampling led to a prediction of stabilization, while continued trampling with poor climatic conditions led to a prediction of accelerated extinction. Maschinski *et al.* (1996) stated that the continued existence of the species would depend on continued protection, environmental conditions that promote recruitment, and recovery efforts such as habitat enhancement and augmentation.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Plant collecting by botanists and other rare plant enthusiasts is a potential, but currently minor, threat to sentry milk-vetch. Although the extent of this threat is unknown, publicity could make this species susceptible to increased visitation and collection (55 FR 50184-50187). Because the number of populations and individuals is so small, even a small or moderate amount of collecting could seriously impact the species. The minor threat of unauthorized collection must be weighed against the potential benefits of education of the general public. The Park receives visitors from all over the globe, and the conservation status of this species could be enhanced by public education in the form of informational signs at Maricopa Point.

Disease and Predation

Disease has not been a factor in the decline of sentry milk-vetch. Plants at all three locations on the South Rim have been identified as having “chlorosis”, a general yellowing of the leaves. This characteristic is often associated with dry years. For instance, many of the plants that had been marked as chlorotic in 2005 looked fine in 2006. It is not known whether the chlorosis is due to a nutrient deficiency or is related to minimal precipitation.

The threat of predation to sentry milk-vetch is not well understood. Damage to plants in 2006 may have been due to predation by rock squirrels, or the damage may have been collateral; that is, the plants were dug up when rock squirrels were digging for roots to eat.

The Inadequacy of Existing Regulatory Mechanisms

The species is protected by National Park Service regulations, as are all plant species within the Park. Sentry milk-vetch is protected by the Arizona Native Plant Law. That law prohibits the collection of the species unless the Arizona Department of Agriculture grants a permit for educational or scientific purposes. However, the law does not provide habitat protection. Protection provided to the species under the Endangered Species Act is discussed below, in Conservation Measures.

Other Natural or Manmade Factors Affecting its Continued Existence.

Mortality of sentry milk-vetch plants surpassed establishment in all years monitored until 1993. The number of seedlings produced per year at Maricopa Point was insufficient to maintain the population and compensate for the annual mortality of adult plants until 1993 (Maschinski and Rutman 1993). Seedling mortality was high (Maschinski and Rutman 1993) relative to the number of plants surviving to reproductive maturity and the total annual mortality within the population until 1994. Since protection by fencing, seedling establishment has increased (Maschinski *et al.* 1994). Seedling numbers from 1988 through 1992 may have been small for several, possibly interdependent, reasons, including trampling, weather conditions, degraded habitat conditions, poor seed dispersal, and potential insect predation.

Seed production may be reduced by hard frosts and freezes during the flowering/fruiting period, a situation that occurred in 1988. Low seed-germination and seedling-establishment rates may have occurred due to insufficient rainfall. Poor seed dispersal may also affect the number of seedlings because seeds fall near the parent plant, where establishment is likely reduced. Insect predation may affect seedling establishment and survival. Although recent monitoring indicates improvements in seedling establishment, fluctuations in seedling survival are anticipated due to the above-mentioned reasons. Annual inventory of the monitoring plots is crucial to determine if natural recruitment levels are sufficient to maintain the population.

Sentry milk-vetch may face other threats that were not addressed in the original listing rule. It is interesting to note that in 2005 there were a total of 506 plants at Maricopa Point and only 332 in 2006. Crawford (2006) notes that many plants, especially in the M2 transect, were removed by rock squirrel activity. Large depressions and much soil disturbance was observed in the M2 transect and plants were missing or lying dead next to the depressions. The previous winter and spring in 2005-2006 were exceptionally dry and

may have contributed to the squirrel activity (digging for roots). A total of 40 plants were missing on just this transect.

There was a dramatic decline in the number of plants that were found outside of the monitoring transects at Maricopa Point. There were 96 individuals noted in 2005, in 2006 there were only 5. Drier than usual conditions may have contributed to this significant decline.

In 2006, Crawford analyzed the 2004-2006 monitoring data to determine if any of the ecological parameters that had been collected correlated with plant presence. The only significant relationship that she documented was that more sentry milk-vetch plants (61 percent) were found without a plant associate than with one (39 percent). Although not statistically significant, 29 percent of the plants were found in large depressions, 21 percent next to limestone, 11 percent in small depressions, seven percent in *Petrophytum* (rock-mat), 17 percent on rock, and 15 percent in gravel.

As mentioned earlier, sentry milk-vetch is experiencing reduced genetic vigor. Allphin *et al*. (2005) demonstrated that the Maricopa plants have low seed/ovule ratios (lower than the other varieties and closely related taxa), along with low observed heterozygosity. The authors surmise that low seed/ovule ratios due to embryo abortion may be the result of inbreeding depression. Inbreeding depression is a serious genetic concern in small, isolated populations where recessive, lethal alleles are expressed more often in the homozygous state due to high levels of breeding among closely related individuals. Also, the Maricopa plants are poor reproducers, exhibiting only 51 percent fruit set. Previous work (Travis *et al*. 1996) had reached a similar conclusion by analyzing AFLP (amplified fragment length polymorphisms) within the populations of sentry milk-vetch, including the Cape Final plants.

In their study, the Grandview plants exhibited an extreme lack of genetic diversity. The results were similar for the Maricopa plants. Travis *et al.* hypothesize that the lack of genetic diversity is due to a pronounced founder effect; while Allphin *et al*. hypothesize the population at Maricopa underwent a bottleneck event (from all the trampling). The bottom line is that the populations of sentry milk-vetch are genetically depauperate and are at risk. With the low levels of genetic diversity and low fecundity, neither population has the genetic resources to withstand catastrophic stochastic changes or man-caused disturbances.

Whether the population at Maricopa Point will persist and recover is unknown. A significant amount of area occupied in 1988 is now unoccupied and plant density is still relatively low. The ultimate response of sentry milk-vetch to reduction in foot traffic is unknown. Current data (Maschinski *et al.* 1994) indicate that the population is responding to protection based on lower mortality, improved seedling establishment, and an increase in plant vigor. Recolonization of unoccupied habitat may take a long time because seed dispersal is restricted and unoccupied areas appear to have been adversely affected. The extremely small populations of sentry milk-vetch make it particularly vulnerable to any

impacts reducing the number or fecundity of plants. As population size decreases, the effect of natural catastrophes and environmental and demographic stochasticity becomes more critical to the survival of the species (Shaffer 1981, Menges 1991). Several consecutive years of unfavorable environmental conditions or any local catastrophic event may have disastrous impacts to sentry milk-vetch. Maximum protection of the populations at Maricopa Point, Grandview, and "Lollipop Point", is critical to the continued existence of this species.

Conservation Measures

Regulatory tools that aid in the conservation of sentry milk-vetch include:

Taking and Trade Prohibitions

The Endangered Species Act prohibits the malicious damage, destruction, or removal and reduction to possession of listed plants under Federal jurisdiction. For areas not under Federal jurisdiction (e.g., private or state-owned lands), the Endangered Species Act prohibits removing, cutting, digging up, damaging, or destroying listed plants in knowing violation of any State law, including the violation of a State criminal trespass law. The Endangered Species Act prohibits a person subject to the jurisdiction of the United States from selling, offering for sale, importing, exporting, or transporting in interstate or foreign commerce any listed plant species in the course of commercial activity. The Lacey Act prohibits the same activities if the species is listed under any State law that provides for the conservation of species threatened with extinction, or is listed on an appendix to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Under certain circumstances, the Endangered Species Act also provides for the issuance of permits to carry out otherwise prohibited activities involving listed species. Sentry milk-vetch is listed as a highly safeguarded plant by the State of Arizona and is protected by the Arizona Native Plant Law. Those protections include the need for a permit to collect the plant and/or seeds, but offer no protection for the habitat.

Endangered Species Act Section 7 Requirements

Section 7 of the Endangered Species Act prohibits actions authorized, funded, or carried out by Federal agencies that jeopardize the continued existence of any listed threatened or endangered species. In addition, if discretionary Federal actions may affect listed species, section 7 consultation is required. The section 7 requirements would apply to future construction, road projects, and other decisions that would affect the habitat and plants on the South Rim.

Other conservation measures and research efforts for sentry milk-vetch include:

In May 1990, the Park constructed a sturdy wooden fence at Maricopa Point to protect sentry milk-vetch from visitor traffic, and wire fabric was added to the fence in 1995.

The fence has successfully rerouted the majority of visitors away from the habitat. In addition, the Park removed the portion of the paved West Rim Trail that circled the point. In 1990, one seedling became established in an area formerly covered with asphalt. Since then, numerous seedlings have germinated in the areas previously under the paved trail. Signs on the fence inform visitors that an ecologically sensitive area exists beyond the fence and instructs them to remain on the current trail that bypasses Maricopa Point and continues to other viewpoints. A small number of visitors still climb over the fence or go around the ends of the fence.

Permanent demographic monitoring plots were established in 1988 (Rutman 1988, Warren 1993). Park and Service personnel and volunteers collect data on plant size, flower production, damage class, recruitment, and mortality for marked individuals. This effort has aided understanding of many aspects of the ecology of sentry milk-vetch and supported the need to construct the fence to exclude visitors from the site.

The Arboretum at Flagstaff began studies of seed germination and seedling survival in 1989 to prepare propagules for reestablishment and development of a greenhouse population of sentry milk-vetch. As of 1994, there were 34 plants in the population at the Arboretum at Flagstaff. By 2000, there were only 5 left, and none were left in 2006. Plants in the greenhouse were destroyed by rabbits and squirrels. The last two remaining plants were destroyed by squirrels that bit the plants off at the base, but did not eat the plants (Maschinski pers. comm. 2006). Because some of the plants in cultivation were easily desiccated, transplanting whole plants is likely to be difficult or impossible without daily irrigation throughout the dry season (Maschinski 1990a).

In July 1990, the Arboretum at Flagstaff conducted an augmentation study by sowing 196 seeds, collected in 1989, into four different microhabitats at Maricopa Point. The microhabitats were: 1) unshaded powdered limestone/fine gravel in pockets in the bedrock; 2) unshaded cracks in the bedrock; 3) 1 inch (2 to 3 centimeters) of soil on the east side of a tree or shrub, where seeds received morning sun; and 4) 1 inch (2 to 3 centimeters) of soil on the southwest side of a tree or shrub, where seeds received mostly afternoon sun. Seven seeds were sown into seven replicates of each microhabitat. Despite good rains at Maricopa Point during the summer of 1990, by September, ten percent of the seeds had germinated, but only two seedlings (one percent) produced true leaves. By April 1991, only one seedling survived. It was established in a crack in the limestone (Maschinski 1993).

In 1991, the Arboretum at Flagstaff conducted a second sentry milk-vetch augmentation study. Using observations of where natural seed germination occurred, 230 seeds collected from mature plants in 1991 were sown. Sites for seed placement included soil at least 5 cm (2 inches) deep, in cracks in limestone, and near nurse plants or other structures that could provide temporary shelter. There was no germination (Maschinski 1991). The Park conducted similar trials by hand, distributing 100 seeds in 1992 at Maricopa Point. No seeds germinated (Warren 1993).

In 2006, sentry milk-vetch seeds were collected from all three South Rim locations. An estimated 500 seeds were collected and turned over to the Arboretum at Flagstaff for the creation of another *ex situ* population and propagules for an introduction trial. The *ex situ* population will be used to produce more seeds that will be used for augmentation efforts at Maricopa Point and to produce additional seedlings for the introduction effort, tentatively scheduled for spring 2008. Grants to support the augmentation and introduction efforts have been written and submitted to the Grand Canyon Foundation and other potential funding sources. A section 6 grant was awarded to The Arboretum at Flagstaff to support the 2006 seed collection, establishment of the ex situ population, and propagules for the introduction experiment.

In 2006, Julie Crawford and Shelia Murray (Arboretum at Flagstaff) surveyed areas that Dr. Joyce Maschinski had mapped (in 1992) as potential introduction sites for sentry milk-vetch based on aerial photographs. Four out of the six sites were evaluated and deemed unsuitable for sentry milk-vetch. The soils and bedrock were not suitable and no sentry milk-vetch was located. Another site south of Grandview was also evaluated and rejected.

Julie Crawford has located a potential introduction site near Maricopa Point. The location contains: a) the associated plant species, b) sunny, open exposure, highly porous Kaibab limestone with cracks and erosional depressions, and c) the presence of the mineral goethite. The soils at this site are slightly deeper than at Maricopa, but deeper soil may allow us to plant slightly larger plants in the area. Goethites are degrading pyrite; in other words, pyrite that has lost its sulfur component leaving only iron. The nodules are not uncommon on the Colorado Plateau, but are associated with Kaibab limestone. All of the sentry milk-vetch sites have goethites lying on the surface, but it is not known if there is an association between the presence of goethites and sentry milk-vetch. The Park in collaboration with the Service and The Arboretum at Flagstaff, intend to augment the Maricopa Point population with seed (and water the seeds to increase the likelihood of germination and seedling survival) and introduce greenhouse-grown sentry milk-vetch propagules into the introduction site and water the plants for at least two growing seasons. Planning has already started and work is planned to begin in spring 2008.

Future augmentation studies may help identify ecological requirements for seedling establishment and may increase the numbers of individuals in the population. However, based on these completed studies, introductions to new locations as well as population augmentation may be very difficult and likely dependant on local weather conditions. Successful augmentation or introduction is likely only if there are sufficient propagules available. Because there are so few individuals, seed production may not be sufficient to provide for reintroductions and augmentation. Investigation of alternative methods, such as tissue culture of plants, may be necessary.

In 2005-2006 the Park has been evaluating alternatives associated with the repair of the Hermit Road, which provides visitors vehicle access to Maricopa Point from December through February. One of the alternatives being considered is the removal of the Maricopa Point parking lot, moving the shuttle stop further away from the sentry milk-vetch enclosure, and rerouting the trail away from the enclosure. The Park has not made a final decision, but if this were chosen as the preferred alternative, it would provide much-needed additional protection for the Maricopa Point population.

Further investigations into the phylogenetic relationships among the varieties of *A. cremnophylax* and closely related taxa are continuing. Dr. L. Allphin is completing additional genetic and morphological studies and results should be finalized within the coming years. New information that is published will be used to update and revise the recovery plan, as appropriate.

PART II - RECOVERY

Recovery Strategy

The sentry milk-vetch recovery strategy is based on the species' current situation. These circumstances include a severely impacted small population, previous attempts to protect that small population, a few newly discovered populations with few individuals, existing unsurveyed habitat, previous unsuccessful efforts to establish individuals in the wild and incomplete information regarding the biology and ecology of the taxon.

In order to address the species' situation, the recovery strategy includes several components: protection of all populations from threats; surveys of habitat to locate any other existing populations; augmentation of existing populations; research regarding the basic biology and ecology of the species; establishment and maintenance of greenhouse/biological garden populations; establishment of additional wild populations; and close cooperation among the entities involved in and responsible for recovery of the species.

Objective and Measurable Criteria

The primary objective of this recovery plan is to ensure that sentry milk-vetch is progressing toward recovery through the maintenance of viable, natural populations. Sentry milk-vetch will be considered recovered when there are at least eight geographically distinct, viable populations protected in perpetuity. The immediate conservation goal for sentry milk-vetch is to minimize the risk of extinction by protecting the known natural sentry milk-vetch populations, increasing the number of individual plants in each population to the maximum extent of the available habitat, and establishing an *ex situ* (botanical garden/greenhouse) conservation program: these actions will begin to alleviate the threats of the small population size, limited genetic material, and possibility of stochastic effects negatively impacting the species' recovery potential. Sentry milk-vetch will remain at high risk of extinction as long as there so few plants (less than 600), scattered in just a few populations.

It is difficult to determine how many populations and how many individuals constitute a viable population when so many basic biological questions regarding this species remain unknown. Factors contributing to the estimation of the effective population size, including mating system, sex ratio, and variation in fertility (Barrett and Kohn 1991), are poorly understood for this species. Recent work suggests that the populations have suffered a loss of fitness due to inbreeding depression, which is a consequence of small population size. In addition, there are few known populations supporting low numbers of individuals and fecundity is low. The small number of populations makes the species highly vulnerable to environmental stochasticity and natural catastrophes, assuming all other threats are removed. The minimum viable population (the minimum number of individuals needed in a population to have an acceptably low probability of extinction) is estimated to be between 1,000 and 1,000,000 (Shafer 1987, Menges 1991, Maschinski 2006). These numbers should

be sufficient to protect the genetic integrity of most of in situ populations (Menges 1991). Unless and until new biological information indicates otherwise, the lower numbers will be used to set downlisting and recovery criteria, as further explained below. The extant populations and in situ established populations should support approximately 1,000 individuals.

Downlisting and Recovery (Delisting) Criteria

Reclassification to threatened status may occur when:

1. There are at least four viable populations of 1,000 individuals each (4,000 total) protected in perpetuity.
2. Naturally occurring populations are stable or increasing over a ten-year period.
3. Reintroduced populations are stable or increasing over a thirty-year period.

Delisting will occur when:

1. There are at least eight viable populations of 1,000 individuals each (8,000 total) protected in perpetuity.
2. Naturally occurring populations are stable or increasing over a ten-year period.
3. Reintroduced populations are stable or increasing over a thirty-year period.

The selected time periods (ten years and thirty years) reflect the low-frequency temporal variation in decadal drought-moisture cycles of the Southwest (Swetnam and Betancourt 1998). Extant populations have presumably been through previous drought periods (such as the one we are currently experiencing) and survived. Newly established populations need longer time periods associated with the recovery goals to ensure that the populations experience and can be sustained through the full range of climatic variation that occurs in these ecosystems.

Each population site must be protected from anthropogenic threats. The eight populations should be geographically separate and, in total, reflect the genetic variability of the species. The population numbers were selected after careful consideration of the limited knowledge regarding the biology of the taxon, its rarity and limited distribution, threats to the species, and current plant conservation research. Eight populations seem necessary to support a species that has naturally small habitats and population sizes, and relatively high probabilities of population extirpations. Eight separate populations lessens the risk that extirpation of individual populations will result in a high risk of extinction of the entire species. If new populations of sentry milk-vetch are discovered or established, the extent of occupied habitat and threats of extirpation/extinction can be re-assessed and the number of populations needed to meet recovery criteria can be modified; the target of eight represents a reasonable, scientifically sound benchmark to demonstrate that threats to the species have been adequately lessened or alleviated, but is not an empirically-derived goal that is set in

stone. The downlisting criteria represent an approximate "half-way" point to recovery, where the species status will have improved significantly by demonstrating viable population persistence in multiple (four) locations. Population persistence for downlisting and delisting will be achieved by implementing recovery actions that directly lessen and alleviate threats to the species; population persistence therefore demonstrates that threats have been sufficiently alleviated such that the species is no longer threatened or endangered throughout all or a significant portion of its range.

Increasing the number and size of populations will require considerable effort and aggressive protection. The very low success of the initial augmentation experiments indicates that increasing population numbers may take many years. Increasing populations, if needed, at newly discovered locations may prove to be equally difficult, especially if sites with the unique soil/bedrock chemistry and hydrology required to sustain sentry milk-vetch prove to be limited. Because of the limited number of plants, the small area of occupied habitat, the low vigor of many reproductive-aged plants, and the degraded condition of much of the known habitat, the recovery criteria may prove to be an unachievable goal. The lower number (1,000) was chosen because of the difficulty that will be associated with augmentation and establishment of new populations, in part due to the current condition of the existing populations.

The Step-down Outline of Recovery Actions recommends recovery actions that are necessary to lessen and alleviate threats to the species so that recovery criteria and goals can be achieved. Actions are arranged according to which listing factor (per section 4(b) of the Endangered Species Act) they address. These actions are preliminary; actions may need to be revised as new biological information is acquired for the species.

Step-down Outline of Recovery Actions

1. The present or threatened destruction, modification, or curtailment of its habitat or range.

1.1. Protect the population at Maricopa Point from disturbance. Trampling is a major threat to sentry milk-vetch and the existing fence that excludes public foot traffic from Maricopa Point should be maintained. The fence may also serve to discourage the public from collecting any plants. Rangers and/or volunteers should enforce the exclusion of persons from the habitat area of sentry milk-vetch. Admittance to the enclosure should be given by explicit permission only. Researchers and Park staff will be able to access the enclosure. The need for additional protection at Maricopa Point should be reviewed at least annually. If the fence built in 1990 provides insufficient protection, additional measures, such as fence improvements, additional signing, and closing the parking lot to visitor parking and shuttle bus stops should be considered. Additional fencing may be

needed to preclude entry to the site by walking around the edge of the fence. A lockable gate may solve the problem.

1.2. Monitor threats and evaluate the need for additional protective measures. Managers should be aware of the types and severity of threats to each population. At a minimum, each site should be visited yearly for an evaluation of current threats and consideration of additional protective measures.

1.3. Conduct surveys to positively identify and determine taxonomic relationships of new populations as they are found. The 1991, 1994, and 2002, discoveries of sentry milk-vetch populations indicate that additional populations may be located if surveys continue. Although some areas have been surveyed for sentry milk-vetch, potential habitat exists along many miles of the rims of Grand Canyon and perhaps at exposures of limestone bedrock away from the canyon's rim. Access to these areas is often difficult. However, finding more populations would decrease our current level of concern about the species' likelihood of extinction and would increase management flexibility by reducing the reliance on any single population toward achieving recovery. In addition, surveys may identify suitable locations for the establishment of introduced populations in a natural setting.

In order to achieve proper management and utilize the best science in augmentation and introduction efforts, populations other than that at Maricopa Point must be accurately identified. Flowers, fruit, and leaves are necessary for proper identification and it maybe necessary to have the specimens verified by experts. The most recent genetic work should be taken into account when identifying the species.

1.4. Increase the number of individuals and the amount of occupied habitat at all occupied sites to the carrying capacity of the habitat. Populations of sentry milk-vetch are so small that any further reduction in plant numbers would seriously increase the risk of extinction of sentry milk-vetch. Efforts to increase sentry milk-vetch numbers should be focused on the Maricopa Point population in particular. Population levels should be increased based on the amount of available habitat. To enhance recruitment into the population at Maricopa Point, seed germination and plant survivorship in all age classes must improve. The survivorship of mature plants began to improve after visitors were excluded from the site. However, a significant proportion of habitat is now unoccupied and, due to poor seed dispersal, the population may need assistance to reoccupy that habitat. Allowing or assisting this population to increase to the capacity of the habitat will reduce the species' probability of extinction. Several manipulative techniques, based on the results of ecological studies, should be considered in order to enhance the species' reproduction, recruitment, and survival. These techniques may include hand pollinating to increase fruit set, caging plants after

fruits are set to prevent seed predation, sowing seeds away from parent plants in favorable microsites, and supplementing water to experimental sites to encourage seed germination and seedling survival. The need to use manipulative techniques should be carefully evaluated by the Park in cooperation with the Service. With the recent alarming decline in plants at Maricopa Point, it is imperative that efforts to conserve the species are implemented before more genetic material is permanently lost to the species. Populations should be increased to the extent possible based on carrying capacity; if sites cannot sustain 1,000 individuals, they should be reassessed in the future to determine their contribution to recovery (downlisting and delisting goals).

1.5. Establish new populations as necessary to meet recovery criteria. Additional surveys may reveal the existence of more populations of sentry milk-vetch. However, additional populations should be established to ensure the species remains extant.

1.5.1. Establish a new population in a natural setting as a pilot project. Establishing a population of sentry milk-vetch could be a valuable tool to learn more about the species' ecological requirements. Experimentation and manipulation are more easily performed on new populations when such factors as seed sources, age of plants, soil conditions, weather conditions, and other factors are known in advance. Results of this pilot project can be used to develop management strategies and protection priorities of natural populations, augmentation methodology for natural populations, and the viability of introduced populations. Such a population would also serve as a seed source if natural populations are lost.

1.5.2. Survey potential suitable habitat. Areas that could be used to support new populations should be identified. Sites that are not and will not be subjected to disturbance or modification will be most desirable for successful establishment and preservation of a new population.

1.5.3. Introduce the species to suitable microsites. Techniques to introduce the species must be developed before introduction will be possible or successful. The plant grows on bedrock or shallow soils, making the transplantation of greenhouse-grown plants difficult, if not impossible. Other techniques such as seed dispersal to new sites and other manipulative techniques should be explored.

1.5.4. Monitor and study the reintroduced population. Monitoring and study should aid in understanding the reasons for the success or failure of the effort. Techniques for creating new populations and managing natural

populations can be learned through this process.

1.5.5. Based on the results of the pilot project and availability of suitable introduction sites, establish additional new populations. The number, size, and distribution of natural populations that are known, upon the completion of the pilot project, will determine the urgency or necessity of further conservation efforts in a natural setting. Individual populations should maintain and reflect the genetic integrity of each known natural population. The introductions should be planned to establish self-sustaining populations to achieve reclassification criteria. A monitoring program for all introduction efforts would need to be developed.

2. *Overutilization for commercial, recreational, scientific, or educational purposes.*

2.1. Coordinate research activities. Careful coordination among investigators and with the Park is needed to insure that the cumulative impact of various studies and research activities does not harm the population. Investigators must obtain permits from the Park and Service prior to initiating most biological studies.

2.2. Develop public awareness, appreciation, and support for preservation of sentry milk-vetch. Public education can be a crucial part of the recovery of a species. The cooperation of the public will also be essential for the ultimate success of on-going recovery actions. Many public interest groups, such as native plant societies, can lend physical support to recovery efforts. Grand Canyon National Park staff can help explain the importance of plant conservation, maintaining biodiversity, and natural resources unique to the Grand Canyon. Materials to educate the public should be developed. If the Maricopa Point parking lot remains open, tour and shuttle bus drivers stopping at Maricopa Point could alert visitors to the protection of the "environmentally sensitive area" and provide general comments regarding plant conservation. Because vandalism is a potential threat to many endangered species, care should be taken to avoid directly identifying the site.

3. *Disease or predation*. – This is not known to be a factor in the endangerment of the sentry milk-vetch, however future monitoring can be used to increase our awareness of possible predation (see Recovery Action 1.2).

4. *The inadequacy of existing regulatory mechanisms.*

4.1. Enforce laws and regulations. All regulations for the protection of threatened and endangered species on Federal lands, including the Endangered Species Act, the

Lacey Act, the Arizona Native Plant Law, National Park Service Organic Act, and Grand Canyon Enlargement Act, should be enforced.

4.2. Ensure long-term protection. All sentry milk-vetch populations should be protected in perpetuity through management agreements with the Park or conservation agreements with private landowners, should new populations be located on private land.

5. *Other natural or manmade factors affecting its continued existence.*

5.1 Provide assistance to Grand Canyon National Park (and other land owners and managers) to recover and protect the species and its habitat. Recovering and protecting populations of sentry milk-vetch is the responsibility of the Park. We will provide technical assistance to the Park, as requested. If new populations of this variety are discovered on other lands, we will provide management assistance to those landowners or managers, if requested. We will assist the Park and land owners and managers in seeking funding to support recovery actions on and off Park lands.

5.2 Adjust management as necessary. As monitoring proceeds, new threats may be identified, or previously unrecognized ongoing threats may become obvious. The Park or other landowner or land manager should respond to any recognized threat promptly by modifying management to minimize or eliminate the threat(s).

5.3 Conduct research on the existing populations. Studies of the wild populations of sentry milk-vetch should be developed to provide information essential for the conservation of the species, including determining the species' status, developing successful augmentation techniques for natural populations, and evaluating management decisions. Because so little is known about the biology and ecology of sentry milk-vetch, a diverse array of studies can contribute to protecting the species from extinction. Also see Recovery Action 2.1.

5.3.1 Continue to gather and analyze demographic data. The annual monitoring of the demographic plots established at Maricopa Point in 1988 should be continued and the data analyzed. In addition, similar monitoring should be established and conducted for all other populations. The monitoring at all sites should include tracking individuals, determining reproductive status, determining the fate of seedlings, and habitat monitoring (e.g., repeat photography). A summary of the data collected as part of each annual monitoring effort should be prepared each year. Every three to five years, an inclusive, detailed analysis of the demographic data should be prepared. The demographic and biological information gathered from these plots will

help the Park and Service determine the status of the species, identify threats, and guide management decisions. In addition, the baseline demographic data will help determine if any management activities (e.g., the construction of the enclosure fence) affect species recruitment and survival. Life-history characteristics and the influence of various environmental parameters may be determined through these demographic studies. For example, a determination of the average age of first reproduction and fecundity, and whether mortality factors are controlled by precipitation patterns, are needed. The Park has a multitude of demographic data; some of which have never been analyzed (e.g. the mylar tracings to estimate basal cover). The Park should strive to archive the data and make it available to researchers to analyze. The data from 1988-1994 was used to create a population viability model for the species. Many of the questions raised in this section may have answers in the Park datasets (e.g., how long-lived are individuals and creating life stage matrices for additional population viability studies).

5.3.2 Peer review of the monitoring protocol. The demographic monitoring protocol has been in place since 1988 at Maricopa Point, with a few changes. The protocol would benefit from peer review to determine if changes can be made to answer some of the most relevant questions regarding the life history of this species. Peer review would be a useful aid in determining if portions of the monitoring protocol are worth carrying into the future (e.g., the mylar tracings).

5.3.3 Study the ecology of the species. Several ecological questions must be answered to understand the reasons for the decline and lack of vigor in sentry milk-vetch populations. Specifically, habitat requirements for seed germination and seedling survival, pollination and seed dispersal ecology, and the effects of potential herbivory and competition on seedling survival should be investigated.

5.3.4 Soil and hydrologic requirements. The different rates of seed germination and establishment on different substrates may be due to hydrologic properties or soil chemistry. Understanding the relationships among seedling mortality, soil depth, soil/bedrock chemical properties, and moisture may be essential for best management of the existing site, conducting successful population augmentation, and establishing new populations in a natural setting.

5.3.5 Seed dispersal. Seed dispersal seems to be extremely limited, that is, the seeds seem to be dispersed by gravity. Studies should be

implemented to investigate patterns of natural dispersal, consequences to seedlings, and if a seed bank exists. It is possible that germination and seedling survival could be improved by physically distributing seeds, particularly into suitable but currently unoccupied habitat.

5.3.6 Biotic factors. Biotic factors may explain patterns of mortality and survival of sentry milk-vetch and should be investigated. For example, seedling distribution may reflect the influence of competition or herbivory. Evidence of whether seedlings fail to survive when growing too close to the parent plant or its neighbors or are subject to greater herbivory when growing in certain microsites would be useful for population augmentation and in establishing new populations in a natural setting.

5.3.7 Phenology. Intrinsic factors of sentry milk-vetch, such as the timing of flowering, fruit set, and seed germination can guide the timing of recovery activities. Studies should be initiated to examine these factors. For example, if plants that flower in the fall set more seed than those that flower in the spring, yet seeds produced in the spring have greater viability, perhaps hand-pollination would be most productive if conducted in the spring rather than in the fall.

5.3.8 Timing and causes of mortality. Presently, we know little about the causes of death of plants of varying ages. To successfully augment known populations and establish new populations in natural settings, we need to know when and which factors most seriously threaten the population.

5.4 Establish an *ex situ* (botanical garden/greenhouse) conservation program. One catastrophic event at Maricopa Point could result in the extinction of sentry milk-vetch. The Grandview and Lollipop Point populations may not be large enough and may never be large enough to support a population that will ensure the continued existence of the species. At this point, it is not clear how the other known populations should fit into the augmentation and establishment of populations. Botanical garden/greenhouse populations of sentry milk-vetch would facilitate research and create a conservation pool should catastrophic events eliminate the species in the wild. If the Maricopa Point population is lost, seeds from such cultivated populations could be used to reestablish the species.

5.4.1 Establish and maintain a seed bank and botanical garden/greenhouse population. Establishment of new populations in a natural setting may be difficult given our current, limited understanding of the species. While efforts are being made to establish a population in a natural

setting, a population in a garden and seed bank can be established to provide some buffer against extinction if catastrophic events cause the loss of the natural populations. Seeds from each natural population should be individually conserved, and the source documented, to maintain the genetic integrity of each population. The Arboretum at Flagstaff, a member institution of the Center for Plant Conservation, maintains a seed bank of sentry-milk vetch, and should continue to maintain its' collection. Seeds are also being maintained at the U.S. Department of Agriculture National Seed Storage Lab. Seed should only be collected from natural populations for garden propagation or storage when fruit production is sufficient to withstand collecting. The number of reproductive plants and the number of fruits per plant is low enough that seed collection must be limited during some years so that the species is not adversely affected.

5.4.2 Investigate alternative methods to generate sufficient propagules for augmentation and introduction. Obtaining a sufficient amount of propagules for augmentation and introduction is likely to remain a problem. For example, it has been estimated that as many as 10,000 seeds may be necessary to achieve augmentation or introduction by seeding alone. Additional methods and techniques, perhaps such as tissue culture of plants, for obtaining a sufficient number of candidates for introduction must be investigated and developed.

5.4.3 Collect seeds from all known populations and encourage mixing of the populations to increase genetic vigor. The Maricopa and Grandview populations have been demonstrated to be genetically depauperate. In an effort to maximize the heterozygosity of the populations, mixing of propagules from the different populations is encouraged in order to improve the vigor of the populations and, hopefully, offset the effects of inbreeding depression.

5.5 Exchange information between agencies, the public, and the scientific community. Scientific information, including results of field and greenhouse research, monitoring data, trip reports, agency reports, and scientific literature should be readily available to all parties interested in the management and survival of sentry milk-vetch. Ideas should be freely exchanged so that optimal recovery strategies can be outlined and implemented. Meetings of interested parties to discuss new information or management issues or strategies should be encouraged. Preliminary or refined research or monitoring data should be presented at local, regional, and national gatherings of professional scientists so that a broad professional audience may have opportunities to comment on, and potentially enhance, the recovery potential of sentry milk-vetch.

6.0 Develop a post-listing monitoring plan. The plant and its habitat will be monitored for 5 years after recovery (delisting) has been achieved.

PART III - IMPLEMENTATION SCHEDULE

The following implementation schedule outlines actions and costs for the sentry milk-vetch recovery program. It is a guide for meeting the objectives discussed in Part II of this plan. The schedule indicates task priorities, descriptions, and duration, responsible agencies or potential partners, and estimated costs. These actions, when accomplished, should bring about the recovery of sentry milk-vetch and protect its habitat. It should be noted that the estimated monetary needs for all parties involved in recovery are identified for the first five years only, and therefore are not reflective of total recovery costs. The costs estimated are intended to assist in planning and should be revisited in a few years. This recovery plan does not obligate any involved agency to expend the estimated funds.

Priorities in the first column of the table are assigned as follows:

Priority 1: An action that must be taken to prevent extinction, or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other negative impact short of extinction.

Agency Abbreviations

FWS - U.S. Fish and Wildlife Service
GRCA - Grand Canyon National Park
ARBO - Contracted studies/arboretum services

RECOVERY PLAN IMPLEMENTATION SCHEDULE

Costs (thousands of dollars)

Priority	Action	Description	Duration in years	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
1	1.1	Protect population at Maricopa Point	Ongoing	GRCA	0.5	0.5	0.5	0.5	0.5	2.5
1	1.2	Monitor threats	Ongoing	FWS GRCA	 5	 5	 5	 5	 5	 25
1	1.3	Conduct surveys	3	FWS GRCA	8 8	8 8	8 8			24 24
1	1.4	Increase number of individuals in natural populations	5	FWS GRCA	14 6	14 6	14 6	14 6	14 6	70 30
1	1.5.1	Establish new population as pilot project	2	FWS GRCA				25 10	25 10	50 20
1	1.5.2	Survey suitable habitat for new pilot population	3	FWS GRCA	8 2	4 1	4 1			16 4
1	1.5.3	Introduce plants to suitable microsites	3	FWS GRCA			4 1	4 1	4 1	12 3
1	1.5.4	Monitor and study pilot population	3	FWS GRCA			4 1	4 1	4 1	12 3
1	1.5.5	Establish additional populations if deemed suitable	2	FWS GRCA				25 10	25 10	50 20
2	2.1	Coordinate research activities	5	GRCA	3	3	3	3	3	15

Priority	Action	Description	Duration in years	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
2	2.2	Education	Ongoing	FWS GRCA	1 1	1 1	1 1	1 1	1 1	5 5
1	4.1	Enforce laws	Ongoing	FWS GRCA	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	2.5 2.5
2	5.1	FWS technical assistance to agencies and landowners	Ongoing	FWS	4	4	4	4	4	20
2	5.2	Adjust management	Ongoing	GRCA	2	2	2	2	2	10
2	5.3.1	Collect and analyze demographic data	5	FWS GRCA	4 20	4 20	4 10	4 10	4 10	20 70
2	5.3.2	Peer review of monitoring protocol	1	GRCA	10					10
1	5.3.3	Study the ecology of the species	5	FWS GRCA	10 20	10 20	10 10	10 10	10 10	50 70
2	5.3.4	Soil and hydrological studies	2	FWS GRCA	5 5	5 5				10 10
2	5.3.5	Seed dispersal	2	FWS GRCA	6 4	6 4				12 8
2	5.3.6	Biotic factors	2	FWS GRCA	10 10	10 10				20 20
2	5.3.7	Phenology	2	FWS GRCA	12 8	12 8				24 16
2	5.3.8	Timing and causes of mortality	5	FWS GRCA	4 4	4 4	4 4	4 4	4 4	20 20

Priority	Action	Description	Duration in years	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
1	5.4.1	Establish and maintain seed bank and garden population	Ongoing	ARBO or other	8	8	8	8	8	40
1	5.4.2	Investigate and develop alternative methods to generate propagules	5	ARBO or other	10	10	10	10	10	50
1	5.4.3	Collect and mix propagules from different locations	5	ARBO GRCA	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	2.5 2.5
2	5.5	Information exchange	Ongoing	FWS GRCA	0.5 1.0	0.5 1.0	0.5 1.0	0.5 1.0	0.5 1.0	2.5 5
1	6.0	Post-listing monitoring plan	5	FWS	10	10	10	10	10	10
Total					**226**	**216**	**141**	**190**	**190**	**963**

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APPENDIX

Summary of Public Comment and Peer Review Process (September 2004 - February 2005)

An earlier version of the draft recovery plan was released for public comment in 1993. Those responses are in the administrative record in our files and are not included in this section because the recovery plan has undergone major revisions since that time and the previous comments are not relevant to this process.

We released the Draft Recovery Plan for the sentry milk-vetch for a 30-day public comment period on September 14, 2004. In January 2005, we requested and received peer review from four independent specialists with expertise regarding sentry milk-vetch and closely related species: Dr. Loreen Allphin Woolstenhulme, Associate Professor, Brigham Young University; Ms. Nancy Brian, botanist, Bureau of Land Management; Dr. Tina Ayers, Curator, Deaver Herbarium, Northern Arizona University; and Dr. Joyce Maschinski, Conservation Ecologist, Fairchild Tropical Botanic Garden. During the comment period we received five responses from individuals, including the peer reviews. The comment period was reopened for 30 days on January 10, 2005, in order to accept comments from Grand Canyon National Park staff. No other comments were received during this period. All comment letters are kept on file at the Arizona Ecological Services Field Office in Phoenix, Arizona.

This recovery plan also received internal review by Service staff at the Albuquerque, New Mexico Regional Office and the Washington office. We reviewed all internal comments and those received during the comment period. Comments ranged from editorial suggestions to providing new information. We have tried to incorporate all applicable comments into this Final Recovery Plan. A summary of the substantial comments and our responses follow.

Summary of Significant Comments and Service Responses

COMMENT: Recent research has shown that the plants from the North Rim of the Grand Canyon are genetically distinct from sentry milk-vetch plants on the South Rim. Consider treating the North Rim plants separately.

RESPONSE: We have incorporated the latest genetic work of Allphin *et al.* (2005) in the final recovery plan and recognize that the North Rim plants, located at Cape Final, are distinct and most likely merit a different taxonomic status. The Cape Final populations of milk-vetch are not included in the sentry milk-vetch recovery plan (pages iii, 5-6).

COMMENT: Consider not publishing a population estimate of sentry milk-vetch at "Lollipop Point" as some of the plants identified as *A. cremnophylax* var. *cremnophylax* were actually a depauperate form of *A. calycosus*.

RESPONSE: There is a population estimate given for "Lollipop Point" in the final recovery plan. Qualified botanists from the Park and the Service provided the 2006 estimate. There was enough morphological evidence in the field to differentiate between *A. cremnophylax* var. *cremnophylax* and *A. calycosus*. Both species were seen at "Lollipop Point" (pages iii, 5).

COMMENT: The statement on page one, referring to the possible loss of contiguous habitat and populations in the last 44 years, cannot be substantiated, and recent genetic work does not support this statement.

RESPONSE: The statement has been removed.

COMMENT: The downlisting and delisting criteria need to be reevaluated in light of the Allphin *et al.* work.

RESPONSE: We used the most recent work and the best available science to create and support the recovery criteria. We also discussed the difficulty that will be associated with trying to attain the recovery criteria (pages 22-23).

COMMENT: Will the monitoring team be allowed to enter the enclosure at Maricopa Point?

RESPONSE: The enclosure is designed to keep the general public from entering the area. The step-down outline recommends that permission from the Park Service be obtained before entering the enclosure. Park personnel and other qualified staff and researchers will have reasonable access to the area to conduct monitoring and other scientific investigations (page 23).

COMMENT: Consider adding language about creating an *ex situ* sentry milk-vetch population at the Arboretum in Flagstaff by seeds and cloning.

RESPONSE: This has been included in the recovery actions (pages 29-30).

COMMENT: The Park Service is considering moving the shuttle stop near Maricopa Point to reduce pedestrian traffic near the enclosure.

RESPONSE: We have included a discussion of the Park Service's proposal associated with the widening of Hermit Road in the recovery plan (page 20).

COMMENT: Add the following three items to "Major Actions Needed" section: a) yearly monitoring continued at Maricopa Point, b) yearly status report prepared, and c) copies of field data be archived with FWS.

RESPONSE: The recommendation for yearly monitoring was added to the above-referenced section (page iv) and the remaining items are addressed in the recovery actions, specifically in 5.3.1 (page 27).

COMMENT: Provide a more technical taxonomic description of sentry milk-vetch.

RESPONSE: The description that is provided is thought to have enough detail without being too technical. References are provided in the Literature Cited section for those interested in the morphological details of the species.

COMMENT: There is confusion in the document regarding the number of sentry milk-vetch plants at Maricopa Point.

RESPONSE: We attempted to clarify the numbers in Table 1 (page 13) and discuss the different population estimates and our ability to compare the numbers on page 6.

COMMENT: Sentry milk-vetch plants are extirpated at the Grandview site and the text regarding this location should be in the past tense.

RESPONSE: Sentry milk-vetch plants were found at the Grandview site in 2006 and we believe they occupy the same site as described in the literature.

COMMENT: Provide more details on the elevation and climate at Maricopa Point.

RESPONSE: More details were added to the final recovery plan (page 8).

COMMENT: Include a citation for the estimation of basal area by the perimeter tracing method.

RESPONSE: There is a discussion of this technique in the final recovery plan, along with the appropriate citation (page 7).

COMMENT: There is no discussion of the breeding system of sentry milk-vetch.

RESPONSE: Discussion has been added on page 5 of the final recovery plan.

COMMENT: Numbers are incorrect (added incorrectly) in Table 1.

RESPONSE: The numbers have been corrected and rechecked against the original data.

COMMENT: Incorporate a discussion of inbreeding depression and associated reproductive problems with this species.

RESPONSE: We have incorporated a discussion of these factors based on Allphin *et al*. (2005) work (pages 5-6).

COMMENT: Recommend using numbers from Lande's work (1995) regarding effective population size. Based on that work, 5,000 individuals may be more appropriate for recovery goal than the 1,000 proposed in the draft recovery plan.

RESPONSE: We used an estimate of 1,000 to 1,000,000 based on estimates for minimum viable population. We chose the lower end of the estimate because of the inherent difficulties that will be associated with attaining the recovery goals. We acknowledge that more individuals in a population would further decrease extinction risk, but wanted to be realistic in terms of what might be achievable, given the current low numbers and reproductive problems of the existing sentry milk-vetch populations.

COMMENT: Suggest that the monitoring protocol be peer reviewed.

RESPONSE: This suggestion was added to the recovery actions (5.3.2).

COMMENT: There is so much basic biology that is unknown that it is premature to proceed with a recovery plan.

RESPONSE: We acknowledge that there are information gaps for this species, but felt that we have adequate preliminary information to proceed with a final recovery plan. The publication of a recovery plan does not preclude the need for continued studies of basic biological and ecological requirements for this species. We discuss those needs in the recovery actions (5.3.1 through 5.3.8) and as studies are completed we revise our recovery plans to reflect new information. We believe we have incorporated all the biological information on this species, including the recently published (2005) reproductive and genetic work of Allphin *et al*. The recovery plan will help draw attention to the species and can be used to garner funding and staff support for implementation of recovery actions.

COMMENT: The recovery plan is premature because all suitable habitat within Grand Canyon National Park has not been surveyed.

RESPONSE: We acknowledge that all potential sentry milk-vetch habitat with the Park has not been surveyed, but much of it has been. The recovery actions recommend further survey work (1.3) and if new populations are discovered, the recovery plan will be revised to include that information. The recovery criteria will be reviewed to determine if they need revision or modification.

COMMENT: We do not provide rationale for the recovery actions pertaining to population augmentation, creation of new populations, and *ex situ* populations.

RESPONSE: We have provided the basis for the recovery actions in our discussions of inbreeding depression and lack of genetic diversity in the existing sentry milk-vetch populations (pages 5-6, 16-17).

COMMENT: A complete demographic study of sentry milk-vetch should be completed. A population viability analysis should be completed.

RESPONSE: We agree that a demographic analysis should be completed and the recommendation is one of the recovery actions (5.3.1). A population viability analysis was completed on an earlier set of information (Maschinski *et al*. 1996), but additional data has been collected and there is a recommendation to complete additional viability analyses.

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