ARIZONA GAME AND FISH DEPARTMENT
HERITAGE DATA MANAGEMENT SYSTEM

Plant Abstract **Element Code:** PDFAB0F2H1
Data Sensitivity: Yes

CLASSIFICATION, NOMENCLATURE, DESCRIPTION, RANGE

NAME: *Astragalus cremnophylax* var. *cremnophylax* Barneby
COMMON NAME: Sentry milk-vetch, Sentry milkvetch
SYNONYMS:
FAMILY: Leguminosae

AUTHOR, PLACE OF PUBLICATION: R. Barneby, Leaflets of Western Botany 5(5): 83-85. 1948.

TYPE LOCALITY: United State of America: Arizona: Coconino County: on South Rim of the Grand Canyon of the Colorado River, west of El Tovar, 3 June 1947.

TYPE SPECIMEN: HT: CAS-336060. H.D.D. Ripley 8473 and R.C. Barneby, 3 June 1947. Also cites Jones s.n. [in 1903] as paratype collection. IT: NY-5386, ARIZ.

TAXONOMIC UNIQUENESS: This genus contains 2,500 species occurring throughout the subtropical and temperate parts of the world; 350 occur in North America. *Astragalus* is the largest genus of flowering plants in Arizona. *Astragalus cremnophylax* and three other species are in the subsection *Humillimi* of *Astragalus* (Maschinski 1993). *A. cremnophylax* is divided into three varieties including *A. c.* var. *cremnophylax*, *A. c.* var. *myriorrhaphis* (cliff milkvetch) and *A. c.* var. *hevronii* (Hevron's milkvetch).

DESCRIPTION: A member of the pea family (Fabaceae), this dwarf, evergreen, perennial, mat-forming herb with a thick taproot, is usually less than 2.5 cm (1.0 in.) high and 2.5 to 25.0 cm (1.0 to 10 in.) in diameter. Short creeping stems have compound leaves 1.3 cm (0.5 in.) long, composed of 5-9 tiny leaflets 1-2 mm long. A large number of tiny, pea flowers are produced; 100-200 per plant is not uncommon. Flowers are whitish or pale pinkish-lilac in color, 5 mm long, and borne on a raceme of 1-3 flowers, held slightly above the mat. The fruit is unilocular, obliquely egg-shaped, and densely hairy, 3-4 mm long. Fruits vary in number from 1->700 per plant depending on size, amount of damage, and health of plant. Each fruit produces 1-6 orange seeds; the average number is 3. Seeds are 1 mm in length. Determination of age is difficult due to the mat-like growth form.

AIDS TO IDENTIFICATION: *A. c.* var. *cremnophylax* may easily be confused with *A. calycosus* (King's milkvetch), a species which is much more common in the surrounding habitat. *A. c.* var. *cremnophylax* is without a leafy stem above the ground and is a mat-former. *A. calycosus* is less prostrate, although it does not have a leafy stem above the ground

and the inflorescence usually surpasses the leaves considerably. *A. c.* var. *cremnophylax* has pale pinkish-lilac flowers and one-celled pods. *A. calycosus* has blue flowers with wing petals deeply notched and two-celled pods. Care should be taken not to confuse *A. c.* var. *cremnophylax* with the other seemingly similar mat-formers at the site-locales, among them *Petrophytum caespitosum* (rock mat).

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).

Per Falk and Jenkins et al. (2001), *A. c.* var. *cremnophylax* can be "distinguished from var. *myriorrphaphis* by lack of spinescent leaf bases; from var. *hevronii* by smaller flowers; and *A. calycosus* by unilocular fruits and teeny leaflets."

According to the Draft Sentry Milk-vetch Recovery Plan (USFWS 2004), several characteristics distinguish *Astragalus cremnophylax* var. *cremnophylax* from the varieties *myriorrhaphis* and *hevronii*. Both of the varieties *myriorrhaphis* and *hevronii* are somewhat larger and coarser than variety *cremnophylax*. Variety *myriorrhaphis* has much longer leaves from 13-35 mm long, which are dimorphic within the growing season. Variety *hevronii* is similar to variety *myriorrhaphis* in foliage, but has larger flowers of brighter color. The three varieties are also distinguished by their geographic ranges. *A. cremnophylax* var. *myriorrhaphis* is known from several sites along the north Kaibab Plateau, *A. cremnophylax* var. *hevronii* is known from two sites on the rim of Marble Canyon, and the distribution of *A. c.* var. *cremnophylax* is as described below.

ILLUSTRATIONS:

Line drawing (Rutman 1992:25)
Line drawing of plant and parts (*in* Falk, Jenkins et al. 2001)
Color photos of plant and habitat (Joyce Maschinski, *in* Falk, Jenkins et al. 2001).
Color photo of plant in flower (Sue Rutman, *in* Falk, Jenkins et al. 2001)
Color photo of flowering plant and habitat (Karen Warren, *in* Brian 2000)
Color photo (P. Rowlands, *in* Brian 2000)
Color photos of plants and habitat (*in* Brian 1997)
Line drawing (*in* USFWS 2004)
Color photo (USFWS 2006)

TOTAL RANGE: There are four known populations on the edges of the South Rim of the Grand Canyon (USFWS 2018). Some of these populations have additional sub-populations and some groups of new plants have been discovered on limestone fingers along and below the rim. Known populations occur only in Coconino County. Three populations have recently been discovered on the North Rim, and preliminary genetic results suggest they would be

ascribed to sentry milk-vetch. This information is awaiting confirmation and publication (USFWS 2018).

RANGE WITHIN ARIZONA: See "**Total Range**."

SPECIES BIOLOGY AND POPULATION TRENDS

GROWTH FORM: Perennial, mat-forming forb/herb.

PHENOLOGY: March-April (late April to early May) and September-November, spring more common; fruits from late May-June. According to Maschinski & Rutman (1993, in CPC 2003), "Plants flower in response to moisture in the spring and fall. There are two bouts of seed set." Falk and Jenkins et al. (2001), report that flowering occurs from late April to May, with rarely a second flowering occurring following summer rains. Fruiting occurs from May to June. Fall flowering is not commonly observed in wild plants, but is common in greenhouse plants which receive supplemental watering (Brian 1997).

BIOLOGY: Many species of *Astragalus* are found in small, highly restricted populations that are endemic to particular geologic formations or geographic regions.

Grand Canyon population forms "lichen-like scabs of minute silvery foliage pressed against the rock pavement" (Barneby 1979). Soil types that retain great amount of water, such as limestone, are critical to the growth and development of seeds. Viability of different seed colors not significantly different. Under control conditions, it was observed that seeds germinated within five weeks after sowing (Maschinski 1990). After germination, branchlets spread in a densely-branched pattern over the surface of the rock. It does not root on rock surface, but rather traps wind-borne sand and silt, building own layer of "topsoil" from which it must extract some nutrition. Flowers are highly susceptible to low temperature conditions such as frost, freezing rain, or snow. These conditions often occur simultaneously with time of flowering. Ants may be primary pollinators. The seeds are so small that they are not wind or rodent dispersed but instead fall in the mat of plant, thus their population does not spread and remains isolated (Phillips 1993).

The following more detailed review of reproduction and seed dynamics was taken from the 2006 USFWS Recovery Plan:

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 1990, 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). Under control conditions, it was observed that seeds germinated within five weeks after sowing. After germination, branchlets spread in a densely-branched pattern over the surface of the rock. It does not root on rock surface, but rather traps wind-borne sand and silt, building own layer of "topsoil" from which it must extract some nutrition. Flowers are highly susceptible to low temperature conditions such as frost, freezing rain, or snow. These conditions often occur simultaneously with time of flowering. Ants may be primary pollinators. It should be noted that seeds are so small that they are not wind or rodent dispersed but instead fall in the mat of the plant. Therefore, population does not spread and remains isolated (USFWS 2015).

Seed germination occurs in September. 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). Soil types that retain great amount of water, such as limestone, are critical to the growth and development of seeds.

Busco (2012) reported finding three generalist pollinators (two mason bees, *Osmia ribiflorus* and *Osmia ribiflorus ribiflorus*, and a hoverfly, Syrphidae) that were observed in multiple populations between 2010 to 2012.

Allphin et al 2005, conducted an investigation into reproductive success and genetic divergence among the varieties of *A. cremnophylax*. This in-depth work analyzed morphological and reproductive data, abiotic and plant community information, genetic variability, population genetics, and phylogentic relationships. They found a number of reasons that merit the endangered status for *A. c.* var. *cremnophylax.* The variety had only about 30% viable seed. The largest South Rim population, which occupies about 2520 m^2, produced no seed under pollinator exclosures indicating that this is likely an obligatory outcrossing population (needs pollen from a different plant to produce viable seed). It also occupied the least fertile of the sites having the highest percentage of sand and the lowest levels of the elements N, P, K. Two of the South Rim populations had the lowest genetic

variability as measured by a polymorphic index, as well as the lowest observed heterozygosity.

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 only two private alleles each (USFWS 2006)

Allphin et al 2005) concluded that the Maricopa Point population was the most genetically depauperate of all the study populations, likely due to an evolutionary bottleneck event triggered by continued human trampling at the lookout before this population was protected by fencing. This bottleneck resulted in severely reduced genetic variation. It can only be hoped that there is adequate variability remaining to support the evolutionary viability of this population.

In contrast, the North Rim Cape Final populations exhibited the highest heterozygosity, the highest seed/ovule ratios, and the highest seed set at about 80%. The North Rim population locations also were significantly higher for almost all of the measured soil parameters. These are the populations that the authors feel merit a separate taxonomic classification. It is also notable that both North (Point Final) and South (Maricopa) populations had rather low fruit set, (51% and 48%, respectively). However, for the Maricopa population, the authors speculated that this may be the result of an inability of pollinators to bring pollen from compatible mates due to familial inbreeding in this small, isolated population, whereas they feel for the North populations, this may be due to the death of flowers from snow and cold temperatures at this higher elevation (Allphin et al 2005). It is also notable that South Rim sentry milk-vetch plants produce orange seeds in contrast to the black seeds produced by the Cape Final plants, and that the North Rim plants are in-breeders, or self-compatible (USFWS 2006).

HABITAT: Plants grow in the uppermost layer of a very peculiar white layer of limestone that is not grossly fractured, but rather weathers in small, shallow pockets and networks of small cracks. This kind of limestone (Kaibab limestone) is exposed for only a few hundred square yards, forms large flat platforms, has shallow soils (< 7 cm deep), is unshaded, and in the pinon-juniper-cliffrose plant community above 1219 m (4,000 ft). In these openings, sentry milk-vetch is co-dominant with rock mat (*Petrophytum caespitosum*).

At one time, the potential habitat for sentry milk-vetch was thought to include all layers of the Kaibab Limestone, 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 slabs. 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), in USFWS 2006.

ELEVATION: 7,000 - 7,360 ft. (2135 - 2243 m) for South Rim populations. About 7900 feet (2410 m) for the North Rim populations.

EXPOSURE: Full; slope of 0-5% (South Rim populations). This plant has not been found on small, shaded ledges or cliffs (USFWS 2006). It appears that the North Rim populations (if these are actually the same variety) might occur on significantly greater slopes.

SUBSTRATE: *A. c.* var. *cremnophylax* appears to occur on one specific, pure white layer of Kaibab limestone where the bedrock forms an unshaded platform.

The following details on suitable substrate based on Prevost's investigation (1991) are taken from the 2006 USFWS Recovery Plan:

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.

PLANT COMMUNITY: Pinyon-juniper woodland. Sentry milk-vetch is co-dominant with rock mat (*Petrophytum caespitosum*). Associated species include: *Agropyron smithii* (wheatgrass), *Arenaria macradenia* (sandwort), *Astragalus calycosus* (King's milkvetch), *Calyophus hartweggi* (Hartweg evening primrose), *Cercocarpus intricatus* (little-leaf mountain mahogany), *Hymenoxys acaulis* (nostem rubberweed), *Juniperus osteosperma* (Utah juniper), *Pinus edulis* (pinyon pine), *Poa pratensis* (bluegrass), *Purshia stansburiana* (cliffrose), and *Selaginella* sp. (spike-moss). 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).

POPULATION TRENDS: The wild population at Maricopa Point appears to be stable to increasing, based on monitoring from 2009 to 2014. Population trends for other natural populations are similar. Three reintroduced populations along the South Rim were established in 2011 and 2012 near known populations (USFWS 2018).

Preliminary results suggest that we would ascribe the populations on the North Rim discovered in 2011 and 2012 to sentry milk-vetch. We are currently waiting on a full report and publication of these results. However, once the authors publish this information, it is likely to result in an increase in the number of sentry milk-vetch populations and an increase in the geographic extent of the species that would include areas on both the South and North rims of Grand Canyon. At this time, the full results of that additional taxonomic work are not available. Thus, the relationship of the populations, and even the current number of populations of the species, remain unconfirmed (USFWS 2018).

SPECIES PROTECTION AND CONSERVATION

ENDANGERED SPECIES ACT STATUS: LE, without critical habitat (USDI, FWS 1990)
Recovery Plan (USDI, FWS 2006)

STATE STATUS: Highly Safeguarded (ARS, ANPL 2016)
[Highly Safeguarded (ARS, ANPL 1993)]

OTHER STATUS: Not Forest Service Sensitive (USDA, FS Region 3 1999)
[Forest Service Sensitive (USDA, FS Region 3 1990)]

MANAGEMENT FACTORS: In general, compacting of soil and trampling by park visitors has caused significant damage to known populations and continues to some extent even after the construction of protective fences. In addition, very strict habitat requirements restrict this plant to highly specific locations. Other threats include its limited distribution, low genetic variation, poor seed production and reproductive potential, and stochastic events such as periodic droughts.

The 2006 USFWS Recovery Plan listed the following threats as reasons for listing the plant. The actual Recovery Plan contains considerably more detail than this summary review:

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. Prior to fencing of the sentry milk-vetch population in 1990, many thousands of visitors per year walked over the population. 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). It is likely that trampling adversely affected sentry milk-vetch seedling recruitment and survival. Trampling does not appear to be a threat to the very small population at Grandview or at "Lollipop Point".

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. The minor threat of unauthorized collection must be weighed against the potential benefits of education of the general public. 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. 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. Busco (2012) also reported damage from digging by bighorn sheep.

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. However, the law does not provide habitat protection.

Other Natural or Manmade Factors Affecting its Continued Existence. The loss (mortality) of plants has declined since the protective fences were installed at Maricopa Point, but it appears that some of the damage has been compounded and lasting, such as soil compaction and displacement of the fragile accumulated soil. Known populations of the species continue to be vulnerable to and threatened by natural events such as trampling by native ungulates, digging by small mammals, sloughing of habitat along the canyon rim, and wildfire. Hard frosts and freezes during the flowering or fruiting period has been shown to reduce seed production. Rock squirrels have been responsible for other damage and loss of plants. Drier conditions have also probably been detrimental. Species characteristics such as low population numbers, low recruitment, high habitat specificity, and vulnerability of individual plants increase risk to the species.

One of the most alarming factors identified by the Allphin et al 2005, and some early studies is that inbreeding depression, a serious genetic condition, is being expressed as low seed/ovule ratios. Allphin et al (2005) surmised that the decades of trampling might have caused an evolutionary bottleneck event and the present populations are genetically depauperate. 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. In 1994, Maschinski et al. indicated that the population was 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. Maximum protection of the populations at Maricopa Point, Grandview, and "Lollipop Point", is critical to the continued existence of this species.

CONSERVATION MEASURES TAKEN:

Astragalus cremnophylax var. *cremnophylax* was listed as endangered in 1990. A draft Recovery Plan was prepared in 1994 and finalized in 1996. This plan outlines the steps necessary to achieve, maintain, and document longterm 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 (USFWS 2006).

Regulatory tools that aid in the conservation of sentry milk-vetch include: 1) 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; 2) Endangered Species Act Section 7 Requirements – Section 7 of the Act prohibits actions authorized, funded, or carried out by Federal agencies that jeopardize the continued existence of any listed threatened or endangered species.

Other conservation measures and research efforts include: 1) In 1984, the National Park Service erected fences to help protect the South Rim population (Maricopa Point), which were extended in 1985. In 1990, the Park constructed a sturdy wooden fence, with wire fabric added to the fence in 1995. 2) Permanent demographic monitoring plots were established in the spring of 1988. Surveys were conducted annually for 8 years, but these plots are no longer formally monitored. 3) Rim Road is closed to private vehicles during mid-May to October, aiding in protection.

Since 1989 the Arboretum at Flagstaff has conducted a number of trials to establish seeds at existing, new and *ex situ* sites. This work has not been especially successful, although lessons are being learned and future augmentations are seen as one of the possible alternative mitigations for this species. [Note: starting around 2008 these efforts have been more successful, see below.]

The 2006 Recovery Plan serves as the newest guide for conservation measures. The 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 un-surveyed 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 this 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.

Downlisting and Recovery (Delisting) Criteria [2006 Recovery Plan]

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 2006 Recovery Plan provides a detailed "Step-Down Outline" for the various recommended actions along with explanatory notes.

Recovery Plan Actions Undertaken from 2006-2018 (from Busco 2012, USFWS 2018):

1. Annual monitoring of Maricopa Point population every year (2006-2008).
2. Complete census of Maricopa Point population in 2008.
3. Installation of permanent photo-points in all three populations (summer 2008).
4. Collected seeds (2600), completed germination trials, initiated greenhouse seed production, established an *ex situ* population.
5. Completed parking lot removal, trail rerouting and shuttle bus stop relocation away from Maricopa Point population location.
6. Established three reintroduction populations at South Rim sites.
7. Identification of three generalist pollinators (two mason bees, *Osmia ribiflorus* and *Osmia ribiflorus ribiflorus*, and a hoverfly, Syrphidae) with repeat observations in multiple Sentry milkvetch populations from 2010-2012.
8. Completion of discovery survey of westernmost portions of South Rim that identified new groups of Sentry milkvetch on limestone fingers along the rim and on lower levels below the rim.
9. Acquisition of a passive solar greenhouse for a dedicated facility for seeding trials, seed and plant production, and to create an *ex situ* population.
10. Work on the restoration of disturbed habitat and seeding/planting trials at Maricopa Point began in 2010. Of 80 greenhouse grown plants and 240 seeds sown in the restored parking lot area in 2011, 51% survived. Fourteen of these later set seed and produced 58 seedlings. Another 44 seedlings have become established from seed that either washed in from adjacent plants or was already present in the soil seed bank. In 2012 there were a total of 181 plants growing on this reintroduction site which was formerly beneath a parking lot.
11. Conducted series of experiments on seedlings. Soil suitability trials to assess seed germination and seedling survival response to soil type, soil depth, irrigation patterns, and light levels.
12. Develop interpretive materials for display at Grand Canyon Visitor Center.
13. Continue collaboration with Grand Canyon NP, USFWS, Arboretum at Flagstaff, Center for Plant Conservation, Northern Arizona University and Coconino National Forest.

SUGGESTED PROJECTS: With the availability of the Recovery Plan (USFWS 2006), all actions and specific "projects" are now identified in the "Step-Down Outline."

LAND MANAGEMENT/OWNERSHIP: National Park Service, Grand Canyon National Park.

SOURCES OF FURTHER INFORMATION

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ADDITIONAL INFORMATION: The genus *Astragalus* is either from a Greek word meaning ankle-borne or dice, perhaps in reference to the rattling of the seeds within the fruit, or it may be derived from *astro* meaning star and *gala* meaning milk in reference to the belief that its use in pasture land improves livestock milk yield. The specific epithet *cremnophylax* is from *cremno* meaning gorge and *phylax* meaning watchman.

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