

SENTRY MILK-VETCH
(*Astragalus cremnophylax* var. *cremnophylax*)
SURVEY HANDBOOK¹

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Sentry Milk-vetch Survey Handbook

Purpose

The purpose of this document is to provide background information for monitoring the status of the sentry milk-vetch² (*Astragalus cremnophylax* Barneby var. *cremnophylax* Barneby) in Grand Canyon National Park. It will assist researchers to understand past work, outline the present methodology, and standardize data collection efforts. Photocopies of color plates are also included for reference. The published and non-published literature on this taxon is also referenced. Modification and improvement of study procedures should be incorporated into this document as warranted. Because this endangered plant may be vulnerable to disturbance or illegal collection, the location information disclosed by this document should be kept confidential by Federal, state, and private organizations and individuals.

Natural History of the Sentry Milk-vetch

The sentry milk-vetch was first collected on April 27, 1903 by Marcus E. Jones (1923) during a one day visit to the South Rim by train (Munz 1965). Jones was especially interested in the genus *Astragalus*, as one of his three main goals in life was to publish a treatment of the genus (Welsh 1982). He mistakenly identified the South Rim collection as a related species, *Astragalus humillimus*, meaning "smallest of all milk-vetches" (Barneby 1964), now known to be endemic to northwest New Mexico and adjoining Colorado (Barneby 1948). Jones reported it as "apparently common at Grand Canyon at the end of the railroad on sandy ledges" (Jones 1923, Barneby 1948).

On June 3, 1947, by H. Dwight Ripley and Rupert C. Barneby (1948) made a collection of the sentry milk-vetch "in fissures of limestone pavement on the south rim of the Grand Canyon of the Colorado River, about 2 miles west of El Tovar, at 7,050 feet." Ripley and Barneby are ranked as the Intermountain Region's finest team of botanical explorers in discovering new taxa (Cronquist et al. 1972), having gathered more new taxa of flowering plants than any other team of living botanists. They were very aware of a group of dwarf, matted *Astragali* which were confined to what they called a "ledge-pavement" habitat which furnished a "balance of environmental factors peculiarly suited to the survival of these eclectic little plants" (Barneby 1948). They also recognized that it resembled the mounded or densely matted growth-form of the *polsterpflanze* (meaning cushion plant in German), a growth form highly developed in the Andes, in Patagonia, and to a lesser extent in North America (Barneby 1964).

In a letter that Barneby (1947) wrote to Dr. Thomas Kearney, he stated, "The common *Astragalus*, far from being, in the words of Jones, 'apparently common', is unquestionably of great rarity. We spent the entire day working east and west from El Tovar, and saw it in only a

²The U.S. Fish and Wildlife Service (1989) hyphenated the word milk-vetch, thus this form is used.

single spot, where it is, however, tolerably abundant over an area of limestone pavement perhaps 50 yards long and not extending more than a few feet in from the canyon rim....you realize at once that it couldn't grow in anything but a very specialized environment, and this particular rock-formation is extremely rare along the South Rim, at least so far as we were able to explore."

Barneby's precise locality was "on the Rim road at the turnout immediately to the east of Powell Monument" -- otherwise known today as Maricopa Point. It is possible that Jones' first collection site was Maricopa Point, rather than the Bright Angel trailhead or the vicinity of El Tovar, where the railroad now ends. The peripatetic Jones could have easily walked the 1.5 miles to Maricopa Point. Barneby (1994) was unable to find the species at or between these localities in the late 1940s and 1950s.

Barneby (1964, 1995) calls the sentry milk-vetch one of our rarest species and "one of Arizona's brightest botanical jewels" (Plate 1:A and B). A member of the pea family (Fabaceae or Leguminosae), the sentry milk-vetch is a dwarf, evergreen, perennial herb endemic to Grand Canyon (Barneby 1948, 1964; Cronquist et al. 1989). The species was described as *Astragalus cremnophylax* by Barneby in 1948; the specific epithet was derived from two Greek words: *cremnos* (gorge) and *phylax* (watchman), meaning sentry, watchman, or overseer of the gorge or chasm, in reference to its dramatic habitat overlooking the Grand Canyon (Barneby 1948).

The typical form (var. *cremnophylax*) was recognized following the identification of two varieties from outside of Grand Canyon National Park which also grow on Kaibab Limestone substrates: var. *myriorrhaphis*,³ the cliff milk-vetch, which grows in rock pockets on the rim and on cliff-faces in the Buckskin Mountains of the Kaibab Plateau (Barneby 1979, Plate 5:C and D) and var. *hevronii*,⁴ Hevron milk-vetch, which grows in crevices on the rim of the Marble Canyon Plateau (Barneby 1992, Plate 5:A and B). These two varieties are distinguished by stiff ascending, prickly leafstalks and larger flowers (Barneby 1992). The cliff milk-vetch is about 88 km north of South Rim and the Hevron milk-vetch is about 40 km northeast. The Hevron milk-vetch site is about 60 km from the cliff milk-vetch site. The differences between the three disjunct varietal populations are not large and might be considered taxonomically insignificant. But because the habitat is narrowly defined, the populations distant from one another, and no pollen is exchanged, Barneby presumed them to be stabilized entities and gave them taxonomic distinction (Barneby 1992).

The most well-known population of sentry milk-vetch grows at 2,100 meters on horizontal, limestone pavement at Maricopa Point (Plate 3:A and B), located on the south rim of the Coconino Plateau in Grand Canyon National Park (Kearney and Peebles 1960, McDougall 1973,

³A population, now known to number about 700 individuals in several locations (Arizona Game and Fish Department 1994) was originally discovered by Ralph Gierisch, botanist with the Bureau of Land Management, and associates.

⁴A population of over 300 individuals in three locations was discovered by Bill Hevron, formerly a botanist with the Navajo Natural Heritage Program (Hevron 1992, pers. comm., 1994).

Phillips et al. 1987). Two other populations of sentry milk-vetch are known from a site near Grandview Point (Plate 4:A) and at Cape Final, on the north rim of Grand Canyon (Plate 4:C and D). These populations are discussed below in the section on "Sentry Milk-vetch Status".

Today, the Maricopa population grows in an enclosed area (see section on Monitoring History). The enclosure area, obtained from scaled maps drawn from aerial photographs (O'Brien 1984 and Rutman 1988), is approximately 2,520 m². The plants occupy seven discrete polygons totaling 240 m² (Figures 1 and 2), about 10% of the site. A majority of the area within the enclosure is vegetated by a pinyon-juniper woodland, classified as the *Pinus edulis* - *Juniperus osteosperma* - *Poa pratensis* community (122.4149) or pinyon pine - Utah juniper - bluegrass (Warren et al. 1982). A list of species collected from the enclosure is presented in Appendix A.

The sentry milk-vetch population at Maricopa Point (Plate 2:A and B) grows in sunny areas between the edge of the woodland and the canyon rim where they are co-dominant with rock mat (*Petrophytum caespitosum*). The plants occupy a pure white layer of highly porous Kaibab limestone (Prevost 1991) within pavement fissures, erosional potholes, and shallow soils about 5 cm deep (Plate 2:A, B, and D). The soil is described as very fine sandy loam (Prevost 1991) which is overlain by a thin layer of gravel. The gravel may act as a type of mulch, protecting the finer soil particles below from the occasionally strong, northeasterly prevailing winds. Frost heaving of the soil follows freezing winter temperatures. The surface of the limestone pavement dips gently to the southwest, away from the rim. Sheet wash following heavy rainshowers is readily apparent and small pools are formed where small ledges in the limestone dam the water.

The climate of South Rim has been described as semiarid, microthermal, and precipitation deficient at all seasons (Merkle 1952). Based upon a 58 year record (Green and Sellers 1964), South Rim receives an average annual precipitation of 40.6 cm (16 inches). April, May and June receive less than 2.54 cm (1 inch), while July averages 4.95 cm (1.95 inches) and August averages 5.72 cm (2.25 inches). Summer precipitation falls in sudden, often heavy showers. Average temperature for January is -3/3°C (26°F) and July is 16.7°C (62°F). Temperatures in July and August can reach a maximum of 36.7°C (98°F). The average growing season is 148 days. The normal first and late date for freezing 0°C (32°F) is October 12 and May 17, respectively.

In the wild, plants are generally less than 2.5 cm high and up to 25 cm in diameter. A tap root penetrates the rim rock to reach a more constant source of moisture. The short, creeping, gnarled, and prostrate stems with marcescent leaflet bases have compound leaves with 5-9 closely crowded leaflets. The appressed nature gives the plant a superficial appearance of a clump of moss. Occasionally, a bare woody stem or branch is visible in older plants. This feature has been described as a "bare woody root" in field notes, but is probably a stem where the compound leaves have been lost. The shapes or outlines of the sentry milk-vetches (Plate 3:D) are quite varied and have been classified as ellipsoid (38%), circular (18%), reniform (17%), triangular (13%), amoeboid (8%), or square (6%) (Rowlands and Brian 1996). Some plants have dead areas within the perimeter or small areas of live area area scattered throughout or on the margin of dead areas (Plate 2:C).

Figure 1. 1988 Map of Maricopa Point.

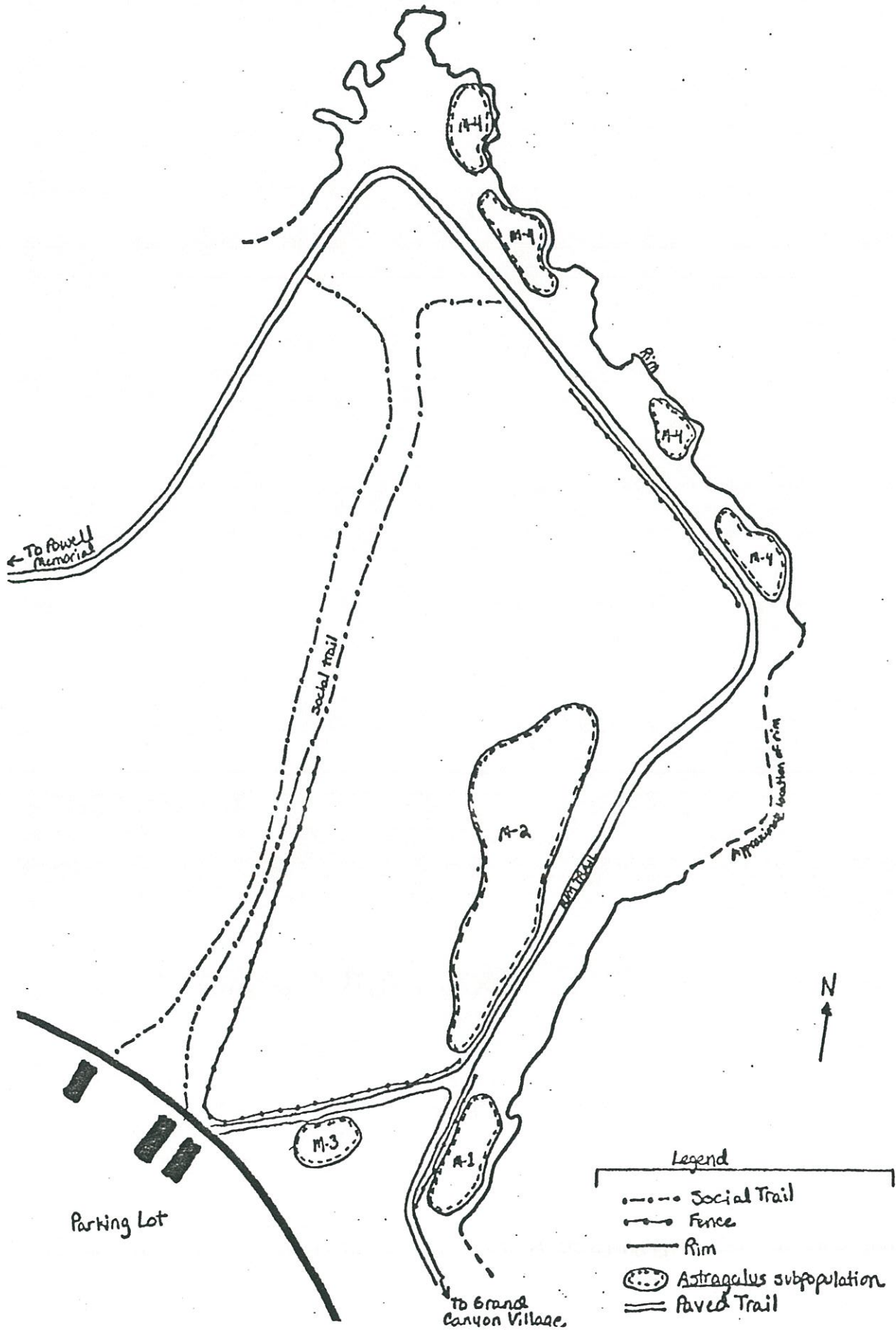
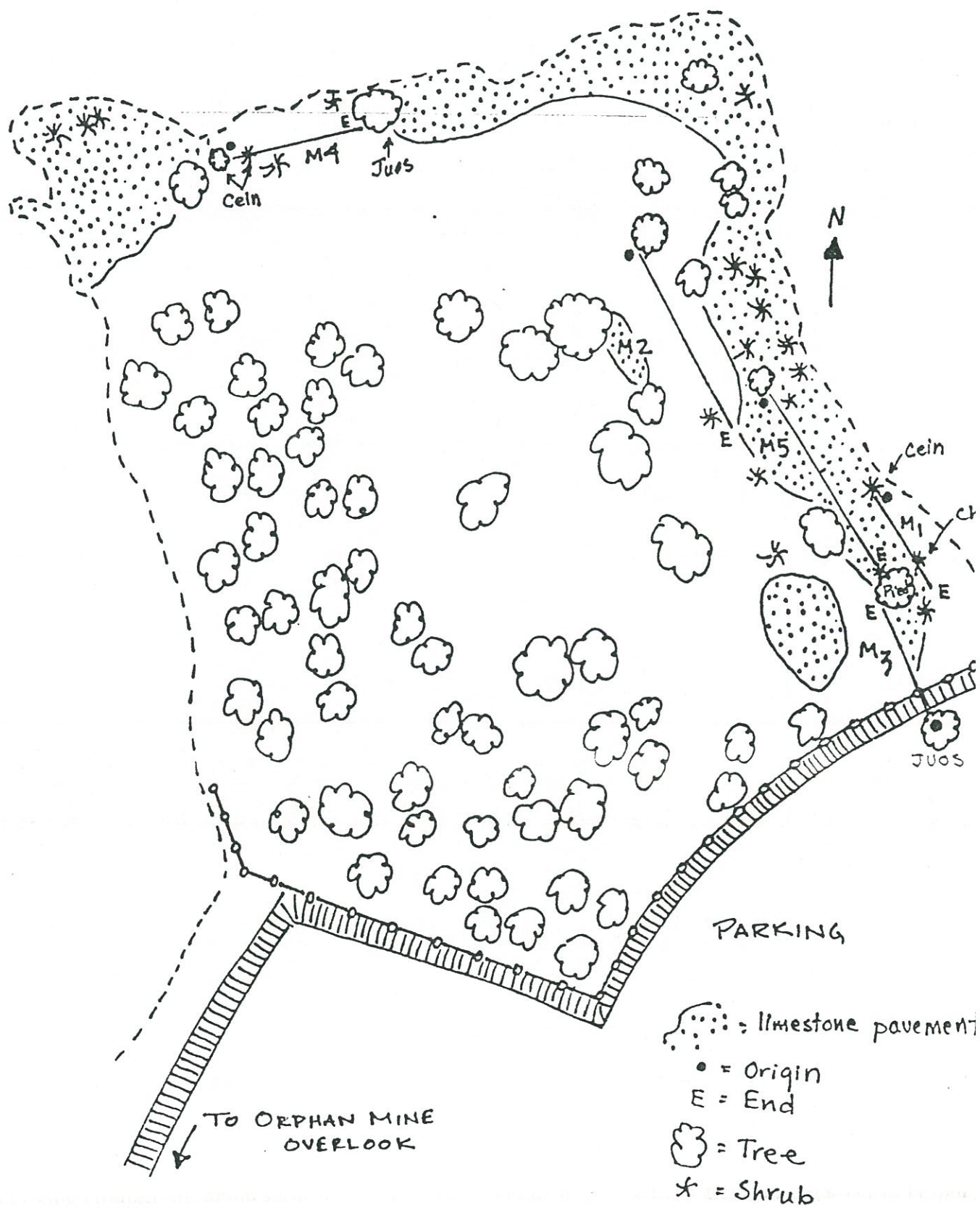


Figure 2. Location of monitoring transects at Maricopa Point.



An *ex situ* population of 28 individuals plants is located in a greenhouse at The Arboretum at Flagstaff (Joyce Maschinski, pers. comm.). These plants do not resemble the typical form of plants growing at Maricopa Point (Plate 4:D). The greenhouse plants are leggy, up to 15 cm or more in height, and produce flowers in the spring and in the fall. Fruits have been produced following hand pollination of flowers. Rupert Barneby also established a temporary population which lived for seven years (Rutman 1988). Plants were grown from seed he teased out of herbarium specimens collected at Maricopa Point in 1947. Four or five plants grew for several years in limestone scree at his home in Greenport, New York (Barneby 1994). Greenhouse grown plants can produce flowers within six months (Loreen Allphin-Woolstenhulme, pers. comm.).

A similar looking species, often confused with sentry milk-vetch especially when it is not flowering, is Gray locoweed (*Astragalus calycosus*). It is commonly found on both rims of the Grand Canyon, as well as elsewhere in northern Arizona and four western states of Wyoming, Idaho, New Mexico, and California (Kearney and Peebles 1960). Gray locoweed has larger flowers with bidentate wings, oblong, compressed, two-celled fruits, and exerted leaves (Barneby 1964). In contrast, the sentry milk-vetch is much more restricted in range, has smaller flowers, one-celled, smaller fruits, and appressed leaves. A very depauperate form of Gray locoweed with leaflets only 2 to 3 mm long was collected by Rose Collom in 1946 and 1947 at Cape Royal, at the edge of the Walhalla Plateau of Grand Canyon's north rim. Previously, this entity had been confused with sentry milk-vetch (Barneby 1947, Rutman 1989, Arizona Game and Fish Department 1994).

Reproductive Biology

Immature flower buds appear in March and April, followed by light purple to nearly white flowers from April through June (Plate 1:A and B). The anthers dehise, or release pollen, while the flowers are in the bud stage (Loreen Allphin-Woolstenhulme, pers. comm., Karron 1989). A second flowering may occur from September through November following the monsoon rains. Fall flowering is not commonly observed in wild plants, but is common in greenhouse plants which receive supplemental watering. Plants at Maricopa Point appear to be obligate out-crossers, while one plant at the Grandview site appears to be self-compatible (Loreen Allphin-Woolstenhulme, pers. comm.). Barneby (1994) reported that though the plants he grew flowered profusely, they did not set seed. This also suggests that the Maricopa plants are obligate out-crossers.

No flying pollinators have been observed at Maricopa Point since studies on the sentry milk-vetch began, although small ants have been noted by many investigators crawling over and living under the plants. The ants may be responsible for pollination and/or seed dispersal (Rutman 1988). Ants are not known to be effective pollinators (Sudd and Franks 1987). In cases where they do aid in pollination, the pollen needs to be sticky and in small quantity, so it will adhere and so the ants will not groom themselves on the source plant. In addition, the ants should visit up to 20 flowers before returning to the nest, so the short or prostrate plants should ideally not have many flowers open at the same time. Ants can also aid in seed dispersal or germination by transporting seeds or bringing up fresh soil to the surface. Two hymenopteran insect species have

been collected from flowering plants at the northern-most Hevron milk-vetch site. Identification is pending, however one is a solitary bee and the other a wasp (Loreen Allphin-Woolstenhulme, pers. comm.). Frequent visitors of four other xerophytic and geographically restricted species of *Astragalus* (Karron 1987) include polylectic, hymenopteran bees (*Bombus* spp., *Osmia* spp., *Anthopora* spp., and *Apis mellifera*) and one nectar feeding dipteran (*Bobylius* sp.).

One celled, densely hairy, 3-4 mm long fruits are produced from May to June which contain one to more amber-yellow, pale orange, or sometimes greenish, seeds. Upon maturity, the seeds fall out of the pods and are often found among the leaves, below the plant mat, or in the gravels next to the parent plant. Seed germination in the wild appears to follow the monsoon rains, occurring more commonly in early September, rather than in early spring (Maschinski 1990a, 1990b, 1993). Average germination is reported as 49% in greenhouse experiments and 10% in field experiments (Maschinski 1993a). Seedling mortality is high, up to 57%, in the months following germination, 20 to 33% in winter months, and lowest in the spring (Maschinski 1991, 1993). Seedling survival is higher for seedlings established near potential nurse plant species, for example snakeweed and cliff rose (Maschinski 1993a), or other sentry milk-vetch plants.

Wojciechowski (1993, 1995) describes sentry milk-vetch as a "*neo-Astragalus*" with an aneuploid chromosome number ($n = 11, 12, 13, 14, 15$), similar to other endemic North and South American species. Chromosome analysis of buds collected from the Maricopa and Grandview sites has shown sentry milk-vetch to be diploid, with $n = 11$ or 12 (Delbert Wiens, University of Utah pers. comm.).

The reproductive biology of sentry milk-vetch may be the primary cause of the species' rarity. A preliminary study of seed/ovule ratios, (i.e., the number of fully-developed viable seeds to the total number of ovules produced) for the three northern Arizona varieties of sentry milk-vetch indicate that the highest ratio is 0.69 for Hevron milk-vetch, 0.57 for cliff milk-vetch, and 0.31 for sentry milk-vetch (Allphin-Woolstenhulme 1994). For comparison, the seed/ovule ratio for Gray locoweed is 0.52 (Allphin-Woolstenhulme 1994). The low seed set for sentry milk-vetch may be environmentally or genetically determined. It is hypothesized that inbreeding depression, reduced genetic variability, or high levels of heterozygosity may be responsible for this condition (Karron 1989, Maschinski 1993a, Allphin-Woolstenhulme 1995).

Travis et al. (1996) conducted an analysis of genetic variation of the three Grand Canyon sentry milk-vetch populations using a molecular technique of amplified fragment length polymorphisms (AFLP). Genetic diversity was greatest in the Cape Final population, least in the Grandview population and also low for the Maricopa population.

Sentry Milk-vetch Status

In 1980, sentry milk-vetch was listed as a Category 1, threatened candidate species (U.S. Fish and Wildlife Service 1980). In 1989, it was proposed for listing (U.S. Fish and Wildlife Service 1989). It received Federal listing as endangered without critical habitat in 1990 (U.S. Fish and Wildlife Service 1990) due to its low population, limited distribution, and trampling by park visitors. "Without critical habitat" means that the location of the species was not described in the

listing package to protect it from collection. This provision does not allow park interpreters or management to place interpretive signs near the population or otherwise draw attention to the plants location.

Visitation at Grand Canyon National Park has increased almost steadily since the establishment of the park in 1919. Since 1955, visitation at South Rim has increased exponentially, with about four million visitors in 1993. Up to six million people are expected to visit the park annually by the year 2005 (Rowlands 1993). The Maricopa Point population has gradually received impacts since the 1910-30s when paved roads, turnouts, and a rim pathway enabled ready access to the South Rim viewpoints (Anderson 1994). In 1962, the rim pathway at Maricopa Point was paved and edged with limestone blocks. Some plants were probably destroyed as the path bisects the population. In May 1983, the National Park Service (NPS) scattered pinyon and juniper branches and logs the areas where the sentry milk-vetch plants were growing to deter foot traffic. In 1984, short sections of fence were constructed at Maricopa Point to divert foot traffic from the plants (Rutman 1987). The fences were extended in 1985 (Rutman 1988, Figure 1). In May 1990, the pathway was rerouted to an adjacent overlook to the west, the old pavement and edging blocks were removed, and enclosed the population with a 1.8 meter high, post-and-rail, wooden fence. Signs stating, "Ecologically Sensitive Area — Please Stay On Trail" were placed on the fence. The enclosure and signs effectively restrict trespass (Plate 1:D). In July 1995, wire mesh was attached to the wooden fence to further restrict visitor access. Mule deer and bighorn sheep are not deterred by the fence as they have been observed inside the enclosure, pellet groups are common, and shrubby plants such as cliff rose and littleleaf mahogany show browsing damage.

In 1991, Therean Taylor found a small population of three sentry milk-vetch plants, comprised of two mature plants and one seedling with ten leaves, east of Grandview Point on the south rim. Four plants were observed in 1993-94. However in 1995, the population was reduced to two individuals. In 1996, one plant produced flowers and fruits (Plate 4:A), but the other has been decreasing in size since 1995 and shows no reproduction. The site is approximately 15 m², with plants occupying less than 0.5 m² of a 30 cm thick raised block of Kaibab Limestone. The plants grow in cracks and grow associated with blue grama grass (*Bouteloua gracilis*), spike moss (*Selaginella* sp.), and nailwort (*Paronychia sessiliflora*). Lichens are plentiful on the limestone substrate.

In 1994, Therean Taylor found a new population on Cape Final, North Rim (Plate 4:B and C). A search of the area found four sites with an estimated minimum population of 970 plants (Brian 1994). The total is higher as the plants are often interconnected in a "carpet" making identification of individual plants impossible. Plants grow in habitats similar to that at Maricopa Point, but in addition, many plants grow in deeper soils shaded by closely adjacent pinyon pine trees. Lichens, tentatively identified as *Caloplaca trachyphylla*, *Aspicilia calcarea*, and *Staurothele* sp. (Thomas Nash, Arizona State University, pers. comm.), are also prominent on the limestone substrate. Flowering Cape Final plants were identified as sentry milk-vetch by Rupert Barneby (1995) and Dr. Stanley Welsh, Brigham Young University (pers. comm., 1995). However recent information (Loreen Allphin-Woolstenhulme, pers. comm, and Travis et al. 1996) suggest that the population may deserve varietal distinction.

In summary, the estimated 1996 population of sentry milk-vetch in Grand Canyon National Park is approximately 1,500 plants: about 450 plants at Maricopa Point, two at the Grandview site, and about 1,000 from Cape Final (Table 1). Many searches have been conducted along the South Rim (Maschinski 1992), however no additional populations have been found. The areas searched include: Hermits Rest to Yaki Point, east and west of overlooks directly south of Shoshone Point, all edges of Eremita Mesa, south of Grandview Point to Hearst Tanks and on to a point west of Buggeln Hill, from Papago Point south to the east rim drive road, Coconino Wash area west of Tusayan, and the Coconino Rim from Grandview Lookout eastward. Additionally the other areas incidentally searched include Point Sublime, Cape Royal, Fishtail Mesa, and Havasupai Point to Bass Camp. Among the areas yet to be searched include: Desert View to Point Solitude, Mimbreno Point to Havasupai Point, and edges of the Walhalla Plateau.

Table 1. The estimated 1996 population size of the sentry milk-vetch. Data for M2 and M3 from Warren (1994) and data from Cape Final from Brian (1994).

Site	Number on Transect	Number outside Transect	Total
Grandview site	2	0	2
Maricopa M1	64	0	63
Maricopa M2	Estimate = 174	100?	274+
Maricopa M3	35	?	35+
Maricopa M4	48	20	68
Cape Final A	Estimate = 227	N/A	227+
Cape Final B	Estimate = 162	N/A	162+
Cape Final C	Estimate = 539	N/A	539+
Cape Final D	Estimate = 49	N/A	49+

Monitoring History

Interest in the sentry milk-vetch followed the second collection by Ripley and Barneby in 1947. McDougall (1964,1973) wrote that "it is not known whether any living specimens are in existence at the present time." Concern about the status of the species led to a 1982 status report (Phillips et al. 1982) prepared by the Museum of Northern Arizona for the U.S. Fish and Wildlife Service (FWS). The survey reported 150 plants in a 250 m² area, or 0.6 plants per m².

In March 1983, the first monitoring project was initiated by John Miller, National Park Service (NPS) staff. Twenty-four individual plants were measured and photographed. Records of these plants have apparently been lost. In 1984, a more thorough inventory was conducted by Susan O'Brien (1984), a Grand Canyon High School student, under the supervision of Kathy Davis and assisted by Nancy Brian (NPS). Comparison with the 1983 measurements was not possible as

these 24 plants could not be relocated. A total of 410 plants were found in a 589 m² area, or 0.7 plants per m². Fifty-five percent of the plants showed trampling damage. Four transects, labeled M1 through M4 were sampled, measured, and locations documented perpendicular to a baseline next to the paved walkway (Figure 2). Photographs were taken for sample areas M1 and. Field sheets and photography are available in the park's sentry milk-vetch files. The study recommended protection of the plant from foot trampling, restricting social trails, and moving the shuttle bus stop to the western end of the parking lot.

In 1988, Sue Rutman (FWS) and Renee Beymer (NPS) established new transects on the four monitoring plots. Each transect "origin" and "end" point was made permanent and marked with steel nails flagged with aluminum tags (Figure 2, Table 2). Photos of plots taken from each endpoint are maintained in the sentry milk-vetch park files and at the Ecological Services Field Office of the FWS in Phoenix. An additional transect, labeled M5, was established in 1992 for a fruit production study (see Appendix C). A Cartesian system using new "x" and "y" location coordinates were recorded and where possible plant numbers were written on nearby rock pavement with marker pens (Plate 1:C). The basal area was estimated using an ellipse-diameter method whereby the area was calculated using major and minor diameters measured to the nearest millimeter. A total of 489 plants were counted with plant densities ranging between 0 and 29 plants per m² (Rutman 1988, Maschinski and Rutman 1992). About 65% of the population showed trampling damage. The study recommended protection of the species and yearly monitoring.

Monitoring has been conducted by NPS, FWS, and others in a cooperative effort from 1988-94. Methodology established by Rutman (1988) has been used. Monitoring responsibility was transferred from the FWS to the NPS in 1993. Refinements and changes to the monitoring program were made from 1993 to 1994 (see section "1988-94 Monitoring Methodologies"). In 1993, a draft recovery plan was prepared (Maschinski 1993b) and a final recovery plan is anticipated (Angela Brooks, FWS, pers. comm.).

Table 2. Length, width, compass orientation and alignment of the Maricopa Point monitoring transects. Compass bearings are read from origin to endpoint with a declination of 13 degrees. See Appendix F for identification of plant species codes.

Plot	Length (m)	Width (m)	Compass	Comments
M1 East	13.3	to rim	226	Plot between 0 m and 12 m; through CHMI at 9 m
M2 East*	21.73	2	224	Align with #178 & #198a
M2 West*	21.73	4	224	Align with #178 & #198a
M3 West	16.4	4	60	Plot between 6 m and 14 m
M4 North	17.5	to rim	165	Through CEIN at 2 m
M4 South	17.5	2	165	Through CEIN at 2 m
M5	24.23		224	Fruit study only

*Plot M2 was originally one plot, but in May 1993, with the east and west sides of the transect were listed separately.

Monitoring methodologies of the sentry milk-vetch were changed in 1994 (see "1995 - Present Perimeter Tracing Methodology"). Because identity of plants was problematic using the Cartesian x and y coordinates and the written plant numbers faded with time and require renumbering, a new numbering system was employed. Five hundred "fish tags"⁵ were purchased after consultation with botanists interested in the sentry milk-vetch study. The tags are 1.6 cm oval, beige colored, plastic pennants (Plate 1:C) attached to double-wire, stainless steel wires. The pennants are printed with sequential numbers from 000 to 500 on one side and "NATIONAL PARK SERVICE -- DO NOT REMOVE" on the other. In May and June 1995, a preliminary 282 plants at Maricopa Point were tagged in the M2 and M4 areas. Seedling and juvenile plants that are too small to securely affix a tag are not tagged. In some cases, the tag is attached to a nearby hole through the rock or a larger, perennial plant immediately adjacent. The stainless steel wire was bent, threaded through the plant mat or soil in order to encircle a branch, and the two end wires twisted. In tagging the plants, the discovery was made that what appears to be one plant can actually be a parent plant and several smaller plants on the perimeter. Confirmation of this observation has not been done as it would entail digging up the plants. This would undoubtedly damage or kill the individuals.

Tagged plants showed no apparent harm from the tags when checked on March 1996. An additional 72 tags were placed in November 1996 (M1 and M4). Plants on M3 and a few plants on M2 have yet to be tagged, with the remaining 146 tags. In November 1996, in one area on M4, one tag was found broken and six tags were missing. These tags may have been removed

⁵Carlin dangle tags are manufactured by the Floy Tag, Inc., 4616 Union Bay Place N.E., Seattle, WA 98105, phone 1-800-843-1172.

and/or broken by grazing deer. A few tags show sun damage (i.e., darkening of the color) but are still readable. An effort should be made to place the "National Park Service" side of the tag up to preserve the readability of the numbered side.

A few plants at Maricopa are also tagged with large, aluminum tags stamped with numbers (Plate 1:C). These were placed by Joyce Maschinski, Arboretum at Flagstaff and include the three following plants identified by M2- tag number, aluminum tag number, and new fish tag number (if established): (1) M2-31, #684, #058, (2) M2-236, #18, and #(not established at present), and (3) M2-243, #679, #(not established at present).

1988-94 Monitoring Methodologies

Ellipse-Diameter Method: The primary monitoring data collected between 1988-94 was basal cover (Warren 1993). Measurements were made by determining the major and minor diameters perpendicular to each other through the approximate center of the plant. Basal area (BA) was estimated by using the formula for calculating the surface area of the smallest ellipse which could be circumscribed around a plant mat: $BA = (3.14 \times a \times b)/4$; where a and b are the major and minor diameters respectively. If a and b are equal, the formula collapses into the area of a circle. Henceforth this is referred to this as the ellipse-diameter method. Measurements were made to the nearest millimeter from 1988-93 and to the nearest centimeter from 1993-94.

A summary of the demographic data (Table 3), collected from 1988 to 1993 reported that the overall size of the population showed a decline every year between 1988-91, with an apparent stabilization and increase between 1991-93 (Warren 1993). In 1993, approximately 100 plants were reported outside of the monitoring plots. In 1994, 337 plants were found within and approximately 100 plants found outside the monitoring plots. Warren (1994) reported a 17% mortality from 1993 to 1994 (Warren 1994). Percent mortality was defined as the number died in present year (or year 2) one divided by the number alive in the previous year (or year 1) time 100.

Year-to-year changes in the number of individuals may be due to soil depth, protection afforded by established plants, seed viability, and/or genetic inbreeding (Maschinski 1993a). Changes in individual plants may also reflect residual effects of trampling, climate, plant competition, natural growth cycles, or other unknown factors.

Table 3. Summary of the demographic monitoring data collected from 1988-94 at Maricopa Point. Numbers in parentheses are percentages. Data from Warren (1993, 1994).

Live stage/Year	1988	1989	1990	1991	1992	1993	1994
Total plants alive	361	349	285	278	273	319	337
Seedlings	46	16	10	31	24	55	69
Adults	314	333	275	247	249	264	268
Percent change	+19	-3	-18	-3	-2	+17	+6
Number of deaths (% mortality)	1 (N/A)	48 (13)	88 (25)	43 (15)	43 (15)	34 (12)	54 (17)
Seedlings	1	13	12	14	14	7	7
Adults	0	35	76	29	29	27	47
Number increase in size	N/A	82 (27)	96 (39)	77 (32)	43 (18)	177 (74)	97 (37)
Number decrease in size	N/A	103 (33)	76 (30)	82 (34)	90 (39)	9 (4)	68 (26)
Number with no change in size	N/A	123 (40)	81 (32)	81 (34)	101 (43)	53 (22)	99 (37)

Data for percent change in living plants has been added to Table 3. Percent change is defined as the present number of individuals minus the past number of individuals, divided by the past number of individuals times 100. The percent change for 1988 was obtained using the population number of 410 as reported by O'Brien (1984). Percent change decreased abruptly from 1988, rebounded some in 1991-92, and increased between 1993-94. Interpretation of data presented in Table 3 should be tempered with the understanding that the tabulation of population numbers is problematical. Population numbers within the permanent monitoring plots differ between those reported by Warren (1993, 1994), Maschinski and Rutman (1993), Maschinski (1993), and yearly data spreadsheets inspected by this author. It may be due to errors in tracking plant numbers. For example, a plant might have been given a number in one year, then be given another number in a subsequent year following difficulties in proper location. In some cases, a plant may be first observed in one year, but due to its size, it is obvious that it was probably present, but missed in the previous years. Also, as mentioned above, separate plant polygons may actually be comprised of one to many individuals, confounding demographic, size, and age analyses. With this in mind, the change or trend in data presented in Table 3 may reflect improved environmental conditions (i.e., no visitor trampling, increased precipitation, etc.) or changes in sampling personnel over the study period.

Corrected spreadsheets were prepared for each transect and are available for interested researchers. The number of seedling, adult, and dead sentry milk-vetches were tabulated (Table 4). If a plant was noted as "new" in a year and it was apparent that it existed the year previous, these numbers were summed with the previous year. In summary, the numbers show that transects M1 and M3, located closest to the parking lot has shown significant improvement in the habitat quality and the success of germination and seedling establishment. Additionally, even though the number of deaths was high in 1990 and 1994, the population has slowly recovering from the damage caused by trampling and has responded positively to protection afforded by the enclosure fencing.

Table 4. Revised sentry milk-vetch population numbers at Maricopa Point by transect for 1988-94.

	1988	1989	1990	1991	1992	1993	1994
M1:							
Total	53	52	44	51	58	80	88
Seedling	13	2	2	10	6	22	14
Adult	40	50	42	41	52	58	74
Dead	1	10	9	4	1	5	5
M2:							
Total	257	233	181	166	167	170	175
Seedling	25	12	5	10	13	23	5
Adult	232	221	176	156	154	147	170
Dead	0	34	47	32	22	26	28
M3:							
Total	3	4	5	5	7	14	36
Seedling	-	-	1	1	1	6	14
Adult	3	4	4	4	6	8	22
Dead	-	-	1	-	-	-	4
M4:							
Total	51	51	26	37	36	42	37
Seedling	1	2	1	6	3	1	2
Adult	50	49	25	31	33	41	35
Dead	-	6	32	3	3	1	19
Sum M1-4:							
Total	364	340	256	259	268	306	335
Seedling	39	16	9	27	23	52	35
Adult	325	324	247	232	245	254	300
Dead	1	50	89	39	26	32	56

A set of four monitoring codes was developed to document characteristics exhibited by each plant or plant unit measured by the monitoring program (Warren 1993). The four codes discussed below are microhabitat, associates, cover, and flowering.

Microhabitat and associates: The microhabitat codes are: 1 = in gravel, 2 = in gravel directly next to limestone pavement, 3 = in crack of limestone pavement, 4 = in small (<5 cm diameter) depression, 5 = in large (>5 cm diameter) depression, 6 = in or next to rock mat (*Petrophytum caespitosum* or PECA), and 7 = other than listed above. The association codes are: 1 = growing with another sentry milk-vetch, 2 = growing with a grass, 3 = growing with an herb (other than rock mat), 4 = growing with conifer seedling, 5 = growing beneath conifer tree or other, larger bush, 6 = growing in or next to rock mat (this is identical to microhabitat code 6), and 7 = no interaction with other plants (i.e., no associates, or growing alone). [Note, the code number 7 for both the microhabitat and association codes listed above were originally listed as "0" in the 1993 monitoring handbook, but was changed for tabulation in the computer spreadsheet.]

An analysis of the 1994 microhabitat and association code data was tabulated for the 49 possible pairs from 335 living plant units within the four permanent monitoring areas at Maricopa Point (Table 5). No microhabitat or association codes were made for dead plants. A majority (54%) of the plant units are found growing in gravel, a majority were found growing separate from any other plant (58%) and over a third of the plant units grow both alone and in a gravel matrix (38%). Few plants grow in a rock mat (5%), grow in cracks in the limestone pavement (3%) or have some other microhabitat (1%), for example duff. This suggests that viable sentry milk-vetches "prefer" open, gravel areas. The gravel may act as a mulch for the plants, holding moisture and limiting the amount of soils that can be blown away on windy days. However, the numbers indicate that the plants can compete for soil moisture and nutrients with associated plants.

Table 5. Summary of 1994 microhabitat and association codes for 335 plants at Maricopa Point. Number in parentheses are percentages and "T" means trace.

Association code⇒ Microhabitat code⇓	With other sentry milk-vetch	With grass	With herb	With conifer seedling	Below tree or bush	In rock mat	Alone	Sum
In gravel	7 (2)	9 (3)	33 (10)	4 (1)	2 (1)	--	126 (38)	181 (54)
Next to limestone pavement	3 (1)	5 (1)	19 (6)	6 (2)	--	1 (T)	45 (13)	79 (24)
Crack in limestone pavement	1 (T)	1 (T)	2 (1)	1 (T)	5 (1)	--	--	10 (3)
Small depression	9 (3)	1 (T)	8 (2)	4 (1)	1 (T)	--	20 (6)	43 (13)
Large depression	--	--	2 (1)	--	--	13 (4)	--	15 (4)
In rock mat	--	--	--	--	--	2 (1)	--	2 (1)
Other	--	1	--	--	--	--	4 (1)	5 (1)
Sum	20 (6)	17 (6)	64 (19)	15 (4)	8 (2)	16 (5)	195 (58)	335

The differences between the "in rock mat" microhabitat and association codes, which should be identical, is unknown. Future data collection efforts could resolve this seeming contradiction. The differences may reflect errors in note-taking or an observer distinction separating plants which grow in gravel or a crack adjacent to a rock mat from those that grow completely within a rock mat. Also it should be noted that because many plant units may be comprised of one "parent" and one to many "offspring", the figure for the association code for plants growing with other sentry milk-vetch plants is probably underestimated.

Cover and flowering: An analysis of the cover and flower data collected from 1988-94 and tabulated from spreadsheets of the field data notes is shown in Table 6. It should be noted that the definition of cover changed over these seven years of survey. In 1988, the feature studied was loss of cover as exhibited by direct damage, death, or removal of canopy cover. Six classes were recognized: healthy plants, slightly trampled plants, moderately trampled plants, severely

trampled plants (Plate 2:C), very severely trampled plants with bare stems or dead areas, and chlorotic plants. In 1989-92, the first five classes were recognized and the chlorotic category became a field note. After 1992, four cover loss classes were used: none, light (<10%), medium (11-50%), or severe (>50%) loss of cover. These terms have been altered and reversed in Table 6 to a semi-quantitative range of cover values of the plant's basal cover: 100% cover, high (>90%), medium (89-50%), and low (<50%). However, the categories are essentially the same.

Table 6. Summary of cover codes and flowering (yes or no) for 1988-94. Dates are noted by month/day/year and numbers in parentheses are percentages.

Code/ Date	4/27-29, 1988	5/8, 1989	5/16-17, 1990	5/29, 1991	5/11, 1992	5/5-7, 29-30, 1993	5/25-29, 1994
Number of plants	355	354	270	271	273	321	336
100 % cover	121 (34.1)	102 (28.8)	81 (30)	88 (32.5)	151 (55.3)	147 (45.8)	169 (50.3)
>90% cover	17 (4.8)	15 (4.2)	20 (7.4)	20 (7.4)	24 (8.8)	43 (13.4)	41 (12.2)
50-89% cover	35 (9.9)	36 (10.2)	28 (10.4)	25 (9.2)	25 (9.2)	48 (15.0)	48 (14.3)
<50% cover	182 (51.3)	201 (56.8)	141 (52.2)	138 (50.9)	73 (26.7)	84 (26.2)	78 (23.2)
No flowers	166 (46.8)	199 (56.2)	129 (47.8)	197 (72.7)	153 (56.0)	212 (66.0)	124 (36.9)
Flowers present	189 (53.2)	155 (43.8)	141 (52.2)	74 (27.3)	120 (44.0)	110 (34.3)	212 (63.1)

Again, differences in the population size between Tables 3 through 5 is unresolved and problematical. In any event, the data presented in Tables 4 and 5 is within the proper range, or "ball park" of Table 3. Generally, plants with <50% cover steadily decreased over time (51 to 23%), plants with >50% and 100% cover increased slowly. This corroborates the observation that fencing and enclosing the Maricopa Point population has succeeded in improving the "health" of the population. About half of the plants flower each year, while non-flowering plants (the numbers include seedlings and juveniles which would not be expected to flower) were in the majority in 1991 and 1993. Notes about the weather are available for three dates of survey: April 1988 had a winter storm which froze flowers, April 1993 had 2 inches of snow, and April 1994 had a snow storm during the week of sampling.

A summary of size with inferred age classes is shown for 1988-94 by Table 7. Age is inferred, as a plant with a small area may actually be quite old. An individual plant in its life cycle changes

shape and cover. A small seedling becomes a somewhat larger juvenile, which in turn becomes a large adult. However a mature plant may slowly become reduced in size and finally become a senescent adult with bare or dead areas subtracting cover from the basal area. Table 6 shows high numbers of small plants and decreasing amounts of larger ones, typical of many plant populations of plants.

A seven year average (1988-1994) of the five size and inferred age classes (Figure 3) following the size classes established by Warren (1993) shows that about a majority or half ($n=159$, 51%) of the plants are very small and classed as seedling and juvenile ($n=63$, 20% and $n=96$ 31%, respectively), over one-fourth are small in size ($n=80$, 26%), one-sixth are medium in size ($n=53$, 17%), and about one-sixteenth are large in size ($n=6$, 6%). Though the size classes differ, these results are similar to that reported by Rutman (1988), who described the population as an inverse J shaped curve where the probability of death decreases exponentially as plants age. This type of concave curve, originally called type 1 by Pearl (1928), illustrates extensive early mortality, with remaining individuals having a high rate of subsequent survivorship (Pearl 1928, Begon et al. 1996). An analysis of 335 plants from 1994 (Figure 4) in 10 cm² increments also shows this population structure. Of course, for a complete understanding of an organism, these survivorship curves ideally should include the ovule or seed formation stages. Seeds may remain in the soil for years. When a seed germinates, it may actually be greater than one or two years old, as based on the original year of ovule formation. Wiens (1984) has shown that 50% of perennial plant ovules may abort. As mentioned previously, about 70% of the sentry milk-vetch ovules cease growth and abort (Allphin-Woolstenhulme 1995) prior to seed dispersal.

Figure 3. A seven year average of the five size and inferred age classes.

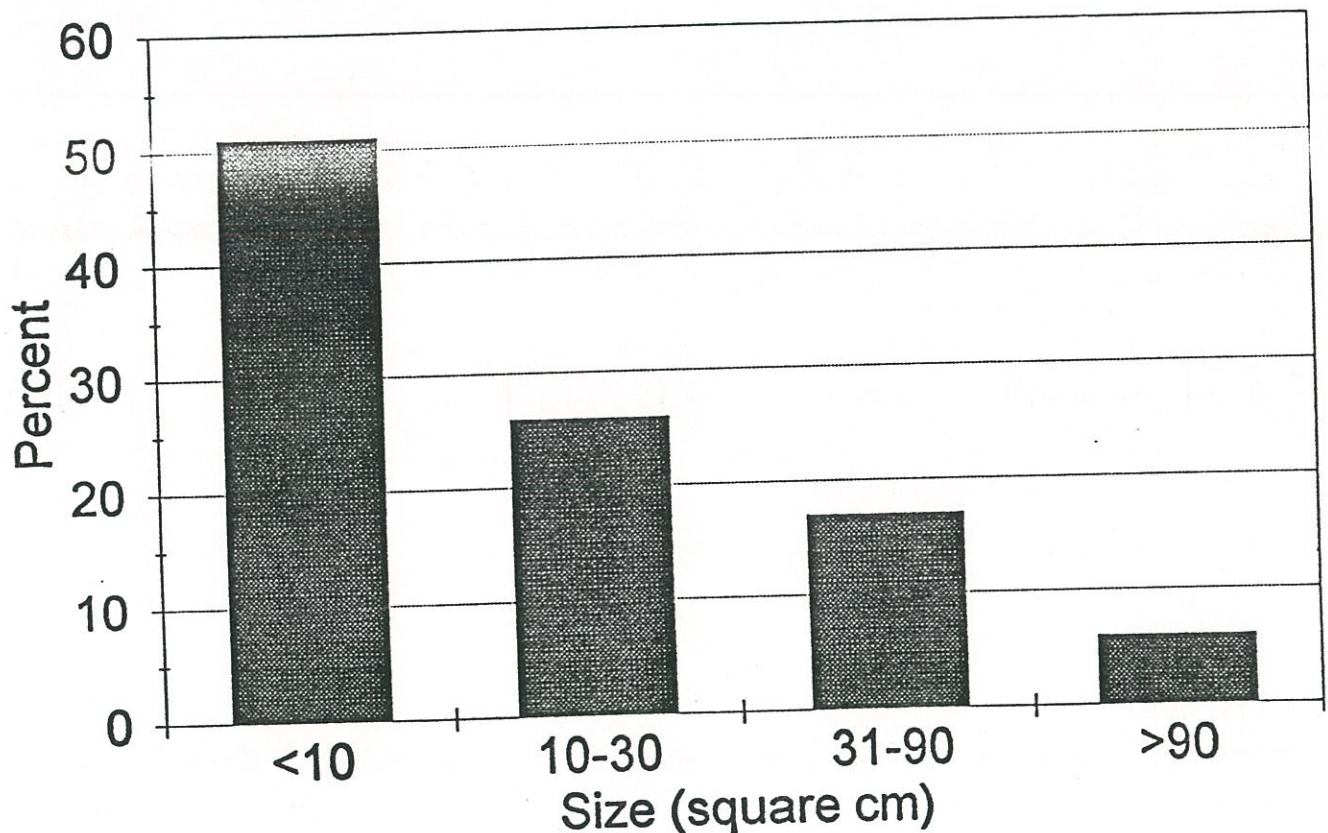
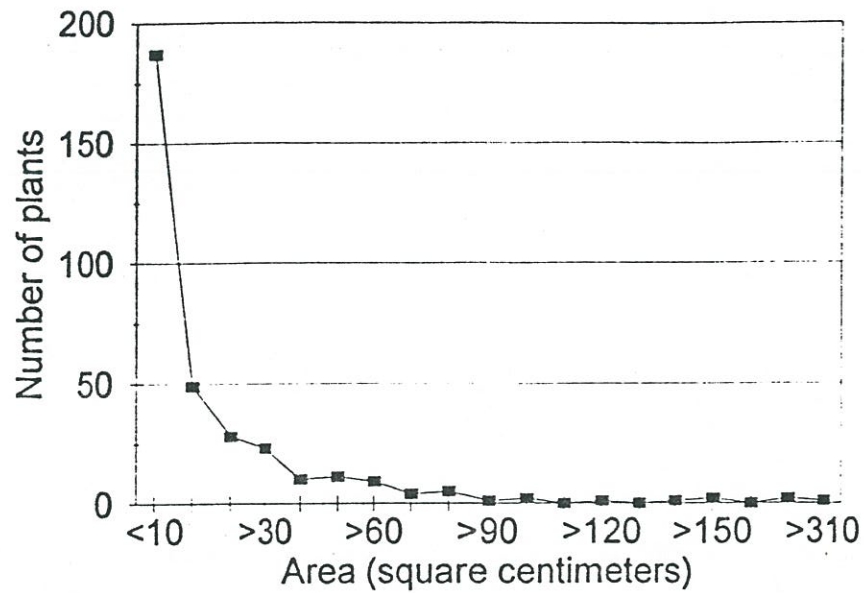


Figure 4. Size analysis of 336 plants from 1994.

Table 7. Summary of size (cm²) and age classes for 1988-94. Dates are noted by month/day/year and numbers in parentheses are percentages.

Code/ Date	4/27-29, 1988	5/8, 1989	5/16-17, 1990	5/29, 1991	5/11, 1992	5/5-7, 29-30, 1993	5/25-29, 1994
Number of plants	355	354	270	271	273	321	336
<0.99 cm ² "Seedling"	61 (17.2)	66 (18.6)	46 (17.0)	81 (29.9)	68 (24.9)	50 (15.6)	67 (19.9)
1-9.99 cm ² "Juvenile"	102 (28.7)	106 (29.9)	94 (34.8)	55 (20.3)	88 (32.2)	108 (33.6)	120 (35.7)
10-30 cm ² "Small"	91 (25.6)	88 (24.9)	71 (26.3)	81 (29.9)	65 (23.8)	81 (25.2)	80 (23.8)
31-90 cm ² "Medium"	66 (18.6)	64 (18.1)	40 (14.8)	39 (14.4)	40 (14.7)	64 (19.9)	58 (17.3)
>90 cm ² "Large"	35 (9.9)	30 (8.5)	19 (7.0)	15 (5.5)	12 (4.4)	18 (5.6)	11 (3.3)

Data was tabulated for 193 sentry milk-vetch plants at Maricopa Point which have died during the seven years between 1988 and 1994. Fifty four plants (or 28%) showed a steady decline in size over three to six years, with an additional 20 plants (or 10%) showing an irregular decline (a loss in one year, a gain in the next, a loss in the third, etc.) over four to six years before eventually dying. A majority of plants ($n=119$ or 62%) had a relatively "quick" death, growing for one to two years before dying. In the latter category, about 43% of the "quick death" group were seedling or juvenile plants. These data suggest that plants stressed by damage, drought, competition, natural growth and death cycles, or other factors can persist for up to six years before eventually dying. Even though the plants were protected from trampling in 1990, damage incurred before protection could have been the cause of death years later.

What is the natural growth cycle of the sentry milk-vetch? The plants grow slowly and often irregularly. Plant area has not been accurately followed and has been overestimated by the ellipse-diameter method. However, data sheets for each sentry milk-vetch tracked by the monitoring program have been prepared for each transect and are available. Plants that have died are filed separately. An idealized growth chart (Figure 5) was prepared following the assumption that a plant begins as a 0.5 diameter circle, followed by a 1 by 0.5 cm ellipse, grows $\frac{1}{2}$ cm in the major diameter each year, while the minor diameter increases by 0.5 cm only after year three. The yearly growth of 0.5 cm was selected following personal observation and Barneby's (1948) statement that, "since the maximum growth of the shoots in a favorable year cannot exceed 5 mm, [plants] must be of considerable age, as well as his (1964) observation that "stems of the year not over 5 mm long." Thus, it is estimated that a minimum of 41 years is necessary for a plant to grow to a 314 m² plant (approximately 20.5 by 19.5 cm), the largest plant living in 1994 (identified as M2-31, Plate 1:C). The largest plant recorded since the monitoring program began was M2-242, with an estimated basal area of 252 m² from the 22.0 by 14.6 cm size in 1989. This plant has since lost basal area and was 16 by 11.5 cm in 1994. Given that it may take one or more years for a seed to germinate, one to four years before a "tuft" can be measured, years of no growth, and years where "negative" growth can occur, a large sentry milk-vetch may be 50-60 years old or older.

An analysis of percent change for a subsample of about 60 plants from all four transects for six years from 1988-94 was made in order to assess changes in growth. A summary of the percent change in cover for all years (Figure 6) shows that a majority of the plants showed little change, with many exhibiting a loss of cover and very few showing substantial change. In the future, this data will be compared with weather data to determine if there is any correlation with summer precipitation (July through September), winter precipitation (October to April), or total precipitation (October to October).

Figure 5. Idealized growth of sentry milk-vetch.

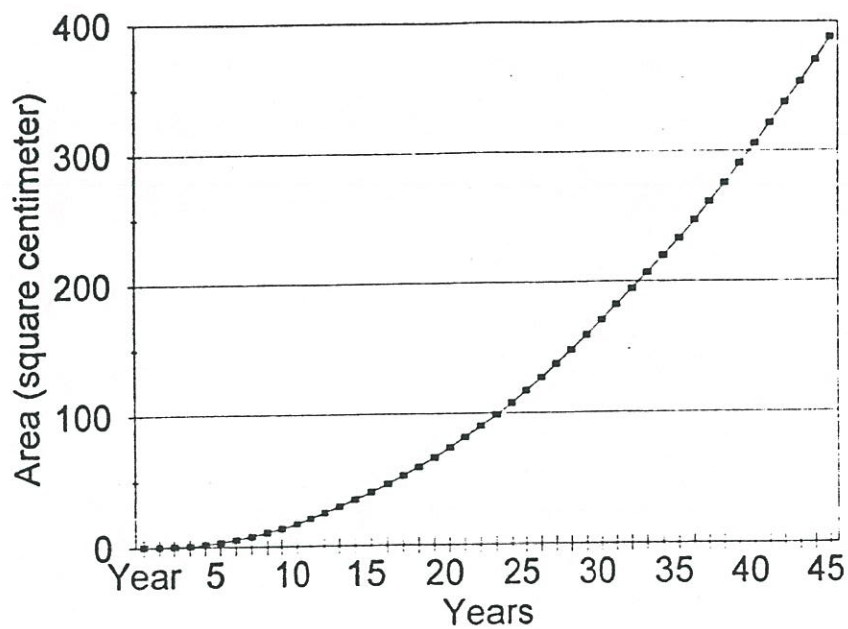
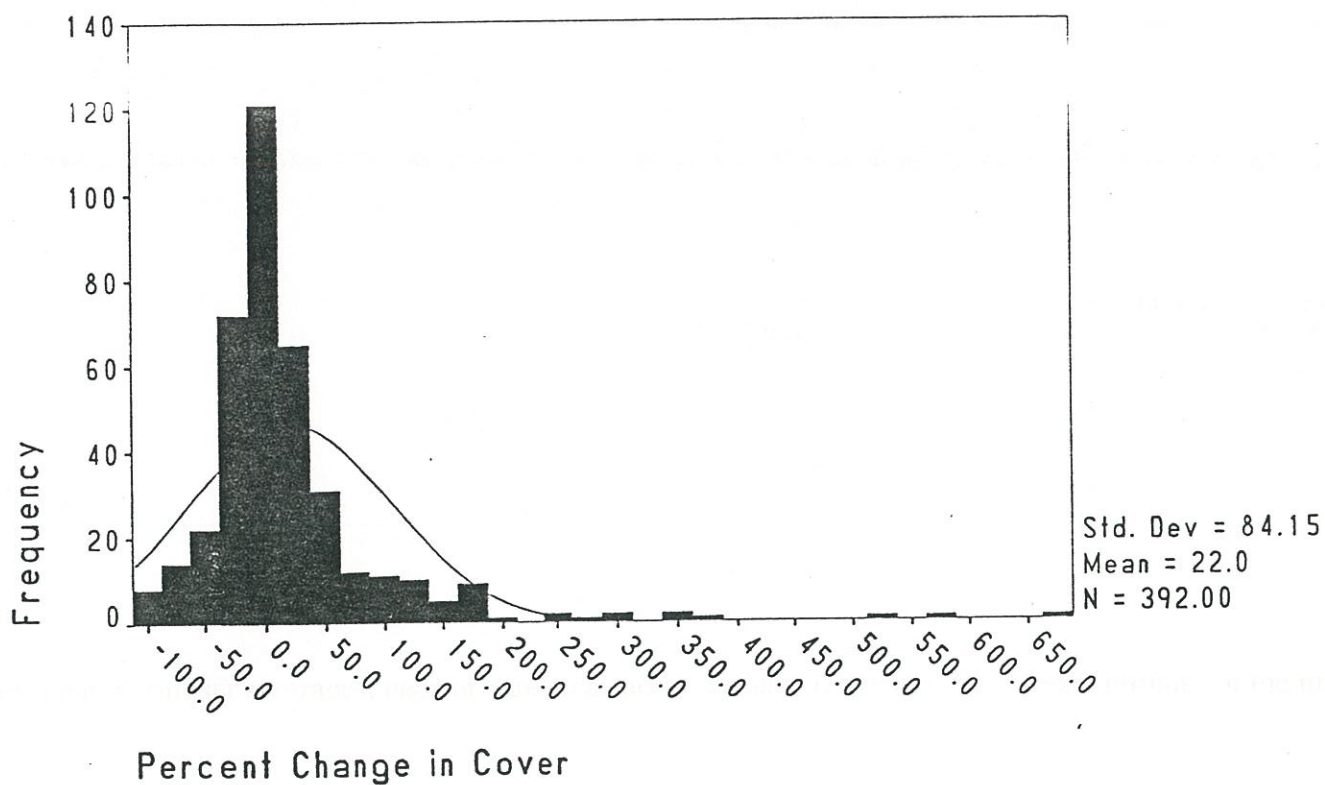


Figure 6. Percent change in size for a subsample of plants between 1988-94.



The demographic survey program (Warren 1993) is discussed below and is fully outlined in Appendix B. Four other studies were also conducted at Maricopa Point: fruit production (Appendix C), seedling survival (Appendix D), research and visitor activity (Appendix E), and photodocumentation (Plate 2:D, Appendix F). In addition, a list of interested and knowledgeable people is provided in Appendix G. It is suggested that when park staff or other researchers visit or conduct research at any sentry milk-vetch site within the park, a record of the visit should be made and kept on file.

Demographic Monitoring Method: The main objectives of the 1988-94 demographic survey (Warren 1993) at Maricopa Point were to: (1) determine the number of individuals in the population, (2) determine the rate of mortality, (3) determine growth and decline rates, (4) determine rate of seedling establishment, (5) assess threats to the population, and (6) from the information gathered, assist appropriate management decisions to insure continuation of the species.

Annual surveys were conducted each spring in the third or fourth week of April from 1988 to 1994 so that flowering could be observed and to compare data collected at the same phenological stage from year-to-year. However, late April weather is often inclement and the ground saturated. Damage through trampling of the plants and compaction of the soil was observed. The ellipse-diameter method data collection required teams of two people. Plants were identified, measured, and habitat notes taken. New and dead plants were documented. Thorough data collection required about one day per plot. Two people could complete the survey in five days, while four people could complete the survey in three days.

1995 - Present Perimeter Tracing Methodology

In July 1994, a perimeter tracing study of 103 plants at Maricopa Point was compared to the ellipse-diameter method. It found that the ellipse-diameter method (described above) overestimates plant area by a factor of 1.24 and that measurements to the nearest millimeter are more accurate than those to the nearest half centimeter (Rowlands and Brian 1996). Weight conversion or digitization of the tracings prove to be more accurate than the ellipse-diameter method. The monitoring program has since been changed to a biannual survey of a minimum of 100 plants using the perimeter tracing method.

Precise basal cover estimates are obtained by a perimeter tracing. Tracings are made by placing a lucite panel on a frame onto which short, 2 cm legs have been welded to each corner. In some cases, the limestone pavement provides sufficient relief and the panel can be placed directly on the ground, without compressing the plant. The tracing is made on a clear piece of drafting mylar (0.13 mm in thickness) placed on the panel using a permanent, ultra-fine point marker. Exact outlines of the plant perimeter are traced, dead or bare areas noted, areas of overlapping

cover by adjacent plants traced, and the plant identifying number noted within each polygon along with the date. Where there is any doubt, accuracy is assured by placing the tracing directly over the plant to assess conformance. Pages of the mylar are photocopied to provide a duplicate, permanent, hard copy. The polygons can be directly digitized and surface areas calculated using Sigma Scan (Jandel 1993). Alternatively, the polygons can be cut out with scissors and weighed. The density of the mylar (0.0176 gm/cm^2) is then used to convert the weight to an estimate of surface area.

The perimeter tracings for each plant unit are archived in three-ring notebooks along with a summary sheet (Figure 7). It is hoped that eventually a better size/age relationship, growth rates, and life-history information can be obtained from this data. Additional areas of inquiry include: effect of climatic regimes, competition, the seed bank and seed viability, and pollinators. Additional searches will be made for new populations.

Miscellaneous Observations

In many instances, there appears to be competition for the available resources and habitat when sentry milk-vetch and rock mat inhabit the same micro-site. Rapid growth by rock mat may limit the size and life span of a co-occurring sentry milk-vetch. It has been suggested that visitor trampling of the site prior to enclosure may also have reduced or restricted the colonization by rock mat.

The interplay between climate and substrate requirements is shown by a gravel area located next to the limestone pavement on transect M4. This area appears to be excellent habitat but is devoid of any plants. In March 1996, it was found to be 1 inch deep in standing water with two plants on the margin (new tags #022 and #024, old tag numbers M4-65 and M4-89 respectively) $\frac{1}{2}$ inch underwater. This suggests that the habitat is not colonized by the sentry milk-vetch due to temporary, yet significant environmental conditions.

In the absence of a pollinator, falling rain, sleet, or hail during April, on on-set of flowering, may transfer pollen. The pollen, in a watert suspension may be transferred between sentry milk-vetches by water "splashing" the pollen from one flower in a plant mat to a nearby flower in an adjacent plant mat.

Figure 7. Summary information on individual sentry milk-vetch plants at Maricopa Point.

M _____ Old Transect - Sequential Number _____ Transect Side _____ New Tag Number _____

Location Coordinates: Please note any differences

AXIS	1988	1989	1990	1991	1992	1993	1994	1995	1996
Long									
Short									

YEAR	Length (cm)	Width (cm)	Oval Area (cm ²)	Actual Area (cm ²)	COMMENT'S (Flw=flower, Dam=Damage, Fr=fruit, BWR=bare root, etc)
1988					
1989					
1990					
1991					
1992					
1993					
1994					
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					

Plate 1-5 information.

Plate 1.

- A. Close up of flowers and leaves by Peter Rowlands, March 1989.
- B. Close up of flowers and leaves by Holger Hunger, April 1994.
- C. Largest plant (ca. 20 by 20 cm) in population showing various tags: M2-31 number written on limestone at "12 o'clock", fish tag #058 at "2 o'clock", and aluminum tag #684 at "3 o'clock", by Nancy Brian, April 1996.
- D. Maricopa Point signing on post-and-rail wooden fence by Nancy Brian, September 1994. Note that wire mesh was affixed to the back of the fence in July 1995.

Plate 2.

- A. Habitat at Maricopa Point on M2 transect, by Nancy Brian, June 1995.
- B. Habitat at Maricopa Point on M2 transect, by Nancy Brian, June 1995.
- C. An example of "severe" damage by Kathy Warren, 1993.
- D. An example of photodocumentation of plants on M4 transect by Holger Hunger, June 1993. Note limestone pavement, small depressions, and gravel microhabitats.

Plate 3.

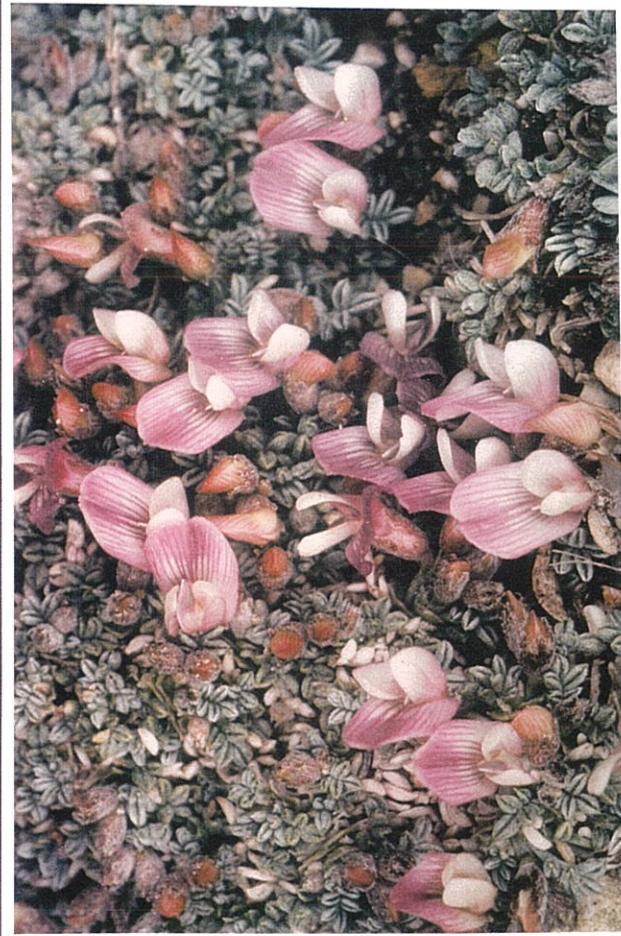
- A. Aerial view (map view) of Maricopa Point by Holger Hunger, June 1993.
- B. Oblique view of Maricopa Point from the east by Holger Hunger, June 1993.
- C. Sentry milk-vetch growing within a clump of rock mat by Nancy Brian, June 1995.
- D. Various shapes of sentry milk-vetches (Rowlands and Brian 1996).

Plate 4.

- A. Grandview site, plant No. 4 by Nancy Brian, April 1995.
- B. Habitat and plants at North Rim, Site B, by Nancy Brian, September 1994.
- C. Close-up of closely growing sentry milk-vetch plants at North Rim, Site B by Nancy Brian, September 1994.
- D. *Ex situ* population at the Arboretum at Flagstaff greenhouse by Nancy Brian, September 1994.

Plate 5.

- A. Habitat at Hevron milk-vetch site, Marble Canyon by Nancy Brian, April 1996.
- B. Close-up of Hevron milk-vetch plants by Nancy Brian, April 1996.
- C. Habitat of cliff milk-vetch site, Buckskin Mountains by Nancy Brian, May 1995.
- D. Close-up of cliff milk-vetch plants by Nancy Brian, May 1995.



A



C



B



D

Plate 1. Sentry milk-vetch photography.



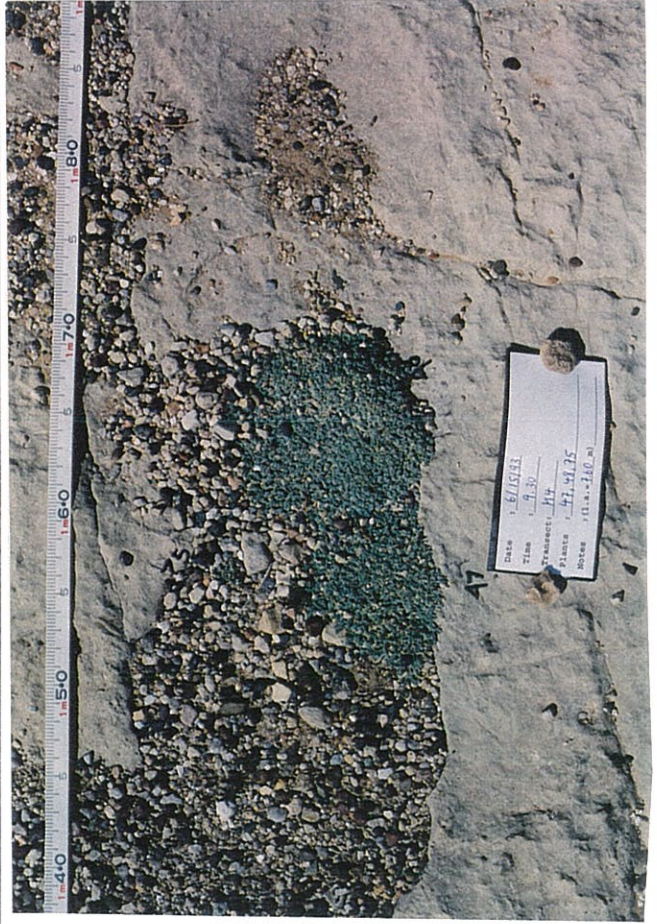
A



B



C



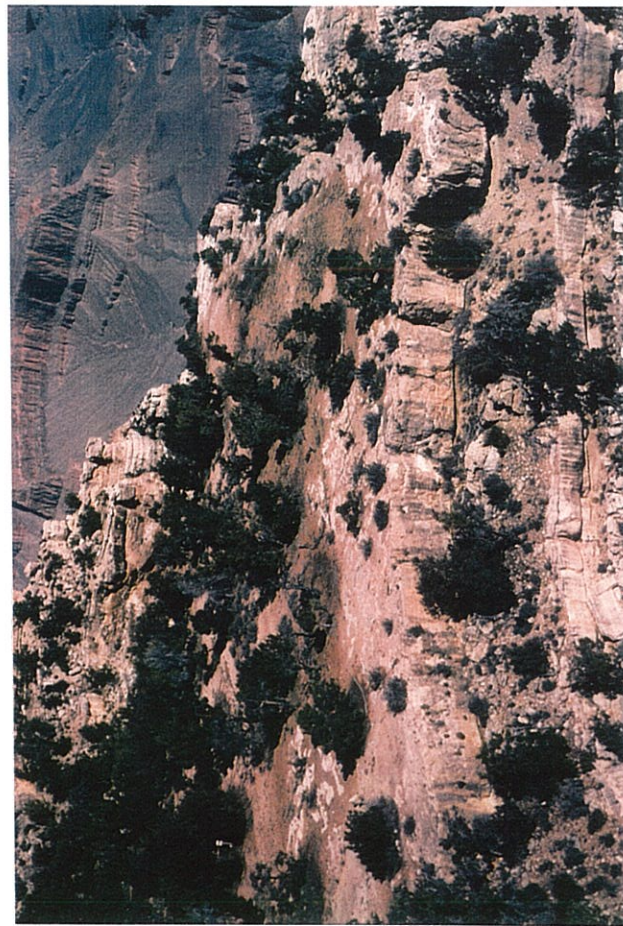
D

Plate 2. Sentry milk-vetch photography.

Plate 3. Sentry milk-vetch photography.



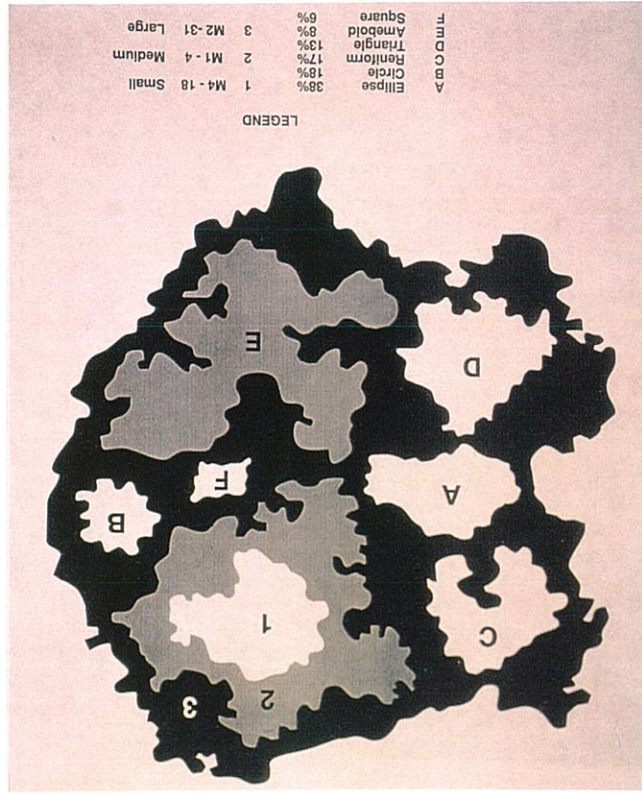
A



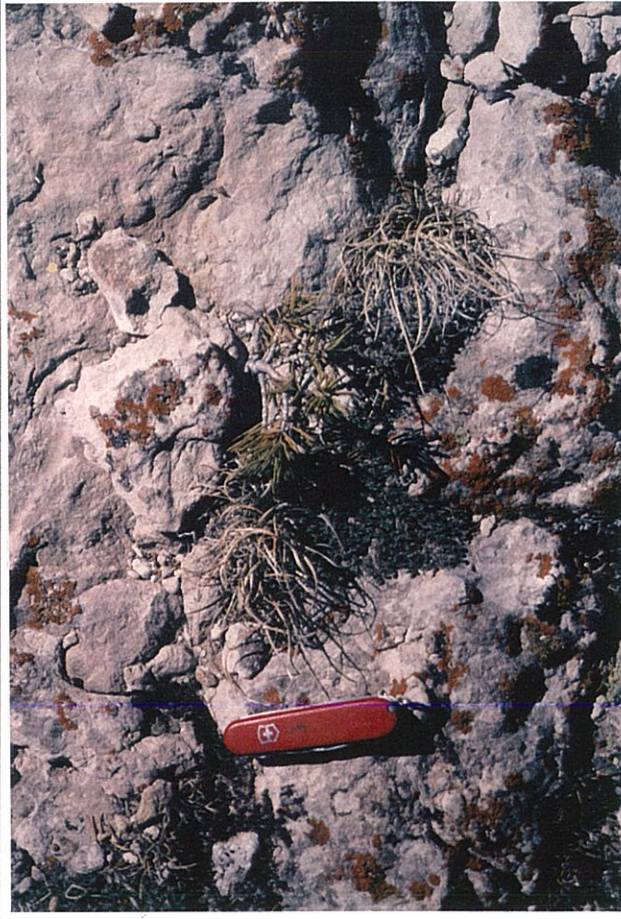
B



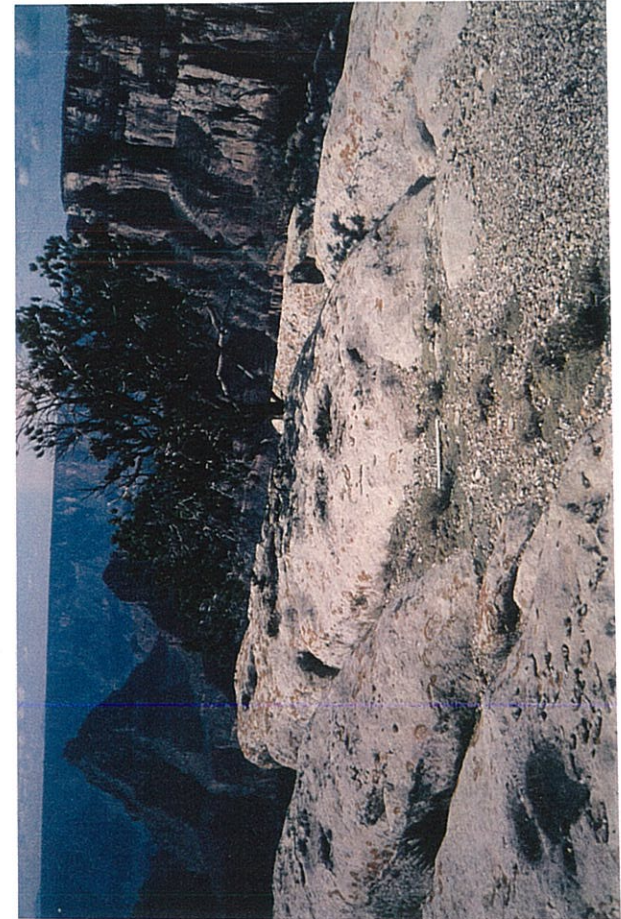
C



D



A



B



C

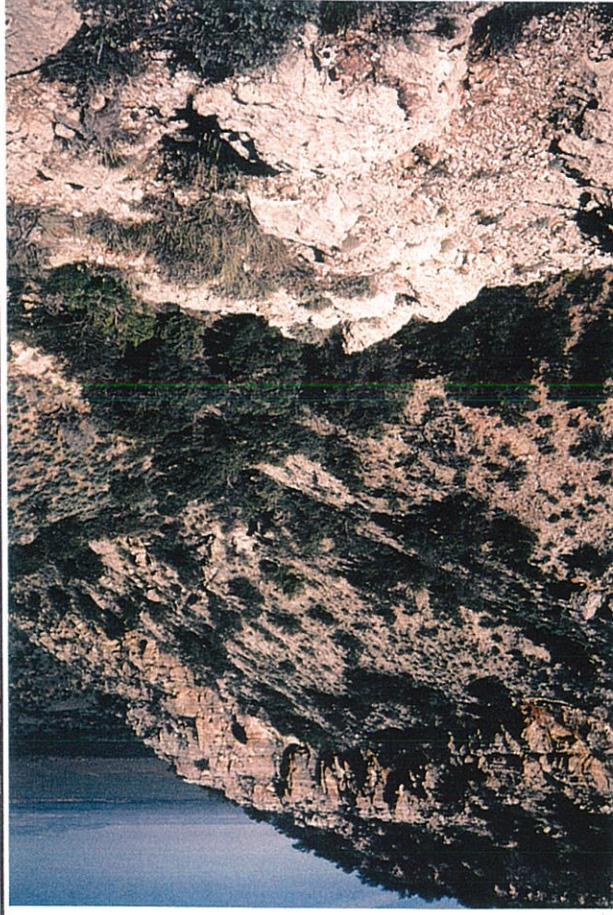


D

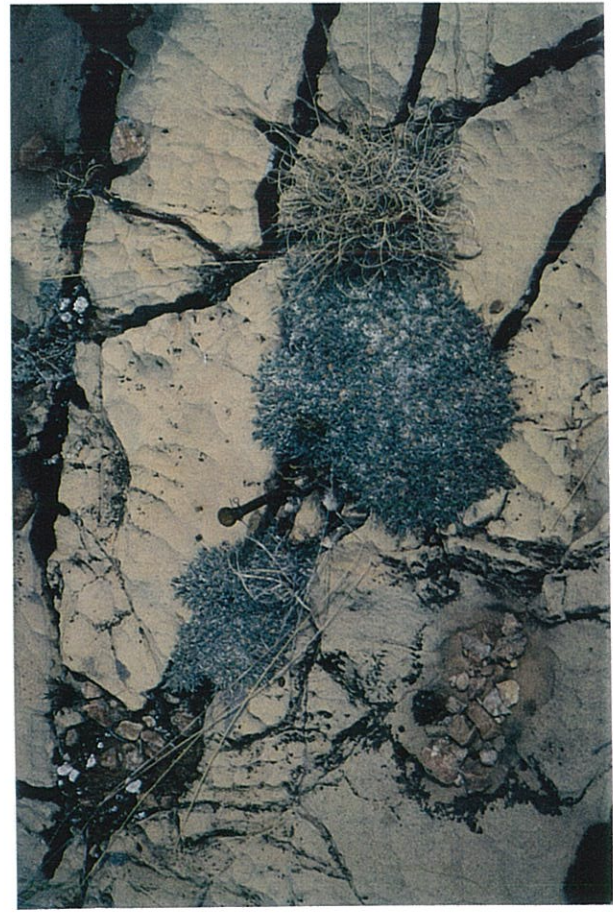
Plate 4. Sentry milk-vetch photography.



A



C



B



D

Plate 5. Sentry milk-vetch photography.

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Appendix A: Plant Species List for Maricopa Point (July 1993)

<u>Scientific Name</u>	<u>Species Code</u>	<u>Common Name</u>
<i>Agave utahensis</i>	AGUH	Century plant
<i>Agropyron smithii</i>	AGSM	Wheat grass
<i>Arabis fendleri</i>	ARFE	Rockcress
<i>Arenaria aberrans</i>	ARAB	Sandwort
<i>Artemisia bigelovii</i>	ARBI	Black sage
<i>Artemisia tridentata</i>	ARTR	Big sage
<i>Aster arenosus</i>	ASAR	White aster
<i>Astragalus calycosus</i>	ASCA	Gray locoweed
<i>Astragalus cremnophylax</i>	ASCR	Sentry milk-vetch
<i>Bouteloua gracilis</i>	BOGR	Blue grama grass
<i>Brickellia grandiflora</i>	BRGR	Brickellia
<i>Bromus tectorum</i>	BRTE*	Cheat grass
<i>Calochortus nuttallii</i>	CANU	Mariposa lily
<i>Calylophus hartwegii</i>	CAHA	Yellow primrose
<i>Cercocarpus intricatus</i>	CEIN	Littleleaf mahogany
<i>Chamaebatiaria millefolium</i>	CHMI	Fernbush
<i>Chrysothamnus nauseosus</i>	CHNA	Rabbitbrush
<i>Cowania mexicana</i>	COME	Cliff rose
<i>Echinocereus triglochidiatus</i>	ECTR	Hedgehog cactus
<i>Ephedra viridis</i>	EPVI	Mormon tea
<i>Erigeron flagellaris</i>	ERFL	Spreading fleabane
<i>Eriogonum fasciculatum</i>	ERFA	Buckwheat
<i>Eriogonum jamesii</i>	ERJA	Antelope sage
var. <i>flavescens</i>		
<i>Erodium cicutarium</i>	ERCI*	Filaree
<i>Euphorbia</i> sp.	EUPHO	Spurge
<i>Fallugia paradoxa</i>	FAPA	Apache plume
<i>Gutierrezia sarothrae</i>	GUSA	Snakeweed
<i>Haplopappus</i> sp.	HAPLO	Haplopappus
<i>Hedeoma drummondii</i>	HEDR	Mock pennyroyal
<i>Juniperus osteosperma</i>	JUOS	One-seed juniper
<i>Opuntia</i> sp.	OPUN	Prickley pear
<i>Penstemon eatonii</i>	PEEA	Eaton's penstemon
<i>Penstemon linarioides</i>	PELI	Linear-leaf penstemon
<i>Penstemon pachyphyllus</i>	PEPA1	Thick-leaf penstemon
<i>Penstemon palmeri</i>	PEPA2	Palmer's penstemon
<i>Perityle congesta</i>	PECO	Perityle
<i>Petrophytum caespitosum</i>	PECA	Rock mat
<i>Pinus edulis</i>	PIED	Pinyon pine
<i>Poa fendleriana</i>	POFE	Mutton grass
<i>Polygonum aviculare</i>	POAV*	Knotweed
<i>Quercus gambellii</i>	QUGA	Gamble's oak

<i>Ranunculus testiculatus</i>	RATE*	Bur buttercup
<i>Salsola kali</i>	SAKA*	Russian thistle
<i>Sitanion hystrix</i>	SIHY	Squirrel tail
<i>Stipa comata</i>	STCO	Needle and thread
<i>Symphoricarpos</i> sp.	SYMPH	Snowberry
<i>Talinum validulum</i>	TAVA	Tusayan flameflower
<i>Verbascum thapsus</i>	VETH*	Mullein
<i>Verbena bracteata</i>	VEBR	Prostrate vervain
<i>Yucca baccata</i>	YUBA	Banana yucca

* = exotic plants that should be eradicated when encountered

Appendix B: Step-by-step Monitoring Procedures for the Ellipse-Diameter Method

1. Complete information on "Monitoring Record Sheet" (Appendix E):

- date
- weather: current weather conditions and any notable weather over the past week or so that may have been of significance to the population (freeze, snow, drought, etc.)
- purpose of site visit
- names of people participating in monitoring and which plots they work on
- visitor activity: note any signs of visitor activity in the area, such as obvious footprints that are not from monitoring, or actual visitors entering the monitoring area. Document with photographs if possible.
- rough count of plants outside plots

2. Lay out transect: Lay a 30 or 50 meter tape along the transect line. Firmly ground the endpoints on the nailheads. Rocks may be needed to anchor the transect line between the endpoints on windy days. The x and y coordinates for each plant is numbered on the data spreadsheets. The location of each plant is indicated by a long (or x coordinate along the transect line) and short (or y coordinate perpendicular to the transect line) measurement to the approximate center of the plant. Actual measurements may change from year to year due to stretching of the measuring tape, any change in anchoring of the endpoints, or deviations in the "perpendicular" angle measured from the long axis. A right angle tool is often useful for finding the correct short axis measurement.

It is extremely important to be thorough and take the time necessary to be as accurate as possible. If people become hot, tired, or hungry, a break should be taken, or work be delayed until another day. In the past, much information was poorly or un-recorded because people were in a hurry to complete the survey. Thorough notes were necessary in following years when confusion about specific plants occurs.

3. Locate each plant and collect the following data. Enter the data on the data collection spreadsheet:

A. Size: Measure the length and width of each plant to the nearest millimeter (used prior to 1993) or half centimeter (used 1993-94). These measurements should be perpendicular to each other through the approximate center of the plant. Use the longest and widest axes. If the plant is a seedling or juvenile, count the number of leaves. Legume leaves are compound, remember to count the leaves, not the leaflets! Note if cotyledons are still present.

B. Damage: Damage originally referred to trampling impacts, which were inferred before the fence enclosure was constructed. Researchers are now reminded that dead area does not necessarily imply trampling, but may also be due to other causes of mortality. Damage assessment has also used different categories in the past, dividing the level of damage into four ranges. Categorize the amount of dead plant area or "damage", using the following categories:

- None (N) = no apparent damage or dead area
- Light (L) = 1-10% dead plant area
- Medium (M) = 11-50% dead plant area
- Severe (S) = more than 50% dead plant area

When assessing dead area, indicate in notes whether it is throughout the plant ("sparse"), or discrete patches of dead area ("patch"). If the percent area is difficult to assess, a clear mylar centimeter square grid can be used to help quantify the area. This is done by counting the number of square centimeters dead area and dividing by the total area of the plant to calculate a percentage that matches the above categories.

C. Flowers: Indicate whether or not the plant has flowers at the time of monitoring; Y=yes, N=no; if yes, indicate the relative quantity of flowers as few (F)=less than 25% of plant area covered with flowers or many (M)=more than 25% of plant area covered with flowers.

D. Notes: If the plant has died since the last survey, write "dead" here. Note if there is anything else unusual about the plant such as insects observed, predation, chlorosis, disease, or morphological features. The number of leaves and presence of cotyledons for seedlings should be noted. When referring to other plant species, use plant species codes (Appendix G).

4. New plants: If new seedlings or previously unmapped plants are found in a plot, give it the next consecutive number for that transect, number it with black permanent marker on nearby rock, and note location axes as well as all of above information.

5. Marking: Rewrite the number for each plant with a black permanent marker ("Sharpie") if it has faded or been grown over.

6. Terms and definitions used in monitoring notes: Over the years, numerous people have been involved in monitoring. In order to clarify and maintain some consistent use of terms used in monitoring notes, the following definitions are provided.

A. Age Classes: Three age classes are used. Seedling (S): new plant with less than 30 leaves, sometimes with cotyledons, Juvenile (J): plant more than 1 year old that has not formed a mat; leaves still erect and in a discrete bunch, Mature (M): plant has formed a mat; may or may not flower (plants flower as early as one year after germination; some have never been documented as flowering after more than five years of monitoring).

B. Size Classes: Size classes are defined as follows: Small: 10-30 cm², Medium: 31-90 cm², and Large: greater than 90 cm²

7. Equipment (for each team of 2 surveyors):

- data sheets; 1 set per plot (Appendix C)
- data sheet legend (Appendix D)
- clipboard
- Sharpie black permanent markers (2)
- pencils (2)
- compass
- 30 m or 50 m tapes (2)
- 10 cm ruler with mm marks
- water and food
- sunhats
- sunscreen
- reference files from previous years (88-previous year)
- monitoring plan (this document)
- camera with 50mm lens
- color slide film
- extra plot end tags (8)
- right angle
- clear mylar centimeter square grid
- knee pads (optional)

8. Data Analysis: Unless data is analyzed, it is of no use to managers. With many years of data collected, there are numerous analyses which should be done to understand the population biology of the species.

A. Annual summary: An annual summary of demographic monitoring activity must be completed. Details that will help explain the current years monitoring, suggestions for improvements or additions to the monitoring program, and general observations of the populations' health should be documented. All data collected should be entered into a spreadsheet each year. Lotus 1-2-3 spreadsheets have been used in the past. These spreadsheets are easily imported to WP51 to create tables.

Change in plant size is determined by finding the sum of the increase or decrease in length and width from the previous monitoring year. If the sum is greater or equal to 1, tally an increase; if the sum is less than or equal to -1, tally a decrease; if the sum is -1/2,

0, or $\frac{1}{2}$, tally no change in size.

B. Other analyses: (1) correlation of population trends with weather data, (2) mapping of plants, (3) growth rates, (4) life history matrix, and (5), and growth rates.

Appendix C: Fruit Production

Fruit production monitoring was initiated in May of 1992 by Kathy Warren. There were two main objectives of this study: (1) to collect data on fruit production in different size and damage classes of plants in order to better construct life history matrices for demographic analysis, and (2) to understand patterns of reproduction in individual plants. The following questions were posed: Do plants produce fruit consistently every year or only periodically? How much fruit do individual plants produce? Are larger plants more productive than smaller plants? How does damage or partial plant mortality affect fruit production? How much seed is potentially produced by the populations? How does fruit production relate to the number of seedlings observed in the population?

Methods: Forty-eight individuals were selected to initiate the study in May of 1992. Five individuals in each of nine size/damage classes are censused for the number of fruits produced twice each year. The plants should be censused both in spring (late May) and fall (late September), as the species produces fruits in two separate time periods. Individual location, size, and damage class are noted. A fifth plot (M5), additional to the four established for demographic monitoring, is used to locate individuals for fruit production monitoring. Each of the individuals used for the study in this plot are labeled with an "F#". Data sheets and annual reports for the study are kept on file folder at Grand Canyon National Park.

Analysis: The number of fruits per square centimeter for each plant is calculated. The average number of fruits per square centimeter for damage class alone are calculated. The average number of fruits per square centimeter for size class alone are calculated. These data are then averaged. Data from May 1992 Summary Statistics produced the following table integrating size and damage classes:

Average # of Fruits/cm² by Size and Damage Class

Size/Damage	Light (<10%)	Medium (10-50%)	Severe (>50%)
Small (10-30cm ²)	0.49 fruits/cm ²	0.44 fruits/cm ²	0.29 fruits/cm ²
Medium (31-90cm ²)	1.67 fruits/cm ²	0.65 fruits/cm ²	0.39 fruits/cm ²
Large (>90cm ²)	2.90 fruits/cm ²	0.61 fruits/cm ²	0.04 fruits/cm ²

Appendix D: Seedling Survival

Seedling survival monitoring was initiated in June 1993 by Kathy Warren. This study should be continued for at least three seasons in order to acquire minimum necessary information to

understand seedling survival patterns.

Objectives: Seedling survival is the crux of a plant populations overall health. By observing seedlings periodically over the course of the growing season, we can better understand mortality factors and germination patterns.

Methods: New seedlings documented during the annual demographic monitoring are tracked approximately monthly and following notable weather events, such as a freeze, snow, or heavy rain. Seedlings are more sensitive to disturbance than adults, so more frequent observation (weekly, bi-weekly) should be carefully considered.

A list of new years' seedlings should be made from the demographic monitoring data to keep track of individuals through the growing season. New seedlings are noted, and given a plant number during each observation period. It is important to realize that new seedlings may have been present at the last observation time, but not seen. Only if a seedling still has cotyledons can we be certain that it was not present but unseen at the previous observation period.

A brief experiment was done during the summer of 1992 by Kathy Warren to see if hand distribution of seeds would help facilitate successful reproduction of the sentry milk-vetch. A sample of 100 seeds were placed in suitable germination locations within the existing Maricopa Point population. The sites were checked monthly during the 1992 and 1993 growing season to see if any had germination, but none did. Apparently, such manipulations were not helpful to augment the population.

Example table from 1993 data:

Observation. Date	# died	# new	# persist
6/7/93	2	11	53
7/22/93	5	7	59
9/15/93	2	22	64

Appendix E: Research and Visitor Activity

Prior to May 1990, visitors had full access to the area. Trampling was identified as a significant cause of mortality to the sentry milk-vetch. After 1990, Maricopa Point was enclosed on two sides (the remaining two being the canyon rim) by a fence. Though trampling by visitors was dramatically reduced as a result of fencing, a study was conducted by Kathy Warren and Holger Hunger in May and June of 1993 to document how much, if any, trampling still continued. If intrusion by visitors over the fence is of a significant level, other protective measures may be indicated, such as restricting access to the Maricopa Point parking area.

The pilot study counted the number of people visiting Maricopa Point and their method of approach, i.e. walking or driving. Any intrusions into the enclosure were documented. These

observations were made before and after the West Rim shuttle operations began for the summer season. No intruders were observed during the pilot study. However, over 100 visitors per hour to Maricopa Point were recorded, which gives an indication of how many may have been walking through the sentry milk-vetch population prior to fencing. A report of the pilot study is on file at Grand Canyon National Park.

Other possible methods of intrusion monitoring have been proposed, including installing trail counters on the inside of the fence, and using a time lapse film camera at the site. Because trail counters cannot distinguish between people and other animals or objects, time lapse film may be used as a long-term and less time consuming method of recording intruders.

Analysis of intrusion data should consider the inevitable impact of research and monitoring at the site as well. For this reason, it is important for records of research activity to be completed using the following form:

Monitoring Activity Record Sheet

Date:

Weather (or any notable recent weather such as rain, snow, freeze, etc.):

Purpose of site visit:

Names of people conducting monitoring:

Plots worked on:

Signs or observation of visitor intrusion:

Other comments:

Appendix F: Photodocumentation

Photodocumentation of the Maricopa Point and Grandview population was initiated in the summer of 1993 by Holger Hunger, an NPS volunteer. A complete instruction manual and photo records are kept in a separate binder in the sentry milk-vetch files. A documentation sheet and photographic identification note sheet were developed for use in photodocumentation (see a sample of the photographic documentation sheet and Plate 2:D).

Recorders : _____
Date : _____
Camera used : _____
Film used : _____
Shutter Speed : _____
Film I.D. : _____

[illegible]

Appendix G: Interested and Knowledgeable People

Dr. Loreen Allphin-Woolstenhulme, Department of Botany and Range Science, Brigham Young University, Provo, UT 84602, Ph. (801) 378-5603

Rupert Barneby, New York Botanical Garden, Bronx, NY 10458-5126

Angela Brooks and/or Bruce Palmer, US Fish & Wildlife Service, 2321 West Royal Palm Road, Phoenix, AZ 85021, Ph. (602) 640-2720

Bill Hevron, 411 Valentina Drive, Gallup, NM, Ph. (505) 722-4203

Lee Hughes, Bureau of Land Management, Arizona Strip District, 345 E. Riverside Drive, Suite 103, St. George, UT 84790, Ph. (801) 628-4491, x 229

Phil Jenkins, Assistant Curator, Herbarium, University of Arizona, 113 Shantz Building, College of Agriculture, Tucson, AZ 85721, Ph. (602) 621-7243

Dr. Aaron Liston, Oregon State University, Dept. of Botany and Plant Pathology, Cordley Hall 4082, Corvallis, OR 97331-2910, Ph. (503) 737-4106 or 737-5301

Dr. Joyce Maschinski, Curator of Plants, The Arboretum at Flagstaff, P.O. Box 670, Flagstaff, AZ 86002, Ph. (602) 774-1441

Linda Mazzu, Botanist, BLM Grants Pass Resource Area, Medford District Office, 3040 Biddle Road, Medford, OR 97501, Ph. (503) 770-2277.

Dr. Arthur M. Phillips, Botanical and Environmental Consulting, P.O. Box 201, Flagstaff, AZ 86002, Ph. (520) 779-2288

Dr. Barbara Phillips, Zone Botanist, U.S. Forest Service, 2323 Greenlaw Lane, Flagstaff, AZ 86004, Ph. (520) 527-3421

Sue Rutman, Botanist, Organ Pipe National Monument, Route 1, Box 100, Ajo, AZ 85321, Ph. (520) 387-6849

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Dr. Stanley Welsh, Room 375, M.L. Bean Museum, Brigham Young University, Provo, UT 84602, Ph. (801) 378-2289