ECOLOGICAL AND LIFE HISTORY CHARACTERISTICS OF VENTURA MARSH MILKVETCH (*ASTRAGALUS PYCNOSTACHYUS* VAR. *LANOSISSIMUS*) AND THEIR IMPLICATIONS FOR RECOVERY.

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ABSTRACT

The Ventura marsh milkvetch (*Astragalus pycnostachyus* var. *lanosissimus*) is known from a single population of plants in Oxnard, California. Studies conducted during 2000 suggest that the breeding system may consist of a mixed mating system characterized by self-compatibility and insect pollination. During 2000, flowering occurred between June and September, and fruiting began in mid July. Reproductive capacity was 38%, estimated as a ratio of seed set to ovule number. Infestation by Bruchid beetles accounted for a 30% reduction in viable seeds. Fruits are semi-persistent, apparently remaining on plants for as long as six months. Recruitment of seedlings in 2000 began after the first fall rain and continued sporadically through April. Probability of flowering and fruiting is approximately 50% at eighteen months following germination. Potential threats to plants at Oxnard may include herbivory by snails and nectar depletion by Argentine ants. Suitable habitat for Ventura marsh milkvetch, based on studies at Oxnard and of the closely related northern marsh milkvetch, was judged to be a coastal shrubland. Potential introduction sites were also characterized by proximity to freshwater, stable, well-drained substrates, vegetative cover in one canopy, and with open sites among shrubs free from competitive annuals or low-growing perennials. Three potential localities at McGrath State Beach, UC Carpinteria Salt Marsh Reserve, and US Navy Base Ventura County were considered as the most eligible areas for potential introduction. Implementation of an introduction effort will need to be accompanied by a management and monitoring effort that ensures survival of transplanted individuals and establishment of successive generations recruited as seedlings from seeds produced by the founder population.

INTRODUCTION

The Ventura marsh milkvetch (*Astragalus pycnostachyus* A. Gray var. *lanosissimus* (Rydberg) Munz and McBurney) is a herbaceous perennial in the legume family (Fabaceae). Diagnostic descriptions were provided by Abrams (1944), Isely (1998), Jepson (1936), Jones (1923), Munz (1963, 1974), and Spellenberg (1993). A more comprehensive description was provided by Barneby (1964). The species may be distinguished from all other Californian *Astragali* by its perennial habit, subsurface meristems, erect, reddish-tinged, leafy stems, villous (grayish green) foliage, dense spike-like racemes, cream-colored corollas, and sessile, semi-persistent, small (6-10 mm long) ovoid to slightly lenticular fruits (Jones 1923, Barneby 1964). Barneby discussed affinities to *A. hornii*, a diffusely branched annual, and *A. nuttallii*, a perennial that differs principally in its larger, strongly inflated fruits and spreading to ascending stems. Although several recent studies have studied general phylogenetic relationships in *Astragalus* (Sanderson 1991, Sanderson and Doyle 1993, Wojciechowski et al. 1993), none have included *A. pycnostachyus*.

The name *A. pycnostachyus* A. Gray (1865) is based on a specimen (Bolander 2513 in 1865; GH; other collections at US) collected at "Baulinas [i.e., Bolinas] Bay, in salt marshes within reach of tide". Typical *A. pycnostachyus* (northern marsh milkvetch) is distinguished by peduncles 4-10 cm long, calyx tubes longer than 3.5 mm, relatively narrow calyx lobes longer than 1.5 mm, and 3-5 ovules per ovary. Variety *lanosissimus* (Rydberg) Munz and McBurney (1932) is based on *Phaca lanosissima* Rydberg (1929), and is distinguished by peduncles shorter than 4 cm, calyx tubes 3-3.5 mm long, relatively broad calyx lobes 1-1.5 mm long, and with 8-12 ovules per ovary. The type was collected by S. Parish and W. Parish in 1882 from "La Bolsa, Los Angeles County" (NY; other collections at ND, UC, and WS). Early collections by S. Parish (1881-1882) have been attributed to at least two general localities, one near Santa Monica, the other in the Ballona Marshes (Barneby 1964).

Astragalus pycnostachyus is apparently restricted to near the coast of California, but the two varieties are allopatric (Barneby 1964, Isely 1998). Historical records indicate that var. *pycnostachyus* occurred in Humboldt, Marin, and San Mateo counties, whereas var. *lanosissimus* occurred in Los Angeles and Ventura counties (Abrams 1944, Barneby 1964, Isely 1998, Jepson 1936, Munz 1963). In most of these floristic manuals and taxonomic treatments, "coastal marshes" is a common element of statements regarding habitat. Notably, at least one population of var. *pycnostachyus* has been reported from an inland freshwater site (Thomas 1961; Crystal Springs Reservoir; Dudley s.n. in 1897, DS). Barneby (1964) provided a comprehensive summary: "salt marshes within reach of high tide or protected by barrier beaches, more rarely near seeps on sandy ocean bluffs, or (according to Jepson) in springy spots along creeks opening to the ocean (0-100 feet) ...".

There are some studies of *Astragalus* biology relative to rarity and conservation biology (Maschinski et al. 1997, Karron 1987a, 1987b, 1989, Karron et al. 1988, Lesica 1995), but none have focussed on the ecology and reproductive biology of *A. pycnostachyus* or any putatively close relatives. Information on habitat and population structure, including demographic data, life history, and breeding system, are considered important to developing a protocol for *in situ* conservation and reintroduction (Harper 1979, Messick 1987).

In 1964, Barneby wrote that var. *lanosissmus* had not been collected for 50 years, and that there was "no hope of its survival near Santa Monica". However, a single population of var. *lanosissimus* was discovered on a site near the northeast corner of 5th Street and Robertson Boulevard, Oxnard in 1997 (Ikeda and Meyer 2000). Staff of Impact Sciences, Inc. (1997) provided preliminary analyses of the site, listed associated species, and reported various estimates of population structure and reproductive status in 1997. Ikeda and Meyer (2000) summarized additional information. Ventura marsh milkvetch was proposed for listing as federally endangered in 1999 (Steeck 1999) and was listed as endangered by the State of California in April, 2000.

Plants of Ventura marsh milkvetch occur on an "old oil sludge landfill" on relatively level terrain. Dominant shrubs associated with the milkvetch include *Baccharis pilularis*, *Baccharis salicifolia*, and scattered *Rhus ovata*, with an understory vegetation composed primarily of *Carpobrotus*, scattered *Lotus scoparius*, and annuals during the late spring. Stands of exotic *Myoporum* and native *Salix lasiolepis*, and natural dune vegetation including *Ambrosia chamissonis*, *Camissonia cheiranthifolia* and *Lotus scoparius* occur nearby. Based on studies within sites among milkvetch plants, bare ground (absence of vegetative cover) was estimated to be ca. 40% (Impact Sciences 1997). Milkvetch plants, overlap of shrub and understory canopies, and herbaceous species contributed to a vegetative cover of ca. 90%.

This study was designed to:

(1) conduct further studies on critical life history stages;

(2) characterize certain environmental variables of sites occupied by both var. *pycnostachyus* and var. *lanosissimus*;

(3) survey appropriate habitats at potential *ex situ* sites; and

(4) develop a preliminary introduction plan based on analyses of data and general observations.

METHODS

Life history survey. Our study began in January, 2000, when plants were dormant and evidence of plants was restricted to dead shoots remaining from the previous year. Searches for some plants were aided primarily by at least 3 different types of metal or foil tags used by previous monitoring teams (Impact Sciences, California Dept. of Fish and Game) and the presence of wire exclosures that had been erected in 1999 to protect certain plants from herbivory. In order to determine the number of surviving plants established prior to 2000, we searched for and temporarily flagged all sites previously marked with tags. A circular area with a radius of ca. 25 cm from each tag was carefully inspected to determine the exact location of a plant. Because no living shoots were evident in January, the distinctive nodal and stipular morphology of *Astragalus* stems was considered evidence of a plant. When potential plants were found, a more permanent metal stake and label was placed approximately 15-30 cm from the "center" of the suspected subterranean shoot(s). Beginning in February the development of silky, grayish green, compound leaves characteristic of marsh milkvetch provided further evidence. Between January and April, we also observed additional plants (late-emerging growing shoots) that apparently had not been tagged prior to 2000. Each individual site was assigned a unique number for purposes of tracking and for estimating ages of plants established prior to 1999-2000.

Beginning in late January and ending in October, we visited and inspected the site at approximately 7-14 day intervals, increasing the visitation rate concurrently with shoot emergence and later with flowering. Initially we estimated the number of dead stems (1999 growth) whenever possible, the number of basal shoots, the number of fully developed leaves, length of the longest leaf, and leaflet number on the longest leaf. The latter four estimates of size were abandoned for two reasons. First, by mid March, severe herbivory of growing shoots and leaves by snails was observed in the site, with subsequent loss of foliage and shoots in some cases. Second, preliminary analyses indicated that leaf size varied considerably among young shoots, and that number and length of mature shoots, especially at time of reproduction, appeared to be potentially better predictors of size class.

For plants presumably established prior to the 1999-2000 winter rainy season, we estimated: (1) the total number of sites, (2) the total number of plants with living shoots, (3) the number of vegetative and reproductive shoots per plant at the end of flowering, and (4) the number of inflorescences per shoot. We attempted to estimate age of plants by comparing the identity of tags placed by previous monitoring teams with ours. The identities and earliest observed presence of the marked plants, based on studies by both Impact Sciences and California Dept. of Fish and Game staff, were provided by Mary Meyer (California Dept. of Fish and Game).

When seedlings appeared, we established seven 250 cm^2 plots to estimate recruitment and survivorship. Plots were chosen haphazardly, but placed to include at least one seedling, and were monitored regularly until plants had apparently died or senesced. Plot placement was biased in the sense that sites were chosen during the earliest period of seedling emergence. We also regularly counted the number of seedlings observed throughout the entire population, to provide an estimate of recruitment during 2000. Beginning in June, we began to mark surviving juvenile plants throughout the population with temporary flags for future monitoring. Flags were replaced with numbered metal stakes later in the season.

Reproductive Biology. To determine flowering and fruiting periods, we recorded the number of inflorescences with a majority of flowers at anthesis and a majority of fully developed fruits at regular intervals. From a subset of haphazardly selected inflorescences, we estimated: (1) the number of flowers, (2) the number of fruits per inflorescence, (3) the number of ovules per ovary, and (4) the number of seeds per fruit. To minimize destructive sampling, we estimated flower and fruit number by inspection of intact inflorescences on plants. The number of ovules per ovary was estimated from a subset of 20 flowers collected from plants with more than one inflorescence. The presence of self-compatibility versus self-incompatibility, and potential effect of pollinators, was estimated by loosely enclosing 19 inflorescences on eight plants with bags composed of a pliable fine mesh "Tulle" cloth. This effectively excluded any organisms less than 0.05 mm in diameter, but permitted near ambient humidity and temperature within the bag. We avoided bagging inflorescences or collecting fruits from plants with less than three inflorescences to minimize effects on the potential seed bank. We did not observe any insects, including aphids, within bagged inflorescences. Fruiting inflorescences were collected late August and early September. Number of fruits per inflorescence and the number of seeds were counted. The number of seeds per fruit was estimated from a subset of fruits collected from unbagged inflorescences on the same or other plants. Firm, fully developed undamaged seeds were counted separately from those that appeared infested or damaged. Seeds were saved and accessioned into the Santa Barbara Botanic Garden's rare seed collection, which is part of the Center for Plant Conservation's national collection.

Northern marsh milkvetch survey. A general field survey of northern marsh milkvetch (var. *pycnostachyus*) populations was conducted to provide a comparative framework for studies at Oxnard. Specimens in the herbarium at the California Academy of Sciences (CAS, DS) and University of California, Berkeley (JEPS, UC) were surveyed for potential localities. Based on specimens, USGS topographic maps, and information from literature sources (Howell 1970, Thomas 1961), historical collection sites were identified and several general areas were selected for study. These included: (1) the coast between Cape Mendocino and the mouth of McNutt Gulch (Humboldt County), several sites near Drake's Estero (Marin County), and the coast between Tunitas Creek and Arroyo de los Frijoles (San Mateo County). We subsequently learned that a collection with label reading "ocean shore, Cape Mendocino to Petrolia" (Jepson 2143, JEPS) may actually have been gathered along McNutt Gulch ca. 2 miles east of the implied location (R. Beidelman, UC Berkeley, personal communication). We found 8 "populations", 6 in San Mateo County and 2 in Marin County. General observations of substrate, associated species, size structure, and reproductive condition were made. Flower and fruit samples were collected at four localities. Soil samples were collected at six localities.

Recommended potential recovery sites included Emma Wood State Beach, McGrath State Beach, Mandalay State Beach, and Naval Base Ventura County (formerly Point Mugu Naval Air Station), all in Ventura County and the University of California's Carpinteria Salt Marsh Reserve in Santa Barbara County (Ikeda and Meyer 2000, Meyer personal communication). Through assistance from Mary Meyer, California Dept. of Fish and Game, permission was obtained from management staff of the California Department of Parks and Recreation , the U. S. Navy, and the University of California Reserve System to gain entrance and conduct field surveys. Areas with suitable habitat, and without potential threat from previously planned development, were given special attention. Additional suggestions and advice were provided by Thomas Keeney (U. S. Navy), Barbara Fosbrink (California Parks and Recreation), and Wayne Ferren (UC Carpinteria Reserve).

Each potential site was surveyed and evaluated on the basis of the following criteria: degree of disturbance, vegetative cover, associated species, proximity to subterranean water table, type of substrate, and potential threats. The following conditions were considered to have high quality potential habitat: absence of man-made structures and debris (e.g., rocks, concrete or asphalt materials, remnants of structures, obvious fill); absence of frequent public use; vegetative cover varying between 25 and 75%; associated species including scattered shrubs (*Baccharis salicifolia, Baccharis pilularis, Salix lasiolepis*) and subshrubs or suffrutescent perennials (e.g., *Lotus scoparius, Ericameria ericoides*); absence of dense stands of annual species; proximity to sloughs and depressions, including sites adjacent to stands of *Salix lasiolepis*, *Typha*, and *Scirpus*; and relatively compact sandy soils lacking evidence of saline conditions (e.g., a white or crystalline crust). Low quality sites included evidence of recent human development (e.g., man-made structures, fill, and debris), vegetative cover near or exceeding 100% cover (e.g., overlapping canopy of herbs, shrubs, and trees, thick stands of *Distichlis*), vegetation composed of alien exotic species (e.g., *Myoporum*, dense stands of *Carpobrotus*, dense colonies of annual *Bromus*, *Brassica*, *Hirschfeldia*, *Conium*, and *Centaurea* species); dunes or other unstable sand deposits; and sites at a considerable distance from sloughs or freshwater channels with native vegetation.

Soil surveys. One to five soil samples were obtained from the Oxnard site, from potential recovery sites, and from northern marsh milkvetch sites. Soil samples from the Oxnard locality were sampled at two levels, one at a depth of 1 to 3 cm, the other from depths between 15 and 30 cm below the surface. All other soil samples were obtained at a depth between 15 to 30 cm below the surface. These were analyzed for certain physical and chemical properties judged to be important to general plant growth. Soil properties included texture, pH, cation exchange capacity, salinity, saturation, primary nutrients (soluble nitrate, available phosphorus, soluble potassium), secondary nutrients (soluble calcium, soluble magnesium, soluble sodium, soluble sulfate), and micronutrients (soluble chloride). Texture was classified into proportions of solids between 2 mm and 1 mm in diameter (primarily sand) and less than 1 mm in diameter (primarily clay and silt). Saturation represents the amount of water required to saturate 100 gms of dry soil, and is approximately twice the field capacity. Samples from the Oxnard site were also inspected for milkvetch seeds. Other properties were analyzed by the soil chemistry laboratory at Fruit Growers, Inc., Santa Paula, California.

Initially we planned to conduct a series of experiments to compare different soil mixtures and planting depths on seed germination. However, sufficient numbers of seeds were not available to conduct an experiment amenable to statistical analysis. The purpose was motivated by the interest in exploring methods for recovery (planting seeds versus container plants). However, *ex situ* studies conducted at Rancho Santa Ana Botanic Garden suggested that transplantation using container plants might prove more successful, thus precluding any further studies of potential planting depths and soil mixtures. Preliminary success with an ad hoc experimental transplantation project at the UC Coal Oil Point Reserve (Cristina Sandoval, Director, personal communication) suggested the same approach. However, we tested germinability of 8 seeds from fruits remaining on plants in January, 2000, and eight seeds obtained from soil samples collected at the Oxnard site. Seeds were placed into a beaker of boiling water, which had been removed from the heat source immediately before use (Emery 1988). After the beaker had cooled, seeds were planted to a depth of ca. 5 mm separately in five inch diameter pots, using a commercial seed germination mix composed of sand, sponge-rock, and milled sphagnum. Pots were watered every 1-2 days until evidence of emergence.

Results

Life history survey. Between January 24, 2000 and September 20, 2000 we marked a total of 113 plants and/or putative plant sites at the Oxnard locality, each site consisting of a circle roughly 50 cm in diameter. Of these, we determined that at least 92 sites had been previously marked with at least one of three types of metal tags, presumably by different monitoring teams. Some tags did not appear to have been staked or attached. Some of these sites did not bear evidence of milkvetch stems. Flags used to mark such sites remained in place until June, when it became clear that no plant occurred or had survived at a particular site (i.e., when other plants in the population had developed easily recognized shoots). At least 12 plants, not accompanied by tags from previous years, appeared to have been recruited prior to the 1999-2000 winter season. Such plants had one or more well-developed shoots; those with one shoot showed no evidence of cotyledons and clearly had observable nodes and basal stem diameters greater than those of concurrent seedlings with persistent cotyledons and 1-2 nodes and leaves. The remaining nine sites were initially flagged, because dead stems were considered to be potential marsh milkvetch. Some of these plants may have been previously tagged, because we were unable to account for all tags used by previous monitoring teams.

Between February and September 20, 2000 we observed a total of 80 living plants that were apparently recruited as seedlings prior to the 1999-2000 winter season. Such plants are referred to as "adult" plants in the following text. Of these, 39 survived to produce either vegetative or reproductive shoots greater than 30-40 cm tall (Table 1). Twenty-two produced shoots with one or more inflorescences; the remaining 17 plants were strictly vegetative. We were unable to determine the exact cause of death of the other 41 plants, but we believe that herbivory by snails may have contributed significantly to decline and death of some. For example, among 66 adult plants that had emerged before March 22, at least 27 had been severely grazed by snails. On April 11 we observed at least 14 plants that had been so severely grazed that all leaf biomass had been removed. By April 28, at least 45 of the 60 adult plants then present showed evidence of snail herbivory. Evidence included the presence of snails on or among defoliated shoots and presence of characteristic slime "stains" and "trails" left by snails. We did not attempt to quantify the number of snails and their effect. However, in some cases we noted that some plants produced new, weakly developed shoots following grazing. In some cases plants did not resprout. Between late March and June we observed and eliminated snails every time we visited. In late March we applied commercial snail "bait" poison (metaldehyde) along the perimeters of living plant clusters at distances no less than 1 meter from living plants. This method appeared somewhat successful in reducing the snail population, because on succeeding visits we observed large numbers (> 100) of dead snails. We repeated the application in late April, especially to mats of adjacent *Carpobrotus*, which appeared to harbor snails among the leaves. Snails were no longer evident or at least active after mid June. Snails were first observed again on February 8, 2001. At least 30 snails were found and killed on February 28, 2001, most of which were found beneath *Carpobrotus* shoots within one meter of some milkvetch plants.

At least two ungrazed plants apparently senesced and died quickly, judging from their apparent health (green leaves and stems) during one day, and complete death (evidenced by dried leaves and light tan stems) 6-10 days later. The two plants did not possess lesions or other external evidence of pathogens. At least two reproductive plants were observed with infestations of aphids, accompanied by Argentine ants. Treatment with a commercial, dry-powder pesticide on March 15 apparently eliminated the aphids. One of the plants died by July 20, but the other survived to produce flowers and fruits. We were unable to determine the exact cause of these deaths.

The highest rate of mortality among adult plants occurred between late April and early June (Figure 1), during which time approximately 20 plants died. Deaths of individuals between March 22 and April 11 may have resulted from snail herbivory. Loss of three plants accounted for a relatively high mortality rate between July 20 and July 26. What appears to be mortality between September 6 and September 20 may be the result of aerial shoot senescence and not whole plant death, because shoots of most plants began to senesce in late September. As of January 29, 2001 some plants either still retained a few green leaves or had begun to produce vegetative shoots. In 2001, buds and shoots were first observed on February 8.. On February 28, we observed buds or living shoots on 30 plants recruited prior to 2000. The total number of surviving plants can't be confirmed until they are observed between March and June, 2001.

Based on a comparison of known locations of all tagged sites, we were able to estimate the age of 39 adult plants (Table 1). At least three plants (SBBG plants 5, 11, and 17) were marked by Impact Sciences in 1997, of which two (5 and 17) flowered in 1997, indicating that the plants were at least 3-4 years old. All three plants produced reproductive shoots in 2000. Similarly, 13 plants marked by Impact Sciences and Dept. of Fish and Game staff in 1998 were judged to be at least two years old. Eleven plants marked by Impact Sciences in 1999 were judged to be at least one year old. Another 12 previously unmarked plants were judged to be at least 1 year old, based on stem diameter and shoot length. These data suggest that Ventura marsh milkvetch may produce flowers in the second summer following germination. However, judging from the few plants observed, the probability of reproduction versus remaining vegetative is approximately 50% among both one-year and two-year old plants (19 reproductive plants versus 17 vegetative plants, Table 1), but increases to 100% among 3-year old plants.

Assuming that strictly vegetative plants are younger than reproductive plants, two *a posteriori* estimates of size appear to be consistent with age estimates (i.e., reproductive plants produce more and longer shoots). Vegetative plants recruited prior to winter 1999-2000, produced a mean of 4.8 shoots per plant versus 6.6 shoots among reproductive plants (Table 2). The mean length of the longest developed shoot among 17 vegetative plants was 11.3 cm versus 46.2 cm among 23 reproductive plants.

Reproductive biology. Twenty-three plants produced one or more inflorescences during 2000. The first buds appeared in mid June, followed by the first open flowers in late June. Peak flowering occurred in mid July, with some inflorescences bearing open flowers as late as early September (Figure 2). A total of 602 inflorescences were counted, distributed among 151 shoots. The average plant had 26.2 inflorescences with 3.2 inflorescences per shoot (Table 2), but not all shoots bore inflorescences. Most flowers had matured into fruits by early September (Figure 3). Fruits of Ventura marsh milkvetch are semi-persistent and appear to be weakly dehiscent. Mature fruits with well-developed seeds were found within inflorescences with dehiscent fruits. Indehiscent, developed fruits were observed in early January, 2000 on several shoots remaining from the previous year. Fruits firmly attached to shoots produced in 2000 were observed as late as January 29, 2001.

The average inflorescence produced 36.8 flowers (Table 2). The sequence of flowering among and within inflorescences was indeterminate (i.e., earliest flowering occurs within lowermost inflorescences and lower buds mature first). We did not measure duration of anthesis, but generally our observations suggest that the flowers may remain at anthesis for at least 3-5 days. We rarely observed potential pollinators at the Oxnard site, even on warm days favoring insect activity. On July 13 we observed a skipper butterfly (Hesperidae) visiting inflorescences on two plants. On July 26 we observed a skipper butterfly, which visited flowers briefly on 2 or 3 adjacent plants before leaving the site. At least one bumblebee (tentatively identified as *Bombus*) visited inflorescences on one plant very briefly before leaving. Both observations were made between 1100 and 1400 hours. These visits coincided with peak flowering in the population (Figure 2). Beginning in early July we began to see increasing numbers of ants tentatively identified as Argentine ants (*Linepithema humile*, formerly *Iridomyrmex humilis*) throughout the site. The latter are recognized by size (ca. 2 mm long), brownish black color, and lack of conspicuous odor when crushed (Newell and Barber 1913, Adrian Wenner, personal communication). Ants were observed visiting inflorescences and entering flowers, presumably to harvest nectar.

Results of manipulations to estimate seed production and determine potential for selfing are shown in Table 3. Flowers produce 7 to 9 ovules per ovary (mean = 7.4). Some open-pollinated flowers produced as many as 6 to 7 seeds, but the mean number of all seeds (fully developed plus empty) was 2.8 per fruit. Flowers in bagged inflorescences produced 2.0 seeds per fruit. This evidence suggests that Ventura marsh milkvetch is self-compatible, and perhaps partly autogamous. In a small subset of open-pollinated inflorescences (n = 20) we observed that 50% of them had been damaged, almost entirely by weevils, tentatively identified as *Macrohoptus* (Terry Seeno, Insect Biosystematics Laboratory, Sacramento, California, personal communication). However, the proportion of damaged fruits in bagged inflorescences was only 20%. The average flower in bagged inflorescences produced 1.7 full seeds and 0.3 empty seeds , whereas the same for open inflorescences were 1.9 and 0.9, respectively.

Five soil samples (ca. 300 cm^3) haphazardly collected from "near" or beneath milkvetch plants yielded 1, 0, 13, 10, and 17 seeds respectively. Five soil samples of equivalent volume from sites ca. 3 meters away from the nearest plants yielded no seeds. Eight seeds were later tested for germinability (see below); the remainder were stored for conservation purposes.

Six of the eight seeds collected from plants in January, 2000 germinated and emerged over a period of from 16 to 42 days, although the first five emerged within 24 days. The first five seedlings had fully expanded cotyledons within 19 to 26 days following planting. The sixth seedling died prior to cotyledon expansion. None of the seeds obtained from soil samples emerged. Pots were allowed to dry for ca. 7 days and the seeds excavated by sieving. All seeds appeared firm, but when dissected did not show evidence of viable embryos or endosperm. The small sample size, However, precludes any conclusions regarding viability of seeds obtained from soil samples.

We first observed putative milkvetch seedlings on February 29 and established three semi-permanent 250 cm^2 plots to monitor recruitment and survival. Timing and distribution of seedling recruitment was not consistent throughout the site and varied from one area to another between March and May. An additional four plots were established on March 22, after more seedlings appeared in the site. By late March, the identity of milkvetch seedlings became apparent after the first leaf expanded. Seedling recruitment in the seven plots continued through mid May, after which the number of seedlings began to decline (Figure 4). The highest rate of mortality occurred between early and late April. Although seedling mortality in plots was 100%, the collective area of 1750 cm^2 represents a very small fraction of the total area in which seedlings were observed.

At least 187 seedlings, including those in quadrats, were observed between February and April, 2000. This number is consistent with numbers reported by other observers between 1997 and 1999 (i.e., between 144 and 192, Ikeda and Meyer 2000). Seedlings were generally found within one to two meters of previously established plants, although in several cases seedlings were found up to 3 meters from such plants. Impact Sciences (1997) reported similar patterns in their study. In most cases, seedlings were found in microsites that were either: (1) minor depressions in the substrate surface away from established plants, but with slightly higher amounts of organic debris and duff, or (2) in flat sites, with organic debris and duff, partly shaded by adjacent plants (e.g., *Baccharis pilularis, Baccharis salicifolia*). The highest mortality occurred between early April and late July (Figure 5), which coincided partly with high mortality rates among adult plants. Part of this mortality was attributable to grazing by snails. It was difficult to determine the cause of mortality of individual seedlings. In most cases, no evidence of dried cotyledons and leaves could be found when the seedling was first found to be absent. Forty-six plants, recruited as seedlings in 2000, survived through October 20, 2000, by which time their aerial shoots were senescing. These plants were marked with stakes for future monitoring. As of January 29, 2001 some plants either still retained a few green leaves or had begun to produce vegetative shoots. On February 28, at least 29 plants were observed with new shoots. The actual number of surviving plants recruited in 2000 cannot be confirmed until they are observed between March and June, 2001.

Northern marsh milkvetch survey. Eight populations of northern marsh milkvetch (var. *pycnostachyus*) were visited (Table 4). Four of the populations (Schooner 1 and 2, San Gregorio 1, and Pescadero 1) were adjacent to or associated with coastal estuarine systems (Ferren et al. 1996). Species common to most of these sites included species of *Frankenia*, *Distichlis*, *Grindelia*, and *Salicornia*, which are often considered dominant taxa in northern California coastal salt marshes (Holland 1986, Holland and Keil 1989, Sawyer and Keeler-Wolf 1995). The four remaining populations San Gregorio 1 and 2, Pescadero 2, and Pomponio) were associated with species generally characteristic of coastal bluff scrub communities (Holland and Keil 1989, Sawyer and Keeler-Wolf 1995). The largest populations, each composed of 50 or more plants, occurred at Schooner 2, San Gregorio 2, Pomponio, and Pescadero 1. Coincidentally, most plants were in the flowering stage when populations were visited in late July. Bumblebees, tentatively identified as *Bombus*, were observed actively visiting flowers at Pescadero 1 and San Gregorio 2 on two consecutive days and at Schooner Bay during one day. We did not observe any clear evidence of seedling recruitment or young plants with shoots less than 30 cm tall, but this may be a result of the relatively late observation dates.

Soil surveys and analyses. Soil properties of northern marsh milkvetch (var. *pycnostachyus*) localities are shown in Table 5. Soil texture at Schooner Bay appears to be more fine grained than other localities. This may be related to topography and depositional differences, which clearly differ between Schooner Bay and the other localities (Table 4). Salinity, calcium, and sodium were also higher at Schooner Bay. Pomponio had much higher saturation values, higher cation exchange capacity, and higher phosphorus levels than other sites. The magnesium levels at Pescadero 2 and Schooner were notably higher than at other localities.

Soil properties from the Ventura marsh milkvetch locality in Oxnard are shown in Table 6. Mean values of 14 soil properties for shallow soil samples within and outside of Ventura marsh milkvetch colonies are compared in Table 8. Statistically significant differences occurred only with respect to soil texture. However, samples from among plants appeared to have a higher proportion of fine particle size than that outside plant colonies.

Several differences between shallow versus deeper soil samples among plants are apparent ("upper 2-3 cm" versus "upper 15-30 cm", among plants Table 6). Shallow soil samples had finer grained soils, higher salinity, and higher levels of calcium, magnesium, sodium, chloride, and sulfate.

A cluster analysis of soil properties from six different *pycnostachyus* sites (PES1-2, POM, SGR2-3, and SCH2) and five representative soil samples from the *lanosissimus* Oxnard site (OXN11-15) are shown in Figure 6. The cluster shows that soil samples of the Oxnard locality are collectively different from those of *pycnostachyus* localities. Mean values of 14 soil properties are compared in Table 7. Individual variances of each of the 14 variables, represented by standard errors, are clearly less among Oxnard samples than among *pycnostachyus* sites. This difference probably resulted partly from sampling from within a locality versus sampling among widely divergent northern marsh milkvetch localities. Mean saturation, salinity, nitrate, phosphorous, magnesium, sodium, and chloride were higher in northern marsh milkvetch soil samples, but cation exchange capacity, pH, calcium, and sulfate were lower. However, based on 95% confidence levels, a significant difference was apparent only with respect to pH. The relatively high similarity among Oxnard samples and relatively high similarity among northern marsh milkvetch samples are based on several properties, especially cation exchange capacity, calcium, magnesium, sodium, chloride, and sulfate. These clearly differed collectively between the two groups (Tables 5-6).

A cluster analysis of soil properties from potential recovery sites (Carpinteria salt marsh, McGrath State Beach, Mandalay State Beach, Naval Base Ventura County), Coal Oil Point Reserve and five representative soil samples from the *lanosissimus* Oxnard site (OXN11-15) is shown in Figure 7. Values for each sample are shown in Tables 6 and 9. The cluster shows that samples derived from the same general localities have relatively high similarity (e.g., McGR3 and 4, McGR1, 2 and 5, CARP2, and 5, OXN 11, 12, and 15). However, there appear to be some notable exceptions. OXN14 appears more closely related to one of the Carpinteria samples (CARP4) than to adjacent samples from Oxnard. OXN13 appears more closely related to samples from McGrath State Beach than to adjacent samples from Oxnard. Notably, samples from Navy Base Ventura County (USN1-3) did not cluster together, and were more similar to different clusters of samples. These differences may be attributable to differences in topography, varying distances from an adjacent estuary, or artificial differences resulting from fill deposition and disturbance (Thomas Keeney, personal communication).

Potential introduction sites. Each of the potential recovery areas was ranked on the basis of five relatively independent criteria that we judged important to the survival of Ventura marsh milkvetch (Table 10). A dominant vegetation composed primarily of native shrubs, with cover between 50% and 75% was ranked higher than a vegetation composed of two or more canopy levels with cover exceeding 75%. A low herbaceous cover, composed of scattered annuals or herbaceous perennials was ranked higher than dense stands of exotic alien taxa (e.g., *Brassica, Bromus, Carpobrotus*). The close proximity of fresh or brackish water, evidenced by a stream channel or presence of either *Salix* or *Baccharis salicifolia* was ranked high, as was the presence of primarily palustrine taxa such as *Typha* and *Scirpus*. Relatively compact, stable sandy substrates with overall physical and chemical properties that were similar to that at Oxnard (Tables 6-9, Figure 7) were assigned a high ranking. Sites bordered by relatively broad stands of relatively native vegetation, with relatively high species and life form diversity were assigned a high ranking as supporting potential pollinator populations.

Based on a summary of these criteria, and rankings of potential sites, we found four areas (McGrath State Beach, Mandalay State Beach, Carpinteria salt marsh, and Navy Base Ventura County) to have potential introduction sites (Figures 8-11). The latter areas are listed relative to their potential for supporting potential recovery populations (Table 10). An initial survey of Emma Wood State Beach indicated that it probably did not offer appropriate sites for marsh milkvetch populations.

Several areas were surveyed in the southern half of McGrath State Beach, including the area along the east side of McGrath Lake and an area south of the campground, between Harbor Boulevard and the sand dunes (Figure 9). The area south of the campground included vegetation similar to the Oxnard site, but appeared to be heavily used by the public. Vegetation was composed primarily of *Baccharis pilularis*, scattered *Baccharis salicifolia*, *Lotus scoparius*, and *Eriogonum fasciculatum*. However, judging from the sparse distribution of *Salix lasiolepis*, and a relatively high frequency of *Baccharis pilularis*, *Lotus*, and *Eriogonum*, the occurrence of a relatively high water table was unlikely. The area also appeared to be characterized by dense stands of annual exotic species. The area immediately east of McGrath Lake appeared to have soils similar to the Oxnard site, but lacked vegetation providing sufficient cover. Judging from the distribution of *Salix* and close proximity coastal marsh taxa such as *Typha*, *Scirpus*, and *Pluchea*, a relatively high water table may characterize the site. Several soil samples were relatively similar to the Oxnard milkvetch site.

The only area within Mandalay State Beach that included potential sites was found immediately north of 5th Street, between Harbor Boulevard and the beach dunes (Figure 10). An underground water table may be close to the surface, judging from the adjacency of dense stands of *Salix* and the presence of scattered *Baccharis salicifolia*. Soils were comparable to the Oxnard site, which is in close proximity east of Harbor Boulevard. However, dense cover by both annual exotic species and continuous patches of *Distichlis spicata* also characterize the area.

At the Carpinteria salt marsh we found likely sites along the north edge of the marsh, south of the railroad tracks, and west of Santa Monica Creek (Figure 8). Vegetation was dominated largely by native species, with a mixture of groundcover and shrub canopies. However, there were a number of sites with deeper soils that apparently support dense stands of *Salicornia*, *Distichlis*, and annual exotic *Bromus*. The area is adjacent to Santa Monica Creek, includes soils comparable to those from the Oxnard milkvetch site and McGrath Lake localities, and is bounded by a relatively large expanse of salt marsh and estuarine vegetation that might support a diversity of native pollinators. However, the salt marsh is bounded on several sides by a residential community, and snails were observed in the vegetation.

Areas surveyed at Navy Base Ventura County included sites: between 13th Street on the north, and Dump Road on the south, west of Calleguas Creek; between Las Posas and Main roads north of 11th; and along Beach Road between Laguna Road and South "G" Avenue. The first two areas were rejected because of dense ground cover, dense shrub vegetation, or a combination of both, and with little evidence of appropriate soils. Some of the areas were dominated by *Salicornia* or *Distichlis*; others were dominated primarily by exotic annuals (e.g., *Brassica*) or shrubs (*Myoporum*). The first area (Figure 11), recommended by Mary Meyer and Thomas Keeney, included sites similar to those at Oxnard, McGrath, and Mandalay beaches with regard to vegetative cover and soil properties, and supported colonies or "ribbons" of *Salix* and *Baccharis salicifolia*.

At Emma Wood State Park we surveyed the area south of the picnic area adjacent to Highway 101 and west of the mouth of the Ventura River. Much of the area supports dense vegetation composed primarily of *Salix* and *Arundo*. A small area with relatively low vegetative cover composed primarily of dune associated species (e.g., *Camissonia*) occurs between the beach and the railroad right-of-way west of the river mouth. Judging from considerable litter (primarily drfited logs and discarded wood), this area also may be significantly impacted by annual high tides and more frequent salt spray.

DISCUSSION

Although results from our experimental field manipulations are not conclusive, Ventura marsh milkvetch appears to be self-compatible and may be partly autogamous. Green and Bohart (1975) reported self-incompatibility in two species of Great Basin *Astragalus*. Karron (1989) studied four species of *Astragalus* in western Colorado and found one to be self-incompatible and three to be self-compatible, of which one was moderately autogamous. *Astragalus* flowers, like those of other legumes, possess structural relationships among petals, stamens, and the pistil that often require insect manipulation to ensure effective pollination, regardless of self-incompatibility or self-compatibility (Faegri and Van der Pijl 1966, Richards 1986). Pollination and seed set in such flowers is generally enhanced by relatively large insects (Faegri and van der Pijl 1966). Bumblebees (*Bombus* spp.) and other bees (e.g., *Osmia*, *Anthophora*) appear to be the principal pollinators of at least nine *Astragalus* taxa (Baskin et al. 1972, Fotheringham and Keeley 1998, Geer et al. 1995, Green and Bohart 1975, Karron 1989). Experimental studies, under controlled conditions, including mechanically pollinated flowers in the absence of insects, are required to confirm self-compatibility and the proportion of outcrossing versus selfing in Ventura marsh milkvetch.

Reproductive capacity, expressed as viable seed production in Ventura marsh milkvetch, appeared to have been limited by pollination or fertilization, and parasitism by weevils (Bruchidae). Although plants were not continuously observed for pollinator activity, the low rate of visitation during monitoring visits suggest that pollinator activity may limit seed production. Overall seed set was ca. 38 % (i.e. 2.8 seeds per fruit compared to 7.4

ovules per ovary). Approximately 50% of all fruits and 30% of all seeds were classified as infested or empty as a result of damage by weevils. Adult bruchids actively search for oviposition sites during early stages of flower and inflorescence development (Robbin Thorp, personal communication). Bagged inflorescences may have protected flowers to some degree from parasitism, because only about 15% of developed seeds in such flowers were classified as empty, as compared to about 32% in open pollinated flowers. We also observed (but did not quantify) significant infestation by weevils of fruits and seeds in some populations of the northern marsh milkvetch. Karron (1989) and Platt et al. (1974) reported similar observations and Green and Bohart (1975) noted that larvae of bruchid beetles and lycaenid butterflies had a significant impact on seed production in the two species they studied.

There appears to be some evidence of decline, based on the number of adult and reproductive plants reported during 4 successive years. However, at least 46 plants (recruited as seedlings during 2000) survived through mid October, 2000. Between 1997 and 1999, the number of reproductive plants was estimated to be between 30 and 94 reproductive plants during separate, apparently independent surveys (Ikeda and Meyer 2000). Ikeda and Meyer (2000) also reported that 44 of 63 adult plants observed in 1999 were considered "unhealthy" as a result of herbivory by rabbits and snails. We observed as many as 65 to 67 plants that could be classified as plants established prior to the 1999-2000 season, but these plants experienced a mortality that resulted in only 40 surviving plants, of which 23 produced flowers and fruits. Some of the mortality could be attributed to herbivory by snails earlier in the growing season. Although Steeck (1999) indicated that the snail population belonged to *Otala lactea* (milk snail), we believe that it may be referable to *Helix aspersa*, the European brown garden snail (Dundee 1974, Pilsbry 1939), which is widely established and common, especially in agricultural lands in southern California (Ohlendorf 1999). During 2000, we did not observe any evidence of rabbits (i.e., fecal pellets, tracks) within the fence-enclosed site.

Although the average reproductive plant produced 6.6 shoots with 3.2 inflorescences per shoot (Table 2), some plants produced as many as 104 shoots, some of which were reproductive. Some plants at Oxnard produced as many as 198 inflorescences with up to 11 inflorescences per shoot. The few plants not apparently tagged prior to 1900-2000 produced relatively few shoots. Only one of them flowered. This suggests that some of the larger plants may be more than three years old. Among 116 eighteen-month old plants grown in containers at Rancho Santa Botanic Garden in 2000, sixty-three remained vegetative and fifty-three produced at least one inflorescence (Susan Jett and Dylan Hannon, personal communication). Thus, even under conditions associated with application of ample water and nutrients, plants may not be expected to reproduce for at least two to three years (i.e., 18 to 30 months) following germination.

Based on our observations of seedling recruitment and survival during 2000, Ventura marsh milkvetch is capable of annual recruitment from a seed bank. Most seedlings emerged sporadically between February and April following several rain storm. We observed 187 seedlings in 2000. This contrasts with the 260 seedlings reported by Impact Sciences in 1997. Average rainfall, based on a 24-year record for Oxnard (NOAA weather records), indicates an annual mean of 16.8 inches, with most precipitation occurring between October and May (monthly means: October = 0.4, November = 1.4, December = 2.2, January = 3.7, February = 4.2, March = 3.3, April = 0.7, and May = 0.2). However, the 1999-2000 season was relatively below average, with several dry months, but with a relatively higher rainfall recorded in February and May, 2000 (i.e., October, 1999 = 0.0, November, 1999 = 1.2, December, 1999 = 0.0, January, 2000 = 1.85, February, 2000 = 6.18, March, 2000 = 2.3, April, 2000 = 2.1, and May, 2000 = 0.0).

In order to germinate, mature legume seeds require a treatment that involves removal of the hard seed coat. In *Astragalus tennesseensis*, Baskin and Quarterman (1969) found maximum germination (100%) only in seeds from which the complete seed coat was removed prior to imbibition with water. Dylan Hannon (personal communication) at Rancho Santa Botanic Garden reported a germination rate of 62% following scarification by knicking milkvetch seeds with a razor blade. Our treatment, using boiling water, was equally effective, although results are based on a much smaller sample size. Under natural conditions, the amount of mechanical abrasion equivalent to that produced by standard scarification techniques seems unlikely to take place in the few months between maturity (late summer) and onset of winter rains (fall and early winter). No data is available on the number of seeds in the soil, the longevity of seeds in the soil, and the demography of germination (e.g., optimal age for germination). Under natural conditions, one can expect weathering and action by microorganisms to degrade the seed coat. Consequently, it is likely that not all seeds produced during any year may germinate in the following year.

It is difficult to characterize the original habitat of the Ventura marsh milkvetch. Historical records, based on herbarium specimens and literature, do not provide specific details on substrate, vegetative cover, associated species, and other features at the scale of the local population. A preliminary survey of the closest relative, the northern marsh milkvetch, suggests both geographical and ecological differences and similarities. First, the geographic distribution, along the coast between San Mateo and Humboldt counties, occurs in an area with higher average rates of winter precipitation. Second, some populations are associated with estuarine, coastal salt march habitats (Marin County), but others occur on relatively dry sites (San Mateo County). The latter are similar to the Oxnard site with respect to general features of vegetation (per cent cover) and substrate (gravelly to compact sandy soils), but not with respect to several soil chemical properties (e.g., salinity, nitrate, phosphorous, magnesium, sodium, and chloride). Some associated species are shared in common (e.g., *Baccharis pilularis*), but most northern marsh milkvetch associates are either typical of northern coastal marshes or northern coastal scrub.

IMPLICATIONS FOR MANAGEMENT AND RECOVERY

Demographic approaches to population biology provide useful and important information, especially with regard to predicting potential survival (Pavlik 1993, Schemske et al. 1994). A minimum of five years has been recommended to obtain sufficient data for preliminary analyses of population "viability" and long-term survival (Elzinga et al. 1998). Consequently, a critical assessment of life history characteristics, demography, and habitat of Ventura marsh milkvetch is premature. A single population with less than 50 plants older than one year, located on a site with considerable history of human intervention, does not provide an ideal opportunity to evaluate environmental and biological parameters important to predicting long-term survival.

Although the only known current locality of Ventura marsh milkvetch is considered unnatural, plants growing there have survived to successfully reproduce for an unknown number of generations. Consequently, attention needs to be given to general features of the locality. One important feature is the structure and texture of the substrate. The soil at the Oxnard locality is primarily fine-grained, composed primarily of sand and some clay and silt, which enhances both field capacity (estimated from saturation) and percolation through adequate drainage. The locality is also at a low elevation and relatively close to a freshwater or brackish water table, evidenced by the presence of *Baccharis salicifolia* and *Salix* in close proximity, and a relatively high water table estimated from an on-site excavation (Impact Sciences, Inc. 1998). Most adult plants were found in relatively open microsites among or adjacent to shrubs. Most surviving seedlings occurred in similar microsites. These observations suggest that survival of seedlings and young plants is enhanced partly by the presence of scattered shrubs that provide shade during the driest, warmest months, but which do not compete substantially for light, water, and nutrients. The absence of Ventura marsh milkvetch plants from adjacent open un-vegetated microsites and from dense stands of *Carpobrotus* and *Baccharis* nearby is consistent with this hypothesis. A similar pattern of adult plant distribution was observed in most northern marsh milkvetch populations in San Mateo County, where plants either grew in open sites immediately adjacent to dense scrub cover, or among shrubs in shrubland with a moderate amount of single canopy cover.

Ventura marsh milkvetch is a perennial with a longevity of at least three years. Plants judged to be from one to two years old apparently have an equal opportunity of either remaining vegetative or reproducing. Seeds produced in previous seasons have been observed to germinate consistently each year since 1997. Although plants at the only known locality experienced mortality resulting partly from exotic herbivores (e.g., snails), the locality has apparently supported a reproductive population for more than four years. The low-lying elevation on the leeward side of coastal dunes and relatively close to a freshwater or brackish aquifer also appear important. These features need to be considered in developing a recovery plan.

Recommendations for an Experimental Introduction Plan

A goal of establishing at least two experimental populations should be considered. The localities should be sufficiently different to provide an opportunity to test for effects imposed by variation in habitat and interaction with other native plants. The sites should also be located in areas that are excluded from human incursion, but easily accessed for planting and frequent monitoring. Based on studies of at least four potential localities (Carpinteria, McGrath, Mandalay, and Navy Base Ventura County), the locality near Lake McGrath at McGrath State Beach may have the best potential (Table 10). Localities at Carpinteria salt marsh, Mandalay State Beach, and Navy Base Ventura County also appear to offer potential recovery sites, ranking only slightly lower than McGrath. Overall, either Carpinteria salt marsh or Navy Base Ventura County ought to be considered over Mandalay. Potential sites at Carpinteria and Navy Base Ventura County have a different assemblage of native species, are close to either a seasonally active stream course or slough, and are geographically more distant from McGrath. Thus, the three areas provide contrasting locations for evaluating survival and reproduction. These localities also have sufficient variation in "microhabitats" and environmental conditions to permit further studies of habitat requirements.

Every effort should be made to place transplants in arrays or clusters that permit evaluation of survival and reproductive success over a gradient. At McGrath Lake, there appear to be subtle differences along a gradient from the edge of the wetland to drier sites at slightly higher elevations. At Carpinteria and Navy Base Ventura County, gradients exist with respect to vegetation and the effects of both high tides and annual freshwater influxes during the winter. At both Carpinteria and McGrath, the gradients are relatively narrow (< 50 meters) and are sufficiently extensive to permit several replications (i.e. several arrays or clusters of plants).

Based on experience and success at Rancho Santa Ana Botanic Garden in germinating seeds and growing plants in containers, it should be possible to grow up sufficient numbers of plants for transplantation (Dylan Hannon and Susan Klett, personal communication). Based on initial results from an ad hoc transplantation experiment conducted at Carpinteria salt marsh and the University of California Coal Oil Point Reserve (Wayne Ferren and Chris Sandoval, personal communication), some experience has been gained in understanding planting techniques and care, at least during the first year. One gallon pots are preferred over larger ones, because they appear to minimize damage to the root system. Regardless, every effort should be made to place healthy, well-rooted plants into sites in the late fall or early winter, concurrently with the onset of winter rains. Based on failures and successes with ad hoc transplants at Carpinteria and Coal Oil Point, a reliable water supply and regular, frequent application of water are required to ensure establishment in the event of a drought.

Considerable attention has been given to genetic diversity and to potential effects of inbreeding as a consequence of reduced population size and limited genetic variation (Fenster and Dudash 1994). The effects may not be expressed at any specific stage in a life history. For example, percent seed set and percent of embryo abortion among selfed progenies in four species of *Astragalus* did not show reduced fitness, but at least one species produced smaller seeds and smaller seedlings following selfing (Karron 1989). Inbreeding depression and genetic variation in Ventura marsh milkvetch has not been studied. Regardless, the entire population is sufficiently small so that a recovery effort can include as much of the genetic variation retained among remaining reproductive individuals and that stored in the current seed bank. Thus, the foundation for a recovery effort should include a seed collection representing every plant in each annual cohort of reproductive plants over several years. Efforts should be taken to partition seed collections by maternal parent, by location within the population, and by year for at least 3 years and preferably longer. The Santa Barbara Botanic Garden has proposed the addition of both varieties of *Astragalus pycnostachyus* to the Center for Plant Conservation National Collection, and plans to develop the collection for this purpose, as long as access to the original population is permitted. The recovery effort should include progenies derived from as many different wild maternal plants as is possible and should include a strategy that ensures that plants from the same maternal lines are not planted in close proximity.

Without a clear understanding of demographic features that contribute to population stability in Ventura marsh milkvetch, it is difficult to estimate a minimum population size. A minimum of at least 100 plants at each locality should be an initial goal, but a greater number (e.g., 200 to 300) needs to be considered, if only to provide for mortality during the first year of establishment. A greater number of transplanted individuals also provides the ability to conduct manipulations with respect to on-site micro-environmental variation. Considering that preliminary studies have shown that only 50% of 18 month old plants produce flowers, the initial introduction should include transplantation in annual increments for at least two to three years. This method would result in a more balanced age structure and would compensate for unpredictable annual patterns of mortality. Staggered planting over several years also permits the introduction of plants derived from different annual cohorts in the Oxnard population. Planning and preparing to raise sufficient container plants over a three year period would also ensure a renewable stockpile of plants in case of unusually high rates of mortality at or within any one site.

Finally, a monitoring protocol should be established to ensure that both strengths and weaknesses are evaluated regularly and synchronized with life history. The protocol depends on specific goals for population size, structure, survivorship, and rates of reproduction. Each plant should be considered as a unit and needs to be monitored for performance over several years. The total number of shoots, their length, the number of vegetative versus flowering shoots, the number of inflorescences, and estimates of fruit and seed set are likely indicators of success. The survival and success of plants with respect to position at the locality needs to be evaluated, but should not be constrained by too small a sample size. Arrays or clusters of 30-500 plants in two or (at most) three different microenvironments or sites within each locality should be considered.

The frequency of monitoring should be carefully considered, especially to monitor recovery populations for potential threats. All monitoring efforts need to consider periods of time and other events that may be critical to plant survival. Monitoring will need to be frequent during the first winter and early spring months to ensure that plants do not succumb to drought and that they remain free from potential threats, which can include snails and aphids. Based on experience at Oxnard, snail populations appear relatively quickly and can cause significant damage within a few weeks. Their control at both Oxnard and at recovery sites needs to be given high priority. Several methods have been tested (Ohlendorf 1999), including the use of iron phosphate, metaldehyde, and introduction of predatory decollate snails (*Rumina decollata*). All three methods have been employed in agricultural lands in southern California with varying success in reducing snail populations. Some thought also needs to be given to control for Argentine ant infestations. It is well known that this species is a generalist and may contribute to lower reproductive fitness in marsh milkvetch through its defense of aphid populations and through its harvesting nectar (Newell and Barber 1913). By defending aphid colonies and by "robbing" nectar, Argentine ants may drive away desirable pollinators, thus contributing to reduced fruit and seed set (Ward 1987, Vandermeer et al. 1990).

Monitoring will need to be less intense during periods after shoots have senesced and when plants are dormant (e.g., September-January). During the second and succeeding years, attention needs to be given to tracking and evaluating reproduction. The production of fruits and seeds will be a critical estimate of success in the first few years. Production of seeds, successful germination, and their recruitment as juvenile plants will be the most important indication of success with recovery. Consequently, it is important to establish a monitoring program that ensures evaluation of transplant success in the first two years, followed by continued monitoring to evaluate reproduction and later establishment of the first cohorts.

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Table 1. Age structure of the Ventura marsh milkvetch population at Oxnard. Ages of plants recruited prior to winter 1999-2000 were estimated from a comparison of numbered tags assigned to specific plants by either Impact Sciences or California Dept. of Fish and Game monitoring staff. The estimated age of plants, the number of plants with reproductive shoots, and the number of plants with strictly vegetative shoots, and total number of plants in each age class are shown.

Age In Years	Number of Reproductive Plants	Number of Vegetative Plants	Total
3	3	0	3
2	7	6	13
1	9	2	11
1	3	9	12
Total Number =	22	17	39

Note: Plants judged to be at least 3-4 years old (Impact Sciences tags in 1997), were marked as SBBG 5, 11, and 17. Plants judged to be at least 2 years old (tagged by Impact Sciences and CDFG in 1998) were marked as SBBG 9, 33, 35, 36, 44, 62, 64, 75, 79, 84, 87, 88, and 90. Plants judged to be at least 1 year old (tagged by Impact Sciences tags in 1999) were marked as SBBG 25, 28, 47, 63, 65, 66, 68, 76, 82, 83, and 89. Plants judged to be at least 1 year old, but not previously tagged, were marked during 2000 as SBBG 30, 34, 49, 50, 94, 97, 100, 101, 105, 108, 111, and 113. Some of the vegetative plants may have been recruited as seedlings during the winter of 1999-2000.

Table 2. Number and length of reproductive and vegetative shoots per plant, for 23 plants recruited prior to winter, 1999-2000, Ventura marsh milkvetch population, Oxnard.

	Mean ± se	Range	Sample Size
Vegetative plants			
Number of shoots per plant	4.8 ± 0.9	1-17	17
Length (cm) of longest shoot	11.3 ± 2.8	1-46	17
Reproductive plants			
Number of shoots per plant	6.6 ± 1.5	1-35	23
Length (cm) of longest shoot	46.2 ± 4.1	13-104	23
Number of inflorescences per plant	26.2 ± 8.7	1-198	23
Number of inflorescences per shoot	3.2 ± 0.4	1-11	151
Number of flowers per inflorescence	36.8 ± 2.1	17-56	24

Table 3. Number of ovules per flower, percent of damaged fruits per inflorescence, and fruit and seed set in unbagged versus bagged inflorescences in Ventura marsh milkvetch. Fruits with clearly developed exit holes and with seeds bearing evidence of insect herbivory were scored as "damaged". Firm, fully developed, "plump" seeds were scored as "full". Incompletely developed seeds, seeds appearing empty judging from texture or weight, and seeds with exit holes were scored as "empty". In nearly all cases, damaged fruits and empty seeds were the result of infestation by weevils.

	Mean ± se	Range	Sample Size
Number of ovules per flower	7.4 ± 0.2	6-9	20
Bagged Inflorescences			
Percent (%) damaged fruits	20	—	20
Number of full seeds per fruit	1.7 ± 0.1	0-6	164
Number of empty seeds per fruit	0.3 ± 0.1	0-3	164
Number of all seeds per fruit	2.0 ± 0.1	0-6	164
Open-pollinated inflorescences			
Percent (%) damaged fruits	50	—	20
Number of full seeds per fruit	1.9 ± 0.1	0-8	868
Number of empty seeds per fruit	0.9 ± 0.1	0-6	868
Number of all seeds per fruit	2.8 ± 0.1	0-8	868

Table 4. Some habitat characteristics of sites supporting *Astragalus pycnostachyus* var. *pycnostachyus* in central coastal California. Shown are: location of sites; number and distribution of plants observed; general description of site and substrate; general proportion of vegetative cover; and associated species immediately associated with milkvetch plants. Latitude and longitude was determined using a hand-held GPS unit with an accuracy of ± 30 m.

Marin County

Schooner 1: ca. 50 m north of Sir Francis Drake Highway, at upper end of Schooner Bay; ca. 38.09211° N, ca. 122.92785° W; ca. 25 m elevation; ca. 8-10 plants, most flowering (July 30-31, 2000), and fruiting (Sep 7-8, 2000), scattered and in small colony; narrow bluff between edge of creek draining into Schooner Bay and drainage from adjacent coastal salt marsh; substrate composed of sandy clay mixed with small rocks; vegetation between 50-75% cover; *Achillea millefolium, Distichlis spicata, Frankenia salina, Grindelia stricta* var. *angustifolia, Lolium multiflorum*.

Schooner 2: Sand spit immediately wnw of Johnson's Oyster Company on Schooner Bay, ca. 38.008328° N, ca. 122.93263° W; ca. 5 m elevation; ca. 35-50 plants, most flowering (July 30-31, 2000), and fruiting (Sep 7-8, 2000), scattered and in small colonies; sand spit between Schooner Bay and upper coastal salt marsh; substrate partly composed of fill obtained nearby, including oyster shells "recycled" from adjacent oyster processing factory, sand, silt, and oyster shell fragments; vegetation between 50-75% cover; *Atriplex triangularis, Distichlis spicata, Frankenia salina, Grindelia stricta* var. *angustifolia, Lolium multiflorum, Polygonum* sp., *Salicornia* sp.

San Mateo County

San Gregorio 1: south side of San Gregorio Creek, steep slope adjacent to Highway 1, ca. 37.32077° N, ca. 122.40133° W; elevation ca. 5 m; ca. 10-15 plants, some flowering (July 28-29, 2000); most scattered in small area; eroded slope immediately above San Gregorio Creek on south side of Highway 1 bridge; substrate composed of gravel, sandy, and clay; vegetation between 50-75% cover; *Baccharis pilularis, Eriogonum latifolium, Eriophyllum stachaedifolium, Mimulus aurantiacus*.

San Gregorio 2: eroded slopes, both sides of State Highway 1, south of San Gregorio Creek, ca. 37.37.31580° N, ca. 122.40245° W, elevation ca. 20 m; more than 100 plants, most flowering (July 28-29, 2000), and fruiting (Sep 8-9, 2000), mostly scattered and evenly distributed, some in small colonies; eroded slopes and colluvium composed of gravelly, sandy clay; vegetation less than 25-50% cover; *Achillea millefolium, Ambrosia chamissonis, Baccharis pilularis, Eriogonum latifolium, Eriophyllum stachaedifolium, Frankenia salina, Lupinus arboreus*.

Table 4 continued

San Gregorio 3: small bluff, above beach and below State Highway 1, south of San Gregorio Creek, ca. 37.31580° N, ca. 122.40290° W; elevation ca. 15 m; ca. 15 plants, most flowering (July 28-29, 2000), and fruiting (Sep 8-9, 2000), in small colony; small bluff, substrate composed of compacted sand and clay; vegetation between 75%-50% cover; *Ambrosia chamissonis, Eriogonum latifolium, Eriophyllum stachaedifolium, Mimulus aurantiacus, Toxicodendron diversilobum.*

Pomponio: eroded slope immediately adjacent to State Highway 1, south of Pomponio State Beach, ca. 37.28953° N, ca. 122.40363° W; elevation ca. 30 m; ca. 80-100 plants, most flowering (July 28-29, 2000), and fruiting (Sep 8-9, 2000), in small scattered colonies or as scattered individuals; eroded slope, substrate composed of compact gravel, sand, and clay; vegetation between 25-50% cover; *Baccharis pilularis, Eriogonum latifolium, Eriophyllum stachaedifolium, Mimulus aurantiacus.*

Pescadero 1: artificial dike, north side of Pescadero Creek, south of land-locked estero or marsh, ca. 37.26506° N, ca. 122.40586° W; elevation ca. 6-8 m; ca. 100 plants, most flowering (July 28-29, 2000), and fruiting (Sep 8-9, 2000) in small colonies or as widely scattered individuals; artificial dike, 8-10 ft above brackish-water marsh, apparently constructed from rocks and soil obtained in close proximity; substrate composed of compact, sandy clay with small rocks; vegetation less than 50-75% cover; *Achillea millefolium, Baccharis pilularis, Conium maculatum, Eriophyllum stachaedifolium, Euthamia occidentalis, Frankenia salina, Grindelia stricta* var. *angustifolia, Scrophularia californica, Toxicodendron diversilobum.*

Pescadero 2: bluff above beach, adjacent to parking lot and State Highway 1, ca. 37.26471° N, ca. 122.41141° W; elevation ca. 10 m; ca. 20 plants, most flowering (July 28-29, 2000), and fruiting (Sep 8-9, 2000), in small colonies or as scattered individuals; bluff above beach; substrate composed of compact fine sand, and clay; vegetation between 50-75% cover; *Ambrosia chamissonis, Baccharis pilularis, Eriogonum latifolium, Eriophyllum stachaedifolium, Lupinus chammisonis.*

Table 5. Some properties of soil samples at sites occupied by northern marsh milkvetch (*Astragalus pycnostachyus* var. *pycnostachyus*). Samples symbolized as SGR, PES, and POM were from sites in San Mateo County and SCH2 was from a site in Marin County (see Table 4). Saturation was reported as a per cent. Salinity was reported as mmhos/cm. Cation exchange capacity, calcium, magnesium, potassium, sodium, chloride, sulfate were reported as meq/100 gm. Nitrate and phosphorus were reported as ppm.

	SGR2	SGR3	PES1	PES2	POM	SCH2
Soil particles < 2 > 1 mm	0.96	0.92	0.93	0.96	0.94	0.89
Soil particles ca. < 1 mm	0.04	0.08	0.07	0.04	0.06	0.11
Saturation	21.7	35.1	28.3	27.9	40.7	27.9
Cation Exchange Capacity	4.2	13.0	6.9	6.9	14.4	6.1
pH	6.5	5.5	6.7	6.0	5.4	5.9
Salinity	1.8	1.5	1.5	1.5	3..1	17.9
Nitrate	3.5	2.0	3.5	4.4	2.8	2.3
Phosphorous	2.0	34.0	6.0	6.0	61.0	45.0
Potassium	0.1	0.9	0.4	0.4	1.9	3.7
Calcium	1.3	4.1	2.1	3.8	3.8	27.0
Magnesium	2.4	4.4	3.1	57.0	4.5	57.0
Sodium	12.0	6.1	8.1	0.4	18.6	95.0
Chloride	11.1	3.5	9.4	48.0	19.7	48.0
Sulfate	2.7	11.2	2.0	2.0	5.5	2.6

Table 6. Some properties of soil samples at the Oxnard Ventura marsh milkvetch site. Saturation was reported as a per cent. Salinity was reported as mmhos/cm. Cation exchange capacity, calcium, magnesium, potassium, sodium, chloride, sulfate were reported as meq/100 gm. Nitrate and phosphorus were reported as ppm.

	Samples from upper 2-3 cm among plants				
	OXN1	OXN2	OXN3	OXN4	OXN5
Soil particles < 2 > 1 mm	0.89	0.87	0.88	0.86	0.87
Soil particles ca. < 1 mm	0.11	0.13	0.12	0.14	0.13
Saturation	24.7	22.4	25.1	22.8	21.5
Cation Exchange Capacity	20.1	14.9	20.4	17.0	17.0
pH	6.8	7.3	7.5	7.6	7.5
Salinity	9.6	12.2	9.1	3.9	4.9
Nitrate (soluble)	2.6	0.9	0.9	1.1	1.3
Phosphorous	17.0	7.0	6.0	6.0	7.00
Potassium	2.7	3.4	2.3	1.5	3.3
Calcium	56.0	70.0	44.3	18.9	31.6
Magnesium	19.0	22.0	16.0	4.8	7.3
Sodium	28.0	33.0	27.1	11.9	19.8
Chloride	54.6	50.8	34.4	19.8	17.3
Sulfate	42.0	62.0	46.3	11.0	32.0

	Samples from upper 2-3 cm outside plant population				
	OXN6	OXN7	OXN8	OXN9	OXN10
Soil particles < 2 > 1 mm	0.95	0.92	0.94	0.93	0.96
Soil particles ca. < 1 mm	0.05	0.08	0.06	0.07	0.04
Saturation	30.5	31.7	23.8	25.7	31.1
Cation Exchange Capacity	16.0	14.2	17.1	6.9	14.5
pH	7.3	7.3	7.3	7.1	7.4
Salinity	2.1	1.9	9.5	1.9	1.7
Nitrate	2.0	0.09	0.9	0.9	2.6
Phosphorous	16.0	10.0	7.0	14.0	10.0
Potassium	2.0	0.6	5.5	1.7	1.3
Calcium	12.6	13.2	53.0	11.7	10.3
Magnesium	2.4	2.2	16.6	2.7	2.6
Sodium	5.6	3.9	28.1	3.9	2.9
Chloride	7.8	5.2	48.7	6.5	3.7
Sulfate	4.7	6.2	43.6	5.1	4.3

Table 6. continued

	Samples from upper 15-30 cm among plants				
	OXN11	OXN12	OXN13	OXN14	OXN15
Soil particles < 2 > 1 mm	0.98	0.97	0.95	0.95	0.97
Soil particles ca. < 1 mm	0.02	0.03	0.05	0.05	0.03
Saturation	21.2	24.4	24.9	25.1	22.1
Cation Exchange Capacity	12.4	18.2	16.3	19.4	16.5
pH	7.5	7.6	7.7	7.6	7.7
Salinity	1.7	3.2	0.7	4.1	1.8
Nitrate	0.9	0.9	1.3	0.9	0.9
Phosphorous	6.0	7.0	7.0	6.0	6.0
Potassium	0.7	0.7	0.3	2.2	0.7
Calcium	13.1	31.9	5.3	22.1	11.5
Magnesium	2.0	5.7	0.7	4.9	2.8
Sodium	2.6	3.2	0.5	10.2	2.7
Chloride	1.5	4.2	0.7	20.4	2.7
Sulfate	11.2	30.0	1.3	14.9	10.3

Table 7. Summary of soil properties of sites supporting *Astragalus pycnostachyus* var. *pycnostachyus* (SGR, PES, POM, SCH, n = 6, Table 5) and var. *lanosissimus* (OXN11-15, n = 5, Table 6). Values shown are the means, ± standard error, and 95% confidence intervals in parentheses. *indicates significant differences at the 95% confidence interval.

	var. *lanosissimus*			var. *pycnostachyus*		
Soil particles < 2 > 1 mm	0.96	± 0.0	(0.01)	0.93	± 0.0	(0.03)
Soil particles ca. < 1 mm	0.04	± 0.0	(0.01)	0.07	± 0.0	(0.03)
Saturation	25.3	± 1.6	(4.4)	31.9	± 2.6	(7.1)
CEC	16.6	± 1.3	(3.5)	9.5	± 1.7	(4.8)
pH*	7.5	± .05	(0.1)	5.9	± 0.2	(0.7)
Salinity	2.3	± 0.0	(1.7)	5.1	± 3.2	(8.9)
Nitrate	1.3	± 0.3	(0.9)	3.0	± 0.4	(1.2)
Phosphorus	7.2	± 0.7	(2.0)	30.4	±10.8	(30.1)
Potassium	1.1	± 0.3	(0.9)	1.5	± 0.6	(1.7)
Calcium	16.5	± 4.7	(13.1)	8.2	± 4.7	(13.1)
Magnesium	3.2	± 0.9	(2.6)	25.2	± 12.9	(36.5)
Sodium	3.9	± 1.6	(4.6)	25.6	± 17.8	(48.8)
Chloride	6.1	± 3.6	(10.1)	25.7	± 9.5	(26.3)
Sulfate	12.3	± 5.0	(13.9)	4.7	± 1.8	(4.9)

Table 8. Summary of properties of shallow soil samples from within and outside Ventura marsh milkvetch "colonies" at Oxnard (OXN1-5 versus OXN6-10, Table 7). Values shown are the means, ± standard error, and 95% confidence intervals in parentheses. *indicates significant differences at the 95% confidence level.

	Within plant colonies			Outside plant colonies		
Soil particles < 2 > 1 mm*	0.87	± 0.1	(0.01)	0.94	± 0.1	(0.03)
Soil particles ca. < 1 mm*	0.13	± 0.1	(0.01)	0.06	± 0.1	(0.03)
Saturation	23.3	± 2.0	(6.2)	28.1	± 2.0	(6.2)
CEC	17.9	± 1.0	(2.9)	13.2	± 2.2	(7.0)
pH	7.3	± .15	(0.4)	7.3	± 0.1	(0.2)
Salinity	7.9	± 1.5	(4.3)	3.8	± 1.9	(6.1)
Nitrate	1.4	± 0.3	(0.9)	1.3	± 0.4	(1.4)
Phosphorus	8.6	± 2.1	(5.9)	10.3	± 1.4	(4.6)
Potassium	2.6	± 0.4	(1.0)	2.3	± 1.1	(3.5)
Calcium	44.2	± 8.9	(24.8)	22.1	± 10.3	(32.9)
Magnesium	13.2	± 3.3	(9.3)	6.0	± 3.5	(11.2)
Sodium	23.1	± 4.0	(11.1)	9.7	± 6.1	(19.5)
Chloride	35.4	± 7.7	(21.3)	16.0	± 10.9	(34.7)
Sulfate	38.7	± 8.4	(23.4)	14.8	± 9.6	(30.6)

Table 9. Some properties of soil samples at potential recovery localities for Ventura marsh milkvetch (*Astragalus pycnostachyus* var. *lanosissimus*). CARP1-5 were collected at Carpinteria Salt Marsh, McG1-5 at McGrath State Beach, USN1-3 at Navy Base Ventura County, and MAN from near Mandalay Beach. COP1-2 were collected at UC Coal Oil Point Reserve. Saturation was reported as a per cent. Salinity was reported as mmhos/cm. Cation exchange capacity, calcium, magnesium, potassium, sodium, chloride, sulfate were reported as meq/100 gm. Nitrate and phosphorus were reported as ppm.

	CARP1	CARP2	CARP3	CARP4	CARP5
Soil particles < 2 > 1 mm	0.99	0.39	0.56	0.70	0.67
Soil particles < 1 mm	0.01	0.61	0.52	0.30	0.33
Saturation	27.6	27.1	28.4	36.8	27.6
Cation Exchange Capacity	4.4	13.9	20.9	28.8	23.6
pH	7.7	7.3	7.9	8.2	7.9
Salinity	1.1	5.2	4.1	14.6	42.3
Nitrate	5.7	3.6	7.8	2.9	3.0
Phosphorous	5.0	165.0	12.0	5.0	160.0
Potassium	0.5	3.7	1.0	2.3	13.7
Calcium	3.2	8.9	14.6	18.0	15.0
Magnesium	3.0	9.5	6.7	22.0	61.0
Sodium	3.5	24.2	27.0	98.0	275.0
Chloride	1.2	52.5	31.1	115.0	365.0
Sulfate	6.5	2.9	7.9	19.0	44.0

	McG1	McG2	McG3	McG4	McG5
Soil particles < 2 > 1 mm	0.93	0.99	0.99	0.99	0.99
Soil particles < 1 mm	0.07	0.01	0.01	0.01	0.01
Saturation	26.9	23.6	27.2	22.6	28.8
Cation Exchange Capacity	5.7	4.6	3.1	2.7	9.4
pH	6.9	7.0	7.3	7.5	7.5
Salinity	0.5	0.5	0.3	0.3	0.7
Nitrate	3.4	4.4	2.8	2.2	3.3
Phosphorous	13.0	9.0	5.0	4.0	15.0
Potassium	0.3	0.2	0.1	0.1	0.3
Calcium	2.3	2.8	2.0	1.4	6.3
Magnesium	1.4	0.9	0.6	0.5	1.3
Sodium	1.4	1.3	0.8	0.9	1.6
Chloride	0.6	1.0	0.5	0.3	1.6
Sulfate	0.6	0.7	0.4	0.3	1.2

Table 9. continued

	USN1	USN2	USN3	MAN	COP1	COP2
Soil particles < 2 > 1 mm	0.98	0.98	0.93	0.96	0.84	0.86
Soil particles < 1 mm	0.02	0.02	0.07	0.04	0.16	0.14
Saturation	23.0	22.9	28.8	36.0	24.1	21.8
Cation Exchange Capacity	6.9	6.5	21.7	14.1	7.2	6.3
pH	8.1	7.7	8.7	7.3	6.9	6.6
Salinity	24.4	0.6	1.7	0.8	1.3	1.3
Nitrate	2.7	2.2	6.0	7.2	2.8	3.2
Phosphorous	4.0	4.0	15.0	17.0	25.0	13.0
Potassium	5.8	0.5	0.6	0.5	0.7	0.5
Calcium	10.0	3.3	1.1	5.4	3.7	2.1
Magnesium	20.0	0.9	0.6	2.4	2.8	2.3
Sodium	161.0	1.5	15.2	0.8	5.9	8.1
Chloride	0.3	1.4	1.6	1.1	3.3	4.9
Sulfate	166.0	0.7	9.2	0.8	4.6	3.5

Table 10. Relative rankings of potential recovery localities for Ventura marsh milkvetch. Localities were ranked on a scale from 1 to 3 for each of 5 criteria, with 1 indicating relatively low quality, and 3 indicating relatively high quality. A high overall ranking was assigned to a site that had: (1) dominant vegetation composed of a single canopy of native shrubs forming 50-75% cover; (2) absence of competitive native plants and annual exotic plants; (3) a fresh or brackish water table judged to be in close proximity and near the surface; (4) relatively compact, stable sandy substrates with overall physical and chemical properties that were consistent with that at Oxnard; and (5) a buffer or border of natural habitat that might support medium or large sized bees. Uncertainty was ranked by using a range of minimum and maximum values.

McGrath State Beach (CA State Parks and Recreation)	
1. Dominant vegetation composed of a shrub canopy with cover < 75%	1-2
2. Absence of competitive annual or perennial exotic plants	2-3
3. Water table in close proximity	3
4. Soils consistent with that of the Oxnard Ventura marsh milkvetch site	2-3
5. Buffer of native habitat supporting bees (pollinators)	2-3
Sum =	10-14
Range in mean ranking =	2.0-2.8
Mandalay (CA State Parks and Recreation)	
1. Dominant vegetation composed of a shrub canopy with cover < 75%	1-2
2. Absence of competitive annual or perennial natives and exotic plants	2-3
3. Water table in close proximity	3
4. Soils consistent with that of the Oxnard Ventura marsh milkvetch site	2-3
5. Buffer of native habitat supporting bees (pollinators)	2
Sum	10-13
Range in mean ranking =	2.0-2.6
Carpinteria Salt Marsh (UC Reserve)	
1. Dominant vegetation composed of a shrub canopy with cover < 75%	2
2. Absence of competitive annual or perennial exotic plants	2-3
3. Water table in close proximity	3
4. Soils consistent with that of the Oxnard Ventura marsh milkvetch site	2-3
5. Buffer of native habitat supporting bees (pollinators)	2
Sum =	11-13
Range in mean ranking =	2.2-2.6

Table 10. continued

Naval Base Ventura County (U. S. Navy)	
1. Dominant vegetation composed of a shrub canopy with cover < 75%	2-3
2. Absence of competitive annual or perennial natives and exotic plants	1-2
3. Water table in close proximity	2
3. Soils consistent with that of the Oxnard Ventura marsh milkvetch site	2
4. Buffer of native habitat supporting bees (pollinators)	2-3
Sum =	9-12
Range in mean ranking =	1.8-2.6
Emma Wood State Beach (CA State Parks and Recreation)	
1. Dominant vegetation composed of a shrub canopy with cover < 75%	1
2. Absence of competitive annual or perennial exotic plants	1-2
3. Water table in close proximity	2
4. Soils consistent with that of the Oxnard Ventura marsh milkvetch site	1-2
5. Buffer of native habitat supporting bees (pollinators)	1-2
Sum =	6-9
Range in mean ranking =	1.2-1.8

Figure 1. Emergence and Survival of Adult Plants

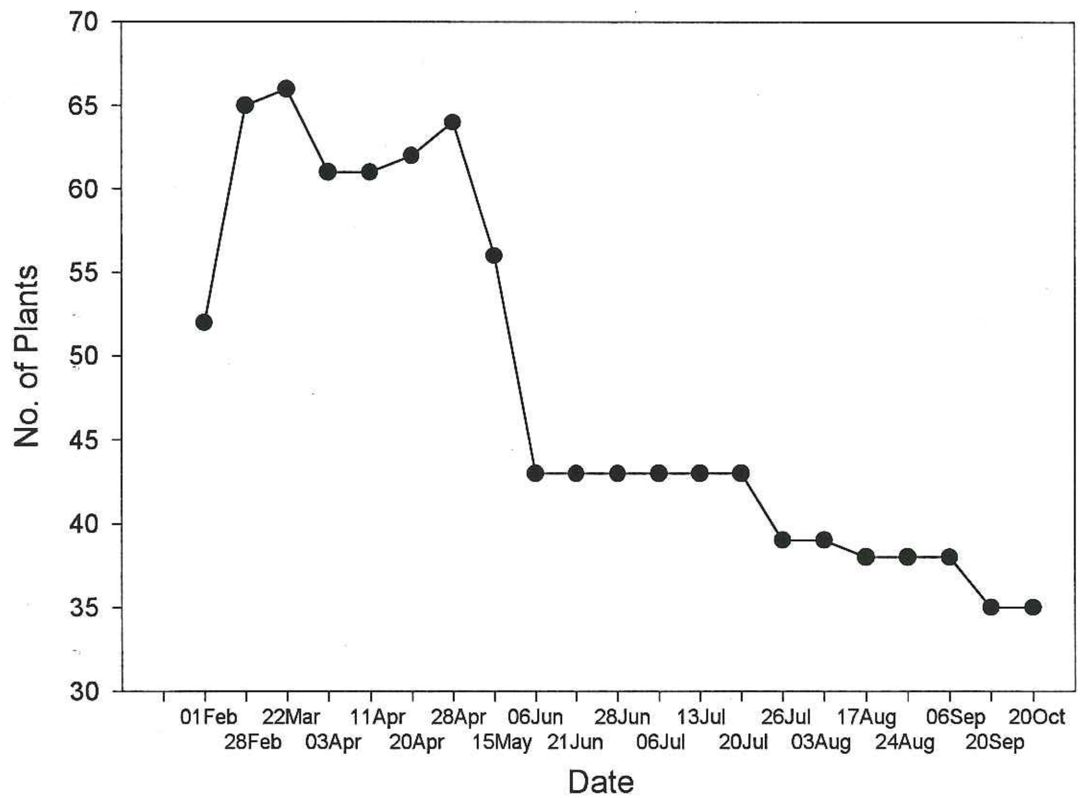

Figure 2. Number of inflorescences with open flowers

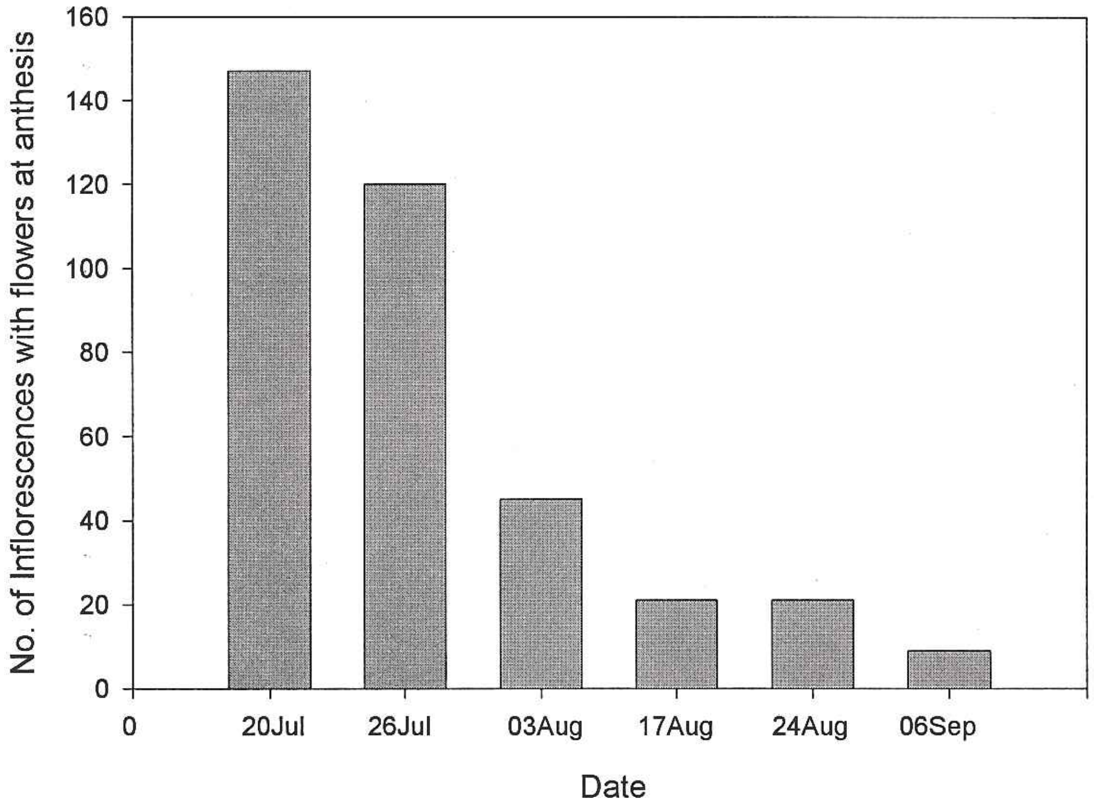

Figure 3. Number of inflorescences with mature fruits

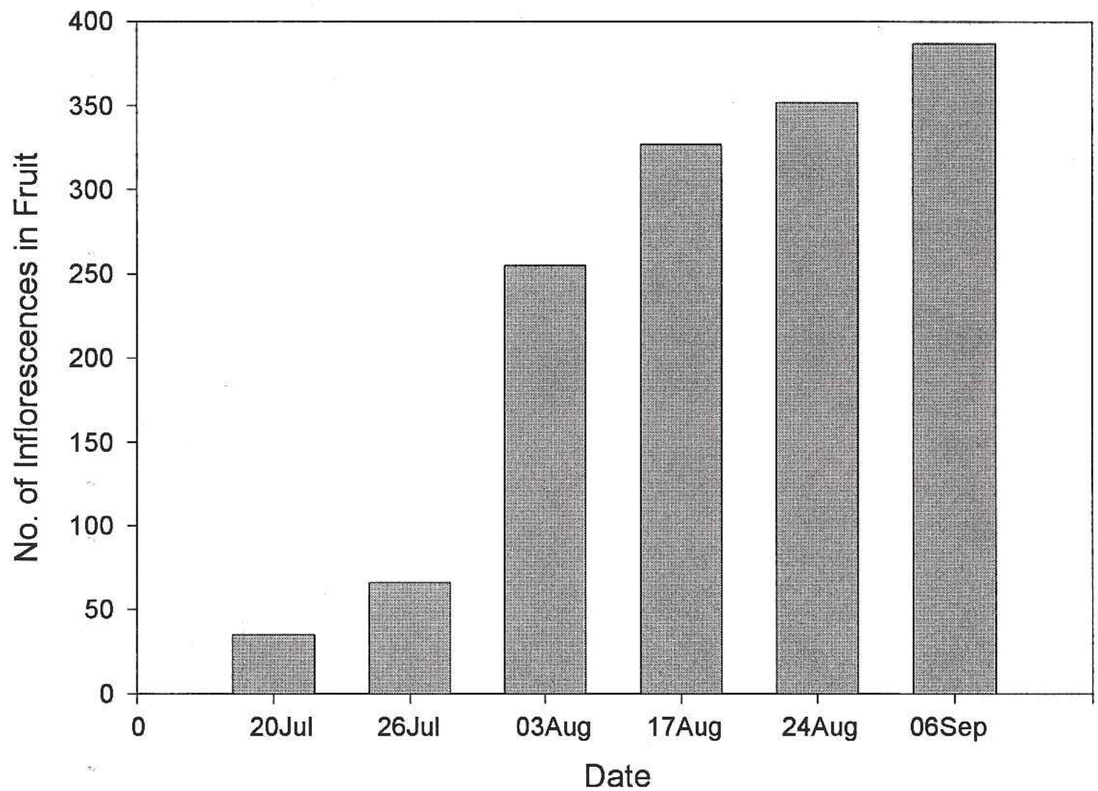

Figure 4. Emergence and Survival of Seedlings in Quadrats

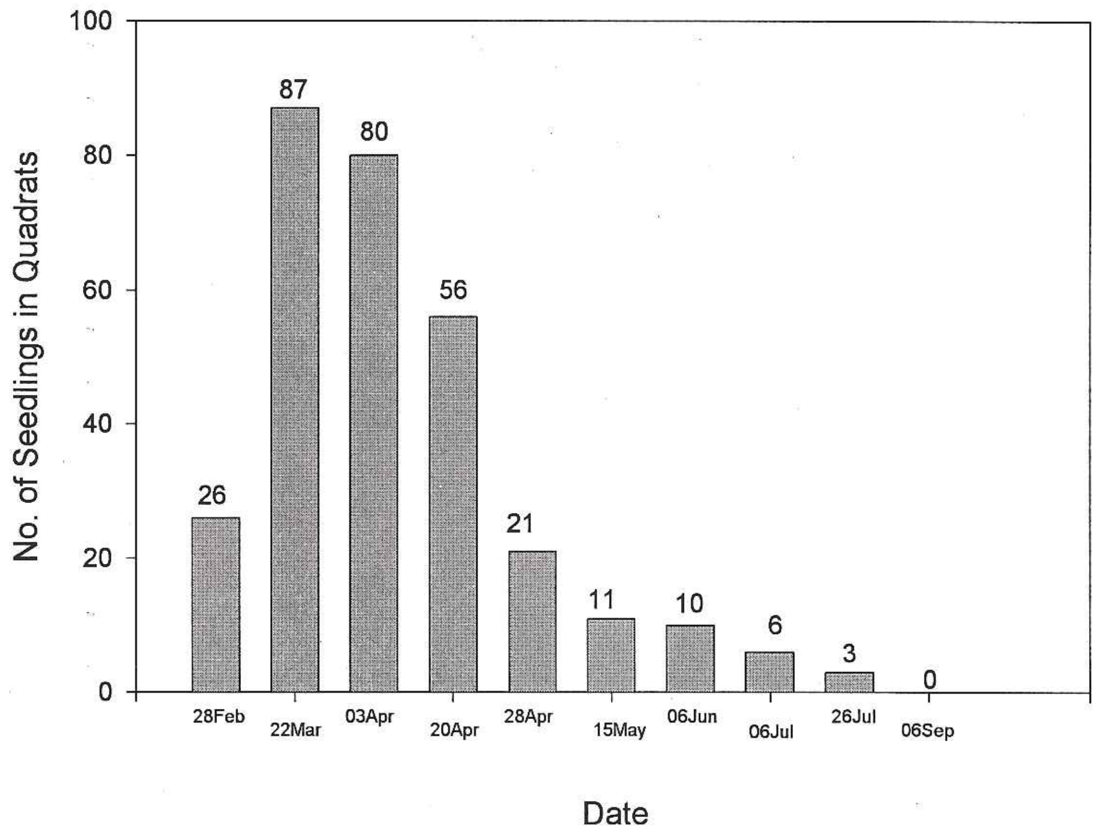

Figure 5. Emergence and Survival of all seedlings

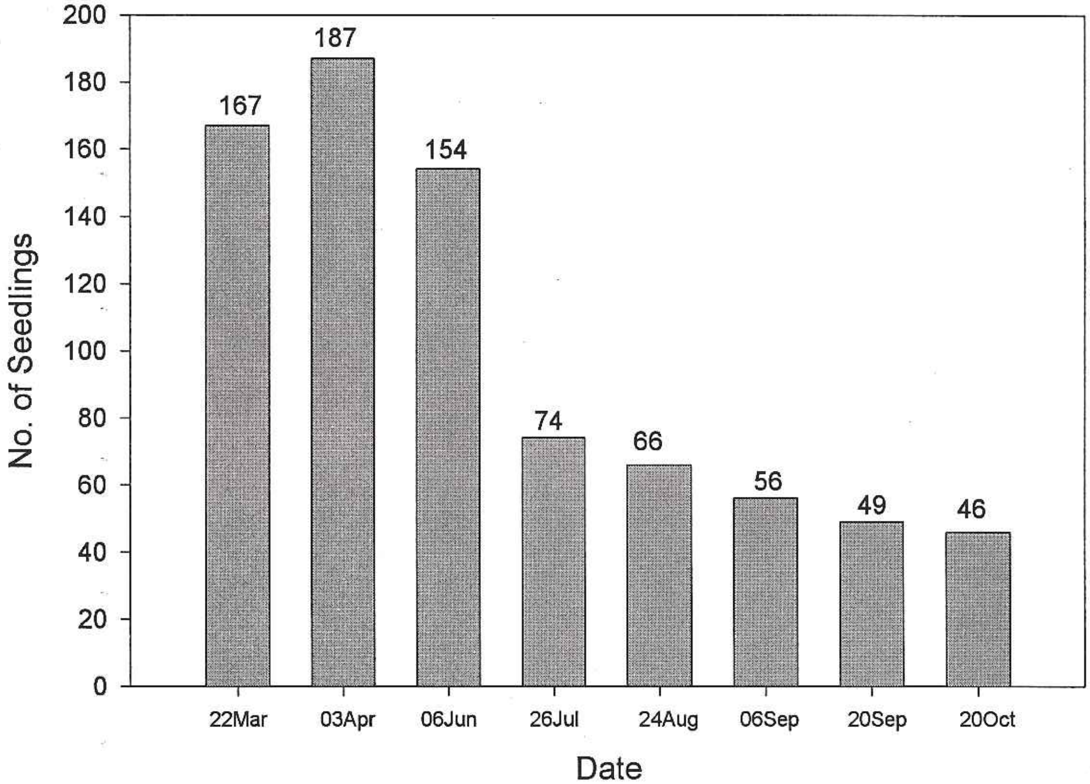

Figure 6. Cluster diagram of relationships among five samples from the Oxnard Ventura marsh milkvetch localities and six samples from four northern marsh milkvetch localities. OXN11–15 were from Oxnard, PES1 from Pescadero, POM from Pomponio, SCH2 from Schooner Bay, and SGR2 and SGR 3 from San Gregorio (see Table 4). Clustering based on a correlation matrix, using average linkage.

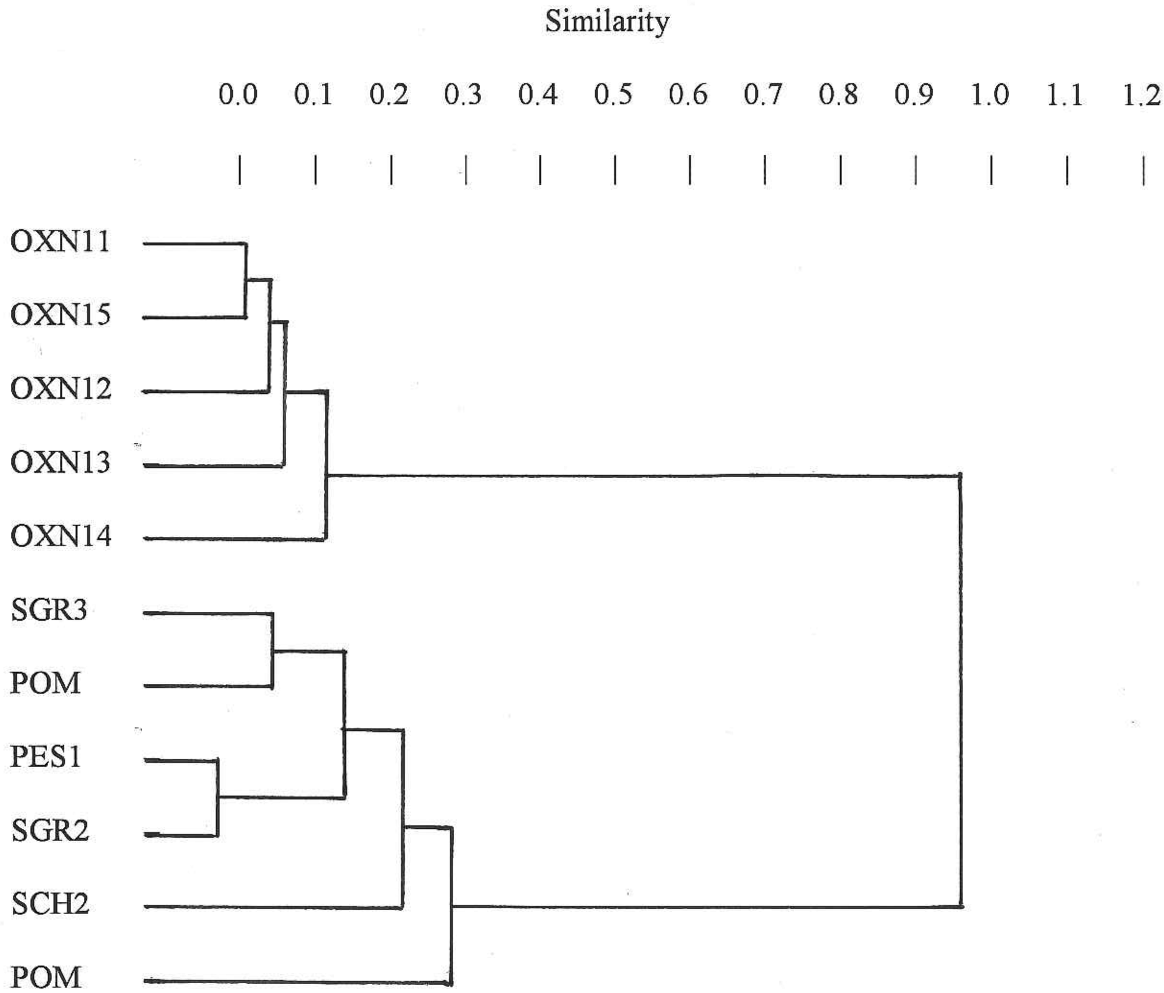

Figure 7. Cluster diagram of relationships among 5 samples from the Oxnard Ventura marsh milkvetch localities and 14 samples from 4 potential recovery localities. OXN11–15 were from Oxnard, CARP1–5 from Carpinteria, McG1–5 from McGrath, MAN from Mandalay, and USN1-3 from Navy Base Ventura County. COP1–2 were from the ad hoc recovery experiment conducted at the UC Coal Oil Point Reserve (see Table 9). Clustering based on a correlation matrix, using average linkage.

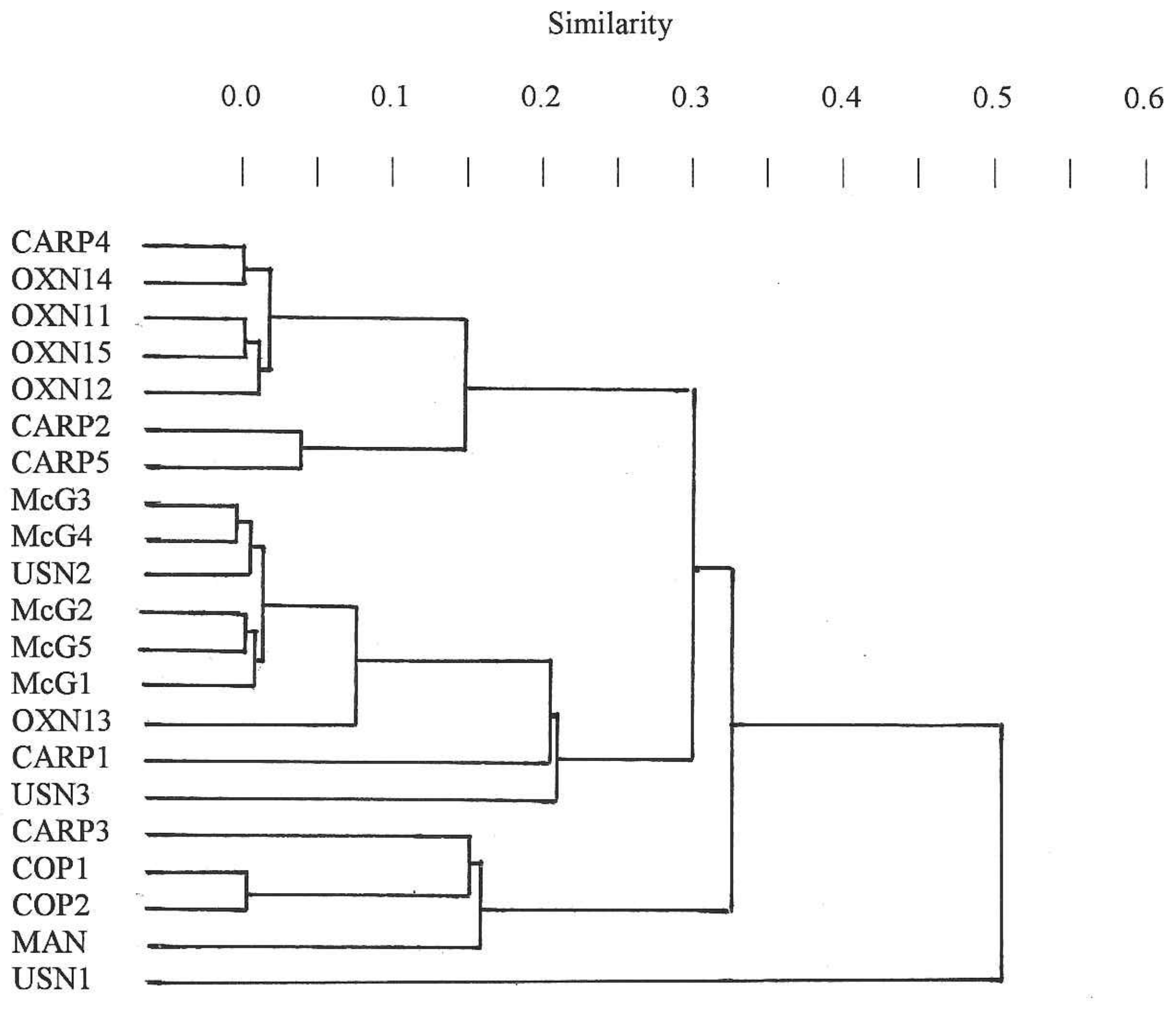

Figure 8. Location of potential Ventura Marsh Milkvetch introduction site at the University of California Carpinteria Salt Marsh Reserve. Map based on USGS 7.5 minute Carpinteria Quadrangle, 1952 version.

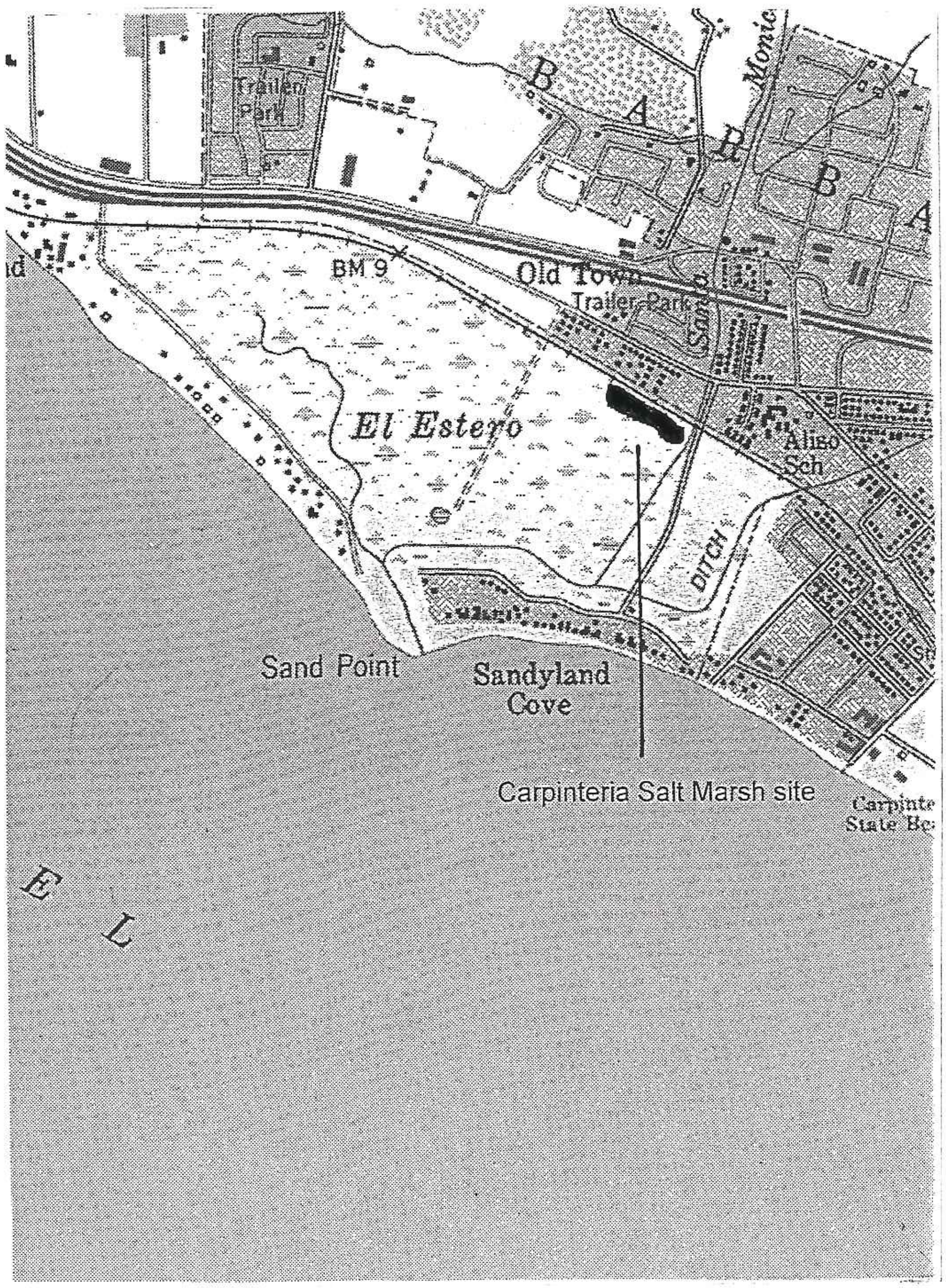

Figure 9. Location of potential Ventura Marsh Milkvetch introduction sites at McGrath Beach State Park (McGrath 1-5). Map based on USGS 7.5 minute Oxnard Quadrangle, 1967 version.

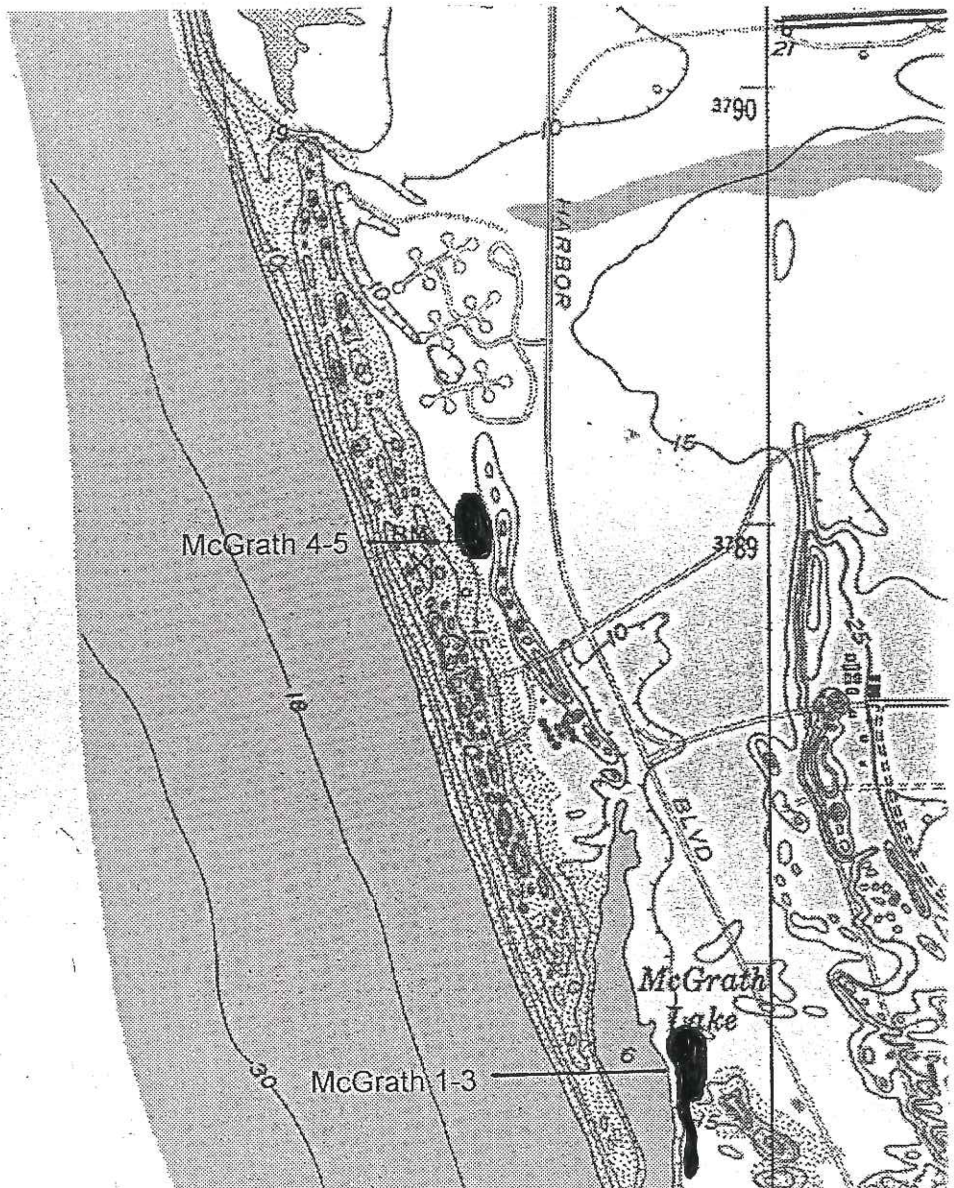

Figure 10. Locations of potential Ventura Marsh Milkvetch introduction site near Mandalay Beach and Oxnard Ventura Marsh Milkvetch site (starred point). Map based on USGS 7.5 minute Carpinteria Quadrangle, 1967 version.

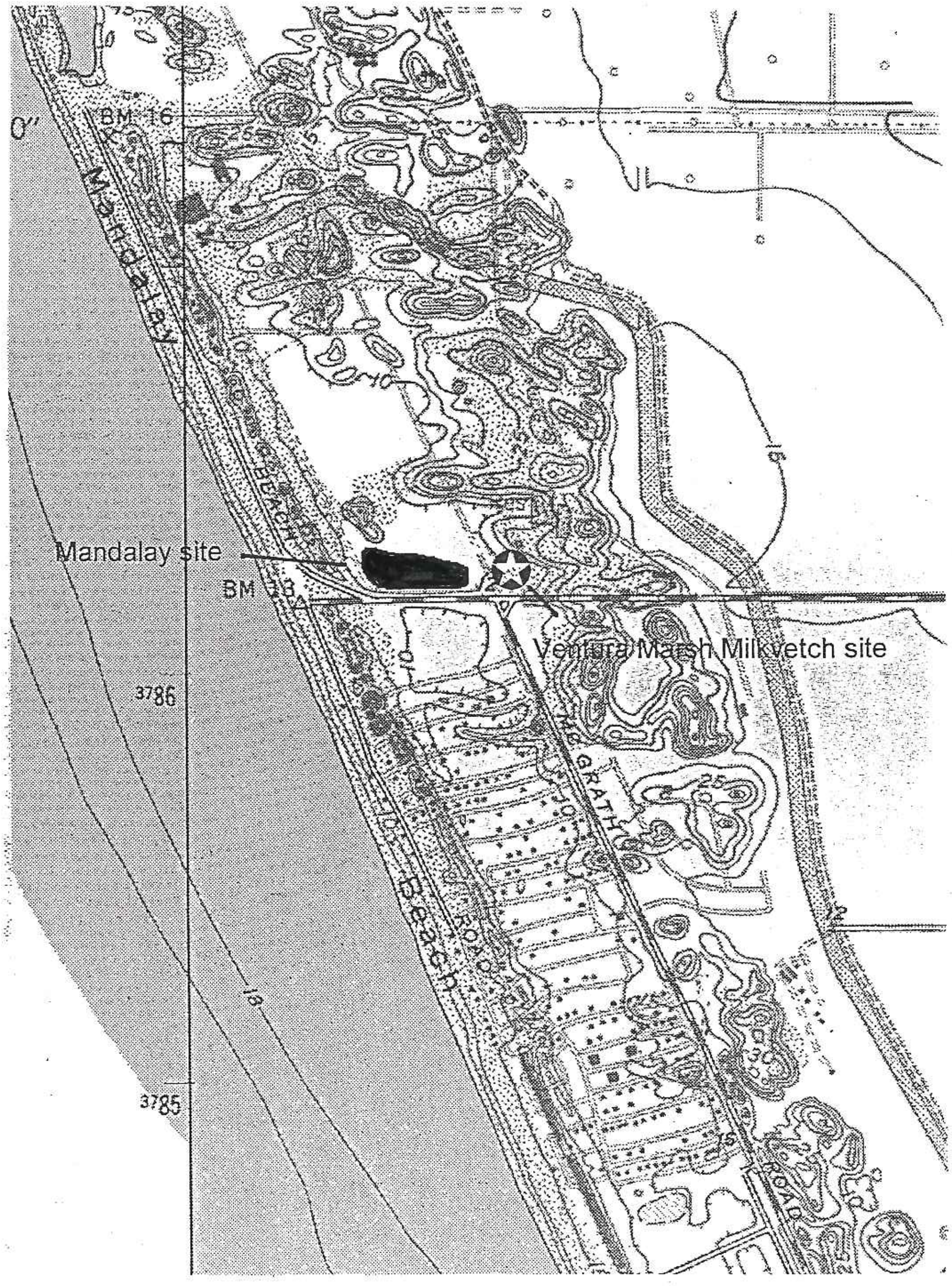

Figure 11. Location of potential Ventura Marsh Milkvetch introduction sites at the US Navy Base Ventura County. Map based on USGS 7.5 minute Point Mugu Quadrangle, 1967 version.