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ECOLOGY AND LIFE HISTORY OF THE SAN BENITO EVENING PRIMROSE

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INTRODUCTION

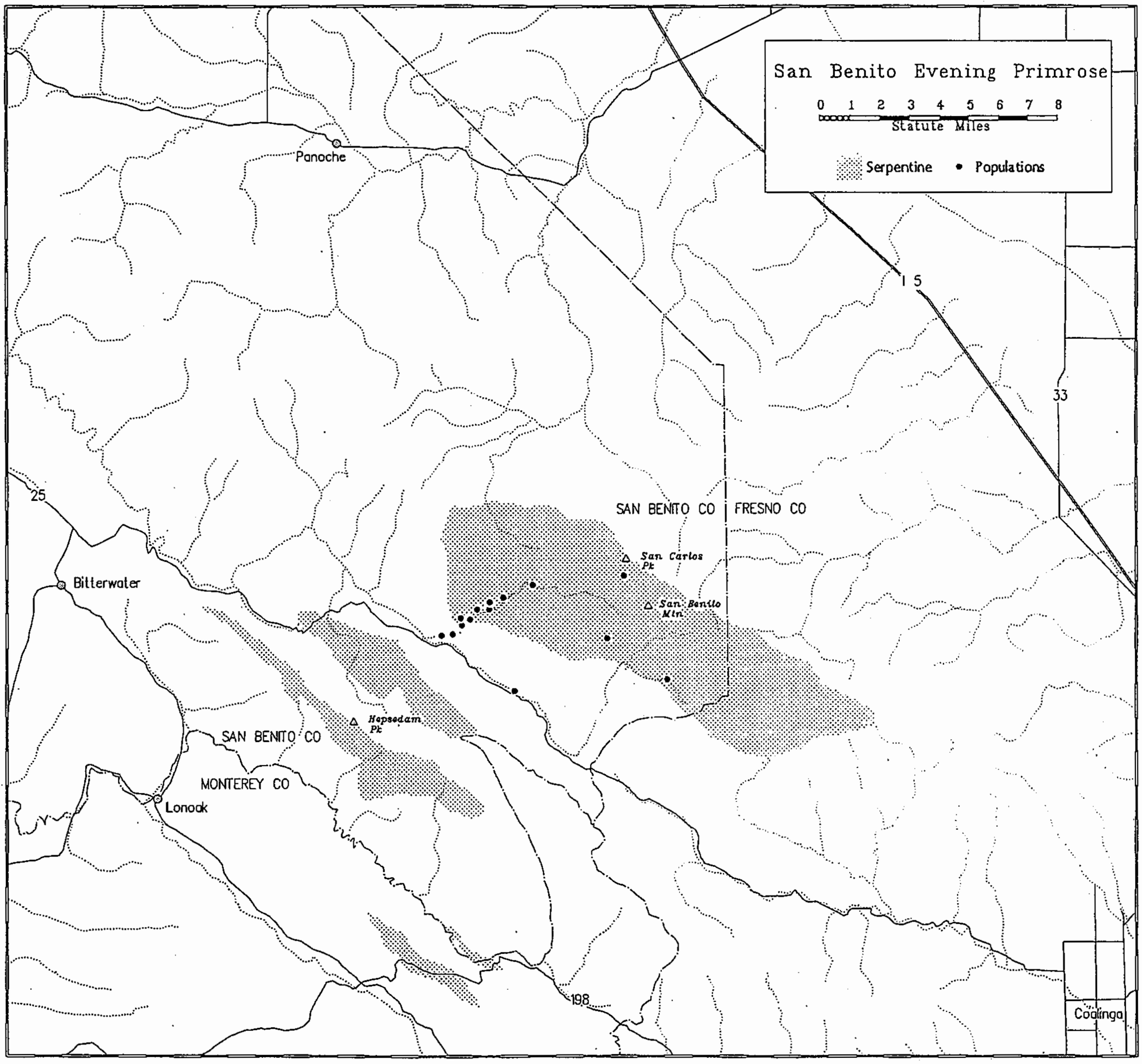
The San Benito Evening-primrose (*Camissonia benitensis*) is a tiny annual plant restricted to serpentine substrates in the San Benito Mountain area of the Inner South Coast Ranges of California (Figure 1). The species was listed as Threatened by the U.S. Fish and Wildlife Service under provisions of the Endangered Species Act of 1973 on 12 February 1985 (50 **Federal Register** 5758). Most of the known populations of the species occur on public lands administered by the Bureau of Land Management (BLM). Presently, 13 populations of *C. benitensis* are known, all but one located on BLM administered lands.

Conflicting land use demands in the BLM Clear Creek Management Area complicate management efforts for this and other rare plants of the San Benito Mountain region. Extensive land disturbance associated with essentially unrestricted use of off-road vehicles (predominately motorcycles) over much of the landscape constitutes the primary endangerment threat to populations of *C. benitensis*. Extensive mining during the period between the 1860's and 1940's impacted a sizable portion of suitable habitat for the species. Today, informal campsites and formal BLM recreational facilities (parking areas, pit toilets) have eliminated most of the remaining habitat.

This report provides the results of three years of research on the life-history and endangerment status of *C. benitensis*. This research is being conducted under a contract (No. CA950-RFP7-13) from the Bureau of Land Management (BLM). The basic objective of the research is to determine the amount and distribution of essential habitat and those ecological parameters necessary to sustain the continued existence of *Camissonia benitensis*.

BLM has formulated a management plan for *Camissonia benitensis* habitat (Clear Creek Management Plan, BLM 1986), and has implemented interim measures, including vehicle barrier construction and signing, to provide some protection to the species and its habitat.

Figure 1. Map of the central South Coast Ranges of California showing the location of the San Benito Mountain region study area, distribution and extent of serpentine and equivalent ultramafic rocks (hatched area), and known locations for *Camissonia benitensis* (dots).



A draft recovery plan for the species has been under development by the U.S. Fish and Wildlife Service (Recovery Plan for the San Benito Evening-primrose, USFWS 1987, 1988).

The studies reported here are designed to provide data on the life history characteristics and population ecology of *Camissonia benitensis*. This information is necessary for the implementation of the proposed recovery plan. The contract funding this research specified research organized into 6 major tasks, each of which focuses on a critical aspect of the life history of *Camissonia benitensis*: 1) demographic monitoring of populations; 2) population census; 3) germination and growth requirements; 4) breeding system and pollination; 5) animal interactions, 6) competitive interactions. In consultation with BLM botanists, an additional task was added: 7) habitat requirements. These tasks are designed to provide data on salient features of the biology of *Camissonia benitensis*.

METHODS

The contract to conduct this research was awarded on 21 April 1987. Research efforts under all 7 tasks were initiated upon award of contract. Because of the timing of the contract award, coming at the end of the growing season for *Camissonia benitensis*, and because of below normal precipitation in 1987, very little data was obtained in the first summer of the research. Only two of the known population sites supported significant *Camissonia benitensis* populations in 1987, due to low rainfall. Severe drought continued during 1988 and 1989. Rainfall in 1988 was adequate for most populations to support plants. Growing conditions in 1989, the third and final year of the contract, were generally very poor. Owing to the drought, the contract period was extended for an additional year. Work on this research was continued into the 1990 growing season, but again severe drought persisted. At this writing, an additional 5th year of work is planned for the 1991 growing season under a separate contract.

Research Methodology - our choice of methodology is influenced by the need to provide an information base relevant to efforts to recover and delist *Camissonia benitensis*. Consequently, this research has, following consultation with BLM botanists, deviated somewhat from the tasks as strictly outlined by BLM in the RFP soliciting this research (J. Willoughby, pers. comm.; T. Prendusi, pers. comm.)

Population Census - in 1987, 1989 and 1990, plants of *Camissonia benitensis* failed to appear at several populations, and were exceedingly sparse at other sites. In these years, each of these populations was completely censused by carefully locating and counting all individuals in the population. At each site, the population was delimited by an artificial grid to facilitate inspection (Figure 2). Different grid sizes were utilized at differing populations, depending on the size and complexity of the site requiring inspection.

Figure 2. Photograph of a *Camissonia benitensis* site (Population 9) during a census to determine size of the population. At larger populations, census of the site was facilitated by the establishment of a grid system to insure all portions of the population were carefully inspected for plants.

In 1988, *C. benitensis* plants appeared in numbers at several of the larger populations too great to determine by direct census. Since the size of these populations varied greatly in both area and number of plants, we used a method of subsampling to estimate population number. Rectangular quadrats (2 dm by 5 dm) were laid at 1 meter intervals along line-transects across each population. Quadrats were placed with the shortest dimension centered at each meter interval, alternating on opposite sites of the tape. The area of the population was estimated from pacing or measured with a tape. The numbers of individuals comprising the population was estimated by extrapolation, using the mean density obtained from the quadrat sampling.

Demographic Monitoring - the study design used for this task is similar to those described by Harper (1977), in which the fate and fecundity of all individuals within small, subjectively selected plots are followed. Such studies can be termed survivorship analysis (White 1985) or cohort analysis (Harper 1977).

Germination - wild collected seed was used for all germination experiments and for establishing *Camissonia benitensis* in cultivation. Seed collected in the fall of 1987 was stored at room temperature for two to four months prior to analysis. Germination studies were carried out at two temperatures, 20°C (room temperature) and 3°C (under refrigeration). Seeds were placed on moist filter paper in petri dishes, and were scored every other day for germination.

Field observations of germination rates and timing were conducted in the fall (early December) and early spring (early February) of each year. Only those populations easily accessible by road were visited.

Soil Seed Storage - density of *Camissonia* soil seed storage was determined for three populations (for *C. contorta* at Population 1, for *C. benitensis* at Population 5, and for both *C. benitensis* at Population 9). At each population, soil from 1 dm by 1 dm quadrats was excavated to a depth of 5 cm. The top and bottom half of the soil column was extracted separately. Soils were returned to the laboratory, passed through a 2 mm screen to remove stones, and were prepared for germination trials. Each soil sample was spread on flats containing non-serpentine soil (UC mix, Baker 1972). The flats were watered, and stored in a refrigerator at 3°C for 30 days to simulate *in situ* winter temperature and moisture conditions. The flats were then placed out-doors in Aptos, CA between October, 1987 and February, 1988 to continue to simulate a degree of any requisite cold-stratification. Appearance of seedlings was tallied at episodic intervals not greater than weekly for a two month period.

Seedling Survivorship - survivorship data and causes of mortality were investigated in 1988 - the sole 'good' year for *C. benitensis* during the study period. On 20 February 1988, we inspected the populations to ascertain the progress of germination and to begin demographic monitoring. On March 20, 10 small rectangular plots were established at each population to monitor seedling survivorship. Plots were visited at monthly intervals during the growing season. Survivorship plots (2 dm by 5 dm) were located in sites where *Camissonia* plants had been seen growing in 1987. To facilitate relocation, the plots were outlined with yellow string between non-galvanized nails set flush with the soil surface. The plots were chosen so as to contain between 30 to 50 *Camissonia* seedlings. Each seedling was marked with a tooth-pick sunk about 3 cm into the soil. Where possible, mortality factors (i.e., drought, frost heaving or predation) were noted. In most cases, the cause of seedling mortality could not be determined, however.

Fecundity Monitoring - survivorship plots were used to collect the bulk of the field data on fecundity. In the field, plants were scored for plant height, number of capsules per plant, and capsule length. At least 10 capsules were collected from each population (under Permit No. PRT-702631 from the U.S. Fish and Wildlife Service). Capsules were opened under a dissecting microscope, counting number of unfertilized ovules, unfilled (shriveled) seeds, and filled seed. Seed so obtained was used for germination experiments and controlled environment culture.

Plants of *C. benitensis* were cultivated in open garden culture. Capsules from these plants were harvested for fecundity monitoring. Garden culture of *C. benitensis* is being conducted in Aptos, CA, on slightly acid (pH 5.8-6.2) Nisene-Aptos loam (Bowman et al. 1980) well supplemented with compost and manure fertilizer.

Breeding System and Pollination - Raven (1969) considered *Camissonia benitensis* and related species in Section *Camissonia* to be autogamous. We conducted controlled emasculation and pollination experiments on plants in cultivation to verify the breeding system of *C. benitensis*.

Unopened flower buds of *C. benitensis* were emasculated by hand under a dissecting microscope. Since these studies confirmed that *C. benitensis* is autogamous, we did not institute a field pollination research effort, because self-fertilization implies that pollination efficency is not likely to be a factor limiting reproduction.

Animal Interactions - Field observations (primarily anecdotal) on the effects of grazing animals on *Camissonia benitensis* were made during 1987-1990. Minor grazing effects within the known populations were noted during our field visits, but no experiments were implemented.

Competitive Interactions - field observations suggest that competition from annual plants is not likely to be significant in limiting populations of *C. benitensis*, since cover of annual plants is quite low in all populations. Furthermore, invasive non-native plants, particularly *Bromus rubens, B. tectorum* and *Avena barbata*, are rare components of the vegetation at *C. benitensis* populations. Consequently, competition experiments growing *C. benitensis* in combination with other annuals were not conducted. Competition from woody plants, however, seems to be a major factor structuring habitat utilization for *C. benitensis*. Studies on the nature of serpentine chaparral succession and vegetation dynamics were initiated (see Habitat Selection, below).

Habitat Selection - vegetation structure and floristic composition at all known populations of *C. benitensis* was sampled in 1989. Each population was considered to constitute a sample unit within which the vegetation was inventoried. Plotless estimation methods (Mueller-Dombois and Ellenberg 1974) were used to characterize vegetation at each site: all vascular species within the population were recorded and their canopy cover was estimated visually using the following scale of precision: $<1\%$ cover, to the nearest 0.1% cover; 1-10% cover, to the nearest 1% cover; $>10\%$ cover, to the nearest 5% cover. Vegetation data was analyzed using standard synecological methodology of combined ordination/classification approaches (Gauch 1982), including TWINSPAN analysis (Hill 1979a, Hill et. al. 1975), Detrended Correspondence Analysis (Hill 1979b, Hill and Gauch 1980), and species group analysis (Ceska & Roemer 1971, Ceska 1988).

Available Habitat Inventory - all suitable habitat for *C. benitensis* was inventoried within its known geographic range. Because *C. benitensis* is limited by physiography (growing only on alluvial serpentine terraces) and density of woody vegetation (openings in serpentine chaparral), the amount of suitable habitat could be estimated. Degree of human disturbance was determined for all alluvial terraces within Clear Creek canyon, the major center of distribution for the species. The proportion of each terrace site that was subject to direct soil disturbance factors (camping, roadways, ORV use, et. cetera) was estimated visually on the ground, aided by 1:12,000 color aerial photographs taken on 9 August 1988). Aerial photographs were inspected with the use of a Bausch & Lomb stereo zoom transfer-scope.

Report Format - the format used for this report follows the general endangered plant status format suggested by Henifin et al. (1981).

RESULTS

CLASSIFICATION AND NOMENCLATURE

Scientific Name: *Camissonia benitensis* Raven.

Bibliographic Citation: Cont. U.S. National Herbarium 37: 332 (1969).

Type Specimen: "on serpentine by small stream 5.4 miles from Hernandez on road to New Idria, along Clear Creek, San Benito County, California", 19 April 1960, *P.H. Raven* **15084** (DS!, Isotype US).

Synonyms: None.

Common Names: San Benito Evening Primrose is used by Smith and Berg (1988), by the Bureau of Land Management (BLM 1986) and by the U.S. Fish & Wildlife Service (USFWS 1986, 1987, 1988). No other common names are known.

Family: Onagraceae (Evening-primrose Family).

Taxonomic Discussion - *Camissonia benitensis* was described from collections made in 1960 from two sites in the canyon of Clear Creek, in southeastern San Benito County (Raven 1969). For the next 15 years, the species was apparently not observed or collected. During the mid-1970's, James R. Griffin collected the species at several localities (Griffin 1978), including in a second watershed on San Benito Mountain, in upper San Carlos Creek. Between 1977 and 1986, BLM staff documented several more populations (Kiguchi 1983 et seq.; Kiguchi and Florence 1986).

Raven (1969) provides the most recent comprehensive treatment of the taxonomy of

Camissonia. The genus is comprised by about 88 taxa distributed within 61 species in 9 sections. *Camissonia benitensis* is classified in Section Camissonia, a group of 11 species. Table 1 provides a comparison of members of Section Camissonia ordered by chromosome number and breeding system. *Camissonia benitensis* is a tetraploid species (n = 14) most closely related to the hexaploid *C. contorta* (n = 21). The species of Section Camissonia are small plants that differ only slightly in overall morphology, and are thus difficult to identify with certainty. Species in Section Camissonia differ primarily in their chromosome number and breeding system - the taxa within the section comprise a set of sibling species that conservative taxonomists would lump into a few highly polymorphic species (cf. Munz 1965). *Camissonia benitensis* is most closely related to *C. contorta*, and seems to fit the catastrophic selection-edaphic endemism model of Raven (1964).

Table 1. Periodic table of species of *Camissonia* Section *Camissonia* ordered by breeding system and ploidy (from Raven 1969). Species occurring in the San Benito Mountain area are indicated by an asterisk. Taxa on the California Native Plant Society Inventory of rare plants (Smith & Berg 1988) are indicated by a box (▪). All infraspecific taxa are subspecies.

	Ploidy Level		
Breeding System	**Diploid** n=7	**Tetraploid** n=14	**Hexaploid** n=21
Self-incompatible	*kernensis kernensis*▪ *kernensis gilmanii* *campestris campestris* *campestris obispoensis*		
Self-compatible	*sierrae alticola*▪ *sierrae sierrae* *pusilla*		
Autogamous		*benitensis**,▪ *dentata dentata* *dentata littoralis* *integrifolia*▪ *lacustris* *pubens* *parvula* *strigulosa**	*contorta**

Six species of *Camissonia* are known from the San Benito Mountain region (Griffin 1975, Griffin and Yadon 1989; personal observations): *C. boothii* ssp. *decorticans, C. campestris, C. benitensis, C. strigulosa* and *C. contorta* (Section Camissonia), and *C. hirtella* (Section Holostigma). Table 2 provides a key to species of *Camissonia* for the San Benito Mountain Region. *Camissonia boothii* is easily separated from the other species of Section Camissonia by virtue of its white to pink, vespertine (evening-opening) flowers. *Camissonia campestris* is similar in general appearance to the other three species of *Camissonia* in the region, but is easily separated on the basis of breeding system (allogamous) as indicated by the ratio of anther length to stigma length at anthesis. This diurnal (day-opening) yellow flowered species is known only from the eastern base of the San Benito Mountain area, in the Panoche Valley.

Table 2. Key to species of *Camissonia* of the San Benito Mountain region.

A. Flowers white to pink, vespertine. *C. boothii* ssp. *decorticans*

AA. Flowers yellow; matinal.

- B. Mature capsules quadrangular in cross-section, the edges approximating a 90-degree angle. Plants with obvious rosettes, the basal nodes usually bearing flowers. *C. hirtella*

- BB. Mature capsule subterete to rounded in cross section. Plants without basal rosettes, the basal 2-4 nodes lacking flowers.

  - C. Petals > 3 mm long, often with a pair of basal red spots; hypanthium with some glandular hairs.

    - D. Stigma longer than longest pair of anthers at anthesis (plants outcrossing). *C. campestris*

    - DD. Stigma surrounded by and equal in length to longest pair of anthers at anthesis (plants autogamous).

      - E. Leaves serrate with obvious teeth, the blade plane, the leaf tip often bearing a minute (ca. 0.5 mm long) terminal gland; hairs of the hypanthium exclusively glandular. Plants erect, virgate. *C. contorta*

      - EE. Leaves entire of with a few minute teeth, the blade often subrevolute, the leaf tip only rarely with a terminal gland; hairs of the hypanthium of two types, glandular and stiff. Plants highly branched, the largest individuals decumbent. *C. benitensis*

  - CC. Petals < 2.5 mm long, lacking basal red spots; hypanthium strigose. *C. strigulosa*

In the immediate vicinity of San Benito Mountain, two species of *Camissonia* Section Camissonia are sympatric or parapatric with *C. benitensis* populations and thus pose problems for field identification. *Camissonia contorta* is sufficiently similar to *C. benitensis* to be of the most confusion.

Table 3 and Figures 3 & 4 provide comparison of the trio *C. benitensis, C. contorta* and *C. strigulosa*. *Camissonia strigulosa* can be easily separated from *C. benitensis* and *C. contorta* in the field, even in highly depauperate individuals, on the basis of its small flowers (petals <2.5 mm long) and densely strigose hairs of the hypanthium (Figure 3b & 3d).

Table 3. Comparative morphology of three annual species of *Camissonia* Section Camissonia occurring in the San Benito Mountain region.

	Species		
Attribute	***C. benitensis***	***C. strigulosa***	***C. contorta***
Habit	low, spreading	low, inclined	erect
Branching	regularly bifurcating	nodal proliferation	unbranched or few branches from lower nodes
Leaf Pubescence	sparse, strigose	dense, strigose	sparse, strigose
Terminal Appendage	reduced or absent	absent	well developed
Leaf Margin	subentire, subrevolute	serrate, plane	serrate, plane
Sepals at Anthesis	reflexed in pairs or individually	reflexed individually	reflexed in pairs only
Flowers	strongly matinal	largely diurnal	largely diurnal
Petal Length	3-4 mm	<2.5 mm	4-6 mm
Hypanthium Pubescence	glandular, stiff-crustose	dense, strigose	sparse, divergent
Petal Spots	2, basal or absent	absent	2, basal

Figure 3. **Scanning electron micrographs of *Camissonia* taxa. Scale bars (in microns) are shown for each frame.**

3A. *Camissonia benitensis*. Trichomes of the hypanthium. Two types of trichomes are present in this species - both types are found in other taxa, but not in combination. The encrusted, unicellular stiff hair in the foreground is less common of the two types. The bicellular soft trichomes in the background are slightly glandular.

3B. *Camissonia strigulosa*. Trichomes of the hypanthium. The strigose, encrusted hairs of this type are diagnostic of this species. Note the difference in shape from the encrusted trichomes of *C. benitensis*, particularly the narrowed base.

3C. *Camissonia benitensis*. Density of trichomes on the hypanthium. The density of trichomes in *C. benitensis* are uniform in density on the ovary, hypanthium and sepals (compare to *C. strigulosa* and *C. contorta*).

3D. *Camissonia strigulosa*. Density of trichomes on the hypanthium. The density of trichomes in *C. strigulosa* are much greater on the ovary-hypanthium junction is much greater than elsewhere on the flower.

3E. *Camissonia contorta*. Density of trichomes on the hypanthium. The density of trichomes on the hypanthium-ovary junction is greater than elsewhere on the flower.

3F. *Camissonia contorta*. Trichomes on the hypanthium. The type of trichome on the hypanthium is uniformly a bicellular, glandular type.

Trichome key to *Camissonia* species

A. Trichomes of the hypanthium of two types, glandular and encrusted. *C. benitensis*

AA. Trichomes of the hypanthium uniformly of a single type.

- B. Hypanthium trichomes unicellular, encrusted, appressed against the epidermis. *C. strigulosa*

- BB. Hypanthium trichomes bicellular, smooth, glandular, divergent from the epidermis. *C. contorta*.

Figure 3. Scanning electron micrographs of *Camissonia* species. See legend previous page.

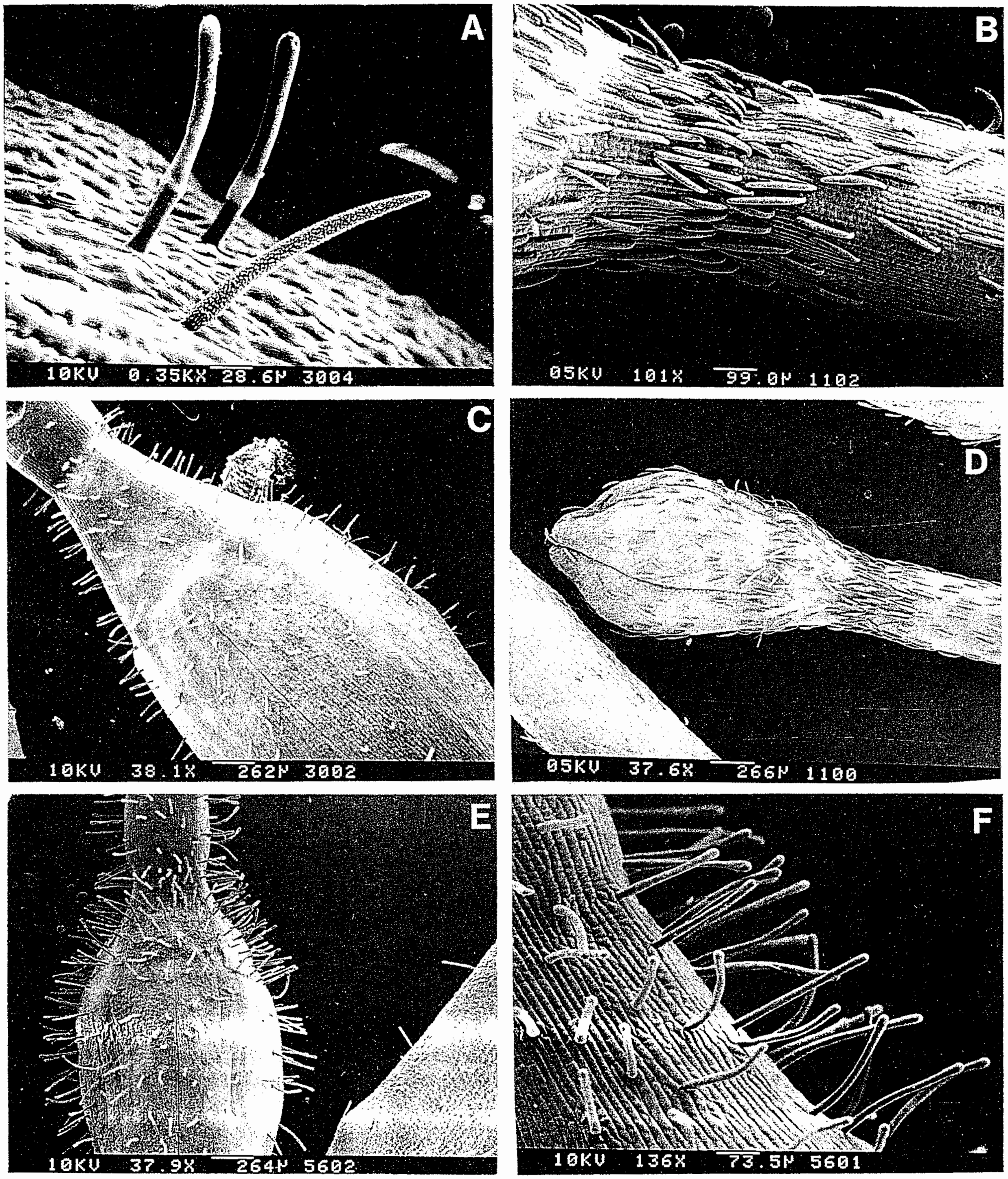


Figure 4. Scanning electron micrographs of *Camissonia* taxa. Scale bars (in microns) are shown for each frame.

4A. *Camissonia contorta*. Terminal leaf appendage. The terminal leaf appendages fo *C. contorta* are large and well developed in this species. These structures superfically resemble elisomes - these structures consist of groups of cells with an attenuated base. These structures are achlorophyllous and anthocyanic - their color differing markedly from the leaves.

4B. *Camissonia benitensis*. Terminal leaf appendage. Eliasomes are poorly developed in *C. benitensis*, being absent from most leaves.

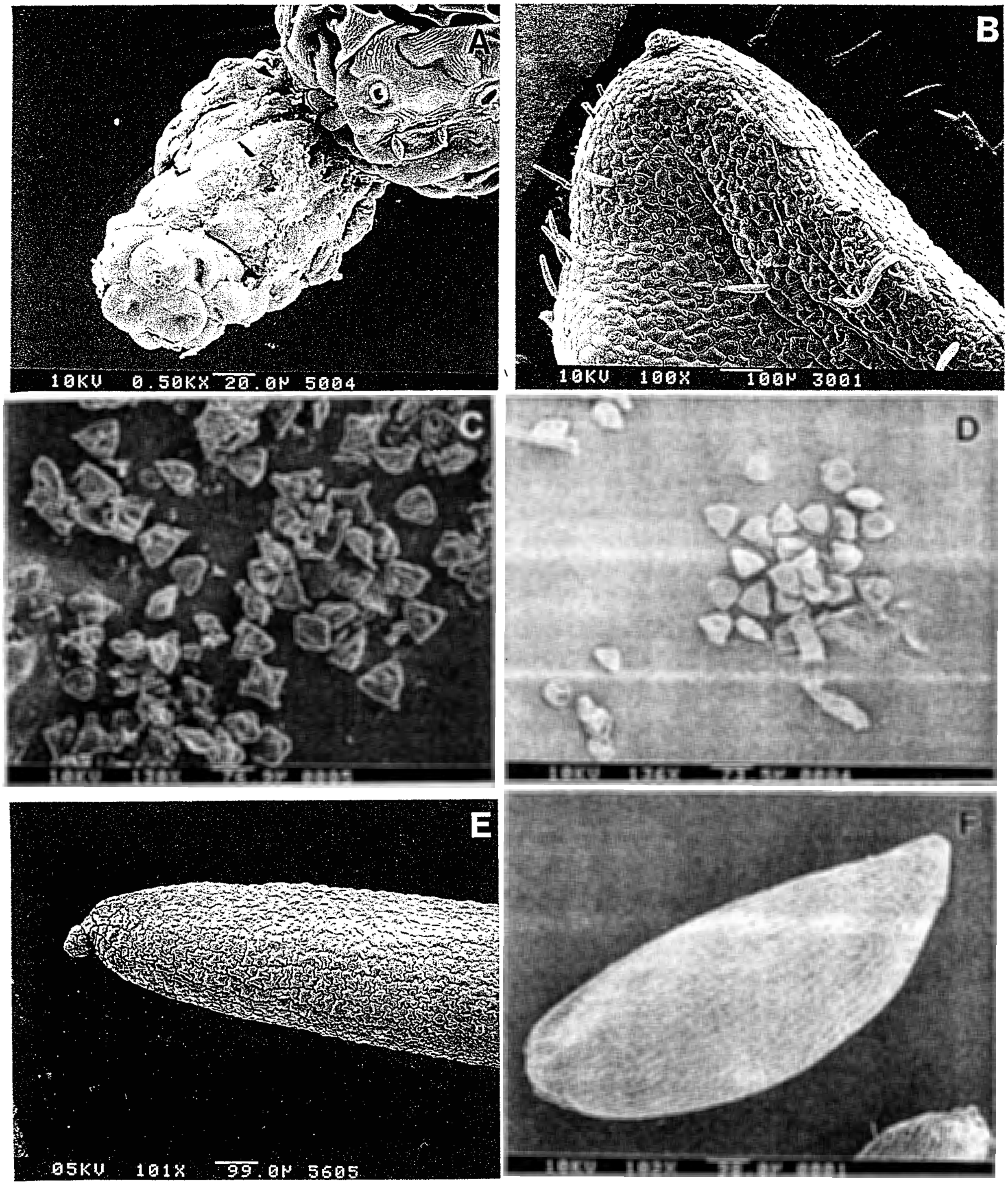
4C. *Camissonia contorta*. Pollen. The majority of pollen grains in *C. contotra* are tetracolpate.

4D. *Camissonia beitensis*. Pollen. The pollen grains in *C. benitensis* are uniformly tricolpate.

4E. *Camissonia strigulosa*. Leaf tip. Terminal elisomes are found on most leaves of *C. strigulosa*, and are fully developed.

4F. *Camissonia benitensis*. Seeds.

Figure 4. Scanning electron micrographs of *Camissonia* species. See legend previous page.



Camissonia benitensis and *C. contorta* are sufficiently alike that they are difficult to distinguish in the field. The morphological characters that can be used to distinguish the two species overlap in frequency of occurrence or size. In some cases, very depauperate individuals can not be unequivocally assigned to either taxon without knowledge of chromosome number, pollen, or microscopic insepction of trichomes. As indicated by Raven (1969), the pollen of the hexaploid species *C. contorta* (n = 21) is predominately 4-pored (Fig. 4c), while pollen of the tetraploid species *C. benitensis* and *C. strigulosa* is predominately 3-pored (Fig. 4d).

In overall growth habit, large individuals of *C. benitensis* are highly branched and decumbent (Appendix A), whereas large individuals of *C. contorta* are unbranched above or a few-branched from the base, and are upright. These growth-form differences so apparent in cultivation fail to appear in small, depauperate plants. The most consistent field characters that can be used to separate *C. benitensis* and *C. contorta* are degree of leaf serration (serrate in *contorta*, subentire in *benitensis*), leaf margin and presentation (plane in *contorta* and subrevolute in *benitensis*), development of a terminal leaf eliasome (large and frequently present in *contorta*, small and rarely present in *benitensis*), and hypanthium hairs (glandular in *contorta*, both glandular and crustose in *benitensis*).

The key to species of Section Camissonia in Raven (1969) has one unfortunate deficiency: attempting to separate taxa on the basis of sepal adherence at anthesis. Raven (1969) reports the sepals remain adherent in pairs at anthesis in *C. benitensis*, a condition that is far from constant in the field or in cultivation. At best, only sepal adherence in a <u>population</u> of plants can be used for identification of *C. benitensis*.

Several species of *Camissonia* are sufficiently rare to be considered threatened or endangered by the California Native Plant Society (Smith and Berg 1988). Of the four other rare *Camissonia* taxa (cf. Table 1), *C. benitensis* is the most restricted geographically, and is the only substrate endemic of the group.

***Populations of* C. benitensis** - Figure 5 provides a topographic map showing the location of known populations of *C. benitensis*. Table 4 is a compilation of population size estimates or census data obtained by various botanists over the past decade, including the data derived from detailed studies reported in this document.

At the outset of this contract research, *C. benitensis* had been reported from 9 populations in the Clear Creek region. Research determined that one population was comprised solely by *C. contorta*, reducing the number of known populations to 8. Subsequently, BLM authorized a contract modification to conduct additional field searches for *C. benitensis* populations in 1989, resulting in documentation of 6 additional populations, raising the number of known populations to 13.

Year to year variability in plant numbers at the various *C. benitensis* populations is extreme. As can be seen from Table 4, 1988 was a 'good' year at all of the populations then known. By contrast, in 1987, 1989 and 1990 no plants were found at several of sites.

Since Population 7 and Population 1C failed to support plants in a 'good' year, it is therefore appropriate to consider *C. benitensis* to be extirpated from these sites.

In the most recent 'good' year for *C. benitensis*, several of the larger populations consisted of thousands of plants, but this is by no means an indication of the any long-term increasing trend in population size, nor in the degree of vulnerability of a population. Prior to the work reported in this paper, population sizes were subjectively estimated but not quantified. Even the density-based population estimates reported herein are not precise because of small sample sizes (i.e., the variation in density was large, and hence exhaustive sampling would be required to reduce error variance).

Table 5 provides data on density at populations of *C. benitensis* that were sampled by transect-quadrat methods in 1988. Absolute density at Population 5 was higher than at

Figure 5. Map showing the location of populations of *Camissonia* taxa in the San Benito Mountain Region.

0 1/2 1 mile
Scale

Source: U.S.G.S. 71/2 Quadrangles

IDRIA (1969)
HESPERDAM PEAK (1969)
SANTA RITA PEAK (1984)

Prepared by BioSystems Analysis, Inc.

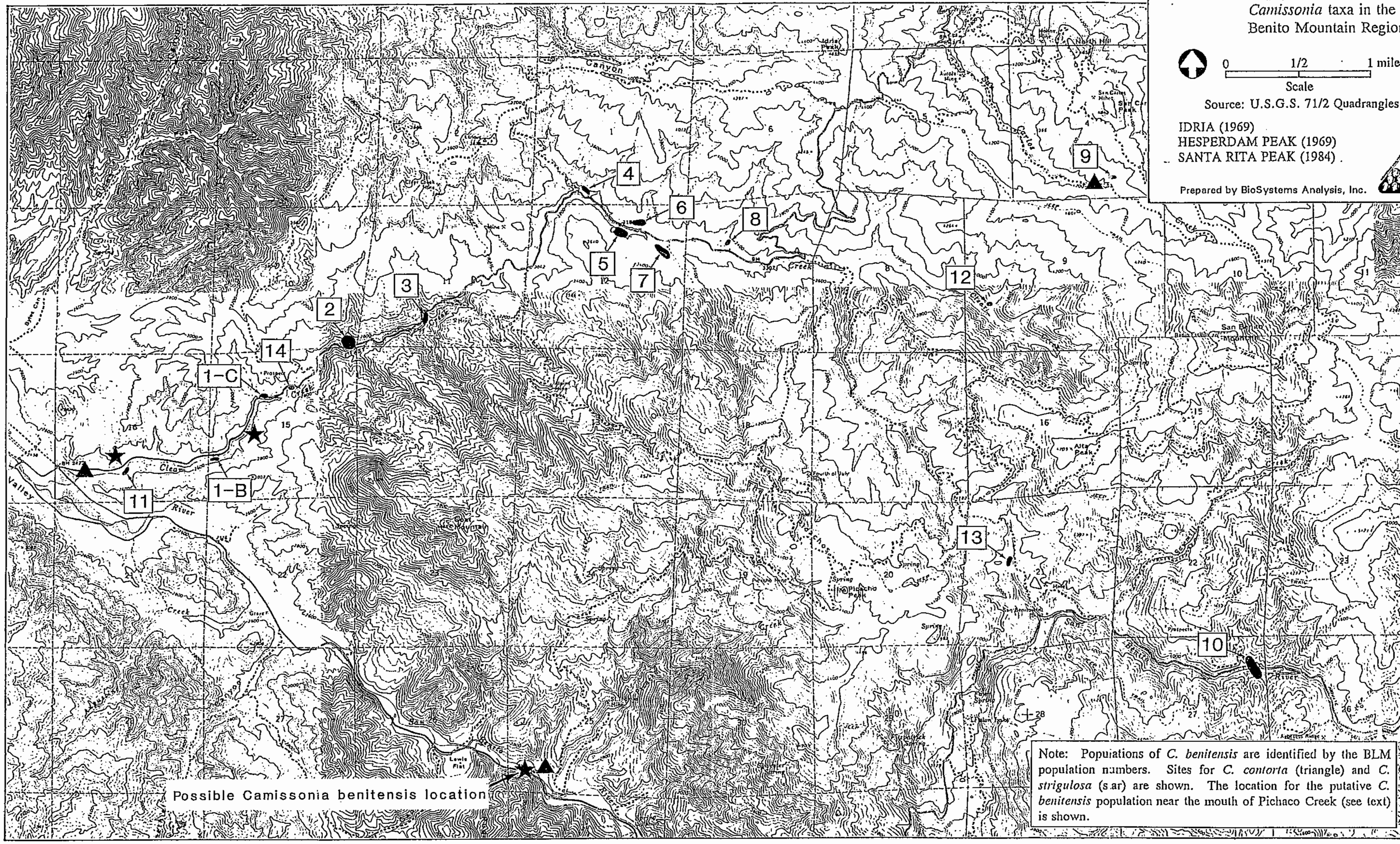


Table 4. Summary of population trends for *Camissonia* populations in the Clear Creek Management Area. Data for years prior to 1987 are rough approximations of population size (Kiguchi 1983, 1984, 1985; Kiguchi and Florence 1986). Standard error of the mean is given for those populations where density data were used to derive size estimates. Other values represent direct counts.

Site	1979	1980	1983	1984	1985	1986	1987	1988	1989	1990
Camissonia contorta										
1	-	-	50-100	10-50	1500	100-200	186	970	4	0
Camissonia strigulosa										
1C	-	-	-	-	-	<50	0	3,360±1,023	1,200	1000
11	-	-	-	-	-	-	-	-	430	250
Camissonia benitensis										
1B	-	-	-	-	-	-	-	18,691±3,763	921	84
1C	-	-	-	-	-	<50	0	0	0	0
2	-	-	50-100	4	80-90	100	0	1,540	0	0
3	-	-	10-50	1	65	50-100	0	672±343	0	0
4	-	200-300	10-50	2	158	<50	2	367±161	27	0
5	-	-	100-1,000	<20	10,000±	2,500±	112	133,507±22,173	357	44
6	-	-	10-50	21	1,900	100±	1	5,976±1,291	0	0
7	-	-	1-10	0	0	0	0	0	0	0
8	-	-	50-100	0	10	15	0	27	0	0
9	<50	-	100-1,000	10-50	1,400	500-1,000	149	4,398±2,690	247	12
10	-	-	-	-	-	-	-	-	102	0
11	-	-	-	-	-	-	-	-	16	1
12	-	-	-	-	-	-	-	-	3	0
13	-	-	-	-	-	-	-	-	21	0
14	-	-	-	-	-	-	-	-	9	5
Total[1]	<50	200-300	381-2460	68-148	15113	3565-4225	264	169,508±32,414	1703	146
Rainfall[2]	-	-	225%	75%	85%	140%	60%	80%	55%	40%

1 for *C. benitensis* populations only.
2 Rainfall records from California Cooperative Snow Survey, Bulletin No. 120.

Table 5. Density of *Camissonia benitensis* at selected populations on 22 May 1988. Density was determined by quadrat sampling. Values given are plants/m^2. Coefficient of variation is expressed as a proportion of the mean density.

Site	Density (No./m^2)	Coef. Var.	Range
Population 1B	29.2	2.26	0-390
Population 4	17.2	1.22	0-430
Population 5	34.9	2.39	0-620
Population 6	15.0	2.08	0-220
Population 9	7.6	1.52	0-393

other populations, and correlates with estimates of population size (cf. Table 4).

The 1988 population estimates for some populations exhibit high variance, but the magnitude of the differences between populations are sufficient to judge their relative size. Population 5 by far supports the largest number of *C. benitensis* individuals, while the newly rediscovered Population 1B is the second largest population. Both of these populations support several thousands of individuals in 'good' years and several hundreds of individuals in 'bad' years. Population 2, Population 3, Population 4, Population 9 and Population 10 are of roughly equivalent importance, consisting of several hundred individuals in 'good' years. The remaining populations support relatively few individuals in 'good' years and generally fail to appear in 'bad' years.

Prior to 1983, the only information on the status of *C. benitensis* populations consists of anecdotal observations (Griffin 1978, Griffin pers. comm.). Annual, non-quantitative monitoring of the status of *Camissonia benitensis* populations was began by BLM in 1983 (Kiguchi 1983, 1984, 1985, Kiguchi and Florence 1986). The observations for 1983 consist of class estimates of the number of individuals in each population (the class-intervals used were as delimited on the California Natural Diversity Data Base field survey form - i.e., 1-10, 10-50, 50-100, 100-1000 plants, et cetera). Beginning with the 1984 annual monitoring, an attempt was begun to estimate the number of individuals as an integer (continuous) variable, rather than as a class variable. The available data suggest that 10-15 years of additional observation may be necessary to determine actual trends (increase or decrease) in population sizes.

In 1984, when the population consisted of relatively few plants, actual census of numbers of individuals was conducted at some populations (Kiguchi pers. comm.). The 1984 estimate of 68-148 is probably more accurate than the estimates of ±15,113 and 3645-4115 for 1985 and 1986 respectively.

Overall, there is a fairly good correspondence between rainfall and population sizes for *C. benitensis*. Populations are small, or do not appear, in dry years. In the only year of this study with moderate rainfall (ca. 80% of average), the numbers of plants was three orders of magnitude greater than in the dryest years! The degree of correlation between rainfall and population size is not strict, however (cf. Table 4). In 1986, a year with well above-average precipitation, the population size was reduced compared to 1985 and 1988, two years with slightly lower than average precipitation.

Although the available census data is insufficient (and inappropriate) to preform a correlation analysis, the largest observed population sizes have occurred in years with 80%-85% of average rainfall. This observation suggests that both extremely wet and extremely dry years will result in reduced germination or density of *C. benitensis*. In very wet years, *C. benitensis* may suffer mortality resulting from muddy conditions during the seedling phase of its life-cycle.

Geographic Distribution - field surveys conduced as part of this study have extended the known range of *C. benitensis* some 10 miles to the southeast of Clear Creek into the upper San Benito River watershed. Populations are known from the Clear Creek watershed, the upper San Carlos Creek watershed, and the upper San Benito River watershed. By far, the largest concentration of plants and populations is in lower Clear Creek (Figure 4), where 11 populations are situated. The four remaining populations are geographically isolated from one-another and the main bulk of the populations in lower Clear Creek. Within the Clear Creek canyon, the occurrence of larger populations in the lower canyon is purely a correlation with physiography (i.e., presence of alluvial terraces), rather than being a function of other factors such as temperature, cold air drainage, or streamflow.

Camissonia benitensis is restricted to flat to gently sloping alluvial serpentine terraces (see page 36). Suitable terrace habitat that superficially appears similar to that occupied by *C. benitensis* populations occurs in the San Benito River near Lewis Flat, and in the upper White Creek watershed (Fresno County). Survey of these areas in 1989 failed to confirm populations, but additional surveys in 'good' years will be necessary to determine if these sites lack populations of *C. benitensis*.

In the vicinity of Lewis Flat (near the mouth of Rudolf Creek), a single, tiny plant with the pubescence and leaf characteristics of *C. benitensis* was collected from a site supporting populations of *C. contorta* and *C. strigulosa* (2 June 1988, *D.W. Taylor 10377 and J.R. Griffin* (JEPS). Since plants did not appear at this site in 1989 nor 1990, confirmation of the size of the *C. benitensis* population at this location was not possible. Observations of this site in a 'good' year will be required to corroborate *C. benitensis* at this site, to determine the extent of the population, and to determine the relative abundance of the three *Camissonia* taxa present.

Population Narratives - population numbers utilized in this section correspond to those employed in previous BLM reports to the California Native Diversity Data Base. Table 6 summarizes salient history and management status features of the known populations of *C. benitensis*.

Population 1

Specimens Known: 19 April 1988, *D.W. Taylor 9553* (BioSystems herbarium); 22 April 1988, *D.W. Taylor 9568* (BioSystems herbarium); 13 May 1988; *D.W. Taylor 9629* (UC, MO BioSystems herbarium); garden grown plants (from Aptos, CA), 19 June 1989, *D.W. Taylor 10389* (JEPS, CAS, DAV, RSA, MO, NY, BioSystems herbarium).

Table 6. History of status of *Camissonia benitensis* populations.

Population	Monitoring Photos Began	Site Fenced	ORV Tracks Within Site 1987	1988	1989	1990	Vegetation Change* Within Exclosure 1980-1990
1B	1988	1987	-	No	Yes	Yes	No photos
1C	none	no	Yes	Yes	Yes	Yes	No photos
2	?	1985	Yes	Yes	Yes	Yes	No photos
3	1980	1981	Yes	Yes	No	Yes	No photos
4	1980	1981	No	No	No	No	Increased shrub cover
5	1980	1981	No	No	Yes	No	Increased shrub and herb cover
6	1980	1985	Yes	Yes	Yes	Yes	Increased shrub cover
7	?	1985	No	Yes	Yes	Yes	Increased shrub cover
8	?	1985	No	No	No	No	No photos
9	1978	1981	No	No	No	No	Increased Shrub and herb cover
10	none	no	-	-	Yes	Yes	-
11	none	no	-	-	Yes	Yes	-
12	none	no	-	-	Yes	Yes	-
13	none	no	-	-	Yes	Yes	-
14	none	no	-	-	No	No	-

* as observed on BLM photographs, cf. Figure 7

This population consists of only *C. contorta*, rather than *C. benitensis* as was reported in BLM reports prior to 1984; Kiguchi (1985) and Griffin (pers. comm) had suspected the identity of plants comprising this population.

The population is situated on the margin of the broad outwash plain of Clear Creek at its confluence with the San Benito River. Although located geographically outside the confines of the serpentine body comprising San Benito Mountain, substrates and soils of this site are largely composed of serpentine derived alluvium.

The site is sparsely wooded by a *Pinus sabiniana* canopy of ca. 10 percent cover. Other woody vegetation is notably absent, save for isolated clones of *Salix breweri* along the margin of a narrow riparian strip bordering active channel of the creek (comprising no more than ca. 10 percent of the site). The floodplain, upon which *Camissonia contorta* grows, is sparsely vegetated by annual herbs which collectively cover no more than 30 percent of the ground surface.

Population 1B

Specimens Known: 13 May 1988, *D.W. Taylor 9636* (JEPS); 19 April 1960, *P.H. Raven 15094* (DS!).

Previous to its rediscovery in 1988, population 1B was undocumented in recent BLM records (Kiguchi 1983 et seq., Kiguchi and Florence 1986) and was assumed extirpated (USFWS 1988). Rather than being extirpated, it had simply managed to slip from the collective botanical memory on the San Benito flora. In 1988, a large population of *C. benitensis* was observed about 1.7 miles east of the Hernandez Road junction on the Clear Creek road. This location corresponds exactly to the location a population of *C. benitensis* (indicated by a circle 0.4 miles in diameter) on topographic maps in the rare plant records of the CNPS (see Smith and Berg 1988, for a history of the nature of CNPS population records). This site is closely proximate to the "1.8 miles from Hernandez" station observed by Raven in 1960 (Raven 1969) and should be considered to represent the same location as the Raven collection (P.H. Raven #15094 DS!). Griffin (1978) collected *C. contorta* just a few hundred meters downstream from this site in 1978 (J.R. Griffin #4077 19 April 1978 MO; #4129, 25 May 1978; fide Raven), but no recent observation of *C. benitensis* at this site can be confirmed (Griffin pers. comm, Kiguchi pers. comm). In BLM records, this site was given the population designation 1B by Kiguchi (1986) in order to differentiate it from nearby Population 1C (which was documented for the first time in that year). No *Camissonia* taxa were observed at Population 1B by Kiguchi (1983 et seg.). No plants were observed in the vicinity of the site in 1987. Judging from the vigor and density of *Camissonia* individuals at this site in 1988, it would not be at all unlikely that plants were indeed present here in 1987 and they escaped detection.

Population 1B is situated on a alluvial terrace adjacent to the active channel of Clear Creek. This terrace has been eroded by the creek on its northern flank, being bounded by a steep bank 3-4 feet above the floor of the channel. The surface of this terrace is covered with a thin layer of fine sand and gravel alluvium, but recent floods have apparently not inundated the site. Woody vegetation on this terrace is moderately dense, with a woodland canopy of ca. 30 percent cover, principally *Pinus sabiniana*, with a few individuals of *Quercus douglasii* and *Q. wislizenii*. *Arctostaphylos glauca* and *Quercus durata* form a sparse (ca. 10 percent cover) shrub canopy. The population occupies an area of ca. 900 m^2.

Evidence of past ORV-disturbance has been visible at this site in the past two years. The population is traversed by a narrow, indistinct roadbed that serves as an access road along a PG&E powerline. This roadbed showed no evidence of traffic prior to 1989, and probably not for several years before that. By chance, the population is enclosed by fencing that was recently erected (fall of 1987) by BLM.

Population 1C

Specimens Known: None.

Plants of *Camissonia* Section Camissonia were first observed at this site in 1986 (Kiguchi and Florence 1986). *Camissonia benitensis* has not been observed at this site since then, and it is therefore appropriate to conclude that this population is extirpated.

This site is located on a toe (bottom) slope adjacent to the channel of Clear Creek. Plants of *C. benitensis* were reportedly observed growing in small alluvial sand deposits derived from serpentine upstream of this site, which is located on the boundary of the main serpentine body. Most of the site has been heavily disturbed from vehicle traffic during the 1987-1990 study period. The site has been used as a campsite, and is unprotected by fencing. This population has undoubtedly been lost due to continued heavy disturbance.

Nearby to Population 1C, a population of *C. strigulosa* plants grows in a small but dense colony in an area of ca. 15 m^2 on the margin of openings in *Ceanothus cuneatus* and *Quercus durata* patches. *Camissonia strigulosa* plants were most dense on a strip ca. 1 meter wide on the outer periphery of the shrub crowns (much in the manner of the grass-free zone bordering many chaparral shrubs). Density of *C. strigulosa* was much less in the dense annual grass (principally *Bromus rubens*, *B. diandrus* and *Avena barbata*) encircling the bare zone bordering the shrubs.

Population 2

Specimens Known: None.

Previous to 1988, this population was estimated to number less than 100 individuals. In previous years, Kiguchi (1983 et seq., Kiguchi and Florence 1986) had noted small numbers of plants on both sides and immediately adjacent to Clear Creek road (which bisects the population). In 1987, *C. benitensis* did very poorly at this site - no plants reached flowering due to drought. Consequently, it was not possible to ascertain the limits of this population.

In 1988, plants were observed ca. 60 m uphill from where the limit of the population had been previously documented. Distribution of individuals at this population in 1988 is of interest: below the Clear Creek road, 16 relatively small were observed plants in an area of ca. 20 m^2. Immediately on the uphill side of the road, adjacent to the fence, another 5 plants occurred in an area of ca. 30 m^2. Collectively, this number of plants is of the same magnitude as the previous population estimates for the population. However, ca. 1540 plants occurred in a third colony (occupying an area of ca. 140 m^2) some distance uphill. This observation leads to the question whether the largest uphill segment of the population had been observed in previous monitoring.

The Clear Creek road roughly bisects this population. Given the level of road construction disturbance at this site, the pristine boundary of suitable habitat at this site is difficult to determine.

Population 3

Specimens Known: None.

Relatively few individuals of *C. benitensis* have been observed at this site in years past, even in 'good' years. In 1988, ca. 672 plants occurred at this site, widely dispersed over ca. 400 m^2. In 1983, plants at this site were observed primarily at the northern (upstream) end of the exclosure. In later years, the original wire-fence exclosure was extended south along the creek with an iron-pipe fence. Since 1987, plants have grown only within the annexed portion. Possibly, the brush has become too dense for the site to support *C. benitensis* in the original, northern portion of the exclosure.

Population 4

Specimens Known: None.

This population was first noticed in 1973 (Griffin 1977). The population consisted of ca. 367 plants in 1988. No plants were observed at this site in 1987, 27 plants in 1989, and none in 1990. In the past, *C. benitensis* grew mainly on the western (downstream) portion of this terrace (J. Griffin, pers. comm.). In 1988, most of the population occurred on the easter (upstream) margin of the terrace, in proximity to dense brush and overtopping *Pinus sabiniana* canopy.

This site has been subject to soil surface manipulation - BLM district office personnel, in an attempt to 'rehabilitate' compacted soil on this site, used a harrow to break up the soil in ca. 1979 (Figure 6). Disking marks have persisted to this date.

Figure 6. Photograph of *Camissonia benitensis* population 4, showing evidence of soil surface disruption from mechanical harrowing undertaken by BLM. Note the circular pattern of ridges surrounding the *Arctostaphylos glauca* shrub in the foreground (Photograph by L. Kiguchi, 6 May 1985).

Population 5

Specimens Known: 19 April 1988, *D.W. Taylor 9552* (JEPS); garden grown plants (from Aptos, CA), 10 June 1989, *D.W. Taylor 10390* (JEPS, CAS, RSA, MO, NY, DAV, BioSystems herbarium); 19 April 1960, *P.H. Raven 15084* (DS!, US); 25 May 1978, *J.R. Griffin 4116, 4118* (MO).

This large populations (many thousands of plants) is located on a large, gently inclined terrace adjacent to Clear Creek. The estimate of ca. 130,000 plants at this site in 1988 (derived from density estimates obtained by quadrat sampling) is indicative of the overall magnitude of this population - the largest known. Although 1988 may represent the best year yet on record for *C. benitensis* at this site, it is also very likely that past estimates of population size at this site have likely been far too low.

The overall size of the population at this site is on the order of 0.5 acre. This site was subject to camping and ORV disturbance prior to 1980, when it was readily accessible by vehicle. Four sets of fire rings indicate the degree of soil compaction disturbance that must have been experienced at this population. A conspicuous motorcycle trail winds through the population, and is still evident nearly a decade after being fenced. Figure 7 provides comparison photographs of this site taken in 1980 and 1989.

This site, collectively with Population 6, corresponds roughly to the type locality as given by Raven (1969) and on the type specimen label information.

Population 6

Specimens Known: 22 April 1988, *D.W. Taylor* 9579 (JEPS).

This population occurs on a elongate terrace paralleling the Clear Creek road directly opposite (north) from Population 5. The population is bisected by a major ORV trail. *Camissonia benitensis* plants occur in both the western (downstream) and eastern (upstream) exclosures at this site. In 1988, plants grew densely on the fringes of this roadway outside the exclosure fencing. In 1989 and 1990, plants in this portion of the population failed to appear, the site having been heavily disturbed by ORV traffic in the intervening period.

The site supports moderately dense serpentine chaparral, with woody vegetation density decreasing to the east within the population. Evidence of past camping is present in the easternmost portion of the population.

Read notes on pg 66

Figure 7. Photographs of *Camissonia benitensis* population 5 showing vegetation change over a 10 year period (Photograph 7A by D. Lehman, May 1980; 6B 6 June 1990). Note the increased size and vigor of *Ceanothus cuneatus* shrubs in background (arrow).

Population 7

Specimens Known: None.

A small colony of *C. benitensis* was observed at this site in 1983, but no plants have been observed at this site in the subsequent 7 years. The occurrence is situated on a large, gently sloping terrace adjacent to Clear Creek. The site is bounded on the side paralleled by the creek by a welded-pipe fence. The terrace is still accessible to ORV's from uphill. ORV tracks have been observed within the site in 3 of the past 4 years.

Camissonia benitensis should be presumed extirpated from this site. The area of the population was mistakenly sprayed with a soil erosion tackifier in 1986. The tackifier was subsequently hand removed by scraping and raking. It is unknown if this treatment had any relation to the extirpation of *C. benitensis* from the site, but any removal of top-soil may have resulted in loss of seed reserves. This site should be considered a potential for reintroduction of *C. benitensis*.

This site is a part of a large serpentine terrace system flanking both sides of Clear Creek. The terrace supporting Population 7 is located at the base of a moderate slope. The terrace surface is bordered by dense serpentine chaparral dominated by *Quercus durata*.

Population 8

Specimens Known: None.

Very few plants have been observed at this site, which is located on a small terrace adjacent to Clear Creek, opposite the road at BLM Staging Area 5. The size and perimeter of the population in 1988 was consistent with those reported in years past. This site is bounded on one side by a woven-wire fence. Vegetation at this site is a dense serpentine chaparral of *Arctostaphylos glauca* and *Quercus durata*. ORV use of this site was not observed during the past 4 years, principally due to the dense brush flanking the terrace that renders it inaccessible.

Population 9

Specimens Known: 13 May 1989, *D.W. Taylor 10354* (JEPS); 2 June 1989, *D.W. Taylor 10374* (JEPS, BioSystems herbarium); 2 June 1973, *J.R. Griffin 3542* (MO); 26 May 1978, *J.R. Griffin 4132* (MO).

This population was first noticed in 1973 (Griffin 1977), and is the only population of *C. benitensis* known from the San Carlos Creek watershed. Two species of *Camissonia* are parapatric at this site: *C. contorta* grows mainly in an herb rich opening in serpentine chaparral on the far westerly margin of the exclosure bounding this site, while *C. benitensis* occurs in the interior of exclosure and the nearby margin of *Quercus durata* clumps.

This population is located within the San Benito Mountain Natural area. Between the time the population was first documented, in 1973, and 1979 when fencing was erected around the site, ORV disturbance of the site was particularly heavy. A 1978 photograph of the site shows many motorcycle tracks and little herbaceous plant cover. A similar view of the site today (Figure 2) shows abundant and diverse herb cover.

Population 10

Specimens Known: 3 May 1989, *D.W. Taylor et. al.* 10267 (JEPS).

This population was first located in 1989, and is one of two populations known from the upper San Benito River. Two colonies or subpopulations of this population occur, separated by the bed of the San Benito River. The site of this population is unfenced and situated proximal to a moderately used motorcycle trail. Construction of the San Benito river roadway cast fill on the alluvial terrace supporting the northerly population.

Population 11

Specimens Known: None.

This population is the sole population of *C. benitensis* located on private land (at this writing, the site is being considered for BLM acquisition). The site is a recent alluvial terrace deposit, and was probably deposited in the last major floods (1982 or 1986?). The surface substrate is fine, raw serpentine sand. Plants grow at this site only in a narrow band adjacent to shading *Pinus sabiniana* bordering the southern edge of the population. The center of this terrace is remarkably devoid of annual plants, possibly owing to the putative youth of the alluvial deposit.

Population 12

Specimens Known: None.

In 1989, three plants of *C. benitensis* were observed in the upper Clear Creek drainage, fully two miles upstream from previously documented occurrences for the species. Plants failed to appear at this site in 1990 (a drought year), so the exact extent of this population could not be determined. The upper Clear Creek watershed in the vicinity of this population has several large alluvial terraces which are suitable *C. benitensis* habitat. This site is presently unfenced and subject to heavy and extensive ORV activity.

Population 13

Specimens Known: None.

This population is located on a small perennial tributary of San Benito River near the San Benito Mill Site. The population was first documented in 1989. Plants were observed growing in a ca. 200 square-meter area in 1989. The area is not fenced, and is subject to diffuse ORV use. A major motorcycle trail traverses the northern (upstream) margin of the population. The vegetation at this site is dissimilar from that of most other *C. benitensis* populations, being dominated by *Arctostaphylos pungens* and *Pinus coulteri*. Surficial substrate at this population is also different from that of many other sites: the population is located in an area with gravelly to rocky soils (Figure 18).

Population 14

Specimens Known: None.

This population is located on a landslide deposit adjacent to Clear Creek, below the county road. The site where *C. benitensis* plants grow is small - ca. 10 square meters total area. A portion of the site is being eroded by discharge from a nearby culvert draining water away from the Clear Creek road. The area of the population is bisected by an old, abandoned roadbed. The site is unfenced, but is not accessible to ORV use owing to the steep banks of the creek.

HABITAT CHARACTERISTICS

Camissonia benitensis is restricted to serpentine soils in the general vicinity of San Benito Mountain. Although the serpentine flora of the South Coast Ranges is rich in endemic species (Kruckeberg 1987), *Camissonia benitensis* the sole taxon endemic to San Benito Mountain. Kruckeberg (1987) lists 37 taxa endemic to serpentine in the South Coast Ranges Several other regional serpentine endemics, including *Layia discoidea*, *Monardella benitensis*, *Streptanthus insignis* ssp. *insignis*, *Allium howellii* var. *sanbenitense* and *Fritillaria viridea*, occur at one or more adjacent serpentine areas in the South Coast Ranges (Howett & Howell 1964, 1973; Griffin and Yadon 1989; Hoover 1969; Sharsmith 1945).

San Benito Mountain is the highest peak in the inner South Coast Ranges, reaching 5,241 feet elevation. Griffin (1975) recorded a number of taxa of vascular plants occurring in the South Coast Range only on San Benito Mountain, including several taxa he hypothesized are disjunct owing to post-Pleistocene climatic change (cf. Raven 1957).

In addition to *C. benitensis*, 11 other taxa listed as rare or endangered by the California Native Plant Society (Smith and Berg 1988) occur on San Benito Mountain (Table 7).

Table 7. Rare plants potentially occurring in the San Benito Mountain region.

Species Common Name[1]	USFWS Listing[2]	State Status[3]	CNPS Status[4]	Habitat Type[5]	Distribution by County[4]	Biological Status[6]
Acanthomintha lanceolata Stata Clara thorn mint	None	None	1-1-3 List 4	quartzite scree in chaparral	ALA FRE MER MNT SBT SCL STA	Stable
Antirrhinum ovatum oval-leaved snapdragon	Cat. 2	None	3-2-3 List 1B	gypsum rich clays	KRN MNT SBT SLO	Endangered List 1B, 3-3-3
Camissonia benitensis San Benito evening-primrose	Threatened	None	3-3-3 List 1B	herb rich serpentine alluvial terraces	SBT	Endangered
Campanula exigua chaparral hairbell	None	None	1-1-3 List 4	herb rich serpentine alluvial terraces	ALA CCA SBT SCL SBT	Stable
Clarkia breweri chaparral hairbell	None	None	1-1-3 List 4	mesic serpentine forests	ALA FRE MER MNT SBT SCL STA	Stable
Fritillaria falcata talus fritillary	Cat. 2	None	2-2-3 List 1B	steep barren serpentine slopes	ALA MNT SBT SCL STA	Declining
Fritillaria viridea San Benito fritillary	Cat. 2	None	3-3-3 List 1B	shrub margins in serpentine chaparral	MNT SBT SLO	Declining
Layia discoidea rayless tidy-tips	Cat. 2	None	2-2-3 List 1B	barren serpentine slopes and terraces	FRE SBT	Declining List 1B, 3-3-3
Madia radiata showy tarplant	None	None	?-?-3 List 3	grassy flats?	CCA FRE KNG KRN MNT SBT SJQ SLO	Unknown
Monardella benitensis San Benito coyote mint	Cat. 3c	None	1-1-3 List 4	serpentine chaparral margins	MNT SBT SLO	Declining List 1B, 1-2-3
Pentachaeta exilis slender chaetopappa	Cat. 2	None	3-2-3 List 1B	herb rich chaparral margins	MNT SBT	Unknown
Quercus lobata Valley oak	None	None	1-1-3 List 4	deep alluvial soils margins	central CA	Stable
Trichosetma rubrisepalum Hernandez bluecurls	None	None	1-1-3 List 1B	serpentine alluvium near streams	MPA NAP SBT TUO	Declining List 1B, 1-2-3

Notes:
1. Nomenclature corresponds to Smith and Berg (1988).
2. Cat. 2 (Under review, insufficient information).
   Cat. 3c (Not presently threatened) (USFWS 1990).
3. Section 1904, California Fish and Game Code (March 1989 listing, CDFG 1989).
4. Smith and Berg (1988), counties abbreviated by a three-letter code.
   Lists catagorize degrees of concern as follows: List 1A: Plants Presumed Extinct in California;
   List 1B: Plants Rare, Threatened or Endangered in California and Elsewhere;
   List 3: Plants about which more information is needed - A Review List.
   List 4: Plants of Limited Distribution - A Watch List.

The R-E-D Numbers are encoded as follows:
Rarity: 1 - Rare, but found in sufficient numbers and distributed widely enough that the potential for extinction or extirpation is low at this time;
2 - occurrence confined to several populations or to one extended population;
3 - occurrence limited to one or a few highly restricted populations, or present in such small numbers that it is seldom reported.
Endangerment: 1 - not endangered; 2 - endangered in a portion of its range;
3 - endangered throughout its range.
Distribution: 1 - more or less widespread outside CA; 2 - rare outside CA; 3 - endemic to CA.
5. Smith and Berg (1988), Munz and Keck (1959).
6. Population trends relfected since publication of 5, including and recommended CNPS status changes.

Regional Climate - climatic data are generally lacking for the San Benito Mountain region. Figures 8 and 9 depict diagrams of available data from recording stations located adjacent to the San Benito Mountain Region. Figure 8 shows the seasonal march of mean monthly temperature and precipitation at Idria, located on the eastern (rain shadow) slope of San Benito Mountain. Mean annual rainfall (Dept. of Commerce 1964) averaged 60.9°F for 26 years of record. Mean annual rainfall averaged 15.86 inches at Idria. Figure 9 illustrates the seasonal march of precipitation for two recording stations on the west slope of San Benito Mountain (near Hernandez, and near Fawn Lake in the San Benito River drainage. Mean annual rainfall averaged 16.12 and 19.35 inches at these two stations, respectively.

Overall, the climatic characteristics at these stations are likely to be generally similar those in the canyon of Clear Creek - rainfall likely averages ca. 17-20 inches, snowfall is infrequent; winter minimum temperatures are ±20°F to 30°F, while summer maxima are in the 90°F to 100°F range.

Figure 8. Seasonal trend of monthly mean temperature and rainfall data for Idria, San Benito County (located in the lower San Carlos Creek drainage, in the rainshadow of San Benito Mountain).

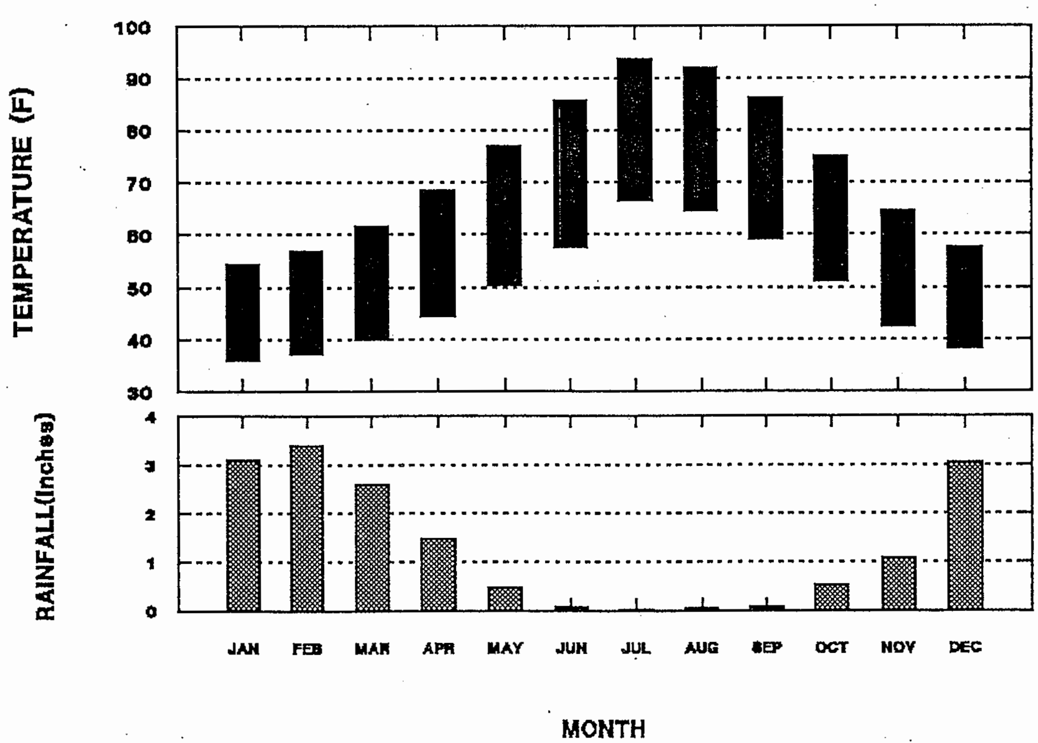
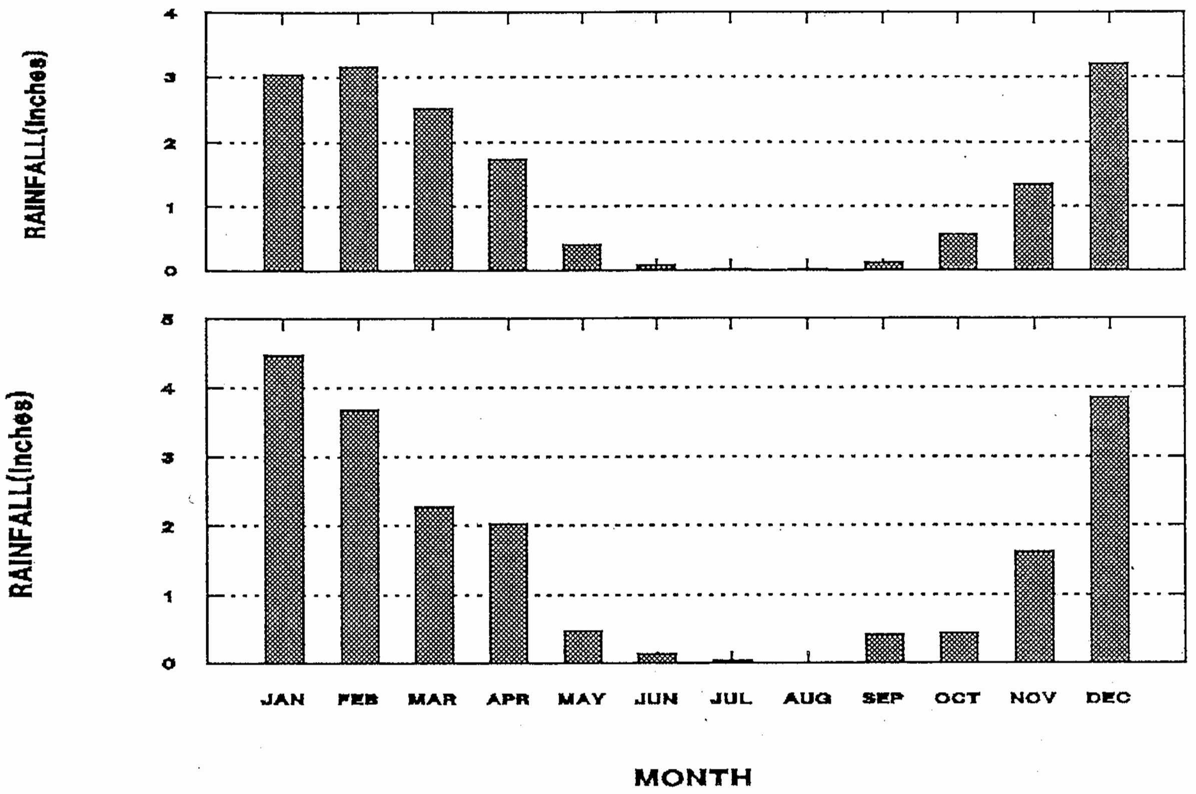


Figure 9. Seasonal trend of monthly mean rainfall for two recording stations on the west slope of San Benito Mountain: Hernandez, near the confluence of Clear Creek and the San Benito River (top diagram) and the upper San Benito River (near Fawn Lake).



Physiographic Setting - *Camissonia benitensis* occurs within only a small fraction of the San Benito Mountain serpentine landscape. In effect, the species is insular, being limited to a single limited physiographic feature - alluvial terraces without dense woody vegetation. Geomorphic and edaphic processes are the primary natural factors that govern the abundance of suitable habitat for the species. Human disturbance of terrace sites is the primary endangerment factor affecting *C. benitensis*.

The terrace sites on which *C. benitensis* grows are in general long-lived landscape features, probably persisting for many hundreds or a thousand years. Formation of these terrace sites is locally controlled by geomorphic factors, principally the configuration of minor order tributaries to Clear Creek and the overall gradient of the Clear Creek canyon. Alluvial terraces are best developed in low-gradient sections of the canyon, and only persist where they escape dissection by Clear Creek or its tributaries.

In general, the soils on these terraces are deep and well developed as compared to nearby, nearly barren serpentine slopes. Woody vegetation cover is often dense on these terraces, owing to the degree of soil development.

Table 8 summarizes salient physiographic and setting characteristics of the 15 sites that now support (or supported in the recent past) *Camissonia benitensis* populations. The majority of populations are located on flat to slightly inclined alluvial terraces bordering creeks (Clear Creek and the San Beinto River). Several populations (i.e., Population 2) extend upslope from the terrace or toe slope. Three populations occur on the floodplain of Clear Creek, and are judged to be of recent origin, probably colonizing these sites following major flooding events.

The exposure of terraces sites supporting *C. benitensis* varies. Most of the larger populations are located at the base of northerly facing slopes. These sites are similar in that they are shaded and cool throughout winter, with little chance of soil desiccation between periods of rainfall. At several of the larger populations (i.e. Population 5 and 1B), the soil surface is subject to churning from frost heaving throughout the winter. In summer, the soil surface on these sites is loose and uneven, being easily compacted by foot travel or vehicles. The smaller populations of *C. benitensis* occur on sites that are more xeric, owing to their southerly exposures, being subject to soil drying in winter.

Erosion rates from the barren serpentine slopes in the Clear Creek watershed is high. Terrace formation results when alluvial material deposited by side tributaries escapes dissection by Clear Creek itself. With time, however, some terraces suitable as *C. benitensis* habitat are eroded by Clear Creek.

Table 8. Physiography and setting characteristics of *Camissonia benitensis* populations.

Population	Site Type	Exposure	Slope Angle	Soil Origin	Soil Profile Development
1B	floodplain	northerly	flat	recent alluvium	limited
1C	floodplain	southerly	1-3°	recent alluvium	limited
2	toe slope	southerly	5-7°	residual	moderate
3	terrace	southerly	flat	residual	moderate
4	terrace	southerly	flat	residual	advanced
5	terrace	northerly	flat	residual	advanced
6	terrace	northerly	1-3°	redidual	moderate
7	terrace	northerly	flat	residual	advanced
8	terrace	southerly	flat	residual	moderate
9	terrace	southerly	flat	residual	advanced
10	terrace	southerly	flat	residual	advanced
11	floodplain	northerly	flat	recent alluvium	limited
12	terrace	southerly	flat	residual	advanced
13	toe slope	northerly	flat	residual	moderate
14	toe slope	southerly	flat	landslide deposit	moderate

Although the dynamics of terrace formation and degradation are clearly important to the long-term stability of *C. benitensis*, data on the relative rates of these processes within the watershed are absent. Certainly, ORV use of the watershed has resulted in an increase in erosion. However, field inspection does not indicate that any of the terrace sites presently occupied by *C. benitensis* have become dissected within recent time.

Vegetation Characteristics - populations of *Camissonia benitensis* share a general overall physiognomic characteristic - lack of dense, complete woody plant cover in association with a diverse flora of annual herbs. Table 10 provides a summary tabulation of vegetation composition data for sampled stands of serpentine alluvial terrace vegetation. Included in this tabulation are vegetation data from 35 alluvial terrace sites that do not support *C. benitensis*. By holding site constant, the ecological relationships that control vegetation can be contrasted against the presence or absence of *C. benitensis*, isolating species that correlate with suitable habitat for the species.

Two general patterns are indicated by the data in Table 9. First, woody plant cover on sites supporting *C. benitensis* is in general lower than non-*C. benitensis* sites, and is comprised by a lesser subset of the phanerophytic flora. *Ceanothus cuneatus* and *Eriodictyon californicum* are shrubs that are more abundant on sites with *C. benitensis* than in the landscape in general. Conversely, a number of trees and shrubs are less common on *C. benitensis* sites than elsewhere in the landscape, including *Pinus jeffreyi, Calocedrus decurrens, Quercus durata, Arctostaphylos glauca* and *Adenostoma fasciculatum*. The second general pattern is that native annual herbs occurring on sites supporting *C. benitensis* are a smaller subset of the therophytic flora than the overall serpentine landscape, but that several taxa reach their greatest abundance on *C. benitensis* sites, including *Lotus subpinnatus, Malacothrix floccifera, Eschscholzia californica, Eriogonum covilleanum, Mimulus fremontii* and *Cordylanthus rigidus*.

Table 9. Summary cover and frequency tabulation of vegetation composition on serpentine terrace sites in the San Benito Mountain region. Separate tabulations are given for sites with and without *Camissonia benitensis*. **Freq.** is the percentage of sampled stands in which a species occurred, **Cover** is the mean cover within those stands in which a species was present, and S.E. is the standard error of mean cover. Nomenclature follows Griffin & Yadon (1989).

	with *Camissonia*			without *Camissonia*		
Taxon	Freq.	Cover	S.E.	Freq.	Cover	S.E.
TREES						
Pinus sabiniana	100.0	6.38	1.57	85.4	6.75	1.04
Pinus coulteri	23.0	0.12	0.08	12.5	1.07	0.60
Juniperus californica	15.3	0.19	0.15	8.3	0.41	0.31
Calocedrus decurrens	15.3	0.42	0.38	20.8	0.91	0.33
Pinus jeffreyi	.	.	.	10.4	0.78	0.37
Quercus douglasii	.	.	.	4.6	0.25	0.22
SHRUBS						
Chrysothamnus nauseosus mohavensis	76.9	1.84	0.46	64.5	1.72	0.37
Ceanothus cuneatus	76.9	7.76	2.41	54.1	3.76	0.90
Eriodictyon californicum	69.2	2.93	0.89	45.8	1.38	0.34
Arctostaphylos glauca	69.2	5.00	1.85	70.8	7.62	1.19
Quercus durata	61.5	9.00	3.25	76.9	17.88	3.05
Adenostoma fasciculatum	53.8	3.00	1.69	39.5	4.98	1.46
Rhamnus californica tomentella	53.8	1.05	0.41	35.4	1.92	0.57
Eriodictyon tomentosum	38.4	0.96	0.45	25.0	0.46	0.16
Garrya flavescens flavescens	30.7	0.52	0.32	41.6	0.84	0.29
Lonicera subspicata	23.0	0.20	0.15	33.3	0.35	0.13
Arctostaphylos pungens	23.0	4.03	3.83	33.3	2.26	1.13
Rhamnus ilicifolia	15.3	0.19	0.15	6.2	0.24	0.20
Mahonia dictyota	15.3	0.26	0.23	16.6	1.35	0.06
Penstemon grinnellii scrophularioides	15.3	0.19	0.15	.	.	.
Quercus turbinella	15.3	0.01	0.01	.	.	.
Cercocarpus betuloides	15.3	0.16	0.15	.	.	.
Heteromeles arbutifolia	15.3	0.26	0.23	16.6	0.22	0.10
Toxicodendron diversilobum	.	.	.	8.3	0.02	0.01
Eriogonum fasciculatum	.	.	.	8.3	0.10	0.06
Yucca whipplei	.	.	.	8.3	1.14	1.04
Gutierrezia bracteata	.	.	.	8.3	0.20	0.16
Eriogonum umbellatum bahiiforme	.	.	.	6.2	0.02	0.01
Haplopappus linearifolius	.	.	.	6.2	0.02	0.02
Salix breweri	.	.	.	4.1	0.05	0.04
NATIVE HERBS						
Camissonia benitensis	100.0	0.30	0.09	.	.	.
Lotus subpinnatus	69.2	1.21	0.61	18.7	0.11	0.06
Eschscholzia californica	61.5	1.88	1.12	16.6	0.46	0.31
Eriogonum covilleanum	61.5	0.68	0.28	37.5	0.21	0.08
Mimulus fremontii	53.8	0.23	0.10	33.3	0.17	0.08
Epilobium minutum	53.8	0.30	0.16	43.7	0.02	0.07
Malacothrix floccifera	53.8	0.33	0.16	12.5	0.02	0.01
Cordylanthus rigidus	53.8	1.20	0.49	50.0	0.67	0.19
Cryptantha micromeres	46.1	0.22	0.15	12.5	0.03	0.01
Hesperolinon disjunctum	46.1	0.16	0.06	16.6	0.08	0.04
Achillea millefolium	46.1	1.11	0.43	25.0	0.33	0.13
Linanthus bicolor	46.1	0.33	0.17	12.5	0.08	0.04
Monardella benitensis	38.4	0.65	0.28	45.8	0.67	0.19
Eriogonum roseum	38.4	0.50	0.25	.	.	.

Table 9 (Continued). Summary cover and frequency tabulation of vegetation composition on serpentine terrace sites in the San Benito Mountain region.

Taxon	with *Camissonia* Freq.	Cover	S.E.	without *Camissonia* Freq.	Cover	S.E.
NATIVE HERBS (Continued)						
Linanthus pygmaeus	38.4	0.38	0.20	6.2	0.02	0.01
Cryptantha sparsiflora	30.7	0.03	0.01	6.2	0.01	0.01
Erysimum capitatum	30.7	0.06	0.03	33.3	0.54	0.02
Psoralea californica	23.0	0.13	0.08	10.4	0.03	0.02
Viola purpurea	23.0	0.05	0.02	20.8	0.13	0.07
Clarkia purpurea	23.0	0.08	0.05	10.4	0.16	0.11
Linanthus androsaceus	23.0	0.83	0.76	4.1	0.07	0.06
Eriogonum vestitum	23.0	0.15	0.08	.	.	.
Monardella douglasii	23.0	0.12	0.08	8.3	0.04	0.02
Galium porrigens	15.3	0.07	0.05	22.9	0.21	0.11
Galium andrewsii	.	.	.	22.9	0.20	0.11
Fritillaria viridea	.	.	.	8.3	0.15	0.14
Eriogonum gracile	.	.	.	6.2	0.03	0.02
Navarretia pubescens	.	.	.	8.3	0.07	0.45
Cirsium proteanum	.	.	.	14.5	0.01	0.05
Calystegia malacophylla	.	.	.	10.4	0.05	0.03
Lomatium macrocarpum	.	.	.	12.5	0.13	0.07
Rigiopappus leptocladus	.	.	.	4.1	0.05	0.04
Camissonia integrifolia	.	.	.	4.1	0.01	0.01
INTRODUCED HERBS						
Erodium cicutarium	53.8	1.43	0.55	14.5	1.63	1.26
Centaurea solstitialis	23.0	0.46	0.33	18.7	0.44	0.31
NATIVE GRAMINOIDS						
Sitanion hystrix	61.5	3.15	1.85	47.9	1.30	0.06
Vulpia microstachys	46.1	0.33	0.17	16.6	0.22	0.11
Melica californica	23.0	0.38	0.30	14.5	0.10	0.59
Poa scabrella	15.3	0.92	0.77	10.4	0.50	0.23
Bromus marginatus	15.3	0.01	0.01	12.5	0.35	0.22
Bloomeria crocea	15.3	0.04	0.03	6.2	0.02	0.01
INTRODUCED GRAMINOIDS						
Bromus rubens	61.5	1.66	0.64	50.0	1.53	0.47
Bromus tectorum	38.4	0.70	0.39	10.4	0.25	0.17
Bromus diandrus	15.3	0.16	0.15	6.2	0.01	0.01
Bromus mollis	15.3	0.69	0.49	.	.	.
Avena barbata	.	.	.	6.2	0.43	0.32

Table 10 provides a tabular ordination of the vegetation data, produced using the association analysis algorithm of Ceska & Roemer (1971). The objective of tabular ordination is to isolate groups of species with similar occurrence patterns within a vegetation array. In effect, the analysis identifies groups of species, which can be inferred to have similar ecological tolerances. Ordering of stands across the tabulation is controlled by Reciprocal Averaging Ordination (Hill 1973).

A dozen groups of species were identified in the association analysis. Unfortunately, even though there is a relatively large body of literature on serpentine habitats of California (Kruckeberg 1984), there is a generally paucity of quantitative synecological data (Griffin 1965; Kruckeberg 1969; McMillan 1956; Walker 1954) with which to contrast against the data collected in this study.

Camissonia benitensis is identified as occurring in a group (Group 10, Table 10) of 7 annual herbs (six of them native): *Lotus subpinnatus, Eschscholzia californica, Cryptantha micromeres, Erodium cicutarium, Vulpia microstachys* and *Malacothrix floccifera*. Four other species groups are located proximal in Table 10 to the group containing *C. benitensis*. Group 7 (containing *Calystegia malacophylla, Poa scabrella* et al.) species occur at Population 9 and Population 14. Species of Group 8, containing several introduced annual herbs (including *Centaurea solstitialis* and *Bromus tectorum*), occur at Population 6, Population 11 and Population 14. Species of Group 9 co-occur with *C. benitensis* only at Population 6 and Population 14. Two groups of species, Group 5 and Group 6 (Table 10) co-occur with *C. benitensis* at 9 of 14 populations. Both of these groups are comprised partly by chaparral shrubs common on both serpentine and non-serpentine substrates in California (cf. Hanes 1977), including *Ceanothus cuneatus, Adenostoma fasciculatum* and *Eriodictyon californicum* (so-called 'bodenvag', or serpentine indifferent taxa, cf. Kruckeberg 1984). Partly, however, these two groups include serpentine indicator taxa, including *Rhamnus californica* ssp. *tomentella, Garrya flavescens* and *Monardella benitensis*.

Table 10. Association table for vegetation on serpentine in the San Benito Mountain region. Arrangement of plots and species was derived by ordination analysis (Ceska and Roemer 1971) of stand data. Abundance data in this tabulation are coded using the Braun-Blanquet scale (Mueller-Dombois and Ellenberg 1974).

Species	POP*13	CLR-21	CLR-18	CLR-32	CLR-16	BEN-35	CLR-20	CLR-23	CLR-04	SAN-05	CLR-27	CLR-53	POP*04	CLR-39	CLR-56	CLR-54	CLR-13	CLR-14	CLR-17
Group 1																			
GALI ANDR	r	r	1	+	1	+	+	+		r			+			r	+		
VIOL PURP		r	+	+			1	r	r				+						
CALO DECU	1	1	2	1		1	1	+	2				1						
MAHO PINI			+	1	+			+				r	+						
PINU COLT	2					2	1		2										
PSOR CALA				+		r	r		r				+						
FRIT VIRI		r			2		r						r						
Group 2																			
MELI IMPE		r			1			+		r				r					
TOXI DIVE		+								+				r					
BROM DIAN														r					
MADI EXIG		r																	
Group 3																			
ERYS CAPI			r				+	r		r	+	r	r	r	r	r			
ERIO CONF										1	1	+			r	1			
ACHE MILL			+	+			r	+		1			+		+				
Group 4																			
HESP DISJ				r									+			+			
MELI CALI												+				+			
ALIU FIMB				+							+		+			+			
BLOM CROC																			
Group 5																			
MONO BENE		+			1		+	r	r		1	+	1	r	+	1	+	+	
ADEN FASC										1			+	2	+	2	1	+	2
GARR FLAX			1		+		r	+		1			1	+		+	+		+
RHAM CALI	1				1	2	r	2	+	2			+		1			+	
Group 6																			
CEAN CUNE						+			1	2			1	+	2				
CORD RIGI			1	1				+		+	+		+	+	+	1			
ERIO CALI						r			r	+		+	r	1	+	1	+		+
Group 7																			
CALY MALA																			
POA SCAB																			
LUPI RUBR																			
NAVA MITI																			
LL HETE																			
Group 8																			
CENT SOLS														r					
BROM MOLL																			
CLAR PURP								r											
BROM TECT														r					
LOMA MACR																			
Group 9																			
LINA ANDR								r											
JUNI CALI																			
AVEN BARB																			
THYS CURV																			
CAST FOLI																			
Group 10																			
LOTU SUBP											r					r			
ESCH CALI													+						
CRYP MICR		r											r			r			
EROD CICU																			
VULP MICR												+	+	r					
MALA FLOC						r													
CAMI BENE													r						
Group 11																			
BROD MULT			+																
GUTI BRAC												+							
CRYP FLAC																			
AMSI MENZ																			
Group 12																			
NICO GLAU		r											r						
CRYP SPAR																			
PINU JEFF				2															
ERIO UMBE																			
PINU SABI	1	1	2	2		2	1	1	1	2	+	2	2	r	2	+	2	2	2
QUER DURA		5	2	2	3	2	2	2	2	3	3	1	3	1	2	2	2	4	2
ARCT GLAU	1	1	2	1	1	2	1	+	2		1	+	2		2	2	2	1	2
CHRY NAUS	r		1		1	+	+	1		1		+	1	2		r	1		
BROM RUBE		r						+			+	+	+	1		+			
SITA HYST	r		1				+	+	r		+	+	+		+	r			
EPIL MINU		r		+				+		r			r						
ERIO COVE											r								
MIMU FREM			+	+		+				r									
LONI SUBS		r	+					r		+		+	+	r			r		
T PUNG	1					2					+		+	+	1		1		
A BICO													+						
LI PORR		r					r		+							+	+		
HETE ARBU												1		1		1			
CIRS PROT																r	r		
LINA PYGM											r		+						

Species	CLR-40	CLR-24	SNC-01	CLR-22	CLR-43	POP*08	CLR-57	CLR-25	CLR-36	POP*03	WHT-07	RNA-30	BEN-34	CLR-28	CLR-44	CLR-03	POP*9A	WHTE-9	CLR-58
Group 1																			
GALI ANDR																			
VIOL PURP			+																
CALO DECU												1							
MAHO PINI	r					1	1												
PINU COLT			+			r						+							
PSOR CALA																			
FRIT VIRI	r																		
Group 2																			
MELI IMPE	r	1																	
TOXI DIVE				r															
BROM DIAN										1									
MADI EXIG									r										
Group 3																			
ERYS CAPI		+	r					r	r	r									
ERIO CONF	r	1						1	r	1				1		+	1		
ACHE MILL					1	1	1			1			1			+	1		+
Group 4																			
HESP DISJ	r	+				r				+				+	r			1	+
MELI CALI								+		+				r	+				+
ALIU FIMB	r								r						+				+
BLOM CROC										r				r	r			+	
Group 5																			
MONO BENE	1		1		+		+	1		+				1	r		1		2
ADEN FASC	3			+	2	2		+	+	1	2			3	2			1	3
GARR FLAX	+	2	2	r	+				r					1	1				1
RHAM CALI					1	1	2					1					2	1	
Group 6																			
CEAN CUNE	1	2	2	+	2	2	2	3	+	1	1	1	1		1	2		1	1
CORD RIGI	+	1	+		+	2	+		+	1		r		+		1	2	+	1
ERIO CALI	1			r	2	2	1		2	2	1	+	1	1					1
Group 7																			
CALY MALA		r														+	r		+
POA SCAB		1						1								2		1	
LUPI RUBR		+															r		
NAVA MITI																+		r	
LL HETE																+		1	
Group 8																			
CENT SOLS										1				+	+	1		r	
BROM MOLL									+					+		2			
CLAR PURP								1								1	r	+	
BROM TECT									r									1	
LOMA MACR									r					r	r			1	
Group 9																			
LINA ANDR								1											
JUNI CALI								1										2	
AVEN BARB								2							+				
THYS CURV																			
CAST FOLI								+										+	
Group 10																			
LOTU SUBP		+								r					+				
ESCH CALI					+					1			1	1			2		+
CRYP MICR							+			r									
EROD CICU															1	+	1		
VULP MICR		1												+			1		
MALA FLOC			r						r	r									
CAMI BENE						r				r									
Group 11																			
BROD MULT																			r
GUTI BRAC															2				+
CRYP FLAC																+			
AMSI MENZ																			
Group 12																			
NICO GLAU																			
CRYP SPAR										r									
PINU JEFF												2							
ERIO UMBE			r																
PINU SABI	+	2	1	1	+	+	1	2	+	1	1	2			1		1	1	
QUER DURA	2	2	2	5	2	2	3	+	1	2		2	1	1	2	3	2		3
ARCT GLAU	2		2			2	2		1	1	3	2		1			1		2
CHRY NAUS	r		1		+		1	1	2	+		1	1		+		1		+
BROM RUBE	r	2			1			2	r	1			1		1		2	1	1
SITA HYST	1				1	1	1	1	2	1	r	+	1	+					
EPIL MINU				r	r	r		r	r	r		r	+	r	r	1	+		
ERIO COVE			r		r				r	1	r	r				r	1	r	1
MIMU FREM			r		r	r						r	r				1		
LONI SUBS		1		r			+	1		r					+	1		+	
T PUNG				1	+		+						1		1				
A BICO						r				r			+					1	
LI PORR				r	r			+							r				+
HETE ARBU	+	1							r	+	+				+				
CIRS PROT		r							r		r								r
LINA PYGM		+								r								+	

Species	POP*6	POP*5	CLR-45	CLR-55	ARL-33	POP-14	POP*2	WHTE-8	POP*1A	CLR-52	POP*11	POP*7	BEN-31	BEN-10	BEN-38	WHTE11	CLR-15	CLR-19	CLR-29
Group 1																			
GALI ANDR					+														
VIOL PURP											+		r	+	+				
CALO DECU															+				
MAHO PINI																			r
PINU COLT					+														
PSOR CALA		+											r						
FRIT VIRI																			
Group 2																			
MELI IMPE																			
TOXI DIVE																			
BROM DIAN					r														
MADI EXIG											r								
Group 3																			
ERYS CAPI	+			r								+							r
ERIO CONF					+	1	1				+								
ACHE MILL	1	1																	
Group 4																			
HESP DISJ		r				+													
MELI CALI	1			r			+												
ALIU FIMB													r	+					
BLOM CROC						+													
Group 5																			
MONO BENE	+	1			1							+							
ADEN FASC		+		2			2	3			+								
GARR FLAX		+	+		+		1					1							
RHAM CALI	1	1			1							1	+		+				
Group 6																			
CEAN CUNE		2	1	+	1	3	2	2					2	1					+
CORD RIGI		1	+	r	1	+		+				1							
ERIO CALI	2	1	2	1			2				r		1						
Group 7																			
CALY MALA							1							r					
POA SCAB						2										1			
LUPI RUBR						1													
NAVA MITI											r								
LL HETE						r													
Group 8																			
CENT SOLS			1	+		1			+	2	r								
BROM MOLL			1	r	2	1				1									
CLAR PURP					+	+					r								
BROM TECT						1			2.		r								1
LOMA MACR			+					1											
Group 9																			
LINA ANDR	+					2					+								
JUNI CALI		+								r						1			
AVEN BARB						+				1									
THYS CURV	+				1	1			+										
CAST FOLI										r									
Group 10																			
LOTU SUBP	+	1			+	2	1	r	r	1	r			r	r				
ESCH CALI	1	+			2		1	+	r	+	+								
CRYP MICR	+	r	+				r		r		1			r					
EROD CICU	1			r	1	1	1	+	2	4	+								
VULP MICR					+					1	r			+	r				
MALA FLOC	+	r	r				1	+	+		r								
CAMI BENE	+	r			+	r	+				r				r				
Group 11																			
BROD MULT							r			r	r								
GUTI BRAC										+									
CRYP FLAC										+	r								
AMSI MENZ			r				1			+									
Group 12																			
NICO GLAU	+											+		+	+				
CRYP SPAR											r	r	r		r				
PINU JEFF												1	1		1				
ERIO UMBE												+		+					
PINU SABI	2	2	+		1	2	+	2	2	2	2	1	1	1	+	2		1	2
QUER DURA	2	3	2	1	2						1	2	2	2	1				
ARCT GLAU	1	1	2	2		1		2					2	2		2	2	1	r
CHRY NAUS	1	1	2	r	1	1	1		1	+	+	1	1	1	+				1
BROM RUBE	1	1	1	+	2		1	1		1	r	1		+		+			1
SITA HYST	+	2	2	+	1	1		+				+		+					
EPIL MINU		1	+		+				1			r	+	r	r	+			
ERIO COVE	+	+			1	+	1	r	+		r	1	r	+	r	+			+
MIMU FREM	+	+			+		+	+	+		r	+	r	+	r	+			
LONI SUBS										1		+							
T PUNG			1					+				2	1		3				
A BICO		+			1				+			+	r	+					
LI PORR														+					
HETE ARBU							1												
CIRS PROT			r		r														
LINA PYGM	1						1				r								

Taxa belonging to Group 3 or Group 4 (Table 10) co-occur with *C. benitensis* only at Population 3 and Population 4, with Population 6 having the latter group. Included in these groups are several obligate serpentine herbs, including *Hesperolinon disjunctum, Allium fimbriatum* var. *diabolense* and *Eriophyllum confertiflorum*. Finally, Group 1 (Table 10) co-occurs with *C. benitensis* at only two sites, Population 13 and Population 4. Group 2 (Table 10) does not co-occur with *C. benitensis*.

Detrended Correspondence Analysis ordination (Hill and Gauch 1980; Gauch 1982) was utilized to identify patterns of variation in vegetation and environmental factors that correspond to the observed habitat utilization patterns of *C. benitensis*. Figure 10 shows the results of the ordination analysis, plotting a variety of vegetation, physiographic and soil attributes within the first two axes of the ordination field.

Environmental scalar variables negatively correlated with the first ordination axis include cover of leaf litter, elevation and slope steepness. Variables correlated with the second DCA axis include cover of large bouders and cobbles. Gravel cover was strongly correlated with the thrid DCA axis. Several other trends are apparent in the plots shown in Figure 10. Populations of *C. benitensis* are clustered within a limited portion of the ordination field, with one outlier (Population 13, cf. Figure 10d). This main cluster of populations seperates from other alluvial terrace sites on the basis of elevation (Fig. 10d), soil development and color (Fig. 10b), total vegetation cover (Fig. 10c), slope steepness (Fig. 10e), cryoturbation (frost-heaving, Fig. 10f), woody vegetation cover (Fig. 10g), cover of leaf letter (Fig. 10h), cover of gravel on the soil surface (Fig. 10j), and herb cover (Fig. 10k).

In general, the woody plant species dominant within and adjacent to populations varies greatly from population to population. The degree of vegetation variability between sites is nearly as great as the overall vegetation variation along attitudinal gradients within the San Benito Mountain region. Woody plants dominating within or adjacent to populations of *Camissonia benitensis* include *Pinus sabiniana, Calocedrus decurrens* or *Pinus coulteri* in the overstory, and *Quercus durata, Arctostaphylos glauca, A. pungens* or *Ceanothus cuneatus* in

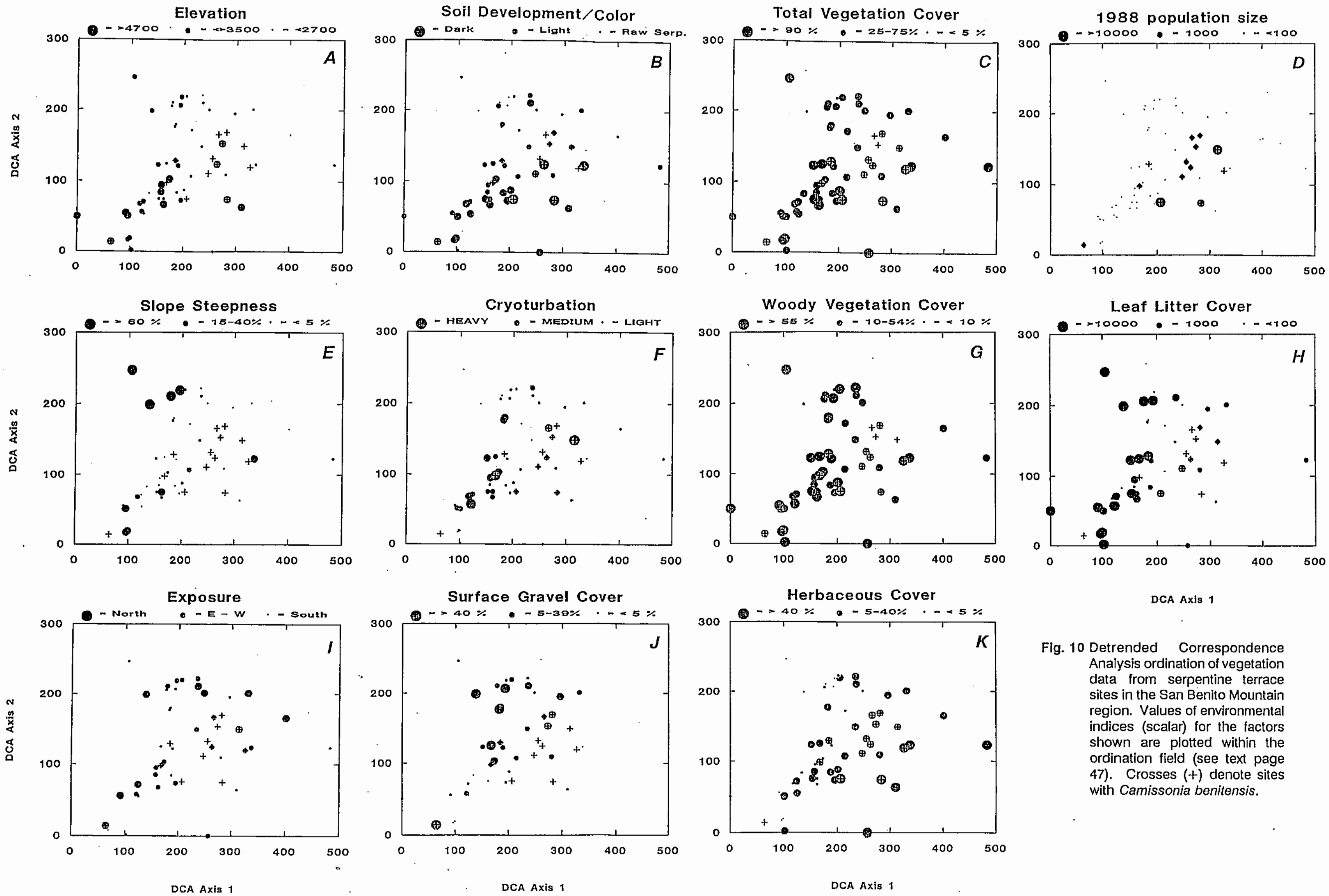


Fig. 10 Detrended Correspondence Analysis ordination of vegetation data from serpentine terrace sites in the San Benito Mountain region. Values of environmental indices (scalar) for the factors shown are plotted within the ordination field (see text page 47). Crosses (+) denote sites with *Camissonia benitensis*.

the shrub chaparral. The reader will discover with careful comparison of the floristic composition of vegetation at populations (as indicated in Table 10) that no single condition of the structure of woody plant cover is indicative of suitable *C. benitensis* habitat.

Perhaps the most important vegetation correlate of suitable habitat for *C. benitensis* is a dense serpentine chaparral or woodland bordered by relatively barren openings that support a diverse and rich flora of annual herbs. Ordination analysis identified a group of six annual herb species that co-occur as an ecological group and that serve to differentiate suitable habitat for *Camissonia benitensis*: *Lotus subpinnatus, Eschscholtzia californica, Cryptantha* ~~*micrantha*~~ *micromeres*, *Erodium cicutarium, Vulpia microstachys* and *Malacothrix floccifera*. All but the *Erodium* are native, and perhaps this is related to the fact that other introduced annuals are sparse or unimportant in the vegetation at sites supporting *Camissonia benitensis* populations, including the nearly ubiquitous *Bromus rubens, B. tectorum* and *Avena barbata*. Total herb cover at *Camissonia benitensis* populations varies from 5% to nearly 40% cover.

Soil Characteristics - the overall edaphic conditions at sites that support populations of *Camissonia benitensis* are reflect somewhat better growing conditions (i.e. generally higher fertility) as compared to nearby serpentine slopes. The barren, rolling serpentine slopes - totally lacking <u>any</u> vegetation - are a unique feature of the San Benito Mountain landscape (Kruckeberg 1984, 1969; Griffin 1984; cf. Figure 17).

The general edaphic relationships that control vegetation pattern on serpentine and other ultramafic substrates in California are well documented (Kruckeberg 1984). The serpentine vegetation syndrome is produced by a combination of low overall soil fertility, skewed calcium/magnesium rations and heavy metal toxicity.

Table 11 provides some descriptive physical data for soils from three populations. The serpentine soils on terraces are gravelly, moderately deep, well drained silty or sandy loams. Organic matter is present in these terrace soils, as indicated by their dark color in comparison to the typical soils of serpentine slopes of the region, which are greenish-white in surface color, and reddish below the surface. Soil depth on alluvial terraces, as judged from roadcuts, is often greater than 2 meters to a lithic horizon, indicating that subsurface rock is generally not limiting effective rooting depth.

Table 11. Selected soil characteristics from populations of *Camissonia benitensis*.

	SOIL CHARACTERISTIC					
	pH	E.C.[1]	%>2mm	%Sand	%Silt	%Clay
Population 1						
Upper 2 cm	7.37 ± .06	115.2 ± 25.5	25.4 ± 9.3	32.2 ± 7.9	33.3 ± 7.3	9.4 ± 3.5
Bottom 2 cm	7.48 ± .12	205.6 ± 57.7	24.7 ± 8.2	43.0 ± 5.7	26.3 ± 2.4	5.9 ± 2.1
Population 5						
Upper 2 cm	6.89 ± 0.8	98.8 ± 21.9	37.6 ± 3.7	29.2 ± 3.6	31.7 ± 3.1	2.7 ± 0.5
Bottom 2 cm	7.08 ± 0.8	77.8 ± 15.0	38.5 ± 2.0	28.0 ± 3.0	33.3 ± 3.6	1.8 ± 0.2
Population 9						
Upper 2 cm	6.79 ± .12	109.6 ± 53.9	36.6 ± 4.3	44.4 ± 4.5	15.6 ± 5.0	5.6 ± 0.8
Bottom 2 cm	6.87 ± .10	85.5 ± 52.0	34.9 ± 2.4	37.2 ± 0.4	16.5 ± 0.2	9.2 ± 7.3

[1] Electrical conductivity (m-mho cm^{-2})

As is typical of ultramafic soils in California, the pH of soils from sites supporting *C. benitensis* is slightly alkaline, and the soils are moderately saline. Ecologically, this is indicated by the presence of *Distichlis spicata* on many serpentine alluvial terraces in the Clear Creek canyon.

Table 12 provides a summary of chemical element abundance in serpentine soils from San Benito Mountain (soil data provided by J. Key, Soil Scientist, Bakersfield BLM District office - samples originating from the upper San Benito River in the vicinity of the Atlas Mine). The elemental composition of San Benito Mountain serpentine soils, as indicated by these data, is typical of that reported for other serpentine areas (cf. Kruckeberg 1984; Table 13).

Table 12. Chemical characteristics of serpentine soils from the San Benito Mountain region. Data for Ca^{++} and Mg^{++} are in milleqivalents/liter, all other values are in parts per million.

Site	Element									
	Ca	Mg	Ca/Mg	Na	P	Zn	Mn	Pb	Fe	Ni
Atlas Mine 1	0.5	11.7	0.043	0.3	0.1	2.9	10.0	3.52	218	124
Atlas Mine 2	0.4	15.3	0.026	0.1	0.1	1.2	10.2	1.39	280	103
White Cr.	0.5	7.1	0.070	0.1	0.5	1.3	8.0	0.47	245	114

Source: J. Key, BLM

Table 13. Comparison of salient soil chemical parameters for various serpentine areas in California. Values for cations given in Table 12 are reported here for comparative purposes, reporting data from NH^4-extraction for comparability. All values are millequivalents/100 grams.

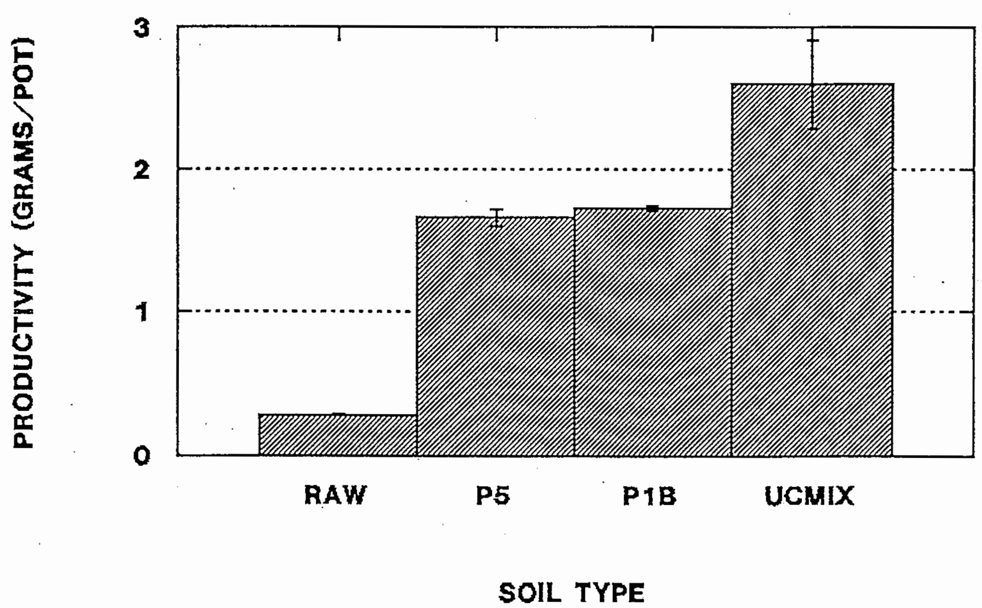
Region (*Source*)	Cation Exchange Capacity	Ca	Mg	Ca/Mg Ratio
Kruckeberg (1984)				
Santa Barbara Co.	17.2	4.1	11.1	0.4
Santa Clara Co.	15.0	2.4	11.4	0.2
Lake County Co.	16.0	2.8	11.8	0.2
Sonoma Co.	5.9	0.5	3.9	0.1
Tehama Co.	43.0	5.0	32.5	0.2
Trinity Co.	17.0	2.8	12.7	0.2
Del Norte Co.	14.0	2.8	7.1	0.4
Butte Co.	15.0	2.4	10.1	0.2
McCarten (1988, range of values reported)				
Lake Co.	4.0	0.2	1.0	0.2
	2.1	0.3	1.8	0.3
	42.4	3.7	35.3	0.1
San Benito Mountain				
Kruckeberg (1984)	15.0	2.4	11.4	0.2
Atlas 1	5.3	2.6	87.4	0.1
Atlas 2	6.8	2.7	15.7	0.2
White Cr.	5.0	0.6	21.3	0.3

No attempt was undertaken to test nickel concentrations in tissue of *C. benitensis*, but, as Reeves et al. (1981) point out, nickel accumulation is not common in the serpentine flora of California.

Relative soil fertility at two populations of *C. benitensis* was determined in bioassay. Barley (*Hordeum vulgare*) was grown in 4" pots (3 replicates) in one of four soil configurations: raw serpentine soil from a barren slope, soil from Population 5 and Population 1B (each watered with distilled water), and UC mix (watered with Hoagland's solution).

The results of this bioassay indicate the relative fertility of terraces in the San Benito Mountain region (Figure 11): barley yield grown on soil from *C. benitensis* sites was nearly 3 times as great as compared to raw serpentine, and nearly 75% of that of highly fertile soil.

Figure 11. Relative fertility of soils from raw serpentine, *Camissonia benitensis* Populations 5 and 1B, and agricultural soil (UC mix watered with Hoagland's solution) in bioassay using *Hordeum vulgare*. Error bar indicates standard deviation of three replicates. RAW = soil from a barren serpentine slope, P5 = *C. benitensis* Population 5, P1B = Population 1B, the former watered with distilled water, and UCMIX = U.C. soil mix (Baker 1972) watered with Hoagland's solution.



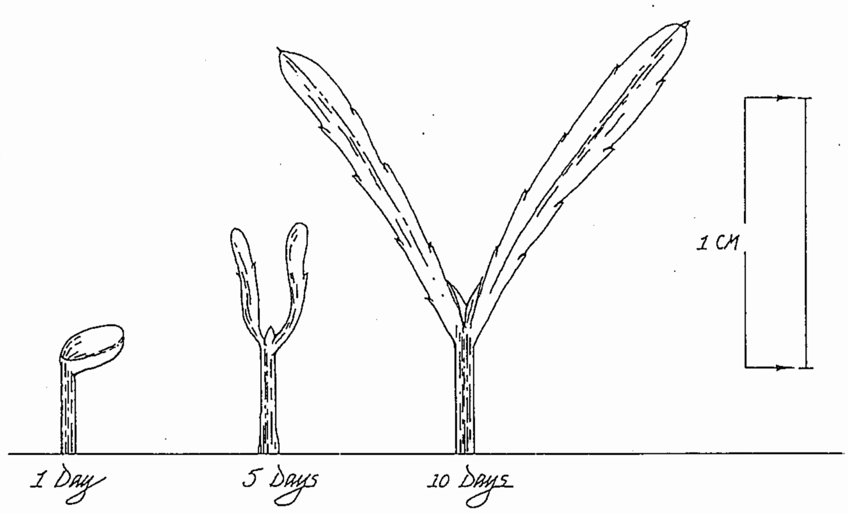
Although fertile relative to the those typical of raw, barren slopes, the soils of serpentine terraces that support *Camissonia benitensis* are deficient in calcium and have skewed Ca/Mg ratios typical of serpentine substrates. For this reason, many annual herbs, particularly introduced alien grasses, can not grow on these sites. A suite of native serpentine herbs is adapted to these openings (cf. Table 10).

LIFE HISTORY CHARACTERISTICS

Seedling Germination - newly germinated seedlings of all *Camissonia* Section Camissonia taxa are easily distinguished from the seedlings of other species by virtue of their cotyledon morphology. However, in both the garden and field, it is not possible to distinguish between seedlings of species of Section Camissonia.

The cotyledons of newly germinated seedlings are oval, and about 2 mm long and 1 mm wide upon emergence from the soil. The cotyledons elongate rapidly, becoming lanceolate, eventually reaching 10-15 mm long and 1.5-2.5 mm wide (Figure 12). As the cotyledons elongate, they develop marginal serrations. During this maturation sequence, the cotyledons essentially take on the morphology typical of foliage leaves.

Figure 12. Illustrations of young seedlings of *C. benitensis*, showing the serrate-margined cotyledons.



Seedling Survivorship - the survivorship of *Camissonia benitensis* and *C. contorta* seedlings was tracked during the spring of 1988. At Population 1 of *C. contorta*, 70 percent of the seedlings died in the first month of observation, and only 22 percent of the original cohort reached flowering. A very similar pattern of mortality was observed for *Camissonia benitensis* at Population 9: 45 percent of the cohort died in the first month, and 17 percent of the cohort survived to flowering. At both Population 5 and 6, cohort survival in the first month was higher, ranging from 80 to 100 percent. Population 5 had a much higher net survivorship, with 52 percent of the cohort reaching flowering, whereas 27 percent of the original cohort reach flowering at Population 6.

The overall pattern of seedling survivorship indicates that considerable mortality occurs prior to flowering, a not to surprising feature, one typical of the demography of many annual plants.

Mortality Factors - most seedlings (79 percent) that suffered mortality disappeared, and the cause of their mortality could not be determined!. Of the seedlings for which a cause of mortality could be ascertained, three mortality factors were evident: 31 percent of the seedlings dying suffered predation; 60 percent suffered from drought; and the remainder (9 percent) suffered from frost heaving. Non-quantitative observations in 1989 indicate that frost heaving is likely to result in considerable mortality of seedlings in cold, dry years.

Predation was imputed to all seedlings where a stump of the hypocotyl or epicotyl remained, but no foliage or stem was evident. Most of the seedlings exhibiting this configuration were probably eaten by phytophagous insects, since they were often no more than 1-3 cm tall when predated. Rabbit grazing may have resulted in some mortality, but it is not possible provide observations that suggest the relative importance of vertebrate vs. invertebrate predation.

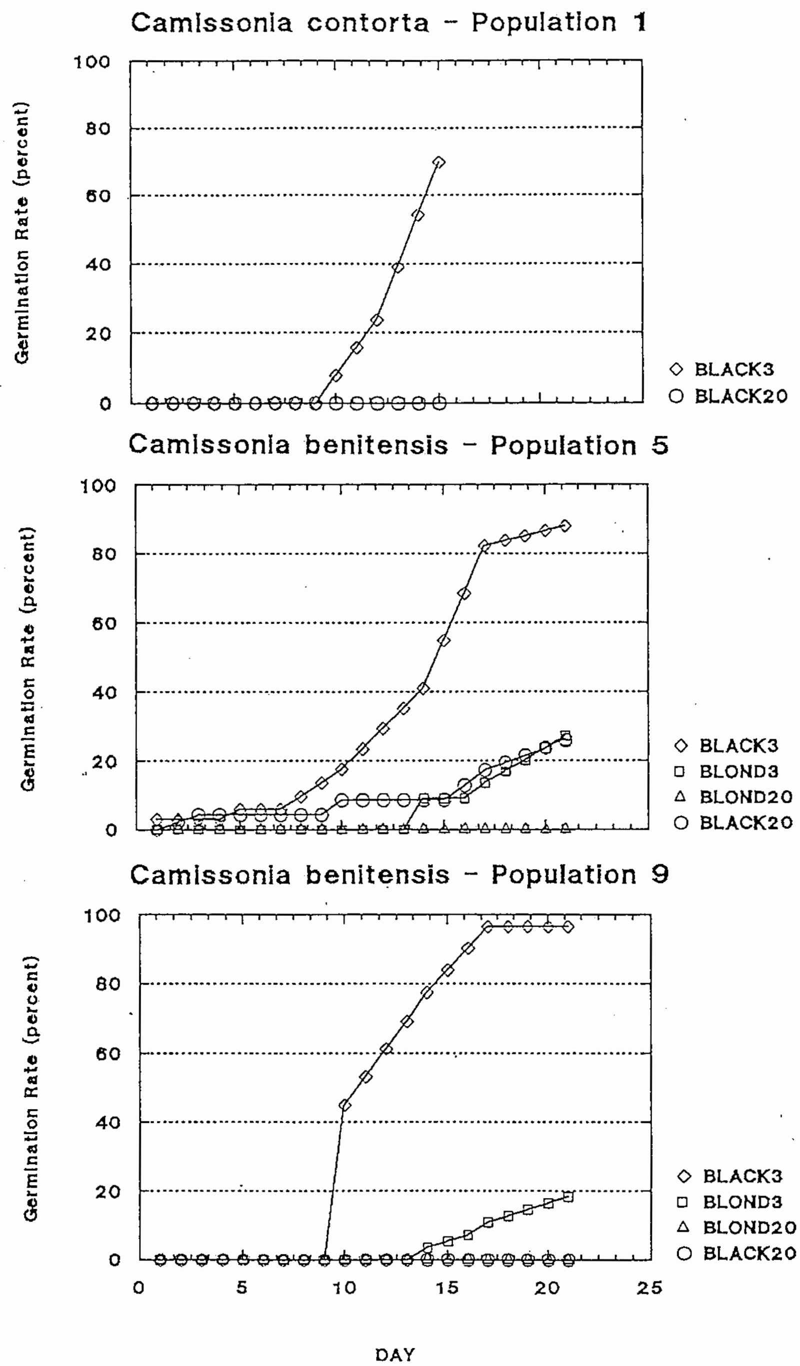
Field Observations of Seedling Germination - to monitor germination, populations of *Camissonia benitensis* were visited at roughly monthly intervals beginning with the first fall rains in each year. Because of poor winter road access, populations in the San Carlos Creek and upper San Beinto River drainages were not visited.

Seedlings were first observed on early to mid-February in each year. From these observations, and based on laboratory results of germination rates in relation to temperature (see below), the conclusion is reached that germination of *Camissonia benitensis* requires some degree of cold stratification during winter, rather than simply being triggered by fall rains. The bulk of the cohort during each year germinates between late-February and early-March. Some seedlings continued to appear after late March (based on the observations at seedling survivorship plots).

Germination Rates - observations indicate that populations of *Camissonia benitensis* produce two color phases of seeds in each capsule. Essentially the two types of seeds represent a developmental or maturation continuum - blond seeds are produced in late maturing capsules, indicating that black seed is fully ripened while the plant is actively growing. A small proportion of seed is rounded and blond in color, while the greater proportion of seeds are darker, more angular seeds. These two seed forms differ in germination behavior, blond seed being more slow to germinate than black seed. By contrast, only the fully ripened, black seed form is produced by *Camissonia contorta*.

Seed germination of black and blond seed in response to temperature is summarized in Figure 13. The two kinds of seed showed differences in germination response that were consistent across the two species. Black seeds invariably germinated faster and more readily than blond seeds. Furthermore, both black and blond seeds showed a significant difference in germination response between 20°C and 3°C. Seeds germinated at 3°C showed much greater and faster germination than seeds germinated at 20°C. *Camissonia contorta* seed was very slow to germinate at 20°C, while the two populations of *C. benitensis* tested differed slightly in germination rates at 20°C.

Figure 13. Rates of seed germination for populations of *Camissonia benitensis* and *C. contorta* at two temperatures. *Camissonia benitensis* produces two types of seed: hard, black angular seed and rounded, blond seed. The two seed types differ in germination behavior.



Production of two types of seed may represent a continuous heterocarpic system, and could have considerable significance in relation to soil seed storage and population ecology.

Soil Seed Bank - Soils collected from the three sites supporting significant *Camissonia benitensis* populations contains germable seed of several species (Table 14). Germability trails indicate that viable seed of *C. benitensis* occurs at high densities. In Population 5, the largest population known for the species, seed densities averaged ca. 1700 germable seeds per square meter - nearly two orders of magnitude larger than the observed density of plants during 1988 at this site (a good growing year!). This findings suggest that year to year fluctuations in population size are largely a function of year to year variation in rainfall, and do not depend heavily on fecundity during the previous years. Other species with high density of buried viable seed at Population 5 were *Vulpia microstachys* and *Linanthus bicolor*. At Population 9, germable seed of *C. benitensis* averaged 615/m^2. Density of buried viable seed of *C. contorta* was also high, 1150/m^2.

Given a possible continuum-type of heterocarpic system operating in *C. benitensis*, soil seed storage would be an expected result, since heterocarpy is a mechanism to discount seedling mortality caused by environmental unpredictability. Seed would be subject to mixing within the soil column, particularly by action of frost heaving and pocket gophers. Both of these factors can be observed to be frequent agents of soil disturbance in *C. benitensis* populations. Thus, seed may remain resident in the soil for long periods (on the order of several decades).

Although the available data are insufficient to infer residence times for buried viable seed of *C. benitensis* in the soil column, the difference in magnitude between germable seed reserves and seedling density in a 'good' year indicates that considerable seed can be retained in the soil, and probably serves to buffer crashes in net fecundity resulting from drought. However, the seed of *C. benitensis* is exceedingly small (ca. 0.8 mm long and 0.3 mm diameter) and likely has a limited longevity in a synecological time-frame.

Table 14. Density of germable seeds in soil samples (0.1 dm^2 by 5 cm depth) from *Camissonia benitensis* populations. Values are expressed as density (number of plants per square-meter).

Species	Population 1			Population 5			Population 9		
	Mean Density	Coef. Var.	Range	Mean Density	Coef. Var.	Range	Mean Density	Coef. Var.	Range
Camissonia benitenssis	-	-	-	1775	0.91	200-4700	615	1.16	100-2400
C. contorta	1150	0.79	300-2400	-	-	-	-	-	-
Bromus rubens	50	1.15	0-100	17	2.33	0-100	392	0.96	0-100
Campanula griffinii	-	-	-	58	1.70	0-300	261	1.71	0-1400
Calyptridium monandrum	-	-	-	17	3.46	0-200	15	2.44	0-100
Claytonia perfoliata	-	-	-	50	1.59	0-200	15	2.44	0-100
Delphinium parishii	-	-	-	-	-	-	30	2.78	0-300
Erodium cicutarium	175	0.97	0-400	-	-	-	23	1.90	0-100
Eriogonum covilleanum	575	1.13	0-1400	-	-	-	-	-	-
Eschscholzia californica	-	-	-	9	3.31	0-100	33	1.47	0-100
Gilia achillaefolia	100	2.00	0-400	-	-	-	-	-	-
Hutchinsia procumbens	350	1.24	0-900	-	-	-	-	-	-
Linanthus bicolor	-	-	-	1983	0.76	600-5600	15	2.44	0-100
Lotus subpinnatus	25	2.00	0-100	-	-	-	-	-	-
Lupinus albifrons	-	-	-	8	3.46	0-100	8	3.60	0-100
Mentzelia sp.	200	0.91	0-400	-	-	-	-	-	-
Mimulus fremontii	-	-	-	25	2.48	0-200	115	1.40	0-500
Stellaria nitens	875	1.20	0-2100	-	-	-	-	-	-
Trifolium tridentatum	-	-	-	-	-	-	15	2.44	0-100
Vulpa microstachys	475	1.05	0-1000	472	0.82	0-1300	1469	1.26	0-5000

Fecundity - data on demographically significant variables related to plant vigor and reproductive output was obtained from both field and garden plants. Review of herbarium specimens of *C. benitensis* indicates extreme plasticity in plant size, degree of branching, and numbers of capsules per plant between years. Plants collected in more dry years have in general been smaller and less branched than those collected in wet years.

Further, observations of garden grown plants indicate the extremely plastic growth and reproductive output in *C. benitensis* is a direct function of site conditions. Plants grow in garden culture on fertile soils often reach sizes (and thus reproductive potential) easily 50-100 times as great as the largest plants occurring in nature.

Tables 15 summarizes the trends observed during monitoring of fecundity in populations of *C. benitensis* over two years. Fecundity of *Camissonia benitensis* populations was generally higher in 1988 than in 1987, as would be expected given the differences in growing conditions between the two years. For instance, mean capsule length for *C. benitensis* ranged between from 19 to 27 mm in 1987, while in 1988 plants had generally larger capsules with generally more ovules. Fertilization rates (number of ovules enlarging) were comparable between years, but may differ greatly between populations.

The number of capsules per plant follows a skewed distribution in all populations (Figure 14). Most plants of *C. benitensis* are able to produce but a single capsule. Capsule length, in contrast, is normally distributed within each population (Figure 15). Garden grown plants of *C. benitensis* mature many hundreds of capsules, by contrast.

Garden grown plants of *C. benitensis* have significantly longer capsules (averaging about 36 mm) as compared to wild populations, indicating that natural growth conditions on serpentine soils limit reproductive output directly.

Figure 14. Frequency distribution of number of capsules per plant for populations of *Camissonia benitensis* and for *C. contorta*. Mean number of capsules per plant (± Standard Error) were: *C. contorta* Population 1, 2.18 ± 0.19; *C. benitensis*, Population 5; 2.63 ± 0.32; Population 9 3.23 ± 0.44.

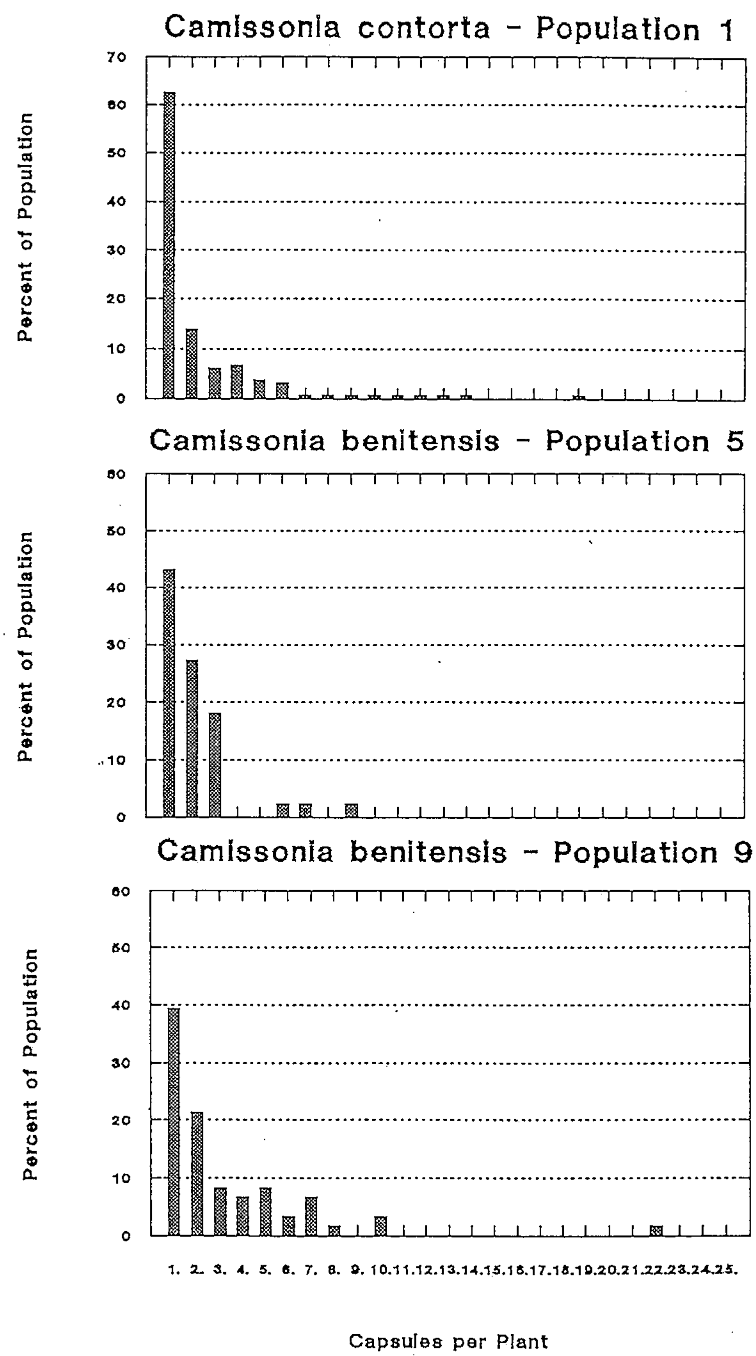


Figure 15. Frequency distribution of capsule length for populations of *Camissonia benitensis* and for *C. contorta*. Mean capsule lengths (± Standard Error) were: *C. contorta* Population 1, 21.8 ± 0.3; *C. benitensis*, Population 5; 19.8 ± 0.5; Population 9 27.2 ± 0.4.

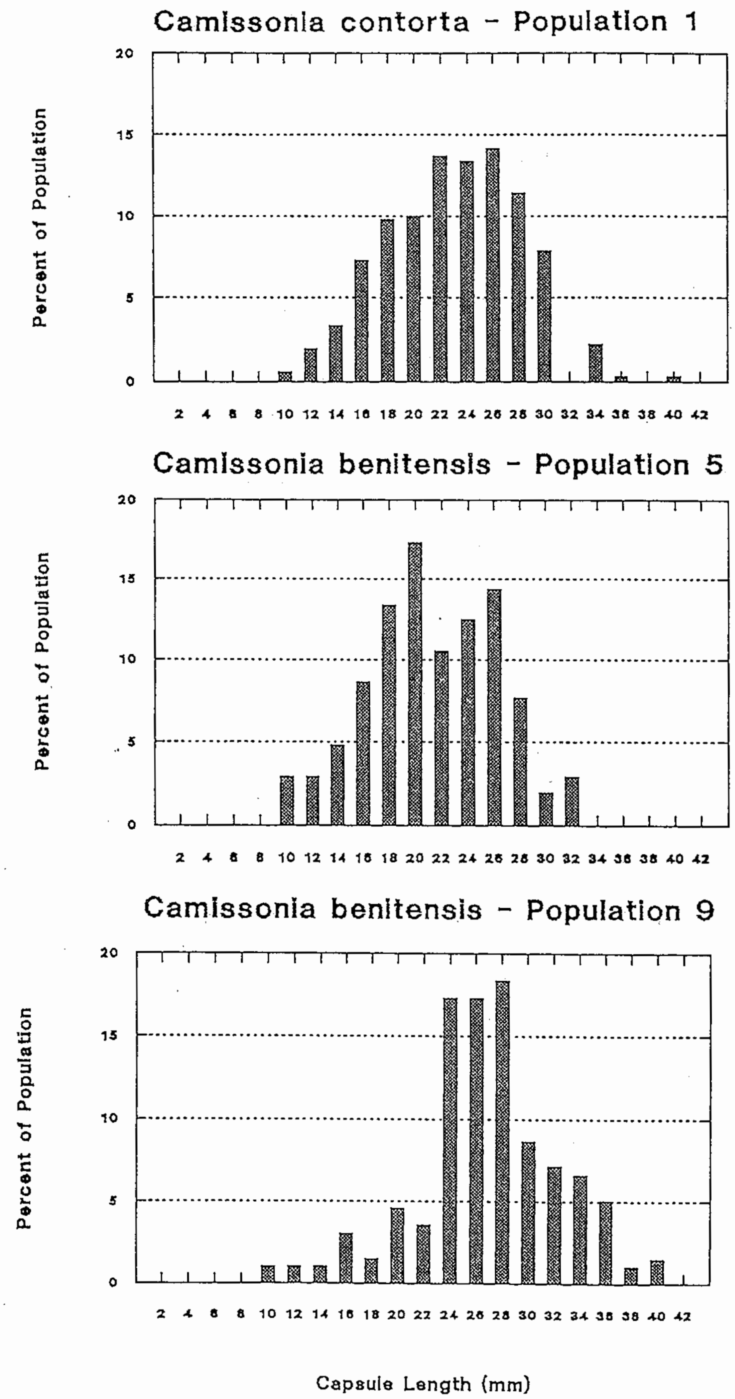


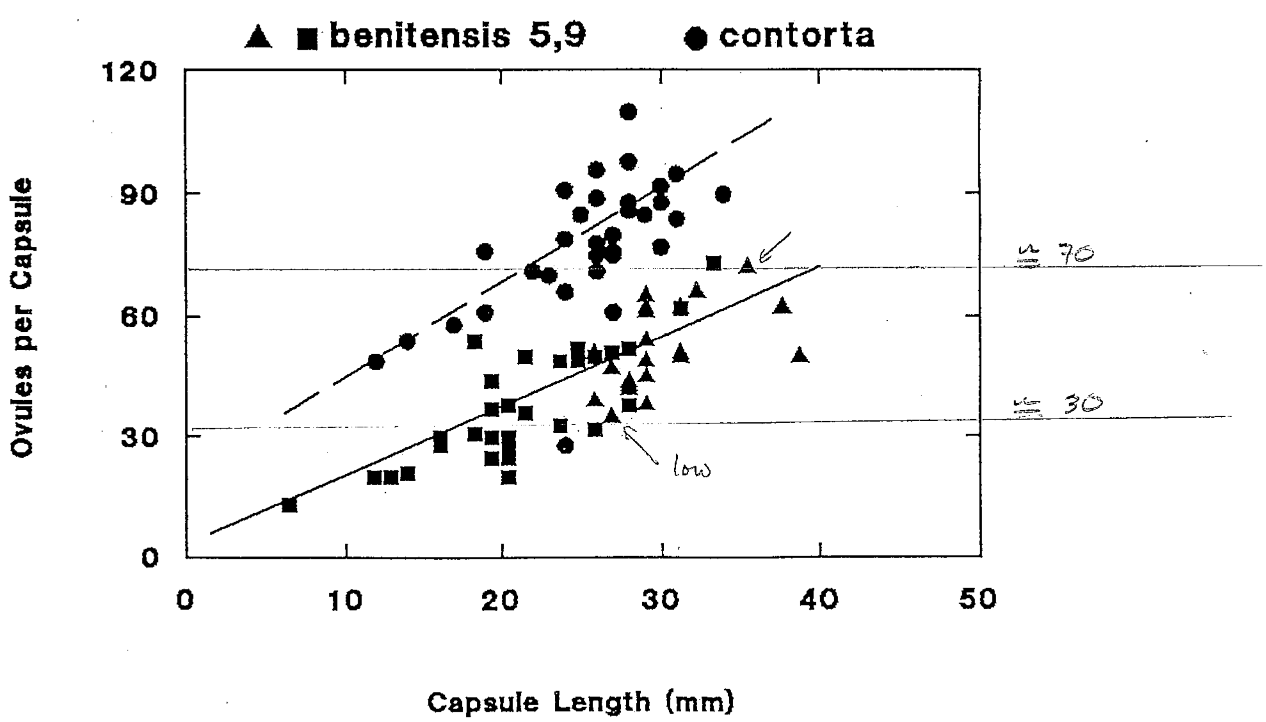
Table 15. Summary of vigor and fecundity statistics for garden grown plants of *Camissonia benitensis, C. strigulosa* and *C. contorta*. Data represent mean and standard error (sample sizes are given for non-synthetic variables only).

		VIGOR		FECUNDITY			
						Percent of Seeds	
Species	Site	Mean Capsule Length (mm)	Ovules/ Capsule	Percent Ovules Fertilized	Percent Ovules Producing Seed	Black	Blond
C. benitensis	Population 5	36.4±1.1	97.7±2.2	84.9±2.1	80.0±2.2	97.2±1.0	2.7±1.0
	n =	29	29	29	29		
C. benitensis	Population 9	36.7±0.8	93.9±3.3	89.2±1.4	80.8±2.3	96.0±1.7	3.9±1.7
	n =	21	21	21	21		
C. strigulosa	Population 1C	12.2±0.6	38.9±4.5	82.1±8.2	80.4±8.2	0.0	100.0
	n =	10	10	10	10		
C. contorta	Population 1	35.8±0.8	88.6±2.6	90.4±2.1	88.0±2.6	0.0	100.0
	n =	19	19	19	19		
C. contorta	Modoc County	22.4±0.8	52.3±2.4	92.5±1.7	67.0±3.2	96.0±2.2	3.9±2.2
	n =	19	19	19	19		

In 1988, the number of capsules per plant varied between populations, but the magnitude of this variation was limited compared to the reproductive potential of garden grown plants. At Population 5, the mean number of capsules per plant increased somewhat in 1988 (ca. 50%), yet the variation between years ranges from only 1 to 3 capsules per plant. By contrast the number of plants at Population 5 increased by three orders of magnitude. Reproductive output at this population was influenced more by density (thus germination and survivorship) than by better conditions during the growing season. Of interest is Population 1B, since the plants at this population were consistently much larger than at other *C. benitensis* populations, with some individuals in the population reaching sizes as nearly as large as plants grown in the garden under optimal conditions. By contrast, plants at Populations 3, 4 and 8 were invariably depauperate, even in 1988, an indication that these sites may be poor quality *C. benitensis* habitat.

Seed production is related to capsule length for both *C. contorta* and *C. benitensis* (Figure 16). For *C. contorta*, a capsule of a given length will contain more seeds than *C. benitensis*.

Figure 16. Scattergram showing the relationship between capsule length and number of ovules for *C. contorta* and *C. benitensis*. Regression equations: *benitensis*; x = 1.691 y + 3.158 (r^2 = 0.53); *contorta*; x = 2.146 y + 23.35 (r^2 = 0.40).



Overall fecundity output in *C. benitensis* is controlled by ecological factors regulating overall plant size: plants can increase fecundity and seed output only by maturing additional capsules, and to a limited degree by allocating growth resources to existing capsules. Tall *C. benitensis* plants are indicative of good growing conditions, and would thus produce more flowers and would support more leaf area than small, unbranched plants. In this instance, height is a relative measure of vigor or fitness. Small, stressed plants should be expected to partition growth reserves to the maturation of existing seeds, rather than growing in height and producing additional flowers. In many populations, plants during drought years support only a single capsule.

Altogether, fecundity data from *C. benitensis* populations indicates that low reproductive potential does not limit the success of the species. Rather, the year to year success at a given population, as measured by reproductive output, usually exceeds the number of seeds required to replace existing individuals. Germination and subsequent survival rates, governed by the timing and quantity of rainfall, are more limiting than is reproductive potential.

Requisite long term population and precipitation data required to understand the influence of precipitation patterns on *C. benitensis* population size are lacking. It would therefore be difficult, absent such data, to model between year variation in reproductive success.

Observations over the past four growing seasons document extreme variation in population size and potential reproductive output. The degree of plasticity in reproduction is probably typical of the long-term behavior to be expected of *C. benitensis* populations.

Breeding System - observations on the flowering phenology of *C. benitensis* are consistent with Raven (1969), and indicate the species is autogamous (self-pollinating). Flowers of *C. benitensis* produce two pairs of anthers, each with different filament lengths. The longer pair of anthers typically reaches anthesis the day before the petals open. The shorter pair of anthers opens with the petals. Typically, flowers of *C. benitensis* last but for a single day - the petals turn orange on the second day post-anthesis, but may occasionally open a second day or rarely a third. As indicated above, the sepals in *C. benitensis* may remain attached in pairs at anthesis, or may be reflexed individually in approximately equal frequency.

Controlled emasculation experiments resulted in no mature fruit - indicating that apomixis is not operational. Some degree of outcrossing is probable in nature, as *C. benitensis* flowers are visited by native bees and bee-flies.

In the field, flowers of *C. benitensis* are strongly matinal: they begin to open in the early morning. Most are closed by solar noon, except on very cloudy days. This flowering phenology makes *C. benitensis* difficult to observe in the field, and may account for the fact that several populations in the San Benito Mountain region escaped detection prior to this study.

Biotic Interactions - few interactions with fauna were observed that could directly influence success of *C. benitensis* were observed. Other than phytophagy, no animal influences were documented. Similarly, no pathogens were observed on *C. benitensis*.

Several taxa of *Camissonia* Section Camissonia possess terminal foliar glands that resemble eliasomes (fat bodies) typical of ant-plant mutualistic systems (Ridley 1910). Figure 4a illustrates the well-developed elisomes that occur frequently on leaves of *C. contorta*. These glands are rudimentary or absent in *C. benitensis* (Fig. 4b) and *C. strigulosa* (Fig. 4e). The role of these glands, if any, in the biology of *Camissonia* is obscure. No interactions were observed with ants that would suggest a role of these foliar eliasomes in defense systems. In *Streptanthus* (Brassicaceae), a California genus with many serpentine endemics, foliar structures serve as egg-mimics that deter oviposition and subsequent larval phytophagy by a butterfly (Shapiro 1981). Whatever the role of the terminal leaf structures in *Camissonia contorta* and allies, their importance to the biology of *C. benitensis* is probably minimal, judging from the rudimentary development of these structures.

Vegetation Change at **C. benitensis** *populations* - As part of management and recovery efforts for *C. benitensis*, BLM began a program of documented photography points at several populations prior to 1980 (cf. Table 6). Comparison of photographs at several population sites indicate observable vegetation change has occurred over the past 10 year interval. However, vegetation sampling was not implemented at the BLM photograph points, so the degree of change can only be assessed qualitatively.

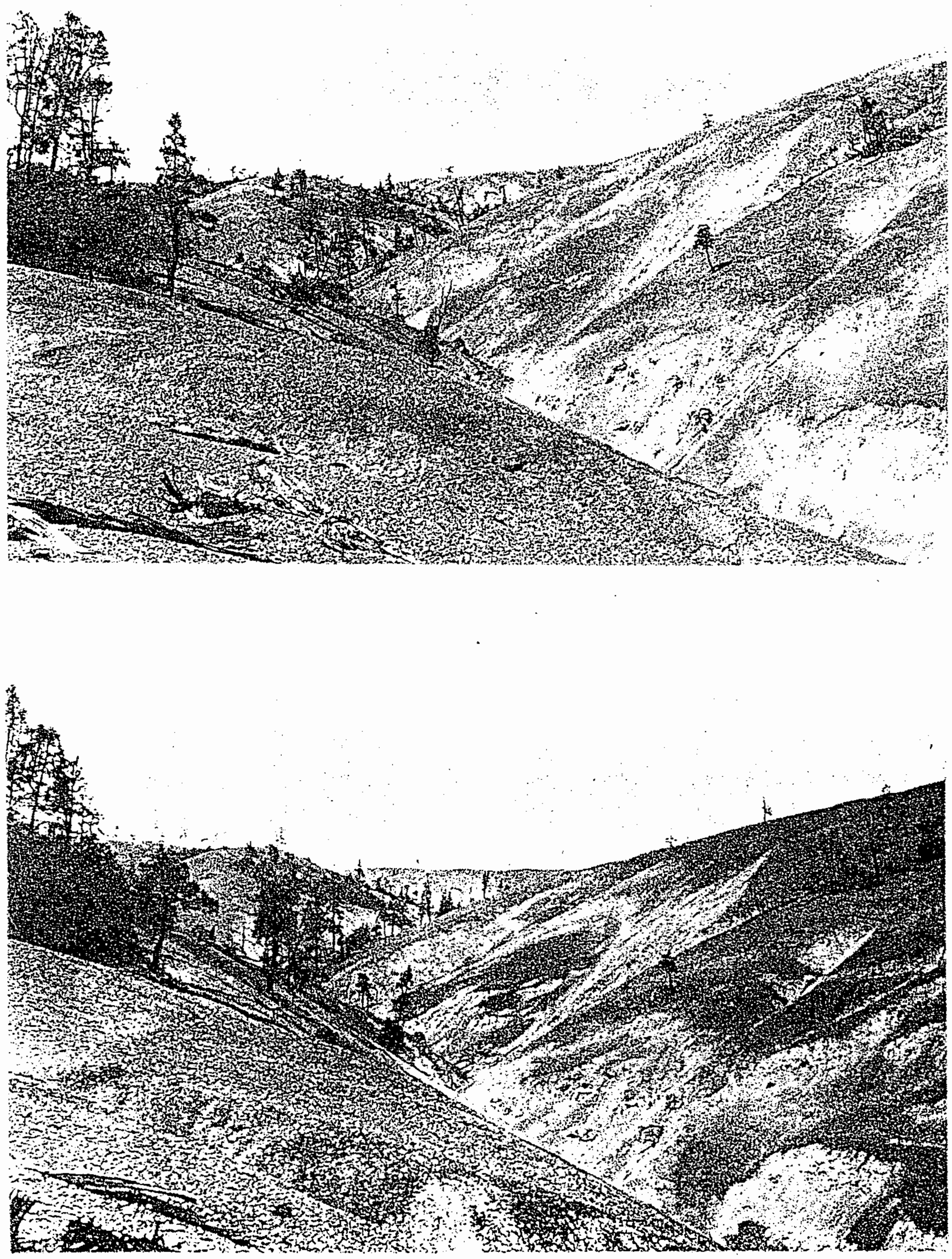
Vegetation change at Population 5 (BLM Photo Point 11) is shown in Figure 7. The 1980 photograph shows ca. 15 shrubs of *Ceanothus cuneatus* in both the foreground and background. All of these shrubs were heavily browsed (presumable by deer), and exhibit a densely-hedged growth-form. By 1985, all of these shrubs exhibited canopy growth that indicates release from heavy browsing pressure. The canopy volume on two shrubs in the immediate foreground increased by about 50 percent over the 5 year period. Herbaceous cover increased somewhat over the period, particularly the cover of the bunch grass *Sitanion hystrix*.

At Population 4, shrub cover has increased between 1980 and 1985: a shrub of *Arctostaphylos glauca* nearly doubled in canopy volume during the interval. By contrast, several small (ca. 1 m tall) saplings of *Pinus sabiniana* exhibited very little growth over the interval. Herbaceous cover has remained similar and low at this site, with the exception of an increase in the size and density of *Sitanion hystrix* in the background of the photo.

At Population 9, a 1978 photograph clearly shows extensive bare soil and numerous ORV-tracks crossing the site, with little herbaceous vegetation evident. By 1985, herbaceous cover has increased to ca. 50 percent over the area.

The degree and nature of vegetation change observed at populations of *C. benitensis* in a 10 year period is in stark contrast to the relatively stability of vegetation conditions on nearby serpentine slopes. Figure 17 is a reproduction of a 1932 photograph taken as part of the Soil-Vegetation Surveys (Colwell 1977) by A.E. Weislander in Clear Creek canyon -

Figure 17. Comparison photographs of serpentine slopes in the lower Clear Creek watershed (view in NE¼ of Section 11, T18S, R11E, M.D.B.& M). **Upper photo:** taken by A.E. Wieslander of the California Soil-Vegetation Survey in 1932; **Lower photo:** the same scene in 1990. Note the general stability of vegetation in this scene, particularly compared to the rapid degree of vegetation change on alluvial terrace sites (cf. Figure 7) typical of *C. benitensis* habitat.



the same scene today is virtually unchanged. These photographs indicate that successional rates on the serpentine terraces which are the principal habitat of *Camissonia benitensis* are several orders of magnitude greater than on barren serpentine.

Stability and Endangerment of* Camissonia benitensis *populations - Historical inference suggests that populations of *C. benitensis* may remain stable at a site for time-intervals of several decades to one-century or more. Success and stability of *C. benitensis* populations is governed by two principal factors: physiographic and successional. Optimal *C. benitensis* habitat consists of geomorphically stable alluvial terraces, surfaces that are sufficiently stable to develop enriched, well-developed soils that are comparably fertile, as compared to the sterile serpentine slopes that predominate the San Benito Mountain landscape.

Monitoring photographs demonstrate increased shrub cover at many *C. benitensis* populations between 1980-1985. Long-term stability of *C. benitensis* populations is likely a direct function of vegetation dynamics in the *Quercus durata-Ceanothus cuneatus-Arctostaphylos glauca* dominated chaparral community. Observations suggest that *C. benitensis* populations are unable to persist in dense chaparral. Over time, increasing shrub cover would result in decrease fecundity of *C. benitensis*. As succession advances, increased shrub cover would eventually lead to elimination of *C. benitensis* from terraces. Given sufficient time between fires, soil seed reserves would become depleted and the species would become locally extinct.

If a disturbance event, such as fire, occurs before soil seed reserves are exhausted, a given population may once again flourish, rebuilding soil seed reserves. Extirpation of a population from a given terrace is the more likely outcome of successional dynamics. Although there is no data with which the question can be tested, it is doubtful that seed reserves of *Camissonia benitensis* are sufficiently long-lived to persist through more than one successional cycle. Once vegetation density on a terrace sites becomes to great to support *C. benitensis*, the seed reserves on that site would likely dwindle away. Following fire, a given terrace could only be recolonized by recruitment from other nearby populations.

Definition of Suitable Habitat for **Camissonia benitensis** - Table 16 summarizes a checklist of the key attributes of essential habitat for *C. benitensis*. Figure 18 provides photographs of additional habitat at Population 13 and suitable but unoccupied habitat in the Clear Creek Canyon (a *Layia discoidea* exclosure) to illustrate the range of variability in these features.

Table 16. Synopsis of key habitat attributes for suitable habitat for *Camissonia benitensis*.

Attribute	Suitable Condition
Physiographic	Alluvial terraces or adjacent toe slopes
Topographic	below ca. 4500 feet
Slope	Flat to gently sloping (<3°)
Geologic	Residual serpentine or serpentine alluvium
Edaphic	Moderately deep, dark-colored, moderately fertile
Clastic	Subject to frost heaving; minimal cover of surface gravel
Physiognomic	moderate woody plant cover; stable edges of shrub patches
Floristic	Presence of herb species in Group 10 of Table 10 (page 46)

HISTORY OF REGIONAL DISTURBANCE

Mining - many of the terrace sites that are suitable habitat for *Camissonia benitensis* in the San Benito Mountain region were heavily disturbed during the mining era that began in the 1860's. Mercury (quicksilver) was the principal resource, chromite a secondary resource, during the period prior to the 1940's. Subsequently, asbestos became a major resource in the 1940's and 1950's. The New Idria mining district, located on lower San Carlos Creek, was the focal point of extensive prospecting in the San Benito Mountain region. Many mining claims were located along Clear Creek. Early camps associated with this mining activity were located on terraces adjacent to the creek, as were small milling operations, retorts and similar facilities (Eckel and Meyers 1946). This mining activity doubtlessly had great negative impact on populations of *C. benitensis*, but the degree of such impact is purely speculative. Judging from the degree of past mining disturbance evident today, somewhat over half of the alluvial terraces along Clear Creek were impacted by this activity.

Figure 18. Photographs illustrating the range of variability of suitable *Camissonia benitensis* habitat. **Top:** representative serpentine terrace in Clear Creek Canyon supporting a population of *Layia discoidea*, representing suitable *C. benitensis* habitat. **Bottom:** Population 13.

Road Construction - the present day county road that traverses the Clear Creek canyon follows essentially the alignment of old wagon roads developed in the mining era. The present roadway traverses many of the alluvial terraces in the canyon, resulting in elimination of suitable *C. benitensis* habitat for approximately a third of its length.

Off-Road Vehicles - cross country motorcycle travel has been a popular activity in the region for several decades. However, its popularity grew markedly by the late 1960's. Presently, most of the Clear Creek canyon is heavily used by cross-country motorcycles. Although most population of *C. benitensis* are partly or wholly enclose by fencing, most have still been subject to ORV disturbance <u>each year</u> over the four year period of this study!

Grazing - limited abundance of annual forage production in the Clear Creek canyon has restricted stocking of livestock. Although the area is grazed, there is little evidence to suggest that past grazing practices has influenced the size and number of *Camissonia benitensis* populations. Even given this, grazing does have a moderate to minor detrimental impact on *C. benitensis* due to trampling of potentially suitable habitat.

DISCUSSION

Management Implications - Many, if not most, of the alluvial terraces within Clear Creek canyon are unsuitable as habitat for *Camissonia benitensis* due to their use as recreational sites. Many terraces are heavily disturbed by camping, vehicle traffic, and ORV use. Other terraces are covered by dense brush, and are thus unsuitable for this reason.

The degree of soil disturbance from recreation evident on alluvial terraces in the Clear Creek canyon was systematically inventoried. A total of 53 terraces in the canyon were inspected for suitability as habitat for *Camissonia benitensis*. The proportion of each terrace lost to various types of soil disturbances was estimated visually (i.e., area lost from vehicle traffic, camping, developed roadways, grading, BLM recreational facilities). Suitability of a terrace to support *Camissonia benitensis* was judged on the basis of three seperate criteria: 1) less than 50% of open sites (i.e. areas between chaparral shrubs) on the terrace was were disturbed by vehicle traffic; 2) at least 50% of the species in Group 10, Table 9 were present on the site; and 3) at least 25% of the site was not covered with chaparral. Figure 19 provides a histogram summarizing the degree of disturbance to alluvial terraces in the Clear Creek canyon. As can been seen in Figure 19, nearly two-thirds of all serpentine terraces (35 of 53) have greater than 50% of the surface of the terrace disturbed from vehicle traffic and thus are presently unsuitable as *Camissonia benitensis* habitat. Figure 20 summarizes the suitability of serpentine terraces in the Clear Creek canyon as habitat for *C. benitensis*.

Of the 53 terraces in the Clear Creek canyon, 9 are occupied by populations and 6 are suitable habitat, for a total of 15 (28%). The remaining 38 terraces (71%) were judged as presently unsuitable as *C. benitensis* habitat on the basis of the three criteria stated above. Clearly, these data indicate the principal factor contributing the endangerment of *Camissonia benitensis* is human recreational disturbances.

Recreational utilization of terrace sites apparently does not always result in extirpation of a *C. benitensis* population. Prior to 1980, camping and ORV-disturbance was heavy within several populations. However, for the most part, recreational impacts to populations of *C. benitensis* are negative. Speculation can be offered that many populations of *C. benitensis* may have become extirpated during the late-1960's and early-1970's, prior to the first reconnaissance botanical surveys of the canyon.

Long-term survival, and thus the listing status of *C. benitensis* under the Endangered Species Act, requires that habitat necessary to maintain the species be protected and managed. From a biological perspective, research suggests that it is insufficient to manage and protect only those terrace sites presently occupied by *C. benitensis* populations, because such a management program does not allow for dynamic and stochastic events which affect populations.

Figure 19. Histogram showing the degree of surface disturbance (given as the area of terrace surface disturbed by roadways, camping and off-road vehicle traffic) in all suitable habitat for *Camissonia benitensis* in the Clear Creek canyon.

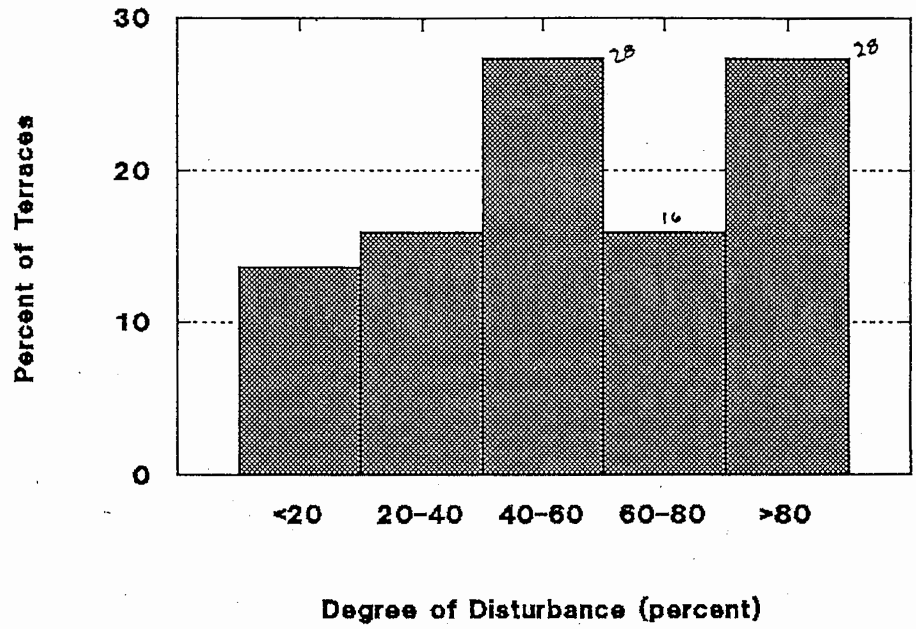
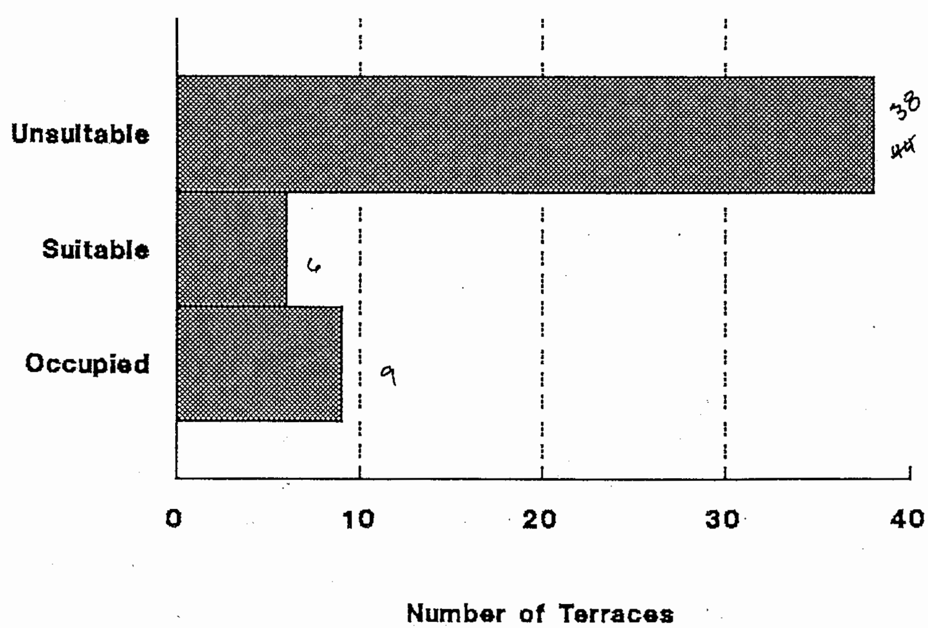


Figure 20. Proportion of alluvial serpentine terraces in the Clear Creek canyon rated for suitability as habitat for *Camissonia benitensis*. Over 70% of all potential habitat has been lost to recreational disturbance.



At present, only occupied habitat for *C. benitensis* is protected by active BLM management, while suitable but unoccupied sites are given over to off-road vehicle disturbance and camping. Were the present course of management to continue for several decades, extinction of the species could result from a combination of stochastic events (such as drought) and vegetation succession coupled with continued off-road vehicle use and camping disturbance.

In a natural setting, long-term persistence of *C. benitensis* is dependent on continued availability of sparsely vegetated terraces. Recreational utilization of these sites has interrupted the array of vegetation configurations, and constitutes the primary threat to stability of *C. benitensis*.

Management Recommendations - the results of this four year study of the biology of *C. benitensis* have demonstrated the extremely vulnerable status of the species. A number of management recommendations are listed below. Implementation of these recommendations will be required to meet the objectives of the Endangered Species Act:

1. The present management policy of allowing off-road vehicle traffic and camping on alluvial terraces has been insufficient to meet the mandates of the Endangered Species Act.

2. The decline in number of populations of *C. benitensis* over the past 5 years is clear and unequivocal evidence that the present Federal listing status of Threatened has been insufficient to provide protection to the species required under the Endangered Species Act. *Camissonia benitensis* should be relisted as Endangered until elements of a recovery plan can be implemented.

3. *Camissonia benitensis* should be listed as Endangered under the California Endangered Species Act, and state fees derived from licensing off-road vehicles should be made available to fund recovery efforts.

4. Successful management of *Camissonia benitensis*, with recovery and subsequent delisting, will only be accomplished over a 15-20 year period of observation and monitoring.

5. Successful recovery will require elimination of all vehicle traffic, fencing and soil surface manipulation by harrowing, and reintroduction of self-sustaining populations on minimally 10 and optimally 15 terrace sites.

6. Prior to full implementation of any final reintroduction and recovery plan, knowledge of the genetic variation within and between populations of *C. benitensis* should be derived from electrophoretic studies. Suitable seed for reintroduction should be obtained from cultivated plants of known genetic makeup.

7. Priorities for recovery should be applied in order to a) historically occupied sites, b) presently suitable habitat but historically unoccupied habitat, c) manipulation of habitat unsuitable by virtue of dense brush, and d) elimination and rehabilitation of heavily disturbed terraces.

Even with implementation of the recommendations states above, *Camissonia benitensis* should be retained as a Threatened species, due to the inability to totally recover habitat lost to roads and permanent mining disruption.

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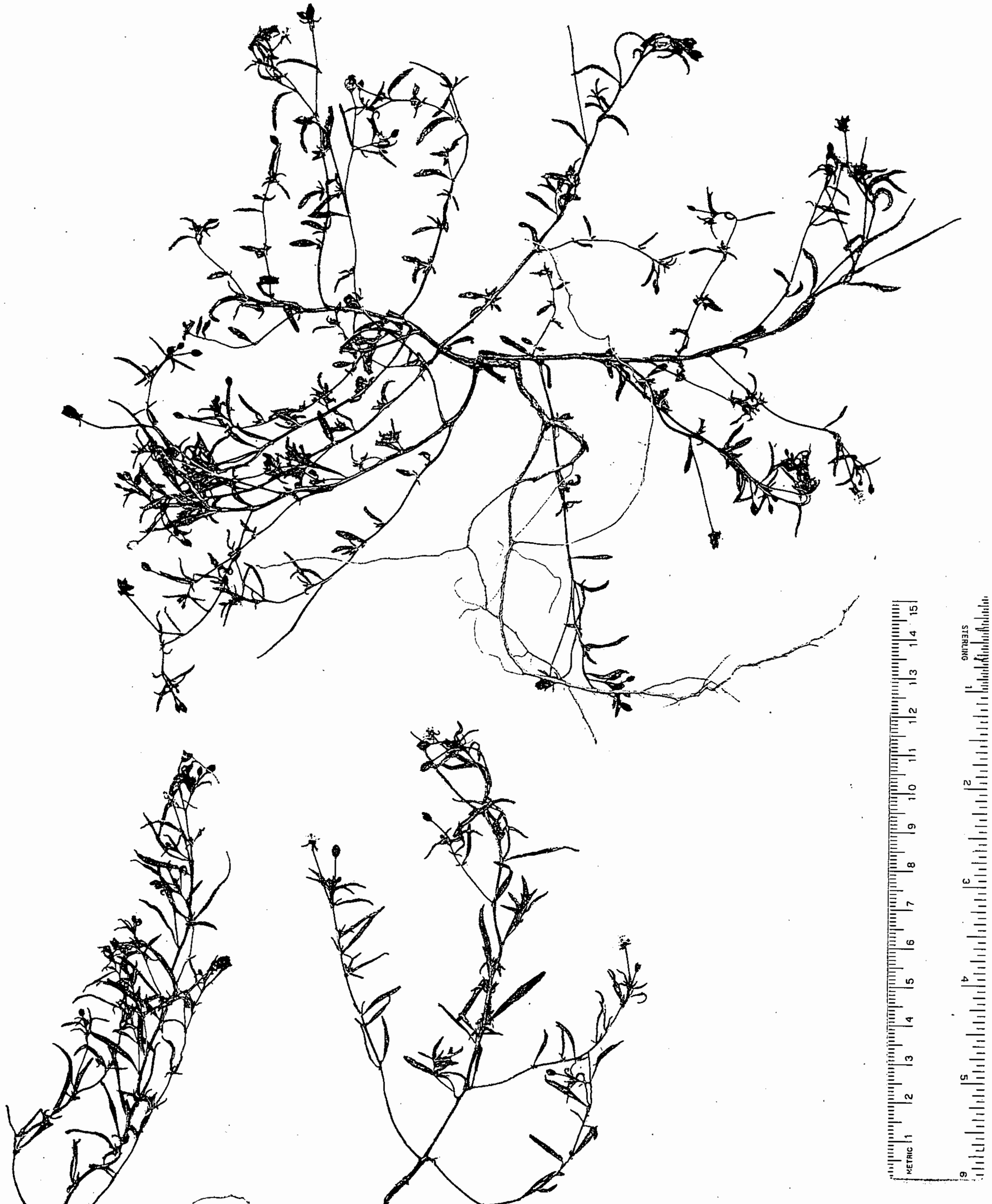
Appendix 1.

Representative Herbarium specimens of *Camissonia* taxa



PLANTS OF CALIFORNIA
SERPENTINE FLORA OF THE SOUTH COAST RANGES

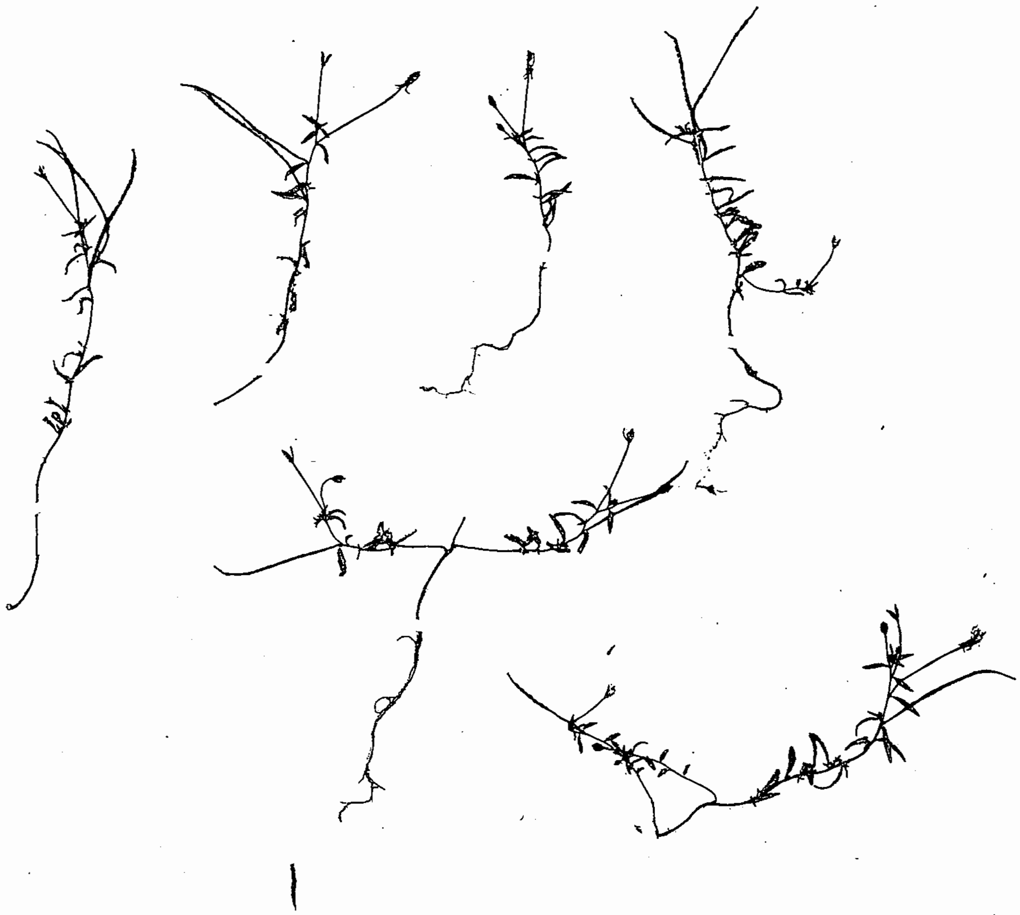
Camissonia benitensis Raven

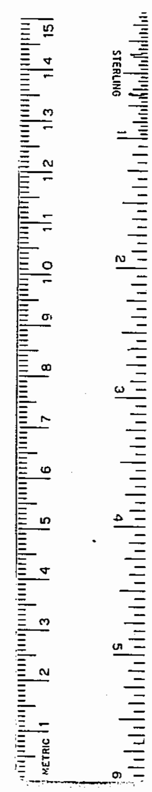
SAN BENITO COUNTY: **San Benito Mountain.** Along Clear Creek about 1.3 miles by road east from the confluence with San Benito River (NE1/4 of SE1/4 Section 16, T18S, R11E, Hesperdam Peak 71/2' quadrangle), 2580 feet elevation.

Flat alluvial terrace derived from serpentine, set 8 feet above creek level dominated by *Arctostaphylos benitoensis, Rhamnus californica, Pinus sabiniana* and with very sparse annual herb understory. Note: This site corresponds to BLM *Camissonia* Population No. 1B.

Dean Wm. Taylor #9636 13 May 1988

Distributed by BioSystems Analysis, Inc., Santa Cruz, CA





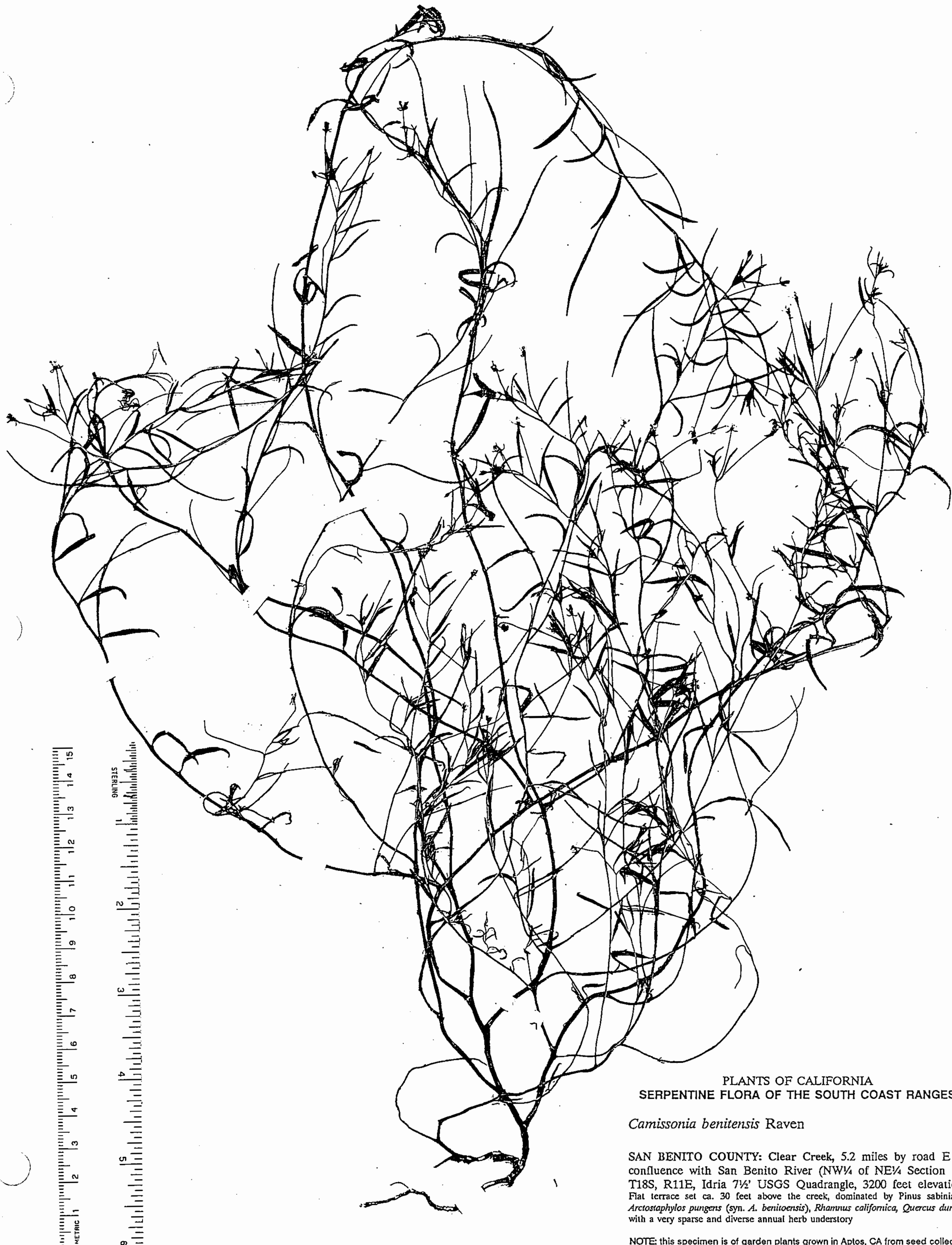
PLANTS OF CALIFORNIA
SERPENTINE FLORA OF THE SOUTH COAST RANGES

Camissonia benitensis Raven

SAN BENITO COUNTY: San Benito Mountain. Along Clear Creek about 5.3 miles by road east from the confluence with San Benito River (NW1/4 of NE1/4 Section 12, T18S, R11E, Idria 71/2' quadrangle), 3200 feet elevation.

Sloping terrace set 20 feet above creek level dominated by *Arctostaphylos benitoensis, Rhamnus californica, Pinus sabiniana* and with very sparse annual herb understory. Note: This site corresponds to BLM Population No. 6.

Dean Wm. Taylor #9570 22 April 1988
Distributed by BioSystems Analysis, Inc., Santa Cruz, CA



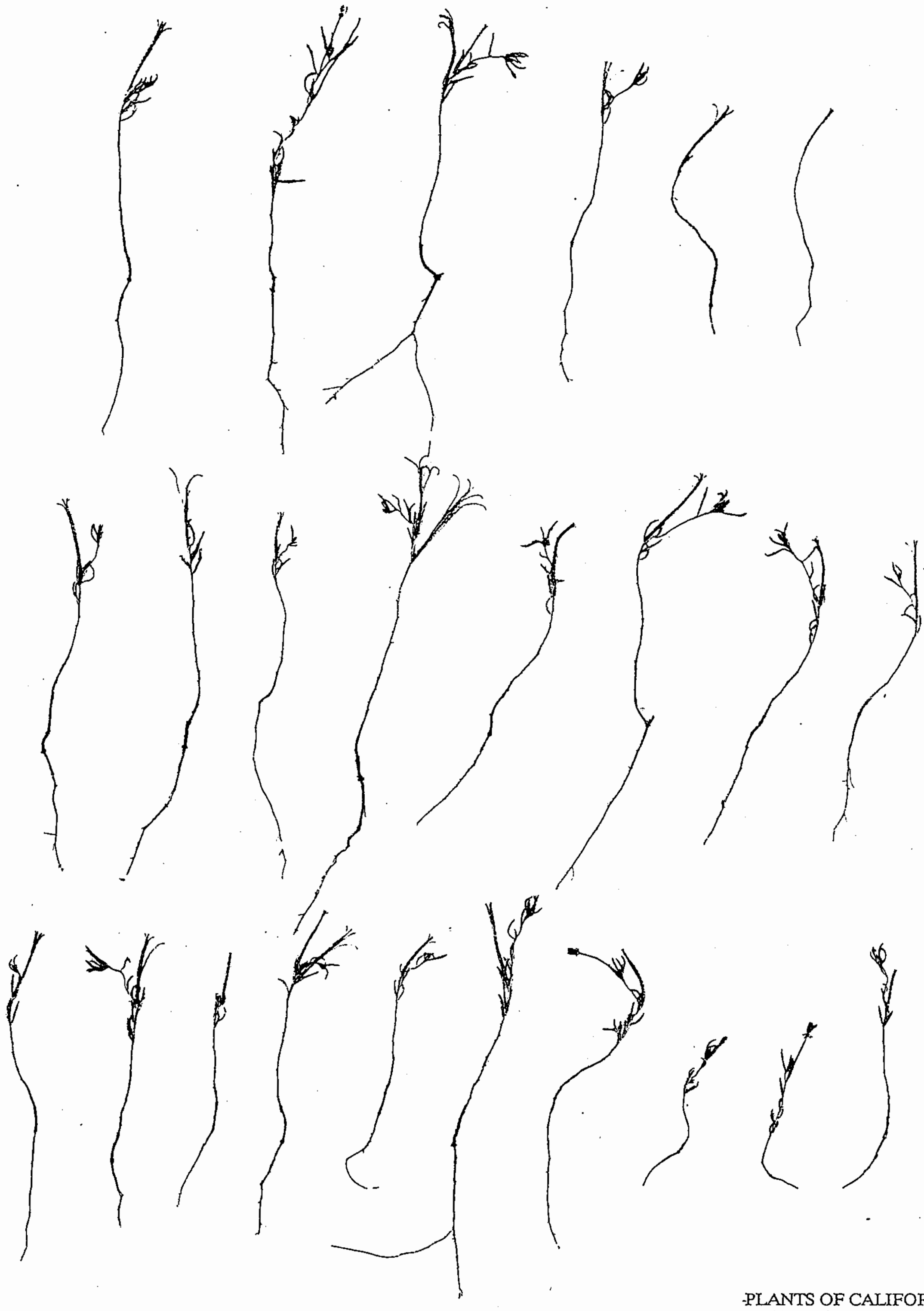
PLANTS OF CALIFORNIA
SERPENTINE FLORA OF THE SOUTH COAST RANGES

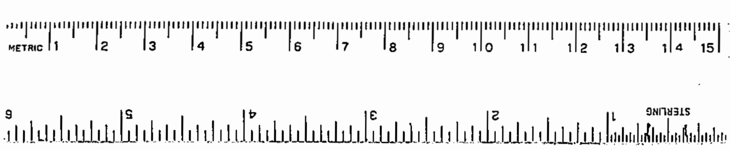
Camissonia benitensis Raven

SAN BENITO COUNTY: Clear Creek, 5.2 miles by road E of confluence with San Benito River (NW¼ of NE¼ Section 12, T18S, R11E, Idria 7½' USGS Quadrangle, 3200 feet elevation. Flat terrace set ca. 30 feet above the creek, dominated by Pinus sabiniana, *Arctostaphylos pungens* (syn. *A. benitoensis*), *Rhamnus californica, Quercus durata*, with a very sparse and diverse annual herb understory

NOTE: this specimen is of garden plants grown in Aptos, CA from seed collected in 1988. The field site represents the Type Location.

Dean Wm. Taylor #10,390 — 10 June 1989





PLANTS OF CALIFORNIA

SERPENTINE FLORA OF THE SOUTH COAST RANGES

Camissonia contorta (Douglas) Kearney

SAN BENITO COUNTY: Along Clear Creek about 0.8 miles by road east from the confluence with San Benito River (SW1/4 Section 16, T18S, R11E, Hesperdam Peak 71/2' quadrangle), 2400 feet elevation.

Alluvial deposits comprised mainly of serpentine on outwash plain set ca. 5 feet above creek level dominated by sparse canopy of *Pinus sabiniana* and with very sparse annual herb understory. Site corresponds to BLM *Camissonia* Pop. No. 1.

Dean Wm. Taylor #9629 13 May 1988

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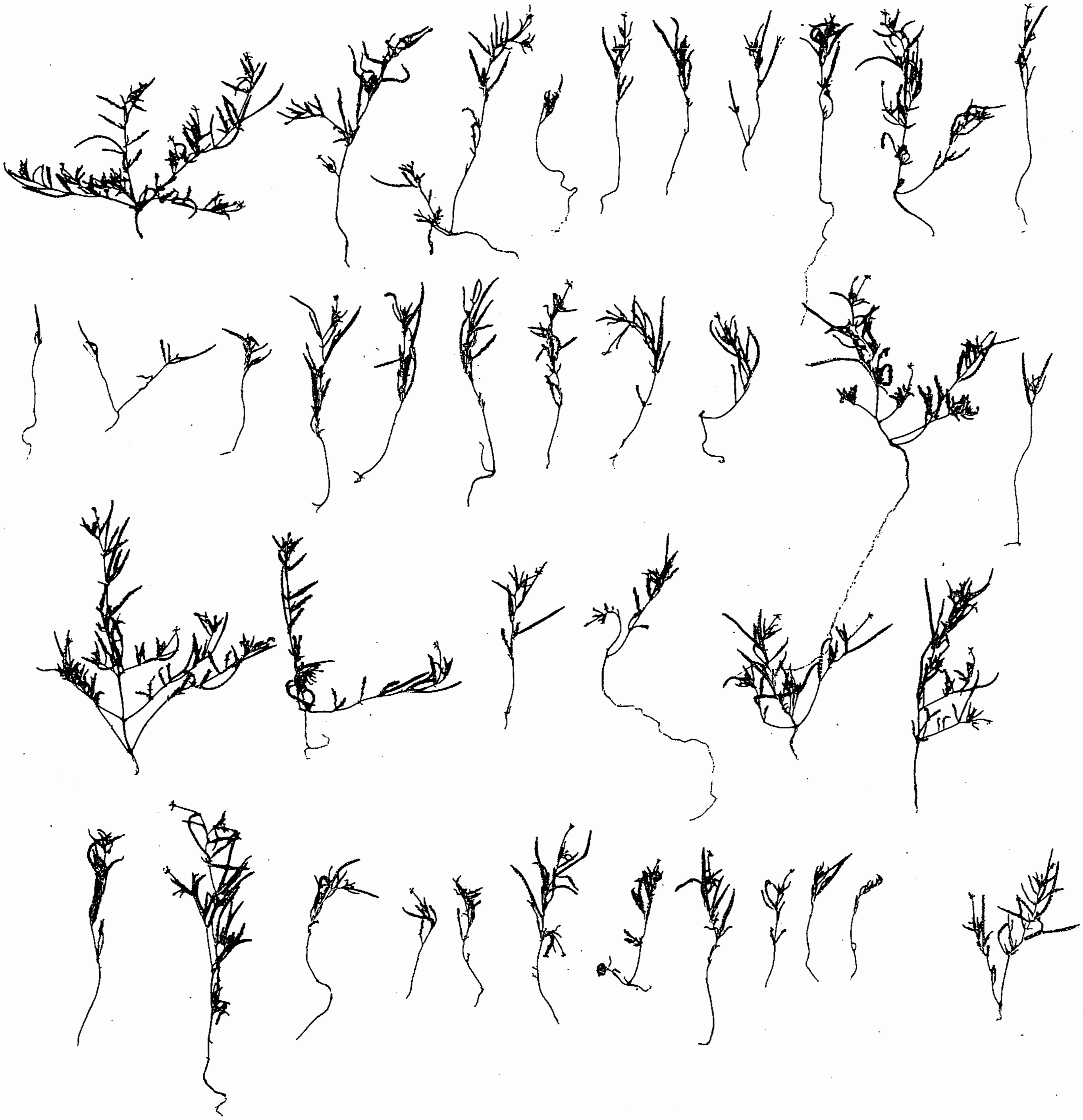
PLANTS OF CALIFORNIA
SERPENTINE FLORA OF THE SOUTH COAST RANGES

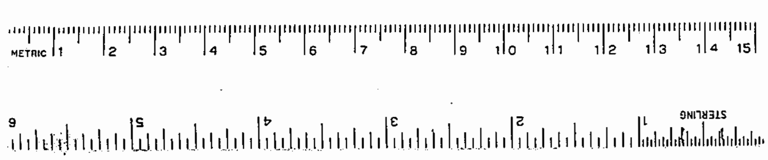
Camissonia contorta (Douglas) Kearney

SAN BENITO COUNTY: Clear Creek, 0.8 miles by road E of confluence with San Benito River, 2400 feet elevation. Flat terrace of cobbly serpentine alluvium with sparse overstory of Pinus sabiniana, los pungens *Rhamnus californica*, with a very sparse and diverse annual herb understory

NOTE: this specimen is of a garden plant grown in Aptos, CA from seed collected at the site in 1988.

Dean Wm. Taylor #10,389 — 10 June 1989



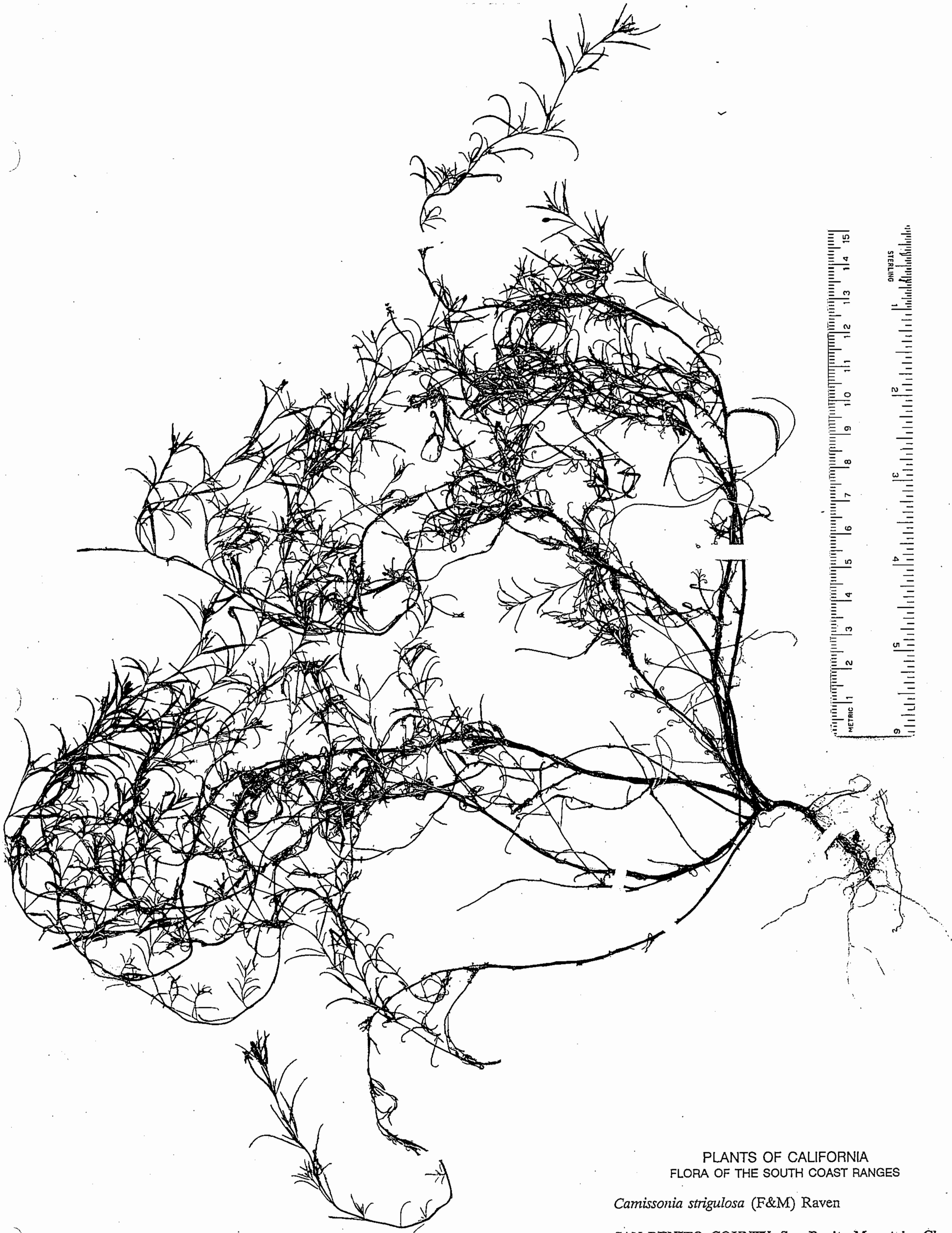


PLANTS OF CALIFORNIA
SERPENTINE FLORA OF THE SOUTH COAST RANGES

Camissonia strigulosa (F&M) Raven

SAN BENITO COUNTY: Clear Creek, ca. 1.7 miles by road upstream (as measured from crossing of San Benito River), SE¼ Section 15, T18S, R11E (Hepsedam Peak 7½' quadrangle), 2590 feet elevation. Barren strip on margin of *Ceanothus cuneatus* clump at base of north facing slope dominated by *Pinus sabiniana*, *Quercus douglasii*, *Fraxinus dipetala*; in a microsite with a very sparse and diverse annual herb understory

Dean Wm. Taylor #10,268 — 3 May 1989



PLANTS OF CALIFORNIA
FLORA OF THE SOUTH COAST RANGES

Camissonia strigulosa (F&M) Raven

SAN BENITO COUNTY: San Benito Mountain, Clear Creek drainage, 1.8 miles (by road) upstream from the San Benito River confluence.

Habitat: margin of shrubs of Ceanothus cuneatus, in barren zone of shrub driplines. This plant grown in Aptos, CA from seed collected in August, 1988.

Dean Wm. Taylor #10199B 1 April 1989