



***Cirsium andrewsii*:**
Natural History Summary and Research Recommendations

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April 22, 2001

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1. Introduction

Cirsium andrewsii (Asteraceae) Gray, is a rare species endemic to the San Francisco Bay Area that is found in seeps, streamsides and coastal sites where a great deal of moisture is available near the soil surface year-round. It is commonly known as Franciscan thistle, and was formerly named *Carduus amplifolius* (Greene). It is listed by the California Native Plant Society as a "watch" species (CNPS-4) and *The Jepson Manual* lists it as "UNCOMMON"; both signify that it is a species of interest because of its potential rarity. In San Francisco County, Franciscan thistle has been limited to three adjacent locations on the coastal bluffs of the Presidio. There are 23 known populations in Marin County, located in the Marin Headlands of the Golden Gate National Recreation Area, Point Reyes National Seashore, and western Marin County.

No published studies exist on Franciscan thistle. A primary objective of this document is to provide insight into the ecology of Franciscan thistle by compiling information from many sources on distribution, habitat associations, phylogenetic relationships, herbivory, life history, reproductive biology and potential threats. The summary also includes research recommendations, and is intended to serve as a foundation for management of the species. Except where noted, information included is based on NPS documentation from Golden Gate National Recreation Area and Point Reyes National Seashore; personal communications with experts; and personal observations by GGNRA natural resources staff and the author.

2. Morphologic Description

The type locality for the species was collected by Alice Eastwood in 1896 from "Tennessee Valley Bay", and is stored in the UC Berkeley botanical collection at the Jepson Herbarium. *C. andrewsii* is characterized by large, shiny green leaves that appear glabrous but may have hairs on the upper surface, and cobwebby-tomentose on the lower surface. Mature leaves may be 90 cm in length with stout spines that are from 1 to 1.5 cm long from the leaf edge. Flowering plants produce one to several flowering stalks and multiple inflorescences per stalk. Inflorescences are magenta to wine-red (although white inflorescences have been recorded in herbaria specimens); flowering occurs May through early July. Phyllaries of the involucre typically have many spines at the base that are visible to the naked eye. The size of plants varies somewhat according to environmental variables, such as exposure to wind; in protected drainages in the Marin Headlands, flowering plants are up to 2 m tall and 2 m across, and plants on the Presidio can be half this size.

The species can be easily confused with *C. vulgare* and *C. brevistylum*, which may grow in similar habitats. At the Point Reyes lighthouse population, *C. andrewsii* has been reported to hybridize with *C. quercetorum*, and plants found in that locale exhibit characteristics typical of both species. *C. quercetorum* is similarly glabrous on the upper leaf surface, faintly cobwebby on the lower surface, and much smaller in size than *C. andrewsii*, perhaps 50 cm in diameter at maturity. In addition, *C. quercetorum* produces white-yellow inflorescences produced on significantly shorter stalks.

3.1 Historic Distribution

Franciscan thistle is limited to regions of increased moisture, including perennial seeps, streams, freshwater wetland areas, and areas of heavy fog moisture accumulation. Historic flora indicate that its range once extended from northern San Mateo County to Sonoma County. The Bay Area flora by Greene (1891) reports Franciscan thistle occurring on stream banks on the east side of Point San Pedro in San Mateo County. This area has not been investigated recently. The Santa Cruz mountains flora by Thomas (1961) reports *C. andrewsii* on moist slopes in San Francisco and northern San Mateo County. Howell's flora of Marin County (1970) reports the distribution from north San Mateo County to Sonoma County.

Herbaria records note occurrences within the current distribution that are now extinct or have not been verified:

Tennessee Valley Cove or lagoon
Rodeo Lagoon near Ft. Barry
Lake Merced

Herbaria specimens document occurrences as far south as Lake Merced in San Francisco County and as far north as Dillon's Beach north of Tomales Bay (see Appendix 4.)

3.2 Current Distribution

Current distribution is, at its southern extent, the Green Valley drainage southeast of Point San Pedro in northern San Mateo County, on California State Park land. Northern-most populations occur in Point Reyes National Seashore.

23 current known occurrences* are, from south to north:

California State Parks, Montara Mountain	1 occurrence
GGNRA, Presidio Ft. Point and coastal bluffs	3 occurrences
GGNRA, Marin Headlands, Rodeo Valley	4 occurrences
GGNRA, Marin Headlands, Gerbode Valley	4 occurrences
GGNRA, Marin Headlands, Tennessee Valley	3 occurrences
Point Reyes National Seashore	6 occurrences
Northwest Marin County	2 occurrences

*For the purposes of this report, "occurrences" will be used interchangeably with "population".)

(Occurrences may or may not constitute distinct populations. Insufficient information on pollination and seed dispersal is known at this time, however, some occurrences are in relatively close proximity with others, separated by 1/4 mile or less. For the purposes of this report, "occurrences" will be used interchangeably with "population".)

Most occurrences are documented in rare plant monitoring by the California Native Plant Society or the governing land agency, however, the following populations have been recently observed and documentation may not yet exist on them: One population was reported but not verified in early 2000 in Contra Costa County on San Pablo Ridge above Orinda (*personal communication*, Brad Olson). One population was located in June 2000 on California State Parks land in a drainage on the south side of Point San Pedro, in the Green Valley coastal drainage of Montara Mountain, by the author and Michael Vasey. One population was located near Abbots Lagoon in Point Reyes National Seashore (P. Baye, pers. comm.). No populations are known to occur in the San Francisco Water District, the Marin Water District, or Marin County State Parks.

4.1 Habitat Description

C. andrewsii occurs in areas where perennial, or near-perennial, moisture is available. Most habitats are characterized by co-occurring plant species that indicate soil moisture, such as rushes, sedges and reed grass; however, two Point Reyes populations occur in the absence of an underground water source as well as moisture-indicator species.

In the regions where *C. andrewsii* is found, other habitat characteristics are highly variable. In the San Francisco Presidio, populations are located on exposed coastal bluffs (40-100 feet altitude) that receive salt spray from wave action below, heavy coastal winds, and accumulated moisture

due to fog. Parent material consists of Franciscan formation (serpentine, shale and soft sandstone/chert), primarily with soil types Henneke (variant)/Pachic Argustoll, Henneke (variant)/Ustorthent, Pablo/Bayview/(variants), and Cronkhite/Barnabe variant. *C. andrewsii* occurs in or adjacent to seeps indicated by the presence of *Scirpus cernuus* and *Salix lasiolepis*. Several plants are located on slumps bare of vegetation that during late summer months are dry on the soil surface. Low-growing native coastal bluff species and a variety of non-native invasive species also occur in these areas: *Mimulus guttatus*, *Plantago maritima*, *Fragaria chilensis*, *Aster chilensis*, *Juncus ssp.*, *Pichris echioides* (non-native), and *Plantago coronopus* (non-native).

In contrast, *C. andrewsii* populations in the Marin Headlands form inland in deep-soil drainages that range from upland seeps (400-500 feet altitude) to wet valley bottomlands (near sea level to 200 feet altitude). Upland seeps are typically moderately sloped, narrow channels bordered on both sides by steep scrub-covered slopes. Bottomlands are wide, marshy areas that flatten out in the valley floors. In the bottomlands, water flows slowly over the breadth of the wide channel, or it forms active rivulets branching across the channel. Soils are derived from chert, sandstone and clay parent materials. In these regions, Franciscan thistle is observed to establish in openings in dense graminoid and herbaceous vegetation associated with moist areas. The species occurs in the absence of riparian tree canopy such as willow and myrtle, or on the edges of canopy; it has not been observed as understory. Dominant native species in Marin Headlands populations include *Scirpus microcarpus*, *Calamagrostis nutkaensis*, *Athyrium felix-femina*, *Juncus balticus*, and *Juncus effusus*.

Populations at Point Reyes National Seashore include seeps indicated by *Juncus effusus* and *Juncus patens* as well as maritime chaparral and coastal bluff communities that do not have an underground water source. One seep population east of the Point Reyes lighthouse receives heavy disturbance due to dairy cattle grazing and is inundated with non-native grasses, particularly *Lolium perenne*. Populations adjacent to the lighthouse itself form a component of communities that include as dominants *Calamagrostis nutkaensis*, *Ceanothus thyrsiflorus*, *Arctostaphylos uva-ursi*, *Vaccinium ovatum*, and *Cirsium quercetorum*. These populations were entirely without obvious water sources and probably accumulate moisture necessary to support *C. andrewsii* through fog condensation.

4.2 Soils

Soil surveys of Marin and San Francisco counties indicate that *C. andrewsii* populations occur on a variety of soil types (Jones and Stokes 1997; Soil Conservation Service 1985).

Presidio populations occur on:

(1) Serpentine soils. Henneke (variant)/Pachic Argustoll and Henneke (variant)/Ustorthent. These are derived from serpentine parent material and are characterized by high levels of heavy metals, low calcium, potassium and other nutrients, a high pH, and xeric conditions.

Marin Headlands populations occur on:

(1) Rodeo clay loam. These are deep, poorly drained soils in narrow valleys and basins characterized by low water permeability, high water capacity, and surface water typically from December to April. (Populations in bottomland, gently sloped areas.)

(2) Tamalpais-Barnabe Variant gravelly loam. Soils are between 50-60% Tamalpais gravelly loams and 30-40% Barnabe Variant gravelly loams, which range from shallow to moderately-deep, well-drained soils and are derived from chert and sandstone formations. (Populations in upland seep areas.)

Point Reyes National Seashore populations occur on:

(1) Sirdak sand. It is characterized by deep sand, excessively drained soil, rolling dunes, and rapid water permeability as well as low water capacity. (Population in dune slack near lighthouse. Soil at this site appears to have inclusion of loamy less well-drained soil.)

- (2) Rock outcrops composed of Xerorthents complex. These are long, narrow rocky areas of sandstone, slate, serpentine and chert. (Populations at the lighthouse and one at Pierce Point.)
- (3) Kehoe Variant course sandy loam. It is deep, well-drained soil derived from quartz-diorite. This soil type has moderately rapid permeability and low to moderate water capacity. (Populations at Tomales Point occur primarily on Kehoe soils.)

4.3 Soil Moisture

Annual duration and amount of observed soil moisture appears to vary from site to site. For populations occurring in seep or stream channels, soil moisture varies seasonally but is typically perennial or near-perennial. In these areas, soils of both perennial and seasonal seeps are saturated and surface water is present in and around main stream channels during the winter wet season. During the late summer and early fall dry season, perennial streams and seeps recede to small water corridors which continue to support water-dependent vegetation, and seasonal seeps become completely dry on the soil surface belying the presence of water during the rest of the year.

Two populations in the Presidio occur on seeps with more seasonally variable soil moisture than populations in the Marin Headlands; soil surface is dry in summer and fall months. As noted above (section 4.1), populations at the Point Reyes lighthouse occur in the absence of apparent underground water sources; moisture appears to accumulate from fog condensation. Soil moisture and atmospheric/precipitation moisture requirements of the species have not been assessed at this time.

4.4 Climate

Northern California exhibits a Mediterranean-type climate, with cool, rainy winter seasons and warm, dry summers. Coastal regions in this floristic province are characterized by year-round fog, especially heavy during the summer after rains have ceased, which provides an additional was source to coastal species.

Local climate and precipitation in the Presidio, Marin Headlands and Point Reyes vary due to geography. Presidio and Point Reyes populations are exposed to cooler annual temperatures and more fog than those in the Marin Headlands, which are slightly inland, warmer and drier. Weather data was unavailable for NPS locations, but comparisons of Western Regional Climate Center data in San Francisco's Richmond district and in Kentfield, Marin County reveal large differences in precipitation and temperature. Overall annual precipitation was higher in Kentfield (mean of 49 inches) than San Francisco (mean of 19 inches), as well as temperature mean and range (Kentfield mean temperature of 58° F, with a range of 40-70° F; San Francisco mean temperature of 55° F, with a range of 49-61° F).

4.5 Disturbance Processes and Competition

C. andrewsii does not appear to be reliant on widespread, persistent disturbance to maintain multi-age populations. However some populations occur in seeps and on streamsides, areas of intense competition among plant species and seasonal, localized hydrologic disturbance. The thistle may take advantage of such localized disturbance for germination, but juvenile and mature plants do not appear rely on these temporary openings in later life stages. For example, in a *C. andrewsii* population on the Presidio coastal bluffs, seedlings were observed to emerge following iceplant removal. Juveniles have been observed in dense vegetation including *Scirpus microcarpus* and tussocks of *Calamagrostis nutkaensis*, as with seep vegetation corridors of the Marin Headlands, as well as *Calamagrostis*-dominated maritime chaparral and coastal scrub of Point Reyes. At maturity, large physical size of the thistle contributes to its competitive ability. David Keil, PhD, of California Polytechnical Institute and author of the *Cirsium* section of *The*

Jepson Manual, notes that most native thistles are not disturbance-dependent, contrary to popular thought influenced by the reputation of invasive congeners (personal communication).

First-year results of an experiment testing the response of outplanted *C. andrewsii* juveniles to interspecific competition show that the experimental juveniles compensated through upright, etiolated growth, which resembled naturally-occurring juveniles where leaves were observed to extend vertically through dense vegetation. Second-year results of the same experiment show that there is no significant difference in growth due to decreased competition. There was a trend of competition affecting survivorship, but it did not affect surviving plants ability to flower. These results suggest that competition has its strongest effect during the seedling growth stage for the species.

5.1 Life History

Little is known about the life history and reproductive biology of *C. andrewsii*. It is typically a monocarpic, short-lived perennial and lifespan may be affected by environmental stresses. *The Jepson Manual* indicates that it is biennial, sometimes perennial, yet studies have not examined the length of time for individuals to reach reproduction. In addition, the conditions required for reproduction are unknown. It forms a basal rosette as a juvenile that persists until flowering, at which time a single rosette may form one to several flowering stalks. In some habitats, such as the Presidio and Point Reyes coastal bluffs, some plants are observed to form multiple rosettes from a single taproot. In this case single rosettes may bolt and die and leave the remainder of the plant unaffected. The mechanism causing multiple rosettes on a single plant is not understood; Dan Gluesencamp suggested it may be due to resprouting from herbivory at the caudex (personal communication). Seeds germinate throughout the wet season, as water availability appears to be the limiting factor; seedlings have been observed from December through June. Length of seed viability is unknown.

5.2 Reproductive Biology

Dispersal is believed to occur primarily via gravity, water flow and wind. The thistle produces relatively large seeds compared to small pappus, which expands when dry to a disc-like shape. The inability of large seeds to travel long distances may contribute to the patchy distribution of individuals within a single area. A small number of seeds disperse from the seedhead, or the seedhead with seeds enclosed may fall to the ground and the seeds germinate in place.

Nothing is known about the pollinators of *C. andrewsii*. *Cirsium* species are visited by bees, beetles, butterflies, and hover-flies (Redfern 1983). Redfern's *Insects and Thistles* contains a key to identifying the genus of insects found on thistles, but does not elaborate on species-specific pollinators. This topic is a question for further research.

All native *Cirsium* are likely outcrossers, where typically low seed set of an individual suggests that abundant pollen produced is not effective in self-pollination; if population size is too low, little seed production is likely (Keil, personal communication). However, in 1998, for example, two *C. andrewsii* isolated by over 1/4 mile from other plants produced approximately 50 viable seeds between them, even after heavy seed herbivory. Nearly all of these seeds produced germinated in the greenhouse and survived. The small populations in the Presidio currently have low reproduction due to lack of bolting plants, not pollination requirements. The extent to which outcrossing and proximity to neighbors are limiting factors for optimal seed production, as well as conditions required for reproduction, are questions for future research.

The extent to which *C. andrewsii* hybridizes with other native thistles is not known. Observations by Howell (1970) note that a population of *C. andrewsii* near the Point Reyes hybridized with *C. quercetorum*. As noted in section (2), characteristics of several individuals on the Presidio coastal

bluffs resembled those of *C. brevistylum* indicating a possible hybrid. The extent of hybridization between *C. andrewsii* and other native thistles is another question for future research.

6.1 Threats - Invasive Plants

Franciscan thistle typically occurs in inaccessible locations, with the exception of the San Francisco Presidio, therefore human-related disturbance is reduced. Currently the greatest threats are invasive exotic plant species that would occupy the same sites as the thistle and create canopy or form groundcovers that could reduce or prevent germination and juvenile plant establishment. Invasive species threats vary from region to region and site to site.

Populations on the Presidio coastal bluffs are threatened by the greatest variety of invasive species within each site. Past military presence either introduced or facilitated introduction of perennials iceplant (*Carpobrotus edulis*) and cape-ivy (*Delairea odorata*) and the annual bristly ox-tongue (*Pichris echioides*). Iceplant and cape-ivy form dense mats over existing vegetation and effectively prevent germination of seedlings. (Iceplant may not damage the seedbank, as *C. andrewsii* seedlings have been observed following iceplant removal in population areas. See Appendix 3 for further discussion of seedling emergence.) Basal rosettes of *Pichris* seedlings occupy virtually all exposed soil surfaces in one *C. andrewsii* population (C1); these bolt and tower over adjacent low-growing native bluff species. *Cortaderia jubata* was once widespread on the coastal bluffs but through ongoing removal by National Park Service staff and volunteers, pampas grass has been nearly controlled.

Marin Headlands populations face few urgent threats as most populations are in remote, difficult to access locations. In bottomland populations, the greatest threats are encroaching harding grass (*Phalaris aquatica*) and tall fescue (*Festuca arundinaceae*) from adjacent grazed slopes. At all sites, poison hemlock (*Conium maculatum*) has been observed in sparse numbers. In the Gerbode Valley, ox-eye daisy (*Leucanthemum vulgare*) is moving from infestations across the valley floor to the wetlands where *C. andrewsii* is located, especially Marin Headlands population number 1.

At Point Reyes National Seashore, cattle may pose a problem and sites that are grazed should be monitored closely. Perennial non-native grasses, especially *Lolium perenne*, occupy these grazed areas. Additionally, iceplant occurs throughout the Point Reyes Lighthouse population.

6.2 Threats - Insect Herbivores

No studies have directly addressed insect herbivory on *C. andrewsii*. Charles Turner (1987) examined the use of native thistles by *Rhinocyllus conicus* as host plants, but no weevils were recovered from *C. andrewsii* inflorescences so it was not included in the study (Herr, pers. comm.). Insect dung and partially eaten seed has been observed in inflorescences, but insect species have not been determined (Strathmann, pers. obs.). Herbivory on other native *Cirsium* has been well documented, especially the effects of *Rhinocyllus conicus*, the exotic weevil introduced as a biocontrol method for exotic thistle species (Louda 1998, Guretzky and Louda 1997, Louda and Potvin 1995, Turner 1987). Soon after introduction, the weevil began to use native thistles as hosts. Experts suspect that sites *C. andrewsii* inhabit are too coastal for the weevil (Gluesencamp, pers. comm.; Keil, pers. comm.; Herr, pers. comm.) but warn that infestations should not be ruled out. Weevils may be found in inland populations, and according to John Herr, weevils reared from *C. andrewsii* seedheads are most likely *Rhinocyllus conicus* (pers. comm.). Future research should include the extent and effects of seed predation on the species.

7. Management and Research Recommendations

Based on the above review of *C. andrewsii* ecology, I have developed management recommendations and suggested research topics.

Management

Of all populations, those on the coastal bluffs and at Fort Point of the Presidio appear to be in the most precarious state. In addition to the abundance of exotic species that infest each of the population areas, the coastal bluffs are also geomorphically active. Slumps occur each year where portions of the bluffs fall into the Pacific ocean. Meanwhile, the bluffs are bordered on the eastern side by military batteries constructed by the Army. Over a period of decades, the current population area of *C. andrewsii* on the coastal bluffs may be greatly reduced. It is highly recommended that to maintain stable populations in the Presidio, new inland sites be found or created where threats of basic habitat loss are reduced.

For all populations, invasive species control (as noted above in section 6.1) is of high priority. Control of exotic species tolerant of or preferring wetland conditions is particularly critical. In Point Reyes, the impacts to *C. andrewsii* due to cattle grazing has not been studied. These sites should be monitored, and grazing regimes should be altered accordingly.

Management and academic research

A multitude of research questions remain about the species. Following are several topics in order of priority:

- Determine the extent of insect:seed predation on the species, especially that of *Rhinocyllus conicus*.
- Determine optimal environmental conditions for reproduction (in order to select priority reintroduction sites).
- What is long-term seed viability of the species?
- What are the insect or aviary pollinators for the species?
- Is *C. andrewsii* a host for other insect species, and what services does it provide to the insects?
- What are the soil moisture and atmospheric moisture requirements for the species?
- What is genetic lineage of *C. andrewsii*? Does it hybridize with other native thistles?
- What is the extent of outcrossing and/or selfing pollination?

Acknowledgments

Many thanks to Marc Albert, Sharon Farrell and Tom Parker for their support and guidance in this project. I am also indebted to the many ecologists and botanists who patiently answered questions and helped to guide this research. Dale Smith was the primary monitor for *C. andrewsii* in the Marin Headlands in 2000. Dale and Tom Elliott helped to census several Marin Headlands populations during 1999 monitoring. For the implementation and monitoring of the Marin Headlands planting experiment, many thanks to Brian Adams, Noreen Dalton, Lisa Sebastian and Dale Smith, without whom data collection during the brief sampling period would not have been possible. Sharon Farrell was key in walking this project through the NPS permitting process, and Maria Alvarez and Hall Cushman gave invaluable advice for the study design. Finally, thanks to Tom Elliott for his support, encouragement and unending enthusiasm for botany and ecological debate. For the Presidio trials, Peter Brastow was responsible for implementing the trials, and Tiffany Romaine meticulously monitored and noted observations throughout their duration.

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Appendices

APPENDIX 1.

Cirsium andrewsii Population Census Results Marin Headlands and San Francisco Presidio, GGNRA

INTRODUCTION

Cirsium andrewsii (Franciscan thistle) is limited to regions of increased moisture, including perennial seeps, streams, freshwater wetland areas, and areas of heavy fog moisture accumulation in the San Francisco Bay Area. Historic flora indicate that *C. andrewsii* range once extended from northern San Mateo County to southern Sonoma County. There are 17 known populations in Marin County, located in the Marin Headlands of the Golden Gate National Recreation Area, Point Reyes National Seashore, and western Marin County. In San Francisco County, *C. andrewsii* has been limited to three proximate locations on the coastal bluffs of the Presidio of San Francisco. Current distribution is at its southern extent a wetland, sheltered drainage in northern San Mateo County, on the south side of Pt. San Pedro, and northern-most populations occur in Point Reyes National Seashore.

Populations occurring in the Golden Gate National Recreation Area have been censused by the California Native Plant Society and the National Park Service since the 1980s. The purpose of this report is to: (1) summarize census methods and findings; and (2) report reproductive data collected in naturally-occurring populations in the Marin Headlands and the San Francisco Presidio.

METHODS

Census

Over the years, monitoring methods have varied. Initially, plants were surveyed by systematically walking the known population area that were discovered and reported by botanists over the years. Rare plant monitors counted individual plants within each population, including seedlings, mature but not flowering plants (juveniles) and flowering individuals; totals for each life stage were not recorded. Counting all plants does not present an accurate account of fluctuations in reproduction, and ultimately longer-term fluctuation in population numbers, since *C. andrewsii* is a monocarpic perennial. More importantly, the method is not reliable: tall and dense vegetation found in many seep communities makes locating seedlings and juveniles very difficult. Flowering individuals are readily visible, even in dense vegetation. Flowering plants are up to 2 meters tall and 2 meters wide, with a panicle of red inflorescences. In 1999, a census method was initiated for Marin Headlands populations to record only number of flowering individuals. Observed juveniles and seedlings were noted separately, but not tallied for the census. Where feasible, the entire length of drainages where populations occur were surveyed by systematically walking the area from the headwaters to its connection at the valley bottom with the larger drainage. Using the new method, several new populations were located: populations 2 through 10 had not been censused prior to 1999.

In the Presidio, where seep vegetation is typically low-growing and population areas are small enough to survey thoroughly, plants are censused by counting all individuals. Seedlings and juveniles are tallied together and flowering individuals are tallied separately. Presidio population C1 had not been identified or censused prior to 1999 and C2 prior to 2000. In January 2000, 10 nursery-grown *C. andrewsii* were outplanted into Presidio C1; survivorship from this outplanting are included in 2000 monitoring. A third population was created by outplanting 15 nursery-grown *C. andrewsii* in January 2000. (See Appendix 3 for a report on these outplantings.)

Reproduction potential

In order to gain information about the reproductive potential of *C. andrewsii*, number of inflorescences produced per individual were counted for selected populations, and number of seeds produced per inflorescence were counted for randomly selected individuals. Seeds were

cleaned and those determined to be inviable were discarded. (Viable seeds were typically glossy, chestnut brown with a hard seedcoat that did not give way to under mild pressure from a sharp instrument.) In the Marin Headlands, three populations were selected to count inflorescences: 2, 3 and 4; eight populations were selected to collect inflorescences: 1, 2, 3, 4, 5, 6, 7, and 11. Two fruiting inflorescences were removed from randomly selected individuals from each population and the seeds were cleaned and counted. In the Presidio, inflorescences were counted for each flowering individual, and two inflorescences were selected randomly from them. Cleaned and counted seed was returned to either the Marin Headlands Native Plant Nursery or the Presidio Native Plant Nursery, depending on seed source.

RESULTS

Census

Marin Headlands census data of flowering individuals is summarized below:

Population	1998	1999	2000
1	210	388	298
2	--	95	54
3	--	187	112
4	--	166	40
5	--	13	19
6	--	37	19
7	--	10	8
8	--	6	9
9	--	22	--
10	--	0 (18 juveniles)	--

Presidio census data of total individuals is summarized below:

Population	1996	1997	1998	1999	2000	2000 Flowering Individuals
Ft. Point	17	7	7	5	3	0
C1	--	--	--	19	27	6
C2	--	--	--	--	49	5

Reproductive potential

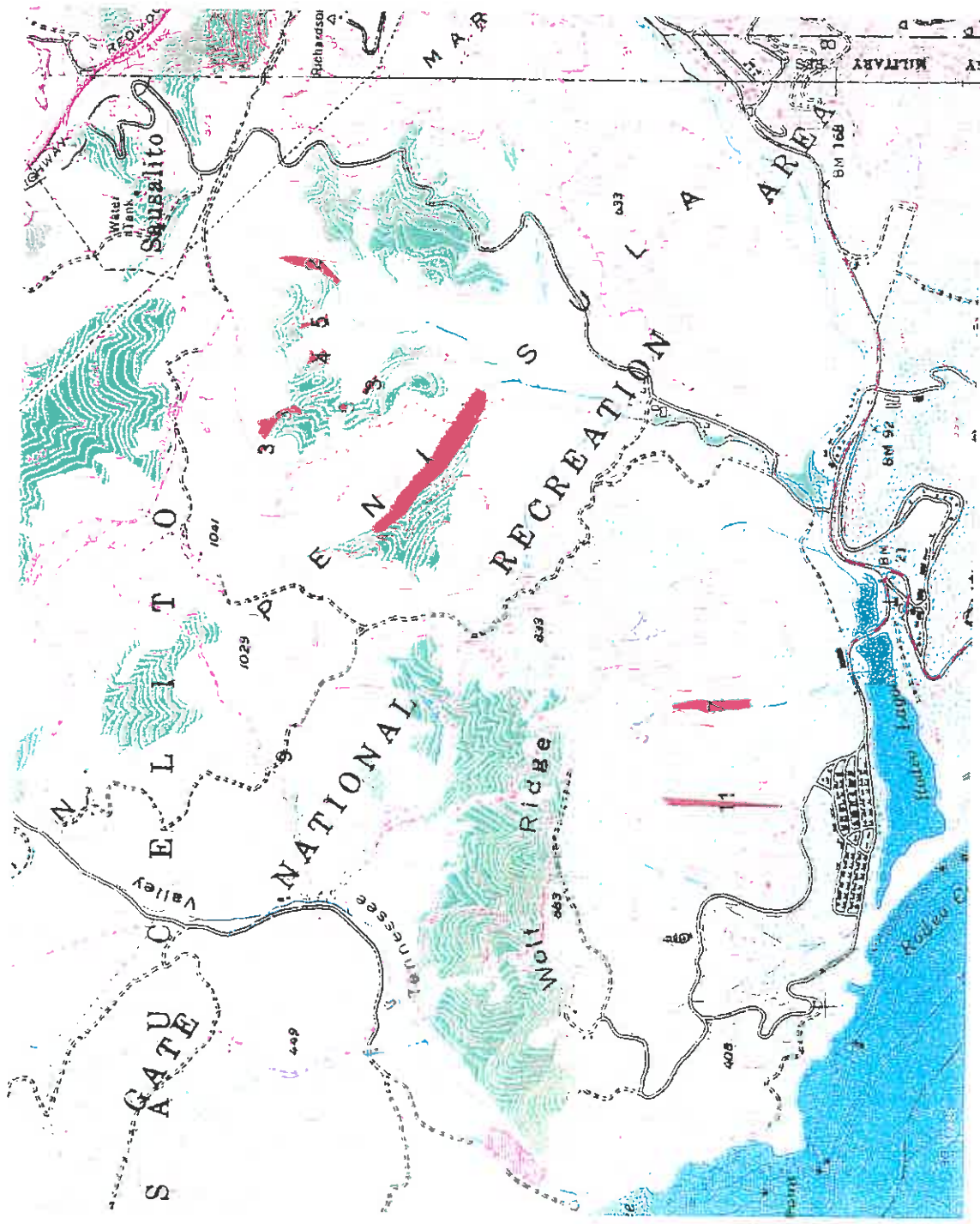
There was large variation in both number of inflorescences per plant and number of viable seeds per inflorescence. For Marin Headlands individuals sampled, flowering plants averaged 88 (+/- 44.7) inflorescences per plant, and inflorescences averaged 42 (+/- 17.3) viable seeds. Presidio flowering plants averaged 98 (+/- 54.7) inflorescences per plant, and 47 (+/- 52.9) viable seeds.

DISCUSSION

Census data for most Marin Headlands and Presidio populations has been collected in a standardized fashion for two years or less. It is critical that systematized monitoring continue in order to detect population trends and trigger management actions in case of population decline. Additional populations may be identified in the GGNRA, particularly in the Marin Headlands and northern lands, as wetland areas in the GGNRA have not been systematically inventoried. Such an inventory would present a better indication of population frequency within the given range. There is a decrease in most Marin Headlands populations from 1999 to 2000, and an overall decrease in the Presidio Fort Point population from 1996 to 2000, however, with limited data thus far, these trends are not conclusive. The species appears to have a persistent seedbank; this will be investigated further via long-term germination trials at the Marin Headlands Native Plant Nursery.

The number of inflorescences per plant and viable seeds per inflorescence were also variable, and are likely influenced greatly by the microsite conditions of the plant and general environmental conditions of the population. While these data provide initial information about the reproductive potential of the species, a future sampling that includes several replicates in each population for number of inflorescences counted, and several replicates per plant for number of seeds per inflorescence, would provide a greater understanding of this variation.

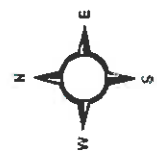
Cirsium andrewsii - Marin Headlands



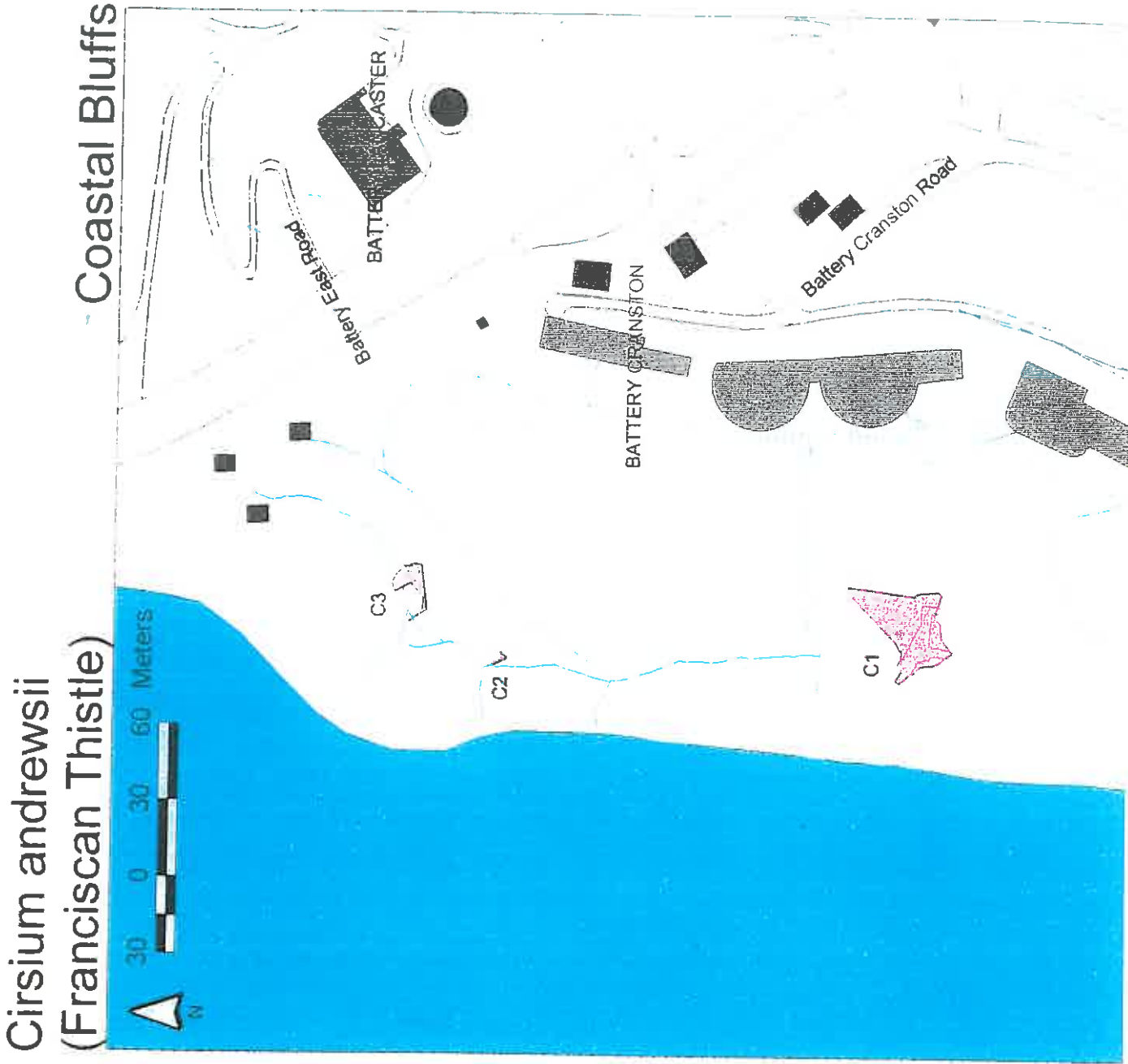
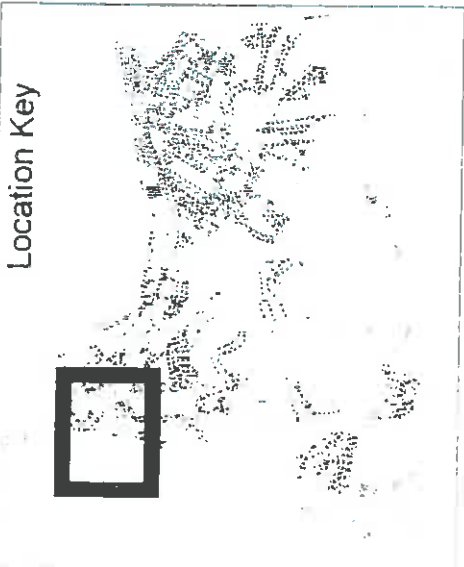
San Francisco South
Point Bonita Quadrangles



Cian_00.shp



Special Status Plant Species 2000



Legend

- Cirsium andrewsii '00
- Cirsium andrewsii '99
- Ocean
- Buildings
- Batteries
- Coastal Trail
- Trails
- Contours
- Roads

Notes

Populations

C1= 27 (10 new outplants)
C2= 49
C3= 14 (all new outplants)

APPENDIX 2.

EFFECTS OF COMPETITION ON A RARE STREAMSIDE ENDEMIC, *CIRSIIUM ANDREWSII*

Katrina Strathmann

Abstract. This study examines the effects of competition on *Cirsium andrewsii*, a rare moist-environment thistle, testing thistle response to interspecific above-ground competition during early growth as well as second year growth and flowering. Etiolation of juveniles in response to increased competition suggests that the thistle is adapted to competition during early growth. Plants did not exhibit this growth response in the second year of the study, but there was a trend of a negative effect competition on survivorship. There was no effect of competition on flowering of plants or number of inflorescences produced. These results suggest that the thistle is more vulnerable to the effects of competition during early growth stages.

INTRODUCTION

In environments of unlimited resources, increased competition can have large effects on less competitive species, including altered morphology, reduced growth, reduced fitness, mortality, and, possibly, local extinction. Disturbance-tolerant species are able to persist under these conditions through colonization of exposed areas (Cavers and Harper 1967). In a stream corridor, gaps are caused by seasonal geomorphologic changes, such as silting, erosion or removal of vegetation, and biotic changes, such as plant senescence or seasonal dormancy.

This study examines a rare endemic, *Cirsium andrewsii*, or Franciscan thistle, in a competitive stream corridor habitat. Rare or endemic species are naturally at odds with highly competitive species, as endemics are correlated with areas of reduced competition (Oostermeijer et al. 1994; Médail and Verlaque 1997). In fact, next to human activity, interspecific competition is believed to be one of the greatest threats to endemics (Médail and Verlaque 1997). Like disturbance-tolerant species, many endemics rely on gap creation for colonization, establishment and persistence of a population (Morgan 1997). In fact, increased surrounding vegetation has been correlated with reduced population size as well as a regressive population structure (Oostermeijer et al. 1994; Washitani et al. 1997). Therefore, these gaps in water corridors may have increased importance for the continued establishment of such species.

To better understand the effects of the competitive environment on this rare plant as well as its adaptive strategies, I asked the following questions regarding the thistle: (1) What is the effect of competition on seedling and mature plant growth? (2) What is the effect of competition on reproduction? and (3) Is there a correlation of environmental factors with plant growth, survival, or reproduction?

STUDY SITE AND ORGANISM

This study took place in the Marin Headlands in Marin County, California, which have 10 known natural populations of *C. andrewsii*. The Marin Headlands are a part of the Golden Gate National Recreation Area, a national park that stretches north and south along the Bay Area coastline. Dominant plant communities include coastal scrub, bluff and grassland, serpentine bluff and grassland, and associated riparian vegetation. The region has a temperate Mediterranean-type climate, which is characterized by dry summers and long, wet winters. As it is a coastal headland, the region is subject to intense fog and strong coastal winds.

The study site is a perennial seep in the location of a now extinct population of *C. andrewsii* that is documented in herbarium records. A long, narrow stream corridor occurs in a moderate to gently sloping draw, with a wide terrace between steep slopes. The corridor widens at its base to a small, chert alluvial fan and empties into a freshwater marsh. The seep occurs between 25-150 ft elevation, and has a northwest-facing aspect.

Cirsium andrewsii (Asteraceae) is a monocarpic, short-lived perennial limited to Bay Area perennial seeps and streams or downstream in marshy, freshwater wetland areas. With its small geographic range and high habitat specificity, it exhibits two of the narrowest forms of Rabinowitz's types of rarity (1986). It is listed as rare by the California Native Plant Society. The thistle is observed to establish in openings in dense graminoid and herbaceous vegetation associated with freshwater wetland communities, and on a variety of soil types. It exists in the absence of tree canopy. The thistle produces relatively large seeds compared to small pappus which may disperse from the seedhead, or fall to the ground undispersed from the seedhead where the seeds germinate in place. Like another streamside thistle (Craddock and Huenneke 1997), dispersal is believed to occur primarily via gravity and water-flow. This type of dispersal may contribute to the patchy distribution of individuals within a single water corridor. Insect herbivory may reduce its reproductive output to only a few viable seeds per seedhead. There is no published literature on the species.

METHODS

Thirty-six juvenile *C. andrewsii* were planted along 150 m of stream corridor at the site. Plants were propagated in the Marin Native Plant Nursery and were approximately 5 months old when planted. The propagule source was two plants in a nursery demonstration garden in Tennessee Valley, first-generation descendants of seed collected from a Marin Headlands population (population 10). Plants were planted on February 28, 1999 in 18 pairs of two treatments: a weeding treatment to reduce competition, and a control. The reduced competition treatment consisted of removing all surface vegetation in a .5 m x .5 m area to a depth of 5 cm of soil and planting the juvenile thistle into the center of this area. For the control treatment, thistles were planted directly into vegetation, and care was taken to create as little disturbance as possible. At the time of planting (February 28, 1999) and two months following planting (April 26, 1999), I measured initial and final rosette diameter, initial and final basal stem diameter and final length of longest leaf and recorded survivorship of each plant.

In the second year, for all plants in the reduced competition treatment all surface vegetation was removed around each plant in a 0.5 x 0.5 m area on November 3, 1999 and February 18, 2000. Final measurements of rosette diameter, plant height and number of inflorescences were recorded on May 29, 2000. Two fruiting inflorescences were collected from each flowering plant, air dried at the Marin Headlands Native Plant Nursery, cleaned, and the seeds from each inflorescence were counted. Observed shade levels and observed soil moisture at the location of each plant were recorded at that time.

Paired treatment results were analyzed statistically using pairing design t-tests and two-way analysis of variance for continuous variables, and nominal variables were analyzed using contingency tables (chi-square) analysis. For shade level and soil moisture level analysis, contingency table (chi-square) analysis was used.

RESULTS

For first year results, percent change in basal stem diameter was not significantly different between treatments (Table 1, Figure 1A). However, there was a strong trend for increased percent change in rosette diameter and final leaf length of control relative to weeding treatments (Table 1, Figures 1B and 1C).

For second year results, there was no significant difference between treatments for percent change in rosette diameter or percent change in height. There was a strong trend of reduced competition treatment on survivorship (Figure 2A) (Pearson $\chi^2=1.8$, $p=0.18$) and no significant treatment effect on flowering (Figure 2B). For all plants that were flowering, there was no significant treatment effect on number of inflorescences produced per plant, and no significant correlation of number of inflorescences with soil moisture or canopy levels. The treatment effect on number of seeds produced per inflorescence was not conclusive due to large variance among data. There was no significant correlation of observed shade level to survivorship (Figure 3A), however, there was a significant relationship of observed canopy level and flowering (Figure 3B) (Pearson $\chi^2=1.8$, $p=0.01$). There were no significant correlations between observed shade level and percent change in rosette, percent change in height, survivorship, flowering, or number of inflorescences.

DISCUSSION

The effect of competition on juvenile thistle growth appears to show that the species is adapted for at least moderate levels of competition, as seen by their response of altered architecture (Figures 1A, B and C). Juveniles observed in the field exhibited a similar etiolated, upright architecture (K. Strathmann, personal observation). The increase in growth in leaves and overall rosette size was not reflected in basal stem diameter growth.

The effect of competition on mature plants is less clear. While competition may have decreased survival, for those mature plants that survived competition did not likewise reduce flowering or number of inflorescences produced per flowering individual. Contrary to first year results, there was no effect of competition on growth, measured as change in height and change in rosette size. Environmental factors may be overshadowing the trend that was visible for survivorship and during the first year; increased canopy had an effect on flowering but not survivorship. It is also possible that two weeding events during the second spring growth season were not adequate to result in a treatment effect on mature plant growth or flowering, given the low number of replicates in this field experiment.

Based on my results, I suggest that seedling thistle establishment and growth from outplants are strongly affected by above-ground competition, and that this effect diminishes in mature plants. Therefore, seedlings appear to be more vulnerable to competition, and may rely on gaps of reduced competition in their wetland habitats for early growth and survival to mature plants. If they survive to mature plants, competition appears to be less of a factor in aspects of reproduction; other environmental factors may in fact play a larger role on mature plants. As would have been expected increased size was a good predictor for flowering: there was a significant positive relationship of growth of rosette diameter to flowering ($R^2=.57$, $F_{1,16}=24.33$, $p=0.0001$) and a positive trend to the number of inflorescences produced per plant ($y=19.41 + 0.17x$, $F_{1,7}=2.05$, $p=0.19$).

The primary management implication of this research is the potential for invasive plant species to have negative effects on this rare plant. Selecting sites of reduced competition from both native and non-native species for seedlings to establish and grow into mature, large rosettes, so that they may ultimately flower and reproduce, are of utmost importance.

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Table 1. Results from a two-way analysis of variance evaluating the correlation between treatment and percent change in basal stem diameter, percent change in rosette diameter and final leaf length, among all pairs.

Two-way analysis of variance

Source	DF	MS	F	P
Basal stem diameter				
Treatment	1	1637.09	1.24	0.28
Pair	17	2449.99	1.85	0.11
Error	17	1321.72		
Rosette diameter				
Treatment	1	6291.37	3.05	0.09
Pair	17	3429.63	1.66	0.15
Error	17	2062.22		
Leaf length				
Treatment	1	150.06	3.06	0.09
Pair	17	130.10	2.65	0.02
Error	17	833.56		

Figure 1.

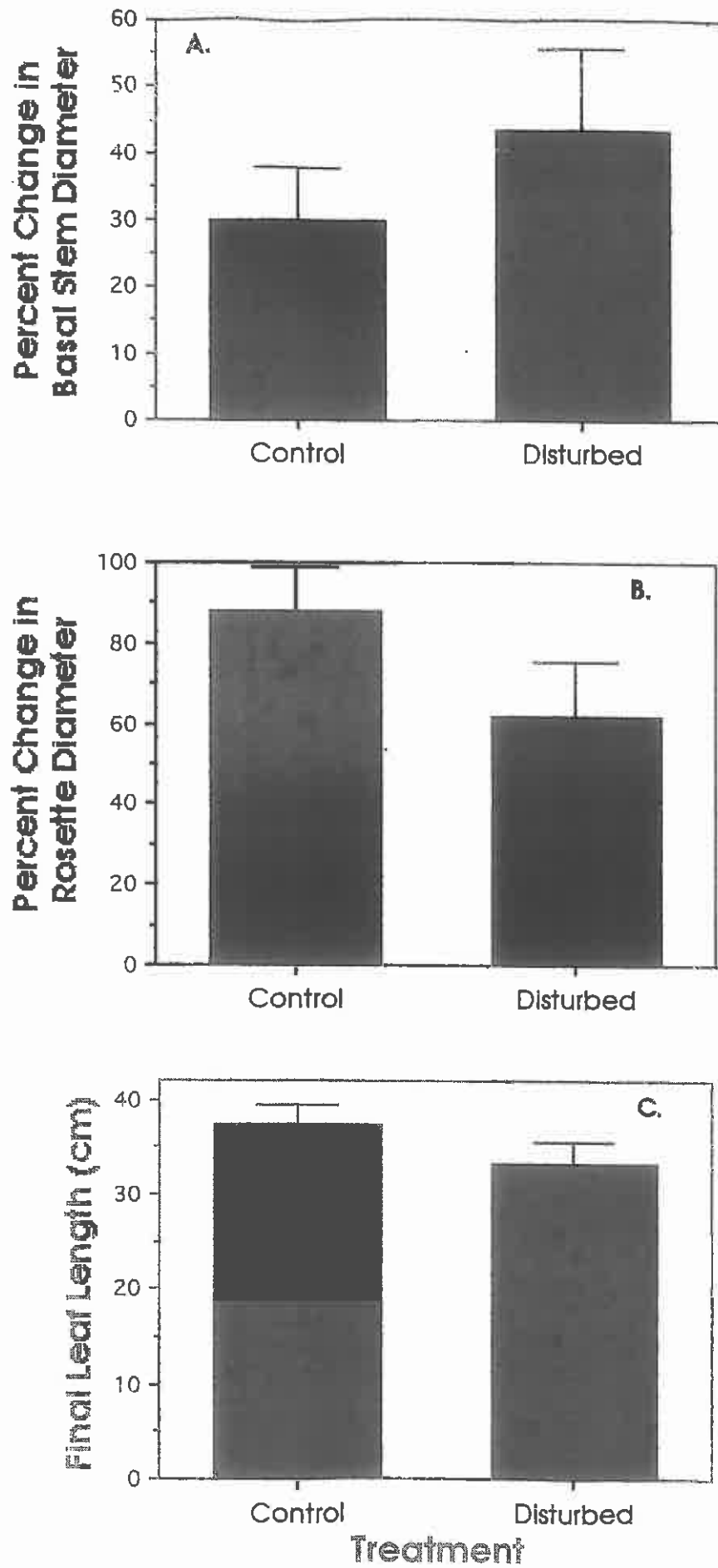


Figure 2.

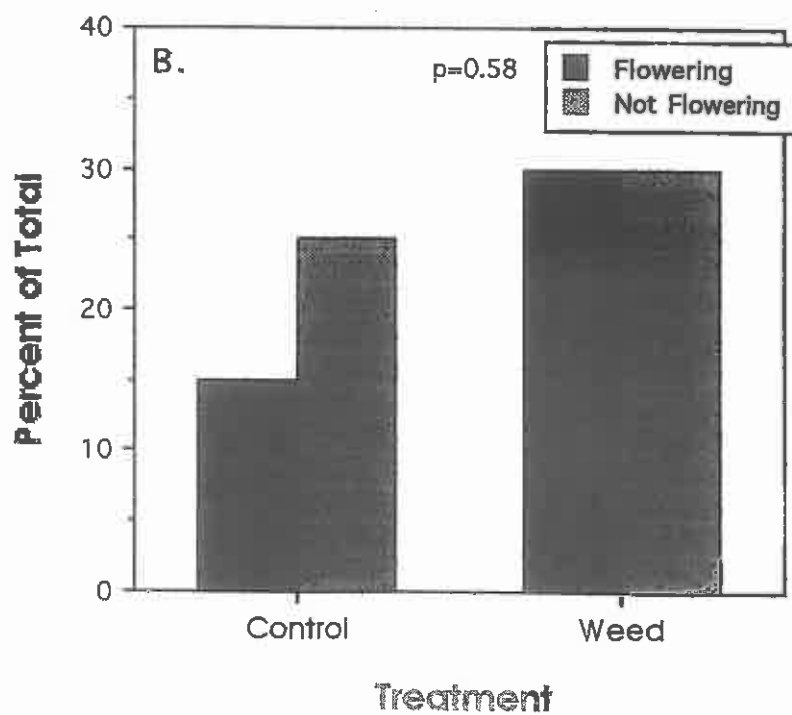
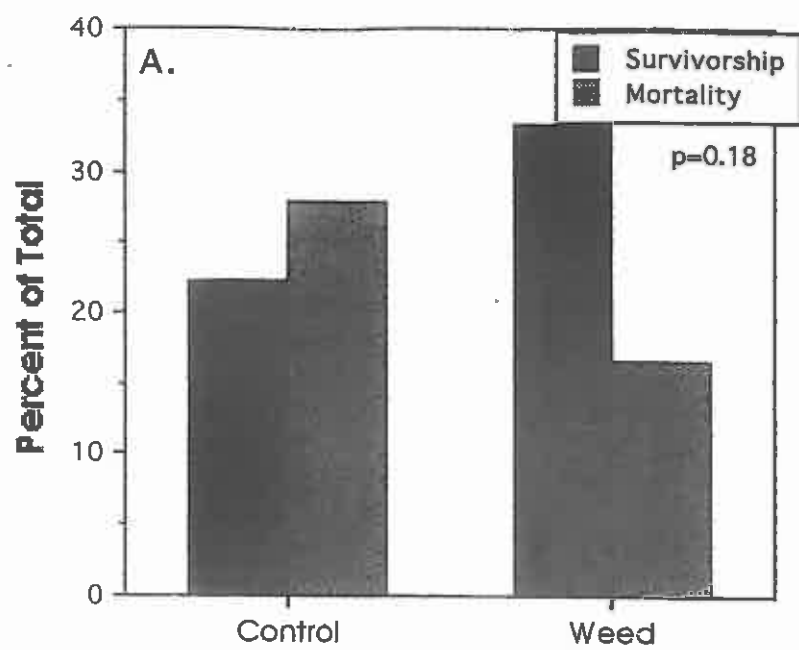


Figure 3.

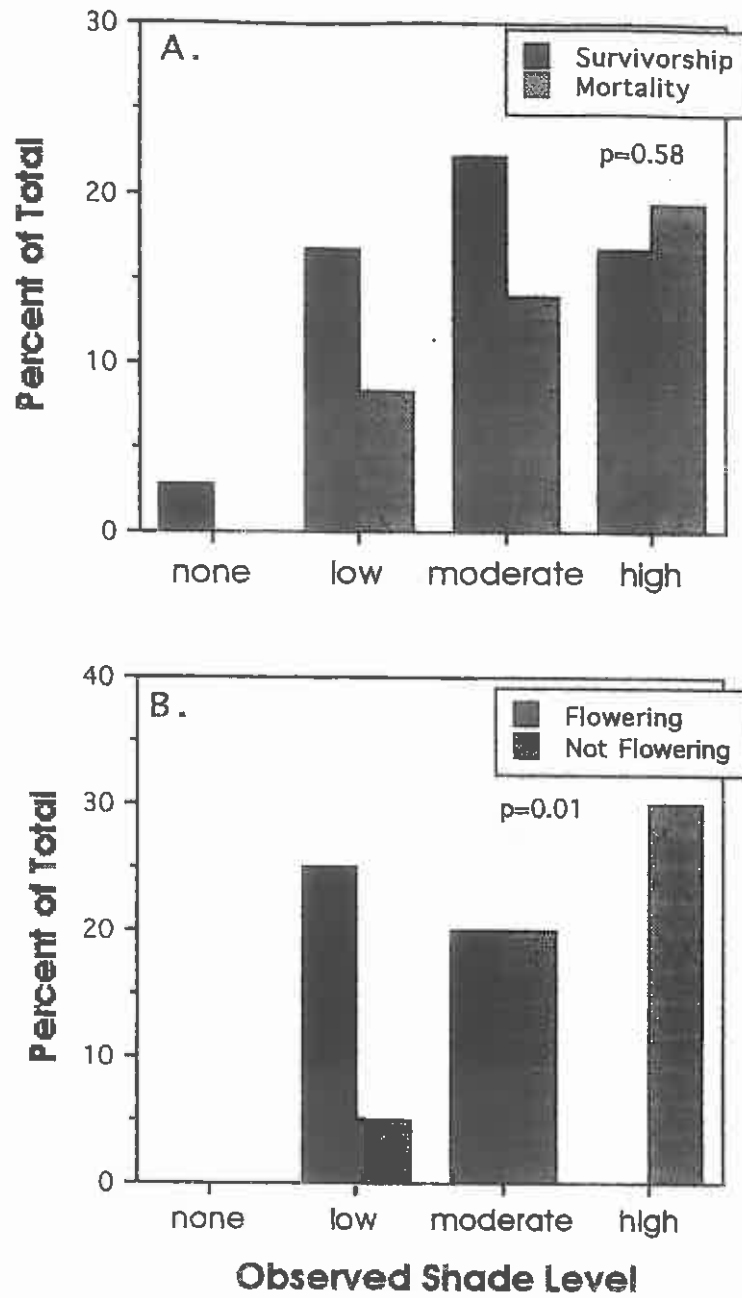


Figure 4.

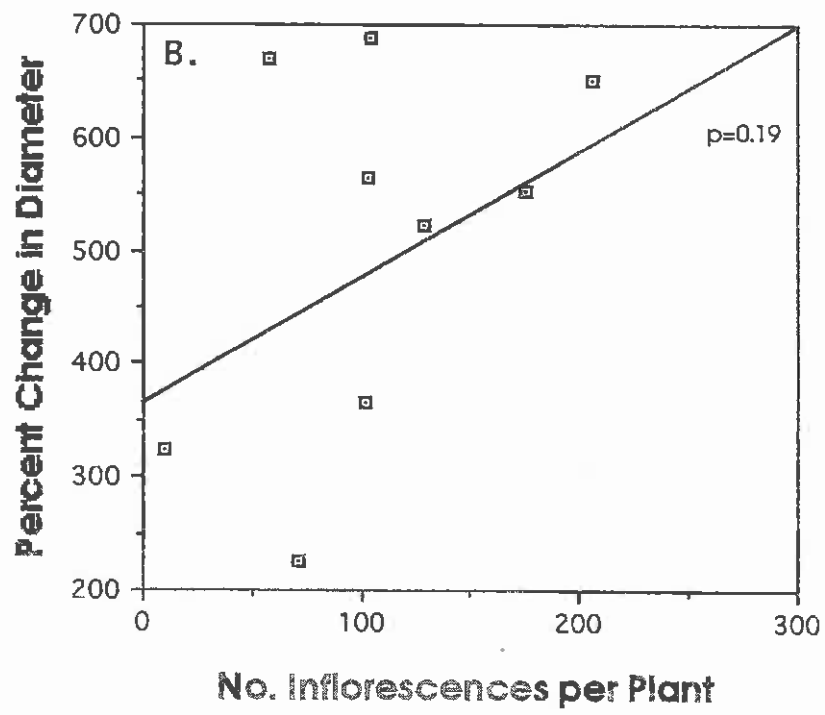
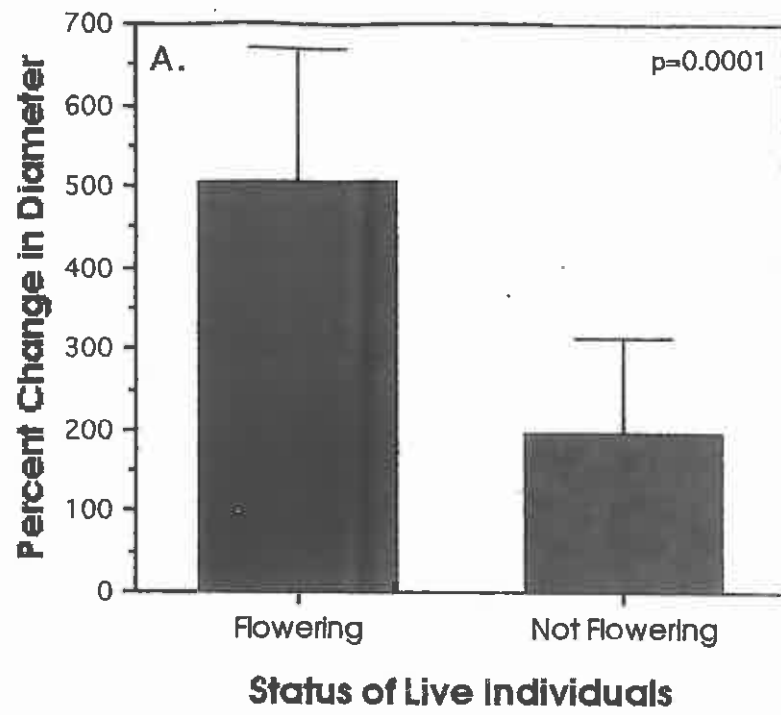


FIGURE LEGEND

Figure 1. Percent change in basal stem diameter (A), percent change in rosette diameter (B), and final leaf length (C) as a function of treatment.

Figure 2. Percent of total survivorship and mortality (A), and percent of total flowering and not flowering individuals (B), as a function of treatment. Error bars are not indicated due to chi-square analysis.

Figure 3. Percent of total survivorship and mortality (A), and percent of total flowering and not flowering individuals (B), as a function of observed shade level. Error bars are not indicated due to chi-square analysis.

Figure 4. Percent change in rosette diameter as a function of flowering status (A), and percent change in diameter correlated with number of inflorescences per plant (B).

APPENDIX 3.

Cirsium andrewsii Outplanting and Seedling Emergence Trial Presidio of San Francisco, Serpentine Coastal Bluffs

INTRODUCTION

The San Francisco Presidio hosts three meta-populations of *Cirsium andrewsii*, located south of the Golden Gate Bridge on the west-facing serpentine coastal bluffs and bluffs near Fort Point. The Fort Point population has been declining; trends are not yet clear for the two coastal bluff populations. (See Appendix 2.)

Threats to Presidio populations include invasive species such as *Pichris echioides*, *Hypochaeris radicata*, *Carpobrotus edulis* and *Cortaderia jubata*, which can easily colonize seep areas and are tolerant of the serpentine conditions on the bluffs. While *Carpobrotus* and *Cortaderia* can be relatively easily controlled by manual removal, *Pichris* and *Hypochaeris* pose a greater problem due to their rapid growth, basal rosette form that competes with *Cirsium andrewsii* and other natives for space, and short time until reproduction. Invasive species may be suppressing seedling emergence from the natural seedbank, as seedlings have been observed following *Carpobrotus* removal (pers. comm., P. Brastow, K. Strathmann). In addition to biological threats, geomorphic processes coupled with long-term development in the Presidio and on the San Francisco peninsula leave little available habitat for the thistle to colonize. The Presidio populations are located in seeps along naturally eroding bluffs, thus current habitat is decreasing while potential habitat is no longer available. Current management strategy is to maintain populations along the bluffs through invasive species control. Future management may include planting container plants and direct seeding the species into seeps along the bluffs.

This test was undertaken to investigate two objectives: (1) The survivorship of outplanted container plants of *C. andrewsii* on the serpentine coastal bluffs of the Presidio, and to identify environmental conditions that contribute to survivorship; and (2) The possibility of stimulating seedling emergence by removing surface vegetation and scarifying the soil surface.

METHODS

Outplanting

Seed was collected in fall 1999 from a *C. andrewsii* individual that had flowered and senesced that season in population C1. The seeds were cleaned, stratified in moistened perlite for approximately one month, and sown into D-16 pots at the Marin Headlands Native Plant Nursery. Plants were sown approximately four months prior to outplanting. Thirty-five individuals survived until outplanting.

Two locations were selected on the serpentine coastal bluffs to outplant the *C. andrewsii* seedlings. Locations were selected based on soil moisture and proximity to existing populations of *C. andrewsii*. One location was selected where no individuals had existed previously (C3); the site is approximately 30 m north of C2, a naturally-occurring population. The C3 site was selected for environmental characteristics that resemble those observed at C2, such as vegetative indicators of soil moisture (i.e., *Scirpus cernuus*, *Juncus patens*, *Phalaris californica*), and wind-protected microsites in the topography. The second location selected for outplanting is C1, the largest naturally-occurring population of *C. andrewsii* on the Presidio, and occurs approximately 1/4 mile south of C3. The population occurs in a large slumped area that continues to actively erode, particularly during the wet winter season. Soil moisture is evident throughout the site during the winter, and is restricted to a seepy corridor with little surface flow during the summer. The population at C1 is threatened by an invasion of *Pichris echioides* which appears to be taking advantage of the perennial wet conditions to the detriment of native species in the area.

All seedlings were planted between January 27 and February 1, 2000. Fifteen plants were planted at C3 and 10 were planted at C1. Plants were numbered and flagged for tracking over the following year. Plant survival (alive, dead), observed soil moisture level (1=water observed on soil surface, 2=soil saturated but no standing water, 3=moist soil, 4=dry surface soil), recent soil movement or disturbance, and herbivory were recorded at outplanting and subsequently at intervals from February through August 2000.

Seedling emergence

Two locations were identified to promote seedling emergence that are within or adjacent to naturally-occurring populations of *C. andrewsii*, C1 and C2. Pairs of plots were selected within each population. For each pair, the vegetation was removed and the soil surface was scarified with a hand tool, and the second plot was a control. Ten pairs were established in C1 and 5 pairs in C2. Vegetation removed in C1 consisted primarily of *Pichris echioides*, and of *Carpobrotus edulis* and duff in C2. Plots were monitored for seven months for seedling emergence. Number of *Cirsium* seedlings and soil moisture were recorded at the time of plot establishment, and subsequently at intervals from February through August 2000.

RESULTS

Outplanting

At C1, 9 plants survived by the end of August 2000, and at C2, 13 plants survived. Observed soil moisture was predominantly "moist soil" at all planting locations, from initial planting date to final monitoring in August 2000. Mortality was correlated with water observed on soil surface ($r^2=0.3484$, $p=0.0019$). By August 2000, most soil moisture was observed as "dry surface". Soil disturbance was observed on or around a few plants, and herbivory was observed for many plants, but it was difficult to correlate these to plant survivorship or growth.

Seedling emergence

Results from the seedling emergence trial were inconclusive. In population C1, no plots showed seedling emergence. In C2, 2 of the 5 disturbance plots showed seedling emergence, but only one seedling persisted to August 2000.

OBSERVATIONS

Outplanting

Observations indicate that subsurface water is more important than surface water. Two individuals that were planted directed in the seep, and were exposed to surface water flow, eventually died. Other plants that were slightly more elevated above water flow than those that are adjacent to water flow appear to be less stressed.

Wind exposure appears to be a considerable factor in survivorship. Those individuals that were planted in protected locations are larger in size and appear to be less stressed.

DISCUSSION

Outplanting appears to be a very successful method for reintroducing *C. andrewsii* to habitable locations. While most plants survived, seedlings planted in or near active water corridors appeared to be subjected to covering from natural slumping during the winter seasons, which caused 2 plants deaths. While observed surface soil moisture provided a rough estimate of appropriate planting locations, seasonal monitoring of sub-surface soil moisture at and adjacent to *C. andrewsii* populations would provide a more complete picture of true soil moisture requirements for this species.

Facilitating seedling emergence may be site-specific, probably related to exact locations of past seedrain occurrences. *C. andrewsii* may drop seedheads onto the soil without dispersing seed,

or the entire bolting plant may fall on site, causing many seeds to be concentrated in a relatively small area. Predicting these areas is difficult without careful, long-term observation. In areas where *Carpobrotus edulis* or other mat-forming exotics surround *C. andrewsii* populations, this vegetation may be inhibiting seedling emergence. Removal of vegetation may stimulate seed germination. Care should also be taken to not discard *C. edulis* duff prematurely should seedbank be present.

Appendix 4. Herbaria collections

Year collected	Location	Notes	Herbarium
1896	Tennessee Valley Bay	marsh	UCB
1911	Tennessee Cove		UCB
1913	Tennessee Valley	moist part of valley	UCB
1913	Tennessee Cove	specimen reported with white flowers, otherwise <i>C. andrewsii</i> characteristics	UCB
1913	Tennessee Cove		UCB
1922	Rodeo Lagoon near Ft. Barry		UCB
1922	Rodeo Lagoon near Ft. Barry		CAS
1927	Pt. Reyes lighthouse	ocean bluffs	CAS
1930	Marsh in valley above Rodeo Lagoon		CAS
1933	Lake Merced		UCB
1933	Between Inverness and Pt. Reyes	marsh near summit of Inverness-Pt. Reyes Rd (2 samples)	CAS
1933	Lake Merced	2 samples	CAS
1935	Between Inverness and Pt. Reyes lighthouse	along summit of road betw. Inverness-Pt. Reyes	CAS
1936	Shell Beach, Point Reyes		UCB
1939	Pt. Reyes lighthouse	possible albino, <i>C. andrewsii</i> + <i>C. quercetorum</i> hybrid (4 samples)	CAS
1939	Elk Valley, east of Tennessee Cove	5 samples taken	CAS
1941	Inverness Ridge, NW of Inverness		UCB
1946	Marsh east of Rodeo Lagoon		CAS
1947	Dillon's Beach	ocean bluffs (2 samples)	CAS
1952	Pt. Reyes lighthouse		CAS
1957	Ft. Point	seepage on serpentine; 4 samples taken	CAS
1958	Ft. Point	reported in wet soil of seepage, serpentine slope	UCB
1958	Ft. Point	wet soil of seep on serpentine; 4 samples taken	CAS
1961	Ft. Point	2 samples taken	CAS
1978	Gerbode Valley, GGNRA	upper dry slopes of valley (only 2 plants observed), 100' altitude	SFSU
1984	Near Marshall along Marshall-Petaluma Road	perennial seep, open serpentine	Jepson