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Jonathan Evans
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National Fish and Wildlife Foundation
28 Second Street, 6th Floor
San Francisco, CA 94105

April 10, 2003

Dear Jonathan,

Attached find our Final Report for CALFED 99-N05: Reintroduction of Endangered Soft Bird's Beak to Restored Habitat in Suisun Marsh. We want to take this opportunity to thank you once again for your enthusiasm, sincere interest in our project, and for your outstanding contract management services. It was a pleasure to complete this project with you.

It is our hope the results of this project contribute to CALFED's goal of improved ecosystem quality through conservation and recovery of soft bird's beak. Information is provided on critical life stages of this rare plant, appropriate reintroduction techniques, and conservation actions that warrant immediate attention. It is our hope these data will be used in the preparation of a biologically relevant recovery plan for this remarkable endangered plant.

Readers with focused interest on this species should feel free to contact us for further information. Our research and analyses continues, and we have manuscripts in preparation that go beyond the scope of this grant and may be useful to those interested in soft bird's beak conservation and recovery.

We believe all of the required contract deliverables are represented in this report, made available to you in electronic format per your request. Please do not hesitate to contact us if you need additional information (erejmankova@ucdavis.edu, bjgrewell@ucdavis.edu).

Sincerely,

Brenda J. Grewell
Eliška Rejmánková

Reintroduction of Endangered Soft Bird's Beak

(*Cordylanthus mollis* ssp. *mollis*)

to Restored Habitat in Suisun Marsh

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CALFED Ecosystem Restoration Program
Contract 99-N05 Final Report

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Executive Summary

The goal of this study was to provide critical ecological data to facilitate rare plant restoration, as a contribution towards CALFED objectives for improved ecosystem quality through native species recovery and conservation. The recovery of rare plants often requires the creation of new populations in order to decrease extinction risk. This project addresses recovery of soft bird's beak (*Cordylanthus mollis* ssp. *mollis*), an endangered plant endemic to Suisun and North Bay high tidal marsh of the San Francisco Estuary.

We have investigated factors critical to survival and fitness of soft bird's beak. The structure and composition of tidal wetland plant communities supporting these endangered plants have unique characteristics that can be altered by regional water management practices and species invasions.

Results of this study provide evidence that our relict tidal marshes are in precipitous decline. Restoration efforts that focus on creating and expanding existing tidal wetlands may be premature, as we must first enhance and protect these remaining historic habitats. Improvement of ecosystem quality, and restoration of sustainable ecosystems are essential precursors to the reintroduction of endangered species, and stewardship needs are high in the North Bay and Suisun tidal marshes supporting the remaining natural populations of soft bird's beak.

Our demographic evaluation of vulnerable life stages of this endangered plant detected significant threats at the seedling life stage. High seedling mortality was strongly correlated with the presence of exotic winter annual plants which are unsuitable hosts for the endangered native parasites. Muted tidal regimes resulting from regional hydrologic alterations and local restoration projects are also influencing the mortality and decline of soft bird's beak populations.

Canopy manipulation to suppress competition and open germination gaps in the community was a successful reintroduction technique, and soft bird's beak responded with improved demographic performance. However, this restoration management technique also resulted in high rates of plant invasions within the restoration site, as invasive plants in the area also benefit from the same management techniques. Invasive plant control will be an essential first step of any tidal wetland or rare plant reintroduction effort in the Suisun region, and it may take several years to accomplish this task.

We have recommended a conservation monitoring approach to facilitate management actions relevant to the conservation and recovery of endangered soft bird's beak, and continue to be involved in public education outreach efforts.

Reintroduction of Endangered Soft Bird's Beak (*Cordylanthus mollis* ssp. *mollis*) to Restored Habitat in Suisun Marsh

Introduction

The goal of this study is to provide critical ecological data to facilitate rare plant restoration, as a contribution towards CALFED objectives for improved ecosystem quality through native species recovery and conservation. The recovery of rare plants often requires the creation of new populations in order to decrease extinction risk. This project addresses recovery of soft bird's beak (*Cordylanthus mollis* ssp. *mollis*), an endangered plant endemic to Suisun and North Bay high tidal marsh of the San Francisco Estuary. Soft bird's beak was listed as endangered by the federal government in 1996, and is listed as a rare plant by the State of California. The U.S. Fish and Wildlife Service has not released or implemented a recovery plan to reverse the endangered status of this and other listed tidal marsh species of the San Francisco Estuary. The recovery of an endangered species requires the best scientific information possible, and the objectives of this study were crafted to contribute to the successful planning and implementation of recovery efforts for soft bird's beak.

Objectives

The over-arching hypothesis surrounding this work is that recovery of endangered populations may require creation of new populations in restoration efforts.
Project objectives were defined to provide restoration managers with critical ecological data to facilitate rare plant restoration success in Suisun Marsh and North Bay tidal wetlands. The project was implemented in two phases: 1) assessment of habitat characteristics of the endangered soft bird's beak and; 2) implementation of an

experimental reintroduction of soft bird's beak with demographic research to generate information about critical life stages for science-based recovery strategies. Specific project objectives are presented in Table 1.

Table 1. Project objectives for soft bird's beak experimental reintroduction.

PROJECT OBJECTIVES
OBJECTIVE 1: Investigate habitat factors critical to soft bird's beak
OBJECTIVE 2: Experimentally test reintroduction methods
OBJECTIVE 3: Track plant demographic fate to identify critical life stages.
OBJECTIVE 4: Recommend a conservation monitoring plan
OBJECTIVE 5: Conduct public education outreach

Soft Bird's Beak

Soft bird's beak is a native, annual parasitic herb. Table 2 presents the current taxonomic hierarchy for this species. The scientific name (*Cordylanthus mollis* ssp. *mollis*) and common name (soft bird's beak) are both used in this report. Soft bird's beak is a root hemiparasite that relies on a host association for survival within the harsh environment of high intertidal salt marsh. *Cordylanthus* species acquire resources from a variety of available hosts and are not host specific (Chuang and Heckard 1976, 1973, 1972, 1971). Hemiparasites are heterotrophic plants capable of photosynthesis, but also receive crucial host subsidies of water, nitrogen, fixed carbon, and mineral compounds through haustorial organ connections to vascular tissues in host plant roots (Press 1989, Press et. al 1999).

It is surprising to many members of the public that we are concerned about the conservation of a plant parasite. Parasites are typically viewed as pests due to their negative impacts on crop yields or animal health. Some parasitic plants are valued and

over-exploited by humans for food, wood, fragrant oils, medicine, or cut flowers (Kujit 1969, Stermitz 1997). More than 3,000 species of plants are known to be parasitic, occurring in more than 18 plant families (Kuijt 1969, Press 1989). At least one species of parasitic plant can be found in almost every natural plant community (Kuijt 1969), and parasitic plants play an important functional role in shaping plant community structure (Gibson and Watkinson 1992, Marvier 1996, Pennings & Callaway 1996, Grewell in prep.).

Table 2. Taxonomic hierarchy for soft bird's beak (USDA, NRCS. 2002).

Taxonomic Hierarchy for *Cordylanthus mollis* Gray ssp. *mollis*

Kingdom	Plantae – Plants
Subkingdom	Tracheobionta – Vascular plants
Superdivision	Spermatophyta – Seed plants
Division	Magnoliophyta – Flowering plants
Class	Magnoliopsida – Dicotyledons
Subclass	Asteridae –
Order	Scrophulariales –
Family	Scrophulariaceae – Figwort family
Genus	*Cordylanthus* Nutt. ex Benth. – bird's-beak
Subgenus	*Hemistegia*
Species	*Cordylanthus mollis* Gray – soft bird's-beak
Subspecies	*Cordylanthus mollis* Gray ssp. *mollis* – soft bird's-beak

Rare species of parasitic plants are an increasing concern to conservation biologists throughout the United States, as many of these native plants are federally listed as threatened or endangered (U.S. Code of Federal Regulations 1994). The California Native Plant Society recognizes many more plant parasites that are rare but have not

received federal protective status (CNPS 2001). Many factors contribute to the endangerment of wetland parasitic plants. Ecosystem restoration goals guiding the CALFED process may be instrumental to the recovery of native species if historic tidal wetlands are reconnected with restored habitat, and if water management can be balanced with restoration of historic variability of physical processes driving tidal wetland community structure. Restoration and recovery of native parasitic plants will require focused consideration of the host needs of parasitic plants, with restoration of host community structure, composition, and host quality to sustain parasite populations (Marvier and Smith 1997).

Natural populations of soft bird's beak have been confirmed from nine sites in Suisun and North Bay marshes, and well over 90% of the remaining plants are found in Suisun Marsh (Ruygt 1994). Historic accounts indicate this species is an anthropogenic rarity that is now endangered due to loss and fragmentation of tidal wetlands (U.S. Fish & Wildlife Service 1995). Our contributions to soft bird's beak conservation and recovery planning are ecological in approach. Understanding habitat and host community requirements critical to this species, critical life stages which may limit population recovery, and appropriate reintroduction strategies will aid in the conservation and recovery of soft bird's beak and other sensitive species sharing historic tidal marsh habitat.

I. HABITAT FACTORS CRITICAL TO SOFT BIRD'S BEAK

ENDANGERED PLANT RESTORATION CRITERIA

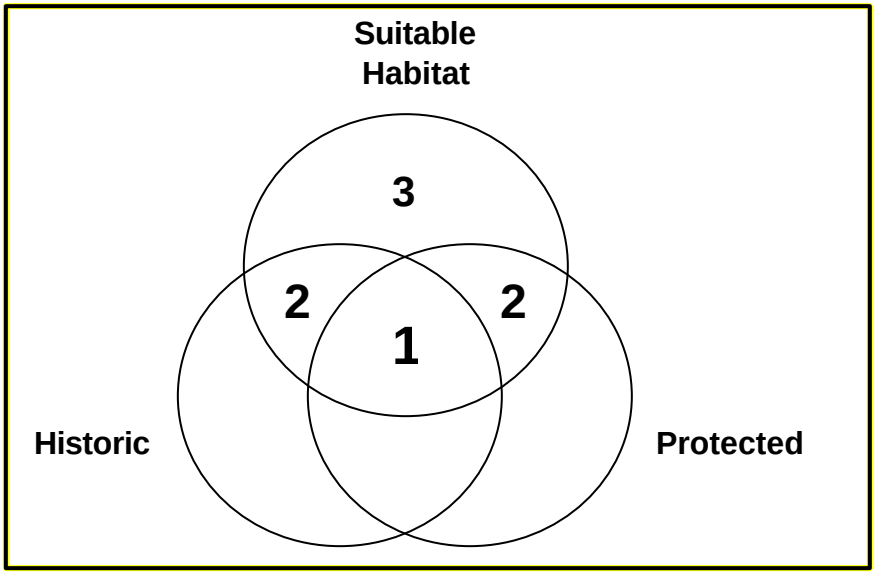
Endangered plant recovery planning should include careful consideration of historical, logistical, physical, and biological criteria to maximize reintroduction success (Table 3, Fiedler and Lavin 1996).

Table 3. Rare plant reintroduction criteria.

RARE PLANT REINTRODUCTION CRITERIA	Potential Data Sources Information Needs
HISTORICAL	Literature, Herbaria Records, Database Records. Historic maps, Botanical Journals, Aerial Photos.
LOGISTICAL	Property Ownership/Access, Regulatory Permits, Safety, Long Term Resource Protection
PHYSICAL	Hydrology, Soil Physico-chemistry
BIOLOGICAL	Plant Community composition, structure, productivity, biogeochemistry; Critical Biological Interactions, Landscape Habitat Matrix

Through careful evaluation of these data we can prioritize potential reintroduction sites. Suitable sites should meet all three criteria shown in the set diagram (Fig. 1). Area 1 within this diagram is the ideal as reintroductions should be within suitable habitat at protected sites within the historic range of the species.

Figure. 1. Site selection criteria for rare plant reintroductions (Falk et al. 1996).



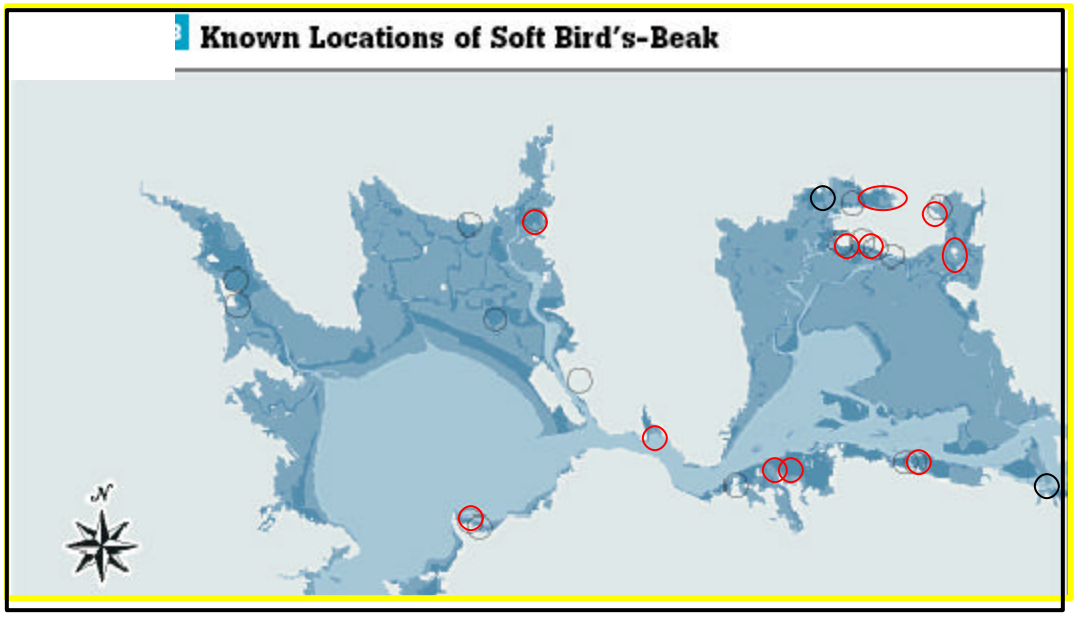
Introductions of rare plants to sites other than historic habitat and/or outside of the historic range of the species are translocations and should be avoided. Diked, artificially muted tidal wetlands within the historic range of the species are not historic habitat for soft bird's beak, and introduce new selective pressures which may be counter to recovery of historic population dynamics.

The first objective of the project was to investigate habitat factors critical to the endangered plant soft bird's beak. We investigated habitat characteristics throughout the extant range of the species for a better understanding of the variation in physical and biological factors associated with rare plant success. A wide range of biological and physio-chemical factors were measured within and outside of the narrow tidal elevation supporting the rare plant. Statistical cluster analysis and multivariate ordination techniques were used to select the most important environmental variables associated with remaining populations of soft bird's beak.

Historical Criteria.

Historical data gathering included a literature search, herbaria record searches, and resource management agency database searches to determine historic soft bird's beak occurrence sites (Fig. 2). A 1992 – 1993 baseline study of this species including census of known occurrences and focused study of the Hill Slough and Fagan Slough Ecological Reserve populations provided important data collected within *Cordylanthus* occupied habitat during drought years (Ruygt 1994). There were nine extant populations of soft bird's beak known in the San Francisco Estuary at the onset of this study, and two additional populations were documented while our study progressed (CDFG 2003). The historic range of the species extended from the Petaluma Marsh and Napa Marsh in the North Bay reach of San Francisco Estuary, through the Carquinez Strait and Suisun Marsh to the mouth of the Sacramento – San Joaquin River Delta at Antioch (Fig. 2). The modern range is restricted to tidal wetlands from Point Pinole, Napa Marsh, Carquinez Strait, to relict tidal wetlands ringing the Potrero Hills in the northeastern reach of Suisun Marsh.

Figure 2. Known historic and modern locations of soft bird's beak across the North Bay and Suisun range of the species. Black circles indicate extirpated populations from historic records, while red circles indicate extant occurrences (adapted/updated from Goals Project 1999).



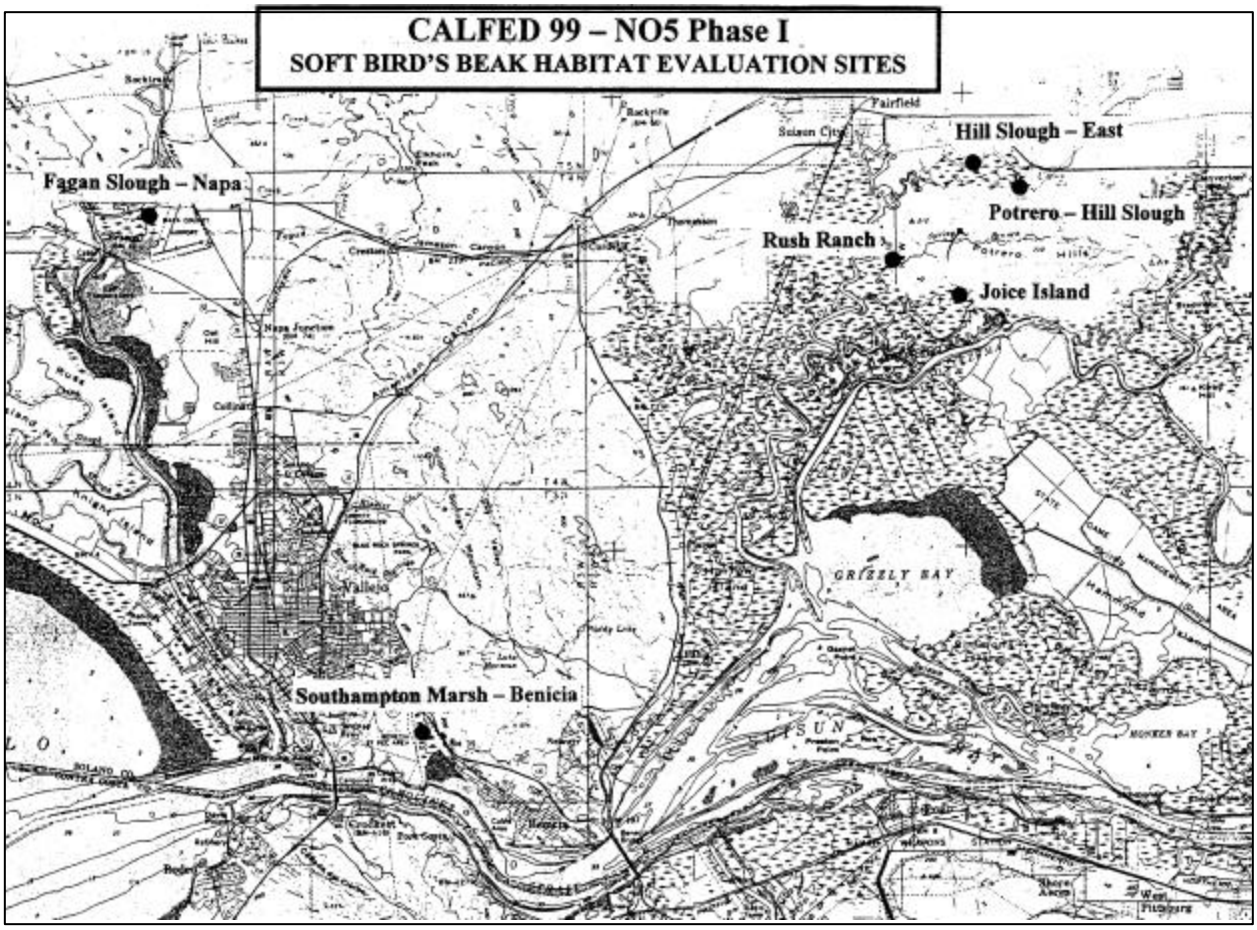
Logistical Criteria.

Data gathering included property ownership of potential evaluation and restoration sites, rare plant research permits, biological collection permits, access, and safety concerns, and permission to conduct research in historic reference populations. Evaluation of all of these sources of information led to the formulation of a field sampling strategy of occupied soft bird's beak habitat, and selection of a preliminary restoration site for the testing of reintroduction techniques and investigation of physical and biological characteristics for further development of reintroduction criteria.

After consulting with property owners/managers of extant populations, two sites were eliminated from Phase I evaluation due to safety concerns (Point Pinole and Point Edith Marsh). The Concord Naval Weapons Station population was eliminated due to security restrictions and access. A very small population persists near McAvoy Harbor which was excluded from Phase I screening because of private property access

restrictions, and conservation concerns. The Denverton area populations were unknown when we initiated this project, and are also on private property. A subset of extant populations was chosen for detailed habitat characterization representing the physical and biological variation across a range of modern occupation, and these sites are shown in Figure 3.

Figure 3. Map of project study sites.



Six reference populations and the Rush Ranch Spring Branch Marsh restoration site were evaluated in Phase I. Comparative studies continued at a subset of five populations sites in Phase II. The property ownership and regional location of the soft bird's beak populations included in this study are listed in Table 4. Table 5 lists environmental permits required for this research.

Table 4. Property management of project study sites.

POPULATION SITE	REGION	MANAGEMENT
1. Hill Slough Wildlife Mgmt Area (NE tidal area)	Suisun	CA Fish &Game
2. Hill Slough Wildlife Mgmt Area (SE/Potrero tidal area)	Suisun	CA Fish &Game
3. Joice Island Wildlife Mgmt Area (tidal area - Cutoff Slough)	Suisun	CA Fish & Game
4..Rush Ranch	Suisun	Solano Land Trust
5. Benicia State Recreation Area (BSRA-NE Southampton Marsh)	Carquinez Strait	CA State Parks
6. Benicia State Recreation Area (BBAY- Southampton Bay area)	Carquinez Strait	CA State Parks
7. Fagan Slough Ecological Reserve	Napa Marsh	CA Fish & Game

Table 5. Project environmental permits.

REGULATORY AUTHORITY	PERMIT
California Department of Fish & Game Region 3, Yountville	Property Access Permit/Letter – included Hill Slough, Joice Island, and Fagan sites.
California Department of Fish & Game Natural Heritage Division, Sacramento	Rare Plant Research Permit 99-08 & Rare Plant Collection Permit
California State Parks Silverado District Office, Sonoma	Property Access/Research Permit and Biological & Soil Collection Permit
Solano Land Trust, Fairfield	Property Access/Research Permit
U.S. Fish and Wildlife Service	Informal Consultation – provided technical advice. Did not require permit.

Population Census

A condition of our California Dept. of Fish and Game rare plant research permit was to provide detailed maps with GPS coordinates of soft bird's beak population patches and population counts in marshes where we received permission to conduct research. We conducted an extensive census during the 2000 season at Hill Slough Wildlife Area Northeast tidal area, and Potrero Hills tidal area), Joice Island Wildlife Area, Rush

Ranch, Benicia State Recreation Area, Fagan Slough Ecological Reserve and submitted the required information to the California Department of Fish and Game's Natural Diversity Database and Natural Heritage Division.

The census was conducted by a team of three professional botanists over a period of 4 weeks from September 5 – October 6, 2000. The soft bird's beak census included a search of all potential habitat within the wetlands . GPS coordinates were acquired for all occupied patches separated by at least 5 meters, and number of soft bird's beak individuals per patch were recorded. GPS coordinates were obtained with a Trimble GeoExplorer 3.

This census effort was very labor intensive, as soft bird's beak populations are locally dense and there are extensive areas of potential habitat within relict tidal wetlands. For conservation reasons, we do not recommend this intensive survey level for future monitoring of this species. Soft bird's beak maintains a very fragile root connection to its host. A fully mature adult plant may be 30 to 50 cm tall above ground, but the root on this plant is typically 5 cm or less. The manipulation of dense population patches for accurate counts can result in significant mortality when hemiparasites are detached from hosts. In addition, even the most careful counts result in a high variance of

detected population size between observers. We recommend an improvement to this monitoring approach for population tracking in the monitoring plan section of this report.

In 2001 and 2002, we continued focused research at Hill Slough Wildlife Area, Benicia State Recreation Area, and Rush Ranch where we conducted reconnaissance surveys for significant changes in population size. The detailed maps and population counts of rare plant population patches are on file with the Department of Fish and Game. They are not included in this public report due to conservation concerns for the endangered populations. Interested parties should contact DFG Natural Diversity Database for these data.

Physical and Biological Criteria: Critical Habitat Factors.

The objective of project Phase I was to investigate habitat factors critical to soft bird's beak. We conducted extensive field studies to explore the environmental and biological factors most important to the endangered plant community.

Methods. In 2000, we conducted an extensive survey of plant community, and soil physico-chemical characteristics at selected population sites across the extant geographic range of the species (Figure 3). Appendix I includes summary tables of in situ habitat field measurements, field samples collections, and laboratory analyses.

Five randomly dispersed, replicated transects intercepting soft bird's beak populations were established along the intertidal gradient at five reference sites. A 3 meter X 5 meter (15 m^2) releve was located in each of three unique vegetation zones along the replicated transects within 1) the highest intertidal zone above soft bird's beak occurrence, 2) the zone supporting soft bird's beak, and 3) the more frequently-inundated mid-intertidal zone immediately below soft bird's beak. The total reference sample included 75 releves (3 releves X 5 replicated transects X 5 population sites). Releves were recorded to describe vegetation pattern and soil conditions within the salt marsh. Plant species presence, percent cover by plant species, canopy height, and percent gaps were measured at maximum summer growth. Each releve was divided

into 15 one meter square subplots, and a quadrat frame with one hundred 10 cm subdivisions was placed over the vegetation. A wire pin was dropped at 10 cm intervals and the point-intercepted vegetation species, bare ground, bare ground with benthic algae, or vegetation litter was recorded for determination of percent cover and characterization of canopy gaps. The maximum vegetation height per subplot was recorded to calculate mean maximum canopy height for each releve. Presence of vegetation species were obtained from the cover intercept measurements, and each releve was visually examined for rare species that may not have been intercepted in the random cover sample. If a rare species was detected, it was added to the list of present vegetation for the plot and assigned a cover value of < 1% (0.5%). Below canopy photosynthetically active radiation (PAR) and sunfleck fraction was measured with a Decagon sunfleck ceptometer model SF-80 concurrent with spring 2000 seedling emergence.

Soil samples were collected for physico-chemical evaluation. Soil samples were evaluated for bulk density, water content, organic matter, salinity, anions, cations, sodium absorption ratio, total nitrogen, and total phosphorus, and total carbon. Bulk density and soil water content analyses required that a known volume of soil be collected with an undisturbed core sampler. An AMS stainless steel core sampler with removable retaining liners was used to collected 5 cm diameter X 10 cm deep undisturbed cores. Soil was weighed before and after oven drying at 105°C for 48 hours. Bulk density was then determined as grams of oven dry soil per volume of soil, and soil water content was calculated as the ratio of water mass to dry soil mass. For analyses of organic matter and total N, P, and carbon, 5 cm X 10 cm soil cores were collected from each releve, ground, sieved, oven dried at 80 degrees C, and stored in

sealed containers. Organic matter content was analyzed by the loss-on-ignition method. Total nitrogen and carbon concentrations were assessed with a CHN analyzer. Total phosphorus was determined by sample digestion followed by a colorimetric method for orthophosphate analysis.

Soil salinity, specific ion concentrations, and sodicity of the soil were determined by analyzing soil solution extracts. Following standard soil saturation extract methodology (Rhoades 1982), soil solutions were vacuum-drawn from saturation pastes placed in Buchner filter funnels. A temperature compensating specific conductance meter was used to determine salinity of saturation extracts. If salinity levels were too high for direct ion analysis, extracts were diluted prior to cation and anion determination. Cations (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}) were analyzed by atomic absorption. Anions (Cl^{-}, SO_4^{-2}, PO_4^{-3}) were measured with an ion chromatographic analyzer.

SYSTAT 9 (SPSS 1999) was used to examine descriptive statistics of these data. A variety of multivariate and cluster analysis techniques were used to evaluate key environmental parameters that may have the strongest influences on the distribution of soft bird's beak. PC-ORD (McCune & Mefford 1999), CANOCO 4.0, CanoDraw 3.1, CanoPost 1.0 (ter Braak and Šmilauer 1998), and SYNTAX (Podani 1995), were used to analyze the plant species and environmental data.

Results. Physical and biological parameters which were most distinctive in the presence of soft bird's beak compared to adjacent intertidal zones outside of its narrow range appear to be soil organic matter content, below canopy PAR, and plant canopy height. The presence of salt marsh dodder (*Cuscuta salina*) is also a potential indicator of soft bird's beak habitat, as this parasitic dodder was the most common plant associate of soft bird's beak throughout its range. Gradients of soil organic matter content, PAR, and maximum plant canopy height from soft bird's beak reference population sites are compared to conditions at the Rush Ranch – Spring Branch Marsh Restoration site in Figures 4 – 6.

Figure 4. Soil organic matter above soft bird's beak, within soft bird's beak, and below soft bird's beak occupied intertidal zones at reference sites (A), and at the Rush Ranch reintroduction site (B) (means ± 1 SE).

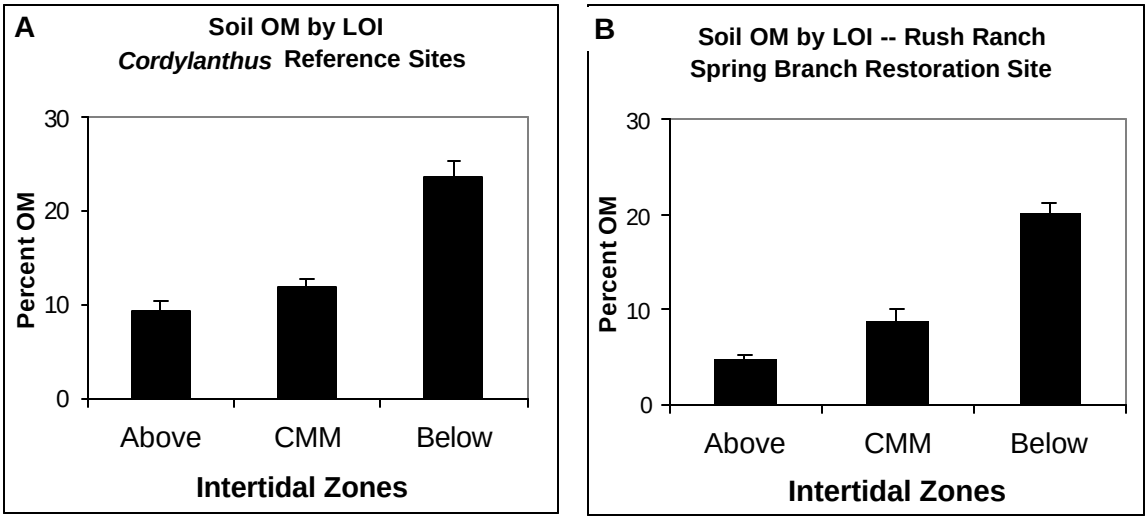


Figure 5. Below canopy photosynthetically active radiation at seedling emergence above, within, and below soft bird's beak occupied intertidal zones at reference sites (A), and at the Rush Ranch reintroduction site (B) (means ± 1 SE).

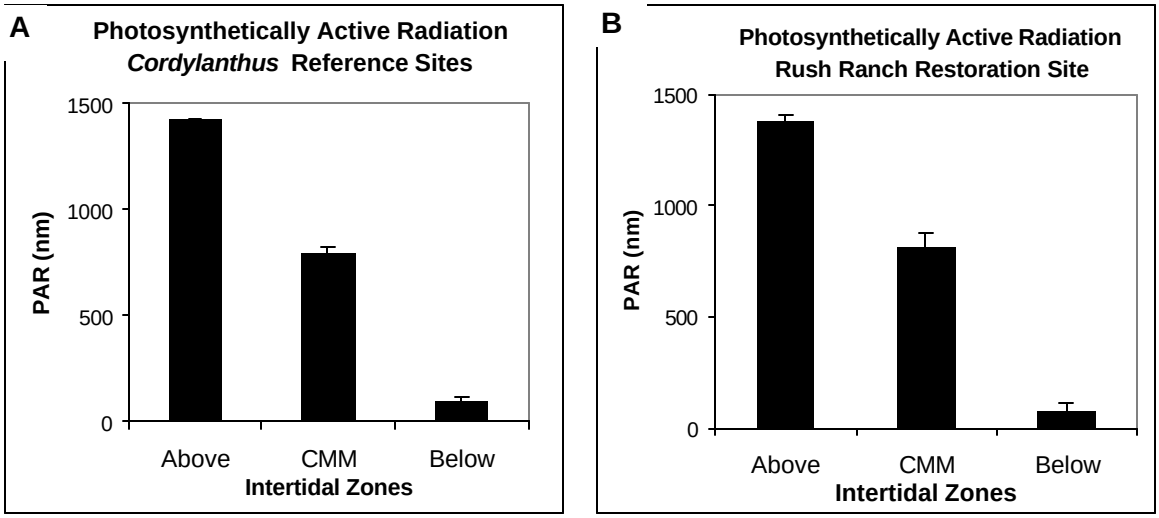
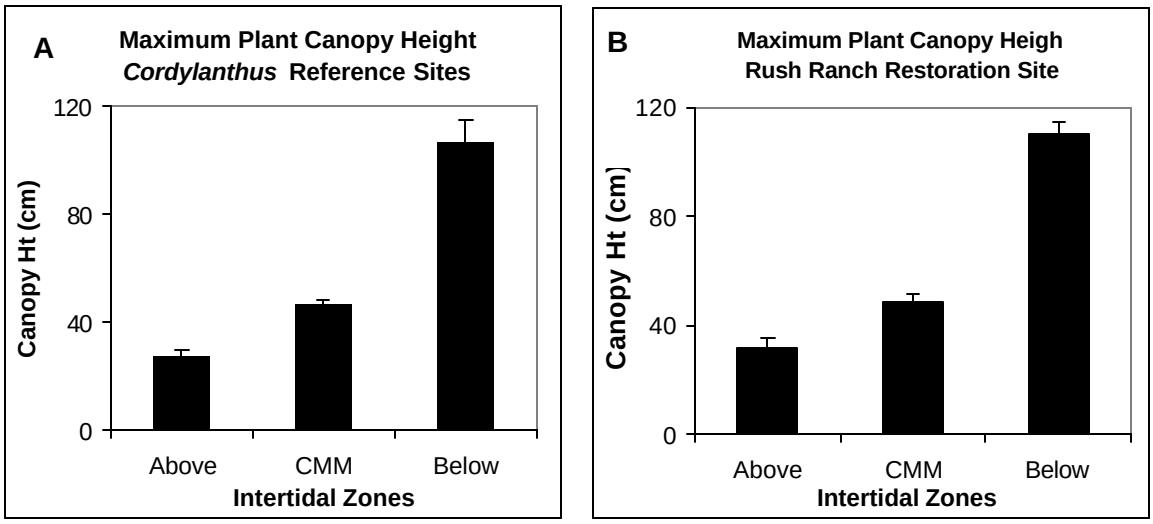


Figure 6. Maximum canopy height above, within, and below soft bird's beak occupied intertidal zones at reference sites (A), and at the Rush Ranch reintroduction site (B) (means ± 1 SE).



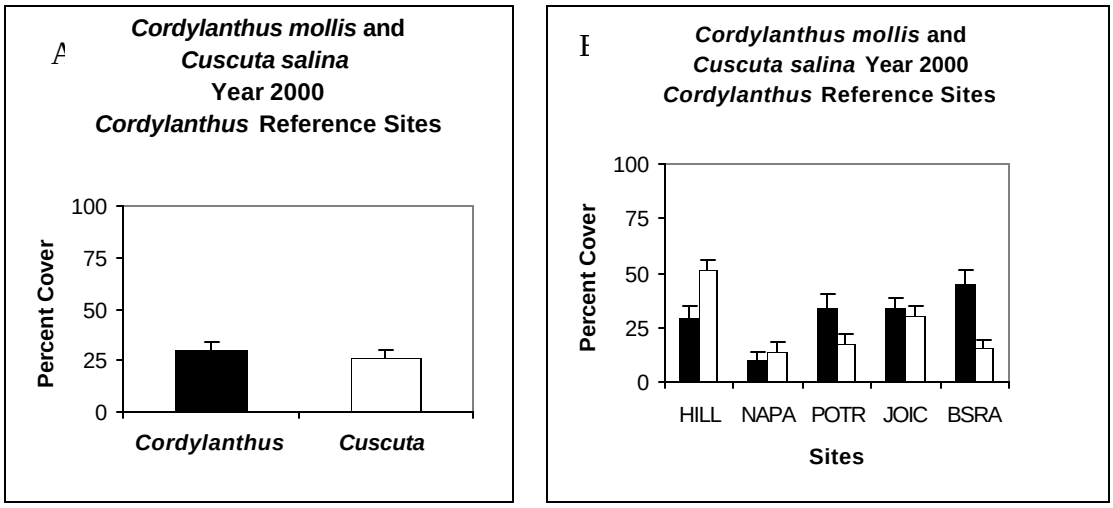
The intertidal zone above soft bird's beak occurrence is greater than mean high water and extends up to highest high water tidal events. Soil organic matter content is lowest in the high infrequently flooded zone, and increases with distance below highest high water. Soil organic matter is highest in the zone below soft bird's beak and lowest in the zone above the rare plants at both reference and reintroduction sites, but the evolving Spring Branch Marsh restoration site at Rush Ranch has less organic matter content when compared to reference marshes (Figure 4).

Although soil conditions differ between the reference and reintroduction sites, plant community characteristics compared favorably among sites. Photosynthetically active radiation measured below the canopy during the spring seedling emergence period revealed a strong light gradient that increased with elevation (Figure 5), while maximum plant canopy height dramatically decreases with increasing intertidal elevation at the project study sites (Figure 6).

While one might predict a number of potential halophyte hosts as the most prevalent

plant associate of hemiparasitic soft bird's beak, a second parasitic plant was the single most common associate. Salt marsh dodder (*Cuscuta salina*) is an easily recognized orange parasitic vine of the salt marsh. Soft bird's beak is rarely observed without dodder, and dodder commonly uses soft bird's beak as a host plant. Percent cover measurements of these co-occuring parasites are shown in Figure 7.

Figure 7. Percent cover soft bird's beak (*Cordylanthus mollis*) and its most common plant associate,salt marsh dodder (*Cuscuta salina*) as they co-occur among reference sites (A), and at individual reference sites (B) in the year 2000 prior to establishment of the reintroducted population at Rush Ranch (means ± 1 SE).



Although salt marsh dodder successfully parasitizes soft bird's beak, the relationship between the two appears to be mutualistic. Dodder forms successful haustorial attachments to soft bird's beak vascular tissues, and acquires water and nutrient resources from the hemiparasite, and other non-parasitic hosts. This interaction is not entirely negative for the hemiparasite. Correlative studies in a central California salt marsh suggest that dodder suppresses community dominant halophytes, and the consequential reduction in host plant cover opens up light gaps that facilitate colonization by rare plants and facilitate cycles of diversity (Pennings and Callaway 1996). Soft bird's beak is dependent on light gaps within the canopy. Experimental

removal of salt marsh dodder from salt marshes adds further evidence to support the positive community role of salt marsh dodder, with direct benefits to soft bird's beak, Point Reyes bird's beak, and other rare plants in California salt marshes (Grewell in prep.). An important screening criterion for soft bird's reintroduction sites appears to be the presence of salt marsh dodder.

We completed several multivariate statistical analyses for a more in depth look at habitat factors that may be critical to soft bird's beak. Plant species and environmental variables measured in the releves are listed in Tables 6 and 7.

Table 6. Plant species present in reference site releves and included in vegetation matrix for multivariate analyses.

CODE	PLANT SPECIES	CODE	PLANT SPECIES
APGR	*Apium graveolens**	LICA	*Limonium californicum*
ARSU	*Arthrocnemum subterminalis (Salicornia)*	LOMU	*Lolium multiflorum**
ASLE	*Aster lentus*	LOCO	*Lotus corniculatus**
ASSU	*Aster subulatus* var. *ligulatus*	HACY	*Hainardia cylindrica**
ATTR	*Atriplex triangularis*	OESA	*Oenanthe sarmentosa*
BRHO	*Bromus hordaceus**	PIEC	*Picris echioides**
CHCH	*Chenopodium chenopodioides* (L.)*	PLMA	*Plantago maritima*
COMO	*Cordylanthus mollis ssp. mollis*	PLSU	*Plantago subnuda*
COCO	*Cotula coronopifolia**	POAR	*Polygonum arenastrum**
CRTR	*Cressa truxillensis*	POMO	*Polypogon monspeliensis**
CUSA	*Cuscuta salina* var. *major*	POAN	*Potentilla anserina* ssp. *pacifica*
DISP	*Distichlis spicata*	PUSI	*Puccinellia simplex*
EPCI	*Epilobium ciliatum* ssp. *ciliatum*	RUCR	*Rumex crispus**
FRSA	*Frankenia salina*	SAVI	*Salicornia virginica*
GLMA	*Glaux maritima*	SCAM	*Scirpus americanus*
GRST	*Grindelia stricta* var. *angustifolia*	SCKO	*Scirpus koilolepis*
JACA	*Jaumea carnosa*	SCMA	*Scirpus maritimus*
JUBA	*Juncus balticus*	SOOL	*Sonchus oleraceus* L.*
JUBU	*Juncus bufonius* L.	SPMA	*Spergularia marina*
JUME	*Juncus mexicanus*	TRWO	*Trifolium wormskioldii*
LELA	*Lepidium latifolium**	TRMA	*Triglochin maritima*

* non-native species

Table 7. Environmental variables measured in reference site releves and included in environmental matrix for multivariate analyses.

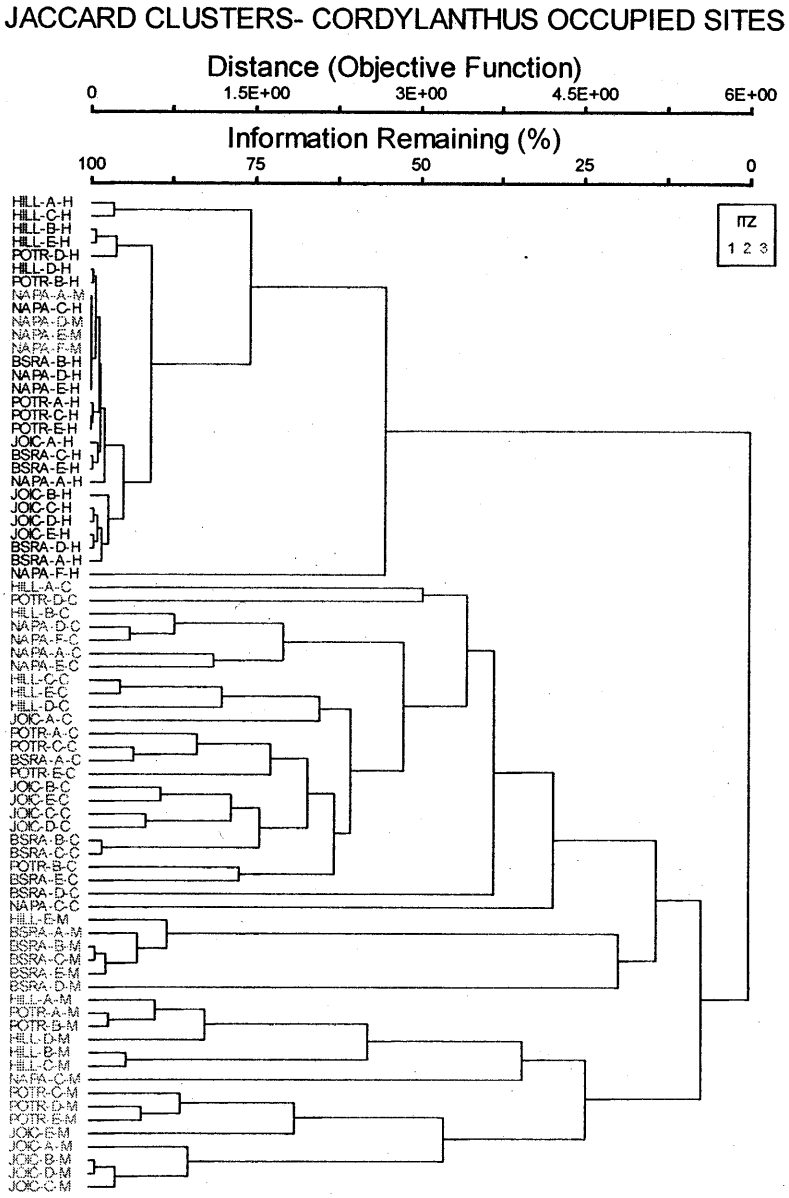
CODE	ENVIRONMENTAL VARIABLE
CNHT	Maximum Canopy Height
SWC	Soil Water Content at Low Tide
SBD	Soil Bulk Density
SSC	Soil Saturated Conductivity
LOI	Loss on Ignition (Soil Organic Matter)
NA	Sodium (soil)
K	Potassium (soil)
CA	Calcium (soil)
MG	Magnesium (soil)
N	Total Nitrogen (soil)
C	Total Carbon (soil)
P	Total Phosphorus (soil)
PAR	Photosynthetically Active Radiation
SAR	Sodicity (Sodium Adsorption Ratio)
CAMG	Ca:Mg Ratio
EL	Elevation (NGVD)

We performed a variety of agglomerative cluster analysis techniques to examine the distinctiveness of vegetation zones observed in the field. We used average linkage clustering to compute dissimilarity between clusters from unweighted pair groups as is recommended for hierarchical classification of vegetation (Gauch 1982). The 1 – Jaccard Dissimilarity Index was calculated for a look at distance cluster analysis, and this method emphasizes rare species. This index was calculated as the proportion of sampling units that occur relative to the total number of sampling units with at least one species from species-absence data arranged in 2X2 contingency tables (Ludwig & Reynolds 1988).

The cluster analysis shown in Figure 8 confirms the distinctiveness of vegetation across intertidal elevations within soft bird's beak occupied wetlands. The dendrograms display results of the clusters by sampling units. These figures suggest that releves identified as high marsh above *Cordylanthus* (last code letter H), within *Cordylanthus* zone (last code letter C), and below Cordylanthus (last code letter M) intertidal zones

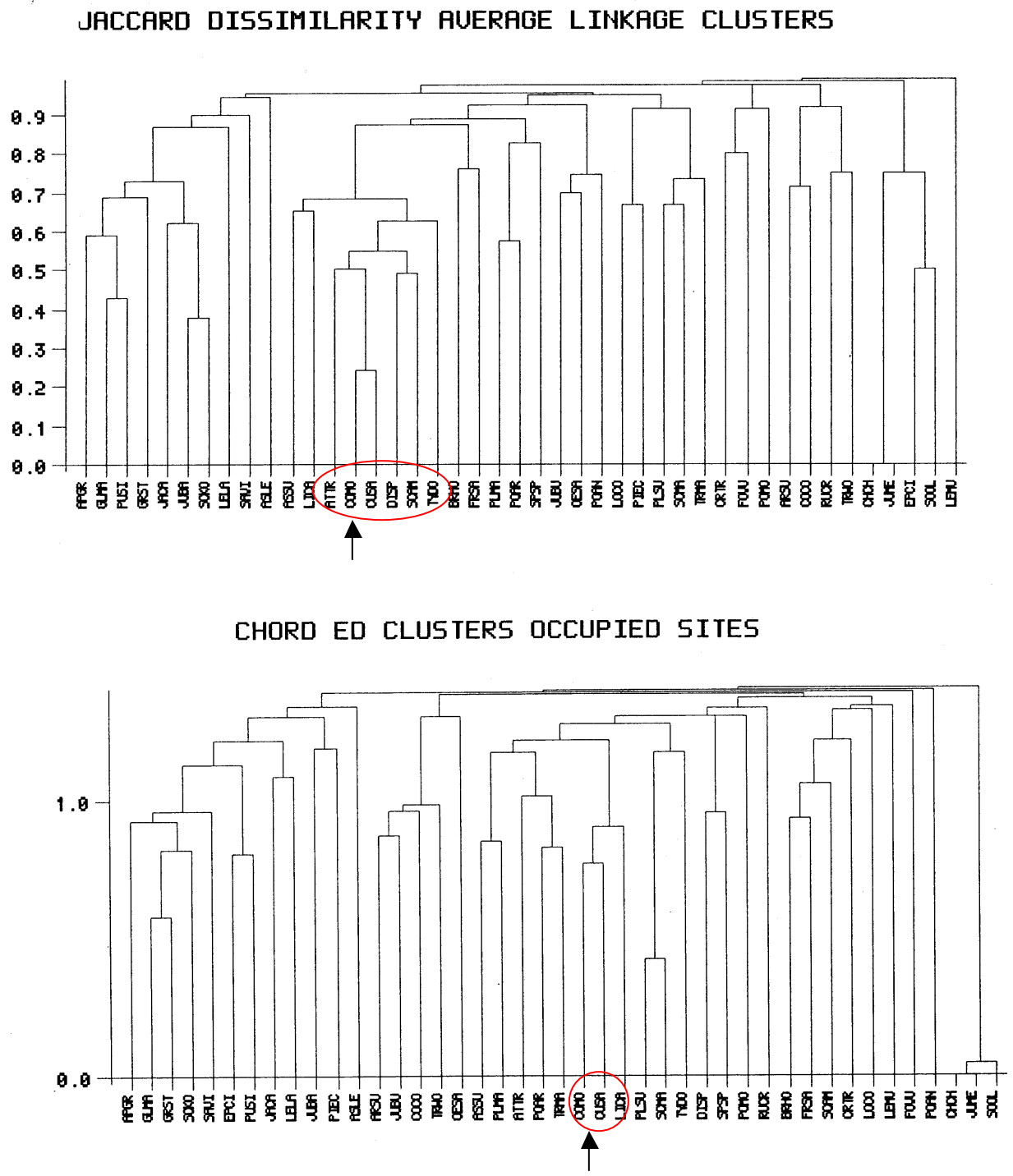
consist of unique vegetation assemblages. However, vegetation species occurrence (primarily *Salicornia virginica* cover) in the zone below *Cordylanthus* at Napa Marsh was more similar to the high marsh sites in Suisun Marsh than other identified sites at intertidal ranges below *Cordylanthus* occurrence.

Figure 8. Jaccard hierarchical cluster analysis by average linkage method clustered by sampling units at soft bird's beak occupied sites.



Jaccard and CHORD ED clusters were also plotted as dendrograms to look at plant species clusters at soft bird's beak occupied sites (Figure 9).

Figure 9. A comparison of Jaccard hierarchical cluster analysis and CHORD Euclidean distance by average linkage cluster analysis of plant species at soft bird's beak sites.

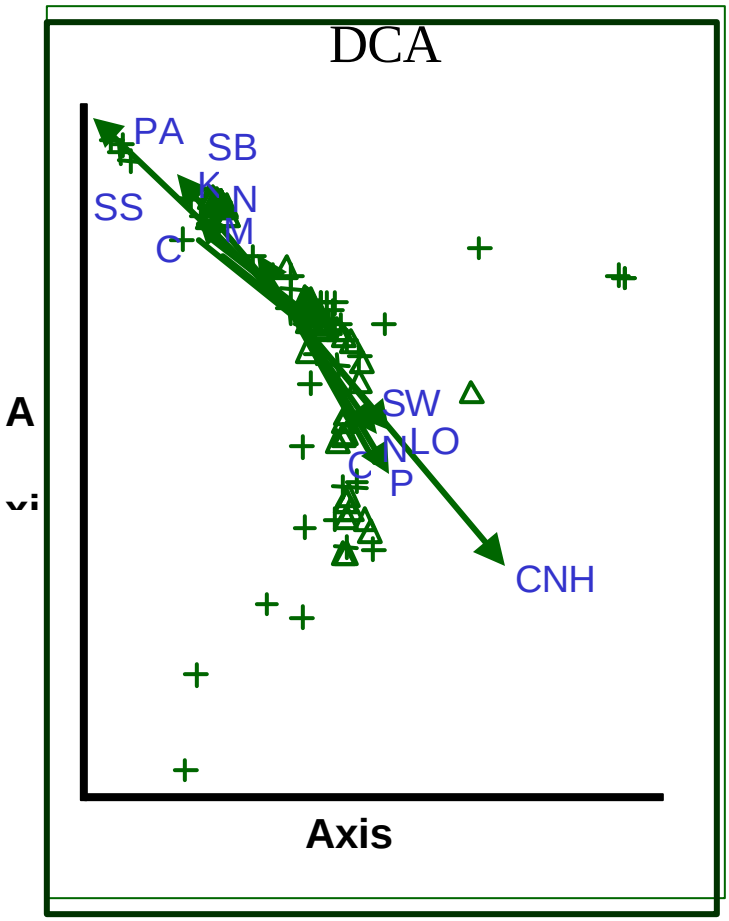


CHORD Euclidean Distance measures by average linkage standardizes Eucledian distance by putting greater importance on the relative proportions of species in sampling units and correspondingly less importance on absolute cover. Both Jaccard Dissimilarity and CHORD ED agglomerative clustering recognized the close association between soft bird's beak (COMO) and salt marsh dodder (CUSA). Jaccard clusters also classified fathen (*Atriplex triangularis*, ATTR), saltgrass (*Distichlis spicata*, DISP), coastal plantain *Plantago subnuda* (PLSU), and western marsh rosemary (*Limonium californicum*, LICA) as close associates of soft bird's beak. CHORD ED was an improved reflection of field observations as this method recognized slender aster (*Aster subulatus*, ASSU), seaside plantain (*Plantago maritima* PLMA), fathen (*Atriplex triangularis*, ATTR), knotweed (*Polygonum arenastrum*, POAR), seaside arrowgrass (*Triglochin maritima*, TRMA), salt marsh dodder (*Cuscuta salina* CUSA), western marsh rosemary (*Limonium californicum* LICA), and soft bird's beak (*Cordylanthus mollis* COMO) and saltgrass (*Distichlis spicata*) as a unique association. These agglomerative clustering results accurately portray the plant community composition in reference marshes, and show promise as a useful tool in the evaluation of plant community composition of evolving restoration sites before experimental reintroduction of the endangered plant is attempted.

Multivariate ordination analyses were then applied to soft bird's beak occupied sites and the Rush Ranch restoration site to see if the vegetation species were distributed along detectable environmental gradients, and which environmental factors best explain the variation. Detrended correspondence analysis (DECORANA) was the first method we applied to computationally place species, environmental data, and sample ordination scores in one integrated analysis to see which environmental variables best explain the vegetation pattern. DECORANA was selected because it removes the arch effect and rescales axes to remove compression near the ends as these effects can be a problem when there are many sampling units with empty data cells (i.e. in this case, absence of many plant species from various sampling units).

Figure 10 shows results of detrended correspondence analysis of 42 plant species and 16 environmental variables at 75 plots from within soft bird's beak occupied tidal marshes.

Figure 10. Detrended Correspondence Analysis ordination showing variation in plant community composition explained by environmental variables at soft bird's beak occupied reference sites.



The dark arrow lines on these scatterplots identify important environmental gradients, and the length of the line represents the strength of the gradient factor. DECORANA ordination revealed some important gradients within these communities. PAR, soil bulk density, soil saturated conductivity, sodium absorption ratio, and soil potassium levels were all elevated in the stressful upper high marsh (above mean higher high water

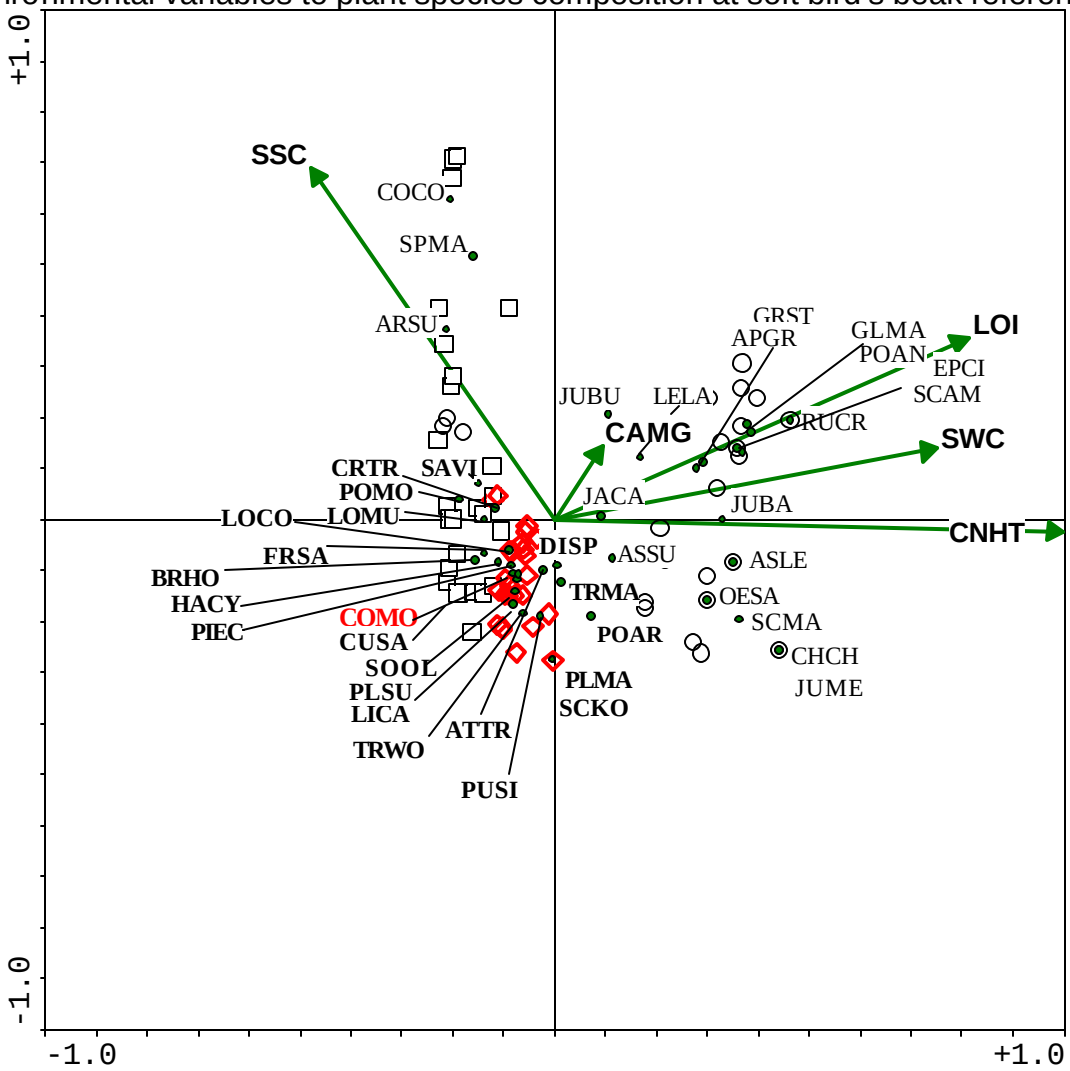
elevation) above the zone of soft bird's beak occurrence. The ordination also emphasized the increase in soil water content, soil organic matter, plant canopy height, and total nutrients (nitrogen, phosphorus, and total carbon) within sampling units below the zone supporting soft bird's beak in occupied tidal marshes. The strongest gradients detected by detrended correspondence analysis were PAR and canopy height , while soil bulk density and soil phosphorus gradients were also significant.

Canonical correspondence analysis (CCA) was performed to further investigate critical habitat factors associated with soft bird's beak at occupied reference wetlands. This direct gradient analysis technique often provides an improvement over indirect methods such as detrended correspondence analysis because species composition is directly and immediately related to measured environmental variables (ter Braak 1987, Palmer 1993). The underlying assumption of CCA is that species frequency or abundance is a unimodal function of position along environmental gradients. The statistical significance of the relationship between the species and environmental variables was evaluated with Monte Carlo permutation tests, and the ordination plot includes significant variables ($p \leq 0.05$). The CCA ordination of vegetation and environmental variables from 75 sampling units among five reference sites are presented in Figure 11. The primary ordination axis is horizontal and the secondary axis is vertical, and the axes are linear combinations of environmental variables. By looking at the signs and relative magnitudes of the standardized canonical coefficients, we may infer the relative importance of each environmental variable for predicting the community composition.

Both CCA and DCA ordination results suggest that structural aspects of the vegetation community as indicated by maximum canopy height and below canopy intercepted PAR explain most of the variation between the zone that supports soft bird's beak, and areas of the marsh where soft bird's beak is absent. The strongest gradient detected was the intertidal variation in canopy height. These results suggest that mere presence of a potential host such as saltgrass or pickleweed is not a reliable indicator of a suitable host community for soft bird's beak. For example, saltgrass and pickleweed are species associates of soft bird's beak, yet they both occur across a broader intertidal range than

the endangered hemiparasite. These data suggest that the structure of the community, microgaps, and photosynthetically active radiation penetration through the canopy may be as important as potential host identity and community composition.

Figure 11. Canonical correspondence analysis (CCA) ordination triplot directly relating environmental variables to plant species composition at soft bird's beak reference sites.



CCA Legend

- Four letter codes (COMO) = plant species (see Table 6)

Open Squares = Releves in intertidal zone above soft bird's beak
Red Diamonds = Releves with soft bird's beak
Open circles = Releves below soft bird's beak
Green Arrow = most significant environmental variables (see Table 7 for codes), length of the line reflects strength of the variable
COMO = *Cordylanthus mollis* (soft bird's beak) (Red Four Letter Code)

CCA confirms the role of soil saturated conductivity as a significant variable for community organization, as a steep soil salinity gradient increases with intertidal elevation to a maximum in the infrequently flooded areas above soft bird's beak. Soil organic matter and soil water content were significant variables that decrease with intertidal elevation and are highest in the zone below soft bird's beak.

Summary. The multivariate cluster and ordination analyses presented suggest that modern populations of soft bird's beak are most often found in mixed halophyte plant communities with average maximum canopy heights in the range of 42 – 52 centimeters. Intercepted PAR below the canopy during the seedling emergence period averages 790 nMol/m^2/s, and this intermediate light level reflects a partially open canopy with many micro-germination gaps. The extreme open community characterized by sparse patches of *Salicornia*, *Arthrocnemum*, and bare salt scalds in the highest intertidal area may support limited numbers of soft bird's beak, but this is not where soft bird's beak thrives.

Salt marsh dodder is the most common species associate of soft bird's beak, while saltgrass, fathen, western marsh rosemary, coastal plantain, sea plantain, and seaside arrowgrass form a close association with the two parasites. *Salicornia viriginica* (pickleweed) is also present in this community, but it is not a good predictor of soft bird's beak habitat because it is found across a broad intertidal gradient and comprises a greater proportion of plant cover away from the parasitic plants. This does not mean *Salicornia* is not important to soft bird's beak, as the hemiparasite and salt marsh dodder use it as a host. The reduced cover of *Salicornia* found with the parasitic plants may be partially explained by suppression due to resource extraction by the parasites. The important thing to consider when screening potential restoration sites for soft bird's beak reintroductions is that physical conditions and plant community composition will change with parasite presence (Grewell, in prep).

Tidal Hydrology

Hydrology is a major environmental determinant of plant community development and patterns of plant zonation in wetlands (Mitch and Gosselink 2000, Pennings and Bertness 2001). The wetland hydroperiod is defined by the depth, duration, and frequency of flooding. Water depth alone is not always a good predictor of wetland plant community composition, and individual plant species respond quite differently to various components of the wetland hydroperiod (Casanova and Brock 2000). Tidal bays and sloughs of the San Francisco Estuary experience mixed semi-durnal tides with two high two low tidal pulses of unequal magnitude over each 25 hour tidal cycle. Interannual variation in hydrology is significant due to managed freshwater outflow regimes from the Sacramento-San Joaquin Delta, and climate-induced variation in local watershed and oceanic influence. Tidal hydrology also varies considerably over the intertidal gradient, and is likely a key environmental factor influencing the limited distribution of *Cordylanthus mollis*. We installed shallow water level monitoring systems within soft bird's beak study sites to study this hydrology, and address the following questions:

- What are the hydrologic differences across an intertidal gradient of soft bird's beak habitat in a natural reference population vs. the reintroduction site?
- What role does hydrology play in determining the differential demographic success within a single site?
- How do hydrologic conditions vary across the geographic range of monitored soft Bird's Beak reference populations at six sites between Napa Marsh and Suisun Marsh in the San Francisco Estuary?

Results of this special study are reported in Appendix II.

Critical Biological Interactions

A preliminary census at the Rush Ranch tidal marsh in 1999 confirmed the presence of a potential pollinator community known to visit soft bird's beak flowers. This information was considered when choosing an evolving tidal restoration area at Rush Ranch for experimentally testing reintroduction methods. During implementation of the project, a floral visitor observation study was conducted to explore these critical biological interactions during the reintroduction process.

Potential Pollinator Observation Study

Introduction. Successful pollination is a necessary life-history component in the successful establishment and recruitment of new individuals of endangered plant species. Therefore, one stage in monitoring the reintroduction of a species is to answer the question: "When individuals flower, are they successfully pollinated by an appropriate agent?" (Primack 1996). Answering this question is especially important when the reintroduced species is an annual, which must set seed in order to reproduce.

Cordylanthus mollis ssp. *mollis* (COMOM) is an outcrossing annual species that relies on insects for pollination and successful reproduction. Ruygt (1994) observed three species of bees active on several populations of *C. mollis* spp. *mollis* in 1993 and 1994. Although he reported low overall numbers of potential pollinators and the possibility of self-fertilization as a reproductive strategy of this species, the importance of pollinators for seed set remains. For example, reintroductions of a related species, *C. maritimus* ssp. *maritimus*, in San Diego Bay were compromised because native pollinators of this species are no longer available at the reintroduction site (cited in Zedler 1996). For these reasons, we conducted a study of insect activity at our reintroduction and reference site during the peak flowering period. Our objectives were to answer the following questions:

1). Will a newly reintroduced population of rare soft bird's beak be apparent to potential pollinators?

2). Will the floral visitor community at a newly reintroduced population of rare soft bird's beak be similar in diversity and composition as the floral visitor community in a natural reference population?

3) Are there other flowering plants in the salt marsh community that may be important attractor species for potential pollinators of *C. mollis* spp. *mollis*?

It is important to recognize that floral visitors may not pollinate the rare plants, and pollination efficiency can vary greatly among animals visiting flowers. Confirmation that a floral visitor is a pollinator requires observation of pollen transfer from the visitor to the stigma, pollen transfer between flowers on a plant or among plants, and determination of pollen viability (Kearns and Inouye 1993). The floral structure of *Cordylanthus mollis* precludes direct observation of pollen transer, and the absolute determination of pollination or pollinator effectiveness will require a dedicated in-depth study beyond the scope of this effort. This observational study is intended to assist restoration managers who must screen future sites for suitability prior to future reintroductions of soft bird's beak at evolving restoration sites.

Methods. Beginning in mid June when the majority of plants were flowering, we conducted timed observations of insect activity at 10 randomly selected 1x1 m soft bird's beak occupied plots at both the reintroduction site, Rush Ranch, and the Hill Slough-Potrero reference population. All potential pollinators as well as seed predators and parasitoid wasps, visiting *Cordylanthus* plants during a 15-minute period were recorded. We also noted insect behavior on *Cordylanthus* and other flowering plants. Timed observations were conducted two times a day, morning and late afternoon, once a week for a period of four weeks. Several observations were recorded during on site visits throughout the growing season. In addition, voucher specimens of insects were collected for positive identification and future reference. Analysis of variance of the insect counts was conducted using SYSTAT version 9. We photographed and prepared illustrations of important insect fauna associated with soft bird's beak and prepared a

field guide to help restoration managers identify potential pollinators within natural populations and at potential reintroduction sites (Appendix III).

Results and Discussion.

***Flower Visitor Abundance*.** Total numbers of pollinators we observed at each site are shown in Figure 12 and Table 8.

Figure 12. Potential pollinators observed at reintroduced and natural populations during 2001.

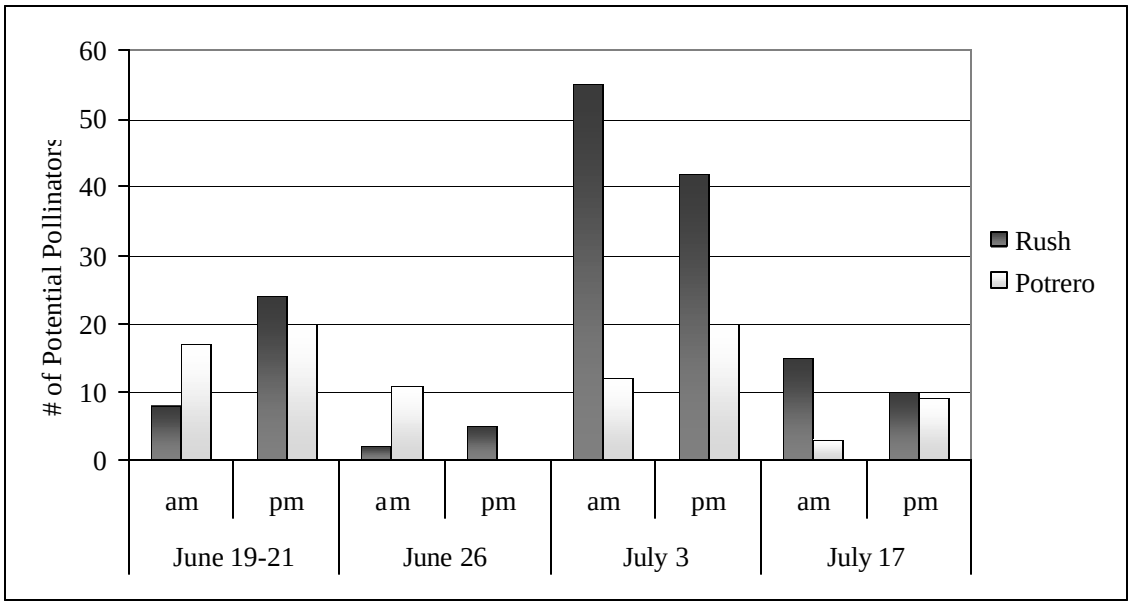


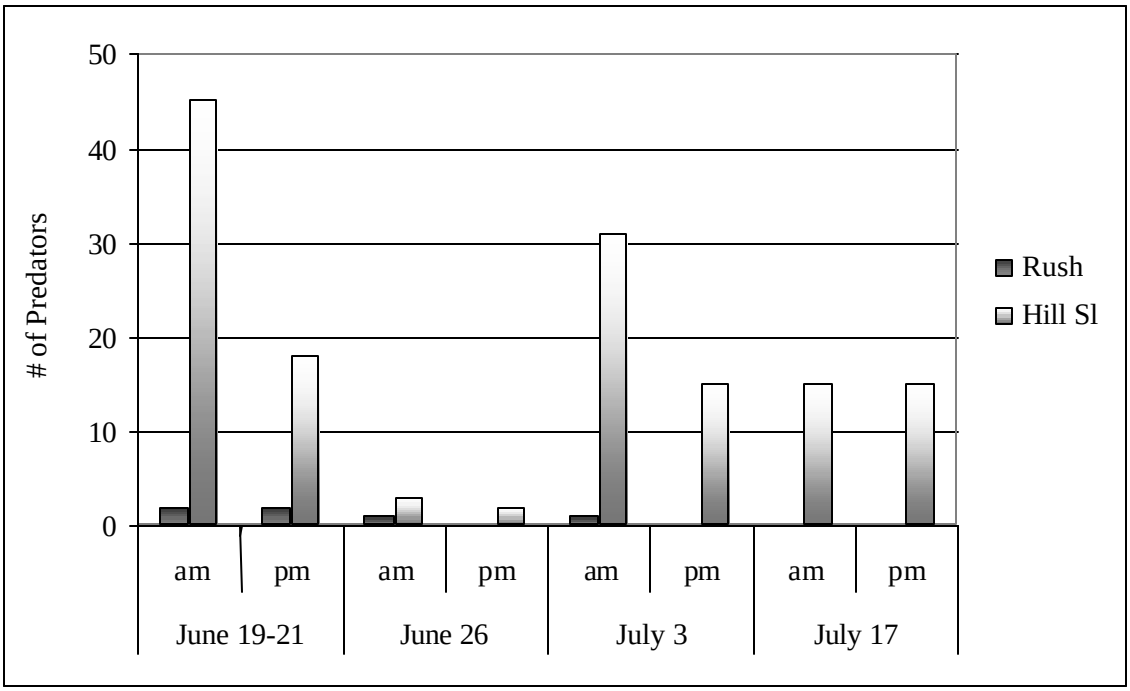
Table 8a. Total number of pollinators observed

June 19-21		June 26		July 3		July 17	
am	pm	am	pm	am	pm	am	pm
8	24	2	5	55	42	15	10
17	20	11	0	12	20	3	9

Table 8B. Total number of predators observed

June 19-21		June 26		July 3		July 17	
am	pm	am	pm	am	pm	am	pm
2	2	1	0	1	0	0	0
45	18	3	2	31	15	15	15

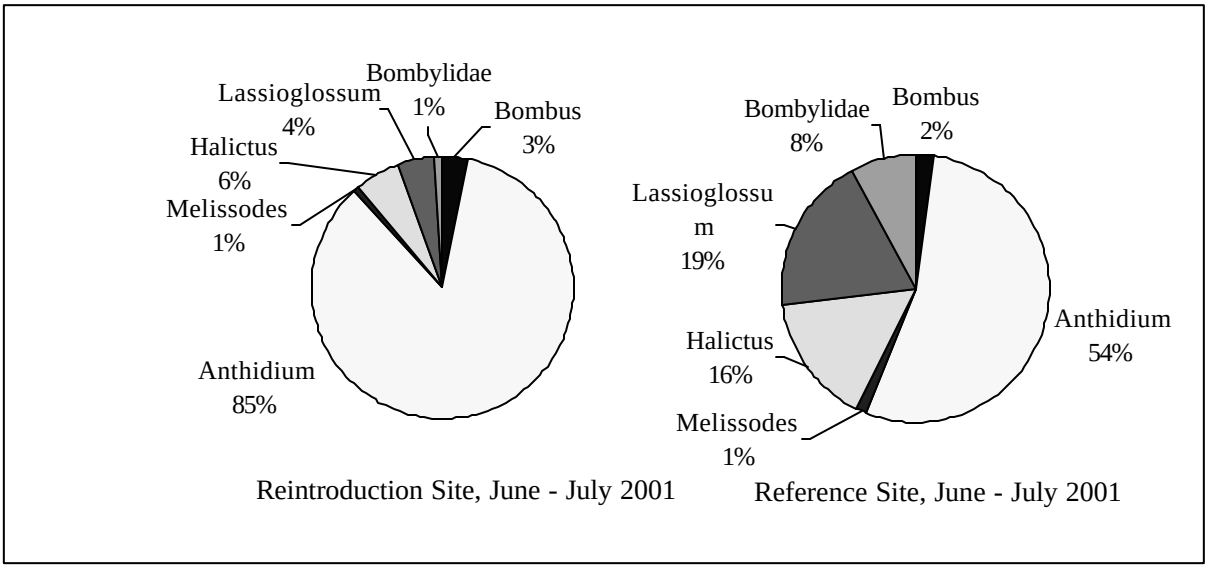
Figure 13. Predator insects observed at reintroduced (Rush) and natural (Hill) populations during 2001 field study.



Insect predator observations are shown in Table 8b and Figure 13. The number of predators observed at our natural population is significantly greater than the number we observed at the reintroduced population (p=0.004). However, there was no significant difference between number of predators observed in the morning and number observed in the afternoon (p=.267). These results suggest that although the new population of soft bird's beak at Rush Ranch is apparent to potential pollinators, this population is not yet apparent to predators. The floral visitors we observed are generalist pollinators, while the main seed predator is a Tortricid moth that may be a specialist granivore associated with soft bird's beak. The moth larvae serve as a food source for abundant wasp parasitoids seen at Hill Slough. This could explain the differences we observed in pollinator and predator numbers at the Rush Ranch introduction site.

***Potential Pollinator Community Composition and Diversity*.** The potential pollinator suites of both sites are shown in Figure 14. This figure shows the observed frequency of each genus expressed as percentage of the total number of pollinators observed over the four weeks.

Figure 14. Frequency of occurrence of potential pollinators observed at the reintroduced (Rush Ranch) and reference population (Hill Slough) during 2001 peak bloom of *Cordylanthus mollis.*



Each genus was observed at both sites. The pollinator suite included bees: *Bombus* (Apidae), *Anthidium* (Megachilidae), *Melissodes* (Anthophoridae), *Halictus* (Halictidae), and *Lassioglossum* (Halictidae); and one bee fly (Bombylidae). *Anthidium edwardsii* was the most common pollinator observed at both sites, but made up a larger percentage of the total at Rush (85%) than at Hill Slough (54%). The Halictid bees, *Lassioglossum* and *Halictus*, were the next most abundant (10% at Rush, 35% at Hill Slough-Potrero). *Bombus* and *Melissodes* were rare at both sites (3%,1% at Rush and 2%, 1% at Hill Slough-Potrero, respectively). Pre-study observations and literature on related plant species suggest these genera may be early season pollinators and may have been more prevalent before the timed study began. Another explanation may be year-to-year variation in insect populations. The only non-bee pollinator, members of the Bombylidae family, were sighted at both locations, but were more prevalent at Hill Slough (8%) than at Rush Ranch (1%).

The potential pollinator community at a newly reintroduced population of rare soft bird's beak is similar in diversity and composition to the pollinator community in the natural population. Although species frequency of occurrence varied between the two sites, the community composition of pollinators was the same between the reintroduced and natural populations. In a previous study, Ruygt (1994) reported a less diverse suite of pollinators, including *Bombus*, *Anthidium* and *Halictus* species. However, individuals from all three of these genera were observed at Hill Slough in 1993 and 1994.

The potential pollinator suite that we observed visiting *C. mollis mollis* was very similar to that visiting a related tidal wetland species, *C. maritimus* spp. *maritimus*. The most common potential pollinators observed over two years for this species were *Bombus*, *Anthidium*, *Melissodes*, and Halictine bees (Parsons and Zedler 1997). The similarity between the pollinator communities for the two tidal wetland species of *Cordylanthus* is shown in Table 9.

Table 9. Comparison of potential pollinator communities associated with *Cordylanthus mollis* ssp. *mollis* and *C. maritimus* ssp. *maritimus* in California tidal salt marshes.

Table 3. Comparison of potential pollinator communities for *C. mollis mollis* and *C. maritimus maritimus*

Pollinator		*C. maritumus* ssp. *maritimus**		*C. mollis* ssp. *mollis*			
				1993/1994**		2001	
Family	Genus	Tijuana Estuary	Sweetwater Marsh	Fagan Slough	Hill Slough	Rush Ranch	Hill Slough Potrero
Anthophoridae							
	Melissodes	X	X			X	X
Apidae							
	Bombus	X	X	X	X	X	X
Bombylidae							
		X	X			X	X
Colletidae							
	Colletes	X	X				
Halictidae							
	Dialictus	X	X				
	Halictus			X	X	X	X
	Lassioglossum					X	X
Megachillidae							
	Anthidium	X			X	X	X

* From Parsons and Zedler (1997)
** From Ruygt (1994)

Observed Pollinator Behavior and Ecology. *Anthidium edwardsii* Cressan bees were the most common potential pollinator we observed. They reached peak activity in early July, but were still active in August through October after we ended the study. They are a mid sized, light-colored bee, with a characteristic “geometric” flight. Ruygt (1994) also identified *Anthidium edwardsii* Cressan as a potential pollinator of *C. mollis* spp. *mollis* in 1994. This species ranges from the California coastal ranges thought the central valley and into the Sierra Nevada foothills. It is a dietary generalist with localized plant

preferences that has been observed on a number of species of Scrophulariaceae (Ruygt 1994). *A. edwardsii* has also been reported as an important pollinator of C. maritimus spp. maritimus (Lincoln 1985).

The *Anthidium* bees hover over the *C. mollis* spp. *mollis* flowers and only occasionally touch down. When the bee does visit a flower, it "dives into" the flower and crawls all the way into to flower. Ruygt (1994) reported visitation times of less than 5 seconds, but we observed that if a bee committed to a flower, it would remain in the flower for up to several minutes. In addition, rather than visit several different plants or flowers, a single bee would return repeatedly to the same flower on a spike. Although abundant, this behavior may limit the effectiveness of *Anthidium* for cross-pollination. These bees also appeared territorial; they chased away other insects (*Bombus*, other *Anthidium*) from the patches of flowering bird's beak.

During our early observations, we saw several individuals from the Halictidae family crawling in and around *C. mollis* spp. *mollis*. Halictid bees, which include species from *Halictus* and *Lassioglossum*, are generalist pollen collectors; this habit was verified by our observations. Although Halictid bees visited *Cordylanthus* when other plants were not flowering, once *Cuscuta salina* began blooming, these bees spend most of their time on these flowers. They were also seen visiting *Frankenia salina* and the non-native *Apium graveolens*. In 2000, Halictid bees were observed visiting *Salicornia virginica* and *Frankenia salina*. When these bees visited *Cordylanthus,* they probed three to four plants in our 15-minute observation periods and moved between flowers of different plants. However, their small size and generalist behavior may limit their pollination efficiency. Although Halictid bees have been reported as pollinators of *C. maritimus* spp. *maritimus* (USFWS 1985) and frequent flower visitors of *C. palmatus* (LC Lee and Assoc. and CCB 2002), other observational studies have suggested they may be inefficient pollinators of *C. palmatus* (CCB 1993). Parsons and Zedler (1997) found *C. maritimus* spp. *maritimus* plants visited exclusively by Halictid bees had significantly less seed production than those visited by a variety of pollinators. These

records and our observations suggest that although Halictid bees may contribute to pollination of *C. mollis* spp. *mollis*, their pollination efficiency is unknown.

We observed only a few individuals of *Bombus* in June and early July. Both *Bombus californicus* and *Bombus vosnesenski* were observed visiting *C. mollis* spp. *mollis* at our sites in 2000 – 2002, but visits were rare. Ruygt (1994) reported common *Bombus californicus* activity on *C. mollis* patches at Hill Slough from June to July (1993) and June to mid-August (1994), though the same species was rare at this site during our study. This documented change in the composition of the soft bird's beak potential pollinator community in Suisun Marsh raises an immediate conservation concern, and the reason for this change is not understood.

Previous studies of related *Cordylanthus palmatus,* an endangered *Hemistegia* species of alkali sink wetlands, have shown *Bombus* individuals are faithful to patches of *C. palmatus* (CCB 1994). *Bombus* was reported as a faithful pollinator of *C. palmatus*, but as only active in the early to mid flowering season (CCB 1993). More recent observations documented *B. vosnesenski* as a frequent flower visitor of *C. palmatus* with activity recorded from June – August 2002 (LC Lee and Assoc. and CCB 2002). Our observational study was restricted to the peak flowering period, and we may have missed peak *Bombus* activity. During casual observations made in early June prior to our study, we reported *Bombus* individuals on *C. mollis* spp. *mollis* at both sites. Bumblebee populations could fluctuate yearly, and experts suggest native *Bombus* species may be in decline (Personal communication, Robin Thorp). However, *Bombus* could be an important pollinator of *C. mollis* spp. *mollis*, since *Bombus* pollinated *C. palmatus* plants produced significantly more seeds than hand pollinated ones (CCB 1994).

Although *Bombus* visits to *C. mollis* ssp. *mollis* flowers were rare during our peak flowering stage observations, we observed *Bombus* visiting flowers of invasive yellow star thistle in adjacent pastures. Non-native invasive plants may attract pollinators away from native species dependent on their services. *Bombus vosnesenski* was also

observed in flower gardens in a recent subdivision development adjacent to the sensitive Hill Slough tidal marsh. Expanding urban subdivisions could be a sink for historic pollinators formerly associated with sensitive native plants.

We observed very few *Melissodes* individuals during our timed study period. *Melissodes* may have been active earlier in the season, before peak flowering and our timed study began. We saw evidence of early activity of *Melissodes* before peak flowering of the population. In May prior to *Cordylanthus* bloom, we observed many *Melissodes* individuals of this genus trapped in the short, open-ended pipes marking our study plots which fill with water on the high tides. According to our demographic records taken in May, very few *Cordylanthus* individuals were flowering at this time. Also, the majority of *Melissodes* individuals we observed during our pollination study were seen in the first week. We responded by capping all marker pipes prior to our timed study and for duration of our project. *Melissodes* were also observed visiting areas of ponded water within the high tidal marsh, and they may be attracted to the area for the water source. This genus was observed visiting *Frankenia salina* and *Cuscuta salina* flowers as well. Early activity prior to the main flowering period and generalist behavior may limit the effectiveness of this genus as a pollinator of *C. mollis* spp. *mollis.*

At both sites, we saw very few Bombylidae individuals. Although the bee flies hovered and probed *Cordylanthus*, most were visiting *Frankenia*. Bee flies were observed at several populations of *C. mollis* spp. *mollis* in September and October 2000. They flew from flower to flower, inserting their long proboscis into the flowers to remove nectar (Battaglia, unpublished). This observation indicates bee flies may be nectar robbers rather than effective pollinators. Also, these flies may be more active later in the season, after we stopped our observations.

Pollinator Attractant Plants. An important consideration when selecting a potential *Cordylanthus* restoration site is whether pollinators will find the new population. Therefore, presence of other flowering plant species that could serve as pollinator attractors is an essential criterion when choosing a site for reintroduction of *C. mollis.*

During the 2000 and 2001 field seasons and this timed study, we have observed several potential pollinators of *C. mollis* spp. *mollis* visiting other flowering plant species. For example, during our timed study, we saw *Anthidium*, the most frequently observed pollinator visiting *C. mollis* spp. *mollis*, visiting *Cuscuta salina* flowers. *Cuscuta* flowers also attracted Halictid bees, *Melissodes* and *Bombus* individuals. During our timed study, we made a general observation that more pollinators tended to be present when parasitic *Cuscuta* vines were in or nearby the study plot. *Frankenia salina* is another native species that was often visited by potential pollinators, including Halictid bees and bee flies. We also noted *Jaumea carnosa* as a potential pollinator attractor species for *Bombus*. Yellow star thistle was not the only exotic host for potential pollinators. *Bombus californicus* was observed on exotic *Lotus corniculatus*, *Bombus vosnesenski* was observed on invasive *Lepidium latifolium* flowers at Benicia State Recreation Area, and *Bombus* and Halictid bees were recorded on exotic *Apium graveolens* within Rush Ranch and Hill Slough tidal wetlands.

Predator Behavior and Ecology. A comparison of the predators observed on *C. mollis* spp. *mollis* in 1993/94 and 2001 is shown in Table 10. The most common pre-dispersal seed granivore we observed on *C. mollis spp. mollis* is a Tortricid moth. This specialist has been observed in *Cordylanthus* communities for some time (Ruygt 1994), but an earlier identification of this moth as *Pytocholoma peritana* by the California Department of Food and Agriculture (as reported in Ruygt 1994) is incorrect (DeBenedictis 2001, pers. communication). The moth is in the *Saphenista* genus of the Tortricidae (DeBenedictus 2001 and Brown 2001), and we have sent loan specimens of adult moths and larvae to colleagues at the Museum of Natural History, Smithsonian Institute for confirmation and description. This microlepidopteran moth appears to be a specialist on *Cordylanthus*, and is likely a previously undescribed species (Brown, personal communication 2001). Voucher specimens are to be returned to U.C.Davis where they will be stored at the Bohart Museum of Entomology, where they may be viewed.

Table 10. Comparison of predator communities associated with soft bird's beak between 1993-19994 and 2001-2002.

Table 4. Comparison of predator communities associated with *C. mollis* spp. *mollis* between 1993/94 and 2001.

Predator		1993/1994*		2001	
Family	Genus	Fagan Slough	Hill Slough	Rush Ranch	Hill Slough Potrero
Pyralidae					
	Lipographis	X	X	X	X
Tortricidae					
	Saphenista	X	X		X
Vespidae					
				X	X
Eumenidae					
			X		X
	Nysius				X

* From Ruygt (1994)

The Saphenista moth is small, 5-10 mm, gray and brown. The adult moths lay eggs in the flowers and the larvae eat the developing seeds. The larvae emerge bore their way out of the seed capsules, and pupate. The pupa moves to the tip of the flower before the adult emerges. Evidence of this moth includes observations of adults, frass/larvae in flowers, and pupa casing on the flower tips.

Saphenista sp. (Tortricidae)

Almost every flower at Hill Slough had frass, larvae and/or a pupa casing on its tip in 2001, and *Saphenista* granivory was confirmed at Hill Slough, Joice Island, Fagan Slough (Napa Marsh), and Benicia State Recreation Area in 2002. There was no evidence of this moth at the new reintroduction site during our timed study. However, a single pupa casing was sighted in November on one flower. Ruygt (1994) observed damage from these moths beginning as early as May. However, he did not consider this species to be the major seed predator of *C. mollis* spp. *mollis*. Instead, he reported *Lipographis fenestrella* Packard (Pyralidae) as potentially the most common seed predator (Ruygt 1994). We did observe adult *Lipographis* moths and larvae at both sites, and observed damage similar to that attributed by Ruygt to *Lipographis* larvae. Identification was confirmed when we reared larvae collected from *C. mollis* fruits. *Lipographis fenestrella* played only a minor role as a granivore during the years of this study, and was far less abundant than *Saphenista*. Ruygt reported that the larvae perforated the calyx and flower to reach the ovary. We saw many flowers, at Rush Ranch and Hill Slough-Potrero, with large boreholes through the bracts that larvae had chewed to get to the developing seeds. *Saphenista* larvae also bore their way out of C. mollis fruits and move between developing fruits on inflorescence spikes. We also saw other unidentified Lepidoptera larvae that were brown and much bigger than the larvae of either *Lipographis* or *Saphenista*.

We also observed small, gnat-like insects in and around *C. mollis* spp. *mollis* plants. These could be False Cinch Bugs (*Nysius raphanus*), which are suspected of feeding on this species (Ruygt 1994). The damage they cause is thought to be minimal.

We included the parasitoids that prey on the seed predators in our predator counts. These included members of the Eumenidae and Vespidae wasp families. These wasps probe *C. mollis* spp. *mollis* flowers looking for Lepidoptera larvae, which they then carry off to provision their nests. As expected, these wasps were rarely seen at Rush Ranch, where few caterpillars were found, and were quite common at Hill Slough.

We observed other predators around the *Cordylanthus* populations at both sites before, during and after our timed study in 2001 and during the 2000 – 2002 field studies. Other invertebrate predators included wandering spiders, jumping spiders, damselflies, robber flies and praying mantids. However, we did not record any of these in our plots during the timed observations in 2001. In addition, two other herbivorous insects, Geometrid moth adults (*Perizoma custodiata*), and Buckeye butterfly larvae (*Junonia coenia*) were identified in *Cordylanthus* populations at Hill Slough in 2000 and observed at both Rush Ranch and Hill Slough in 2001 and 2002.

Conclusions.

A preliminary census at the Rush Ranch tidal marsh in 1999 confirmed the presence of a rich insect fauna including potential pollinators known to visit soft bird's beak flowers (Grewell, unpublished data). The reintroduced population of soft bird's beak at Rush Ranch also supports a diverse insect fauna, and reintroduced soft bird's beak flowers were immediately visited by potential pollinators. Floral visitor numbers in the reintroduction community did not differ significantly from those of a reference population at the Hill Slough Wildlife Management Area. Although the numbers of individual potential pollinator species differed somewhat between the two sites, the same community of insects visited both sites.

Anthidium edwardsii, *Bombus vosnesenski,* and Halictid bees, including species from *Halictus* and *Lassioglossum* appear to be important potential pollinators. Our observational study bracketed the June – July peak bloom of soft bird's beak, but flowering individuals were observed from May through November. Different pollinating insects may be present and at different times throughout the flowering life stage of soft bird's beak, and there may be interannual differences due to variation in weather and hydrology. We documented a dramatic shift in composition of the flower visitor community at the Hill Slough Wildlife Area from that reported by Ruygt (1994). This apparent change in bee fauna is poorly understood, and points to the need for more in depth study and frequent monitoring critical biological interactions.

Frankenia salina (alkali heath) and *Cuscuta salina* (salt marsh dodder) are native plant associates of *Cordylanthus mollis* that attract many potential pollinators. The presence of these potential pollinators and plants may prove useful in screening the evolution of tidal marsh restoration communities prior soft bird's beak reintroduction attempts. An immediate conservation concern is the prevalence and spread of invasive plants within soft bird's beak occupied habitat, and in adjacent uplands. Flower visitors of soft bird's beak were observed visiting flowers of exotic *Lepidium latifolium* (perennial pepperweed) , *Apium graveolens* (wild celery), *Lotus corniculatus* (bird's foot trefoil) , and *Centaurea solstitialis* (yellow star-thistle).

The life cycles of soft bird's beak and rare micro-lepidopteran moths are closely coupled, and these predispersal granivores are significant members of this parasitic community. *Saphenista (*Tortricidae*) and Lipgraphis fenestrella (*Pyralidae*)* moths do not have protective status, but should be considered threatened and endangered fauna.

Increasing urbanization at historic and restoration wetland ecotones is a conservation concern relative to maintenance of critical native plant – pollinator interactions. Indirect effects of off-site urban development include competition sinks for critical pollinators attracted to landscape plantings, direct trampling and disturbance of ground-nesting bees by creation of trails by hikers and domestic animals. Direct losses of pollinators can occur when development displaces critical nesting sites, as many of these pollinators nest in adjacent uplands and forage in wetlands. Urban development has been linked to loss of historic pollinators, and reproductive effectiveness of *Cordylanthus maritimus* ssp*. maritimus* in San Diego County (Parson and Zedler 1997).

This observational study should be considered preliminary to a full understanding of *Cordylanthus mollis* pollination biology. Future research which could improve our understanding of this critical biological interaction includes confirmation of pollination success and effectiveness by species through the entire flowering period. Appendix III is provided as a field guide to important insect fauna associated with soft bird's beak which may aide restoration managers in future site screening evaluations.

II. Experimental Reintroduction

Introduction. Soft bird's beak is an endangered, limited range species endemic to the North Bay and Suisun reaches of the San Francisco Estuary. Creation of new populations of species that face endangerment may be critical to their recovery, but the best available scientific information is often insufficient. Our objective was to attempt an experimental reintroduction of soft bird's beak with the explicit goal of generating biologically relevant data for recovery and restoration planning. Genetic and demographic approaches to rare plant conservation and restoration are both important, and should be considered in conservation planning. In this study, steps were taken to address genetic concerns during propagule collection, but our overall project approach was ecological.

The working hypothesis for this experiment is that demographic performance will not vary between natural and reintroduced populations of soft bird's beak. We designed an experiment to answer the following research questions:

1. Does timing of seeding improve restoration success?
2. Can reintroduction through direct seeding coupled with competition suppression enhance the demographic performance of soft bird's beak?
3. What is the demographic status of reintroduced vs. natural populations of soft bird's beak?
4. What biological and physical conditions of soft bird's beak influence demographic success?

We first describe the experimental framework and general results of the reintroduction. Within this framework, we also conducted demographic research that is reported in the section that follows.

Methods.

***Site Selection*.** A reintroduction experiment was established at Solano Land Trust's Spring Branch Wetland Restoration Site at the Rush Ranch open space preserve in Suisun Marsh. Spring Branch is the upper reach of the First Mallard Branch tributary to Cutoff Slough, Suisun Slough, Montezuma Slough, and Suisun Bay. Rush Ranch includes nearly 1000 acres of relict tidal wetlands between Suisun Slough, Cutoff Slough, and the Potrero Hills. Review of historic aerial photographs and maps suggest the Spring Branch watershed was isolated from tidal action sometime between 1903 and 1930, when the channel was filled for a farm road. The Spring Branch tidal wetland is now an evolving restoration site. In 1991, Phase I of the restoration project was implemented when Solano Land Trust installed 48" culverts under the road, and tidal water flowed into the area for the first time in decades. Restoration progress can be viewed in Figure 15. Solano Land Trust hopes to secure funding for continued watershed restoration to extend the tidal prism further upstream, and enhance seasonal runoff into the tidal wetlands through removal of upstream berms and stock ponds.

By 1999, when we considered this experimental reintroduction, a tidal wetland plant community was well established, and the high intertidal area appeared to have to community composition and structure typical of natural soft bird's beak populations. The area was monitored each year since tidal flow was reintroduced, but soft bird's beak had not established through dispersal from regional populations (Grewell, unpublished data). Preliminary soil and vegetation sampling in 1999-2000 suggested plant community succession had progressed to the point where a small-scale experimental reintroduction may be appropriate. The experiment could serve as a model that could prove invaluable to larger regional restoration planning efforts.

CALFED funding and permits were secured to do this work when Solano Land Trust agreed that long term protection of a newly reintroduced endangered plant population in the Spring Branch restoration site was in keeping with their stewardship and wetland restoration mission.

Figure 15. Spring Branch wetland restoration progress at Solano Land Trust's Rush Ranch.

1985	**1991**	**1994**
Pre-Project Upper Spring Branch Isolated from Tidal Flow by Rush Ranch Farm Road	Phase I (2) 48" Culverts Tidal Flow Partially Restored	Tidal Wetland Community Evolves through Natural Succession

Approach. Direct seeding from wild collection, horticultural seed production, or transplantation are potential reintroduction approaches. When considering options for rare plant reintroduction an important consideration is the life history characteristics of the species. Transplantation of seedlings is often prescribed in mitigation and restoration protocols, although this approach has proven unsuccessful for many rare plants (Fiedler 1991, Howald 1996). In the case of a hemiparasitic plant reliant on a fragile host connection, transplantation of seedlings to establish new populations is not advised. We did not test transplantation in our experimental reintroduction for three reasons. Careful research on establishment of *Cordylanthus maritimus* ssp. *maritimus*

for CALTRANS mitigation projects in San Diego tidal wetlands suggests direct seeding is preferable to transplantation (Fink and Zedler 1989a,b), and small test trials with the more common *Cordylanthus maritimus* ssp. *palustris* at Bodega Marine Reserve confirms that mortality of transplanted hemiparasites is extremely high, even when blocks of sediment are moved with hosts and hemiparasites (Grewell, unpublished data). The second reason for not including transplants in our experimental trials is that the regulatory agencies issuing our research permit agreed this was not a sensible approach for soft bird's beak.

A final important reason for not including horticultural transplants or seeds concerns maintenance of the genetic integrity of the population. The biological goal of rare plant reintroductions should be to establish self-sustaining, resilient populations with sufficient diversity to undergo adaptation and evolutionary change (Guerrant 2002a). While details of the genetic status of soft bird's beak populations are unknown, we endorse ecological rather than horticultural approaches to rare plant restoration as a conservative approach to maintaining genetic integrity of the populations. Horticultural propagation of plants for seed production is not advised, as field collection of wild seeds can provide a greater mix of alleles from a donor population than cultivated transplants or seeds produced from horticultural cultivations (Pavlik 2002). Cultivation is especially problematic for rare annual species where there may be poorly understood selection factors associated with germination. The best strategy for restoring an annual plant is to bank a wild seed collection in years or from populations where the species is abundant to attempt to assemble a new population with naturally mixed genotypes (Guerrant 2002b, Pavlik 2002).

Propagule Collection. Reciprocal transplant experiments have consistently demonstrated that individual survivorship and fecundity are greatest when plants are replanted into the same microhabitat from which they were collected (Chapin and Chapin 1981, McGraw and Antonovics 1983, Schmidt and Levin 1985, Silander 1985), suggesting that local selection is important and seed should be collected from the closest populations in comparable environments for best success in reintroduction

attempts. A strategy for obtaining a representative sample size to capture genetic diversity present within a plant population is a logarithmic function of the sample size regardless of the plant's mating system (Brown and Briggs 1991). For this reason, a stratified random sampling design that includes microhabitats across a population and 50 to 100 maternal parents within a given population provides a 95% chance of capturing all alleles present in a frequency greater than 5% (Marshall and Brown 1975, Holsinger and Gottlieb 1991).

In October 1999, prior to initiation of our CALFED contract, propagules were collected from the two closest natural populations to the restoration site at the Hill Slough and Joice Island Wildlife Areas. The collection sites were between 1 and 2 miles from the restoration site, and were approved by the Department of Fish and Game rare plant program botanists. Propagule collections followed research permit guidelines, and total seed collection was < 1% of available seed in the natural populations. Like many annual plants reliant on seed reproduction, fecundity of adult soft bird's beak can be quite high. We have measured seed production of up to 32,000 propagules per single adult. Mature soft bird's beak plants are multi-branched, and each branch supports numerous ripe seed-filled capsules. Our collection strategy did not require the sacrifice of any individual plants. We stratified the large Hill Slough population site into six subregions, and the Joice Island population into two subregions. We then moved

through the population and pruned branches with mature seed capsules from fifteen mature plants within each subregion for a total sample of 120 maternal donors. The branches were transported to the laboratory at UC Davis where seeds were separated from capsules, air-dried, and then held in cold, dry storage in our laboratory at UC Davis.

Experimental Design. A reintroduction experiment was established at Rush Ranch in early spring 2000 prior to emergence of *Cordylanthus mollis* at natural population sites. Our goal was to test timing of seeding, and canopy manipulation for soft bird's beak establishment. Technical advisors asked that we test both spring and fall seeding. While soft bird's beak naturally disperses seed in the fall, there was some concern that artificial fall seeding may result in losses of propagules from the reintroduction plots during extreme winter tides.

Cordylanthus species are gap colonizers, and *C. maritimus* ssp. *maritimus* does not grow well when the host canopy casts too much shade (Fink and Zedler 1989). We clipped vegetation to simulate gaps created by competitive or parasitic suppression or a variety of physical disturbance processes. Prior to establishing clip plots, we checked subcanopy PAR measurements in natural populations, and tested clip strategies to mimic the conditions that best represented pre-seedling emergence light gaps within natural populations. We manually pruned away a mosaic of vegetation patches to achieve and maintain a mosaic of approximately 50% micro-gaps within each square meter clip treatment plot.

A split plot design was arranged in randomized blocks, with treatments randomized within blocks. Blocks were replicated 10 times. Reintroduction treatments included: 1) planting time in 5 levels (March, April, May, November, December), 2) canopy management (clip, no clip), 3) experimental controls (no clip, no seed), and 4) manipulation controls (clip, no seed). One meter buffers were established around the

perimeter of each block. An example of an experimental block setup is shown in Figure 16.

Figure 16. Representative block diagram with experimental reintroduction treatments.

BLOCK A

BUFFER

CLIP (MANIPULATION CONTROL)	MAY SEED CLIP	MARCH SEED CLIP	NOVEMBER SEED CLIP	MARCH SEED	DECEMBER SEED CLIP
DECEMBER SEED	APRIL SEED	NOVEMBER SEED	APRIL SEED CLIP	MAY SEED	CONTROL

We consulted with experienced botanists, and agreed to follow fixed seeding density and pre-seed treatment guidelines developed in the establishment of a closely related salt marsh bird's beak in south coastal wetlands (Fink and Zedler 1989 a,b). Seed lots of 300 per experimental treatment were counted and placed on filter paper lined petri dishes. Seed was brought to room temperature, subjected to a freshwater flush treatment, and transported to the field for planting. Vegetation was clipped in the canopy manipulation treatments prior to seeding, and the clip mosaics were maintained

through the 2000 growing season until the potential host community reached above ground dormancy stage. Clip plots were visually inspected every 2 weeks, and pruned as needed to maintain the 50% microgap treatment.

March, April, and May seed treatments with clipped and unclipped vegetation were established during the designated treatment month March – May 2000. Plots designated for fall/winter seeding treatments were planted in November and December 2000. We visually inspected treatments for seedling emergence weekly following treatment establishment through the 2000 growing season.

The large soft bird's beak population at the Hill Slough Wildlife Area tidal wetland was selected as the reference population for comparative demographic studies associated with this work. We used a stratified random selection process to designate ten one meter square monitoring blocks for comparative demographic studies associated with this reintroduction. The reference population was also checked on a regular basis for seedling emergence, and supported a population of soft bird's beak through the 2000 growing season.

Plant response variables measured in 2001 experimental plantings included density of surviving reproductive adults, species presence, percent cover of plant associates, and maximum canopy height. Above ground biomass samples were evaluated from each block to compare environmental conditions and potential host community productivity between microhabitats within the site. In 2002, density of emergent seedling and density of surviving reproductive adults were recorded from the treatments established in 2000.

2001 Results. No experimental soft bird's beak seedlings emerged in the spring or summer of 2000 following spring 2000 treatment establishment. Fall treatment establishment was completed in December 2000, and we continued to visually inspect plots biweekly for seedling emergence through the winter, as soft bird's beak seedlings emerged as early as December during the drought of the early 1990s (Ruygt 1994).

Emergent soft bird's beak seedlings were first observed in the Hill Slough reference population and in the Rush Ranch experimental plots on April 5, 2001. At the Rush Ranch experimental site, seedlings were observed in both spring and fall 2000 seeded plots, after all seed bank treatments had over-wintered in the field.

Density response of surviving reproductive adults to experimental treatments was evaluated in July 2001 (Figure 17). Time of seeding data were pooled by season (fall vs. spring) for an ANOVA hypothesis test of the effect of timing of seeding (spring, fall), canopy manipulation (clip, no clip), or block (environmental heterogeneity) on surviving density of reproductive adult plants. Results of the ANOVA are reported in Table 11.

Figure 17. Soft bird's beak survivorship within experimental treatments in the first season following seed bank treatment establishment (2001).

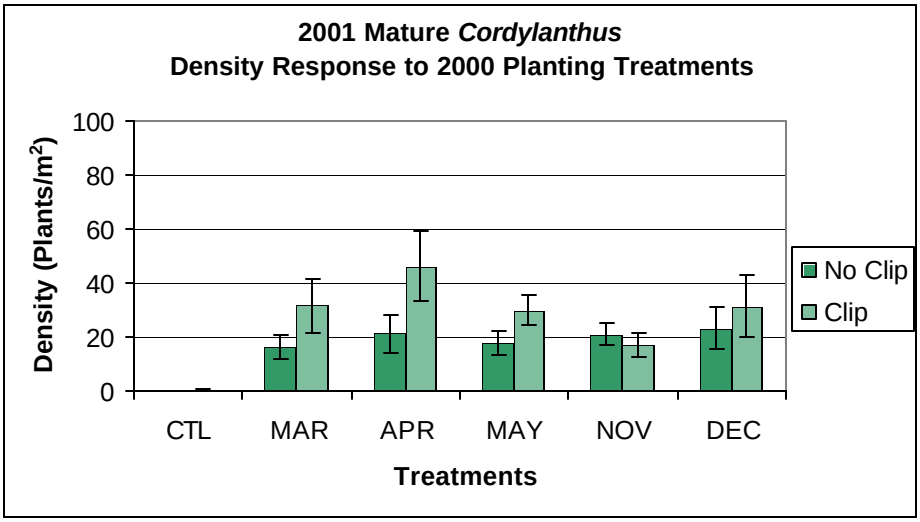
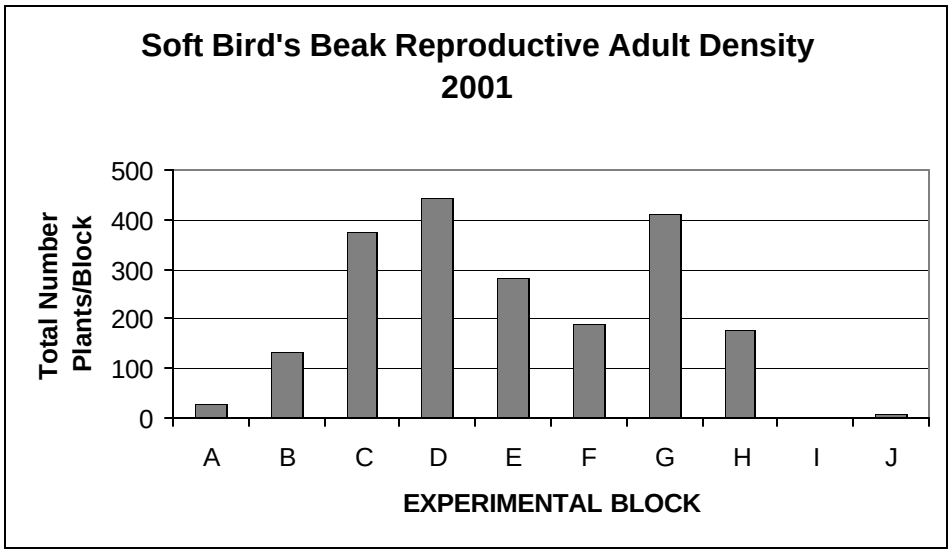


Table 11. ANOVA results examining how survivorship of soft bird's beak reproductive adults (density) varies with location (block), season of reintroduction seedbank establishment (spring or fall seeding), and canopy manipulation (clip, no clip) one year following seed bank establishment.

Factor	df	F	P
Block	9	13.976	0.000
Season	1	1.245	0.269
Canopy	1	8.361	0.005
Block * Season	9	1.479	0.177
Block * Canopy	9	3.019	0.005
Season * Canopy	1	4.794	0.032
Blk* Season * Canopy	9	1.989	0.056

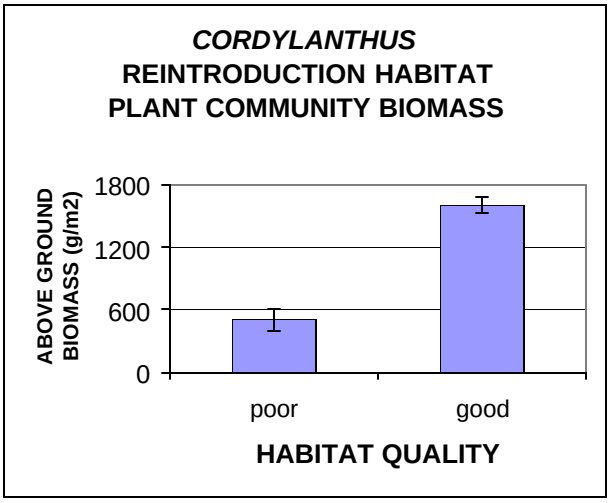
Soft bird's beak survivorship was spatially variable, as revealed by the significant block effect detected by this experimental design (p=0.000), and shown in Figure 18.

Figure 18. Distribution of surviving soft bird's beak adults among blocks indicate microsite differences in successful establishment.



Above ground biomass measurements from sample plots located in the buffer around the seeded treatments also revealed significant differences in potential host plant productivity between these microsites (Fig. 19).

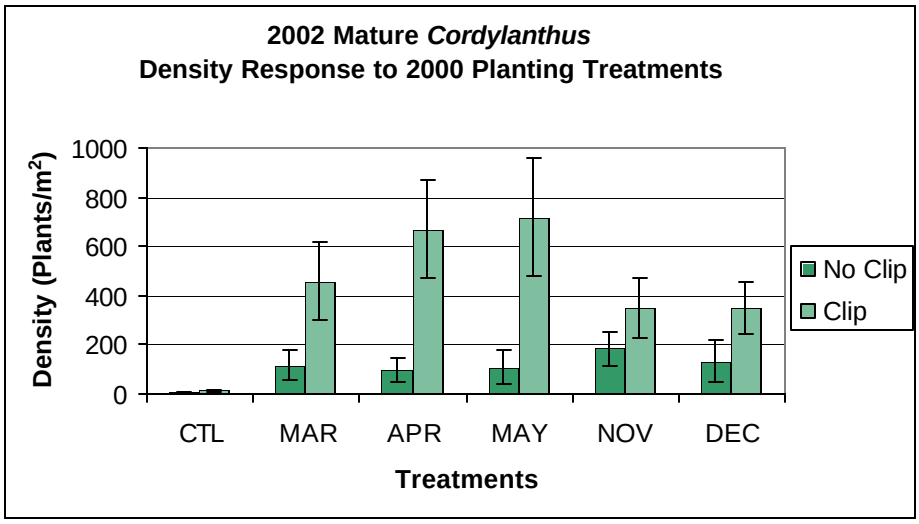
Figure 19. Potential host plant biomass within soft bird's beak habitat at the reintroduction site. Samples from experimental blocks with low survivorship (n=4) were considered poor habitat, while samples from high survivorship areas (n=6) were designated good habitat.



Soft bird's beak survivorship was not significantly different between fall and spring seeded plots in the first year following seed bank establishment (p= 0.269). However, canopy manipulation appears to be a positive restoration technique, as adult survivorship was significantly higher in clipped plots than in controls (p = 0.005). The interaction between block and canopy manipulation is linked to the best survivorship, adding further evidence that clipping is a good approach for establish in sites that are suitable for the parasites (p = 0.005).

2002 Results. At the end of the first season of soft bird's beak establishment, reproductively mature plants augmented the experimental seed banks through natural disperal processes. No seed was experimentally added to the blocks aside from the treatment establishment in the year 2000. We were unsuccessful in establishing a population in two of the ten experimental blocks in 2001, and eliminated these locations from further study. In 2002, density response of treatments was exponentially higher than densities observed during the first year (Figure 20).

Figure 19. Soft bird's beak survivorship within experimental treatments in the second season following seed bank treatment establishment.



We examined the 2002 survivorship data with the analysis of variance model, and results are shown in Table 12.

Table 12. ANOVA results examining how adult survivorship density varies with location (block), season of seedbank establishment (spring or fall seeding), and canopy manipulation (clip, no clip) two years following seed bank establishment.

Factor	df	F	P
Block	7	9.295	0.000
Season	1	3.816	0.057
Canopy	1	39.517	0.000
Block * Season	7	1.247	0.296
Block * Canopy	7	3.837	0.002
Season * Canopy	1	8.023	0.007
Blk* Season * Canopy	7	1.206	0.318

The 2002 results continue to detect a spatially variable environment regarding soft bird's beak success, even after the two poorest sites were dropped from study after 2001 (p= 0.000). Huge increases in soft bird's beak density established following natural seed dispersal processes from the founder population in 2001. It is interesting to note that two years after seed bank establishment, we detected a somewhat significant effect of timing of seeding on adult survivorship (p = 0.057) with spring seeded plots. It appears that plots seeded in April and May of 2000 had significantly higher adult survivorship in 2002 than treatments planted in other months (Fig. 19).

The clipped canopies were labor intensive, but obviously worth the effort in a restoration attempt as clipped treatments as soft bird's beak survived much better when the canopy was clipped (p = 0.000). The ANOVA results once again reinforce the fact that if you clip the host canopy and other site factors provide appropriate habitat, adult survivorship responds favorably (p=0.002). In 2002, the interaction between season and canopy clipping was also significant suggesting plots that are clipped and planted in the spring may succeed (p=0.007).

Discussion

The results of this experiment suggest that it may be possible to establish a population of soft bird's beak in a restoration site. The reintroduction technique that shows the most promise is canopy manipulation coupled with direct seeding in appropriate habitats. Canopy clipping is a surrogate for the competitive suppression of dominant host plants, parasitic suppression of these hosts once parasites are in the community, and it also provides a surrogate for physical processes which may result in canopy gaps. While canopy clipping is labor intensive, the density of reproductive soft bird's beak plants is much higher when plots are clipped. In a reintroduction attempt, it is important to manage for survivorship and accelerate the growth of the founder population. This strategy will minimize decreases in average individual viability associated with small population sizes (Templeton 1991), and help build a sustainable population over time.

The significant block effect seen in this experiment emphasizes the importance of microsite conditions. Our measurements of above ground biomass across the study site indicate better establishment in areas with higher above ground biomass of potential host plants. Potential host plant biomass may be one a good indicator for soft bird's beak reintroduction sites, because potential host plant communities with extremely low biomass production may not successfully support the additional parasite load.

While our results indicate short term success in a soft bird's beak restoration attempt, we must be conservative in the interpretation of these data. It will be important to track the fate of this population for some years to come before we can report this reintroduction as a success.

Figure 20. Soft bird's beak reintroduction plots at the Spring Branch Wetland Restoration Site, Rush Ranch in the Suisun Marsh, Solano County, California.

III. Demographic Analysis – Critical Life Stages

Introduction. It is essential to evaluate the demographic status of rare and endangered species to understand potential causes of population decline. We must have an understanding of the life history stages that have the greatest impact on population growth so we can design and implement biologically relevant and effective recovery efforts (Schemske et al. 1994).

We used the experimental framework established for the experimental reintroduction of soft bird's beak to track the demographic fate of marked individuals in reintroduced and natural populations. Our objective was to identify critical life history stages of soft bird's

beak, and identify causes of demographic variation at those stages. We also investigated how reintroduction techniques may alter demographic success, and identify some of the physical and biological processes that are affecting critical stages.

We used the experimental framework described in section II. Experimental Reintroduction for our investigation of soft bird's beak demography, in addition to some special companion studies on critical life stages of the rare plant.

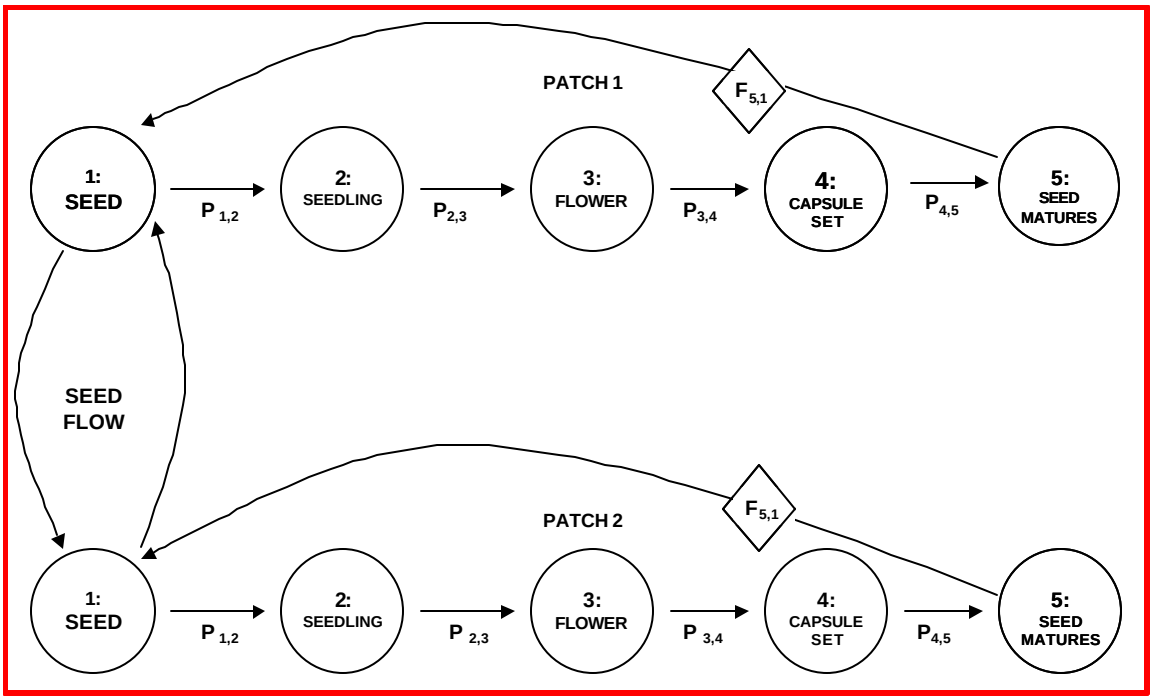
***Life Cycle Model*.** A demographic study begins with field study of the natural history and population dynamics of a species, and through careful observation we can formulate a conceptual model of potentially significant life stage transitions of a species. We started by creating simple graphical model of the life cycle of soft bird's beak based on our extensive experience with this rare plant. We chose a set of stages which best describe the life of soft bird's beak, and determined an appropriate projection interval for the model. From the life cycle graph, we designed demographic studies to quantify survivorship, transitions between life stages, and fecundity of reproductively mature adults.

We developed a simple life cycle graph for a metapopulation of two patches (populations) of soft bird's beak linked by seed flow (Figure 21). We have assigned five life stage classes to the populations that are designated by circles and include: seed, seedling, flowering, set capsule set, and seed maturation. The values $P_{x,x+1}$ indicate rates at which plants move up a stage class, and the values $F_{x,1}$ within diamonds represent the fecundity of the population which links the individual to the population level. Demographic research was designed to quantify the parameters of this model so we may identify stages that impact population growth.

The methods, results and discussion of our demographic analyses are reported is the following subsections: A. 2001 marked plant demography, B. 2001 special study on near-neighbor relationships in soft bird's beak seedling communities, C. expanded 2002 marked plant demography and dispersal observations and this demographic analysis

section concludes with a summary of demographic research are reported as subsections of this report.

Figure 21. Life cycle graph of soft bird's beak.



III. A. 2001 Marked Plant Demography.

Introduction. During spring 2001 emergence of soft bird's beak seedlings at the reintroduction site and Hill Slough reference plots described in Section II, we initiated comparative demographic monitoring. Soft bird's beak seedlings emerge at different times through the spring, though large numbers of seedlings are apparent at intial emergence. Since differential emergence times could effect the demographic outcome for plants and the population, we decided to evaluate both and late emerging seedlings in 2001.

Methods. In early April at initial 2001 emergence, we tagged 30 individual emergent seedlings at each of the two sites. Five weeks later in late May, we tagged an additional 30 emerging seedlings at both sites for a total of 120 tagged plants. Seedlings were tagged with engraved aluminum plant tags modified with wire loops and corrosion-proof anchors so that tags could be anchored some distance from the marked plant to prevent potential severing of hemiparasite seedling roots or host-parasite root connections. Anchors were placed a minimum of 5 cm from the seedling to avoid this potential seedling root disturbance. This method also prevented tags from interfering with seedling growth, and from washing away during high tides while the seedlings are quite small (< 1 cm tall), but ensured that experimental plants could be identified.

Figure 22. Tagged soft bird's beak seedlings for demographic study.

Plant growth (height) and life stage were recorded for each marked plant every two weeks through their life cycle. Stage and date of mortality was recorded as marked plants died. Demographic analyses of these data included basic life table analyses to quantify standardized survivorship within each population. We evaluated life stage transitions and fecundity of late and early emerging plants in the reintroduced and reference population.

Results: 2001 Marked Plant Demography. Results of biweekly plant growth measurements show that early emerging soft bird's beak plants grew more than late emerging plants at both reference and reintroduction sites, and plants achieved greater heights at the reintroduction site than were observed at the Hill Slough reference site (Fig. 23)..

Figure 23. Biweekly growth of early and late emerging marked plants at the Rush Ranch restoration and Hill Slough reference populations in 2001 (n = 120, Mean ± 1 SE).

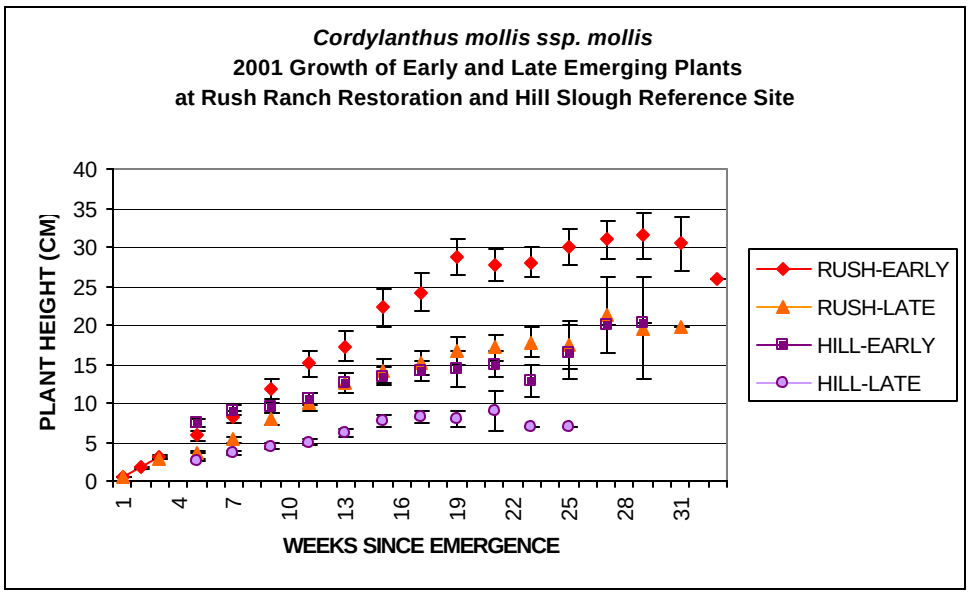
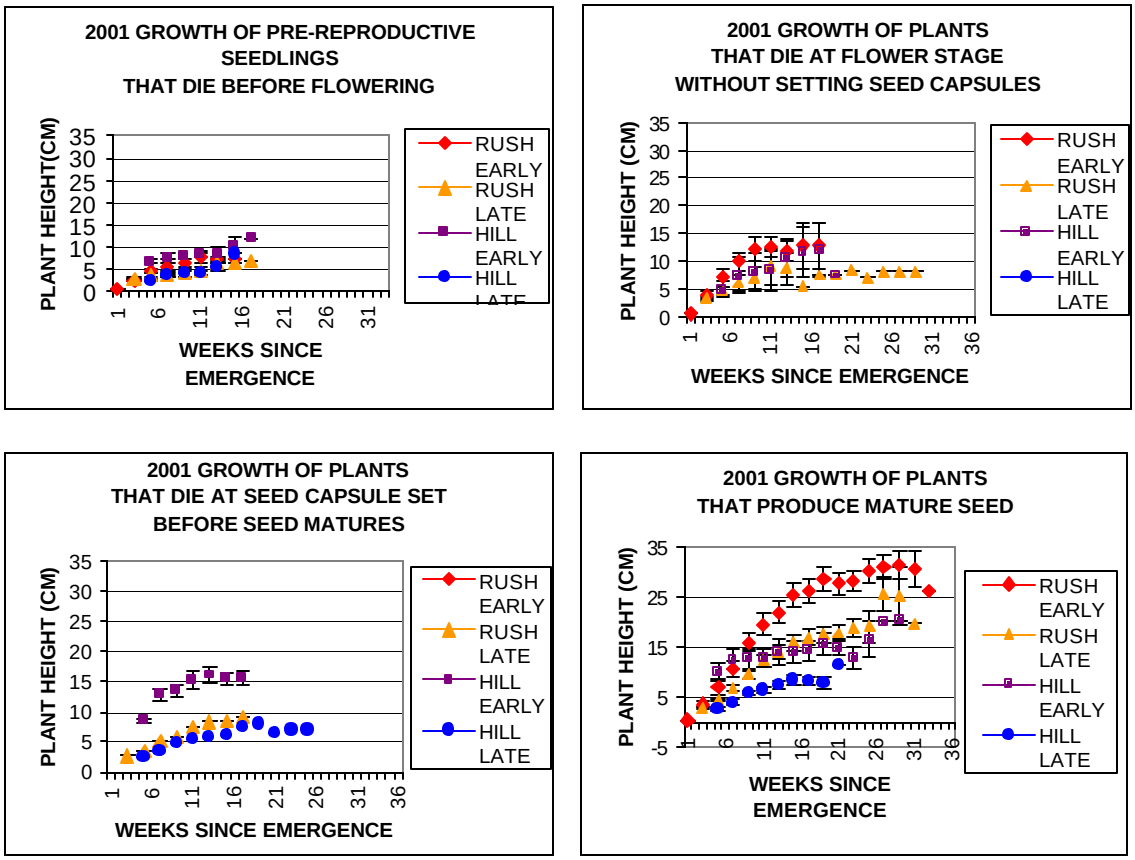


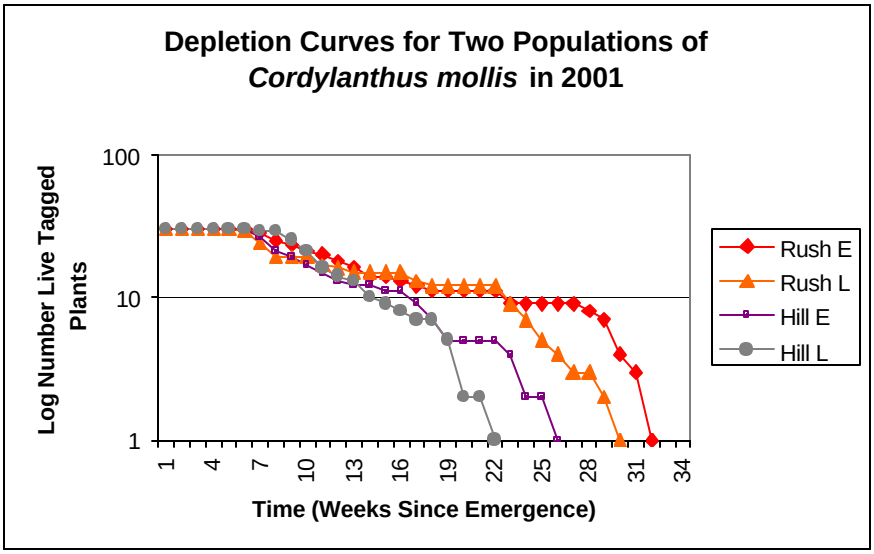
Figure 24 compares the growth of plants that died at various life cycle stages in 2001. Growth of plants that die as seedlings was poor in both populations. Plants that came to the end of their life cycle as pre-reproductive seedlings grew poorly regardless of emergence time, and the mean height of plants that succumb to seedling mortality is less than 10 centimeters. There are a number of plants with poor growth as seedling that manage to transition to flowering stage, but the mean height of plants that die at flower stage is still only 5 to 15 centimeters. Very few plants died at seed capsule set stage in 2001, and most plants that died at this late reproductive stage before producing mature seed did not grow well as seedlings. As expected, the plants that achieve reproductive maturity and produce ripe seed also display the most vigorous growth.

Figure 24. Comparative growth of marked plants that died at various life cycle stages at the reintroduction and reference sites in 2001 (means ± 1 SE).



For a first look at survivorship, the log of the proportion of plants surviving is plotted against a biweekly time axis in Figure 25. The first thing to notice in this graph is the 33 week emergence period, which is a very long life cycle for an annual plant. These depletion patterns suggest seedling mortality may be a limiting factor in these populations. We proceeded with life table analyses of the early and late emerging cohorts for the reference and reintroduction sites. Numbers marked plants that survived to transition between life stages were summarized in life tables (Tables 13 and 14), and Figure 26 illustrates standardized survivorship between populations.

Figure 25. Depletion curves for two populations of soft bird's beak in 2001.



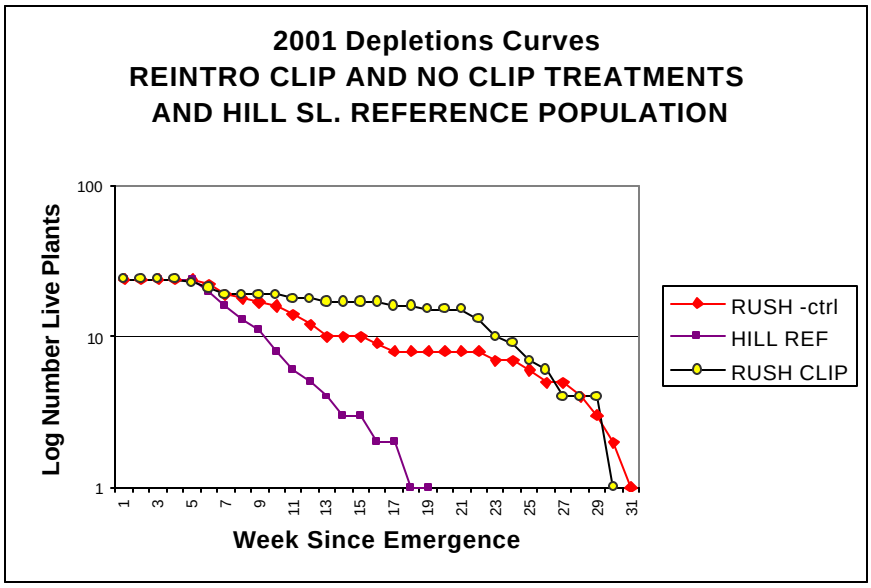


Table 13. Partial life tables for marked plants at the Rush Ranch reintroduction site in 2001.

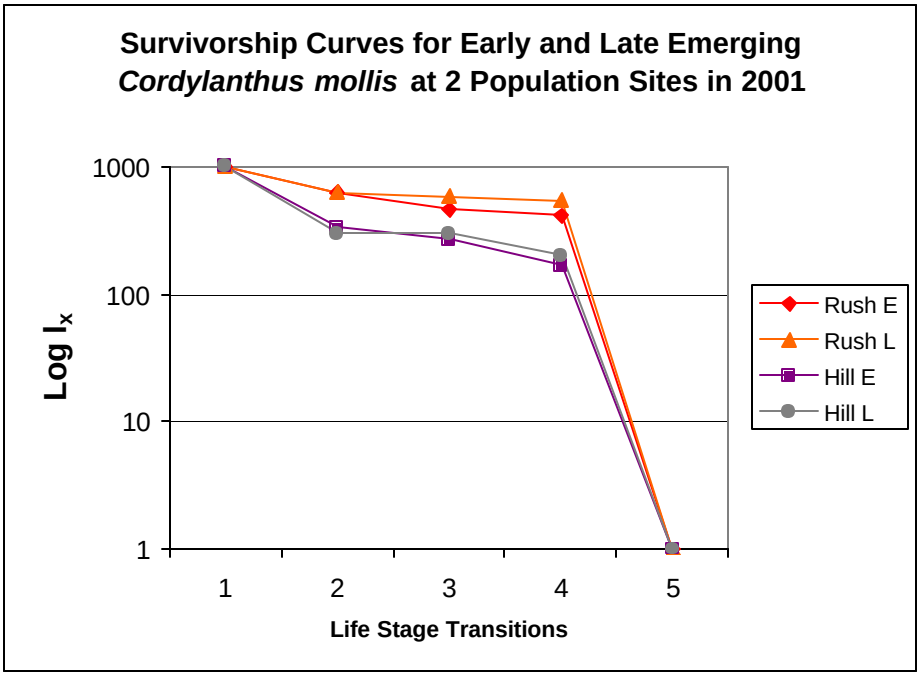
RUSH RANCH REINTRO SITE EARLY EMERGING PLANTS 2001	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
Life Cycle Stage	**D_x**	**A_x**	**N_x**	**l_x**
SEEDLING	73	0-73	30	1000
FLOWER	30	74-104	16	533
SEED CAP SET	31	105-136	11	367
SEED MATURES	127	137-264	10	333
RUSH RANCH REINTRO SITE LATE EMERGING PLANTS 2001	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
Life Cycle Stage	**D_x**	**A_x**	**N_x**	**l_x**
ESTABLISHED SEEDLING	73	0-73	30	1000
FLOWER	30	74-104	15	500
SEED CAPSULE SET	31	105-136	13	433
SEED MATURATION	127	137-264	12	400

Table 14. Partial life table for marked plants at the Hill Sl. Reference site in 2001.

HILL SLOUGH REFERENCE EARLY EMERGING PLANTS 2001	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	**D_x**	**A_x**	**N_x**	**l_x**
ESTABLISHED SEEDLING	73	0-73	30	1000
FLOWER	30	74-104	10	333
SEED CAPSULE SET	31	105-136	8	267
CAPSULE MATURATION	127	137-264	5	167

HILL SLOUGH REFERENCE LATE EMERGING PLANTS 2001	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	**D_x**	**A_x**	**N_x**	**l_x**
ESTABLISHED SEEDLING	73	0-73	30	1000
FLOWER	30	74-104	9	300
SEED CAPSULE SET	31	105-136	9	300
CAPSULE MATURATION	127	137-264	6	200

Figure 26. Standardized survivorship curves for emergent life stage transitions of soft bird's beak at the reintroduction site and Hill Slough reference population site in 2001.



Discussion.

The first year of demographic monitoring of tagged plants at the reintroduction and reference sites suggests the soft bird's beak populations are subject to high seedling mortality. The depletion plots in Figure 25 show the survival of the proportion of plants on a given biweekly census through time, but these plots reveal details of stage specific mortality risks within the population. The life table analysis and resulting survivorship curve (Fig. 26) allowed us to examine potentially critical life stages. Marked plants in 2001 exhibited a Type III survivorship curve, reflecting high rates of seedling mortality in the late seedling stage (Fig. 26). Mortality risk for the rare plants was highest for pre-reproductive seedlings and declined with age. The demographic fate of early emerging and late emerging plants was similar within sites, but differences between sites are of

conservation concern. These 2001 survivorship curves provide a visual assessment of the population level risks that soft bird's beak faces at the Hill Slough Wildlife Area where seedling mortality was much higher than is typically expected for an annual plant. This is of particular conservation concern, because the Hill Slough population is the largest remaining population of soft bird's beak in the San Francisco Estuary. It was also a concern for this study, because the Hill Slough population was our primary reference site.

There are several possible explanations for the observations at Hill Slough. Hydrologic monitoring at the site indicated tides are significantly muted at Hill Slough (Appendix III), and a restoration project implemented in 2000 to open up tidal flows in the upper reaches of Hill Slough has resulted in elimination of tidal pulses in a portion of the endangered soft bird's beak habitat. A second problem at Hill Slough has been repeated, unauthorized grazing of cattle in the DFG tidal marsh by ranchers who lease adjacent pastures. Exotic annual grasses within the community may be linked to hemiparasite seedling mortality, and these winter annuals are most prevalent in tidal wetlands that have a history of grazing. Observed levels of seedling mortality were also a concern at the Rush Ranch reintroduction site, but the demographic outcome was better at the reintroduction site than at the reference site (Tables 13 and 14). These results made it difficult to interpret the status of the reintroduced population. The outcome of the first year of demographic monitoring emphasized the need to expand demographic studies to include more reference sites in 2002.

III-B. Near-Neighbor Relationships in Soft Bird's Beak Seedling Communities.

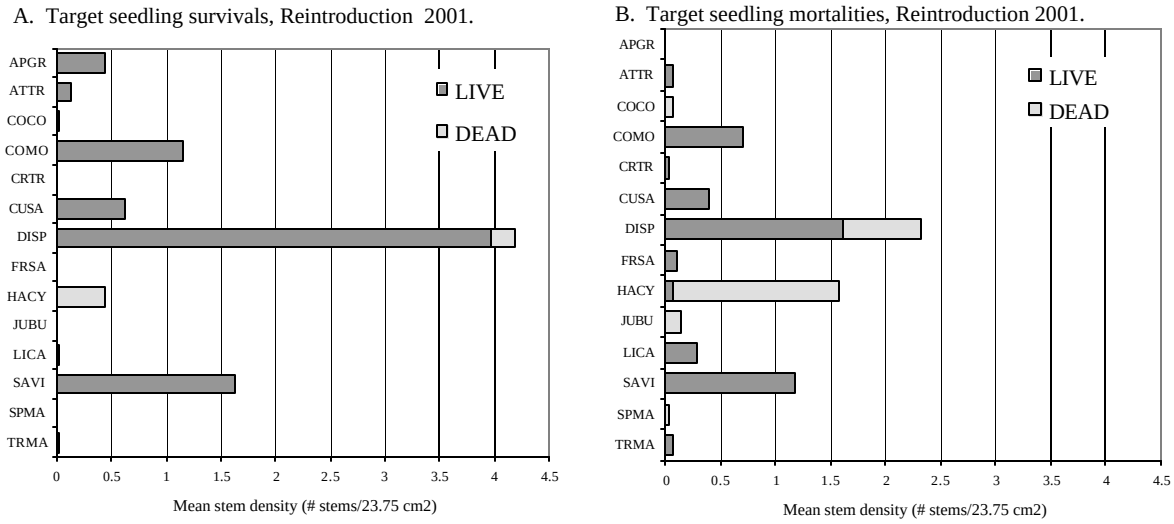
Introduction. During the 2001 pre-reproductive seedling stage, we observed significant seedling mortality within some experimental units. We also observed that plots with many exotic winter annual plant species, such as sickle grass (*Hainardia cylindrica*) and rabbitsfoot grass (*Polypogon monspeliensis*), appeared to be strongly associated with seedling mortality. We conducted a special seedling community study to explore near-neighbor relationships between live seedlings, dead seedlings, and potential host plants.

Methods. To determine sample size, we investigated hemiparasite root lengths from senescent and live seedlings outside of our plots, as well as root lengths of closely associated species. During seedling emergence, a host plant root must be in very close proximity to a *Cordylanthus* seedling for host establishment because *C. mollis* seedling roots are less than 5 centimeters long, and seedling root lengths are typically less than 2 centimeters. The above ground portion of *C. mollis* is between 0.3 and 10 centimeters tall during the seedling stage, and many of the community associates are also quite diminutive. While it is possible some rhizomes from hosts with above ground growth more distant from C. mollis, it appears that in early spring the roots of most potential hosts are within a few centimeters of the hemiparasite seedling. We identified and recorded stem density counts of all plant species located within a 5.5 centimeter diameter circular plot around each marked *C. mollis* ssp. *mollis* seedling. Every two weeks we measured *C. mollis* seedling growth, and mortality or transition to reproductive stage. Plants that senesced before reaching reproductive stage were recorded as mortalities, while plants that transitioned to flowering stage were considered successful seedlings and survivors. We calculated Pearson's correlation coefficients to examine the relationship between *C. mollis* seedlings and near-neighbor plants considered to be potential hosts, and used a variety of descriptive statistics to explore stem densities of native and exotic species associated with parasite mortality.

Results: *C. mollis* sp. *mollis* seedling neighborhood plant communities for the reference and reintroduction sites in May 2001 are shown in Figures 27 and 28. Figure 27 shows the mean stem densities of the potential host plant communities for surviving (Figure 27.A) and non-surviving (mortality) (Figure 27.B) target *C. mollis* sp. *mollis* seedlings at the reintroduction site. Figure 28 shows the same for the community at the Hill Slough reference site in May 2001.

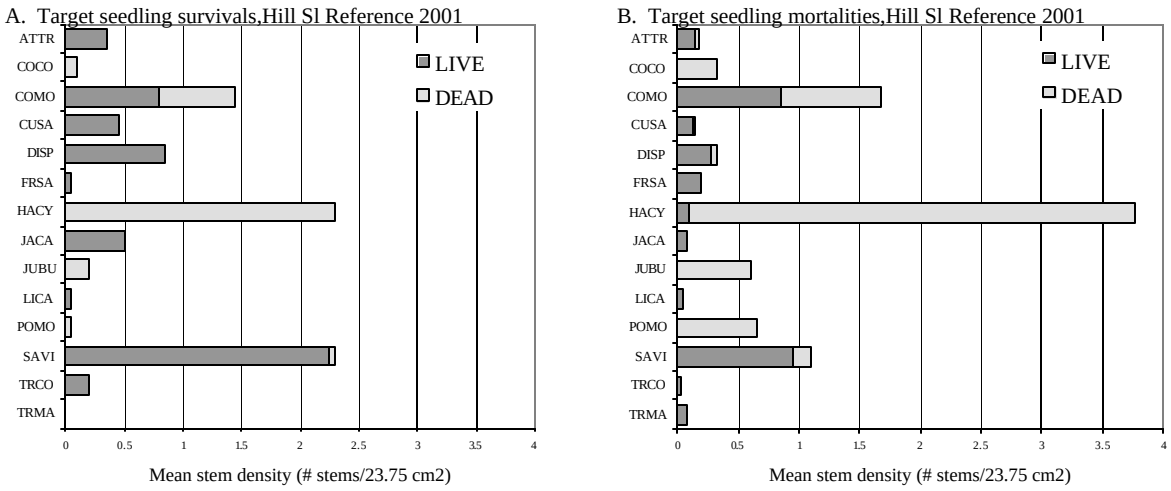
These graphs also indicate whether the potential host plant was live (solid bars) or senescent (hatched bars). The majority of the introduced annuals, including *Hainardia cylindrica*, *Polypogon monspeliensis*, and *Cotula coronopifolia*, were alive when C. mollis seedling emerged, and were alive through the early seedling stage, but most of the winter annuals were senescent by late May at the time of these measurements.

Figure. 27. Close associates of target *C. mollis* sp *mollis* seedling survivals (A.) and mortalities (B.) at Rush Ranch, the reintroduction site, May 2001. Solid bars indicate live stems; hatched bars indicate senescent stems. Data are mean stem densities, *n*= 28 (mortalities), *n*= 32 (survivals).



Species codes are
APGR = Apium graveolens, ATTR = Atriplex triangularis, COCO = Cotula coronopifolia, COMO = Cordylanthus mollis sp. mollis, CRTR = Cressa truxillensis, CUSA = Cuscuta salina, DISP = Distichlis spicata, FRSA = Frankenia salina, HACY = Hainardia cylindrica, JUBU = Juncus bufonius, LICA = Limonium californicum, SAVI = Salicornia virginica, SPMA = Spergularia marina, TRMA = Triglochin maritima.

Figure 28. Close associates of target *C. mollis* sp *mollis* seedling survivals (A.) and mortalities (B.) at the reintroduction site, May 2001. Solid bars indicate live stems; hatched bars indicate senescent stems. Data are mean stem densities, *n*= 28 (mortalities), *n*= 32 (survivals).



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APGR = Apium graveolens, ATTR = Atriplex triangularis, COCO = Cotula coronopifolia, COMO = Cordylanthus mollis sp. mollis, CRTR = Cressa truxillensis, CUSA = Cuscuta salina, DISP = Distichlis spicata, FRSA = Frankenia salina, HACY = Hainardia cylindrica, JUBU = Juncus bufonius, LICA = Limonium californicum, SAVI = Salicornia virginica, SPMA = Spergularia marina, TRMA = Triglochin maritima.

The positive and negative associations between host community species and C. mollis are shown in Table 15. *H. cylindrica* was most negatively associated with survival of C. mollis sp. mollis seedlings (r = -0.32), while native perennials *Salicornia virginica* and *Distichlis spicata* were most positively associated with seedling survival (r = 0.21 and 0.38, respectively). Also, *Cuscuta salina*, a native annual parasitic species was positively correlated with seedling survival (r = 0.22).

Chi square tests were used to see if the proportion of seedlings that died or survived to maturity were different between the reitroduction and reference site or between early and late emerging seedlings.

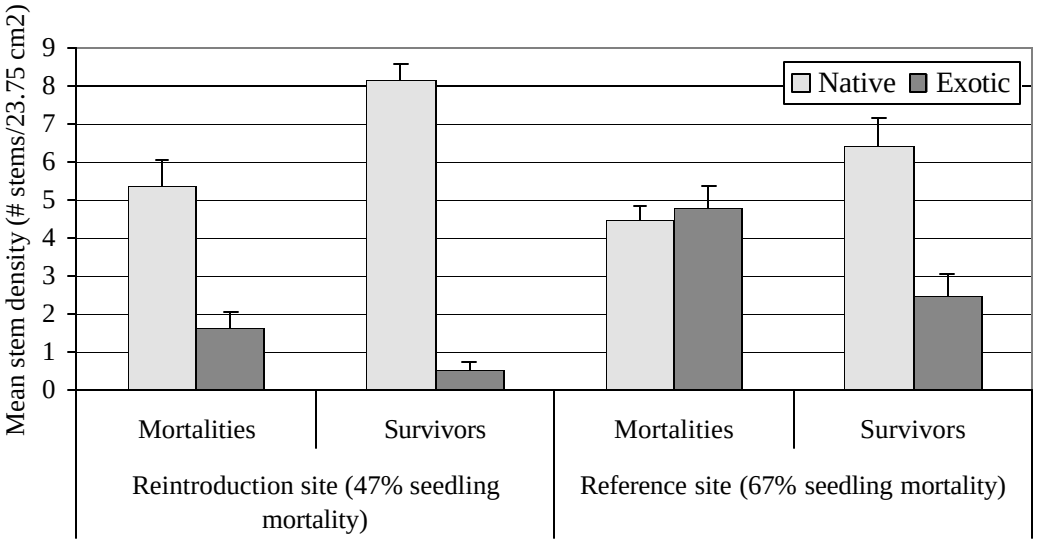
Table 15. Correlations between host plant species and *C. mollis* seedling survival.

Species	Origin	Condition	orrelation coefficien	P value
Apium graveolens	Exotic	Living	0.147	1.000
		Senescent	n.a.	n.a
Atriplex triangularis	Native	Living	0.114	1.000
		Senescent	n.a.	n.a
Cordylanthus mollis sp. *mollis*	Native	Living	0.082	1.000
		Senescent	-0.106	1.000
Cotula coronopifolia	Exotic	Living	0.105	1.000
		Senescent	n.a.	n.a
Cressa truxillensis	Native	Living	-0.080	1.000
		Senescent	n.a.	n.a
Cuscuta salina	Native	Living	0.223	0.104
		Senescent	-0.080	1.000
Distichlis spicata	Native	Living	**0.375**	**0.000**
		Senescent	-0.093	1.000
Frankenia salina	Native	Living	-0.162	1.000
		Senescent	n.a.	n.a
Hainardia cylindrica	Exotic	Living	-0.156	0.637
		Senescent	**-0.324**	**0.002**
Jaumea carnosa	Native	Living	0.182	1.000
		Senescent	n.a.	n.a
Juncus bufonius	Native	Living	n.a.	n.a
		Senescent	-0.209	0.480
Limonium californicum	Native	Living	-0.123	1.000
		Senescent	n.a.	n.a
Polypogon monspeliensis	Exotic	Living	n.a.	n.a
		Senescent	-0.176	1.000
Salicornia virginica	Native	Living	0.223	0.104
		Senescent	-0.074	1.000
Spergularia marina	Native	Living	n.a.	n.a
		Senescent	-0.080	1.000
Triglochin concinna	Native	Living	0.103	1.000
		Senescent	n.a.	n.a
Triglochin maritima	Native	Living	-0.086	1.000
		Senescent	n.a.	n.a

***Bold coefficents** are significant (Bonferroni probabilities).

Figure 29 illustrates the association between seedling survival and origin of host plant community.

Figure 29. Origin of plants with target *C. mollis* seedling survival and mortality at reference (Hill Slough Wildlife Area) and reintroduction (Rush Ranch) sites, May 2001.



There was no significant difference in native stem density around seedlings at the reference and reintroduction sites. At both sites, surviving target seedlings had significantly more native stems in the immediate vicinity than seedlings that did not survive to reproductive maturity (mortalities) ($p = 0.000$). At Hill Slough-Potrero, the reference marsh, the density of exotic host plants exceeded that of natives in the 23.5 cm^2 area surrounding seedling mortalities, but this difference was not significant. There were significantly more native stems than exotic stems around surviving seedlings at this site ($p = 0.003$). At Rush Ranch, the difference in exotic and native stem densities was significant for both seedling survivals and mortalities ($p = 0.000$ and 0.001, respectively). Seedling survival at Rush Ranch was significantly higher than that at Hill Slough-Potrero ($X^2 = 4.887$, critical value at $a = 0.05 = 3.841$). However, survival appears to be similar for early and late germinating seedlings ($X^2 = 0.136$).

Table 16 shows the correlation coefficients between host plant origin and seedling survival. Although exotic species are negatively associated with seedling survival, and natives are positively associated, not all exotic and native species follow the same pattern. Exotics include both introduced winter annuals, which end their life cycle in spring when *C. mollis* sp. *mollis* seedlings are getting established, and other species, such as *Apium graveolens*, a biennial that grows throughout the *Cordylanthus mollis* sp. *mollis* growing season. However, *A. graveolens* was present in the circular plot around only two seedlings and did not significantly affect these associations (Table 16). In addition, some native species, such as *Juncus bufonius* were also senescent at the time of this study and were negatively associated with *C. mollis* sp. *mollis* survival (Table 15).

Table 16. Correlations between host plant origin and *C. mollis* seedling survival at reference and reintroduction sites, May 2001.

Species	Correlation coefficien	P value
All Native Species	**0.361**	**0.001**
All Exotic species	**-0.307**	**0.014**
Winter annual exotics (not including *Apium graveolens*)	**-0.353**	**0.002**
Natives plus *Apium graveolens*	**0.407**	**0.000**
Exotics, not including *Apium graveolens*, plus *Juncus bufonius*	**-0.373**	**0.001**
Natives plus *Apium graveolens*, not including *Juncus bufonius*	**0.445**	**0.000**

***Bold coefficents** are significant (Bonferroni probabilities).

Discussion.

This study shows that there are correlations between nearest neighbor species and *Cordylanthus mollis* sp. *mollis* seedling survival. There was also a correlation between neighbor origins (exotic vs. native) and seedling survival. Winter annuals, both exotic and native have the most negative correlations with *C. mollis* sp. *mollis* seedling survival. The presence of exotic winter annuals far exceeds the presence of native winter annuals such as *Juncus bufonius*, and we documented haustorial connections between *C. mollis* seedlings and the exotic winter annuals *Hairnardia cylindrica* and *Polypogon monspeliensis* (Grewell, unpublished data). Exotic winter annuals are unsuitable hosts for soft bird's beak parasitism. They are only available to soft bird's

beak during the early seedling stage, and then die before the hemiparasite can complete its life cycle.

Results of this study suggest that nearest plant neighbors affect *Cordylanthus mollis* sp. *mollis* seedling survival, and the presence of winter exotics in the community is highly correlated with premature mortality of the endangered plant seedlings. These results suggest that control of invasive exotic plants in the community prior to restoration attempts enhance attempts to create sustainable populations of soft bird's beak.

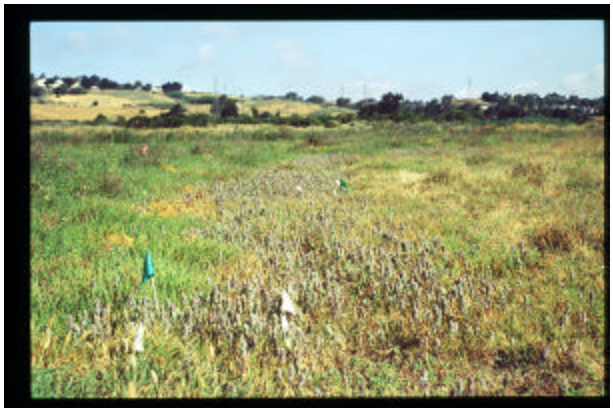
Figure 30. Sensecent exotic winter annuals associated with soft bird's beak seedlings. Senescent exotic winter annuals in the photograph include *Hainardia cylindrica*, *Polypogon monspeliensis*, and *Cotula coronipfolia* (brass buttons).

III-C. 2002 Marked Plant Demography

Introduction. We refined and expanded our marked plant demographic studies in 2002. Field observations and evaluation of 2001 data revealed significant threats to the Hill Slough reference population that influence demography at the site, and it was clear that our reference demographic studies should be expanded. We obtained a CALFED contract extension to continue through the 2002 season, and obtained permission to conduct additional reference monitoring at two population sites within the Benicia State Recreation Area.

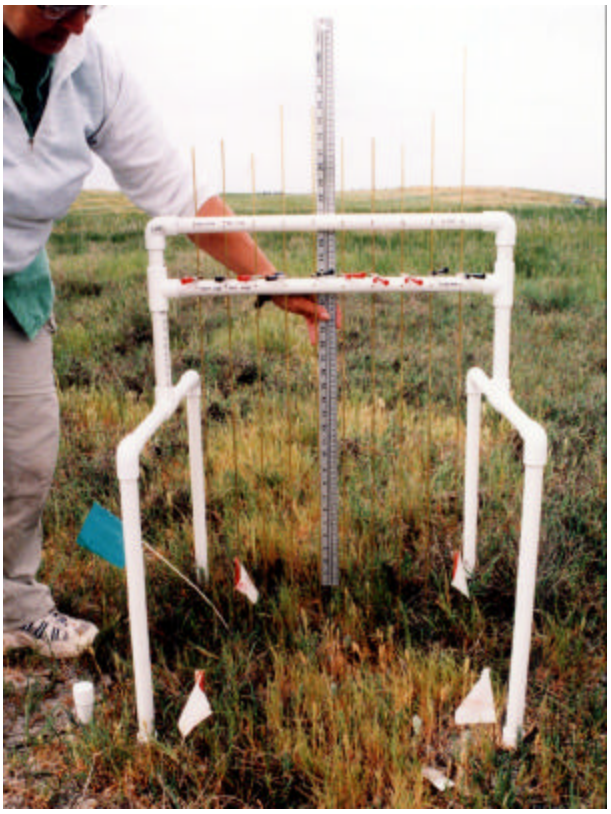
Methods. We visited Rush Ranch, Hill Slough, and Benicia population sites biweekly through the 2001 – 2002 winter dormancy period to check for soft bird's beak seedling emergence. Five one meter square sampling quadrats were randomly located within each of the four soft bird's beak reference sites during the dormant season. When seedlings appeared (early March 2002), we marked five emergent seedlings in each monitoring quadrat over a period of 4 weeks for a total of 25 seedlings in at each of three reference population sites (Hill Slough, Benicia-Southampton Bay, and Benicia State Recreation Area- mound), and also tagged 25 plants at the reintroduction site using the same tagging method as decribed for 2001 marked plant demography study.

Figure 31. Benicia Bay and BSRA (Benicia mound) reference population sites.



In an attempt to quantify some aspects of the seed bank portion of the life cycle, we established 24 new reintroduction plots at the Rush Ranch reference site. These new 0.5 X 0.5 meter plots were randomly stratified within the Cordylanthus zone, and were all outside of the buffer zones of the large reintroduction plots established in 2000. In November 2001, we placed a planting grid over each O.25m^2 plot and planted 3 soft bird's beak seeds in each 10-centimeter subdivision of the grid for a total seed bank density of 75 seeds per plot. Twelve randomly selected plots received a 50% mosaic clip treatment prior to planting, and the remaining twelve were designated controls. When seedlings emerged in early March, one soft bird's beak seedling was tagged in each plot with 12 plants tagged in clipped treatments, and twelve in controls. The planting grid was placed over each plot, and numbers of live seedlings were recorded weekly to determine proportion of emergence from the seed bank and seedling survivorship.

Figure 32. Pin frame used to evaluate seedling community composition and structure.



Environmental and biological conditions within the seedling communities were evaluated. Each O.25m^2 plot was subdivided into 5 transects, and vegetation height, composition, and canopy architecture were evaluated along each transect by point intercept with a pin frame consisting of ten 2 mm diameter brass pins spaced 10 cm apart in a 0.5 meter frame constructed to correspond with the sampling units (Figure 23). The number of canopy layers, canopy height, and percent cover were recorded according to detailed methods described in Keer and Zedler 2002.

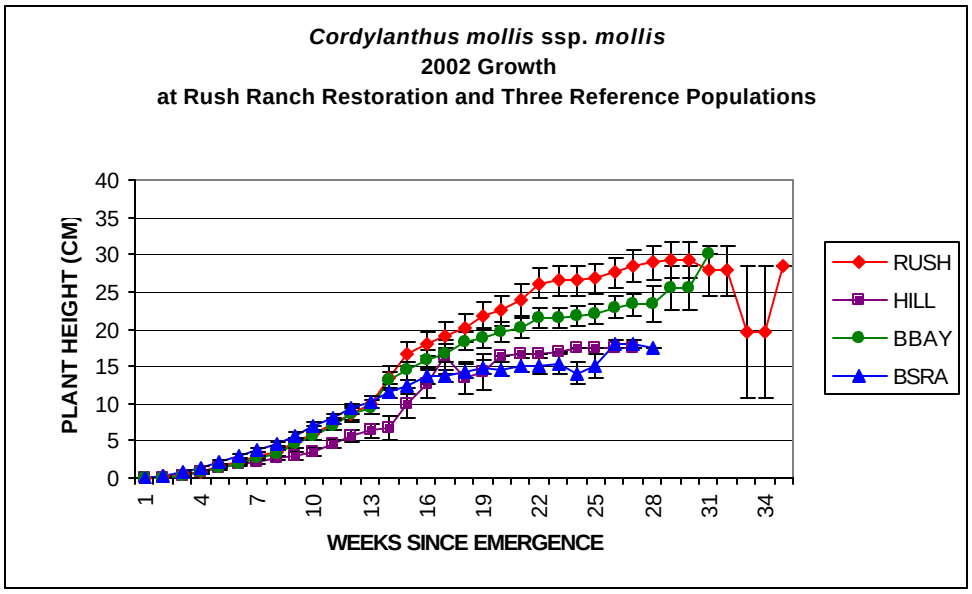
All tagged plants were measured weekly through the 2002 growing season, and plant growth (height) and life stage were recorded through their life cycle. Stage and date of mortality was recorded as marked plants died. Senescent marked plants were dissected to determine final height, number of branches, number of inflorescence spikes, flowers, and seed capsules. Percentage of seed capsules with evidence of pre-dispersal seed predation was recorded. Evidence of predation included observation of moth larvae within seed capsules, frass, and/or boreholes in reproductive tissues. It was not possible to accurately determine how many seeds were produced per plant because seed capsules mature sequentially through the reproductive phase, and primary dispersal from the plant begins well before senescence. It is possible to carefully determine capsule production evidence of mature capsules that have already dispersed seeds remain on the plant and are evident at senescence. Twenty-five mature seed capsules from each site were dissected to obtain an estimate of seeds produced per capsule for populations fecundity calculations. We evaluated life stage survivorship, and transitions and fecundity of soft bird's beak at the reintroduction and reference sites. Discriminant function analysis was used to evaluate differences in demography between reference and reintroduction sites. Demographic performance of soft bird's beak in clipped vs. control plots was evaluated to assess the effectiveness of restoration management on soft bird's beak growth and demographic success.

In 2002, soft bird's beak plants emerged in areas outside of our planted reintroduction plots. As this site has been searched each year since tidal hydrology was reintroduced in 1991, and no soft bird's beak plants had naturally colonized the site from distant

dispersal or a long dormant seed bank, we assume these plants originated from seeds that underwent secondary dispersal by tidal flows during the winter of 2001-2001, and landed in safe sites for germination. We flagged and measured minimum distance of each rare plant to the nearest possible source seeded plot for a conservative estimate of dispersal distance. In the winter of 2001 –2002, we also conducted limited dip net surveys for dispersing seeds during extreme flooding tides.

Results: 2002 Marked Plant Demography. Weekly measurements of plant height were comparable among sites for the first nine weeks following seedling emergence, but significant differences in growth among sites were observed after that time (Figure 33). Marked plants in the Rush Ranch reintroduced population, and plant at the Benicia Bay site grew comparably, and lived longer than the shorter stature plants at the BSRA and Hill Slough Wildlife Area populations that are subject to more muted tidal regimes (see Appendix II).

Figure 33. Weekly growth of marked plants at the Rush Ranch restoration site and three reference population sites in 2002 (n = 100, Mean ± 1 SE).



The proportion of plants surviving at each weekly sampling date is plotted as depletion curves (Figure 34). These plots illustrate substantial seedling mortality observed at the Hill Slough Wildlife Area. The control plots at the Rush Ranch restoration site

experienced a moderate level of seedling mortality, while a high proportion of tagged plants in Rush Ranch clipped plots and at the two Benicia area population lived through a long 34 week emergence period.

Figure 34. Depletion curves for marked plants in clip and control plots at the reintroduction site compared to marked plants at three reference sites.

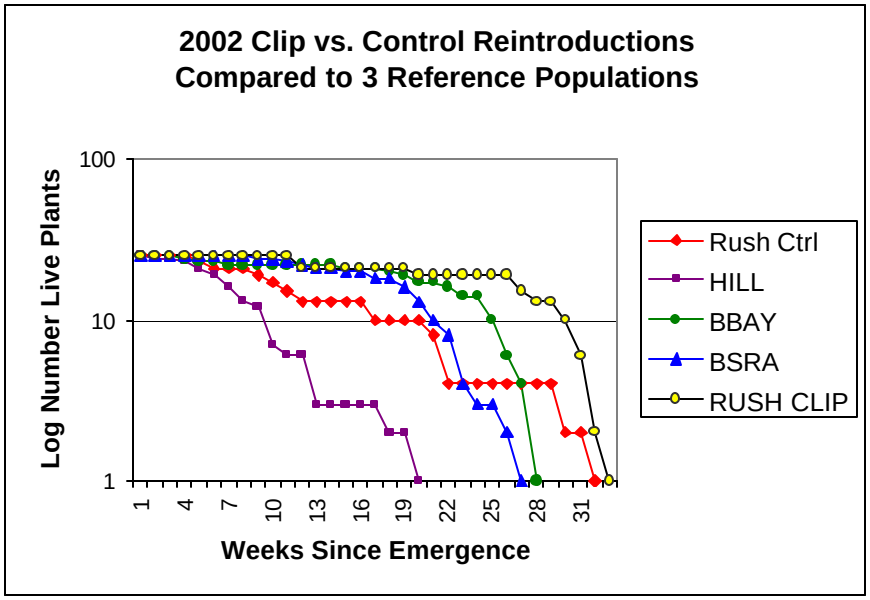


Figure 35. Survivorship curves for four populations of soft bird's beak in 2002.

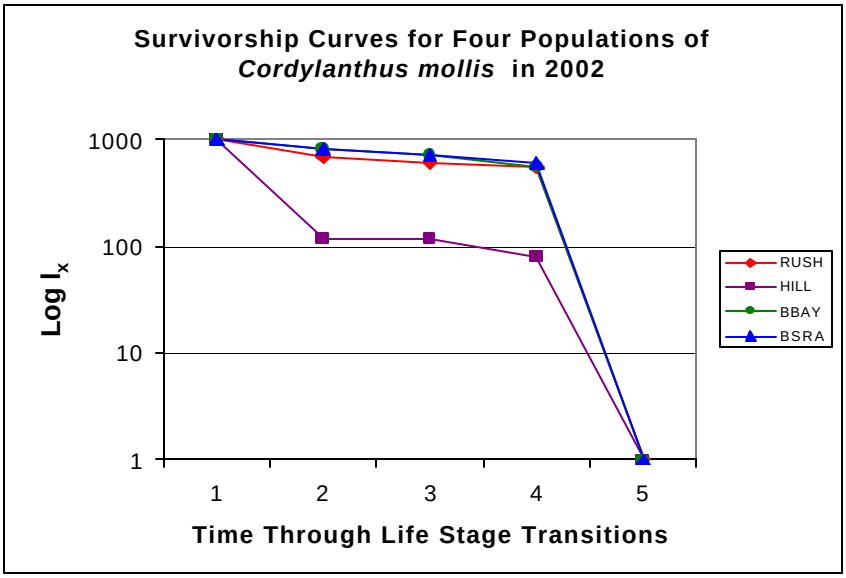


Table. 17. Partial life tables for the reintroduced population at Rush Ranch and three reference populations.

RUSH RANCH REINTRO POPULATION 2002	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	D_x	A_x	N_x	l_x
ESTABLISHED SEEDLING	73	0-73	25	1000
FLOWER	30	74-104	17	680
SEED CAPSULE SET	31	105-136	15	600
CAPSULE MATURATION	127	137-264	14	560

HILL SLOUGH REFERENCE POPULATION 2002	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	D_x	A_x	N_x	l_x
ESTABLISHED SEEDLING	73	0-73	25	1000
FLOWER	30	74-104	3	120
SEED CAPSULE SET	31	105-136	3	120
CAPSULE MATURATION	127	137-264	2	80

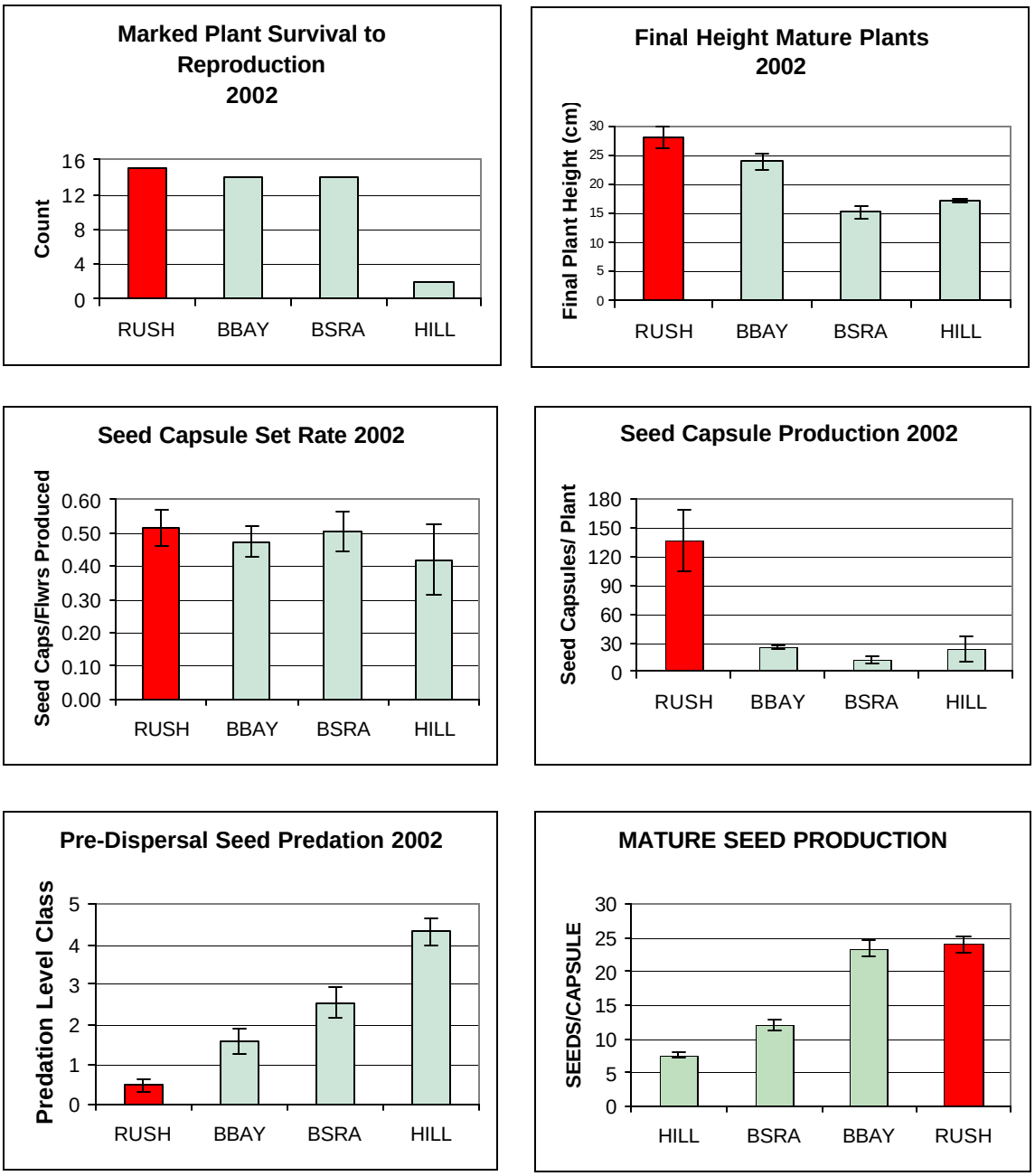
BENICIA - BAY SITE REFERENCE POPULATION 2002	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	D_x	A_x	N_x	l_x
ESTABLISHED SEEDLING	73	0-73	25	1000
FLOWER	30	74-104	21	840
SEED CAPSULE SET	31	105-136	18	720
CAPSULE MATURATION	127	137-264	14	560

BENICIA STATE REC. AREA MOUND REFERENCE POP. 2002	Mean Stage Length (Days)	Population Age (Days)	Number Surviving to Stage x	Standardized Survivorship
LIFE CYCLE STAGE, x	D_x	A_x	N_x	l_x
ESTABLISHED SEEDLING	73	0-73	25	1000
FLOWER	30	74-104	21	840
SEED CAPSULE SET	31	105-136	18	720
CAPSULE MATURATION	127	137-264	15	600

We prepared partial life tables to compare the demographic performance of the reintroduced population of soft bird's beak relative to the three reference populations (Table 17). There was no significant difference in survivorship among the reintroduced population at Rush Ranch, and the Benicia Bay, and the BSRA mound reference sites. The Type I survivorship curves for these three sites indicates that mortality risk increases as the maximum life span is reached, and these curves are typical for many annual plant species (Figure 35). The Hill Slough Wildlife Area stands out as a population with extreme mortality risk for the endangered plant seedlings, and the risk of mortality declines with age (Figure 35 and Table 17). Only 8 percent of the monitored plants survived to reproductive maturity at Hill Slough, raising serious conservation concerns for this historically large population.

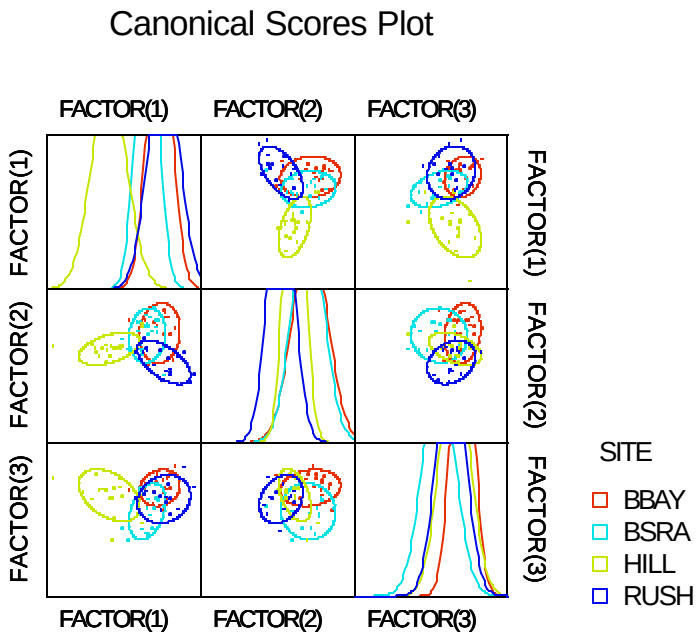
Reproductive performance of marked plants was evaluated at the end of their lifespan. Selected fitness measures of plants that survive to produce mature seeds are shown in Figure 36. It is important to note that the soft bird's beak population at Hill Slough exhibits high pre-reproductive mortality, and plant that survive to maturity suffer from strong pre-dispersal seed predation pressure. Seed capsule production at Rush Ranch, and ultimate mature seed production at the reintroduction site was substantially higher than the reference sites. The very low levels of pre-dispersal seed predation at the reintroduction explains much of this difference. The seed capsule set rates (seed capsule production/flower production) at Rush Ranch compared favorably to the reference sites suggesting that the new population was evident to pollinators, but has not yet attracted a large seed granivore population.

Figure 36. Fitness measures of *Cordylanthus mollis* plants that survive and produce mature seed in 2002 at Rush Ranch reintroduction and three reference population sites (Means + 1 SE).



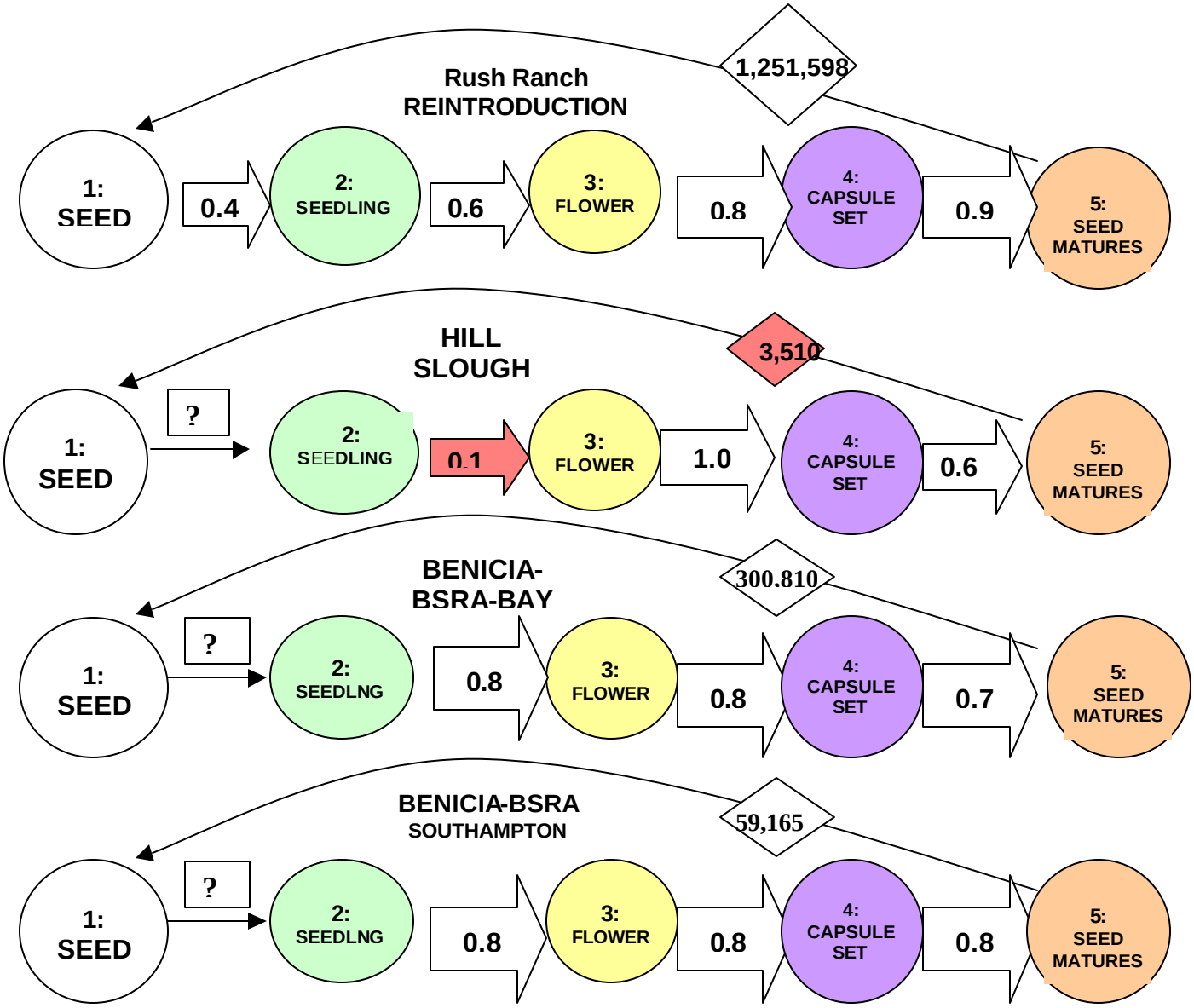
We used discriminant function analysis to evaluate the population sites based on measured demographic parameters. This eigenanalysis technique allows us to maximally separate the soft bird's beak population sites using canonical discriminant functions to show the among population relative to the within population variation in demography (Figure 37). The population sites form the predefined groups required for discriminant analysis, and the demographic performance metrics of marked plants are the independent variables The multivariate test of whether demographic performance differs significantly among population sites was highly significant ($p < 0.001$).

Figure 37. Canonical scores plot of the discriminant function analysis of among variation in demographic performance relative to within variation at among the Rush Ranch reintroduction site and three reference populations. Color codes as shown in the legend: BBAY (red), BSRA (sky blue), HILL (green), and RUSH (deep blue).



Summary life cycle graphs showing life stage transitions and fecundity of monitored reintroduction and reference populations is presented in Figure 38.

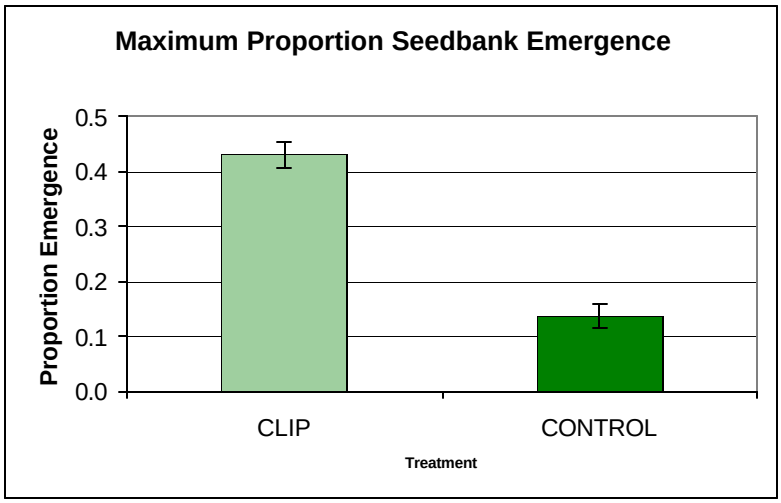
Figure 38. Life cycle graphs showing transitions between life stages and fecundity of soft bird's at Rush Ranch and three reference population sites.



Results of Canopy Manipulation Effects on Demography. Results of an in depth evaluation of the effect of restoration management techniques on soft bird's beak critical life stages, survivorship, and fecundity are presented here. Interested parties should contact the authors for results of additional analyses in progress, as our demographic evaluation of this population has continued beyond the scope of this project.

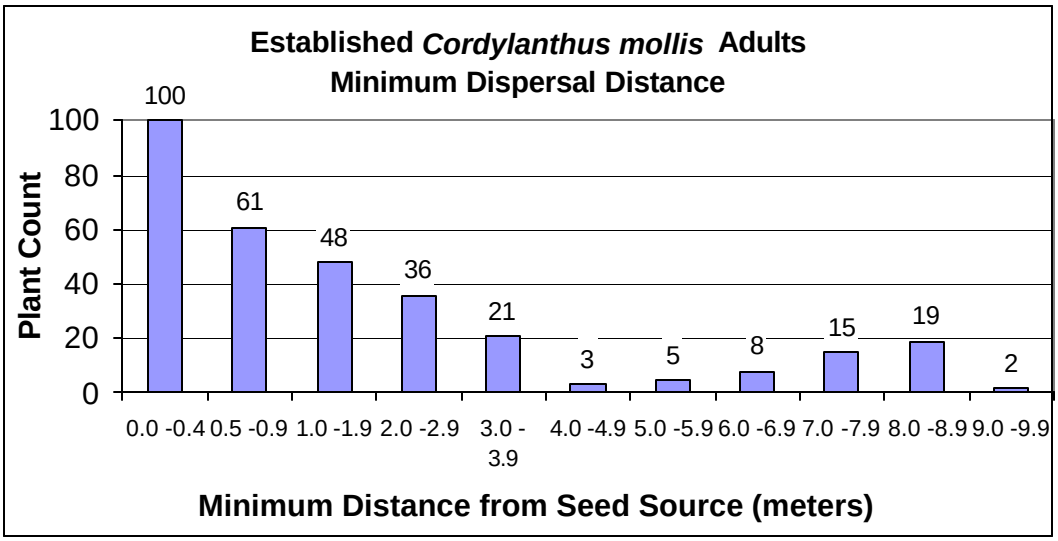
After seed ripens on a mature plant, there are many possible fates important to the life cycle of soft bird's beak. Post dispersal predation may eliminate a proportion of seed from the seed bank. Some plants may die as seed and never transition to seedling stage. Seeds may remain dormant in the seed bank for one or more seasons. Seed may also be transported away from their population origin by secondary dispersal agents such as tidal flows or animals. Little is known about the seed bank dynamics of soft bird's beak, and dormant seed may be a critical life stage. Experimental seed banks of 75 seeds/0.25m^2 were planted in 24 experimental plots in November 2001 (see methods), to better understand one component of the seed bank life stage. Seedling emergence was recorded weekly for ten weeks following spring 2002 emergence in planted seedbank plots (see methods). Maximum emergence of seedlings was greater in plots manipulated to suppress competition and increase germination gaps than was observed in un-manipulated controls (Figure 39).

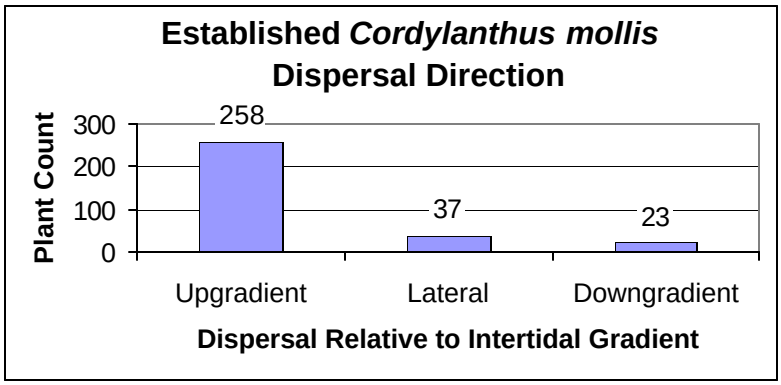
Figure 39. Maximum proportion of seedling emergence from experimental seed banks.



Following seedling establishment in 2002, we observed many soft bird's beak plants growing outside of planted experimental plots, and outside of the larger experimental reintroduction plots planted in 2000. No plants were observed growing outside of these plots in 2001. We measured the dispersal distance of each of the plants found outside of our seeded experimental plots to the nearest experimentally seeded location and considered this minimum dispersal distance for the seed. The majority of the plants were within 4 meters of a seed source, but some individuals were found 10 meters from reintroduction plots (Figure 40). It is unknown what proportion of soft bird's beak seed undergoes secondary dispersal, and we do not have direct evidence of the dispersal mechanism. Most plants were found upgradient of seeded plots (Figure 40). We have netted soft bird's beak seeds floating within the community during winter high tide events, and suspect this may explain the seed movement.

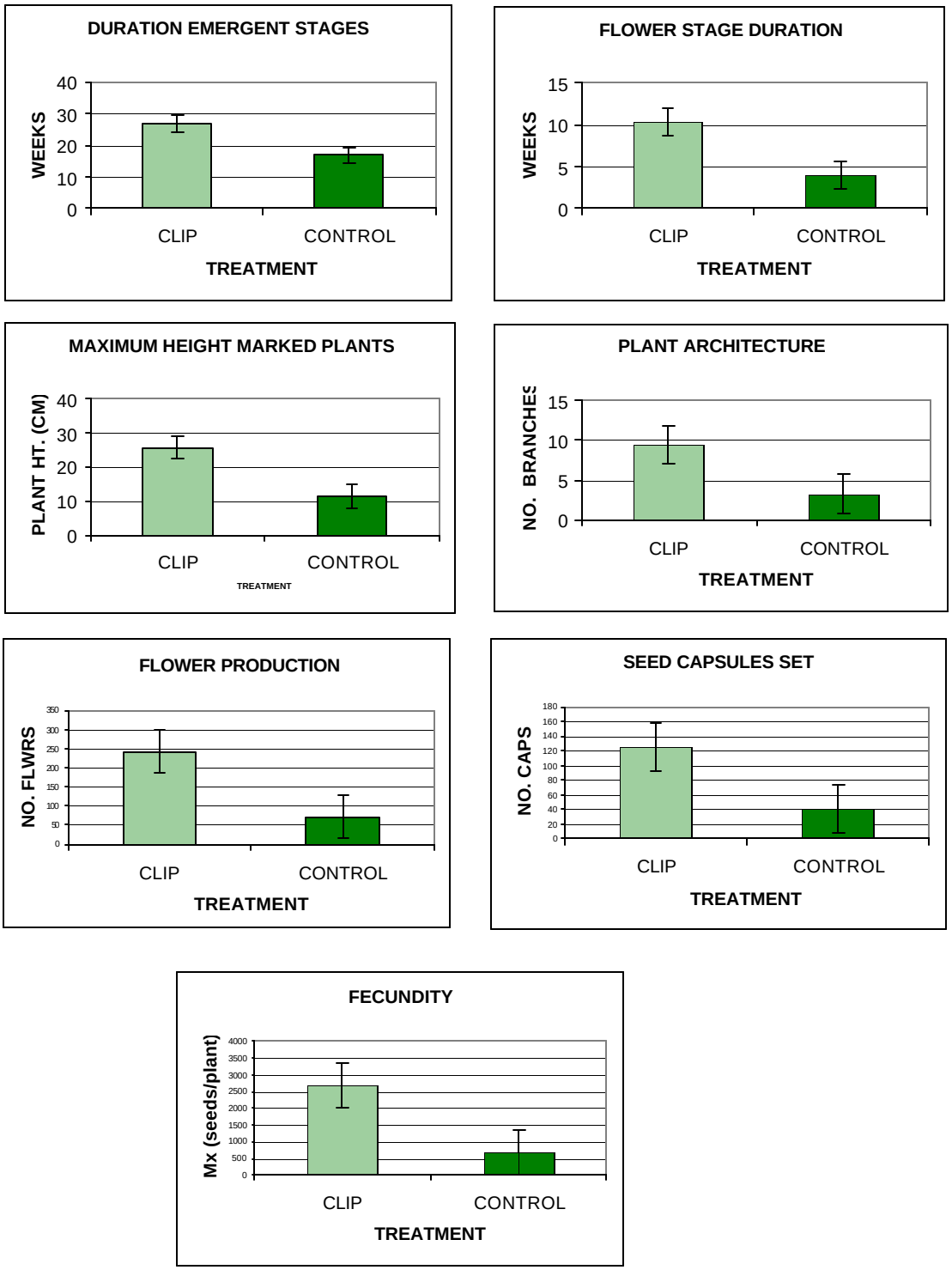
Figure 40. Minimum dispersal distance and direction of soft bird's beak plants that established outside of seeded reintroduction plots.





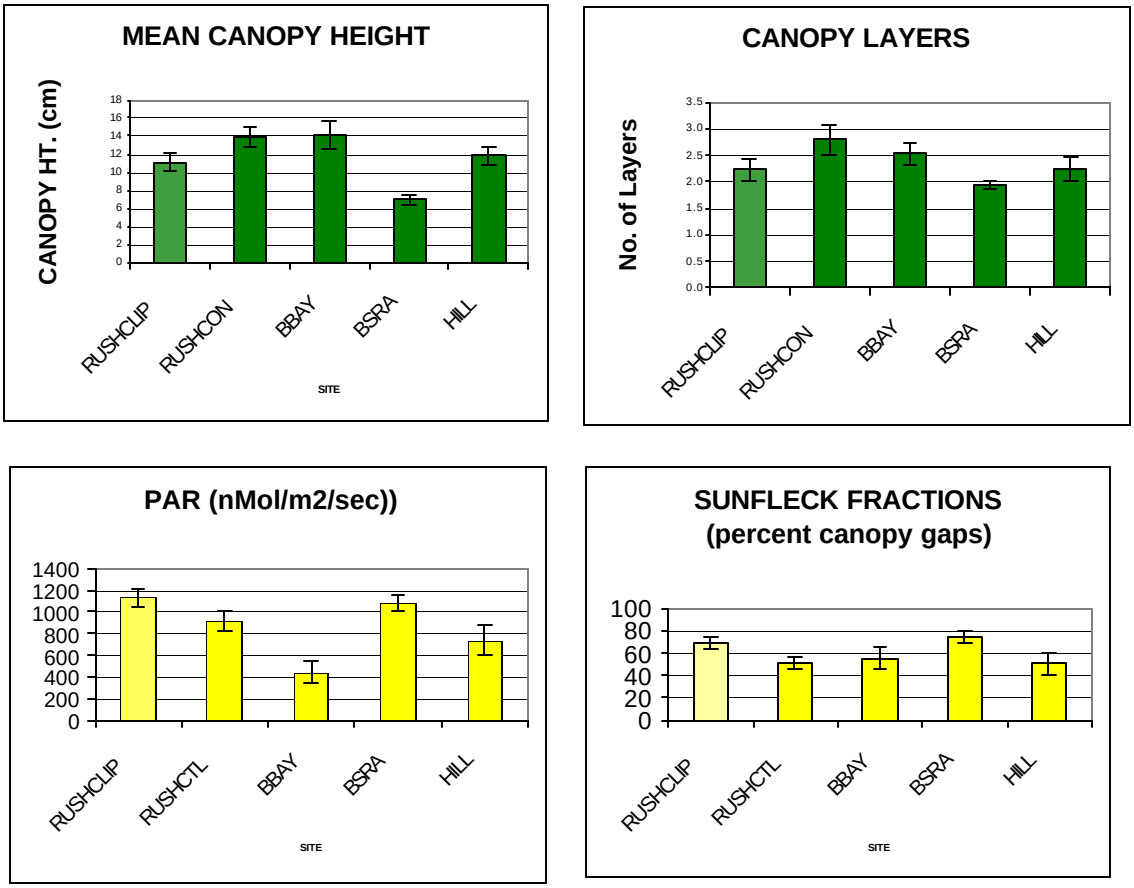
Demographic performance of soft bird's beak appears to benefit from canopy manipulation in restoration efforts. The results of the experimental reintroduction reported previously showed that density of reproductively mature plants was greater in clipped treatments than controls. Figure 41 compares the demographic performance between treatments at Rush Ranch.

Figure 41. Demographic performance of tagged soft bird's beak plants in 2002 experimental clip and control plots at Rush Ranch.



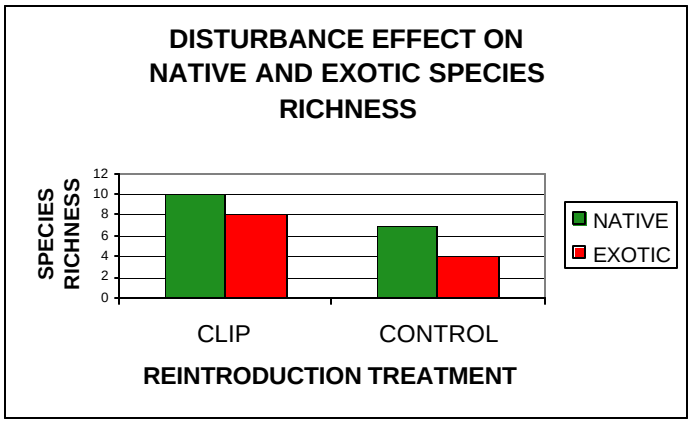
Results of plant community structure and light environment conditions measured during the seedling life stage at all monitored sites are reported in Figure 42. Clip plots and control plots at Rush Ranch are both included in the graphs to facilitate comparison of the manipulation treatment with all reference sites.

Fig. 42. Plant community structure and light environment during the seedling life stage of soft bird's beak in 2002.



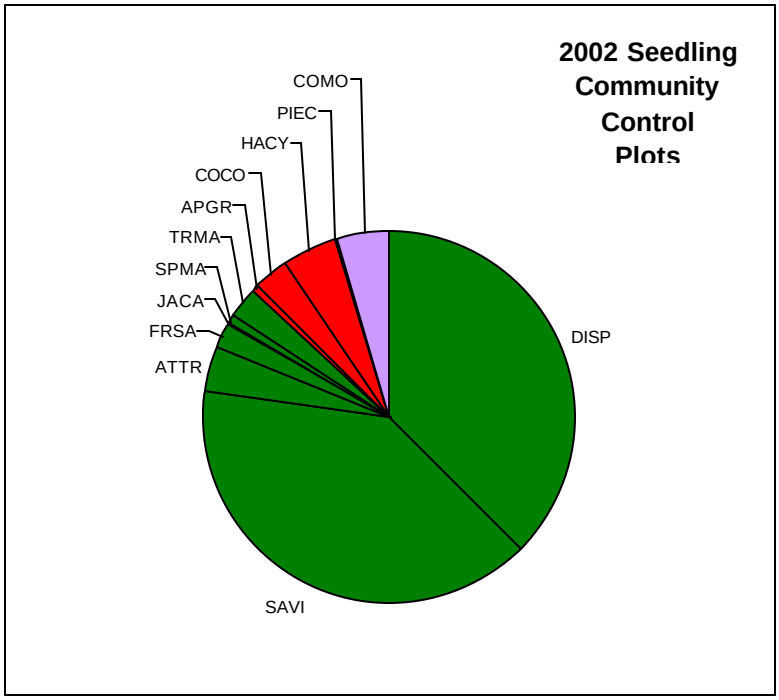
Origin of species associates were evaluated from records of species presence and percent cover of plants within soft bird's beak experimental units. Species richness of exotic plants exceed that of natives in the clipped reintroduction plots (Figure 43).

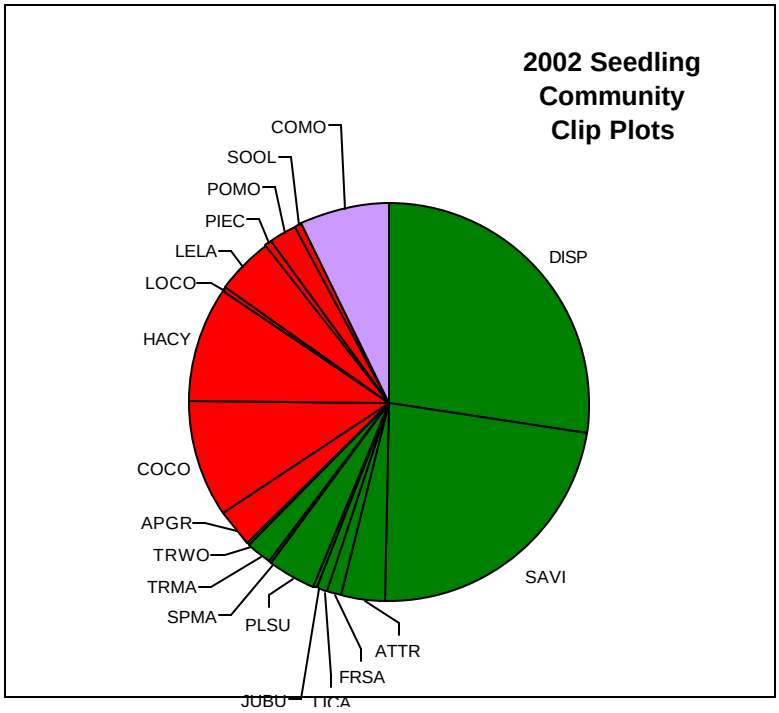
Figure 43. Native and exotic species richness in clip disturbance vs. control reintroduction treatments at Rush Ranch in 2002.



Relative frequency of native and exotic spcies detected within experimental clip plots and control plots are shown in Figure 44. When the plant canopy was manipulated (in this case, clipped) to promote conditions that result in the highest density of soft bird's beak with positive demographic performance, it was highly invaded by exotic plants within the first year of treatment. Four species of non-native plants were present in the control plots. When plots were clipped to improve soft bird's beak establishment, the number of invasive plant species doubled to eight, and the frequency of exotic plants increased. Of special conservation concern is the spread of *Lepidium latifolium* (LELA, perennial pepperweed) into these plots. This aggressive invader has the potential to displace the rare plants and thwart restoration attempts. *Lepidium latifolium* stands were present in the Rush Ranch tidal wetland community, but were not in the Spring Branch Marsh restoration site when we started this project. The *Lepidium* that invaded the clipped restoration plots established as seedlings, and could have been transported in by tides or wind.

Figure 44. Native and exotic species composition in 2002 Seedling Emergence Clip and Control Plots. Red indicates exotic species, while green areas represent native cover. COMO (soft bird's beak) cover is shown as purple.





Discussion. Results of the 2002 demographic monitoring elevate concerns raised in after the 2001 season regarding the soft bird's beak population at the Hill Slough Wildlife Area. Survivorship and fecundity of soft bird's beak in this historic population are very low. The size of the population has decreased since the survey by Ruygt (1994) in 1993, and we have documented further decreases in population size between 2000 and 2002.

The hydrology of this has undergone significant changes since the early 1990s. A large channel was dug to serve as a buffer ditch as mitigation for development of a large subdivision adjacent to the sensitive Hill Slough tidal wetlands. The channel is approximately 1.5 miles long, and diverts substantial flows from Hill Slough. Changes in regional hydrology are magnified in the high intertidal zone, where depth and duration of flooding are reduced. The Hill Slough population of soft bird's beak occupied a narrow elevational band that compares favorably with other reference site, yet the tides are more restricted (Appendix II).

In 2000, a second mitigation project was underway immediately upstream of the Hill Slough soft bird's beak population. This wetland restoration project extended tidal flow further upstream into adjacent vernal pools, but in doing so precluded tidal pulses from reaching a portion of endangered plant habitat. This further muting of tidal hydrology has resulted in die back of the mixed halophyte host community in addition to a reduction of the endangered plant population.

During the course of this project, unauthorized cattle grazing continued in the Hill Slough soft bird's beak population. Soft bird's beak has been impacted by direct trampling by cattle. Potential secondary effects of cattle in this sensitive area include introductions of invasive plants, and changes to biogeochemical cycling from nutrient loading.

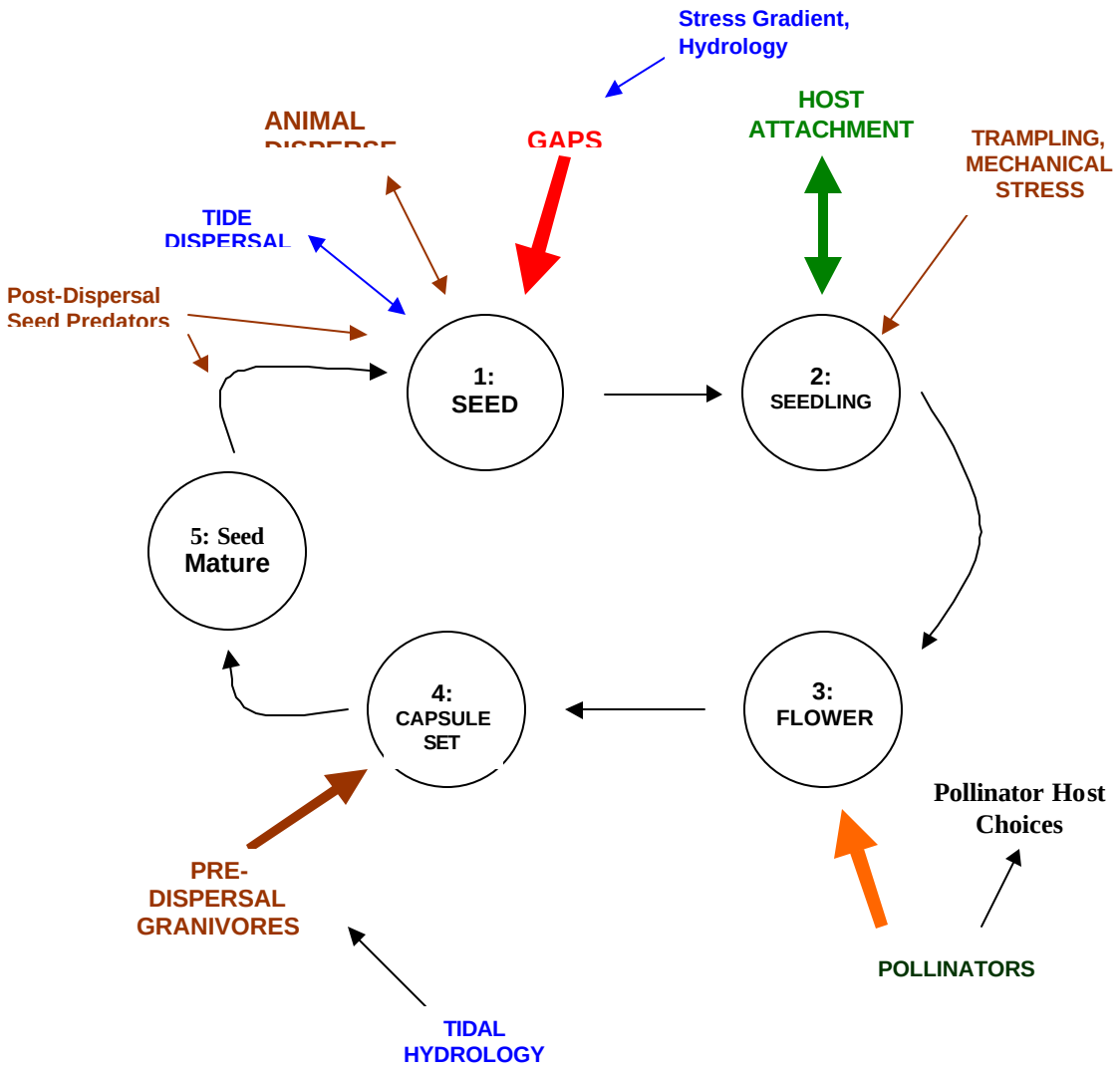
Plant species invasions plague all of the reference tidal wetlands that support natural populations of soft bird's beak. We have presented evidence that premature seedling mortality of soft bird's beak is highly correlated with the presence of invasive plants.

We have demonstrated effective reintroduction techniques to establish soft bird's beak. We have also demonstrated that canopy manipulation during the restoration process can enhance demographic performance of the rare plants, and may increase the possibility of establishing sustainable populations over time. We have also documented significant threats to the development of a sustainable population.

In this work, we have identified life stages that impact soft bird's beak population growth. The seedling stage of the plant is especially vulnerable, and management actions should target improved seedling survivorship. We have revealed another demographic limit to soft bird's beak success that is not apparent from examination of life stage transition rates. Some populations of soft bird's beak are highly impacted by pre-dispersal seed granivores. The rates of granivory at the Benicia Bay site, and Fagan Slough are low, and these populations do not appear to be limited by granivores at this time.. At sites where hydrology is muted, pre-dispersal granivory is extremely high. Future studies into the life cycle of the *Saphenista* moth would help explain the dynamics of this interaction. This animal spends part of its life cycle buried in the sediment, and it is possible muted hydrology is advantageous to its population growth.

Our knowledge of the seed bank dynamics of soft bird's beak is incomplete. Future focus on seed bank dynamics will help put the rest of this demographic information in context, and allow us to make informed projections of population dynamics.
We have generated information on the emergent stages of the plant that provides valuable insight and identifies vulnerable life stages and threats to the maintenance of sustainable populations of soft bird's beak. The schematic diagram in Figure 45 summarizes factors influencing critical life stages of soft bird's beak.

Figure 45. Factors influencing critical life stages of soft bird's beak.



The goal of this study was to provide critical ecological data to facilitate rare plant restoration, as a contribution towards CALFED objectives for improved ecosystem quality through native species recovery and conservation. Results of these demographic studies point to the need for immediate stewardship at soft bird's beak natural population sites. Relict tidal marshes in the North Bay and Suisun Region are in precipitous decline, and continue to be impacted by species invasions and hydrologic alterations. Results of this experimental work demonstrate how some of these factors may limit the population growth and sustainability of an endemic endangered plant. Our historic tidal wetlands are in trouble, along with the endangered species they support. Results of this study emphasize the need to restore sustainable ecosystems prior to attempts to restore the range of endangered species. Restoration and enhancement of historic tidal wetland should take priority over attempts to restore other habitat types to tidal wetlands.

IV. Hierarchical Monitoring Recommendations

The fourth objective of this project was to develop monitoring recommendations appropriate for the newly established population site at Rush Ranch, and for conservation monitoring of natural populations. Inadequate endangered species monitoring is a recognized shortcoming of endangered species management, and many recovery plans lack provisions for monitoring key factors such as species status, threats, and the implementation and outcome of recovery actions (Clark et al. 2002, Campbell et al. 2002, Boersma 2001). The goal of a rare plant reintroduction should be to establish a population that can carry on its basic life cycle processes such that the probability of extinction by random or chaotic forces is low (Gilpin and Soule 1986, Menges 1992, Pavlik 1994, Pavlik 1996). As new populations are established in restoration and recovery projects, it is especially important to implement monitoring to determine whether the actions are reducing the probability of extinction of the species and if the reintroduced populations are self-sustaining.

We do not provide a detailed monitoring plan for uniform application, because the methods and success criteria in such a plan will vary with the goals, objectives, and budget of individual land managers. The reality of conservation monitoring is that thorough assessment and tracking of endangered plant populations is time consuming, requires specialized botanical expertise, and requires a significant commitment of resources. At the present time, there is no commitment of resources for continued monitoring of the reintroduced population that was the subject of this report, or the natural populations of soft bird's beak throughout the North Bay and Suisun Marshes. Noss (1990) lists five categories of species that warrant special conservation effort and intensive monitoring. Soft bird's beak is a priority candidate for intensive monitoring because it is an ecological indicator that signals the effects of perturbations on a number of other rare species with similar habitat requirements, and the sessile nature this plant through most of its life cycle makes it an ideal subject for intensive, repeated scrutiny.

We do not provide a comprehensive overview of rare plant monitoring for conservation and ecology because excellent references are available on this subject (Palmer 1987, Cropper 1993, Pavlik 1994, Menges and Gordon 1996, Pavlik 1996), not to mention numerous volumes on general plant monitoring techniques. Monitoring plans for rare plant reintroduction attempts should include the objectives and methods typical of general biological monitoring, and should explicitly define performance measures for evaluation of success. A review of rare plant reintroduction attempts in California found few projects that made the attempt to define success criteria and monitor performance (Fiedler 1991). Pavlik (1996) provides a good overview of how to define success with monitoring goals and objectives and suggests long term and short term objectives for evaluating reintroductions of rare plants.

Our intent is provide a hierarchical framework for monitoring with specific focus on information needs and approaches relevant to soft bird's beak conservation. The majority of the land managers have an interest in population monitoring, need to know where endangered plants are on their property, but also need to understand the biological condition of these populations, and to detect threats and changes so they may apply appropriate management strategies for conservation. We suggest a five level hierarchy of increasing intensity for monitoring soft bird's beak, with sampling and analysis methods appropriate to each level.

A hierarchical schematic of this monitoring strategy follows in Table 18. Level 1 includes the most minimal, low intensity monitoring, while monitoring activites increases with each additional level included in the program. The ultimate plan should include specific objectives that will result in management actions for the best possible stewardship for endangered species conservation and recovery.

Table 18. Hierarchical monitoring for soft bird's beak conservation and recovery.

Level	Monitoring Strategy
1	Population Distribution
2	Population Status
3	Threat Assessment and Diagnosis
4	Population Response to Conservation Actions
5	Adaptive management to Improve Status

***Level 1. Population Distribution*.** To date, conservation monitoring of soft bird's beak has been limited to sporadic surveys of species presence and size. One notable exception, is the long term monitoring grid maintained by the Napa chapter of the California Native Plant Society in Fagan Slough Ecological Reserve, where a subsample of the population has been counted for more than ten years (Ruygt 1994 and CNNDB).

Presence – absence surveys tell resource managers the location and apparent size of populations, and this information is useful for protection from the most direct impacts of human activities. Unfortunately, population presence and size monitoring does not tell us the most critical information needed for rare plant conservation (Pavlik 2002). This is especially true in the case of annual plant populations that are expected to vary considerably over time. The descriptive results of population census can help us monitor trends across populations if monitoring includes all extant populations. Monitoring counts of fixed population grids within larger populations of soft bird's beak can provide misleading results, especially given seed dispersal characteristics of this species, and full evaluations of occupied habitat are preferred. If PVC pipe is used to mark field population monitoring sites, these pipes should be capped. Open pipes function as piezometers and fill with water on the higher tides. Critical pollinators enter the pipes in search of water, and many perish inside the pipes.

Population census can help us formulate hypotheses regarding trends in population size which can be tests in more intense monitoring and research efforts. Simple population census does not tell us why populations fluctuate, or the biological status of populations. A snap shot of population size can be misleading and should not be confused with more detailed population status assessment.

The current practice of requiring detailed counts of soft bird's beak population patches as a permit condition is also problematic, as these plants occur at high densities and are easily dislodged from their fragile root connections with hosts. We recommend a population census approach implemented by plant ecologists at the Humboldt Bay National Wildlife Refuge which was developed to track the distribution of Humboldt Bay owl's clover and Pt. Reyes bird's beak, two rare hemiparasitic plants (Pickart 2001). Mapping of the distribution of soft bird's beak should be done between mid-June and early October to maximize detection of flowering plants. The ideal time for census is July – September when plants are most visible. The abundance of soft bird's beak should be estimated visually within GPS identified polygons of discrete population patches, and placed into logarithmic abundance classes (for example: 1-10, 11-100, 101-500, 501 – 1000, 1001 – 5000, 5001 – 10,000). The geographic extent of soft bird's beak, acreage summaries of occupied habitat, and midpoints of annual population abundance class estimates can be evaluated with time series methods for trend evaluation. Conservation volunteers working with professional oversight by land managers could be quite helpful in assessing population distribution and abundance.

Level 2. Population Status. The next level of monitoring includes demographic monitoring of individuals to assess critical life stage transitions and anticipate population trends. Demographic monitoring can help us make informed hypotheses of threats to critical life stages. Our goal should be to restore critical demographic processes rather than specific numbers of individuals (Pavlik 1994). To protect endangered species, demographic monitoring is essential if we are to improve survival and fertility, and

increase population growth rates and equilibrium population size (Caswell 2001). This level of monitoring provides an individual based warning system that a population is in trouble, or it can confirm positive population response to management actions. The demographic monitoring described in this report provides a look at individuals and population condition for only a short time period. Repeated demographic monitoring over time is crucial to resolving population status and factors affecting population change (Menges and Gordon 1996). Demographic monitoring is necessary if we are to make intelligent decisions regarding processing regulating popuation density and persistence. Demographic monitoring is also useful in the evaluation of restoration efforts. Demographic monitoring is also time consuming, and must be implemented by qualified botanists. These botanists must maintain active communication with land managers so action plans can be formulated to improve population status.

Additional monitoring and research into soft bird's beak population status concerns the population genetic structure, effective population size, and the resistance of the population to perturbations.

Level 3. Threat Assessment and Diagnosis. A more complete approach to soft bird's beak monitoring includes assessment of population threats in tandem with demographic monitoring efforts. If a population exhibits demographic challenges, it is important to conduct controlled monitoring and research to confirm the problem. The spread of invasive *Lepidium latifolium*, and the presence of exotic winter annual plants within seedling communities should be the immediate target of soft bird's beak threat monitoring. Other threats identified through this project are continued cattle grazing in sensitive tidal wetlands, and the spread of feral hogs in Suisun tidal wetlands. Potential pollinator studies indicate we must also look at threats in adjacent landscapes for a full assessment of demographic impacts to soft bird's beak, as potential pollinators may be attracted to invasive plants in adjacent pastures or urban horticultural plantings.

Level 4. Population Response to Conservation Actions. As threats are identified, Level 2 demographic monitoring should be adapted to evaluate their influence at the individual and population level.

Level 5. Adaptive management to Improve Status. Monitoring results from Levels 1 – 4 should progressively contribute to management decisions regarding soft bird's beak conservation. As actions are implemented, the monitoring process must be continuously adapted to assess and reassess their success from the individual to population level.

V. Education Outreach

Through the course of this research, we have taken time to inform interested land managers, and the public of our progress. A listing of key education outreach meetings is provided in Table 19. Per contract deliverable obligations, though many other educational outreach activities took place as we implemented the project.

Table. 19. Meeting participation for education outreach and project coordination..

Date	Site	Outreach Meeting
5/20/00	Benicia	BSRA Site Mtg. - Project Coordination w/DFG
3/20/01	Suisun Marsh	Information provided to DWR/CALFED project implementation
3/21/01	Fagan Sl	Teresa LeBlanc, DFG Ecological Reserve Manager coordination
4/5/01	Hill Slough	DWR staff mtg. Re: Hill Slough area potential restoration project
4/11/01	Rush Ranch	Site Visit with Mary Pakenham-Walsh-UCD/Project Coord.
5/17/01	Suisun	Site mtg. W/Cecelia Brown, USFWS re: conservation needs
5/29/01	Rush Ranch	Mtg. W/PRBO biologist - rare plant conservation/research coord.
7/11/01	UCD	Monitoring/Education w/ Solano Land Trust and NEER
7/13/01	UCD	Monitoring Needs - SF Bay National Esturarine Research Reserve
7/18/01	Suisun Marsh	Jonathan Evens/contract inspection Rush Ranch
8/29/01	UCD	Todd Hopkins, CALFED project - NEER coordination/phone conf.
10/3/01	Rush/Hill	Mtg Peter Baye: Field Briefing - Project Progress/USFWS
12/7/01	UCD	Brief DFG staff project progress & conservation needs
2/4/02	Benicia	State Park Permit renewal/project update mtg
3/1/02	UCD	Mtg. With Solano Land Trust about project education outreach
3/13/02	Suisun	Mtg. With Rush Ranch Education Council: educational display
4/2/02	UCD	Mtg with UC Weed Science advisors re: invasive plants/project
7/19/02	Rush Ranch	Mtg. W/Todd Hopkin, SF-NEER, monitoring and public education
7/30/2002	Suisun	Field - Site Visits with Lauren Hastings, CALFED
9/10/02	Benicia	Mtg. W/M.Baumgratz, State Parks re: conservation needs-
9/11/02	Rush Ranch	Mtg w J.Meisler, Solano Land Trust: rare plant conservation
10/7/02	Rush Ranch	Mtg. With Solano Land Trust and Solano Mosquito Abatement
11/6/02	Rush Ranch	Attended DWR site meeting regarding potential restoration
11/9/02	Rush Ranch	Mtg with SLT, SWA, and USFWS re: Spring Branch Restoration
12/5/02	Rush Ranch	Mtg w/ SLT staff re: restoration plans, rare plant threats
1/7/03	Suisun	Educational Display - Solano Land Trust and RREC
1/16/03	Sacramento	CALFED Science Conference presentation
2/5/03	Rush Ranch	Calfed project followup w/Solano Land Trust staff
2/7/03	Benicia	CALFED project followup w/ State Parks staff, Baumgratz
2/14/03	Rush Ranch	Mtg w DWR staff re: restoration plans, soft bird's beak threats
3/4/03	Rush Ranch	Public Education Presentation: CALFED project results for
		Rush Ranch Education Council and California Native Plant
		Society, Willis Jepson Chapter board members.

We worked closely with Solano Land Trust staff and members of the Rush Ranch Education Council, and together constructed an outdoor education kiosk to information the public of the importance of rare plants, why they are endangered, and how we approach the recovery and restoration of endangered soft bird's beak (Figure 46).

Figure 46. Outdoor education display regarding soft bird's beak restoration efforts at Rush Ranch.

References

Boersma, P.D., P. Kareiva, W.F. Fagan, J.A. Clark, and J.M. Hoekstra. 2001. How good are endangered species recovery plans?" BioScience 51:643-649.

Brown, A.H.D. and J.D. Briggs. 1991. Sampling strategies for genetic variation in *ex situ* collections of endangered plant species. Pp. 99-119 in: Falk, D.A. and K.E. Holsinger (eds.) Genetics and conservation of rare plants. Center for Plant Conservation. Oxford University Press, New York.

Campbell, S.P, J.A. Clark, L.Crampton, A.D. Guerry, L.R. Hatch, P.R. Hosseini, J.J. Lawler, and R.J. O'Connor. 2002. An assessment of monitoring efforts in endangered species recovery plans. Ecological Applications12:674-681.

Casanova, M.T. and M.A. Brock. 2000. How do depth, duration, and frequency of flooding influence the establishment of wetland plant communities. Plant Ecology 147:237-250.

Caswell. H. 2001. Matrix population models, second edition. Sinauer Associates, Sunderland, Mass.

CCB. 1993. Conservation of the palmate-bracted bird's beak, *Cordylanthus palmatus*. Center for Conservation Biology, Stanford, CA.

CCB. 1994. Conservation of the palmate-bracted bird's beak, *Cordylanthus palmatus*. Center for Conservation Biology, Stanford, CA.

Chapin, F.S. III and M.C. Chapin. 1981. Ecotypic differentiation of growth processes in *Carex aquatilis* along latitudinal and local gradients. Ecology 62:1000-1009.

Chaplin, S.J., R.A. Gerrard, H.M. Watson, L.L. Master, and S.R. Flack. 2000. The geography of imperilment: targeting conservation toward critical biodiversity areas. Pages 159-199 in B.A. Stein, L.S. Kutner, and J.S. Adams, editors. Precious heritage: the status of biodiversity in the United States. Oxford University Press, Oxford, U.K.

Chuang, T. I., and L. R. Heckard. 1971. Observations of root-parasitism in *Cordylanthus* (Scrophulariaceae). American Journal of Botany 58: 218-228.

Chuang, T. I., and L. R. Heckard. 1972. Seed coat morphology in *Cordylanthus* (Scrophulariaceae) and its taxonomic significance. American Journal of Botany 59: 258-265.

Chuang, T. I., and L. R. Heckard. 1973. Taxonomy of *Cordylanthus* subgenus *Hemistegia* (Scrophulariaceae) (Original Publication). Brittonia 25: 135-158.

Clark, J.A., J.M Hoekstra, P.D.Boersma, and P.Kareiva. 2002. Improving U.S. Endangered Species Act recovery plans: key findings and recommendations of the SCB Recovery Plan Project. Conservation Biology 16: 1510-1519.

CNPS 2001. Inventory of Rare and Endangered Plants of California (Sixth Edition). Rare Plant Scientific Advisory Committee, D.P. Tibor, convening editor. California Native Plant Society. Sacramento, CA.

Cropper, S.C. 1993. Management of endangered plants. CSIRO Publications, East Melbourne, Victoria, Australia.

Dobson, A.P., J.P. Rodriguez, W.M. Roberts, and D.S. Wilcove. 1997. Geographic Distribution of Endangered Species in the United States. Science 275:550-553.

Falk, D.A., C.I. Millar, and M. Olwell. 1996.Restoring diversity: strategies for reintroduction of endangered plants. Island Press, Washingto, D.C.

Fiedler, P.L. 1991. Mitigation-related transplantation, relocation, and reintroduction projects involving endangered, threatened, and rare plant species in California. Unpublished report. Sacramento: Department of Fish and Game, Endangered Plant Program.

Fink, B. and J.B. Zedler 1989a. Endangered plant recovery: experimental approaches with *Cordylanthus maritimus* ssp. *maritimus.* In: H..G. Hughes and T.M. Bonnicksen, eds. Proceedings of the first annual meeting of the Society for Ecological Restoration and Management. Madison, Wisconsin. January 16-20, 1989.

Fink, B., and J. B. Zedler. 1989b. Maximizing growth of *Cordylanthus maritimus* ssp. *maritimus*, an endangered salt marsh plant. Progress Report for the California Department of Transportation (Interagency Agreement # 11B351.26). November 20, 1989.

Gibson, C.C. and A.R. Watkinson. 1992. The role of the hemiparasitic annual *Rhinanthus minor* in determining community structure. Oecologia 89:62-68.

Gilpin, M.E. and M.E.Soule. 1986. Minimum viable populations and process of species extinctions. In M.E.Soule (ed.) Conservation Biology: the science of scarcity and diversity. Sinauer Associates, Sunderland, Mass.

Helenurm, K., and L. S. Parsons. 1997. Genetic variation and the reintroduction of *Cordylanthus maritimus* ssp. *maritimus* to Sweetwater Marsh, California. Restoration Ecology 5 (3): 236-244.

Hickman, J. C. 1993. The Jepson manual: Higher plants of California. University of California Press. Berkeley. 1400 pp.

Holsinger, K.E. and L.D. Gottlieb. 1991. Conservation of rare and endangered plants: principles and prospects. Pp. 195 – 208 in: Falk, D.A. and K.E. Holsinger (eds.) Genetics and conservation of rare plants. Center for Plant Conservation. Oxford University Press, New York.

Howald, A. M. 1996. Translocation as a mitigation strategy: lessons from California. pp 293 – 330 in: Falk, D.A., C.I. Millar, and M. Olwell. 1996. Restoring diversity: strategies for reintroduction of endangered plants. Island Press, Washington, D.C.

Kearns, C.A. and D.W. Inouye. 1993. Techniques for pollination biologists. University Press of Colorado. Niwot, Colorado.583 pp.

Keer, G.H. and J.B. Zedler. 2002. Salt marsh canopy architecture differs with the number and composition of species. Ecological Applications 12:456-473.

Kuijt, J. 1969. The Biology of Parasitic Flowering Plants. University of California Press. Berkeley, CA.

L.C. Lee and Associates and Center for Conservation Biology, Stanford University. 2002. The palmate bird's beak at the Springtown Alkali Sink Wetlands, Livermore Valley, California: rapid assessment of *Cordylanthus palmatus* primary flower visitors. Technical report prepared for: Zone 7, Alameda County Flood Control & Water Conservation District, Pleasanton, California, Oct. 31, 2002.

Lesica, P. and B.M. Steele. 1997. Use of permanent plots in monitoring plant populations. Natual Areas Journal 17:331-340.

Lesica, P. and B.M. Steele. 1996. A method for monitoring long-term population trends: an example using rare arctic-alpine plants. Ecological Applications 6:879-887.

Marshall, D.R. and A.H.D. Brown. Optimum sampling strategies in genetic conservation. Pp. 370 – 391 In: O.H. Frankel and J.G Hawkes (eds.) Crop genetic resources for today and tomorrow. Cambridge University Press, Cambridge.

Marvier, M. 1998. A mixed diet improves performance and herbivore resistance of a parasitic plant. Ecology 79: 1272-1280.

Marvier, M. 1996. Parasitic plant-host interactions: plant performance and indirect effects on parasite-feeding herbivores. Ecology 77: 1398-1409.

Marvier, M. A., and D. L. Smith. 1997. Conservation implications of host use for rare parisitic plants. Conservation Biology 11 (4): 839-848.

Menges, E.S. and D.R. Gordon. 1996. Three levels of monitoring intensity of rare plant species. Natural Areas Journal 16:227-237.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

McCune, B. & M.J. Mefford 1999. PC-ORD. Multivariate analysis of ecological data, version 4. MJM Software Design, Gleneden Beach, Oregon.

McGraw, J.B. and J. Antonovics. 1983. Experimental ecology of Dryas octopetala ecotypes. I. Ecotypic differentiation and life-cycle stages of selection. J. Ecol. 71:879-897.

Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. Third Edition. J. Wiley &Sons. New York.

Noe, G. B., and J. B. Zedler. 2000. Differential effects of four abiotic factors on the germination of salt marsh annuals. American Journal of Botany 87: 1679-1692.

Noe, G. B., and J. B. Zedler. 2001. Spatiotemporal variation of salt marsh seedling establishment in relation to the abiotic and biotic environment. Journal of Vegetation Science 12: 61-74.

Noss, R. F. 1990. From endangered species to biodiversity. Pp. 227-246 In: K.Kohm (ed.) Balancing on the brink of extinction: the Endangered Species Act and lessons for the future. Island Press, Washington, D.C.

Palmer, M.E. 1987. A critical look at rare plant monitoring in the United States. Biological Conservation 39:113-127.

Parsons, L. S., and J. B. Zedler. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. Ecological Applications 7 (1): 253-267. FEB.

Pavlik, B.M.2002. Looking ahead: the near future of plant conservation. Keynote address. Proceedings of the California Native Plant Society – North Coast Rare Plant Symposium, Feb. 6- 8, 2002 Arcata, CA.

Pavlik, B.M. 1996. Defining and measuring success. Pp. 127 – 156 In: Falk, D.A., C.I. Millar, and M. Olwell. 1996. Restoring diversity: strategies for reintroduction of endangered plants. Island Press, Washington, D.C.

Pavlik, B.M. 1994.Demographic monitoring and the recovery of endangered plants. p. 322-350 In: M.Bowles and C.J. Whelan (eds) Recovery and Restoration of Endangered Species.Cambridge University Press, Cambridge, U.K.

Pennings, S.C. and M.D. Bertness. 2001. Salt Marsh Communities. Pp.289-316 in: Bertness, M.D., S.D. Gaines, and M.E. Hay, eds. Marine Community Ecology. Sinauer Associates, Sunderland, MASS.

Pickart, A. 2001. The distribution of *Spartina densiflora* and two rare salt marsh plants in Humboldt Bay 1998 – 1999.

Pennings, S.C. and R.M. Callawy. 1996. Impact of a parasitic plant on the structure and dynamics of salt marsh vegetation. Ecology 77:1410-1419.

Press, M.C. 1989. Autotrophy and heterotrophy in root hemiparasites. Trends in Evolution and Ecology 4:258-263.

Press, M.C., J.D. Scholes, and J.R. Watling. 1999. Parasitic plants: physiological and ecological interactions with their hosts. pp. 175-197 in: Press, M.C., Scholes, J.D. and Barker, M.G.(eds.) Physiological Plant Ecology. British Ecological Society. Blackwell Scientific, Oxford, U.K.

Piehl, M. A. 1966. The root parasitism of *C. maritimus* and some of its ecological implications (abstract). American Journal of Botany 53: 622.

Podani, J. 1995. SYNTAX-5.02. Computer programs for multivariate data analysis on the Mactintosh system. Scientia Publishing, Budapest, Hungary.

Ruygt, J. 1994. Ecological studies and demographic monitoring of soft bird's beak *Cordylanthus mollis* ssp. *mollis* a California listed rare plant species. Napa Botanical Survey Services report to Natural Heritage Division, California Department of Fish and Game.

Parsons, LS and JB Zedler. 1997. Factors affecting re-establishment of an endangered annual plant at a California salt marsh. Ecological Applications 7:253-267.

Primack, RB. 1996. Lessons from ecological theory: dispersal, establishment and population structure. In *Restoring Diversity: strategies for reintroduction of endangered plants*, eds. DA Falk, CI Millar and M Olwell. Washington, DC: Island Press.

Schemske, D.W., B.C. Husband, M.H.Ruckelhaus, C. Goodwille, I.M. Parker, and J.G. Bishop. 1994. Evaluating approaches to the conservation of rare and endangered plants. Ecology 75(3):584-606.

Schmidt, K.P. and D.A. Levin. 1985. The comparative demography of reciprocally sown populations of *Phlox drummondii*. I. Survivorships, fecundities, and finite rates of increase. Evolution 37:292-301.

Silander, J.A. 1985. The genetic basis of the ecological amplitude of *Spartina patens*. II. variance and correlation analysis. Evolution 39:1034-1052.

Stermitz, F.R. 1997. Plant parasites. In: M.Wink and M.F. Roberts (eds.) Plant alkaloids: biochemistry, ecology, and medicinal applications. Plenum Press, New York.

Templeton, A.R. 1991. Off-site breeding of animals and implications for plant conservation strategies. Pp. 182-194 in: Falk, D.A. and K.E. Holsinger (eds.) Genetics and conservation of rare plants. Center for Plant Conservation. Oxford University Press, New York.

ter Braak, C.J.F. and P. Šmilauer 1998 CANOCO 4.Software for canonical community ordination. Center for Biometry, Wageningen, The Netherlands.

Thorp, R.W. , D.S. Horning, and L.L Dunning. 1983. Bumble bees and cuckoo bumblebees of California (Hymenoptera: Apidae). Bulletin of the California Insect Survey 23:viii + 79 pp.

U.S. Code of Federal Regulations. 1994. Endangered and threatened plants. 50 §17.12.

U.S. Dept. of Agriculture, NRCS. 2002. The PLANTS Database, v. 3.5. National Plant Data Center. Baton Rouge, LA.

U.S. Fish and Wildlife Service 1995. Endangered and threatened wildlife and plants, proposed Endangered status for two tidal marsh plants: the Suisun thistle and soft bird's beak from the San Francisco Bay Area; Proposed Rule. June 12, 1995. Federal Register 60(112):30999-31006.

USFWS. 1985. Salt Marsh Bird's Beak (*C. maritimus* subsp *maritimus*) recovery plan. Portland OR. 92 pp.

USFWS. 1984. Recovery plan for salt marsh bird's beak (C. maritimus maritimus ssp. maritimus). U.S. Fish and Wildlife Service. Portland, Oregon. U.S.A.

Vanderwier, J. M., and J. C. Newman. 1984. Observations of haustoria and host preference in *C. maritimus* ssp. *maritimus* at Mugu Lagoon. Madroño 31: 185-186.

Zedler, J. B. 1998. Replacing endangered species habitat: the acid test of wetland ecology. Pages 364-379 in Conservation Biology for the Coming Age. P. L. Fiedler and P. M. Karevia, editors. Chapman and Hall. New York.

Zedler, JB. 1996. Ecological function and sustainability in created wetlands. In *Restoring Diversity: strategies for reintroduction of endangered plants*, eds. DA Falk, CI Millar and M Olwell. Washington, DC: Island Press.

Appendices

Appendix I.

Sample Collection and Analysis Summary

Appendix II.

Soft Bird's Beak Micro-site Hydrologic Studies-2001

Appendix III.
Field Guide to Insect Fauna Associated with Soft Bird's Beak

Appendix I.

Sample Collection and Analysis Summary

As Specified in Contract Deliverables, Scope of Services, CALFED 99-NO5

CALFED 99 - NO5 Phase I. Deliverable Work Product
RECORD OF ANALYSES AS SPECIFIED IN CONTRACT SCOPE OF SERVICES

Table 1. Research site and code names

SITE NAMES	SITE CODES
Southampton Marsh- Benicia	BSRA
Hill Slough - East	HILL
Joice Island	JOIC
Fagan Slough - Napa	NAPA
Potrero - Hill Slough	POTR
Rush Ranch	RUSH

Table 2. Total In Situ Field Measurements: Habitat Data

	BSRA	HILL	JOIC	NAPA	POTR	RUSH
Plant Species Presence	45	60	45	45	45	60
% Plant Cover	45	60	45	45	45	60
Plant Canopy Height	45	60	45	45	45	60
PAR*	45	60	45	45	45	60
% Gaps	45	60	45	45	45	60
Hydrologic Position	45	60	45	45	45	60
Relative Elevation	45	60	45	45	45	60
Bird Species Presence	45	60	45	45	45	60

*PAR=Photosynthetically Active Radiation

Total field measurements: 2040

Table 3. Total Field Sample Collections

	BSRA	HILL	JOIC	NAPA	POTR	RUSH
Soil - Texture	45	60	45	45	45	60
Soil - Bulk Density	45	60	45	45	45	60
Soil - % Water Content	45	60	45	45	45	60
Soil - Organic Matter	45	60	45	45	45	60
Soil - Salinity	45	60	45	45	45	60
Soil - Cations	45	60	45	45	45	60
Soil - Anions	45	60	45	45	45	60
Soil - Nutrients	45	60	45	45	45	60
Plant Seed	0	9000	800	0	9000	0

Total samples collected: 20,840

CALFED 99 - NO5 Phase I. Deliverable Work Product

Table 4. Total Phase I Lab Analyses

	BSRA	HILL	JOIC	NAPA	POTR	RUS
Soil Wet Weight	45	60	45	45	45	60
Soil Oven Dry Weight	45	60	45	45	45	60
Grinding of soil	45	60	45	45	45	60
Seiving of soil	45	60	45	45	45	60
Soil Bulk Density	45	60	45	45	45	60
Soil % Water Content	45	60	45	45	45	60
Loss-On-Ignition	45	60	45	45	45	60
Soil Texture	45	60	45	45	45	60
Soil Saturation Pastes	45	60	45	45	45	60
Saturation Paste Extract	45	60	45	45	45	60
Soil Salinity	45	60	45	45	45	60
Cation Dilutions	45	60	45	45	45	60
Anion Dilutions	45	60	45	45	45	60
Ca:Mg	45	60	45	45	45	60
K	45	60	45	45	45	60
Na	45	60	45	45	45	60
Cl	45	60	45	45	45	60
SO_4	45	60	45	45	45	60
PO_4	45	60	45	45	45	60
Total N	45	60	45	45	45	60
Total C	45	60	45	45	45	60
Total P	45	60	45	45	45	60
Sodium Absorption Ratio	45	60	45	45	45	60
Seed Counts	45	60	45	45	45	60
Seed Packaging/Cold Storage	45	60	45	45	45	60
Seed Pregermination Treatments	45	60	45	45	45	60

Total samples analyzed: 6630

CALFED 99 - NO5 Phase i. Deliverable Work Product

Table 5. Area, number of plants and number of patches of COMO populations surveyed in 2000.

		2000		
LOCATION	SITE	AREA (m2)	# PLANTS	# PATCHES
Fagan Slough	NAPA	1307	3716	11
Hill Slough	HILL	18972	271215	145
Joice Island	JOIC	638	3076	13
Southampton Marsh	BSRA	1956	29809	29
Beldons Landing	JOIC	0	0	0
Rush Ranch	JOIC	0	0	0

CALFED 99 - NO5 Phase II Deliverable Work Product

Table 6. Supplemental Soil Analyses Phase II

SITE	Total Carbon	Total Nitrogen	Total P	OM by LOI
Rush	12	12	12	12
HILL SLOUGH	12	12	12	12

PHASE II. Reintroduction Experiment.
Planted ten Experimental Blocks with C. mollis seed collected and processed in Phase
Soft bird's beak plant density counts in 120 experimental units.
Ten above ground biomass samples collected from 0.25m^2 plots, oven dried and weighted in laboratory.

PHASE II. Demographic Measures

2001. Tagged 60 plants at Hill Slough
2001. Tagged 60 Plants at Rush Ranch
Measured growth and recorded life stage biweekly through season.
Measured plant performance metrics, 120 samples.

2002 Tagged 25 plants, Hill Slough
2002 Tagged 25 plants Rush Ranch
2002 Tagged 25 plants Benicia Bay site
2002 Tagged 25 plants Benicia BSRA mound site
Additional special seedbank Study:
Planted 24 plots with 75 seeds each, clipped 12, 12 controls
Tagged 12 control plants, 12 clip plants Rush Ranch
Tracked weekly growth and recorded life stage transitions all plants.
End season – performance metrics measured. All plant material returned to field sites.

Plant community composition and structure data, PAR, and sunfleck fraction data collected from 39 experimental plots during seedling emergence period, 2002.

PHASE II. Potential Pollinator Study.
Voucher specimens stored in Wetland Research Lab, UCD. Lepidopteran voucher specimens submitted to UC Davis Bohart Entomology Museum. Saphenista, sp. Moth specimens on loan to Systematic Entomology Laboratory, USDA National Museum of Natural History, Washington, D.C.

PHASE II. Hydrology Study.
Tide stage data collected hourly through 2001 and 2002 growing season from six Remote Data Systems continous recording shallow water data acquisition system. Data downloaded from field recorders biweekly and processed on PC in laboratory.

Appendix II. Soft Bird's Beak Micro-site Hydrologic Studies-2001

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Introduction:

Tidal hydrology is one of the key environmental factors influencing the limited distribution of *Cordylanthus mollis* (*C. mollis*). Hydrologic study and evaluation of the habitat where these rare plant populations are found was conducted to develop information which may facilitate success in future rare plant restoration efforts.

Tide stage data is recorded continuously by the Department of Water Resources (DWR) in various large channels and sloughs throughout Suisun Marsh. However, these data do not characterize the micro-site hydrologic conditions associated with *Cordylanthus mollis* ssp.*mollis*. We hypothesize that water regime characteristics such as depth, duration, and frequency of flooding within this intertidal zone are essential components in determining the establishment and success of *C. mollis.* We obtained six Remote Data Systems WL-20 capacitance sensor water level recorders with wireless Hewlett-Packard infrared data links for data retrieval and programming. These shallow water level monitoring systems continuously monitor hydrologic conditions in selected soft bird's beak habitat. A comparative hydrologic study was conducted in 2001 to begin to understand the intricate link between soft bird's beak success and tidal regimes

Research Questions:

- What are the hydrologic differences across an intertidal gradient of soft bird's beak habitat in a natural reference population vs. the reintroduction site?

- What role does hydrology play in determining the differential demographic success within a single site?

- How do hydrologic conditions vary across the geographic range of monitored soft Bird's Beak reference populations at six sites between Napa Marsh and Suisun Marsh in the San Francisco Estuary?

II-1. Hydrology Across an Intertidal Gradient

Methods:

Experimental Design

Hydrologic monitoring was established in a transect across an intertidal gradient at our reference site, Hill Slough - Potrero, and at our restoration site, Rush Ranch. At each site a recorder was installed in the highest intertidal zone above C. mollis (upper zone), within the *C. mollis*, and in the intertidal zone just below C. mollis (lower zone). The water recorders were calibrated to record surface water depth and were set to take hourly readings. The field recorders stored data for approximately three weeks, after which a manual download was necessary. A hand-held calculator with IR technology mediated data transfer between the water recorders and personal computer.

In addition, we obtained stage data from DWR for their S-4 field station in the main channel of Hill Slough. The spatial separation between the channel and the tidal creek at the restoration site is approximately one mile. Depth, duration, and frequency of flooding will be compared between sites and intertidal zones. The study was conducted from March 1 through June 30, 2001.

Results and Discussion:

The Hill Slough stage recorder (S-4) takes readings in the main channel every fifteen minutes. The metrics of this data were formatted for comparison with the data collected from our water level recorders. The graphical representation of the Hill Slough data is characteristic of the mid-Pacific Coast mixed semi-diurnal tide cycle, which represent two tidal sequences daily. The timing of the high tide at the S-4 station is delayed approximately four hours from the high tide occurrence at the Golden Gate entrance to the Central San Francisco Bay. The high tide occurrence between the main channel station and the *Cordylanthus* intertidal zone at the restoration site is further delayed by approximately one hour. The lag time associated with the reference plant

population at Hill Slough is an additional 1.5-2 hours from the S-4 station in the main channel.

During a large tidal cycle event (March 4-9), the flooded Hill Slough channel at high tide corresponded with the occurrence of a gradient of standing water within the intertidal zones at both the restoration site and the reference site. The depth of standing water in each of the intertidal zones was greater at the restoration site than at the reference site, which indicates a stronger hydrologic influence. At Rush Ranch, the timing of the high tide mark over this particular cycle was approximately one hour later than at the S-4 station. The tidal pulse within soft bird's beak habitat at the reference tidal marsh at Hill Slough Wildlife Area, Potrero Hill, which is further east in proximity to the tidal source, was two hours delayed from the S-4 station. This general timing pattern was characteristic of the data collected over the duration of the study.

The three hydrologic parameters determined to be of key interest to our restoration efforts were frequency, depth, and duration of flooding. The values for these three parameters showed a decreasing trend with an increasing distance away from the tidal source to produce an intertidal hydrologic gradient. At both the reference and restoration sites, the lower zone just below the *C. mollis* zone experienced the most frequent flooding, most cumulative hours of flooding, and the greatest depth of flooding. Conversely, the upper zone just above *C. mollis* experienced the lowest values of those same metrics at both sites. When comparing between the two sites, however, there are some marked differences in hydrology that may play a role in the differential demographic success we observed between populations of *C. mollis*. The total flooding frequency in all three zones at Rush Ranch for the duration of this study was 58. The reference site only experienced a total of 47 flooding occurrences in the three zones (Table II-1, II-2). Looking at the *Cordylanthus* zones between the reference and restoration populations, the maximum flooding depths were 9.9cm and 15cm, and the duration of flooding was 31 hrs.and 207 hrs. respectively (Table II-1, II-2).

Table II-1.1. Rush Ranch Spring Branch Restoration Site Hydrology 2001.

Hydrologic characteristics between intertidal zones at Rush Ranch *Cordylanthus* site March 1-June 30, 2001

Hydrologic Parameter	**Above *Cordylanthus***	**Within *Cordylanthus***	**Below *Cordylanthus***
Maximum Depth of Flooding (cm)	11.2	15	25.4
Average High Tide Flooding Depth	4.6	6.8	6.8
Average Flooding Depth (cm)***	1.8	2.4	3.1
Depth of Flooding Range (cm)	1.3 to 11.2	1.3 to 15	1.3 to 25.4
Cumulative Hours of Flooding*	193	207	1070
Cumulative Hours Dry**	2735	2721	1858
Frequency of Flooding^	9	11	38

*Hours flooded with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

Table II-1.2. Hill Slough Reference Marsh Comparative Hydrology, 2001.

Hydrologic characteristics between intertidal zones at Hill Slough/Potrero reference site March 1-June 30, 2001

Hydrologic Parameter	**Above Cordylanthus**	**Within Cordylanthus**	**Below Cordylanthus**
Maximum Depth of Flooding (cm)	6.1	9.9	20.1
Average High Tide Flooding Depth (cm)	4.7	4.12	7.8
Average Flooding Depth (cm)***	2.2	3.6	5.2
Depth of Flooding Range (cm)	1.3--6.1	1.2 to 9.9	1.3to 20.1
Cumulative Hours of Flooding*	28	31	1160
Cumulative Hours Dry**	2905	2894	1783
Frequency of Flooding^	6	14	27

*Hours flooded (Duration) with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

Table II-1.3. Tidal wetland hydrologic characteristics within *Cordylanthus* occupied habitat at reference and restoration sites March – September 2001.

Tidal wetland hydrologic characteristics within Cordylanthus mollis occupied habitat March 1-September 30, 2001.

Hydrologic Parameter	**Reintroduction Habitat/ Rush Ranch**	**Reference Habitat/Hill Slough-Potrero**
Maximum Depth of Flooding (cm)	15	9.9
Average High Tide Flooding Depth (cm)	4	5.1
Average Flooding Depth (cm)***	2.2	3.3
Depth of Flooding Range (cm)	1.3 to 15	1.3 to 9.9
Cumulative Hours of Flooding*	760	63
Cumulative Hours Dry**	4376	5073
Frequency of Flooding^	37	23

*Hours flooded with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

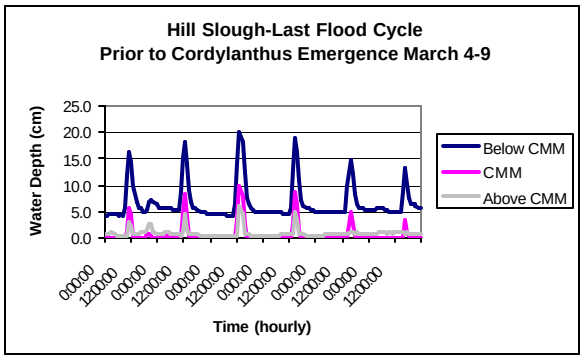
Hydrology Across an Intertidal Gradient

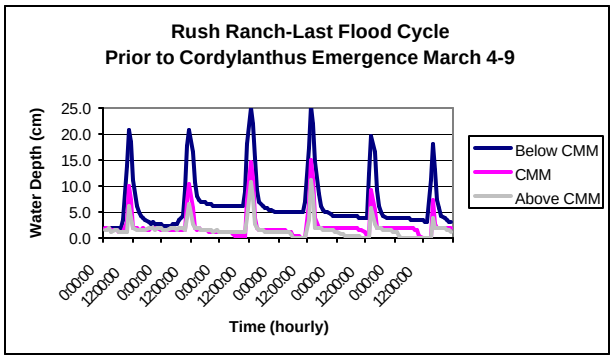
At Soft Bird's Beak Occupied Sites, 2001

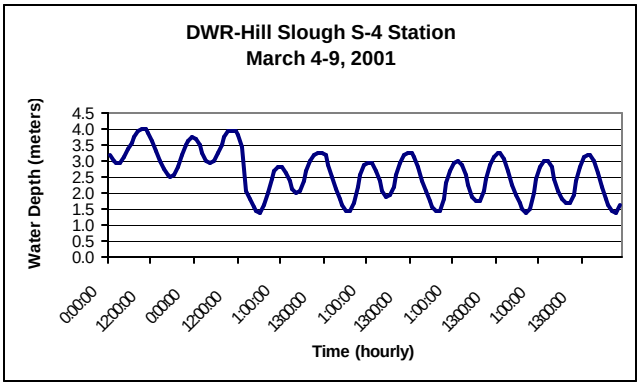
Comparison Graphs – Representative Tidal Cycles

During Soft Bird's Beak Key Life History Stages

Fig. II.1.1.March 2001– Last Inundation Prior to Soft Bird's Beak Seedling Emergence

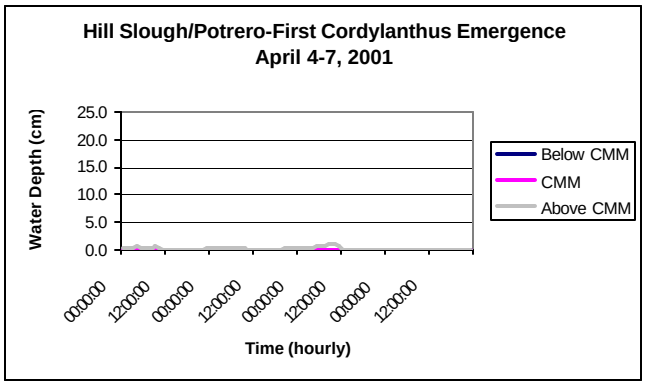


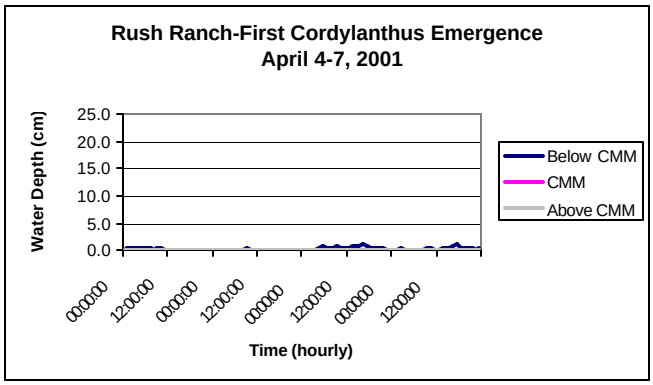


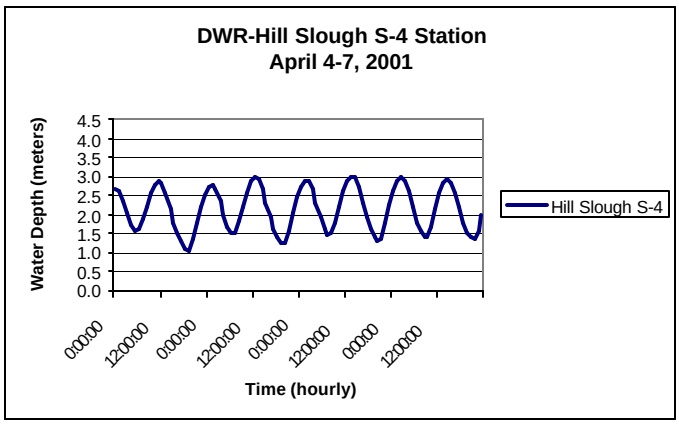


--Over this particular study period, there appears to be a 1-hour lag time of the high tide max. water depth between the Cordylanthus zone at Rush Ranch and the main channel @Hill Slough (S-4).
--There appears to be approx. a 2-hour time lag of the high tide max. water depth between the main channel and the Cordylanthus zone @ Hill Slough /Potrero.

Fig. 11.1.2. April 4-7, 2001 Tidal Conditions During First Seedling Emergence

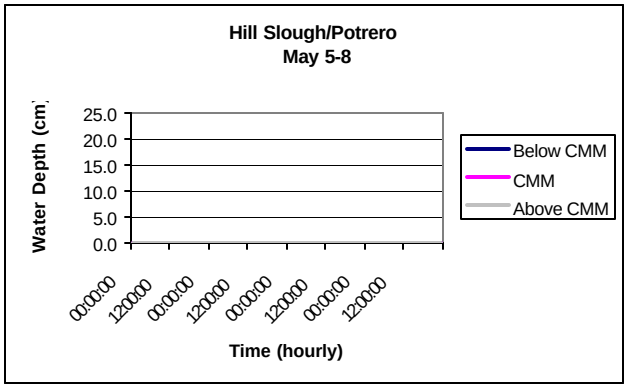


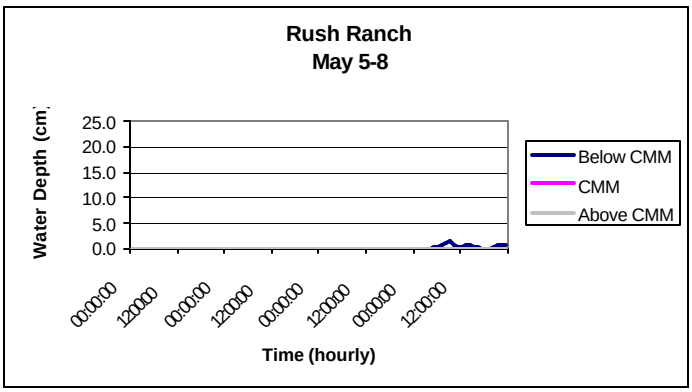


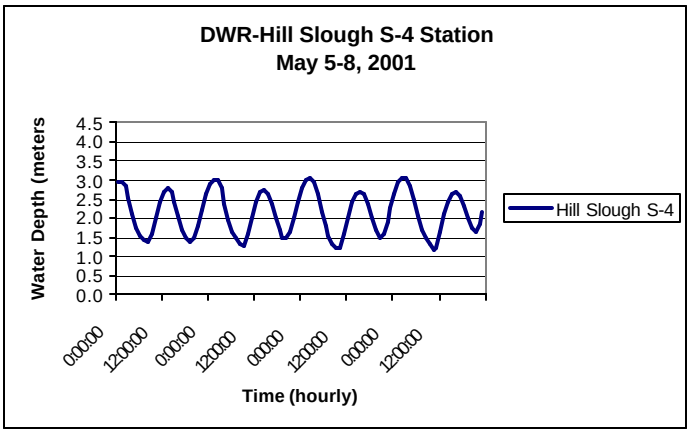


--The average depth in the main channel (S-4) is 2.1 meters over this partucular period. In comparison, the average depth in the main channel during a wet period (March 4-7) was 2.6 meters This translates into relatively dry microsite hydrologic conditions in the Cordylanthus zone.

Figure II.1.4. May 5-8, 2001. Tidal Conditions During Seedling Growth. Flooding does not reach soft bird's beak during these reduced tidal range cycles.

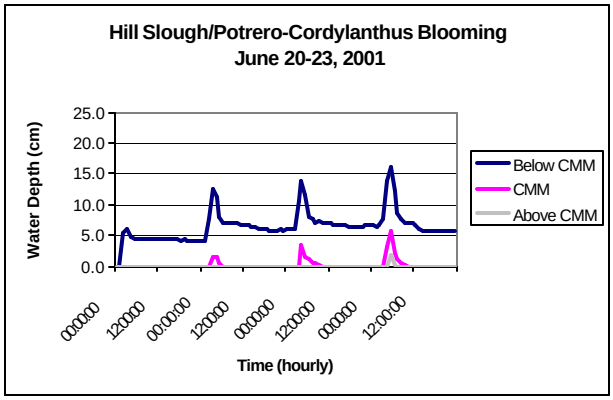


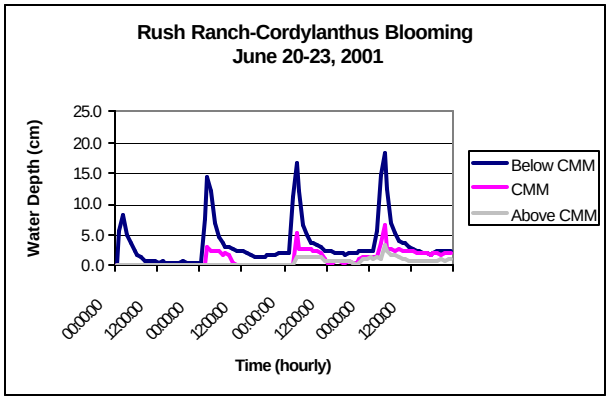


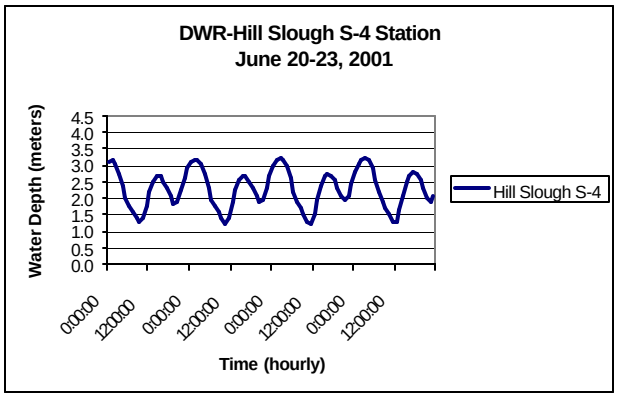


--The average water depth in the main channel is 2.2 meters over this period. This is slightly higher than the value generated for April 4-7, however, the tides still aren't high enough to translate into standing water conditions in the Cordy zone at either site.

Fig. II.1.5. June Flowering Period – June 20-23, 2001 Tidal Cycles.







--A similar lag effect is observed over this time period, with a high tide depth reaching its maximum initially at the main cahnnel, followed an hour later by Rush Ranch, and two hours later at Hill Slough/Potrero.

II-2. Within Marsh Microsite Hydrology: Successful vs. Unsuccessful Soft Bird's Beak Habitat

Methods:

Experimental design

Recorders were positioned within *Cordylanthus* occupied habitat at both the reference site (Potrero Hills) and at the reintroduction site (Rush Ranch). Two recorders were placed in the lower-high zone at each site, one recorder in an area of high seedling mortality and low plant density (unsuccessful) and another in an area of low seedling mortality and high plant density (successful). The role of hydrology in shaping the differential establishment and survival of *Cordylanthus* in this middle intertidal zone was evaluated in terms of depth, duration, and frequency of flooding.

The recorders were calibrated to measure standing water levels in the *Cordylanthus* zone and were set to record hourly data. The study was initiated on July 19, 2001 and commenced on August 13, 2001, and the time period bracketed significant summer tidal cycles that flood soft bird's beak habitat.

Results and Discussion:

The timing of the intra-site hydrology study captured a special tidal cycle event, which spanned from approximately the 19th through the 22nd of July 2001. Over the course of this particular event, the frequency of flooding between the successful and unsuccessful plots was identical with 5 occurrences at the restoration site. However, at the reference site, there were 5 flooding occurrences in the successful plot and only 3 in the unsuccessful plot. At both the reference and the restoration site, the maximum flooding depth was greater in the successful plots versus the unsuccessful plots with values of 8.4cm and 5.1 at Hill Slough - Potrero and 14.0 and 10.2 at Rush (Table II-4,II-5). The flooding duration values were similar when comparing the successful to the unsuccessful at each respective site. However, Rush experienced a total of 95 flooded

hours in the successful plot, whereas Hill Slough - Potrero was flooded for only 23 total hours in the successful plot (Table II-4,II-5).

Table II-4.

Hydrologic characteristics Hill Slough/Potrero reference site July 19-23, 2001

Hydrologic Parameter	Successful Habitat	Unsuccessful Habitat
Maximum Depth of Flooding (cm)	8.4	5.1
Average High Tide Flooding Depth (cm)	5.4	2.4
Average Flooding Depth (cm)***	3.3	2.8
Depth of Flooding Range (cm)	1.3--8.4	1.5--5.1
Cumulative Hours of Flooding*	23	22
Cumulative Hours Dry**	97	98
Frequency of Flooding^	5	3

*Hours flooded (Duration) with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

Table II-5.

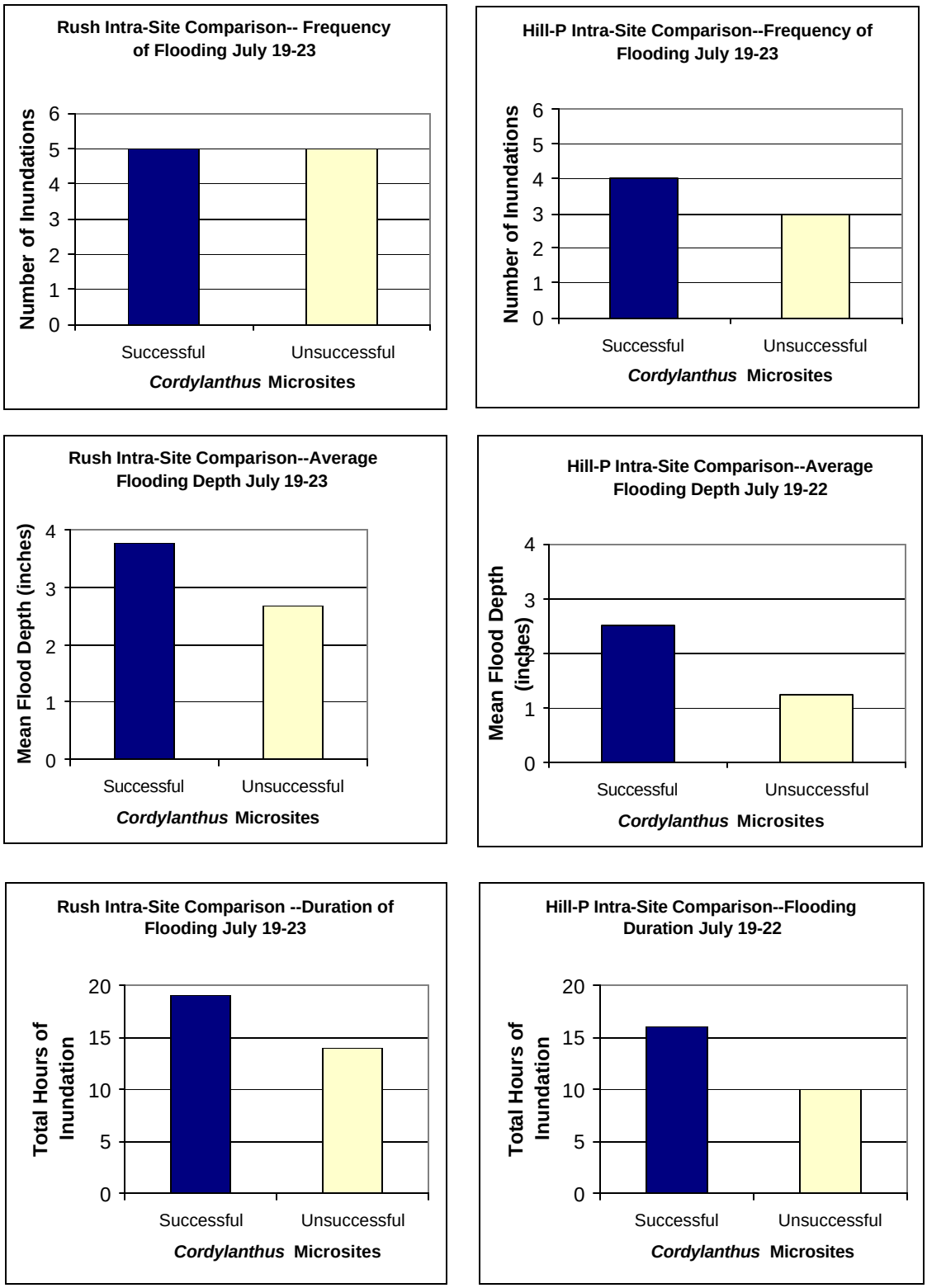
Hydrologic characteristics at Rush Ranch reintroduction site July 19-23, 2001

Hydrologic Parameter	Successful Habitat	Unsuccessful Habitat
Maximum Depth of Flooding (cm)	14	10.2
Average High Tide Flooding Depth (cm)	9.5	6.8
Average Flooding Depth (cm)***	2.5	2.8
Depth of Flooding Range (cm)	1.3--14	1.3--10.2
Cumulative Hours of Flooding*	95	94
Cumulative Hours Dry**	25	26
Frequency of Flooding^	5	5

*Hours flooded (Duration) with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

Within a single site or population of *C. mollis*, there can be successful microsites where plants are vigorous, of incredible size and stature for this species. There are also less successful microsites where plants appear reduced, stunted, and demographic success reported elsewhere in this report is poor. While there are numerous “environmental factors” responsible for determining the success of individual plant growth, it is evident from this study that subtle differences in hydrology may play a key role. These hydrologic differences (in terms of frequency, depth, and duration) that we observed from this micro-site study seem to offer part of the answer as to why plants within the same site experience such large differences in demographic success (Fig.II-2.1).

Fig. II-2.1. Frequency, depth, and duration of flooding within successful and unsuccessful soft bird's beak habitat.



II. 3. Inter-Site Hydrology Study

Methods:

Experimental Design

Hydrologic monitoring was established in four separate populations of *Cordylanthus* for a special 14-day study marking the tidal cycle associated with the new moon high tides for the month of August. Recorders were placed in successful *Cordylanthus* habitat at Hill Slough - Potrero Hill, Rush Ranch, Southampton Marsh site at the Benicia State Recreation Area, and at Fagan Slough Ecological Reserve in Napa Marsh. Differences in standing water depth, duration, and frequency of flooding over a regional estuarine gradient and throughout the range of soft bird's beak habitat will be evaluated.

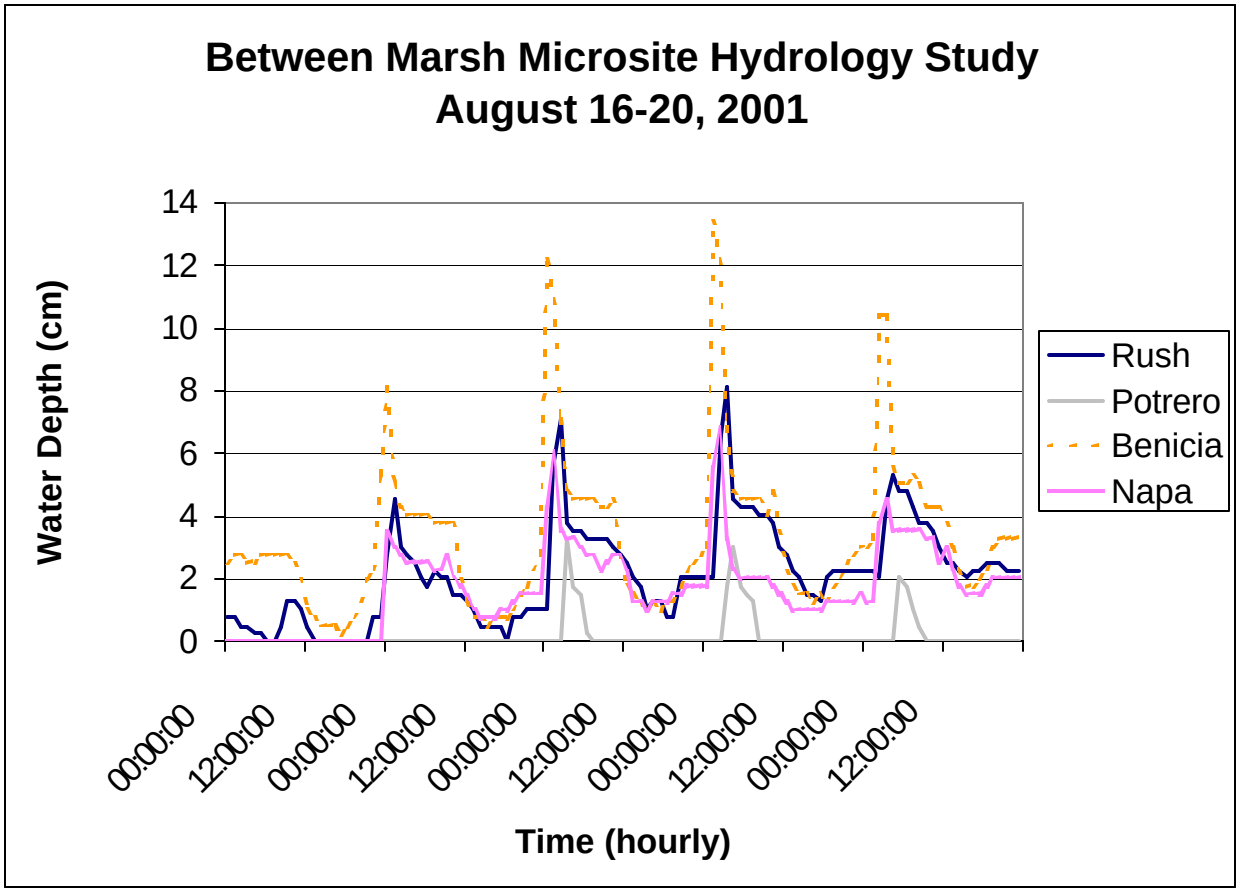
The recorders were calibrated to take hourly measurements of standing water depth. This study was initiated on August 13, 2001 and ended on August 27, 2001.

Results and Discussion.

The most pronounced flooding throughout the estuary for this particular tidal cycle occurred between the 16th and 20th of August. Over the course of these five days, there was an inter-site variance of flooding within the different *Cordylanthus* zones. Benicia experienced the greatest frequency of water inundation with 5 occurrences. Napa and the restoration site at Rush Ranch experienced flooding on 4 and 5 occasions respectively. Hill Slough - Potrero experienced the lowest flooding frequency with only 3 occurrences (Figure II.3.1).

The maximum flooding depths between the four different sites were equally as variable. The deepest flooding occurred at Benicia with a depth of 13.5cm. Rush Ranch experienced 8.1cm of standing water in the Cordylanthus zone and Napa and Potrero had 6.9cm and 3.3cm of standing water respectively (Figure II.3.1). The total number of

Figure. II.3.1. Between marsh hydrology Aug. 16-20, 2001.



hours flooded was greatest at the Benicia site with 103 hours. Napa and Rush were similar with 83hrs. and 84hrs. respectively. Potrero experienced the fewest total hours of flooding, resulting in a total of only 11 hours flooded.

Analysis of the three water regime characteristics displays physical hydrologic differences between the sites (Table II.3.1).

Table II.3.1. Hydrologic characteristics between occupied habitats,Aug. 2001.

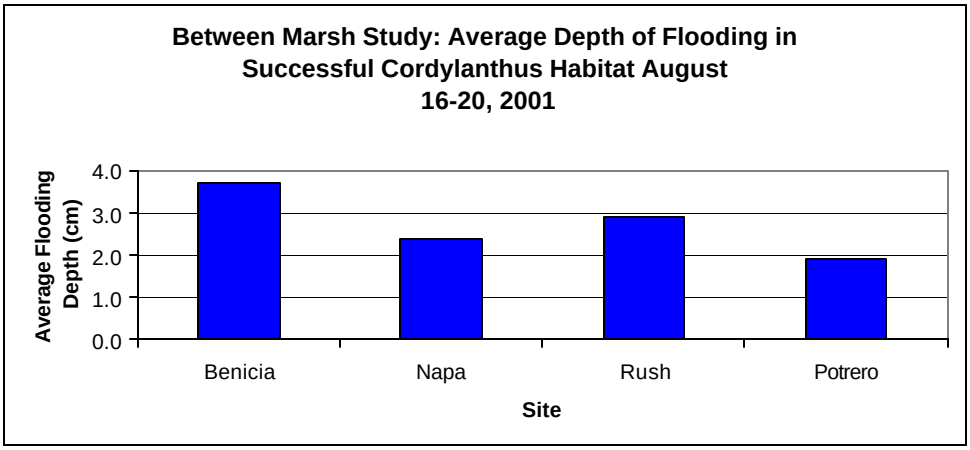
Hydrologic characteristics between *Cordylanthus* occupied habitats across extant range August 16-20, 2001

Hydrologic Parameter	**Rush**	**Potrero**	**Benicia**	**Napa**
Maximum High Tide Depth of Flooding (cm)	8.1	3.3	13.5	6.9
Average High Tide Flooding Depth(cm)	5.3	1.7	9.4	4.2
Average Flooding Depth (cm)***	2.9	1.9	3.7	2.4
Depth of Flooding Range (cm)	1.3-- 8.1	1.3--3.3	1.3--13.5	1.3--6.9
Cumulative Hours of Flooding*	84	11	103	83
Cumulative Hours Dry**	36	109	17	37
Frequency of Flooding^	5	3	5	4

*Hours flooded (Duration) with depth>1cm
**Hours with < 1cm standing water in Cordylanthus zone
^Tidal Frequency (# of Tidal pulses)
***Avg. Depth of Flooding over study period>1cm

By looking at the timing of the high tide mark each day, it is evident that there are also fairly distinct temporal distinctions regarding depth, duration, and frequency of flooding throughout the estuarine gradient of Cordylanthus habitat. Using the 19th of August as a representative day within this particular tidal cycle, the high tide mark at Benicia occurred at 2 a.m. Water reached its maximum depth at 3 a.m. in the Napa marsh. The high tide mark at Rush occurred at 4 a.m. and Potrero an hour later at 5 a.m.. The temporal separation associated with these flooding parameters increases as one travels upstream from the Golden Gate tidal source.

Figure II.3.2 Depth characteristics of hydroperiod between sites. August 2001.



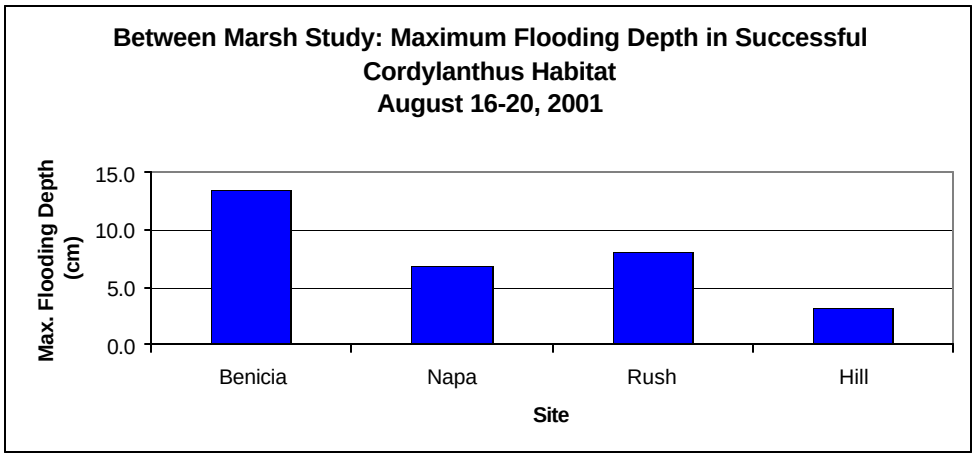


Figure. II.3.3. Duration of flooding August 16-20, 2001 among sites.

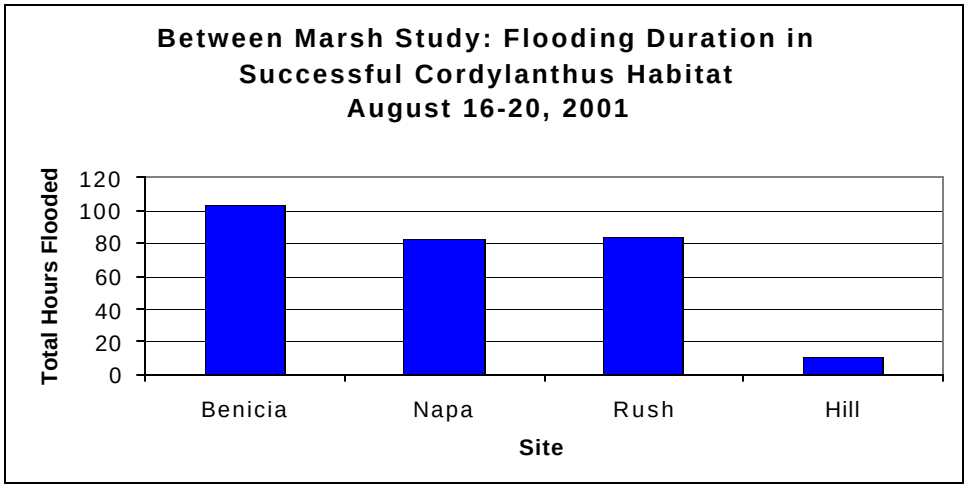
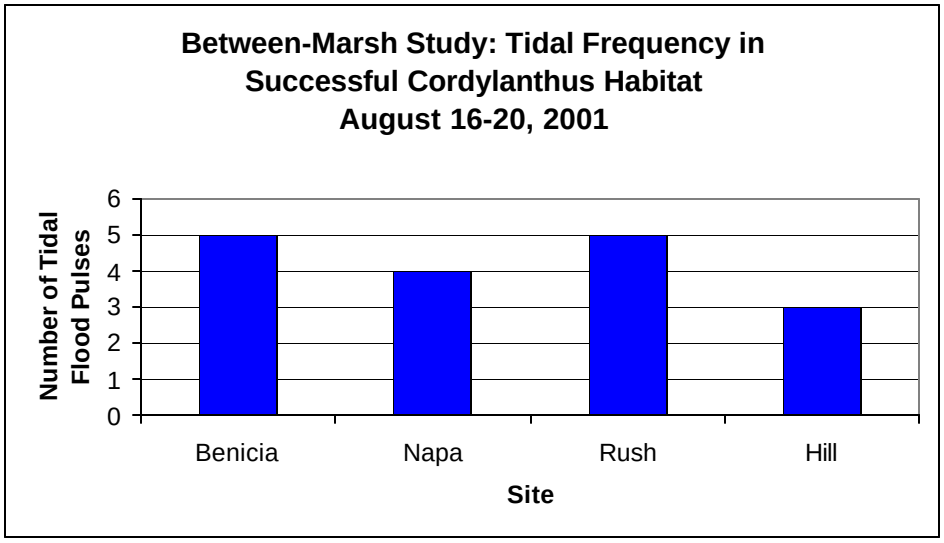


Figure II.3.4. Frequency of flooding hydroperiod characteristic between sites, August 16-20, 2001.



Appendix III.

FIELD GUIDE TO INSECT FAUNA ASSOCIATED WITH SOFT BIRD'S BEAK

Prepared by Prairie Rose Hyde and Miles A. DaPrato,
Line illustrations by Prairie Rose Hyde
Department of Environmental Science and Policy
University of California, Davis

Carder Bee

Anthidium edwardsii Cressen
Anthophoridae

DESCRIPTION

A edwardsii are medium sized bees with a characteristic rapid flight and high-pitched whine. Adults range from 6-12 mm; they are stout, cylindrical, with the abdomen curled downward toward the tip; gray or black, marked with yellow spots distinctively arranged in rows along the abdominal segments. Females have black base color with yellow bands. Males have distinctive reddish-brown (to dark brown, black) coloration with bright yellow bands.

Figure 1. *Anthidium edwardsii* Cressen

DISTRIBUTION

Ranges throughout CA, ID, OR, and WA. In California, this species is found in the coastal ranges through the central valley into the Sierra Nevada foothills. *A. edwardsii* is one of the most common bee species in California.

BEHAVIOR AND ECOLOGY

Dietary generalist associated with a number of plant families (Grigarick and Stange). Has been observed on a number of species in Scrophularaceae family. Important pollinator of *Cordylanthus maritumus* ssp. *maritimus* in southern California (Lincoln, Parsons and Zedler). Observed pollinating *Cordylanthus mollis* sp. *mollis* populations at Fagan Slough (1993), Hill Slough (1994, 2000, 2001) and Rush Ranch (2001).

Moves rapidly, hooked hairs on underside of abdomen used to pry open flower and aid in pollen collection (Ruygt). Grasps flowers and inserts head and abdomen or crawls totally inside. May visit same flower repeatedly. Aggressive towards other *Anthidium* individuals and other bee species.

Burrows may be formed in plant stems or in abandoned burrows of other insects or spiders. Females
gather cottonlike plant fibers from various plants to line cells. A pollen ball is provided for the larvae. Natural enemies include parasitoids from other hymenopterous families (Grigarick and Stange)

Figure 2. *A. edwardsii* pollinating *C. mollis* ssp *mollis* at Rush Ranch, 2001.

Grigarick, A. A. and L. A. Stange. 1968. Bulletin of the California Insect Survey, Vol. 9: The pollen-collecting bees of the Anthidiini of California (Hymenoptera: Megachilidae). University of California Press, Berkeley.

Ruygt, J. 1994. Ecological studies and demographic monitoring of soft bird's beak, *Cordylanthus mollis* spp. *mollis*, a California listed rare plant species. Napa Botanical Survey Services, Napa CA. A report to California Department of Fish and Game, Sacramento, CA.

Parsons, LS and JB Zedler. 1997. Factors affecting re-establishment of an endangered annual plant at a California salt marsh. Ecological Applications 7:253-267.

Leaf Cutter Bee

Melissodes sp.
Megachilidae

DESCRIPTION

Robust, hairy medium sized bees capable of swift and powerful flight. Bands of pale hair on the abdomen.

Melissodes species collected at Rush Ranch, 2001 (P.R. Hyde, illustration).

DISTRIBUTION

BEHAVIOR AND ECOLOGY

Generalist pollinator, M. Microseita and M. rustica forage for pollen early in the day, a similar pattern has been observed throughout the genus (Cameron et al.). This species has been observed in *Cordylanthus mollis* ssp. *mollis* populations at Hill Slough (2000, 2001) and Rush Ranch (2001). It was also seen visiting *Frankenia salina* flowers at the same time. It is probable that all Melissodes are solitary nesters, but gregarious nesting is common throughout the genus (Miliczky).

REFERENCES

Hurd, 1979. Genus Melissodes Latreille. Pp 2130-2156 *In* K.V. Krombein et al. Catalog of Hymenoptera in America north of Mexico.

La Berge, W. E. 1961. A revision of the bees of the genus Melissodes in Morth and Central America. Univerisity of Kansas Scientific Bulletin 37: 911-1194.

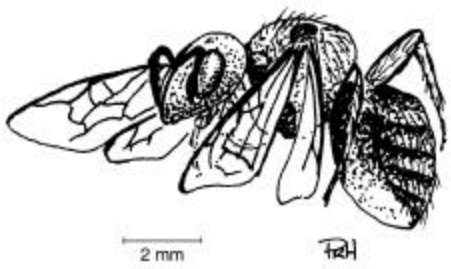
Cameron, et al. 1996. Nesting biology and foraging behavior of… Journal of the Kansas Entomology Society 69: 260-273.

Sweat Bee

Halictus (Seladonis) tripartitus Cockerell
Halictidae

DESCRIPTION

Adults are small to medium sized (4-15 mm body length); brown/black with faint metallic tints, often with distinct, pale hair bands on the abdomen. In females the last visible abdominal segment is split longitudinally on the upper side. Distinguished from *Lassioglossum* by presence of pale hair bands on the posterior margins of metasomal terga.



Halictus (Seladonis) tripartitus Cockerell

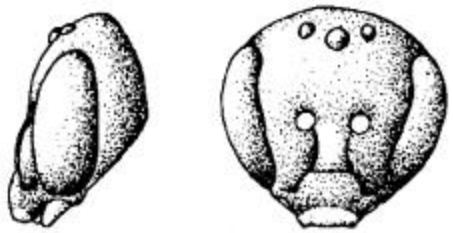
DISTRIBUTION

Ranges from Idaho, Colorado, and Texas west to Washington, California and Baja California. Among California's most common bees. They are found virtually throughout the state except at the highest ranges.

BEHAVIOR AND ECOLOGY

As a genus, these *Halictus* bees visit a large number of flowering species for pollen and nectar. May visit distinct or restricted groups of flowering species as aggregates or species at the local level. We have observed this species on *Cuscuta salina*, *Frankenia salina*, and *Apium graveolens* in addition to *Cordylanthus mollis* sp. *mollis*. We have observed this species on *C. mollis* sp. *mollis* populations at Hill Shough-Lawler Ranch (1994), Hill Slough-Potrero (2000, 2001), and Rush Ranch (2001). Small size may limit pollination effectiveness for C. *mollis* sp. *mollis*.

Most species in this genus are aggregatory and nest in fine, loosely grained bare soil with the capacity to retain moisture in drought and shed water during rains (Roberts 1973). Nests are vertical burrows with contiguous brood cells below the "level of cultivation." Overwinter as inseminated immature queens in abandoned burrows. Will produce three or more generations over the season. Workers have three-week life span (Roberts 1973).



Head of male H. tripartitus (from Roberts 1973).

Sweat Bee

Lassioglossum (Dialictus)
sp.Halictidae

DESCRIPTION

Minute to moderated sized bee, large for Halictidae (6-11 mm). Normally black, with no apical bands. Basal tergal bands or basal lateral patches of pale hair overmuch of tergal surface. Weakened distal veins of forewing is typical of genus.

DISTRIBUTION

Abundant, most common genus of bees in most north temperate localities. Nineteen species north of Mexico. California??

BEHAVIOR AND ECOLOGY

In our observations, this bee is a generalist, visiting several different plant species, including Frankenia salina and Cuscuta salina in addition to Cordylanthus mollis sp. mollis.

Species in this genus include both solitary and eusocial species. Most are assumed to be solitary, but communal behavior has been reported for some species.

REFERENCES

McGinley, F. J. 1986. Studies of Halictinae (Apoidea: Halictidae) I: Revision of new world Lasioglossum Curtis. Smithsonian Institute Press, Washington, D.C.

Californian Bumble Bee,

Bombus (Fervidobombus) *californicus*
Smith
Bombilidae

DESCRIPTION
The queens are 20 to 24 mm long, and have yellow pile on the anterior half of the thorax and a single yellow stripe across the fourth abdominal segment. The workers have the same general yellow markings. They vary greatly in length, from 12 to 22 mm. Neither queens nor workers have yellow pile on the head. This species has been confused with B. vosnesenskii, but has black pile on the face.

DISTRIBUTION
This species ranges form the eastern slopes of the Rocky Mountains to the Pacific Ocean and from British Columbia to Baja California.

BEHAVIOR AND ECOLOGY
Annually social, colonies die out each winter. New colonies are formed in spring by fertile queens that overwinter in protected areas. Nest in cavities in the ground.

Generalist pollinator, we have observed bumble bees pollinating several species, including *Frankenia salina*, *Cordylanthus mollis* sp. *mollis*, and *Lotus corniculatum.*

RELATED SPECIES

Vosnesenski's Bumble Bee,

Bombus (Pyrobombus) *vosnesenski* Radoszkowski

Like *B. californicus* but has yellow pile on face.

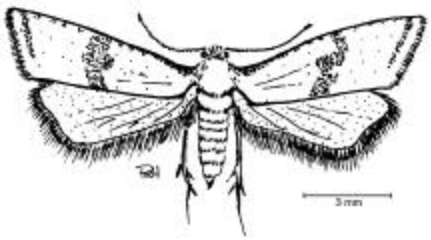
Bombus sp. Observed visiting soft bird's beak flowers and also invasive yellow star thistle in adjacent pastures:

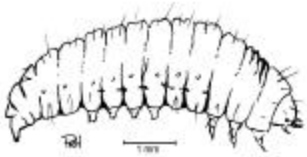
Salt Marsh Leaf Roller Moth

Saphenista sp.
Tortricidae

DESCRIPTION

Adult is dull colored and inconspicuous, 12-16 mm wing span, 5 mm length. Larva is pale, dark brown head, 4 – 6 mm. Adults remain hidden during daylight in foliage, fly in early evening and at night.





Adult and Larva of undescribed Saphenista sp. seed predator of C. mollis sp. mollis.

DISTRIBUTION

Subfamily Tortricidii is cosmopolitan. This is a previously undescribed species; possibly restricted to populations of *Cordylanthus mollis* ssp. *mollis*.
Observed at several marshes ….

BEHAVIOR AND ECOLOGY

Active in early evening and mornings. Emergence observed in early morning after daybreak. After emergence, adults dry wings prior to first flight. Prior to emergence, pupa migrate upward, aided by spines on abdominal segments of pupa.
Eggs are flat, scale like and deposited singly. Ovipostition may be aided by chemical and physical stimuli.
Larvae are capable of rapid ambulatory movement upon emergence. Unknown overwintering strategy.
Enemies include parasatoid wasps (Ichneumonidae, possibly Vespidae), Tachinid, and Sarchophagid flies, ants, and spiders.

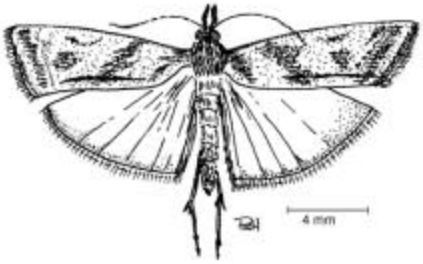
. Adult drying wings and, larva on bract of *C. mollis* sp. *mollis*

REFERENCES

Powell, J. A. 1964. Biological and taxonomica studies on Tortricine moths, with reference to the species in California. University of California Press: Berkeley and Los Angeles.

Salt Marsh Snout-nosed Moth

Lipographis fenestrella

Pyralidae

Pre-dispersal seed granivore which feeds on soft bird's beak developing seed capsules.