THE STATUS AND DISTRIBUTION OF CONTRA COSTA GOLDFIELDS IN SOLANO COUNTY, CALIFORNIA

RESULTS OF CONTRA COSTA GOLDFIELD POPULATION MONITORING FOR 2006, 2007, 2008, AND 2009

SOLANO COUNTY, CALIFORNIA

LSA

June 30, 2010

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RESULTS OF CONTRA COSTA GOLDFIELD MONITORING, 2006-2009

SOLANO COUNTY, CALIFORNIA

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Solano County Water Agency

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TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

Cover Photograph: Director's Guild property playa pool; Photo courtesy of Tim Lacy

INTRODUCTION

In 2006, the Solano County Water Agency (SCWA) received an Endangered Species Act (ESA) Section 6 grant from the US Fish and Wildlife Service to conduct a series of studies to address the life history and status of Contra Costa goldfields (*Lasthenia conjugens*) (CCG) in Solano County to assist in the development of the Solano Habitat Conservation Plan (HCP). These studies include analyses of populations, genetic diversity, and seed bank viability. This report presents the results of the population study conducted over the last several years, a summary of the results of the genetic analysis, the results of the seed bank study, and additional information collected on the distribution of the species throughout the HCP Plan Area as a result of this work.

The purpose of the population study was to develop a sampling program that can provide repeatable and valid density estimates of CCG for management strategies and for monitoring long-term population trends at CCG preserves. Because the majority of the remaining populations within the County are surrounded by or planned for urban development, preserves dedicated to the conservation of this species will have special management needs. A sampling program that will provide repeatable and valid density estimates is essential for assessing the effectiveness of the management program. Already, data collected during the population study has greatly improved our understanding of the distribution, population levels, and typical density ranges for CCG, as well as information on associated species. This data will be useful for developing criteria for restoration efforts currently proposed under the Solano HCP.

Dr. Jennifer Ramp-Neale, at the University of Colorado, conducted the genetic study on CCG in Solano County. The purpose was to expand on her previous work examining DNA-level genetic variation in CCG (Ramp 2004). Ramp's (2004) previous research demonstrated a high level of genetic variability among each CCG population, as well as apparent levels of distinctness between populations (three populations were sampled in Solano County). Given Ramp's findings and general concerns about potential genetic differences among the various extant populations in Solano County, additional genetic studies were implemented for all presumed/potentially distinct populations in the Solano County. The additional genetics studies were considered necessary to develop and support the conservation program for this species and to aid in the development of adaptive management and restoration techniques.

The primary objective of the seed bank study was to determine the carryover and contribution of the soil seed bank to CCG that are growing in any given year. This was done to provide insight into the long-term persistence of populations of CCG and their ability to withstand periods of low to little seed production. Another intention of this study was to address adaptive management techniques that may aid in restoring populations of CCG and/or prevent loss of genetic diversity in the face of future climate change (e.g., prolonged drought).

During the initial development of the Conservation Strategy for the Solano HCP, there was limited information on the distribution and status of CCG populations throughout the County. Distribution information was based on limited CNDDB occurrence data, representing only a few parcels. Based on this occurrence data, known CCG populations and potential habitat areas within Solano County were designated into seven core areas based on similarities in soil types and watershed location. These seven population centers are shown on Map 1 (Appendix A). Additional habitat surrounding these hypothesized core population areas was also identified as potential habitat and/or important watershed/corridor areas. As can be seen on Map 1, the majority of these areas are located around the periphery of, or within, the existing and proposed developed lands within the cities of Fairfield and Suisun City. Large areas of designated core habitat also exist southeast of Suisun City and Travis Air Force Base (TAFB) in subarea 1F and north of TAFB in subarea 1C. The cut off for CCG areas was roughly based on the watershed divide between the Sacramento River/Delta and San Francisco Bay Drainage Province; however, there is limited information on the distribution of CCG in the eastern portions of these core areas.

The research performed as part of the Section 6 grant award to SCWA and the completion of multiple working drafts of the Solano HCP for review, has inspired and facilitated the sharing of information between consultants, private property owners and SCWA on the distribution and status of this species. Several private property owners have either allowed SCWA to survey their property for CCG or have funded independent surveys themselves for the species. In combination, these survey efforts have greatly expanded our understanding of the distribution of the species throughout the County. In addition, landowners have been extremely cooperative in allowing SCWA to collect tissue samples for genetic analysis. As such, samples have been collected from almost every single population identified during these surveys. The distribution surveys in combination with the results of the genetic analyses have greatly aided in refining the boundaries of our core population areas and the conservation needs of this species.

CONTRA COSTA GOLDFIELDS

Contra Costa goldfields was federally-listed as endangered on June 18, 1997 (62 FR 33029) and is a CNPS List 1B species. This species is an annual herb in the sunflower tribe (Heliantheae) of the sunflower family (Asteraceae). Individual plants range from approximately 10 to 40 cm tall. Being in the sunflower family (Asteraceae), the characteristic yellow flower of this plant actually consists of many flowers (numerous disk flowers and 6 to 13 ray flowers) which combined are referred to as a radiate head. The blooming period ranges from March through June, but appears to be extremely dependent on environmental conditions (i.e. rainfall, edaphic conditions etc.) (CNDDB 2007, CNPS 2007; personal observations). Contra Costa goldfields grow in vernal pools, swales, and other depressions in open grassland and woodland communities, often in alkaline soils but also under a wide variety of moisture, soil, and salinity conditions.

Historically, CCG were found in several counties surrounding the San Francisco Bay and along the coast, from Santa Barbara County to Mendocino County. However, several of the historic occurrences, such as the occurrences in Santa Barbara and Mendocino Counties, are extirpated. Currently, this species is known from only 15 populations, with the largest number of populations occurring in the Fairfield-Suisun area in Solano County. Other presumably extant populations are in Alameda (1), Contra Costa (1), Napa (1), Marin (1), and Monterey (2) counties (CNPS 2003).

Within Solano, CCG have been designated into seven core populations in order to address issues related to potential genetic variations between various locations in the County (Map 1). These core area boundaries were based in part on watershed divides and other physical barriers. The majority of these core areas are located around the periphery of, or within, the existing and proposed developed lands of the cities of Fairfield and Suisun City. Thus, the major threat to populations within the County is loss of habitat to urban development. Additional conservation issues include declining population numbers from lack of proper habitat management, habitat degradation posed by indirect effects of urban development (i.e. changes in hydrology and loss of pollinator populations), invasive species competition, and potential changes in climate. Because the majority of the remaining populations within the County are surrounded by or planned for urban development, preserves dedicated to the conservation of this species will need to have special management considerations. It is important to develop a sampling program that will provide repeatable and valid density estimates that can be used to determine population trajectories and to assess the effects of management strategies.

GENERAL SITE CHARACTERISTICS

Six study sites, representing four core population areas within Solano County (Conservation Subareas 1B, 1E, 1F and 1G: Map 1), were chosen to conduct population studies for estimating total population size of CCG on each property. These six sites were chosen because they represent a range of habitat types for which CCG are known to grow (i.e. seasonally saturated annual grassland, old hayfields, playa pools, typical vernal pool/swale complexes, and highly disturbed areas). Map 2, in Appendix A, shows the general location of each study site, with respect to the core areas identified in the Solano HCP. In addition to these six sites, population counts were also conducted on Noonan Ranch Conservation Bank as part of the first year of monitoring for the bank. Thus, seven sites were used to estimate CCG populations in this study. The general characteristics of each site (e.g. hydrology and vegetation) are discussed in the sections below.

Barnfield

The Barnfield Study Site is located to the south of Suisun City and east of Fairfield, just northeast of the intersection of Cordelia Road and Orehr Road, or south of Cordelia Road and east and west of Ledgewood Creek (Map 2 and 3). The majority of the habitat and growing conditions in which CCG are found on the Barnfield property (Count Areas A, B, and C) consist of seasonally saturated annual grassland (Raney Planning and Management, Inc. 2006). Count Areas A, B, and C represent patches of *Lasthenia* spp. (patches consisted mostly of California goldfields (*Lasthenia californica*) intermixed with CCG). (as mapped on Map 3) that comprise only a small portion of the area mapped as seasonally saturated annual grassland by Vollmar Consulting in 2000 (Raney Planning and Management, Inc. 2006). The seasonally saturated annual grassland areas are characterized as broad transitional wetland areas between the low-lying seasonal wetlands (vernal pools and alkali seasonal marsh) and the surrounding upland annual grasslands (Raney Planning and Management, Inc. 2006). These transition areas have prolonged periods of surface and subsurface saturation, but are rarely inundated. Dominate species include Italian ryegrass (*Lolium multiflorum*), Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*), alkali weed (*Cressa truxillensis*), and alkali heath (*Frankenia salina*). *Lasthenia* spp. (primarily *californica*) are also dominant within the seasonally saturated annual grassland areas mapped on Map 3.

Count Area D-X consists of smaller more discrete vernal pools. California goldfields were not present in these pools and the only species of *Lasthenia* present were CCG and smooth goldfields (*Lasthenia glaberrima*), indicating longer inundation periods than Count Areas A, B, and C. Dominant species include Italian ryegrass, Mediterranean barley, and tarplant (*Centromadia* sp.). Count Area J was distinct from the other pool in this group in that it occurs within an area mapped as alkali seasonal salt marsh by Vollmar in 2000 (Raney Planning and Management, Inc. 2006). Dominant species in Count Area J include pickle weed (*Salicornia virginica*), alkali heath, alkali weed, and brass buttons (*Cotula coronipifolia*).

Director's Guild

The Director's Guild parcel is located just south of State Highway 12, southwest of the intersection of Scally Road and Killdeer Road (Map 2). The topography of this parcel is flat, ranging in elevation between 6 and 9 feet above sea level. The majority of the Director's Guild site consists of an extensive, hydrologically-connected seasonal wetland (i.e. approximately 61.87 acres out of 84 acres). The majority of this wetland area can be characterized as seasonally saturated annual grassland and is heavily dominated by Italian ryegrass, with the exception of a large playa pool (approximately 8.83 acres) in the southeastern portion (Map 4). The playa pool and the surrounding seasonally saturated annual grassland represent two distinct growing conditions with drastically different densities of CCG.

All of the wetlands on this property have been subject to various levels of disturbance. The grassland area, particularly the northern portion of the site, is a former hayfield. It has been leveled and irrigated for hay and possibly other crops since at least the 1930s. The playa pool is bisected by a county road and an excavated ditch drains the playa pool westward, into the adjacent Potrero Hills Lane mitigation site and then on to the CDFG Hill Slough Wildlife Area.

Vegetation on the Director's Guild site includes the usual exotic annual grasses and a variety of wetland plants ranging from facultative to obligate. Plants noted during the wetland survey are Italian ryegrass, Mediterranean barley, curly dock (*Rumex crispis*), fiddle dock (*Rumex pulcher*), and semaphore grass (*Pleuropogon californicus*). Plants on the parcel that indicate alkaline or saline conditions include brass buttons, alkali heath, pickle weed, and salt grass (*Distichlis spicata*).

Goldfield Conservation Bank

The Goldfield Conservation Bank (GCB) Site consists of three parcels located southeast of the intersection of Walters Road and Air Base Parkway, and west of Travis Air Force Base (Map 5). An auto dismantler/salvage yard is located between the parcels in the northern portion of the study area. An infrequently used railroad track leading to Travis Air Force Base separates the two northern parcels from the southern parcel.

Some of the wetlands on the property have well defined pool or swale edges and a predominance of native wetland vegetation. However much of the site is dominated by exotic grasses and contains subtle topographical features, likely due to the highly disturbed nature of the site (LSA 2007a). For example, the northwestern parcel has been leveled and is a former hayfield. Much of the northeastern parcel has a subtle mound and swale topography that is visible both on the ground and on aerial photographs. The southern parcel contains a large, shallow seasonal pond near its eastern edge and a shallow seasonal wetland on its northwestern edge (Map 5).

Native plants that dominate these seasonal wetlands include spreading alkali weed, coyote thistle (*Eryngium vaseyi*), annual hairgrass (*Deschampsia danthonioides*), slender popcorn flower (*Plagiobothrys stipitatus*), smooth goldfields, creeping spike rush (*Eleocharis macrostachya*), toad rush

(*Juncus bufonius*), spreading rush (*Juncus phaeocephalus*) and meadow barley (*Hordeum brachyantherum*). Non-native plant species that dominate wetlands on the GCB site are rabbit's-foot grass (*Polypogon monspeliensis*), Mediterranean barley, Italian ryegrass, curly dock, and spiny-fruit buttercup (*Ranunculus muricatus*) (LSA 2007a and 2007b).

Jehovah's Witness Complex

The Jehovah's Witness Complex site consists of a small vernal pool complex located to the northwest of the Jehovah's Witness Assembly Hall on the corner of Walters Road and Tabor Road (Map 5). Historically, this pool complex was under the same ownership as the western and central portions of the GCB site (e.g., Parker Ranch). This small vernal count area was included in the CNDDB rare plant record for the northwestern GCB site and was reported to contain at least 100 CCG plants in 1995. For our analysis, we consider this area as a separate count area because it is hydrologically separated from the remainder of the GCB site by the infrequently used railroad tracks leading to Travis Air Force Base and is under different management regime than the GCB (i.e. no management). The CNDDB record characterizes this count area as an alkaline vernal pool/swale, dominated by exotic grasses. The pools themselves contained Italian ryegrass, slender popcorn flower, cupped downingia (*Downingia insignis*), fringed downingia (*Downingia concolor*), coyote thistle, annual semaphore grass, and docks (*Rumex spp*.). In 2006, the pools were primarily dominated by semaphore grass and docks, but also contained large areas of dried algal mats, which formed a thick crust on the bottom of the pools (particularly in the deeper portions). In 2007, the pool was also dominated by semaphore grass and docks, but also contained higher densities of CCG, smooth goldfields and alkali mallow (*Malvella leprosa*).

McCoy Basin

The McCoy Basin site is located between Air Base Parkway and Cement Hill Road in Fairfield. The predominant feature on this site is the 42-acre McCoy Storm Water Detention Basin (McCoy Basin). Three natural creeks and a few manmade ditches and canals flow into the detention basin, including the McCoy Creek Wasteway, which traverses the Strassberger Industrial Park site to the north, prior to draining into McCoy Basin. The area surrounding the basin consists of relatively undisturbed annual grassland habitat with pockets of interspersed vernal pools, particularly to the northeast of the basin (Vollmar Consulting 2000). There is a shallow terrace on the northeastern rim of McCoy Basin, which supports a mix of vernal pool and seasonal brackish marsh vegetation. Species include Ferris's goldfields (*Lasthenia ferrisiae*), alkali heath, saltgrass, brass buttons and CCG in scattered depressions within the terrace (Map 6). Other species observed in the vernal count areas include coyote thistle, meadow barley, Italian ryegrass, annual hairgrass, sand-spurrey (*Spergularia* sp.), and smooth goldfields.

Strassberger Industrial Park

The Strassberger Industrial Park site is located directly north of McCoy Basin and south of Cement Hill Road (Map 2). Most of the Strassberger Industrial Park site was graded and leveled prior to 1980, for construction of the industrial park. However, development of the industrial park was abandoned, and the site now consists of highly disturbed, scraped, and leveled old building pads interspersed among upland ruderal habitat and highly disturbed seasonal wetlands (Vollmar Consulting 2000). Prior activities stripped and/or buried topsoils with alkaline subsoils from road bed and utility line construction. Grading activities also eliminated the native mound/basin vernal pool topography leaving a nearly flat topography with a few scattered low-lying basins that appear to have resulted from differential settlement and grading irregularities, which remain inundated for prolonged periods (Vollmar Consulting 2000) (Map 7). Many of these basins currently act as, and are visually similar to, vernal pools (the cover photo is one of the pools that has developed on one of the Strassberger site building pads) and are dominated by CCG, downingia, popcornflower, and on the western side of the McCoy Creek Wasteway, Ferris's goldfields, California goldfields, and pickle weed.

Noonan Ranch Conservation Bank

Noonan Ranch Conservation Bank is located east of the City of Fairfield and south of the City of Vacaville, along the eastern side of Vanden Road and the parallel Southern Pacific railroad tracks, south of their intersection with Canon Road, immediately north of the Travis Air Force Base. All of the site drains either to the natural Union Creek channel, which runs southeastward through the eastern portion of the site, or the replacement bypass channel, which runs southwestward around the western edge. Site vegetation consists of exotic annual grassland that appears heavily grazed year-round by cattle. Exotic species observed include long-beaked filaree (*Erodium botrys*), white-stem filaree (*Erodium moschatum*), medusa-head (*Taeniatherum caput-medusae*), soft chess (*Bromus hordeaceus*), hare barley (*Hordeum murinum* ssp.*leporinum*), Italian ryegrass, and purple star-thistle (*Centaurea calcitrapa*).

With the exception of the hills, much of the property consists of a broad vernal pool/grassland association, with varying densities of wetlands dispersed throughout. The majority of the native species on the property occur in the vernal pool components of the grassland matrix. Species found in the vernal pool areas include Mediterranean barley, Italian ryegrass, bird's-foot trefoil (*Lotus corniculatus*), and tarweed. In the pools, obligate and facultative-wetland plants include woolly-marbles (*Psilocarphus brevissimus*), semaphore grass, annual hairgrass, slender popcorn-flower, and CCG. Additional species observed in the pools include coyote thistle, brass buttons, cowbag clover (*Trifolium depauperatum* var. *depauperatum*), Pacific foxtail (*Alopecurus saccatus*), rabbit's-foot grass, purslane speedwell (*Veronica perigrina*), common lippia (*Phyla nodiflora.*), salt grass (*Distichlis spicata*), alkali mallow, and meadow foam (*Limnanthes* sp.). The presence of salt grass and alkali mallow indicate that some of the soils are slightly alkaline.

METHODS

POPULATION STUDIES

Field Surveys

In 2006, 2007, 2008 and 2009 SCWA was granted access to conduct CCG population counts on the Barnfield, GCB[1], Jehovah's Witness California Fairfield Assembly Hall, McCoy Basin, Strassberger Industrial Park, and the Director's Guild Parcels (Map 2). These six sites represent a variety of growing conditions found in four of the six subpopulation areas identified in the Solano HCP (SCWA 2009). Prior to conducting the counts, preliminary field visits were made to each study site to assess the phenological development of CCG. Table 1 lists the dates for which the population data was collected.

Table 1. Survey dates for each study site.

Site	Survey Dates			
	2006	2007	2008	2009
Barnfield	May 11 and 12	April 6 and 9	April 10, 11, and 15	April 20, 21, and 22
Director's Guild	May 17	April 5 and 12	April 22 and 25	April 16, 22 and May 4, 6, 7, and 12
GCB	May 10 and 23	April 16 and 17	April 21 and 23	April 24 and 27
Jehovah Witness Pool	N/A	April 17	May 2	May 11
McCoy Basin	May 16	April 18	April 28 and 29	April 28
Strassberger Industrial Park	May 10 and 18	April 9, 18, and 19	April 23, 24, and 28	April 22, 27, and 28
Noonan Ranch Conservation Bank	N/A	N/A	N/A	May 8, 11, 12, 16

Previous survey data for CCG was available for each parcel (Table 2) and these data were first used to identify pools with large CCG densities. The intent of the surveys was not to identify the extent of occupied habitat on each site; but instead, to map the locations where CCG were concentrated (i.e. the large, densest patches of goldfields). Once identified, the boundaries of each patch were mapped using a Trimble Geo XT GPS unit with submeter accuracy. Within mapped patches, 50 cm wide belt transects were randomly established and 5 to 10, 0.25 m^2 (50 cm by 50 cm) quadrats were randomly selected along each transect. If the patch was too small to establish a transect, 1-3 quadrats were randomly placed inside the patch by randomly throwing the quadrat over the shoulder into the patch. Within each 0.25 m^2 quadrat, CCG density was determined. An individual plant that had several stems originating from the same root base was counted as one plant. Then, cover of CCG and all other *Lasthenia* species was visually estimated within each quadrat, which was grided with strings spanning at 10 cm intervals.

[1] Surveys conducted in 2009 were done by Huffman-Broadway Group, Inc.

In 2006, an estimate of radiate heads per plant was made per patch or by site and then in 2007 this estimate was made for each quadrat, with the exception of the Director's Guild parcel. In 2008 and 2009, data on the average number of radiate heads per plant was collected at all locations. In 2006 and 2007, notes characterizing vegetation was collected for each pool but was not quantified. In 2008, some preliminary data was collected on the percent cover of certain species in each quadrat; however, data collected were not consistent across sites. In 2009, percent cover for the three dominant plant species observed in each quadrat, with dominance being based on cover, was recorded at all sites.

Initially, a minimum of 50 quadrats were targeted for each site; however, property boundaries proved to be an ineffective way of dividing up areas to assess population numbers and densities. Each site was subdivided, as necessary, into regions based on two criteria: hydrological connectivity or similarity in growing conditions. For example, Strassberger West represents very different growing conditions from Strassberger East and these two areas are hydrologically isolated by the McCoy Creek Wasteway. Similarly, the habitat in the playa pool on the Director's Guild parcel is extremely different than the surrounding seasonal wetlands. Separating properties into separate count areas increased the total number of plots sampled at each property in subsequent years. The six sites were divided up into count areas the following way:

- For the Barnfield property, pools (or patches) A, B, and C were analyzed separately, but transects and plots for patches D through X were lumped together (Map 3).
- The Director's Guild parcel was divided into two separate areas, the Playa Pool Analysis Area (PPAA), which consists of the playa pool plus the areas directly connected to the playa pool via the ditch that runs east to west across the property and the Grassland Analysis Area (GAA), which consists of areas mapped with goldfields throughout the remainder of the property (Map 4).
- The GCB was divided into three separate units: northeast, northwest, and south (Map 5). The northeast area consists of all of the pools north of the railroad and east of the salvage yard, the northwest parcel consists of all of the pools north of the railroad and west of the salvage yard, and the area to the south consist of all of the pools south of the railroad.
- The pools northwest of the Jehovah's Witness Assembly Hall were considered one area but were analyzed with the data from the GCB Site for within and between site comparisons (Map 5).
- All of the small pools northeast of McCoy Basin were treated as one area (Map 6).
- For the Strassberger Industrial park, only the goldfields south of Strassberger Drive were surveyed and this was divided into two areas: the larger area to the west of the McCoy Creek Wasteway and the areas to the east of the Wasteway (Map 8).
- The Noonan Ranch Conservation Bank was divided up into three regions based on hydrological connectivity. These three regions, termed northeast, southeast, and southwest, are separated from each other hydrologically by Union Creek and the constructed Union Creek Bypass Channel (Map 9).

Data Analysis

Mean Density and Total Population Estimates. All of the plots from each count area were combined to calculate mean density of Contra Costa goldfields per 0.25 m^2 and then per square meter. The total number of plants for each count area was estimated by multiplying the mean density of CCG per square meter by the total goldfield area mapped in the field. Standard errors were calculated for the mean density per square meter and 90% Confidence Intervals were calculated for the count area population estimates. For count areas with fewer than 30 plots, the 90% Confidence Intervals were adjusted to account for a small sample size by using the student's t distribution (Hayek and Buzas 1997, Zar 1996). Finally, population estimates per count area and corresponding confidence intervals were used to obtain a final population estimate for each study site.

Between Year and Area Comparisons. Contra Costa Goldfields density data were lognormal transformed and then analyzed using a Tukey-Kramer HSD (honestly significant difference) test at $\alpha = 0.05$. Density of CCG was compared between years and between sites within a year at varying sample sizes. Tukey-Kramer HSD test was used to test for differences between all pairs because it is conservative when comparing means with different sample sizes (Hayter 1984). All analyses were conducted using JMP®.

Analysis of Vegetation Data. To identify possible correlations between the cover of CCG and other vegetation sampled, a Spearman's correlation test was conducted. For wetland species with significant correlations, a stepwise regression analysis was also conducted.

To identify relationships between the CCG and other plant species observed, CCG cover data were divided into seven cover classes: 0 percent, ≤5 percent, 6-15 percent, 16-25 percent, 26-50 percent, 51-75 percent and 76-100 percent. These, uneven cover class intervals were chosen based on similar methodology used in vernal pool vegetation monitoring (Mueller-Dombois and Ellenberg 1974). The frequency and average non-zero cover (i.e. all zero values were excluded from the calculation of average cover) of each species observed in the study was estimated for each CCG cover class.

GENETIC STUDIES

In 2006, tissue samples were collected from the core CCG populations where access could be obtained (Map 1). In 2007, additional tissue samples were collected from new occurrences found on the Peterson and Johnson Trust Lands, Pullin Property, and Noonan Ranch (Map 2). Additional tissue samples were sought at Union Creek Mitigation Bank, Parker Ranch, Meyer Cookware Wetland Preserve, Sheldon Oil Property, Wilcox Ranch, Craig Ranch and Muzzy Ranch in 2006 and 2007, but CCG were not found at any of these locations.

Tissue samples consisted primarily of leaf material and were placed in Silica Gel to preserve the tissue until DNA could be extracted. If multiple pools were present, samples were collected from a large proportion of the pools, or in some cases, all of the pools were sampled. From larger pools, 10 samples were collected along a transect to examine fine-scale spatial genetic variation from the center to the periphery of pools. In addition to the tissue samples, a voucher specimen was collected from each location. All of the samples and voucher specimens collected by LSA were sent to Dr. Jennifer Ramp-Neale at the University of Colorado for further processing.

Fourteen of the fifteen study sites sampled for the study: Barnfield Property, Biggs Property, Director's Guild Site, GCB Site, Edenbridge, Jehovah's Witness Complex, McCoy Basin, Noonan Ranch (2007), North Suisun Mitigation Bank (2007), Peterson and Johnson Trust Lands West (2 parcels: one sampled in

2006, one sampled in 2007), Pullin Property (2007), Strassberger Industrial Park, and Travis Air Force Base Aero Club. The Villages property was not included in genetic study because only 1 individual was collected.

Population genetic diversity and structure was analyzed by property, sub-property, and by pool (*i.e*. population). The two collections from the Peterson and Johnson Trust lands were combined for the property analysis and the sample from the Villages property was not included resulting in an all property-level analysis being conducted with 13 properties. Properties with sub-structure include: Barnfield Property (4 sub-areas), Director's Guild Site (2 sub-areas), Edenbridge (4 sub-areas), North Suisun Mitigation Bank (4 sub-areas), Noonan Ranch (3 sub-areas), Peterson and Johnson Trust Lands West (7 sub-areas total, 3 from the West parcel and 4 from the South parcel), Strassberger Industrial Park (5 sub-areas), and Travis Air Force Base Aero Club (4 sub-areas). For the sub-property level analysis there was a total of 33 sub-areas. Samples from a total of 42 pools were used in the population analysis, assuming that each pool represents a population. The total sample size for the entire study was 341 individuals, with a range of 8-50 individuals per population (pool). Microsatellite markers for CCG was developed by Genetic Identification Services. Seven (7) loci were used in this analysis. For more details on the methods used in the genetic study see Ramp (2009) in Appendix D.

SEED BANK STUDY

We conducted a pilot study to assess alternative techniques to determine whether CCGs, an annual vernal pool plant, maintains an interannual seed bank. The existence of a persistent seed bank helps buffer populations from years with poor seed production, and suggests that estimates of population size based on counts of flowering plants in any given year may underestimate the true size and extent of the population in an area. We evaluated two methods to assess the presence of an interannual seed bank. The first involved collecting soil cores from within a known population, spreading the soil in pots, and watering them to stimulate germination. The second method, involved removing CCGs from plots and measuring germination the following year.

Soil Cores

Nine soil cores (15 cm deep by 5 cm diameter) were collected between May and July 2006 from random locations within the large playa pool at the Director's Guild property. Seeds that were produced that season (i.e. 2006) were blown from the surface to exclude them from the sample. Three of these samples were then stratified by depth (0-5 cm, 5-10 cm, 10-15 cm), and each stratified sample was homogenized into fine soil particles and placed into pots. Six of the pots received 1/3 of a full 15 cm deep core (one pot per depth per sample) and another six pots received 1/6 of a full 15 cm deep core (each 5 cm deep sample is split between 2 pots). Soil from an additional core sample was homogenized over all depths and divided between another six pots, with each pot received 1/6 of a full 15 cm deep core. In total, 18 pots were set up containing soil and seeds from the core samples taken at the Director's Guild. The pots were then placed on the balcony of LSA's Point Richmond office where they were watered several times per week from January to May 2007. Germination of all species was recorded.

Removal Plots

Three, $1m^2$ plots were randomly established in May 2006 on the Director's Guild site in the same vernal pool used for the soil core experiment and monitored each growing season through 2009. Towards the end of each growing season, all CCG individuals were removed before setting seed. A screen was placed over a wooden frame enclosing the plots in order to prevent seed dispersing into the plots from wind and water. The screens were removed in early spring and during peak CCG blooming period. At the end of the experiment, all plants were removed from the plots and counted. The density of CCGs growing in removal plots was then compared to the densities of plants from the population count at this study site, which served as a control. A two sample independent *t*-test was used to compare CCG densities found in the removal plots versus the control for each year.

DISTRIBUTION STUDY

Over the last several years, biologists, funded both by private property owners and by SCWA, have conducted additional surveys for CCG within the core population areas and potential habitat areas. The research performed as part of the Section 6 grant award to the SCWA and the completion of working drafts of the Solano HCP for review, has inspired and facilitated the sharing of information between consultants, private property owners and SCWA on the distribution and status of this species. Several private property owners either have allowed SCWA to survey their property for CCG or have funded independent surveys themselves for the species. In combination, these surveys have greatly expanded our understanding of the distribution of the species throughout the County.

Map 2 shows all of the areas within the potential distribution of CCG that have been surveyed at least once over the past few years since the original core area boundaries were identified for the Solano HCP in 2000. Approximately 14,165 acres of land within the previously designated Core Population areas and potential habitat and watershed areas has been surveyed on at least one occasion/year during appropriate time periods and only approximately 7,680 acres, to our knowledge, have not been surveyed.

Methods and levels of information collected vary greatly between sites and consultants. Distribution data from these various sources was taken and reported "as is" from the base documents and maps provided to SCWA and LSA. In most cases, polygons of occupied habitat were mapped using GPS technology, although the level of accuracy of the equipment employed for each study was not always reported. Also, most population estimates reported by various authors appear to be based on "best guess" visual estimates rather than direct count data or systematic count methods. The landowners, consultants, and agencies that contributed to these efforts are further detailed in the Acknowledgment section below. Table 2 lists the property, property owner, the biologist or consultant that conducted the survey and the month and year the surveys were conducted for that property.

Table 2 Survey Dates for Contra Costa Goldfields for various properties in Solano County

Property	Property Owner	Consultant	Survey Date(s) Month/Year
Gentry Properties	Gentry Company	Vollmar Consulting	4/2005
Tooby Property	Gentry Company	Vollmar Consulting	4/2005
Barnfield Property	Gentry Company	Vollmar Consulting	4/2005
		LSA Associates	4/2006, 4/2007, 4/2008, and 4/2009
Meyer Cookware Wetland Preserve	Meyer Cookware Company	Vollmar Consulting	5/2005
		LSA Associates	3 and 4/2007, 4/2008, and 4/2009
Sheldon Oil Property	Sheldon Oil Company	LSA Associates	3 and 4/2007 and 4/2008
South Watney Way	Amir Development Co.	LSA Associates	4/2007
Burke Ranch	Dennis Kilkenny	Vollmar Consulting	4 and 5/2005
Thompson Ranch	Leonard Thompson	Vollmar Consulting	3/2005
Craig Ranch	Pete Craig	Vollmar Consulting	3/2005
		Virginia Dains	5/2006
		LSA Associates	4/2007
Rush Ranch	Solano Land Trust	Vollmar Consulting	3/2005
Wilcox Ranch	Solano Land Trust	Bob Holland, Carol Witham and other volunteer botanists	3/2002
		Virginia Dains	5/2006
I-80/Hwy 12 Interchange Parcel	Unknown	Vollmar Consulting	3/2005
Solano Union Creek	Subdivision Management Service	LSA Associates	4/2007 and 4/2008
Potrero Hills Landfill Property	Potrero Hills Landfill	LSA Associates	Multiple times in 2004, 2005, 2006, 2007, 2008 and 2009.
Director's Guild Site	Potrero Hills Landfill	LSA Associates	4/2004, 4 and 6 2005, 5/2006, 4/2007, 4/2008, and 4 and 5 2009
Potrero Hills Lane	Potrero Hills Landfill	Virginia Dains	5/1995
		Jane Valerius	4, 5, and 6/2003, 2004, 2005 and 2006
Peterson and Johnson Trust Lands (West)	Peterson and Johnson Trust	LSA Associates	5/2006 and 3 and 4/2007

Property	Property Owner	Consultant	Survey Date(s) Month/Year
Peterson and Johnson Trust Lands (East)	Peterson and Johnson Trust	LSA Associates	5/2006 and 3 and 4/2007
Peterson and Johnson Trust Lands (South)	Peterson and Johnson Trust	LSA Associates	5/2008
Biggs Property	Ed Biggs	LSA Associates	5/2006
Burke Property	Pat Burke	Vollmar Consulting	2003
		LSA Associates	4/2009
Parker Ranch	Bancor Properties LLC	LSA Associates	4/2007 and 4/2009
Mangels Property	Lewis Operating Corp.	Ramona Robinson	6/2006
North Suisun Mitigation Bank	Wildlands Inc.	Wildlands Inc.	2000 and 2009 (2009 data not shown)
		LSA Associates	5/2006
Muzzy Ranch	ASB Properties	LSA Associates	4/2007
Edenbridge Property	Edenbridge, Inc.	Jones and Stokes	2005 and 2006
McCoy Basin	Edenbridge Inc.	Vollmar Consulting	4, 5 and 6 2000
		Jones and Stokes	5 and 6/2006
		LSA Associates	5/2006 and 4/2007
Cross Industrial Park	City of Fairfield	Vollmar Consulting	4, 5 and 6 2000
		LSA Associates	4/2008
Strassberger Industrial Park	City of Fairfield	Vollmar Consulting	4, 5 and 6 2000
		LSA Associates	5/2006, 4/2007, 4/2008, and 4/2009
Manuel Campos Wetland Preserve	City of Fairfield	LSA Associates	4/2004, 4/2007, and 4/2008
Noonan Ranch Conservation Bank	Canon Station LLC	LSA Associates	4/2007, 5/2008, 4 and 5/2009
Noonan North of Canon Rd.	Canon Station LLC	LSA Associates	4/2008, 4 and 5/2009
Noonan South of Canon Rd.	Canon Station LLC	LSA Associates	5/2008, 4 and 5/2009
Kelley Ranch	Canon Station LLC	LSA Associates	4 and 5/2009
City of Fairfield Property	City of Fairfield	LSA Associates	4 and 5/2009
Solano Irrigation District Property	Solano Irrigation District	LSA Associates	4 and 5/2009
Church/East Ranch	Canon Station LLC	LSA Associates	4 and 5/2009
Travis Aero Club	TAFB	Sharon Collinge	4/2008
Goldfield Conservation	QLC Management	Virginia Dains	5/2006

Property	Property Owner	Consultant	Survey Date(s) Month/Year
Bank		LSA Associates	5/2006, 4/2007, 4/2008, and 4/2009
Jehovah's Witness Complex	Jehovah's Witness Church	LSA Associates	5/2006, 4/2007, 5/2008, and 5/2009
Villages	Bill Mellerup	LSA Associates with Ramona Robinson	5/2006
Hill Slough Wildlife Area	CDFG	LSA Associates	4/2007
Pullin Property	Jerry Pullin	LSA Associates	4/2007 and 4/2008

RESULTS

POPULATION STUDIES

The following section presents the results of data collected as part of the population study. This includes: average density per $0.25m^2$, average cover (%), average number of flowers per individual, and population estimates for each site; comparisons of these population parameters between years and between count areas within a year; and an analysis of the vegetation data collected in 2009 as it relates to CCG.

Density, Cover, Average Number of Flowers per Individual, Population Estimates, and Between Year Comparisons

Barnfield. The distribution of CCG on the Barnfield Study Site for 2006, 2007, 2008, and 2009 is shown on Map 3. The area mapped, population estimate, average density, percent cover, and average number of flowers per individual is summarized in Table 3. CCG population estimates for the entire site ranged from 6.1 million plants (±1.14 million) in 2008 to 8.2 million plants (±2.5 million) in 2009.

Within Pool Comparisons. For Count Area A, densities in 2006 and 2008 were significantly higher than densities in 2007 and 2009 (Figure 1). For percent cover, 2006 was significantly higher than all other years, and 2008 was significantly higher than 2009 but not 2007. The average number of flowers per plant was higher in 2007 than in 2008 or 2009. The differences in plant size may explain the differences observed between density and cover.

In Count Area B, the density in 2007 was significantly higher than 2008, but was not significantly different from 2006 or 2009 (Figure 1). There were also no significant differences between cover or average number of flowers per plant between years (Figure 1).

For Count Area C, there were no significant differences in the density or cover of plants between years. However, the average number of flowers per plant was significantly higher in 2009 (1.3 flowers/plant) than in 2007 (1.0 flowers/plant) or 2008 (1.0 flowers/plant) (Figure 1).

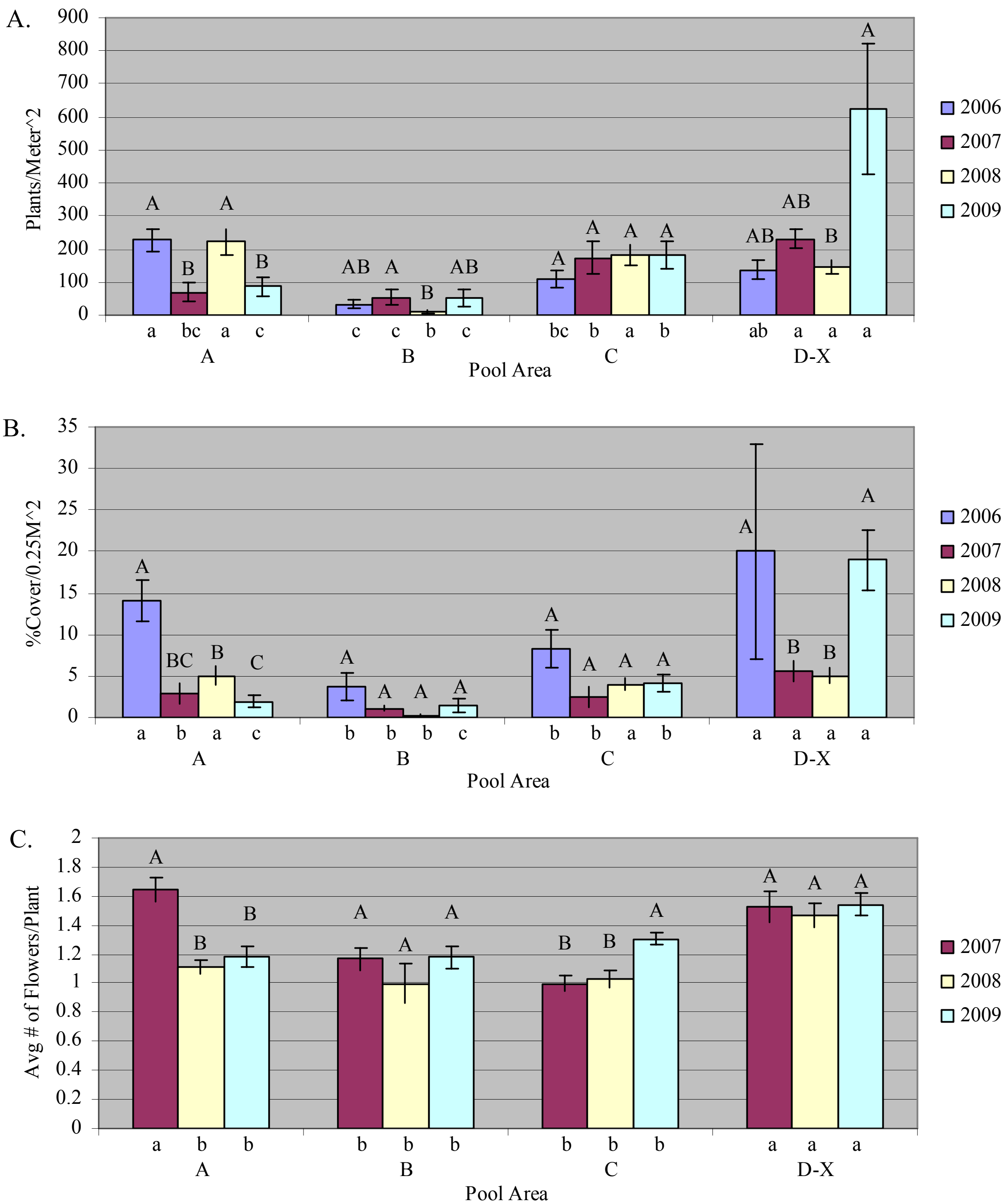
For Count Area D-X, the density in 2009 was significantly higher than in 2008, but there were no significant differences between the other years. The percent cover in 2006 and 2009 were significantly higher than 2007 and 2008, and there were no significant differences in the average number of flowers per plant between years (Figure 1).

Between Pool Comparisons. There was a lot of variation in the grouping of count areas between years and, in general, there was more variation in density than in cover (Figure 1). Count Area B, consistently had the lowest density and cover of CCG. This area is one of the driest areas on the site and likely represents the shallower extreme of wetland types for which Contra Costa goldfields occur. Count Area D-X was consistently on the higher end of the density, cover, and average number of flowers per plant for this site. The wetlands that comprise Count Area D-X can be categorized as discreet vernal pools versus seasonally saturated annual grassland like Count Areas A, B, and C. These pools are more comparable to some of the smaller vernal pools found around McCoy Basin.

Table 3. Barnfield Site Contra Costa goldfield population data

Count area	Area		Estimated CCG Density/Count Area		Average Density/m²			% CCG cover	# Flowers /Plant	% *Lasthenia californica*
	Acres	m²	Plants	90% CI	Plants /m²	SE	N			
2006										
A	4.48	18,149	4,145,009	± 1,006,613	228	± 34	31	14%	*	4%
B	8.47	34,275	1,142,484	± 725,754	33	± 13	30	4%	*	21%
C	3.55	14,348	1,555,359	± 636,722	108	± 27	30	8%	*	7%
D-X	0.34	1,361	186,974	± 64,656	137	± 27	15	20%	*	0%
Total	**13.60**	**68133**	**7,029,826**	**± 1,396,275**					*	
Average					**131**	**± 17**		**11%**	*	**8%**
2007										
A	4.75	19,230	1,342,915	± 922,113	70	± 28	24	3%	1.6	10%
B	11.90	481,412	2,551,501	± 1,892,352	53	± 24	32	1%	1.2	7%
C	4.18	16,903	2,909,487	± 1,384,603	172	± 50	32	3%	1.0	1%
D-X	0.58	2,324	540,858	± 118,568	231	± 28	22	6%	1.5	0%
Total	**21.40**	**86,599**	**7,344,760**	**± 2,522,394**						
Average					**132**	**± 43**		**2%**	**1.3**	**5%**
2008										
A	2.87	11,622	2,588,559	± 757,772	223	± 40	50	5%	1.1	18%
B	9.21	37,256	360,639	± 331,631	10	± 5	50	0.2%	1.0	8%
C	3.98	16,117	2,922,943	± 781,074	181	± 29	50	4%	1.0	0.6%
D-X	0.38	1,525	224,521	± 50,990	147	± 20	35	5%	1.5	0.1%
Total	**16.44**	**66,521**	**6,096,661**	**± 1,138,804**						
Average					**140**	**± 13**		**4%**	**1.2**	**7%**
2009										
A	5.17	20907	1,806,354	± 1,017,020	86	± 29	50	2%	1.2	23%
B	10.09	40824	2,175,127	± 1,774,434	53	± 26	50	2%	1.2	18%
C	4.05	16385	2,975,429	± 1,193,123	182	± 44	50	4%	1.3	7%
D-X	0.68	2758	1,254,256	± 672,319	624	± 198	35	19%	1.5	0%
Total	**19.98**	**80,874**	**8,211,165**	**± 2,461,402**						
Average					**236**	**± 52**		**7%**	**1.3**	**12%**
* Data not collected										

Figure 1. CCG density per meter squared (A), percent cover per ¼ meter squared (B), and average number flowers per plant (C) on the Barnfield Property. Upper case letters above bars indicate significant differences between years within count areas. Lower case letters below bars indicate significant differences between count areas within the same year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Director's Guild. The distribution of CCG on the Director's Guild site is shown in Figure 2 and the average density and total number of plants is summarized in Table 5. The densities of CCG in the GAA are extremely different than the PPAA. The GAA, particularly the northern area, has shown a steady decrease in the total number, density and cover of plants since 2006 (Figure 5b and d). This portion of the property burned in the fall of 2004, which could explain the higher numbers in 2006 and the steady decline since then. The GAA area probably also represents the shallower extreme of wetland types for which Contra Costa goldfields occur in. 2006 was a very wet year and the higher densities in this year may also correspond to increased rainfall, but the differences in densities is likely a combination of time since disturbance (i.e. fire) and rainfall, with 2007, 2008 and 2009 being drier years.

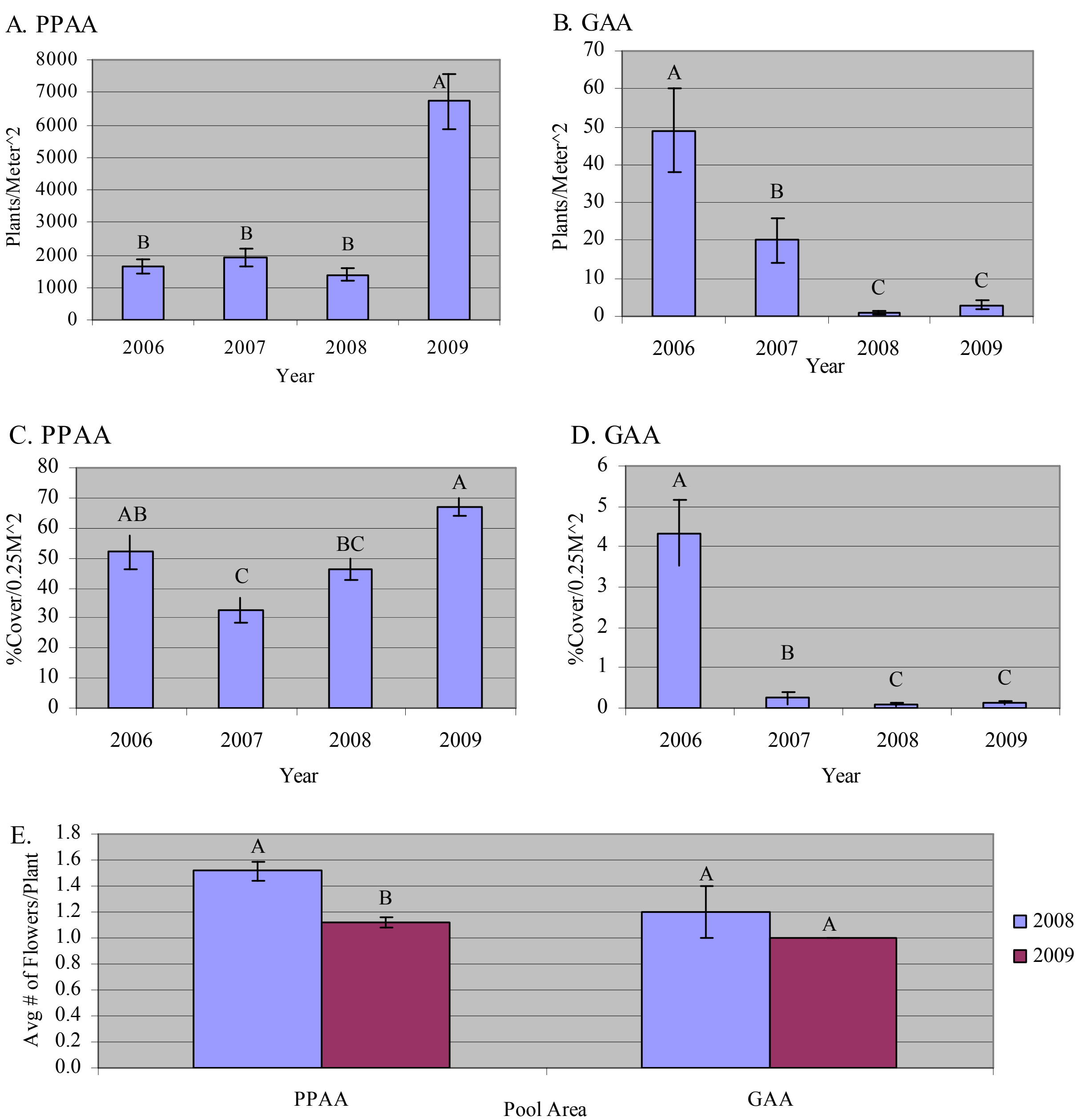
For the PPAA there were very different patterns in the density data and cover data between years. Large differences in densities did not necessarily equate to large differences in cover (Figure 5a and c). This can be attributed to differences in the size of the plant. There were significant differences in the average number of flowers per plant in 2008 and 2009 (Figure 1). Data on the average number of flowers per plant was not collected quantitatively in 2006 and 2007; however, in 2007, the average number of flowers per plant was approximately 1, but in 2008 the average flowers per plant was 1.5. The average number of flowers per plant was probably more important from a population dynamic perspective because it determines the amount of seed produced in any given year. Given this, the total number of flowers in the PPAA is approximately 43.4 million. This yields a higher fecundity for Contra Costa goldfields in 2008 versus 2007 and can explain the higher percent cover in 2008 versus 2007 even though the density of plants was higher in 2007 versus 2008. 2009 had the highest density of plants and percent cover of plants. The total number of plants estimated was over 163 million plants ± 34.2 million (Table 5). This is 4 to 5 times more plants than estimated in 2007 and 2008 and over 10 times as many plants estimated in 2006 (Table 5). These plants were exceptionally small, not just in terms of average number of flowers per plant, but also in terms of overall size. This is likely due to the exceptionally high densities. The flowers themselves appeared only large enough to contain only a few seeds; therefore, even though the number of plants was considerably higher in 2009, these plants may not have produced significantly more viable seeds than 2007 or 2008.

Another reason the total population estimate for the PPAA was considerably higher in 2009 was because it was the largest area mapped with a total of 6.027 acres. Area mapped could not be statistically compared, but there was an increase in total area mapped from 2006 (2.28 acres), 2007 (4.77 acres), 2008 (5.08 acres), and 2009 (6.027acres), with 2006 being the smallest area and 2009 being the largest area (Figure 4). The 2005-2006 water year (from June-July) was a wet year, which resulted in a much smaller distribution of Contra Costa goldfields around the playa pool (Figure 4). The total rainfall in 2007-2008 was actually higher than 2008-2009, but the rainfall was spread through more of the spring months versus primarily occurring during the month of January as in the 2007-2008 water year. It appears that both the amount and the timing of rainfall are important factors in determining the distribution and density of Contra Costa goldfields on the site.

Table 4. Director's Guild Site Contra Costa goldfield population data

Habitat Area	Area		Estimated CCG Density/Count Area		Average Density/m²			% CCG cover	# Flowers /Plant	% *Lasthenia californica*
	acres	m²	Plants	90% CI	Plants /m²	SE	N			
2006										
GAA	2.77	11,200	552,260	± 193,113	49	± 11	55	4	*	4
PPAA	2.28	9,211	15,120,631	± 3,871,079	1,642	± 214	30	52	*	0
Total	**5.04**	**20,411**	**15,672,891**	**± 3,875,893**						
2007										
GAA	3.09	12,524	251,106	± 122,868	20	± 6	80	0.2	*	0.3
PPAA	4.77	19,283	33,688,601	± 9,442,754	1,921	± 298	66	28	*	0
Total	**7.86**	**31,807**	**33,939,707**	**± 9,443,553**						
2008										
GAA	3.10	12,524	10,019	± 8,492	1	± 0.4	60	0.08	1.2	0.4
PPAA	5.08	20,549	28,672,289	± 43,087	1,395	± 171	50	46	1.5	0
Total	**8.17**	**33,073**	**28,682,308**	**± 43,916**						
2009										
GAA	23.81	96,355	185,001	± 114,860	1.9	± 0.72	100	0.14	1.0	1
PPAA	6.027	24,390	163,880,992	± 34,243,302	6,719	± 854	50	61	1.1	0
Total	**3.08**	**12,471**	**164,065,994**	**± 34,243,494**						
* Data not collected										

Figure 2. CCG density per meter squared (A – PPAA and B - GAA), percent cover per ¼ meter squared (C - PPAA and D - GAA), and average flowers per plant (E) on the Director's Guild Property. Upper case letters above bars indicate significant differences between years within count areas. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Goldfield Conservation Bank. The distribution of CCG on the Goldfield Conservation Bank Study Site for 2006, 2007, 2008, and 2009 is shown on Map 5. The total population estimate, average density, percent cover, and total number of plants is summarized in Table 7. CCG population estimates on the site ranged from 296,000 plants (±104,000) in 2006 to 47.9 million plants (±35.9 million) in 2009. This site had particularly large variations in CCG densities due to changes in management after becoming a conservation bank (i.e. the addition of grazing in 2009). The large standard error for 2009 is the result of sampling in the Southern Area. Fewer plots were sampled in 2009 versus 2007 and in 2008 there were five plots with extremely high densities of plants. This makes comparison of the 2009 data from the southern area to the rest of the years difficult. Figure 3 shows the comparison of density (plants/meter squared) (A), percent cover (per ¼ meter squared) (B), and average number of flowers per plant (C).

Within Pool Comparisons. For the Northeast Area, there were differences observed in patterns of density versus abundance between years. For density, the number of plants steadily increased from 2006 through 2009, with 2007 being significantly higher than 2006, and 2009 being significantly higher than 2007. This was not the pattern observed for cover. Cover in 2006 was significantly higher than in 2008, which was the lowest year. Interestingly, the average number of flowers per plant showed the opposite trend as density: the average number of flowers per plant declined steadily from 2007 to 2009, but these differences were not statistically significant

For the Northwest Area, count data was only collected in 2007, 2008, and 2009, because the densities in 2006 were too low. The density of plants was significantly higher in 2007 and 2009 than in 2008 (Figure 3 and Table 11). This same general pattern was also observed in cover, where 2007 and 2009 are higher than 2008, but only 2007 is significantly higher than 2008. The difference between 2007 and 2008 is more pronounced with cover because the average number of flowers per plant is significantly higher in 2007 than in 2008 or 2009 (Figure 5 and Table 13).

For the Southern Area, the patterns of significance are different from what is reflected in the graphs because there were only a few quadrates sampled in this area in 2006 and the variance in 2009 is high due to a smaller sample size and five plots with extremely high densities. This makes between year comparisons difficult for this region. Nevertheless, 2006 was still significantly lower than 2007 and 2008 (Figure 3 and Table 11). For cover, 2009 was significantly lower than 2007 and 2008 (Figure 3 and Table 11). The average number of flowers per plant was significantly higher in 2008 than they were in 2007 and 2009 (Figure 5 and Table 13).

Between Count Area Comparisons. In 2007, the density and cover of CCG was significantly higher in the Northwest and Southern Areas than the Northeast Area and the Jehovah's Witness pool (Figure 3). There were no significant differences in the average number of flowers per plant between areas in 2007. In 2008, density, cover, and average number of flowers per plant in the southern area was significantly higher than in the northeast and northwest areas. There were no significant differences between areas in 2009 (Figures 3 and 5 and Tables 11 and 13).

Table 5. Goldfield Conservation Bank Site CCG population data

Count Area	Area		Estimated Density/ Count Area		Average Density/m²			% CCG cover	# Flowers /Plant
	acres	M²	Plants	90% CI	Plants /m²	SE	N		
2006									
Northeast	3.54	14,320	265,455	± 99,332	19	± 4	52	6%	*
South	0.60	2,417	30,610	± 31,972	13	± 7	6	10%	*
Northwest	*	*	211	*	*	*	*	*	*
Total	**4.14**	**16,736**	**296,276**	**± 104,351**					*
Average					**16**	**± 3**		**8%**	*
2007									
Northeast	1.46	5,907	821,305	± 227,614	139	± 23	75	5%	1.7
South	1.92	7,756	4,748,870	± 1,961,240	612	± 146	33	26%	1.8
Northwest	2.09	8444	3,820,167	± 1,081,234	452	± 78	55	26%	1.9
Total	**5.46**	**22,106**	**9,390,342**	**± 2,174,839**					
Average					**401**	**± 56**		**19%**	**1.8**
2008									
Northeast	1.655	6,699	1,075,458	± 533,022	161	± 48	75	4%	1.3
South	1.149	4,651	2,266,512	± 737,572	487	± 96	50	28%	2.8
Northwest	1.416	5,732	**338,114**	± 135,676	59	± 14	75	3%	1.4
Total	**4.22**	**17,082**	**3,680,084**	**± 920,072**					
Average					**236**	**± 36**		**11%**	**1.8**
2009									
Northeast	1.72	6958.946	1,672,736	± 698,962	240	± 61	43	6%	1.2
South	3.83	15510.82	47,924,387	±35,894,989	3090	± 1,407	23	20%	1.4
Northwest	1.49	6014.384	1,898,785	±1,121,979	316	± 113	41	7%	1.2
Total	**3.83**	**15,511**	**47,924,387**	**±35,919,590**					
Average					**1217**	**± 471**		**11**	**1.3**

Figure 3. CCG density per meter squared on the GCB Study Site. Upper case letters above bars indicate significant differences between years within count areas. Lower case letters below bars indicate significant differences between count areas within the same year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.

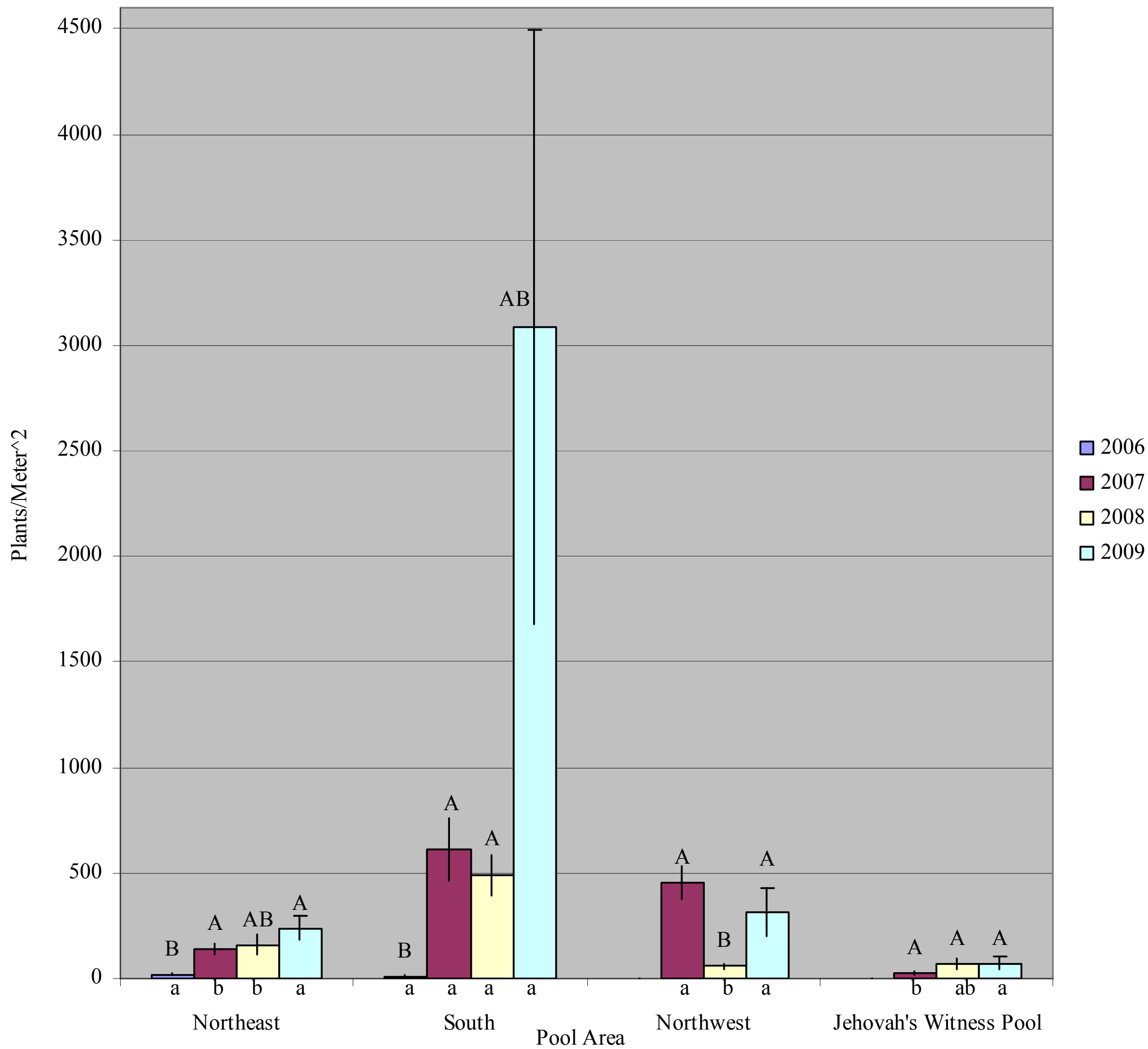
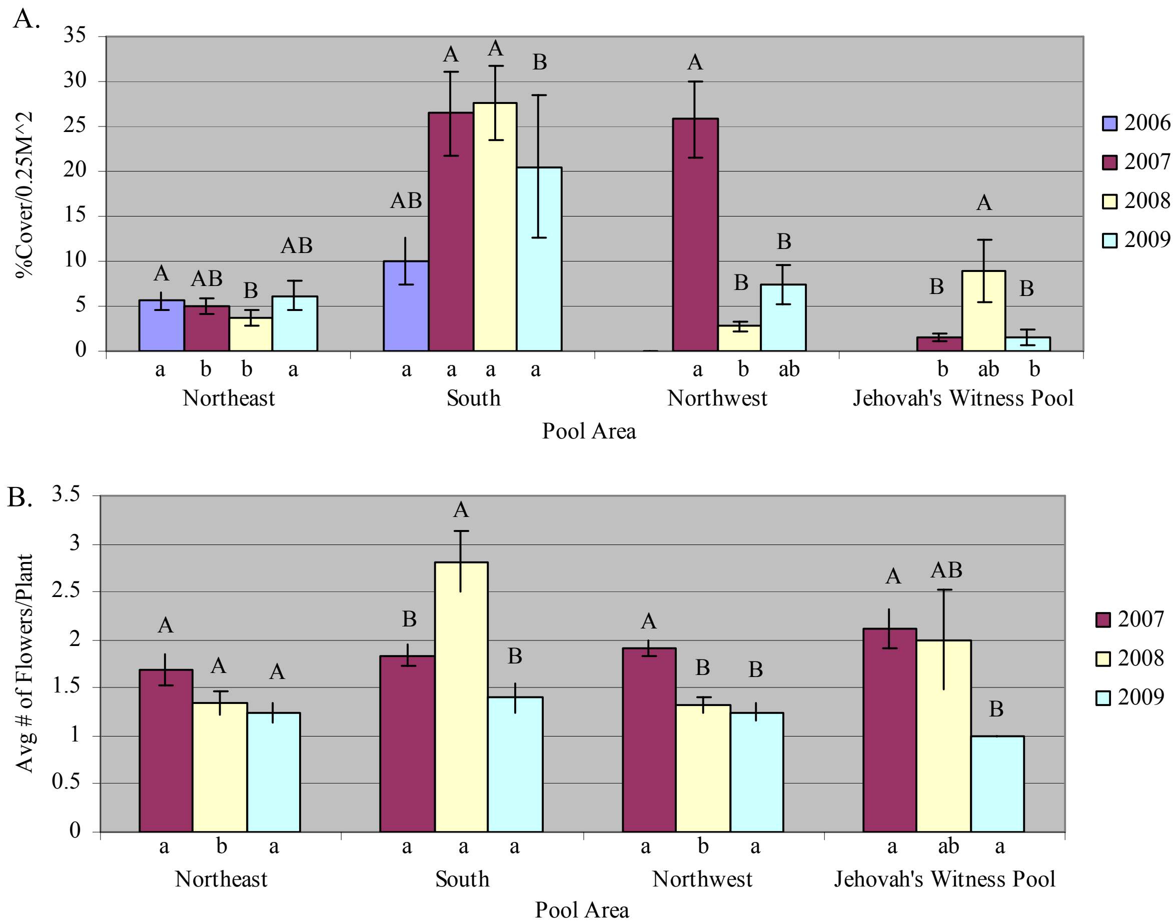


Figure 4. CCG percent cover per ¼ meter squared (A) and average number of flowers per plant (B) on the GCB Study Site. Upper case letters above bars indicate significant differences between years within count areas. Lower case letters below bars indicate significant differences between count areas within the same year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Jehovah's Witness Parcel. The Jehovah's witness parcel was separated from the remainder of the Goldfield Conservation Bank because of differences in management. Population estimates on the site range from 69,486 CCG plants (± 25,122) in 2007 to 148,853 CCG plants (± 88,124) in 2008. Similar to GCB Northwest, counts were not conducted in 2006 because the densities were extremely low. The estimate of 145 plants in 2006 (Table 10) was obtained from counting individual plants over the entire area.

For the Jehovah's Witness pools there was no significant difference in the densities between years but there was a significant difference in cover. Cover in 2008 was significantly higher than 2007 and 2009. Similarly, the average number of flowers per plant was significantly higher in 2007 than in 2009.

Table 6. Jehovah's Witness Parcel Contra Costa goldfield population data

Year	Area		Estimated Density/ Count Area		Average Density/m^2			% CCG cover	# Flowers/ Plant
	acres	m^2	Plants	90%CI	Plants /m^2	SE	N		
2006	-	-	145	-	-	-	-	-	-
2007	0.64	2,599	69,486	± 25,122	27	± 5.6	19	1.5	2.1
2008	0.527	2,133	148,853	± 88,124	70	± 25	9	9	2
2009	0.27	1,100	79,881	± 58,681	72.6	± 32	20	1.	1

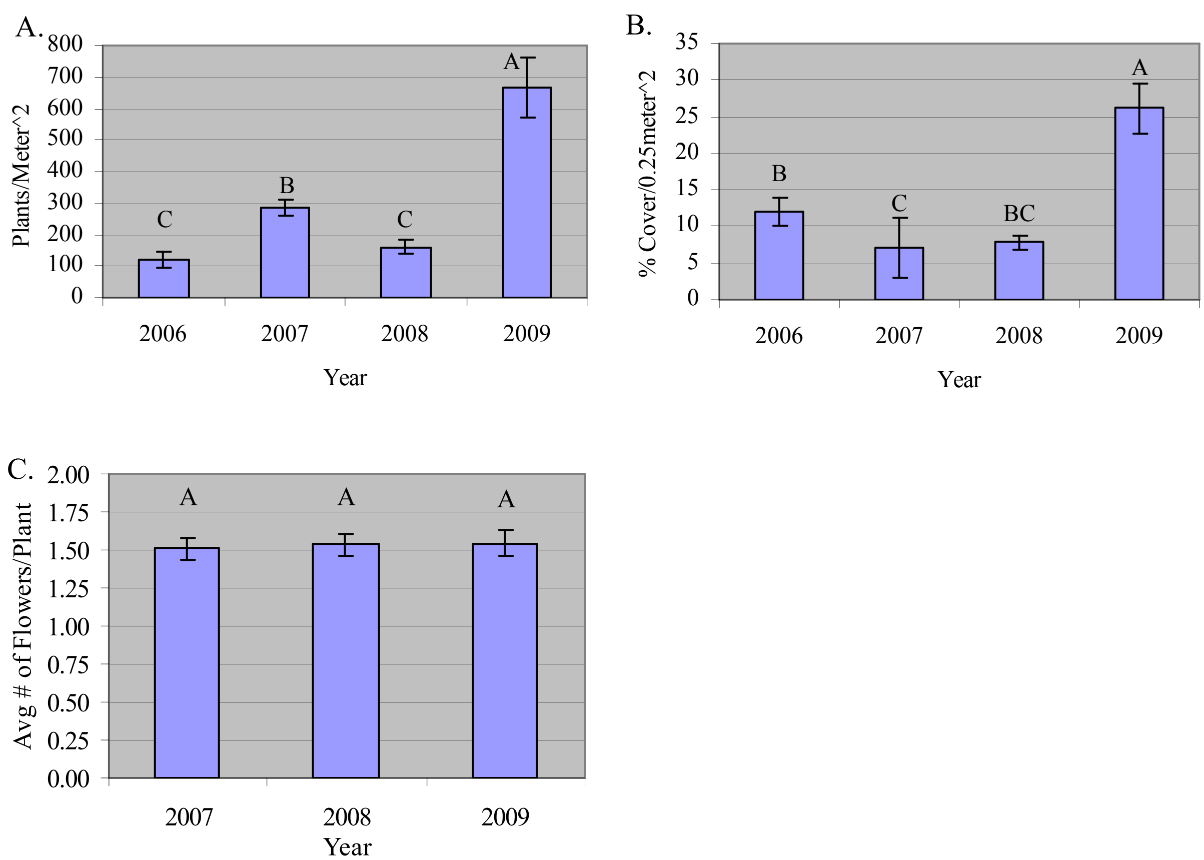
McCoy Basin. The distribution of CCG on the McCoy Basin site for 2006, 2007, 2008, and 2009 is shown in Map 6. The total population estimate, average density, percent cover, and total number of plants is summarized in Table 10. CCG population estimates range from 521,790 plants (± 170,343) in 2006 to 2.5 million plants (± 0.6 million) in 2009. Figure 4 shows the comparison of density (plants/meter squared) (A), percent cover (per ¼ meter squared) (B), and average number of flowers per plant (C).

For density, 2009 was significantly higher than 2006, 2007, and 2008, and 2007 was significantly higher than 2006 and 2008. Similarly, cover for 2009 was significantly higher than all other years, but unlike density, cover in 2006 was significantly higher than 2007. Quantitative data on average number of flowers per plant was not collected in 2006, but field notes indicate that plants in some pools in 2006 had on average 3-10 flowers per plant. This is considerably higher than the 1.5 flowers per plant estimated in 2007, 2008, and 2009, which may explain the difference in the pattern observed in density and cover between years.

Table 7. McCoy Basin Contra Costa goldfield population data

Year	Area		Estimated Density/ Count Area		Average Density/m²			% CCG cover	# Flowers/ Plant
	acres	m²	Plants	90%CI	Plants /m²	SE	N		
2006	1.06	4,280	521,790	± 170,343	122	± 24	50	12%	Na
2007	1.28	5,183	1,475,980	± 222,435	285	± 26	97	7%	1.51
2008	0.97	3,921	630,870	± 143,655	161	± 22	50	8%	1.53
2009	0.93	3,776	2,513,018	± 587,223	666	± 95	30	26%	1.54

Figure 5. CCG density per meter squared (A) percent cover per ¼ meter squared (B), and average number of flowers per plant (C) on the McCoy Basin Property. Letters above bars indicate significant differences between years within count areas. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Strassberger Industrial Park. The distribution of CCG on the Strassberger Industrial Park study site (south of Strassberger Drive) for is shown in Map 7. The total population estimate, average density, percent cover and total number of plants is summarized in Table 8. CCG population estimates for the site range from 1.2 million plants (± 404,744) in 2006 to 5.8 million plants (± 1.8 million) in 2007. Figure 6 shows the comparison of density (plants/meter squared) (A), percent cover (per ¼ meter squared) (B), and average number of flowers per plant (C).

The pools on the eastern portion of the Strassberger site contain the highest densities of CCG sampled in Solano County. For density and cover, 2007 was significantly higher than 2009. The sample size in 2006 was much smaller than the other years and may have affected comparisons between years. There were no differences in the average number of flowers per plant.

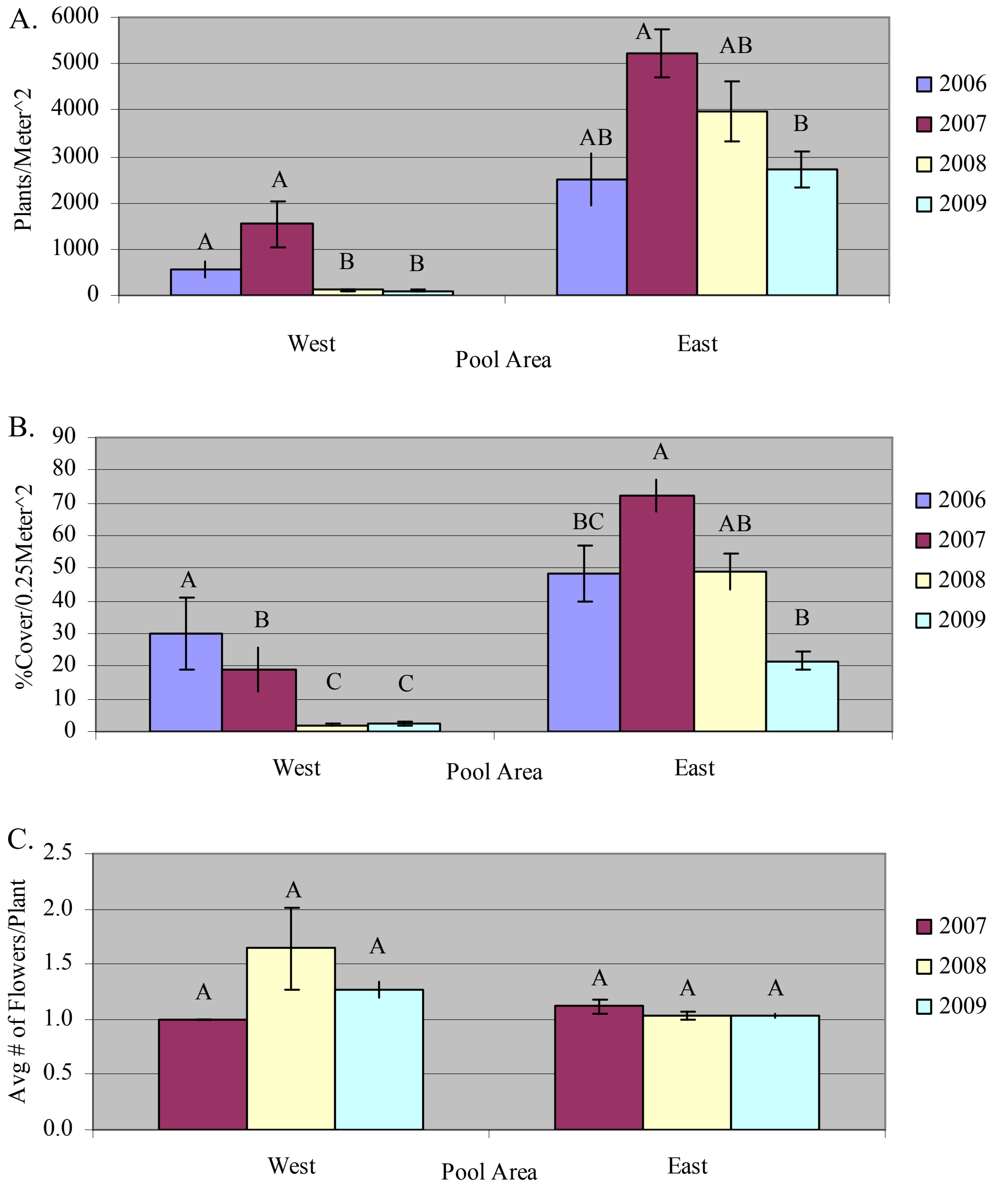
For Strassberger West, there were fewer samples collected in 2006 and 2007 than in 2008 and 2009 and the methodology used to sample this area was slightly different in 2006 and 2007 than in 2008 and 2009, making comparisons between years difficult for the area. The western area contains a large mosaic of different goldfields, including California goldfield, Ferris's goldfields and CCG. The area mapped in the western section in 2008 and 2009 represents the entire area of goldfields without distinguishing between goldfield species. Within this larger area there are a few discrete pools with denser stands of CCG; however, CCG were also found throughout the entire area mapped, though at much lower densities. Surveys and mapping in 2006 and 2007 focused more on sampling in the few dense count areas. This difference in methodology can account for the significant differences found between density and cover between the years, with 2006 and 2007 and 2008 and 2009.

For the eastern portion of the property, there was a smaller sample size for 2006, this may explain why no significant differences were found between 2006 and 2007 and 2008. For the remainder of the years, the density and cover of CCG was significantly higher in 2007 than in 2009.

Table 8. Strassberger Site Contra Costa goldfield population data

Count Area	Area		Estimated Density/ Count Area		Average Density/m²			% CCG cover	# Flowers /Plant	% *L. californica*	% *L. ferrisiae*
	acres	m^2	Plants	90% CI	Plants /m^2	SE	N				
2006											
West	0.24	957	538,782	± 305,647	563	± 159	5	30%			
East	0.07	269	670,543	± 265,325	2,497	± 554	12	48%			
Total	**0.30**	**1,225**	**1,209,325**	**± 404,744**							
2007											
West	0.50	2,015	3,095,779	± 1,753,356	1,536	± 508	23	19%	1.0	0.4	1.6
East	0.13	527	2,751,995	± 478,337	5,224	± 532	26	72%	1.1		
Total	**0.63**	**2,541**	**5,847,774**	**± 1,817,433**							
2008											
West	0.88	3558	395,196	±205,222	111	±35	60	2%	1.6	0.7	1.2
East	0.10	422	1,674,269	±452,657	3,970	±653	30	49%	1.0		
Total	**0.98**	**3,980**	**2,069,465**	**±497,006**							
2009											
West	1.02	4124	392,310	±179,928	95	±27	50	3%	1.3	0.9	1.4
East	0.11	446	1,207,461	±289,359	2,710	±395	50	22%	1.0		
Total	**1.13**	**4,570**	**1,599,771**	**±344,588**							

Figure 6. CCG density per meter squared (A) percent cover per ¼ meter squared (B), and average number of flowers per plant (C) on the Strassberger Property. Letters above bars indicate significant differences between years within count areas. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.

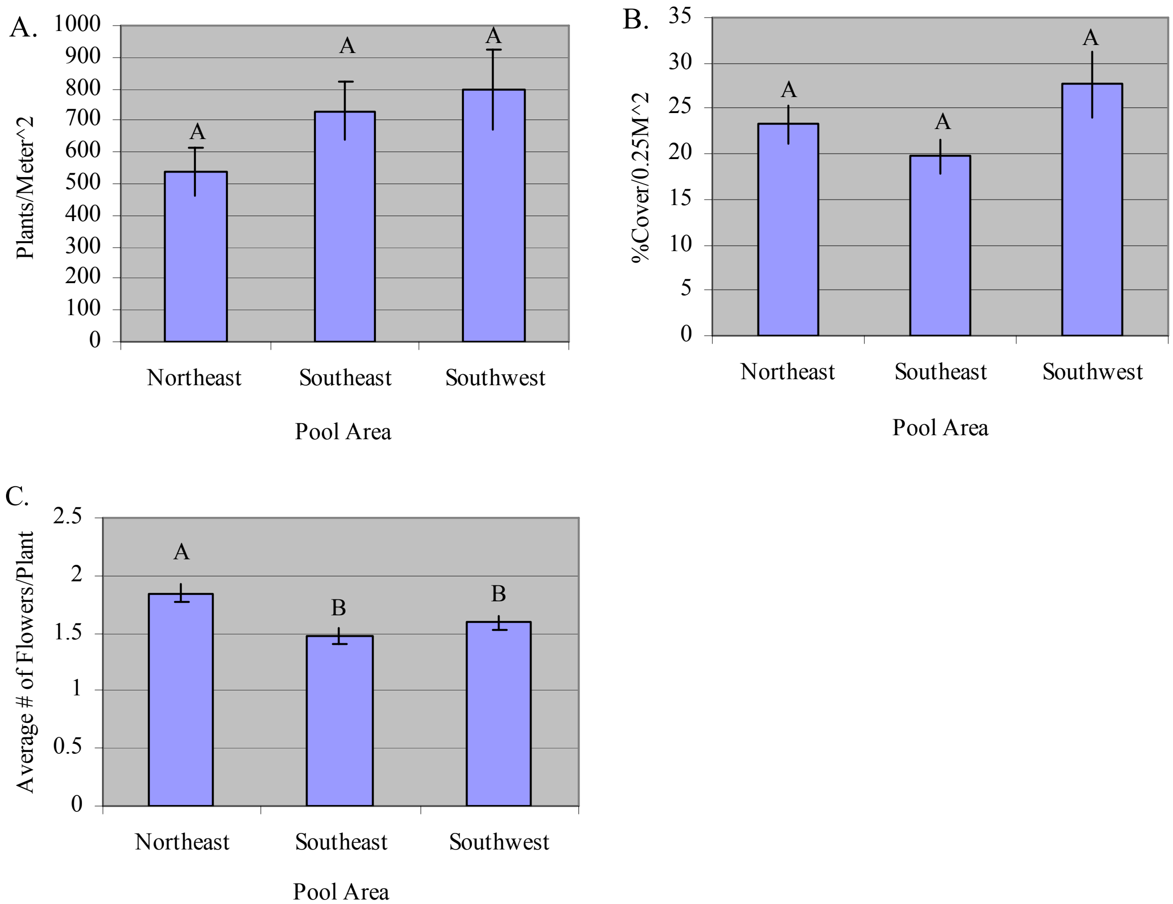


Noonan Ranch Conservation Bank. CCG occur in the majority of the wetlands on the Noonan Ranch Conservation Bank (Map 8). In 2008, during the first detailed mapping of CCG, there was 5.2 acres of CCG mapped in a total of 54 wetlands comprising a total wetland area of 23.20 acres. In 2009, 4.98 acres of CCG was mapped in a total of 78 wetlands comprising a total wetland area of 24.19 acres. For the CCG population monitoring, this site was divided up into three regions based on hydrological connectivity. These three regions, termed northeast, southeast, and southwest, are separated from each other hydrologically by Union Creek and the constructed Union Creek Bypass Channel (Figure 5). The total number of plants for the existing Bank was estimated to be between 12.4 million and 17.2 million plants (14.8 [±2.4] million) (Table 15). There were no differences in the density or cover between the three regions; however, there was a significant difference in the average number of flowers per plant, where the northeastern portion had a higher number of flowers per plant on average than the southeastern and southwestern areas (Figure 6 and Table 15).

Table 9. Noonan Ranch Conservation Bank 2009 Contra Costa Goldfield Population Data

Parcel	Area		Estimated Density/ Count Area		Average Density/m^2		% CCG cover	# Flowers/ Plant
	Acres	m^2	Plants	90%CI	Plants /m^2	SE		
Northeast	0.26	1,047	562,130	± 133,987	537	± 78	23	1.84
Southwest	1.09	4,411	3,521,537	± 943,028	798	± 130	28	1.59
Southeast	3.64	14,711	10,731,871	± 2,255,13(	730	± 93	20	1.47
Total	**4.98**	**20,168**	**14,815,539**	**2,448,033**		±		
Average					**688**	**59**	**24**	**1.6**

Figure 7. CCG density per meter squared (A) percent cover per ¼ meter squared (B), and average number of flowers per plant (C) on the Noonan Ranch Conservation Bank. Letters above bars indicate significant differences between years within count areas. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Between Study Site Comparisons

There is some variation in the densities and cover between sites between years but generally, certain study sites consistently lump together. Strassberger East and Director's Guild PPAA are consistently the two sites with the highest density and cover of CCG. However, they were also associated with GCB South, McCoy Basin and Barnfield Count Area D-X in a few years. On the other end of the extreme, Barnfield Count Area B and Director's Guild GAA consistently had the lowest densities and always grouped together. Apart from these two extremes there is more variation between years on how the other sites grouped together. The variation is likely a combination of variation in weather and management regimes but the consistency between sites is likely due to the morphology, structure, and soil characteristics of the wetlands themselves.

Generally, all of the Count Areas within the different study sites can be lumped into two general categories based on the characteristics of the wetlands containing CCG: areas with discrete pools and broader areas characterized as more seasonally saturated annual grassland. The areas that contain more discrete vernal pools include Strassberger East, Director's Guild PPAA, all of the areas on the GCB (South, Northeast and Northwest), McCoy Basin, Jehovah's Witness Pool, Barnfield Count Area D-X, and all of the areas on the Noonan Ranch Conservation Bank (Souteast, Southwest and Northeast). The sites that consist of larger more general wetland areas are Strassberger West; Barnfield Count Areas A, B, and C; and Director's Guild GAA.

Given some overlap, the broader wetland areas tend to group together in comparisons of both density and cover. The Director's Guild GAA and Barnfield Count Area B are the driest out of all of these areas and based on the 2009 vegetation data, contained high numbers of upland species (12 species for Director's Guild GAA) and (7 species for Count Area B). Count Area A, Count Area C, and Strassberger West consistently had higher densities and cover than Count Area B and Driector's Guild GAA. Count Area A is a smaller area than both the GAA and Count Area B and appears to stay saturated longer. Of the shallower wetland areas, density and cover appeared to vary between years based on rainfall, with wetter years (2006 and 2008) having higher densities than the drier years (2007 and 2009). The variation observed in Strassberger West was most likely the result of variations in sampling design, but densities between 2008 and 2009 did not show significant differences, neither does density and cover in Count Area C.

In general, areas with discrete pools had higher densities and cover than the seasonally saturated annual grassland areas. The areas that contained deeper pools, such as Strassberger East, Director's Guild PPAA, McCoy Basin, and GCB South, contained the highest densities of CCG. For areas with deeper pools, such as Director's Guild PPAA, GCB South, and McCoy Basin, wetter years (2006 and 2008) had lower CCG densities. This was not necessarily true for cover. For Director's Guild PPAA, 2006 and 2008 had higher cover than 2007. For GCB South, there was no difference in cover between 2007 and 2008. This difference between the patterns observed in density versus cover could be due to larger plant size. For areas with some of the deeper pools (GCB South and Director's Guild PPAA) plant size was larger in 2008 than in 2007 and 2009, which may account for the differences in density but not in cover. Thus, these deeper pools yielded fewer but larger plants in the drier years.

The sites with alkaline soils, based on plant composition, include: Barnfield, Director's Guild Strassberger Industrial Park, McCoy Basin, and the Northeastern portion of Noonan Ranch Conservation Bank. The highest densities and cover of CCG occur in areas with discreet vernal pools and moderately high soil alkalinity: Strassberger East and Director's Guild PPAA. In addition, McCoy Basin and Count Area D-X frequently had higher densities and cover than pools on the GCB. This may be the result of a decrease in competition from non native grasses due to higher levels of alkalinity.

Figure 8. CCG density per meter squared for each area for 2006, 2007, 2008, and 2009, minus Strassberger East and Director's Guild South. Letters above bars indicate significant differences between count areas within a year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.

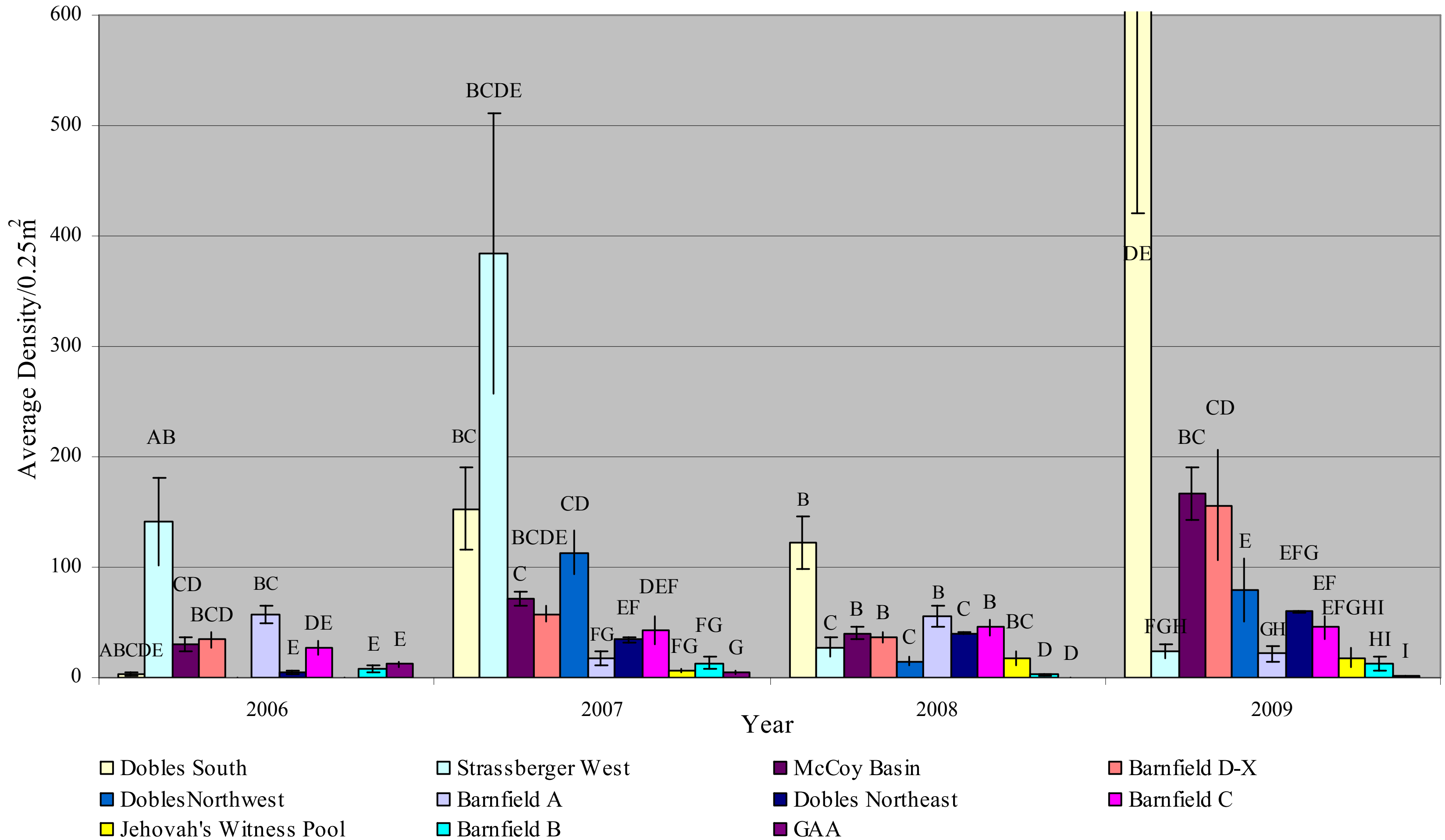


Figure 9. CCG percent cover per ¼ meter squared for each area for 2006, 2007, 2008, and 2009. Letters above bars indicate significant differences between count areas within a year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.

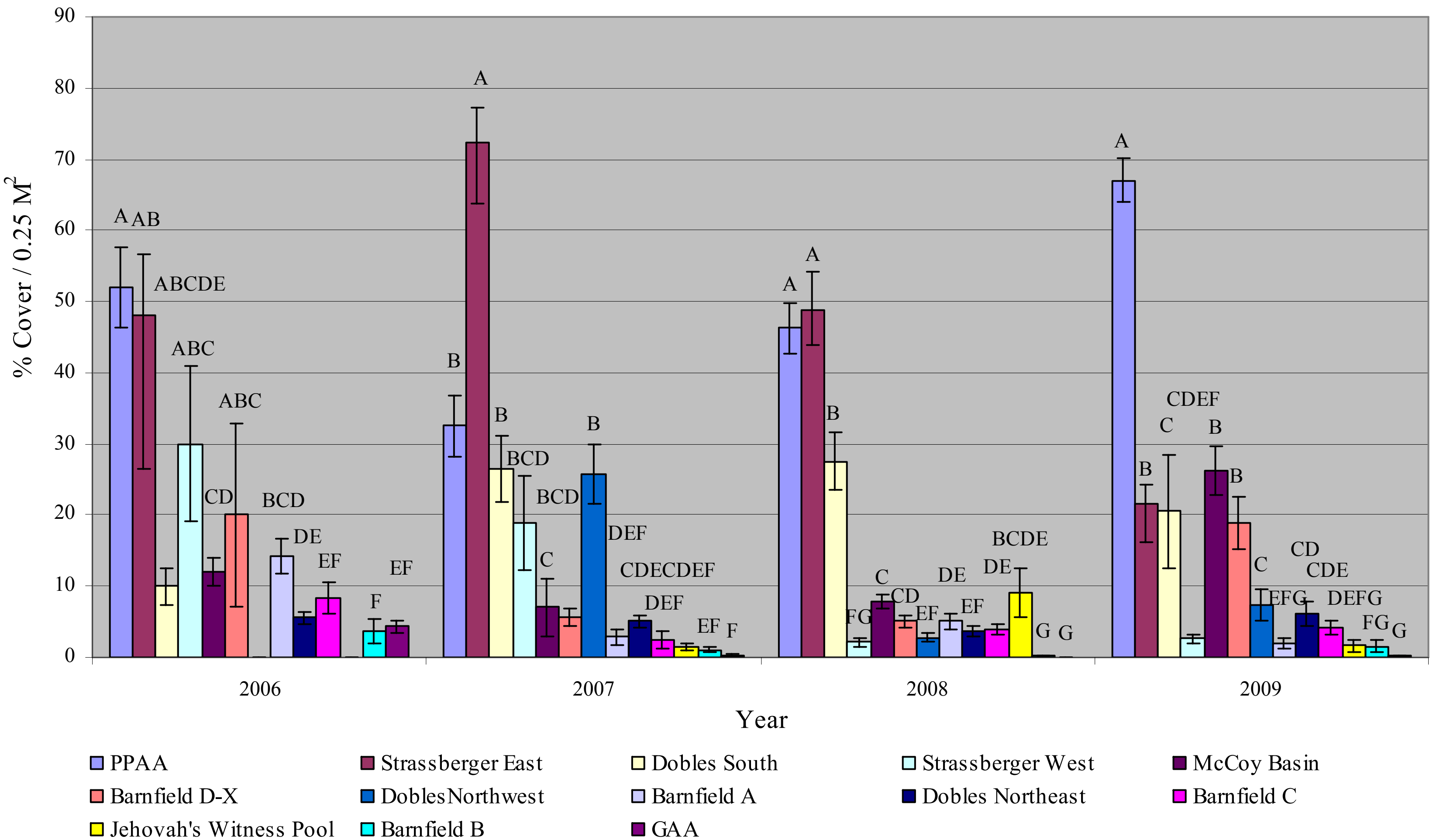
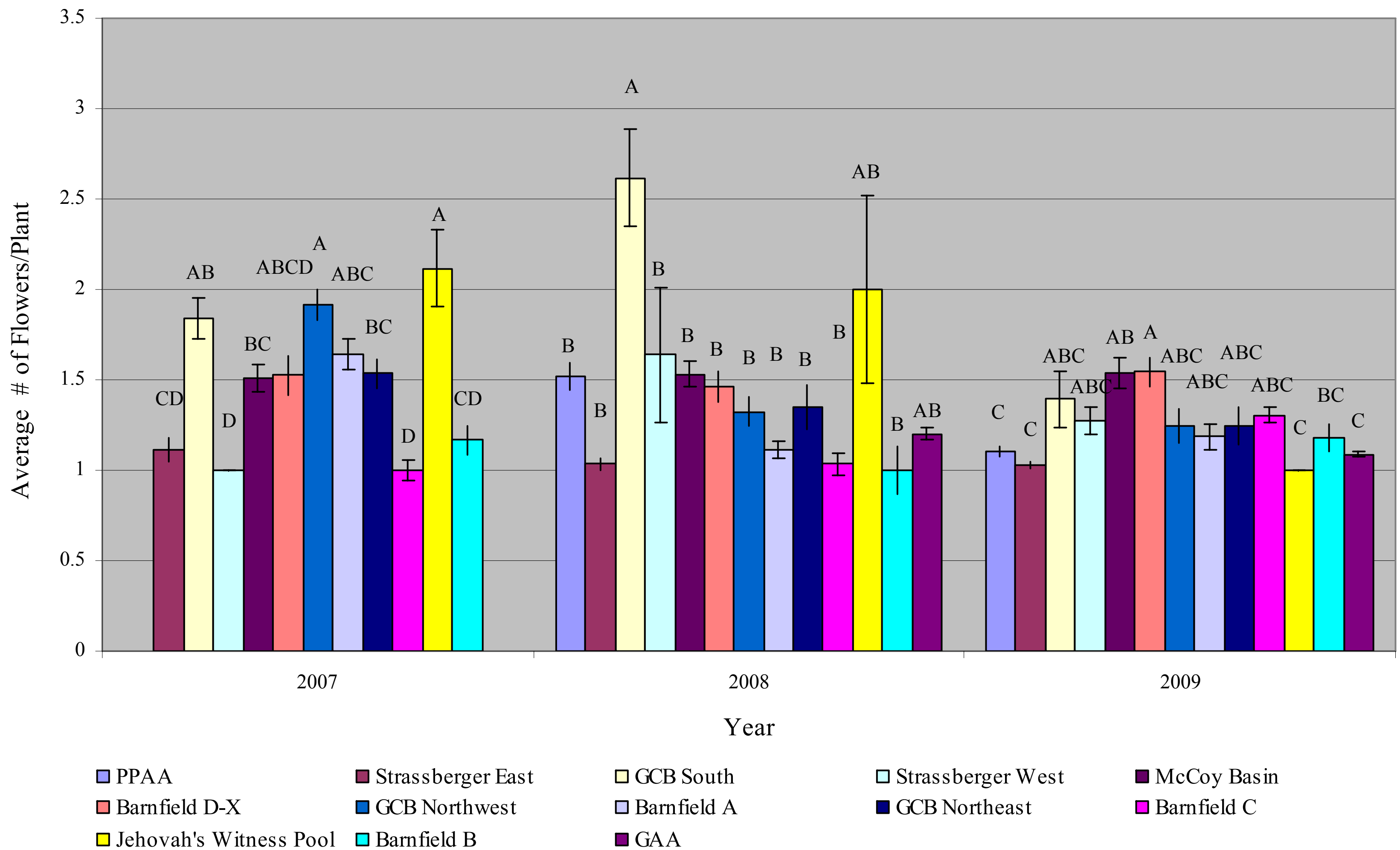


Figure 10. Average number of flowers per plant for each area for 2006, 2007, 2008, and 2009. Letters above bars indicate significant differences between count areas within a year. Areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Analysis of Vegetation Data

To identify possible correlations between the density of CCG and other dominant vegetation a Spearman's correlation test was conducted. From this analysis, 23 species were identified as having either a positive or negative relationship with CCG. Table 10 lists the results of that analysis for each species with significant results. Thirteen species showed positive correlations with CCG and ten species showed negative correlations. Seven of the 10 species with negative correlations were upland species. This is expected since CCG is listed as a FACW species. In addition, it is not surprising that it had the largest negative correlation with California goldfields (*L. californica*). Three species with negative correlations were wetland species: *Lotus corniculatus*, *Trifolium depauperatum var. truncatum*, and *Lolium multiflorum*. These are all species that are common in shallow wetlands or in marginal wetland areas.

Based on the results of the Spearman's correlation analysis, a stepwise regression analysis was performed using only the wetland species (species with a wetland designation of FAC, FACW or OBL) with significant correlations. The corrected Akaike's Information Criterion (AIC_C) was used to select the best model. Table 11 shows the results of this analysis (the top 10 models plus the full model with all 16 wetland species). The model with the highest AIC_C contained 13 of the 16 species assessed. The three species excluded were *Achyrachaena mollis*, *Lythrum hyssopifolium*, and, *Malvella leprosa*. The parameters estimates for these species in the full model were not significant and they were not significant when found in any of the other top 10 models assessed. Table 12 summarizes the parameter estimates for each species.

The relationships between CCG and other dominant species were also assessed by dividing the sample plots into seven categories based on CCG cover classes (0%, <5%, 6-15%, 16-25%, 26-50%, 51-75%, and 76-100%) and identifying which of the other dominant species recorded in each plot was associated with these CCG cover classes. Tables 13 and 14 list all of the species found in plots with CCG.

Centromadia sp., the species group with the most significant correlation with CCGs, was associated with medium value CCG cover classes ranging from 6% to 50%, with itself having an average non-zero cover of between 16% and 19% for those CCG cover categories. Other species that had similar distributions in relation to CCG cover were *Lasthenia glaberrima*, *Polypogon monspeliensis, Achyrachaena mollis*, *Lythrum hyssopifolium*, and *Malvella leprosa*. This pattern was not necessarily reflected in the frequency distribution for *Pleuropogon californicus*, but it was reflected in the average cover values. Similarly, *Cressa truxeliensis* was observed at higher frequency with higher CCG cover classes, but had higher percent cover in plots with lower CCG cover (≤5%, and 6%-15%).

Downigia concolor, *Plagiobothrys stipitatus*, *Psilocarphus brevissimus*, and *Layia chrysanthemoides* were the species found more frequently with high densities of CCG (between 51-100% cover), however, the average cover of each species in these plots was low. In addition, there were only a few plots containing *Layia chrysanthemoides* located on the Noonan Ranch Conservation Bank. More detailed vegetation data from this location does not support the association of *Layia chrysanthemoides* in plots with high densities of CCG. *Layia chrysanthemoides* was more commonly found in the drier areas of the wetland with only a little overlap with CCG. *Lolium multiflorum* was found associated with all CCG cover classes, but had the highest average cover in plots where CCG were either absent of at low densities (i.e. cover ≤5%).

Table 10 Results of Spearman's Correlation tests for correlations between the percent cover of CCGs and other dominant species observed in monitoring plots.

Species	Wetland Status	N	Spearman's P	p
Centromadia sp.	FAC	69	0.33	<0.0001
Psilocarphus brevissimus	OBL	28	0.27	<0.0001
Plagiobothrys stipitatus	OBL	15	0.17	<0.0001
Cressa truxeliensis	FACW	31	0.17	<0.0001
Downingia concolor	OBL	4	0.12	0.0013
Pleuropogon californicus	OBL	13	0.11	0.0029
Lasthenia glaberrima	OBL	90	0.14	0.0001
Malvella leprosa	FAC	15	0.11	0.0034
Achyrachaena mollis	FAC	12	0.12	0.0014
Layia chrysanthemoides	FACW	3	0.09	0.0165
Eryngium sp.	FACW or OBL	167	0.09	0.0130
Lythrum hyssopifolium	FACW	19	0.11	0.0040
Polypogon monspeliensis	FACW	91	0.11	0.0034
Lotus corniculatus	FAC	8	-0.11	0.0032
Erodium cicutarium	FACU	18	-0.12	0.0014
Lupinus bicolor	FACU	8	-0.13	0.0004
Vulpia myuros	FACU	35	-0.13	0.0005
Trifolium depauperatum var. truncatum	FAC	11	-0.15	<0.0001
Lolium multiflorum	FAC	445	-0.15	<0.0001
Erodium botrys	FACU	35	-0.27	<0.0001
Triphysaria eriantha	FACU	51	-0.29	<0.0001
Bromus hordeaceus	FACU	216	-0.46	<0.0001
Lasthenia californica	FACU	167	-0.47	<0.0001

Table 11. Results of a stepwise regression analysis using the wetland species found to be correlated with CCG.

Model	Species	# of Species	r^2	RMSE	AIC_C
1	*Centromadia sp., Cressa truxeliensis, Downingia concolor, Eryngium sp, Lasthenia glaberrima, Layia chrysanthemoides, Lolium multiflorum, Plagiobothrys stipitatus, Pleuropogon californicus, Polypogon monspeliensis, Psilocarphus brevissimus, Trifolium depauperatum var. truncatum, Lotus corniculatus*	13	0.2959	1.2962	2507.28
2	Model 1 + *Malvella leprosa*	14	0.2974	1.2957	2507.73
3	Model 1 + *Achyrachaena mollis*	14	0.2968	1.2963	2508.37
4	Model 1 + *Lythrum hyssopifolium*	14	0.2966	1.2964	2508.59
5	Model 1 + *Achyrachaena mollis* and *Malvella leprosa*	15	0.2984	1.2957	2508.78
6	Model 1 + *Malvella leprosa* and *Lythrum hyssopifolium*	15	0.2982	1.2958	2508.98
7	Model 1 - *Lasthenia glaberrima*	12	0.2919	1.299	2509.39
8	Model 1 - *Lotus corniculatus*	12	0.2918	1.299	2509.43
9	Model 1 - *Lasthenia glaberrima*, + *Malvella leprosa*	13	0.2938	1.2982	2509.48
10	Model 1 + *Achyrachaena mollis* and *Lythrum hyssopifolium*	15	0.2976	1.2964	2509.65
11	Full Model[1]	16	0.2993	1.2958	2509.99

[1]the full model includes all species in Model 1 plus *Achyrachaena mollis*, *Lythrum hyssopifolium*, and, *Malvella leprosa*.

Table 12. Summary of the parameter estimates for each species for each species for model 1.

Parameter	Estimate	Std Error	t Ratio	p-value
Intercept	1.315	0.084	15.698	<0.0001
Centromadia sp.	0.478	0.041	11.537	<0.0001
Psilocarphus brevissimus	1.296	0.238	5.437	<0.0001
Cressa truxeliensis	0.575	0.116	4.943	<0.0001
Lolium multiflorum	-0.139	0.031	-4.420	<0.0001
Eryngium sp.	0.215	0.060	3.593	0.0004
Polypogon monspeliensis	0.161	0.048	3.359	0.0008
Pleuropogon californicus	0.509	0.152	3.351	0.0009
Plagiobothrys stipitatus	0.575	0.193	2.977	0.003
Downingia concolor	2.851	0.959	2.972	0.003
Layia chrysanthemoides	2.116	0.765	2.766	0.0058
Trifolium depauperatum var truncatum	-0.775	0.295	-2.628	0.0088
Lotus corniculatus	-0.353	0.173	-2.041	0.0416
Lasthenia glaberrima	0.218	0.107	2.032	0.0425

Table 13. Frequency in which other species were counted as dominants in plots associated with various CCG cover classes. Bold species represent those with significant correlations.

Species	CCG Cover Class						
	0%	≤ 5%	6%-15%	16%-25%	26%-50%	51%-75%	76%-100%
Number of Plots	**221**	**224**	**93**	**60**	**87**	**33**	**34**
Lasthenia conjugens	0	100	100	100	100	100	100
Achyrachaena mollis	**1**	**0**	**1**	**7**	**6**	**0**	**3**
Achyrachaena caralophylacea	0	1	0	0	1	0	0
Astragulus tener	1	0	0	0	0	0	0
Avena barbata	1	0	0	0	0	0	0
Bare Ground	66	83	81	85	97	85	79
Brodiaea elegans	1	0	0	0	0	0	0
Bromus hordeaceus	**58**	**27**	**15**	**10**	**8**	**3**	**6**
Centaurea calcitrapa	0	1	0	0	0	0	0
***Centromadia* sp.**	**5**	**22**	**42**	**55**	**49**	**27**	**12**
Convolvulus arvensis	0	4	2	0	5	0	0
Cotula coronopifolia	1	3	1	2	1	0	6
Cressa truxeliensis	**1**	**3**	**8**	**2**	**7**	**9**	**18**
Deschampsia danthonioides	2	2	5	7	2	3	0
Distichlis spicata	9	9	6	5	5	9	0
Downingia concolor	**0**	**0**	**0**	**0**	**1**	**3**	**6**
Downingia cuspidata	0	1	0	0	0	0	6
Eleocharis macrostachya	1	3	1	5	3	0	0
Eremocarpus setigerus	0	1	0	0	0	3	0
Erodium botrys	**16**	**1**	**0**	**0**	**0**	**0**	**0**
Erodium cicutarium	**5**	**1**	**0**	**3**	**1**	**0**	**0**
Erodium sp.	1	0	0	0	0	0	0
***Eryngium* sp.**	**19**	**22**	**19**	**25**	**28**	**36**	**26**
Frankenia salina	27	20	10	8	13	39	53
Geranium dissectum	1	1	0	0	1	0	3
Hordium brachyantherum	3	1	3	0	0	3	0
Hordeum marinum	35	60	62	58	57	42	21
Hypochaeris radicata	1	1	0	0	0	0	0
Hypochaeris sp.	1	0	0	0	0	0	0
Lasthenia californica	**52**	**23**	**9**	**0**	**2**	**0**	**0**
Lasthenia ferrisea	2	1	2	0	0	0	0
Lasthenia glaberrima	**5**	**14**	**15**	**28**	**11**	**12**	**9**
Lasthenia platycarpha	1	0	0	0	1	0	0
Layia chrysanthemoides	**0**	**0**	**0**	**0**	**1**	**6**	**0**
Layia platyglossa	0	0	1	2	2	0	0

Species	CCG Cover Class						
	0%	≤ 5%	6%-15%	16%-25%	26%-50%	51%-75%	76%-100%
Number of Plots	**221**	**224**	**93**	**60**	**87**	**33**	**34**
Layia sp.	2	3	0	3	0	0	0
Lepidium latifolium	1	0	0	0	0	0	0
Lepidium sp.	0	1	2	0	0	0	0
Lolium multiflorum	**57**	**58**	**73**	**62**	**67**	**58**	**26**
Lotus corniculatus	**3**	**0**	**1**	**0**	**0**	**0**	**0**
Lotus micranthus	1	0	0	0	0	0	0
Lupinus bicolor	**4**	**0**	**0**	**0**	**0**	**0**	**0**
Lythrum hyssopifolium	**0**	**3**	**5**	**5**	**2**	**9**	**0**
Malvella leprosa	**1**	**1**	**1**	**3**	**7**	**3**	**3**
Medicago polymorpha	6	3	6	5	1	0	0
Meliotis indica	1	1	0	0	0	0	0
Microseris douglasii tenella	7	2	3	0	0	0	0
Myosurus minimus	0	0	0	0	1	0	0
Plagiobothrys micranthus	0	1	2	2	0	3	0
Plagiobothrys stipitatus	**0**	**1**	**0**	**2**	**5**	**9**	**15**
Plantago elongata	1	0	2	0	0	0	0
Plantago sp.	0	1	1	0	0	0	0
Pleuropogon californicus	**1**	**1**	**2**	**2**	**2**	**9**	**6**
Poa annua	1	1	0	0	0	0	0
Polypogon monspeliensis	**6**	**15**	**11**	**12**	**16**	**24**	**12**
Psilocarphus brevissimus	**0**	**1**	**2**	**2**	**6**	**21**	**32**
Psilocarphus tenellus	0	1	0	0	0	0	0
Rumex crispus	1	0	1	0	0	0	0
Rumex pulcher	1	4	4	7	2	3	0
Salicornia virginica	4	1	4	0	1	3	9
Trifolium depauperatum	0	0	1	0	0	0	0
Trifolium depauperatum var. *depauperatum*	1	4	1	0	0	0	0
Trifolium depauperatum* var. *truncatum	**5**	**0**	**0**	**0**	**0**	**0**	**0**
Trifolium dubium	0	1	0	0	0	0	0
Trifolium fucatum	1	7	2	2	0	0	3
Trifolium sp.	0	1	1	0	0	0	0
Trifolium willdenovii	1	1	0	0	0	0	0
Trifolium wormskioldii	1	1	0	0	0	0	0
Triphysaria eriantha	**19**	**4**	**0**	**0**	**0**	**0**	**0**
Triphysaria sp.	1	1	0	0	0	0	0
Triteleia hyacinthina	1	2	1	0	0	0	0
Vulpia myuros	**8**	**6**	**3**	**2**	**0**	**0**	**0**

Table 14. Average non-zero cover of other dominant species in plots with CCG. Bold species represent those with significant correlations.

Species	CCG Cover Class						
	0%	≤ 5%	6%-15%	16%-25%	26%-50%	51%-75%	76%-100%
Number of Plots	**221**	**224**	**93**	**60**	**87**	**33**	**34**
Lasthenia conjugens	0%	2%	12%	21%	36%	67%	84%
Achyrachaena mollis	**2%**	**0%**	**1%**	**3%**	**1%**	**0%**	**1%**
Achyrachaena caralophylacea	0%	3%	0%	0%	10%	0%	0%
Astragulus tener	4%	0%	0%	0%	0%	0%	0%
Avena barbata	3%	0%	0%	0%	0%	0%	0%
Bare Ground	17%	16%	17%	14%	15%	9%	7%
Brodiaea elegans	1%	0%	0%	0%	0%	0%	0%
Bromus hordeaceus	**31%**	**21%**	**18%**	**4%**	**4%**	**10%**	**1%**
Centaurea calcitrapa	0%	20%	0%	0%	0%	0%	0%
***Centromadia* sp.**	**11%**	**19%**	**18%**	**19%**	**16%**	**12%**	**6%**
Convolvulus arvensis	0%	16%	13%	0%	9%	0%	0%
Cotula coronopifolia	38%	6%	5%	15%	10%	0%	2%
Cressa truxeliensis	**1%**	**9%**	**16%**	**5%**	**6%**	**3%**	**4%**
Deschampsia danthonioides	32%	10%	19%	29%	15%	5%	0%
Distichlis spicata	9%	13%	28%	10%	15%	10%	0%
Downingia concolor	**0%**	**0%**	**0%**	**0%**	**1%**	**1%**	**1%**
Downingia cuspidata	0%	1%	0%	0%	0%	0%	3%
Eleocharis macrostachya	10%	15%	10%	8%	9%	0%	0%
Eremocarpus setigerus	0%	1%	0%	0%	0%	1%	0%
Erodium botrys	**25%**	**5%**	**0%**	**0%**	**0%**	**0%**	**0%**
Erodium cicutarium	**7%**	**22%**	**0%**	**16%**	**1%**	**0%**	**0%**
Erodium sp.	1%	0%	0%	0%	0%	0%	0%
***Eryngium* sp.**	**6%**	**6%**	**8%**	**9%**	**8%**	**6%**	**4%**
Frankenia salina	11%	12%	11%	8%	21%	9%	8%
Geranium dissectum	2%	1%	0%	0%	2%	0%	1%
Hordium brachyantherum	28%	42%	9%	0%	0%	1%	0%
Hordeum marinum	29%	28%	24%	19%	20%	6%	5%
Hypochaeris radicata	1%	5%	0%	0%	0%	0%	0%
Hypochaeris sp.	1%	0%	0%	0%	0%	0%	0%
Lasthenia californica	**14%**	**16%**	**5%**	**0%**	**2%**	**0%**	**0%**
Lasthenia ferrisea	14%	4%	1%	0%	0%	0%	0%
Lasthenia glaberrima	**3%**	**3%**	**3%**	**4%**	**4%**	**2%**	**5%**
Lasthenia platycarpha	2%	0%	0%	0%	10%	0%	0%
Layia chrysanthemoides	**0%**	**0%**	**0%**	**0%**	**1%**	**2%**	**0%**
Layia platyglossa	0%	0%	5%	5%	10%	0%	0%

Species	CCG Cover Class						
	0%	≤ 5%	6%-15%	16%-25%	26%-50%	51%-75%	76%-100%
Number of Plots	**221**	**224**	**93**	**60**	**87**	**33**	**34**
Layia sp.	16%	16%	0%	13%	0%	0%	0%
Lepidium latifolium	5%	0%	0%	0%	0%	0%	0%
Lepidium sp.	0%	25%	5%	0%	0%	0%	0%
Lolium multiflorum	**39%**	**30%**	**16%**	**15%**	**11%**	**4%**	**3%**
Lotus corniculatus	**13%**	**0%**	**30%**	**0%**	**0%**	**0%**	**0%**
Lotus micranthus	9%	0%	0%	0%	0%	0%	0%
Lupinus bicolor	**9%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Lythrum hyssopifolium	**0%**	**5%**	**3%**	**12%**	**5%**	**4%**	**0%**
Malvella leprosa	**1%**	**13%**	**10%**	**10%**	**7%**	**2%**	**1%**
Medicago polymorpha	13%	20%	14%	5%	5%	0%	0%
Meliotis indica	5%	2%	0%	0%	0%	0%	0%
Microseris douglasii tenella	15%	10%	4%	0%	0%	0%	0%
Myosurus minimus	0%	0%	0%	0%	10%	0%	0%
Plagiobothrys micranthus	0%	5%	21%	5%	0%	5%	0%
Plagiobothrys stipitatus	**0%**	**4%**	**0%**	**10%**	**9%**	**6%**	**5%**
Plantago elongata	2%	0%	13%	0%	0%	0%	0%
Plantago sp.	0%	5%	2%	0%	0%	0%	0%
Pleuropogon californicus	**10%**	**6%**	**6%**	**30%**	**20%**	**17%**	**7%**
Poa annua	10%	20%	0%	0%	0%	0%	0%
Polypogon monspeliensis	**16%**	**39%**	**37%**	**45%**	**32%**	**9%**	**17%**
Psilocarphus brevissimus	**0%**	**11%**	**4%**	**5%**	**1%**	**2%**	**1%**
Psilocarphus tenellus	0%	1%	0%	0%	0%	0%	0%
Rumex crispus	28%	0%	10%	0%	0%	0%	0%
Rumex pulcher	2%	2%	7%	4%	2%	10%	0%
Salicornia virginica	16%	10%	21%	0%	15%	2%	1%
Trifolium depauperatum	0%	0%	1%	0%	0%	0%	0%
Trifolium depauperatum var. *depauperatum*	18%	14%	25%	0%	0%	0%	0%
Trifolium depauperatum* var. *truncatum	**3%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Trifolium dubium	0%	2%	0%	0%	0%	0%	0%
Trifolium fucatum	5%	27%	15%	5%	0%	0%	5%
Trifolium sp.	0%	2%	10%	0%	0%	0%	0%
Trifolium willdenovii	5%	1%	0%	0%	0%	0%	0%
Trifolium wormskioldii	18%	1%	0%	0%	0%	0%	0%
Triphysaria eriantha	**9%**	**9%**	**0%**	**0%**	**0%**	**0%**	**0%**
Triphysaria sp.	5%	1%	0%	0%	0%	0%	0%
Triteleia hyacinthina	2%	1%	1%	0%	0%	0%	0%
Vulpia myuros	**21%**	**13%**	**6%**	**1%**	**0%**	**0%**	**0%**

GENETIC STUDIES

Detailed information on the results of the genetic study is presented in Appendix D. Overall, there is a high level of genetic diversity present among all populations; however, there is very little geographic structure to the data. The majority of the genetic variation was partitioned within pools (97.78%) and the remaining variation was distributed among properties (2.22%). With the inclusion of sub-areas, the among property variation was 1.14% of the total variation, with 2.86% of the variation found among sub-areas within properties, and the remaining 96% of the variation found within pools. There is no strong clustering of pools by property or geographic proximity; however, low to moderate levels of inbreeding (f) was detected both within properties and within pools. The detected inbreeding suggests a more recent limitation on gene flow among pools and among properties.

SEED BANK STUDY

Soil Cores

Table 15 shows the results of the preliminary growing experiment conducted in Point Richmond. Of the four soil cores distributed in pots, 62 CCGs germinated and grew large enough to identify. This extrapolates to a minimum of 7,894 seeds per m^2 that have survived dormant in the soil for more than one growing season. In addition, several other species germinated in the pots including, toad rush (*Juncus bufonius*), brass buttons (*Cotula coronopifolia*), popcorn flower (*Plagiobothrys* sp.), and several unidentified individuals. Two of the three samples show a drastic decline in the number of CCGs that germinated by depth; however, the third sample showed the opposite results. In addition, there was no apparent difference in the number of CCGs that germinated in plots treated with 1/3 of the soil core versus 1/6 of the soil core. The concern for applying 1/3 of the soil core was that this created two deep of a soil layer for CCGs to germinate. Based on the results, it appears that only the seeds in the upper portions of the pots containing a full 1/3 of a soil core were able to germinate and the actual number of seeds per soil core is much higher.

Table 15. Results of the soil core experiment conducted in Point Richmond.

Amount of Soil Core Received	Pot #	Soil Core (sample)	Depth (cm)	CCGs	Other Species Identified			
					toad rush	brass buttons	popcorn flower	Unknown
1/3 (i.e. one pot per depth per sample)	1	1	0-5	7	23	1	3	
	2	1	5-10					
	3	1	10-15		2			1
	4	2	0-5	12	3	4		7
	5	2	5-10	2				
	6	2	10-15	1				
1/6 (i.e. each 5 cm deep sample was split between 2 pots)	7	3	0-5		5			
	8	3	0-5		4			1
	9	3	5-10	6	11	1		1
	10	3	5-10	7	13	1		
	11	3	10-15	13	41	1		2
	12	3	10-15	5	74	1		4
1/6 (homo-genized over all depths)	13	4	0-15		12			
	14	4	0-15	2	8			1
	15	4	0-15		7			1
	16	4	0-15	1	5			
	17	4	0-15	4	2			1
	18	4	0-15	2	11			1
Totals				**62**	**221**	**9**	**3**	**20**

Removal Plots

In May 2006, three removal plots were established in the playa pool on the Director's Guild site (See Appendix E). In spring 2007, 2008 and 2009, CCGs were counted in the three removal plots. Based on the number of CCGs growing outside of the plots in the surrounding count area calculated for the population count data, the density inside the plot for each year was found to be significantly different from the density of CCG plants growing outside of the removal plots (Figure 11 and Table 16). Even though there was a significant difference between densities inside and outside of the removal plots, this difference did not increase substantially from 2007 through 2009. The density of plants in the removal plots was on average 15% percent of the natural density.

Figure 11. Difference in CCG densities both inside and outside of the removal plots.

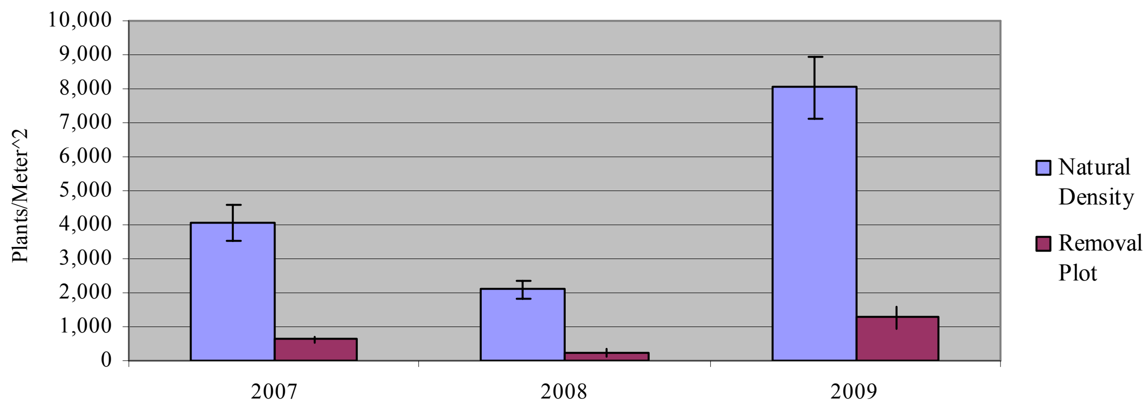


Table 16. Average density of CCG plants found inside and outside of the removal plots.

Year	Natural Count Area			Removal Plots		% of Natural Density	P-value
	Plants /M^2	SE Mean	N	Plants /M^2	SE Mean		
2006	1922	± 674	5	3501	± 1125	182%	0.24
2007	4046	± 537	10	632	± 79	11%	0.0062
2008	2109	± 263	10	241	± 123	18%	0.0033
2009	8035	± 936	9	1277	± 340	16%	0.0025

DISTRIBUTION

The distribution results presented in this report represent data from a combination of sources and a collaborative effort to better understand the distribution and status of this species. The landowners, consultants, and agencies that contributed to these efforts are further detailed in the Acknowledgment section at the end of the report. Maps 1 and 9 illustrate the most current distribution of CCG within the County. New populations of CCG were found on the Peterson and Johnson Trust Lands (west and east) by LSA Associates in 2006, on the parcel in between this and the Solano-Union Creek

Mitigation Bank by LSA Associates in 2007, on the Mangles Property by Ramona Robinson in 2006, on the Pullin Property in Fairfield by LSA Associates in 2007, on what is now the Noonan Ranch Conservation bank by LSA Associates in 2007, on Noonan North and South of Canon Road by LSA Associates in 2009.

In 2007, CCG were found in numerous vernal pools on what is now the Noonan Ranch Conservation Bank. In 2009, CCGs were observed in seven other locations outside of the existing Bank, one in the area north of Canon Road and six in the area south of Canon Road (Map 9); however, none of the wetlands outside of the bank area contained large populations. Fremont's goldfields were not observed in any of the wetlands on the Noonan Ranch Conservation Bank or adjacent parcels; however, it was the dominant goldfield on Craig's Ranch, approximately one-half mile southeast, and in the wetlands south of Travis Air force Base and north of Highway 12.

LSA Associates surveyed the Pullin Property in 2007 (a small infill property just off of Dobe Lane within the potential habitat area designated 2C in the Solano HCP) and found an isolated population of CCG in the large pool on the southwestern corner of the property and in a few smaller pools on the southwestern portion of the property. This isolated population found in subarea 2C suggests that more of the infill parcels in these areas could contain isolated wetlands with CCG.

Prior to 2000, much of the large Core Area 1F, located south of Travis Air Force Base, had remained unsurveyed. This area, given the large amount of potential habitat outside of the urban limit lines of the cities, represented one of the largest contiguous blocks of habitat for this species. More extensive surveys in this Core Area in recent years have revealed that much of the potential habitat is not occupied by CCG, but instead by Fremont's goldfields. There were only a few pools occupied by CCG on the Mangels Property and the Peterson and Johnson Trust Lands (West and East).

For the Mangels Property, Ramona Robinson in surveys conducted in June of 2006 observed CCG in six locations. All of the locations were located in the northern portion of the property and apparently either occupied relatively small areas or occurred in low numbers with the exception of one of the wetlands on the eastern edge of the property. This wetland (i.e. wetland 4 in her report) contained "thousands" of CCG plants along with many other native wetland plants such as alkali sida (*Malvella leprosa*), popcorn flower (*Plagiobothrys stipitatus* var. *micranthus*), spikerush, brass buttons (*Cotula coronopifolia*), and three types of downingia (*Downingia concolor, Downingia insignis,* and *Downingia pulchella*) (Robinson 2006). These plants are consistent with those found to be associated with CCG in other areas of the County.

For the Peterson and Johnson Trust Lands East, only one plant was observed in a vernal pool in 2006 and no plants were observed in 2007. For the western parcels, CCG were only found in the western and northern portions of the property. On the parcels south of Hwy 12, CCG were found in three small count areas. On the parcels north of Hwy 12, three small pools in the southwest corner, one pool in the northern part of the property and one pools just to the east of the property boundary were dominated by CCG. Additional plants were found in a few scattered count areas but the majority of these pools were dominated by Fremont's goldfield.

In addition to a limited CCG distribution in Core Area 1F, several individual plants were found with mixed traits (i.e. *conjugens* and *fremontii* traits). These plants had no pappus (a characteristic of Contra Costa goldfields), but their phyllaries are not fused (a characteristic of Fremont's goldfields).

These plants could represent mutant Fremont's goldfields, mutant CCG or a hybrid of these two species. Whether or not they are hybrids can not be determined without genetic analysis. In addition to the Peterson and Johnson Trust Lands (West), plants that contained these mixed traits (i.e. free phyllaries and no pappus) were also found on the Craig Ranch by Virginia Dains in 2006, along the western edge of Muzzy Ranch by LSA Associates in 2007, and on wildlands in 2009 (M. Tovar Personal Communication). Voucher specimens, plus tissue samples were collected from several of these potential hybrid plants for future analysis.

DISCUSSION

POPULATION ESTIMATES

Population Estimate Methodology

One of the purposes of this initial study was to develop a sampling program that can provide repeatable and statistically valid density estimates. Our observations show CCG densities can range from as little as one plant per pool to up to more than 8,346 CCG per 0.25 m^2.

Previous population estimates for CCG have been based on visual estimation methods. The disadvantage of visual estimation methods is that the population estimates are subjected to extreme amounts of variability and bias by individual observers, particularly for large areas and dense populations. For large areas and dense stands, visual estimation methods tend to underestimate the size of the population. For example, when comparing the population estimates recorded in CNDDB records to the population estimates obtained from count data, in most cases the number of plants is orders of magnitude larger. The CNDDB occurrence record for the Director's Guild property lists a population of 100,000+ plants in 1993; however, once more accurate population counts were conducted, the population was estimated to contain approximately 18 million plants in 2004, 14.7 million in 2005, 15.7 million in 2006 and a maximum of 164 million in 2009. Even though there are considerable fluctuations in these numbers from year to year, all of the quantitative counts are at least ten times larger than the visual estimate reported in the CNDDB record. Without a standardized method density measures cannot be compared between years.

Several surveys for Contra Costa goldfields have been conducted for the GCB Study Site and these estimates vary wildly from year to year. However, since there was no standard method in estimating population numbers it is difficult to compare the data. The population on the GCB northwest area was estimated to contain 100,000 individuals in 1995 and more than 300,000 individuals in 2000 (Zentner and Zentner 2000). Based on the data from this study, an estimated 2.5 to 4.5 million plants occurred on the northwestern parcel in 2007. Mapping of occupied habitat from Zentner and Zentner in 2000 shows a much larger area occupied by CCG than what was mapped in 2007. If we assume that CCG densities were similar between years, it is likely that the total population in 2000 was much larger than the 2.5 to 4.5 million plants estimated in 2007, making the estimate of 300,000 individuals a gross underestimate. But, other than this one parameter of mapped occupied habitat, there is no way to directly compare the population estimates between these years.

In 2006, Jones and Stokes Associates (JSA 2006) surveyed the McCoy Basin Site for Contra Costa goldfields for Edenbridge, Inc., mapping stands and estimating the number of individuals at each location. JSA (2006) reports that for stands smaller than 25 square feet all plants were counted. For larger stands, the plant number was calculated by visually estimating plant density and multiplying it by the stand size. Their estimates yield a population of approximately 17,720 CCG plants. Conversely, population estimates conducted by LSA using plots and transects yielded an estimate of 511,559 CCG. Again, this is a much higher estimate than obtained by visually estimating density.

Vollmar Consulting conducted rare plant surveys on the Barnfield site in 2005 and estimated approximately 8 million CCG plants on the property. The methods used to derive the estimate of 8 million were not detailed in the report. This estimate is very close to the population estimates for 2006 and 2007of 7 million and 7.3 million plants but the total number of plants estimated for each pool area are extremely different. In Count Area A, Vollmar estimated approximately 7,695,000 plants and only 3,000 and 10,000 plants in Count Areas B and C, respectively (Raney Planning and Management, Inc. 2006). The estimate for Count Area A is much larger than LSA's estimate in 2006 and 2007 and considerable lower in Count Areas B and C.

In general, population estimates based on visual estimation methods can be subject to high observer bias and are difficult to compare from year to year. Density and population estimates calculated by the method outlined in this report are repeatable, statistically valid, and can be compared between sites and between years. This type of statistically comparable data is necessary, for tracking changes in population levels caused by weather, management strategies, or other environmental variables and is critical for developing a successful adaptive management and monitoring program. The downside to this method is that it can require a considerable amount of time and resources. Therefore, it may not be cost effective to monitor every single population with this level of detail. Instead, count data can be used to compliment surveys conducted over more extensive areas, which primarily focus on presence/absence or rough population estimates based on visual estimates. In addition, having detailed density estimates from count data on a few sites can be used to increase the accuracy of visual estimates.

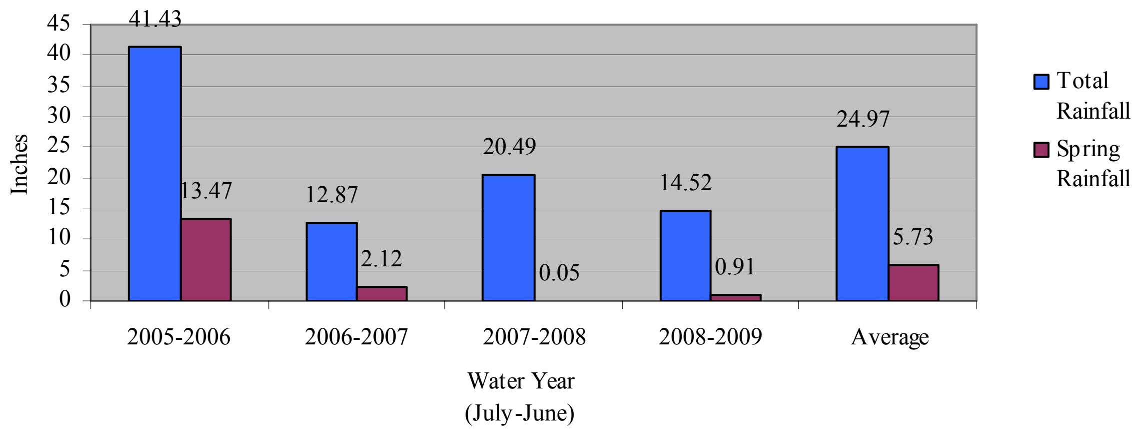
Between Year Comparisons

The population data collected for each site represents much needed information on the spatial and temporal variation in abundance and distribution of CCG. The biggest factor affecting CCGs between years is rainfall. Annual variation in hydroperiod has been linked to strong year-to-year variation in the composition of vernal pool plant communities (Bliss and Zedler 1998). To assess the effects of variation in rainfall on CCG populations, rainfall data for each study year was obtained from the Vacaville weather station (NCDC #9200). Total rainfall, spring rainfall, and monthly rainfall for each study year was compared to the average total rainfall calculated from 58 years of data available from the Vacaville weather station (Figure 12). These three components of rainfall were assessed because both the amount and timing of rainfall affect the hydroperiod of vernal pools.

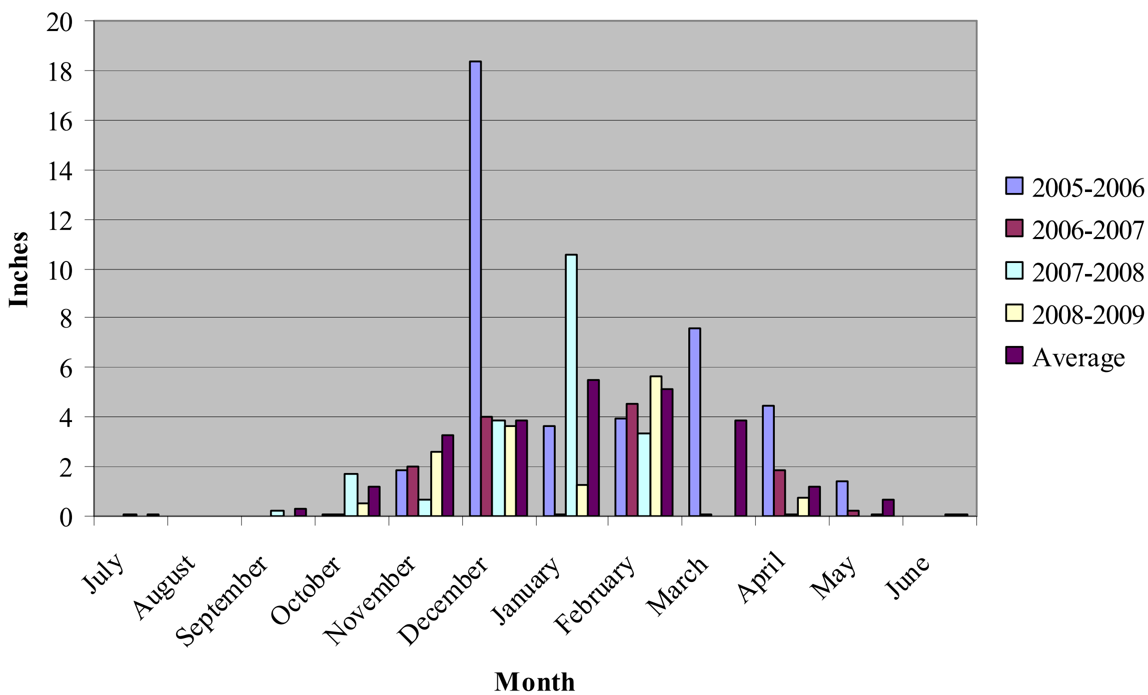
The rainfall patterns for each year were unique and they all differed substantially from the average (Figure 12). The 2005-2006 rain year was extremely wet, with a total rainfall of approximately 41.4 inches (166% of average) and above average rainfall in both the winter and spring months (Figure 12). The 2006-2007 rain year was extremely dry, with a total of 12.9 inches of rain (51% of average). The 2007-2008 rain year was the closest the total rainfall was to the average (82%); however, it was the driest spring, with a total spring rainfall of only 0.05 inches or less than 1% of the average spring rainfall. The 2008-2009 rain year was both a below average rainfall year (58% of average) and an exceptionally dry spring (approximately 15% of average).

Figure 12. Total rainfall (A), spring rainfall (A), and monthly rainfall (B) for each study year. Rainfall data was obtained from the Vacaville weather station (NCDC #9200) and the average total rainfall was calculated from 58 years of data.

A.



B.



The distribution and density of annual plants are highly subject to variations in the amount and timing of rainfall. How CCGs responded to differences in rainfall patterns depended on the hydrologic conditions of the vernal pool/swale. CCG distribution and densities were higher in deeper vernal pools and playa-type pools, such as the Director's Guild PPAA, GCB South, and McCoy Basin, during drought or below average rainfall years. Below average rainfall lead to shallower waters and earlier drying times expanding suitable areas for CCG germination and growth. Average and above rainfall years lead to deeper waters and prolonged inundation periods limiting suitable areas for CCG germination and growth to the edges of the pool. The best examples of the change in the distribution of CCGs between a wet year (2006) and a dry year (2007, 2008, and 2009) are the Director's Guild PPAA and GCB South pool P (Maps 4 and 5).

Conversely, CCG cover was lower in shallower, short-duration hydroperiod wetlands in drought/low rainfall years. CCG cover was higher at Barnfield Count Areas A, B, and C and Director's Guild GAA, all seasonally saturated annual grassland areas, in 2006 (a wet year) than in drier years. This pattern was also observed throughout the County, in expanded surveys conducted by LSA Associates. One of the places surveyed in 2007 and 2009, was Parker Ranch just north of Hwy 12 and east of Branscombe Rd (Map 2). This is a location of a historic CNDDB Record that was first reported by R. Ornduff in 1960. This area was resurveyed for CCG in 1988, 1999, 2007, and 2009. It was not found in either 1988, 2007, or 2009, all dry springs, but it was found in 1999, which was an above average rainfall year. There was a limited distribution of CCGs in suitable habitat areas south of Travis Air Force Base and north of Hwy 12, the limited distribution of CCG in this area may be due to loss of deeper pool areas from past agricultural practices and potential competition from Fremont's Goldfield (*Lasthenia fremontii*).

Based on the observed changes in the distribution and density of CCGs in various wetlands between years with different rainfall patterns, when considering restoration of vernal pools for the benefit of this species, it is important to have a variety of pool and swale depths. A broad variation in pool and swale depths will guarantee that in any given year, regardless of weather, there will be suitable habitat for the species in at least a few places of the pool complex. Not enough variation in depths may eliminate this natural buffering mechanism for the species.

The second biggest factor affecting the distribution and density of CCGs on each site was management regimes and other environmental factors such as fire. Two sites burned shortly before the study began: the GCB Northeast and the Director's Guild GAA. The northern portion of the Director's Guild GAA burned in the fall of 2004. This area has shown a steady decrease in the total number, density and cover of CCGs since 2006 (Figure 5b and d). 2006 was a very wet year and the higher densities in this year may also correspond to increased rainfall. The differences in densities are likely a combination of time since disturbance (i.e. fire) and rainfall.

The GCB northeast and the eastern portion of the GCB south burned in late August of 2005. CCGs are more widely distributed throughout these wetland complexes in 2006 versus 2007, 2008 and 2009 (Map 5). The broader distribution is likely due to the combination of the burn in 2005 and above average rainfall. The GCB Northwest did not burn in 2005 and these wetlands had the most limited CCG distribution in 2006.

Between Area Comparisons

Differences in vernal pool/swale hydrologic conditions and management strategies affected how CCGs responded to different rainfall patterns. However, differences between other environmental factors, such as soil alkalinity, also affected CCG densities. Because there is a lot of variation between years, an additional analysis was conducted combining data from 2007, 2008, and 2009 to compare patterns of CCG density and cover between regions (Figure 13). This analysis supported some general patterns observed in the analyses conducted for each year. The general patterns that emerged were:

1) Strassberger East and Director's Guild PPAA had the highest densities and group together.

2) McCoy Basin and Barnfield Count Area D-X group together

3) GCB South contains a large deep pool containing higher densities of plants, separating it from GCB Northeast and GCB Northwest, and grouping it with McCoy Basin, Barnfield Count Area D-X and Barnfield Count Area C.

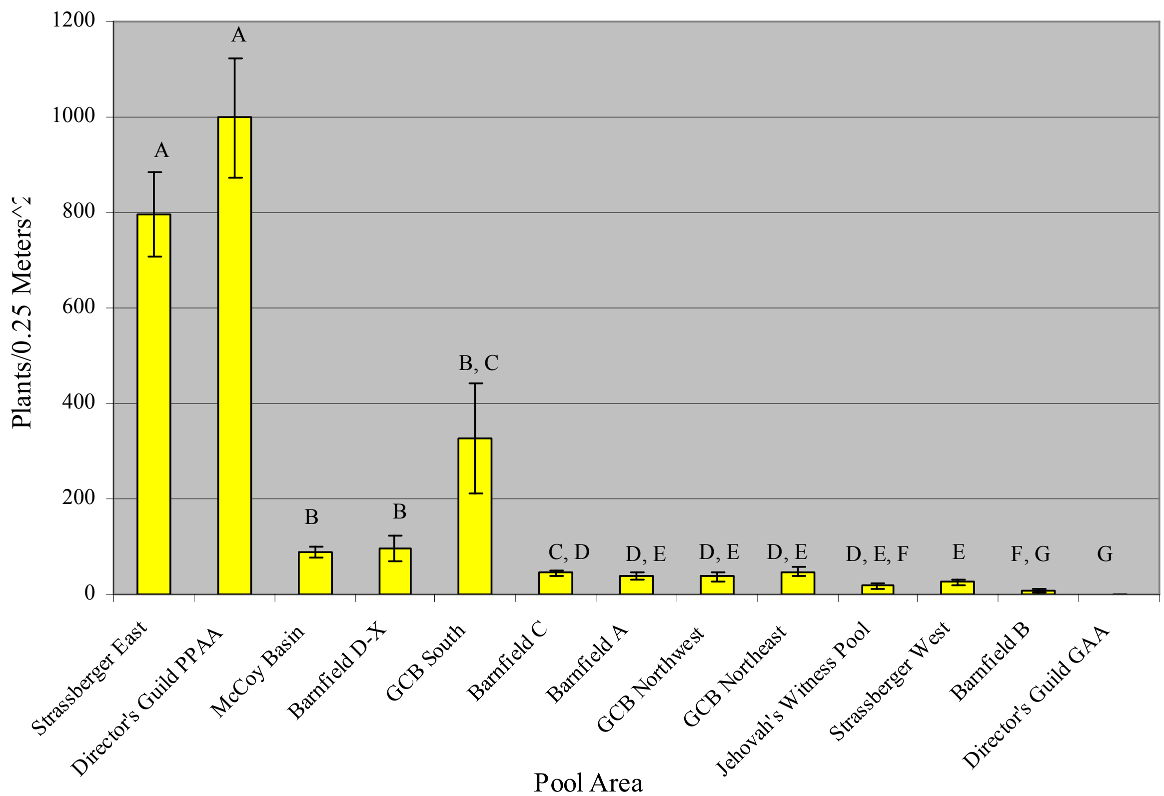
4) Barnfield Count Area B and Director's Guild GAA had the lowest densities and always grouped together.

All of the study areas can be divided into two general wetland categories: sites where suitable CCG habitat consisted primarily of either moist grassland or discreet vernal pools. The sites dominated by moist grassland are Director's Guild GAA, Barnfield Count Area B, Barnfield Count Area A, Barnfield Count Area C, and Strassberger West. The sites dominated by discreet vernal pools are Strassberger East, Director's Guild PPAA, McCoy Basin, Barnfield Count Area D-X, GCB South, GCB Northeast, GCB Northwest, and Jehovah's Witness Pool. In general, regions with higher density and cover contained deeper pools, such as Director's Guild PPAA, Strassberger East, McCoy Basin, and GCB South. Regions with the lowest densities were the driest moist grassland areas, such as Director's Guild GAA and Barnfield Count Area B.

Another key environmental factor that appears to have an affect on CCG densities is soil alkalinity. Sites with alkaline soils include Barnfield, Director's Guild, McCoy Basin and Strassberger. Sites with more neutral soils include GCB and the Jehovah's Witness Pool. A study by Collinge et al. (2003) found that soil alkalinity had an adverse affect on germination, time to emergence, and seedling height of CCG seeds and they suggest that populations should be larger on neutral rather than alkaline or saline sites. For our study sites, the higher densities occurred in areas with more alkaline soils (Strassberger, Director's Guild, and McCoy Basin) than the more neutral sites, GCB and Jehova Witness Complex. Instead of higher densities of plants, there was an increase in the robustness of plants between the more neutral sites and the more alkaline sites. Generally, the alkaline areas (Strassberger and Barnfield) had fewer numbers of flowers per plant than the more neutral sites (GCB or the Jehovah's Witness Complex; Figure 10). The difference in population densities may be due to reduced competition with annual grasses. The more alkaline sites tend to have less grass cover within pools than the more neutral sites, where grass and residual thatch can be very thick.

In general, the highest densities and cover of Contra Costa goldfields occurred in areas with discreet vernal pools and moderately high soil alkalinity, such as Strassberger East and Director's Guild PPAA. However, some of the largest plants occurred on more neutral soils such as GCB South. Based on the distribution study, Contra Costa goldfields occurred in substantial numbers and densities in a broad spectrum of wetland conditions. We documented Contra Costa goldfield populations in conditions ranging from moist grassland/wet meadow/swales with saturated soils, distinctly ponded shallow pools, and deeper playa pools. They were observed in areas with natural vernal pool/swale topography and also in highly modified fields used for hay production. This variation in habitat types makes defining suitable habitat characteristics extremely difficult.

Figure 13. Mean CCG density per ¼ meter squared for each area for 2007, 2008, and 2009. Letters above bars indicate significant differences between count areas within a year. Areas connected by the same letter are similar and areas not connected by the same letter are significantly different. Error bars represent Standard Errors of the Mean.



Vegetation Data

The analysis of vegetation cover data from 2009 provides insights into vegetation alliances and wetland plant species associated with Contra Costa goldfields. Positive relationships for occurrence were identified between CCG and the following wetland plant species: fringed downingia (*Downingia concolor*), woolly marbles (*Psilocarphus brevissimus*), alkali weed (*Cressa truxillensis*), alkali mallow (*Malvella leprosa*), slender popcornflower (*Plagiobothrys stipitatus*), annual semaphoregrass (*Pleuropogon californicus*), tarplant (*Centromadia* spp.), coyote thistle (*Eryngium* spp.), smooth goldfields (*Lasthenia glaberrima*), and rabbitsfoot grass (*Polypogon monspeliensis*). In addition to these positive correlations, looking at the associations these species had with different CCG cover classes (0%, <5%, 6-15%, 16-25%, 26-50%, 51-75%, and 76-100%) yielded some interesting patterns. Appendix C shows photos of CCG growing with several of these species.

A Manual of California Vegetation (Sawyer, Keeler-Wolf, and Evens 2009) was recently published revising several of the vernal pool vegetation classifications. Most of these vegetation classifications were based on studies conducted by Barbour et al. 2003, 2005, and 2007. Some of the dominate species that were correlated with CCGs were identified as diagnostic species for certain vernal pool classes, alliances, and associations as identified by Sawyer, Keeler-Wolf, and Evens (2009) and Barbour et al. (2007). For example, the species with the strongest correlation with CCG was tarplant (*Centromadia* spp.). With an average cover of 18%, it was associated with CCG Cover ranging from >5% to 50%. *Centromadia* was also identified as an herbaceous alliance by Sawyer, Keeler-Wolf, and Evens (2009). Habitat characteristics of this alliance include vernally wet habitats, including edges of alkaline vernal pools, bottoms of shallow pools, and alkaline flats subject to intermittent water inundation. The correlation of CCG with this species also supports the observation that higher CCG densities occur on more alkaline soils.

Other indicators species of alkali soils that CCGs were positively associated with were alkali weed (*Cressa truxillensis*) and alkali mallow (*Malvella leprosa*). These species were found at low densities (1-15% cover) in all CCG cover classes but were found more frequently in plots with higher cover classes. Alkali weed was also an important component of the *Cressa truxillensis*-*Distichlis spicata* Herbaceous Alliance (Sawyer, Keeler-Wolf and Evens 2009). The habitat for this alliance is described as alkaline or saline vernal playas and alkali sinks. Other species associated with this alliance that CCGs were positively correlated with include alkali mallow, coyote thistle (*Eryngium vaseyi*), woolly marbles (*Psilocarphus brevissimus*), and slender popcornflower (*Plagiobothrys stipitatus*). Slender popcornflower (*Plagiobothrys stipitatus*) was observed in low densities (5-10% cover) in plots with CCG cover classes ranging from 25-100%. Coyote thistle (*Eryngium* spp.), an obligate wetland species, was found with all CCG cover classes but most frequently in the 26-50% and <5% categories.

The timing of the surveys for CCGs was too early to accurately distinguish the different species of (*Eryngium* spp.) in the plots, but other botanical surveys at some of these sites have identified both *Eryngium aristulatum* var. *aristulatum* and *Eryngium vaseyi*. Sawyer, Keeler-Wolf, and Evens (2009) identifies an *Eryngium aristulatum* alliance. Habitat associated with this alliance is characterized by shallow, flashy vernal pool bottoms and edges. *Eryngium* spp. are characteristic of vernal pools in general but *Eryngium aristulatum* is characteristic of alkaline pools in the Central Valley. In general, the *Eryngium aristulatum* alliance is very similar to the *Cressa truxillensis-Distichlis spicata* alliance, which are both included in the broader *Downingia-Lasthenia* class recognized by Barbour et al. (2007).

The majority of the pools surveyed in the study by Barbour et al. (2007) did not contain CCG and the predominant *Lasthenia* sp. referred to in the *Downingia-Lasthenia* class is Fremont's goldfields (*Lasthenia fremontii*). However, fringed downingia (*Downingia concolor*), was one of the species found to be associated with CCGs in this study. Plots with high CCG cover (50 -100%) were associated with low densities (1% cover or less) of fringed downingia (*Downingia concolor*).

Barbour et al. (2007) also identifies fringed downingia as an indicator of the *Pleuropogon californicus-Lasthenia glaberrima* association. Both Smooth Goldfields (*Lasthenia glaberrima*) and annual semaphoregrass (*Pleuropogon californicus*) were found to have positive correlations with CCG. The *Pleuropogon californicus-Lasthenia glaberrima* association is part of the broader

Lasthenia glaberrima alliance (Barbour et al. 2007). Habitats within the broader *Lasthenia glaberrima* alliance are described as vernal pool bottoms and vernal marshes. Smooth Goldfields, an obligate wetland species, was found with all CCG cover classes but was identified as a dominant species most frequently with CCG cover of less than 5%. This suggests that inundation periods required to support the *Lasthenia glaberrima* alliance may represent the deeper range of pools in which CCG occur in.

Annual semaphoregrass was also observed with CCGs in all cover classes, but it was found at moderate densities (20-30% cover) with CCG densities ranging from 15%-50% cover. This species appears to grow in similar areas of the pool as CCG and when present it may compete with CCGs, decreasing the densities of the latter. Even though vegetation data was not collected in 2006, a wetter than average year, semaphoregrass was much more abundant in plots and in wetlands throughout the region than in subsequent years (personal observation). A similar observation was made with rabbitsfoot grass (*Polypogon monspeliensis*), a nonnative annual grass. It was found in plots with all CCG cover classes, but was most frequently observed with an average cover of 35% in CCG cover classes 26-50 and <5%. This species may also compete with CCGs.

The nonnative annual grass that had a strong negative correlation with CCGs was Italian rye grass (*Lolium multiflorum*). Even though it was present in plots with all Contra Costa goldfield cover classes, goldfield density decreased as ryegrass cover increased. There are two likely factors associated with this negative correlation. First, Italian rye grass grows in a broad range of wetland types and is extremely abundant in very shallow wetland such as the seasonally saturated annual grassland areas of the Director's Guild GAA. Wetlands dominated by Italian rye grass may represent the drier end of the growing range of CCGs. Second, Italian rye grass appears to outcompete CCGs in pools where they co-occurred. Interestingly, Barbour et al. (2007) noted that Italian rye grass commonly occurred in the *Pleuropogon californicus-Lasthenia glaberrima* association and was sometimes abundant.

Negative correlations were also found for broadleaf birdsfoot trefoil (*Lotus corniculatus*) and dwarf sack clover (*Trifolium depauperatum var. truncatum*). Broadleaf birdsfoot trefoil is a nonnative species common in disturbed areas of wetlands. Dwarf sack clover occurs in shallow pools or on pool edges. It is likely that it can not survive the longer inundation periods in the areas of a pool dominated by CCGs or plants associated with the *Pleuropogon californicus-Lasthenia glaberrima* association.

When looking at the species that CCGs are correlated with and the vernal pool vegetation classes, alliances, and associations those species are diagnostic of, it appears that Contra Costa goldfields occur in a broad range of pool types. They can occur in seasonally saturated annual grasslands, vernal pools and even deeper playa type pools. However, their densities decline in the drier seasonally saturated annual grasslands and in the bottom of deeper pools characteristic of the *Lasthenia glaberrima* alliance. CCG are found in higher densities in alkaline pools despite the fact that soil alkalinity has an adverse affect on germination, time to emergence, and seedling height (Collinge et al. 2003). They appear to be poor competitors with annual grasses, particularly nonnative annual grasses, such as Italian rye grass. The higher densities in alkaline areas is probably the result of a decrease in competition from annual grasses and other vernal pool species. The results of these studies provide useful information on the habitat and species that CCG are associated.

However, the results of this study cannot define, with certainty, what is unsuitable wetland habitat for this species.

GENETIC STUDY

The results of the genetic study indicate that there are high levels of genetic diversity within CCG populations within Solano County, CA. The variation is widely distributed both among pools within a single property and across properties within the County. The lack of geographic structure to the data indicates that no property or pool is genetically distinct from other properties or pools. The high level of diversity detected here and lack of structure indicates that either the recent (approximately one hundred and fifty years) isolation of populations has not led to the development of strong genetic structure among populations, or that gene flow is still occurring among populations within the region. However, the detection of inbreeding may be the result of this more recent isolation, suggesting that gene flow may not still be occurring and that genetic diversity is currently being lost.

The results of the population genetic structure analysis revealed that there is greater diversity among pools within a single property than among properties. This indicates that the genetic makeup of each pool is unique in that each pool is composed of a unique allele composition across the sampled individuals. Even though there may not be unique alleles in each population (not assessed in this study), the composition (number and distribution) of alleles sampled in the populations is unique for each population. This implies that property boundaries are biologically irrelevant and that the loss of individual pools will have a negative impact on genetic composition of the species. However, the results also indicate that no pool or set of pools is more distinct than any others. The loss of any CCG populations in Solano County will likely reduce the overall level of diversity within the species, but is unlikely to have a large negative impact on the evolutionary potential of the species given the high diversity and low population differentiation detected here.

Given the results of the present study, conservation efforts should aim to conserve as many individual pools as possible. However, given the development pressures on the land supporting vernal pool habitat in Solano County, it is understood that this is not always possible. The results indicate that although there is widespread diversity and minimal structure, no pool or group of pools is more diverse, or more distinct than any others. Any restoration or reintroduction efforts should aim to sample the existing populations widely so as to capture the diversity found in all populations. Seed collection efforts should not be focused on single populations but rather on all populations for which collection is possible. Restoration efforts could then utilize seed from either a single or multiple sources when necessary. It is recommended that pool initiation is done in a conservative manner with seeds from a single source pool or small group of closely located pools. When necessary, multiple pools could be used as source material for new populations. The geographic proximity of restored sites to seed sources should be considered in restoration efforts, but does not need to dictate where restoration occurs given the lack of geographic structure to the genetic data. In all cases, careful documentation of both source and restored pools should be kept so that genetic diversity and structure could be tracked over time.

SEED BANK STUDY

Both the core sample method and the removal plot method show that CCGs maintain a robust interannual seed bank. However, estimates from the soil cores for seed density were much higher than for the removal study. For example, the total estimated seeds in the seed bank, across all depths, were estimated to be 7,894 seeds/m^2. If only the top layer of seeds were taken into consideration (i.e. from depths between 0-5cm) this would extrapolate to approximately 3,225 seeds/ m^2. Both of these estimates are much higher than the average 632, 241, and 1,277 plants/m^2 that grew in the removal plots. This may be due to several factors. First, conditions for germination and growth were likely much more favorable in the pots (on a protected balcony in Point Richmond) than in the removal plots (exposed to natural field conditions). Soil cores placed in pots received ample water and benign growing conditions, compared to the removal plots which experienced lower than average rainfall for the year and extreme temperatures. Second, blowing seed off the surface of soil cores may not have removed all of the seed dispersed in 2006, possibly artificially elevating the estimate of seed bank abundance. However, of the three cores that were stratified by depth, the majority of CCGs that germinated (34 of 53) came from between 5 and 15 cm below the soil surface, where contamination from seed produced in 2006 would not be expected. Lastly, germination in the removal plots may have been lower because the screening covering the plot frames was left on through the winter germination period. If the germination of seeds of CCGs or if seedlings are sensitive to relative humidity, temperature, or solar exposure, the altered conditions inside the plots may have affected their germination rates or seedling survival; although it is not clear whether these alterations would increase or decrease germination and seedling survival. Regardless of the discrepancy between these two experiments, these estimates are lower than what would be expected based on seed production alone.

Ramp (2004), in her population and genetic studies of CCGs, counted the number of viable seeds produced per flower head to be approximately 126. The average density of CCGs in that area of the playa pool on the Director's Guild in 2006 was estimated to be approximately 3,740 plants/m^2 (LSA 2006). Based on these numbers, there were approximately 477,972 seeds produced per m^2 in the playa pool in 2005. There were 4,722, 4,528 and 1,253 plants removed from plots 1, 2, and 3, respectively, in 2006. Collinge, in some of her unpublished work on Travis Air Force Base, estimated seedling survival to be approximately 14%. Based on this survival rate and the number of adult plants removed in 2006 from the removal plots, approximately, 33,230, 31,865 and 8,818 seeds may have germinated in the plots in the spring of 2006. This still leaves a potential residual seed bank of over 400,000 seeds/m^2 from 2005 seed production alone. Given this enormous potential seed bank, no difference in the number of plants in 2006 and 2007, 2008, and 2009 would have been expected in the removal plots; however, this was not the case (Figure 11).

The first factor affecting germination rates and density of plants is weather, but the number of plants in the removal plots was considerably lower than outside of the plots (Figure 11). Unfortunately, another factor that likely affected CCG densities in the removal plots was the wooden enclosures and mesh screening that the plots were made. It wasn't as evident in 2007 because it was such a dry year and that portion of the pool did not completely fill with water, but in 2008 and 2009 when the plots were fully submerged in the winter, the structure of the plot itself had an affect on the inundation period, soil moisture, and probably temperature inside the plots. This difference in environmental conditions likely affected CCG germination. The main difference in the vegetation in the removal plots than outside of the plots was the density of brass buttons (*Cotula coronopifolia*).

Barbour et al. (2007) found this species to be diagnostic of the *Downingia insignis-Lasthenia glaberrima* association. Within the Director's Guild playa pool brass buttons is found in the deeper portions of the pool and along the bottom edges of the drainage ditch. Its increased abundance in the removal plots indicates that the conditions inside the plots were wetter than the areas outside the plots. Differences in the environmental conditions inside and outside the plots, particularly in 2008 and 2009, make assessing the affects of the seed removal almost impossible. In addition, portions of the plot frames started to rise above the soils surface slightly when inundated; therefore, seed may have moved into the plots from the surrounding areas of the pool. If similar types of experiments are conducted in vernal pools, a different plot design is recommended.

Nevertheless, the results of the soil core samples and the 2007 data indicate a robust seed bank. Because this is an annual plant, seed production is the only way for new individuals to occur in the population and for new populations to be established. Given that environmental conditions have a strong affect on their densities and distribution from year to year, knowing that there is a residual seed bank during years of low densities provides an increased level of stability to each population. In addition, the distribution of seeds throughout a potentially broader range of the pool than what is actually observed from flowering plants in any given year greatly increases the area occupied and may potentially act as a natural buffering mechanism to cope with extreme environmental conditions. In other words, there is the potential for seeds to be distributed throughout the entire pool, which may germinate in any given year provided the hydrology of that particular region of the pool is suitable. For example, in 2007, when the large playa pool on the Director's Guild site did not fill like in previous years, the seeds remaining farther in the pool were at the right inundation required for germination. Thus, the distribution of plants within the pool was significantly different than from previous years.

When considering restoration of vernal pools for the benefit of this species, these results suggest the importance of having a variety of pool and swale depths so that in any given year, regardless of weather, there will be suitable habitat for the species in at least a few places of the pool complex. Large, deeper playa pools may also serve as an important seed reservoir for periods of drought. In normal and wet years, CCG do not appear to emerge and grow in the bottoms of these larger pools. However, in below normal rainfall years, the bottoms of the larger playa pools may be the only wetlands that receive any standing water or experience prolonged saturated soil conditions such as occurred during the 2006-2007 rainy season. Not enough variation in pool depths may eliminate this potential buffering mechanism.

DISTRIBUTION STUDY

The population count data suggests that the previous population estimates have grossly underestimated the number of plants at each location; however, the distribution study shows that CCG have an even more restricted range in the County than previously thought. From a vulnerability perspective, the Solano population is much more threatened or vulnerable to urban development than previously realized. In 2000, when the core CCG population areas were established for the Solano HCP, large areas to the north and south (i.e. subareas 1C and 1F: Map 1) contained the largest potential habitat areas outside of the urban limit lines of the cities of Fairfield and Suisun City were largely unsurveyed. Core area boundaries were based on watershed boundaries and what were essentially contiguous tracts of suitable habitat. After surveying most of subarea 1C, CCG were only found to occupy the southwestern corner. Subarea 1F contains large stands of *Lasthenia* that are visible from highway 12. These were presumed to be *conjugens*. After conducting more detailed surveys of these areas, only a small fraction of the *Lasthenia* was *conjugens* and, in fact, the majority of the habitat was dominated by Fremont's goldfield.

At first glance, Core Area 1F (Map 1), which also includes the majority of the designated critical habitat for CCG, appears to represent a relatively large block of vernal pool habitat, but most of this area has a long history of intensive agricultural use. As early as the 1930s and as recently as 30 years ago, the majority of these areas were active hay fields (Figure 6). This historic leveling of the land has drastically decreased the natural pool/swale topography characteristic of more pristine vernal pool habitats. For example, instead of discrete pools, there are large expanses of grassland that contain marginal wetland characteristics (LSA 2008). The southern portions of the Peterson and Johnson Trust lands (West), Parker Ranch, and the northern portion of the Director's Guild study site are excellent examples of this, particularly the Director's Guild. Based on the wetland delineation for the property, the entire northern portion of the site has been mapped as seasonal wetland, but only small amount of this wetland area supports CCG and other vernal pool plants (Map 4)), except in limited circumstances where annual grass cover is greatly suppressed by fire (2004) or extremely wet conditions (2006). . Similar conditions exist on the Peterson and Johnson Trust lands (West), the southern portions of the site (north of Hwy 12), show characteristics of being a large seasonal wetland; however, only small portions of the site support significant stands of CCG (Map 8). The Parker Ranch property has mound and swale micro-topography. However, this micro-topography has been somewhat muted by past agricultural cultivation on the three eastern quadrants and has been practically eliminated by land leveling on the westernmost quadrant (LSA 2008). The majority of these old pasture areas, while meeting wetland criteria, are primarily dominated by introduced annual grasses such as ryegrass (*Lolium* spp.) and various wild barleys (*Hordeum* spp.).

In addition to the decrease in suitable pool habitat for CCG in subarea 1F, areas that appear suitable are dominated by Fremont's goldfields. A general observation was made throughout this area that Fremont's goldfields occupied a broader range of hydrologic conditions, particularly dominating in drier conditions (i.e. shallow swales and pools); whereas, CCG were only found in clearly defined, wetter, pool/depression areas. Potential causes for this distribution pattern include unsuitable conditions for CCG or some sort of competitive interaction between CCG and Fremont's goldfields. Based on the range of habitats CCG were observed in other portions of its range, in the absence of Fremont's goldfield, it appears that CCG may be competitively excluded from the more desirable habitat areas by Fremont's goldfield, except possibly in areas with higher soil alkalinity. Fremont's goldfields were found on the Director's Guild property in earlier surveys (LSA 2006), but were not observed during CCG count surveys conducted for this study. If present, Fremont's goldfields are at much lower densities than CCG. Soils in this area, particularly in the play pool, also appear to have higher alkalinity based on the co-occurrence of alkaline-tolerant plant species.

There is also the possibility that Fremont's goldfields are hybridizing with CCG. CCG and *L. fremontii* are closely related (Chan et al. 2001) and early work by Ornduff (1969) showed that these species are freely intercrossable in the lab, but that the majority of hybrids are sterile. In the field, in areas where CCG and Fremont's goldfields co-occur, several individual plants were found with mixed *conjugens* and *fremontii* traits. These plants had no pappus (a characteristic of CCG), but their phyllaries were not fused (a characteristic of Fremont's goldfields). These plants could represent either mutant Fremont's goldfields, mutant CCG or a hybrid of these two species, but this can not be verified without genetic analysis. If they are hybridizing and hybrids between these two species are sterile, this could have a significant affect on CCG populations, drastically reducing seed production and recruitment for subsequent years in areas where they are already sparsely distributed.

Fremont's goldfields also appear to be more tolerant of a broad range of hydrological conditions. It also has pappus, which makes wind based seed dispersal a more viable option for this species. In general, Fremont's goldfields have a broader ecological range and higher dispersal potential; therefore, it is not surprising that the majority of the habitat areas within subarea 1F are dominated by Fremont's goldfields instead of CCG. It is unclear whether or not this area was previously dominated by CCG prior to habitat disturbance and that the current distribution of Fremont's goldfields represents a range expansion, or if CCG were historically sparse in this region and it has always been dominated by Fremont's goldfields. Understanding the interactions between these two species is important if we want to conserve and potentially restore populations of CCG to their historic levels, particularly within Core Area 1F. If Fremont's goldfields outcompete CCG then it will be vitally important to keep Fremont's goldfields out of vernal pool areas currently dominated by CCG. It is possible for Fremont's goldfields to be introduced into these areas by cattle, seed mixes for vernal pool restoration projects, and on the clothing of field biologists conducting serves.

IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

The results of and general field observations made during the ESA Section 6 grant studies, combined with increased awareness and surveys for CCG, provide important information for developing a comprehensive conservation strategy for CCG for the Solano HCP. The following section lists the key observations and conclusions from these studies and there implications for the Solano HCP Conservation Program.

Avoidance and Minimization and Conservation Measures

Occupied Habitat. Population numbers and occurrence/distribution on a site can vary substantially between years. Based on the drastic increase in plants on the Northwestern and Southern Count Areas on the GCB site during this study, the CCG distribution mapped by Zentner and Zentner in 2000, and the documented presence of inter annual seed bank, the presence or absence of CCG can not be determined based on the density and distribution of CCG in a single year. CCG have a seed bank that likely carries over for multiple years. How many years it is not known. The GCB site is an excellent example of pools that either did not contain plants in previous years or only contained a limited number of plants, but may have large numbers of plants in subsequent years given appropriate growing conditions (e.g., proper management and weather conditions). Seeds may lie dormant for many years until appropriate conditions exist for seed germination and plant growth. The Solano HCP Conservation Strategy defines occupied habitat as the entire wetland area even if only a portion of the wetland is occupied by CCG. This assumption appears valid. The current draft of the Solano HCP requires a minimum of 2 years of field surveys/mapping at a site to determine occupied/unoccupied habitat. However, based on the review of the 5 years of occupied habitat mapping at the GCB site and the extreme variations in occupied habitat between years at other sites, it appears multiple years of surveys over a variety of weather and management conditions are needed to accurately assess species distribution on a site.

Defining Suitable Habitat. Contra Costa goldfields occur in a broad range of wetland conditions. We documented Contra Costa goldfield populations in conditions ranging from moist grassland/wet meadow/swales with saturated soils, distinctly ponded shallow pools, to deeper playa pools. They were observed in areas with natural vernal pool/swale topography and also in highly modified fields used for hay production.

The vegetation data also supports these observations. Based on the species that CCGs are correlated with and the vernal pool vegetation classes, alliances, and associations those species are diagnostic of, Contra Costa goldfields can occur in a broad range of pool types. They can occur in seasonally saturated annual grasslands, vernal pools and even deeper playa type pools. However, their densities decline in the drier seasonally saturated annual grasslands and in the bottom of deeper pools. CCG are found in higher densities in alkaline pools despite the fact that soil alkalinity has an adverse affect on germination, time to emergence, and seedling height (Collinge et al. 2003). CCG appear to be a poor competitor with annual grasses, particularly nonnative annual grasses, such as Italian rye grass. The higher densities in alkaline areas are probably the result of a decrease in competition from annual grasses and other vernal pool species. The results of these studies provide useful information on the habitat and species that Contra Costa goldfields are associated. However, the results of this study cannot define, with certainty, what is unsuitable wetland habitat for this species. In addition, the variation in habitat types makes defining suitable habitat characteristics extremely difficult.

The Solano HCP takes a conservative approach and considers all wetlands within core areas to be considered suitable habitat for Contra Costa goldfields. Applicants may appeal this assumption to SCWA, USFWS, and CDFG, but the appeal will require detailed field surveys for species occurrences, habitat characterizations, and hydrological analysis of all wetlands on the site. The current problem with this approach is that there is still limited data on the habitat characterizations (other wetland vegetation, soils, etc.) and hydrological conditions for the full range of wetland types that CCG are know to occur in. This data would be needed to compare the results of site specific studies to determine if wetlands truly are unsuitable for CCG under all possible weather and management conditions.

Minimizing the Loss of Genetic Diversity. Based on the results of the genetic study conservation efforts should aim to conserve as many individual pools as possible. The results indicate that although there is widespread diversity and minimal structure, no pool or group of pools is more diverse, or more distinct than any others. This result is beneficial for the HCP Conservation Strategy because mitigation need not occur in the same subareas for which impacts occurred in. Despite this, the Solano HCP defines clear conservation objectives for each subarea and strict site design standards for core areas. This will minimize the total number of pools that are lost and maximize the number of individual pools that are preserved.

The genetic study did identify a small amount of in-breeding within parcels. While Ramp (2009) did not believe that immediate action is necessary at this time, this is something that should be monitored and long-term conservation actions to maintain genetic diversity may require actions to intermix seeds from different areas given that urban development and other land uses have likely effectively isolated gene flow between the identified core population areas.

Preserve a Variety of Pool Types. As would be expected for an annual plant, population parameters are highly subject to significant variations in timing and amount of rainfall; however, differences in rainfall patterns have different affects depending on vernal pool/swale hydrologic conditions. CCG populations are highest in deeper vernal pools and playa-type pools during drought/below average rainfall years or even wet years with early rains and drier winters and springs (conditions were pools dry early) because the shallower water and earlier drying provide suitable areas for plant germination and growth. The deeper and prolonged inundation during normal to above normal rainfall years limits goldfield establishment to the edges of the pool. Conversely, Contra Costa goldfield populations are highest in shallow pools and swales during above normal total rainfall years or years with prolonged rains into late spring. Contra Costa goldfield populations tend to extremely low to absent in these shallower, short-duration hydroperiod wetlands in drought/low rainfall years.

Based on these observations, it is important to preserve a variety of pool and swale depths. A broad variation in pool and swale depths will guarantee that in any given year, regardless of weather, there will be suitable habitat for the species in at least a few places of the pool complex. Not enough variation in depths may eliminate this natural buffering mechanism for the species. The Solano HCP has a conservation measure that is designed to preserve a variety of pool types within a reserve. It requires that all impacted seasonal wetlands be characterized according to type and mitigated by preservation of the same category of wetland.

Restoration

Current Distribution. Based on the results of the distribution study, it is much more apparent that conservation and management should not only focus on preserving existing populations, but also focus on increasing occupied habitat areas and potentially expanding the current range of the species.

Restoration of vernal pool habitats and reestablishment of CCG through direct seeding should be considered essential to the conservation of the species. CCG is lacking or extremely rare in large areas of what is considered to be its current range in the County and within its designated critical habitat. Most of the lands within the designated critical habitat were leveled and altered for agricultural production. Most of this area is no longer used for intensive agriculture and supports extensive acreages of wetland habitat; however, the altered habitats conditions appear to be favoring the presence of or providing a competitive advantage to the more abundant Fremont's goldfields.

Restoration Criteria. Conservation actions should incorporate restoration of more natural vernal pool landforms in order to provide a broader range of pools sizes, depths (hydroperiods) and soil alkalinity in addition to preservation of the larger extant colonies. Most of the current populations, including the three currently preserved populations at Noonan Ranch, the Goldfields Bank, and North Suisun Mitigation Bank, occur on lands that have a long history of agricultural crop cultivation. In these areas, the natural mound, pool, and swale topography has been severely altered or eliminated. Vernal pools tend to be shallow, with short hydroperiods, and the boundary between the wetlands and uplands is often very indistinct. In addition, soil alkalinity has also likely been reduced over time as salts were leached from the soils. The results of the seed bank and population study suggest that it is important to have a variety of pool and swale depths. A broad variation in pool and swale depths will guarantee that in any given year, regardless of weather, there will be suitable habitat for the species in at least a few places of the pool complex. Not enough variation in depths may eliminate this potential natural buffering mechanism for the species and decrease genetic diversity within the population.

Deeper playa-type pools should be restored where suitable soil conditions are present as these deeper pools are likely important seed reservoirs that may be important for population persistence during periods of drought. These larger play pools in extremely dry years are typically the only pools to retain water for a sufficient period to allow Contra Costa goldfields and associated vernal pool plants to produce seed successfully.

Seed Collection and its use in Reestablishing Populations. Any restoration or reintroduction efforts should aim to sample the existing populations widely so as to capture the diversity found in all populations. Seed collection efforts should not be focused on single populations, but rather on all populations for which collection is possible. Restoration efforts could then utilize seed from either a single or multiple sources when necessary. It is recommended that pool initiation is done in a conservative manner with seeds from a single source pool or small group of closely located pools. When necessary, multiple pools could be used as source material for new populations. The geographic proximity of restored sites to seed sources should be considered in restoration efforts, but does not need to dictate where restoration occurs given the lack of geographic structure to the genetic data. In all cases, careful documentation of both source and restored pools should be kept so that genetic diversity and structure could be tracked over time.

Adaptive Management and Monitoring

Standardized Monitoring Methods. Different methods used to estimate CCG populations can have drastically different results. Specifically, there are large differences in population estimates based on visual estimation methods, which are subject to high observer biases, versus actual population count data. Density and population estimates calculated using quadrat sampling provide repeatable and statistically valid data that can be compared between sites and between years. The ability to compare population parameters between sites and between years is necessary for tracking changes in population levels caused by weather, management strategies or other environmental variables, and is critical for developing a successful adaptive management and monitoring program.

Monitoring the Effect of Different Management Regimes. Weather conditions in combination with management regimes, such as grazing and burning, play a large role in the distribution and density of CCG plants on a site. The presence of dense, residual thatch cover is detrimental to CCG populations and CCG are negatively correlated with some nonnative annual grasses such as Italian rye grass. Removal/control of annual grasses such as ryegrass is critically important to the Contra Costa goldfield and other vernal pool plant populations. Livestock grazing, fire, and mowing are effective methods for removal of thatch and limiting grass competition. These factors should be carefully monitored and documented for each reserve area established for the species under the Solano HCP.

Vegetation Monitoring. The vegetation data provides useful information on the habitat and species that CCG are associated. However, the current results of this study cannot define, with certainty, what is unsuitable wetland habitat for this species. All preserves established for CCG should continue to conduct vegetation monitoring in association with CCG densities to better understand which species and habitat types CCG are associated and how these associations change with weather and management strategies. It would be even more useful to have more detailed information on hydrological conditions of wetlands with CCG.

Fremont's Goldfields. The distribution study has revealed another important issue that needs to be addressed to successfully preserve populations of CCG. In the CCG Subarea 1F southeast of Fairfield and North of Hwy 12, there are a limited number of wetlands occupied by CCGs and the majority of the wetlands in this area are dominated by Fremont's goldfield. Based on the results of the vegetation data, CCG appear to be a weak competitor. Fremont's goldfields may be competitively excluding CCG from wetlands in this area. In addition, these closely related species may be hybridizing. Based on research by Ornduff (1969) it is probable that these hybrids are sterile. This hybridization could drastically affect CCG recruitment. Additional information is needed on the interactions between these two species in order to conserve and potentially restore populations of CCGs to their historic levels. Additional studies needed include:

- A genetic study to determine if the two species are hybridizing.
- Ecological studies to understand competitive interactions between these two species.

Reserves established fully or in part to preserve Contra Costa goldfields should take a conservative approach and incorporate monitoring and management programs to address potential negative interactions with Fremont's goldfields. Reserves in the McCoy Creek watershed (McCoy Basin, Strassberger, Burke/Biggs, Goldfields Mitigation Bank, and Jehovah Witness mitigation site) and Upper Union Creek watershed (Noonan Ranch) need to monitor for Fremont's goldfield establishment and implement control/eradication measures if found. Currently, Fremont's goldfields do not appear to be present in these areas.

Reserves in the areas with previously identified intermediate characteristic plants (e.g., between Highway 12 and Travis Air Force Base) should continue to monitor Contra Costa goldfield populations and develop and implement, as appropriate, adaptive management measures to address hybridization issues. We recommend that habitat restoration and/or Contra Costa goldfield reestablishment in these areas focus on establishing high-density populations in restored and natural vernal pools lacking or with limited Fremont's goldfield populations. Previous establishment efforts by Colinge (2003), established Contra Costa goldfields by planting up to 300 seeds per site/study pool. We recommend substantially higher seeding rates, especially where Fremont's goldfields are present.

These recommendations are based on field observations during the distribution study. Limited observation data from two other sites which supporting both species indicates Contra Costa goldfields may have greater tolerance or a competitive advantage for the deeper, longer inundation portions of pools and in areas with higher soil alkalinity. Any restoration/establishment efforts need to be followed by intensive, long-term monitoring to assess potential hybridization and implement applicable adaptive management actions.

REFERENCES

Barbour, M.G., Solomeshch, A.I., and Witham, C.W., Holland R, Macdonald, R., Cilliers, S., Molina, J.A., Buck, J. 2003. Vernal pool vegetation of California: variation within pools. Madroño 50:129-146.

Barbour, M.G., Solomeshch, A.I., Holland, R.F., Witham, C.W., Macdonald, R.L. Cilliers, S.S., Molina, J.A., Buck, J.J., and Hillman, J.M. 2005. Vernal pool vegetation of California: communities of long-inundated deep habitats. Phytocoenologia 35(2-3): 177-200.

Barbour, M.G., Solomeshch, A.I., and Buck J., with Contributions from Holland, R.F., Witham, C.W., Macdonald, R.L., Starr, S.L., and Lazar K.A.. 2007. Classification, Ecological Characterization, and Presence of Listed Plant Taxa of Vernal Pool Associations in California. USFWS Agreement/Study No. 814205G238. UC Davis Account No. 3-APSF026 and Subaccount No. FMGB2.

Bliss, S. A., and Zedler, P. H.. 1998. The germination process in vernal pools: sensitivity to environmental conditions and effects on community structure. Oecologia 113:67–73.

California Department of Fish and Game (CDFG). 2006. *California Natural Diversity Data Base*. CDFG, Sacramento California.

California Native Plant Society (CNPS). 2006. *Inventory of Rare and Endangered Plants of California.* Electronic Version. CNPS, Sacramento, California.

Collinge, S.K. 2003. Constructed vernal pool seeding experiment aids in recovery of Contra Costa goldfields (California).Ecological Restoration 21:4, 316-317.

Collinge, S.K., Wise,C.A., and Weaver, B. 2003. Germination, early growth, and flowering of a vernal pool annual in response to soil moisture and salinity. Madrono, Vol. 50. No. 2, pp 83-93.

Dains, V. 2007. Botanical Survey Report, Dobles Property, Fairfield, Solano County, California. Prepared for Huffman-Broadway Group, Inc.

Environmental Stewardship and Planning, Inc. (ESP). 2004. Fifth and Final Annual Wetland Mitigation and Monitoring Report, Potrero Hills Lane, Solano County, California. Corps File Number 20527N. Prepared for Potrero Hills Landfill. Prepared by Environmental Stewardship and Planning, Inc., Sacramento, CA. 14 pp.

Federal Register. 1997. Endangered Status for Four Plants From Vernal Pools and Mesic Areas in Northern California, Final Rule. FR 62 (117) 33029-33038.

Hayek, L. C. and Buzas, M. A. 1997. Surveying Natural Populations. Columbia University Press, New York.

Hayter, A.J. (1984), "A proof of the conjecture that the Tukey-Kramer multiple comparisons procedure is conservative," Annals of Mathematical Statistics, 12 61-75.

Huffman Broadway Group. 2006. *Draft Ecological Constraints Stud for the, Dobles Property, City of Fairfield, California.* August 2006. San Rafael California. 39pp. plus exhibits. Prepared for Robert A. Karn and Associates, Inc. Fairfield, California.

Jones and Stokes, 2006. Special-status plant survey summary for Edenbridge Study Area A. Memorandum to Kathy Oesterreich and Tom Simonson, Edenbridge, Inc. July 25, 2006

Lafer and Associates. 1994. Focused Environmental Impact Report, Peabody-Walters Master Plan. SCH No. 94013047. Prepared for the City of Fairfield.

LSA Associates, Inc. (LSA). LSA. 2004. *Delineation of Waters of the United States on the Griffith Ranch and Director's Guild Study Sites, Potrero Hills Landfill*. Prepared for Potrero Hills Landfill. Prepared by LSA Associates, Inc., Pt. Richmond, CA. 15 pp. + appends.

LSA 2006. Special-status Plants and Sensitive Communities/Habitats Survey Results; Southern Hills, Eastern Valley, Griffith Ranch and Director's Guild Parcels, Potrero Hills Landfill Property, Solano County. Prepared for Potrero Hills Landfill, Inc., Richmond CA. LSA, Point Richmond, CA.

LSA. 2007a. Preliminary Wetland Delineation: Airbase Parkway Conservation Bank. Solano County, California. August 7, 2007

LSA. 2007b. Draft Resource Management Plan: Airbase Parkway Conservation Bank. Solano County, California. August 15, 2007

Muller-Dombois and Ellenberg. 1974. Aims and Methods of Vegetation Ecology. Wiley Press, New York, NY.

Ornduff, R. 1969. The Origin and Relationships of *Lasthenia burkei* (Compositae). American Journal of Botany. 56(9):1042-1047.

Raney Planning and Management, Inc. 2006. Gentry-Suisun Project Draft Environmental Impact Report SCH# 2004092077. Prepared for the City of Suisun. April 2006.

Ramp, J. 2004. Restoration genetics and pollination of the rare vernal pool endemic *Lasthenia conjugens* (Asteraceae). Masters Thesis, Department of Ecology and Evolutionary Biology, University of Colorado, Boulder, CO.

Robinson, Ramona. 2006. Mangels Property Reconnaissance-Level Plant Survey Report. Letter to Bill Mellerup, Vice President, Community Development, Sacramento Region, Lewis Operating Corporation. June 23, 2006.

Sawyer, J.O., Keeler-Wolf, T., and Evens, J.M., 2009. A Manual of California Vegetation, Second Edition. California Native Plant Society Press. Sacramento, Ca.

Solano County Water Agency (SCWA). 2009. Solano Multispecies Habitat Conservation Plan (Final Administrative Draft). Prepared by LSA Associates for the Solano County Water Agency, Vacaville, CA. April 2009.

UC IPM Online. www.ucdavis.edu/weather/wxretrieve.html

U. S. Fish and Wildlife Service (USFWS). 2003. Contra Costa Goldfields (*Lasthenia conjugens*). www.sacramento.fws.gov/es/plant_spp_ accts/contra_costa_goldfields.htm.

USFWS. 2005. Recovery plan for vernal pool ecosystems of California and Southern Oregon. U.S. Fish and Wildlife Service, Portland, OR.

Vollmar Consulting. 2000. Wetland delineation report and special status species survey report for the Strassberger Industrial Park, Cross Industrial Park, and McCoy Detention Basin properties, Fairfield, Solano County, California. Prepared for City of Fairfield, Dept of Planning and Development.

Vollmar Consulting 2005a. Gentry, Tooby and Barnfield Properties: Special-status Plant Survey Report 2000-2002 and 2005 Field Seasons. Prepared for Tom Gentry California Company. Prepared by Vollmar Consulting, Berkeley California.

Vollmar Consulting. 2005b. SCWA Regional Special-Status Species Surveys. 2005 Survey Report. Prepared for the Solano County Water Agency. July 2005.

Zar J. H. 1999. Biostatistical Analysis. Fourth Edition. Prentice Hall. New Jersey.

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APPENDIX A

MAPS

APPENDIX B

POPULATION STUDY SITE PHOTOS

APPENDIX C

VEGETATION ANALYSIS PHOTOS

APPENDIX D

POPULATION GENETIC ANALYSIS OF *LASTHENIA CONJUGENS* (ASTERACEAE) (CONTRA COSTA GOLDFIELDS) POPULATIONS WITHIN SOLANO COUNTY, CA

APPENDIX E

SEED BANK STUDY PHOTOS

APPENDIX F

CCG HABITAT PHOTOS