Habitat Evaluation and Reintroduction Planning for the Endangered Palos Verdes Blue Butterfly

Final Technical Report
to
California Department of Fish and Game
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1. Introduction

On March 10, 1994 — completely by accident — a rare and wonderful opportunity for the preservation of biodiversity presented itself. On that day, the Palos Verdes blue butterfly (*Glaucopsyche lygdamus palosverdesensis* Perkins and Emmel), thought extinct (Arnold 1987; Arnold 1990; Mattoni 1993), was rediscovered at the Defense Fuel Support Point in San Pedro, California (Anonymous 1994; Mattoni 1994). The Lazarus-like reemergence of this species gave hope for a second chance to preserve and enhance its habitat, and, with careful stewardship, the potential to reintroduce the species to its former range.

The decline and presumed extinction of the Palos Verdes blue butterfly, henceforth the "PVB," had mirrored the inexorable transformation of its coastal sage scrub habitat on the Palos Verdes peninsula to urban land uses (Arnold 1987; Arnold 1990; Mattoni 1994; Mattoni 1993). Now, its long-term conservation will require the protection and enhancement of as many as possible components of the biotic and abiotic characteristics that constitute its ecosystem. This requires that the historic community be mimicked by reestablishing a community of species over as large an area as possible. Although at least several species of larger mammals obviously cannot be supported on the limited space remaining and most of the many invasive exotic species cannot be eliminated, an attempt to achieve this ideal goal would do most to conserve the butterfly, provide useful information for ecological theory, and create a valuable resource for instruction. Management of the species will require balancing the Hippocratic admonition to "do no harm" with the need to undertake an active program of habitat enhancement, captive breeding, and reintroduction.

This report provides the biological basis for habitat enhancement, creation and reintroduction planning for the PVB. Specifically, the report includes research efforts to describe and quantify the known population of the species and its habitat relationships, new behavioral observations of the species, description and evaluation of all natural remnant habitat across the Palos Verdes peninsula[1] for potential reintroduction of the

[1] Only portions of the City of Rancho Palos Verdes are included in this study as other individuals have been retained to complete habitat evaluation in that city.

species, discussion of current conservation efforts and their lessons for habitat enhancement, and recommendations for reintroduction methodology.

2. Biological and Historical Background

The Palos Verdes blue butterfly was listed as an endangered species on July 2, 1980 (45 Federal Register 44939). After 1983, the species was thought to be extinct as the result of cumulative effects of development (e.g., Chambers 1987). In spite of extensive searches for the butterfly across all known locations during the following years none were sighted (Morton, Mattoni, pers. com., Feldman 1984). In March 1994 the butterfly was discovered at the Defense Fuel Support Point (DFSP) in San Pedro, which was not a Critical Habitat designated for the species at the time of listing (Anonymous 1994; Mattoni 1994). Currently, the only known extant population of the Palos Verdes blue butterfly is located at this site.

The probability of the survival and recovery of the species has been increased by captive breeding and restoration efforts initiated by the Defense Logistics Agency at the DFSP and funded by the Department of Defense Heritage program and Chevron Pipeline Company. However, extinction of this animal in the foreseeable future remains a distinct possibility due to PVB occurrence in low numbers at a single locality. The extinction probability is predicted by possible catastrophic events as well as from environmental, demographic, and genetic stochasticity. The small, isolated Palos Verdes blue butterfly population may already exhibit reduced heterogeneity due to genetic drift and possible bottleneck effects over its 40 years of isolation. In all likelihood, fitness of the population has been reduced, although there is no direct evidence of this. Reduction of the risk of extinction can best be achieved by establishing additional populations on historic sites across the Palos Verdes peninsula in addition to expanding the number and quality of habitat patches at DFSP.

Our PVB recovery team has worked intensively over the past year to complete a detailed vegetation survey of the peninsula. These data constitute the basis for prioritizing PVB reintroduction plans across the peninsula. The butterfly historically has been associated with coastal sage communities and open grassy patches within coastal sage aggregates. Successful establishment of additional populations of PVB demands the creation of the complex and diverse ecological community structure of the coastal sage scrub habitat.

Restoration planning must take into consideration all of the biotic and abiotic factors that maintain the coastal sage scrub ecosystem (Gaskin 1995). The configuration of the different community components in various habitat patches will be crucial to ensure maximum biological integrity at sites of reintroduction, and to minimize the risk of stochastic elements that threaten the survival of the butterflies. It has taken a relatively short time and few careless mistakes (e.g., Chambers 1987) for this species to reach its current endangered status. To bring the PVB back from such a brink will require a long-term commitment, exhaustive efforts, and a readiness to face and manage uncertainty.

2.1. Taxonomy

The Palos Verdes blue butterfly is one of 11 subspecies of the silvery blue butterfly (*Glaucopsyche lygdamus*), a widespread species in North America (Miller and Brown 1981). The PVB was described from specimens mostly collected in the 1970s in and near Agua Amarga Canyon and Hesse Park in the City of Rancho Palos Verdes (RPV). The subspecies is distinguished from all other subspecies by a combination of morphological and behavioral characteristics described and illustrated by Mattoni (1994). The PVB was originally distinguished from the southern blue (*G. lygdamus australis*) by its exclusive use of rattlepod (*Astragalus trichopodus lonchus*) as a larval foodplant, a relatively fast flight in comparison to *australis*, an earlier flight than *australis*, and several wing characteristics, including a slightly darker underside ground with larger macules well set off by white halos (Mattoni 1994:181). The discovery of the population at DFSP revealed that *palosverdesensis* also used *Lotus scoparius* as a larval foodplant (Mattoni 1994). On the Palos Verdes peninsula the co-occurrence of *Lotus* and *Astragalus* together in significant number is unique to DFSP (Mattoni 1994).

2.2. Life History and Autecology

Adult butterflies of all silvery blue subspecies are closely associated with their legume larval foodplants. In general, a silvery blue butterfly population at any one locality is monophagous — its larvae eat a single plant species. The reason often invoked for this specificity is local adaptation of larvae to particular suites of alkaloids that each plant species presumes to produce for defense. Breedlove and Ehrlich (1972) provided evidence consistent with this hypothesis of coevolution for the case of Rocky Mountain subspecies of the silvery blue and its *Lupinus* plant hosts. Although the validity of this theory that attempts to explain the mechanism of insect-foodplant specificity is still in debate, such specificity is a definite characteristic of the PVB, whose foodplants are restricted to the deerweed (*Lotus scoparius*) and rattlepod (*Astragalus trichopodus lonchus*) found within coastal sage scrub habitat.

2.2.1. Early Stage Biology

The Palos Verdes blue butterfly is single brooded with a flight period extending from late January into early May. Eggs are usually individually laid on the flowerheads of the foodplants, where the larvae hatch and feed. Ants tend the last two instars of the larvae. At DFSP *Astragalus* pods have been located with typical larva entry holes. The larvae were not found, but Argentine ants (*Linepithema humile*) were present in the pods. A “honeydew” exuded from the larva rewards the tending ants, while the larva receives the benefit of protection from parasitism (Pierce and Eastseal 1986). There are no data to assess whether the invasive Argentine ant tends larvae more or less effectively than the native species (e.g., *Formica pilicornis*), but there is no biological reason to expect that they would not function equally well.

When the larvae are mature, they crawl into the leaf litter under the base of the foodplant and pupate. The pupae may remain in diapause for several years with adults of any brood emerging over a period of years. The mechanism for this attenuated eclosion is not understood (Mattoni 1994) although the strategy provides buffering against extirpation in poor weather years and serves to magnify effective population size (N_e) across generations.

2.2.3. Adult Behavior

The flight and habitat usage patterns of adult PVB have not previously been documented. Quantification of flight direction and distance of adult PVB is important to predict the possible recolonization of appropriate habitat and to determine the appropriate spatial distribution of foodplant for the purpose of habitat creation and en-

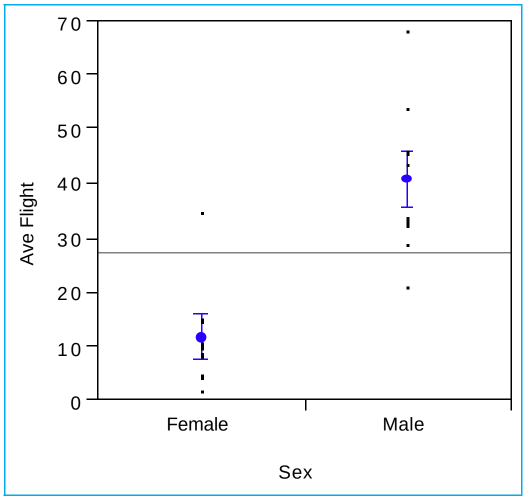

Figure 1. Differences in average flight time in seconds between male and female PVB.

hancement. During the 1999 flight season, a pilot study was undertaken to quantify adult behavior during morning and afternoon periods and to evaluate the null hypothesis that adult flight direction and duration is random. The study also addressed two behavioral questions: 1) what proportion of adult butterfly activity time is spent nectaring, basking, ovipositing, and flying, and 2) do adults recognize habitat?

In a small habitat patch (240 ft x 60 ft), two teams followed individual butterflies while recording, timing, and mapping all activities. Each butterfly was followed until it was lost from sight. The observations were conducted on three days during the week of March 12, 1999 in the morning and afternoon under varying weather conditions. Data were collected for 11 males and 7 females.

Females spent more time basking on cloudy (mean = 90.9 sec.) than sunny days (mean = 32.6 sec.), consistent with the need for more thermoregulation under cooler conditions. Males basked 49.2 seconds on sunny days, but no males were observed under cloudy conditions. The amount of time spent at rest — not basking with wings open — increased later in the day. Males spent a greater proportion of the time observed in flight than females, with a significantly longer average flight time (ANOVA, $p<0.05$; Figure 1). The longer flight time was also associated with flights that covered more distance.

Direction of flights by males and females was not random. Females were not observed leaving the food patch. Males occasionally left the patch to the north or south, in the direction of other food sources. When leaving to the east side of the patch, one male was repeatedly observed skirting the edge of the patch and reentering at another point (Figure 2). The eastern fence and the northern meadow were the most frequent directions of departure for males, but crossing these boundaries was often followed by return. These results suggest that butterflies recognize their home patch and return to it in the landscape. Such patch recognition and "homing" behavior has been shown in other Lycaenid species with relocation experiments (Keller et al. 1966).

The observations of male and female flight behavior confirm that the species has a low probability of recolonizing unoccupied, distant habitats without human intervention. Under historic conditions, where the foodplant was distributed patchily in a coastal sage scrub mosaic, the greater wandering of males would increase genetic flow among populations. It is therefore likely that the concentrations of adults found at DFSP are all part of one panmictic population.

Oviposition was only observed on *Lotus scoparius.* Subjective observation suggested that females showed no preference for specific sizes or ages of deerweed.

In addition to the common behaviors observed, an instance of predation by a yellowjacket was recorded. A yellowjacket (*Vespula pensylvanica*) attacked a male PVB that was resting on a blade of grass. The PVB was knocked into a deerweed. After regaining balance, it was hit by the yellowjacket a second time. The PVB was then lost from view, but later another observer noticed a yellowjacket leaving the deerweed

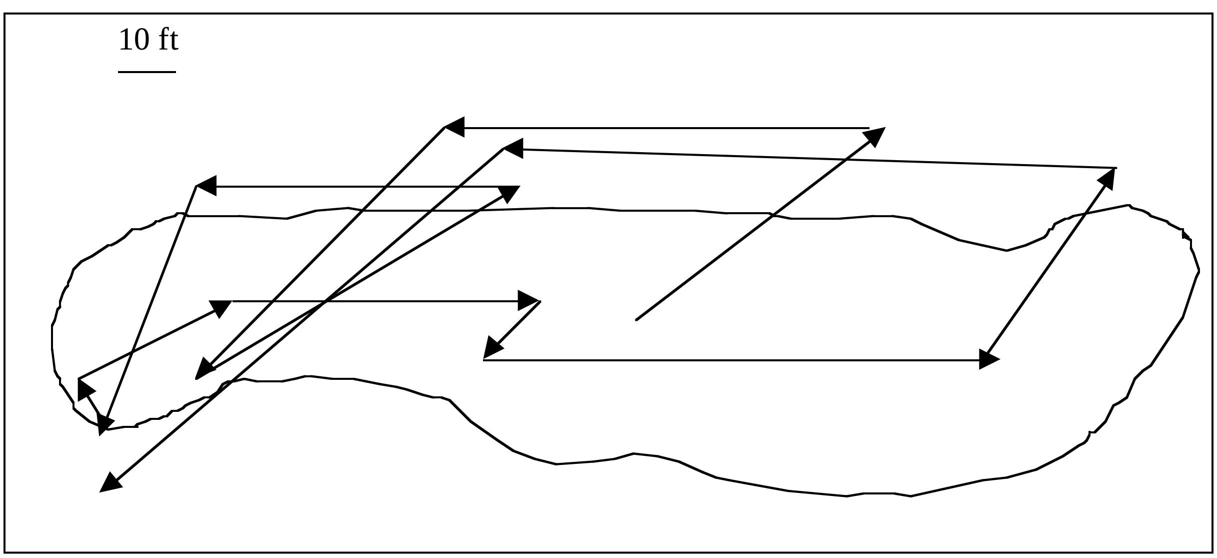

Figure 2. Flight path of one male PVB in relation to extent of foodplant.

with a flash of white underneath, possibly the butterfly. Predation by yellowjackets had heretofore not been observed, but may be significant, given their common occurrence at DFSP.

The observations from this pilot behavioral study are useful and suggestive, but they must be augmented by a more comprehensive sampling effort during the 2000 flight season. Furthermore, they represent only an example of behavior in relation to a habitat patch with *Lotus scoparius*; probable behavior in *Astragalus*-only habitat will have to be deduced. However, the results obtained are similar to those found for a rare Oregon butterfly in relation to its foodplant. The results showed that Fender's blue butterflies (*Icaricia icarioides fenderi*) stayed within 10 m of their *Lupinus* foodplant 95% of the time (Schultz 1998). Schultz concluded that while the species could disperse between habitat patches historically less than 0.5 km apart, it was unlikely to disperse the average 3 km between patches in the fragmented landscape of today.

2.2.3. Population Dynamics

Population transect counts have been conducted every year since the butterfly

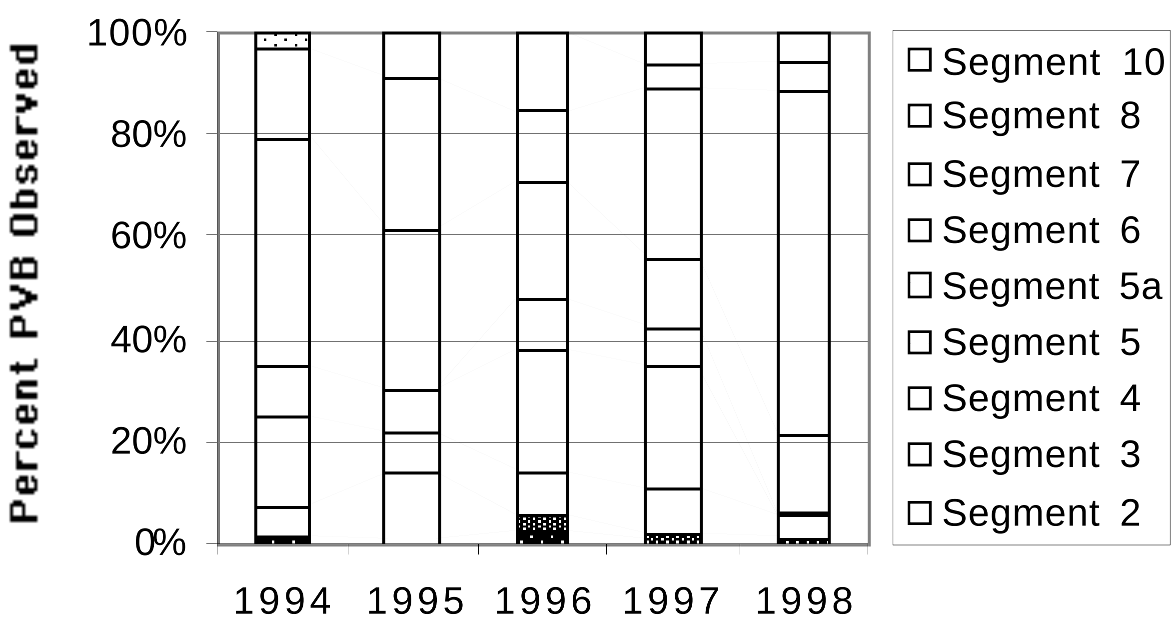

Figure 3. Percent adult PVB observed per transect segment at DFSP, 1994–1998 (Mattoni et al. 1998)

was rediscovered in 1994 (Mattoni et al. 1998). Zonneveld has incorporated results of these counts into his (1991) mathematical model that estimates a population index and individual longevity based on transect counts. The model shows a variable total population index and death rate (Zonneveld, unpublished report; Table 1), a variation that is related more to weather conditions than available habitat. The low population estimate for 1997 is likely a result of a severe rainstorm in 1996 that came at the height of the flight season, presumably killing many gravid females. Variation in longevity from 4.11 to 11.9 days as estimated by the model further suggests a density independent population regulation, probably weather. This yearly variation lends further support to the presumed role of weather in the original decline and disappearance of the species (Mattoni 1994). Climate has been shown to be the primary population regulation mechanism for other butterflies as well (Dobkin et al. 1987; Weiss et al. 1988).

Transect surveys at DFSP also showed significant yearly variation among distinct areas. Different parts of the transect support drastically different proportions of the individuals observed in different years (Figure 3).

These presumed population regulation mechanisms — climate (wet vs. dry years) and weather (intense rain) — vividly illustrate the importance of stochastic events on the long-term dynamics of the species. In a period of presumed climate change with unpredictable local effects, conservation efforts will depend on planning for unexpected weather events, and ultimate success might require waiting for the precise set of meteorological conditions to promote population growth of the species.

2.3. Distribution

The historic range of the PVB likely extended over most of the Palos Verdes peninsula in Los Angeles County, California, usually at elevations greater than 300 feet above sea level. Within its range, the butterfly was extirpated from all areas by 1984, except for the DFSP location in San Pedro.

Table 1. PVB population parameter estimates, 1994–1998 (est. ±S.D.) (Zonneveld, unpublished data based on transect counts in Mattoni et al. 1998).

	1994	1995	1996	1997	1998
Population index	45.0±16.1	78.0±41.2	82.4±12.3	21.6±12.9	55.1±12.5
Death Rate (d^{-1})	0.21±0.0074	0.23±0.12	0.084±0.013	0.096±0.062	0.096±0.022

The twelve known sites of historic occurrence are shown on the map (Figure 4) in Mattoni (1994). They are:

1. Hesse Park
2. Agua Amarga Canyon
3. Alta Vista Terrace
4–8. Palos Verdes Drive East (“The Switchbacks”)
9. San Pedro Hill
10. Upper Filiorum
11. Crenshaw extension
12. Klondike Canyon

The butterfly was unknown prior to the early 1970s when Perkins discovered it near his residence and recognized it as a distinct taxon (Perkins and Emmel 1977). Jess Morton instituted an effort to find as many populations as possible shortly after the PVB listing. The sites given in Figure 4 are the result of this effort. Of these sites, three have been destroyed by construction activity. Most others are more highly degraded than in 1984 because of sporadic clearing for fire control and general elimination of na-

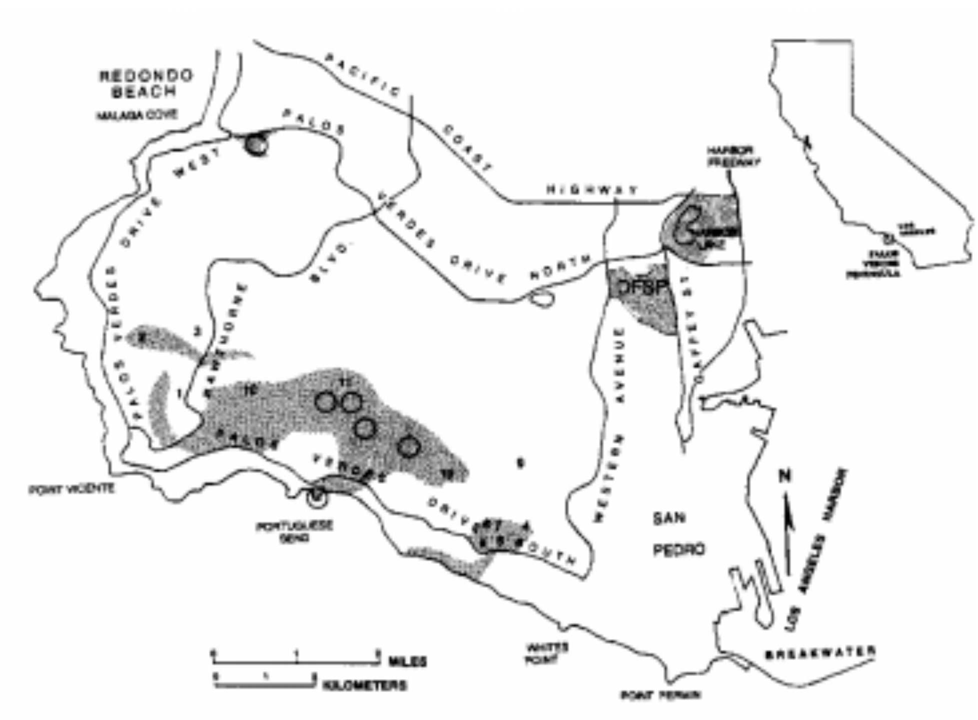

Figure 4. Map of the known distribution of the PVB prior to its disappearance in 1984 (Mattoni 1994). Numbered sites are described in the text.

tive plants by spreading non-native invasive species. The historic sites are important because they at least represent abiotic conditions that were congruent with PVB adaptedness. They consequently represent the most likely sites for which enhancement and reintroduction should be attempted.

During 1998 and 1999 potential sites for undocumented or persisting PVB populations were scrutinized during spring flight season. The sites identified for surveys, based in part on the new knowledge of *Lotus scoparius* as a foodplant, were the Chandler Preserve (some *Lotus* present), Malaga dune (*Lotus*), Valmonte (*Lotus*), Forrestal (few *Astragalus*) and Friendship Park (few *Astragalus*). No PVB were located at these localities and no other likely sites were identified.

Surveys during the 1999 flight season at DFSP included habitat areas in the adjacent abandoned military housing. Adult PVB were found in the housing complex in all areas with deerweed. These results confirm that the only extant population of the species is at DFSP and the adjacent housing facility.

2.4. Habitat Characteristics

Defining the habitat necessary to support PVB requires a consideration of scale. At the micro-scale, the butterfly requires foodplants, but the natural distribution of *Astragalus* and *Lotus* is patchy within the coastal sage scrub community. Both species exploit disturbance to establish, and *Astragalus* can, but does not necessarily, persist in more mature scrub. The foodplants — *Astragalus* especially — can be found in gaps within the coastal sage mosaic so small that they are unnoticeable unless surveyed carefully for.

The butterfly may need some critical number of foodplants and nectar sources to maintain a population, but this can be a small number if located in appropriate physical conditions in a confined area. For example, the southern blue has persisted for over ten years on about 20 deerweed in a one-acre area at Manhattan Beach. Similar persistence is found at the Ballona dune.

2.4.1. Historical Habitat (South Slope)

Limited data are available about the habitat characteristics of the south slope localities. The information is based on recollections as no quantitative surveys were conducted before the PVB was extirpated. Several localities have been lost to construction or highly degraded through disking for fire control.

In 1983, the Hesse Park population was persisting on highly degraded grassland with thin soil on a shale substrate. There were a few coastal sagebrush (*Artemisia californica*) and *Astragalus* left after repeated disking, yet these conditions sustained a population for at least several years. San Pedro Hill exhibited similar conditions, with a few *Astragalus*, mostly within regularly disked grassland.

Habitat conditions at Palos Verdes Drive East and Friendship Park are similar today as when they supported the butterfly, with substantial patches of native scrub and *Astragalus* remaining, but not the butterfly.

The degraded nature of the localities where the butterfly was known to persist illustrates the dynamic nature of the habitat of the species. It is predictable that the areas where *Astragalus* — the sole south slope foodplant — was found are areas that are classified as "degraded." *Astragalus* exploits early successional habitat and in the modern landscape those areas have been provided by human disturbance. Historically, *Astragalus* likely followed natural disturbances such as fire, landslides, and animal digging and burrowing. While some foodplant patches may have remained stable for long periods, perhaps persisting in areas where competition is limited by poor or rocky soils, the foodplant and the butterfly likely shifted their distribution in the landscape over time.

This history of disturbance-associated distribution makes interpreting the current habitat and prospects for management difficult, as the introduction of Mediterranean grasses has shifted the dynamics of post-disturbance succession. There is now severe competition in disturbances from exotic grasses. In addition, the historic natural disturbance regimes have been replaced by much more frequent anthropogenic disturbances, combined with fragmentation of the habitat mosaic.

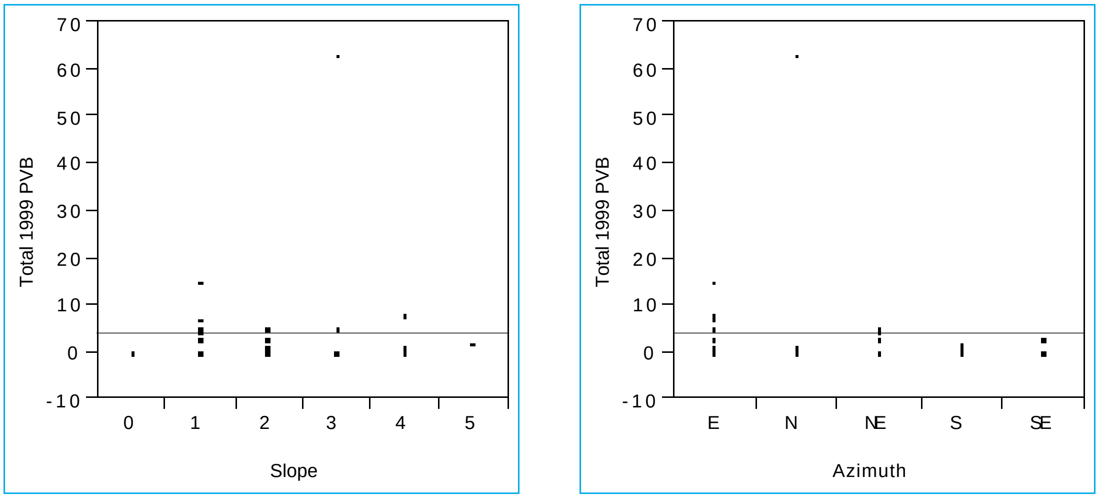

Figure 5. Number of adult PVB observed during 1999 flight season in relation to slope and azimuth.

2.4.2. Current Habitat (North Slope)

To quantify the relationship between habitat parameters and PVB incidence, a study of the population monitoring transect at DFSP was completed. The same transect used to monitor yearly population was walked and both vegetation and topographic variables recorded, including percent native shrub cover, number and species of native shrubs, soil history (cut, fill, native, terrace), aspect, and slope. These parameters were then used to describe conditions at occupied sites and to develop a multiple regression model to explain the number of butterflies observed along each transect sub-segment.

The model shows that the best predictors of PVB abundance at DFSP are *Lotus scoparius*, *Astragalus trichopodus*, slope, and azimuth. This model explains 50% of the variation in adult abundance (adjusted $r^2=0.495$, $p<0.0003$). Most PVB were found at intermediate slopes facing north through east (Figure 5) with higher numbers of *Lotus* and *Astragalus*. The large concentration of individuals along one transect segment prohibits a better fit of the model. The importance of slope and azimuth in explaining PVB abundance is consistent with the role of weather and climate in population regulation. Adult PVB seem to respond to specific topoclimatic variables, and given the yearly spatial variation discussed above, it seems that different sites provide optimal conditions in different years.

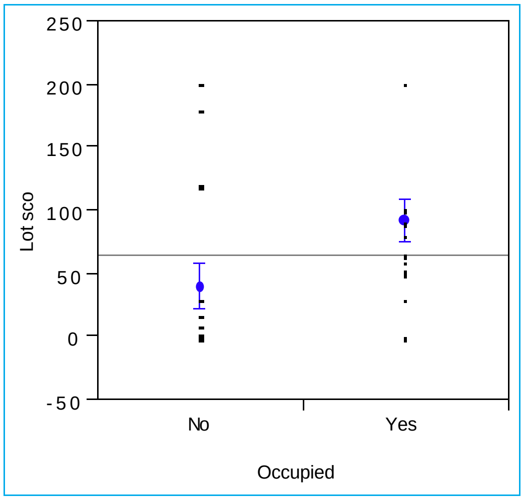

Figure 6. Number of *Lotus scoparius* in transect segments occupied and unoccupied by PVB.

Occupied transect segments have significantly (ANOVA; $p<0.01$) more *Lotus scoparius* individuals (92.9 ± 17.6 S.E.) than unoccupied segments (29.6 ± 17.6 S.E.). However not all segments with large numbers of *Lotus* support PVB (Figure 6). Similarly, occupied sites have more *Astragalus* individuals on average (1.92 vs 0.69; N.S.), but not all sites with *Astragalus* are occupied.

Shrub cover of occupied transects ranged 20–85%, with maximum PVB abundance on a segment with 20% shrub cover. Sites with lower and higher native shrub cover were not occupied.

Extrapolation of these results is complicated by a number of factors. First, the spatial pattern of adult abundance during 1999 is unique, different years with different vegetation and climatic conditions may show another pattern. Testing of abiotic factors with previous transect counts will be conducted to investigate this. Second, the vigor and percent cover of exotic grasses and herbs varies from year to year and remains an unexplored variable in explaining PVB habitat utilization. Third, these data may be unique to the northern slope of the peninsula and to areas with *Lotus* and *Astragalus* co-occurring. Nevertheless, the habitat relationship does provide specific information to guide attempts at recreating PVB habitat elsewhere.

2.5. Long-term Viability — The Fallacy of PVA

Population viability analysis (PVA) is often invoked to evaluate the probable outcome of conservation options. These efforts depend largely on the ability to define habitat requirements of the species in question. For the PVB, the data above show that the species correlates with foodplant distribution. The foodplants also likely serve as nectar sources but other flowering species, including annual species not included in the analysis, are important. Many native annuals have been extirpated on the peninsula or persist at lower than historical densities. Identification of these features for the purpose of PVA relies largely on the intuition of experts on what constitutes suitable habitat.

Expert intuition about what constitutes appropriate habitat is often incorrect. At DFSP, transect segment 1 has dense foodplant and was assumed to constitute adequate habitat but only once in five years was a single male PVB observed in the area. Furthermore, population density shifts over time. Transect segments 6 and 7 have increased in proportion of PVB observed since 1994, while transect segment 5 has decreased. PVB thus exploits habitat opportunistically and ultimately depends on the ability to move among patches as climatic and successional variation dictate. The variability in habitat utilization and identification make PVA particularly difficult.

While a metapopulation model (sensu Hanski et al. 1995; Hanski and Thomas 1994) could be suggested as the basis for a PVA, several other features of PVB biology render such a model unsuitable. First, the observed limited dispersal ability of the PVB means that genetic flow among concentrated patches is likely low. It is likely panmictic over many acres as has been shown for *Plebejus argus* (Lewis et al. 1997). However, the PVB is even more sedentary than that species as PVB have not been documented to colonize habitat patches 1 km distant (Lewis et al. 1997). A dynamic regional metapopulation model characterized by frequent local extinction and recolonization is therefore inappropriate for the PVB. There may be regional gene flow, but not such mobility that local extinction is followed by reestablishment. Such a model is further complicated by the necessary disturbance regime to maintain sufficient hostplant densities within colonization distance. Second, the lack of concrete information on the genetic and demographic structures of this species inhibits the ability to build a solid model; only one small population has been available for study for five years. Third, PVA inherently depends on density-dependent assumptions. Previous population viability analysis completed for another coastal sage scrub species — the California gnatcatcher — has shown to be biased and of little value for sound management policies due to their inherent reliance on density-dependent assumptions, inaccurate parameters, and missing information (Akcakaya and Atwood 1997). In cases of *r*-selected species such as butterflies, the biotic, density-dependent factors such as competition and predation are less important than the abiotic, density-independent factors such as weather (Reed et al. 1998). Due to the large swings in parameter ranges caused by abiotic events, the PVA, which can only offer a mean time of survival, is highly ineffective.

Because of the lack of a sufficient model to estimate accurately PVB population viability, it is advisable to be as conservative as possible in outlining habitat requirements of the butterfly. Critical minimal habitat should require large continuous tracts of healthy coastal sage habitat. This requirement lies at the basis of the reserve design, and clarifies which areas should be conserved (high quality patches, in close proximity, with matrix areas in between targeted for restoration), and which should be excluded (low quality, distant patches).

2.6. Ecosystem Context

Planning for the recovery of the Palos Verdes blue butterfly must include consideration of all environmental factors of the ecosystem into which it is embedded (see Gaskin 1995). Conservation planning is often guilty of overemphasizing individual species within given communities. For example, regulators often concentrate only on the El Segundo blue butterfly when considering decisions about the El Segundo dunes, when there are ten other invertebrates restricted to the dunes that should be included (Mattoni et al. in press). Therefore, assessment of potential reintroduction sites reaches beyond the most obvious requirements of its biology to encompass the diversity of the ecosystem in which it evolved. The butterfly thereby functions as an umbrella species for the consideration of non-status, but unique, populations on the peninsula. For example, there are unique local ecotypes of *Horkelia cuneata*, *Eriogonum fasciculatum*, and *Dudleya lanceolata* found on the peninsula. In addition, present day Palos Verdes communities are all but vestiges of their historic compositions, as documented by the plant inventories by Gales (1988) and Brinkmann-Busi (1992), and historic analysis of the adjacent Los Angeles coastal prairie (Mattoni and Longcore 1997).

While the PVB is monophagus, the species depends on the larger ecosystem for the conditions that support its survival. The most important indication of this is the reliance of butterflies on sufficient nectar sources. Nectar sources have been experimentally demonstrated as crucial to female fecundity in other butterflies (Murphy and Weiss

1988). Other research has shown that the microdistribution of some butterfly species varies according to the phenology of its nectar sources (Loertscher et al. 1995). The relative abundance and diversity of predators and parasites also depends on overall ecosystem health. Although we do not have sufficient information to foresee the direct mechanism, a depauperate system is more likely to have an over- or under-abundance of critical species. Notably, the one observed incidence of predation on adult PVB was by a species promoted by human activity. By recognizing the PVB as part of a greater ecosystem, greater conservation benefit will be achieved, both through purposeful inclusion of rare populations in protection and enhancement plans and by increased conservation of unsurveyed ecological components (e.g., fungi, lichens, mosses).

3. Vegetation Survey

Coastal sage scrub is a facultatively deciduous shrubland community predominantly composed of species of *Artemisia, Salvia, Eriogonum,* and *Rhus* with open spacing (Epling and Lewis 1942; Mooney 1988). This general community type is distributed from San Francisco Bay to the El Rosario region of Baja California and is limited by many environmental factors such as mean temperature, soil factors, and moisture (Westman 1981). Currently, coastal sage scrub is extremely limited and fragmented due to urban development, with 70–90% of its pre-settlement distribution lost (O'Leary 1990; Westman 1981). The Palos Verdes peninsula is now largely a fragmented region with its formerly relatively large coastal sage scrub community in pieces.

3.1. Historical Species Richness

The goal of the vegetation survey was to establish current plant community conditions. To compare current with historical diversity plant diversity, a list of plant species recorded from the Palos Verdes peninsula was assembled from available sources (Brinkmann-Busi 1992; Gales 1988; Mattoni and Brinkmann-Busi 1997). These sources, and the current survey, show 229 native vascular plant species from the peninsula (see Appendix). We also prepared a list of exotic species that was augmented with survey results.

3.2. Survey Methods

To identify potential sites for enhancement and reintroduction we conducted a quantitative survey of all apparent open spaces on the Palos Verdes peninsula outside the City of Rancho Palos Verdes. The results of this survey should be combined with habitat assessments conducted in Rancho Palos Verdes for complete coverage of the historic habitat of the species. Open spaces greater than 1 acre (~0.5 ha) were identified from aerial photographs and through consultation with local experts.

Each of these areas was inspected and divided into polygons based on slope and vegetation type. For example, areas with predominantly grassland species were included in a separate polygon from sage scrub areas. Riparian areas were indicated by linear corridors. East facing slopes were divided into separate polygons from west facing slopes. Each polygon was visited and surveyed by random transects walked throughout the length and width of the polygon. All vascular plant species were ranked and recorded on an ordinal scale using a hand-held computer according to the following categories:

1. One individual or one stand of an annual species
2. Rare, but more than one individual or stand
3. Sporadic
4. Common
5. Cover

Alison Lipman and Angelika Brinkmann-Busi identified plant species according to *The Jepson Manual* (Hickman 1993). Voucher specimens of most species were prepared and stored at the research facility at DFSP. Unknown specimens were vouchered and sent to herbaria for identification; not all specimens have been identified at the time of this writing.

Native and exotic species richness was calculated for each polygon. Summing the abundance values of native and exotic species separately and expressing native species as a proportion of the total produced a measure of the overall natural character of the vegetation, referred to as the “native index.” Although this index is correlated with percent native cover, the index is based on ordinal classifications and therefore not appropriately referred to as a percentage.

3.3. Results

Between February 1998 and February 1999, 195 polygons were identified and mapped (see accompanying map). Of these, surveys were completed of 172 polygons. Other polygons were omitted because they had been surveyed before (e.g., Chandler Preserve, Brinkmann-Busi 1998), were completely inaccessible, disked, covered with ornamental vegetation, or were outside the scope of work.

Of 229 species of native plants originally known from the peninsula, 140 species were recorded in the survey. We also recorded at least 109 species of exotic plants as some classes of exotic species were lumped for simplicity (e.g., *Eucalyptus* sp.). All survey data are included as a digital spreadsheet file with this report.

The combined native index for all surveyed polygons was 0.43 (±0.01 S.E.) with a maximum value of 0.84. The number of native plant species per polygon ranged up to 32 with a mean of 12.04 (±0.52 S.E.) Exotic species ranged up to 40, with a mean of 15.53 (±0.61 S.E.). These values indicates that exotic species have invaded all open spaces at the acre scale, and that any revegetation and management effort will face a considerable challenge from exotic species but that significant areas supporting native plant diversity remain.

The results provide a quick method for prioritizing overall conservation efforts on the Palos Verdes peninsula exclusive of the City of Rancho Palos Verdes. For example, the native index and number of native species identifies sites with high general habitat value, while the database can be queried for sensitive plant species to identify areas with unique resources (Table 2). Analysis of the data collected for this study would provide the baseline data for extension of the NCCP beyond the City of Rancho Palos Verdes. Completion of comparable survey work in the City of Rancho Palos Verdes would provide a basis for quantitative comparison of habitat value across the peninsula.

4. Reintroduction Site Evaluation

Querying the database for appropriate criteria identified potential reintroduction sites. These criteria are determined based on known habitat associations, including vegetation cover and slope. Because of the difference in foodplant between the northern and southern slope of the peninsula, separate criteria were developed for each. Logistical feasibility was then combined with these biophysical criteria to prioritize potential reintroduction sites.

4.1. Criteria

Criteria to filter polygons on the north slope of the peninsula for were defined as follows:

1. *Lotus scoparius* present,
2. North to eastern slope,
3. Native index at least 0.44.

Table 2. Most diverse polygons by native plant species richness.

ID#	Name	Native Species	Exotic Species	Native Index
122	Geroge F Canyon 6	32	15	0.67
117	George F Canyon 1	32	30	0.52
31	Malaga Dune 1	32	32	0.49
37	Malaga Canyon 2	29	34	0.41
121	George F Canyon 5	28	18	0.61
119	George F Canyon 3	27	28	0.48
34	Malaga Dune 4	27	26	0.47
164	Coolridge 1	26	16	0.62
188	RPV City Hall 1	25	22	0.47
108	Dev. Canyon 2 1	24	9	0.73
120	George F Canyon 4	24	15	0.60
171	Forrestal 1	24	26	0.46
61	Agua Amarga 6	23	16	0.57
107	Dev. Canyon 1 3	23	25	0.47
76	Agua Negra Canyon 2	22	18	0.59
33	Malaga Dune 3	22	28	0.44
84	Agua Manga 3	21	11	0.65
57	Agua Amarga 2	21	15	0.60
118	George F Canyon 2	21	27	0.44
73	Chadwick Canyon 5	21	35	0.38
72	Chadwick Canyon 4	21	40	0.36
62	Agua Amarga 7	20	21	0.53
175	Forrestal 5	20	19	0.51
59	Agua Amarga 4	19	20	0.50
176	Forrestal 6	18	24	0.45
21	Upper Malaga Canyon 1	18	28	0.43
182	Crenshaw Extension 3	18	31	0.41

Given the lack of historic data for the species on the north slope, the best approach is to concentrate on areas that already have deerweed and augment the habitat from that baseline. Technically, because the only recorded north slope locality is DFSP, any additional populations established on the north slope are “introductions” of the species. Such introduction is warranted as the areas are within the presumed historic, but undocumented, range of the species.

For the southern slope, the sole vegetation criterion is the presence of *Astragalus*. All sites with the foodplant and all historic sites should be considered for reintroduction. Because *Lotus scoparius* was not historically a significant part of the habitat on the south slope the species should neither be considered in reintroduction planning nor included in revegetation efforts.

4.2. Site Specification and Priority

4.2.1. North Slope

Deerweed was recorded from only seven polygons on the north slope, with an additional population known from previous surveys at the Chandler Preserve (Table 3). All of these polygons have significant native species cover and in three localities deerweed occurs on a north to east facing slope. These criteria identify polygons at Via Valmonte, Malaga Dune, and Chandler Preserve as the most likely sites for successful habitat enhancement and reintroduction of the PVB. The sites are similar to the known PVB habitat at DFSP in that they are located on the lower, rolling slopes of the northern slope rather than farther up in canyons. Priority for these areas should be as follows:

Table 3. North slope polygons with *Lotus scoparius*.

ID#	Name	Slope	Native Species	Exotic Species	Native Index	*Lotus scoparius*
1	Via Valmonte 1	S	17	12	0.52	3
2	Via Valmonte 2	N	16	21	0.39	2
31	Malaga Dune 1	S	32	32	0.49	4
33	Malaga Dune 3	N	22	28	0.44	4
34	Malaga Dune 4	N	27	26	0.47	3
37	Malaga Canyon 2	S	29	34	0.41	1
119	George F Canyon 3	S	27	28	0.48	2
157	Chandler Preserve 2	NE	~20	n/a	n/a	2

1. Linden H. Chandler Preserve. This 38-acre site (ID# 156–159) is already protected from development and has a restoration and enhancement plan in place (see below, Brinkmann-Busi 1998).

2. Malaga Dunes. This 10-acre dune system in and around the Palos Verdes Country Club (ID# 31–35) has scattered large deerweed plants. The whole area is suitable for revegetation with foodplants and nectar sources. The site is important to regional biodiversity as it has a number of unique plants to the Palos Verdes peninsula present. It has potential as a regionally important habitat for many more species than the PVB.

3. Via Valmonte. The site, comprising approximately 20 acres (ID# 1–5), may have development plans, but the north part, with hundreds of deerweed and a small patch of undisturbed coastal sage on the summit, is suitable for habitat enhancement and PVB reintroduction. The severe geomorphology of this old quarry site may make it dangerous or expensive for development, thus making an outright purchase or conservation easement a possibility.

4.2.2. South Slope

Because historic localities are known for the PVB on the south slope of the peninsula the best approach is to select historic sites where at least the microclimatic conditions are known to be favorable. The survey results confirm foodplant presence at the two historic PVB localities (Palos Verdes Drive East and Forrestal) where surveys were completed. In addition, the survey results show the presence of *Astragalus* in two polygons at the Rancho Palos Verdes City Hall (ID# 190–191), downslope from the historic locality at Hesse Park (Table 4).

Table 4. South slope polygons with *Astragalus trichopodus*.

ID#	Name	Native Species	Exotic Species	Native Index	*Astagalus trichopodus*
146	Palos Verdes Drive East 1	15	20	0.41	2
151	Palos Verdes Drive East 5	11	16	0.43	2
171	Forrestal 1	24	26	0.46	3
190	RPV City Hall 3	13	19	0.31	2
191	RPV City Hall 4	17	22	0.42	2

Success for reintroduction on the south slope is questionable over a long period because of difficulties in maintaining adequate *Astragalus* populations in the face of an unnatural disturbance regime. However, the best locations for such attempts are as follows:

1. Palos Verdes Drive East and Friendship Park. This area (ID# 140–152, 163) formerly supported the densest populations of PVB. *Astragalus* individuals persist in two of the polygons in this area (Table 3). Revegetation will require careful effort with comprehensive planning for the entire contiguous area. Disturbance should be kept to a minimum and special attention paid to soil conditions, including cryptobiotic crusts (see below).

2. Landslide Area. PVB were recorded historically at several localities within this area but we have no information on plant community detail other than superficial knowledge from other studies. There are no doubt many potential enhancement and reintroduction sites, but their identification will require more study. The large open space in this area is the only site where quasi-natural patch dynamics could be reestablished. From the limited polygon surveys completed in this area it is clear that this area would preserve the greatest number of plant species as well as small mammals that together certify greatest overall conservation success.[2]

3. Forrestal. This site (ID#171–178) supported a relatively dense PVB population historically and is in public ownership. With careful habitat enhancement, it would be a suitable reintroduction site. However, without proper control, recreation-associated disturbance poses a threat to the health of the habitat.

4. Agua Amarga Canyon. This historic locality (ID# 58–66) does not currently support *Astragalus*. Enhancement would require significant exotic species control and establishment of most coastal sage components. It will likely require more effort than for other areas on the south slope to succeed, but its location as the westernmost potential site makes it attractive for the long-term goal of spreading reestablished PVB populations across the historic range of the species.

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[2] Pitfall trapping for an insect survey for the City of Rancho Palos Verdes showed the presence of ornate shrews (*Sorex ornatus*) in upland coastal sage scrub and fennel(!) near Kelvin, Portuguese, and Klondike canyons across the landslide area.

There are other open spaces with potential for PVB reestablishment on the south slope of the peninsula. For example, *Astragalus* is present at RPV City Hall (Table 3), at Shoreline Park, and could be planted at White's Point (ID# 155). However, because there are no historical records of the PVB from the coastal bluff and areas adjacent thereto, initial reintroduction efforts should not be concentrated in these areas. The historic PVB distribution indeed may have reached to the bluff edge and such sites should still be considered potential habitat for long-term planning, but without historical records, limited resources should be directed to historic localities.

5. Habitat Enhancement and Creation

Two clearly different approaches to habitat enhancement and creation emerge from the ecological parameters presented by the PVB. First is to provide new populations of PVB with habitats in which success is virtually guaranteed but will require intensive continuing management. Second is to provide a buffered complex of community patches that will become self-perpetuating with diminishing management over time.

While the first approach may be necessary in the short term to lesson the risk of catastrophic loss at DFSP, the second approach should guide long-term planning. Therefore, enhancement and creation efforts require an integrated program designed to reestablish and support as many species as possible, especially the associated endemic and rare species inhabiting the Palos Verdes peninsula. Implementing programs not designed in this manner will affect listed species adversely as well as degrade the status of other endemic organisms of management concern. The most important requirements for recovery of these species is preventing activities that destroy or damage coastal sage scrub habitat on the Palos Verdes peninsula followed by control of invasive, exotic vegetation.

5.1. Revegetation

After target areas are selected, and removal of perennial non-native species completed, revegetation efforts will aim to establish a late successional coastal sage scrub community with a high density of *Artemisia californica* including dense *Astragalus* and, on the north slope, *Lotus* foodplant for the PVB. The emphasis should placed on a creating a biologically cohesive and functional plant community, based on a combination of historical distribution patterns for which there is some information and present assemblages comprising undisturbed habitat patches. Simply planting food and nectar plants will not be enough, nor will random combinations of a few native plants be sufficient in recreating a community with complex sets of interaction that satisfies all trophic levels.

From the field survey of the peninsula and historical data, we have assembled an extensive list of plant species targeted for revegetation. Revegetation efforts at DFSP have produced a considerable stock of locally collected native plants, common and rare, that provides the source for propagation at the peninsula. Both the plant density and species composition will be selected to create the most complete community structure at each patch undergoing revegetation. Special care will be given to the rarest species to increase their numbers and restore their occurrence in the coastal sage ecosystem. Irrigation will likely be needed to help in the initial establishment of newly planted seeds and transplanted shrub species. Irrigation efforts at DFSP have produced positive results for the establishment of native plants.

5.2. Control of Invasive Exotic Plants

Exotic species have had a long history in the coastal sage system and their eradication is not possible. The primary goal is to keep the abundance of these species at a low and manageable level while applying revegetation efforts, so that eventually, in critical butterfly habitats, the native species will be able to outcompete the exotic ones.

Disturbed areas with varying abundance of non-native species are widely distributed throughout the peninsula. Although the temptation is to use intrusive mechanical means for exotic removal (e.g., grading), other considerations suggest against such action. In a comparison of three coastal sage restoration attempts in southern California, two on the Palos Verdes peninsula, we found that disturbance history was the most likely determinant of terrestrial arthropod diversity in completed restorations (Longcore 1999). This result is confirmed by other research showing the decline of native arthropod communities in response to disturbance (Abensperg-Traun et al. 1996a; Abensperg-Traun et al. 1996b). Remnant populations of native arthropods persist under exotic-dominated plant communities. These populations are important to ecosystem function should be protected during the revegetation process by avoiding herbicides and mechanical disturbance beyond hand removal of exotic plants.

5.3. Soil Enhancement

Cryptogamic (or cryptobiotic) soil crusts composed of lichens, mosses, algae, fungi, and bacteria are common in arid and semiarid regions of the world (Belnap 1993; Lesica and Shelley 1996; St. Clair and Johansen 1993), including habitats as diverse as the high arctic (Gold 1998) and grassland (Hodgkins and Rogers 1997), but are not well studied in coastal sage scrub. Cryptobiotic crusts increase the ability of the soil to hold moisture and decrease erosion through the adhesive qualities of mucilaginous polysaccharides exuded by certain blue-green algae and fungi (Belnap and Gardner 1993). Crusts also increase essential mineral availability (N, P, K, Ca, Mg, Fe) and promote mychorrhizal associations (Harper and Pendleton 1993). These benefits are important in coastal sage scrub because the relatively shallower roots of the most the dominant coastal sage scrub species result in the plants having higher nutrient requirements and less control of water loss.

We have hypothesized elsewhere (Mattoni et al. 1997) that crusts play the role of "gatekeeper," allowing more germination of native species than exotic species. There is a strong correlation observed at DFSP between crust formation and native plant diversity. Areas without an intact layer of crust on top contain more invasive species and less native plant coverage. Once disturbed, crusts recover slowly, but inoculation methods are under development (Belnap 1993; Johansen et al. 1997).

Further research should be conducted on the role of crusts in coastal sage scrub vegetation dynamics and the possibility for crust inoculation. Immediate management actions should include identification of areas with intact crusts and protecting them from trampling and other unnecessary disturbance.

5.4. Patch Dynamics and Fire

Coastal sage scrub is adapted to regularly recurring fire (Mooney 1988). After fire, the community is dominated by a profusion of annual species (Keeley and Keeley 1984) that arise from a dormant seed pool that is stimulated by both smoke (Keeley and

Fotheringham 1997) and the physical conditions created by fire. The species composition varies in response to abiotic conditions created by the interactions of slope, topography, aspect, and the fire itself (O'Leary 1988). *Astragalus* is a fire-following herb; its seeds can remain viable in the soil for over 100 years (Mattoni 1994), and it has been observed sprouting following fires in areas on the Palos Verdes peninsula where it had not been observed before the fire (Brinkmann-Busi, pers. com.). A regular fire regime and the successional communities created by it were integral to the conditions under which the PVB thrived on the Palos Verdes peninsula. It is difficult to envision large-scale management actions that include such fire dynamics on the Palos Verdes peninsula due to the dense human populations and urban development that surround the open space. However, smaller scale options are available and should be investigated for their potential efficacy in maintaining habitat patches for the butterfly. For example, the use of a 2 x 2 m "fire box" has been pioneered for the reestablishment of populations of a rare *Amsinckia* with good success (Pavlik et al. 1993). Similar innovative approaches should be explored for the long-term management of PVB habitat areas.

6. Reintroduction Considerations

Experience from captive rearing efforts at DFSP and documented reintroduction projects provide guidance for planning this crucial stage of the conservation effort.

6.1. Reintroduction Methodology

Butterfly reintroductions have been undertaken with variable success using every stage of the life cycle as propagules. Adult relocation has been used with some success; a Finnish team relocated 10 Baton blue butterfly (*Pseudophilotes baton schiffermuelleri*) females to a restored site. After two years there was a population of fifty adults at the site (Marttila et al. 1997). However, short-term success can be misleading. Using relocated eggmasses as propagules, Williams (1995) reintroduced *Euphydryas gillettii* to eight mountain meadows. At one site, the larvae survived to produce larvae the following year. This population increased rapidly for two years then declined and disappeared. Reintroduction of two *Maculinea* butterflies in the Netherlands met with mixed success — one species expanded from the reintroduction site while the other persisted in small numbers (Wynhoff 1998). In Great Britain, repeated attempts to reestablish the large copper (*Lycaena dispar batavus*) have failed, due to overwintering mortality of the larvae (Webb and Pullin 1996). These experiences indicate that reintroduction is not simple, and that early success may be misleading.

The choice of life cycle stage for reintroduction of the PVB is an important one. Eggs are not practicable because the species does not lay eggs in masses. A decision to use adult females as propagules must weigh the effect on the donor population against the number needed for reintroduction. The PVB population is not sufficiently robust to donate the number of females necessary to provide a reasonable chance at reintroduction success. The method that produces the maximum number of propagules with the smallest effect on the donor population is to collect a small number of females, allow them to oviposit, and rear the next generation in the laboratory. By eliminating predation and parasitism, many more pupae can be produced from a small number of females.

Captive reared butterflies can be released either as pupae or adults. Because we know little about the mechanisms by which the species orients itself in its habitat, we strongly support "seeding" pupae into the reintroduction site by placing them in the duff under foodplants approximately one week before the presumed start of the flight season. In this manner, the emerging adults first orient themselves to the new habitat and may be more likely to stay.

6.2. Captive Rearing

A captive rearing program has been in place at DFSP to investigate and perfect captive breeding and rearing techniques for the potential future reintroduction of the species at other localities. The 1999 season has represented the most intensive effort to date and has produced a stock of ~600 pupae. This result compares favorably to 33 Karner blue (*Lycaeides melissa samuelis*) pupae reared from 20 females for a reintroduction project in Michigan (Herms et al. 1996).

Wild-caught females were found to oviposit best on whole, potted deerweed, enclosed by a cylindrical screen. Best results with the larvae were obtained when the first two instars were allowed to eat the plant upon which they were laid as eggs. Third instar larvae were then transferred to individual creamer cups where they were fed fresh deerweed daily until pupation. The creamer cups were kept in boxes with loosely fitting lids and damp paper towels to keep humidity high and prolong the freshness of the foodplant. Captive rearing requires a large commitment of personnel hours, with full-time, daily attention required for up to four months to rear successfully a generation of larvae from eggs to pupae. With sufficient financial resources, our team working at DFSP can produce adequate pupae for future reintroduction efforts.

7. The Bottom Line: Time Frames and Projections

Successful habitat enhancement and creation followed by reintroduction of the PVB with long-term success depends on the availability of funding and the application of proper scientific oversight to implement an appropriate program. The current study has identified suitable sites for the development of a detailed recovery plan. Once sites are selected and permission granted for habitat enhancement, complete establishment of the primary plant community could take up to five years, with ten years required to ascertain if reintroduction has been successful.

Such an effort will require significant financial resources both to acquire land either through fee ownership or conservation easement and to implement the enhancement and reintroduction program. This effort should build on the two interrelated programs already in place.

7.1. Programs in Place

7.1.1. Defense Fuel Support Point, San Pedro

A program to enhance and augment existing habitat at DFSP was started immediately following the rediscovery of the species in 1994. This effort, directed by Mattoni and administered through UCLA, has achieved considerable success and positive public attention through its community-based approach and noteworthy participants (Brosseau 1997; Cone 1994; Dworetzky 1997; Gross 1997; Isbell 1996; Slater 1996). Despite a substantial increase in the amount of foodplant available and an overall increase in coastal sage scrub habitat, there has been no significant trend in the yearly estimate of PVB population. As discussed above, density-independent factors beyond the control of management, i.e. weather, explain the large yearly population fluctuations. The

PVB population is still imperiled, and efforts continue to increase several habitat patch sizes without impacting pristine areas. A captive population has been established at DFSP and captive mating and rearing techniques investigated and refined. There is currently a substantial stock of pupae from wild-caught females ready for release at the Chandler Preserve when habitat and permit conditions are met.

7.1.2. Linden H. Chandler Preserve

Enhancement of this preserve, owned by the Palos Verdes Peninsula Land Conservancy, is underway. Additional funding specifically earmarked for PVB habitat enhancement and introduction was recently granted from Proposition A (1996) monies through the Los Angeles County Regional Park and Open Space District. Depending on the success of plantings in 1999 and the acquisition of the proper permits, introduction could be attempted as soon as the 2000 flight season. The efforts at DFSP and Chandler Preserve are integrated and share both staff and management. This allows a "critical mass" of experience with the butterfly and habitat enhancement at all levels (nursery propagation, site preparation, captive rearing, monitoring, etc.) to be applied to both projects.

7.2. Work Plan for Habitat Enhancement

A conceptual work plan for habitat enhancement for reintroduction sites is as follows:

Phase 1. The first phase consists the first two years after approval. Actions include the first plantings of food and nectar plants at five selected sites. Tentative success criteria for this phase are the density and distribution of the foodplants. For foodplants, north slope sites should include *Astragalus trichopodus* and *Lotus scoparius*, while south slope sites should include only *Astragalus trichopodus*. Other native species will be selected based on slope, aspect, and topography from the list of native species historically present on the peninsula (Appendix).

Phase 2. The second phase extends from year three to year six and includes more intensive efforts to establish site specific rare plants on the selected sites. Success criteria include the density and distribution of rare plants, as their biological and ecological status will provide an indicator for the overall integrity of the enhanced ecosystem. The specific target criteria of success will be recruitment of food and nectar plants from the initial outplantings. Successful recruitment of *Astragalus* is crucial to the outcome of habitat enhancement. At DFSP, plantings of *Astragalus* have thrived for two to three years then died, without recruitment. Until *Astragalus* populations can be shown to be self-sustaining, reintroduction of the PVB on the south slope will be futile.

Phase 3. The last phase has no definitive time limit. The success criteria for the long term, beyond year seven, will be the maintenance of a complex community dominated by native species, with successional diversity occurring on a small scale, dictated by patch dynamics within a series of variably composed coastal sage scrub patches and grassland patches. Potential small-scale fire manipulations may play a role in maintaining habitat patches. A key requirement of the plan is establishment of a permanent review committee of credible biologists and stakeholders to provide an annual evaluation.

An adaptive and responsible ecosystem management plan should recognize that flexibility and acknowledgement of uncertainty must be incorporated to meet the unpredictable demands of a dynamic natural system. Management objectives and actions will likely change with increased knowledge of the ecology and biology of the butterfly and its coastal sage scrub-grassland patch habitat. Predicted secular climate change will impose further problems.

Habitat enhancement and reintroduction of the Palos Verdes blue butterfly is feasible, but will require carefully directed management of a scientifically credible program and sufficient financial support to undertake concomitant research and experimentation to inform management efforts. This report has provided prioritized lists of likely sites for enhancement and reintroduction along with the best available information on the species and the issues that must be considered to develop a successful conservation strategy. In the effort to preserve species and their habitats, second chances like this one are rare. It should not be missed.

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10. Appendix: Native Plants Recorded on the Palos Verdes Peninsula

FERNS	
POLYPODIACEAE	**POLYPODY FAMILY**
Polypodium californicum Kaulf.	CALIFORNIA POLYPODY
PTERIDACEAE	**BRAKE FAMILY**
Adiantum jordanii C. Mueller	CALIFORNIA MAIDEN-HAIR
Pellea andromedifolia (Kaulf.) Fée	COFFEE FERN
Pentagramma triangularis (Kaulf.) G. Yatskievych, M.D. Windaham & E. Wollenweber	SILVERBACK FERN
DRYOPTERIDAECEAE	**WOOD FERN FAMILY**
Dryopteris arguta (Kaulf.) Maxon	WOOD FERN
ANGIOSPERMS: DICOTS	
AIZOACEAE	**FIG-MARIGOLD FAMILY**
Sesuvium verrucosum Raf.	
ANACARDIACEAE	**SUMAC FAMILY**
Malosma laurina (Nutt.) Abrams	LAUREL SUMAC
Rhus integrifolia (Nutt.) Brewer & S. Watson	LEMONADEBERRY
Rhus ovata S. Watson	SUGAR BUSH
Toxicodendron diversilobum (Torrey & A. Gray) E. Greene	WESTERN POISON OAK
APIACEAE	**CARROT FAMILY**
Apiastrum angustifolium Nutt.	WILD CELERY
Daucus pusillus Michaux	RATTLESNAKE WEED
Sanicula arguta J. Coulter & Rose	
Sanicula crassicaulis DC.	
ASCLEPIADACEAE	**MILKWEED FAMILY**
Asclepias fascicularis Decne.	NARROW-LEAF MILKWEED
Asclepias eriocarpa Benth.	INDIAN MILKWEED
ASTERACEAE	**SUNFLOWER FAMILY**
Acourtia microcephala DC. [=*Perezia m.*]	
Amblyopappus pusillus Hook. & Arn.	
Ambrosia acanthicarpa Hook.	ANNUAL BUR-SAGE
Ambrosia chamissonis (Less.) E. Greene	BEACH-BUR
Ambrosia psilostachya DC.	WESTERN RAGWEED
Artemisia californica Less.	CALIFORNIA SAGEBRUSH
Artemisia douglasiana Besser	MUGWORT
Artemisia dracunculus L.	TARRAGON
Aster subulatus Michaux var. *ligulatus* Shinn. [=*A. exilis*]	
Baccharis emoryi A. Gray	
Baccharis pilularis DC. [= var. *consanguineae*]	COYOTE BRUSH
Baccharis salicifolia (Ruíz Lopez & Pavón) Pers.	MULE FAT
Brickellia californica (Torrey & A. Gray) A. Gray	BRICKELLBUSH
Chaenactis glabriuscula DC.	YELLOW PINCUSHION
Conyza canadensis (L.) Cronq.	HORSEWEED
Eclipta prostrata (L.) L. [=E. *alba*]	

Encelia californica Nutt.	CALIFORNIA SUNFLOWER
Ericameria ericoides (Less.) Jepson [=*Haplopappus e.*]	
Ericameria palmeri (A. Gray) H.M. Hall [=*Haplopappus p.*]	
Erigeron foliosus Nutt.	FLEABANE DAISY
Eriophyllum confertiflorum (DC.) A. Gray	GOLDEN-YARROW
Filago californica Nutt.	HERBA IMPIA
Gnaphalium bicolor Bioletti	TWO-TONE EVERLASTING
Gnaphalium californicum DC.	CALIFORNIA EVERLASTING
Gnaphalium canescens DC. ssp. *beneolens* (Davidson) Stebb. & Keil	
Gnaphalium canescens DC. ssp. *microcephalum* (Nutt.) Stebb. &Keil	
Gnaphalium ramosissimum DC.	
Grindelia camporum E. Greene var *bracteosum* (J. Howell) M.A. Lane [= *G. robusta*]	GUMPLANT
Gutierrezia californica (DC.) Torrey & A. Gray	MATCHWEED
Hazardia squarrosus (Hook. & Arn.) E. Greene	SAW-TOOTHED GOLDENBUSH
Helianthus annuus L.	SUNFLOWER
Hemizonia fasciculata (DC.) Torry & A. Gray	TARWEED
Hemizonia parryi E. Greene ssp. *australis* Keck	
Heterotheca grandiflora Nutt.	TELEGRAPH WEED
Heterotheca sessiflora (Nutt.) Shinn.	
Isocoma menziesii (Hook. & Arn.) G. Nesom var. *mensiezii* [=*Haplopappus venetus* ssp. *oxyphyllus*]	COAST GOLDENBUSH
Lasthenia californica Lindley	GOLDFIELDS
Lessingia filaginifolia (Hook. & Arn.) M.A. Lane	CALIFORNIA-ASTER
Malacothrix coulteri A. Gray	SNAKE'S-HEAD
Malacothrix saxatilis (Nutt.) Torrey & A. Gray	CLIFFASTER
Pentachaeta lyonii A. Gray	LYON'S PENTACHAETA
Pluchea odorata (L.) Cass. [=*P. purpurascens*]	SALT MARSH FLEABANE
Rafinesquia californica Nutt.	CALIFORNIA CHICORY
Senecio californicus DC.	
Stephanomeria virgata Benth.	WAND CHICORY
Uropappus lindleyi (DC.) Nutt. [=*Microseris linearifolia*]	SILVER PUFFS
Xanthium strumarium L.	COCKLEBUR
BOROGINACEAE	
Amsinckia menziesii (Lehm.) Nelson & J.F. Macbr. var. *intermedia* (Fischer & C. Meyer) Ganders	RANCHER'S FIREWEED
Cryptantha clevelandii E. Greene	
? *Cryptantha flaccida* (Lehm.) E. Greene	
Heliotropium curassavicum L.	HELIOTROPE
BRASSICACIAE	
Descurainia pinnata (Walter) Britton	TANSY MUSTARD
Erysimum capitatum (Douglas) E. Greene [=*E. suffrutescens*]	WESTERN WALLFLOWER
Guillenia lasiophylla (Hook. & Arn.) E. Greene [=*Caulanthus l.*]	CALIFORNIA MUSTARD

Lepidium nitidum Torrey & A. Gray	PEPPERGRASS
Rorippa palustris (L.) Besser	WATER CRESS
CACTACEAE	**CACTUS FAMILY**
Opuntia littoralis (Engelm.) Cockerell	PRICKLY PEAR
Opuntia oricola Philbr.	
Opuntia prolifera Engelm.	CHOLLA
CAPPARACEAE	**CAPER FAMILY**
Isomeris arborea Nutt. [=*Cleome isomeris*]	BLADDERPOD
CAPRIFOLIACEAE	**HONEYSUCKLE FAMILY**
Lonicera subspicata Hook. & Arn.	HONEYSUCKLE
Sambucus mexicana C. Presl	BLUE ELDERBERRY
Symphoricarpus mollis Nutt.	CREEPING SNOWBERRY
CARYOPHYLLACEAE	**PINK FAMILY**
Spergularia marina Griseb.	SAND-SPURREY
CHENOPODIACEAE	**GOOSEFOOT FAMILY**
Aphanisma blitoides Moq.	APHINASMA
Atriplex californica Moq.	SALTBUSH
Atriplex lentiformis (Torrey) S. Watson ssp. *lentiformis* [=var. *breweri*]	BIG SALTBUSH
Atriplex pacifica Nelson	SOUTH COAST SALTBUSH
Chenopodium californicum (S. Watson) S. Watson	PIGWEED
? *Chenopodium leptophyllum* Moq.	
Salicornia subterminalis Parish	PICKLEWEED
Suaeda taxifolia (Standley) Standley	WOOLLY SEA-BLITE
CONVOLVULACEAE	**MORNING-GLORY FAMILY**
Calystegia macrostegia (E. Greene) Brummitt	
Calystegia piersonii (Abrams) Brummitt	PIERSON'S MORNING-GLORY
Convoluvulus simulans Perry	
Cressa truxillensis Kunth	ALKALI WEED
Dichondra occidentalis House	WESTERN DICHONDRA
CRASSULACEAE	**STONECROP FAMILY**
Crassula connata (Ruíz Lopez & Pavón) A. Berger	PYGMY PLANT
Dudleya lanceolata (Nutt.) Britton & Rose	
Dudleya virens (Rose) Moran	BRIGHT GREEN DUDLEYA
CROSSOSOMATACEAE	
Crossosoma californicum Nutt.	CATALINA CROSSOSOMA
CUCURBITACEAE	**GOURD FAMILY**
Cucurbita foetidissima Kunth	CALABAZILLA
Marah macrocarpus (E. Greene) E. Greene	WILD CUCUMBER
CUSCUTACEAE	**DODDER FAMILY**
Cuscuta californica Hook. & Arn.	
Cuscuta pentagona Engelm. [=*C. capmestris*]	
EUPHORBIACEAE	**SPURGE FAMILY**
Chamaesyce albomarginata (Torrey & A. Gray) Small	RATTLESNAKE WEED
Chamaesyce polycarpa (Denth.) Millsp.	
Croton californicus Muell. Arg.	CALIFORNIA CROTON
Eremocarpus setigerus (Hook.) Benth.	TURKEY MULLEIN
Euphorbia crenulata Engelm.	CHINESE CAPS

FABACEAE	**LEGUME FAMILY**
Astagalus trichopodus (Nutt.) A. Gray var. *lonchus* (M.E. Jones) Barneby	RATTLEPOD
Lathyrus vestitus Nutt. var. *vestitus*	WILD PEA
? *Lathyrus vestitus* Nutt. var. *alefeldii* (T. White) Isely	
? *Lotus heermannii* (Durand & Hilg.) E. Greene	
Lotus purshianus (Benth.) Clements & E.G. Clements	
Lotus salsuginosus E. Greene	
Lotus scoparius (Nutt.) Ottley	DEERWEED
Lotus strigosus (Nutt.) E. Greene	
Lupinus bicolor Lindley	MINATURE LUPINE
? Lupinus chamissonis Eschsch	DUNES LUPINE
Lupinus longifolius (S. Watson) Abrams	
Lupinus succulentus Koch	ARROYO LUPINE
Lupinus truncatus Hook. & Arn.	
Trifolium wildenovii Sprengel [=T. *tridentatum*]	TOMCAT CLOVER
FRANKENIACEAE	**FRANKENIA FAMILY**
Frankenia salina (Molina) I.M. Johnston	ALKALI HEATH
GERANIACEAE	**GERANIUM FAMILY**
Geranium carolinianum L.	
GROSSULARIACEAE	**GOOSEBERRY FAMILY**
Ribes californicum Hook. & Arn.	HILLSIDE GOOSEBERRY
HYDROPHYLLACEAE	**WATERLEAF FAMILY**
Emmenanthe penduliflora Benth.	WHISPERING BELLS
Eucrypta chrysanthemifolium (Benth.) E. Greene	
? Nemophila menziesii Hook. & Arn.	BABY BLUE-EYES
Phacelia cicutaria E. Greene	CATERPILLAR PHACELIA
Phacelia ramosissima Lehm.	
Phacelia viscida (Benth.) Torrey	STICKY PHACELIA
Pholistoma auritum (Lindley) Lilja	
Pholistoma racemosum (Nutt.) Constance	WHITE FIESTA FLOWER
LAMIACEAE	**MINT FAMILY**
Salvia columbariae Benth.	CHIA
Salvia leucophylla E. Greene	PURPLE SAGE
Salvia mellifera E. Greene	BLACK SAGE
Stachys ajogoides Benth. ssp. *rigida* Jepson & Hoover	HEDGE NETTLE
Trichostema lanceolatum Benth.	VINEGAR WEED
LOASACEAE	**LOASA FAMILY**
Mentzelia affinis E. Greene	BLAZING STAR
Mentzelia micrantha (Hook. & Arn.) Torrey & A. Gray	
LYTHRACEAE	**LOOSESTRIFE FAMILY**
Ammannia coccinea Rottb.	
NYCTAGINACEAE	**FOUR O'CLOCK FAMILY**
Mirabilis californica A. Gray	FOUR O'CLOCK
ONAGRACEAE	**EVENING PRIMROSE FAMILY**
Camissonia bistorta (Torrey & A. Gray) Raven	CALIFORNIA SUN CUP

Camissonia cheiranthifolia (Sprengel) Raim	BEACH EVENING PRIMROSE
Camissonia micrantha (Sprengel) Raven	
Clarkia purpurea (Curtis) Nelson & J.F. Macbr.	PURPLE CLARKIA
Epilobium canum (E. Greene) Raven	ZAUSCHNERIA
Epilobium ciliatum Raf. [=*E. adenocaulon*]	
Ludwigia peploides (Kunth) Raven	FALSE LOOSESTRIFE
OROBANCHACEAE	**BROOM-RAPE FAMILY**
Orobanche californica Cham. & Schldl.	BROOM-RAPE
PAPAVERACEAE	**POPPY FAMILY**
Eschscholzia californica Cham.	CALIFORNIA POPPY
Platystemon californicus Benth.	CREAM CUPS
PLANTAGINACEAE	**PLANTAIN FAMILY**
Plantago erecta E. Morris	MINIATURE PLANTAIN
Plantago ovata Forsskal [=*P. insularis*]	
POLEMONIACEAE	**PHLOX FAMILY**
Gilia angelensis V. Grant	ANGEL’S GILIA
Gilia capitata Sims	GLOBE GILIA
? *Linanthus dianthiflorus* (Benth.) E. Greene	LINANTHUS
POLYGONACEAE	**BUCKWHEAT FAMILY**
Eriogonum cinereum Benth.	ASHY-LEAF BUCKWHEAT
Eriogonum elongatum Benth.	WAND BUCKWHEAT
Eriogonum fasciculatum (Benth.) Torrey & A. Gray var. *fasciculatum*	CALIFORNIA BUCKWHEAT
Eriogonum gracile Benth.	
Eriogonum parvifolium Smith	COAST BUCKWHEAT
Polygonum hydropiperoides Michaux	WATERPEPPER
Polygonum lapathifolium L.	WILLOW WEED
Polygonum puctatum Elliott	
Pterostegia drymarioides Fischer & C. Meyer	THREAD STEM
Rumex hymenosepalus Torrey	WILD-RHUBARB
Rumex salicifolius J.A. Weinm.	WILLOW DOCK
PORTULACACEAE	**PURSLANE FAMILY**
Calandrinia ciliata (Ruíz Lopez & Pavón) DC.	RED MAIDS
Calandrinia maritima Nutt.	SEASIDE CALANDRINIA
Claytonia perfoliata Willd.	MINER’S LETTUCE
RANUNCULACEAE	**BUTTERCUP FAMILY**
Clematis ligusticifolia Nutt.	VIRGIN’S BOWER
Delphinium parryi A. Gray	LARKSPUR
Ranunculus californicus Benth.	CALIFORNIA BUTTERCUP
RESEDACEAE	**MIGNONETTE FAMILY**
Oligomeris linifolia (M. Vahl) J.F. Macb.	
ROSACEAE	**ROSE FAMILY**
Heteromeles arbutifolia (Lindley) Roemer	TOYON
Horkelia cuneata Lindley ssp. between *cuneata* and *puberla* (E. Greene) Keck	
Horkeliea cuneata Lindley ssp. between *cuneata* and *sericea* (A. Gray) Keck	
Prunus ilicifolia (Nutt.) Walp. ssp. *ilicifolia*	HOLLY-LEAFED CHERRY
Prunus ilicifolia ssp. *lyonii* (Eastw.) Raven	CATALINA CHERRY

Rosa californica Cham. & Schldl.	CALIFORNIA ROSE
Rubus ursinus Cham. & Schldl.	CALIFORNIA BLACKBERRY
RUBIACEAE	**MADDER FAMILY**
Galium angustifolium Nutt.	NARROW-LEAVED BEDSTRAW
SALICACEAE	**WILLOW FAMILY**
Salix exigua Nutt.	NARROW-LEAVED WILLOW
Salix goodingii C. Ball	GOODDING'S BLACK WILLOW
Salix laevigata Bebb	RED WILLOW
Salix lasiolepis Benth.	ARROYO WILLOW
SCROPHULARIACEAE	**FIGWORT FAMILY**
Antirrhinum coulterianum Benth.	
Antirrhinum kelloggii E. Greene	KELLOGG'S SNAPDRAGON
Antirrhinum nuttallianum Benth.	PURPLE SNAPDRAGON
Castilleja affinis Hook. & Arn.	INDIAN PAINTBRUSH
Castilleja exserta (A.A. Heller) Chuang & Heckard [=*Orthocarpus purpurascens*]	PURPLE OWL'S-CLOVER
Collinsia heterophylla Graham	CHINESE HOUSES
Keckiella cordifolia (Benth.) Straw	CLIMBING PENSTEMON
Linaria canadensis (L.) Dum.-Cours.	BLUE TOADFLAX
Mimulus aurantiacus Curtis [=*M. longiflorus*]	BUSH MONKEY FLOWER
SOLANACEAE	**NIGHTSHADE FAMILY**
Datura wrightii Regel	JIMSON WEED
Lycium brevipes Benth. var. *hassei* (E. Greene) C. Hitchc.	SANTA CATALINA ISLAND DESERT-THORN
Lycium californicum Nutt.	BOX THORN
Solanum douglasii Dunal	NIGHTSHADE
URTICACEAE	**NETTLE FAMILY**
Parietaria hespera B.D. Hinton	PELLITORY
Urtica dioica L. ssp. *holosericea* (Nutt.) Thorne	HOARY NETTLE
VERBENACEAE	**VERVAIN FAMILY**
Verbena lasiostachys Link	
VIOLACEAE	**VIOLET FAMILY**
Viola pedunculata Torrey & A. Gray	JOHNNY-JUMP-UP

ANGIOSPERMS: MONOCOTS

ALISMATACEAE	**WATER-PLANTAIN FAMILY**
Sagittaria montevidensis Cham. & Schldl. spp. *calycina* (Engelm.) C. Bogin	ARROWHEAD
CYPERACEAE	**SEDGE FAMILY**
Eleocharis macrostachya Britton	SPIKERUSH
Eleocharis parvula (Roemer & Schultes) Link [= var. *coloradoensis*]	SMALL SPIKERUSH
Scirpus californicus (C. Meyer) Steudel	
Scirpus robustus Pursh	
JUNCACEAE	**RUSH FAMILY**
Juncus bufonis L.	TOAD RUSH
LEMNACEAE	**DUCKWEED FAMILY**
Lemna minor L.	DUCKWEED

LILIACEAE	**LILY FAMILY**
Bloomeria crocea (Torrey) Cov.	GOLDENSTAR
? *Brodiaea coronaria* (Salisb.) Engl.	
Brodiaea jolonensis Eastw.	
Calochortus catalinae S. Watson	CATALINA MARIPOSA LILY
Dichelostemma capitatum (Benth.) A.W. Wood	BLUE DICKS
POACEAE	**GRASS FAMILY**
Bromus carinatus Hook. & Arn.	CALIFORNIA BROME
Distichlis spicata (L.) E. Greene	SALTGRASS
Hordeum jubatum L.	FOXTAIL BARLEY
Leptochloa uninerva (C. Presl) A. Hitchc. & Chase	MEXICAN SPRANGLETOP
Leymus condensatus (C. Presl) A. Löve [=*Elymus c.*]	GIANT RYE
Melica imperfecta Trin.	MELIC
Muhlenbergia microsperma (DC.) Trin.	LITTLESEED MUHLY
Nassella cernua (Stebb. & Löve) Barkworth [=*Stipa c.*]	NODDING NEEDLEGRASS
Nassella lepida (A. Hitchc.) Barkworth [=*Stipa l.*]	FOOTHILL NEEDLEGRASS
Nassella pulchra (A. Hitchc.) Barkworth [=*Stipa p.*]	PURPLE NEEDLEGRASS
Panicum sp.	MILLET
Paspalum distichum L.	
Poa secunda J.S. Presl ssp. *secunda*	ONE-SIDED BLUGRASS
Vulpia microstachys (Nutt.) Munro	
TYPHACEAE	**CATTAIL FAMILY**
Typha domingensis Pers.	SOUTHERN CATTAIL
? *Typha latifolia* L.	BROAD-LEAVED CATTAIL