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FINAL REPORT FOR 2006 PALOS VERDES BLUE BUTTERFLY ADULT SURVEYS ON DEFENSE FUEL SUPPORT POINT SAN PEDRO, CALIFORNIA

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FINAL REPORT
FOR
2006 PALOS VERDES BLUE BUTTERFLY ADULT SURVEYS
ON
DEFENSE FUEL SUPPORT POINT
SAN PEDRO, CALIFORNIA

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1. Introduction

A program to monitor the distribution and abundance of the endangered Palos Verdes blue butterfly was initiated immediately following its discovery at the Defense Fuel Support Point (DFSP) in 1994 (Mattoni 1994). The first half of this report addresses the results of surveys along a standard transect for the species that has been completed every year since 1994. The second half of this report describes a sampling scheme for presence of Palos Verdes blue butterfly and its larval hosts across the entire installation.

2. Standard Transect Results

In 1994, Mattoni established a transect at that time that included the obvious larger stands of larval foodplant at DFSP (Mattoni 1994). This standard transect was subsequently extended several times in following years to include areas where butterflies were later found (Mattoni and Longcore 2002). The 13 years of annual counts provide data to assess trends in the butterfly's patterns of distribution and abundance. Below we present results of surveys from 1994 to 2006 and include an estimate of the adult population using a standardized algorithm developed for this purpose. Furthermore, we analyze the trends in occupancy within the habitats that the different segments of the transect traverse. Finally, we update a population viability analysis for the species at DFSP using parameters derived from the transect count.

2.1. Methods

Our technician (Rick Rogers) counted butterflies on Pollard transect walks throughout the flight period of the butterfly (Pollard 1977, Pollard and Yates 1983). For purposes of population estimation, regular walks along a standard transect have been shown to be superior to the other survey methods that also do not involve handling butterfly individuals (Royer et al. 1998). Mark-recapture methods of population estimation are not completed on this endangered species because of the damage done to small butterflies by marking and handling (Singer and Wedlake 1981, Morton 1982). Walks were initiated at the first sighting of Palos Verdes blue butterflies in the spring.

The transect is ~3.2 km long (Figure 1), which is divided into segments based on habitat characteristics. The transect remains the same as instituted in 1994, with segments 5-3 and 9 added in 1996, segment 10 added in 1997, segment 11 added in 1999, and segment 5-4 added in 2005. The transect included all areas where Palos Verdes blue butterfly had been observed and along corridors between habitat patches. We have learned this year that additional areas are occupied by the butterfly but not included on the transect.

We estimate total adult population size (N_t) with the formula

$$N_t = \sum_{i=1}^{n} \frac{x_i d_i}{LSR}$$

where N_t is total population size, n is number days of observations, x_i is the number of individuals on the ith day of observation, d_i is the number of days from the ith survey to the ith + 1 survey, L is the average lifespan of each individual (9.3 days), R is the average sex ratio observed (70%), and S is the assumed search efficiency (40%) (Mattoni et al. 2001). This technique is a modification of the estimate of brood size proposed by Watt et al. (1977).

We also used the free software INCA (INsect Count Analyzer) to analyze the count data for 1994 through 2006 (Zonneveld 1991, Longcore et al. 2003a). For some years solutions failed to converge with the data alone, so we provided prior information about the flight period by constraining the distribution of the death rate based on results from previous years.

Butterfly abundance varies widely with environmental conditions, most notably weather (Pollard 1988). Large increases and decreases in population are therefore expected and make the detection of trends difficult. The geographic area occupied by a species makes a somewhat greater predictor of population stability and, indeed, occupancy forms the basis of mathematical models of persistence of butterflies in metapopulations (Hanski 1999). Establishing occupancy is confounded by butterfly abundance. During a year when butterflies are not common, no butterflies may be seen at a site because of rarity, not because the butterfly has become extinct. With constant effort, detection of occupancy increases with population size (Zonneveld et al. 2003).

We tested for trends in occupancy of Palos Verdes blue butterfly by constructing a multiple logistic regression, in which: (1) the independent continuous variables were year and estimated population size and (2) the dependent categorical variable was presence or absence of butterflies along each transect segment. While the dependent variable may exhibit some degree of spatial autocorrelation, the well-documented asynchronous fluctuation of abundance among transect segments suggests that these responses are statistically independent (Mattoni and Longcore 2002). To identify the geographic distribution of trends in occupancy, we then completed logistic regressions for each transect segment with year as the independent variable and butterfly presence as the dependent variable.

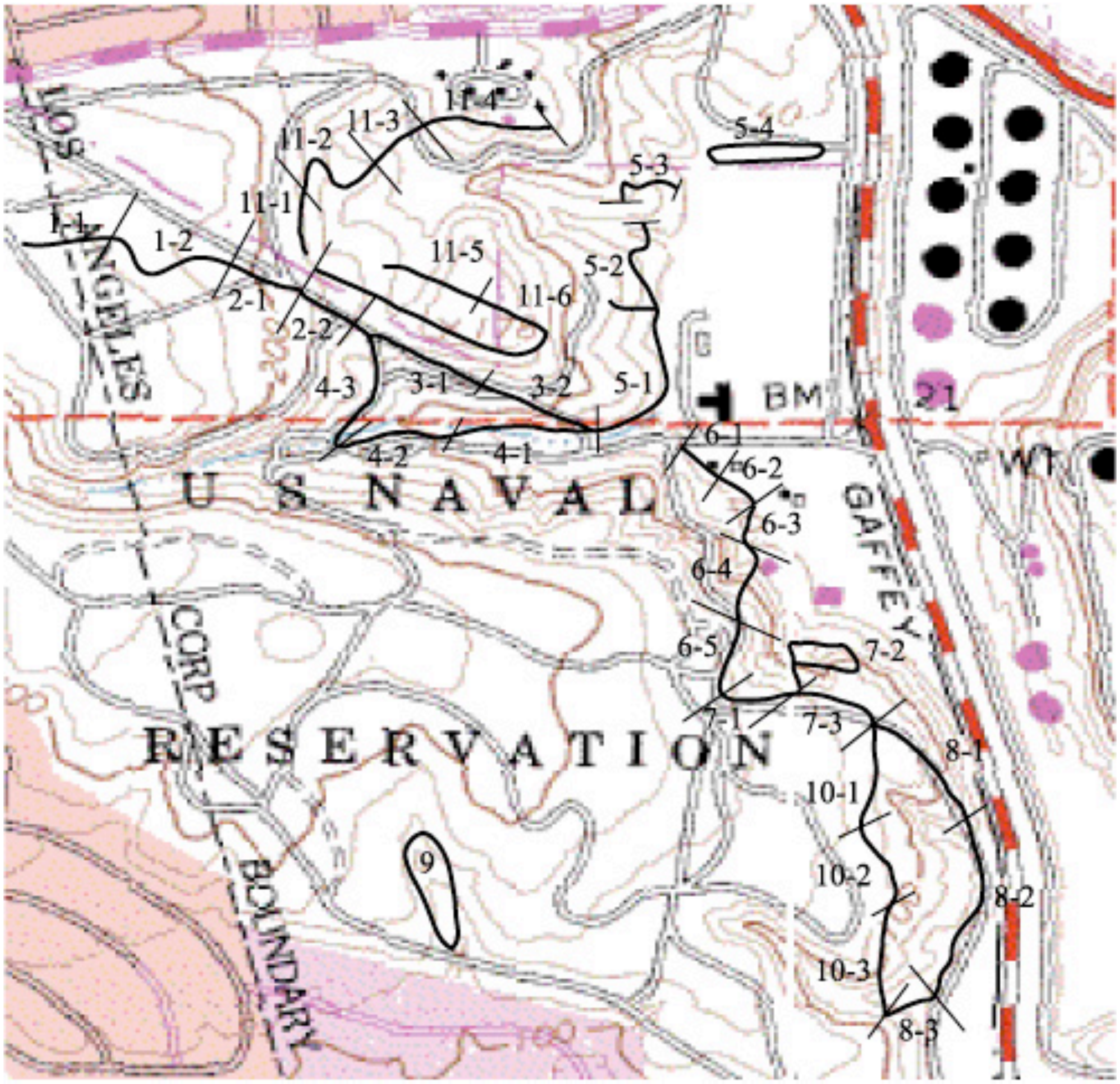


Figure 1. Location of Palos Verdes blue butterfly transect at DFSP (segments 1–10) and Palos Verdes housing (segment 11).

Finally, we implemented a population viability analysis for Palos Verdes blue butterfly at DFSP (Morris et al. 1999). This method uses the total population size each year to calculate the average growth rate (λ) and its variance (σ^2), and assumes that surveys of the species have recorded the normal variability in population growth rates that can be exhibited by the population. The method then uses a diffusion approximation (Dennis et al. 1991) to estimate the probability of extinction under user-designated conditions (i.e., initial population size and extinction threshold).

We used the total population size for each year as estimated from transect surveys for 1994–2005. Because the species may undergo multiple year diapause, we set the extinction threshold at 1. Even if population size in any given year is extremely low, pupae remain in the ground that have not eclosed and can "rescue" the population during the next year. This was illustrated by the dramatic rebound in population in 2004, following an all-time low of 30 adult butterflies in 2003.

Table 1. Abundance and phenology of Palos Verdes blue butterfly at DFSP and Palos Verdes housing, 1994–2006.

Year	*First Observed*	*Last Observed*	*Flight Period (days)*	*Daily Maximum*	*Estimated Population*
1994	March 12	April 8	30	14	69
1995	February 28	March 26	27	29	105
1996	March 1	May 5	67	30	247
1997	February 23	April 7	50	12	109
1998	February 28	April 8	50	23	199
1999	February 24	May 4	77	14	209
2000	March 13	April 26	45	25	132
2001	March 12	April 27	46	13	139
2002	February 21	April 19	47	22	215
2003	February 21	March 28	35	3	30
2004*	March 6	April 14	39	43	282
2005	February 28	April 5	36	31	204
2006	February 23	April 30	73	13	219

*Transect followed from map by two observers working together (G. Pratt/C. Pierce). All other transects by R. Mattoni (2003) or R. Rogers (1994–2002, 2005).

3. Results

3.1. Transect Counts and Abundance

The 2006 population estimate was is the upper half of years although about 25% less than the banner year of 2004 (Table 1). Flight period (i.e., the number of days between the first and last observation) continues to be predicted by estimated population size (r^2=0.27, $F_{1,11}$=4.26, P=0.06). For every additional 100 butterflies estimated in the population, the flight season seems a little over a week longer.

During 13 years of monitoring, the estimated population of Palos Verdes blue butterfly has fluctuated without a discernable trend (Figure 2). No trend is evident based on overall abundance alone. Similar results are obtained with the Zonneveld method (Figure 3), which shows the population fluctuating without a statistically significant trend.

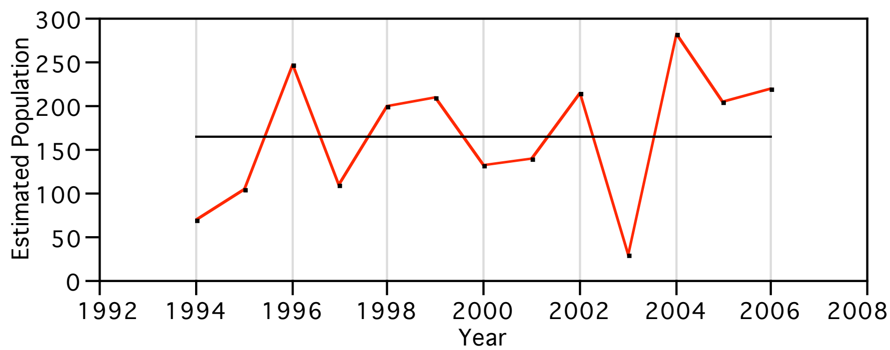


Figure 2. Estimated population of Palos Verdes blue butterfly at DFSP, 1993–2006. The horizontal line indicates the 13-year mean annual population.

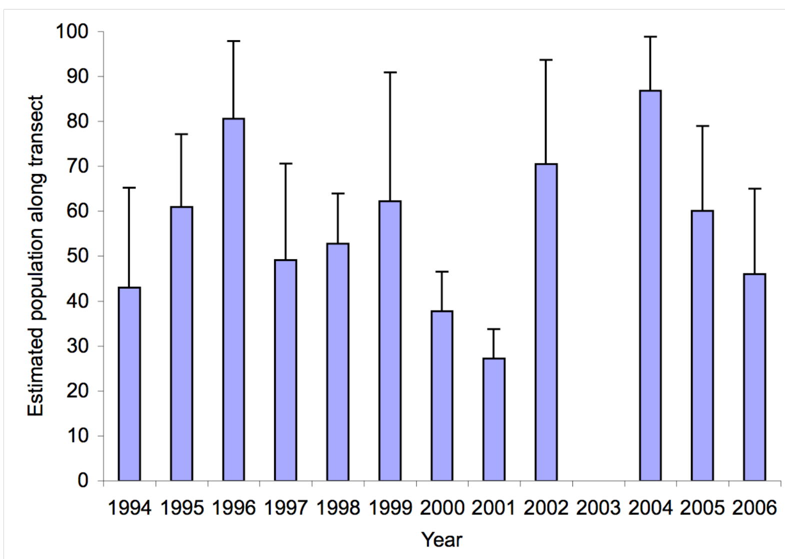
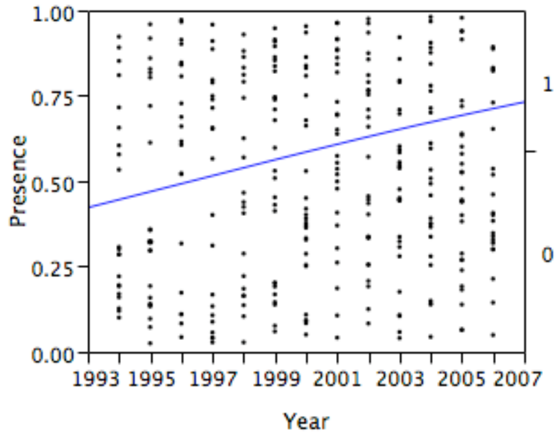
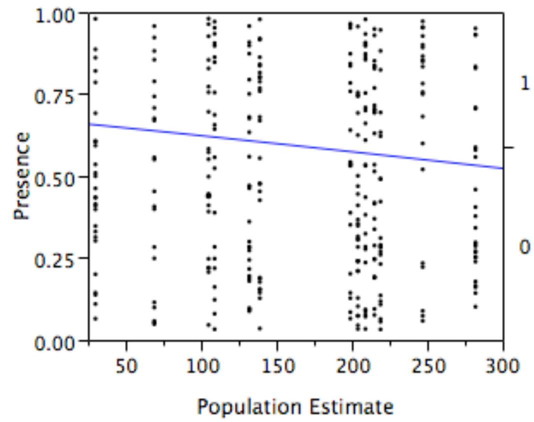


Figure 3. Estimated population of Palos Verdes blue butterfly at DFSP, 1993–2006, calculated by Zonneveld method from transect counts. This index is not adjusted for sex ratio or search efficiency. Error bars + 1 S.D. Too few butterflies were observed in 2003 to produce an estimate.



a)



b)

Figure 4. Logistic regression of Palos Verdes blue butterfly presence a) by year (χ^2=8.76; P =0.003) and b) by estimated population (χ^2=1.63; P =0.20). These show a decrease in the number of transect segments occupied over time (shown as an increase in the percentage unoccupied transects, which is why the line has a positive slope), and an increase in the number of transect segments occupied when total population estimates are large (shown as a decrease in the percentage unoccupied transects, which is why the line has a negative slope).

3.2. Patterns of Occupancy

As would be expected, results of the multiple logistic regression indicate that estimated abundance is a significant predictor of the number of transect segments where butterflies are observed each year (Figure 4a). The pattern of occupancy across DFSP shows a slightly negative trend over time (Figure 4b), even when the effects of population size have been removed in the multiple regression. This trend is statistically significant (P=0.03). Although the total estimated population size for Palos Verdes blue butterfly has been greater than the cumulative average for the past two years, this result shows that butterflies are concentrated in fewer locations along the transect.

Logistic regressions for each transect segment separately show that of the eight significant trends, seven were negative (Table 2). Those sites showing negative trend over time are sites that were occupied when the butterfly was rediscovered in 1994, or were revegetated shortly thereafter. Occupied segments that have been more recently restored show no trend (segment 6). The only area with a significant positive trend is segment 9, which was restored more recently and the butterfly introduced (Mattoni et al. 2002). Segment 7 continues to supports a high proportion of the butterflies.

Table 2. Status and trends of Palos Verdes blue butterfly occupancy by transect segment at Defense Fuel Support Point, San Pedro as of 2006. Status indicates presence (+) or absence (–) in 2005. Trend indicates stable (0), positive (+), or negative (–) trend in occupancy from logistic regression with chi-squared probability (P). Significance values of 0.2 and lower reported.

Segment	*2006 Status*	*Trend*	P
1-1	–	+	*ns*
1-2	–	+	*ns*
2-1	–	0	
2-2	–	–	0.09
3-1	–	–	< 0.01
3-2	–	–	0.04
4-1	–	–	<0.01
4-2	–	–	*ns*
4-3	+	+	*ns*
5-1	–	–	<0.01
5-2	–	+	*ns*
5-3	+	–	*ns*
5-4	+	n/a	
6	+	0	
7	+	0	
8-1	–	–	0.17
8-2	–	–	0.01
8-3	–	–	*ns*
9	+	+	< 0.01
10-1	–	–	0.03
10-2	–	–	0.10
10-3	–	+	*ns*
11-1	–	–	*ns*
11-2	–	–	*ns*
11-3	–	–	*ns*
11-4	–	–	0.10
11-5	–	–	0.02
11-6	–	0	

3.3. Population Viability Analysis

The population viability analysis produced a probability of extinction of 33% (Table 3). For those future scenarios that result in extinction, the mean time to extinction is 56 years (Figure 5). Because of the high variance in population growth from year to year, the population at DFSP would have to be several orders of magnitude higher to reduce extinction risk below 10%. The predicted extinction risk since the 2005 surveys decreased slightly from 35% and the mean time to extinction under those scenarios increased from 54 years. This suggests progress toward long-term viability of the population at DFSP. By contrast, the predicted probability of extinction in 2003 was 100%, within 37 years based on the low population size and a low estimate of the average growth rate of the species resulting from a relatively short period of observation at that time. After the dramatic increase in population in 2004, the estimate of extinction risk decreased to 24%. This extremely large difference is attributable to the revised growth rate estimate, which was greatly influenced by the population rebound from 2003 to 2004.

Table 3. Results of population viability analysis after each season 2003–2006.

Year	*Probability of Extinction*	*Years to Extinction (for extinction scenarios)*
2003	100%	37
2004	24%	40
2005	36%	53
2006	33%	56

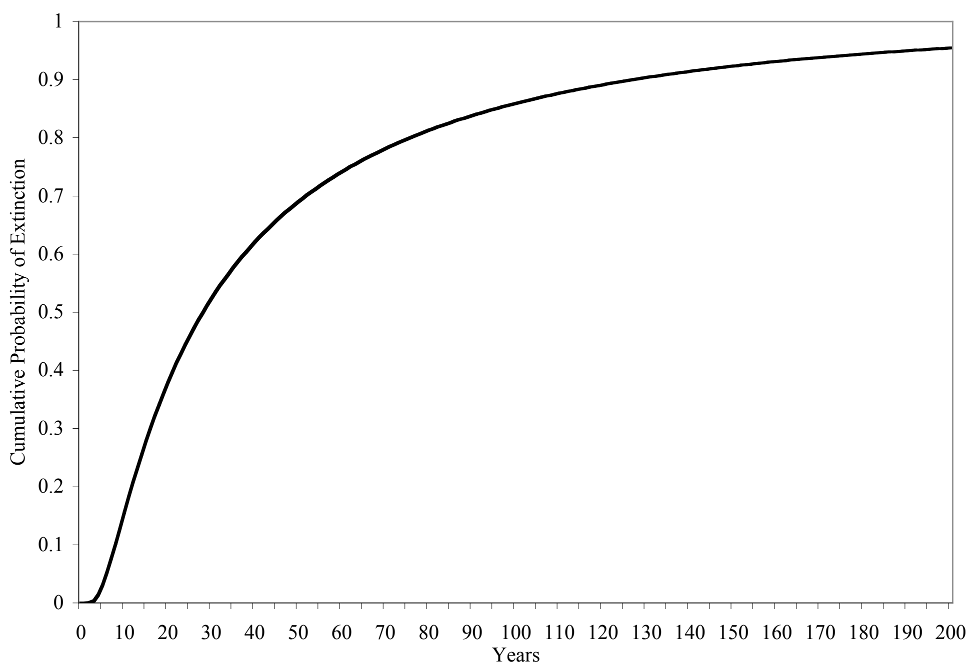


Figure 5. Cumulative probability of extinction of Palos Verdes blue butterfly at DFSP, for the 33% of future scenarios that result in extinction as of 2006.

4. Discussion

The adult Palos Verdes blue butterfly population in 2006 continues to shows a stable population in terms of total butterfly abundance. We know from the dramatic increase from an estimated 30 adult butterflies in 2003 to 282 in 2004 that the species can withstand drought years, probably through the mechanism of multi-year diapause.

The patterns of decreased occupancy along the transect underscore the need for ongoing management to enhance habitat for the butterfly. It shows that occupied, suitable habitat can become unsuitable over time. The mechanism for this is the replacement of early successional habitat with foodplant with later succession dominated by larger species.

We identified previously that the negative occupancy trends may not represent a real population decline, but rather shifts in areas of occupancy (Longcore and Mattoni 2005). To begin to investigate this possibility in 2006 we implemented a basewide survey for presence of the species, which is described in the next section.

Few Palos Verdes blue butterflies were observed in the Navy Housing area (segment 11) in 2006. None were seen on the regular transect and a few individuals were found during foodplant mapping by a permitted observer. This does raise some concerns, and active management of this area should be a priority. Because the butterfly subpopulation in the housing area varies asynchronously with other subpopulations on discrete regions of DFSP, it is also possible that weather conditions did not favor the slopes of the housing area and that pupae remained in diapause. Only several years of absence with intensive surveys should be interpreted to mean that the butterfly is no longer present. Based on dispersal ability of the species, suitable habitat could be reoccupied by butterflies from the adjacent occupied areas on the DFSP.

5. Basewide Presence Surveys and Foodplant Mapping

Long-term monitoring plans for butterflies may be more efficient and statistically reliable if they emphasize tracking species occupancy rather than species abundance (Longcore 2003b). Insects, especially butterflies, are notorious for large population fluctuations (e.g., Palos Verdes blue butterfly from 2003 to 2004). Because of the ability of populations to increase an order of magnitude in a year, the number of locations that support the butterfly may be far more important than the total number of butterflies at those locations. Schultz and Hammond (2003) have illustrated this for other lycaenid butterflies — adding additional occupied sites decreases extinction risk faster than increasing population size at fewer sites.

At DFSP, we have not conducted sufficient behavior studies to determine if the butterflies in different parts of the facility are part of one population or rather a number of quasi-independent populations. We have previously reported that butterfly numbers appear to fluctuate asynchronously in different areas of the transect, suggesting a loose metapopulation (Longcore and Mattoni 2005). This asynchrony may also result from changes in successional stage, rather than independent populations. Because the original transect was established to sample the best habitat at that time, it is to be expected that the habitat will become more average. Essentially, great habitat does not always stay great habitat, especially because both foodplants are early succession species, and other areas may become habitat.

To better detect Palos Verdes blue butterflies colonizing new habitats at DFSP, we conducted surveys for presence in all available habitats. This effort involved two parts: a base-wide survey for the larval hostplants for the species and a subsequent set of surveys for adults.

For both surveys we divided the property into 46 polygons that follow discernable landmarks on the ground. Maps of each polygon with 1-m aerial photographs were then used in the field during surveys for foodplant and butterflies. Surveys were conducted by Gordon Pratt, Cecelia Pierce, and Ken Osborne, in addition to the regular transects conducted by Rick Rogers.

5.1. Foodplant Surveys

Before the flight season we surveyed each polygon for presence of deerweed (*Lotus scoparius*) and locoweed (*Astragalus trichopodus*). Surveyors drew polygons on the survey map to show the extent of areas with foodplant and recorded the percent foodplant cover within those polygons and the total percent cover within the polygon. Field maps were then digitized at the USC GIS Research Lab.

5.2. Butterfly Surveys

All polygons were surveyed for butterflies. Sixteen polygons are covered by the regular transect and therefore were already being surveyed by Rick Rogers. The other polygons were assigned randomly to the three other surveyors. Three surveys were conducted of each polygon during the peak of the flight season (i.e., the three weeks around March 15). Surveyors recorded the location of all adult butterflies. Polygons were surveyed in random order to avoid systematic biases of surveying early or late in the day.

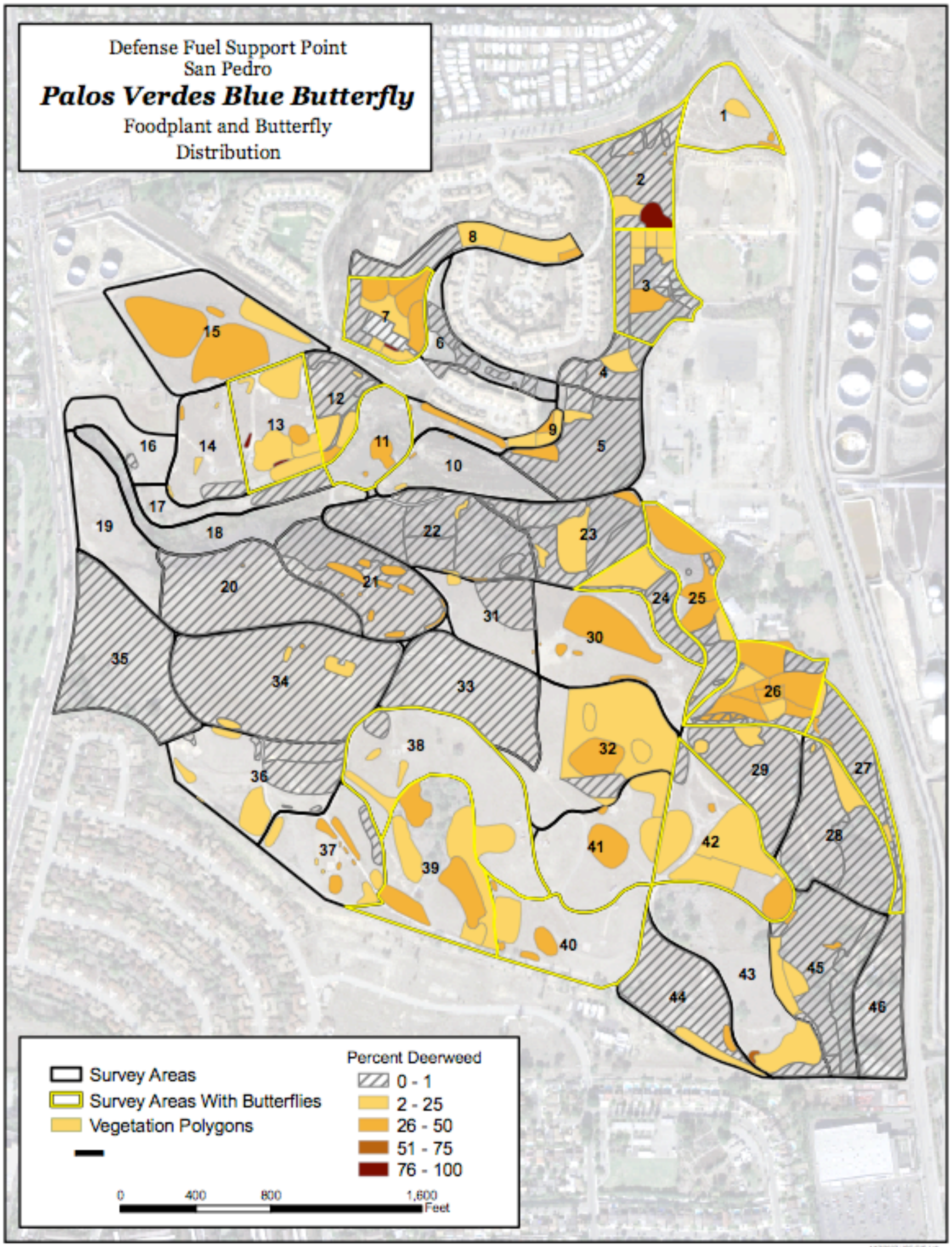


Figure 6. Distribution of Palos Verdes blue butterfly and foodplant at Defense Fuel Support Point, San Pedro, Spring 2006.

Surveyors recorded deerweed across a large portion of the property, although it was sparse throughout much of this area (Figure 6). Butterflies were observed in 14 of the 46 polygons delineated on site. The surveys found butterflies in areas where they had not previously been recorded (e.g., polygons 1, 2, 13, 42). Some polygons where only occupied at edges where they were contiguous with areas previously known to be occupied (e.g., polygons 24, 38. 40). These results extend the known range of the butterfly at DFSP, but also suggest its absence in areas previously known to be occupied (e.g., polygons 4, 5, 10). This result was also shown above with the transect counts.

The results of these surveys can be used as a baseline to track the status of Palos Verdes blue butterfly over time. This survey is more comprehensive than the previous transect surveys and allows managers greater certainty when addressing issues of potential impacts. Based on these results, it is highly unlikely that the butterfly occupies the large areas with low-density foodplant (e.g., polygons 33, 34, 35). It may be reasonable to repeat this survey every few years, or even every year if funds are available.

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