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FINAL REPORT
FOR
2007 PALOS VERDES BLUE BUTTERFLY ADULT SURVEYS
ON
DEFENSE FUEL SUPPORT POINT
SAN PEDRO, CALIFORNIA

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Executive Summary

Surveys for adult Palos Verdes blue butterfly were completed along a standardized transect that has been surveyed since 1994. Estimates of total population size and other population attributes were calculated using established formulas and software. The distribution of butterflies was analyzed and a population viability model was used to estimate extinction risk based on population characteristics derived from all annual surveys. The status for Palos Verdes blue butterfly at DFSP in 2007 is as follows.

- The estimate of the wild adult population along the transect is 211 and has been stable the last few years.
- Adult butterflies had short lives in 2007, probably as a result of the dry conditions and a lack of nectar sources.
- Dry conditions during the 2007 flight season will probably depress the adult population size in 2008.
- The probability of extinction is around 35%, which as been constant for several years, but far lower than five years ago.
- The adult butterflies are concentrated on fewer locations along the transect as a result of the habitat filling in with larger shrubs, but new areas off the transect are now known to support butterflies.

Based on these results, the following management actions should be considered.

- Continue to create new habitats where possible to offset the effects of habitat succession.
- Establish new populations of the species, either at DFSP or elsewhere, to decrease extinction risk the most.
- Continue to maintain a captive population to allow for reintroduction if an extended drought limits butterfly distribution at DFSP.

1 Introduction

The federally endangered Palos Verdes blue butterfly (*Glaucopsyche lygdamus palosverdesensis*) was discovered at the Defense Fuel Support Point in 1994 after ten years of presumed extinction (Mattoni 1994). Since that time, we have monitored the adult population of butterflies along a fixed transect each year. Each year the results increase information about a range of attributes for the species and allow for refined estimates of population viability and population trends. This report describes the transect, results of the surveys in 2007, and updates analysis of population parameters and viability.

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 14 years of annual counts provide data to assess trends in the butterfly's patterns of distribution and abundance on the transect. Below we present results of surveys from 1994 to 2007 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 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 learned last year that additional areas are occupied by the butterfly but not included on the transect (Longcore 2007).

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% males), 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 software program INCA (INsect Count Analyzer; downloaded at http://www.urbanwildlands.org/INCA/) to analyze the count data for 1994 through 2007 (Zonneveld 1991, Longcore et al. 2003). 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 (see INCA documentation for details).

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 the independent continuous variables were year and estimated population size and 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.

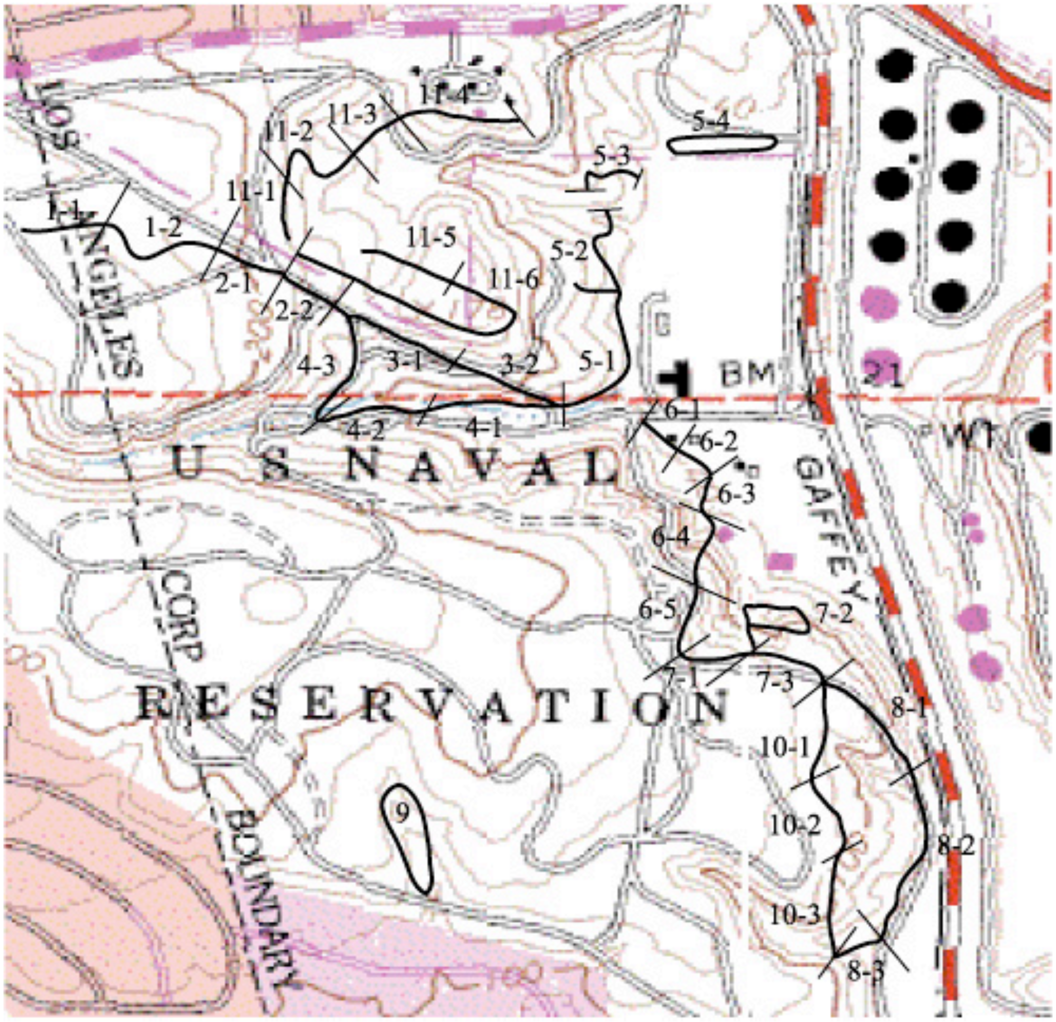

Figure 1. Location of Palos Verdes blue butterfly transect at DFSP (segments 1–10) and Palos Verdes housing (segment 11).

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 statistical model known as 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
2007	February 26	April 12	46	27	211

*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, 2005–2007).

3 Results

The 2007 population estimate of 211 adults was in 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, although weakly (r^2=0.26, $F_{1,12}$=4.34, P=0.06). The length of the season can be estimated as 30 days plus 10 days for each 100 butterflies in the population, simply because of the added probability of observing an early or late individual with increased population size (Figure 2).

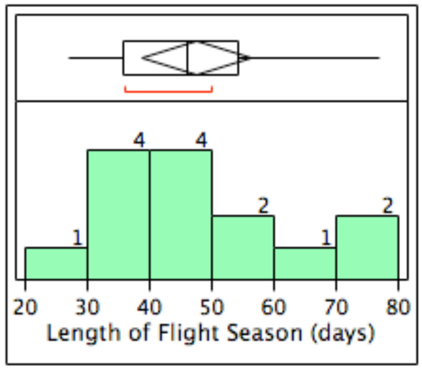

Figure 2. Length of flight periods for Palos Verdes blue butterfly, 1994–2007. Bars show number of years with the flight season within the interval.

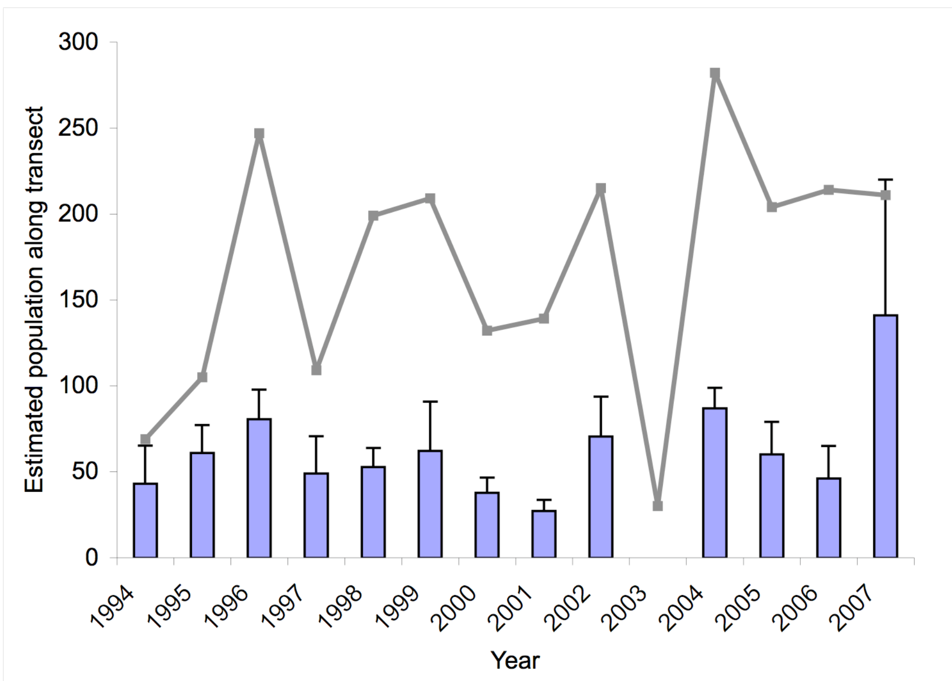

Figure 3. Solid line: estimated population of Palos Verdes blue butterfly at DFSP, 1994–2007. Bars: estimated population of Palos Verdes blue butterfly at DFSP, 1994–2007, calculated by Zonneveld method from transect counts. This index is not adjusted for sex ratio or search efficiency. Error bars + 1 S.D. Too few butterflies were observed in 2003 to produce an estimate so no bar for the Zonneveld method is given for 2003.

During 14 years of monitoring, the estimated population of Palos Verdes blue butterfly has fluctuated without statistically significant trend (Figure 3). 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.

3.1 Patterns of Occupancy

The multiple logistic regression of Palos Verdes blue butterfly presence by year and by estimated population show a decrease in the number of transect segments occupied over time (χ^2=4.02; P =0.05), and an increase in the number of transect segments occupied when total population estimates are large (χ^2=2.18; P =0.13). This result shows that butterflies are concentrated in fewer locations along the transect. Although the explanatory power of these regressions is low, they are consistent with the known properties of butterfly surveys and the habitat dynamics at DFSP. Larger population sizes will result in observation of butterflies on more transects simply because of increased detectibility. Observations at fewer transects, as documented further below, is a result of habitat succession along the transect segments.

Logistic regressions for each transect segment separately show that of the ten significant (p<0.10) 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 (2-2. 3-1, 4-1, 5-1). Occupied segments that have been more recently restored show no trend (segment 6). The three areas with a significant positive trend are segment 9, which was restored more recently and the butterfly introduced (Mattoni et al. 2002) and segments 11-5 and 11-6 on the former housing site. Segment 7 continues to support 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 2007. Status indicates presence (+) or absence (–) in 2007. Trend indicates stable (0), positive (+), or negative (–) trend in occupancy from logistic regression with chi-squared probability (P). Significance values of 0.1 and lower reported.

Segment	*2007 Status*	*Trend*	*P*
1-1	–	+	*ns*
1-2	–	+	*ns*
2-1	–	0	
2-2	–	–	0.07
3-1	–	–	< 0.01
3-2	+	–	*ns*
4-1	+	–	0.07
4-2	–	–	*ns*
4-3	+	+	*ns*
5-1	+	–	0.09

5-2	+	+	*ns*
5-3	+	+	*ns*
5-4	+	n/a	
6	+	0	
7	+	0	
8-1	+	–	*ns*
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	+	–	*ns*
11-5	+	+	0.02
11-6	+	+	0.01

3.2 Population Viability Analysis

The population viability analysis produced a probability of extinction of 35% (Table 3). For those future scenarios that result in extinction, the mean time to extinction is 62 years (Table 3). 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 2006 surveys increased slightly from 33% although the mean time to extinction under those scenarios increased from 56 years. This suggests progress toward long-term viability of the population at DFSP since 2003. 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. Similar analyses have been completed for Fender's blue butterfly (*Icaricia icarioides fenderi*) with eight years of population data (Schultz and Hammond 2003) for Oregon silverpot by Crone et al. (2007). The population growth rate and its variance for Palos Verdes blue are within the range of values found for individual populations of Fender's blue butterfly. The changes in extinction probability from 2005 to 2007 are not sufficiently large to be interpreted as biologically meaningful, but the situation has definitely improved since 2003. Schultz and

Hammond demonstrated that extinction risk decreased more with additional populations than with increased numbers at the same populations. Consequently, releases of Palos Verdes blue butterflies from the captive population in 2008 should, if successful, reduce extinction risk substantially.

Table 3. Results of population viability analysis after each season 2003–2007.

Year	*Probability of Extinction*	*Years to Extinction (for extinction scenarios)*
2003	100%	37
2004	24%	40
2005	36%	53
2006	33%	56
2007	35%	62

4 Discussion

The adult Palos Verdes blue butterfly population in 2007 continues to show 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. Although pupae in the laboratory can remain viable for two years, the proportion of viable pupae decreases rapidly after two years, at least in captivity. From this observation we can predict that multiple drought years in a row are likely to cause substantial population declines and potentially lead to extinction. Hotter and drier conditions predicted for southern California from global climate change are therefore likely to adversely affect Palos Verdes blue butterfly. This risk is not reflected in the population viability analysis.

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. At DFSP, restored and enhanced habitats have been occupied by the butterfly and indeed have become important population centers. As long as additional restoration or enhancement sites are available near existing habitats, these should be managed to provide the needed mosaic of early succession habitat. In limited circumstances, deerweed has remained stable for many years (e.g., Segment 7), but this is an exceptional situation. If additional habitat areas are no longer available, intentional disturbance of sage scrub habitat might be considered to ensure regeneration of suitable foodplant patches.

We previously concluded that the negative occupancy trends may not represent a real population decline, but rather shifts in areas of occupancy (Longcore and Mattoni 2005). A basewide survey in 2006 confirmed that additional areas of the depot were occupied but not included on the existing transects (Longcore 2007). This result, combined with the relatively steady population estimate along the transect further indicates a stable population at DFSP. Those transect segments where butterflies are no longer found are of less concern knowing that other areas are now occupied. The dynamic nature of this distribution should be a focus of long-term planning and management for the species.

After very low numbers of Palos Verdes blue butterflies being observed on the housing area in 2006, more segments were occupied in 2007. Five of the six subsegments along segment 11 were occupied. Management of these areas to increase foodplant density would be advised, however, given the lack of butterflies observed on segment 10.

Our methodology of estimated total population size remains preferable to other methods. Pickens (2007) recently suggested the use of maximum daily count as an index for butterfly abundance. For Karner blue butterfly he showed that maximum daily count correlated highly with a variant of the Watt et al. method that we employ (Pearson's correlation; $r = 0.70$ and 0.89 for two different sites; both numbers log-transformed). The same correlation for our data was significant, but with $r = 0.61$. Furthermore, daily maximum is influenced by average temperature, while the total population size is less influenced by temperature because it incorporates the length of the season as well (unpub. data). Based on these results, we will continue to report both the estimated total population and the maximum daily count as indicators of population trends.

INCA continues to be a useful tool to analyze data. It provides estimates of longevity, which have varied widely over the years of surveys. While INCA and the underlying model (Zonneveld 1991) assume that longevity is constant within years, this assumption may be broken (Gross et al. 2007). Nevertheless, INCA is particularly good at describing peak eclosion as a measurement of timing and the spread of eclosion within a season. The estimates of death rate (corresponding to longevity) are useful in identifying differences between years. For example, results from 2007 indicated a high death rate (short lifespan of 4.1 days, below the average of 8.7 days), which was consistent with the hot dry conditions during the flight season.

We are initiating a study to relate climatic conditions with various flight season parameters.

Initial results confirm that previous season rainfall is associated with larger populations and high mean and maximum temperatures during the flight season decrease estimates of longevity of adults (Longcore, unpub. data). This suggests that multiple drought years in a row will be detrimental to the Palos Verdes blue butterfly population. Identifying the various climatic influences of population dynamics will aid in long-term planning in the face of a changing and variable climate.

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