THE URBAN WILDLANDS GROUP, INC.
P.O. Box 24020, Los Angeles, California 90024-0020, Tel (310) 247-9719

FINAL REPORT
FOR
2011 PALOS VERDES BLUE BUTTERFLY ADULT SURVEYS
ON
DEFENSE FUEL SUPPORT POINT
SAN PEDRO, CALIFORNIA

COOPERATIVE AGREEMENT NUMBER:
N62473-11-2-2304

Contracting Officer:
Linda Protocollo
Naval Facilities Engineering Command (NAVFAC), Southwest
1220 Pacific Highway
San Diego, CA 92132-5190
Tel: (619) 532-1159, Fax: (619) 532-1155
Email: Linda.protocollo@navy.mil

Agreement Representative:
Albert Owen, Ph.D.
Natural Resources Specialist
Naval Facilities Engineering Command (NAVFAC), Southwest
937 North Harbor Drive
San Diego, CA 92132-5190
Tel: (619) 532-3775, Fax: (619) 532-4160
Email: albert.owen@navy.mil

FINAL REPORT
FOR
2011 PALOS VERDES BLUE BUTTERFLY ADULT SURVEYS
ON
DEFENSE FUEL SUPPORT POINT
SAN PEDRO, CALIFORNIA

Prepared By:
Travis Longcore, Ph.D.
The Urban Wildlands Group
P.O. Box 24020
Los Angeles, CA 90024-0020

Ken H. Osborne, M.S.
Osborne Biological Consulting
6675 Avenue Juan Diaz
Riverside, CA 92509-6242

Prepared For:
Albert Owen, Ph.D.
Natural Resources Specialist
Naval Facilities Engineering Command (NAVFAC), Southwest
937 North Harbor Drive
San Diego, CA 92132-5190

October 15, 2011

Recommended Citation:
Longcore, T., and K. H. Osborne. 2011. Final Report for 2011 Palos Verdes Blue Butterfly Adult Surveys on Defense Fuel Support Point, San Pedro, California. Los Angeles: The Urban Wildlands Group (Defense Logistics Agency Agreement # N62473-11-2-2304).

Executive Summary

Surveys for adult Palos Verdes blue butterfly at the Defense Fuel Support Point (DFSP), San Pedro, 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 estimated extinction risk based on population characteristics derived from all annual surveys. The status for Palos Verdes blue butterfly at DFSP in 2011 is as follows:

- The estimate of the wild adult population along the transect is 45 at DFSP and 8 in the Navy Housing area, which is in the bottom 25% of yearly population estimates.
- The probability of extinction calculated is 100%, which would occur on average in 151 years.
- The geographic distribution of the butterfly (excluding release sites) is limited to two areas (near the current nursery and behind the old nursery).
- The distribution of the species on the property has decreased in extent since the mid-1990s when surveys were initiated, commensurate with the maturation of coastal sage scrub vegetation.

Based on these results, the following management actions are strongly recommended:

- Begin a regular program of targeted disturbance to clear vegetation and allow development of early successional habitat near existing Palos Verdes blue butterfly habitat.
- Continue to establish new populations of the species, either at DFSP or elsewhere, to decrease risk of extinction.
- 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 ([DFSP] Figure 1; see also Supplemental Figures 1 and 2) in 1994 after ten years of presumed extinction (Mattoni 1994). Since that time, surveyors have monitored the adult population of butterflies along a fixed transect each year (Mattoni and Longcore 2002, Osborne 2002, Longcore and Mattoni 2003, 2005, Longcore 2007a, b, 2008, Longcore and Osborne 2010, Longcore et al. 2010). 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 transect surveys, and updates analysis of population parameters and viability.

In 1994, Mattoni established a transect that included the larger stands of larval foodplant (*Acmispon glaber* [=*Lotus scoparius*] and *Astragalus trichopodus lonchus*) at DFSP at that time (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 18 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 2011 and include an estimate of the adult population using a standardized algorithm developed for this purpose (see Mattoni and Longcore 2002). 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 parameter estimates derived from the transect count.

2 Methods

2.1 Transect Counts

Surveyor Rick Rogers counted butterflies on Pollard transect walks (Figure 2) 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 on January 17, well before the first sighting of Palos Verdes blue butterflies in the spring. The early surveys were done because of some unseasonably warm weather.

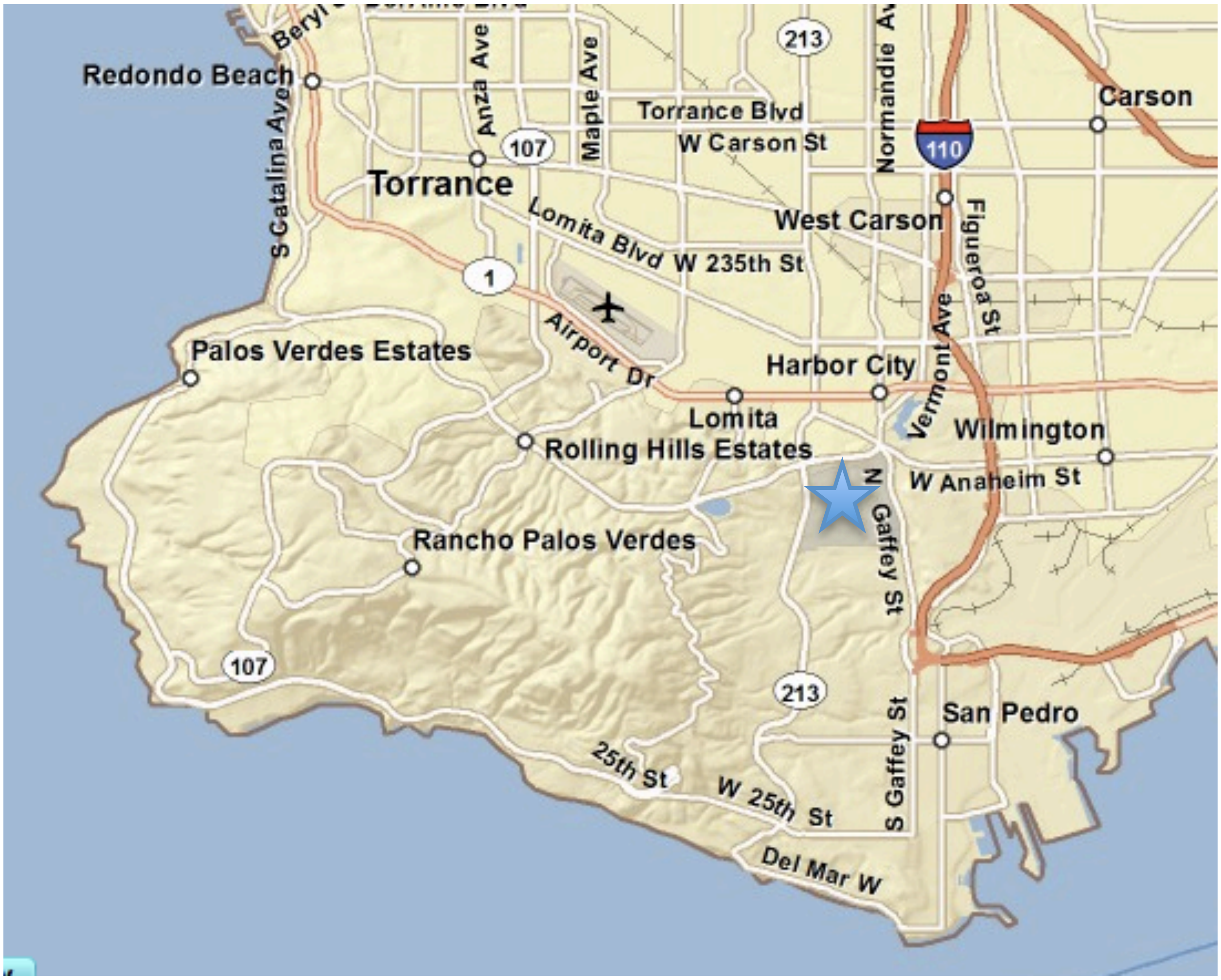


Figure 1. Location of Defense Fuel Support Point, San Pedro in southwestern Los Angeles.

The transect is ~3.2 km long (Figure 2), 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. When established, the transect included all areas where Palos Verdes blue butterfly had been observed and along corridors between habitat patches. We learned from a base-wide survey in 2006 that additional areas were occupied by the butterfly but not included on the transect (Longcore 2007a). All butterfly surveys, years 2005 to present, have been conducted under the USFWS 10(a)(1)(A) recovery permit of Ken H. Osborne, number TE837760.

2.2 Population Estimates

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 adult 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 2011 (Zonneveld 1991, Longcore et al. 2003). For some years solutions failed to converge with the count 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). This model fits a curve to the transect numbers by estimating four parameters: day of peak emergence, spread of emergence, longevity, and total population size (Zonneveld 1991, Longcore et al. 2003). The statistical model underlying this method is not particularly robust to calculation of population size and longevity when the peak number of butterflies observed in a day on the surveys is less than 25, but other parameters can be estimated robustly (Gross et al. 2007). The population and longevity results from this method should be interpreted with caution, given that the peak number of Palos Verdes blue butterflies at DFSP is usually lower than 25,

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).

Figure 2. Location of Palos Verdes blue butterfly transect at DFSP (segments 1–10) and Palos Verdes housing (segment 11), as found on the Torrance, California 7.5' USGS quadrangle.

2.3 *Occupancy Analysis*

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.

2.4 *Population Viability Analysis*

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 1994–2008. We set the extinction threshold at 1 because individuals of this species may undergo multiple year diapauses; whereby 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. If the pupae could not undergo multi-year diapause the extinction threshold would be higher because the number of butterflies flying each year would be all of the individuals extant, not a proportion of the total.

2.5 *Climatic Models*

Finally we obtained climatic data from the nearest station (Long Beach) and ran a multiple regression analysis to relate the estimated population size to precipitation and temperature. We evaluated a series of candidate models, using total larval year rainfall (September through May of previous season), larval year spring rainfall (March through May of previous season), larval year winter rainfall (September through March of previous season), mean maximum temperature during previous flight season (March and April), and estimated population during previous flight season. Models were evaluated with Akaike's Information Criterion (AIC). These variables were chosen for model construction because of the observed relationship between rainfall and availability of larval foodplant. Rainfall during winter and spring were tested separately because rain during the flight season (spring) could adversely affect adults. Mean maximum temperature during the flight period was used to identify the possible influence of heat stress on adults.

3 Results

3.1 Population Estimates

Surveys were conducted on 24 days between January 17 and May 11 (Table 1).

Table 1. Survey conditions and observations for Palos Verdes blue butterfly at Defense Fuel Support Point and adjacent housing area. Additional butterflies that were released from the captive rearing program in 2011 are identified separately and were identified in the survey data by the geographically distinct locations they were released and the timing of those releases. Offspring from previously released individuals are included in the regular counts.

Date	Male PVB (released)	Female PVB (released)	Temp °F (start/finish)	Wind Speed mph (start/finish)	Percent Cloudy (start/finish)
January 17	0	0	75/77	1/1–2	0/0
January 26	0	0	73/77	1–2/2–4	25/10
February 4	0	0	70/71	3–6/3–6	10/0
February 10	0	0	70/72	1–2/3–4	0/0
February 21	0	0	62/64	1–3/2–4	20/10
February 23	0	0	68/67	2–5/3–8	30/10
March 1	0	0	67/68	1–2/1–3	50/20
March 4	0	0	74/75	1–3/1–3	0/0
March 8	0	0	71/74	1–4/2–4	0/0
March 10	2	0	78/81	1–2/1–3	0/0
March 14	0	0	72/74	1–3/1–3	0/0
March 16	2	1	69/72	2–5/2–5	10/0
March 22	2 (6)	0 (4)	60/68	1–2/1–3	40/20
March 24	4 (6)	0 (2)	65/67	1–3/1–3	40/20
March 30	5 (2)	1 (0)	67/70	1–3/1–4	0/0
April 1	2 (3)	0 (0)	79/80	1–3/2–4	0/0
April 5	5 (0)	1 (1)	65/70	3–4/3–6	40/10
April 7	0 (0)	2 (0)	63/65	3–9/3–9	90/40
April 12	0	0	66/68	2–4/3–6	40/0
April 14	0 (3)	0 (1)	71/71	1–3/1–3	0/0
April 18	0	0	64/67	2–5/2–5	100/40
April 21	1 (1)	1 (0)	68/71	2–5/2–5	60/10
April 21	0	0	87/88	2–6/4–6	0/0
April 29	0	0	68/70	1–3/4–5	5/0
May 2	0	1	87/89	1–2/1–4	0/0
May 6	0	0	73/75	1–3/2–4	0/0
May 11	0	0	77/79	1–3/2–4	0/0

The population estimate of 53 adults (45 at DFSP, 8 at Navy Housing) for 2011 was in the bottom quarter of years surveyed (Table 2). Flight period (i.e., the number of days between the first and last observation) continues to be modestly predicted by estimated population size (r^2=0.32, $F_{1,16}$=7.45, *P*=0.014). The length of the season can be estimated as 31.4 days plus 10.3 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 3). The log-transformed maximum daily count was highly correlated (Pearson's correlation; r = 0.87).

Table 2. Abundance and phenology of Palos Verdes blue butterfly at DFSP and Palos Verdes Naval Housing area, 1994–2011.

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	23	243
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
2008	March 4	April 7	34	7	45
2009	February 27	May 1	67	28	214
2010	March 10	April 10	32	7	47
2011	March 16	May 2	47	6	53

*Transect followed from map by two observers working together (G. Pratt/C. Pierce). All other transects by R. Mattoni (2003), K. Osborne (2002, 2011 Naval Housing only), or R. Rogers (1994–2001, 2005–2011).

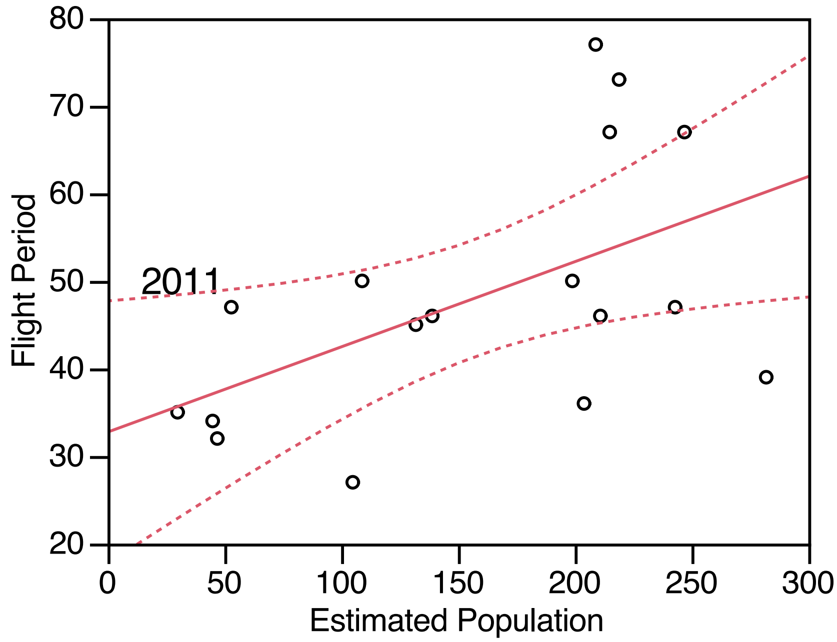


Figure 3. Influence of population size on observed flight periods for Palos Verdes blue butterfly, 1994–2011, defined as number of days between first and last observation. Linear regression and 95% confidence intervals for the regression are shown. Relative to the population size, the 2011 season was long, probably as a result of the cool weather during the flight season.

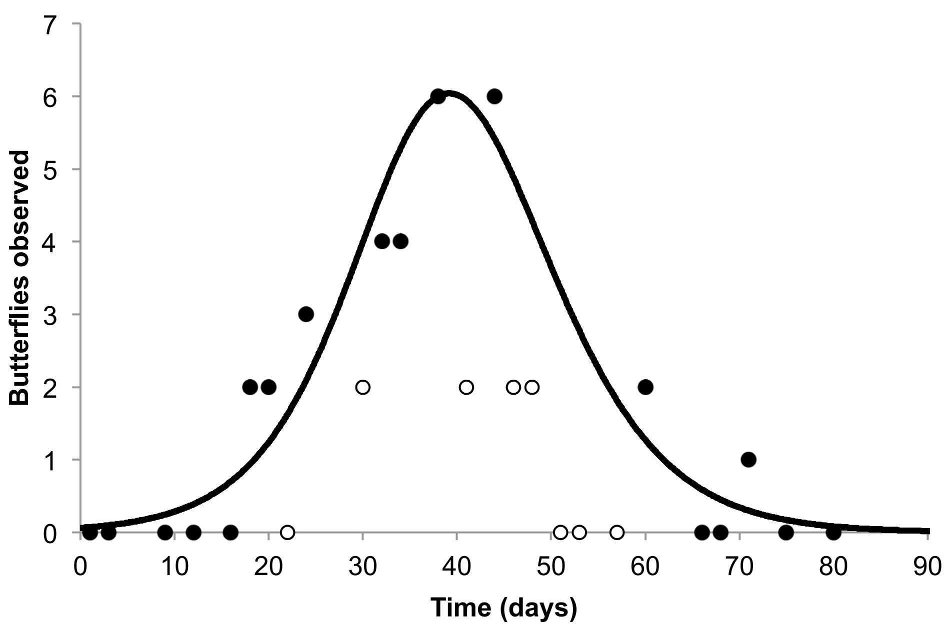


Figure 4. Raw data from transect counts with curve fit by INCA, 2011. The open circles represent counts that were omitted to allow the curve to be fitted to the data. The start of surveys (time = 0) was February 21, 2011.

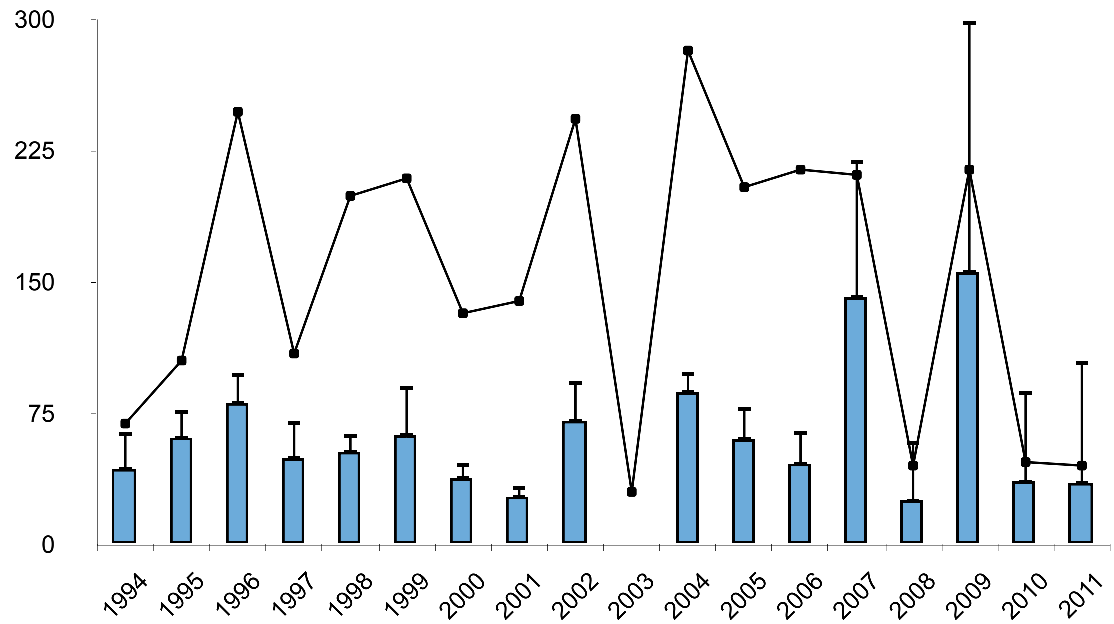


Figure 5. Solid line: population of Palos Verdes blue butterfly at DFSP, 1994–2011, estimated by Mattoni et al. (2003) method. The 2011 estimate omits the Navy Housing area, which previously was included in the estimates but is now surveyed under a different Cooperative Agreement, and would add 8 butterflies to the Mattoni et al. estimate. Bars: estimated population of Palos Verdes blue butterfly at DFSP, 1994–2011, calculated by Zonneveld (1991) 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 18 years of monitoring, the estimated population of Palos Verdes blue butterfly has fluctuated without a statistically significant temporal trend (Figure 5). No trend is evident based on overall abundance alone. Similar results are obtained with the Zonneveld method (Figure 5), which also shows the population fluctuating without a trend.

3.2 Patterns of Occupancy

The multiple logistic regression of Palos Verdes blue butterfly presence by year and by estimated population shows no significant change in the number of transect segments occupied over time, but a significant decrease in the number of transect segments occupied when total population estimates are low (χ^2=16.55; P <0.001). This result shows that butterflies are concentrated in fewer locations along the transect when numbers are low. Although the explanatory power of these regressions is modest (r^2 values for the logistic regression are low; 0.02–0.4), they are consistent with the habitat dynamics at DFSP. Larger population sizes result in observation of butterflies on more transects simply because of increased ease in detecting them and expanded habitat use during such years. Significant negative trends in occupancy at segments, as documented further in a segment-by-segment analysis, is most likely the result of foodplants being replaced by later succession species (e.g., *Artemisia californica*, *Eriogonum fasciculatum*, and *Encelia californica*) over time (personal observations).

Logistic regressions for each transect segment separately show that of the 14 significant ($p<0.10$) trends, 10 were negative (Table 3). 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). Two segments show positive trends, 5-2 and 11-3.

Table 3. Status of Palos Verdes blue butterfly by transect segment, 1994–2011: <u>present (black), not detected (white), not surveyed (grey)</u>. Trends by logistic regression reported with chi-squared probability (P), with only trends significant at (P < 0.1) reported. Segments 6 and 7 were split into subsegments in 2002.

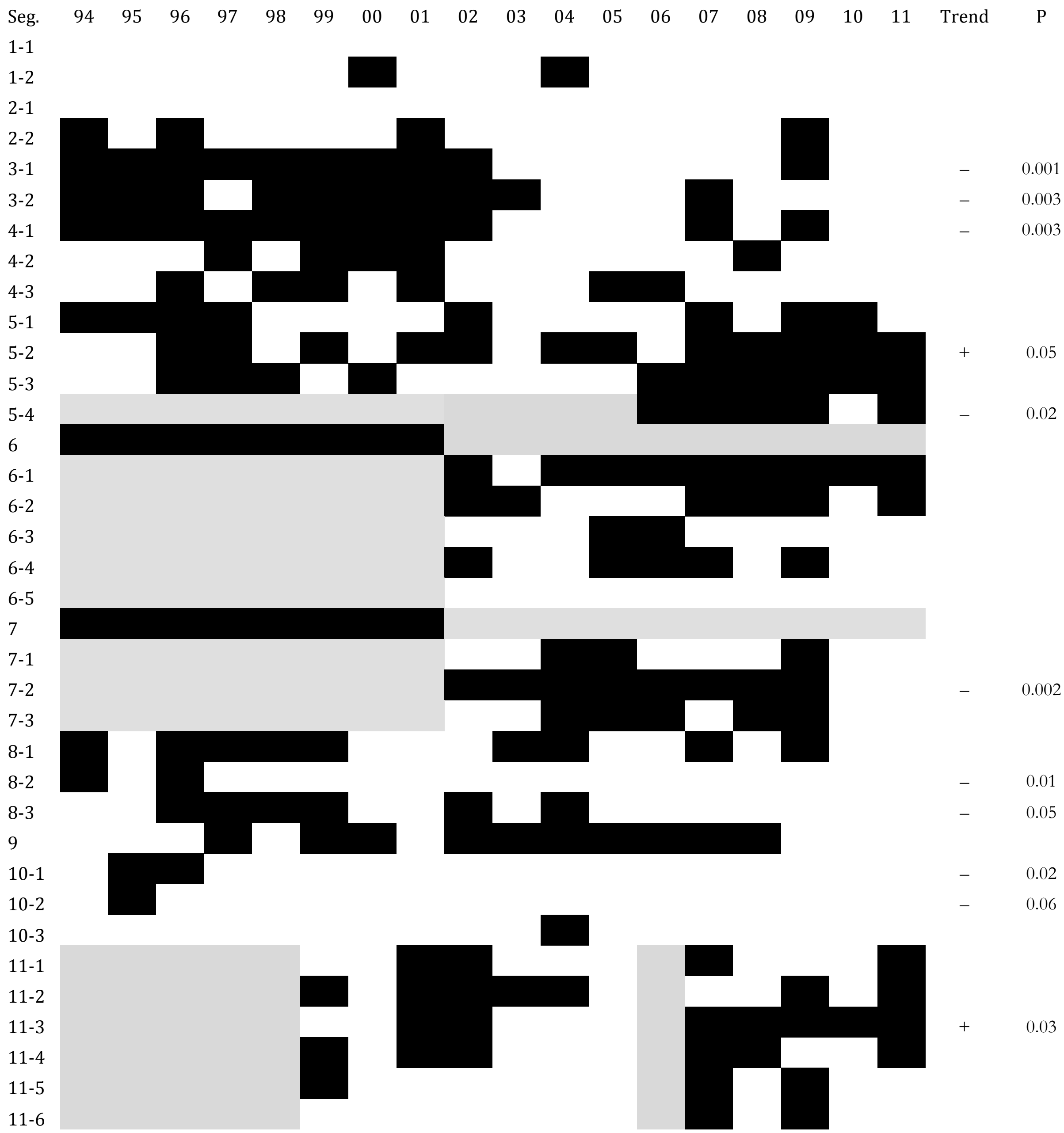


Table 4. Results of population viability analysis after each season 2003–2011.

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
2008	100%	125
2009	43%	71
2010	100%	165
2011	100%	151

3.3 Population Viability Analysis

The population viability analysis produced a probability of extinction of 100% with the average time to extinction for the scenarios calculated with the updated 2011 parameter estimates is 151 years (Table 4). This analysis is sensitive to the number of butterflies observed during the season, so "good" years result in estimates of lower extinction risk, perhaps more so than is biologically warranted. Similar analyses have been completed for Fender's blue butterfly (*Icaricia icarioides fenderi*) with eight years of population data (Schultz and Hammond 2003) and for Oregon silverspot (*Speyeria zerene hippolyta*) with 14 years of population data (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. Schultz and Hammond (2003) demonstrated that extinction risk decreased more with additional populations than with increasing populations at existing sites. Consequently, off-site release of Palos Verdes blue butterflies from the captive population should, if found to be successful, reduce overall extinction risk substantially. To date, butterflies have been released from the captive propagation program at three off-site localities that are permitted to receive the butterfly and managed for natural resource values.

3.4 Climate Influence on Observed Population

The models that best described estimated population size all included precipitation measures (Table 5). Flight season temperature and previous year's population were not included in any of the best models. The best model was the natural log of total larval year rainfall (Table 5; Estimated Population = 11.8 + 64.4 * ln(Larval Year Rainfall)), which explains 33% of the variation in estimated population size. Larval year rainfall alone was positively associated with butterfly population size, but the relationship is much stronger when rainfall is log-transformed. This can be interpreted as meaning that a moderately wet year is good, but there is no marginal benefit of an extremely wet year. Because the sample size is still relatively small (n = 17), these results must be interpreted with caution.

Table 5. Regression models predicting estimated population size.

Variables	R^2	P	AIC
Ln (Larval Year Rainfall)	0.33	0.02	197.82
Ln (Larval Winter Rainfall)	0.17	0.06	200.30
Ln (Larval Spring Rainfall)	0.05	0.38	203.66

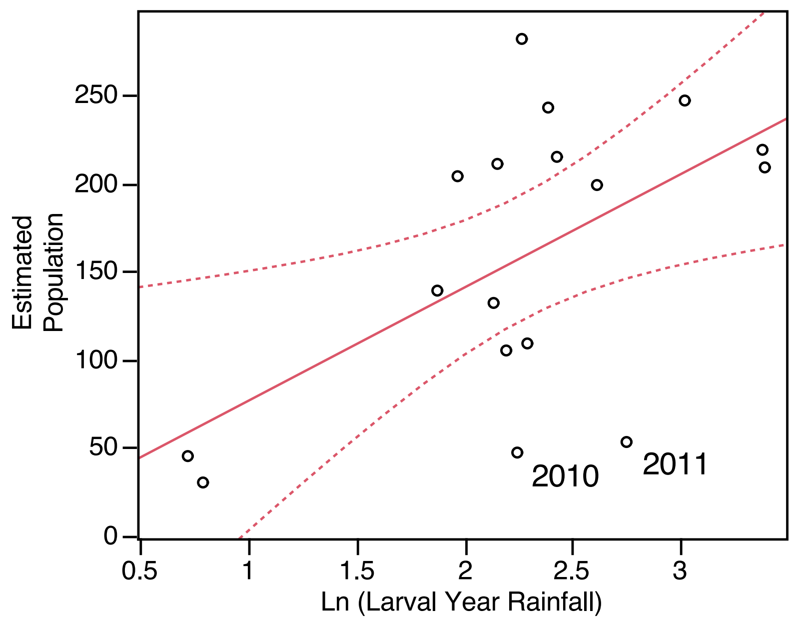


Figure 6. Estimated population of Palos Verdes blue butterfly at DFSP by log-transformed rainfall during larval year. Linear regression with 95% confidence limits for regression shown.

Both 2010 and 2011 are outliers in the relationship between precipitation and population size (Figure 6). Even though the 2009 and 2010 larval years had sufficient rainfall to be associated with a good flight of butterflies in 2010 and 2011, this did not occur. This would occur if inadequate foodplant were available to take advantage of the rainfall in areas occupied by the butterfly.

4 Discussion

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 (*Lycaeides melissa samuelis*) 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) compard with r = 0.87 for our 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.

The adult Palos Verdes blue butterfly population in 2011 was below average for the past several years, and the trend of contraction of range within the installation has continued. Our previous understanding that larval year rainfall explains a large portion of annual variation in observed numbers (r^2 = 0.46; Longcore et al. 2010) remains intact, but 2011 was again an outlier to this relationship and the explanatory power was reduced (Table 5). The likely explanation for this lies in the die-off of deerweed recorded in 2009 during basewide foodplant surveys (Longcore et al. 2010). The extent of mortality of deerweed foodplants, combined with succession from more open to more closed scrub habitats resulting from an increase in dominance of species such as *Artemisia californica* and *Encelia californica*, seems to have lead to a situation where adequate rainfall was available, but not enough foodplant was alive to take advantage of it. This decoupling of rainfall with butterfly numbers is troubling because it suggests an ongoing degradation of the foodplant resources, which are unlikely to recover without intervention.

Figure 7. Disturbance experiment area at transect segment 9. The scraped area has many annual weeds, but also seedlings of the perennial deerweed (*Acmispon glaber* [=*Lotus scoparius*]), which should become more dominant. Photo taken April 28, 2011 by K. Osborne.

We have for many years made the observation that disturbance would need to be used as a management tool to keep the early successional host plant of Palos Verdes blue butterfly abundant (Osborne 2002, Longcore 2007a, b). A pilot experiment that mechanically disturbed 1 acre of habitat around transect segment nine is underway. Preliminary, there is recruitment of deerweed seedlings and these may grow sufficiently to be potential habitat in the 2012 season, but are more likely to be of sufficient size in 2013 (Figure 7 and Figure 8). Further efforts to create early successional habitats at DFSP are needed.

Figure 8. Deerweed (*Lotus scoparius*) seedlings in disturbance experiment area. Seedlings are to the right and left of the pen, surrounded by *Erodium* plants, but no grasses. Photo taken April 28, 2011 by K. Osborne.

5 Bibliography

Crone, E. E., D. Pickering, and C. B. Schultz. 2007. Can captive rearing promote recovery of endangered butterflies? An assessment in the face of uncertainty. Biological Conservation 139: 103–112.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61: 115–144.

Gross, K., E. J. Kalendra, B. R. Hudgens, and N. M. Haddad. 2007. Robustness and uncertainty in estimates of butterfly abundance from transect counts. Population Ecology 49: 191–200.

Hanski, I. 1999. Metapopulation dynamics. Oxford University Press, Oxford.

Longcore, T. 2007a. Final report for 2006 Palos Verdes Blue Butterfly adult surveys on Defense Fuel Support Point, San Pedro, California (Defense Logistics Agency Agreement # N68711-06-LT-R0011), pp. 1–13. The Urban Wildlands Group Los Angeles.

Longcore, T. 2007b. Final report for 2007 Palos Verdes blue butterfly adult surveys on Defense Fuel Support Point, San Pedro, California. (Defense Logistics Agency (Agreement #N68711-07-LT-R0011), pp. 1–12. The Urban Wildlands Group, Los Angeles.

Longcore, T. 2008. Final report for 2008 Palos Verdes blue butterfly adult surveys on Defense Fuel Support Point, San Pedro, California. (Defense Logistics Agency Agreement #62473-08-LT-R0011), pp. 1–16. The Urban Wildlands Group, Los Angeles.

Longcore, T., and R. Mattoni. 2003. Final report for Palos Verdes blue butterfly year 2003 adult surveys on Defense Fuel Support Point, San Pedro, California. The Urban Wildlands Group (Defense Logistics Agency Agreement # N68711-03-LT-C3003), Los Angeles.

Longcore, T., and R. Mattoni. 2005. Final report for 2005 Palos Verdes blue butterfly adult surveys on Defense Fuel Support Point, San Pedro, California, pp. 1–11. The Urban Wildlands Group (Defense Logistics Agency Agreement # N68711-05-LT-A0012), Los Angeles.

Longcore, T., and K. H. Osborne. 2010. Final report for 2010 Palos Verdes blue butterfly adult surveys on Defense Fuel Support Point, San Pedro, California. The Urban Wildlands Group, Los Angeles.

Longcore, T., K. H. Osborne, and A. Dalkey. 2010. Final report for 2009 Palos Verdes blue butterfly adult surveys on Defense Fuel Support Point, San Pedro, California, pp. 1–24. The Urban Wildlands Group, Los Angeles.

Longcore, T., R. Mattoni, C. Zonneveld, and J. Bruggeman. 2003. INsect Count Analyzer: a tool to assess responses of butterflies to habitat restoration. Ecological Restoration 21: 60–61.

Mattoni, R., and T. Longcore. 2002. Census results for Palos Verdes blue butterfly and associated species, 1994–2001, pp. 2-10. *In* R. Mattoni (ed.), Status and trends: habitat restoration and the endangered Palos Verdes blue butterfly at the Defense Fuel Support Point, San Pedro, California, 1994–2001. The Urban Wildlands Group, Los Angeles.

Mattoni, R., T. Longcore, C. Zonneveld, and V. Novotny. 2001. Analysis of transect counts to monitor population size in endangered insects: the case of the El Segundo blue butterfly, *Euphilotes bernardino allyni*. Journal of Insect Conservation 5: 197–206.

Mattoni, R. H. T. 1994. Rediscovery of the endangered Palos Verdes blue butterfly, *Glaucopsyche lygdamus palosverdesensis* Perkins and Emmel (Lycaenidae). Journal of Research on the Lepidoptera 31: 180–194.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fierberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy, Arlington, Virginia.

Morton, A. C. 1982. The effects of marking and capture on recapture frequencies of butterflies. Oecologia 53: 105–110.

Osborne, K. H. 2002. Population monitoring for the Palos Verdes blue on the Defense Fuel Support Point, San Pedro, California: year 2002 survey results. Osborne Biological Consulting, Riverside, California.

Pickens, B. A. 2007. Understanding the population dynamics of a rare, polyvoltine butterfly. Journal of Zoology 273: 229–236.

Pollard, E. 1977. A method for assessing change in the abundance of butterflies. Biological Conservation 12: 115–132.

Pollard, E. 1988. Temperature, rainfall and butterfly numbers. Journal of Applied Ecology 25: 819–828.

Pollard, E., and T. J. Yates. 1983. Monitoring butterflies for ecology and conservation. Chapman & Hall, London.

Royer, R. A., J. E. Austin, and W. E. Newton. 1998. Checklist and "Pollard walk" butterfly survey methods on public lands. American Midland Naturalist 140: 358–371.

Schultz, C. B., and P. W. Hammond. 2003. Using population viability analysis to develop recovery criteria for endangered insects: case study of the Fender's blue butterfly. Conservation Biology 17: 1372–1385.

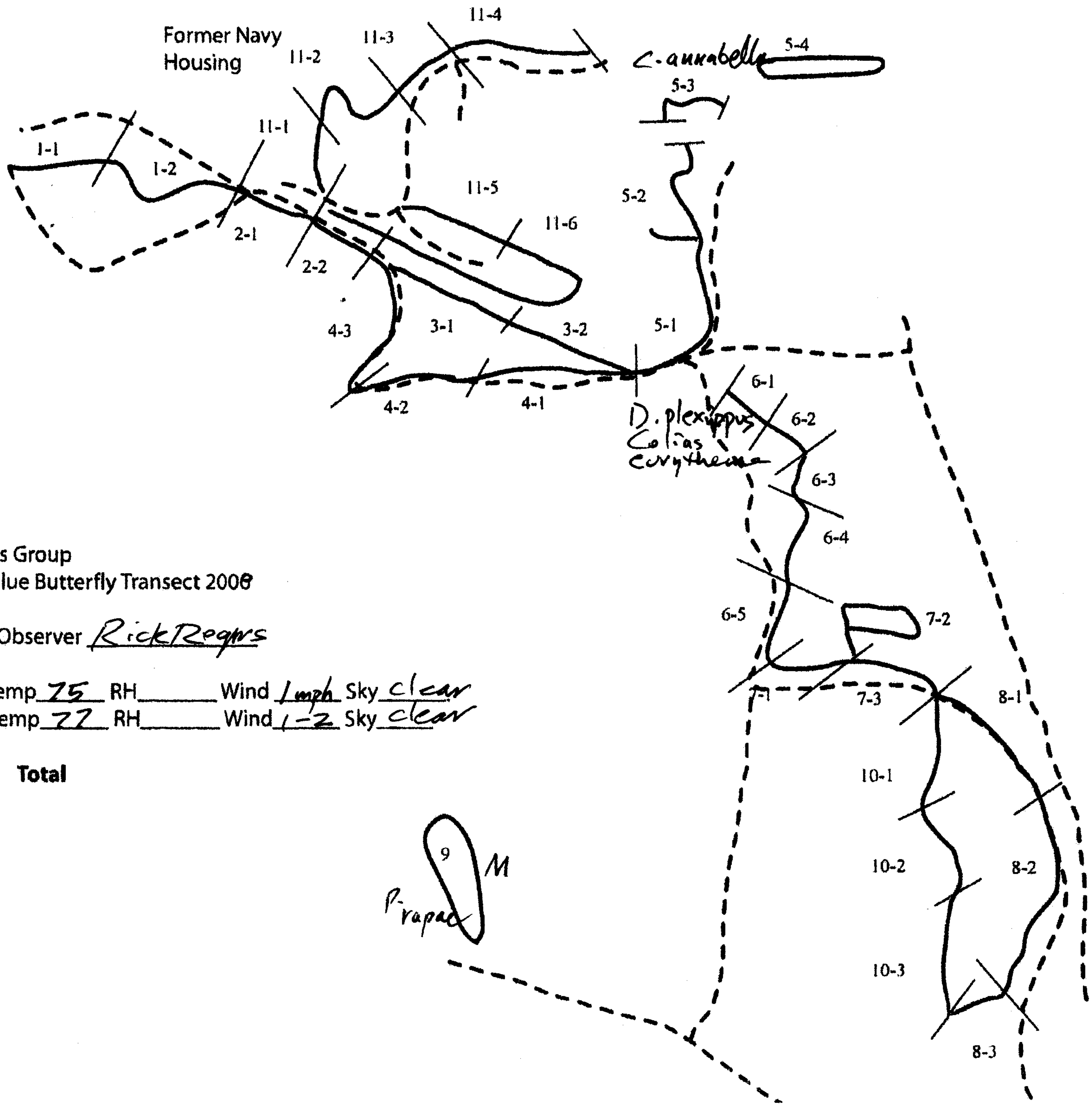
Singer, M. C., and P. Wedlake. 1981. Capture does affect probability of recapture in a butterfly species. Ecological Entomology 6: 215–216.

Watt, W. B., F. S. Chew, L. R. G. Snyder, A. G. Watt, and D. E. Rothschild. 1977. Population structures of Pierid butterflies I. Numbers and movements of some montane *Colias* species. Oecologia 27: 1–22.

Zonneveld, C. 1991. Estimating death rates from transect counts. Ecological Entomology 16: 115–121.

Zonneveld, C., T. Longcore, and C. Mulder. 2003. Optimal schemes to detect presence of insect species. Conservation Biology 17: 476–487.

Appendix: Survey Data Sheets



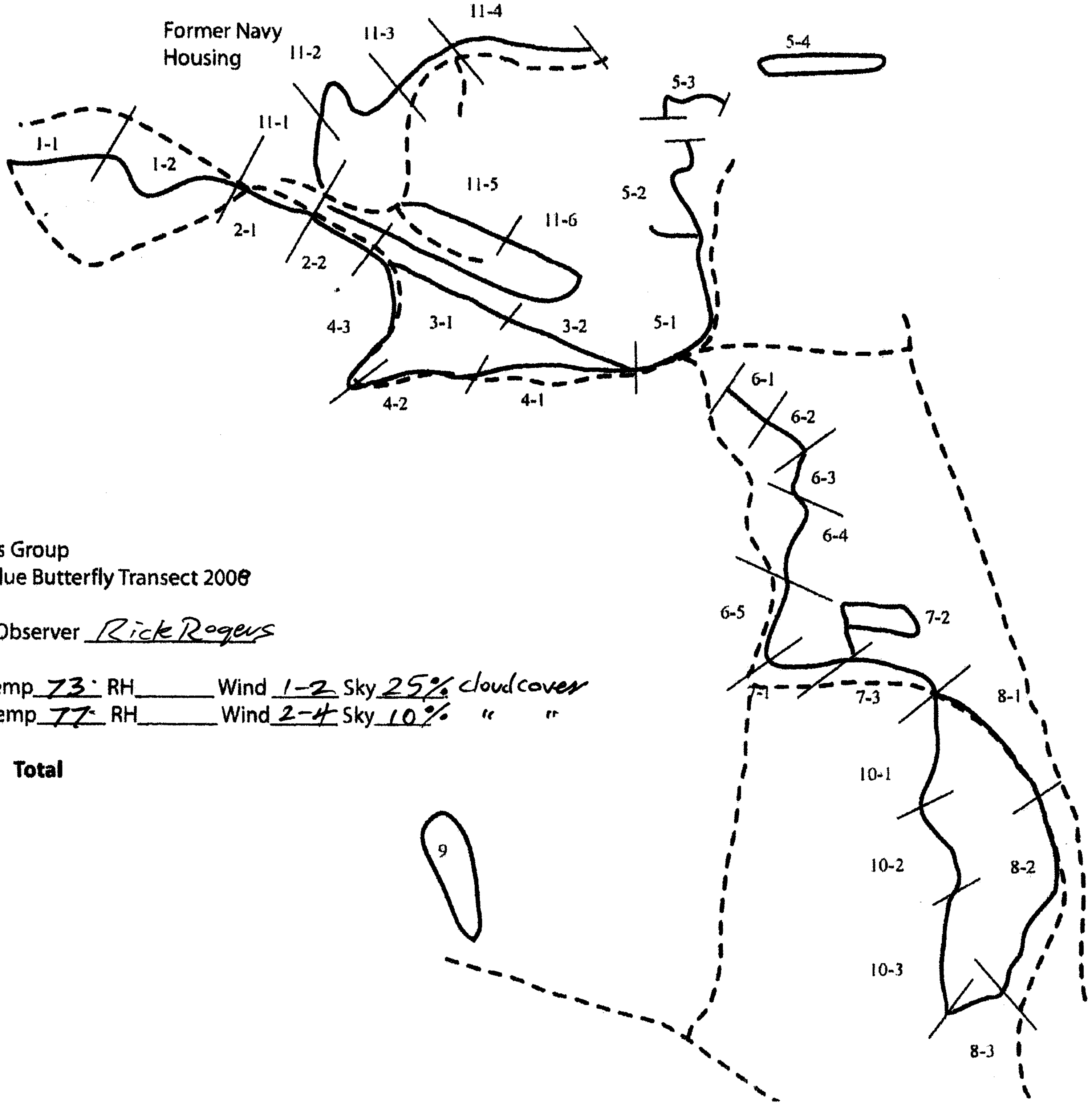
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Jan 17 2011 Observer Rick Rogers

Time start 11:00 Temp 75 RH______ Wind 1 mph Sky clear
Time finish 1:00 Temp 77 RH______ Wind 1-2 Sky clear

Legend **Total**

♀♂	*G. lygdamus*
F	*E. funeralis*
M	*L. marina*
G	*C. perplexa*
H	*S. melinus*
B	*B. diegoensis*



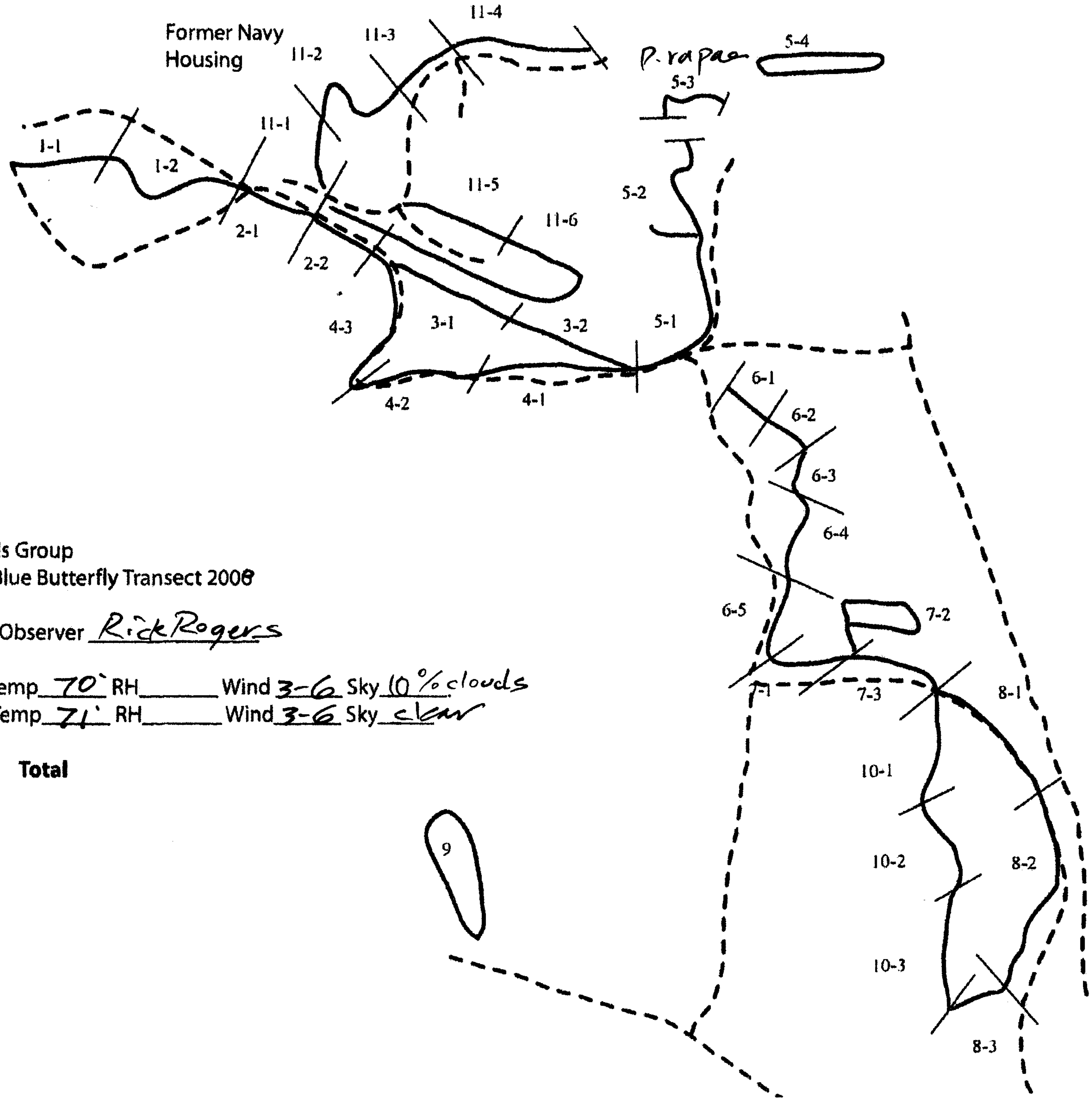
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Jan 26, 2011 Observer Rick Rogers

Time start 11:45 Temp 73° RH______ Wind 1-2 Sky 25% cloudcover
Time finish 1:45 Temp 77° RH______ Wind 2-4 Sky 10% " "

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



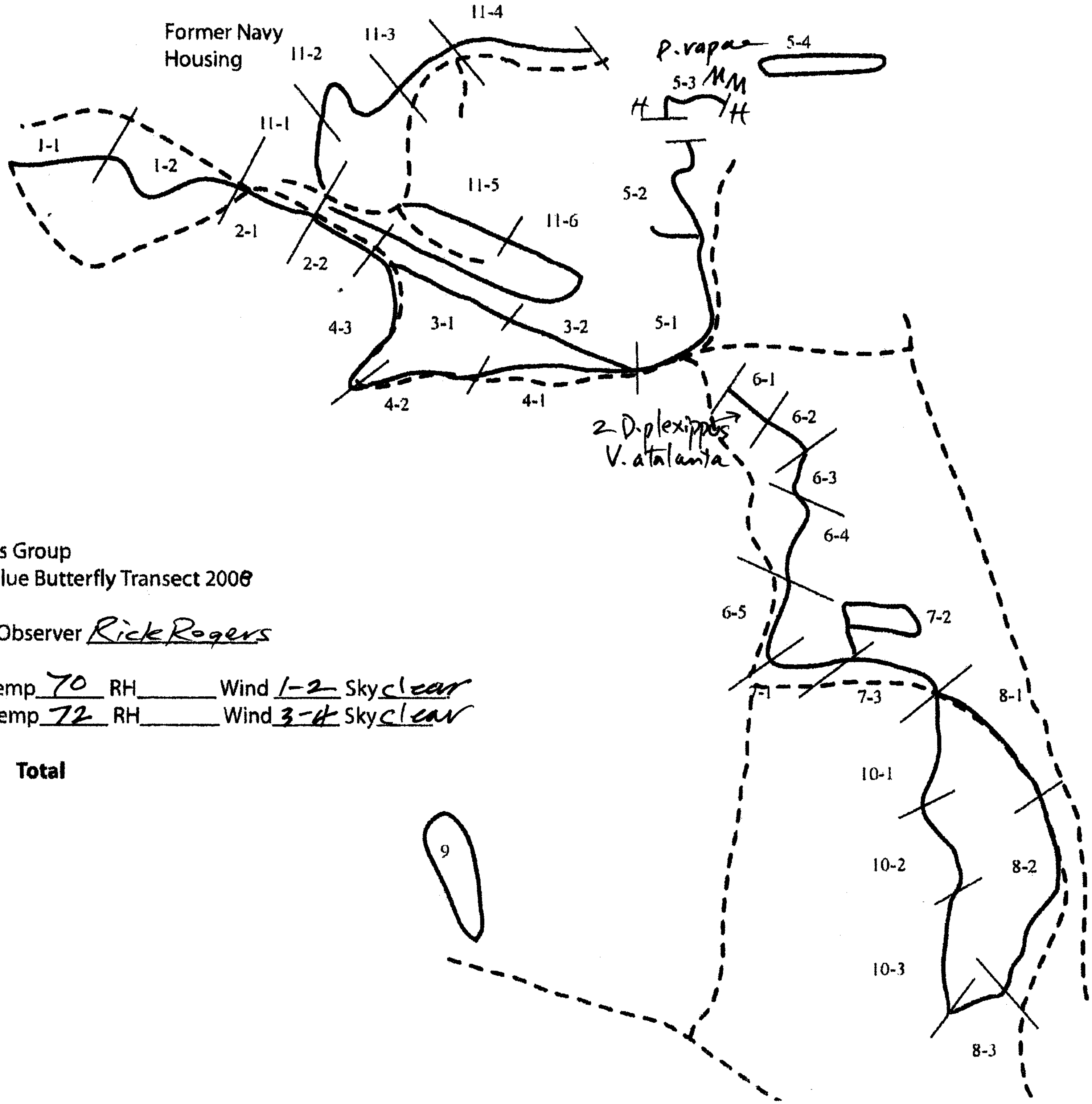
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Feb.4, 2011 Observer Rick Rogers

Time start 10:30 Temp 70° RH______ Wind 3-6 Sky 10% clouds
Time finish 1:30 Temp 71° RH______ Wind 3-6 Sky clear

Legend		Total
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



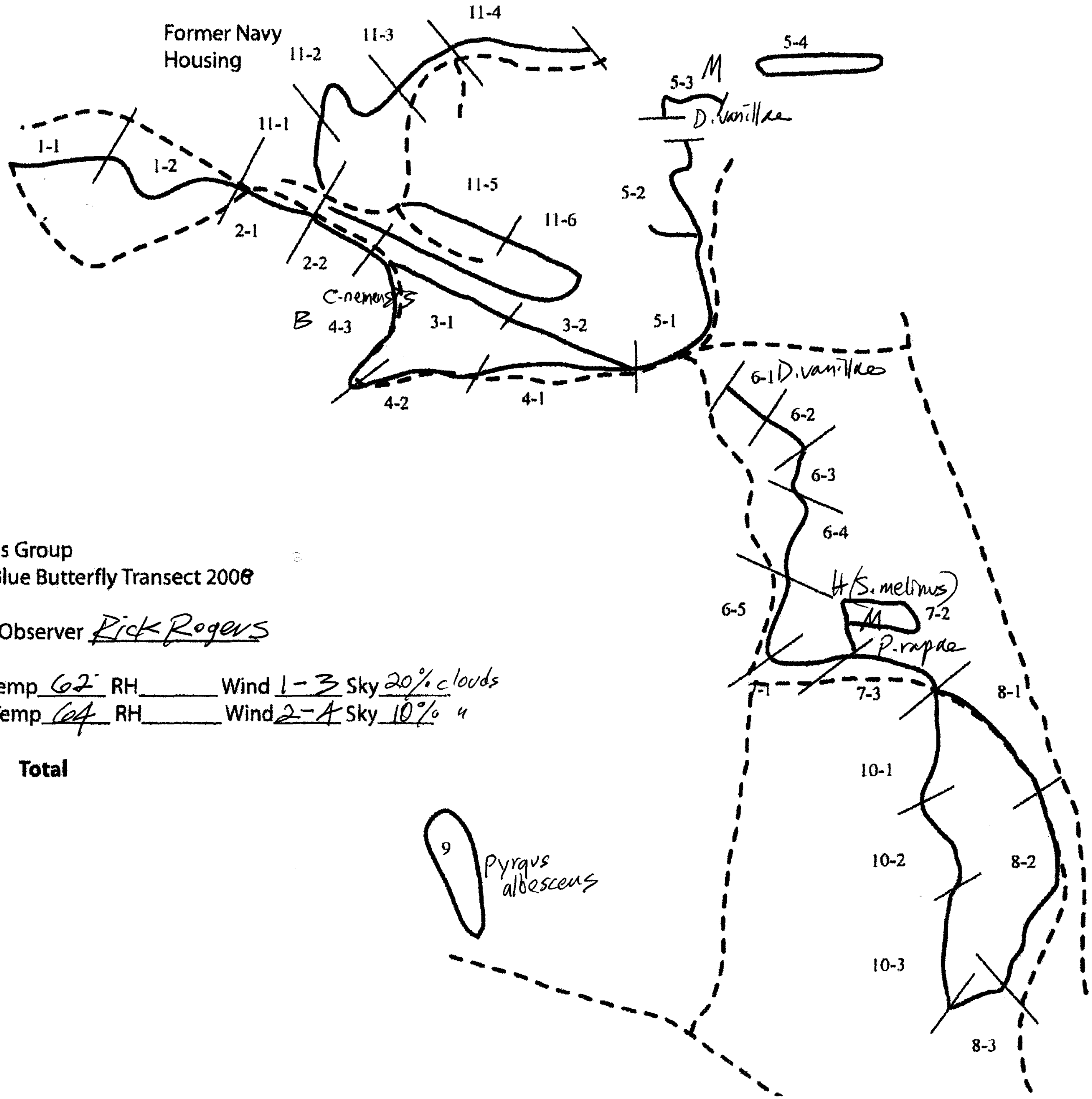
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Feb 10, 2011 Observer Rick Rogers

Time start 10:30 Temp 70 RH_______ Wind 1-2 Sky clear
Time finish 1:30 Temp 72 RH_______ Wind 3-4 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

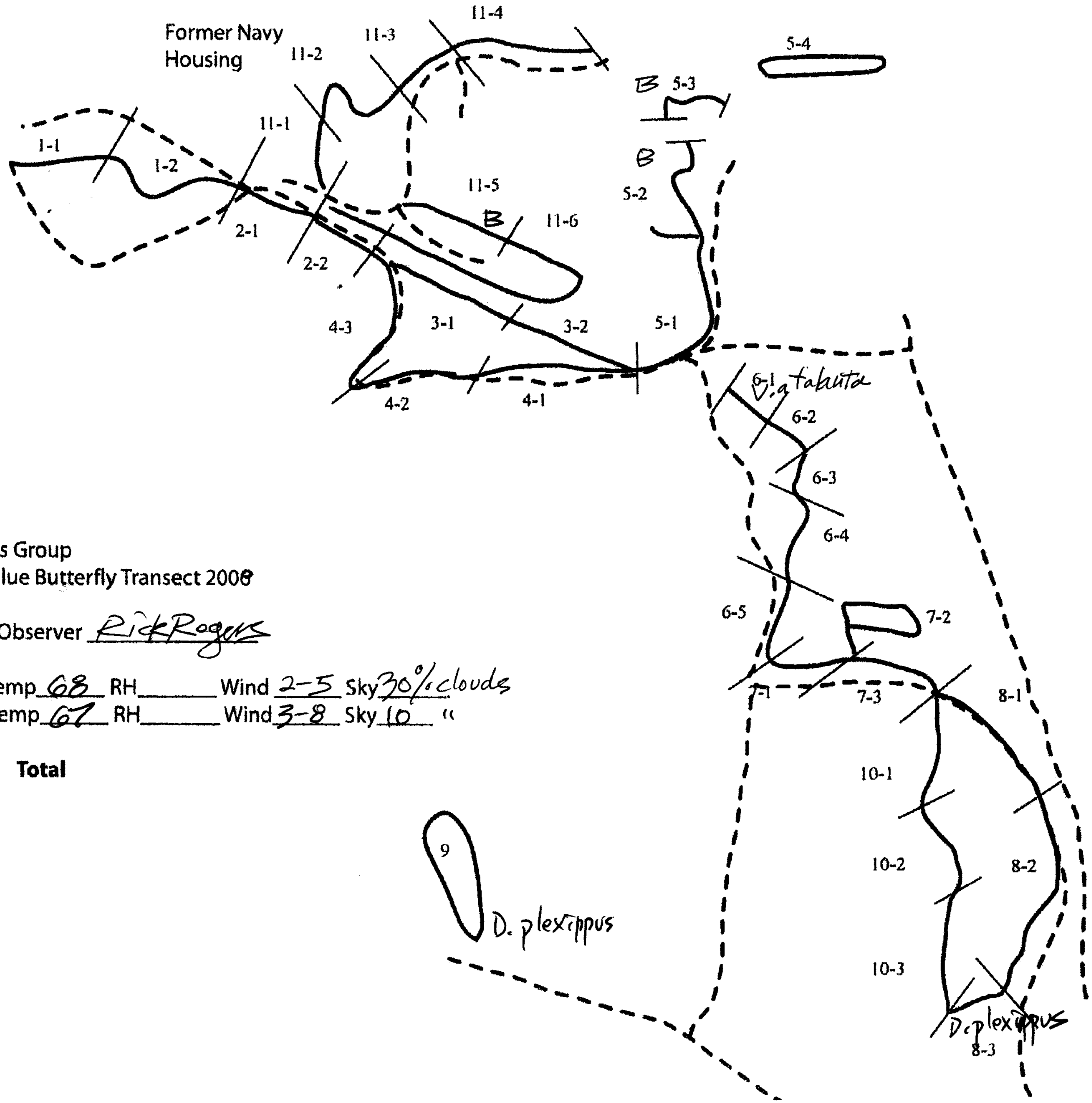
Date Feb. 21, 2011 Observer Rick Rogers

Time start 12:00 Temp 62° RH______ Wind 1-3 Sky 20% clouds
Time finish 2:00 Temp 64 RH______ Wind 2-4 Sky 10% "

Legend **Total**

♀♂ *G. lygdamus*
F *E. funeralis*
M *L. marina*
G *C. perplexa*
H *S. melinus*
B *B. diegoensis*

No PVB's



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

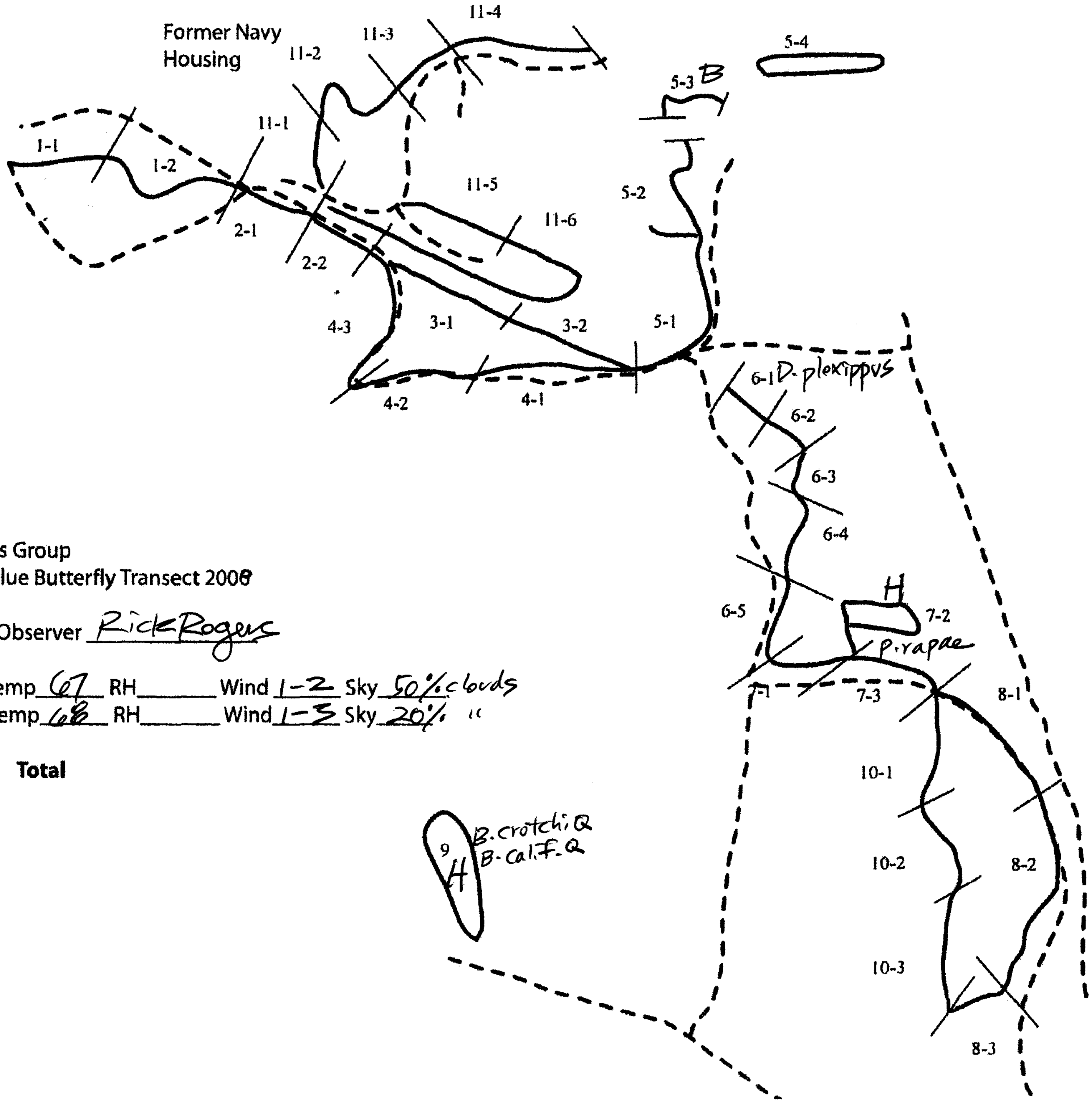
Date Feb 23, 2011 Observer Rick Rogers

Time start 11:25 Temp 68 RH______ Wind 2-5 Sky 30% clouds
Time finish 1:25 Temp 67 RH______ Wind 3-8 Sky 10 "

Legend **Total**

♀♂	*G. lygdamus*
F	*E. funeralis*
M	*L. marina*
G	*C. perplexa*
H	*S. melinus*
B	*B. diegoensis*

No PVB's



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

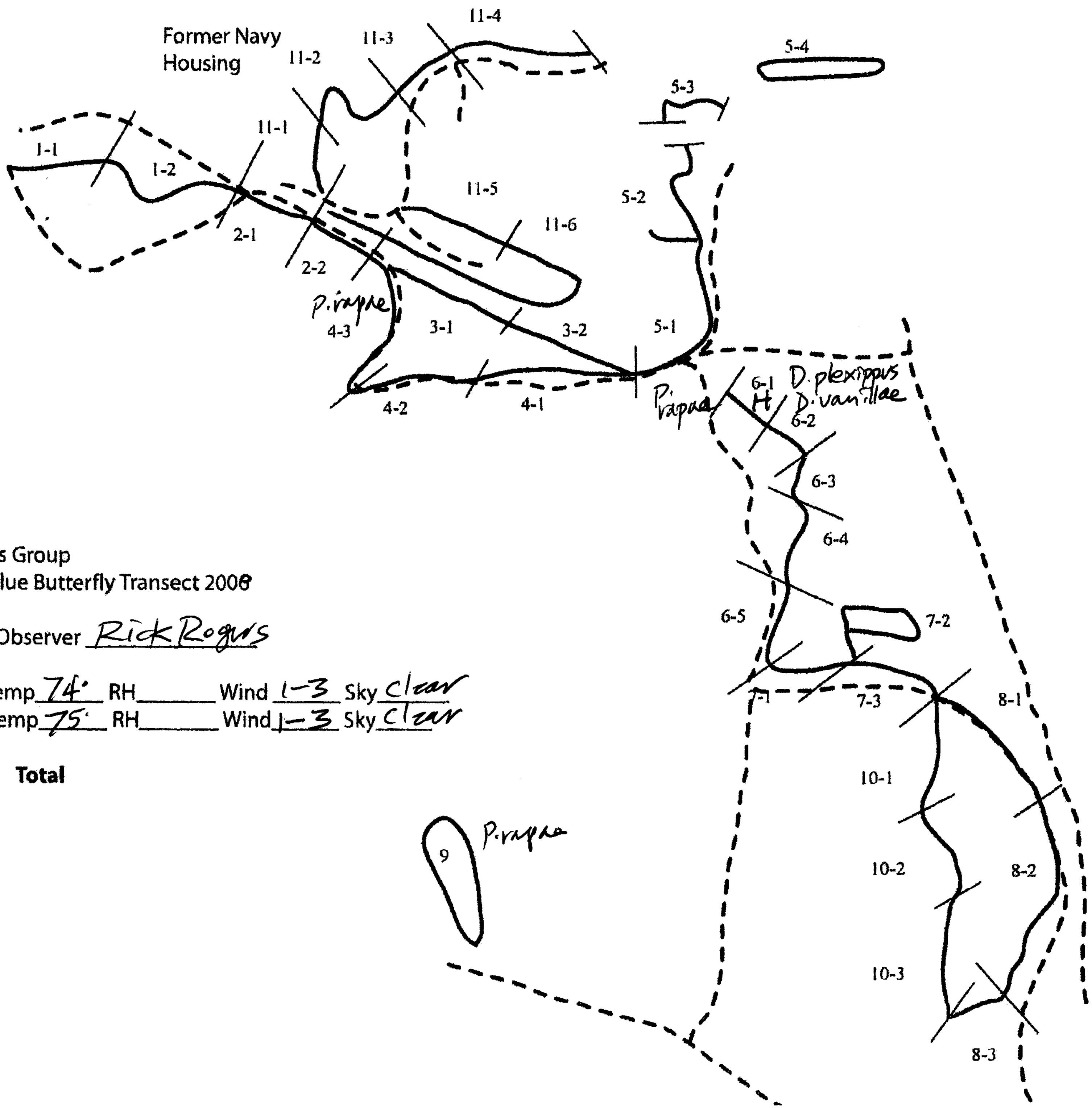
Date Mar 1, 2011 Observer Rick Rogers

Time start 11:25 Temp 67 RH ______ Wind 1-2 Sky 50% clouds
Time finish 1:25 Temp 68 RH ______ Wind 1-3 Sky 20% "

Legend **Total**

♀♂	*G. lygdamus*
F	*E. funeralis*
M	*L. marina*
G	*C. perplexa*
H	*S. melinus*
B	*B. diegoensis*

No PVB's



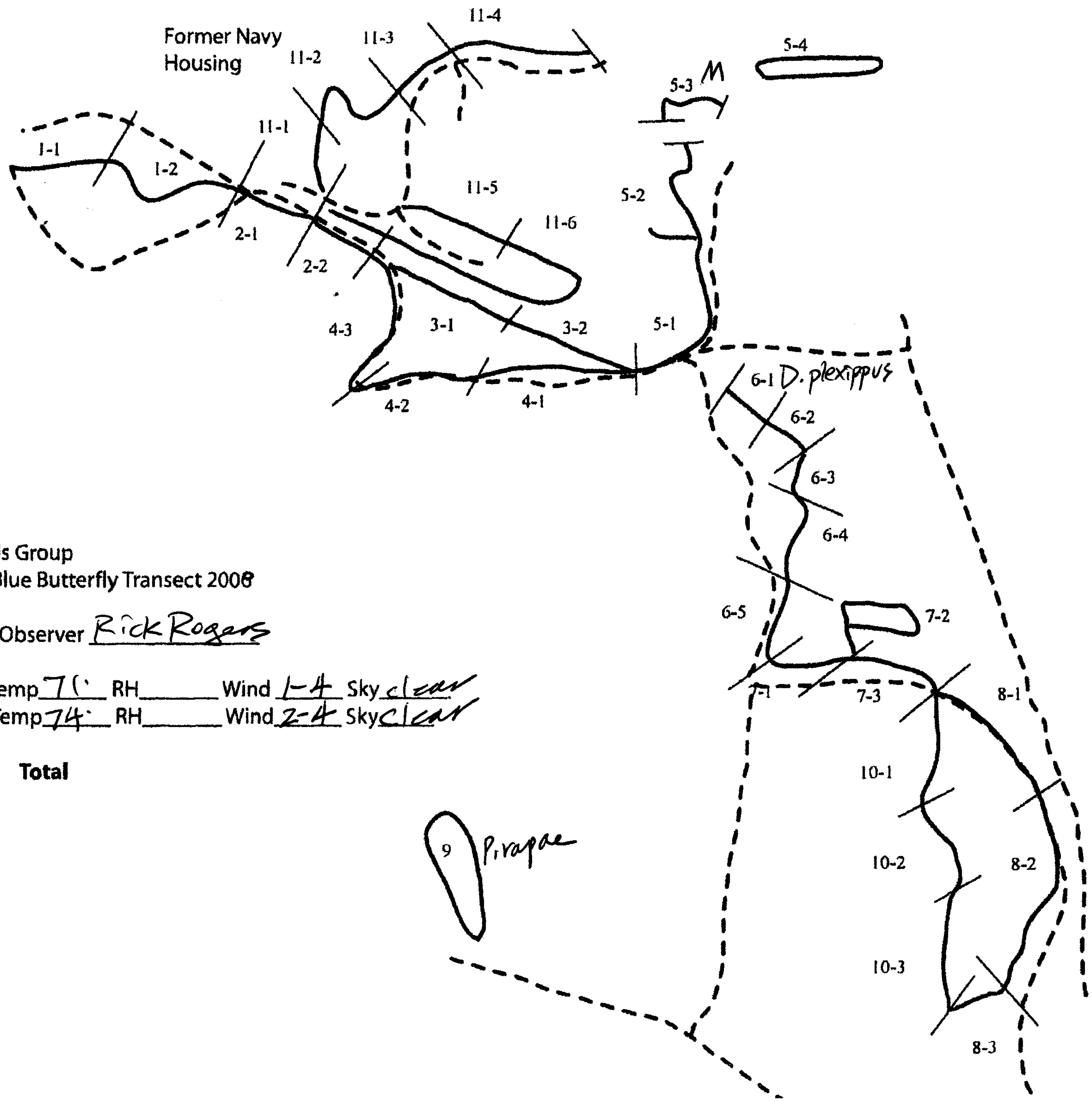
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 4, 2011 Observer Rick Rogers

Time start 11:20 Temp 74° RH______ Wind 1-3 Sky Clear
Time finish 1:20 Temp 75° RH______ Wind 1-3 Sky Clear

Legend		Total
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



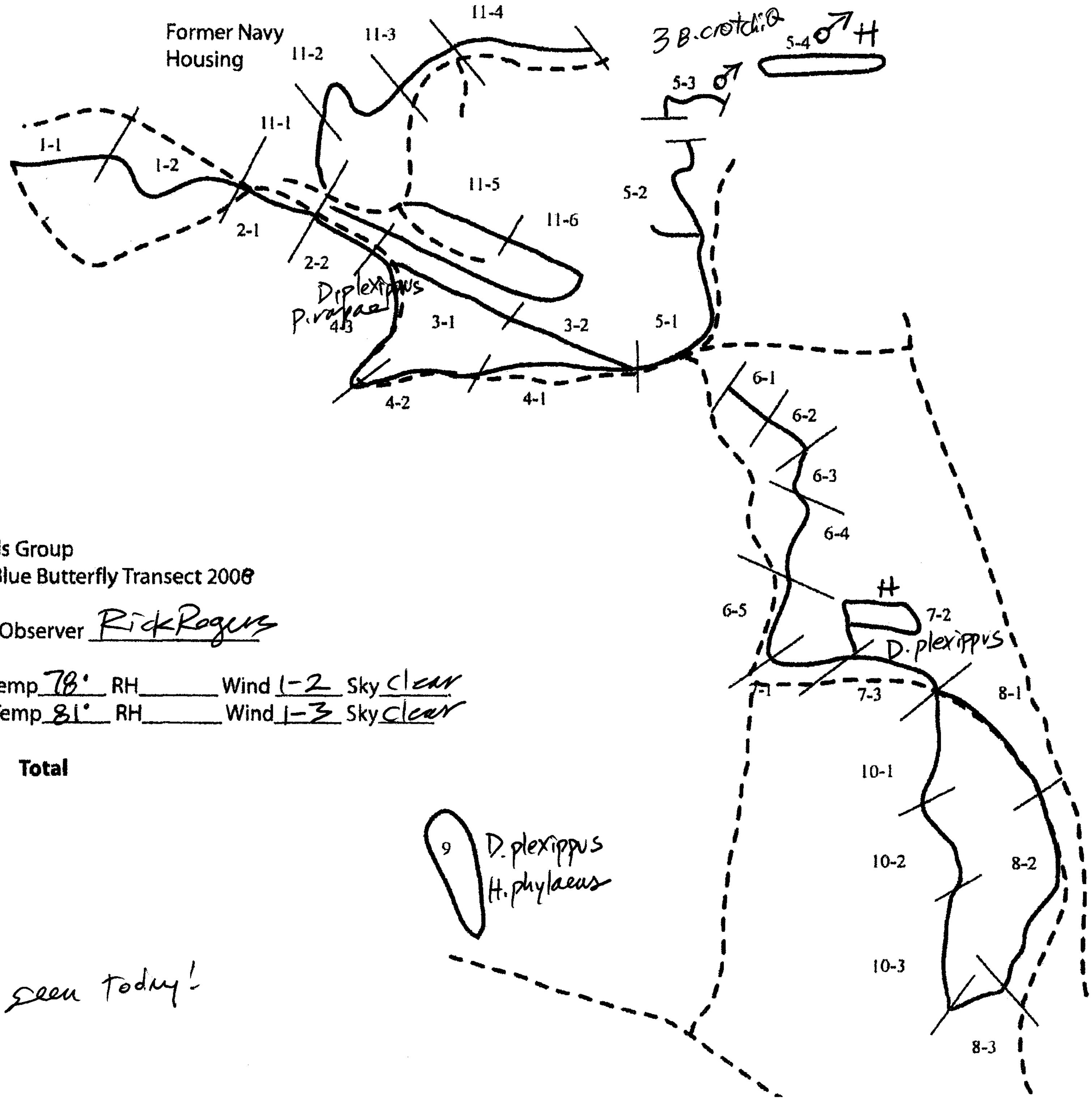
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 8, 2011 Observer Rick Rogers

Time start 11:00 Temp 71° RH______ Wind 1-4 Sky clear
Time finish 1:00 Temp 74° RH______ Wind 2-4 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



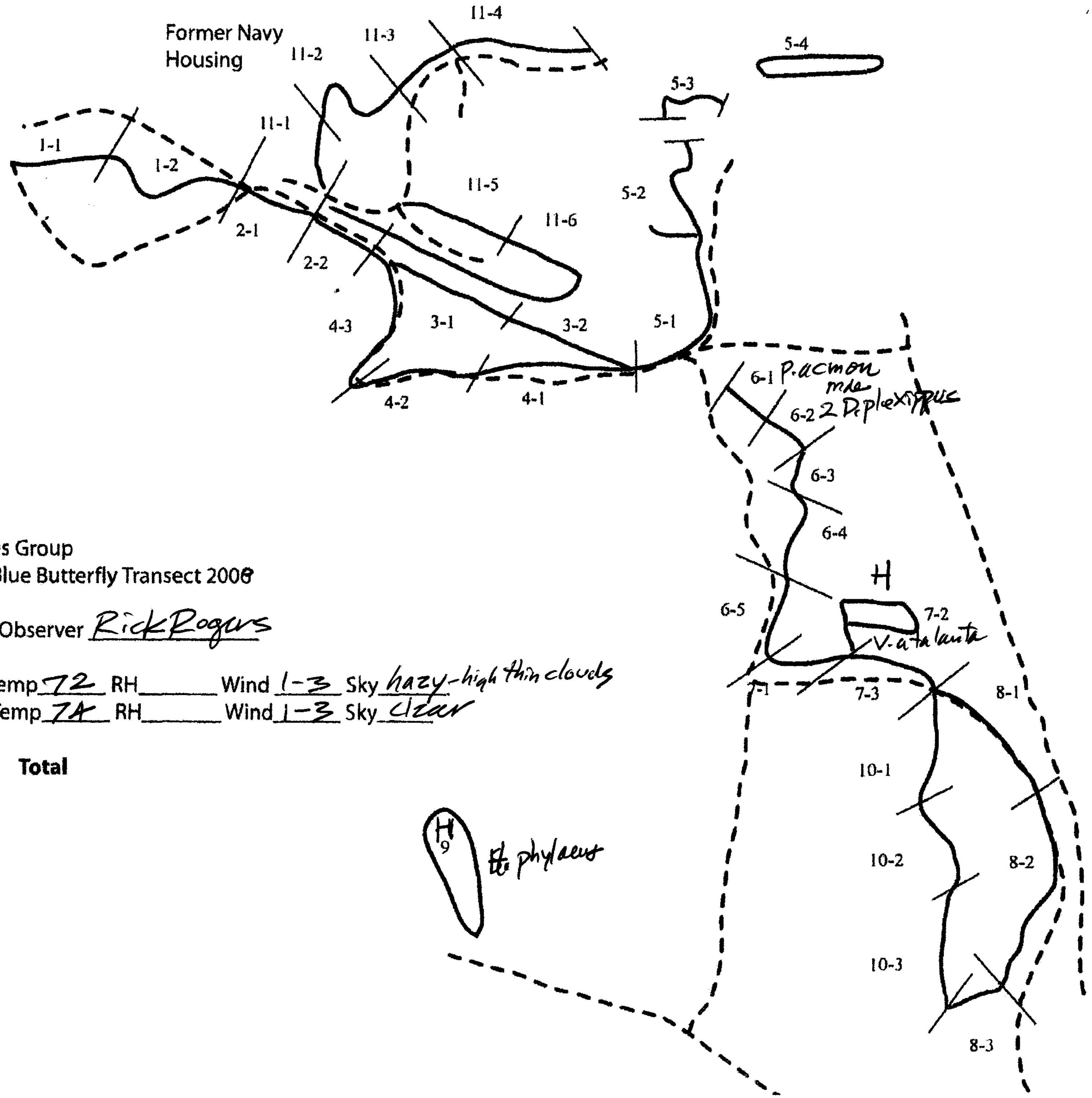
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 10, 2011 Observer Rick Rogers

Time start 12:00 Temp 78° RH______ Wind 1-2 Sky clear
Time finish 2:00 Temp 81° RH______ Wind 1-3 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

2 ♂ PVB's seen today!



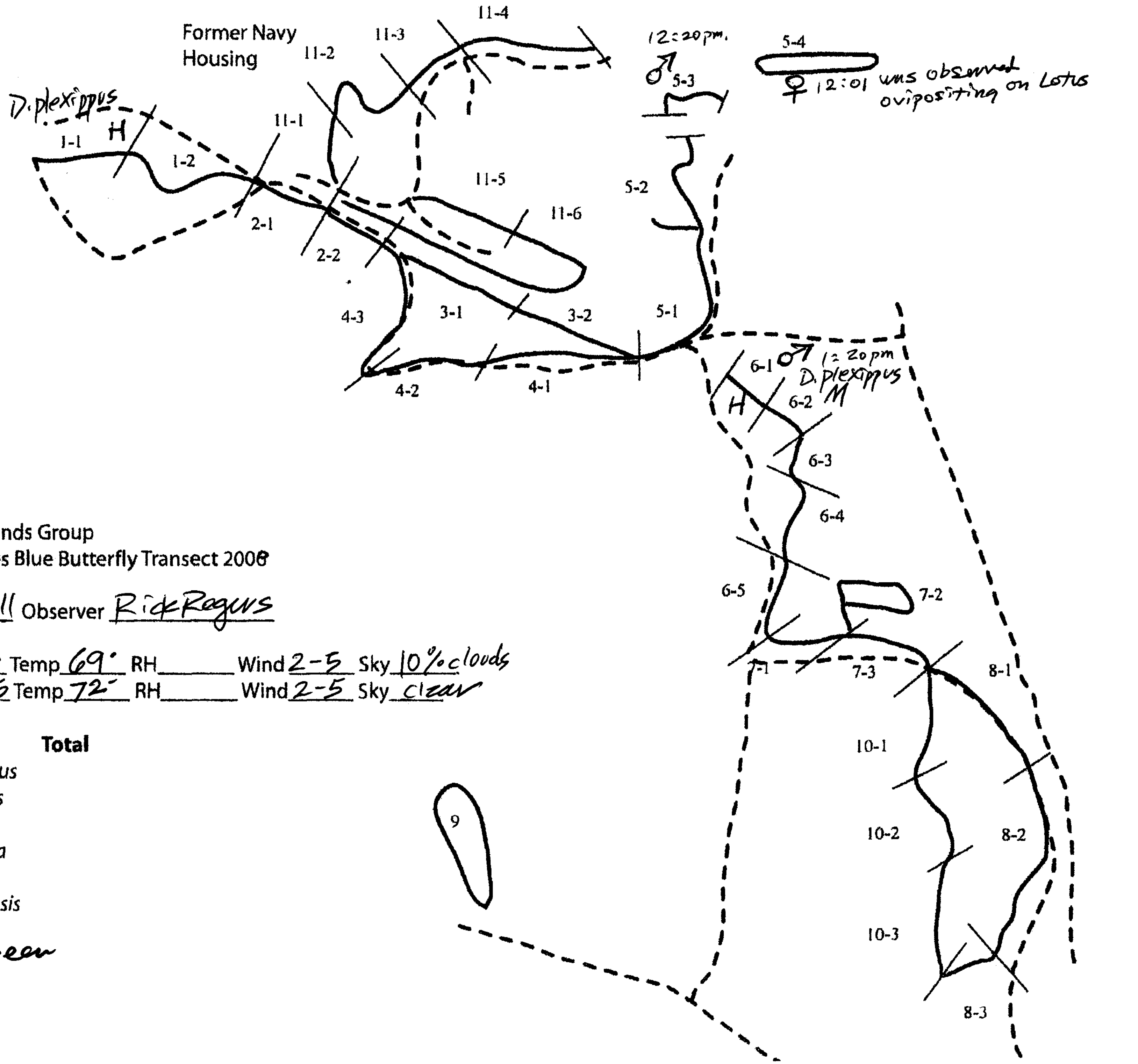
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 14, 2011 Observer Rick Rogers

Time start 11:45 Temp 72 RH______ Wind 1-3 Sky hazy-high thin clouds
Time finish 1:45 Temp 74 RH______ Wind 1-3 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



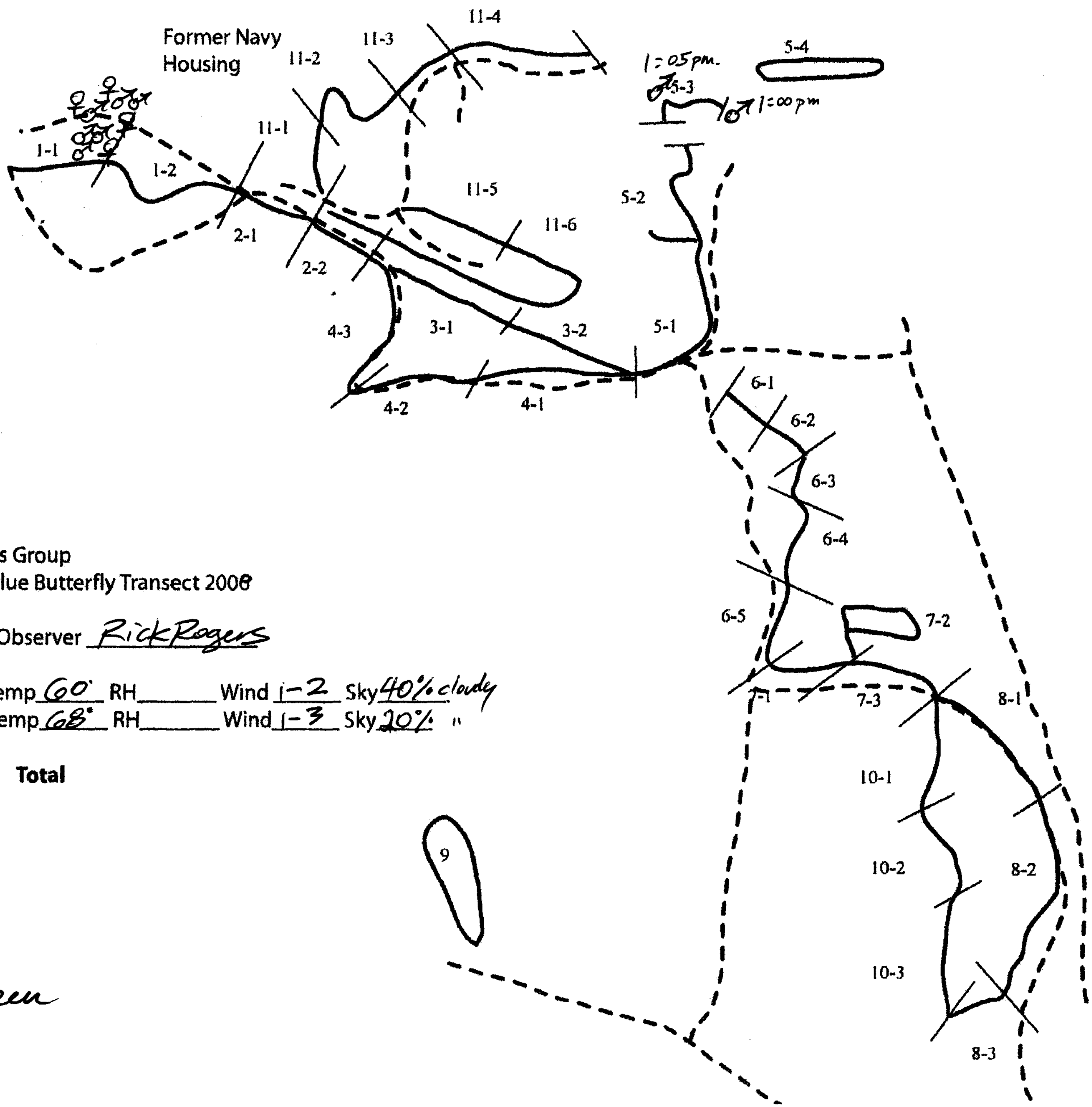
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date mar 16, 2011 Observer Rick Rogers

Time start 11:45 Temp 69° RH______ Wind 2-5 Sky 10% clouds
Time finish 1:45 Temp 72° RH______ Wind 2-5 Sky clear

Legend		Total
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

3 PVB's seen



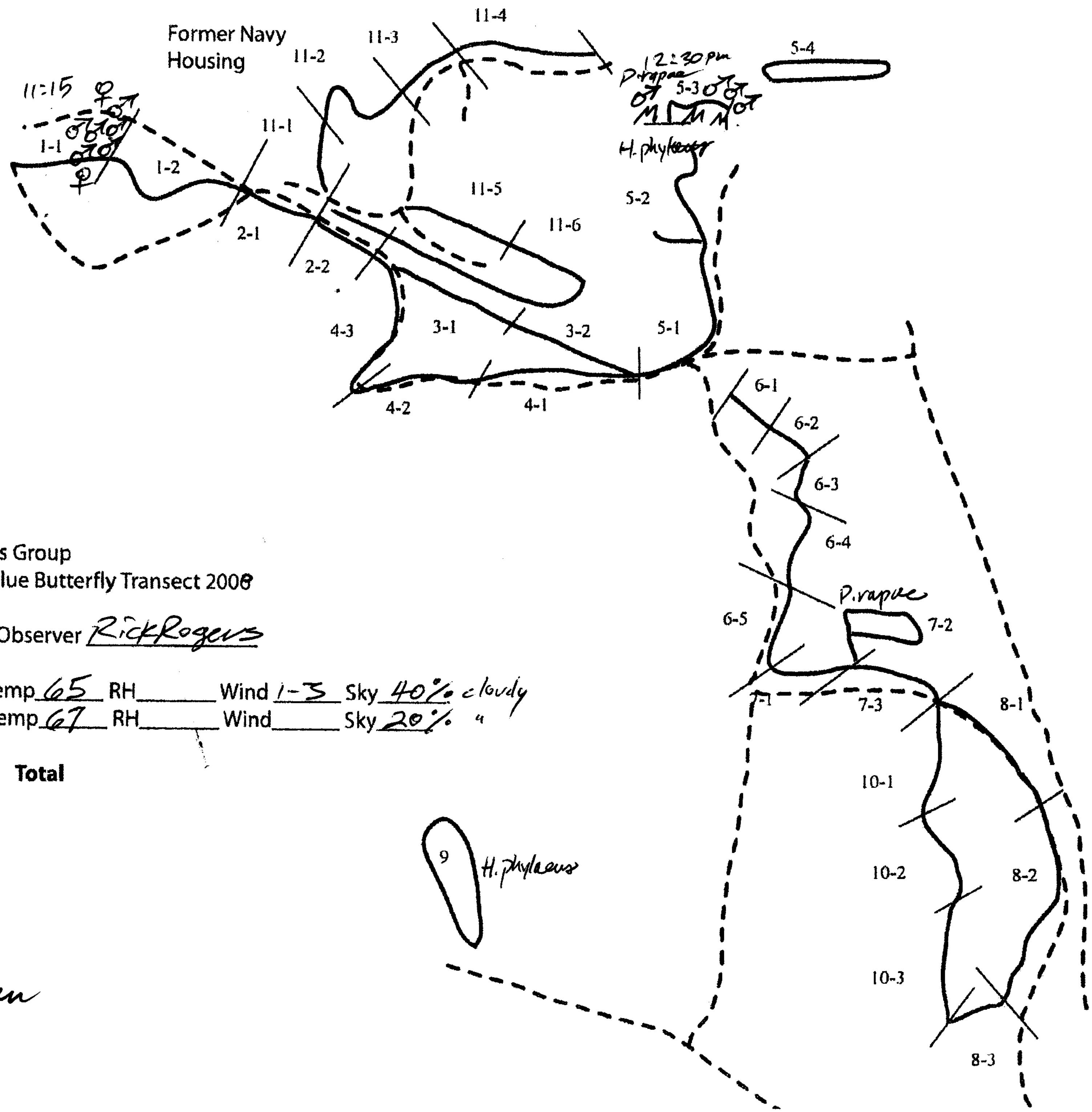
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 22 2011 Observer Rick Rogers

Time start 11:00 Temp 60° RH____ Wind 1-2 Sky 40% cloudy
Time finish 1:00 Temp 68° RH____ Wind 1-3 Sky 20% "

Legend		Total
♀♂	G. lygdamus	
F	E. funeralis	
M	L. marina	
G	C. perplexa	
H	S. melinus	
B	B. diegoensis	

12 PVB's seen



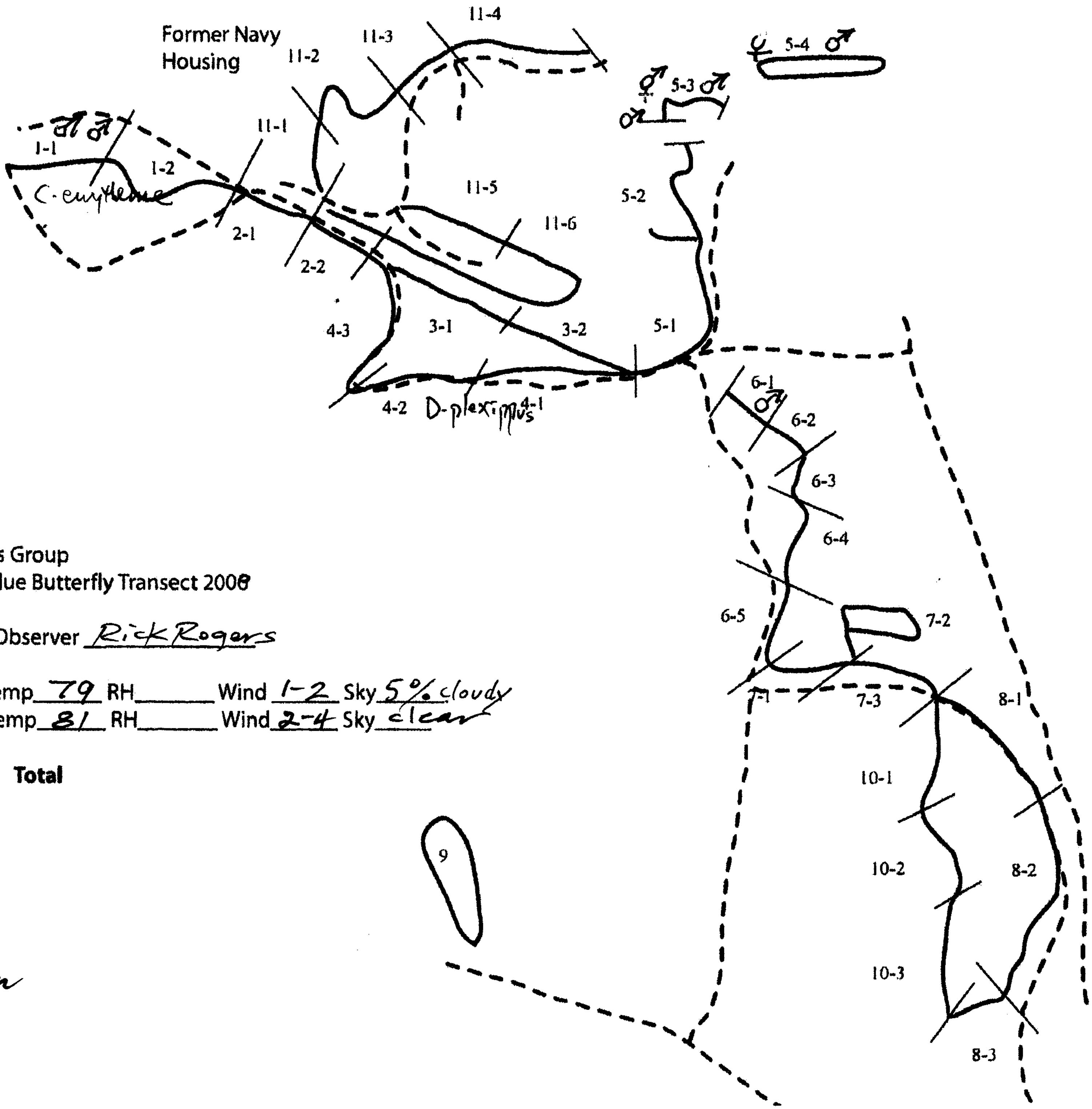
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 24, 2011 Observer Rick Rogers

Time start 11:00 Temp 65 RH_____ Wind 1-3 Sky 40% cloudy
Time finish 1:00 Temp 67 RH_____ Wind_____ Sky 20% "

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

12 PVB's seen



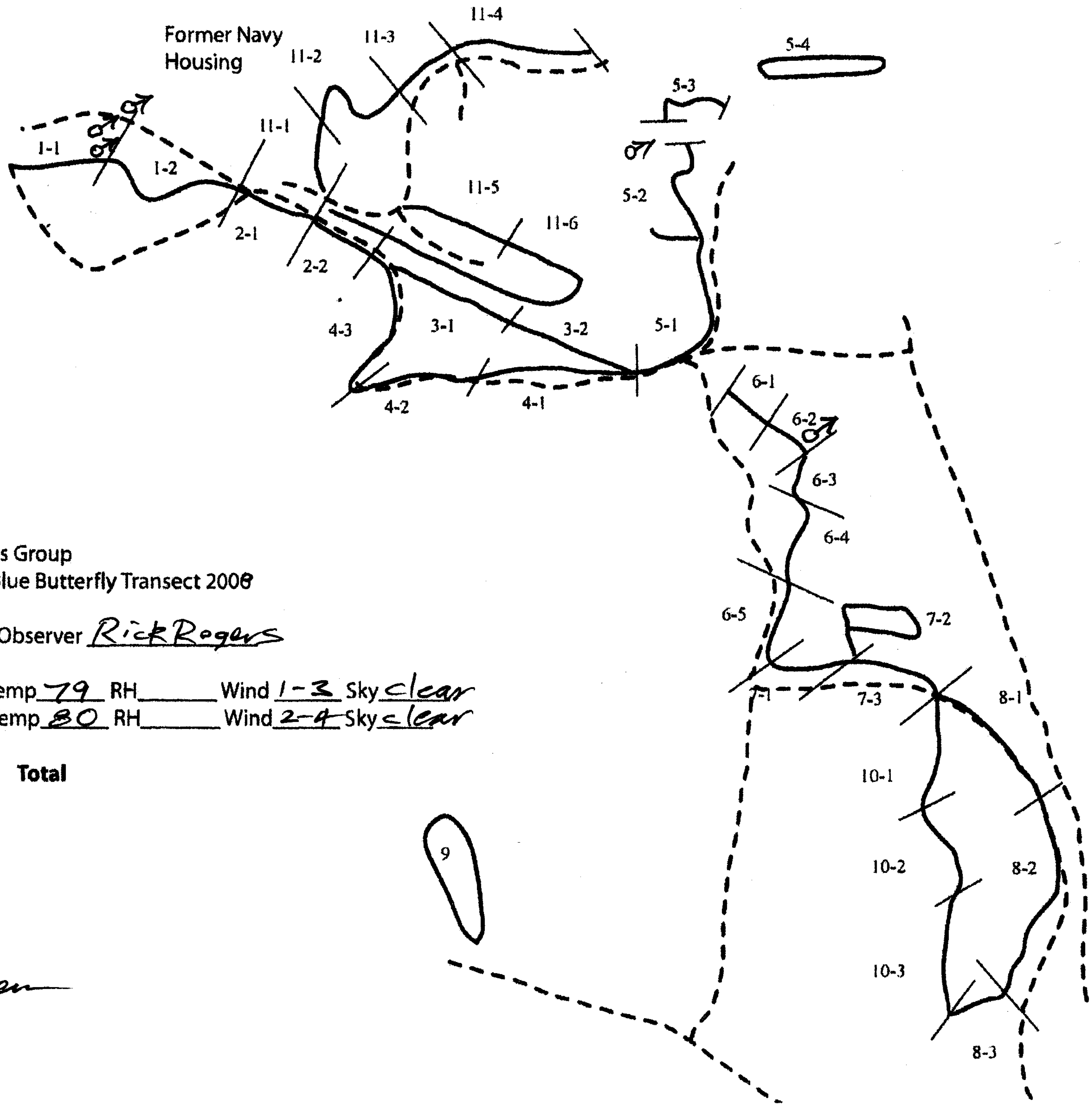
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date Mar 30, 2011 Observer Rick Rogers

Time start 11:18 Temp 79 RH______ Wind 1-2 Sky 5% cloudy
Time finish 1:30 Temp 81 RH______ Wind 2-4 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

8 PVB's seen



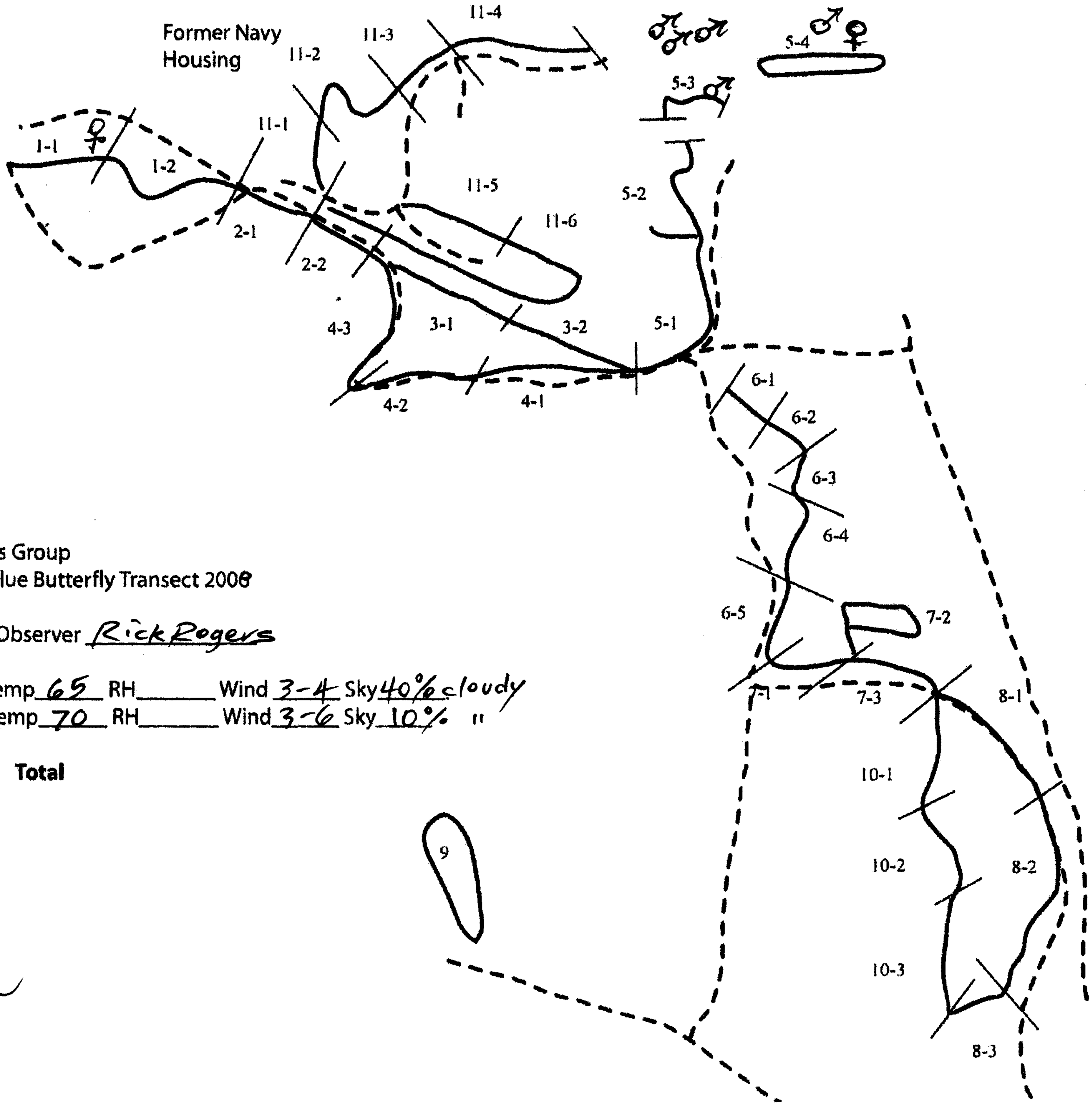
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 1, 2011 Observer Rick Rogers

Time start 11:25 Temp 79 RH______ Wind 1-3 Sky clear
Time finish 1:25 Temp 80 RH______ Wind 2-4 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

5 PVB's seen



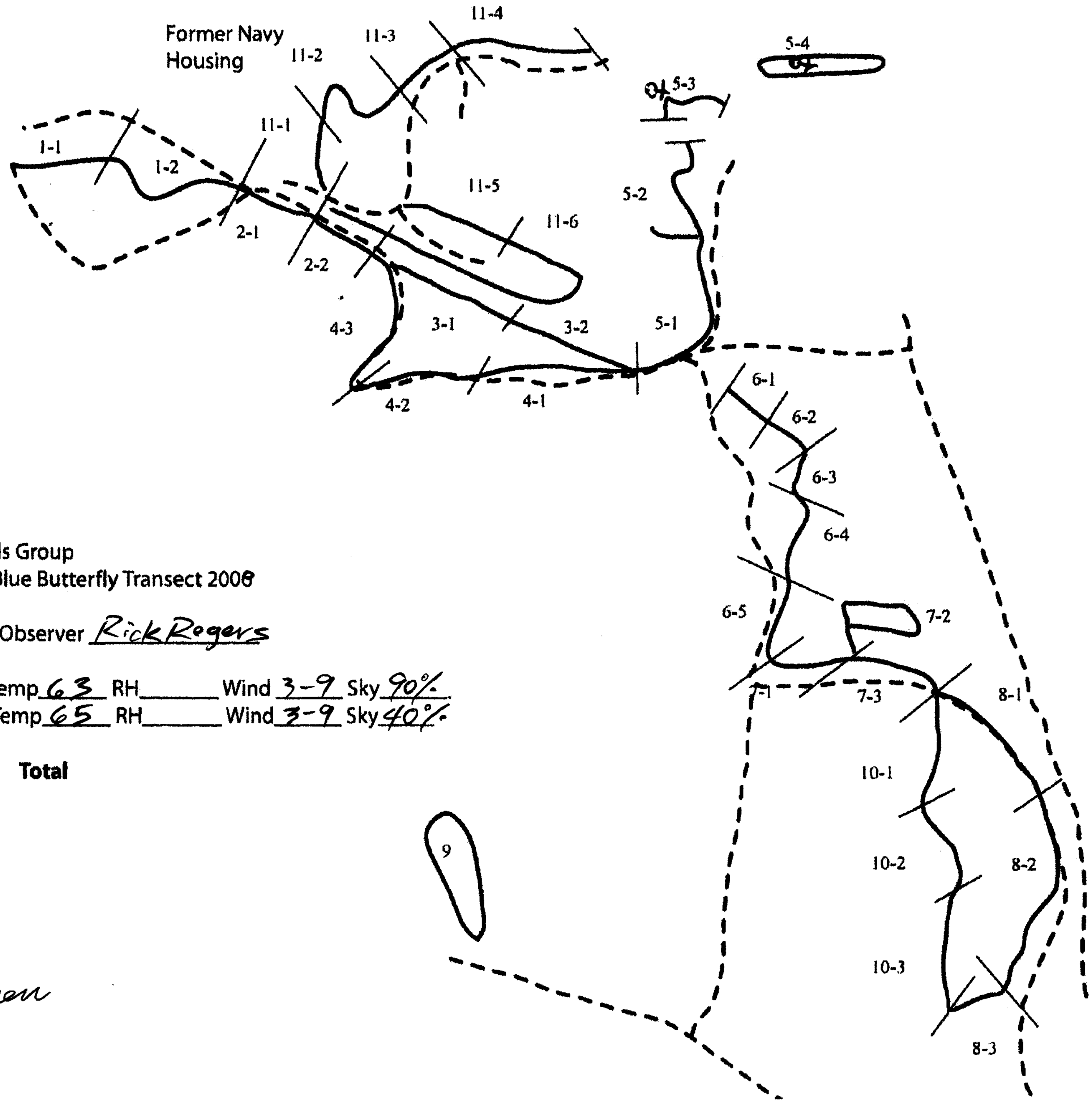
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 5, 2011 Observer Rick Rogers

Time start 10:30 Temp 65 RH______ Wind 3-4 Sky 40% cloudy
Time finish 1:30 Temp 70 RH______ Wind 3-6 Sky 10% "

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

7 PVB's seen



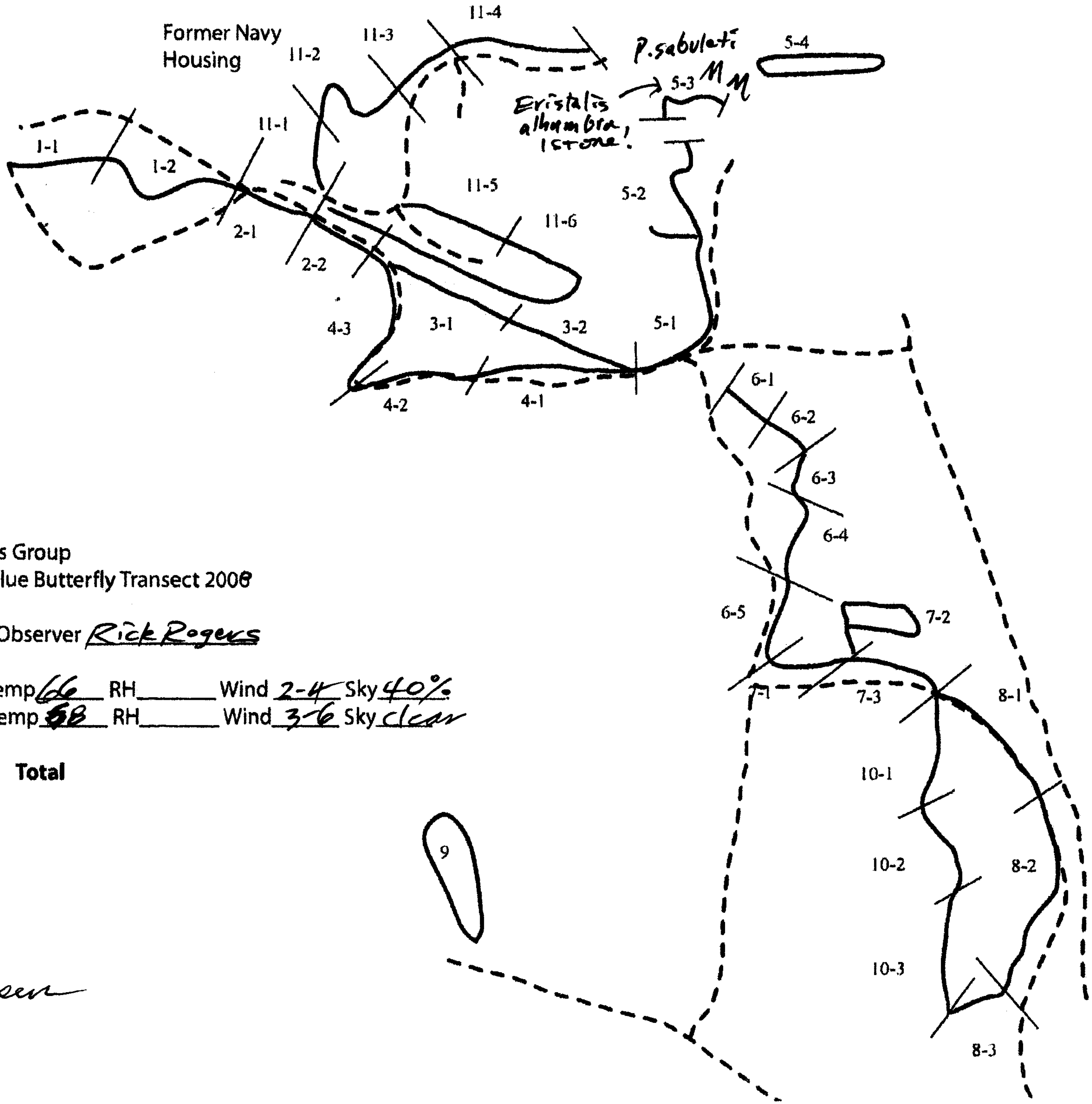
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 7, 2011 Observer Rick Rogers

Time start 11:00 Temp 63 RH______ Wind 3-9 Sky 90%
Time finish 1:00 Temp 65 RH______ Wind 3-9 Sky 40%

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

2 PVB's seen



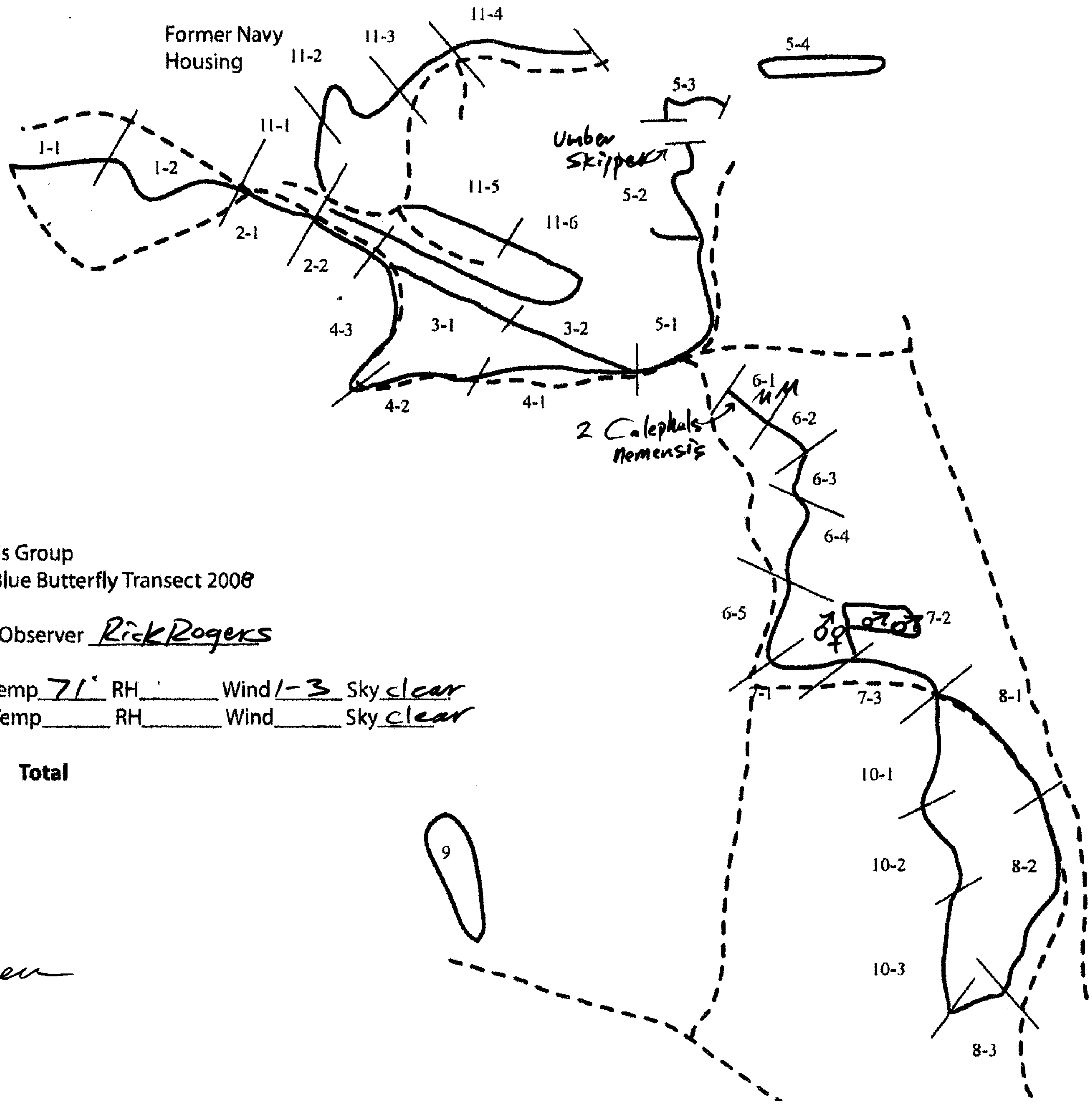
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 12, 2011 Observer Rick Rogers

Time start 11:00 Temp 66 RH______ Wind 2-4 Sky 40%
Time finish 1:00 Temp 58 RH______ Wind 3-6 Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's seen



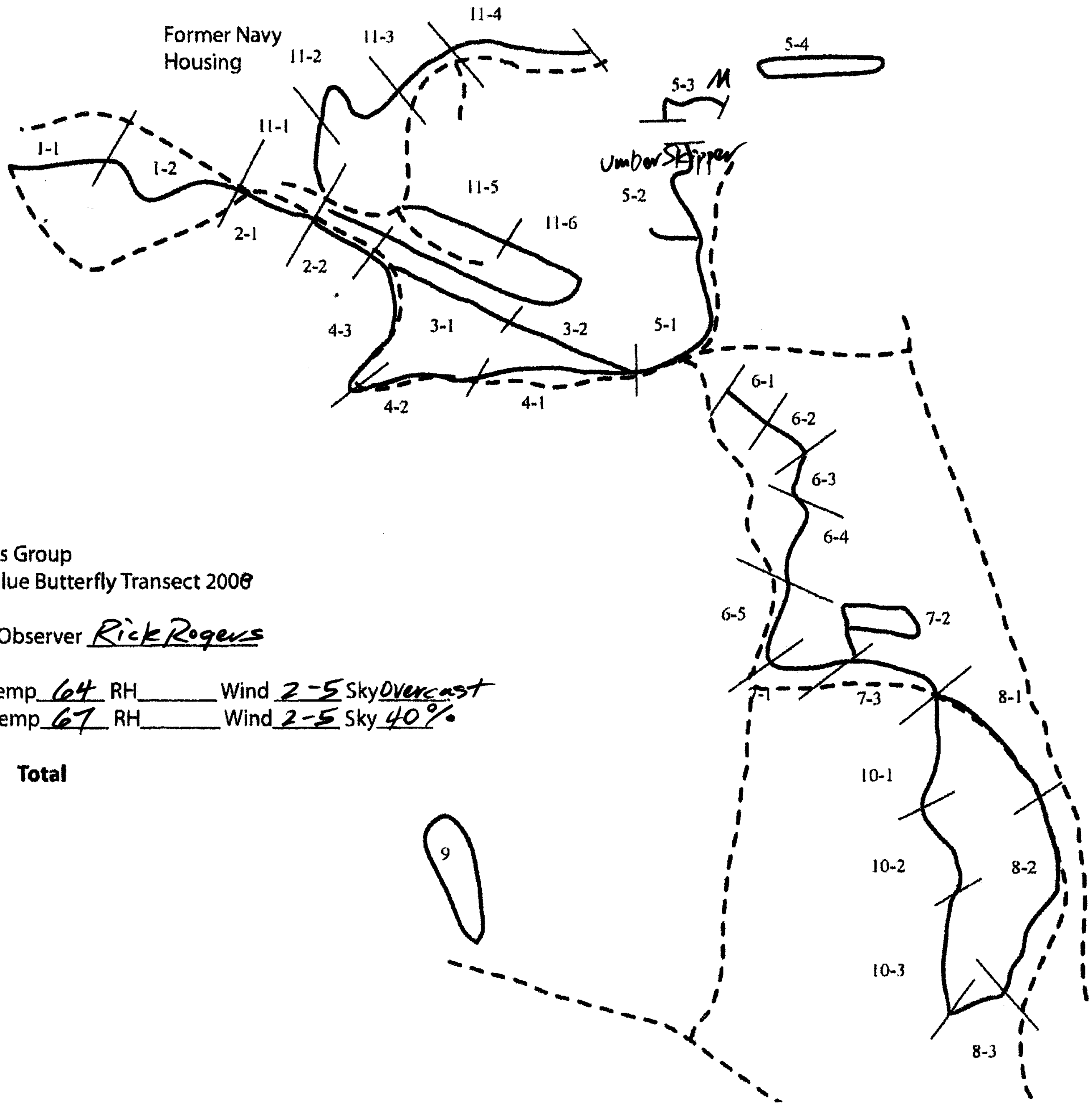
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 14, 2011 Observer Rick Rogers

Time start 11:00 Temp 71° RH______ Wind 1-3 Sky clear
Time finish 1:00 Temp______ RH______ Wind______ Sky clear

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

4 PVB's seen

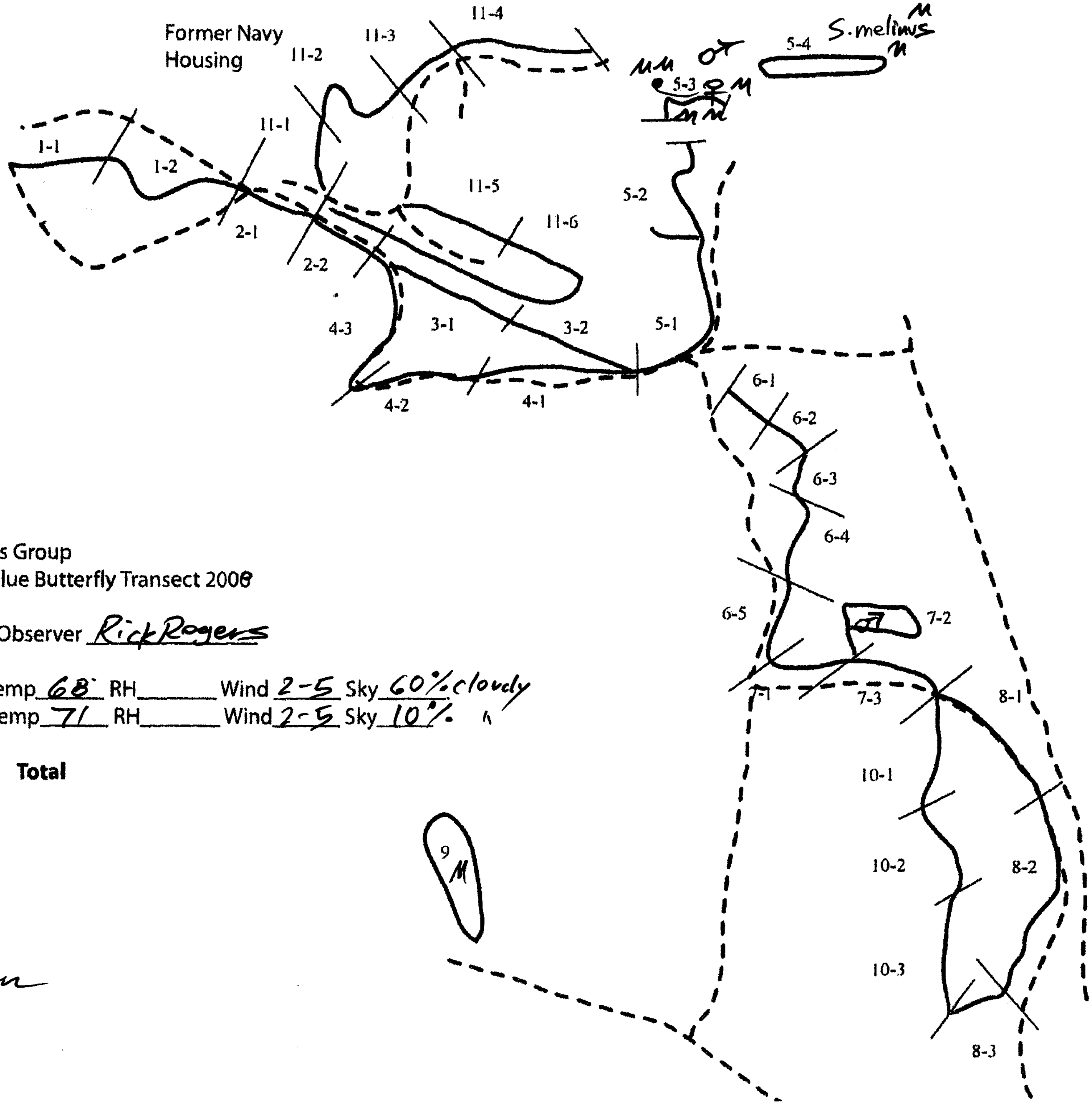


The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 18, 2011 Observer Rick Rogers

Time start 11:30 Temp 64 RH______ Wind 2-5 Sky Overcast
Time finish 1:30 Temp 67 RH______ Wind 2-5 Sky 40%

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	



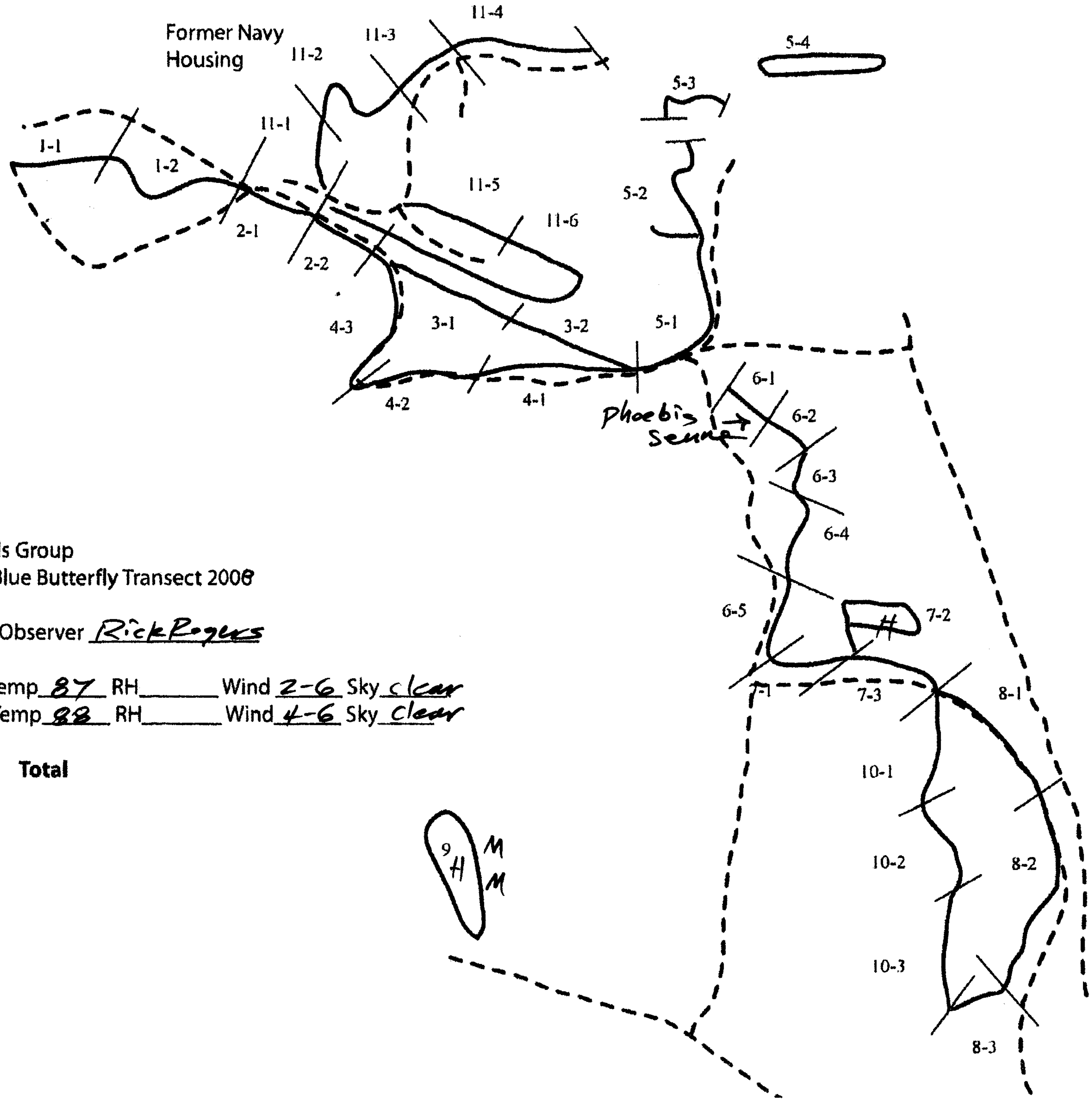
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date April 21, 2011 Observer Rick Rogers

Time start 11:20 Temp 68° RH______ Wind 2-5 Sky 60% cloudy
Time finish 1:20 Temp 71 RH______ Wind 2-5 Sky 10%

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

3 PVB's seen



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

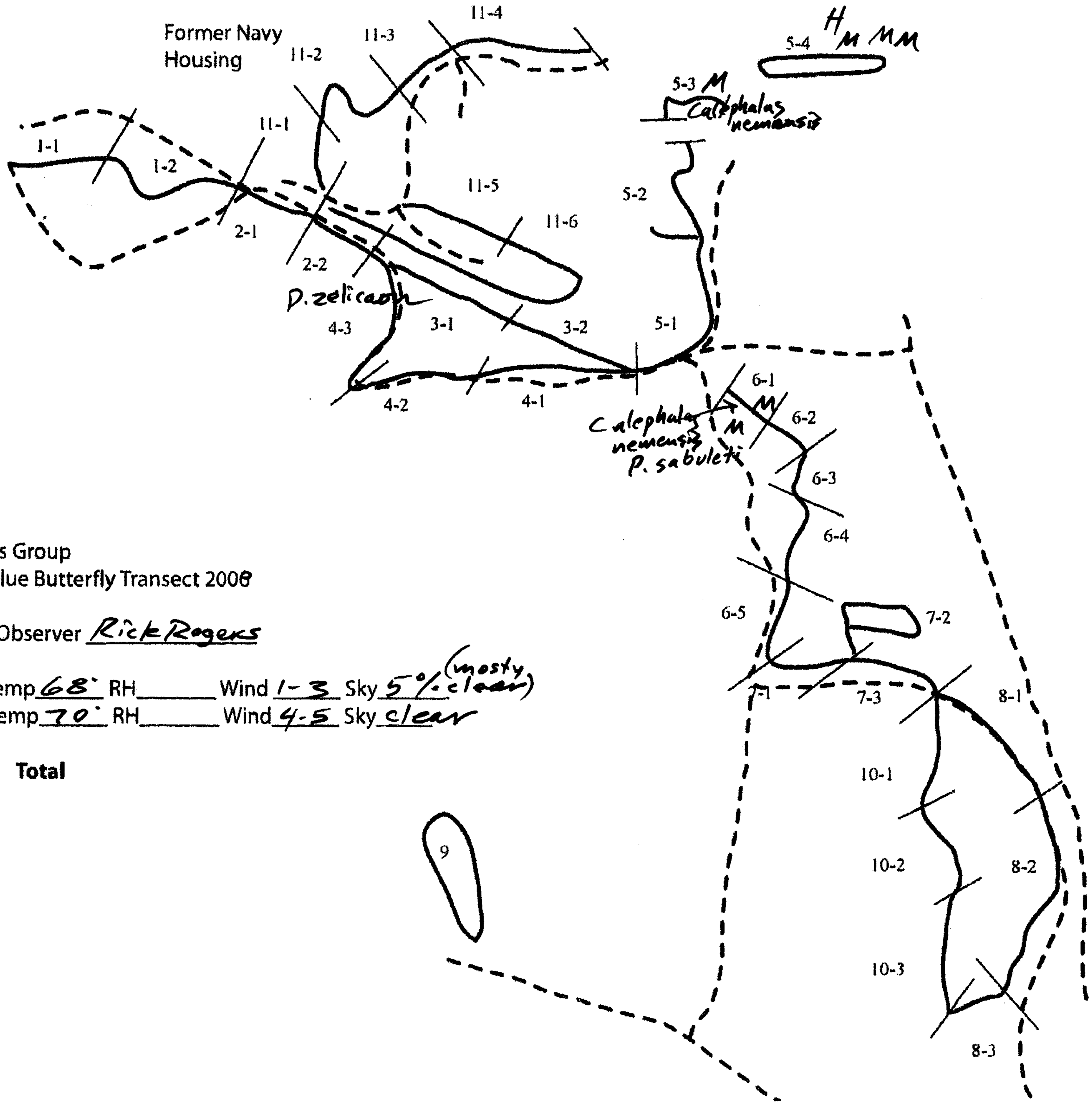
Date April 27, 2011 Observer Rick Rogers

Time start 11:30 Temp 87 RH______ Wind 2-6 Sky clear
Time finish 1:30 Temp 88 RH______ Wind 4-6 Sky Clear

Legend **Total**

♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

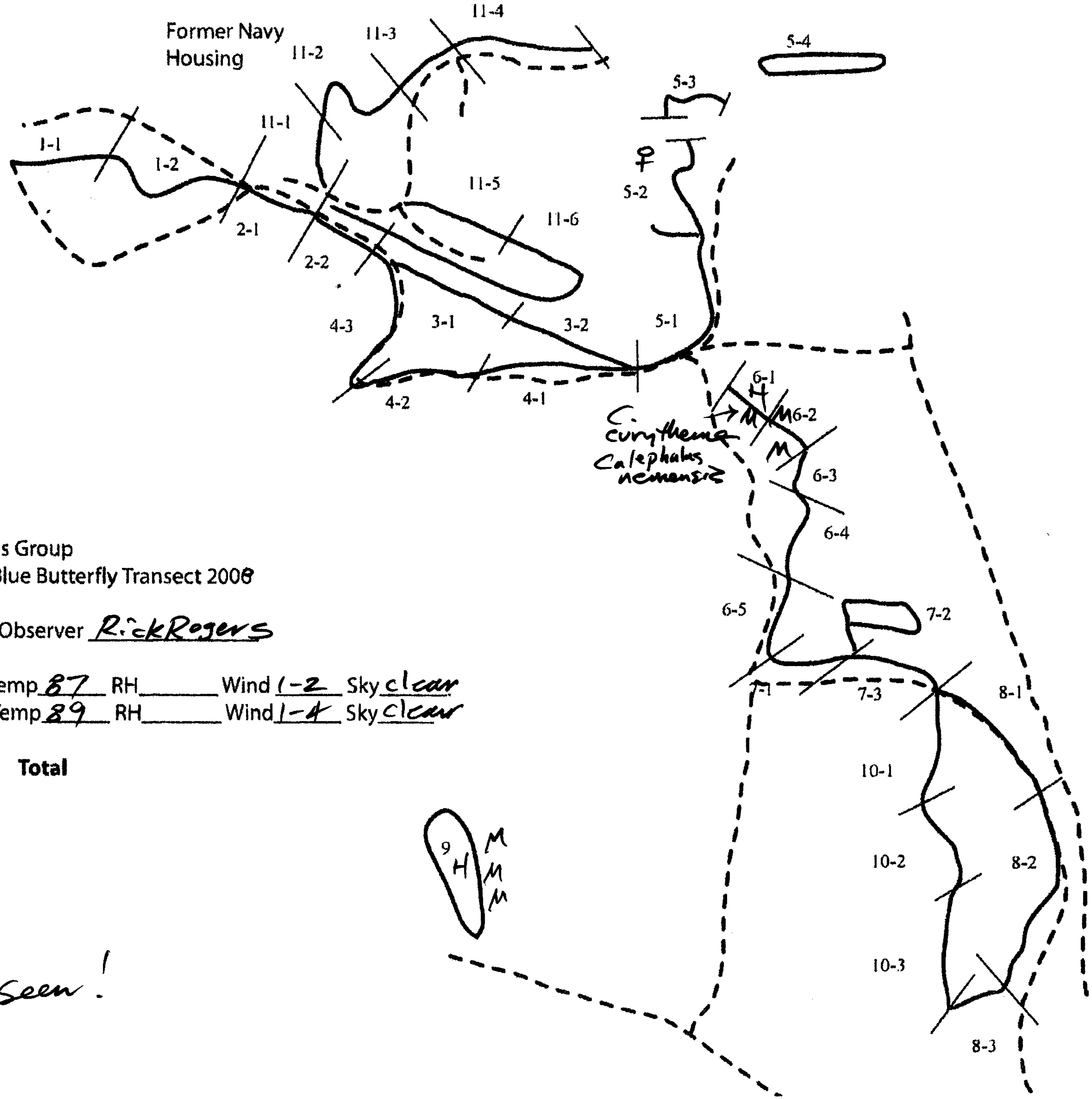
Date April 29, 2011 Observer Rick Rogers

Time start 11:40 Temp 68° RH______ Wind 1-3 Sky 5% (mostly clear)
Time finish 1:40 Temp 70° RH______ Wind 4-5 Sky clear

Legend **Total**

♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



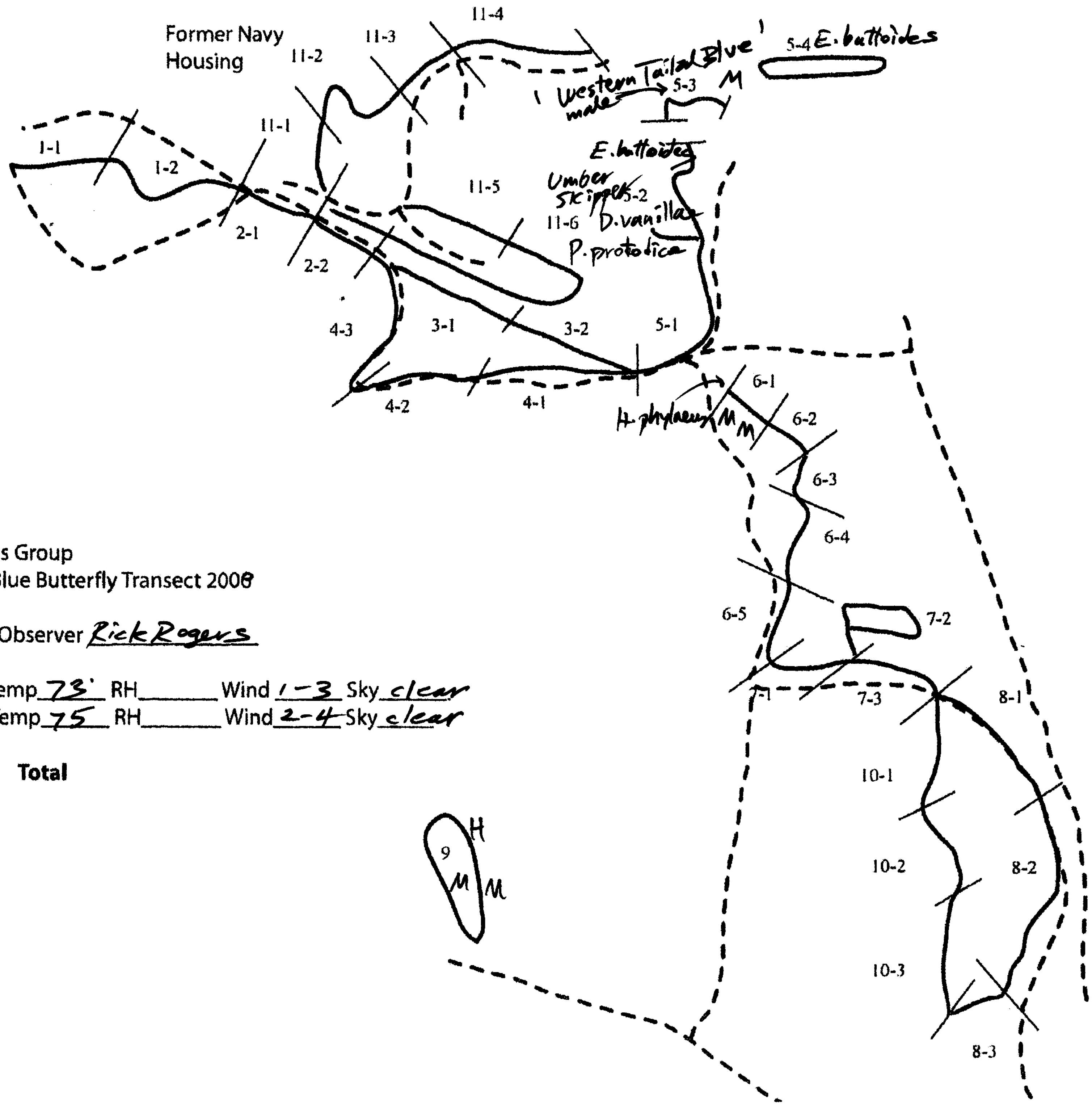
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date May 2, 2011 Observer Rick Rogers

Time start 11:30 Temp 87 RH______ Wind 1-2 Sky clear
Time finish 1:30 Temp 89 RH______ Wind 1-4 Sky clear

Legend		Total
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

one ♀ PVB seen!



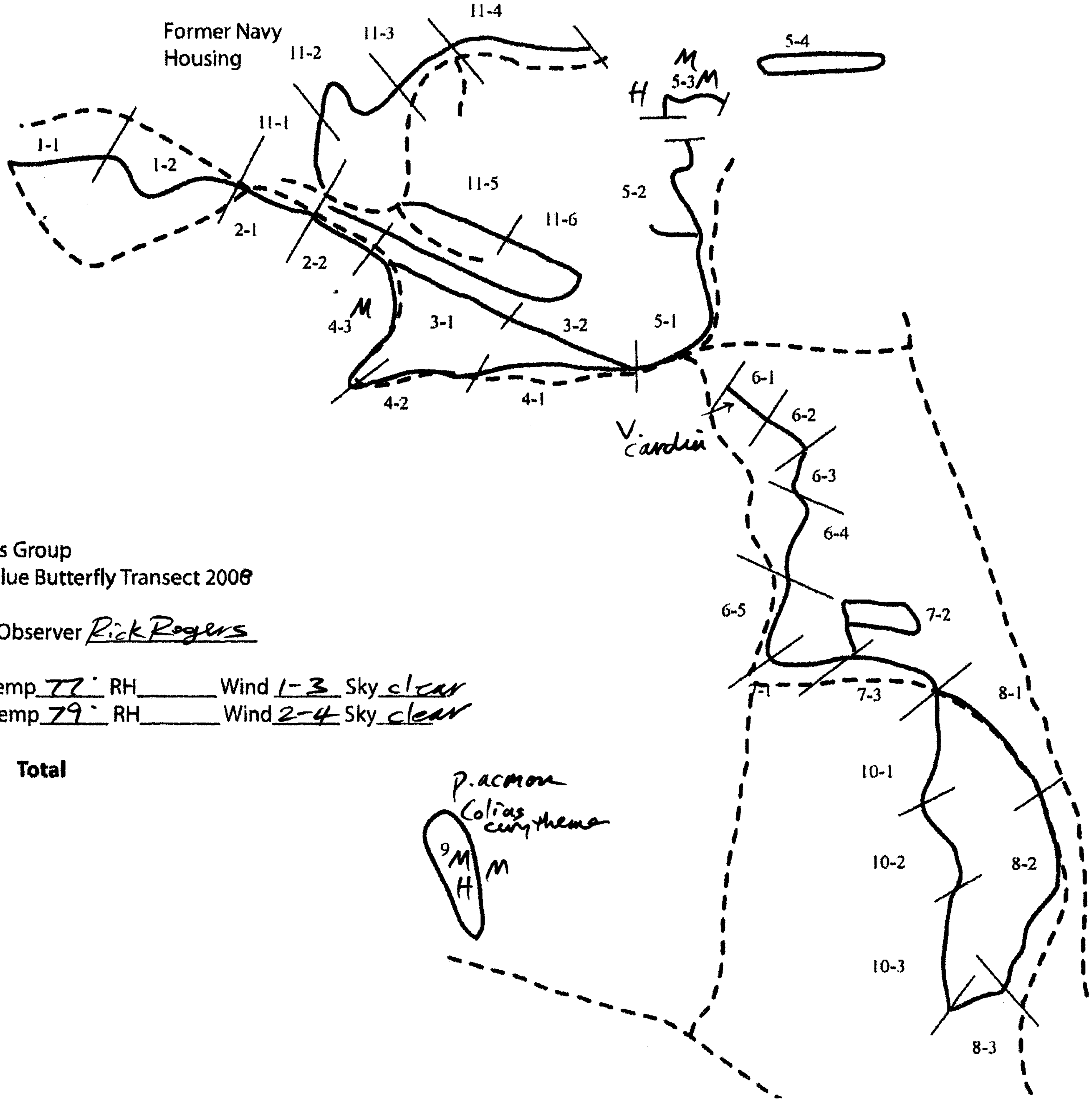
The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

Date *May 6, 2011* Observer *Rick Rogers*

Time start *11:30* Temp *73°* RH______ Wind *1-3* Sky *clear*
Time finish *1:30* Temp *75* RH______ Wind *2-4* Sky *clear*

Legend		**Total**
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVBs



The Urban Wildlands Group
DFSP Palos Verdes Blue Butterfly Transect 2008

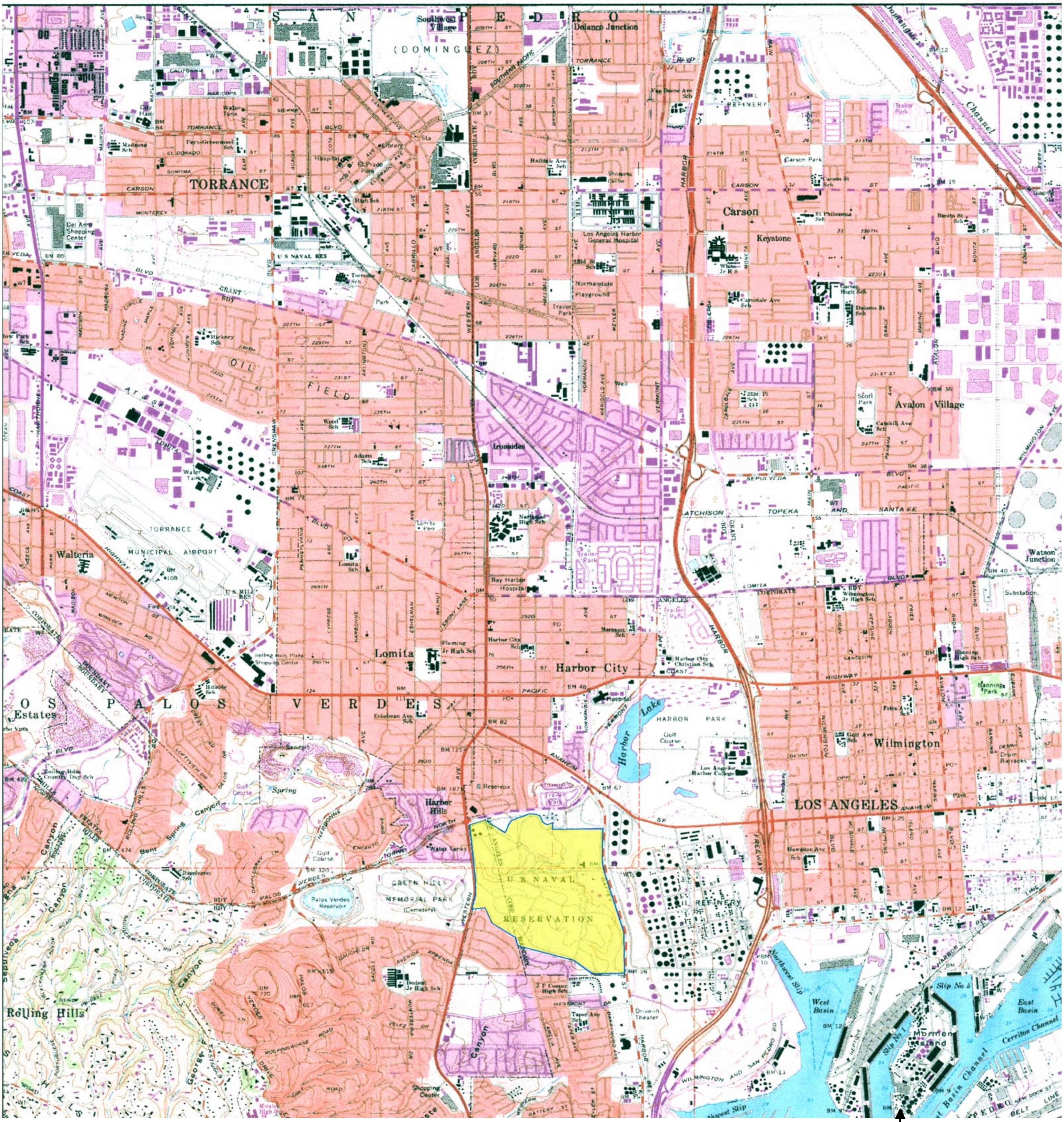
Date *May 11, 2011* Observer *Rick Rogers*

Time start *11:30* Temp *77°* RH______ Wind *1-3* Sky *clear*
Time finish *1:30* Temp *79°* RH______ Wind *2-4* Sky *clear*

Legend **Total**

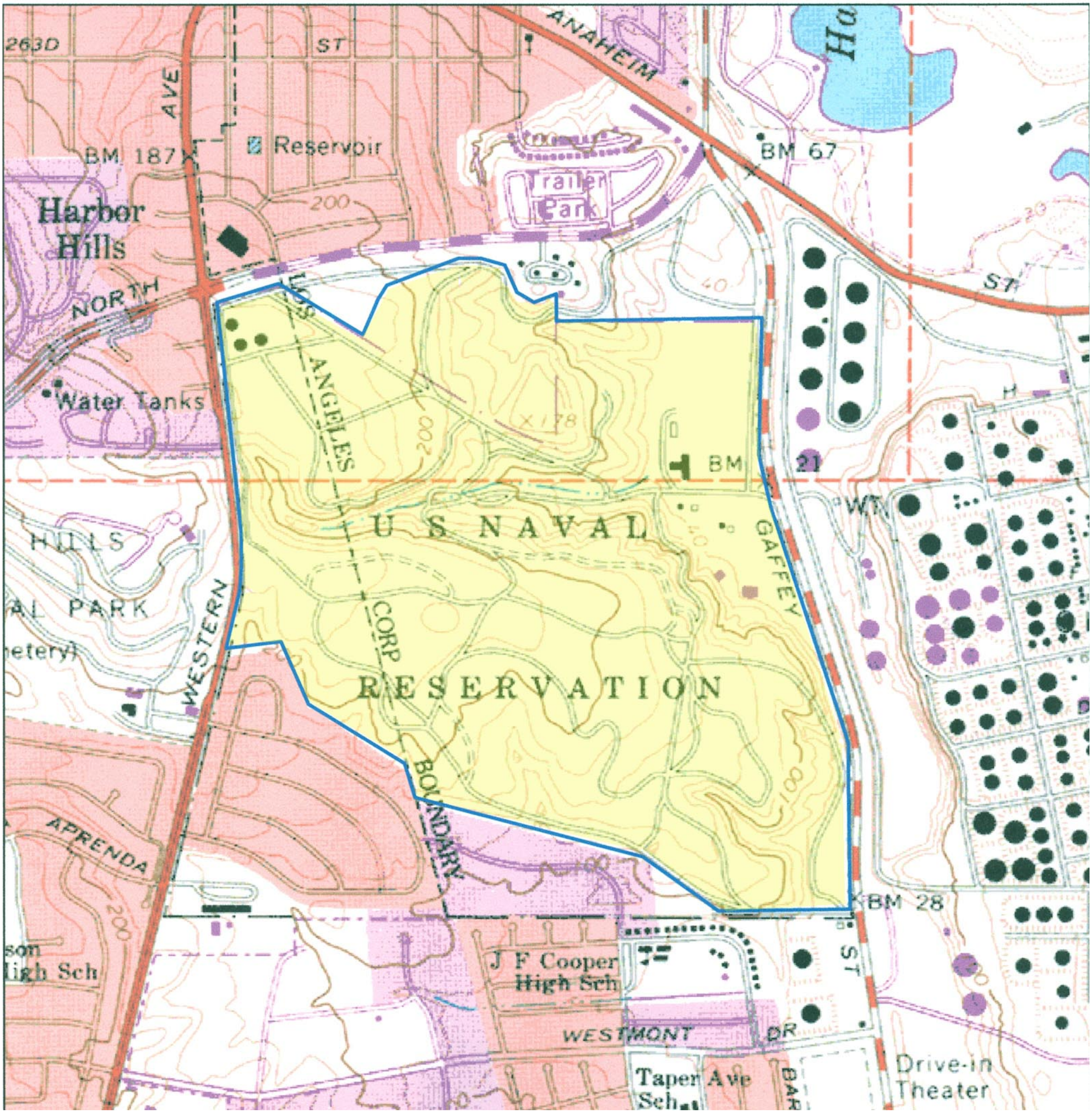
♀♂	*G. lygdamus*	
F	*E. funeralis*	
M	*L. marina*	
G	*C. perplexa*	
H	*S. melinus*	
B	*B. diegoensis*	

No PVB's



= 1 mile N

Supplemental Figure 1. General vicinity of survey site, Torrance, California USGS 7.5' quadrangle at 50%. The DFSP and associated survey areas are outlined in blue and highlighted in yellow.



——= 100 meters N

Supplemental Figure 2. General vicinity of survey site, Torrance, California USGS 7.5' quadrangle at 200%. The DFSP and associated survey areas are outlined in blue and highlighted in yellow.