Monarch Butterfly Population Dynamics in Monterey County, California

Winter 2007-2008

Prepared for Helen I. Johnson
by Ventana Wildlife Society

Jessica L. Griffiths[1] and Nellie Thorngate

[1] Ventana Wildlife Society; e-mail: jessicagriffiths@ventanaws.org

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INTRODUCTION

Monarch Alert is a program that was established to study the ecology and population dynamics of the monarch butterfly (*Danaus plexippus* L.). The mission of Monarch Alert is the conservation of the western population of the monarch butterfly, with special attention to its wintering and breeding grounds. The primary sponsor of Monarch Alert is Helen I. Johnson of Pacific Grove, California. This year, the research funded by Monarch Alert was conducted exclusively by Ventana Wildlife Society and focused entirely on the butterflies overwintering in Monterey County.

Ventana Wildlife Society has been monitoring monarch butterflies in Monterey County for Monarch Alert since 2001. The continued long-term monitoring of monarch populations is vital to their conservation. Only by understanding natural population cycles, identifying population declines, and preserving overwintering habitat can we hope to conserve and protect the phenomenon of monarch butterfly migration. The International Union for Conservation of Nature and Natural Resources classified monarch migration and overwintering as a "threatened phenomenon" due to the alarming rate that wintering habitat was being eliminated or degraded in both Mexico and along the California coast (Wells et al. 1983). This concern was further expressed at the 1997 North American Monarch Butterfly Conference (Morelia, Mexico), which was a tri-national attempt among representatives from Canada, Mexico, and the U.S.A. to establish an integrated and regional conservation strategy. Similar concerns were raised about the preservation and restoration of monarch spring and summer generation breeding grounds at the 2001 Monarch Population Dynamics Meeting (University of Kansas).

This report summarizes the monitoring conducted during the winter of 2007-08. Surveys were conducted at nine overwintering sites throughout Monterey County. All were located within a few kilometers of the coast. Some were dominated by Blue Gum Eucalyptus, some were dominated by Monterey Pine, and some were a mixture of species. We conducted extensive tagging at one site, the Monarch Grove Sanctuary in Pacific Grove. Permission to tag was obtained from the Pacific Grove City Council and tagging was conducted with the assistance of several local volunteers. In addition to being trained at tagging sessions on how to handle and tag monarch butterflies, local volunteers received

training at a hands-on Monarch Butterfly Monitoring Workshop held at the Monarch Grove Sanctuary on 3 November 2007. The workshop provided instruction to 30 volunteers on how to count overwintering monarchs. During the monarch butterfly wintering season, communication and cooperation were maintained with the local government and the community, resulting in the involvement of several "citizen scientists" in this critical research.

The primary objectives of this study were 1) to monitor climax and transitional roosting sites[1] along the California coast in Monterey County and San Luis Obispo County; 2) to document overwintering monarch butterfly population densities, fluctuations, and movements; and 3) to implement a tagging study to gain information on monarch butterfly movements among overwintering habitats and spring migration timing and routes. This long-term monitoring study increases our understanding of western monarch population dynamics and patterns of habitat occupancy by incorporating a small-scale local focus as well as a larger-scale county-wide approach.

METHODS

Study sites

We conducted field surveys of monarch butterflies at nine overwintering sites in Monterey County. These sites included Monarch Grove Sanctuary, George Washington Park, Point Lobos State Reserve, Palo Colorado Canyon, Andrew Molera State Park, Sycamore Canyon, a site on private property, Prewitt Creek, and Plaskett Creek Campground. (Figure 1 and Table 1). A tenth site, Rancho Grande (Packard Ranch) was investigated in December but did not have any butterflies present.

Seasonal Abundance Pattern of Monarchs

Site surveys. We surveyed each of the sites once each week from the first week of November 2007 through the last week of February 2008. Surveys were conducted in the mornings while temperatures were low (usually below 13°C) and monarch butterflies were

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[1] Leong (1991) defined climax sites as sites that maintain a stable monarch butterfly population throughout the winter season. In contrast, transitional sites function as a stopover for migrating monarch butterflies on their way to their climax

still clustered. We did not survey during heavy precipitation because visibility was poor. We recorded the following survey data at each site using a standard data form (Appendix 1): date, site, observers, pre-count time start and end, count time start and end, presence of nectar and water sources, and observations of tagged or mating monarch butterflies. Weather data included: sky, percent cloud cover, wind speed and direction, temperature, precipitation, and percent fog. Sky was indexed from 0-8 by the following criteria: (0) Clear or few clouds, (1) Scattered clouds, (2) Mostly cloudy, (3) Overcast, (4) Fog or smoke, (5) Drizzle, (8) Showers. Wind was estimated using the Beaufort's wind scale (Appendix 2). For every tree that had roosting monarch butterflies, we recorded the number of monarch butterflies (see below), tree species, tree identification number, and the aspect and height of clusters. We also counted and recorded separately the number of monarch butterflies on the wing and on the ground.

Cluster estimations. At each of the overwintering sites, we recorded estimates of butterflies roosting in specific trees and exhibiting other behaviors, e.g. basking, flying, etc. in the study area. To estimate the number of butterflies in a cluster, we estimated the number of monarch butterflies in a small area of the cluster and then extrapolated this count to arrive at a total count for the entire cluster. We recorded the average of the total counts of all observers. Prior to the overwintering period, we conducted training workshops for project assistants designed to refine our estimating skills. Small clusters of butterflies were estimated by each participant, and the cluster was captured and counted. This process was repeated many times. Each biologist gauged his/her individual accuracy rate, corrected for his/her individual bias, and calibrated with all observers. We practiced and implemented these techniques throughout the season to ensure that all observers were calibrated in their estimates.

Cluster aspect. We recorded aspect as the direction or range of directions that butterflies were roosting from the base of the tree (e.g., N; SE; NE – S). For analysis, directions were converted to degrees. If there was a range of directions, the median in degrees was used.

Cluster height. For each tree with clustering monarchs we measured the height of the cluster or the vertical range of heights used. Heights were estimated by measuring a standard

known height at the base of the tree below the clusters, such as the height of one of the researchers, then extrapolating that known height to the cluster positions.

Tagging program

We used tags identical to those used in previous years by Ventana Wildlife Society for Monarch Alert, printed by Watson Label Company. Each tag is pre-printed with "Monarch Alert" and the words "Free Call", along with a unique 5-digit number and a toll-free telephone number (Figure 2). Five tagging sessions took place at the Monarch Grove Sanctuary in Pacific Grove from November 2007 to February 2008 (Figure 3). Tags used in the first three sessions were color-coded for ease of re-sighting.

We captured butterflies early in the morning when temperatures were below flight threshold (13°C) to increase sample size and to avoid injuring butterflies. To reach clustering butterflies, we used a telescoping painter's pole with an attached soft mesh net. We collected butterflies from different locations within the sanctuary and from different heights, when possible, to ensure random samples. Butterflies were placed in large paper bags in groups of 40-80 and processed immediately. Butterflies were drawn from bags and a tag placed on the underside of the right hindwing over the discal cell. The tag identification number and the sex of the butterfly were recorded. If the temperature was above flight threshold, the butterfly was released. If the temperature was too cold for flight, the butterfly was placed back in a large paper bag with up to 50 other butterflies and held until conditions were ideal for flight. This prevented butterflies from carpeting the ground in the Sanctuary and being stepped on by researchers or visitors.

Statistical Analysis

All statistical analyses were performed using R Statistical Software (RDCT 2008).

Annual trends. Annual population trends of overwintering monarch butterflies were modeled for all sites together and for each overwintering location using linear regression. The linear regression model is defined as

$$Y_i = a + bX_i + z_i$$

where Y is related to X by *a* and *b* population parameters, given *z* residuals (Zar 1999). Linear regression determines the presence and strength of the linear relationship between a

dependent variable Y and an independent variable X. Calculation of a linear regression yields an R^2 value, which indicates the percent of variation in Y explained by the regression model. Thus, for the purposes of this study, an R^2 value of 0.800 would indicate that 80% of the variation in annual monarch abundance (Y) is explained by time (X). Linear regression models were generated using the *lm* function in R (RDCT 2008).

      Habitat use and response to weather variables. Patterns of habitat use and monarch response to climate variables were described using Pearson correlation for linear variables, and a linear-angular correlation (Johnson and Wehrly 1977) for aspect. Pearson correlation coefficients were calculated using the formula

$$r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{(\sum X^2 - \frac{(\sum X)^2}{N})(\sum Y^2 - \frac{(\sum Y)^2}{N})}}$$

where X and Y are continuous variables, and N is the sample size.

      Linear-angular correlation coefficients were calculated following Johnson and Wehrly (1977) using the formula

$$r_{al} \ ? \ \sqrt{\frac{r_{XC}^2 \ ? \ r_{XS}^2 \ ? \ 2 r_{XC} r_{XS} r_{CS}}{1 \ ? \ r_{CS}^2}}$$

where r_{XC} is the Pearson correlation coefficient of linear variable *x* and the cosine of angular variable *a*, r_{XS} is the Pearson correlation coefficient of linear variable *x* and the sine of angular variable *a*, and r_{CS} is the Pearson correlation coefficient of the sine and cosine of linear variable *a*.

      Only data from the Monarch Grove Sanctuary and the Private Property site were correlated with weather variables, as these sites were the only ones with appropriately high numbers of butterflies and multiple roost tree species. Weather data from the 24-hour period preceding each monarch count was chosen as the set of weather variables most likely to have potentially affected monarch roosting behavior.

      Weather data was gathered from the Central California Weather Data Archives. We

used weather data from the Monterey Peninsula Airport for analysis with the Pacific Grove monarch data, while the private property monarch data was analyzed with weather data from the Big Sur Multi-agency Facility weather station.

Habitat variables analyzed included survey day, monarch count, number of roost trees, percent of total monarch count on each roost species, and roosting aspect. Weather variables included precipitation, dew point, humidity, temperature, and wind speed.

Overwintering Survival. Overwintering survival of monarchs at the Monarch Grove Sanctuary was calculated using the *openp* function in the Rcapture package for R Statistical Software, which fits the Jolly-Seber population model to data from an open population using a loglinear approach (Baillargeon and Rivest 2007). The *openp* function calculates the demographic parameters of survival and population size, as well as the deviance, degrees of freedom and Aikake's Information Coefficient (AIC) for the fitted Jolly-Seber model. We calculated overall winter survival in R from the *openp* output, using a test for homogeneity as described in Baillargeon and Rivest (2007).

RESULTS

Seasonal Abundance Pattern of Monarchs

The peak number of monarch butterflies recorded in Monterey County at any one time during the winter of 2007-08 was 18,179. This is a 70% decrease from the peak population of the previous winter (Figure 4). Despite the decrease, linear regression analysis of both individual sites and combined populations of all years (2001-2008) showed no significant trends.

Climax Sites

Monarch Grove Sanctuary. An estimated 7,611 monarch butterflies were present at Monarch Grove Sanctuary on the initial survey date of 6 November 2007. (Figure 5). Weekly estimates averaged 7,277 monarch butterflies during the months of November and December. The maximum weekly estimate was 9,345 monarch butterflies recorded on 27 November 2007. Weekly estimated declined during January 2008 due in part to a severe winter storm (weekly average 4,104). The butterflies persisted in good numbers through the

first half of February 2008 (weekly average 3,824), but declined rapidly in the last two weeks of that month. By the end of February, almost all of the monarchs had dispersed. The final count, which was recorded on 25 February 2008, was 767 monarch butterflies.

Blue Gum Eucalyptus, Monterey Cypress, and Monterey Pine were the predominant tree species at Monarch Grove Sanctuary. Monarch butterflies preferred to cluster mainly on Blue Gum Eucalyptus throughout November and early December. In mid-December, they began clustering more frequently on Monterey Pine, and by late January they had completely abandoned the Eucalyptus for Monterey Pine and Monterey Cypress (Figure 6). In November, 79% of butterflies clustered on Blue Gun Eucalyptus while only 18% percent clustered on Monterey Pine. In January only 18% of the butterflies clustered on Blue Gun Eucalyptus while 60% clustered on Monterey Pine, and by February 73% clustered on Monterey Cypress and 27% on Monterey Pine.

Private Property Site. An estimated 4,158 monarch butterflies were present at the private property site on the initial survey date of 7 November 2007 (Figure 5). Weekly estimates averaged 5,861 monarch butterflies during the month of November, and the weekly average increased to 8,065 in December. The maximum weekly estimate was 9,503 monarch butterflies recorded on 3 December 2007. Weekly estimates decreased during January 2008 (weekly average 5,569 monarch butterflies) and dropped further as the butterflies dispersed in February (weekly average 2,692). The final estimate, which was recorded on 26 February 2008, was 1,406 monarch butterflies.

Coast Redwood, Blue Gum Eucalyptus, and Monterey Cypress were the predominant tree species at the private property site. Most of the monarch butterflies at the private property site clustered on a single Coast Redwood tree through February 2008 (Figure 7). From 7 November 2007 through 4 February 2008, 98% of the total estimated number of butterflies clustered on Coast Redwood, while 2% clustered on Blue Gum Eucalyptus. After the butterflies began dispersing in February, they clustered on Monterey Cypress (14%) and Blue Gun Eucalyptus (21%) as well as Coast Redwood (64%).

Transitional Sites

Andrew Molera State Park. An estimated 571 monarch butterflies were present at Andrew Molera State Park on the initial survey date of 9 November 2007. Weekly estimates

averaged 641 monarch butterflies during the months of November and December, with a maximum of 773 overwintering butterflies counted on 4 December 2008. In January 2005, following a major storm, butterflies abandoned the site completely. The final estimate, recorded on 18 January 2008, was 66 butterflies.

Blue Gum Eucalyptus was the predominant tree species at the grove at Andrew Molera State Park and was the only tree species used by monarch butterflies.

Other Sites

There were six sites where monarch butterflies were rarely observed, and therefore could not be classified as climax or transitional. Fewer than 10 butterflies were recorded in any given week at George Washington Park, Point Lobos, Palo Colorado Canyon, Sycamore Canyon, Prewitt Creek, and Plaskett Creek.

Habitat use and response to weather variables

Monarch Grove Sanctuary. Monarchs at the Monarch Grove Sanctuary roosted on Eucalyptus, Monterey pine, and Monterey cypress trees, as well as occasional ornamental shrubs. Number of roost trees ranged from three to 16, and was negatively correlated with survey day (-0.795, df = 11, P = 0.001), such that there were fewer roost trees as the season progressed. Total number of roosts was correlated with number of monarchs on Eucalyptus (r = 0.645, df = 11, P = 0.017), number of monarchs on Monterey cypress (r = -0.587, df = 11, P = 0.018), and number of monarchs on ornamental shrubs (r = 0.733, df = 11, P = 0.004).

Number of monarchs on each tree species was negatively correlated with survey day for Eucalyptus (r = -0.864, df = 11, P = 0.001), and positively correlated with survey day for Monterey cypress (0.717, df = 11, P = 0.006). Number of monarchs on Monterey pines decreased as total numbers of monarchs increased (r = -0.588, df = 11, P = 0.035), while number of monarchs on Eucalyptus increased with increasing total monarch count (r = 0.576, df = 11, P = 0.039).

The most abundantly used roosting aspect ranged from 0° to 337.5° throughout the season, and clustering aspect was positively correlated with survey day (r = 0.584, df = 11, P = 0.036). Aspect was also positively correlated with total monarch count (r = 0.604, df = 11,

P = 0.029).

The only weather variable that correlated significantly with monarch behavior was temperature, which was associated with number of monarchs roosting on Monterey pines (r = -0.626, df = 11, P = 0.022), such that the lower the temperature, the higher the percentage of the total monarch count that was found on Monterey pines.

Private Property Site. Monarchs at the private property site south of Big Sur roosted on Coast Redwood, Eucalyptus, Monterey pine, and Monterey cypress. Number of roost trees ranged from one to five, with most butterflies usually clustered on a single Coast Redwood, as in previous years. Total number of roosts was positively correlated with number of monarchs on Eucalyptus (r = 0.775, df = 13, P = 0.001) and negatively correlated with the number of monarchs on Coast Redwood (r = -0.814, df = 13, P = 0.0002).

Number of monarchs on a single tree species was negatively correlated with survey day for Coast Redwood (r = -0.563, df = 13, P = 0.029), and positively correlated with survey day for Monterey cypress (0.540, df = 13, P = 0.038). Number of monarchs on Coast Redwood increased as total numbers of monarchs increased (r = 0.742, df = 13, P = 0.002), while number of monarchs on Monterey cypress decreased with increasing total monarch count (r = -0.604, df = 13, P = 0.017).

The most abundantly used roosting aspect ranged from 45° to 337.5° throughout the season, and clustering aspect was positively correlated with survey day (r = 0.555, df = 13, P = 0.032).

Increases in humidity (r = 0.581, df = 13, P = 0.023) and dew point (r = 0.542, df = 13, P = 0.037) were both associated with changes in cluster aspect. Temperature was positively correlated with number of monarchs on Eucalyptus (r = 540, df = 13, P = 0.038).

Tagging Program

From 8 November 2008 to 15 February 2008 we tagged 3,561 butterflies in five tagging sessions at the Monarch Grove Sanctuary in Pacific Grove (Table 2). In addition to this, 40 butterflies were tagged as part of a demonstration at the Pacific Grove Museum of Natural History and subsequently released in Salinas by Helen Johnson. During the five tagging sessions 260 butterflies were recaptured, representing 7.3% of the tagged pool of

monarchs. Of the butterflies tagged, 67% were male and 37% were female, an approximately 2:1 male to female ratio.

Two tagged butterflies were resighted on 3 December 2007 by researchers at the private property site in Big Sur. One had been tagged at the Monarch Grove Sanctuary on 8 November 2007, traveling approximately 50 kilometers south, and one had been released in Salinas on 24 November 2007, traveling approximately 88 kilometers south. Two monarchs released in Salinas on 24 November 2007 were recaptured at the Monarch Grove Sanctuary (one on 19 December 2007 and one on 6 January 2008), traveling approximately 25 kilometers southwest.

There were 55 reports (call-backs) of tagged butterflies made to the toll-free phone number from 7 December 2007 to 17 May 2008. The proportion of call-backs to the number of butterflies tagged was 1.5%, which is three times higher than the proportions reported in previous years (Frey et al. 2003; Frey et al. 2005). Of those 55 call-backs, 31 butterflies were reported from within the boundaries of the Monarch Grove Sanctuary, and 22 were found locally within 10 kilometers of the Monarch Grove Sanctuary. One was found in Carmel (11 kilometers south) and one was found in Capitola (50 kilometers north). Both of these had been tagged on 8 November 2007 and both were reported on 7 December 2007. The average number of days between a butterfly being tagged and its being reported was 59, compared to 33 days in 2005 (Frey et al. 2005) and 54 days in 2003 (Frey et al. 2003).

Overwintering survival

Overwintering survival was calculated using butterflies from three of the five tagging sessions. Tagged butterflies from the sessions conducted on 12 January 2008 and 1 February 2008 were excluded from the survival analysis because the session sample sizes were too small. Survival analysis in Rcapture estimated an overwintering survival rate of 0.69 ± 0.024 s.e. for the Monarch Grove Sanctuary butterfly population. See Table 3 for model fit and period-specific survival values.

DISCUSSION

The abundance of monarchs in Monterey County during the winter of 2007-08 was the lowest since the winter of 2002-03, and the second-lowest since monitoring began in 2001 (Frey et al. 2006). There are several possible explanations for the low numbers, the most likely being the drought during the summer of 2007. Severely dry conditions have been linked to a decrease in milkweed biomass and a subsequent decrease in wintering butterfly populations (Frey and Stevens 2004). The same conditions existed in 2002, where a severe drought was followed by a winter characterized by very low butterfly numbers (Frey et al. 2003). Alternative hypotheses for the low numbers include an increase in mortality of late-summer monarchs due to parasitism or predation (Cherubini, unpublished data). Whatever the cause, it is important to note that there has not been an overall statistically significant decrease in the Monterey County overwintering population since 2001. The changes in numbers of overwintering butterflies have been normal between-year population fluctuations.

However, there has been a definite and significant decline in the total California overwintering population as measured by the annual Monarch Thanksgiving Count. Since 1997, the overwintering population has declined precipitously from over 1.2 million butterflies to around 200,000, where it has hovered since 2001 (Figure 8). This means that Monterey County now hosts a significant portion of the Western population in any given winter. For example, in 2006-07, Monterey County contained 26% of the total statewide monarch population. Because of the vital importance of Monterey County overwintering habitat to the entire Western population, it is critical that this habitat is preserved and, if possible, restored.

This year there were only two sites in Monterey County that could be classified as climax sites: the Monarch Grove Sanctuary and the private property site in Big Sur. These two sites have been climax sites in every year since monitoring began in 2001, and normally contain the majority of the county's overwintering population. This year, the private property site and Monarch Grove Sanctuary accounted for 96% of the monarch population in Monterey County. This is similar to the distribution of monarchs in the winter of 2002-03, when those two sites accounted for 93% of the overwintering Monterey County population. Contrast this with the winter with the highest overwintering total, 2003-04, where the top two

sites contained 72% of the county's population. This suggests that the Monarch Grove Sanctuary and the private property site are especially critical to overwintering butterflies in dry weather years.

An analysis of tree species used by roosting monarchs revealed some interesting patterns. At the Monarch Grove Sanctuary, the number of butterflies roosting on Eucalyptus decreased significantly over the course of the season, while the number roosting on Monterey Cypress increased significantly over time. Additionally, when monarch numbers began to decrease later in the season, significantly more butterflies roosted on Monterey Pine and fewer roosted on Eucalyptus. This suggests that conditions at the Monarch Grove Sanctuary at the beginning of the overwintering period were conducive to monarchs roosting on Eucalyptus, and as the season progressed, conditions changed and they switched to pine and cypress. The same was true at the private property site, where monarchs switched to Monterey Cypress near the end of the season. A similar pattern of tree-switching has been observed in years past at these sites (Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004).

An examination of weather variables sheds some light on this habitat preference. At the Monarch Grove Sanctuary, as temperature decreased, the percentage of monarchs roosting on Monterey Pine increased significantly. At the private property site, as temperature increased, the number of butterflies roosting on Eucalyptus increased significantly. Both of these results suggest that at higher temperatures, monarchs prefer to roost on Eucalyptus, but as temperatures drop, they switch to coniferous native species. One likely explanation for this is the fact that the wide-spaced structure of Eucalyptus leaves and branches does not provide as much shelter from wind and cold as the densely-packed needles of pine and cypress trees. Butterflies may be able to cluster in larger numbers on and hang on tighter to needles than to the broad, slippery leaves of Eucalyptus.

The sex ratio of male to female monarch butterflies was found to be approximately 2:1, which is the same ratio found at this site in tagging done in the winter of 2006-07 (VWS unpublished data). In fact, this male bias has also been found at other Monterey County sites and other sites on the Central Coast (VWS unpublished data; Frey and Leong, 1993, 1995). The male-biased sex ratio at the Monarch Grove Sanctuary was consistent throughout the winter from November to February and cannot be explained by earlier departure or dispersal by females, as theorized by Frey and Leong. Possible explanations include a male-biased

tendency to enter diapause, resulting in males being over-represented at wintering sites or the possibility that females are more reproductively active in the fall, leading to higher mortality (Nylin et al. 1995). Alternatively, it is possible that there is female-biased mortality during migration (Frey and Leong 1993).

Monarch movement between overwintering sites as measured by tagged butterfly resightings and callbacks took place in November and December. Migration movement does not seem to be directional, as movements of over 50 km to the north and to the south took place. No long-distance movements or between-site movements occurred after January 1. There was one butterfly tagged in Salinas that was recovered in the Monarch Grove Sanctuary on January 6, but it is extremely likely that this butterfly arrived at the site prior to that date. Thus, it seems that migration movement continues through the fall into December, and seems to cease after that. This indicates that the monarchs settle into their overwintering sites by January. However, the fact that the butterflies use multiple sites during the first three months of the winter highlights the importance of preserving multiple nearby overwintering sites.

Overwintering survival analysis calculated that throughout the winter there is an average survival rate of 69% for butterflies wintering at the Pacific Grove Monarch Grove Sanctuary. Survival was higher between the first two tagging sessions in November and December (70%) than between the second and third tagging sessions in December and February (60%). It is possible that the difference could be due to the increased mortality caused by severe weather in late December and early January. These are the first survival estimates calculated for this site, and further research may elucidate the effects of weather and initial population on overwintering survival.

SUMMARY AND CONCLUSIONS

Monarch Alert project investigators completed the seventh consecutive year of western monarch butterfly research in Monterey County. The overwintering population in Monterey County during the winter of 2007-08 decreased 70% from the previous winter, but when placed in the context of population fluctuations since 2001, this was not a statistically significant decline. Only two of nine sites in Monterey County had butterflies throughout the

winter: the Monarch Grove Sanctuary and a private property site in Big Sur. At these sites, butterflies reacted to changes in the climate by shifting their tree species preference. When temperatures declined, they moved from Eucalyptus to Monterey Pine and Monterey Cypress trees, preferring denser native conifers in colder weather. Over the course of 5 tagging sessions, 3,561 monarchs were tagged which resulted in an increased callback rate of 1.5%. Significant monarch movement in November and December was detected, with butterflies moving up to 50 km north and 88 km south of where they were tagged. Overwintering survival at the Monarch Grove Sanctuary was calculated to be 69%, with survival decreasing in the second half of the winter, possibly due to weather-related mortality.

These results indicate that Monterey County contains some of the most critical monarch butterfly habitat in the state of California, sometimes hosting over a quarter of the entire western monarch wintering population. Preservation and restoration of this habitat is absolutely critical to the continued survival of the western population. It is also vital that summer breeding habitat be maintained, as well as habitat for migrating individuals. Only by continuing the research and outreach pioneered by Monarch Alert can we hope to ensure that monarch migration remains one of the great natural phenomena of the west.

ACKNOWLEDGEMENTS

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Table 1. Study sites and surveys on the coast of Monterey County, California during winter 2007-2008.

Site Name	Site Location	Predominant Tree Species	Survey Period	Number of Surveys
Monarch Grove Sanctuary	8.0 km N[a]	Blue Gum Eucalyptus Monterey Cypress Monterey Pine	11/6/07- 2/28/08	15
George Washington Park	8.0 km N	Monterey Pine	11/6/07- 2/28/08	14
Point Lobos State Reserve	5.0 km S[b]	Monterey Pine	11/6/07- 2/28/08	14
Palo Colorado Canyon	16.0 km S	Blue Gum Eucalyptus	11/6/07- 11/19/08	3
Andrew Molera State Park	34.0 km S	Blue Gum Eucalyptus	11/9/07- 2/29/08	12
Sycamore Canyon	42.0 km S	Monterey Cypress	11/13/07- 11/19/07	2
Private Property	70.0 km S	Blue Gum Eucalyptus Coast Redwood Monterey Cypress	11/7/07- 2/26/08	15
Prewitt Creek	95.0 km S	Blue Gum Eucalyptus	11/7/07- 2/12/08	7
Plaskett Creek Campground	96.5 km S	Blue Gum Eucalyptus Monterey Cypress Monterey Pine	11/7/07- 2/12/08	7

[a] North of Carmel River
[b] South of Carmel River

Table 2. Total number of monarch butterflies tagged in six tagging sessions in Monterey County, California during the winter of 2007-2008.

Date	Location	New	Recaptured	Total
11/8/2007	Monarch Grove Sanctuary	1526	0	1526
11/24/2007	Salinas	40	0	40
12/19/2007	Monarch Grove Sanctuary	956	121	1077
1/12/2008	Monarch Grove Sanctuary	41	7	48
2/1/2008	Monarch Grove Sanctuary	35	5	40
2/15/2008	Monarch Grove Sanctuary	963	127	1090
Totals		**3,561**	**260**	**3,821**

Table 3. Jolly-Seber model fit and session-specific survival estimates for a population of Monarch butterflies tagged at the Pacific Grove Monarch Sanctuary during the winter of 2007-08.

Model Fit			
	Deviance	df	AIC
Fitted Jolly-Seber Model	0.836	2	58.75
Survival Probabilities			
	Probability	s.e.	
Period 1 - Period 2	0.7014	0.026	
Period 2 - Period 3	0.6009	0.077	

Figure 1. Locations of eight study sites on the coast of Monterey County, California surveyed during the winter of 2007-2008.
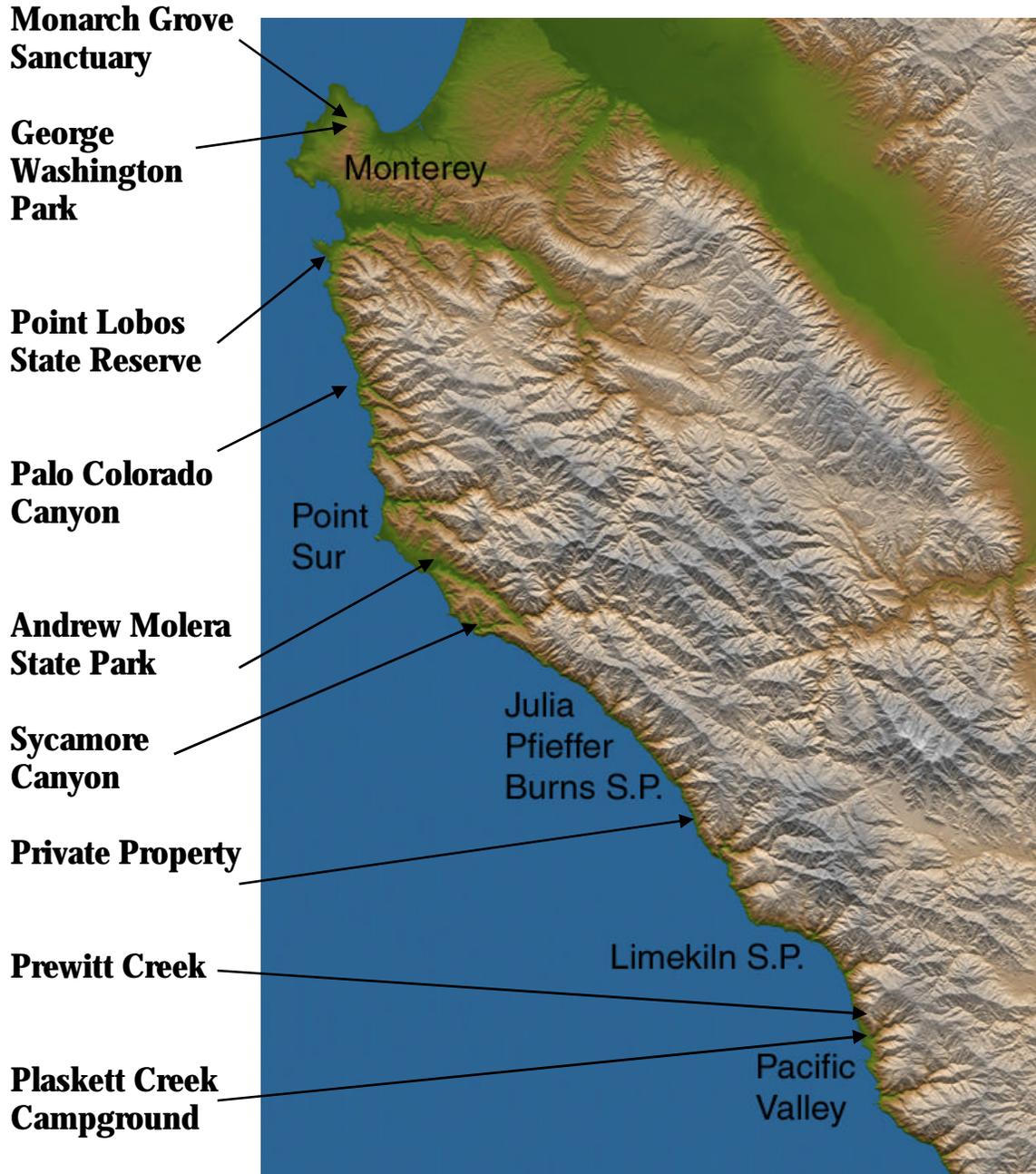
Figure 2. (a) Watson Label Company tag used to mark monarch butterflies during the 2007-08 season. (b) Tagged monarch nectaring on English ivy.
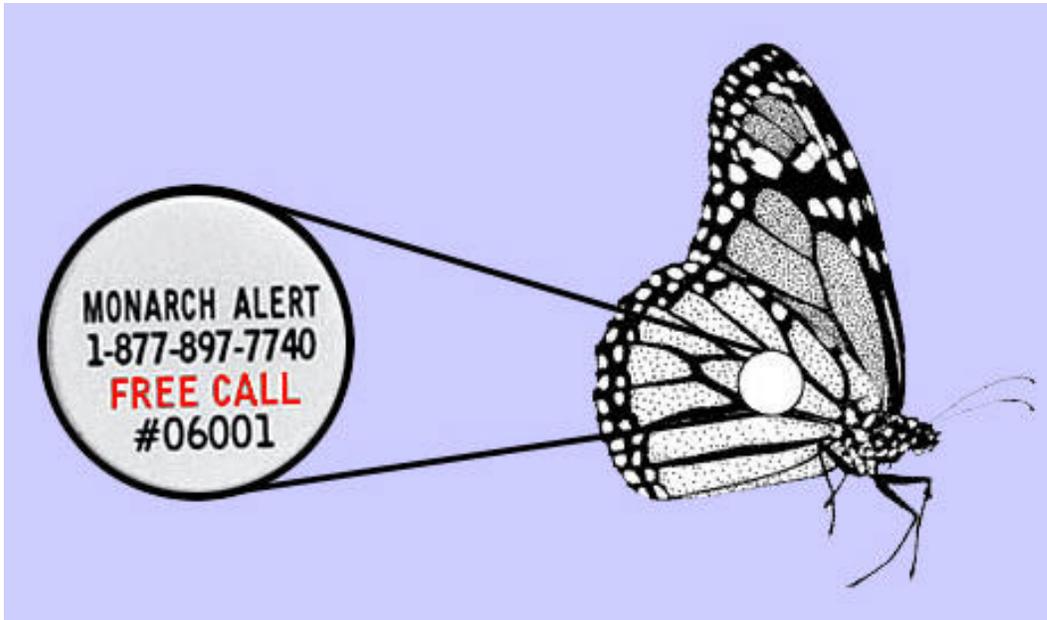
(a)

(b)

Figure 3. VWS staff and local volunteers tagging monarch butterflies at (a) Pacific Grove Monarch Grove Sanctuary and (b) a backyard directly behind the sanctuary.

(a)

(b)

Figure 4. Peak monarch butterfly populations in Monterey County, California from 2001-2008.
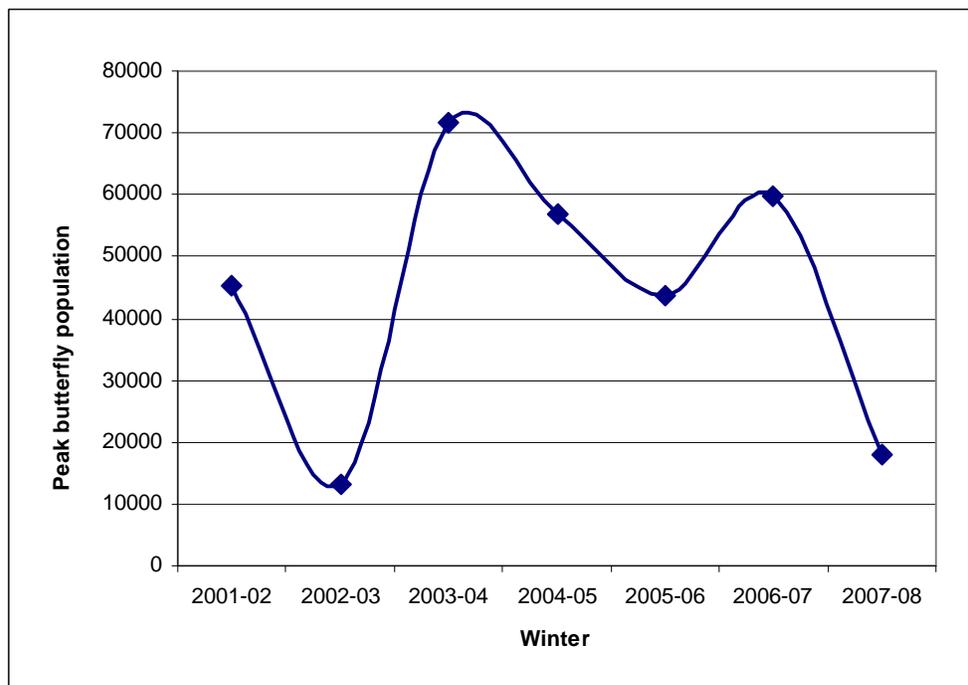
Figure 5. Weekly estimates of overwintering monarch butterflies at two climax sites in Monterey County, California during the winter of 2007-08.

Figure 6. Estimated numbers of monarch butterflies using different tree species at the
Monarch Grove Sanctuary in Pacific Grove, California during the winter of 2007-08.
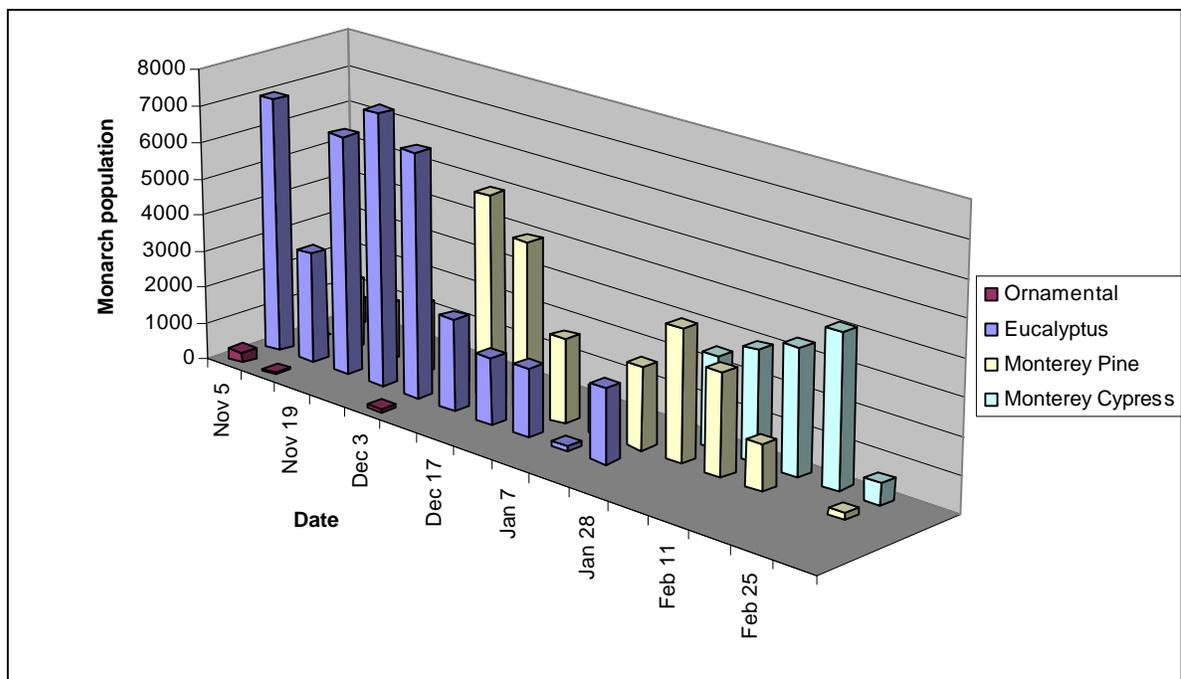
Figure 7. Estimated numbers of monarch butterflies using different tree species at a private property site in Big Sur, California during the winter of 2007-08.

Figure 8. Total monarch abundance in the state of California by year as measured by the annual Monarch Thanksgiving Count.

Appendix 1. Monarch butterfly site specific data sheet.

<u>Over-wintering Monarch Butterfly Project</u>
Site Specific Data Sheet

DATE _____ **SITE NAME** _____

 # Observers _____ **Observers** _____

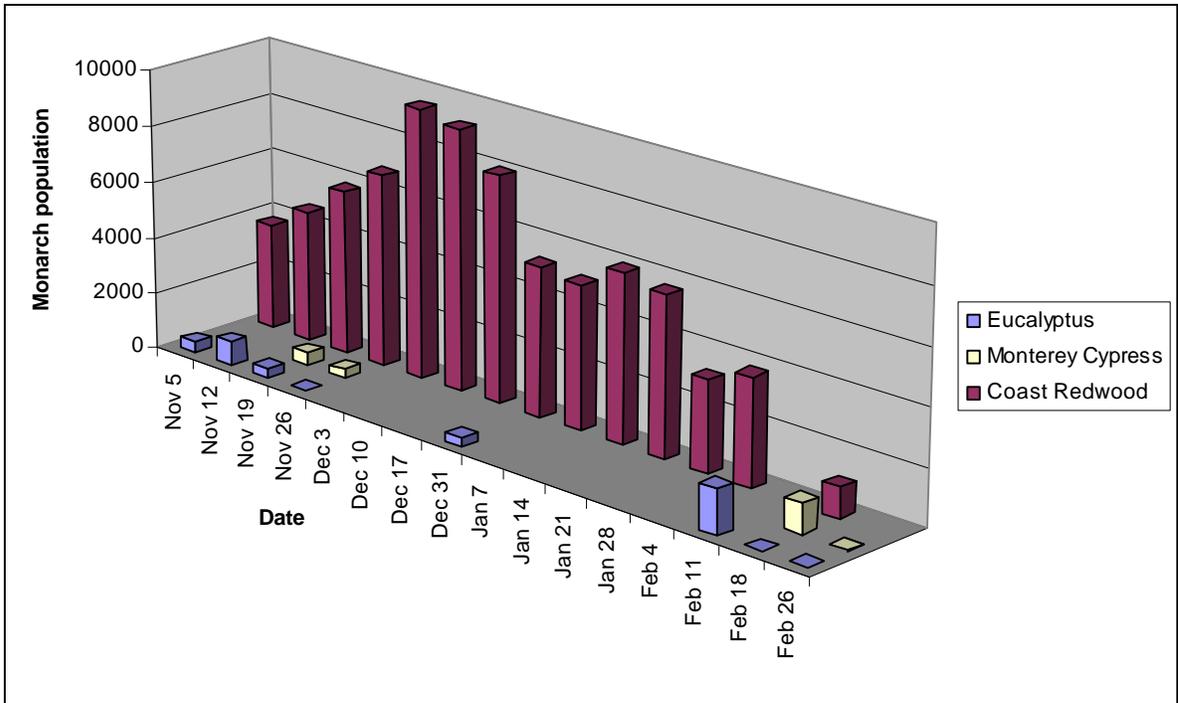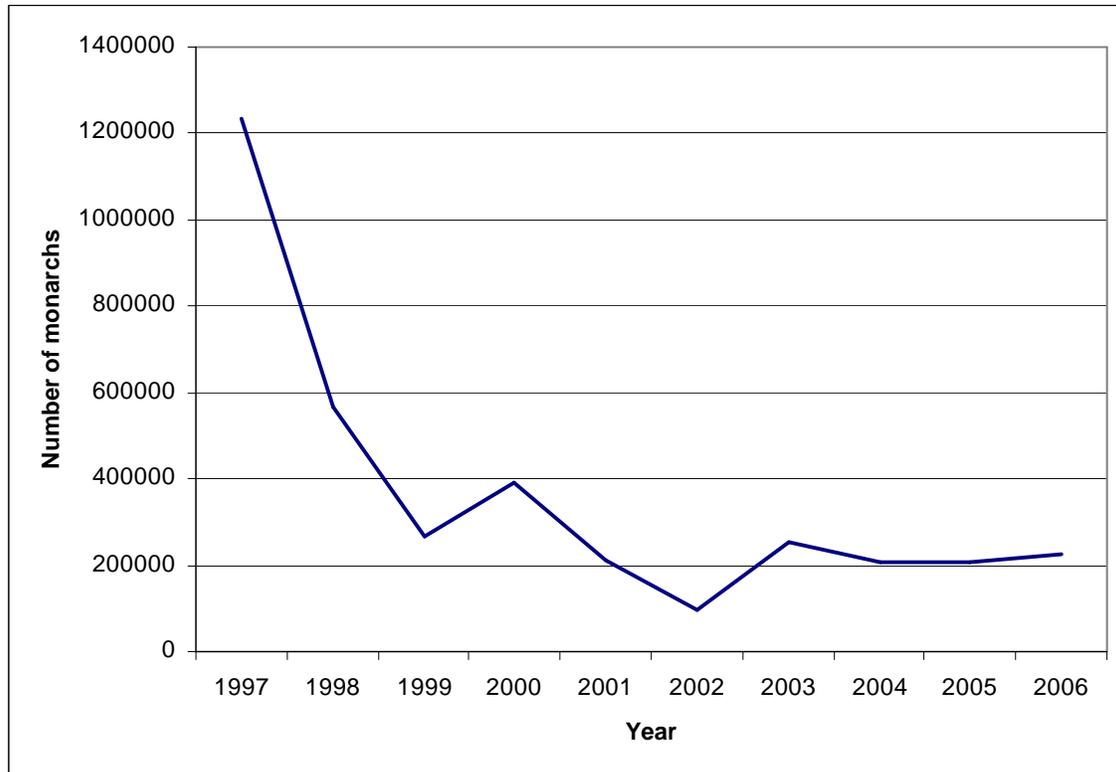**Precount Time Span** _____ **to** _____ **Total Precount (Min)** _____

Count Time Span _____ **to** _____ **Total Count (Min)** _____

Weather: Cloud/Fog Cover_____% **Precip: none, drizzle, rain, downpour   Sky**

(bft) _____ **Wind (bft)** _____   **Wind (km/h)** _____   **Wind Dir** _____   **Temp (^{o}C)** _____

# Monarchs Clustered	# Monarchs Sunning	Tree Species	Cluster Aspect	Cluster Height

Total:	**Total Trees:**	
# of Loners:		
# of Fliers:		
# of Grounders:		
Grand Total:		

	Yes	No	Notes
Water Source			
Nectar Source			
# Tagged Monarchs			
# Observed Matings			

Additional Notes:

Appendix 2. Weather and tree codes used during monarch surveys.

<div align="center">

<u>Temp:</u> in Celsius degrees

</div>

<u>Sky:</u>   0 = Clear, few clouds
          1 = Partly cloudy, scattered
          2 = Mostly cloudy, broken
          3 = Overcast
          4 = Fog or smoke
          5 = Drizzle
          8 = Showers

<u>Wind (Beaufort Scale):</u>

<u>Beaufort #</u>	<u>mph</u>	<u>Indicators</u>
0	< 1	Smoke rises vertically
1	1 - 3	Smoke drifts
2	4 - 7	Wind felt on face, leaves rustle intermittently
3	8 - 12	Leaves in constant motion
4	13 - 18	Dust raised, branches moving
5	19 - 24	Small trees sway
6	>25	Large branches sway
7		Whole trees sway

<u>Tree Species Codes:</u>

EUSP	Blue Gum Eucalyptus	*Eucalyptus spp.*
PIRA	Monterey Pine	*Pinus radiata*
SESE	Coast Redwood	*Sequoia sempervirens*
CUMA	Monterey Cypress	*Cupressus macrocarpa*
QUAG	Coast Live Oak	*Quercus agrifolia*