

Monarch Butterfly Population Dynamics in Monterey County, California

Winter 2008-2009



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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 by Jessica Griffiths in cooperation with the Pacific Grove Museum of Natural History and Ventana Wildlife Society, and focused entirely on the butterflies overwintering in Monterey County.

Monarch Alert has been funding the monitoring of monarch butterflies in Monterey County 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 2008-09. 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 9 November 2008. The workshop provided instruction to 10 volunteers on how to count overwintering monarchs. In addition to this, another monitoring workshop for San Francisco Bay area volunteers was conducted in San Leandro at the San Leandro Golf Course on 16 November 2008 and was attended by approximately 25 people. 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 sites¹ along the California coast in Monterey 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 near the Naval Postgraduate School in Monterey was discovered late in the season and visited twice in December and once in January.

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

Seasonal Abundance Pattern of Monarchs

Site surveys. We surveyed each of the sites once each week from the first week of November 2008 through the last week of February 2009. Surveys were conducted in the mornings while temperatures were low (usually below 13°C) and monarch butterflies were 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 observer 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 (in degrees) that butterflies were roosting from the base of the tree (e.g., 0; 90; 120-150). If there was a range of directions, the median in degrees was used.

Cluster height. For each tree with clustering monarchs we measured in meters 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 observers, then extrapolating that known height to the cluster positions.

Climate correlates of population dynamics and habitat usage

Regional weather data for Monterey County was obtained from a California Department of Water Resources California Irrigation Management Information System weather station (CIMIS station #210) located near Carmel, California (36°32'27" N, 121°52'55" W). Climate data examined included temperature, precipitation, evapotranspiration, and wind velocity. The data was examined in order to identify extreme weather events that may have been associated with the abandonment of transitional sites, roost switching or changes in tree species usage, and spring dispersal. Data that were far out of normal range were flagged by CIMIS and were easily identified.

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). Four tagging sessions took place at the Monarch Grove Sanctuary in Pacific Grove from November 2008 to January 2009 (Figure 3). In addition, two tagging sessions took place at the Pacific Grove Museum of Natural History, one on 20 September 2008 in conjunction with the Museum event known as Insect Insanity and one on 29 November 2008 in conjunction with the Museum event known as Monarch Madness.

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

Annual trends. Annual population trends of overwintering monarch butterflies were modeled for all sites together 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).

RESULTS

Seasonal Abundance Pattern of Monarchs

The peak number of monarch butterflies recorded in Monterey County at any one time during the winter of 2008-09 was 34,150. This is an 88% increase from the peak population of the previous winter (Figure 4). The average peak population over all years (2001-2009) is 42,803, which means that this year's peak was below average. Despite this, linear regression analysis of combined populations of all years (2001-2009) showed no significant trends.

Climax Sites

Monarch Grove Sanctuary. An estimated 12,470 monarch butterflies were present at Monarch Grove Sanctuary on the initial survey date of 4 November 2008 (Figure 5). Weekly estimates averaged 16,376 monarch butterflies during the months of November and December. The maximum weekly estimate was 19,203 monarch butterflies recorded on 7 December 2008. Weekly estimates declined only slightly in January (weekly average 15,484), and only slightly more in February (weekly average 12,771). The butterflies remained at the Sanctuary in large numbers late into the season, finally dispersing in the first two weeks of March. The final count, which was recorded on 4 March 2009, was 4,136 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 into mid-December. In late December, they began clustering more frequently on conifers and by January they were clustering predominantly on Monterey Pine (Figure 6). In February the Monarchs shifted again, this time to primarily Monterey Cypress, almost completely abandoning the Blue Gum Eucalyptus. In November, 62% of butterflies clustered on Blue Gum Eucalyptus while 19% clustered on Monterey Pine and 19% on Monterey Cypress. In December, only 48% clustered on Eucalyptus while 33% clustered on Monterey Cypress and 19% remained on Monterey Pine. In January, 43% of monarchs were located on Monterey Pine while only 37% remained on Eucalyptus and 20% were on Monterey Pine. Finally, in February, 58% were located on Monterey Cypress with 18% clustering on Monterey Pine and just 12% remaining on Eucalyptus.

Private Property Site. An estimated 3,449 monarch butterflies were present at the private property site on the initial survey date of 6 November 2008 (Figure 7). Weekly estimates averaged 5,103 monarch butterflies during the months of November and December, with a maximum weekly estimate of 7,140 butterflies recorded on 18 November 2008. During January, the number of butterflies at the site dropped sharply (weekly average 1,570 monarch butterflies) and continued to decline into February (weekly average 782 monarch butterflies). The final estimate, which was recorded on 26 February 2009, was 918 monarch butterflies.

Coast Redwood, Blue Gum Eucalyptus, and Monterey Cypress were the predominant tree species at the private property site. Monarchs partially clustered in Coast Redwood during the first two weeks of November, and shifted to primarily Eucalyptus for the remainder of the winter (Figure 8). In November, 79% of monarchs clustered on Blue Gum Eucalyptus while 12% clustered on Monterey Cypress and only 8% clustered on Coast Redwood. In December, 86% of butterflies clustered on Eucalyptus and in January 100% clustered on Eucalyptus. In February 89% of monarchs clustered on Eucalyptus and 11% clustered on Monterey Cypress.

Andrew Molera State Park. An estimated 4,336 monarch butterflies were present at Andrew Molera State Park on the initial survey date of 7 November 2008 (Figure 7). Weekly estimates averaged 4,931 monarch butterflies during November, with a maximum of 5,425 monarchs recorded on 20 November 2008. Monarchs declined somewhat in December (weekly average 3,520), and then declined sharply in late December. The January weekly average was 603, and by February the weekly average had dropped to 198. The final estimate, recorded on 26 February 2009, was 15 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.

Transitional Sites

Point Lobos State Reserve. Just two butterflies were present at Point Lobos on the initial survey date of 4 November 2008 (Figure 9). The number of butterflies at the site increased steadily in November (weekly average 646 butterflies) and December (weekly average 1,555 butterflies), with a peak weekly estimate of 2,008 monarchs recorded on 6 January 2009. The number of butterflies at the site declined rapidly in January until the site was empty at the end of the month. The last date on which monarchs were seen at the site was 27 January 2009.

Monterey Pine was the predominate tree species at Point Lobos, and was the only tree species used by monarch butterflies.

Sycamore Canyon. 706 monarch butterflies were present at Sycamore Canyon on the initial survey date of 7 November 2008 (Figure 9). The number of monarchs increased steadily and averaged 1,065 for the months of November and December, with a peak weekly

estimate of 1,363 recorded on 9 December 2008. As with the monarchs at Point Lobos, the monarchs at Sycamore Canyon dispersed from the site in January. The last date on which monarchs were seen at the site was 29 January 2009.

Monterey Cypress was the predominate tree species at Sycamore Canyon, and was the only tree species used by monarch butterflies.

Plaskett Creek. 96 monarch butterflies were present at Plaskett Creek on the initial survey date of 6 November 2008 (Figure 9). The number of monarchs increased steadily in November (weekly average of 298 butterflies) and December (weekly average of 458 butterflies), with a peak weekly estimate of 797 butterflies recorded on 9 December 2008. The monarchs persisted at the site until early January, when they dispersed. The last date on which monarchs were seen at the site was 29 January 2009.

Blue Gum Eucalyptus, Monterey Pine and Monterey Cypress were the predominant tree species at Plaskett Creek. This year, Blue Gum Eucalyptus was the only tree species used by monarch butterflies.

Other Sites

There were three sites where monarch butterflies were rarely observed, and therefore could not be classified as climax or transitional. Fewer than 5 butterflies were recorded in any given week at George Washington Park, Palo Colorado Canyon, and Prewitt Creek. A tenth overwintering site was located by Paul Cherubini in a Blue Gum Eucalyptus grove near the Naval Postgraduate School in Monterey, California, and that site was visited three times. On the first visit on 10 December 2008, 400 monarchs were counted. On the next visit on 18 December 2008, 135 monarchs were counted. When the site was visited a third time on 4 January 2009, no butterflies were left.

Habitat use patterns

Cluster aspect and height. Monarch butterfly clusters were observed facing all aspects (0 to 360°), with the majority of monarchs (54%) observed at 90° (E) to 180° (S) aspects (Figure 10). All of the overwintering sites except the private property site had similar dominant aspects. At Andrew Molera State Park, the Monarch Grove Sanctuary, Plaskett Creek, Point Lobos, and Sycamore Canyon the majority of butterflies faced between east and

south (Figure 11). However at the private property site, the monarchs were split evenly between facing 20 and 40° (NE) and 240 to 260° (SW) (Figure 11).

Over 72% of monarchs clustered between 6 and 9 meters off the ground. The average cluster height averaged across all sites was 7.9 meters.

Spatial pattern of roost trees. In Monterey County, monarchs clustered on four tree species: Blue Gum Eucalyptus, Monterey Pine, Monterey Cypress, and Coast Redwood. The locations of the core area used by roosting monarchs changed from week to week at the two climax sites with the highest number of butterflies, the Monarch Grove Sanctuary and the private property site, but did not change at the other four sites with clustering monarchs.

The core area used by roosting monarchs at the private property site and Plaskett Creek differed from previous years. At the private property site, for the first time in eight years, the monarch butterflies did not remain clustered on a single Coast Redwood tree all winter. During the first week of November they clustered in the redwood tree, but then shifted approximately 300 meters north to a grove of Eucalyptus and Monterey Cypress in a drainage. They stayed within a 100-meter radius of that grove for the rest of the winter, though after mid-January they rarely used the same roost tree twice. At Plaskett Creek in previous years, the monarchs had clustered almost exclusively in native conifers surrounding the campground to the south of Plaskett Creek. This year the monarchs moved about 150 meters north of Plaskett Creek and clustered solely in the Eucalyptus trees next to Pacific Valley School.

The number of roosting trees in which the monarchs clustered each week differed widely among sites (Table 2). The Monarch Grove Sanctuary, Andrew Molera State Park, and the private property site had the highest number of roost trees (26, 23, and 14 trees respectively). The Monarch Grove Sanctuary had the largest average number of roost trees (12.3) and Plaskett Creek had the fewest (1.8). For all six sites with clustering monarchs, the highest number of roost trees used occurred in November. However, at the Monarch Grove Sanctuary, the number of roost trees also peaked in January.

Climate correlates of population dynamics and habitat usage

The CIMIS weather system identified two periods of hot temperatures and high evapotranspiration: 14 November to 17 November 2008 and 11 January to 20 January 2009.

The November warm spell corresponds exactly to the week that the monarchs at the Monarch Grove Sanctuary moved from clustering primarily in Monterey Pine to clustering primarily in Blue Gum Eucalyptus (Figure 6). The second warm spell corresponds with another tree switching event at the Monarch Grove Sanctuary: between 11 January and 18 January, the monarchs once again moved from clustering in Monterey Pine and Monterey Cypress to clustering almost entirely in Eucalyptus (Figure 6). This January warm spell also corresponds to monarch dispersal at three transitional sites (Point Lobos, Sycamore Canyon, and Plaskett Creek) (Figure 9) and secondary dispersal at one climax site (the private property site) (Figure 7).

High precipitation days were recorded on 14 December 2008, 22 January 2009, and 6 February 2009. The mid-December storm was followed almost immediately with a period of cold, where temperatures dropped almost to freezing. The rain and the cold spell correspond with tree switching behavior by the monarchs in the Monarch Grove Sanctuary. They switched from roosting predominantly on Blue Gum Eucalyptus to clustering mainly on Monterey Pine and Monterey Cypress (Figure 6). A similar switch at the Monarch Grove Sanctuary occurred the week of February 6, when the monarchs completely abandoned the Eucalyptus to cluster exclusively on Monterey Cypress and Monterey Pine. The December rainfall and cold spell also corresponds exactly with early monarch dispersal at both Andrew Molera State Park and the private property site (Figure 7).

Tagging program

From 20 September 2008 to 31 January 2009 we tagged 2,915 butterflies in four tagging sessions at the Monarch Grove Sanctuary in Pacific Grove (Table 3). In addition to this, a total of 102 monarchs were tagged and released at the Pacific Grove Museum of Natural History as part of educational events. During the four tagging sessions at the Monarch Grove Sanctuary, 60 butterflies were recaptured, representing 2.1% of the tagged pool of monarchs. Of all butterflies tagged, 51% were identified as male, 48% were identified as female, and 1% were unknown.

In addition to the Pacific Grove tagging, Monarch Alert gave tags to “citizen scientist” Leslie Gilson to tag monarchs in Huntington Beach. She and her volunteers tagged

96 monarchs at Norma Gibbs Park from 1 December 2008 to 18 February 2009. 55% of these tagged monarchs were male and 45% were female.

One tagged butterfly was resighted on 22 January 2009 by researchers at the private property site in Big Sur. That butterfly had been tagged in Pacific Grove and had traveled approximately 50 kilometers south, but because the ID number could not be read, it is uncertain when it was tagged. No other intersite movement was observed.

There were 30 reports (call-backs) of tagged butterflies made to the toll-free phone number from 25 December 2008 to 31 March 2009. 20 of those were monarchs tagged in Pacific Grove, which means that the proportion of call-backs to the number of butterflies tagged was 0.7%. That is approximately equal to the proportion reported in past years (Frey et al. 2003; Frey et al. 2005) but lower than the proportion reported last year of 1.5% (Griffiths 2008). All 20 call-backs were from within Pacific Grove city limits. Ten of the call-backs were from the Huntington Beach monarchs, which means a call-back proportion of 10.4%. Nine of the ten call-backs were from within Huntington Beach, but one was from Laguna Beach (20 miles southeast).

The average number of days between a butterfly being tagged at Pacific Grove and its being reported was 68, compared to 59 days in 2008 (Griffiths 2008), 33 days in 2005 (Frey et al. 2005), and 54 days in 2003 (Frey et al. 2003). The average number of days between a butterfly being tagged in Huntington Beach and its being reported was eight.

DISCUSSION

The abundance of monarchs in Monterey County during the winter of 2008-09 was below average, and was in fact the third lowest since monitoring began in 2001 (Griffiths 2008). Yet the peak monarch population increased 88% over last year's peak population, representing a significant seasonal increase. The below-average population may be linked to the ongoing drought in California. Severely dry conditions have been linked to a decrease in milkweed biomass and a subsequent decrease in wintering butterfly populations (Frey and Stevens 2004). 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.

This year there were three sites in Monterey County that could be classified as climax sites: the Monarch Grove Sanctuary, the private property site in Big Sur, and Andrew Molera State Park. The Monarch Grove Sanctuary and the private property site have been climax sites every year since monitoring began in 2001, and normally contain the majority of the county's overwintering population. Those two sites accounted for 72% of the monarch population in Monterey County from November until mid-December, and in January and February they accounted for 96% of the county's monarch 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 roost tree numbers and species used by clustering monarchs revealed some interesting patterns. Tree species switching corresponded very closely with both above-average temperatures and high levels of rainfall. Monarchs at the Monarch Grove Sanctuary moved from non-native Eucalyptus trees to native conifers in times of high precipitation. They moved from the conifers to Eucalyptus when temperatures were hot and back again when temperatures dropped. This pattern has been observed multiple times in past years (Hamilton et al. 2002, Frey et al. 2003, Frey et al. 2004, Griffiths 2008). 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 the elements 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. Higher temperatures also corresponded to an increased number of roost trees, which implies that the butterflies do not cluster as tightly in warm weather. During the two warm spells (one in November and one in January), the number of trees used by clustering monarchs at the Monarch Grove Sanctuary increased dramatically.

While the warm spell in January appears to have caused dispersal at the transitional sites, dispersal at Andrew Molera State Park seemed to correspond with high precipitation and cooler temperatures. This site is dominated entirely by Blue Gum Eucalyptus, so it is possible that the changing weather conditions rendered the site unsuitable for monarchs and

they departed to find a site that contained conifers for them to cluster in. Perhaps it was not true dispersal, but merely movement to another overwintering location. Unfortunately because there was no tagging conducted at that site, there is no way to know for certain.

In contrast to the other sites, the Monarch Grove Sanctuary retained large clusters of monarchs later into the season than in any other year. By the last week of February, over 50% of the monarchs still remained at the site. The likely reason for this was steady rainfall throughout the month of February and into early March. Dispersal had already occurred at most of the other sites before the February storms moved through, so only the Monarch Grove Sanctuary retained its butterflies. Dispersal finally occurred during the first two weeks of March.

Point Lobos State Reserve also had an interesting pattern of monarch occupation this year. Instead of peaking in November or December like all other Monterey County overwintering sites, monarchs continued to increase at Point Lobos into January. After peaking in early January, the monarchs then rapidly declined at the site and were gone by the end of that month. It is unclear why they continued to increase so late into the winter. Perhaps monarchs were moving from other locations; populations were already declining at all of the other overwintering sites. Tagging at multiple locations may shed light on this issue in the future.

Movement within overwintering sites was another interesting pattern observed this winter. This year, the monarchs at the private property site in Big Sur abandoned the Coast Redwood that they have clustered on since 2001. They left the redwood during the warm spell in mid-November and switched to a stand of Eucalyptus about 300 meters north of their previous position. But interestingly, they stayed there for several weeks, and did not switch back to the redwood once temperatures dropped at the end of December. In fact, the butterflies appeared to temporarily abandon the site completely in early January (Figure 7). This movement is somewhat puzzling, but there is a possible explanation. The last time the monarchs changed roost sites drastically at the private property site was prior to 2001, when the monarchs moved from their favored spot in a large Eucalyptus when that tree was either trimmed severely or cut down. They moved to the Coast Redwood, and came back to it for eight consecutive years. Then in the summer of 2008, the Basin Complex Fire burned very close to the property, and many trees were trimmed or cut down near Highway 1 in order to

form a fire break. The redwood tree is approximately 50 meters from Highway 1, so it is possible that trimming the trees along the highway somehow altered the microclimate around the redwood. It is too early to tell whether the butterflies have permanently abandoned the redwood roost, or whether it was just an aberration.

It is also worth noting that sometime between 9 December and 16 December 2008, the Eucalyptus trees at Pacific Valley School (at the Plaskett Creek site) in which the monarchs roost were trimmed for safety reasons, with several lower limbs removed. It is unclear whether this had any effect on the clustering monarchs. The monarchs stayed in their clusters in the trimmed trees for another month, until they dispersed in early January during the period of unusually warm weather. It will be interesting to note whether the tree trimming has any effect on the clustering behavior of monarchs returning to the site next fall.

The sex ratio of male to female monarch butterflies was found to be approximately 1:1 this winter (51% male and 48% female). This nearly even sex ratio is markedly different than the 2:1 male-to-female sex ratios recorded in past years. For instance, in both the winters of 2006-07 and 2007-08, 63% of monarchs tagged in Pacific Grove were male and 37% were female (VWS unpublished data, Griffiths 2008). A preliminary study of four overwintering sites in Monterey County in 2003-04 found an average sex ratio of 65% male and 35% female (unpublished VWS data), while studies conducted in San Luis Obispo County found similar 2:1 sex ratios (Frey and Leong, 1993, 1995). The 1:1 sex ratio found in Pacific Grove this year is similar to the 1:1 sex ratio found on the Mexican wintering grounds of the eastern monarch population (Brower et al. 2004). It is unknown whether other sites in Monterey County had similar sex ratios this winter, since the Monarch Grove Sanctuary is the only location where tagging was conducted. Further investigation is warranted; if tagging was conducted in San Luis Obispo County this winter it would be important to learn the ratio of males to females at those locations.

Tagging totals were lower this year in Monterey County than in past years, which could partially explain the lower percentage of call-backs. Another possible explanation is the extremely late dispersal of monarchs from the Monarch Grove Sanctuary, which means that call-backs may continue to be reported even after this report is finalized. The very high call-back proportion in Huntington Beach may be due to the extremely high population density in that area; Huntington Beach is located in Orange County which is more urbanized

and has a much higher population than either Monterey County or San Luis Obispo County. This could also explain the much shorter tag reporting time for Huntington Beach (eight days) versus Monterey County (68 days).

Monarch movement between overwintering sites seemed to be very low this year. There was no intersite movement recorded in November or December, in contrast to previous years. The only movement recorded was a monarch that traveled from Pacific Grove to the private property site in January, which is much later than usual. However, it is interesting to note that this monarch was resighted just a few days after the warm spell in mid-January. It is possible that the monarch was dispersing early in response to the high temperatures. If that is the case, then it may indicate that monarchs use multiple overwintering habitats throughout the winter, and not just in November and December. This highlights the importance of preserving multiple nearby overwintering sites.

SUMMARY AND CONCLUSIONS

Monarch Alert project investigators completed the eighth consecutive year of western monarch butterfly research in Monterey County. The overwintering population in Monterey County during the winter of 2008-09 increased 88% from the previous winter, but when placed in the context of population fluctuations since 2001, this was not a statistically significant change. Three of nine sites in Monterey County were climax sites with monarchs clustering throughout the winter: the Monarch Grove Sanctuary, Andrew Molera State Park, and the private property site in Big Sur. Three of nine sites were transitional sites, with monarchs departing by early January: Point Lobos, Sycamore Canyon, and Plaskett Creek. Two new sites, the Eucalyptus grove outside the Naval Postgraduate School in Monterey and Rancho Grande in Big Sur, should be monitored next year for overwintering monarchs.

At the Monarch Grove Sanctuary and the private property site, butterflies reacted to changes in the climate by shifting their tree species preference. When temperatures declined and when precipitation increased, they moved from Eucalyptus to Monterey Pine and Monterey Cypress trees, preferring denser native conifers in colder, wetter weather. A hot and dry spell in January triggered tree species switching and early dispersal at the transitional

sites. Over the course of 6 tagging sessions, 2,915 monarchs were tagged, with a callback rate of 0.7%, down from the callback rate of 1.5% from last year.

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.

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Table 1. Study sites and surveys on the coast of Monterey County, California during winter 2008-2009.

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	11/4/08- 3/4/09	17
George Washington Park	8.0 km N	Monterey Pine	11/4/08- 2/6/09	11
Point Lobos State Reserve	5.0 km S ^b	Monterey Pine	11/4/08- 2/6/09	14
Palo Colorado Canyon	16.0 km S	Blue Gum Eucalyptus	11/7/08- 11/11/09	2
Andrew Molera State Park	34.0 km S	Blue Gum Eucalyptus	11/7/08- 2/26/09	16
Sycamore Canyon	42.0 km S	Monterey Cypress	11/7/08- 2/6/09	11
Private Property	70.0 km S	Blue Gum Eucalyptus Coast Redwood Monterey Cypress	11/6/08- 2/26/09	16
Prewitt Creek	95.0 km S	Blue Gum Eucalyptus	11/6/08- 2/6/09	10
Plaskett Creek Campground	96.5 km S	Blue Gum Eucalyptus Monterey Cypress Monterey Pine	11/6/08- 2/6/09	10

^a North of Carmel River

^b South of Carmel River

Table 2. Tree use pattern at monarch butterfly overwintering sites in Monterey County, California.

Site	Trees occupied (mean \pm S.E.)	Minimum no. trees	Maximum no. trees	Month of maximum
Monarch Grove Sanctuary	12.3 \pm 1.6	5	26	November, January
Point Lobos	3.8 \pm 0.5	2	7	November
Andrew Molera	6.6 \pm 1.7	1	23	November
Sycamore Canyon	2.3 \pm 0.5	1	4	November
Private Property	5.2 \pm 0.8	1	14	November
Plaskett Creek	1.8 \pm 0.3	1	3	November, December

Table 3. Total number of monarch butterflies tagged in six tagging sessions in Pacific Grove, California during the winter of 2008-2009.

Date	Location	New	Recaptured	Total
9/20/2008	PG Museum of Natural History	43		43
11/14/2008	Monarch Grove Sanctuary	16		16
11/15/2008	Monarch Grove Sanctuary	464	1	465
11/29/2008	PG Museum of Natural History	59		59
12/17/2008	Monarch Grove Sanctuary	1,021	11	1,032
1/31/2009	Monarch Grove Sanctuary	1,312	48	1,360
Totals		2,915	60	2,975

Figure 1. Locations of nine study sites on the coast of Monterey County, California surveyed during the winter of 2008-2009.

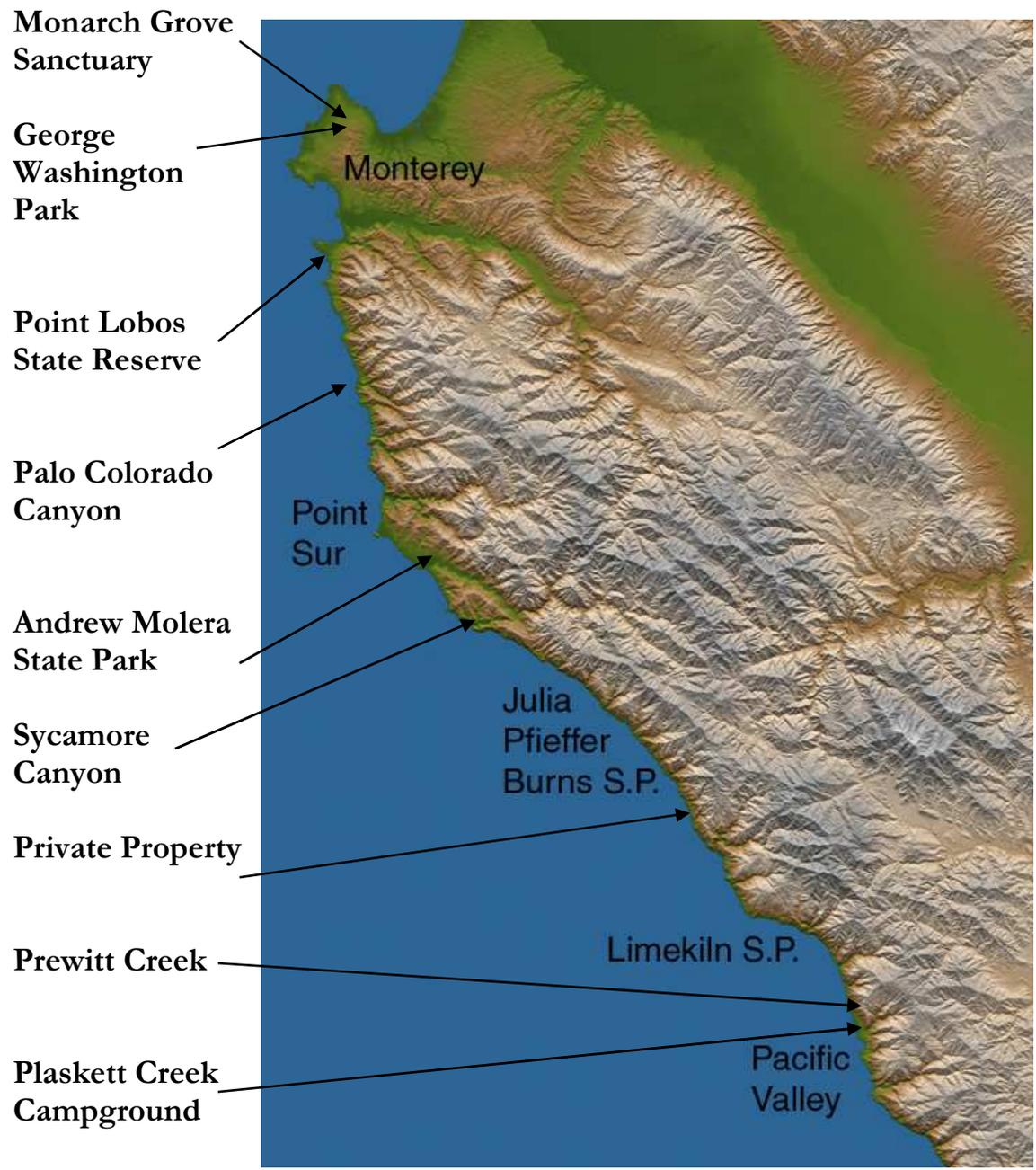
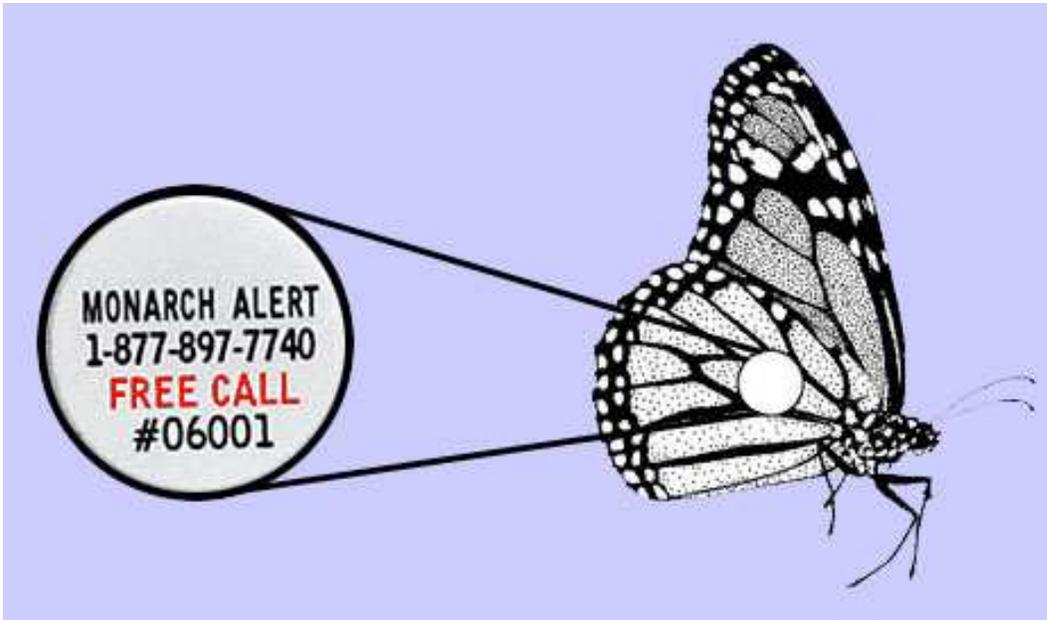


Figure 2. (a) Watson Label Company tag used to mark monarch butterflies during the 2008-09 season. (b) Tagged monarch nectaring on English ivy.



(a)



(b)

Figure 3. Docents and volunteers tagging monarch butterflies at the Pacific Grove Monarch Grove Sanctuary.



(a)



(b)

Figure 4. Peak monarch butterfly populations in Monterey County, California from 2001-2009.

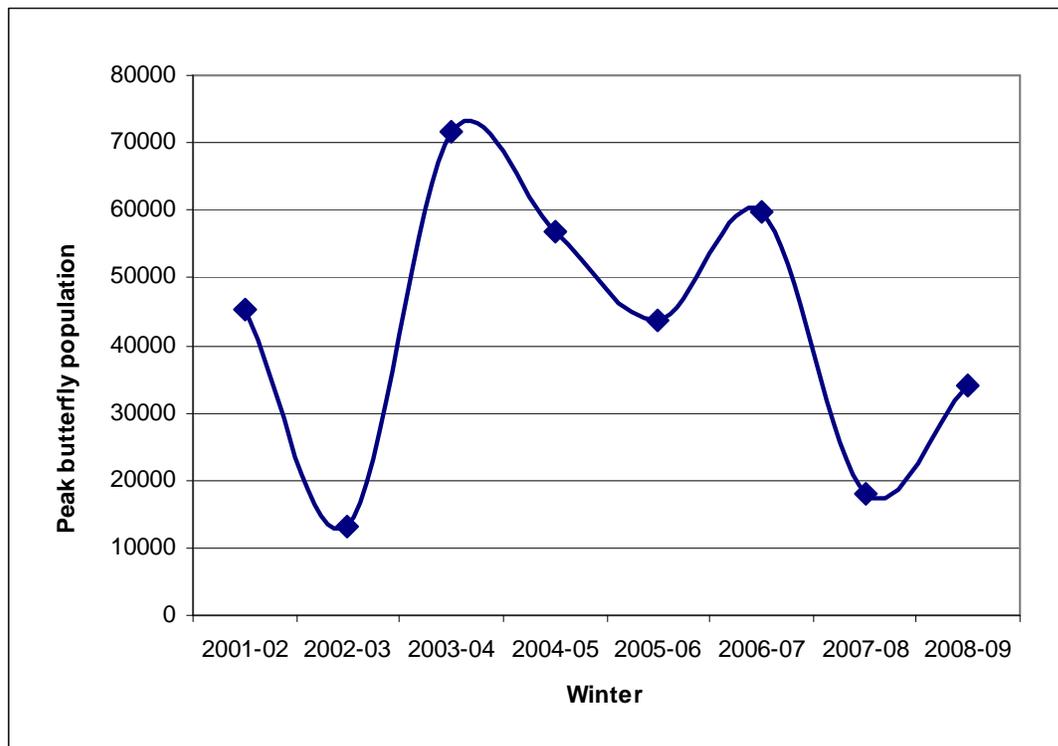


Figure 5. Weekly estimates of overwintering monarch butterflies at the Monarch Grove Sanctuary in Pacific Grove and weekly totals for all sites in Monterey County, California during the winter of 2008-09.

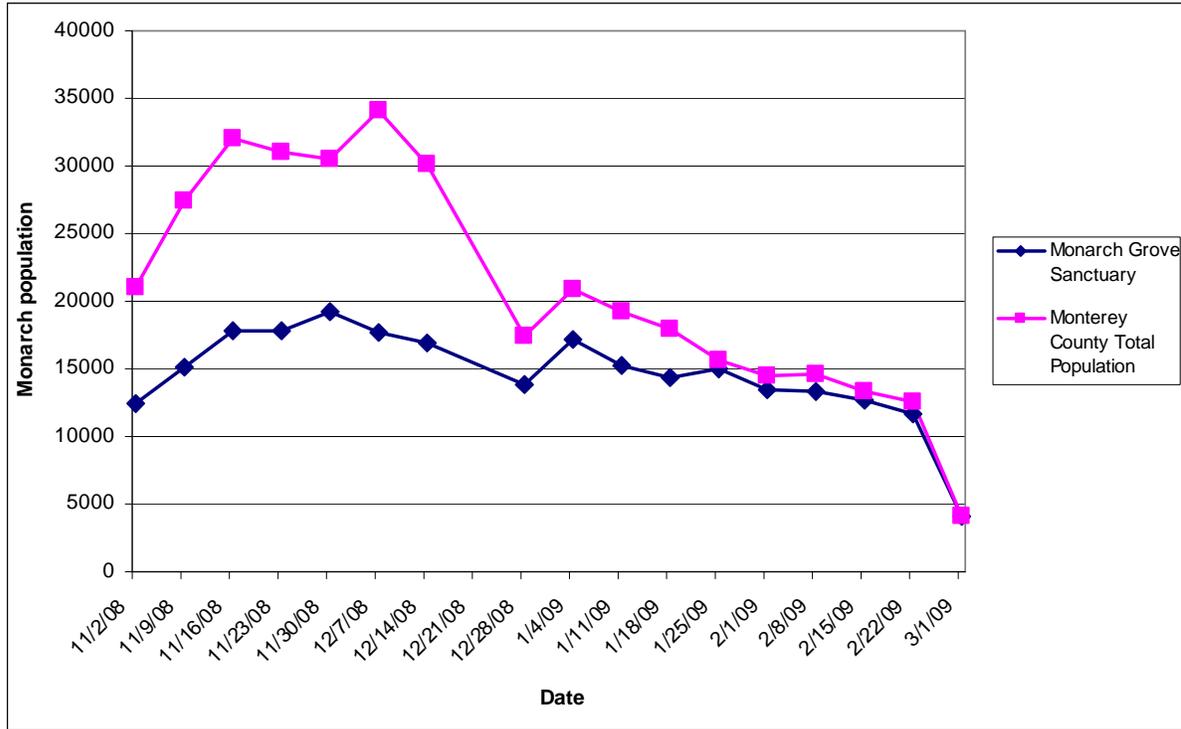


Figure 6. Estimated numbers of monarch butterflies using different tree species at the Monarch Grove Sanctuary in Pacific Grove, California during the winter of 2008-09.

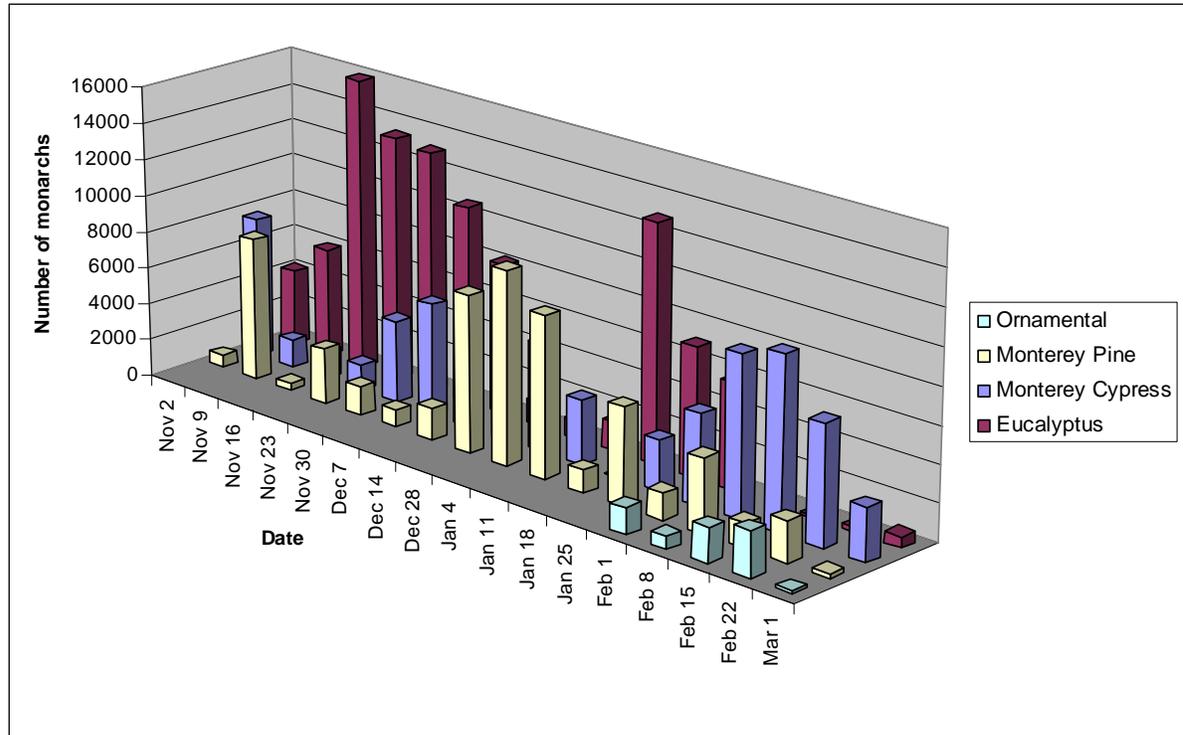


Figure 7. Weekly estimates of overwintering monarch butterflies at a private property site in Big Sur and at Andrew Molera State Park in Monterey County, California during the winter of 2008-09.

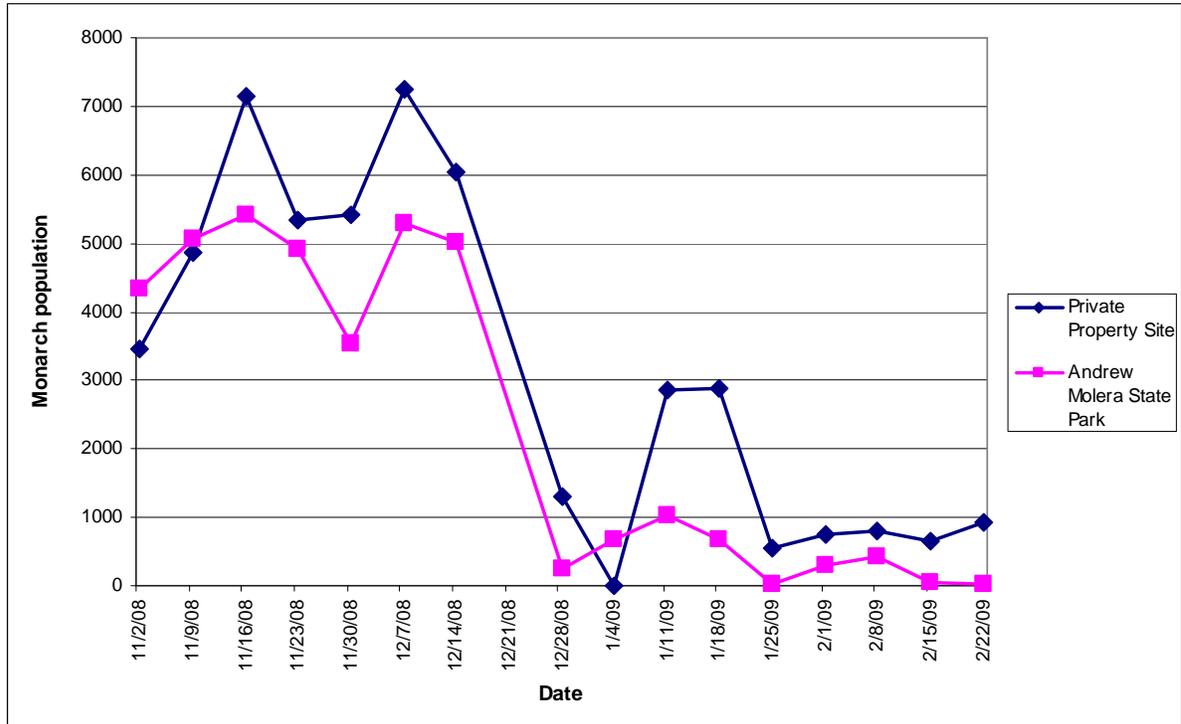


Figure 8. Estimated numbers of monarch butterflies using different tree species at a private property site in Big Sur, California during the winter of 2008-09.

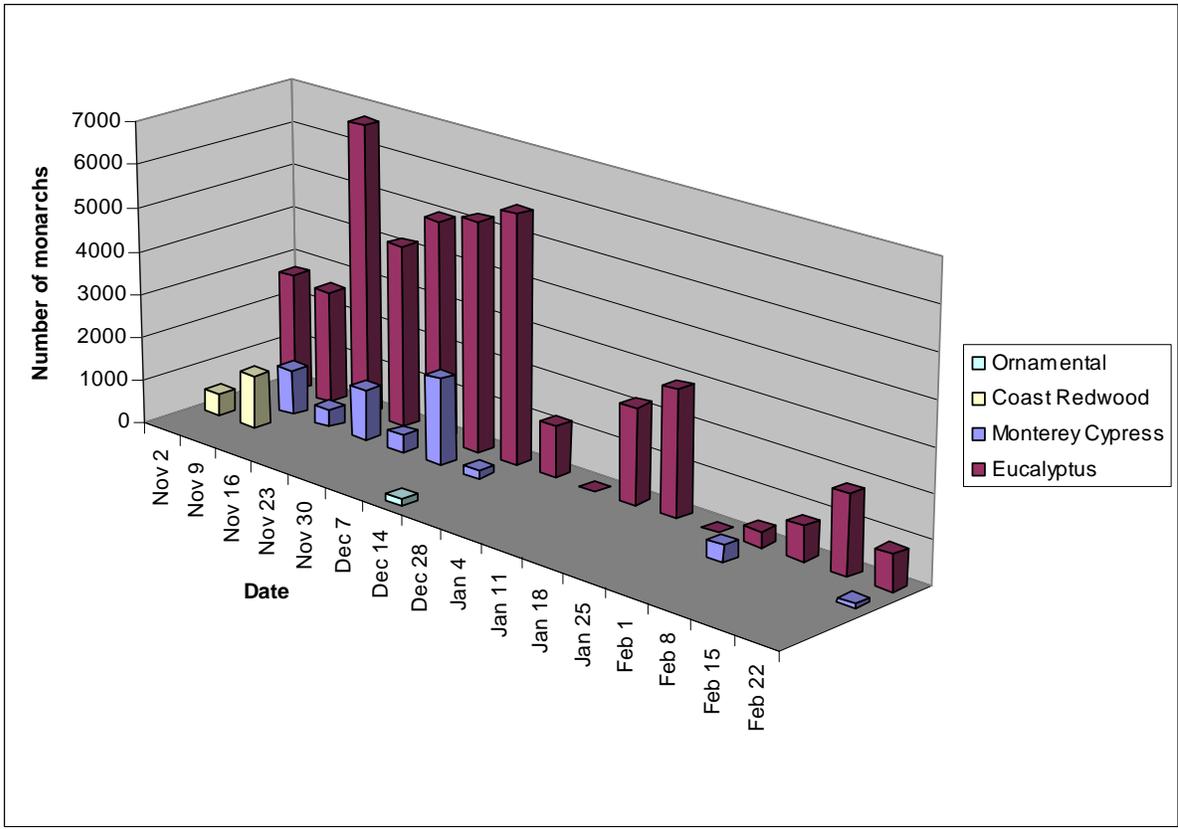


Figure 9. Weekly estimates of overwintering monarch butterflies at Point Lobos State Reserve, Sycamore Canyon, and Plaskett Creek, all located in Monterey County, California, during the winter of 2008-09.

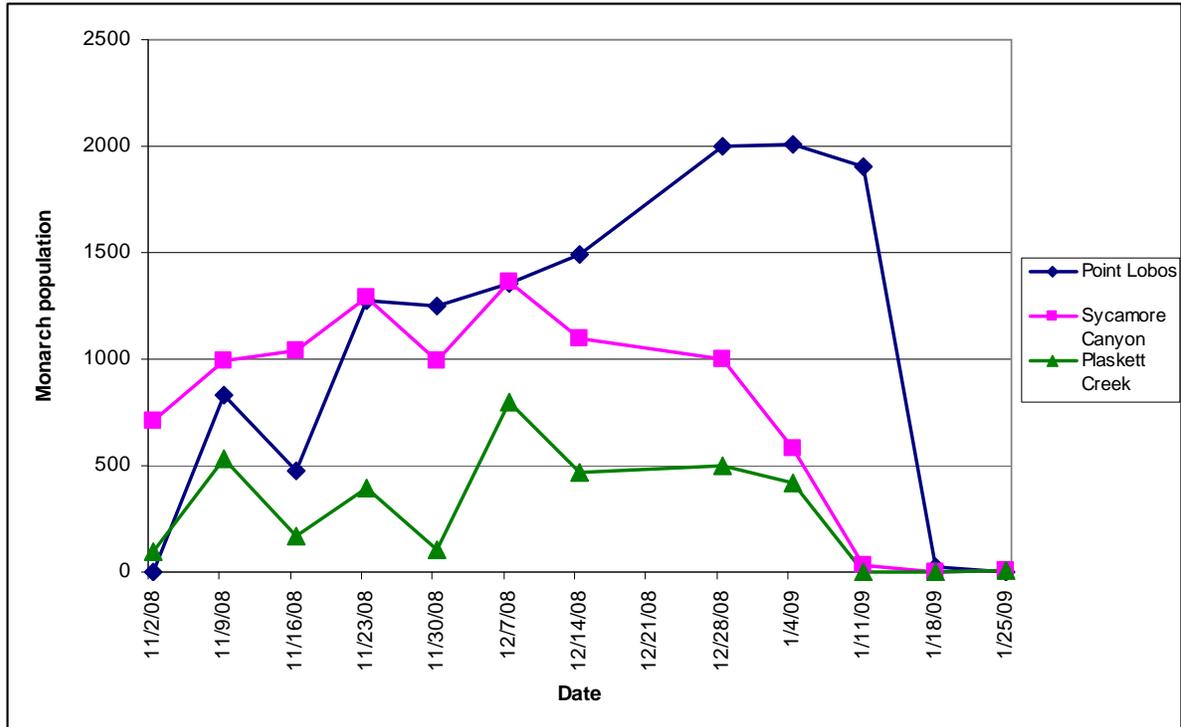


Figure 10. Distribution of clustering monarch butterflies in roost trees relative to aspect in degrees at nine overwintering sites combined in Monterey County.

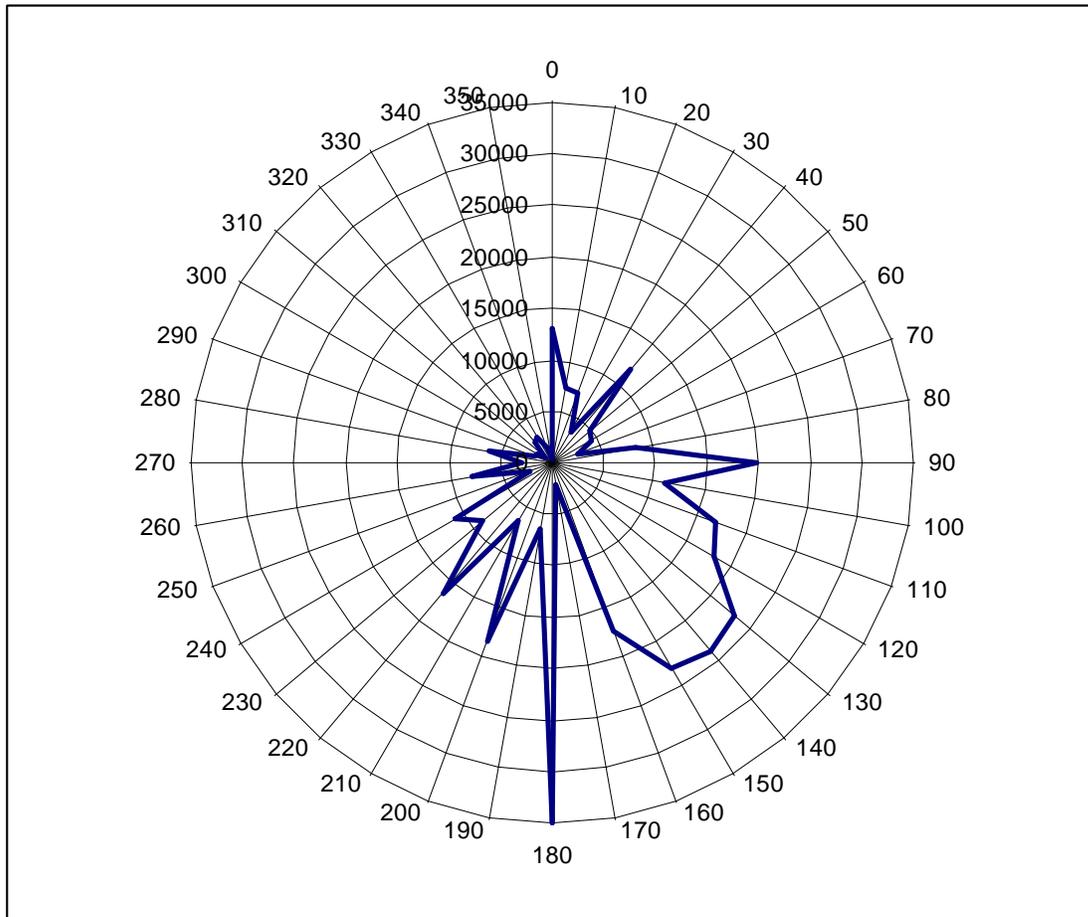
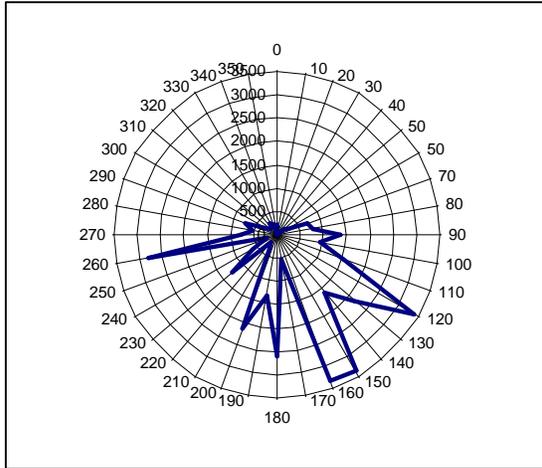
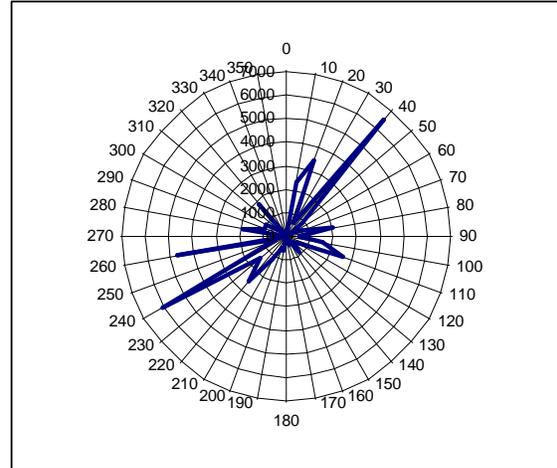


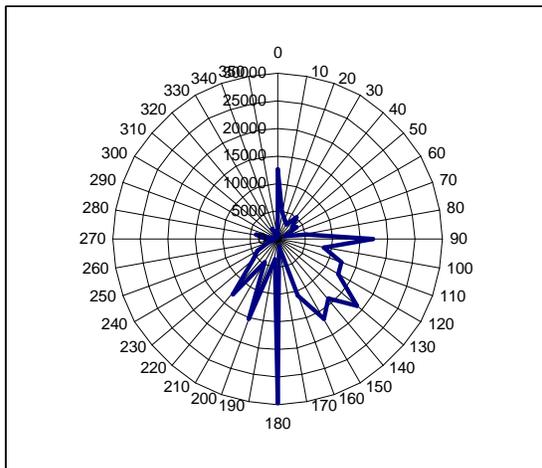
Figure 11. Distribution of clustering monarch butterflies in roost trees relative to aspect in degrees at six overwintering sites in Monterey County.



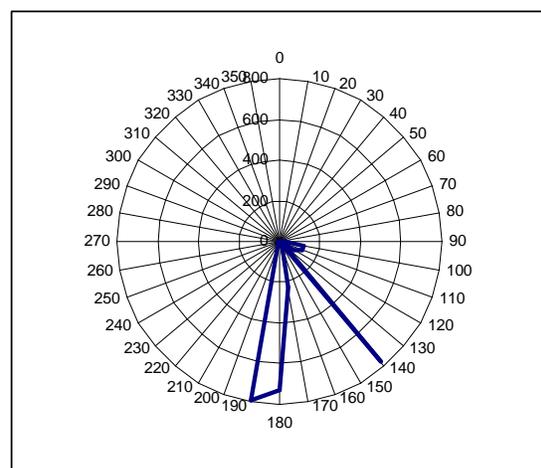
(a) Andrew Molera State Park



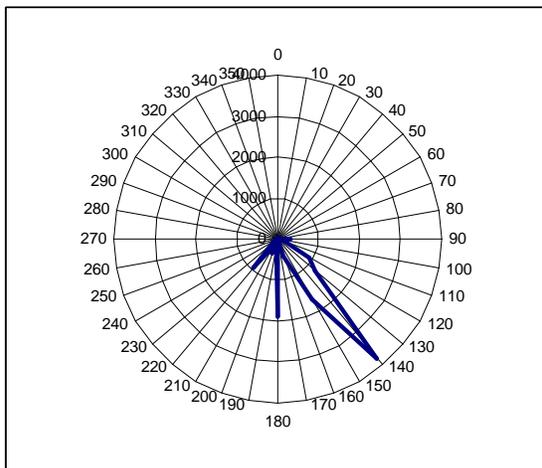
(b) private property site



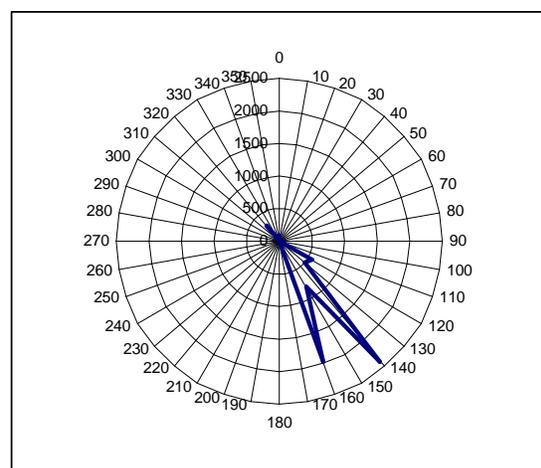
(c) Monarch Grove Sanctuary



(d) Prewitt Creek



(e) Point Lobos



(f) Sycamore Canyon

Appendix 1. Monarch butterfly site specific data sheet.

Over-wintering Monarch Butterfly Project
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 (°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.

Temp: in Celsius degrees

Sky:

- 0 = Clear, few clouds
- 1 = Partly cloudy, scattered
- 2 = Mostly cloudy, broken
- 3 = Overcast
- 4 = Fog or smoke
- 5 = Drizzle
- 8 = Showers

Wind (Beaufort Scale):

<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

Tree Species Codes:

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