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INTRODUCTION

This report summarizes the status of 2009-2010 overwintering monarch butterflies at 18 sites in San Luis Obispo and Monterey Counties, California. All of the data collection follows protocols established by Monarch Alert in 2004. The methodologies are briefly outlined here. The focus of this report is to summarize the results from population and habitat census efforts. The number of monarchs in individual roosting clusters at each site, was used to estimate the weekly population size for each site, and for the entire overwintering population. The habitat census was based on weekly visits to assess occupancy, and to characterize the microhabitat being used by individual clusters of roosting monarchs. Where ever possible data are compared to results from previous years.

METHODOLOGY

Study sites.

We monitored the number of overwintering Monarch butterflies at multiple (n=18) study sites in Monterey (Figure 1, and appendix 1) and San Luis Obispo Counties (Figure 2 and appendix 2), California. To determine if monarch butterflies utilized a site, we visited prospective sites beginning on October 1st 2009. Before 9am we evaluated habitat characteristics, and stand condition, and determined the presence/absence of Monarch butterflies in nighttime roosting clusters. If monarchs were present, the site was monitored weekly, stating on Oct 23rd and continuing through March. If the habitat looked suitable, but monarchs were not found or not in clusters, follow-up visits were conducted at 10-days intervals from October 1st until Dec 1st 2010, and then at 14-day intervals through April 1st 2011.

Figure 1. Monarch Alert population monitoring sites in Monterey County sampled during the 2009-2010 overwintering season.

Figure 2. Monarch Alert population monitoring sites in San Luis Obispo County sampled during the 2009-2010 overwintering season.
Population Monitoring.

We obtained estimates of the number of butterflies in nighttime roosting clusters in order to estimate the population size at each of the 18 sites. Estimates were obtained weekly. The survey work was done during the morning and only while temperatures remained below flight threshold (13°C). Only butterflies that were still in nighttime roosting clusters are considered here. The number of butterflies in a cluster was estimated by first counting the number of monarch butterflies in a small area of a cluster, and then extrapolate the count over the entire cluster. The number of butterflies per tree was calculated by summing the counts of all the clusters in each tree. Only one survey was aborted due to rain that was sufficiently heavy to impair visibility. The following data were recorded onto field data forms: a) Site name, b) Date, c) Observers (number and names), d) Count start and end times, e) Number of clusters detected, f) Estimated number of butterflies per cluster, g) Aspect of cluster relative to roost tree, h) Height of cluster, i) Estimated number of butterflies per tree, j) Tree species, k) Number of mating monarch butterflies, l) Number of monarchs in flight and on the ground, m) Presence of nectar and water sources.

Thanksgiving counts.

We coordinated with the Xerces Society in order to contribute to the annual statewide count. Specifically, we coordinated with Ernest Glenesk, Richard Welch, and Peggy Coon. We also coordinated with Tama Olver and undertook the entire count for Monterey County. Our data were provided to Xerces for posting on their web site.

RESULTS

Long term statewide population trends.

Monarch butterfly abundance in the state of California as measured by the Xerces Society Annual Thanksgiving Count from 1997-2008 is shown in Figure 3. Monarch Alert contributed all of the 2009 data for Monterey County and some of the 2009 data for San Luis Obispo County. 2009 data had not been posted to the Xerces site (http://www.xerces.org/california-monarchs/) as of 20 Aug 2010. Apparently they are waiting for data to be turned in. Therefore, long-term trends are only known from 1997-2008.

Figure 3. Plot of the long-term population trend (1997-2008) for overwintering Western monarchs in California based on Xerces (http://www.xerces.org/california-monarchs).
Long term trends in Central Coast Counties of California.

The Xerces Society Thanksgiving Count data should allow us to consider County-by-County trends. To date, no data have been posted for Santa Cruz County, all of the data have been posted for Monterey County (all contributed by Monarch Alert), and only some of the date has been posted for San Luis Obispo County (those provided by Monarch Alert). The only County for which trends can be determined is Monterey County. No trends can be evaluated for San Luis Obispo County or Santa Cruz Counties. Figure 4 shows County trends from 1997 through 2008 or 2009 depending on the availability of data. In Monterey, the 2009 count is the lowest on record.

Figure 4. Long term population trends by year and county. Total monarch abundance as estimated by the Xerces Society Annual Thanksgiving Count 1997-2009. Data for 2009 were not available (http://www.xerces.org/california-monarchs/) for all Counties. Therefore only results for Monterey County are graphed through the year 2009.

Sampling effort in Monterey County 2009-2010.

In addition to the Thanksgiving Count, Monarch Alert conducted weekly surveys of overwintering sites in Monterey County. Surveys were conducted by Jaime Miller, with assistance from Tama Olver. The survey season was from October through February. A summary of the survey site names, locations, dominant tree species, and survey effort is presented in Table 1 (see Figure 1 for acronyms). Four of the nine sites monitored in Monterey County were consistently occupied by overwintering monarchs (PG, AM, EI, and PK). Five of the nine sites were either not occupied (PC and SC), or were occupied by a small number of butterflies (GWP, PL, and PR). These last three sites (GWP, PL, and PR) were potentially just autumnal sites (not overwintering sites), but they were monitored weekly nonetheless in order to be able to establish that fact. In total 19 weeks worth of surveys were conducted. The potential overwintering sites were: the Monarch Grove Sanctuary, Andrew Molera State Park, the Private Property in Big Sur, and Plaskett Creek Campground in Big Sur.
Table 1. Description of the monarch butterfly overwintering sites monitored in Monterey County during the 2009-2010 season. Sites that were surveyed 9-10 times were not occupied by monarch butterflies. Sites that were surveyed 16-19 times were occupied. Site locations are also shown in Figure 1.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Location</th>
<th>Predominant Tree Species</th>
<th>Survey Period</th>
<th>Number of Surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarch Grove Sanctuary</td>
<td>8.0 km N&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus Monterey Cypress Monterey Pine</td>
<td>10/22/09-2/21/10</td>
<td>19</td>
</tr>
<tr>
<td>George Washington Park</td>
<td>8.0 km N&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Monterey Pine</td>
<td>11/7/09-2/21/10</td>
<td>16</td>
</tr>
<tr>
<td>Point Lobos State Reserve</td>
<td>5.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Monterey Pine</td>
<td>11/11/09-2/21/10</td>
<td>16</td>
</tr>
<tr>
<td>Palo Colorado Canyon</td>
<td>16.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus</td>
<td>11/8/09-2/14/10</td>
<td>9</td>
</tr>
<tr>
<td>Andrew Molera State Park</td>
<td>34.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus</td>
<td>11/8/09-2/21/10</td>
<td>17</td>
</tr>
<tr>
<td>Sycamore Canyon</td>
<td>42.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Monterey Cypress</td>
<td>11/8/09-2/14/10</td>
<td>10</td>
</tr>
<tr>
<td>Private Property</td>
<td>70.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus Coast Redwood Monterey Cypress</td>
<td>11/6/09-2/21/10</td>
<td>17</td>
</tr>
<tr>
<td>Prewitt Creek</td>
<td>95.0 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus Monterey Pine</td>
<td>11/6/09-2/21/10</td>
<td>16</td>
</tr>
<tr>
<td>Plaskett Creek Campground</td>
<td>96.5 km S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Blue Gum Eucalyptus Monterey Cypress Monterey Pine</td>
<td>11/6/09-2/21/10</td>
<td>17</td>
</tr>
</tbody>
</table>

<sup>a</sup> North of Carmel River,  <sup>b</sup> South of Carmel River

Long term population trends in Monterey County.

Data are available for all of the Monterey County sites for the overwintering season from 2001-2002 through 2008-2009. These data have all been collected by Monarch Alert, and do not depend on information from Xerces. For each year, we can calculate the maximum population size for the entire county. This would be the “peak” population size, and does not necessarily represent a count that was sustained. Nevertheless, these data provide the best estimate of the
Monterey County population trends available (Figure 5). In the short-term these data suggest that the monarch population at monitored sites in Monterey County declined from about 35,000 in 2008-2009 to about 5,000 in 2009-2010. The long-term trend (beginning in 2001) fits either a stable limit cycle model, or a stochastic (random) population growth model. The stable limit model cycles (or oscillates) around a norm or mean. The stochastic model is more haphazard and inherently less predictable. Yet, there is no overall linear decline evident in these data.

Figure 5. Long-term maximum, or peak, size of the overwintering monarch population for nine sites that have been monitored in Monterey County beginning with the fall of 2001 and ending with the spring of 2010. This is a smoothed line function of nine data points that represent the estimated overwintering population size (based on estimation of the number of monarchs in roosting clusters).

Weekly population estimates at Monterey County sites.

The temporal variation in population size at each site can be used to recognize, or define, which sites are overwintering sites, and which are autumnal sites. The population at a site must persist in order for it to be classified as an overwintering site. These sites are often those with the largest number of butterflies. But, a large population size, does not, in itself, indicate that the site will continue to be occupied for the entire overwintering period. Only three sites in Monterey County qualified as overwintering sites in the 2009-2010 season (Figure 6). Therefore the actual overwintering sites were: the Monarch Grove Sanctuary, the Private Property in Big Sur, and Plaskett Creek Campground in Big Sur. Importantly, Andrew Molera State Park, appears to have acted as an autumnal site in the season being considered by this report. There is no obvious reason for this, other than this site had the lowest population estimate of the sites that were consistently occupied (Figure 6).
Figure 6. Estimated weekly population size for overwintering monarchs across each site that was monitored in 2009-2010. Site codes are as in Figure 1. Site locations are shown in Figure 1. Three sites appear to be true overwintering sites (PG, EI and PK), all other sites with monarchs present at some time during the winter were ultimately categorized as autumnal sites.

*Pacific Grove Monarch Sanctuary.*

The Monarch Sanctuary at Pacific Grove was the center of some intense scrutiny during the 2009-2010 overwintering season. City arborist crews were responsible for some extensive pruning in the sanctuary. Some monarch advocates speculate that the Sanctuary would only act as an autumnal site, and would never qualify as an overwintering site because of a significant reduction in windbreak and change in the thermal profile of the remaining canopy. In addition, there was speculation that the trimming caused a disproportionately greater decline in the monarch population at the Sanctuary than at any other site in Monterey County.

The issue of whether the Sanctuary provided only an autumnal site or an overwintering site is addressed in *Figures 6 and 7*. If we define the overwintering season as the time over which monarchs were present at monitored sites in Monterey County, then Figure 7 shows that monarchs still occupied survey sites during the week of 2/14/2010, but none were recorded at survey sites the week of 2/21/2010. So, in the sites we surveyed, the overwintering season in Monterey County continued through the week of 2/14/2010, but had ended by the week of 2/21/2010. Monarch butterflies persisted at the Sanctuary until the last week that can be considered the overwintering season (as defined by monarchs being present at other monitored sites in Monterey County *Figure 7*). The data (*Figure 6*) clearly show that monarchs still occupied the Sanctuary during the week of 2/14/2010, but none were recorded at the Sanctuary.
the week of 2/21/2010. Therefore, the speculation that the Sanctuary would function only as an autumnal site was not supported by data.

Figure 7. Estimates of weekly overwintering monarch butterfly abundance for all Monterey County sites combined (for the winter of 2009-2010). The overwintering season (at monitored sites) ended the week of 2/21/2010, as sites were no longer occupied after that date. Two sites were still occupied on 2/14/2010: the Private Property in Big Sur (El) and the Pacific Grove Sanctuary (PG).

There is also the issue of whether the tree trimming caused a disproportionately greater decline in the monarch population at the Sanctuary than at any other site in Monterey County. As has already been noted, in 2009-2010 there was an overall decline in the estimated population size of overwintering monarchs across the monitored sites in Monterey County relative to 2008-2009 (Figure 5). Yet that conclusion was reached with data from the Sanctuary being included in the analysis (Figure 5), and population estimates could be biased (downward) by that inclusion.

One way to address this issue is to ask the question, was the Sanctuary the only site that declined in 2009-2010 causing Monterey County to show an overall decline, or did all sites show a decline? As is often the case in Science, one’s conclusion regarding the alternatives may hinge on what is considered a “comparable” site for Monterey County. The data are shown in Figure 8.

Three of the sites in Figure 8 were autumnal: MO (AM), PL and SC. Three of the sites in Figure 8 were overwintering sites: PG, PR (El) and PK. The percent change is calculated for each site using the maximum population count for each year as well as the average population count for each year. The figure shows that all sites show a decline between years, except when
we consider the *average* population estimate at the Private Property in Big Sur (though the *max* population size is indeed lower in 2009-2010 than it was in 2008-2009). This demonstrates that one’s conclusion is dependent on how a decline in estimated (i.e.: what does one compare, the maximum between years or the means?), in addition to what is considered a “comparable” site.

Unfortunately, there is *no clear or un-equivocal evidence* to support the prediction that the Monarch Sanctuary at Pacific Grove showed a pattern that is any different from other sites in Monterey County. All sites declined. Indeed if that very statement, that all sites declined, depends on what sites were compared and how, then we lack un-equivocal evidence. With one year worth of data it will be impossible to determine if the pruning at the Sanctuary was the *cause* of the reduced population size in 2009-2010 relative to the previous year, because, overall, all sites declined.

But, this is an important issue. So, let us address it by asking another question: *did the Sanctuary decline significantly more than other sites in Monterey County?* This would be our prediction if there had been a “site-specific” effect at the Sanctuary (such as tree trimming): an effect above and beyond those affecting all other sites in Monterey County. In other words, did the Sanctuary show a *disproportionately greater decline* than other sites? The only way to evaluate this possibility is to compare the percent decline at the Sanctuary to the average percent decline across all sites in Monterey County (**Figure 8**). If we consider all sites, except the Sanctuary itself, the average decline in the maximum population estimate between years is 84%. The decline at the Sanctuary was 97%, which is a 13% greater decline than the average. We can do the same for the change in the mean population estimate. If we consider all sites, except the Sanctuary itself, the average decline in the mean population estimate between years is 60%. The decline at the Sanctuary was 97%, which is a 36% greater decline than the average.

Thus *it appears that there was a greater decline at the Sanctuary than at other sites*, but how much of this excess can be attributed to the tree trimming and how much to chance and variation between sites is unknowable. Likewise, it might be instructive to do a similar analysis but using only the true overwintering sites (excluding the autumnal sites). Except that the small sample size (n=2 overwintering sites) if we exclude the Sanctuary would make such a comparison even more speculative than the one presented above.

It might simply be that we will need to collect more data (in the future) before we can actually determine if there is a real and substantial probability that the tree trimming in 2009 lead to a disproportionate decrease at the Sanctuary relative to other sites in Monterey County. It is still possible that the tree trimming was the cause of the low population size at the Sanctuary, it is just that such a conclusion is not yet substantiated by data.
Figure 8. Change in the estimated population size of monarch butterflies at overwintering sites in Monterey County in 2009-2010 relative to the 2008-2009 overwintering season. The percent change at each site is shown by the broader (yellow and blue) columns. The blue columns show the percent change between years calculated as the (2009 population estimate - 2010 population estimate) / 2009 population estimate based on the maximum population size. The general formula is shown at the top of the figure. The yellow columns show the same data but calculated as the percent change in the average population size per site. The red lines, in the blue columns, show the average decline in maximum population size across all sites (excluding the Sanctuary). The red lines, in the yellow columns, show the average decline in mean population size across all sites (excluding the Sanctuary). The Pacific Grove Sanctuary results are shown in the orange box to the left side of the figure. PG, PR and MO are overwintering sites. PL, SC, and PK are autumnal sites.

Tree use patterns by monarchs overwintering in Monterey County sites.

There were several occasions where the entire monarch population at an overwintering site was restricted to a single tree (Table 2). It is important to note that even though this happened at three different sites in Monterey County, the species of tree that the population “condensed” onto was not the same (Table 2). Thus, it seems that tree use pattern, and the importance of individual roosting tree species, will differ across sites in Monterey County. This suggests that the microclimate at individual trees (or groves) may be more important than the tree species.
Table 2. Tree use pattern at monarch butterfly overwintering sites in Monterey County, California during winter 2009-2010. * Monterey Pine, †Eucalyptus, § Coast Redwood

<table>
<thead>
<tr>
<th>Site</th>
<th>Trees Occupied (mean ± SE)</th>
<th>Minimum no. trees</th>
<th>Maximum no. trees</th>
<th>Month of Minimum</th>
<th>Month of Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarch Grove Sanctuary</td>
<td>4.4 ± 0.6</td>
<td>2</td>
<td>10</td>
<td>October, November</td>
<td>December, February</td>
</tr>
<tr>
<td>Point Lobos</td>
<td>0.1 ± 0.1</td>
<td>1*</td>
<td>1*</td>
<td>November</td>
<td>November</td>
</tr>
<tr>
<td>Andrew Molera</td>
<td>1.7 ± 0.4</td>
<td>1†</td>
<td>5</td>
<td>January</td>
<td>December</td>
</tr>
<tr>
<td>Private Property</td>
<td>2.4 ± 0.7</td>
<td>1§</td>
<td>12</td>
<td>November, December</td>
<td>January, February</td>
</tr>
<tr>
<td>Plaskett Creek</td>
<td>1.8 ± 0.3</td>
<td>1*</td>
<td>4</td>
<td>November</td>
<td>February</td>
</tr>
</tbody>
</table>

Individual sites can have different tree species composition. This can be though of as defining what tree species are available for roosting. It is interesting that in some cases the entire (or nearly entire) overwintering population will shift from one species of tree to a different species. For example (Figure 9) on 12/28/09 the monarch population at the Sanctuary shifted from a Eucalyptus roost to a Monterey Pine roost. A similar pattern (Figure 10) was observed at the private property site in Big Sur. Almost the entire population shifted from a single redwood tree to a Monterey Cypress on 2/14/2010. It is possible that Monarch Alert has enough data (from enough years) to explore the environmental conditions associated with these shifts.

Figure 9. Estimated numbers of monarch butterflies using different tree species at the Pacific Grove Sanctuary during the winter of 2009-2010.
Figure 10. Estimated numbers of monarch butterflies using different tree species at the Private Property Site in Big Sur, California during the winter of 2009-2010.

Sampling effort in San Luis Obispo County 2009-2010.

In addition to the Thanksgiving Count, Monarch Alert conducted weekly surveys of overwintering sites in San Luis Obispo County. All surveys were conducted by Jamie George, with assistance from several Cal Poly undergraduate students. The survey season was from October through February.

A summary of the survey site names, locations, dominant tree species, and survey effort is presented in Table 3 (see Figure 2 for acronyms). Note that San Luis Obispo County sites have three letter acronyms, and Monterey sites have two letter acronyms. Eight of the nine sites monitored in San Luis Obispo County were consistently occupied by overwintering monarchs (MBG, LOP, LOM, SLC, PBC, OCG, GBP, HCH). One of the nine sites was an autumnal site (SLB). All sites (except SLB) were potentially overwintering sites, so all sites were monitored weekly. In total 17 weeks worth of surveys were conducted. Fewer surveys were conducted at LOP because the site was not discovered until later in the season.

Table 3. Description of the monarch butterfly overwintering sites monitored in San Luis Obispo County during the 2009-2010 season. All sites were occupied for the survey period, with the exception of San Luis Bowden Estates, which was an autumnal site. Overwintering sites were surveyed 16-17 times. One overwintering site was only surveyed 3 times because it was discovered late in the season. Site locations are shown in Figure 2.
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Location</th>
<th>Predominant Tree Species</th>
<th>Survey Period</th>
<th>Number of Surveys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morro Bay Golf Course</td>
<td>48.5 km</td>
<td>Blue Gum Eucalyptus</td>
<td>10/31/09 – 2/27/10</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monterey Pine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Los Osos Monarch Lane</td>
<td>53.5 km</td>
<td>Monterey Pine</td>
<td>10/31/09 – 2/27/10</td>
<td>17</td>
</tr>
<tr>
<td>Los Osos Pecho Rd.</td>
<td>53 km</td>
<td>Blue Gum Eucalyptus</td>
<td>1/14/10 – 2/27/10</td>
<td>3</td>
</tr>
<tr>
<td>San Luis Obispo, Bowden Estates</td>
<td>56.5 km</td>
<td>Blue Gum Eucalyptus</td>
<td>11/10/09 – 2/22/10</td>
<td>10</td>
</tr>
<tr>
<td>San Luis Obispo Cemetery</td>
<td>58.5 km</td>
<td>Blue Gum Eucalyptus</td>
<td>11/10/09 – 2/27/10</td>
<td>16</td>
</tr>
<tr>
<td>Pine spp. (Yellow Pine)</td>
<td></td>
<td>Pine spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pismo Beach State Park</td>
<td>73.5 km</td>
<td>Blue Gum Eucalyptus,</td>
<td>11/1/09 – 2/26/10</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monterey Cypress</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monterey Pine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oceano Campground</td>
<td>75.5 km</td>
<td>Blue Gum Eucalyptus</td>
<td>11/11/09 – 2/26/10</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monterey Pine</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grover Beach, Pike Street</td>
<td>76.0 km</td>
<td>Blue Gum Eucalyptus</td>
<td>11/11/09 – 2/26/10</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monterey Pine</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pine spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halcyon Hill</td>
<td>76.5 km</td>
<td>Blue Gum Eucalyptus</td>
<td>11/11/09 – 2/26/10</td>
<td>16</td>
</tr>
</tbody>
</table>

* South of the Monterey-San Luis Obispo County line.

Long term population at the largest site in San Luis Obispo County.

The single largest, monitored, overwintering population in San Luis Obispo County is at the Pismo Beach State Park. The population size at the Pismo Beach State Park is estimated by cluster counting (by Monarch Alert). The population size is also estimated using mark-release-recapture methods. Those methods are more labor intensive, but may provide better estimates of the population size (if the requisite assumptions of the method are actually met).

The long-term population pattern at Pismo Beach State Park shows a gradual decline (Figure 11). There has been approximately a four-fold decrease in the estimated population size from 1990 through 2009. This decline has not been linear. A linear regression line does not fit the data as well as a polynomial (curved) regression line (as shown in Figure 11). The curved regression line is consistent with a decrease in population size that is slowing down as time goes on. The prediction is that eventually this population would go to extinction (given the present trends), but that the progression to extinction will be gradual (given the present trends). That is both sobering and exciting news. A slow progression is one that is more likely to be reversible than a very rapid one. Yet, it should be noted that any single, random (or stochastic),
fluctuations, could be sufficient to result in extinction. So are monarchs worse off today than 10 or 20 years ago? Maybe no. Fluctuations down, like that seen from 1991 to 1992 suggest that declines can be enormous. But the rebound, in 1996, suggests that the western monarch population, under the right conditions, can be quite resilient and fecund. Maybe yes. They are closer to an absolute population size of zero.

Figure 11. Long-term population trend at the Pismo Beach State Park (San Luis Obispo County) overwintering site based on mark-release-recapture data. The black line is a best fit polynomial regression line. The regression explains 37% of the variation in estimated population size over time.

Weekly population trends for San Luis Obispo sites.

The combined population estimates for all monitored sites in San Luis Obsipo County for the 2009-2010 season are shown in Figure 12. Weekly values are presented. The data show that the overwintering season (defined based on the persistence of monarchs at overwintering sites) lasted one week longer in San Luis Obispo County than in Monterey County (Figure 7). The substantial drop on 1/23/2010, and subsequent recovery suggest that there is a meta-population structure at overwintering sites in San Luis Obispo County. The only way to explain this pattern would be to infer that monarchs must leave the major sites and either disperse to multiple lower density areas, or to overwintering sites which are not being monitored. Monarch Alert may now have enough data (from enough years) to test whether this type of pattern is associated with low pressure inclement weather patterns, or with high pressure fair weather patterns.
Figure 12. Weekly population estimate for all San Luis Obispo County overwintering sites combined. Data are from counts of roosting clusters of monarchs. The figure shows the population peak in December and January, and an overwintering season that extends through 2/26/2010, or one week longer than was documented for Monterey County.


The data set for San Luis Obispo County is not as extensive as for Monterey County. The last set of weekly population estimates for all overwintering sites in San Luis Obispo County is from 2002-2003. Those data are compared to the weekly data across all sites for 2009-2010 (Figure 13).

The data (Figure 13) show that in 2009-2010 the fluctuations from week to week were not as pronounced as in 2002-2003. This may be due to actual fluctuations, or in differences in detection probability between weeks (in 2002-2003). Variation in detection probability is something that needs to be addressed by Monarch Alert. There needs to be validation of the Monarch Alert methods, such that we determine if population sizes are fluctuating, or if instead our ability to detect fluctuates and effects the population counts. Such a validation is currently being proposed for the 2010-2011 field season.

The figure (Figure 13) also suggests that the overwintering season was shorter in 2010 than in 2003. Monarch Alert may now have enough data (from enough years) to begin to look for correlated between indices of global climate change and the length (or end date) of the Western Monarch overwintering season.
Figure 13. Weekly population estimates (based on counts from roosting clusters) for monarchs overwintering in monitored sites within San Luis Obispo County. Data from 2003 and from 2009 were collected in the same manner, using the same methods and from the same sites. There are no data available from San Luis Obispo County for the intervening years.

Weekly population trends at individual sites in San Luis Obispo County.

The data collected during the 2009-2010 overwintering season can be evaluated for variation in the estimated population size across monitored sites (Figure 14). The most important overwintering site in San Luis Obispo County continues to be the Pismo Beach State Park (Grove). This site accounts for nearly as many monarchs as all other monitored sites combined. Numerically, the next most important site is the Morro Bay Golf Course. Finally, the Halcyon Hill and Pike Street sites may also be numerically important.

The substantial drop on 1/23/2010 (Figure 14), which is most pronounced at Pismo Beach State Park suggest that there is a meta-population structure at overwintering sites adjacent to Pismo Beach State Park. It is difficult to conceive of any other means by which the Pismo Beach State Park could have “rebounded” within one week. The butterflies must simply have moved. It is important to note that we did not record an increase in monarchs at other monitored sites when we recorded the decrease at the Pismo Beach State Park. This has an important implication. We do not seem to have been monitoring all sites that monarchs were using, or the monarchs from Pismo Beach State Park dispersed to non-overwintering sites during that time (i.e.: we were monitoring all the overwintering sites). Either of these alternatives is possible, though it is more likely that roosting clusters formed, temporarily, at sites we were not monitoring. Clearly, this phenomenon requires additional investigation. One means of exploring the alternatives would be to tag monarchs at some of the smaller sites close to the Pismo Beach State Park, and then attempt to monitor their movement. This is exactly what is being proposed for the 2010-2011 field season.
A third possibility is that we saw on 1/23/2010 at Pismo Beach State Park was not an actual fluctuation in population size, but a shift in detection probability between weeks. One way in which detection probability could shift would be if clusters were substantially denser at some points in time (meaning we might under estimate the density and therefore infer a lower population estimate). Variation in detection probability is something that needs to be addressed. There needs to be further validation of the Monarch Alert methods. We need to determine if population sizes are fluctuating, or if our ability to detect, and therefore count, fluctuates and effects our population estimated. Such a validation is currently being proposed for the 2010-2011 field season.

Figure 14. Weekly estimated population sizes at each of the monitored overwintering sites in San Luis Obispo County, and their partial contribution to the total monitored population size. Site locations are shown in Figure 2.

Figure 14.

Tree use patterns by monarchs overwintering in San Luis Obispo County sites.

There were several occasions where the entire monarch population at an overwintering site was restricted to a single tree (Table 4). This happened at four different sites in San Luis Obispo County. In contrast to the results from Monterey County (see above), when this happened in San Luis Obispo County the monarch clusters were most likely to be restricted to eucalyptus, even when other species of trees were present (for example, see Figures 15 and 16). In other cases, the entire population shifted off of Eucalyptus onto a different species (Figure 17). Thus, it seems that tree use pattern, and the importance of individual roosting trees, will differ across sites in Monterey County, while, for some reason, the system is not as dynamic in San Luis Obispo County. It is still possible that the microclimate at individual trees (or groves) may be more important than the tree species, but suggests that in San Luis Obispo County, the appropriate microclimates may be occupied by a eucalyptus rather than by a tree of another
species. Generalizations about the overall utility of eucalyptus tree for overwintering monarchs may need to be tempered if monarchs are selecting microclimates and not eucalyptus. Indeed, it is quite likely that tree species, and microclimate characteristics, will be correlated along different parts of the Central California Coast. This will make it more difficult to detangle the “tree effect” from the “microclimate effect” and may indicate why efforts to do so in the past have been contentious.

Table 4. Tree use pattern at monarch butterfly overwintering sites in San Luis Obispo County, California during winter 2009-2010. * Monterey Pine, †Eucalyptus.

<table>
<thead>
<tr>
<th>Site</th>
<th>Trees occupied (mean ± S.E.)</th>
<th>Minimum no. trees</th>
<th>Maximum no. trees</th>
<th>Month of Minimum</th>
<th>Month of Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morro Bay Golf Course</td>
<td>7.9 ± 1.2</td>
<td>4</td>
<td>14</td>
<td>February</td>
<td>January</td>
</tr>
<tr>
<td>Los Osos Monarch Lane</td>
<td>2.9 ± 0.5</td>
<td>1†</td>
<td>7</td>
<td>February</td>
<td>January</td>
</tr>
<tr>
<td>San Luis Obispo Cemetery</td>
<td>1.5 ± 0.3</td>
<td>1†</td>
<td>4</td>
<td>November</td>
<td>January</td>
</tr>
<tr>
<td>Pismo Beach State Park</td>
<td>7.9 ± 0.8</td>
<td>3</td>
<td>16</td>
<td>January</td>
<td>February</td>
</tr>
<tr>
<td>Oceano Campground</td>
<td>2.1 ± 0.3</td>
<td>1*†</td>
<td>5</td>
<td>February</td>
<td>January</td>
</tr>
<tr>
<td>Grover Beach, Pike Street</td>
<td>1.6 ± 0.4</td>
<td>1†</td>
<td>5</td>
<td>November</td>
<td>December</td>
</tr>
<tr>
<td>Halcyon Hill</td>
<td>2.3 ± 0.4</td>
<td>2</td>
<td>6</td>
<td>January</td>
<td>December</td>
</tr>
</tbody>
</table>
Figure 15. Estimated numbers of monarch butterflies using different tree species at the Pismo Beach State Park North Campground in Pismo Beach, California during the winter of 2009-2010.

Figure 16. Estimated numbers of monarch butterflies using different tree species at the Morro Bay Golf Course in Morro Bay, California during the winter of 2009-2010.
CONCLUSIONS

In spite of a substantial drop in the overwintering Western monarch population, progress is still being made in our understanding of the population fluctuations and habitat use of Western monarchs. Specifically, decline trends do not appear to be linear, and instead appear to slow gradually as the population size get smaller. Population fluctuations may follow a stable limit cycle pattern, or alternatively, and unfortunately, may reflect chance or stochastic fluctuations. This is only unfortunate because it makes it more difficult to truly understand the drivers of population fluctuations. The population decline at the Pacific Grove Sanctuary was consistent with declines across overwintering sites in Monterey County. Though drops at that specific site may be associated with tree management, it is still within reason that such a drop was independent of tree management. This may be an “unpopular” conclusion, but there simply are not enough data available to make an unequivocal statement. Definitive statements would be in the realm of opinion because the data do not yet allow us to reject one alternative over the other. Tree use patterns at overwintering sites suggest that microclimate may be as significant, or more significant, than tree species in determining the location of overwintering roosting clusters of monarchs. The lack of independence between tree species and microclimate (or the correlation between species, microclimate and geography) may be one of the reasons that previous claims to explain microhabitat use, and previous claims to explain the importance of Eucalyptus may need to be tempered. Finally, it is clear that variation in the detection probability (or variation in our ability to count monarchs in clusters) or meta-population dynamics will need to be invoked to explain some of the weekly fluctuations seen at overwintering sites on the Central California Coast.
Appendix I. Survey sites for Monterey County. All elevations are 1,000 meters, with two exceptions: the Sanctuary elevation is 600m and Andrew Molera is 1,250. Images show the parking and trail access (black arrows). The figures also show the transects that were walked, or the areas that were searched for monarch butterflies (white lines). Each site name is to the left and above each figure.

Pacific Grove Monarch Sanctuary (PG)

George Washington Park (GW)
Point Lobos State Preserve (PL)

Palo Colorado (PC)
Andrew Molera State Park (AM)

Sycamore Canyon (SC)
Plaskett Creek (PK)
Appendix II. Survey sites for San Luis Obispo County. All elevations are 1,000 meters. Images show the parking and trail access (black arrows). The figures also show the transects that were walked, or the areas that were searched for monarch butterflies (white lines). Each site name is to the left and above each figure.

**Morro Bay Golf Course (MBG)**

![Morro Bay Golf Course Map](image)

**Los Osos, Monarch Lane (LOM)**

![Los Osos Monarch Lane Map](image)
Los Osos, Pecho Rd (LOP)

San Luis Obispo Cemetery (SLC)
San Luis Obispo, Bowden Estates (SLB)

Pismo Beach State Park North Campground (PBC)
Grover Beach, Pike Street (GBP)