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Assessment and proposed management activities Monarch Grove Sanctuary and George Washington Park for 2022

Monarch clusters in Monarch Grove Sanctuary November 23, 2021

Executive Summary

In 2021, the Western monarch butterfly migration made a great comeback from perilously low numbers in 2020. The California overwintering population was estimated at ~250,000 butterflies during the Thanksgiving Counts. The severe fluctuations are the result of multiple causes; in short, in 2020 nearly everything went wrong during the breeding and migration seasons, and in 2021, everything went right, at least in the southern part of the range. Brief narratives in this report will address potential causes of the declines and rebound.

Peak numbers at Monarch Grove Sanctuary (MGS) were estimated at 12,000-14,000 from early-November through mid-December. Numbers dropped to 9,500 in early January, following a series of intense storms in mid- and late-December. This 32% drop from December to January was similar to historical observations at MGS and many other sites. Mass emigration started in early February with the onset of warm weather.

After arriving in October, the butterflies clustered in sunny areas on the southern edge of the grove, primarily on Monterey cypress. By mid-November, they clustered in the interior of the grove on Monterey pines and largely remained there through the remainder of the season. Eucalyptus was hardly used at all in the 2021-22 overwintering season.

New plantings of Monterey cypress were installed in 2021 and the trees have established and are actively growing. Boxed trees were placed along the eastern edge of the Sanctuary, and on the western edge of the Hotel property.

The major management actions recommended for 2022 are:

1) Two tall dead Monterey pines pose a major risk to other trees and potentially to visitors should they fall uncontrolled. These trees are recommended for removal – they do not provide wind shelter or other habitat value and are a liability. Leaving the trunks as wildlife snags, with irregular tops (not “telephone poles”) can create a more natural appearance.
2) Thinning a group of Monterey cypress (planted in the mid-2000’s) in the NW section MGS Removing 2-3 trees in this group will allow for faster growth of the remaining trees without compromising wind shelter

The time is ripe for developing a new comprehensive site management plan that will guide activities well into the future. Funding is likely available via the Monterey County Resource Conservation District (as part of a large statewide program) and with the participation of California Department of Fish and Wildlife (which hold the conservation easement on MGS). The key elements of this management plan are discussed in some detail, including some examples of habitat mapping with LiDAR.

Introduction

The following recommendations and assessments are based on site visits and consultations with City Arborist Albert Weisfuss and Public Works Director Daniel Gho in Spring 2022. They are presented in the context of the 2011 Management Plan (Weiss 2011) and subsequent consultations with City staff and residents, including annual recommendations from 2014-2021 (Weiss 2014-2021). The recommendations are based on previous scientific work, professional judgment, input from stakeholders in Pacific Grove, and field assessments. They attempt to carefully balance monarch habitat needs, hazard reduction, and forest health, based on both short-term and long-term perspectives.

In 2020, City Arborist Albert Weisfuss completed a detailed report with his recommendations, and those were considered in the 2020 report (Weisfuss 2020). The assessments and recommendations (with a few noted exceptions) are a solid foundation for guiding management, and the input of a professional arborist is essential especially on matters of tree health and species suitability.

Background data on monarch numbers at Monarch Grove Sanctuary (Xerces Society Thanksgiving Counts and New Year's Counts) provide context of the entire California monarch population. Butterfly monitoring data from the Pacific Grove Museum since 2013 have documented monarch use patterns and habitat suitability relative to weather and time of season. This reporting on monarch abundance and distribution provides a long-term accessible record for the local community.

The major elements of this report are:

1. Explanation of potential causes of the western monarch population collapse in 2020, followed by a sharp recovery in 2021.
2. The monitoring data from the PG Museum on monarch numbers and distribution, and interpretation.
3. A graphical view and description of the output of the new Ambient Weather station in the Sanctuary, and a comparison to Monterey Airport data
4. A brief review of management actions completed in 2020 and 2021
5. Recommendations for management actions in summer 2022
6. Discussion of opportunities for a new management plan and the elements of that plan.
7. A repeat and update of the long-term management considerations from previous reports, where still relevant.
8. Photographs of monarchs and habitat with notes.
9. A supplemental document with some visualizations and analysis of LiDAR data from 2016, as a demonstration of the potential of this new technology.

Monarch Crash of 2018-2020

The overwhelming reality of the 2020-21 overwintering seasons in California was a population crash to less than 2,000 butterflies at the overwintering sites during the Thanksgiving Counts (Table 1). None were observed in Pacific Grove that year.

The causes of this crash, a 99+% decline from the most recent peak of ~300,000 monarchs in 2015 and 2016, are complicated and multifaceted. The following is an account of the declines, based on published information (see Literature Cited) and discussions with monarch experts. The exact mix of causes remains uncertain; the narrative here should be viewed as hypotheses rather than absolute fact.

The Western Monarch Population as a whole

The long-term decline from the 1980s and 1990s has been described and analyzed elsewhere (Crone et al. 2019, Crone and Schultz 2021, Espeset et al. 2016, James and Kappen 2021, Pelton et al. 2019, Schultz et al. 2017). The loss of breeding habitat in the Central Valley, changes in pesticide composition, weather fluctuations, and losses of overwintering sites are among the important causes. From 1999 to 2016, the California population fluctuated between ~60,000 and ~500,000, with a geometric mean size of 200,000 (Table 1). Notable lows included 86,000 in 2007, and 58,000 in 2009, coinciding with relative drought conditions across the West. But the population weathered the 2012-2015 drought, and recovered to ~300,000 in 2015 and 2016, and declined to 190,000 in 2017 (a very wet year). There are no simple relationships between annual precipitation in California and monarch numbers – causes are spread across the whole breeding range and season.

In 2018, the population declined sharply to ~30,000 butterflies, a record decline to date. A leading hypothesis for this decline was a record warm February 2018 with coastal high temperatures greater than 70^{O}F, which stimulated monarchs to break diapause and leave the overwintering sites. The record warmth was followed by the return of winter with a vengeance in March (extended rains, some freezing nights, snow down to <1000 ft). Such winter weather immobilizes and can directly kill adult monarchs, especially away from the mild coastal zone, and cold also delays the emergence of milkweeds. The phenological gap between monarch emigration and milkweed emergence has been identified as a key bottleneck, and the temperature signal at the coast does not perfectly correlate with the temperature signal inland.

Much of the spring 2018 generation was lost, and the subsequent generations were not able to make it up the rest of the season. No monarchs made it to Washington State in 2018. Only 30,000 returned to California that fall.

In 2019, the overwintering population declined by ~30% to 22,000, a relative change well within the historical range of variability. But again, no monarchs reached the Pacific Northwest for breeding that year.

The 2020 season was a disaster – nearly everything that could go wrong did go wrong. February 2020 was warm and followed by a cool rainy March (but not as severe as 2018). August and September 2020 brought on record heat- monarch larvae cooked to death in the Santa Barbara area (115^{o}F or higher, and hotter closer to the ground with little shade). The heat extended across nearly all the breeding range in California. An example of the record heat is the average temperature for Monterey County in August and September (Figure 2). Four million+ acres of fires directly took out some of the breeding habitat in the South Coast Ranges that produce many monarchs that migrate to Pacific Grove (Yang et al. 2016). The weeks of smoke, which is harmful to insects, came just as the monarchs were initiating the migration. Then there was a hard freeze in some inland areas, for example 22^{o}F in Paso Robles in mid-November (Dan Meade pers. comm.). The monarchs had not yet flown to the coast because of warm temperatures in October. The extreme fluctuations in temperature and rainfall have been termed "weather whiplash," and are a feature of the rapidly changing climate.

The mild fall and early winter weather also allowed breeding to continue - reproductive diapause is not completely hardwired in by photoperiod. Monarchs have been breeding year-round in SoCal for more than a decade, and in 2020 winter breeding was observed in the Bay Area and other mild coastal climates (Crone and Schultz 2021, James and Kappen 2021). Even the native milkweeds, especially showy milkweed, did not senesce and the widespread availability of tropical milkweed means that hostplant resources are available in urban areas throughout the winter. The presence of breeding resident monarchs in coastal areas could have intercepted migratory butterflies and short-circuited diapause.

In addition, the widespread use of mobile and persistent neonicotinoid pesticides has produced toxic host plants and nectar in the Central Valley, even in non-agricultural settings such as wildlife refuges (Fordyce et al. 2020). Much of the migration beyond the Coast Ranges needs to cross the Central Valley (and other heavily agricultural areas like the Salinas Valley) twice. These areas potentially act as population sinks.

In summary, the collapse of the migratory western monarch population in 2020 was likely driven by weather whiplash and record heat waves (both symptoms of climate change), exacerbated by continuing toxification of breeding habitat in agricultural regions. However, any assertions and conclusions are conditional on deeper analyses and consideration of the entire western monarch migration.

Recovery in 2021

Monarch observers were truly despondent after the 2020-2021 overwintering season with only 2,000 butterflies at the overwintering sites. But in 2021, the monarchs exhibited a remarkable recovery to ~250,000 overwintering butterflies, observed in the November-December 2021. How could this 100-fold increase happen?

First, the awesome reproductive potential of monarch butterflies (each female produces ~400 eggs) can be expressed if conditions on the breeding grounds are good. Four-fold increases per generation are well within the range observed in monarch populations – over 4 generations such increases multiply out to 256-fold increase (4x4x4x4x4 = 256).

As opposed to 2020, nearly everything went right in 2021, at least in the southern portion of the monarch range. Spring weather following the emigration from the overwintering sites was mild. No megafires occurred in the South Coast Ranges, which produce many of the overwintering butterflies and provide for short migrations that avoid the toxic Central Valley. Resprouting milkweeds in the 2020 fire scars may have provided high quality larval food. The record heatwaves of 2020 did not recur. And a near record Southwest Monsoon season (July-September) provided excellent breeding conditions in Arizona with lush milkweed growth all summer long (Southwest Monarch Project, pers. comm.). Most late summer Arizona monarchs migrate to Southern and Central California- sites in Ventura, Los Angeles, and Orange Counties had more monarchs in 2021 than since the early 2000s, and numerous sites on the Central Coast, including Pacific Grove, were occupied by numbers not seen for many years.

There was not a spectacular recovery north of Pacific Grove. The Santa Cruz sites showed moderately increased numbers from 2020, but not to the degree further south. East Bay and Marin sites supported only a few hundred monarchs in 2021. Several megafires occurred in the northern breeding ranges, including the record Dixie Fire (>1,000,000 acres), Caldor Fire, and a series of fires in NW California. Smoke lingered in Northern California through the September-October migration season.

While we will never know for sure the exact contributions of these factors in the decline and recovery, the western monarch population has given us a second chance and it is incumbent on all of us to improve the breeding and overwintering habitats.

Pacific Grove in California Context

The numbers of monarchs at Pacific Grove primarily reflect the ups and downs of the overall California population ($r^2 = 0.82$), with some variations among years (Table 1). MGS has served as one of the major overwintering sites in California, accounting for an average of 7% (range 1% to 14%) of the Thanksgiving Counts since 1999. Its rank among all CA sites ranged from 1st (2006) to 17th (2009), and MGS is almost always in the top 10 sites. For Monterey County (from 2001 on), MGS accounted for an average of 37% (range 17% to 58%) of the county population.

Seasonal Monarch Behavior

In general, monarchs seek wind-sheltered but sunny sites within forest groves along the coast. They “crowdsource the microclimate” - taking flight when conditions are too warm or too cool, too sunny, or too shady, and especially too windy. They tend to land where other monarchs are clustered, because the best indicator of good conditions for monarchs is the presence of other butterflies. The butterfly clusters move around

according to the weather and time of year; lack of wind shelter is often the proximal cause of shifts. They often cluster just outside MGS to the south; and they use a mixture of tree species (eucalyptus, pine, and cypress) that varies from week to week and year to year.

The seasonal course of monarch numbers at MGS for 2013-2022 is shown in Figure 3. Monarchs arrive in October, and typically reach peak numbers in late-November – December. Butterflies move around MGS, often associated with wind events – they often start the season along the sunny southern boundary and move into the interior following southerly storm winds. Emigration and mortality (Monarch Photo 4) reduce numbers for the remainder of the season, with a final exodus by mid-February into early-March. The details of recent seasons (2013-2019) are described in previous reports.

In 2022 (thick black line in Figure 3), monarchs arrived in October and numbers reached 13,700 by early November. After a plateau through mid-December, numbers dropped to 9,500 by January 7 and ~8,000 by January 22 - February 3. The mass emigration occurred in the weeks after Feb 3, and the last significant numbers were observed on March 10.

Most monarch overwintering sites exhibit a decrease in numbers following a peak in November (Table 2). The decrease from December to January followed a series of intense storms in the second half of December, with high winds (Figure 4). Over the period 2017-2021, the decrease in numbers from November (Thanksgiving Counts) to January (New Year's Count) has been similar or less than the decreases observed at other sites in Monterey and Santa Cruz Counties. This observation indicates that monarchs find the habitat suitable for the entire season. The only time that MGS has been totally abandoned mid-season was in December 1995, when a record windstorm swept through coastal California with hurricane force winds.

Monarchs clustered on a variety of tree species and shift through the season (Figure 3b). In 2021-22, monarchs started on eucalyptus, primarily along the southern edge. By late October, after storms and high winds, they moved to nearly 100%, Monterey pines (Cover photo, Monarch Photos 5 and 6) in the interior and remained there through January. In February, as weather warmed, they broke diapause and started mating (all the butterflies observed on February 12 were flying). They spread out again, and clustered on a mix of pines, cypress, and eucalyptus.

The preference for pines for most of the season is the result of the wind-sheltered interior being dominated by pines, not an intrinsic preference for that species. In previous years, monarchs have used eucalyptus much more frequently during the bulk of the season.

Weather 2021-2022

A weather station was installed on the southern fence within the historical cluster area in that zone. Weather data were recorded every 5 minutes. This microsite is often occupied early in the overwintering season, or during long periods of calm weather in the middle of the season. 2021-2022 provided the first opportunity to use the weather station data in conjunction with monarch movements.

Temperatures

Temperatures were typically mild at MGS. A notable heat wave (80°F) occurred in mid-October, and 75°F days occurred in late November and early December. December was generally cool (maximum temperatures of 50-60°F). During the stormy periods in late December, diurnal ranges were low. January had many days above 60°. Mid-February saw another warm period (70+°), which likely contributed to the final emigration from overwintering.

Minimum temperatures never were less than 41°, so there was no freeze danger in 2021-2022.

Wind

Wind drives short-term monarch movements within overwintering sites more than any other weather factor. The PGMS station is in a relatively well-sheltered spot. Average 5-minute winds (Figure 4A, second graph) only exceeded 5 mph for short periods in October and December. Gusts would exceed 5 mph much more often (third graph) and maximum daily gusts (fourth graph) reached 10 mph during the stormy periods in October and December. These windspeeds often drive monarchs from local microsites (Leong 1991).

Monterey Airport (KMRY) winds were substantially higher, as expected for an exposed site with anemometer at 10 m height (Figure 4B). The periods of high winds are the same as at PGMS. KMRY serves as an indicator of high regional wind events that can be tied to historical monarch movements within MGS.

The high winds in October drove the monarchs off the eucalyptus on south boundary, into the pines in the interior of the grove. The December storms and winds were the most notable stress on the monarchs in 2021-2022, and nearly all the monarchs remained on the pines in the interior. Mild conditions returned in January and February.

Wind direction at the weather station were predominantly between S and W, especially higher winds, and gusts (Figure 4C). This observation is not surprising given the location of the station, with relatively open southern exposure and more sheltered northern exposure.

Nectar

Monarchs will visit many species of flowers for nectar. Early season nectar helps keep monarchs at MGS, where they can attract other monarchs arriving from the breeding grounds. Nectar provides energy for flight, and the high availability at many California overwintering sites allows monarchs to conserve fat reserves and maintain body mass.

The major species used at MGS are tree daisy (Monarch Photo 1), bottlebrush (2), and English Ivy (3). Yellow butterfly bush (Buddleia) is also frequently used, but the bushes are overgrown and need some cutting back to freshen flower production and force flowering during the critical October-November period. Blue gum eucalyptus come into flower in January and provide copious nectar for the latter part of the season. The flowering red gum (*E. filicifolia*) sometimes blooms in the fall and is visited frequently during warm weather. Monarchs will avoid shade when air temperatures are cool, so the sunny areas near the nectar beds are crucial and should be used to the fullest.

Current state of Monarch Grove Sanctuary

Monarch Grove Sanctuary continues to provide high quality overwintering habitat. Large numbers of monarchs persisted through a very stormy period in December, indicating that there is sufficient wind shelter and dappled light in the interior. Most hazard trees and branches have been removed over time, but two large dead trees remain. The new plantings are established and will fill in some wind gaps, as well as provide cluster sites in favorable microsites.

Habitat photos, with documentation of location and photo orientation, of various parts of MGS are presented below with brief descriptions.

Management Actions in 2020 and 2021

Many of the minor actions recommended for 2020 were carried out. Mainly, some small dead trees were removed.

The major action in fall 2020 was plantings of boxed Monterey cypress that had been brought into MGS in 2019. Several cypress trees were planted in the open area south of the main entrance and kiosk, where 1 or 2 trees were recommended as cluster trees. More cypresses were planted south of the main trail. Cypresses were also planted to the east of the nectar beds. Some bottlebrush and eucalyptus trees were also planted (Photos 1-4). Some toyon and ceanothus were planted and caged.

The irrigation scheduling has worked, as there has been a tendency to overwater in past years.

The recommendation that new low-growing native nectar plants be established along the trail through the nectar beds has not been implemented. Suggested management of the existing nectar plants by selective pruning was not observed by June 2022.

The new tree plantings have not been mapped as of 2022, pending a new mapping effort for all trees, so a complete inventory is not available. A new map of MGS is a central element of a new management plan, as discussed below.

2022 Recommendations

The specific 2022 recommendation include:

1. A hiatus on major plantings until a full inventory and structural assessment is completed as part of a new management plan (see below). There are plenty of new trees in the ground for now.
2. Boxed trees (Habitat Photo 1) can be moved around as desired. ***However, trees should not be put into the ground until the new assessment is completed, and planting sites selected.***
3. The only exception is that ***one or two*** potted trees in the gap on the Hotel property can be planted (Habitat Photo 2). Avoiding overplanting is essential for individual tree health and rapid growth.
4. Remove two large standing dead trees, one toward the NW corner, and one just east of the nectar beds (Habitat Photos 9 and 10). These trees pose large hazards primarily to other trees.
5. Thinning the cypress stand toward the NW corner (Habitat Photo 7) with removal of two trees to be selected in the field, to allow for more room for the remaining trees while maintaining wind shelter.
6. Initiate thinning the weakest crowded eucalyptus in the SE corner to allow for development of healthier trees (Habitat Photo 4). Some of these trees are nearly dead. Plan on removing a few trees each year until a suitable density (10' spacing) is achieved. The remaining trees should respond strongly to increased space and fill in the canopy rapidly.
7. The yellow Buddleia bushes be pruned to refresh growth and force flowering in the fall. Consultations with a master gardener or other horticultural expert is recommended.
8. Maintain and cage pine saplings in the interior (Habitat Photo 14).
9. The irrigation regime for new plantings be continued, but trees and shrubs should be weaned off irrigation after a few years once established.

History of Habitat Management

This section provides a brief history of management plans and actions over the past 25 years. More complete accounts can be found in the 2011 Assessment and Management plan and in subsequent annual reports.

In the 1990s and 2000's, monarchs primarily clustered along the southern boundary, often on the neighbor's pine tree. They would move into the Sanctuary proper to escape southerly storm winds, but returned to the southern boundary when winds swung around to the NW. Based on the 1998 assessment and management plan (Weiss 1998), a shelterbelt of blue gum eucalyptus was planted in 1999 to protect the site against NW winds.

Following the planting of the shelterbelt, little was done in the grove. Attempts to plant a second row of eucalyptus to reinforce the southern boundary, as recommended in the 1998 plan, failed because trees were pulled up. The many dead and dying pines (from old age and pitch canker) were not removed, despite a recommendation in the same report. In 2005, a dead branch fell and killed a woman, and the grove was closed to the public for the remainder of the season. Following the overwintering season, the dead trees were taken down, and many wildlife snags were retained. Several more hazard trees were removed in 2007-2008 following additional consultations.

In fall 2009, several large branches on the southern boundary were cut, without consultation, because a branch had fallen into the neighbor's yard, and other branches posed hazards to the neighbors. These branches included favored monarch cluster sites. This action coincided with the (then) record low point of the California population, and only 900 monarchs overwintered in Pacific Grove. The situation stimulated the development of a new management plan, completed in 2011.

In fall 2011, potted trees were brought into the grove and placed in the SE corner near where the branches had been cut, to create some temporary wind shelter. Based on the new management plan, in 2012 several of these trees were planted in an additional row of eucalyptus just north of the southern boundary trees, at 10-15 ft spacing.

By 2012, the 1999 shelterbelt trees had grown tall enough (50-60') to provide wind shelter in conjunction with nearby pines and cypress, and monarchs moved into the interior of the grove and remained there for the remainder of the season, clustering on pines and cypress trees that receive more insolation than surrounding branches (see below for a discussion of shading).

In spring 2013, potted trees that had been brought into the grove as a temporary wind shelter were planted in the ground, creating a dense stand of small trees in the southeast corner of the grove. It was a period of conflicts over grove management.

In recent years, most hazard trees have been removed, and management actions have been relatively minor.

A New Site Management Plan

The 2011 Assessment and Management plan is now 11 years old. Conditions have changed enough that development of an updated plan is necessary. The annual funding that covers this annual report is not sufficient to develop a comprehensive plan using the latest assessment tools, as well as addressing the institutional issues that have arisen over the nearly three decades since Monarch Grove Sanctuary was established.

Funding is likely available via the Monterey County Resource Conservation District (RCD), as part of national and statewide initiatives to recover the western monarch population. Discussions among the City, the RCD, and monarch scientists are ongoing, and once RCD funding is secured the process can start.

Some key elements of a new assessment and management plan, first are suggested in the 2021 review, include:

Produce a New Base Map of Monarch Grove Sanctuary
Managing MGS is an exercise in landscape architecture, with the goal of maintaining wind shelter from all directions, but allowing sufficient light in the interior so that monarchs can choose a mix of sunny, dappled, and shaded spots within the forest. Also, management of hazard trees and tracking of new plantings and subsequent growth are desirable so that a record of actions is maintained, and precise plans for each year can be laid out and executed as planned.

The foundation of a long-term management plan is an accurate map of the Sanctuary, including property boundaries, tree locations, tree species, tree diameter at breast height (DBH), tree height, and tree health. In addition, new plantings, understory plants, trails, and other features should be added on an annual basis.

In 2010, a working map of MGS was produced for the 2011 Assessment and Management Plan (Figures 5 and 6). The 2011 map used triangulation with tapes to lay down a 10 m grid, and trees were mapped out within those grids to within 1-2 meters. Hemispherical photographs were taken at each 10 x 10m point. Attempts to tie the grid to surveyed property lines were stymied by poor GPS accuracy within the forest, and distortions of horizontal distances by topography. Therefore, the working map is not georeferenced and has its own local coordinate system. This map has served adequately since 2011 for management, but is now out of date because of tree mortality and new plantings.

Rather than update the current map, it is recommended that a new map be produced with surveying equipment such as a Total Station, and be tied into the parcel map, digital elevation model (DEM), and other base data for Pacific Grove. GPS is not accurate enough within the denser parts of the grove.

Remapping all the trees is an opportunity to reassess their health, requiring the city arborist to be involved. Although the soaking rains of October and December 2021 alleviated some drought stress, the dry winter and spring of 2022 once again herald drought stress. Special note should be made of drought symptoms where visible.

Repeat hemispherical photography
Nearly exact relocation of photopoints is possible through triangulation from the SE fence corner, even without a formally surveyed base map. Some photographs were

reshot in 2018 but never fully analyzed. Repeat photos should be taken so that the change in conditions from 2011 and 2018 can be quantified.

Methods for interpolating wind and light have improved since the 1998 and 2011 reports, and can be redone in such a manner as to directly compare sites through time and understand the effects of canopy changes through time.

LiDAR

LiDAR (Light Detection and Ranging) is a state-of-the-art method for quantifying the 3-dimensional structure of vegetation at fine scales. A laser scanner is used from either above (airborne) or below (ground-based). The reflections are timed to calculate distance, and a "point cloud" of reflections is produced. There are software packages, including ARCGIS Pro, that can analyze and display the point cloud and describe vertical structures in detail.

Projects at other monarch sites (in Sonoma County) has developed some methods for quantifying wind and solar radiation at the outer canopy surface, using ARCGIS Pro and Wind Ninja software.

LiDAR data can be collected from airplanes, drones, or from ground-based scanners. A LiDAR flight over Pacific Grove was completed in 2018, with resolution of 5.68 pts/square meter and is available at:
https://portal.opentopography.org/usgsDataset?dsid=CA_FEMA_Z4_B1_2018

Example images and analyses from this LiDAR product are presented and discussed in the supplemental report "Examples of LiDAR for Assessment of Monarch Butterfly Habitat in Pacific Grove." The point density (5.68 pts/square meter) is lower than that used in Sonoma County (9-12 points/square meter) but is sufficient to capture many canopy features. But it is not adequate to fully map the middlestory and understory. One advantage is that it is possible to map the surrounding urban forest and assess wind shelter from a broader area.

It is possible to contract for drone LiDAR that can produce a map of several acres at high point densities (>100 points/square meter). Laguna Drones in Los Gatos, or other vendors, can provide services for $5-10,000 depending on the amount of processing. A drone flight would produce the best up to date map and capture nearly full understory structure.

Many innovative LiDAR analyses are being developed at Ellwood Mesa in Goleta, where a drone flight acquired 200 pts/m^2. It is now feasible to simulate hemispherical photographs ay any height above the ground, hence quantifying light and wind exposure exactly where the monarchs choose cluster sites

Ground-based LiDAR is feasible, but requires accurate ground locations, and would be difficult to deploy on private property outside MGS. No vendors are known at this time.

Airborne LiDAR could also cover George Washington Park (GWP) and provide base data for a management plan there. GWP images are included in the LiDAR document

Wind mapping

Kingston Leong (1990, 1991) has developed a method for mapping wind on a grid using hand-held wind meters. The meters are held for a short period (2 minutes or more) and the mean, max, and min windspeed recorded. These measurements are done under a variety of wind directions, and can be correlated with monarch occupancy at fine scales. Monarchs tend to leave sites when ground-level winds exceed ~5 mph (2 m/s). Leong used this method in his 1990's report on MGS.

This wind mapping procedure could be executed by volunteers or students under supervision. The wind attenuation from outside conditions can be correlated with Wind Site Factors (WSF) from hemispherical photography, which would allow for better inference of wind exposure. A well calibrated wind attenuation model would be of great use across all monarch sites. LiDAR data could also be correlated with measured wind.

A fluid dynamic wind modeling program called Eddy3D has been used in Santa Barbara County to model wind at fine scales within monarch sites and assess management options. The LiDAR point cloud provides the 3-D structure as model input.

Weather Stations

The initial trial runs with the Ambient Weather station proved to be successful. The full season of data presented here is informative on monarch response to weather, especially wind. Several questions need to be answered for future deployment:

1. *Is the station in the optimal location for understanding conditions in the grove?* The current site on the south fence within the historical cluster zone is a good initial choice. It captures the wind exposure from the south an especially important aspect of the grove and surrounding area. It was not possible to correlate the weather with monarch movements in 2020-21, but in 2021-22 the high winds in October along the southern boundary that drove the monarchs into the interior were captured.
2. *Can the results be extrapolated to the rest of the grove?* Temperature varies with height, minimum temperatures are coolest at the ground, and increase with height – some vertical movements of monarchs are associated with avoiding cold temperatures low in the canopy. There are simple models of temperature with height, which could be calibrated with small temperature sensors. Absolute humidity is more consistent across a forest grove, but relative humidity is a function of air temperature. Wind and insolation vary strongly from point to point according to fine scale canopy structure, which is captured with

hemispherical photography and calibrated via the wind mapping protocol described above.

3. *Would additional stations be useful?* More sites in complex environments are generally better. But costs escalate rapidly when full stations are considered. Temperature can be mapped using small data loggers (iButton Thermochrons or HOBOs) placed in a network to capture important gradients. A network of recording anemometers would be useful, as an adjunct to the wind mapping. Exactly where one or more additional stations would be placed for maximal efficiency is a question that requires some considerable thought. A weather station in an open field at the Adult School could be a useful "outside the grove" baseline. A substantial amount of micrometeorological equipment – temperature, humidity, light, and wind sensors - is available from Francis Villablanca (Cal Poly SLO) and USFWS and has been offered to California monarch researchers and managers.
4. *Is there a good "base station" that captures the general weather in the open for long timer periods?* There are many weather stations in Pacific Grove and surrounding areas. But the wind at any station in the urban matrix will be very site-specific with obstructions like trees and buildings – official wind measurements are taken on 10 m tall towers in open areas to avoid ground effects. The Monterey Airport has the longest record, but the wind there is influenced by the local topography, so wind direction is modified, but wind speed is still a useful parameter (see previous reports) that identifies large scale synoptic (storm front) events. Hopkins Marine Station has a weather station right at the water's edge, which would be good for regional wind, but temperatures will be much more buffered than at MGS. A thorough investigation of available weather stations would be a critical step.
5. *Can weather in MGS be correlated with regional conditions?* Yes, methods exist to create a model that transfers conditions from a base station to a local station. The key is to have a calibration period (one year or more) where a wide variety of conditions are experienced.

A combination of short-term spatially distributed measurements and longer-term base station(s) is an optimal way to understand the microclimate withing MGS. Quantitatively correlating measurable forest structures to microclimate is key to assessing management options.

Assessing New Plantings

The numerous newly planted cypress and eucalyptus will eventually greatly change the canopy structure and microclimate in the grove. While providing additional wind shelter is an important goal, it is important to remember that it is possible to have too dense a canopy that does not let in enough light for monarchs. This careful balance must be maintained (see below).

It is standard practice to overplant trees to account for mortality, and eventually thin them to a density that encourages individual tree health (Habitat Photo 7). The overplanted eucalyptus in the SE corner (Habitat Photo 4) are an example The spreading structure of Monterey cypress can deeply shade a site for decades, until the lower branches drop and open the understory.

At this point, it is important to evaluate the eventual growth of these new trees and plan accordingly so that they do provide additional wind shelter, but are not overcrowded and competing with one another, and do not provide excessive shade in key parts of the grove.

Tree health

As mentioned above, the health of each tree and prospects should be documented. In 2021-2022, the continuing drought conditions make it imperative that drought stress symptoms be carefully noted.

In particular, the redwoods along the western boundary have not been performing well, especially during droughts. The weakest of these trees should be removed in phases and replaced with cypress or pines to maintain wind shelter. Some of the older tall pines are in poor shape, and may pose hazards to people, structures, and other trees. Prompt attention to hazard trees with "targets" should they fall is an essential annual activity.

Evaluation of Shade Limitations

While wind shelter is paramount, monarchs often seek sunny or dappled light habitats for clustering. The consistent use of the sunny southern boundary trees and adjacent trees to the south reflect this preference. But the high southerly wind exposure in those sites means that monarchs move north into the more protected interior of the grove. Such a move occurred in October 2022 following an intense early season storm, and this behavior has been noted in many years.

But, in the wind-sheltered interior of the grove, shade may be limiting use by monarchs. The large eucalyptus on the southern boundary cast shade deep into the grove, and additional pines and cypress north of the path add to the shading. Maintaining some open habitat in this area is essential (Habitat Photos 17 and 18).

The 2011 Assessment and Management Plan has insolation maps that are copied here (Figure 7). These maps show that there are some higher insolation sites in the interior – note the small halos within the deep blue areas near the center of the grove - which are where monarchs tend to cluster on pines (see Monarch Photos 5 and 6) when they move into the interior. Repeat photography of these sites would establish if the canopy has grown and filled enough to cast more shade.

Shade can also limit access to nectar. The nectar beds are just west and north of the outline of the former building (removed in 2011). The southern portions of the nectar

beds are deeply shaded for much of the winter, and are inaccessible except when high air temperatures allow monarch flight in shady habitat. The northern section of the nectar bed area is the best area for season-long nectar access. In the longer term, the growth of trees to the south and west of the nectar beds could increase shade limitations. Again, reshooting hemispherical photographs could quantify any differences in shade patterns.

A thorough evaluation of shade limitations, and potential ameliorations through selective pruning or even removal of trees to decrease deep shade should be conducted. Of course, maintaining wind shelter is essential. Modification of hemispherical photographs can provide a first order estimate of effects on both sunlight and wind. If LiDAR is available, then a similar modification of the canopy can be simulated by deleting potions of the point cloud.

Any such modification of the canopy by opening will require rigorous documentation and a cautious approach, given the sensitivity of the site and the Pacific Grove community.

Long-term Management Considerations to be Incorporated Into the New Management Plan

Management of Monarch Grove Sanctuary is a long-term process. This section looks ahead to anticipated changes and issues over the next decades, so that current management recommendations can be put into context. Much of this section is reiterated from previous reports, with a few updates.

1) **NW Windbreak**: The 1999 blue gum plantings are now 60-80' tall and provide critical NW wind shelter and allow monarchs to remain in the interior of the grove following storms that drive them from the wind-exposed southern boundary. *These eucalyptus trees are the anchor of a multi-species windbreak and are absolutely necessary to maintain long-term windbreak functions* because pines may succumb to pitch canker and cypress will lose lower branches. The mid-story of pines and cypress currently contributes to windbreak function, as the foliage on the blue gums is concentrated in the upper canopy.
2) **Eucalyptus threat?**: The ground along narrow zone below the NW windbreak eucalyptus is being affected by leaf and litter fall, but less than 0.1 acres are affected. The comments on page 2 in the 2020 arborist report ("potential catastrophic effects") greatly exaggerate the threat to native forest, especially since the eucalyptus will not be allowed to spread, and the litter deposits can be occasionally raked up. The remainder of the interior and northern reaches is available for native forest management.
3) **Southern Boundary:** The 2011 blue gum plantings inside the southern boundary, authorized by the City, have grown to heights of 25-30' and are beginning to provide additional wind shelter. Monarchs clustered on some of these trees in November and December 2019, with a peak of 53 (~15% of the population) on

December 5 (see 2020 report). As these trees continue to grow, eventually monarchs can cluster in a wind sheltered dappled light environment as envisioned in the 2011 Assessment and Management plan. These trees will provide redundancy for the large southern windbreak trees, and will eventually replace them decades from now. These trees are in a difficult environment for rapid growth, with shade and root competition from the large southern boundary trees, so they will continue to grow relatively slowly, but will be healthy. Planting some additional trees, *Callistemon viminalis* and *Eucalyptus ficifolia* as recommended by the arborist report in key locations would fill gaps, diversify the windbreak, and provide a multi-age structure.

4) **SE Corner**: The densely planted blue gums (2013) in the SE corner are showing signs of overcrowding (some were planted 3' apart), with poor growth relative to more widely spaced trees. There has been a consistent recommendation over the years to thin these trees back to a more appropriate density, but it has never been implemented. The Weisfuss 2020 arborist report also recommends thinning these trees. Thinning will increase the health of the remaining trees, and their canopies will expand to fill in the available space. Several of them are now dead, and should be removed. These trees will continue to grow poorly in crowded conditions and eventually self-thin, and they are competing with several of the authorized plantings from 2011.
5) **Wind gaps**: Farther west on the southern boundary, there are several larger gaps that should be filled. The arborist report recommends *Callistemon viminalis* and *Eucalyptus ficifolia* to diversify the windbreak and provide mid-story and low windbreaks. Cypresses are not recommended along the southern boundary because of sprawling growth form. Trees were planted in this gap in 2020.
6) **Pines:** Pines continue to succumb to pitch canker, and despite some wet years in 2017 and 2019, drought effects are still being expressed in some trees. The dry year in 2020 and very dry year in 2021 produced more drought stress. The soaking rains of October and December 2021 provided some relief with deep soil recharge, but the dry winter and spring 2022 means that trees will remain drought stressed. Continued plantings to maintain a substantial pine component in the grove is important, but pines still cannot be counted upon to provide long-term overstory. Pine plantings need to be protected from browsing and getting knocked over by deer. Removal of pines heavily infested with pitch canker can slow, but not stop the spread of this disease.
7) **Previous cypress plantings**: Many of the cypress planted over the last two decades are in their period of rapid growth and will provide significant wind shelter in coming years and decades. The cypress along with blue gums will provide the backbone of the grove, given the uncertainties of pine survival in the long run. Some densely planted cypress stands have been thinned in recent years to encourage more rapid growth of remaining trees, and continued selective thinning is recommended in several spots.
8) **New Plantings 2020** More than 20 potted Monterey cypress were brought into the Sanctuary as temporary windbreaks in 2019. These trees have been planted

in several parts of the grove (Habitat Photos 3 and 12). *The locations of these trees should be recorded on the new base map*. The cypresses are overplanted as discussed above, and eventually should be thinned once it is apparent which trees are strongest. If they are not appropriately thinned, the individual trees will be stressed and grow poorly. The spreading canopy of Monterey cypress can become too dense for monarchs, especially when tree crowns interlock. Special care should be taken to balance wind shelter and shade.

9) **Oaks**: Understory live oaks are scattered among the pines and cypress, and more plantings could fill in understory in select parts of the grove and provide good native habitat. Oaks can eventually provide low and mid-story windbreaks. Planting of acorns, with protection by tree tubes is an efficient method for oak plantings that allow roots to penetrate deep on their own. Planting plugs may appear more efficient, but the constricted roots of oak plugs often lead to long-term failure.
10) **Native forest management**: Overall, there are many sections of the Sanctuary where management for native forest is appropriate, with an emphasis on overstory pines. The northern reaches, beyond the NW windbreak is a prime example. The old pines have died or fallen, leaving wildlife snags and an open canopy. In addition to oaks, native shrubs (toyon and ceanothus are present, but a large palette of native shrubs is available) can contribute to understory structure. Non-native cover like the calla lilies can be removed in phases, and native forest floor forbs could be introduced in parts of the Sanctuary. All native plantings need to be protected from deer browsing. Some control of the dense annual grass cover is needed while understory is establishing, and annual grasses will always be a component of the forest floor. Some mowing of annual grasses is desirable for fire safety.
11) **Irrigation:** Maintaining the irrigation system for tree establishment and for watering during droughts, as well as developing a rigorous irrigation management plan overseen by City staff and implemented by volunteers, is critical. But irrigation should only be provided for the first year or two (unless severe drought occurs). The irrigation management has greatly improved in recent years, according to volunteers Habitat (Habitat Photos 19 and 20).
12) **Nectar:** Attractive fall blooming nectar plants help to retain arriving butterflies early in October and November. *Nectar plants in sunny areas can be used far more frequently than those in the shade and sunny areas are at a premium.* Yellow Buddleia and tree daisy are the most attractive species in the beds, and replacement of some of the other species in the beds (i.e., the mallow) should be considered. The sunny edges along the trail are perfect for planting native nectar species for fall nectar. Away from the nectar beds, butterflies nectar on the flowering red gum when it occasionally blooms in the fall. Use of bottlebrush was noted every year. Later in the season, early blooming *Prunus* has provided winter-spring nectar in addition to the blooming blue gums. As mentioned above, a thorough evaluation of present and future shade limitations is desirable.

13) **The neighbors:** While there are some policies and ordinances with respect to the activities within a buffer zone around the Sanctuary, the truth is that the City has little control over tree removal and maintenance, and even may have obligations to protect the neighbors. Activities in recent years at the Hotel – tree trimming and removal - have had impacts on MGS, and the same can be said about the southern neighbors at a lesser scale. A clear policy and lines of communications about tree work will avoid some of the worst outcomes, but unless there is a strict ordinance that mandates consultations such actions will continue to have impacts. On a positive side, cooperation with the neighbors could enhance MGS.

An Adaptive Management Framework

In the 2011 Assessment and Management Plan, there is a section that discusses how to have an annual cycle in which decisions are considered and acted upon. This section is excerpted into the Appendix of this report. *Adaptive management* requires data, open minds, and a process. Some additional thoughts as of 2021 are warranted.

1. *An official management plan is the key document and foundation of adaptive management*. Having everything possible written and ordered in a living document creates a common platform for decision making. The elements of a management plan are discussed above
2. *A regular annual scheduled cycle of reporting, comments, and consultations is desirable*. Starting in 2013, such a cycle was established and was a quantum leap from the ad hoc decision-making process prior to that. In some years, the presentation to BNRC and the public tour were later than optimal. A more formal schedule would keep the timing on track and allow for unhurried actions prior to the October 1 restriction.

George Washington Park

George Washington Park (GWP) is ready for a more detailed site restoration and management plan, which should be part of the proposed new management plan. Observations and recommendations to be incorporated (largely repeated from previous years) include:

1) This is a unique site for California monarchs; it is one of the few remaining Monterey pine/live oak habitats for monarchs.
2) GWP has been used intermittently by monarchs, a few individuals can be found there every year at some point, but major clusters were observed only in 2003, 2004, and 2006 (Table 1). In 2006, there were more than 10,000 monarchs at GWP and very few at Monarch Grove Sanctuary. Since then, there has been only one year (2011 with 61 observed) with monarchs at Thanksgiving, none were observed from 2012 to 2019. Individual monarchs have been observed here during other times of the overwintering season.
3) The historic cluster sites in GWP are losing sufficient wind shelter for monarchs, and additional senescence of mature trees threatens this important component

of habitat suitability. In particular, the largest pine at the historical overwintering site died several years ago, but there are several mid-story pines that are in positions to replace this tree over coming decades. Losses of forest cover to the south and west through overstory tree mortality is reducing wind shelter.

4) Removal of dead standing trees is recommended where they have stationary targets, especially around the edge of GWP. Dead trees that may fall across trails in the interior should be evaluated on a case-by-case basis. Trees can be left as safe wildlife snags where appropriate, but a more naturalistic topping should be considered.
5) Reduction of accumulated deadfall by CALFIRE in 2014, 2015, and 2016 removed large piles of downed tree debris. This is important preparation for eventual site restoration. Some branch and log piles have been retained and downed logs are used to redirect foot traffic to fewer trails. Selective removal of large debris piles is recommended, with some piles retained for wildlife habitat.
6) Natural pine recruits, most common in disturbed areas, should be protected.
7) Less frequent deep irrigation of pines is preferable to frequent shallow irrigation. A water trailer can be provided by the City for such a purpose
8) Plantings of pine seedlings has proven successful and should continue (Habitat Photos 21 and 22). Eventual thinning is required of establishment rates are high.
9) Live oak plantings can provide the under- and middle-story necessary for wind shelter in a mature pine forest.
10) Similarly, ceanothus and toyon can provide understory structure.
11) Operations on the perimeter of the park are the priority, to maintain safety from falling dead trees on adjacent roads, and to create a fire buffer.
12) The full impact of the recent and ongoing drought will continue to be expressed. Trees may take one or two years to die after major drought stress and high rainfall season like 2016-2017 and 2018-2019 may not allow for recovery once drought stress has weakened trees.
13) Establishment of a designated trail system and decommissioning of meandering paths impacting root systems of the trees is occurring. Ingrowth of poison oak is effectively shutting some social trails.
14) Now that there have been reductions in downed trees and debris, and the full impact of the drought on mature trees will become apparent, the long-term suitability of George Washington Park for monarchs should be assessed, using a combination of hemispherical photography, LiDAR and other suggested methods.
15) An assessment of pitch canker and tree health is especially important in GWP.
16) Once assessments are done, a long-term planting scheme (pines, oaks, and native understory shrubs) should be developed and implemented. The key elements of such a planting scheme should be to provide eventual replacements for canopy trees, create and maintain a mid-story of oaks and pines, and maintain wind shelter from all directions around defined canopy gaps.

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Table 1. Monarch Butterfly Thanksgiving Counts Xerces Society Monarch Grove Sanctuary (MGS) George Washington Park (GWP), Monterey County, and California Totals. *MGS was the only site counted that year.

Year	MGS	GWP	CA Total	Monterey Co.	MGS % CA	MGS % Monterey	MGS CA Rank
1997	45,000		1,235,490	45,000	4%	100%*	10 (tie)
1998	35,000		564,349	41,000	6%	85%	5
1999	25,000		267,574	25,000	9%	100%*	3 (tie)
2000	20,000	0	390,057	20,000	5%	100%*	6 (tie)
2001	14,960		209,570	31,203	7%	48%	4
2002	4,700		99,353	11,593	5%	41%	5 (tie)
2003	22,802	2,750	254,378	68,979	9%	33%	2
2004	10,867	4,325	205,085	54,481	5%	20%	4 (tie)
2005	12,199	2	218,679	37,540	6%	32%	4
2006	28,746	11,795	221,058	59,957	13%	48%	1
2007	8,181	2	86,437	15,426	9%	53%	3
2008	17,866	0	131,889	31,063	14%	58%	2
2009	793	0	58,468	4,735	1%	17%	17
2010	4,968	0	143,204	8,634	3%	58%	4
2011	12,265	61	222,525	27,788	6%	44%	4
2012	10,790	0	144,812	29,048	7%	37%	4 (tie)
2013	13,420	1	211,275	35,772	6%	38%	3 (tie)
2014	18,128	0	234,731	55,879	8%	32%	3
2015	11,472	0	292,888	27,787	4%	41%	3 (tie)
2016	17,100	0	298,464	64,804	6%	26%	3
2017	7,350	0	192,629	35,657	4%	21%	8
2018	705	0	28,429	2,758	2.5%	26%	15
2019	642	0	21,944	2,792	2.9%	25%	8
2020	0	0	1,914	58	0	0	--
2021	13,608	0	247,237	26,502	5.5%	51%	5

Table 2. Comparisons of Thanksgiving (NOV) with New Year's (JAN) counts at Monterey County and Santa Cruz County sites that had butterflies at Thanksgiving Counts.

SITE NAME	NOV 2021	JAN 2022	Ratio 2021	NOV 2019	JAN 2020	Ratio 2020	NOV 2018	JAN 2019	Ratio 2019
Lighthouse Field, Santa Cruz	410	637	155%	3402	2600	76%	1802	1933	107%
Natural Bridges State Beach	2,100	1,700	66%	1997	25	1%	1120	765	68%
Private Property near Big Sur	11,200	10,100	90%	1750	50	3%	819	29	4%
Butterfly Grove Sanctuary	13,608	10,055	74%	642	316	49%	705	685	97%
Moran Lake, Moran Lake	1,100	725	66%	400	30	8%	1373	346	25%
CH1 Private Site	1,193	2,623	220%	-----	-----	-----	-----	-----	-----
Seascape Golf Course	700	32	5%	-----	-----	-----	-----	-----	-----

Figure 1. Relationship between total California monarch numbers and MGS numbers, Xerces Thanksgiving Counts

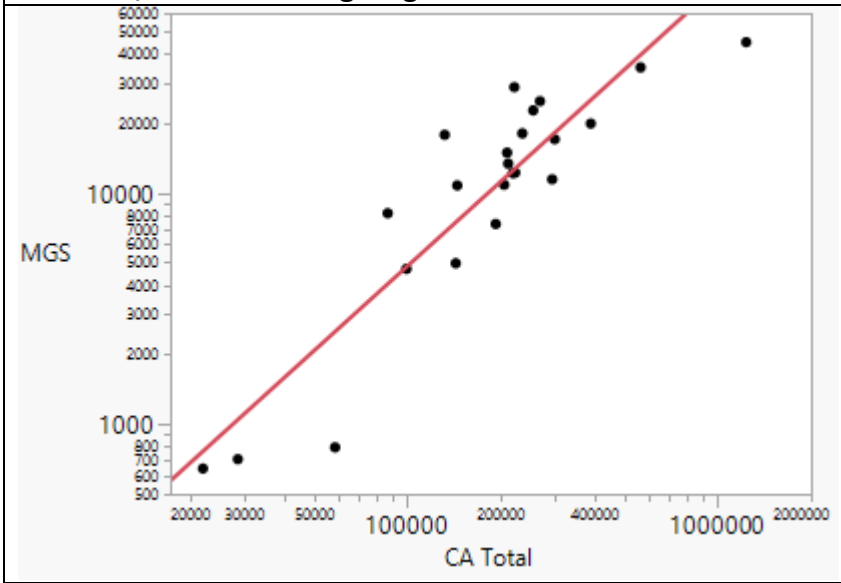


Figure 2. Monthly Mean Temperature for Monterey County, August-November 2020. From Westmap (https://cefa.dri.edu/Westmap/Westmap_home.php)

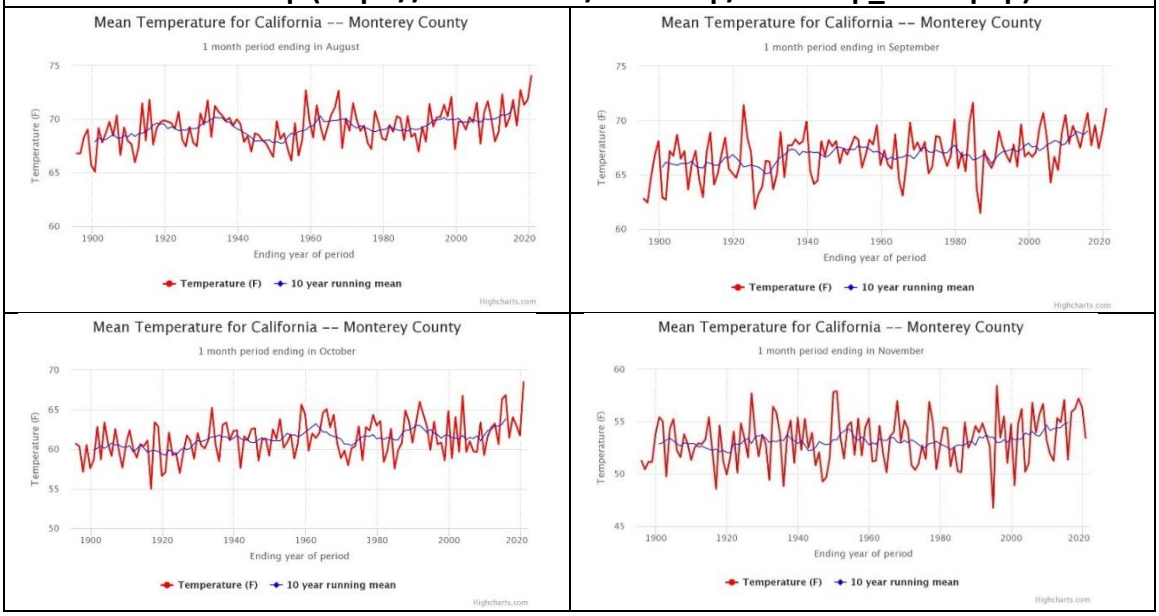


Figure 3a. Monarch numbers through seasons. Data from Pacific Grove Museum

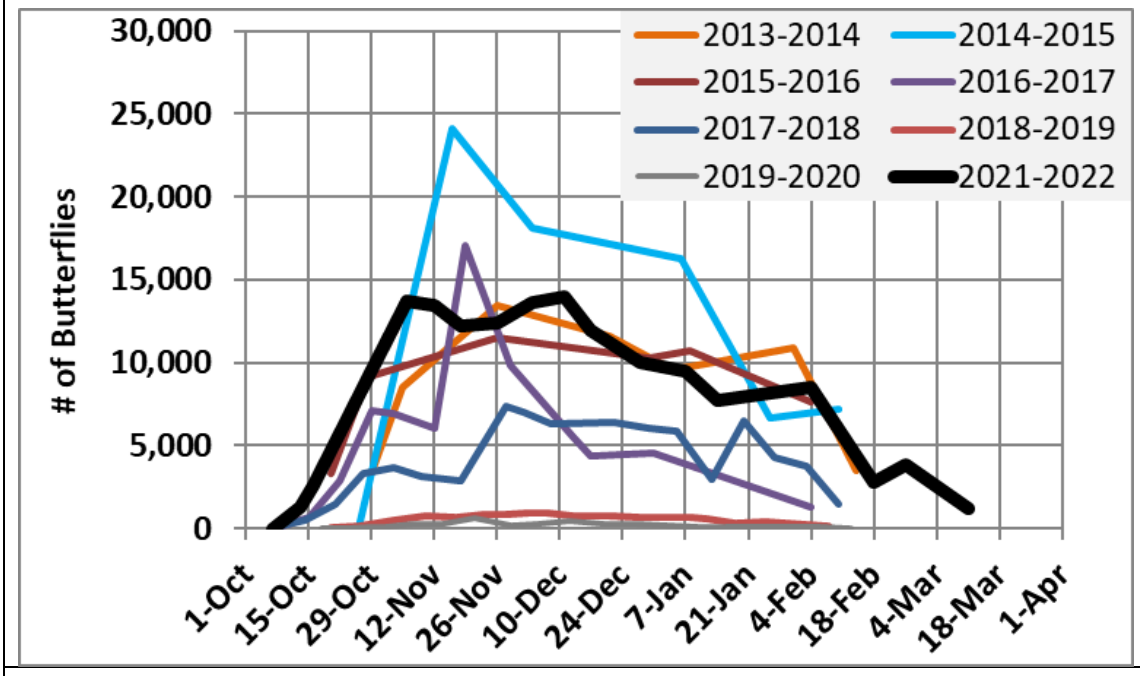


Figure 3b. Monarch Tree Preference

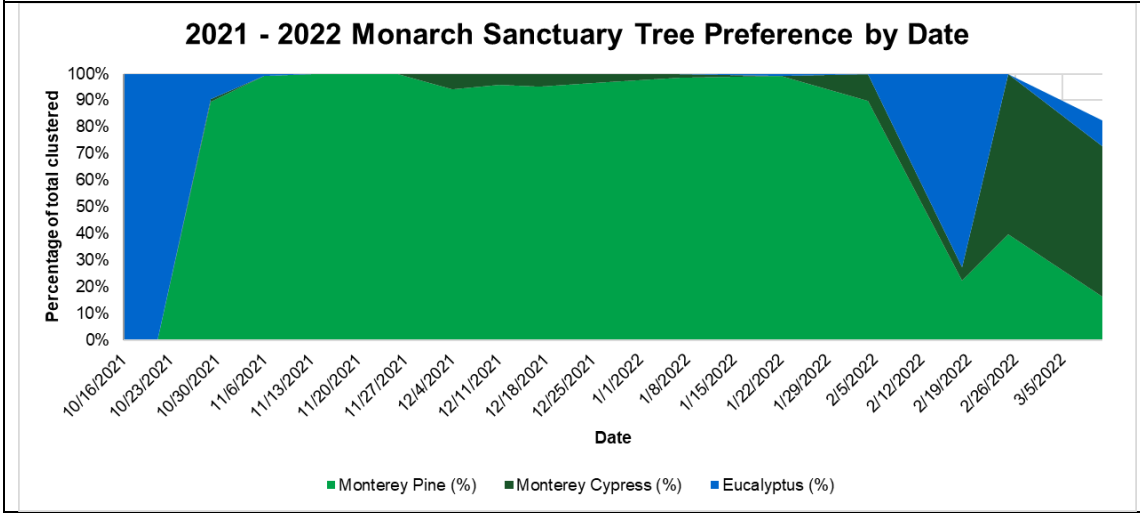


Figure 4a. Temperature and Wind Speed at PGMS Weather Station

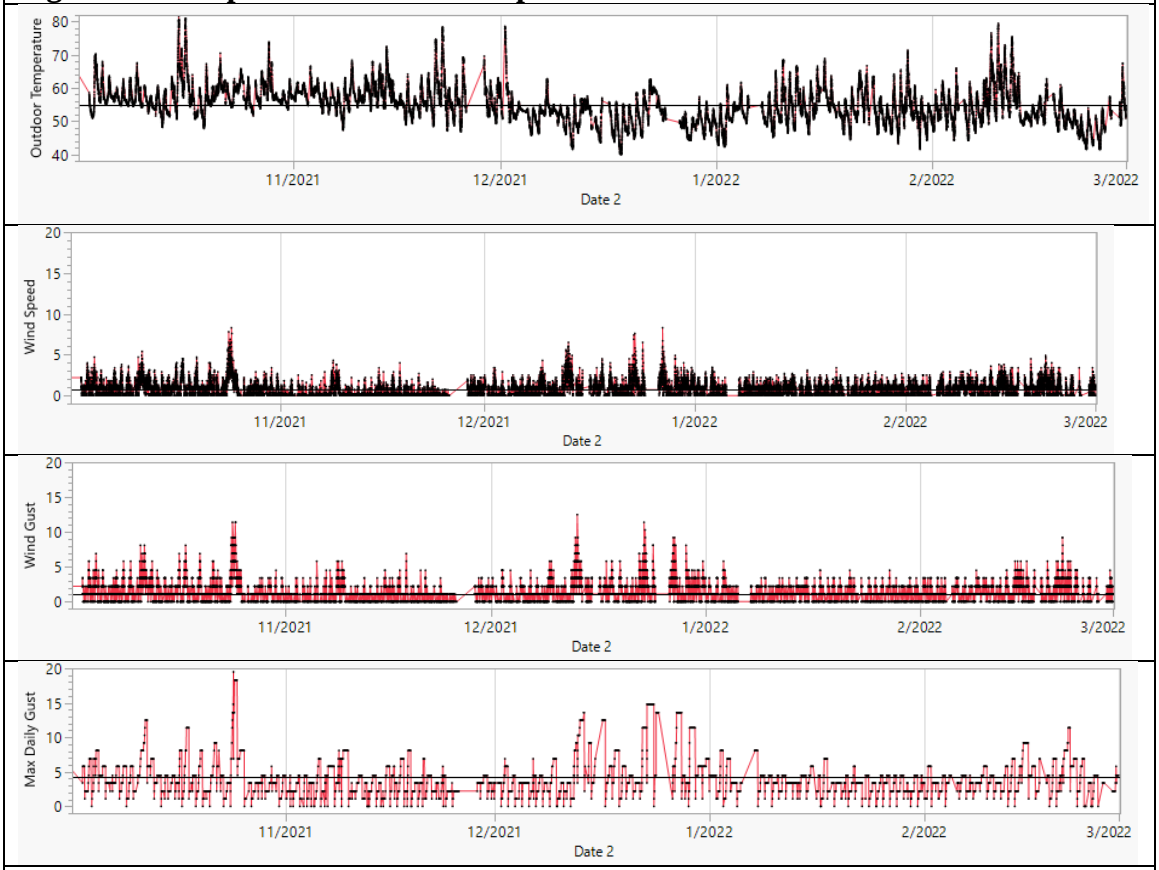


Figure 4b. Wind Speed at KMRY (Monterey Airport)

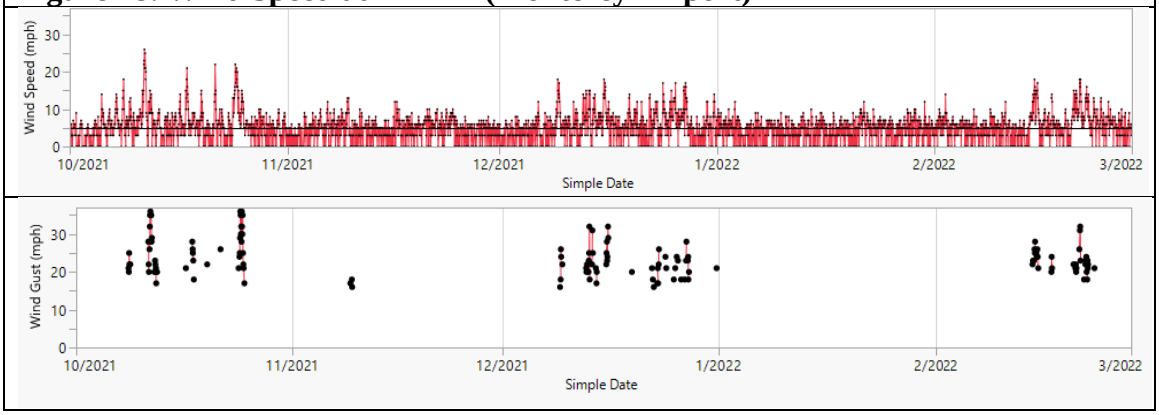


Figure 4C. Wind Speed and Direction PGMS October 2021-February 2022. The density of points is indicated by the color ramp (red and yellow = higher density). Wind gusts were ~ 30% higher than 5-minute wind speeds, although intermittent gusts could be more than twice the 5-minbute wind speed.

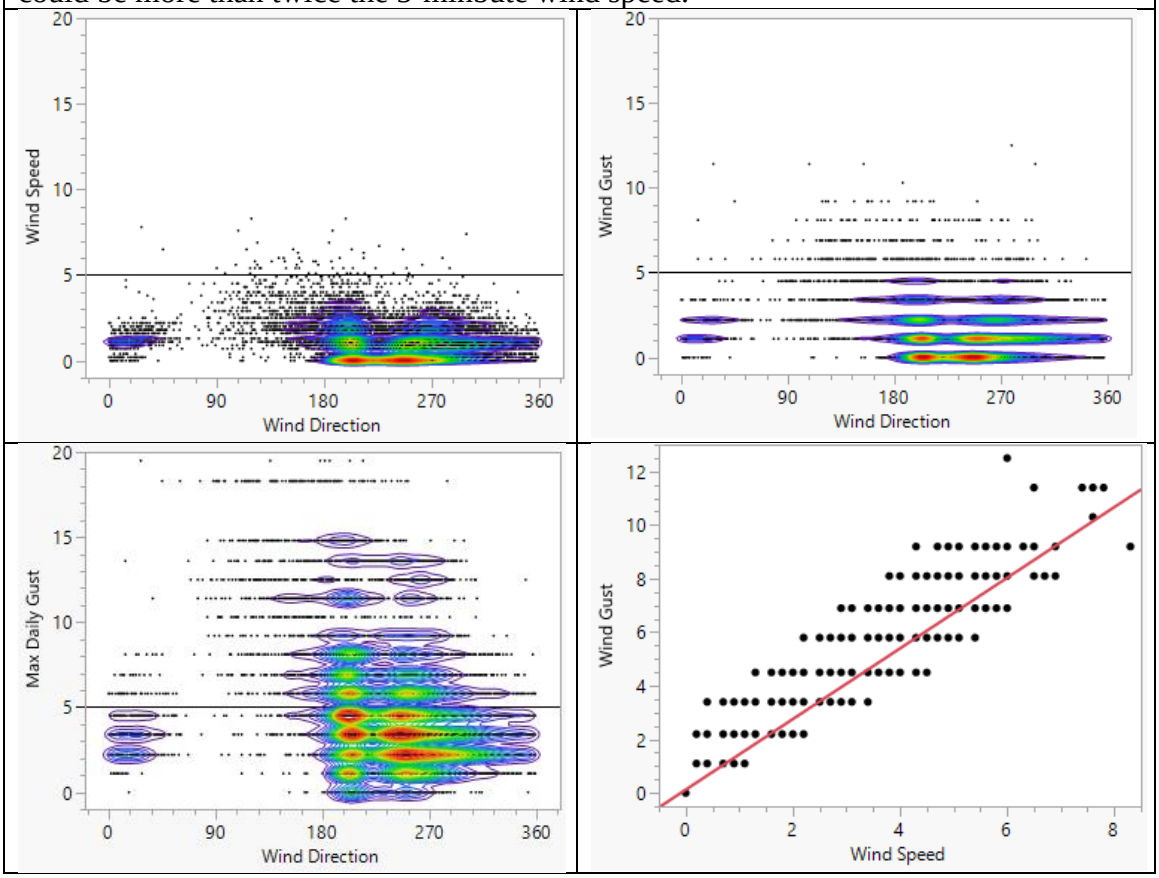


Figure 5. Monarch Occupied Trees (Green Triangles) and cluster zones, Grid in meters

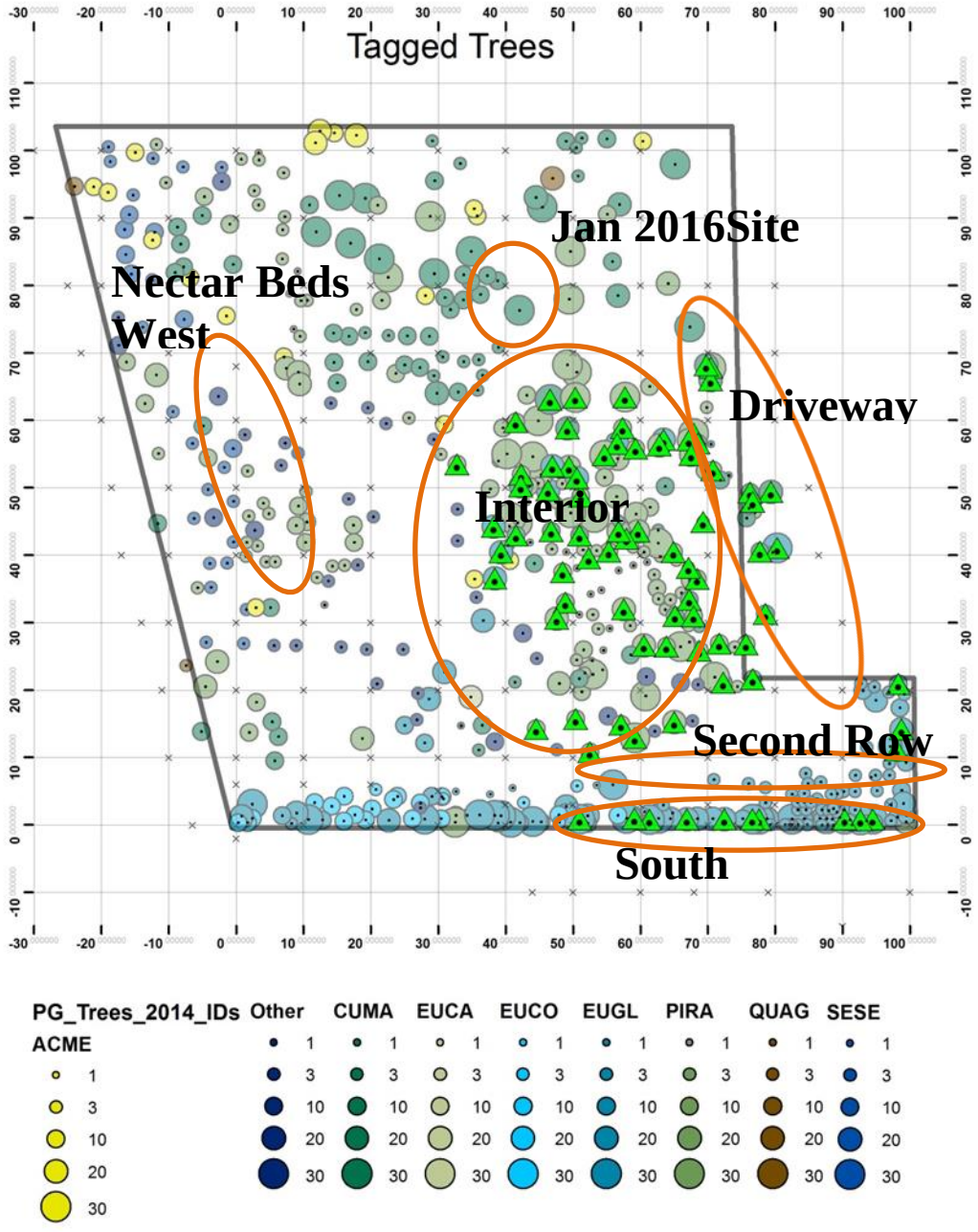


Figure 6. Management Zones. Grid in Meters

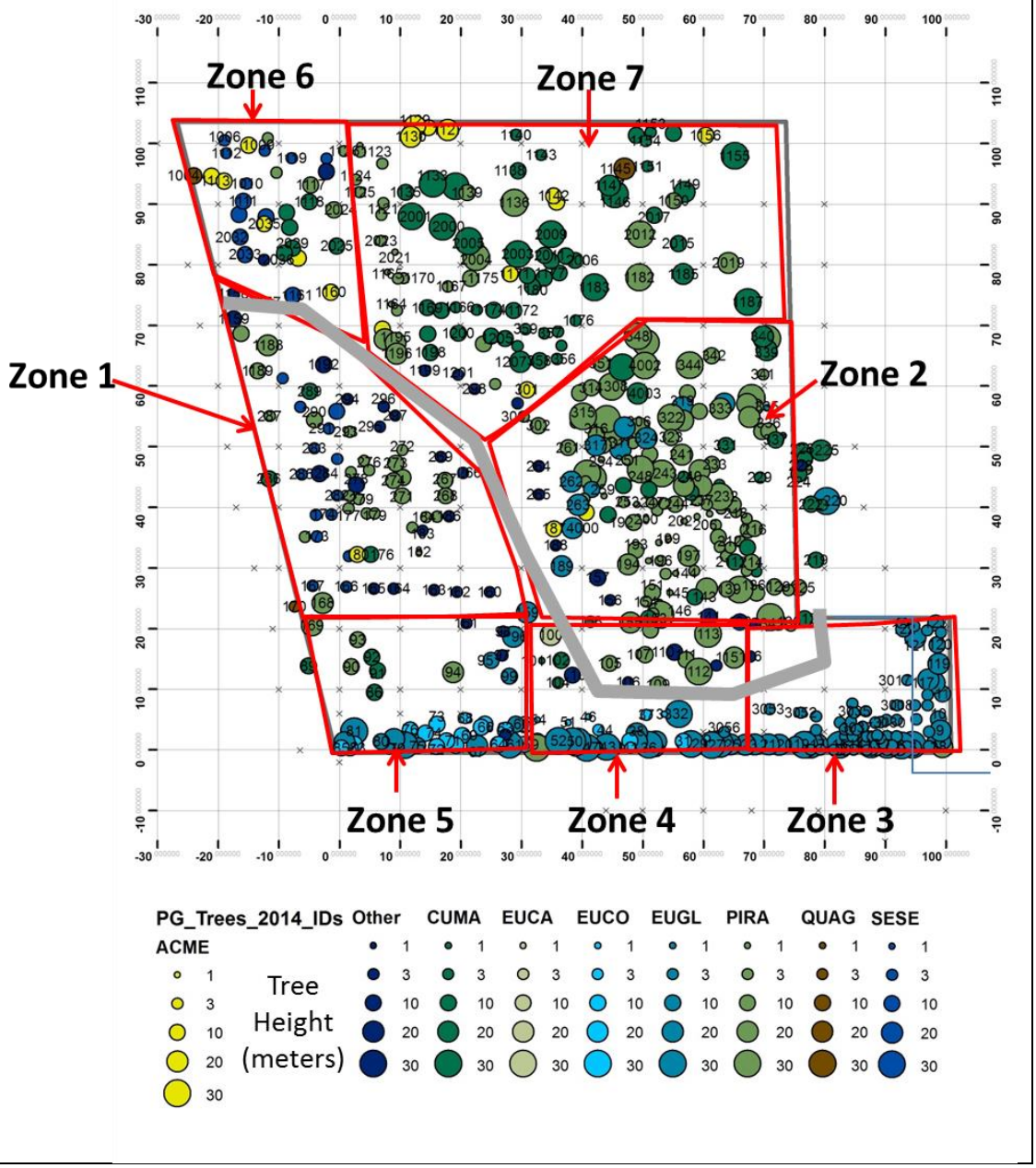
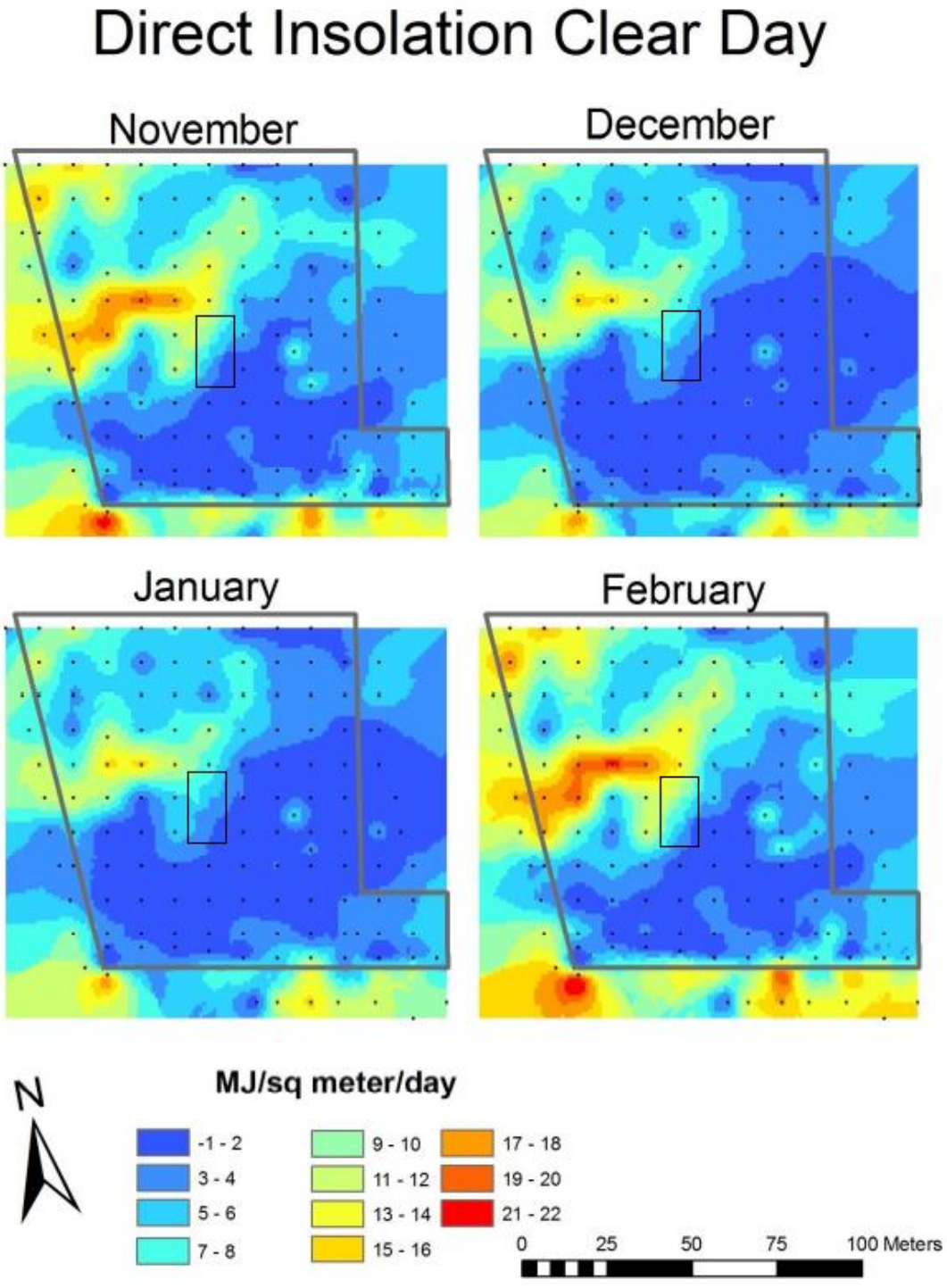
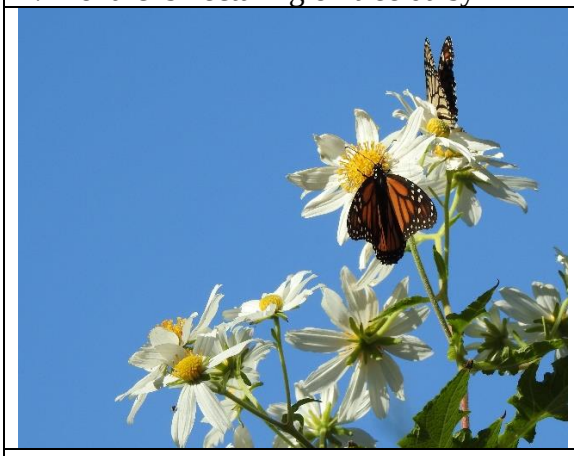


Figure 7. Insolation maps from 2011 report. Note the small halos in the interior east of the outline of the old building footprint; which is the interior cluster zone. The high insolation areas NW of the old building are where nectar (primarily tree daisy and bottlebrush) is available the entire season



Monarch photos November 23, 2021

1. Monarchs nectaring on tree daisy	2. Monarchs nectaring on bottlebrush
	
3. Monarchs nectaring on English ivy	4. Monarch wings on forest floor, with abdomens eaten.
	
5. Monarch clusters in interior pine, from hotel driveway	6. Dense clusters in interior pine, from trail
	

Habitat Photos

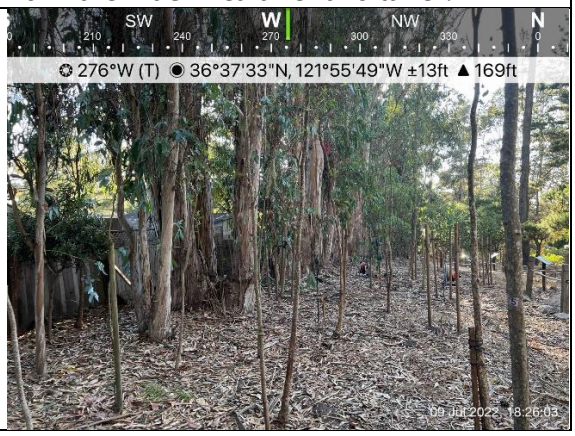
Photo 1. Eastern boundary with boxed eucalyptus trees. At their current size, these trees provide marginally increased wind shelter above that provided by the houses to the east.	Photo 2. Potted trees placed in a gap on the hotel property. Originally, these trees were planted in the ground, but were dug up after consultation with city staff. Planting two trees at most in this gap would be the best way to fill this gap with a healthy trees
	
Photo 3. Two cypress planted in the open area of the SE corner of MGS. These trees may develop into cluster trees in a wind-sheltered area with dappled light	Photo 4. SE corner. These eucalyptuses were planted too dense in 2013 (3-5' apart) and are growing poorly and in poor shape. The well-spaced trees (10-15' apart) that were officially authorized in 2012 are much healthier and taller.
	

Photo 5. Eucalyptus planted in 2012 at appropriate spacing (10-15') are now 25+ ft tall and are establishing a second row north of the main eucalyptus row. Monarchs have clustered on these trees early in the season.	Photo 6. Second row of eucalyptus planted in 2021, to fill in gaps in the southern boundary.

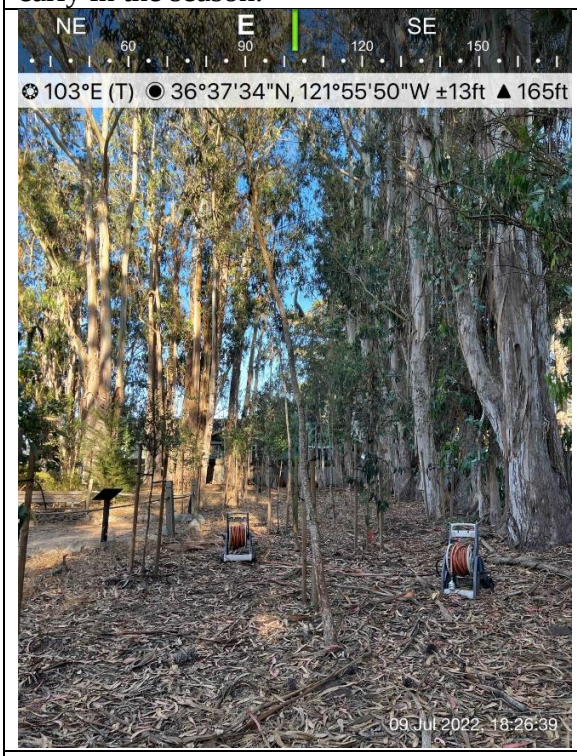
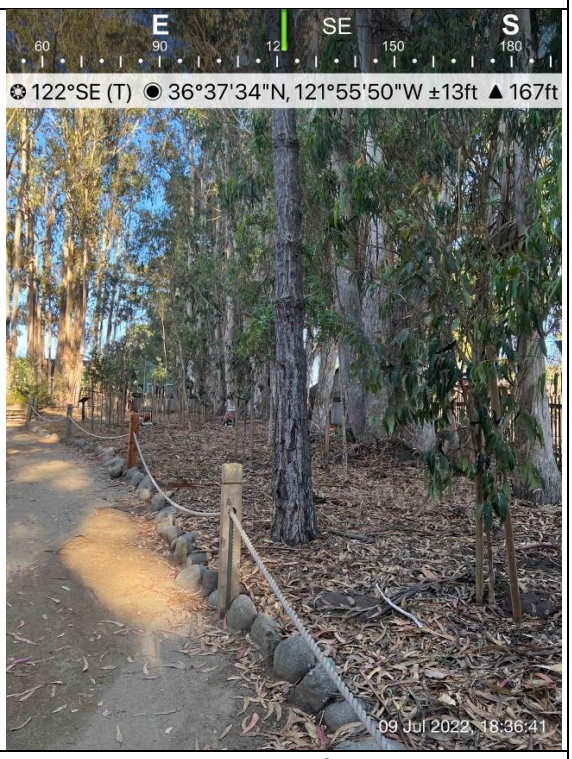

	

Photo 7. Group of cypress panted in mid-2000s, ready to be thinned by removing two trees to allow for more rapid growth and health of remaining trees. Wind shelter will not be compromised, and the remaining trees will fill in.	Photo 8. The NW-side of the eucalyptus windbreak planted in 1999. This mixed species shelterbelt provided critical NW wind protection for the interior of the grove where monarchs clustered in 2021-2022 (and other years).
	

Photo 9. Dead standing pine east of nectar beds. This tree threatens numerous important trees and should be removed before it falls on its own.	Photo 10. Dead pine near NW corner. Even though this tree is leaning away from the trail, it threatens important windbreak trees and should be removed. An irregular-topped snag can be left behind.

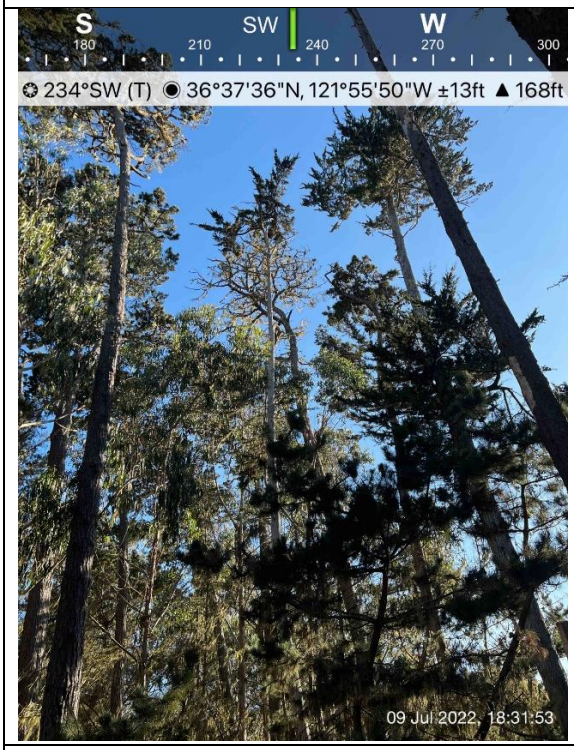
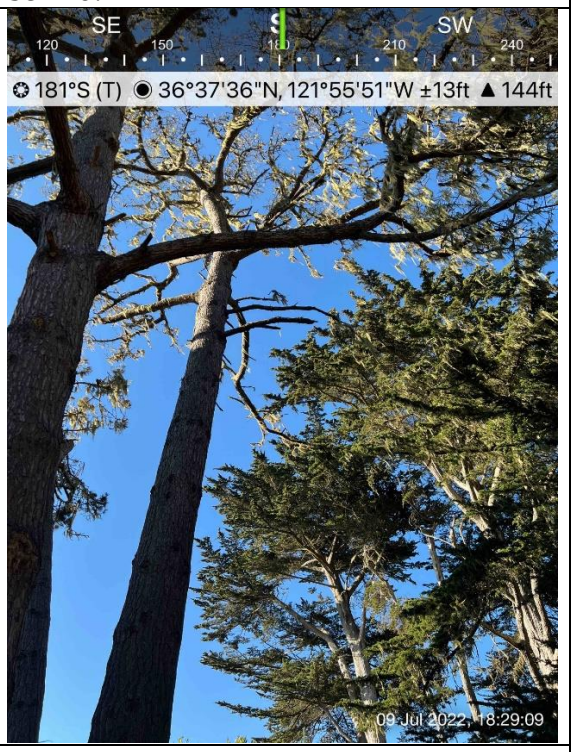

	

Photo 11. View from interior to east showing the hotel, which acts as a windbreak from this direction. The view N is blocked by an array of pines, eucalyptus, and cypress. The gap to the SE is where potted trees were placed.	Photo 12. Newly planted cypress east of nectar beds, part of a double row of trees planted to seal up this edge and protect the interior cluster zone.
	

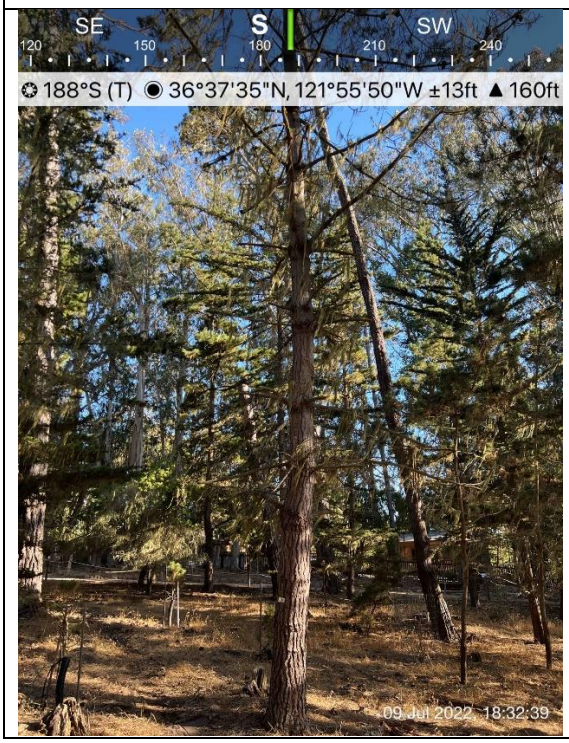
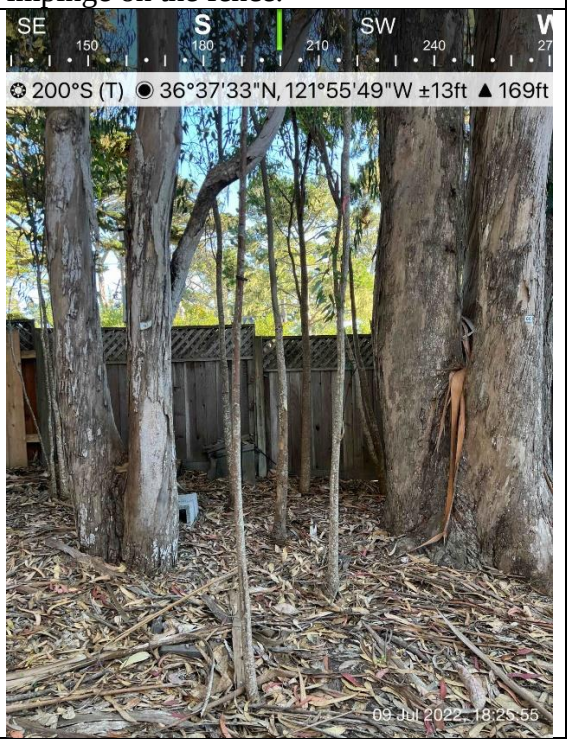
Photo 13. View to SSW from trail, rapidly growing cypress between trail and Grove Acre Ave.	Photo 14. Pine saplings planted in interior.
	
Photo 15. Nearly dead pine in interior. This relatively small tree does not threaten other trees and can be retained for now, the lichen provides some wind shelter function	Photo 16. Dense eucalyptus plantings along southern fence. Thinning one or two trees here would allow for better growth of remaining trees. The trees right up against the fence will eventually impinge on the fence.
	

Photo 17. View into interior cluster zone of pines. Maintaining some relatively open habitat with dappled light in this area is important for monarchs.	Photo 18. Cypress sapling near bend in the trail, with 1999 eucalyptus shelterbelt in background and relatively open interior to east.
	
Photo 19. Irrigation Zones	Photo 20. Irrigation documentation

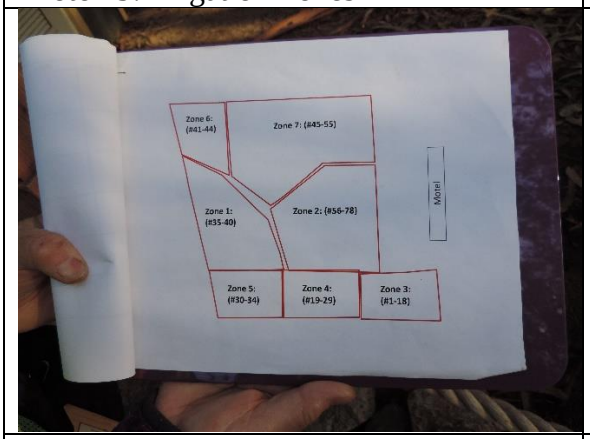
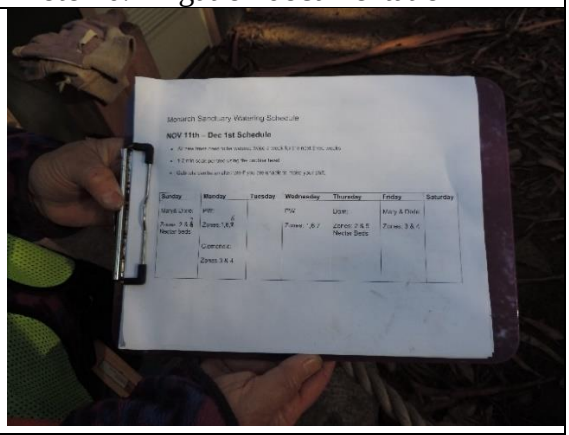

	

Photo 21. Pine plantings in George Washington Park	Photo 22. Pine plantings in George Washington Park
	

Appendix (From 2011 Assessment and Monitoring Plan)

Principles

The key principles for the adaptive management plan include *resiliency, redundancy, dynamic ecosystems, proactive adaptive management, and decision making in the field.*

Resiliency provides a range of conditions that buffer environmental variability. In the case of the Sanctuary, the key variables are wind, sunlight, and temperature. Ambient conditions outside the grove are filtered by the forest canopy, creating a complex fine-grained environment where microclimates change meter by meter through the site, and hour by hour through the season. As the varied combinations of wind shelter and light exposure change through the day and season, and monarch butterflies move about on fine-scales within grove, and broader scales among groves, as they attempt track their preferred environmental envelope, and avoid extremes. In particular, extreme windstorms can drive monarchs from sites.

Redundancy within the habitat means multiple lines of "defense" – two rows of trees, rather than one row, wind shelter from multiple directions, areas of full sunlight, dappled sunlight, and shade, multiple openings where appropriate, and other features. The loss of branches, individual trees, groups of trees, or species of tree should not fully degrade habitat. Locally complex habitat may provide more opportunities within smaller areas.

Dynamic ecosystems – trees grow and die over years and decades, and even centuries, leading to incremental and even catastrophic changes in microclimate. On a smaller scale, branches naturally fall and may be removed for public safety. Decisions made today have repercussions for decades to come.

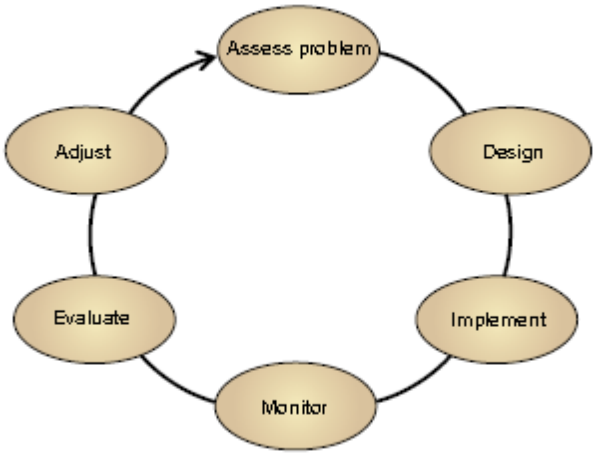
Proactive adaptive management means that changes are anticipated well in advance, and appropriate management carried out at a deliberate and measured pace. This requires a systematic adaptive management process among institutions and stakeholders to evaluate, plan, execute, assess, and re-evaluate, on an annual cycle in synchrony with the resource. Continued and refined monitoring of the distribution and abundance of monarchs over the season at the Sanctuary is an essential component of adaptive management.

Decision making and supervision in the field – All final decisions regarding tree management should be made in conjunction with a field visit, so that exact instructions can be communicated. Management activities – planting and trimming - should be monitored by qualified and interested individuals when possible.

Adaptive Management Plan

Resource management to protect and enhance Monarch Grove Sanctuary, or any monarch site, should be undertaken within the adaptive management model. Under this model, problems are assessed using existing information. Management regimes are designed and implemented in order to achieve stated objectives. Results are assessed through monitoring, and information gained is used to assess and adjust the management regime. Through each iteration of the cycle, information is gained that further refines the optimal management regime (Figure 4).

The adaptive management process.



Stated Objectives

1) Implement forest and tree management to create a mosaic of microclimates that allow monarchs to locally adjust their distribution in response to variable weather, including extreme wind storms.
2) Maintain public safety by timely treatments of hazard trees and branches without compromising monarch habitat.
3) Establish and maintain diverse and abundant nectar resources in and near the Sanctuary to provide early and season-long nectar for the butterflies.
4) Establish and institutionalize the annual adaptive management cycle.
5) Reduce conflict and increase cooperation among the City and stakeholders.
6) Maintain the site for decades to come as the forest inevitably changes.

If these actions are successful, then monitoring of the local distribution and abundance of the population will indicate success at:

1) Attracting monarch butterflies each fall.
2) Maintaining persistent monarch butterfly aggregations through the overwintering season
3) Establishing use of new/modified/old trees and branches as the forest changes through time.

Quantitative goals can eventually be developed from detailed analysis of monarch monitoring data over past years, the relative proportions at different sites south and north of the Sanctuary. These analyses are beyond the scope of this report.