CREEKSIDE SCIENCE
P.O. BOX 1553, LOS GATOS, CA 95031

Stuart B. Weiss, Ph.D.
www.creeksidescience.com
stu@creeksidescience.com
650 269-2876

Assessment and proposed management activities Monarch Grove Sanctuary and George Washington Park for 2023

Monarchs reforming clusters in strong NW winds afternoon Jan 1 2023

Monarchs on large cypress tree near northern boundary March 1, 2023

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Executive Summary

In 2022, the California overwintering population was estimated at ~335,000 butterflies during the Thanksgiving Counts. The Western monarch butterfly migration has made a great comeback from perilously low numbers (~2000) in 2020, rising to ~250,000 in 2021. Hypothesized causes of the crash and the recovery are covered in the 2022 report (and attached to this report as an Appendix).

Peak numbers at Monarch Grove Sanctuary (MGS) were estimated at 12-16,000 from early-November through December. Numbers dropped to 12,000 in early January, following a series of intense storms in mid- and late-December. This 18% drop from December to January was one of the best performances of any large site in California. Numbers declined to 9,000 by mid-January, and to 5,000 remained by early March. Only 300 remained by mid-March. It was a relatively late emigration, reflecting an absence of mid-winter heatwaves in the coldest winter in many decades.

After arriving in October, the butterflies clustered in sunny areas on the southern edge of the grove, primarily on eucalyptus. By mid-November, they clustered in the South Interior of the grove on Monterey pines and then retreated farther into the grove as many storms brought strong winds. By early February they were deep in the grove on a few cypresses close to the north fence, and by March some spread to the driveway and back south into the interior.

The general health of the trees has improved with the sustained and heavy rainfall in 2022-23. A large live (but old) tree fell in the interior of the grove and took out a healthy young pine. New plantings of Monterey cypress (2021) are well established and are actively growing. Boxed trees remain along the SE fence and in a gap near the hotel driveway.

The major short-term management actions recommended for 2023 are:

1) Removing hazard trees and branches
2) Buck up and distribute the large fallen tree in the interior.

3) Hiatus on new tree plantings except for one spot by the hotel driveway
4) Initiate and continue thinning of overly dense trees.
5) Remove boxed trees before they root in place.
6) Remove old stakes and cages.
7) Manage nectar beds, and plan for replacement and pruning of poor-performing species and beds.
8) Re-examine irrigation scheduling and implementation. Implementing deep watering at George Washington Park is one immediate area of adjustment.

Longer-term management actions will benefit from 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 were presented in the 2022 report in some detail. including some examples of habitat mapping with LiDAR. They are included as Appendices in this 2023 report for completeness and ease of reference.

Introduction

The following recommendations and assessments are based on site visits over the 2022-2023 season and on-site consultations with City Arborist Albert Weisfuss and environmental manager George Fuerst in Spring 2023. 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 2014-2022 (Weiss 2014-2022). The recommendations are based on previous scientific work at dozens of monarch sites, 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.

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. The numbers at Pacific Grove in California context, including both Thanksgiving and New Years' Counts.
2. The monitoring data from the PG Museum on monarch numbers and distribution through the season, and interpretation.
3. A graphical view of Monterey Airport data, to identify high wind events and aid in interpreting the movement of monarchs within MGS.

4. A brief review of management actions completed in recent years.
5. Recommendations for management actions in summer 2023.
6. Photographs of monarchs and habitats with notes.
7. Discussion of opportunities for a new management plan and the elements of that plan (Appendix A).
8. An exposition on potential causes of the Western monarch crash from 2015-2020, and subsequent recovery (Appendix B).
9. A repeat and update of the long-term management considerations from previous reports, where still relevant (Appendix C).
10. A supplemental separate document with some visualizations and analysis of LiDAR data from 2016, as a demonstration of the potential of this new technology (Appendix D).

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.

A horticultural report (Regan Biological and Horticultural Consulting 2022) was developed that addresses issues with the nectar beds.

Pacific Grove in California Context

Monarch Grove Sanctuary supported a peak of 15,960 monarch butterflies in late fall 2022 (Thanksgiving Counts). The California total was 335,479 monarchs at more than 100 sites from Sonoma County to Baja California. 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, Figure 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.

In 2022-23, MGS supported 4.8% of the CA population, and 62% of the Monterey County population during the Thanksgiving Counts. It was the 4th largest site in California.

The New Years' counts (Table 2) across several sites are an indication of how well sited maintained monarch numbers through December and early January. MGS retained 82% of its butterflies, its highest retention rate since 2019. It is one of the better retention rates in California, similar to Lighthouse Field (84%) and higher than Pismo North (75%),

Moran Lake (70%), and Natural Bridges (60%). And it compares favorably to the overall retention rate for California as a whole (42%).

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 2013-23 (Figure 2a) shows arrival in October, peaks in late-November through early-December, and declines in January and February as monarchs die or leave the site. 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 (2013-2022) are described in previous reports.

In 2022-23 (thick black line in Figure 3), monarchs arrived in mid-October, quickly rose to 12,000 by the end of October, and peaked at 16,000 by the end of November. Numbers dropped to 12-13,000 into early January, and slowly declined through mid-February to 9,000. A decline to 5,000 occurred in late-February, and the final mass emigration occurred by mid-March. The emigration was the latest among all nine years plotted here.

Monarchs clustered on a variety of tree species and shifted through the season (Figure 2b). In 2022-2023, monarchs started primarily on eucalyptus along the southern edge. By late October, after storms and high winds, they moved to nearly 100%, Monterey pines in the interior and remained there through January. Many monarchs were clustered on lace lichen hanging from the pines. There was a shift to cypress trees toward the end of the season.

The spatial distribution of monarchs changed over the season (Figure 2c, 2d). They started out primarily on the south edge (blue), and progressively moved deeper into the grove, first to the South Interior just N of the E-W trail by late-November (light green), and then into the Interior (darker green) during December-January, and nearly 100% of the butterflies were in the North Interior (darkest green) by early early-February. In mid-February and March, large numbers (more than 50% of the population) started clustering along the Driveway, and some were near the nectar beds.

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

Weather 2022-2023

The daily weather at Monterey Airport (KMRY, Figure3) provides a view of the regional synoptic meteorology (passage of storm fronts, high wind events, and temperature extremes). While KMRY does not absolutely represent the conditions within MGS, high winds there are representative of the conditions outside the canopy at MGS. KMRY serves as an indicator of high regional wind events that can be tied to historical monarch movements within MGS.

2022-2023 was a stormy wet winter, with many rain days numerous periods of high winds. The first high winds in October (>20 mph) drove the monarchs off the eucalyptus on south boundary, into the more sheltered pines in the South-Interior of the grove (Figure 2b, 2c). A series of strong wind events in December drove them further north, so by early January they were in the Interior. More strong winds in early-January drove them even further north to the North Interior. In February, many monarchs moved to the Driveway area and reoccupied the Interior.

The season was also notable for being cooler than average, with a distinct absence of mid-winter heatwaves (>70°F) that stimulate monarchs to break diapause. Some monarchs remained on the site well into March, compared with emigration in January and February in most other years (Figure 2a).

The weather station along the South fence (presented in the 2021-22 report) was functional only through December so will not be reported on further.

Nectar

Monarchs will visit many species of flowers for nectar. Early season (October-November) 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). The ivy-covered stump at the NE corner attracts hundreds of butterflies in the fall.

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.

Another species that should be considered is orange colored Mexican sunflower, which is heavily used in the fall at the Gill Tract in Albany (Photo 4). More on that in the recommendations.

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 winter, indicating that there is sufficient wind shelter and dappled light in the interior.

The depth of MGS allowed monarchs to take refuge from strong southerly winds in the far Northern Interior section (also observed in 2017 and other years). The shelterbelt of eucalyptus and other species planted in 1999 is well established and now provides solid NW wind protection so that monarchs can remain in the Interior zone when winds shift from southerly to northwesterly following storms.

In terms of recent active management, most hazard trees and branches have been removed over time, but some dead pines remain, and others are close to death. One large old tree fell in a storm. New tree plantings are established and will eventually 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. The detailed analysis of the forest structure and microclimate is found in the 2011 Siter Assessment and Management Plan (Weiss 2011).

Recent Management Actions in 2020- 2022

The major recent 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 Some toyon and ceanothus were planted and caged.

Identified hazard trees and branches have been removed each year.

The irrigation scheduling appears to be working better, 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 2023.

The new tree plantings have not been mapped as of 2023, 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 in Appendix A).

In 2022, the neighbors at 1070 Short removed a cypress in their backyard that was developing into a good windbreak tree. This emphasizes how important it is to have MGS as self-contained as possible in the absence of enforceable restrictions on neighboring properties.

General 2023 Recommendations

The general recommendation is that good forestry practices be consistently implemented. These practices include:

1. This is not a “natural” forest, and direct thoughtful forestry and arborist prescriptions are necessary to maintain the microclimatic structure of wind shelter and moderate light that attracts and retains monarchs.
2. Manage stem densities through selective thinning to allow for the development of healthy individual trees. The overly densely planted areas in the SE corner have had 10 years of growth, and have developed into a thicket of crowded, unhealthy trees. The removal of selected trees will reduce canopy competition for light and reduce root competition for water and nutrients. The remaining trees will expand their canopies and grow faster, producing better wind shelter that will more than compensate for the loss of sickly canopies. This work can be phased in over several years but should start in 2023. An eventual minimum spacing of 10’ is the target. This also applies to some of the cypress stands behind the nectar beds, where thinning started in 2022.
3. Slow down new plantings. Several dozen trees, including cypress, eucalyptus, and pines have been planted in recent years. The performance of these trees needs to be evaluated. A hiatus in new plantings, except in very limited areas discussed below, is recommended, along with more attention on taking care of the recently planted trees with well-planned (deep and infrequent) irrigation.
4. Proactive hazard reduction of dead trees and branches that threaten people and other trees. The path is the obvious target and several hazards have been identified in 2023 (discussed below). But interior dead trees that do not have a trail as a target are a threat to other trees - the large tree that fell this last season in the Interior Zone took out a desirable healthy young pine tree (Habitat Photo 21). There is a large dead tree in the NE interior that will do the same thing when it falls (Habitat Photo 10).

Specific 2023 short-term recommendations

1. **Remove large standing dead trees and hazard branches (Habitat Photos 9, 10, and 18).** One tree along the main path has already been removed in summer 2023, because it posed an immediate hazard (Habitat Photo 18). Toward the NW corner, there are dead branches overhanging the main path that urgently need to be dropped safely. All dead and nearly dead branches within reach of the trail should be identified, inspected, and removed. Near the hotel driveway, a large dead standing pine (Habitat Photo 10) is poised to eventually fall and take out desirable trees, like what happened in 2023 (Habitat Photo 21).
2. **Manage large, downed wood.** Buck up the trunk of the large fallen pine so that the trunk is in contact with the ground. Cut smaller branches and either scatter, pile, or chip onsite (Photo 19). Collect a good sample of the cones, to spread in areas where pine seedling recruitment is desired. Leave the upturned trunk as potential wildlife habitat (Photo 20). The major goal over time is to avoid excessive fuel accumulation. This tree took out a healthy mid-sized pine tree (Habitat Photo 21), serving as a lesson as to why large snags need to be dealt with.
3. **A hiatus on major tree plantings** until a full inventory and structural assessment is completed as part of a new management plan (see Appendix). There are plenty of new trees in the ground for now and their growth and health should be monitored closely. Eventually, it may be necessary to thin some trees to encourage individual tree health.
4. **Remove boxed trees from their current locations along the SE fence (Habitat Photo 1).** They are currently rooting through the bottoms of the boxes. These trees are too crowded relative to the large trees just west, too close to the fence, and unnecessary for wind shelter given the structures and the dense tree canopies developing to the further west of the large trees.
5. **New limited plantings of large trees.** The exception to the hiatus on new plantings is that ***one or at most two*** potted trees in the gap on the Hotel property can be planted (Habitat Photos 2, 11). If two trees are planted (to have one backup) then the less vigorous one should be thinned after several years once survival of the desired tree is clear. Avoiding overplanting is essential for individual tree health and rapid growth to fill this gap.
6. **Shrub plantings.** Planting native shrubs like toyon along the south boundary with 1070 Short will help fill in the wind gaps produced by the removal of the cypress in the backyard and create a more attractive edge. Newly planted cypress and eucalyptus just inside MGS facing this gap will provide mid-story wind protection after a few years. Planting native shrubs along trails and in open understory areas can diversify the understory, but plants need protection from deer browsing.
7. **Further thinning the cypress stand toward the NW corner (Habitat Photo 7)** with removal of two more trees to be selected in the field, to allow for more room for the remaining trees while maintaining wind shelter. Two trees were

thinned in 2022. The remaining trees will expand their canopies in the absence of competition and fill out the canopy openings.

8. **Initiate thinning small eucalyptus in the SE corner (Habitat Photo 4).** 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, after ten years of growth in crowded conditions. Plan on removing a few trees each year until a suitable density (10' spacing) is achieved. Some of the trees immediately along the fence (Habitat Photo 16) should be thinned as well. The remaining trees will respond strongly to increased space and fill in the canopy rapidly, and individual trees will be much healthier and grow more rapidly.
9. **Remove old stakes and cages (Habitat Photo 17).** Many trees planted in the last decade still have stakes, collars and cages that are no longer needed. Each staked tree should be evaluated, and the stake/cage removed if no longer needed.
10. **Manage nectar beds.** A report on the nectar beds was produced recently (Regan Biological and Horticultural Consulting 2022), and provides excellent assessments and recommendations. The yellow Buddleia bushes should be pruned to refresh growth and force flowering in the fall. Half of the canopy should be pruned to a density determined by consultations with a master gardener or other horticultural expert. Some nectar beds support species that are not used by monarchs (such as the mallow) and should be replaced. Mexican sunflower (*Tithonia rotundifolia*, Monarch Photo 4) is an excellent addition – it is heavily used at the Gill Tract in Albany. Additional native nectar plantings in sunny trailside areas should be considered but should wait until the rope fencing is replaced.
11. **Manage pine seedlings**. Maintain and cage pine saplings in the interior (Habitat Photo 14). Apply irrigation as needed in the first one or two years for establishment of planted pines – the emphasis should be on relatively few deep irrigations over the dry season, not frequent shallow irrigations. There are several natural recruits from seed east of the nectar beds that should be retained and encouraged. Trees that naturally recruit develop resilient root systems that explore the soil to great depth. Experiments with pine seeding on patches of freshly bare soil could develop a method for recruitment of healthy pines. Collecting cones from fallen trees could provide a good source of seeds for such experiments.
12. **Irrigation.** The irrigation regime for new plantings be continued, but trees and shrubs should be weaned off irrigation after a few years once established. An evaluation of the irrigation program by the City arborist is recommended. Again, the emphasis should be on a few deep irrigations over the dry season, not frequent shallow irrigation.
13. **Neighbors.** Take a broader view of the site and work with neighbors. Trees in the surrounding neighborhoods can provide critical wind shelter. For example, a growing cypress south of MGS at 1070 Short Street was taken out leaving a gap in the wind shelter. New plantings of cypress and eucalyptus within MGS will

eventually seal this gap. The trees on the hotel property are also integral to the monarch habitat. Working out lines of communications and responsibilities will help site management progress more smoothly.

2023 Recommendations for George Washington Park

The bulk of the consideration of GWP is in the Appendix as part of the long-term management plan outline. No major actions, except immediate hazard tree management, are recommended until a full site assessment is completed.

One immediate issue is adjusting the irrigation schedule for the numerous pines that have been planted in recent years. Long-term survival and health of these pines requires that they grow roots to tap deep soil water once irrigation is stopped after several years. Volunteers have devoted much time and effort in irrigating these trees, and it is important to have an effective irrigation schedule for deeper watering. The current irrigation schedule only provides shallow water, which encourages the pines to grow roots in the shallow wet zone at the expense of deeper roots. *It is highly recommended that the watering regime be changed to deep irrigation so that each tree receives much more water in each watering, with less frequent watering.* The exact schedule needs to be worked out, but as a start, twice the water at half the frequency is suggested.

Photo Gallery

The photo gallery documents many of the observations and recommendations, and some (not all) are referenced in the text above.

Literature cited.

Crone, E.E., Pelton, E.M., Brown, L.M., Thomas, C.C. and Schultz, C.B., 2019. Why are monarch butterflies declining in the West? Understanding the importance of multiple correlated drivers. Ecological Applications, 29(7), p.e01975.

Crone, E. and Schultz, C., 2021. Resilience or Catastrophe? A possible state change for monarch butterflies in the West. Ecology Letters, *24*(8), pp.1533-1538.

Espeset, A.E., Harrison, J.G., Shapiro, A.M., Nice, C.C., Thorne, J.H., Waetjen, D.P., Fordyce, J.A. and Forister, M.L., 2016. Understanding a migratory species in a changing world: climatic effects and demographic declines in the western monarch revealed by four decades of intensive monitoring. Oecologia, 181(3), pp.819-830.

Fordyce, J.A., Baert, N. and Forister, M.L., 2020. Pesticide Contamination of Milkweeds Across the Agricultural, Urban, and Open Spaces of Low-Elevation Northern California. Frontiers in Ecology and Evolution, 8, p.162.

James, D.G., 2019. A neonicotinoid insecticide at a rate found in nectar reduces longevity but not oogenesis in monarch butterflies, Danaus plexippus (L.).(Lepidoptera: Nymphalidae). Insects, 10(9), p.276.

James, D.G. and Kappen, L., 2021. Further insights on the migration biology of monarch butterflies, Danaus plexippus (Lepidoptera: Nymphalidae) from the Pacific Northwest. Insects, 12(2), p.161.

Leong, K.L.H. 1990. Microenvironmental factors associated with the winter habitat of the monarch butterfly (Lepidoptera:Danaidae) in central California. Annals of the Entomological Society of America 83:906-910

Leong, K.L.H. 1991. Use of multivariate analyses to characterize the monarch butterfly (Lepidoptera:Danaidae) winter habitat. Annals of the Entomological Society of America 84:263-267.

Pelton, E.M., Schultz, C.B., Jepsen, S.J., Black, S.H. and Crone, E.E., 2019. Western monarch population plummets: status, probable causes, and recommended conservation actions. Frontiers in Ecology and Evolution, 7, p.258.

Regan Biological and Horticultural Consulting. 2022. City of Pacific Grove Monarch butterfly Sanctuary Horticultural management.

Schultz, C.B., Brown, L.M., Pelton, E. and Crone, E.E., 2017. Citizen science monitoring demonstrates dramatic declines of monarch butterflies in western North America. Biological Conservation, 214, pp.343-346.

Weisfuss, A. 2020. Monarch Grove Sanctuary. An Assessment with Recommendations. Arborist report to the City of Pacific Grove.

Weiss, S.B. 1998. Habitat Suitability, Restoration, and Vegetation Management at Monarch Grove Sanctuary, Pacific Grove, California. Report to the City of Pacific Grove.

Weiss, S.B. 2011. Management Plan for Monarch Grove Sanctuary:
Site Assessment and Initial Recommendations. Report to the City of Pacific Grove.

Weiss, S.B. 2013-2020. Proposed management activities Monarch Grove Sanctuary and George Washington Park. Annual memorandum/report to the City of Pacific Grove.

Yang, L.H., Ostrovsky, D., Rogers, M.C. and Welker, J.M., 2016. Intra-population variation in the natal origins and wing morphology of overwintering western monarch butterflies Danaus plexippus. Ecography, 39(10), pp.998-1007.

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
2022	15,960	0	335,479	25,920	4.8%	62%	4

Table 2. Comparisons of Thanksgiving (NOV) with New Year's (JAN) counts at selected sites from 2019 to 2022. 2020 had so few butterflies that it is not included.

SITE NAME	NOV 2022	JAN 2023	% 2022	NOV 2021	JAN 2022	% 2021	NOV 2019	JAN 2020	% 2019
MGS	15,960	13,149	82%	13,608	10,055	74%	642	316	49%
Lighthouse Field	3,365	2,836	84%	410	637	155%	3402	2600	76%
Natural Bridges	7,500	4,500	60%	2,100	1,700	66%	1997	25	1%
Moran Lake	5,701	4,000	70%	1,100	725	66%	400	30	8%
Pismo North	24,128	18,073	75%	20,871	16,695	80%	6,735	3,625	54$
CA Total	285,332	120,492	42%	249,250	154,121	62%	24,899	12,526	50%

Figures

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

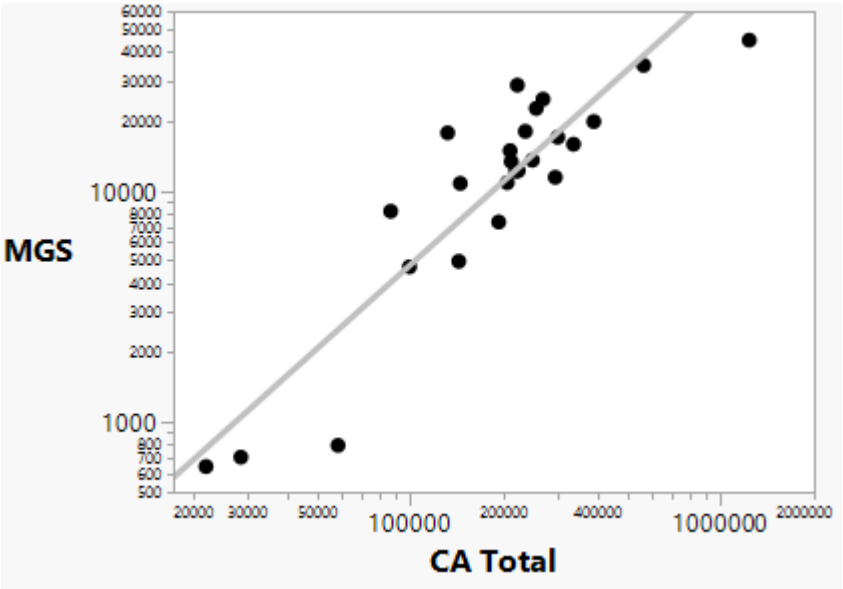


Figure 2a. Monarch numbers through seasons. Data from Pacific Grove Museum

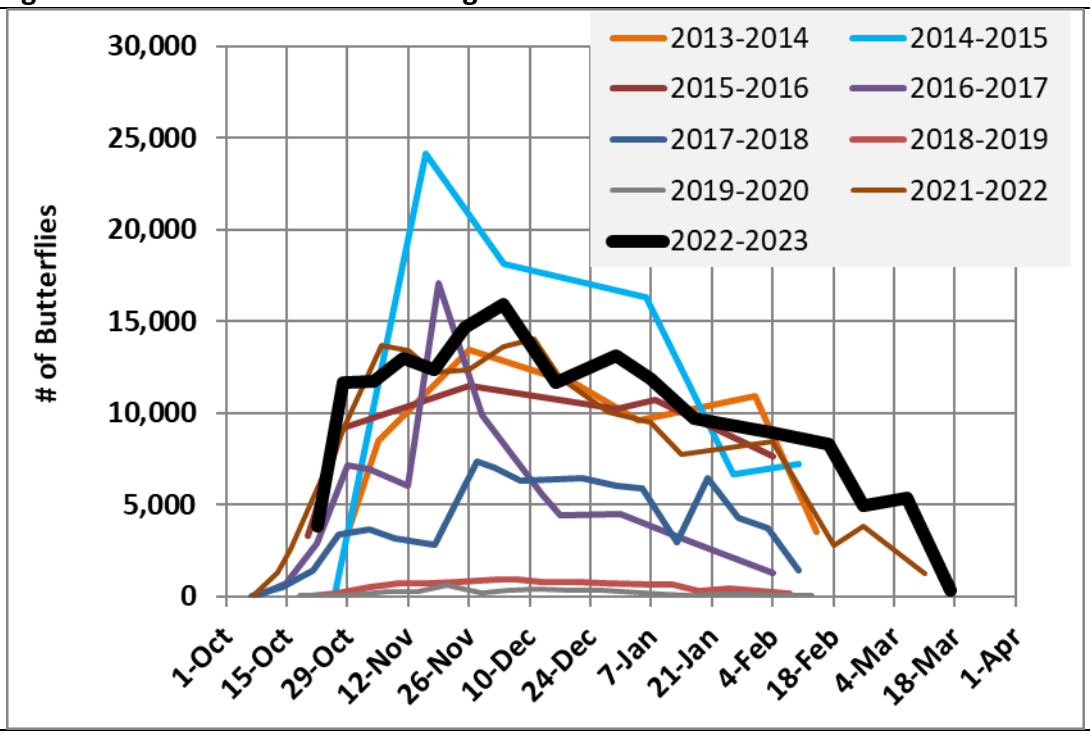


Figure 2b. Monarch Tree Occupancy through Time

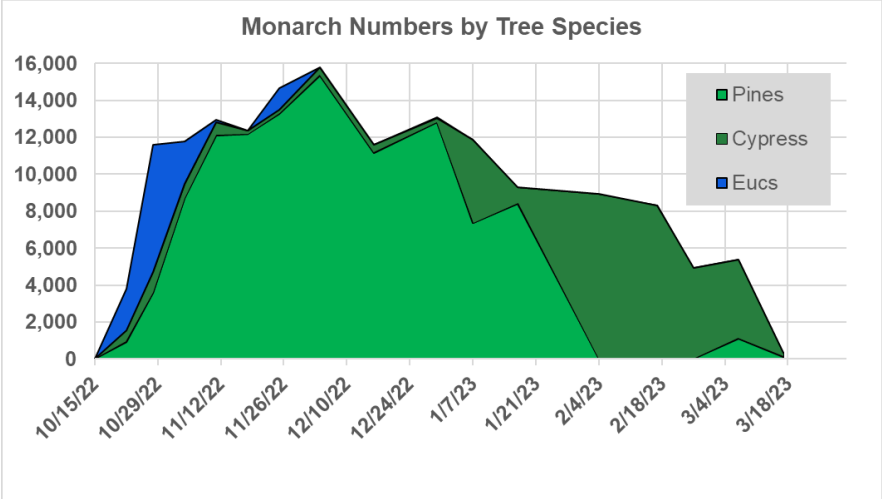


Figure 2c. Monarch Spatial Distribution by Zones

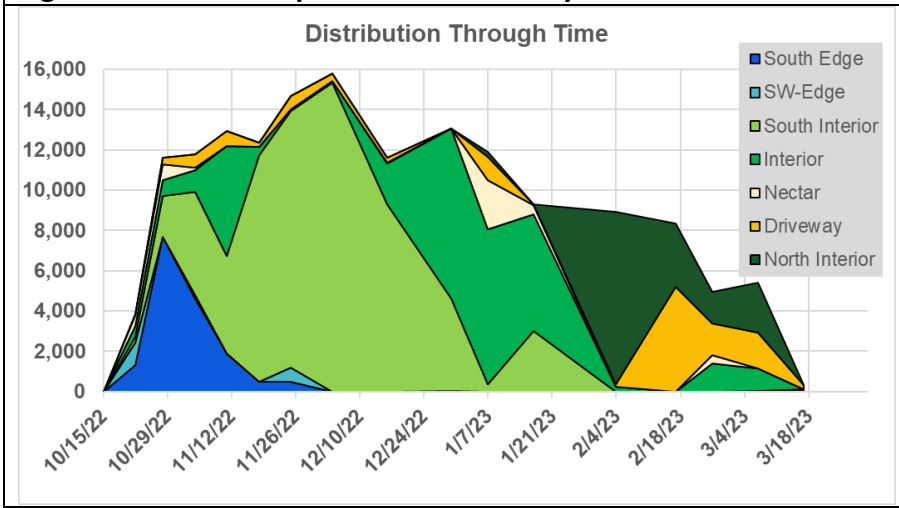


Figure 2d. Map of monarch cluster zones in Figure 2c and text.

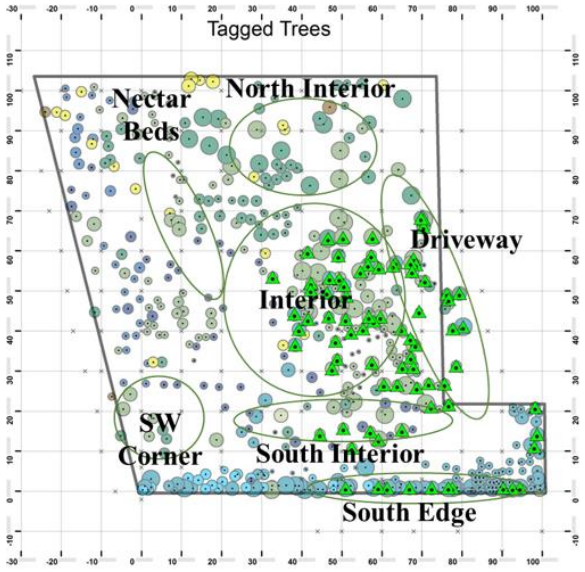


Figure 3. Temperature and Wind Speed at Monterey Airport

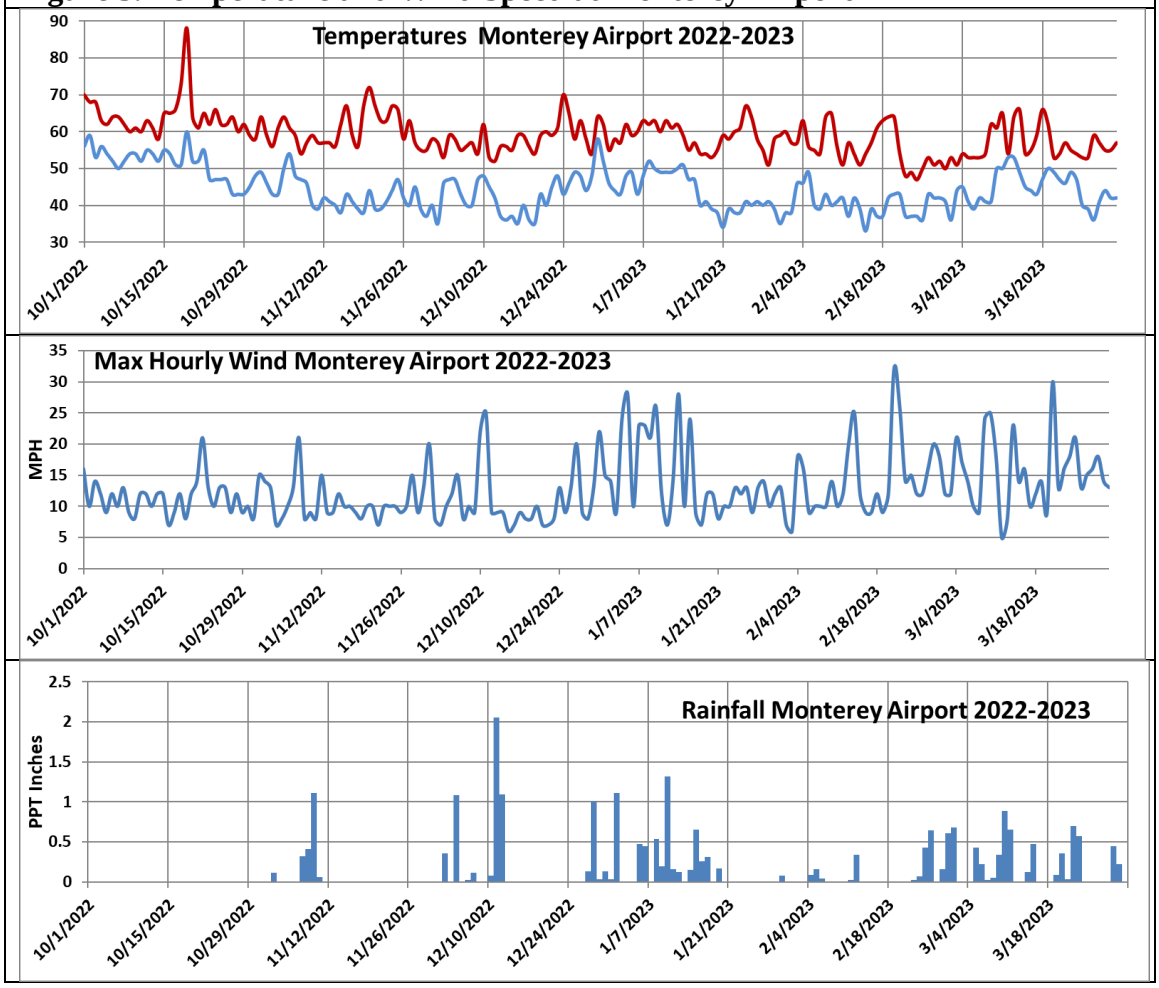


Figure 4. Monarch Occupied Trees (Green Triangles) and cluster zones, Grid in meters

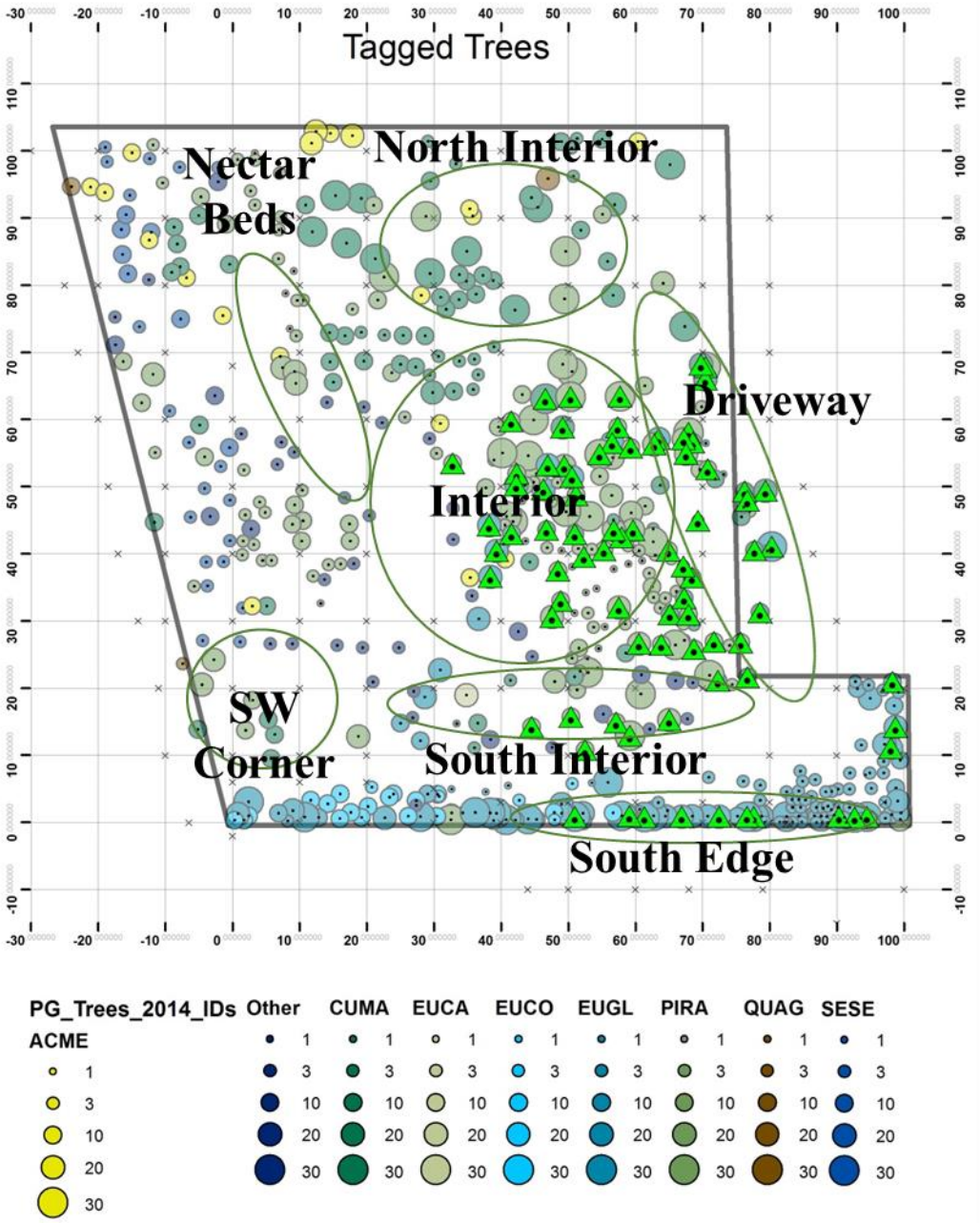


Figure 6. Management Zones. Grid in Meters

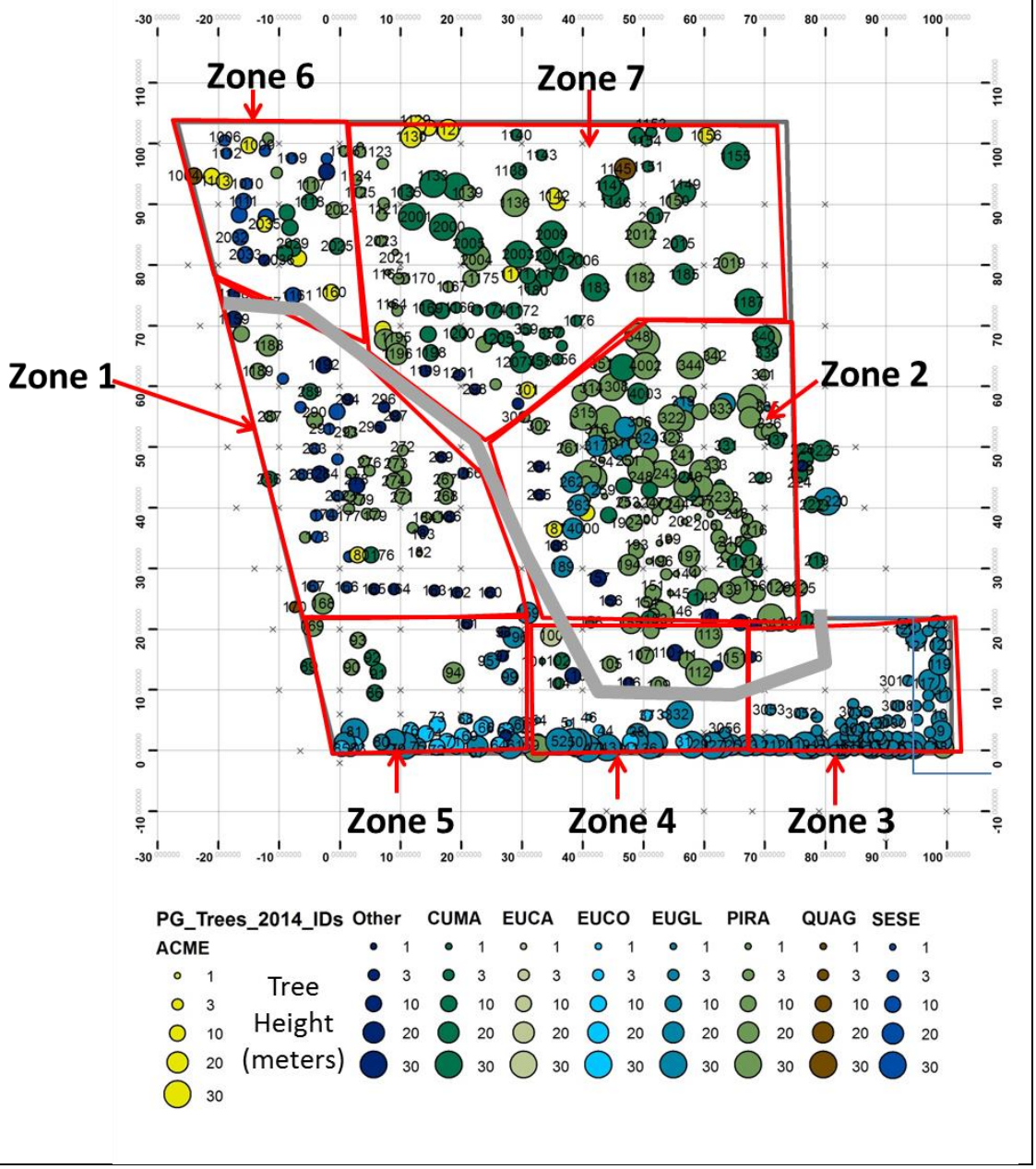
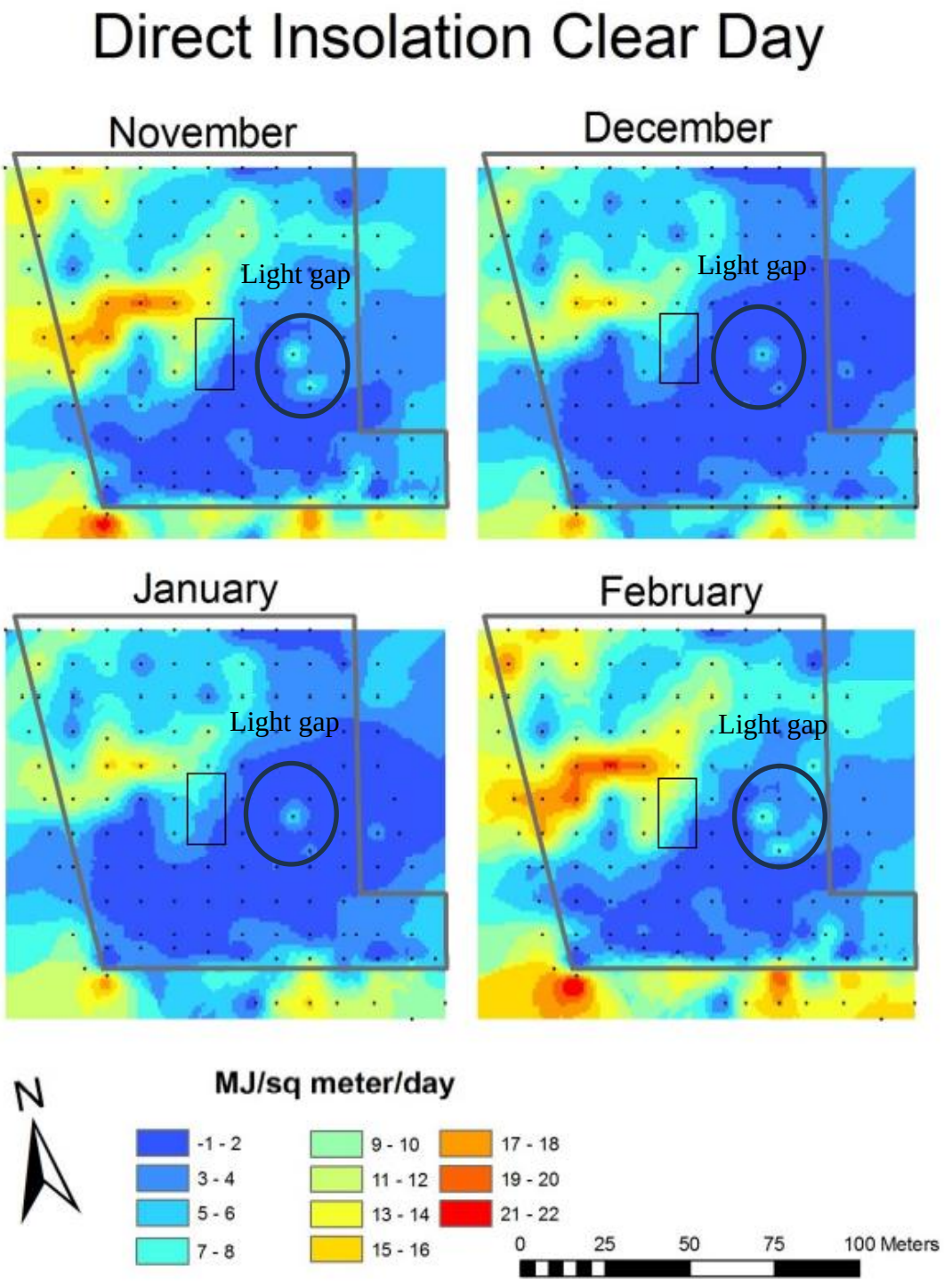
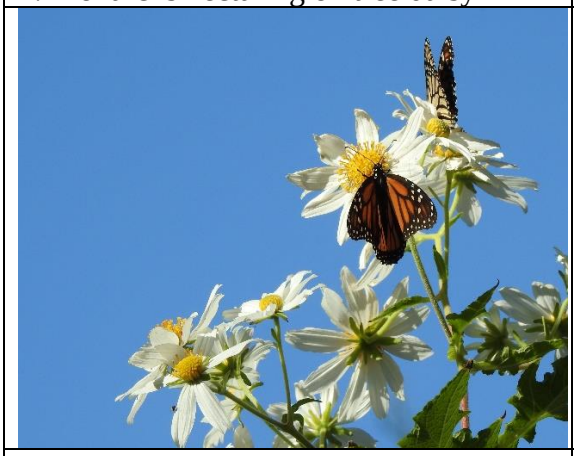
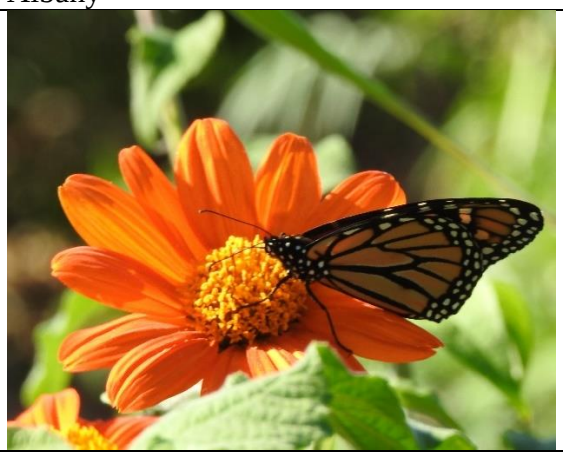


Figure 7. Insolation maps from 2011 report. Note the small halos in the interior east of the outline of the old building footprint; which is the interior cluster zone. The high insolation areas NW of the old building are where nectar (primarily tree daisy and bottlebrush) is available the entire season



Monarch photos

1. Monarchs nectaring on tree daisy	2. Monarchs nectaring on bottlebrush
	
3. Monarchs nectaring on English ivy	4. Monarchs on Mexican sunflower (*Tithonia rotundifolia*) at Gill Tract, Albany
	
5. Monarchs forming clusters late afternoon, January 2023. Strong NW winds	6 Monarchs on large cypress in North-Interior, March 2023.
	

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
	

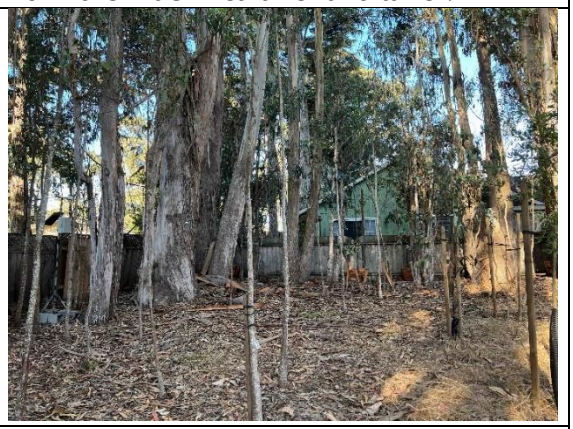
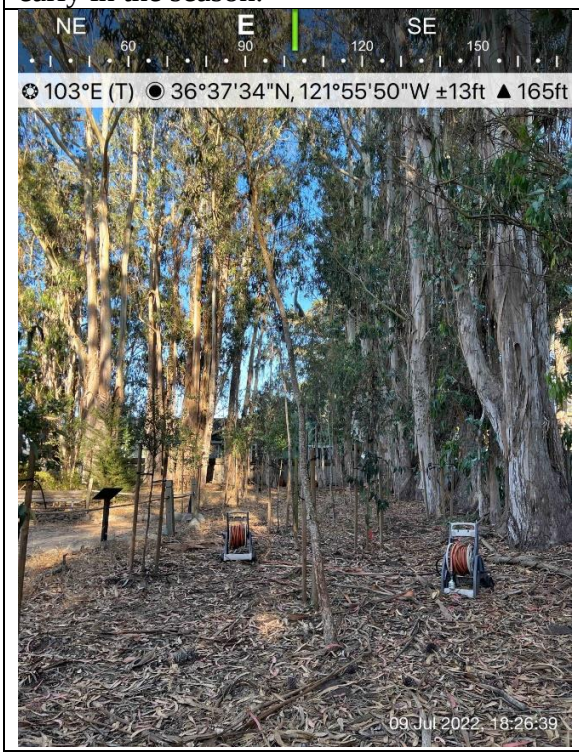
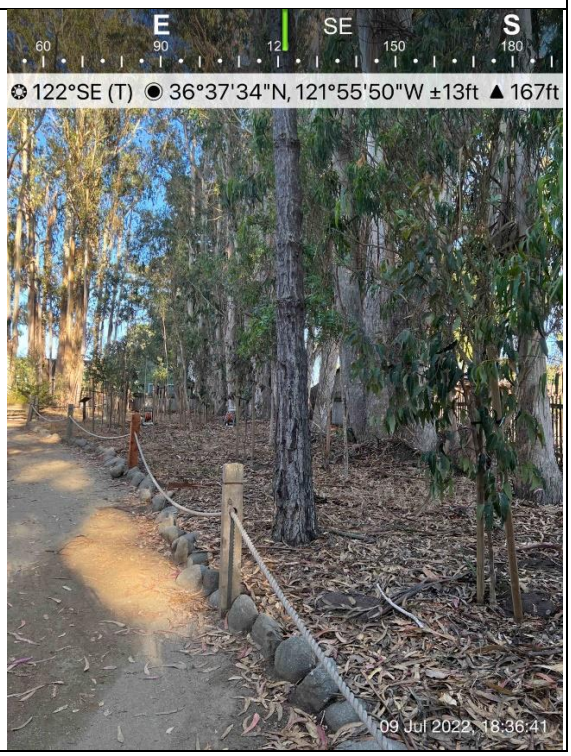
Photo 3. Two cypress planted in the open area of the SE corner of MGS. These trees may develop into cluster trees in a wind-sheltered area with dappled light	Photo 4. SE corner. These eucalyptuses were planted too dense in 2013 (3-5' apart) and are growing poorly and in poor shape. The well-spaced trees (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, thinned in 2022 by removing two trees to allow for more rapid growth and health of remaining trees. One or two additional trees should be removed in 2023. 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 branch over the trail NW of nectar beds, to be removed.	Photo 10. Dead pine near NE corner. This tree threatens important interior 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 and cluster opportunities	Photo 16. Dense eucalyptus plantings along southern fence. Thinning trees here would allow for better growth of remaining trees. The trees right up against the fence will eventually ruin the fence.

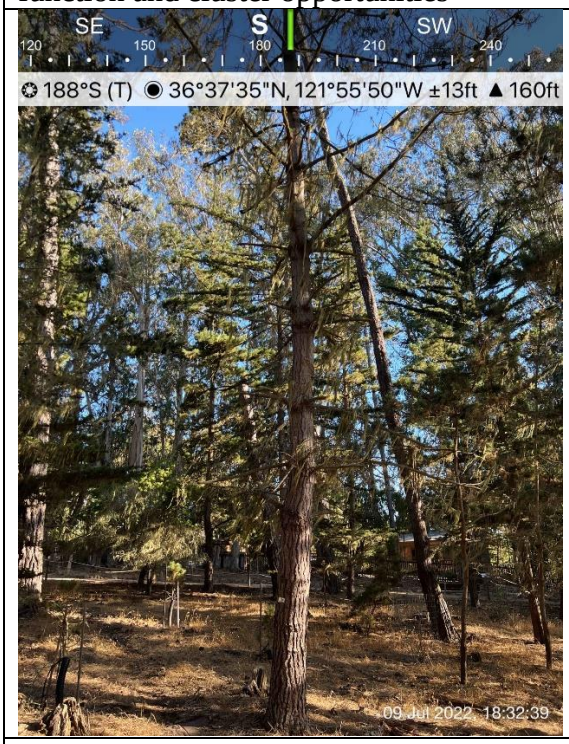
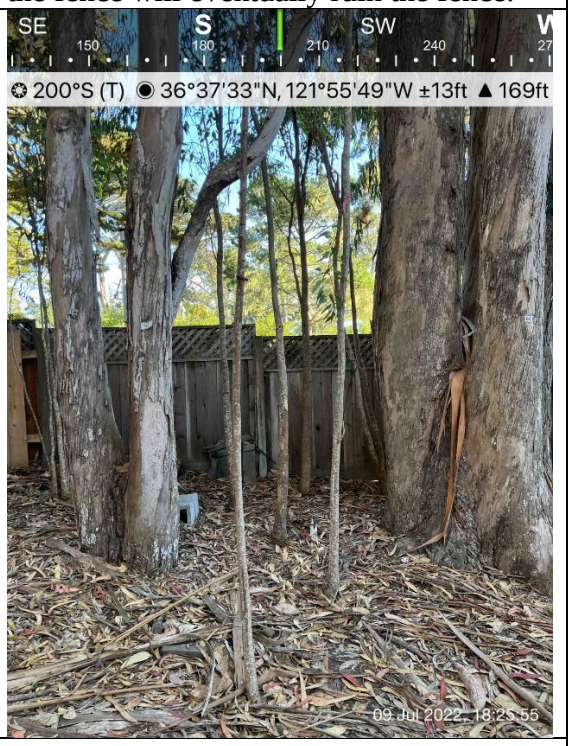

	

Photo 17. Typical unnecessary old stakes	Photo 18. Dead pine tree along path. **Major hazard, r**emoved in June 2023
	

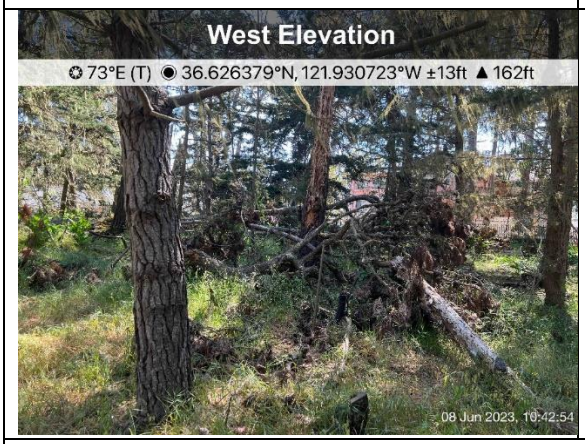
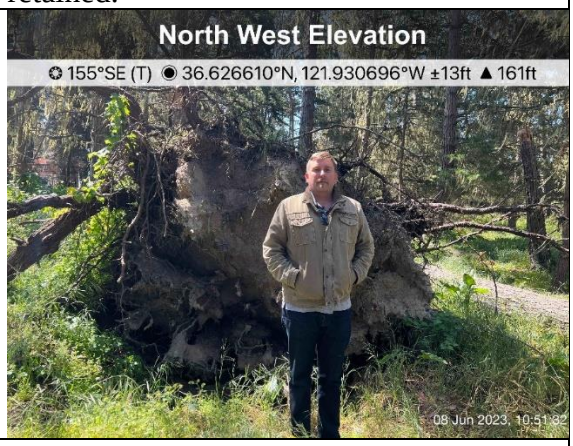
Photo 19: Crown of fallen tree in Interior	Photo 20.Upturned root ball to be retained.
	

Photo 21. Medium-sized healthy pine taken out by treefall, an example of why it is important to remove large standing dead trees.

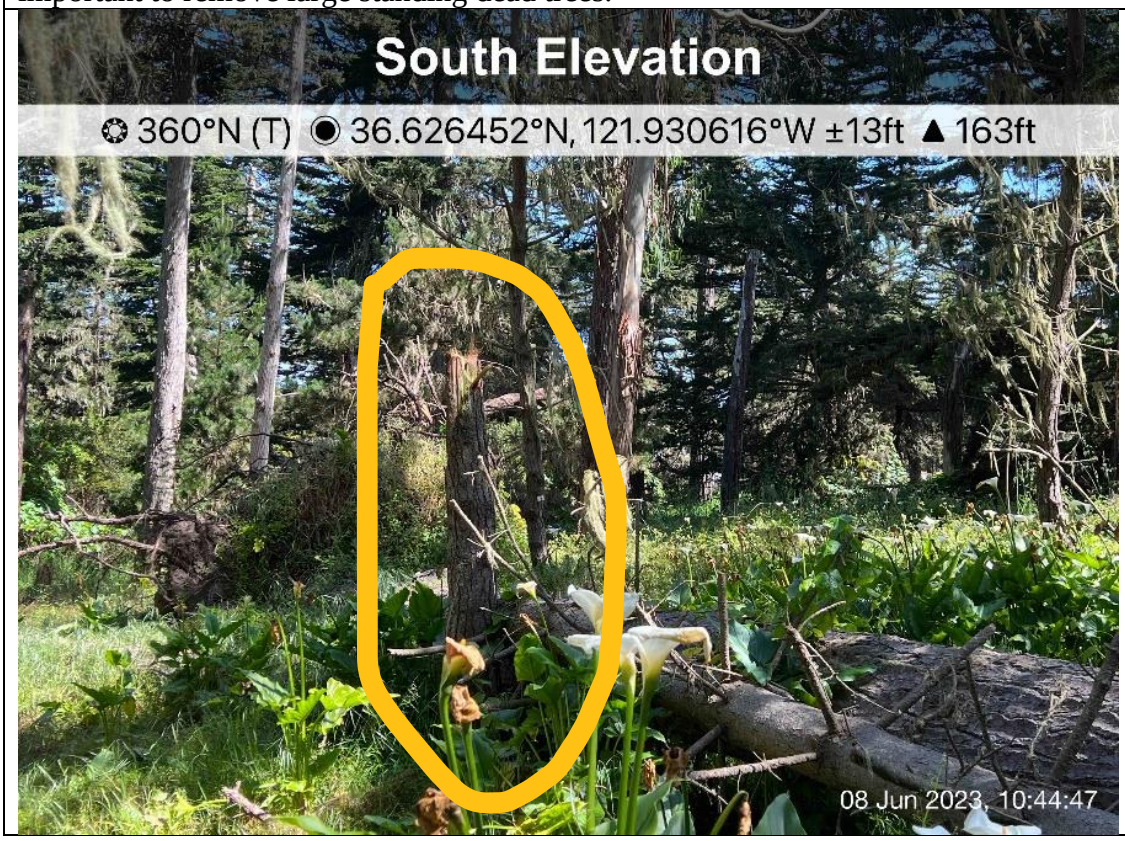


Photo 22. View into interior cluster zone of pines. Maintaining some relatively open habitat with dappled light in this area is important for monarchs.	Photo 23. Cypress sapling near bend in the trail, with 1999 eucalyptus shelterbelt in background and relatively open interior to east.
	
Photo 24. Irrigation Zones	Photo 25. Irrigation documentation

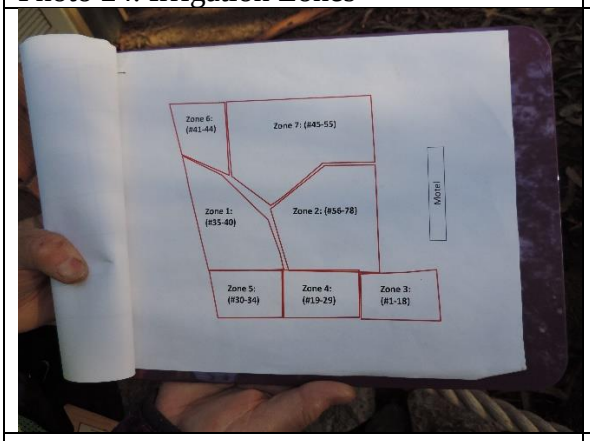
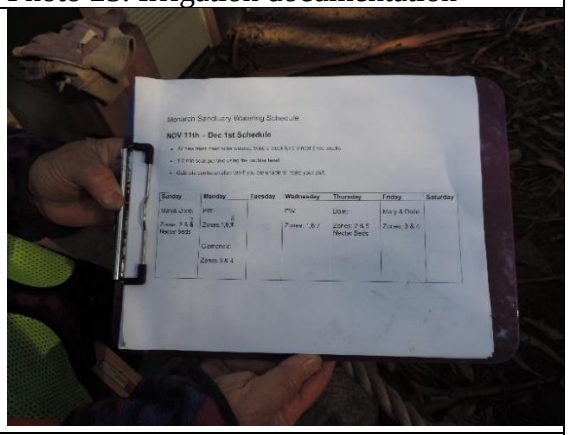

	

Photo 25. Pine plantings in George Washington Park	Photo 26. Pine plantings in George Washington Park
	

Appendices

In 2022, some site history and the components of a new management plan and its implementation were outlined. These sections are repeated here

Appendix A. Site history and New Management Plan

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. Some historical perspective is necessary to set the stage for a new management plan.

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 1998 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). Note the light gap area of higher insolation circled in in Figure 7.

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 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 LiDAR, 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, but was relieved by a very wet season in 2022-23. 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." (Appendix D). 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 at any height above the ground, hence quantifying insolation 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 (Appendix D).

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 average and maximum 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 of where thinning is necessary to enhance individual tree health, and recent thinning of the cypress behind the nectar beds is a good example.

Another consideration is that 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 by a professional arborist.

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.

Pine pitch canker is an ongoing threat to Monterey Pines and should be monitored.

Other diseases and insects should be noted.

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 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 (note the orange and yellow zones NW of the old Brokaw Hall outline). 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 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 24 and 25).
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 25 and 26). Eventual thinning is required if 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, 2018-2019, and 2022-2023 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.

Appendix B. Hypothesized causes of the 2020 population crash and subsequent recovery.

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 through 2017

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.

Monarch Crash of 2018-2020

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?

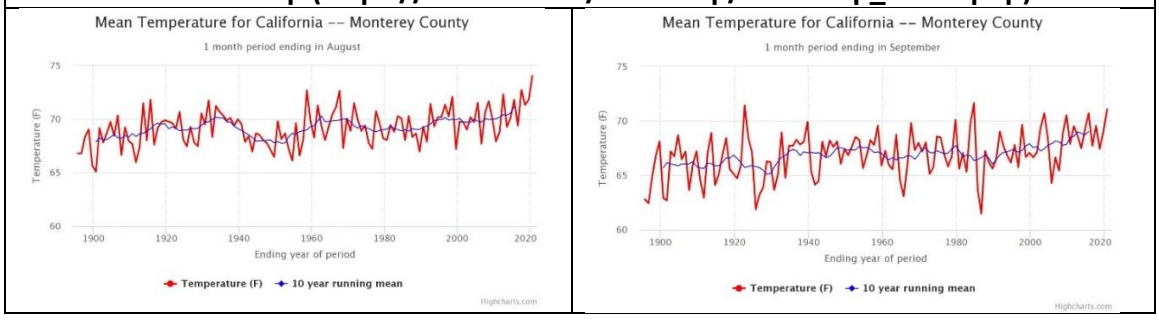
First, the awesome reproductive potential of monarch butterflies (each female produces ~400 eggs) can be expressed if conditions on the breeding grounds are good. Four-fold increases per generation are well within the range observed in monarch populations – over 4 generations such increases multiply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

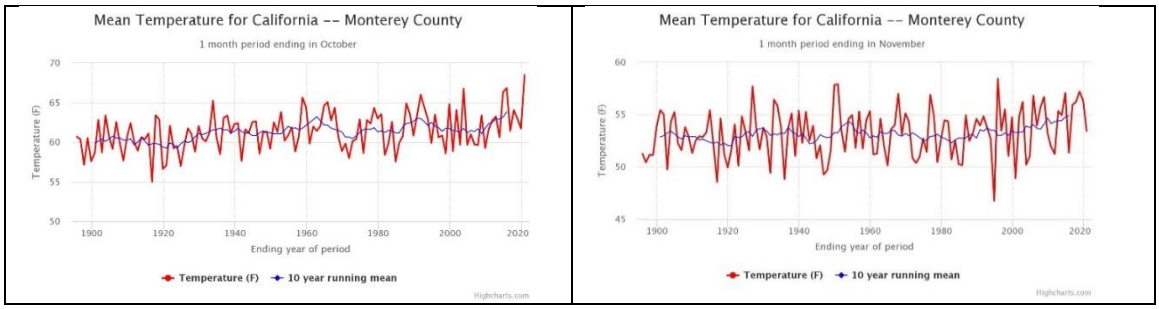
As opposed to 2020, nearly everything went right in 2021, at least in the southern portion of the monarch range. Spring weather following the emigration from the overwintering sites was mild. No megafires occurred in the South Coast Ranges, which produce many of the overwintering butterflies and provide 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.

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





Appendix C (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.

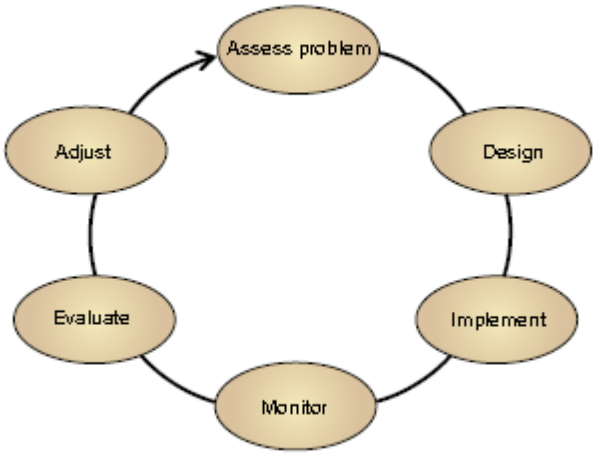
Proactive adaptive management means that changes are anticipated well in advance, and appropriate management carried out at a deliberate and measured pace. This requires a systematic adaptive management process among institutions and stakeholders to evaluate, plan, execute, assess, and re-evaluate, on 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.

Appendix D. LiDAR snapshots and discussion.

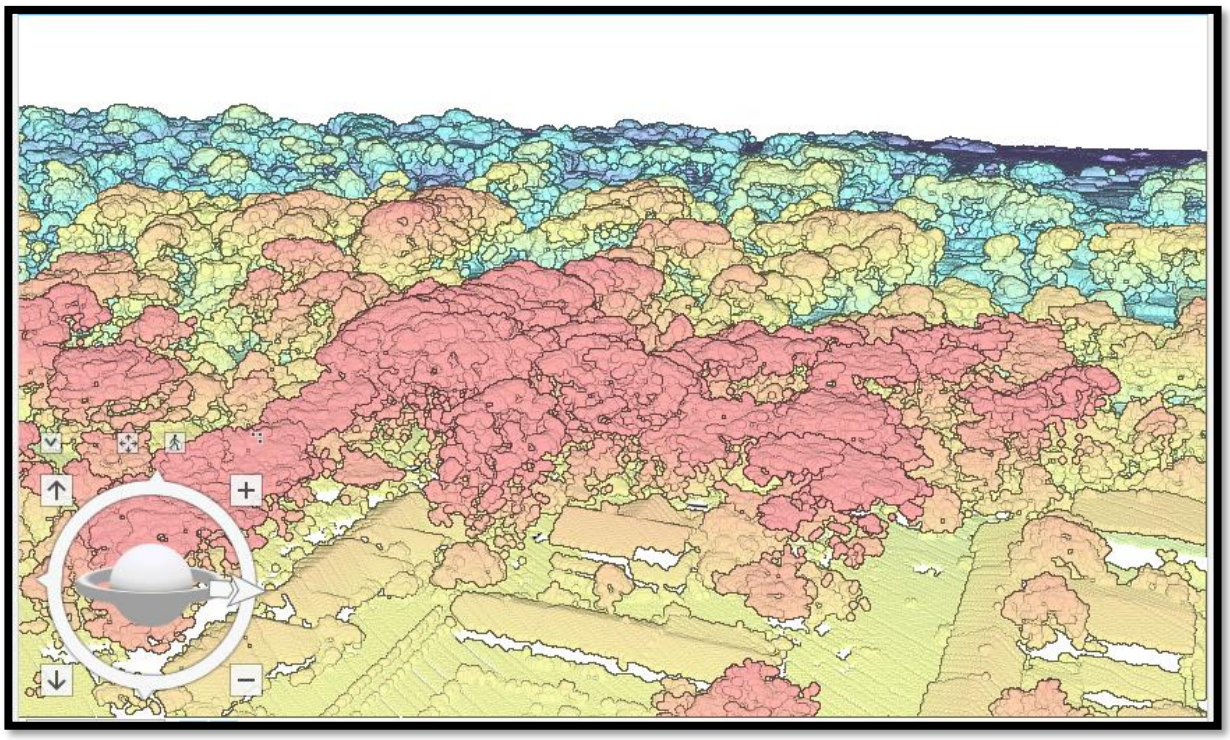
This is presented as a s separate pdf document.

CREEKSIDE SCIENCE
P.O. BOX 1553, LOS GATOS, CA 95031

Examples of LiDAR for Assessment of Monarch Butterfly Habitat in Pacific Grove

Stuart B. Weiss, Ph.D.
www.creeksidescience.com
stu@creeksidescience.com
650 269-2876

December 2021



View of Monarch Grove Sanctuary looking west. The hotel is in the foreground. The colors represent elevation.

Introduction

This document shows example of LiDAR (airborne laser scanning) at Monarch Grove Sanctuary and George Washington Park. LiDAR is now being used at numerous monarch sites to assess 3-dimensional forest canopy structure and resulting wind and insolation (sunlight) patterns in the habitat. After consultations with Caleb Schneider, the LiDAR data set CA FEMA Z4 B1 2018 (https://portal.opentopography.org/usgsDataset?dsid=CA_FEMA_Z4_B1_2018) was processed and some sample images produced.

The survey dates were Feb-Apr 2018. The resolution is 5.69 points/m^2 relatively low resolution.

This is not the final analysis, but is a demonstration of the utility of LiDAR in monarch habitat assessment in Pacific Grove, both at Monarch Grove Sanctuary and George Washington Park. The following examples show:

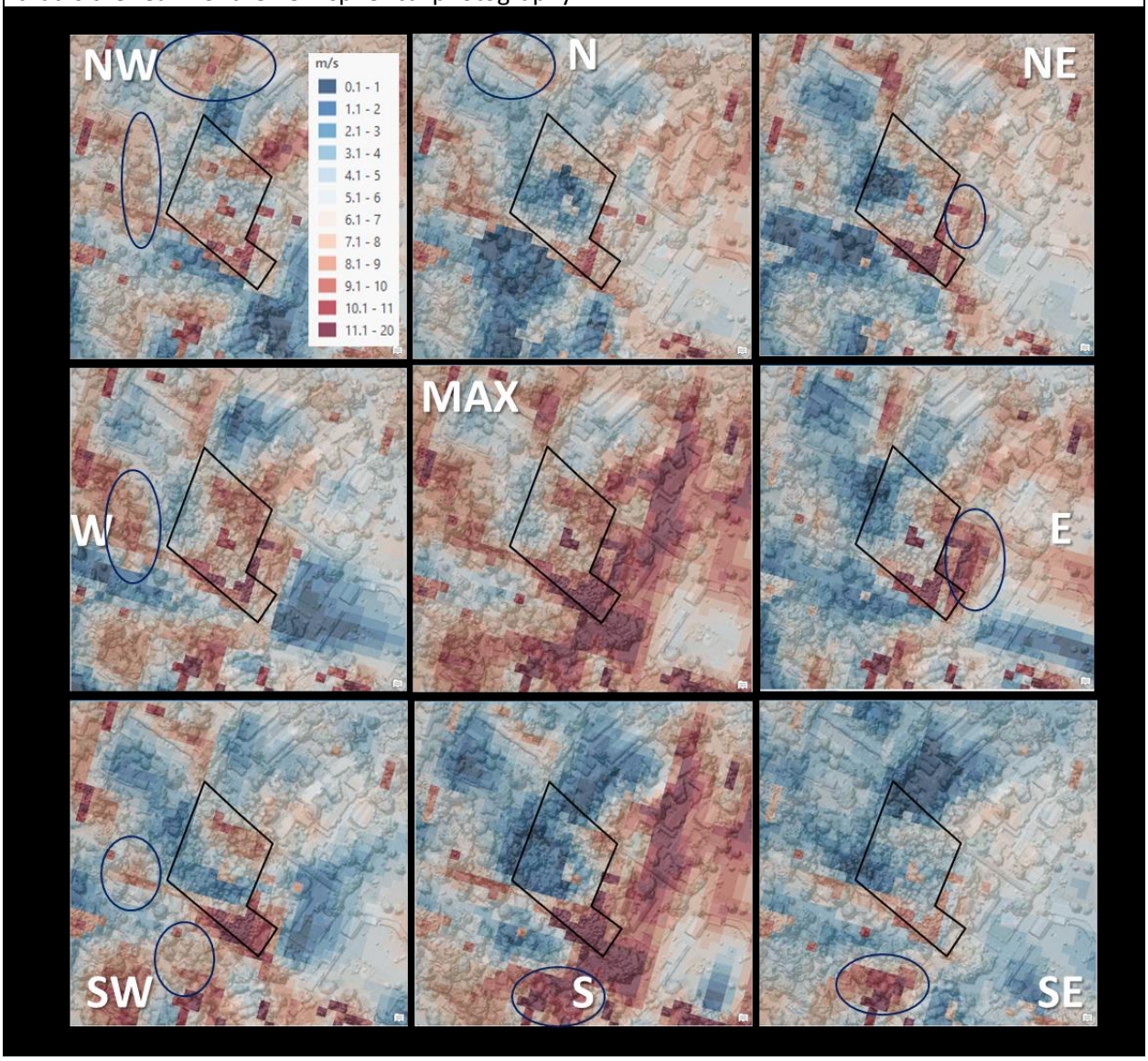
1) wind modeling as a first approximation of the important wind shelter provided by trees outside of the Sanctuary (a direct request from Caleb Schneider)
2) Oblique views of the Sanctuary showing wind shelter in the nectar bed clearing
3) Insolation and some visuals of canopy height
4) Oblique views of the Sanctuary showing some of the 3-dimensional canopy structure
5) A vertical view of George Washington Park, both B-W LiDAR height and an aerial photograph.
6) Oblique views of George Washington Park showing some of the 3-dimensional canopy structure.

A few notes are in the captions.

This LiDAR was flown in 2018, and there have been some small changes in canopy structure since then. As part of a comprehensive assessment and formal management plan, a new LiDAR flight (from a drone) is suggested, as it can have resolution of > 50 points/m^2 (10 X the resolution here). With that level of resolution, understory will become more apparent, as will individual tree crowns and trunks. It will be a crucial baseline for mapping the Sanctuary and George Washington Park and complement a tree stem map as part of a comprehensive management plan. Elements of a comprehensive management plan are presented in the 2021 memo from Creekside Science (Weiss 2022, *Assessment and proposed management activities Monarch Grove Sanctuary and George Washington Park for 2022*). Caleb Schneider indicated that a request for proposals would be developed in 2022.

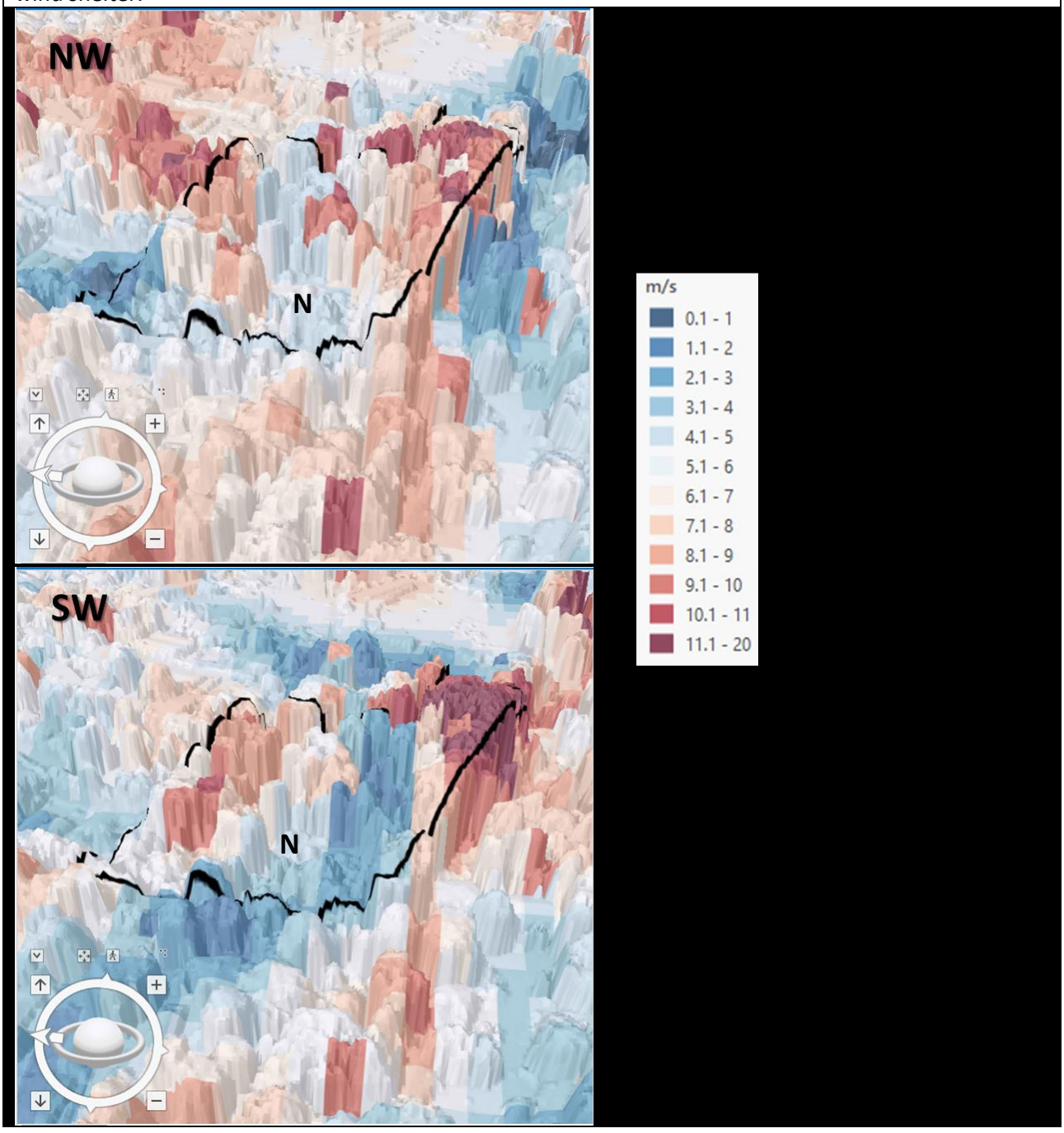
Identifying trees outside Monarch Grove Sanctuary that provide key wind shelter

The program WindNinja models wind dynamics over complex terrain (here a speed of 10 m/s (22 mph) and has been applied to the outer canopy envelope as a first-order approximation to identify which stands of trees provide wind shelter for the Sanctuary. The ovals show the critical wind shelter trees outside the Sanctuary, as evidenced by the low wind (blue) areas in the leeward areas of the tree stands. Note also how the western part of the Sanctuary where the nectar beds are is well sheltered from all directions. The analysis does not account for open areas below the outer canopy, that is the realm of the hemispherical photography.



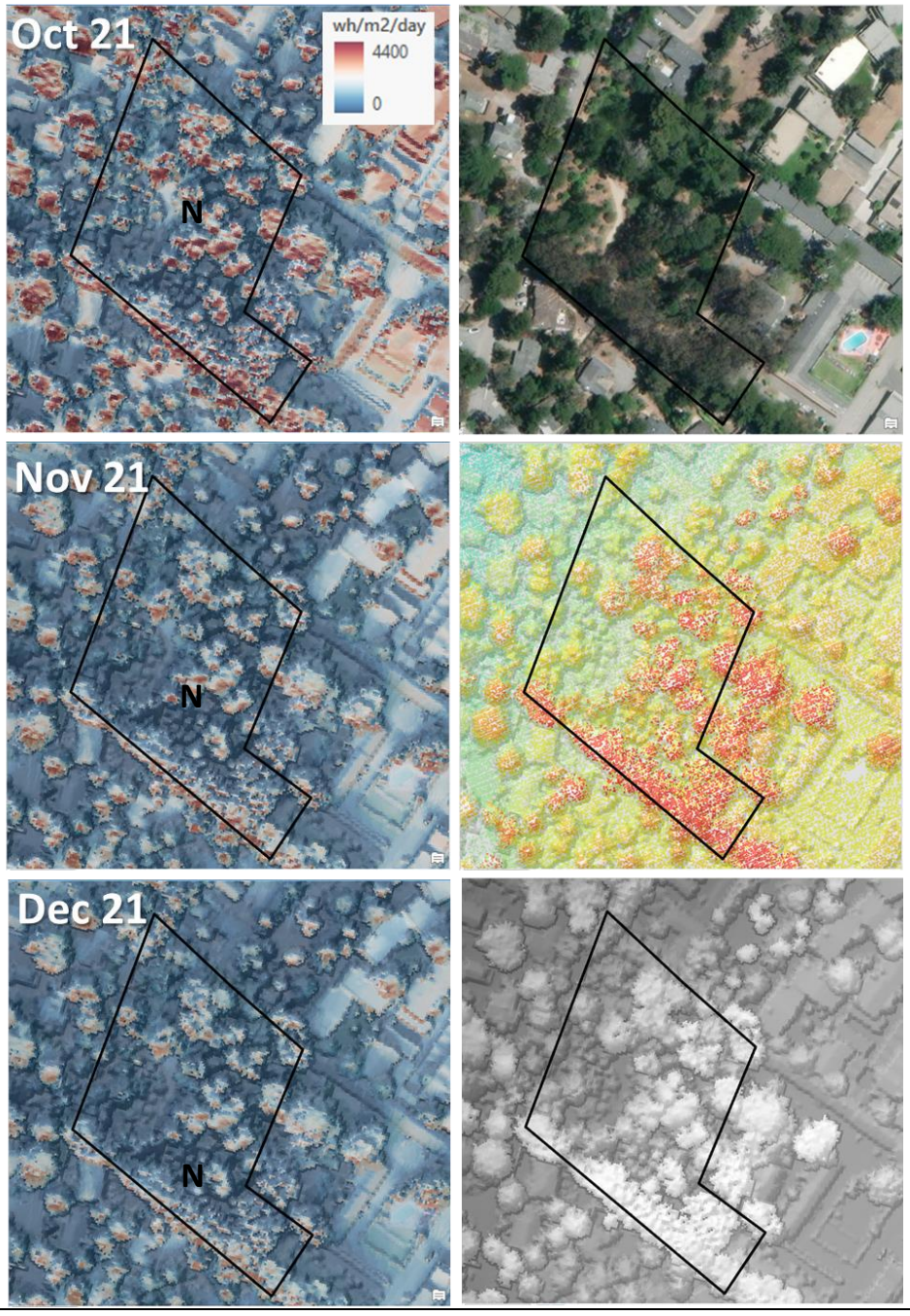
Wind exposure viewed obliquely from the west

These oblique views show how trees provide wind shelter on their lee sides. In particular, the area around the nectar beds (N) is well sheltered, as are the areas east where the monarchs cluster. In this area, filling the holes in the foliage wall (as has been done with the cypress plantings, provides further wind shelter.



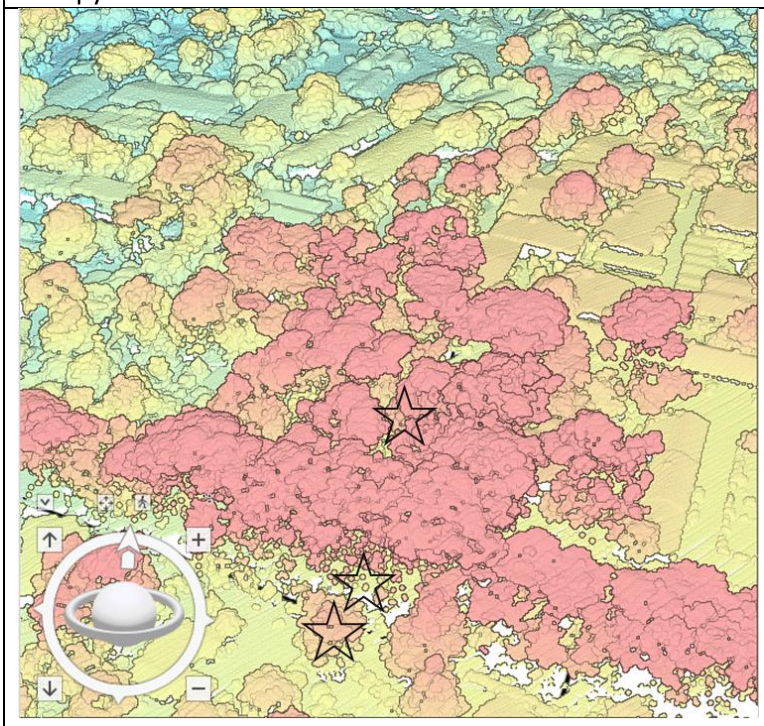
Solar Radiation and LiDAR Height Representations

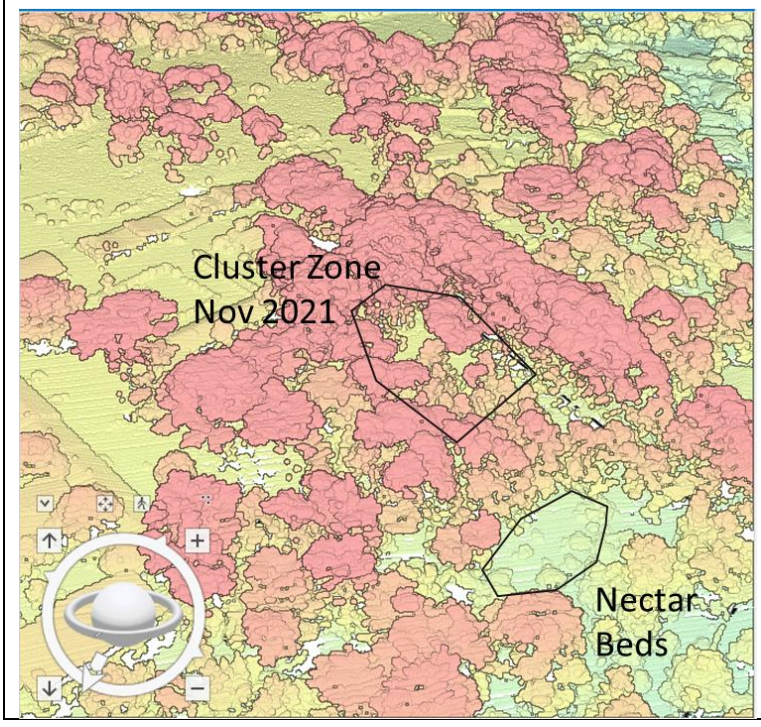
The solar radiation maps for the 21st of each month show how the south-facing tree canopies, and the south edge are high insolation areas. The area behind the southern eucalyptus row has a few tree canopies with higher insolation, but insolation at monarch heights depends on light filtering through the tree canopies. Note how insolation decreases from October through December (and will increase through January and February). The right-hand column shows an aerial photograph, and two renderings of LiDAR heights, one in color and one in B-W.



Oblique Views of the Sanctuary.

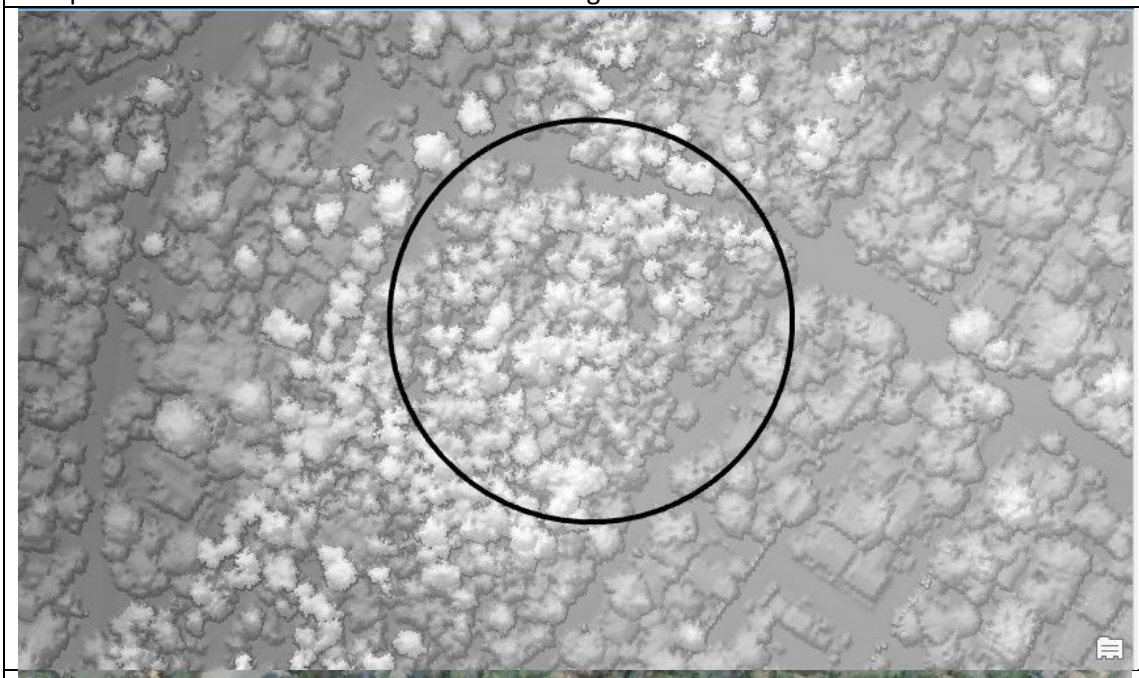
The top view is from the south, and the stars represent cluster locations in recent years; the pine tree south of the city property, the southern edge, and the interior where most butterflies were in November 2021. The view from the NW shows the open are around the nectar beds, and the broken canopy above the November 2021 cluster zone.

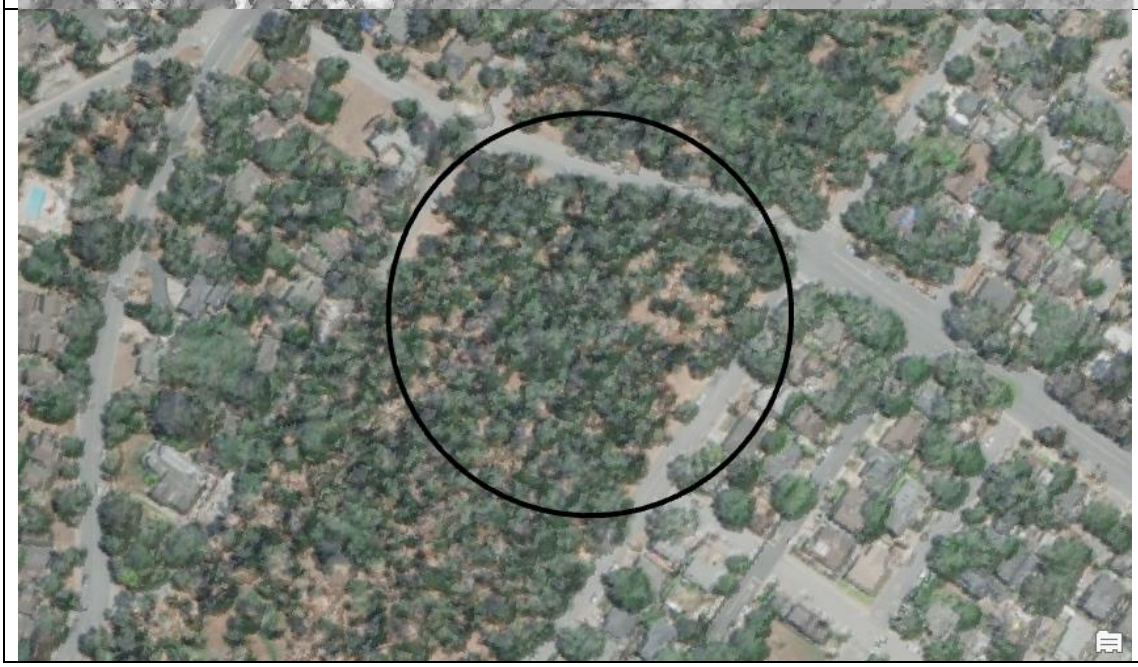




George Washington Park

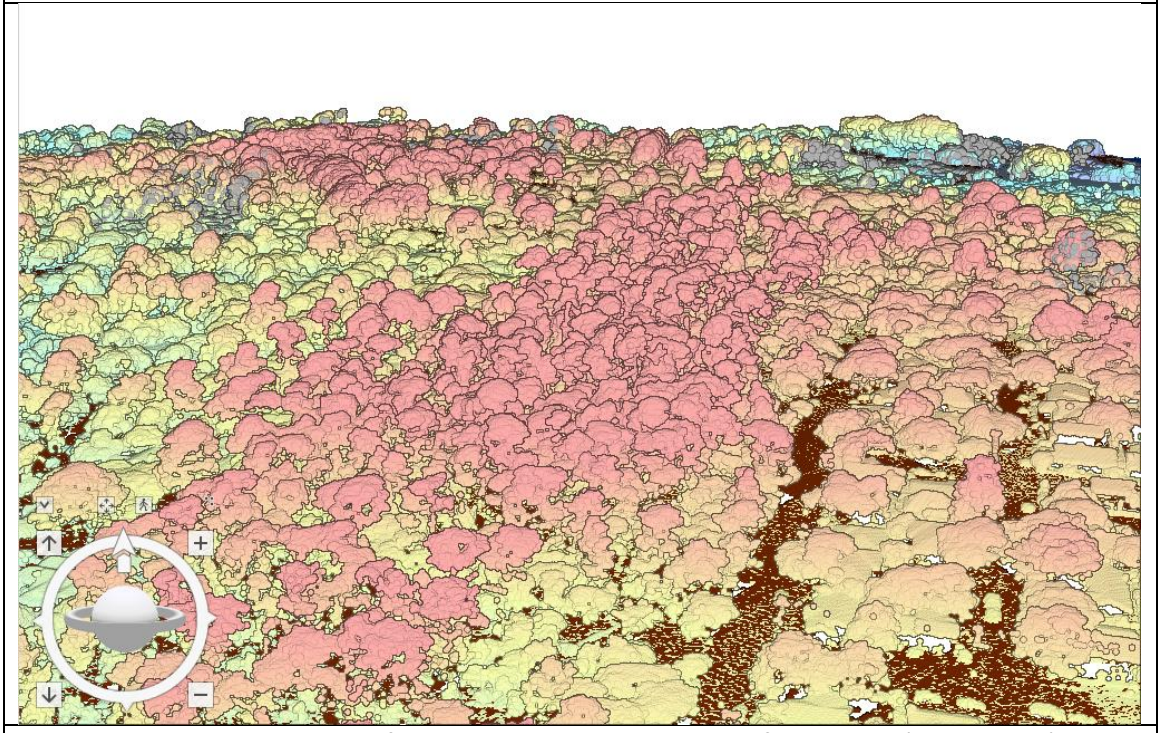
This B-W version of LiDAR height shows the George Washington Park overwintering site (approximated by the circle taken from the Xerces Society database). Below is the aerial photograph with a hillshade based on the LiDAR. Note how much denser and higher the canopy in the park is compared with the residential areas surrounding it.





Oblique views of George Washington Park

This oblique view from the south shows the broken Monterey pine canopy in the heart of the park. The darkest areas are ground points, mainly streets (Alder to the east of the grove).



George Washington Park view from the north. Pine Ave in the foreground (dark brown), Alder running south just to the east of the park.