Management Plan for Monarch Grove Sanctuary: Site Assessment and Initial Recommendations

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Photo: hemispherical photograph of Sanctuary from 18m height, looking toward North

Introduction

Monarch Grove Sanctuary is a site in Pacific Grove that supports one of the larger and more permanent aggregations of overwintering monarch butterflies along the California Coast. The site was bought by the City via a bond issue in the mid-1990s. A number of studies and management plans were developed in the 1990s (Leong ,1994, Weiss 1998). The Weiss 1998 report was done in conjunction with TRA Environmental, and is attached as Appendix B.

The Weiss 1998 report covered the following topics, and should be consulted for background information.

1) Current (1998) site suitability
2) Review of previous studies, 1989 EIR, 1994 Leong report
3) Analysis of short weather record for 1995-96 season, including a record windstorm on December 11-12
4) Review of forest canopy structure and microclimate
5) Description of tree/shrub map
6) Hemispherical photo analysis of canopy cover, solar radiation, and wind
7) Comparison to monarch distribution
8) Restoration plan
9) Consideration of different tree species
10) Three plans: Moderate, Full, and Minimal Eucalyptus
11) Forest management – disease, hazards, and fire
12) Review of the 1994 Master Landscape Plan
13) Continued monitoring
14) Implementation guidelines

A forestry report by Steve Scott identified hazard trees and branches and made recommendations on a nearly tree by tree basis. This is attached as Appendix C, and includes guidelines for tree management.

The 1998 plan identified, among a series of assessments and recommendations that: 1) the site was too exposed to northwest wind; 2) the overstory of pines was falling apart from old-age and disease; and 3) the single row of blue gum along the southern boundary needed reinforcement,. The plan called for establishment of a new row of blue gum trees near the center of the grove that will eventually create NW wind shelter for the main clustering areas. These trees were planted in 1999 as 30 gallon containers and are now 30-50' tall. Additional pines and cypress were planted in this windbreak area provide a mixed forest.

Other recommendations were not followed. Hazard trees were not limbed and snagged, and the second row of blue gum was not planted in full. Numerous pines, cypresses, compact blue-gums, and redwoods have been planted with minimal coordination. Overall management in the last decade has been haphazard, and in the absence of a defined planning process, last minute decision making and reactive management has led to a series of crises well known to the City and stakeholders.

The City of Pacific Grove contracted Creekside Center for Earth Observation in summer 2010 to undertake a quantitative assessment of the forest at Monarch Grove Sanctuary. Additional funding was provided by the Xerces Society. This project revisits the Weiss 1998 management plan. Dr. Weiss has developed a systematic approach to assessing monarch habitat. The scientific bases for the assessment are:

1) Monarch butterflies dynamically seek areas of appropriate microclimate within forest groves, defined by air temperature, wind, and sunshine.
2) Microclimate is a predictable function of the tree canopy structure

3) That structure can be measured and mapped using hemispherical photography
4) Wind exposure and insolation (solar exposure) can be mapped across the grove and related to trees and canopy structure
5) The forest and resultant microclimates will change through time; anticipating these changes is essential to long-term management over years and decades
6) A long-term adaptive management plan is essential for success into the future.

This report is based on an assessment of current conditions, conducted in late August 2010. The detailed results are presented as Appendix A and consist of maps/graphs of trees, wind, and insolation, and discussion on meaning of the results for grove management. The measurements and analyses include:

1) Mapping of every tree in the Sanctuary by species, number of boles, height class and diameter at breast height (DBH)
2) Acquisition of a 10 x 10 meter (~30 ft) grid of hemispherical photographs across the entire Sanctuary, as well as additional photographs to capture details not adequately covered by the main grid.
3) Acquisition of three vertical transects using a lift/bucket truck, up to 18 m height.
4) Analysis of the photographs to determine open sky.
5) Analysis of the photographs to determine relative wind exposure from 8 wind directions
6) Analysis of the photographs for clear-sky daily insolation during the November-February overwintering season
7) Creation of maps in a Geographic Information System (GIS), including interpolations and overlays of tree distributions, wind exposure, and insolation.

The assessment and recommendations are summarized and discussed immediately below. These management recommendations are a starting point for stakeholder discussion of immediate, short-term, mid-term and long-term management goals and options, including tree plantings and removal, hazard abatement, and provision of nectar sources.

It is recommended that the City of Pacific Grove establish a forum with a mandated schedule through the year in which current and future issues of resource management will be discussed, decisions made, and executed. The exact procedures of establishing this forum are up to the local government and stakeholders, but the City is ultimately responsible for management and maintenance of Monarch Grove Sanctuary.

Appendix A contains the more detailed results of the microclimate analysis, Appendix B is the Weiss 1998 report, and Appendix C is the 1998 Steve Scott arborist/forestry report.

Summary and Discussion

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.

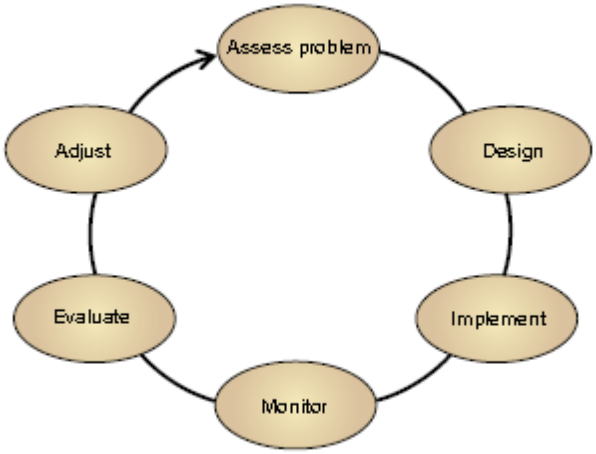
Proactive adaptive management means that changes are anticipated well in advance, and appropriate management carried out at a deliberate and measured pace. This requires a systematic adaptive management process among institutions and stakeholders to evaluate, plan, execute, assess, and re-evaluate, on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

Site Assessment

1) The Sanctuary and surrounding forest still contains the necessary components to support monarch butterflies, as evidenced by their persistence for many months at the site in 2009-2010 and 2010-2011 (Villablanca 2010, Pacelli and others, 2011). But, it is on the edge, and butterflies have largely abandoned the site after large storms in previous years – during record winds in Dec 1995 (Weiss 1998) and in late January 2010, intense winds (50+ mph at Monterey Airport) greatly reduced the population numbers (Villablanca 2010). The L-shaped grove of blue gum Eucalyptus trees provides the key structure for microclimate suitability. The tall wall of foliage provided by these trees is variable from point to point, and some light and wind can penetrate. But the single row is vulnerable to incremental and catastrophic events.
2) The butterflies cluster for much of the season in the SE corner of the Sanctuary along the south edge, and on a pine tree several meters south of the sanctuary. These areas have high to medium insolation, high exposure to SE, S, and SW winds, and medium to low exposure to NW winds. There is considerable fine-scale variability in all these factors, as the influence of individual trees, branches, and gaps is felt with changing weather conditions.
3) Large parts of the Sanctuary are still highly exposed to NW winds, which diminish the quality of the site and often drive the monarchs to cluster on trees on the southern neighbors' property. These neighbors' trees have serious short-term, mid-term, and long-term issues, and their senescence is likely within a decade or two. Trees further south of the Sanctuary, ranging across Ridge Road and Short Lane provide some southerly wind shelter in areas south of the Sanctuary boundary. The long-term health of these trees needs to be

assessed, but some will eventually be removed in the next years and decades+ as crowns senesce and become hazards.

4) Conditions have changed since the last assessment in 1998. In particular, there has been a loss of high canopy Monterey pines to senescence and disease.
5) New plantings from the late 1990s are reaching 50+ ft high, and include blue gums, pines, and cypress, planted to provide better wind shelter from the NW. But, 5-15 more years will be required before a full windscreen develops to adequate height. This wind screen will consist of a mix of blue gum, cypress, and pine.
6) The southern blue gum row is still relatively intact, but gaps in the canopy allow some wind and light penetration from the NW and from the SE, S and SW. There are many gaps at low levels, and in the mid-canopy (10 m).
7) These trees are approaching 90 years old, and will continue to develop hazard branches. Blue gum trees are very plastic and will respond to new patterns of light availability by growing foliage.
8) The boxed trees placed in the interstices of the blue gum row in 2010-2011 filled in low gaps to heights of 3-9 m. They supported monarch clusters on many days, and decreased wind and light exposure at low heights along the southern edge (Pacelli and others 2011). These trees essentially provided the equivalent of low branches, and were used by monarchs on many occasions. The use of these trees indicates that reproducing these effects with live trees over the long-term should be effective in providing favored monarch habitat.
9) Regrowth of trimmed trees was noted qualitatively.

Management Recommendations

The following management recommendations are starting points for stakeholder discussion, with the goal of developing a series of specific alternatives for management. Development of initial ideas and site design will be carried forward in an adaptive management process, and initial suggestions for a timeline are attached to each item. Note that exact decisions will be made in a combination of meetings in the field and office

1) In order to provide more resiliency and redundancy on the southern edge of the Sanctuary, a second row of Blue gum (tall form, not var. compacta) should be established 3-4 meters (10-15 feet) north of the existing row to provide wind shelter and habitat complexity. The variable microclimate conditions just north of the existing row appear to be in a “sweet spot“ of intermediate solar exposure and better wind shelter, but there are no trees or branches on which to cluster. These trees will provide cluster sites, and serve much the same role as the potted trees in 2010-11.
2) Tree spacing should be on the order of 3.5-4 m (12-15 ft) to allow space for growth. These trees will grow relatively slowly at first because of the intermediate light just north of the existing row, but will rapidly fill in understory, and eventually (50+ years) be the replacements for the existing trees. 12-15 trees needed, some can be provided by the potted trees but others may need to be procured. Irrigation is desirable for the first several years to establish the trees. Winter-spring 2011.
3) There will be continued needs for removal of senescent tree crowns, especially pines, for safety. Safe wildlife snags should be created as desired in appropriate areas. Hazard branch trimming will be necessary in some circumstances, to be carefully examined and considered as hazards develop. Arborist inspections and immediate needs should be addressed in summer 2011.
4) **More Optional:** While the newly planted row of blue gums will provide some of the same functions as the potted trees, in the short and mid-term it might be desirable to more closely duplicate the potted trees roles as wind break and branches. Some understory coast live-oaks, or small blue gums, could be added to the

southern boundary to seal the larger gaps, similar to what the boxed trees have done. But these trees will have to be carefully managed to maintain desired density – coast live oak forms extremely dense canopies, and somewhere down the line, these trees may have to be thinned or removed. These trees, however, may block viewing of the monarchs Oaks could be considered for understory plantings elsewhere in the Sanctuary. Consider in summer 2011, plant in winter 2011-12 if desired

5) The trees in the surrounding neighborhood provide cluster sites and wind shelter, hence should be considered part of the monarch habitat. The trees on the southern neighbors' properties need a full evaluation by arborists to determine health and potential longevity. The more distant tall trees to the south, along Ridge Road, and Short Lane, also need to be assessed. Coordination with the southern neighbors on tree plantings and maintenance to provide some healthy well-spaced trees – pines and cypress most likely – that will replace existing trees. Summer 2011.
6) There will be a reduction of sunny open areas in coming decades because many trees have been planted where they will eventually shade currently open areas. Some grassy open areas should be maintained for dew/water/nectar for monarchs, which will require removal of some recently planted trees. The most likely areas are west of Brokaw Hall. These decisions do not need to be made immediately, but an initial identification of areas to remain open should be conducted in spring 2011, remove first round of trees summer 2011.
7) Some thinning of small and medium saplings within recent tree plantings should be considered to allow for faster growth of selected individuals trees. Site visits with arborist and stakeholders spring 2011, first round proposed removals summer 2011
8) A detailed assessment of the planted Monterey Pines is necessary to understand pitch canker risks, and designate "back-up trees" should individual pines succumb. Summer 2011
9) Nectar sources, especially high concentration known non-native species that provide copious nectar, should be provided by boxed plants in sunny areas in and around the grove. While monarchs do overwinter in areas with little or no nectar, they readily use available nectar on sunny days. Fall and early winter nectar may be especially important for keeping monarchs at the site. Also, a nectar garden in a sunny part of the schoolyard could be established, and become a test bed for evaluating nectar sources with the students as observers. Existing bottlebrush trees should remain for late season nectar. If suitable natives are identified, plantings in the ground can be considered. Observations of nectar availability (including blue gum) and use would help guide nectar provisions. A discussion of some nectar plants from Jan Southworth at Ardenwood/Coyote Hills is included at the end of Appendix A. This list should be widened and updated through time. Establish nectar plan for 2011-2012 in spring 2011, grow and deploy plants by Oct 2011 with irrigation available.
10) Native plant zones, can be established, especially in the NE corner of the Sanctuary, where attempts can be made to nurture existing native plants and re-establish native plant cover. Native perennial forbs and shrubs are the most likely to thrive in these areas, as aggressive annual grasses minimize success of native annual wildflowers. Deer fencing may be necessary for establishment of many species. Ongoing, begin planning in summer 2011.
11) Ornamental plant zones can be established, where appropriate planter boxes and non-invasive ground plantings can be considered. Ongoing, begin planning in summer 2011.
12) Removal of some sprawling black acacias could be considered. Ongoing, begin discussion in spring 2011.
13) Monarch distribution among trees and in the X-Y grid should be recorded in future monitoring. And, any previous data collections should be examined for spatial information. Ongoing.

Adaptive Management Plan Phase 1

This report and initial conclusions and recommendations are starting points for a long-term adaptive management process to be run by the City with stakeholder and scientific involvement. The City of Pacific Grove is the owner of the property, and has fundamental responsibility and authority for management and public safety. A well-run process, with an annual cycle of meetings and site visits, is essential for effective and timely decision-making for the long-term benefit of Monarch Grove Sanctuary. Detailed institutional arrangements will be up to the City and citizens of Pacific Grove.

Critical action items:

February-March 2011: The first time-critical management action is planting new blue gums along the southern row after the monarchs leave. Planting while the soil is still charged with water is important, and deep irrigation during the summer will greatly assist tree establishment. A one-year delay is possible, since this is a long-term (decades) action, but it would be preferable to start this year.

The second time-critical action is assessment of potential hazards by City arborist. Arborist safety standards should provide the first round of suggested actions, but these should be subject to examination in light of their effect on monarch habitat, and alternatives explored if there are conflicts. March-June 2011.

Proposed stakeholder engagement for the remainder of 2011:

February 2011: Initial meeting and site visit(s), presentation of this study, discussion of current and previous years monarch observations, and discussion of results and proposed adaptive management process.

Early spring 2011: Delivery of a revised report based on feedback, scope out management alternatives.

Late spring 2011: meeting to discuss 2011 management actions,

Summer 2011 – execute management actions before September 15 (pre-monarch season)

October-November 2011 – Monarchs return, docent training on the management plan, Monarch magic at Museum and other public forums.

APPENDIX A: Detailed methods and results

Methods

Field measurements were carried out in late August 2010. A 10 x 10 meter grid was established in the Sanctuary using measuring tapes and triangulation techniques. The 0, 0 (X, Y) point was set at the SE corner, where two fences intersect. The eastern boundary of the Sanctuary follows magnetic north-south, and the southern boundary follows magnetic east-west. Positive X numbers are to the west, and positive Y numbers are to the north (both magnetic). The magnetic declination for the site is 14°E, so true north is 14° west of magnetic north. All maps are shown with magnetic north to the top.

Individual trees were mapped within the grid. For each tree species, number of boles (large trunks,) diameter (DBH) of each bole, and height class were recorded, along with any tag information, as well as obvious dead boles. For sprawling trees such as black acacia, the location of the rootstock was noted.

Hemispherical photographs were taken at each grid point, at 1.5 meters above the ground. The camera rig includes a Nikkor 8mm lens (180° field of view) on a Kodak DCS camera body, mounted on a gimbals (self-leveling platform). The camera was oriented to true North using a hand-held compass. Additional photographs were taken in key areas – along the 3 m north line just north of the southern row of Blue gum, and along the east boundary (hotel property) and west edges (middle of Grove Acre Ave) of the Sanctuary. A set of photographs was also taken on neighboring properties to the south (with gracious owner permission). All photographs were taken at dusk or dawn, or under overcast skies, to maximize contrast between the sky and foliage. Digital images were saved in 1500 x 1500 jpeg format. Unless otherwise noted in the vertical transects, all numbers refer to values at 1.5m.

City staff provided a lift-bucket truck for vertical access. At three points (20, 40, and 60 m) near the southern edge (10 m north from the fence), photographs were taken at 5 m, 10 m, 15 m, and 18 m (maximum possible). This unique data set provides key information on microclimate conditions closer to heights where monarch cluster.

Photographs were analyzed using Hemiview 2.1 software (Delta-T Devices). A thresholding procedure differentiates sky from foliage – because the photographs were taken under near-optimal conditions this process was straightforward. Hemiview overlays on a grid consisting of 45° azimuth (compass direction) wedges, and 5° zenith (vertical angle) rings. Within each azimuth/zenith sector, the proportion of sky versus obstruction is calculated. The measure of visible sky is called ISFU (Indirect Site Factor Uncorrected). ISFU was interpolated across the site in ARCGIS Geostatistical Analysis using Radial Base Functions, a flexible and robust technique. Canopy cover is calculated as 1 – ISFU.

Figure 2 and the accompanying discussion show how to read a hemispherical photograph. The proportion of visible sky in each 45° azimuth wedge is a measure of wind exposure, and is referred to as Wind Site Factor, specific to each direction (WSF-S, WSF-SW, WSF-W, etc). WSF for each direction is presented as graduated sizes of arrows in the appropriate direction with the largest arrow showing a 85-90% open sky in the azimuth wedge. Because the proportion of total sky area at high elevation angles is much smaller than that at lower angles (the area from 60-90° is 11% of the sky, from 30-60° is 33%, and from 0-30° is 56%) the low elevation angles contribute the most to WSF. But, it is important to realize that openings at the higher elevation angles contribute to wind exposure higher up in the canopy. This issue is explored more in the vertical transects (Figures 10 and 11).

Insolation is calculated by overlaying on a sunpath grid with half-hourly intervals by each month. The proportion of open sky in each time-month cell is calculated, and translated into direct insolation according to solar zenith angle (the higher the sun is in the sky, the more intense the solar beam). Because monarchs are primarily present from November – February, only those months are considered. Monthly insolation values were interpolated across the site in ARCGIS

Geostatistical Analysis using Radial Base Functions. Changes in insolation with height are less predictable than wind exposure, this issue is explored in more detail in the vertical transects (Figures 10 and 11)

Figure 1 below shows the photo grid overlaid onto the Sanctuary boundary, and highlights some other features. Note that the X coordinates increase from east to west. Brokaw Hall is the rectangle near the center. The blue circles are the position of example photos in Figure 4. The red lines are horizontal transects discussed below in Figures 8 and 9, labeled by the X coordinate in the text boxes below the transects. The red dots are the position of the vertical transects discussed in Figures 10 and 11. The viewing area is at 40, 10 (small box).

Figure 1 Grid map and transect locations.

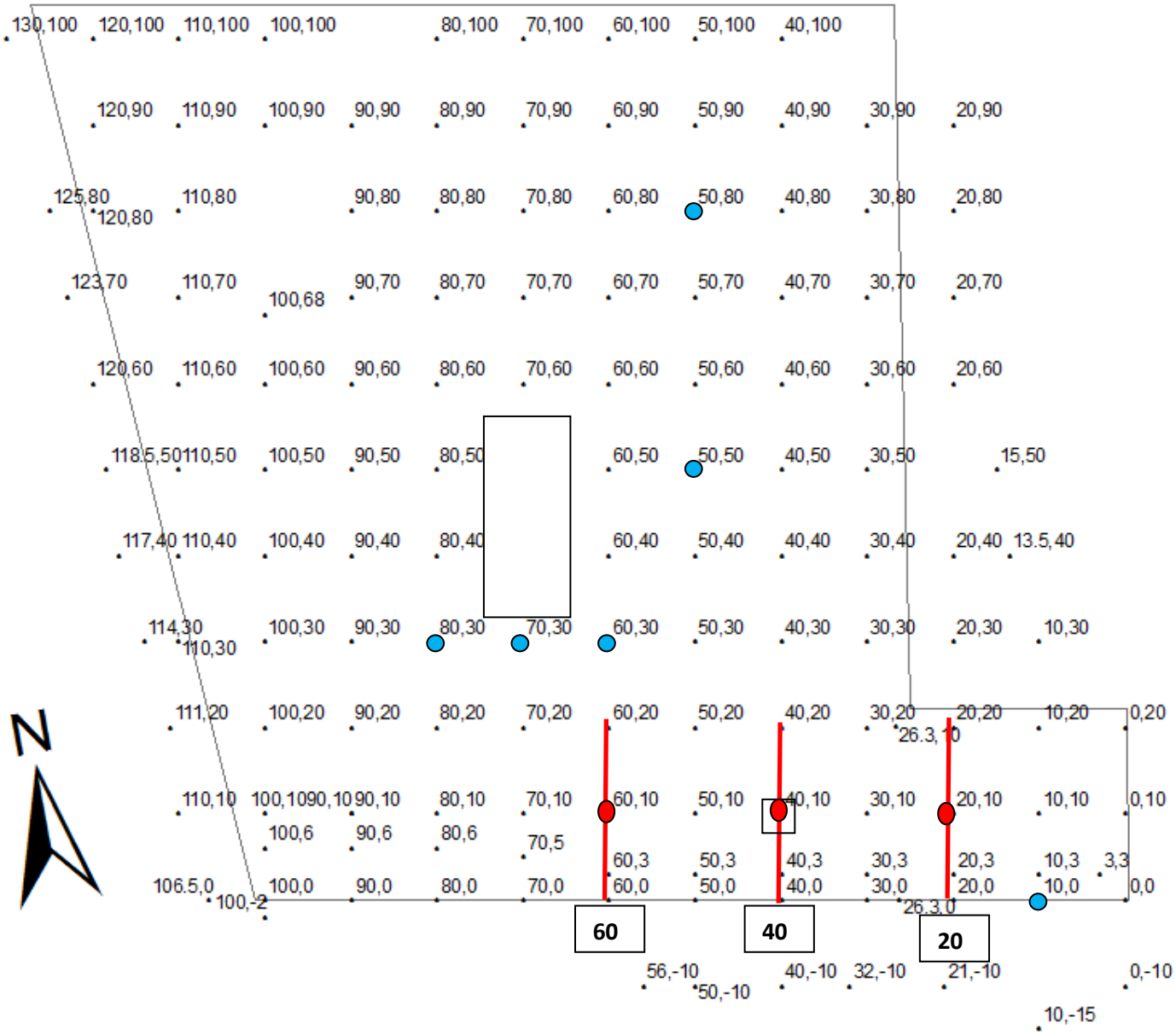
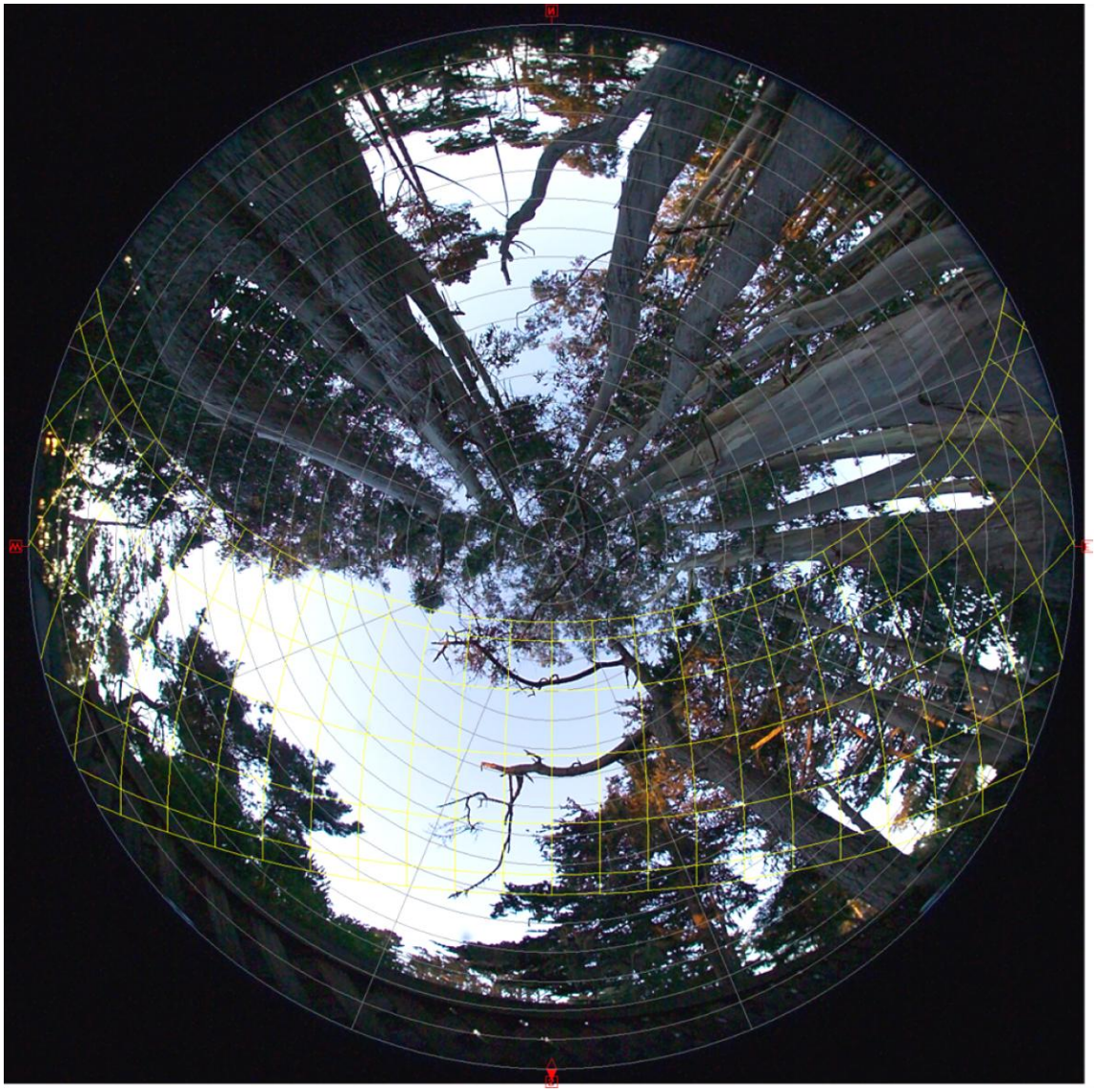


Figure 2 Reading a Hemispherical Photograph

The photograph below shows the elements of a hemispherical photograph. The center of the photo is the zenith, directly overhead. The edge of the photograph is the level horizon. The grey grids show 45° azimuth sectors, centered on the 8 ordinal directions. North is at the top of the photograph. The rings are 5° increments of elevation angle – the 45° circle is halfway between the center (90°) and the edge (0°). The yellow grid shows sunpaths (see below).

This photograph was taken at the southern edge of the Sanctuary, at position 10, 0 (see Figure 1). The border fence is seen at the southern edge up to about 10° elevation. Dead pine branches are seen in the S and SE sectors, and trees outside the Sanctuary are seen reaching to 15-45° elevation in the S-SW sectors. The northern directions are dominated by the blue gum row, but trees to the north in the Sanctuary are visible through gaps between the trunks. The proportion openness in each octant, as described below, is a measure of wind exposure

The yellow sunpaths are in half hour increments as the sun arcs from east to west across the image, the N-S line is noon, solar time. The Dec. 21 sunpath is the most southerly arc, reaching 30° elevation at noon. The next arc is Jan 21, and the next is Feb 21. Daily totals by month are the sum of each half hour segment. In this image, direct sun during the winter is limited to a few hours in late morning. It is important to realize that insolation can change dramatically with height above the ground, as obstructions fall below the sunpaths, or denser tree-crowns are encountered.



Results

Tree map (Figure 3)

The tree map is shown below in Figure 3. A total of 475 live trees were mapped. The key structure of the grove is the "L"-shaped row of tall (20-30+ m) blue gums (*Eucalyptus globulus*) on the southern and part of the eastern edge. Many of these blue gums have several large boles. Note also the smaller blue gums (10-20 m) on the diagonal in the middle of the grove – these are the trees that were planted in 1999. The tallest of these trees are now ~17 m (55') in height.

Compact blue gums (*Eucalyptus globulus* var. *compacta*) were planted in the 1990s and early 2000s along the southwest portion of the grove along the southern fence. These trees are now 3-10 m tall, with multiple stems.

Tall Monterey pines and cypress (20-30 m) are distributed across the central part of the grove, with cypress more abundant to the north. These trees provide overhead canopy, but are very sparsely foliated, if at all, below the upper canopy. Many of the tall pines are senescing and will have to be removed in the next decade. Some of the inoculated pine plantings from the 1990s in the center of the grove are now 15-17 m tall.

The new plantings of coast redwood are along the western boundary. The numerous small pines and cypresses planted in recent years are the small dots (1-3 m) scattered through the grove.

An additional 27 dead trees (including wildlife snags) were mapped. Several of these trees are standing pines that have not been topped and turned into safe snags, and will have to be treated in the near future.

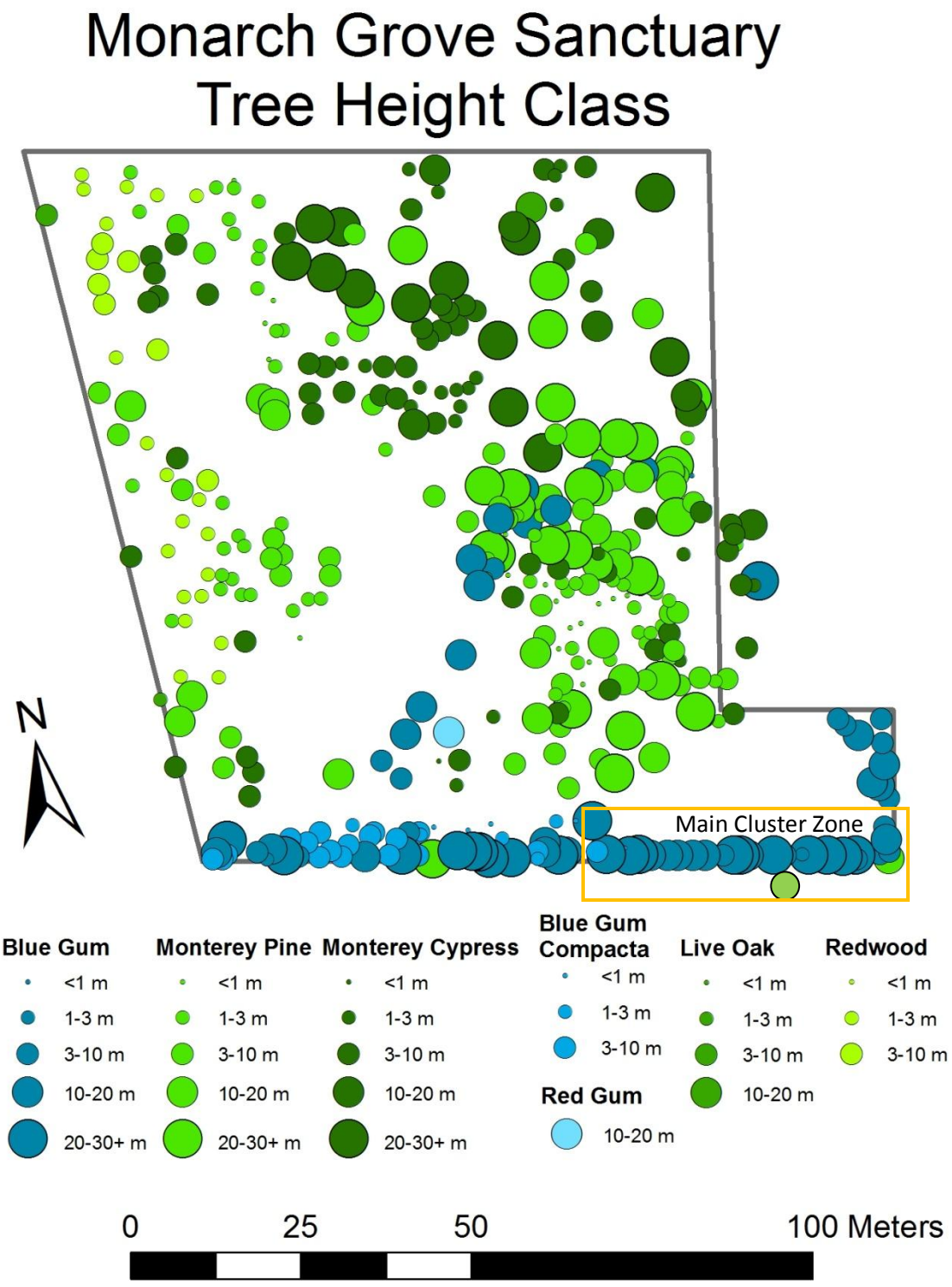
Monarch distribution

The major monarch cluster zone is shown as the orange box in the SE part of the grove. Monarchs often cluster on the south-side of the blue gums, and in the pine tree on the neighbor's noted as "Cluster Pine." Monarchs also cluster on the north side branches. They also cluster at various heights depending on temperatures. In 2010-2011, they clustered on potted trees (3-9 m tall) placed in the interstices of the blue gum row. Current monitoring tracks numbers and height (Villablanca 2010).

The distribution of monarchs within the grove has not been systematically mapped on horizontal grid, or tree by tree basis. Therefore, at this time, it is not possible to quantitatively relate monarch distribution to the insolation and wind maps. But a qualitative assessment is both necessary and useful at this point, because the main features of the distribution indicate the type of conditions

Future monarch monitoring

Figure 3: Tree map by Height Class



Sample Hemispherical Photographs (Figure 4)

The array of photographs below shows a variety of conditions in the grove. Compass directions are given on the edge of the table. These compass directions are true, not magnetic.

The photograph at 10,0 is in the main cluster area along the south fence, with the main row of trees to the north. Note how the blue gums provide shelter from the NE and NW, with a significant gap due N. This site is highly exposed to the southwest. The pines that often support clusters are visible both to the SW and SE. This is also the example photograph in Figure 3 above.

The photograph at 50,80 shows typical conditions in the northern part of the grove, where a high canopy of older pines and cypress towers over an open understory.

The photograph at 50,50 is in the middle of the 1999 plantings of blue gum, and includes several pines as well. Overstory pines and cypress are visible beyond the mid-story trees.

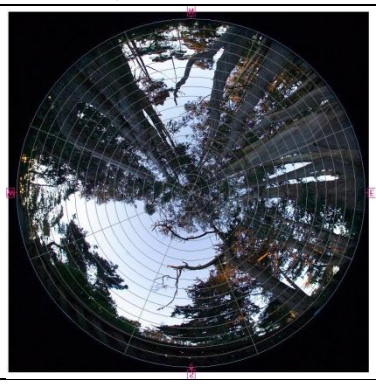
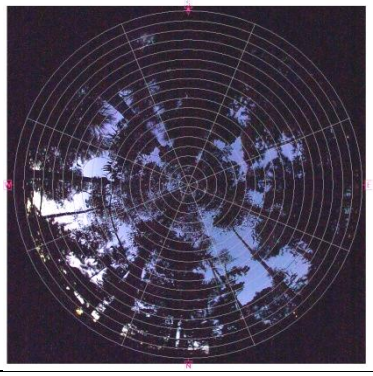
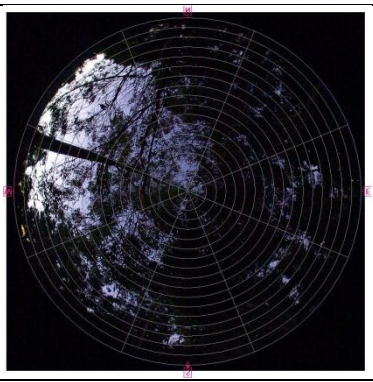
The photograph at 80,30 was taken in the opening west of the building (seen to the E), and is the most open spot within the grove.

The photograph at 70,30 was taken 10 m to the E of 80,30. The building is clearly seen to the NW, Noted the blue gum visible due E (the rounded tree crown on the narrow trunk) – this tree was planted in 1999 in a relatively open area and is the tallest (17 m) of all the recent blue gum plantings. The southern border blue gums are visible to the south.

The photograph at 60,30 is in the dense stand of trees in the center of the grove. The site is more open to the west, and the blue gum mentioned in the previous photo (the straight trunk just north of west) is visible.

Because more than 100 photographs were taken, it is not possible to consider each site in detail. The results are generally presented as maps. But, specific horizontal and vertical transects are explicitly considered and described to illustrate key properties of the forest canopy.

Figure 4 Sample photographs

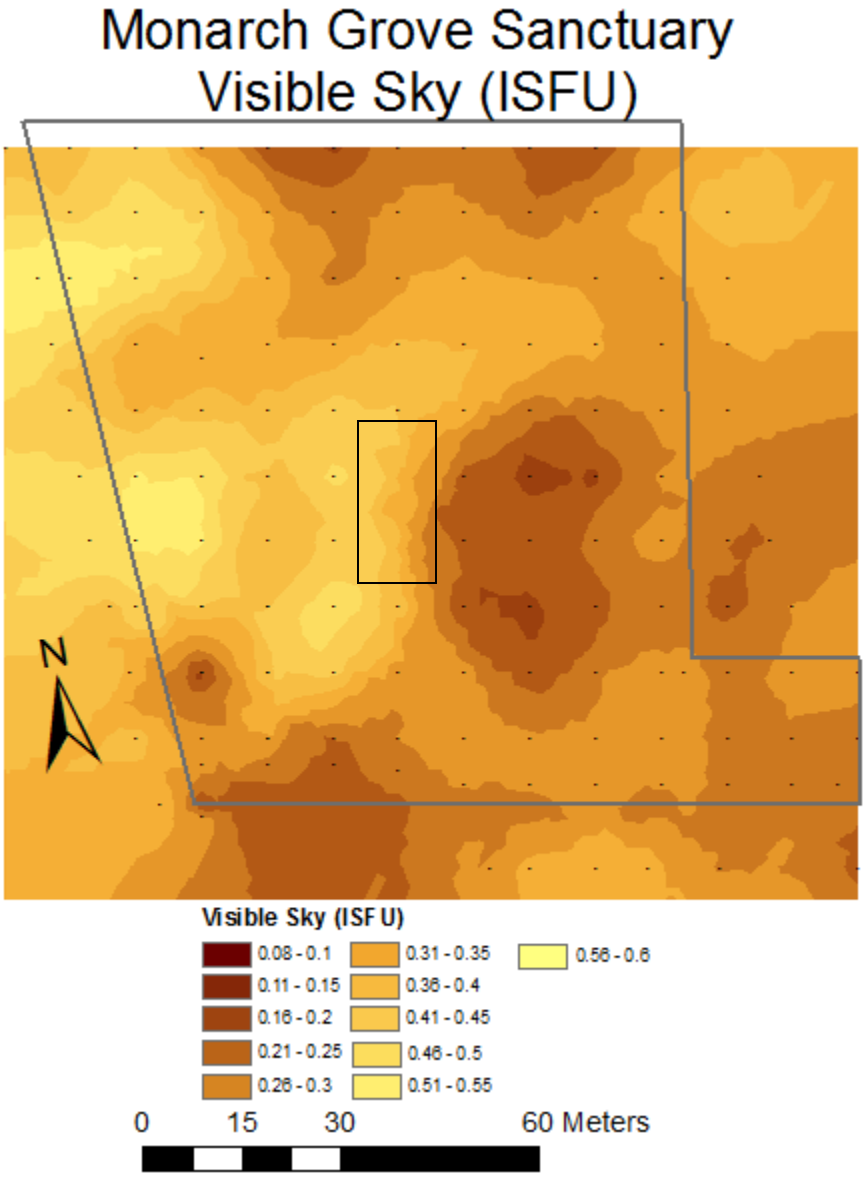
		N		
	10,0 ISFU = 0.247	50,80 ISFU = 0.298	50,50 ISFU = 0.118	
				
W	80,30 ISFU = 0.529	70,30 ISFU = 0.392	60,30 ISFU = 0.097	E
				
		S		

Canopy Cover and Visible Sky (Figure 5)

The map below shows an interpolated surface of visible sky. The small dots are photograph locations. The least open areas are in the middle of the grove, and in the SW corner. The most open areas are west of the building, and in NW corner.

The frequently used monarch cluster sites are in the SE corner of the grove (lower right), along and south of the southern boundary. Visible sky in these cluster areas is in the range of 0.16 to 0.25.

Figure 5. Visible Sky Map



Wind Exposure (Figure 6)

The map array below (Figure 6) presents wind exposure from 8 different directions. As mentioned in the methods, wind exposure (WSF) is the proportion of visible sky in the 45° wedge facing toward the wind, and lower elevation angles are more highly weighted. Larger arrows indicate higher wind exposure. The grey scale overlay is Visible Sky from the map above, so that overall canopy density can be considered.

The main monarch cluster sites are in the SE (lower right) corner of the grove.

Starting in the upper left map, NW wind exposure is high across much of the site. The high NW exposure is particularly critical in the SE corner monarch cluster sites, but extends across much of the site. This reflects the position of the grove on a NW-facing slope, and the loss of canopy and mid-story trees. NW exposure drops substantially on the S-side of the blue gum row.

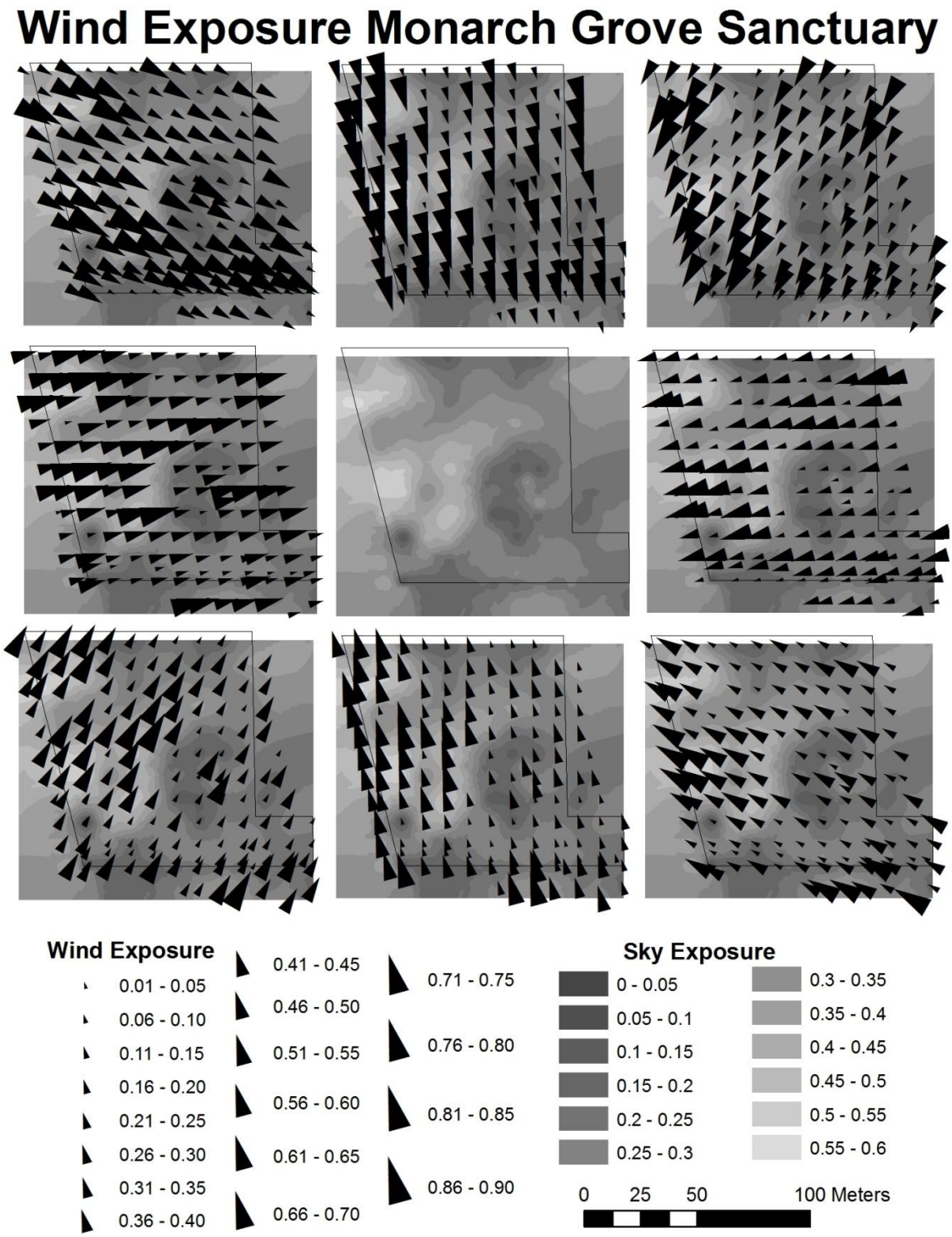
The cluster sites in the SE corner are generally better protected from W winds than from NW, but the areas south of the property line are more highly exposed than those on or just north..

SW, S. and SE winds are the strongest storm winds. The SE corner is highly exposed in these directions. Areas north of the blue gum row are relatively well sheltered, although gaps in the trees allow for some wind penetration. The movements of monarchs in response to storm winds reflect this southerly exposure: they tend to move to the north side of the blue gum row.

E and NE winds tend to be warm and not particularly strong, and the SE corner has relatively good shelter form these directions.

N winds can be strong and the exposure is similar to NW winds, with the SE corner cluster sites on and north of the blue gum row highly exposed.

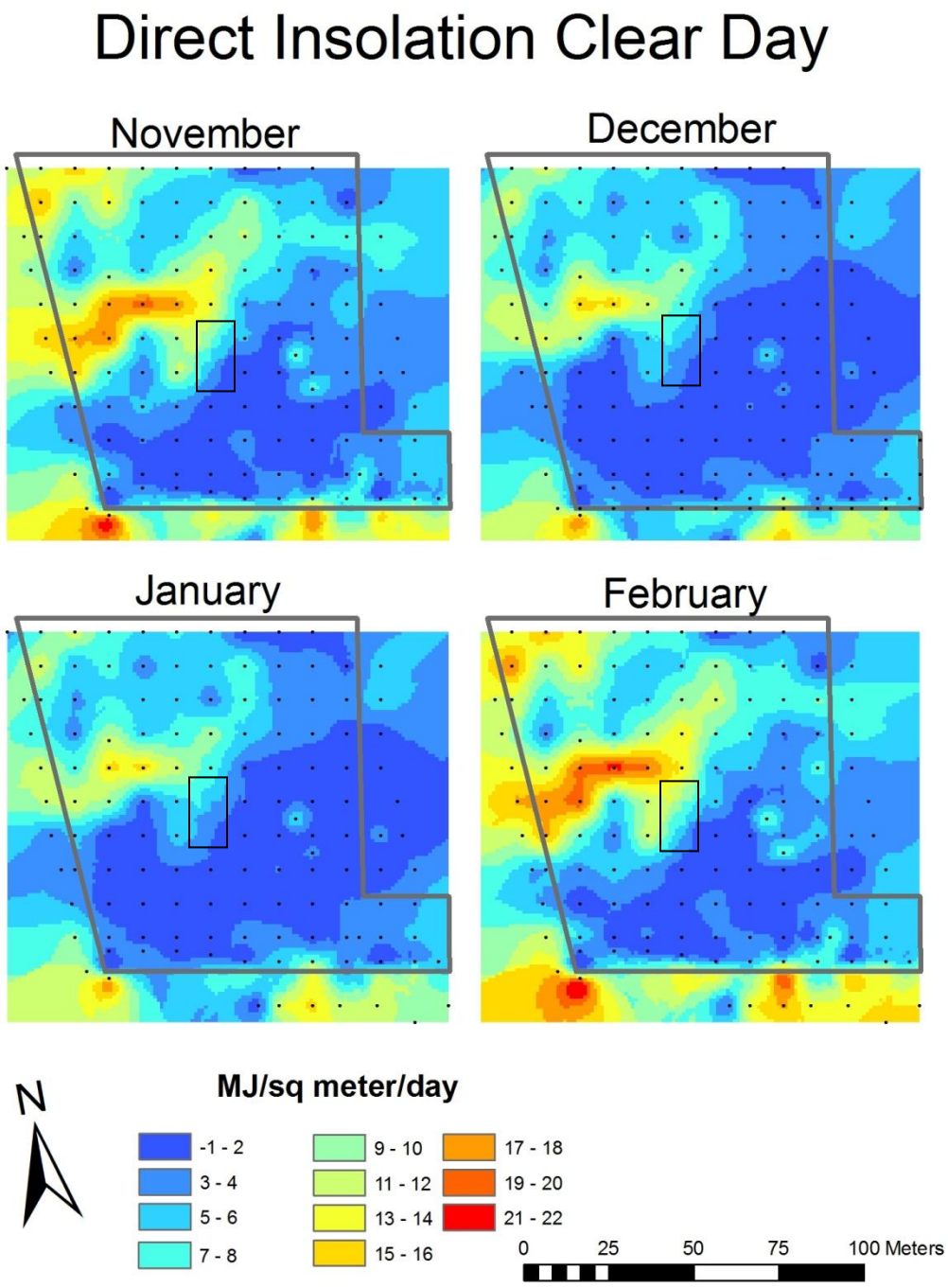
Figure 6 Wind Exposure Index Map



Direct Insolation Map (Figure 7)

Direct insolation shows the sunlit and shaded parts of the Sanctuary. Higher insolation levels (up to 20 MJ m^{-2} d^{-1}) are found along the southern boundary, and in the NW portion. Insolation is lowest in the area north of the Blue gum row. The spatial pattern remains intact through the key months, with slightly higher intensities in November/February, than in December/January.

The main cluster area in the SE has a range of insolation from 5-14 MJ m^{-2} d^{-1}; it is highly variable spatially, and monarchs can choose between high, moderate, and low insolation within a few meters, especially if they cross the blue gum row.



Horizontal Transect Examples (Figure 8 and Figure 9)

The following photographs (Figure 8) are three transects that show the progression from north to south through the blue gum row, in order to demonstrate how wind and light are attenuated across the southern boundary of the grove. Graphs of the results are presented further below (Figure 9), and the patterns can also be noted on the wind maps (Figure 7).

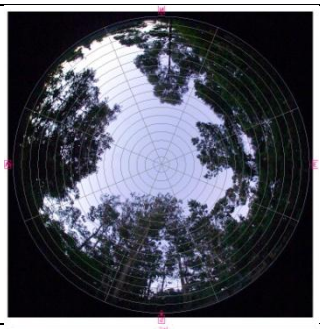
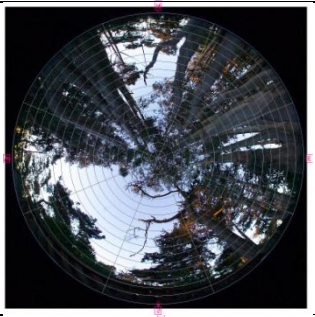
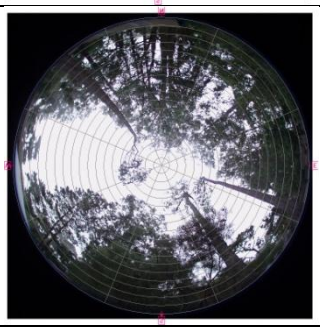
The photos here closest to the main cluster sites are 20-W, 0-N and 20-W, 10N. Butterflies often cluster along the blue gum row from 10-W through 40-W, on either side of the trees depending on wind direction and sunlight, and on the pine tree near 20-W, 10-N. The potted trees were placed in this area in 2011.

The most northerly sites (20-N) show the blue gum row to the south, with some overhead old pines, and a large cypress in 20-W, and the dense new plantings to the north. Note the high NW exposure in all of the photos north of the blue gum row. Moving toward the south, at 10-N, the blue gum row looms larger, and is overhead at 3-N. At 3-N note the gaps between the blue gum, especially at 3-N, 40-W. Also note the high NW exposure in the 3-N photos. At 0-N and 10-S, the southern sky becomes more open as the northern closes off, and SE-S-SW exposure greatly increases.

The insolation graphs (Figure 9) show the brightly lit the S-side and more shady N-side. Potential full sunlight is ~24 MJ m^{-2} d^{-1}. At 20-W and 40-W, insolation drops from 12-16 MJ m^{-2} d^{-1} (> 50% potential) to 1-3 MJ m^{-2} d^{-1} crossing south to north across the row, with little change among months except right at the 0-N position. 40-W is also brighter at 3-N because of the gap noted in the photograph. At 60-W, 10-S is in a pocket of shade created by relatively dense trees to the south.

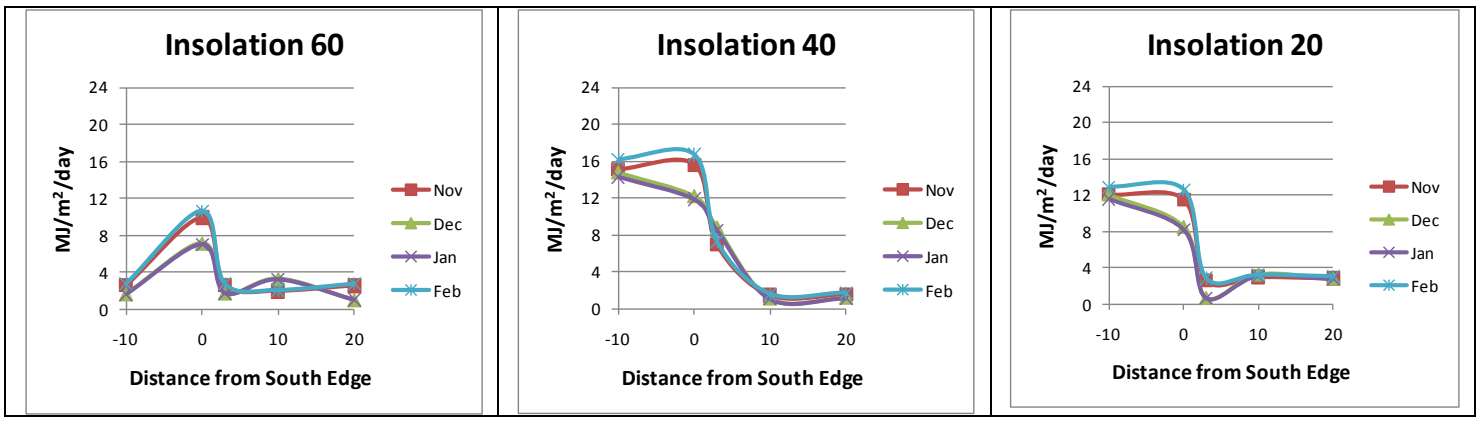
It is very important to note that in 0-N and 10-S that the trees outside the Sanctuary play an important role determining wind exposure along the southern edge.

Figure 8 Horizontal Transects

		North ↑		
		60 - W	40 - W	20 - W
20-N				
10-N				
3-N				
0-N	West			
10-S				
			South		

East

Figure 9 Insolation Graphs across the Southern Edge



Vertical Transects (Figures 10 and 11)

Below (Figure 10) are photographs of the three vertical transects, at heights of 18, 15, 10, 5, and 1.5 meters. From the top down note how the south blue gum row becomes more prominent and occupies more of the sky. Note also that the row is somewhat porous, with varying amounts of gaps between branches and trees. The newer trees to the north are virtually absent from the top photos because those trees are 15-17 m tall. Some tall trees to the NW and W are visible. In the center column (40 West) there is one tall pine with a relatively small crown.

Wind exposure is highest from the northerly directions, especially NW. Wind exposure progressively increase with height (Figure 11, upper row), especially from the exposed northerly directions, but also from the southerly directions as well. At 18 m, there is almost no obstruction to the NW in 60,10 and 40,10.

Insolation shows a more complex pattern (Figure 11, lower row). Most sites show a seasonal dip in January and February. But the relationship is not general; for example, at 60,10 at 1.5 m in December/January, an opening allows more direct light in. The relationship with height is also variable; 40,10 is well-shaded low down, and more open up higher, but 20,10 show the opposite.

The important message here is that the porous nature of the blue gum row creates fine-scale horizontal and vertical heterogeneity in insolation ranging from 1-4 MJ/m^2/day (~10-20% of full sunlight). Remember that these photos were taken 10 meters from the row. The ideal place for a second row of blue gums is 4-6 m south of the photo sites here. Here, 3-4 meters off the existing blue gum row, the effects of gaps are more pronounced and local variability increases. At ground level (1.5 m), the gaps provide insolation ranging up to 8 MJ/m^2/day, or 40 of full sunlight, some in full direct beam, but also in dappled light. As these newly planted trees grow, they will provide cluster sites in a mix of higher direct light, dappled light, and shade. At the same time, the blue gum row will provide SE, S, and SW wind protection. And, as NW and N wind shelter develops from the windbreak plantings to the north and west, the main limiting factors in this area at various heights will be ameliorated, giving the monarchs a locally complex environment with numerous options for wind shelter and insolation exposure at various heights.

Figure 10 Vertical Transects

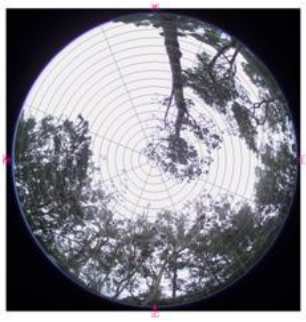
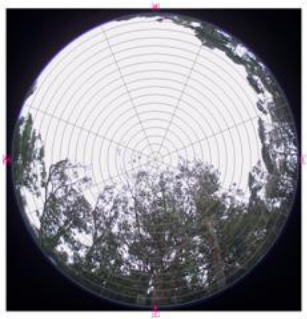
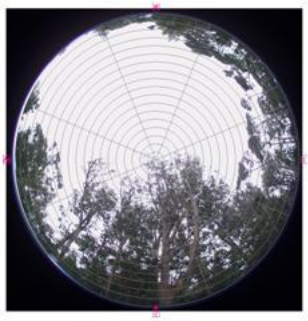
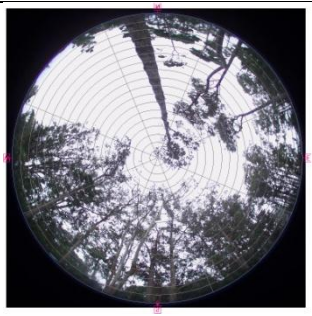
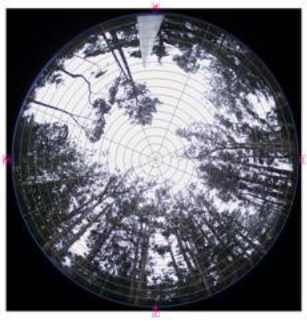
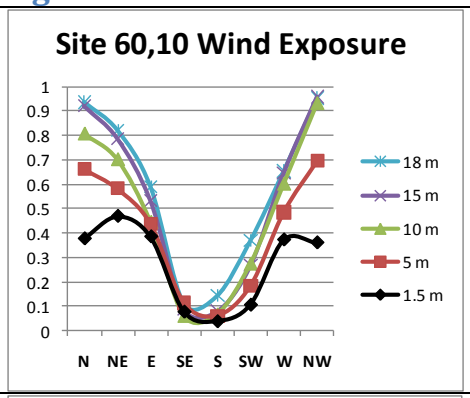
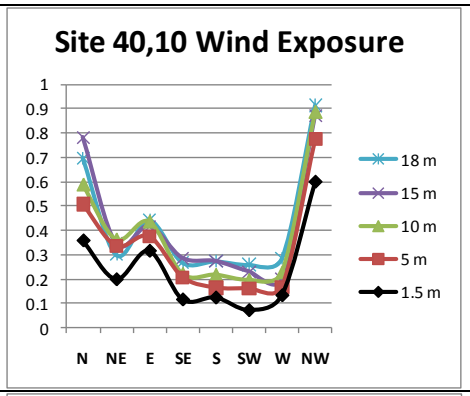
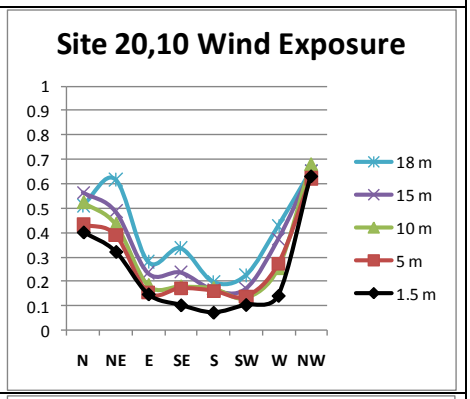
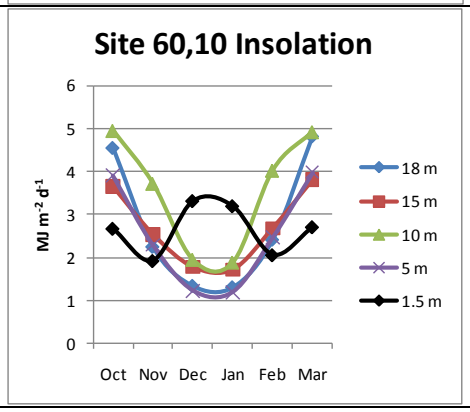
			North		
		60,10	40,10	20,10	
18					
15					
10	West				East
5					
1.5					
			South		

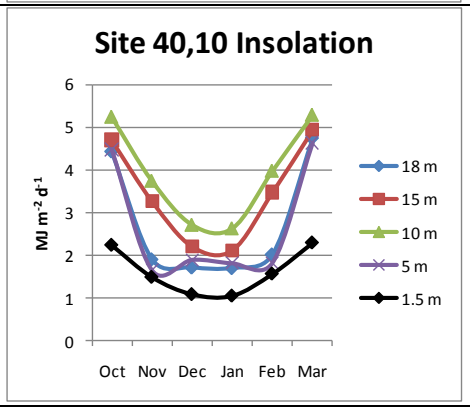
Figure 11

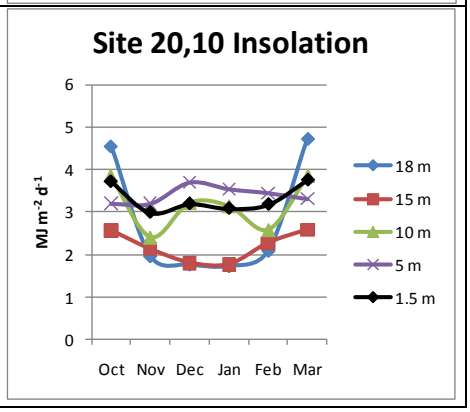












Discussion of Nectar Sources

The following letter (January 2011) was forwarded from Jan Southworth, and contains numerous suggestions for nectar source, primarily non-native. The urban/suburban environment is well suited to non-native nectar sources, but within the Sanctuary, it is suggested that they be in planter boxes, not directly planted in the ground. Useable nectar needs to be in sunny areas. Also open areas in the schoolyard may be a perfect place to plant a diverse nectar garden, and provide the students/teachers the opportunity to observe and assess monarch's use of various nectar species.

Hi Paul & Helen

Thanks for sharing the photos of the [Coyote Hills] nectar garden. Thanks also for the info regarding the Westside Nursery in Gilroy, that is a great price for Vitex, I think I'll try to get down there next week to pick some up.

Another fantastic nectar resource for all fall butterflies, but especially Monarchs is the shrubby Daisy Tree in the center of the courtyard in the nectar garden. Because it is not a Calif. Native we are not allowed to grow it anywhere else in the park, but I am looking for some for my own home garden. The latin name for this wonderful plant is Montanoa grandiflora. It is a fall bloomer -- covered with clusters of daisy-like flowers beginning in late October until late Dec. and is often covered with nectaring Monarchs, Swallowtails, West Coast Ladies, Red Admirals, etc. An added benefit that park visitors enjoy is the wonderful "spiced cookie" fragrance produced by the flowers This might also contribute a tremendous nectar resource to the Pacific Grove site, if they are allowed to grow a non-native species.

Yes I also noticed that the Monarchs (at least those that migrate through the garden at C. H.) seem partial to the white blossoming Vitex as opposed to the purple. I don't know if that's a result of the white one coming into bloom a little later in summer and therefore having more nectar in comparison to the purple by the time the fall Monarchs arrive. As to light pruning in June, that might be worth trying, Vitex is a summer to early fall bloomer, so delaying the onset of

bloom with light pruning might encourage a more profuse bloom as well. I never tried that in the nectar garden. My goal with the Vitex was to produce a tree-like shape with pruning, so we pruned all the sucker-sprouts around the base. It is normally a multi-trunked shrub, but by pruning the sucker-sprouts we were able to encourage the Vitex to reach up into the sunlight, which did encourage better bloom. Too much shade has always been a difficulty in the garden due to the early afternoon shade produced as the sun sinks behind the Coyote Hills.

As to the Salvia species popular with Monarchs, they seemed to like Salvia clevelandii, a Ca. native, but most of the other species of Salvia were mainly attractive to the hummers. Two non-native shrubs very attractive to the Monarchs were Lemon Bush Marigold (Tagetes lemonii) and Lilac Verbena, aka Verbena de la Minna, (Verbena lilacina) which is native to the Channel Islands. Both are very profuse bloomers (spring thru fall) and quite hardy, plus the gold and purple of flowers look great when grown together. I'm growing the Lilac Verbena now and I pruned it back to 6 inches in late November due to its ragged, bloomed-out appearance and, surprisingly, it rebounded robustly and is now in full bloom again and on sunny days, like today, in spite of the cold temps, is visited constantly by Gulf Frits. So I'm thinking I can, with two of these Verbenas, pruned at different times, produce nectar all year round. But of course, nothing beats the nectar magnet of the Daisy Tree.

As a side-note, last year I found a nursery back east which has cultivated a new variety of buddleia which grows only 24" wide and high. It's called Lo & Behold Blue Chip Buddleia. I found it online and ordered three specimens. They are proving to be rich in nectar and butterfly favorites as well. They are great for planting in hedge-like rows and wonderful because they don't require the heavy pruning that other buddleias do and are so appropriate for small yards. Unfortunately this unusual form of buddleia is not available widely in the west yet and must always be mail-ordered from Wayside Gardens Nursery, which I think is in North Carolina.

Anyway, I hope some of this is helpful. I'm so glad you are aiding the enhancement work on the Pacific Grove Monarch site.

Best Regards,
Jan

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