CREEKSIDE SCIENCE

Albany Hill Monarch Habitat Assessment

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Cover photo: Early season cluster site on ridgetop near bench

Executive Summary

The monarch butterfly overwintering site at Albany Hill was assessed in 2017-2018 using hemispherical canopy photography to quantify insolation (solar radiation) and wind exposure. The following conclusions were drawn from the study:

1) Monarch occupancy patterns indicate that the site can provide suitable conditions throughout the overwintering season when the butterflies move short distances.
2) The Eucalyptus canopy provides a variety of insolation and wind conditions, including sites with adequate insolation and good wind shelter.
3) Butterflies start the season in October and November along the ridgetop, where they can cluster in sunny spots. But the first high southerly winds of the season associated with storms drive them to seek shelter on the SW slope, where canopy gaps and larger openings provide suitable conditions. Butterflies have not used the eastern slope for clustering.
4) A discriminant analysis identified January insolation, S and SW wind, and a measure of the distribution of visible sky overhead versus toward the horizon. More visible sky overhead relative to the horizon is a good indicator of general wind shelter, higher values are better.
5) There are several hectares of forest on the SW slope that encompass the core cluster sites. These sites are in an area of forest with small openings that provide sufficient insolation, but retain wind protection. Monarchs can move short distances to track insolation and wind within this zone, and three other photo sites in this area fall within the envelope described by the discriminant analysis.
6) The overall functioning of the site is described, and general management recommendations are provided. This study can be used as a baseline for evaluating specific impacts of modifications to existing conditions, but further .

Introduction

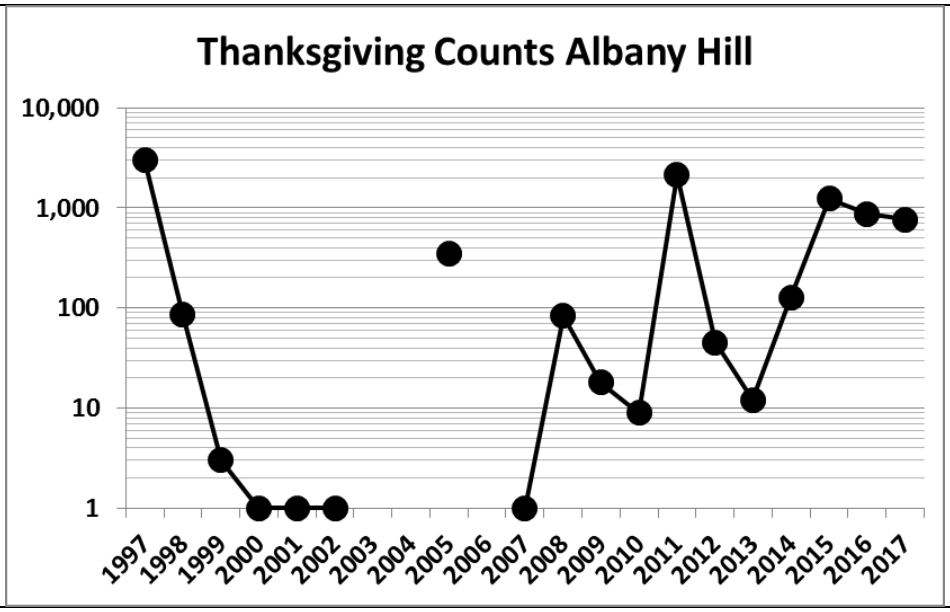
Monarch butterflies (*Danaus plexippus*) overwinter at Albany Hill near the shores of San Francisco Bay. Overwintering monarchs seek sites that rarely freeze, provide protection from wind, and have a varied light environment ranging from full sun to dappled light to deep shade (Leong 1990, 1991). Monarchs will adjust their cluster locations to track these microclimatic conditions. Sites that reliably provide all three criteria attract and retain monarchs through the entire overwintering season.

Most California monarch sites are based on groves of non-native Eucalyptus trees (Pelton et al. 2016, Xerces 2017), primarily blue gum (*Eucalyptus globulus*). Albany Hill is dominated by blue gums, with some middle story of native live oak (*Quercus agrifolia*) and non-native acacia. The shrub understory layer is dominated by poison oak (*Toxicodendron diversilobum*), which, along with very steep slopes, greatly restricts access to much of the site.

Monarch Butterfly Distribution and Abundance

Numbers have been between the low thousands (1997 and 2011) and zero (2000-2002, 2007). From 2015 to 2017, there have been approximately 1000 butterflies counted around Thanksgiving (Xerces Society Thanksgiving Counts).

Figure 1. Historical Monarch Counts



A typical seasonal cycle for monarchs at Albany Hill is to start clustering along the ridgetop in October-November as they arrive, and then retreat down the west slope after the first storms of the season. During long mild periods in mid-winter, they may re-occupy the ridgetop. In February and into March, butterflies mate and leave the site, depending on weather conditions.

The primary purpose of this report is to assess the forest canopy and its ability to shelter monarchs, through the following analyses:

1) Acquire hemispherical photographs in an array of accessible sites, including known cluster sites from 2016 and 2017
2) Analyze those photographs and extract out measures of visible sky, wind exposure, and insolation (solar radiation)
3) Create maps of these factors
4) Do a discriminant analysis that identifies important features of cluster versus non-cluster sites
5) A discussion of monarch dynamics at the site relative to the canopy analysis.
6) Recommendations for site management

This report builds on previous work at several other monarch overwintering sites (Weiss and Murphy 1992, Weiss 1998, Weiss 2011, Weiss 2017).

Methods

On November 10, 2017, a site visit was arranged with local monarch observers (Bill Shephard, Carol Fitzgerald, and Margot Cunningham). A circuit of the site started at the ridgetop bench (~100m elevation), south along the ridgetop, down the southwest slope on a trail to an elevation of 40m, and back up through the main cluster areas. Then north along the ridgetop, down the west side on a trail to 80m elevation, down the north trail to just inside the edge of the Eucalyptus forest, and back up to the turnaround area.

Photographs were taken at opportune places to illustrate features of the forest canopy. All sites along the circuit where monarchs have been observed were photographed. Nearby unoccupied sites were photographed as well. Example representative photographs are presented in this report.

Photographs were analyzed with Hemiview software, and the following "site factors" were extracted:

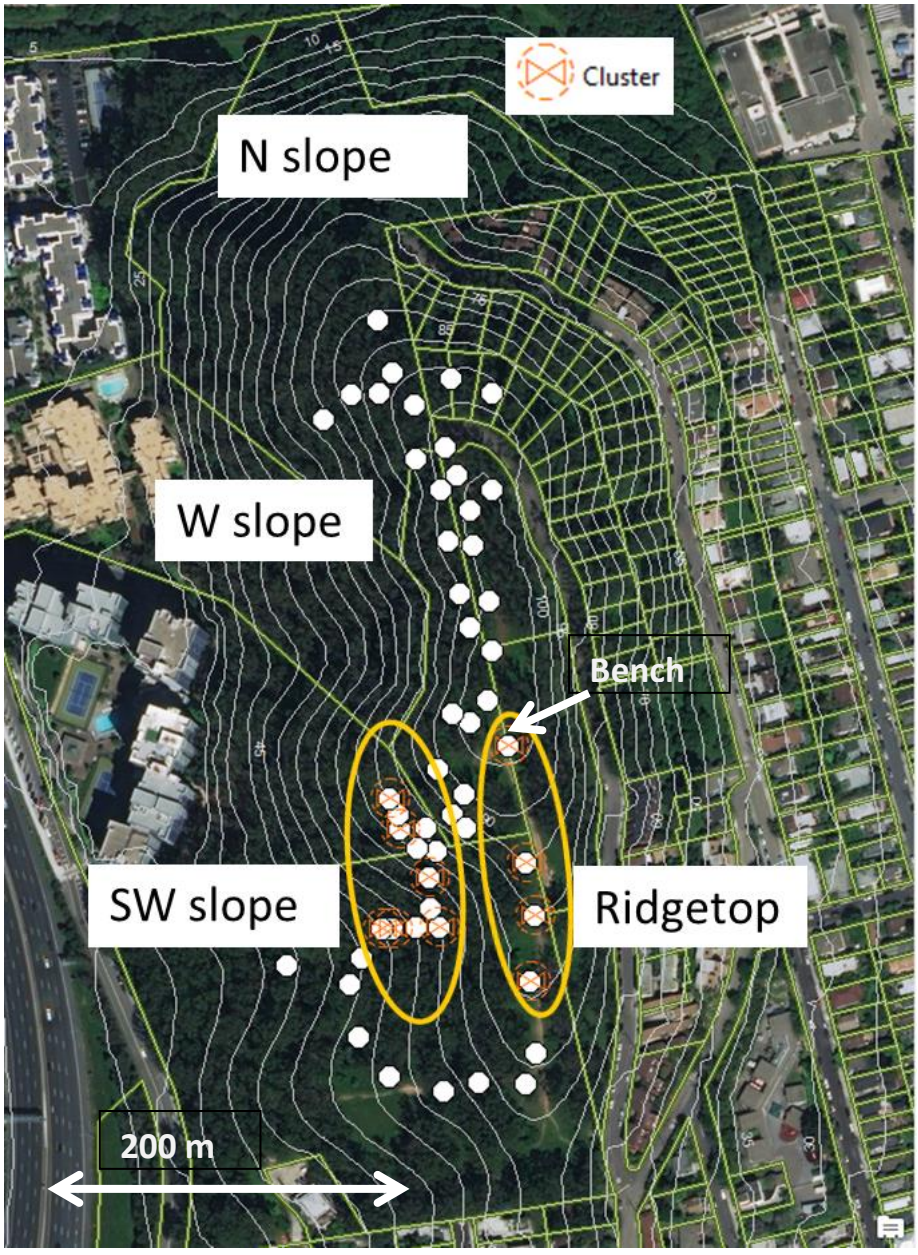
1) ISFU – Indirect Site Factor Uncorrected, the fraction of visible sky in all directions.
2) ISF – visible sky cosine-corrected for zenith angle, emphasizes overhead and deemphasizes sky near the horizon. The ratio ISF/ISFU is a measure of protection from the sides (higher values indicates relatively more visible sky overhead and less near the horizon, conversely lower values indicate more visible sky closer to the horizon).
3) Nov/Feb and Dec/Jan potential direct insolation – calculated from fraction of unobstructed monthly sunpaths assuming clear skies.
4) Wind Site Factors (WSF) – the fraction of sky visible in eight compass directions, a measure of relative wind exposure. The maps are symbolized by arrowheads of different sizes in the wind direction.

A brief description of these site factors in an example photograph is presented below.

Maps were made in ARCGIS, showing the values of site factors at each photo point. It was not possible to access enough of the site (due to poison oak and steep slopes) to create interpolated maps.

A discriminant analysis in JMP 10.1 synthesized the data into a "signature" of cluster sites versus non-cluster sites versus ridgetop cluster sites (where monarchs aggregate early in the season prior to the onset of stormy weather, and during extended calm sunny periods in winter). A forward selection procedure identified the significant combinations of site factors that differentiate the three different types of sites.

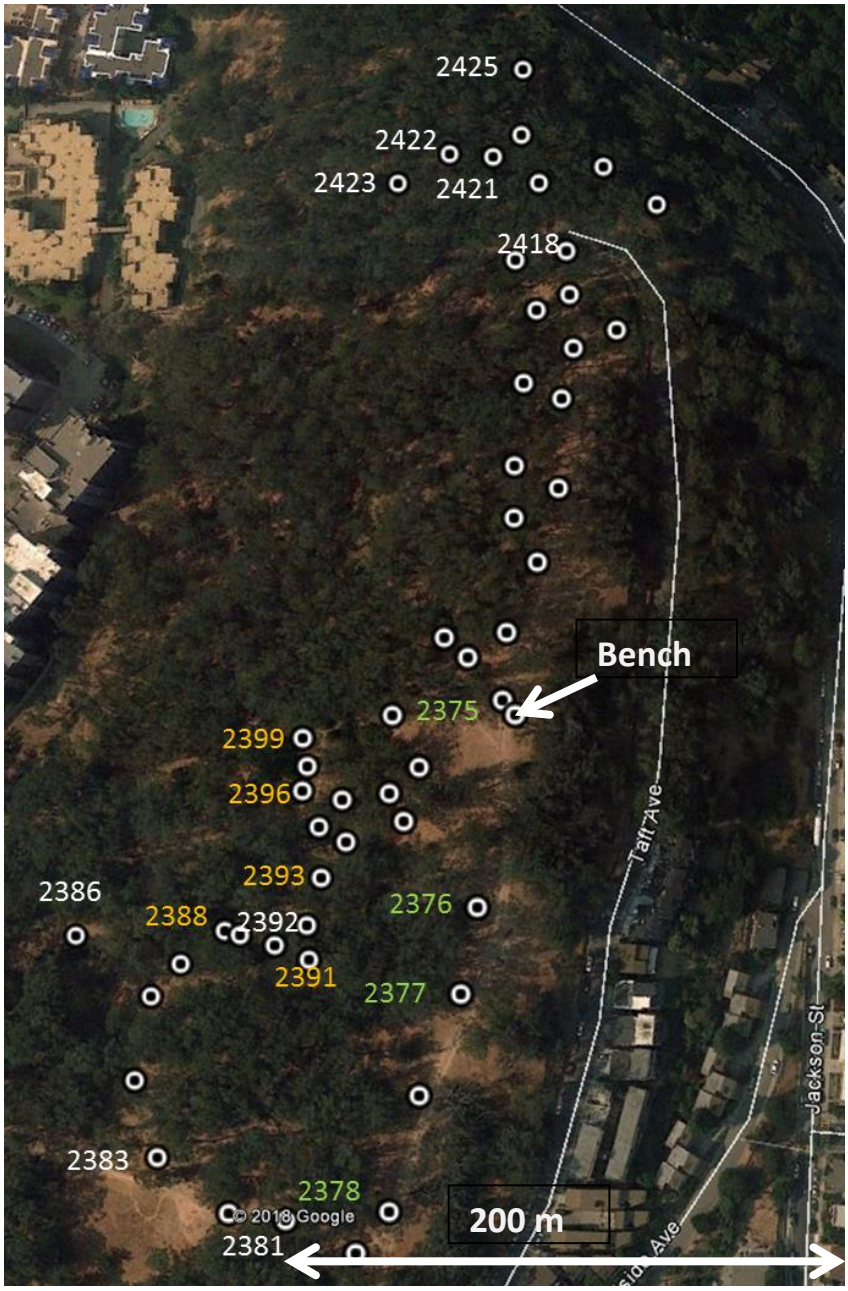
Map 1. Photo points, Cluster Sites, and Area Names



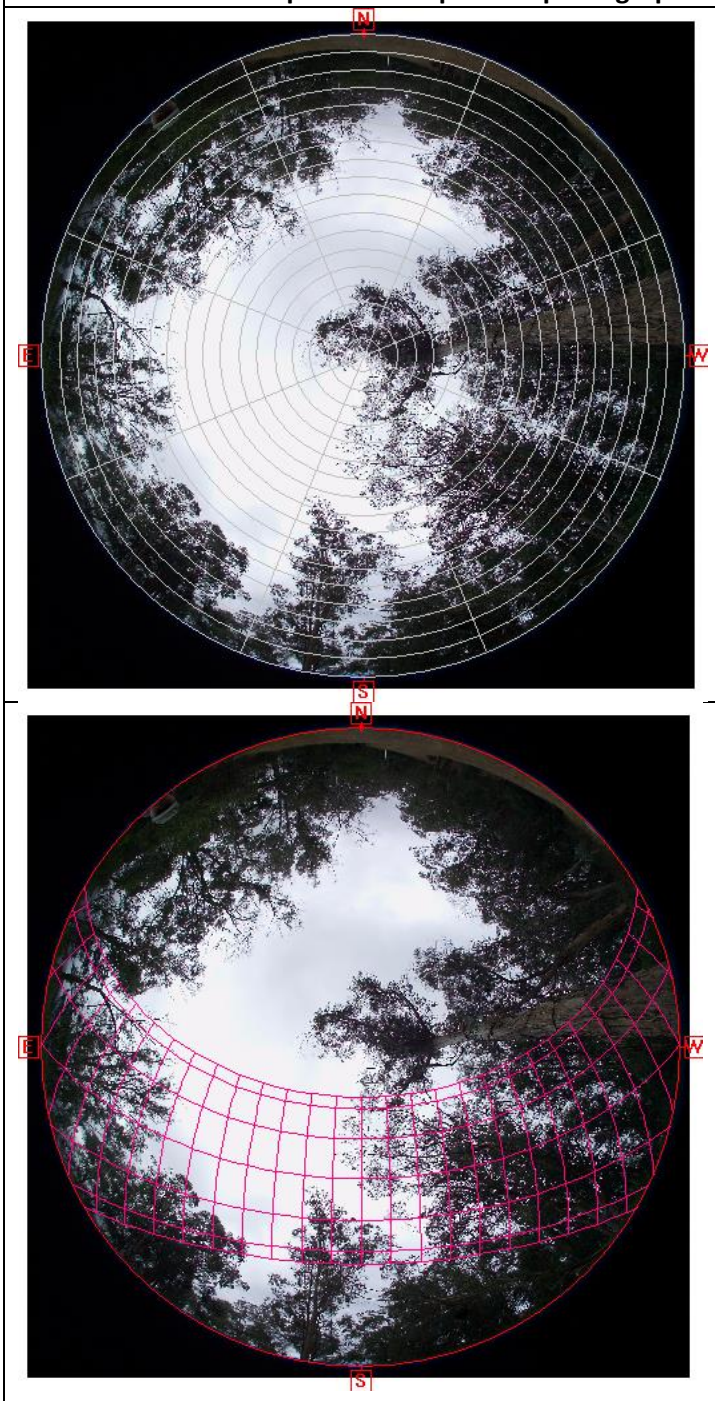
Example photographs

The positions of the 18 example photographs in Figure 2 are identified in Map 2. A discussion of each site is below the photograph in Figure 2.

Map 2. Example Photopoints Labeled, on Google Earth image where the ground is apparent. Orange numbers are Cluster sites, Green are ClusterRidge, and white are No Cluster



How to read and interpret a hemispherical photograph



The sky grid is divided into 8 x 45° azimuth (compass direction) octants, and 18 x 5° zenith angle (zenith angle overhead = 0°, zenith angle at horizon = 90°. Note that East and West are reversed from a map because the photo is pointed up, not down. In this photo 0.43 of the sky is visible in all directions (ISFU); when cosine corrected to a horizontal surface (which emphasizes overhead sky) ISF = 0.59. ISF/ISFU ratio of 1.37 is about average for all photographs

The wind exposure, calculated for eight directions, ranges from 0.12 (W very closed) to 0.65 (SE very open).

The same photo below has the sun grid on it, with E-W monthly tracks (Dec 21 is the lowest/most southerly track, Nov 21/Jan 21 is the next track, and Oct 21/Feb 21 is the third track). The day is divided into ½ hour intervals. For Nov/Feb, 52% of the potential insolation is received, and for Dec/Jan 37% is received, primarily in late-morning/mid-day.

ISF	0.59	
ISFU	0.43	
ISF/ISFU	1.37	**Potential MJ**
Nov MJ	246	468
Dec MJ	143	377
Jan MJ	140	365
Feb MJ	247	468
N	0.52	
NE	0.47	
E	0.64	
SE	0.65	
S	0.55	
SW	0.24	
W	0.12	
NW	0.25	

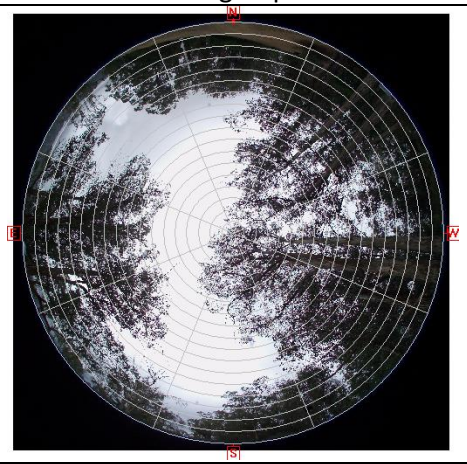
Photo 2375 Ridgetop Cluster Site at Bench	Photo 2376 Ridgetop Cluster Site
	
At the top of the hill open to the S and SE providing high insolation but poor southerly wind shelter	Further south along the ridgeline. Better S canopy cover, lower insolation, but open to SE wind
Photo 2377 Ridgetop Cluster Site	Photo 2378 Ridgetop Cluster Site
	
Open to S and SE wind, high insolation, good shelter SW and W	Open to SE wind, morning sun, afternoon shade

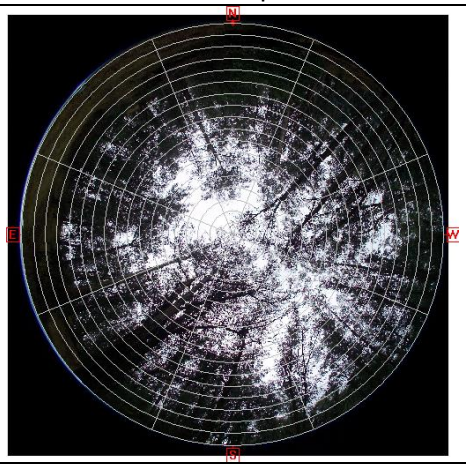
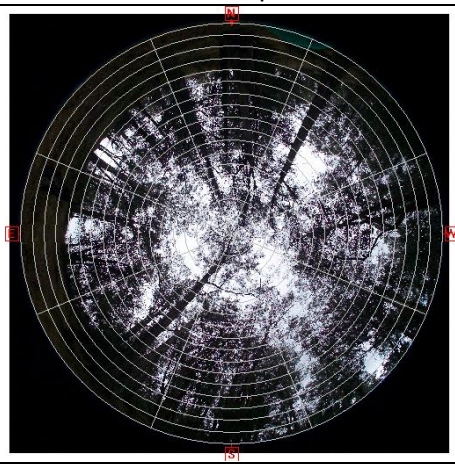
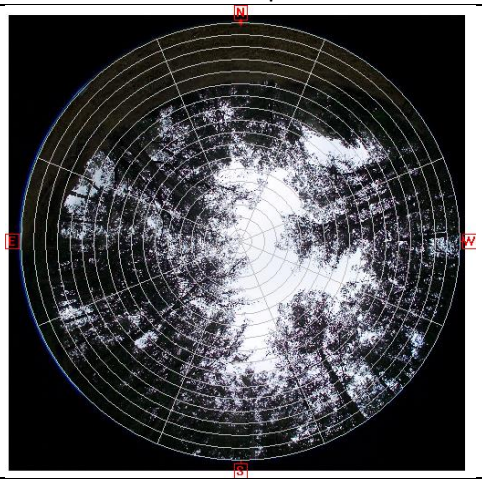
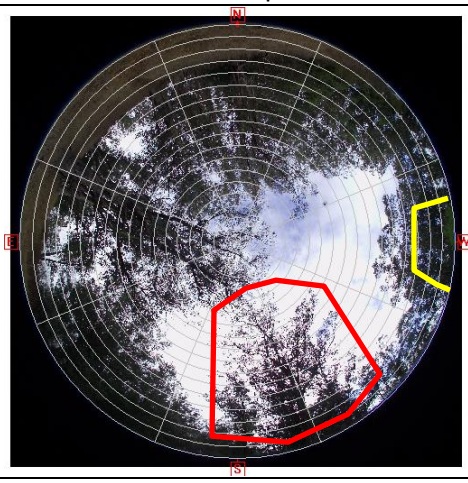
Photo 2388 SW Slope Cluster Site	Photo 2391 SW Slope Cluster Site
	
Good wind shelter from most directions, most open to SW, dappled afternoon sun from the SW	Good wind shelter from most directions, including SW, low insolation
Photo 2393 SW Slope Cluster Site	**Photo 2396 SW Slope Cluster Site**
	
Good wind shelter from all directions, dappled afternoon sun from SW	Site in small clearing. The red outline is a Very Important Tree (VIT) that provides key wind shelter. The yellow highlights an acacia. Relatively high exposure to SW wind

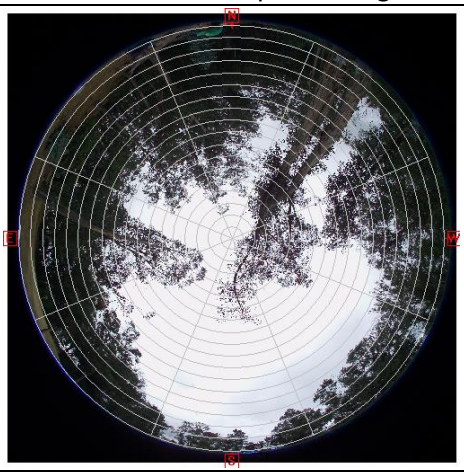
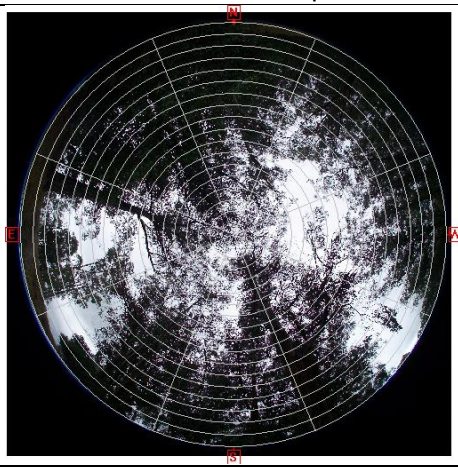
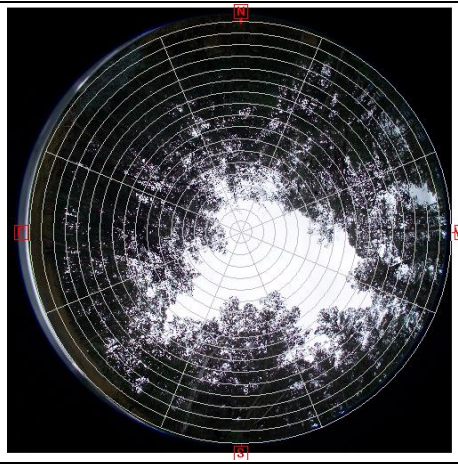
Photo 2399 SW Slope Cluster Site	Photo 2383 SW Slope Clearing NC
	
At north end of opening. High insolation,with dappled afternoon light moderate wind shelter from SW and S. The VIT in Photo 2396 is outlined in red, key wind shelter from S and SE. The Yellow is an acacia that also provides key wind shelter	North edge of lower opening, high exposure to southerly winds and insolation.
Photo 2381 SW Slope NC	**Photo 2386 Low SW Slope NC**
	
Site along downslope trail just below ridge. Trail runs through gap WSW direction High cover to south, low insolation. High wind exposure from SW and W.	Lowest elevation poto on SW slope, on trail. Good wind shelter except at higher angles in SW.

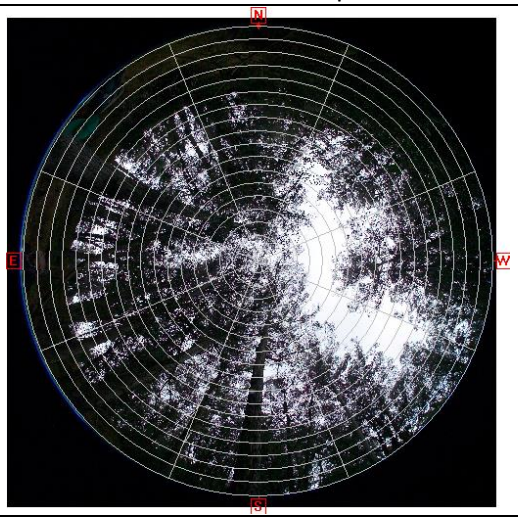
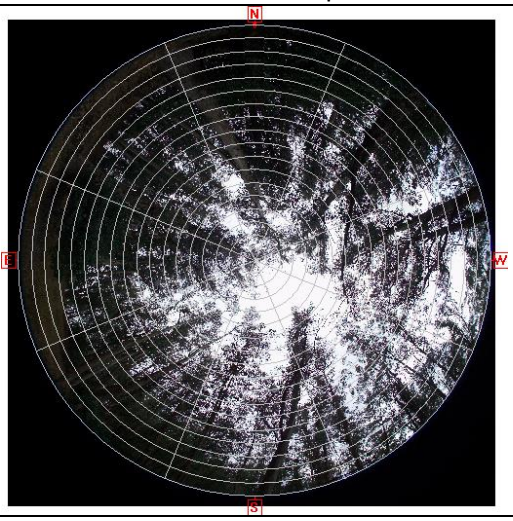
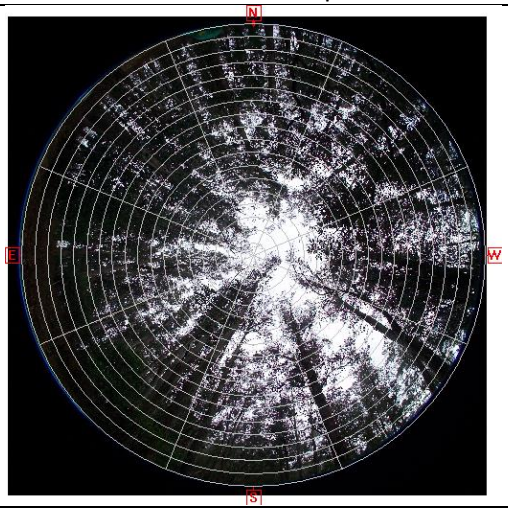
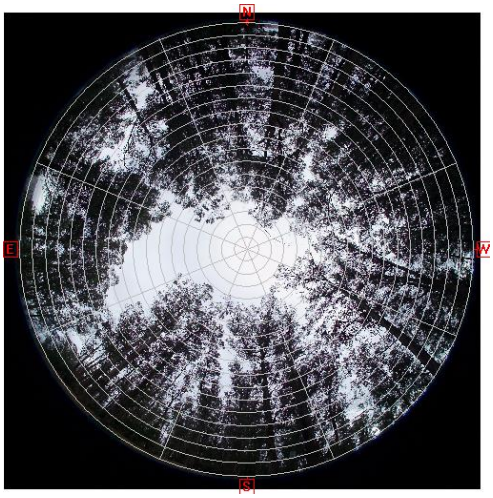
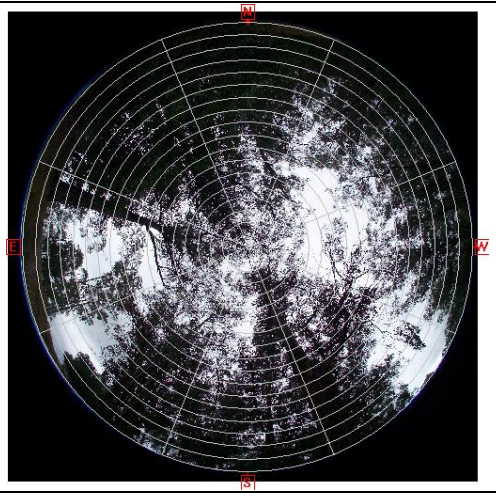
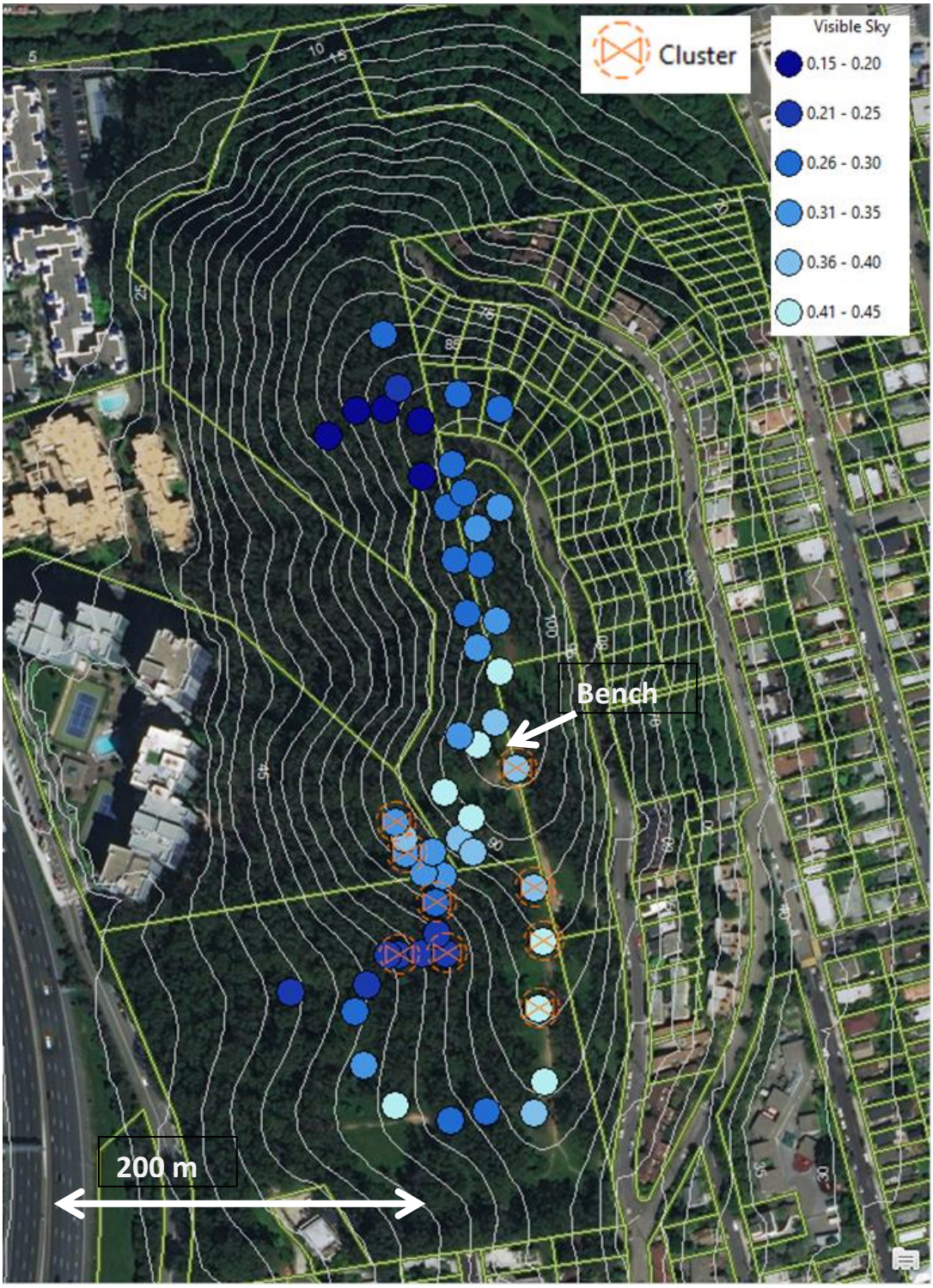
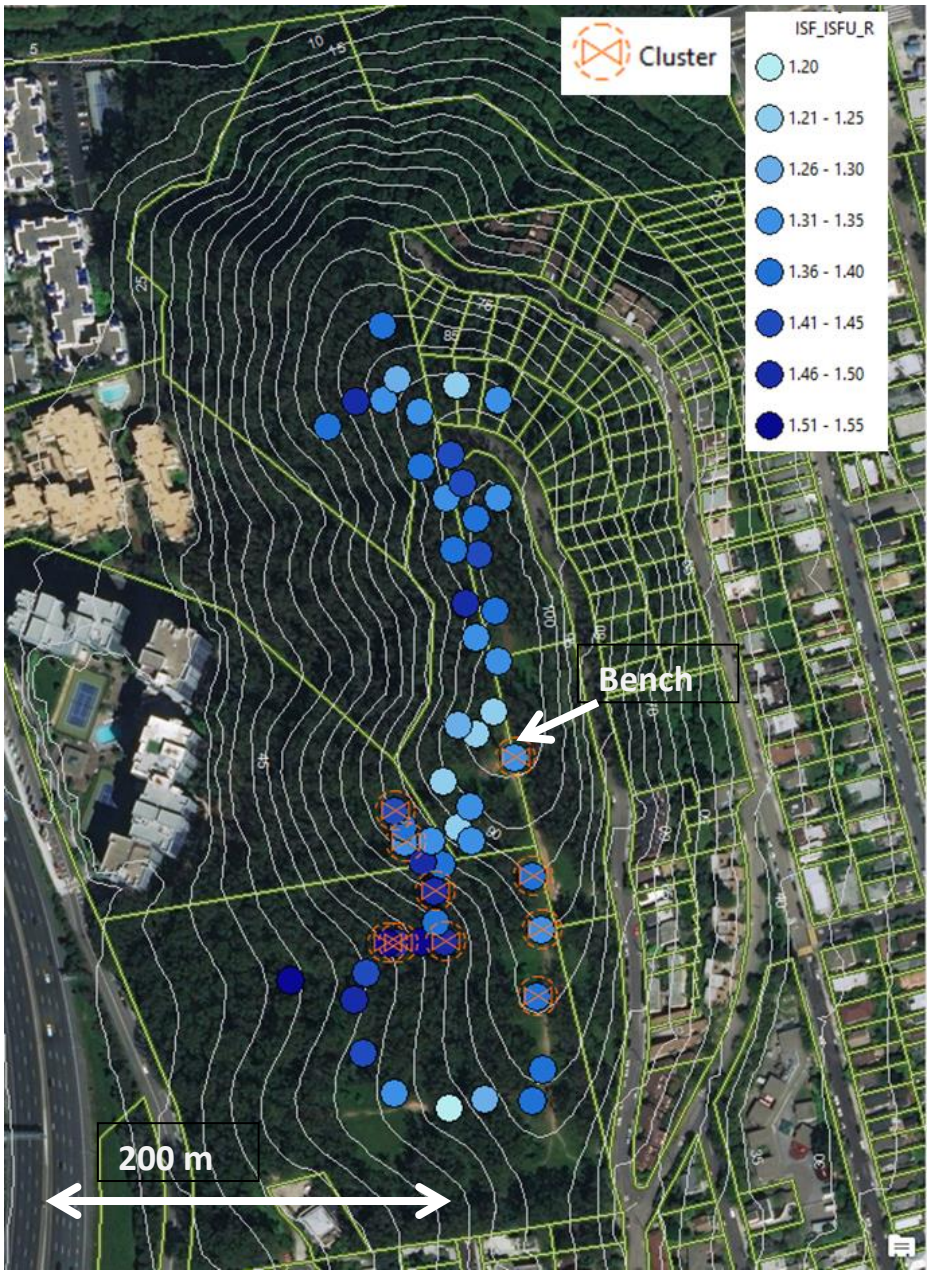
Photo 2392 SW Slope NC	Photo 2423 W Slope NC
	
Site within the cluster zone, but not occupied. High SW wind exposure, low insolation	Site on W slope trail in northern part of hill. Low insolation,, high W wind exposure, moderate SW exposure. Low Visible Sky
Photo 2422 W Slope NC	**Photo 2418 Road Circle**
	
Along trail above 2423. Low insolation, low exposure to wind from all but SW. Low Visible Sky.	Center of road circle. Low insolation, moderate SW wind exposure. Moderate Visible Sky.

Photo 2421 West of Road Circle	Photo 2425 North Edge
	
Low insolation. High exposure to WSW wind, and some SE wind (gap is where road enters the circle.	Low insolation, with dappled afternoon sun to SW. High exposure to NE and NW wind, refelcting position at edge of Eucalyptus stand (live oak canopy to north beyond tall Eucalyptus.

Map 3. Visible Sky (ISFU) and Cluster Sites

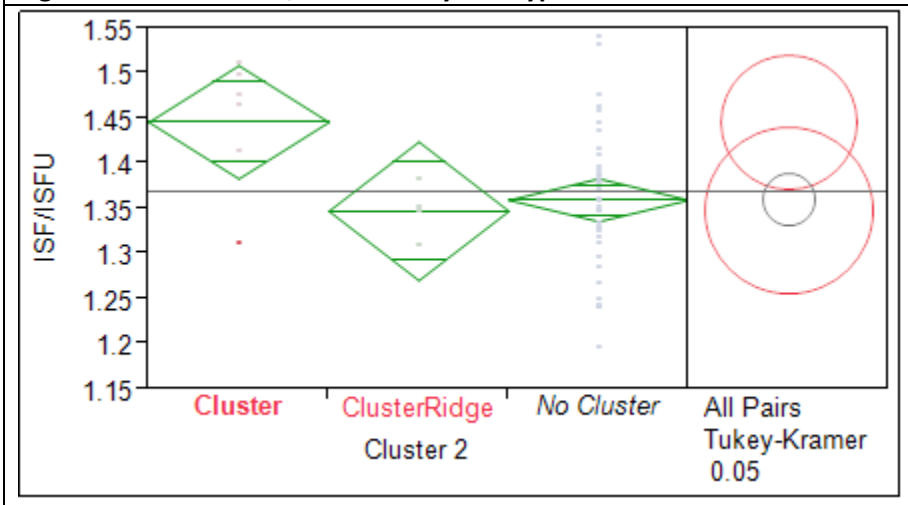


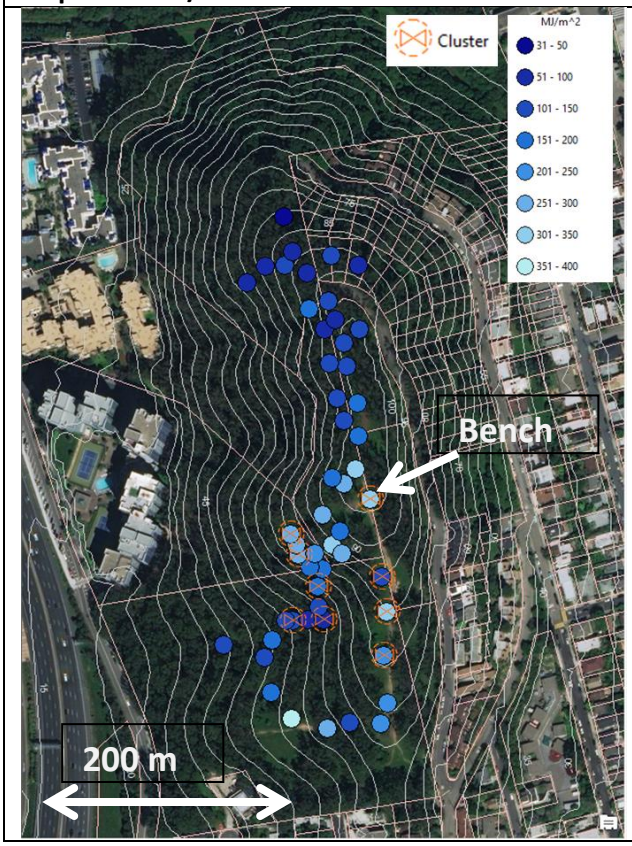
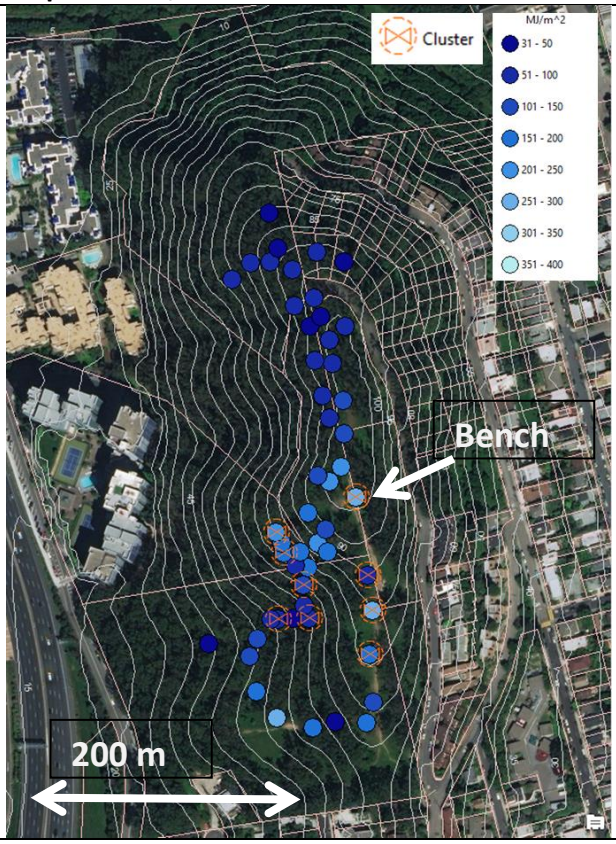
Map 4. ISF/ISFU Ratio (measure of canopy closure toward the horizon)



The ISF/ISFU Ratio is higher (darker blue) in the Cluster sites, indicating that these sites have relatively more open sky above than to the sides, i.e. they are better sheltered from winds from all directions. A comparison of Photo 2393 (ISF/ISFU = 1.48) and Photo 2396 (ISF/ISFU = 1.31) illustrates the nature of this measure. The Cluster sites have significantly higher ISF/ISFU than the No Cluster sites ($p<0.05$, Figure 2), and 5/6 Cluster Sites are in the range 1.4-1.5.

Figure 2 ANOVA of ISF/ISFU ratio by site-type.



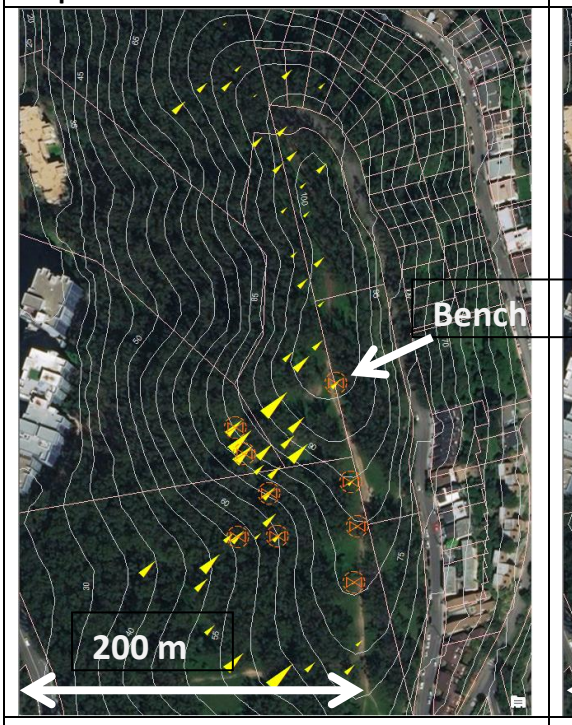
Map 5a. NOV/FEB Insolation	Map 5b. DEC/JAN Insolation
	

The insolation maps (Maps 5a and 5b) show a mix of sunny, dappled, and shaded sites across Albany Hill. The Cluster sites are in relatively well-lit areas. The Cluster Ridge sites receive high winter insolation at ground level; monarchs seek sunny spots early in the season. The northern sites are more highly shaded from winter insolation, and are likely too dark to attract and retain monarchs.

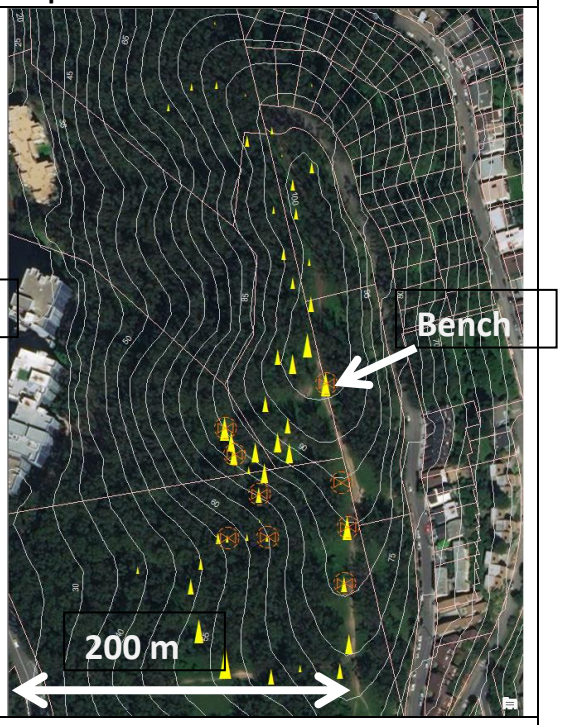
The wind maps (Maps 6a-h) show relative wind exposure from 8 directions. The larger arrows indicate higher relative wind exposure. The Cluster sites are in an area where there is higher SW (6a), S (6b), and W (6H) exposure, not surprising in canopy gaps on a W-SW facing slope. SE exposure is lower in the cluster sites than on the ridgetop (6c). Only the ridgeline has high exposure to E (6d) and NE (6e). Almost the entire set of sites is sheltered from NW winds.

The interplay between insolation and wind is likely the driver of seasonal movements of monarchs within Albany Hill. See the Discussion and Recommendations section for more interpretive detail

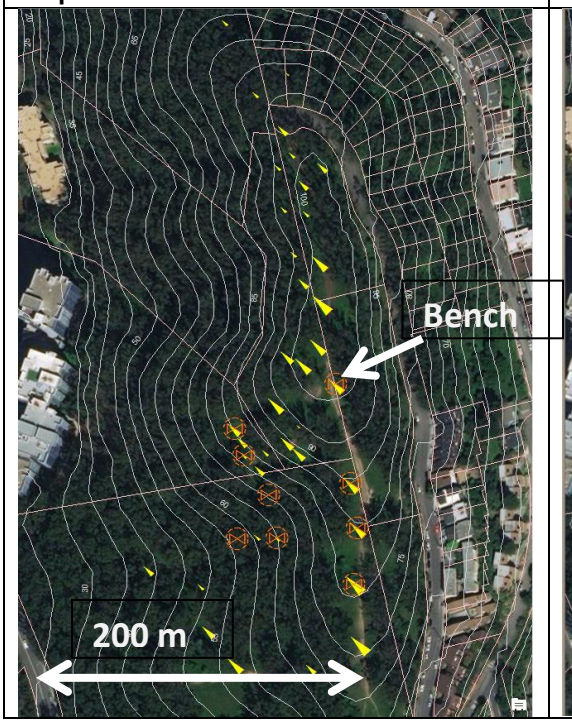
Map 6a SW Wind



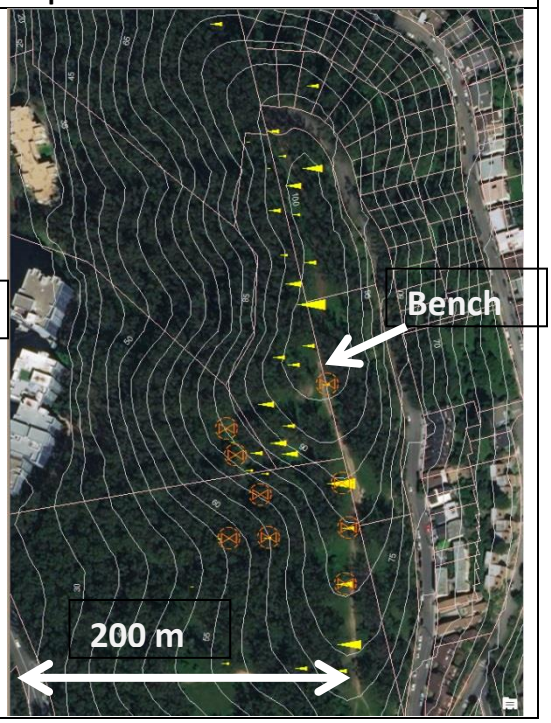
Map 6b S Wind



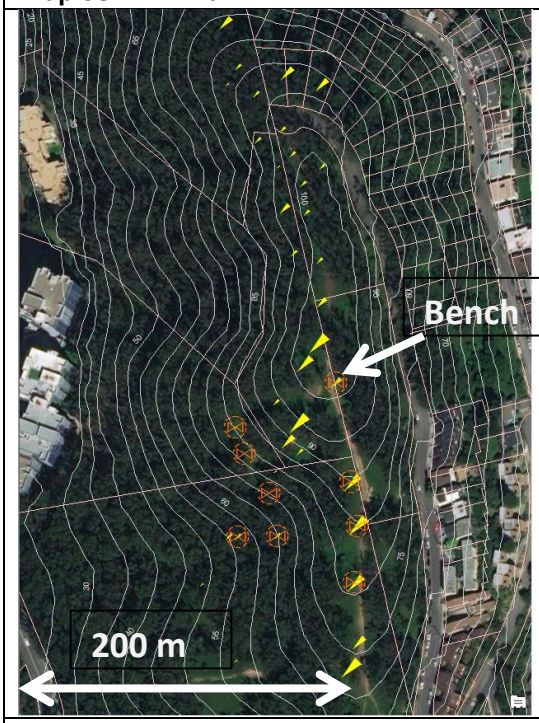
Map 6c SE Wind



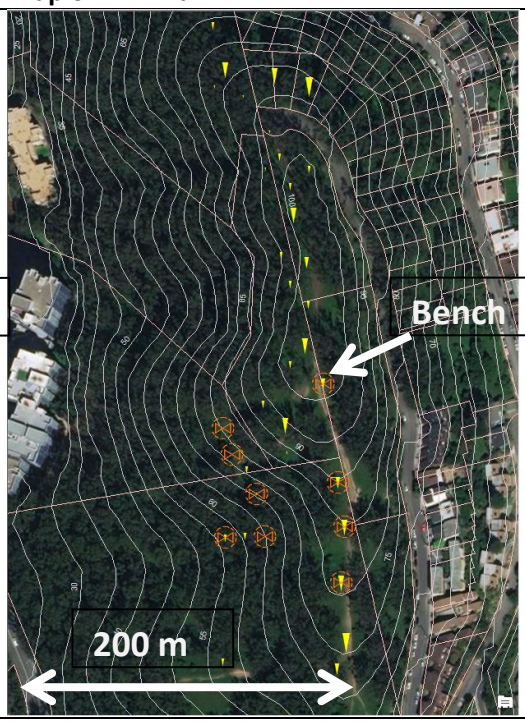
Map 6d E Wind



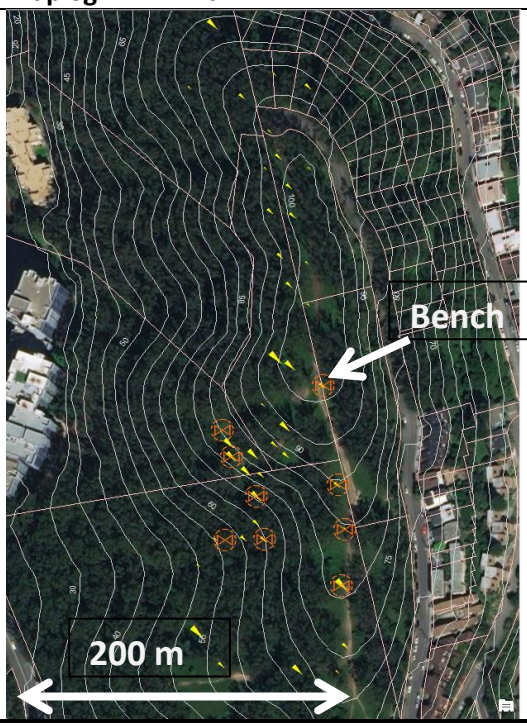
Map 6e NE Wind



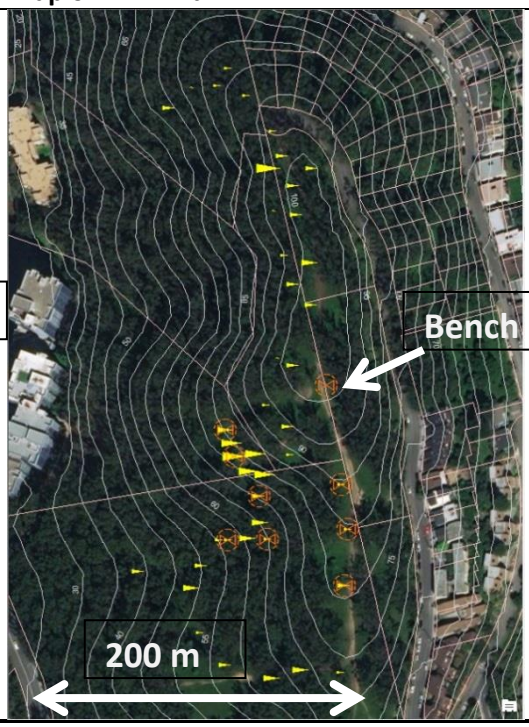
Map 6f N Wind



Map 6g NW Wind



Map 6h W Wind



Map 7. Slope and Parcels Contour Interval 5m

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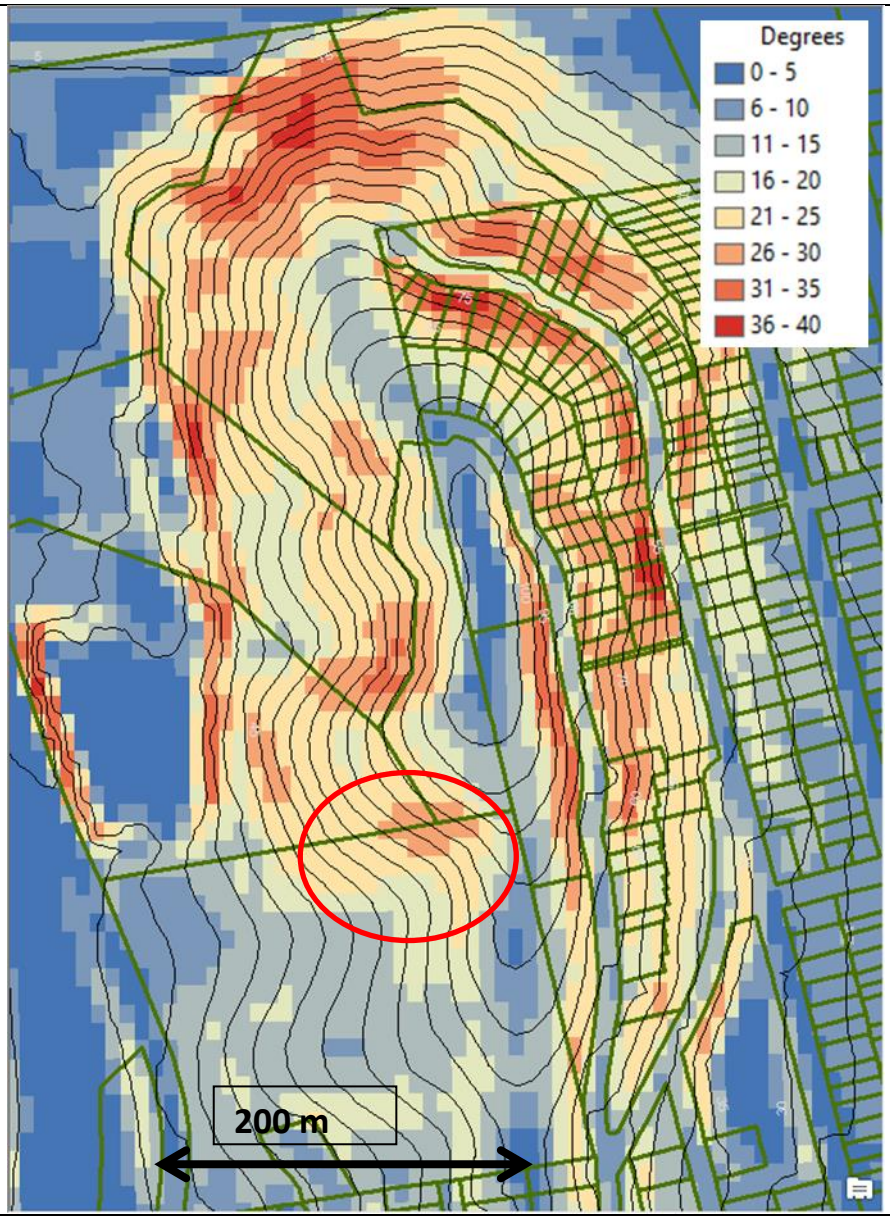
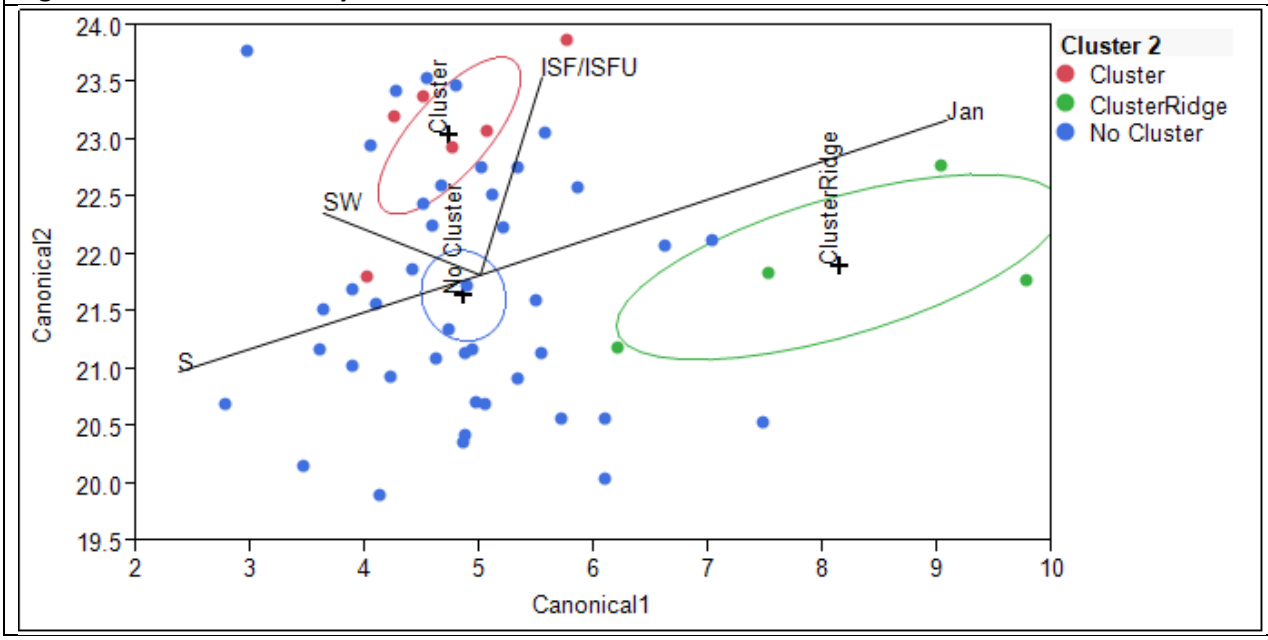


Slopes on the site are quite steep (>20°, up to 35+°), especially on the west and north slopes. The Cluster sites (the red circle) are on steep slopes (21-30°).

Figure 3 Discriminant Analysis of Cluster Sites



Counts: Actual Rows by Predicted Columns	Predicted Cluster	Predicted ClusterRidge	Predicted No Cluster
Cluster	6	0	0
ClusterRidge	0	4	0
No Cluster	3	8	31

The discriminant analysis (Figure 3) shows the environmental vectors in different directions, and the position of each photopoint color-coded by Cluster (red), ClusterRidge (green), and No Cluster (blue). Conclusions from this analysis include:

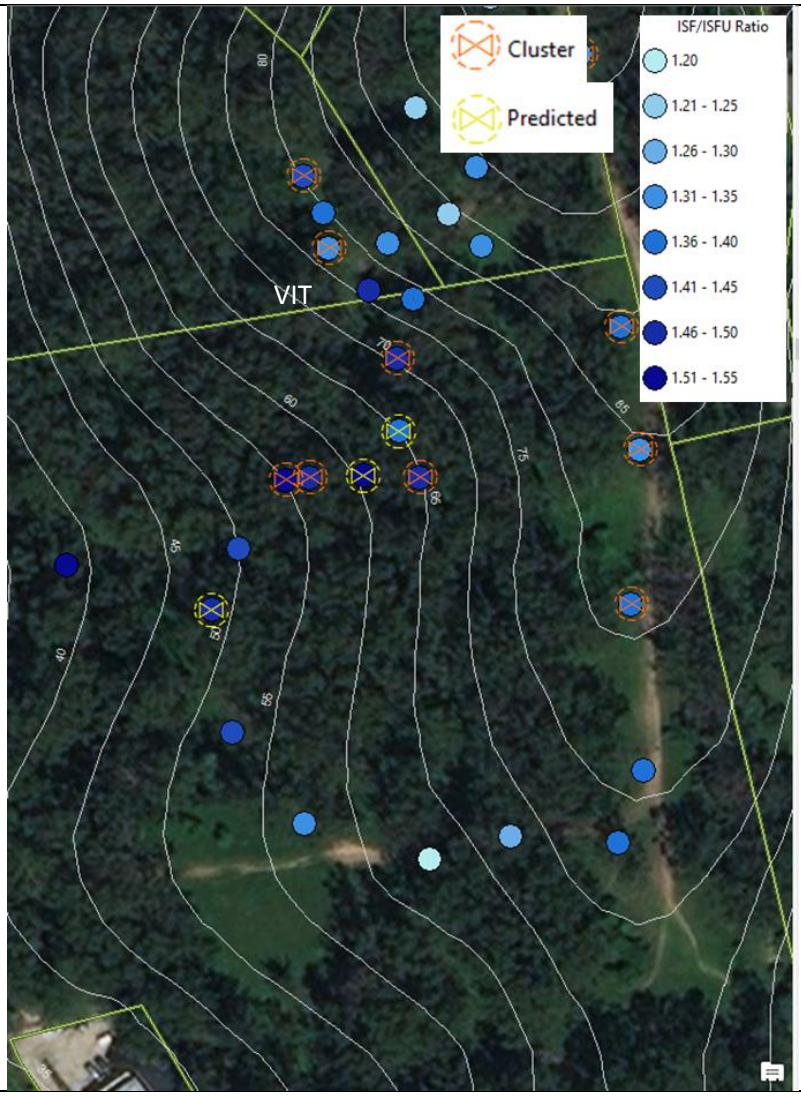
1) Jan (insolation) differentiates the ClusterRidge sites, which have higher values of Jan insolation than the other sites. Note that Nov, Dec, and Feb are highly correlated with Jan, so this represents well-lit sites at ground level.
2) The S (wind) vector runs opposite Jan, because exposure to S wind means that high zenith angles in the South octant are relatively open; these sky sectors coincide with winter sunpaths.
3) The main differentiation between Cluster and No Cluster sites is the ISFU/ISF ratio, which shows that monarchs prefer sites with higher visible sky overhead (low zenith angles)and lower visible sky close to the horizon (high zenith angles).
4) The SW (wind) indicates that the cluster sites are more likely to have some sky exposure to the SW, perhaps a function being on a steep SW slope. This could also suggest that exposure to

afternoon direct light (not calculated) could be an important factor when monarchs form clusters in the afternoon.

5) In summary, the Cluster sites are gaps in the forest that are well protected from most sides (ISFU/ISF ratio), and are somewhat open to the SW because of their position on the SW slope.

The matrix showing the predicted versus actual classification shows that all 6 Cluster sites, and all 4 ClusterRidge sites were correctly identified. Of the No Cluster sites, 3 were identified as Cluster – these 3 sites are near the Cluster sites on the SW slope (Map 7).

Map 8. Location of 3 Non Cluster Sites Predicted to be Suitable



Discussion and Recommendations

Monarch dynamics

The monarchs have occupied Albany Hill for entire overwintering seasons, indicating that the mix of canopy conditions provides suitable wind and light conditions. The aggregations are dynamic; monarchs begin the season on the ridgetop (ClusterRidge sites), likely attracted by high insolation. Following the first storms of the season accompanied by strong winds, they move down the SW slope when storm winds (generally southerly) are too strong. The structure of the forest in the Cluster zone consists of a series of openings surrounded by denser forest, allowing some insolation with adequate wind shelter. These cluster sites tend to have visible sky overhead with relatively few canopy openings toward the horizon (ISF/ISFU ratio), and moderate exposure to the SW (which may be related to afternoon insolation). Monarchs can move short distances to seek wind shelter within this zone. There appear to be several other sites within the Cluster zone that have suitable wind and insolation (Map 8). When extended periods of calm and sun occur mid-season, some monarchs may re-occupy the ClusterRidge area.

A clearer picture of the Cluster zone uses a Google Earth image from the dry season, so that the forest canopy gaps are more apparent with the dry grass below (Map 9).

Monitoring

We note the difficulty of the terrain and vegetation may make a full accounting of the monarch distribution and abundance difficult, especially small numbers that may be roosting in dense inaccessible forest. But the monarch monitors have captured the major dynamics, and their efforts have been exemplary. While ~1000 monarchs were observed in November 2017, a “New Year’s Count” in January 2018 estimated that 400 monarchs were still on Albany Hill (Mia Monroe pers. comm.). Similar drops in numbers between November and January are often observed at monarch overwintering sites.

Site Suitability

The Cluster sites are particularly dependent on an intact canopy to the S, SW, and W to shelter from winds. The hill itself and trees on it provide shelter from the SE There are a few Very Important Trees (VITs, which disproportionately contribute to habitat suitability). One of the largest trees, in particular (noted in Photos 2396 and 2399), provides key wind protection for monarchs clustering the northern opening (position shown in Maps 8 and 9, labeled as “VIT”).

The areas north of the summit around the road turnaround and on the W slope and N slope appear to have too dense canopies with low insolation, and are not attractive to large numbers of monarchs. Individual monarchs, but no large clusters, have been noted in these areas. We suggest consideration of creating appropriately sized canopy gaps by selective tree removal to let in more insolation while maintaining wind shelter, but no specific sites and configurations can be detailed at this time.

Forest demographics

The blue gum forest on Albany Hill appears generally healthy, with a variety of size and age classes. It is inevitable that some trees will fall over or die *in situ* over the next few decades. There appear to be sufficient saplings among the understory of poison oak (and other shrubs) to provide advance regeneration that can fill gaps created by treefall or death. If standing trees die near trails or pose a threat to neighboring houses areas (such as the undermined trees along Taft), it is appropriate to remove them following assessment by an arborist.

The live oaks are an important native component of the forest and should be encouraged where commensurate with maintaining high canopy of the Eucalyptus. Live oaks provide middle story and wind protection for the monarchs, as well a wildlife habitat/food for many native species.

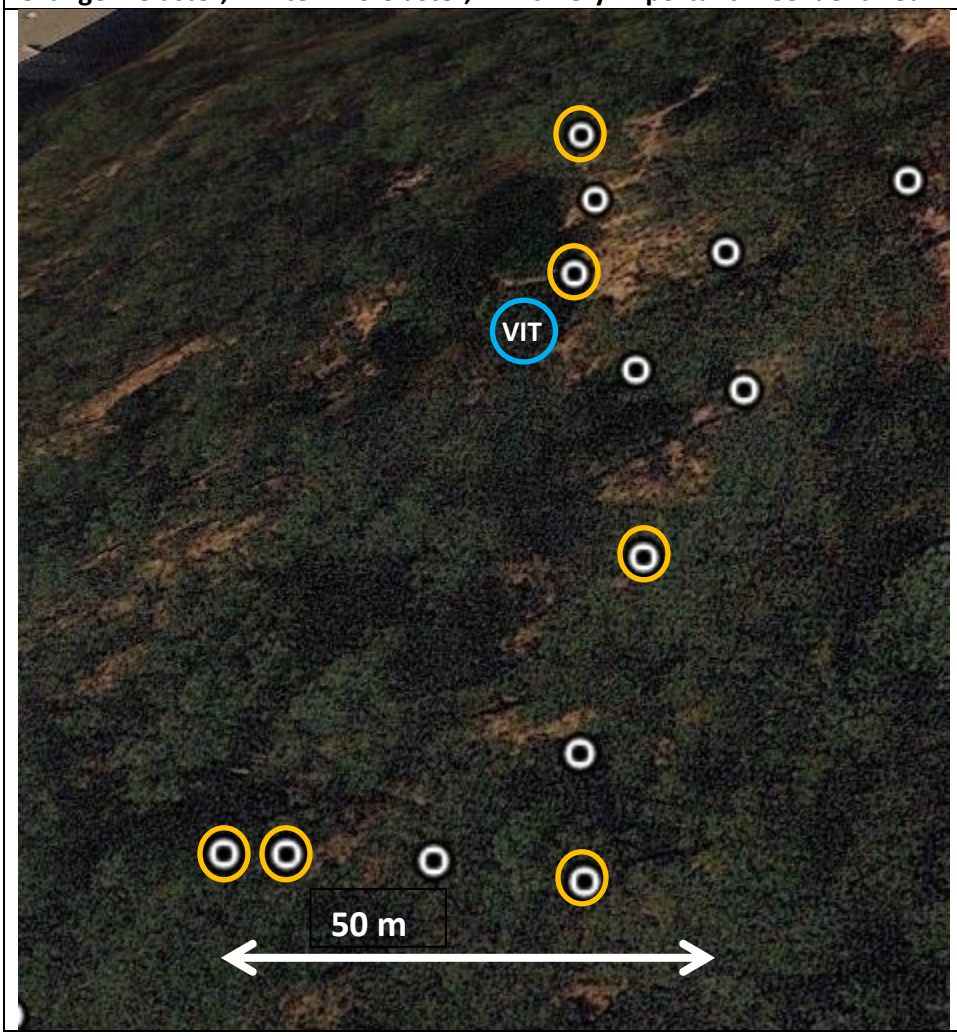
Invasive Species Management

There are non-native acacias in the understory, and these can potentially spread and choke out native understory shrubs and live oaks. There is one acacia that could be considered a VIT (just W of the opening with Photos 2396 and 2399, identified in yellow on those photos) because it provides wind shelter. At minimum, acacia seedlings and saplings should be removed where possible, but each larger tree should be carefully considered, especially those adjacent to cluster sites. Live oaks could replace acacias, but take many years to grow.

Use of This Assessment

This assessment provides baseline information and an initial description of how Albany Hill functions as overwintering monarch habitat. Some conceptual management recommendations are presented. At this point, it is not possible to evaluate specific management actions and development projects without additional details on the scope and configuration of impacts to the forest canopy and understory.

Map 9. Photopoints on Google Earth Image.
Orange = Cluster, White = No Cluster, VIT is Very Important Tree identified in Photo 2396



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