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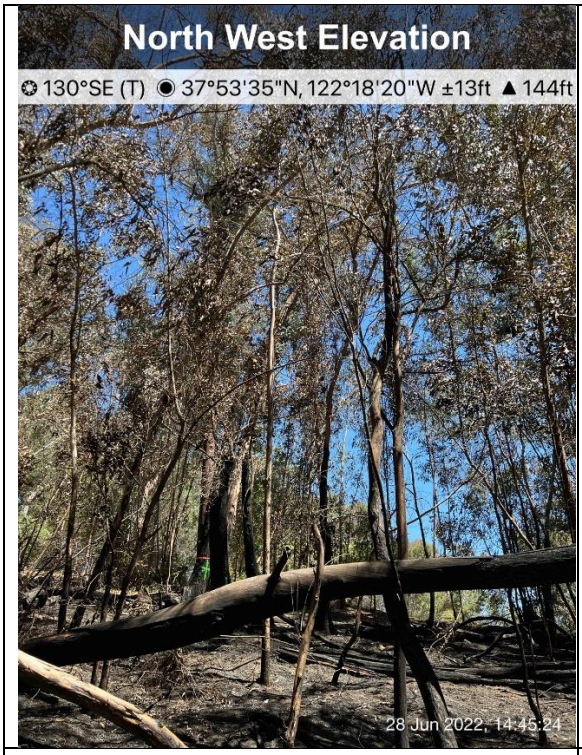
Assessment of Drought and Fire Impacts and Fuels Managment on Monarch Butterfly Habitat on Albany Hill



Burnt trees in fire perimeter below crossroad.

Monarchs clustering near summit November 3, 2022

Summary

Albany Hill supports overwintering monarch butterflies because of specific forest canopy structures that provide suitable wind shelter and insolation (sunlight). The recent drought (2020-2022) has caused reductions in canopy cover as drought and associated disease have led to loss of leaves, branches, and entire trees. Proposed management of fuel loads could also affect monarch habitat. In June 2022, a small (1.4 acre) fire starting along Pierce Street penetrated key wind shelterbelt areas, highlighting the need for a systematic assessment of fire risks, mitigations, and the habitat needs of monarch butterflies.

Topics covered:

1. A review and new analysis of monarch habitat on Albany Hill, using a recent LiDAR flight to describe canopy structure, in addition to hemispherical photographs (hemiphotos).
2. An assessment of the immediate effects of the 2022 fire, and longer-term view of fire recovery and monarch habitat
3. An assessment of the effects of canopy dieback and recent recovery on monarch habitat suitability
4. An assessment of fuels management options that balance fire management needs and monarch habitat suitability.
5. Long-term habitat management issues, including tree planting and working across property lines.

Summary and Conclusions

1. The blue gum forest on Albany Hill serves as overwintering monarch habitat because it contains sites that are wind sheltered but receive sufficient insolation. The core overwintering microsites are in two areas. First is a small meadow on the W slope (Upper Meadow) that is sheltered by surrounding trees and the hill itself, where monarchs cluster at low heights. Second is an area in a topographic "bowl" on the SW slope (SW Bowl) and higher cluster sites are protected from SW and W winds by a dense shelterbelt of small trees just below the crossroad, by trees S of the large SW meadow, and the hill itself to the E. 3-D views and profiles from the LiDAR flight clarify the vulnerabilities in addition to hemiphotos.
2. The 1.4-acre fire was primarily on the lower slopes and penetrated a critical wind shelterbelt below the crossroad. Some spotting higher up the hill west of the crossroad impacted understory and scorched the bases of two key trees. A single upslope tree ignited from flying embers and was cut down to stop fire spread. There was considerable scorching of overstory foliage in the shelterbelt. Several hazard trees at the base of the hill have been removed for safety reasons. Removal of other live but damaged trees farther upslope should be conservative about maintaining wind shelter. The impacts on the shelterbelt will only be apparent in coming months when trees and saplings either are confirmed dead or resprout. There is already evidence of substantial resprouting from stems and trunks within the burnt area.
3. The effects of canopy dieback and subsequent epicormic sprouting following soaking rains in October and December 2021 are still playing out, but the

trajectory is moving toward re-establishing canopy cover in most areas. The death of entire trees and large branches poses safety hazards near trails. Standing dead trees and branches do not provide monarch habitat and will eventually fall and potentially damage live trees. Timely removal after monarch season (Oct-Mar) is recommended.

4. The urban interface of Albany Hill requires management of fuel loads. The main fuels management options are lifting of ladder fuels and forest floor management (mowing grass). The standard prescription of s understory clearing along property lines would destroy the integrity of "bowl" cluster area, as the property lines cut directly through the aggregation site. Much of the urban boundaries on the S and W have been treated for ladder fuels. The crossroad provides an important interior fuel break that served well in the 2022 fire – only one finger of fire penetrated upslope but became a ground fire because there were few ladder fuels. Most importantly, the shelterbelt below the crossroad must be maintained in the short-term and long-term. Fuels treatments (i.e. 100' ladder fuels treatment) along the edges east of the high rises would not affect monarch habitat.
5. Maintaining wind shelter in the long-term will require additional plantings. Replacement of tall blue gums that have been and will be removed will likely require likely use of non-native eucalyptus, but it may be desirable to use more drought resistant species, such as *Eucalyptus diversicolor* (karri) which is from SW Australia in a Mediterranean climate.
6. The favored tree species for new middle story plantings is coast live oak, which currently thrives on Albany Hill and can grow to middle story heights. It is relatively fire resistant (a favored tree for shaded fuel breaks) with appropriate understory management for ladder fuels. Where additional wind shelter is needed, such as in the middle story of the shelterbelt, coast live oaks are the favored tree to replace eucalyptus and acacias. Toyon is another species that can fill understory gaps. The key consideration for understory and middle story plantings is fuel continuity, both horizontal and vertical versus the need for ground to upper canopy wind shelter.
7. Repeat hemispherical photography showed that the effects of canopy dieback are being ameliorated by extensive epicormic sprouting. This transition had led to a densification of foliage close to the trunks and branches, and loss of diffuse foliage at the tips of branches which results in longer periods of fill direct insolation as compared to previous periods of dappled light. This is a transient effect, and as the canopies fill in and some epicormic sprouts are lost, there should be a convergence to prior conditions.
8. A transect of profiles from near the base of the Hill through the overwintering site and to the crest shows important structures, including the dense shelterbelt below the crossroad, the cathedral-like structure of the SW Bowl, and the discontinuous canopy near the ridgeline.

Specific Management Recommendations

SW Bowl cluster zone

1. Maintain the understory and middle story structures surrounding the SW Bowl aggregation zone for wind shelter (see Map 2) This necessitates accepting some ladder fuels. The key areas are delineated in Map 2 in the blue outline.
2. Maintain the existing cleared understory within the SW cluster zone, as well as the cleared crossroad zone. The low fuel loads here were critical in minimizing the damage from the fire spotting across the road. These areas can be mowed in late spring to reduce grass fuels.
3. Remove piles of fallen dead materials, especially branches with fine fuels. Applies throughout the site.
4. Allow regrowth/resprouting of the understory/middle story shelterbelt trees to refill the gaps created by the fire.
5. Maintain overstory trees below crossroad, down to Pierce Street. Minimize removal of live trees for fire damage within ~300' of the cluster trees..
6. Plant new live oaks and nurture live oak saplings in key areas to fill in gaps in wind shelter around the SW Bowl.
7. Fill in low gaps with toyons
8. Keep live canopy trees unless truly in danger of falling
9. Allow trees with canopy die off to resprout and reestablish canopy cover.

Ridgetop

1. Remove dead stranding trees because of hazards to visitors and surrounding trees and shrubs
2. Remove dead hanging branches where they threaten high use areas like trails, benches, and openings.
3. Maintain a horizontally discontinuous patchwork of understory and middle story trees and shrubs, to ensure some wind shelter while reducing fuel continuty.
4. Mow tall grasses along the ridgetop road to maintain a fuel break.

Upper meadow cluster zone

1. No actions appear to be necessary at this point, except to maintain the integrity of the wind shelter on the SW, W, and NW sides of the meadow.

Forest edges

1. At the edges of the forest, most of the understory/ladder fuels have been cleared. Maintain these cleared areas.
2. The edge east of the high rises can be cleared of ladder fuels, since the buildings themselves provide wind shelter along those edges.
3. Interior shelterbelts are sufficient to protect the cluster sites from wind, i.e. the edge does not need to be solid foliage.

Monarch Habitat on Albany Hill

Monarchs seek wind-sheltered microsites that receive moderate amounts of sunlight. These conditions are met on the SW slope of the hill, in a small topographic bowl "SW Bowl," and in a grassy clearing to the north, below the crest (Upper Meadow on Map). Monarchs use trees along the crest of the hill only when weather is mild, and winds are low. The June 2018 habitat assessment (link)describes more about how and why monarchs use Albany Hill as overwintering habitat.

https://www.albanyca.org/home/showpublisheddocument/43371/637136609082570000

The taller trees low on the hill, below the crossroad, provide a primary windbreak. But prevailing westerly winds penetrate the open middle story and understory at the base of the hill. A dense shelterbelt of small eucalyptus and other trees growing just west of the crossroad provides the critical windbreak for the SW bowl.

Albany Hill itself provides good wind shelter from the north and east. Southerly wind shelter is provided by trees surrounding the Lower Meadow.

Monarchs will cluster along the ridgetop during periods of calm sunny weather but leave when storms generate strong southerly winds. The open canopy along the ridgeline cannot provide enough wind shelter for the butterflies to remain on the ridgetop during strong southerly and easterly wind events.

A more comprehensive assessment of the key monarch habitat from the LiDAR flight and repeat hemiphotos is presented below.

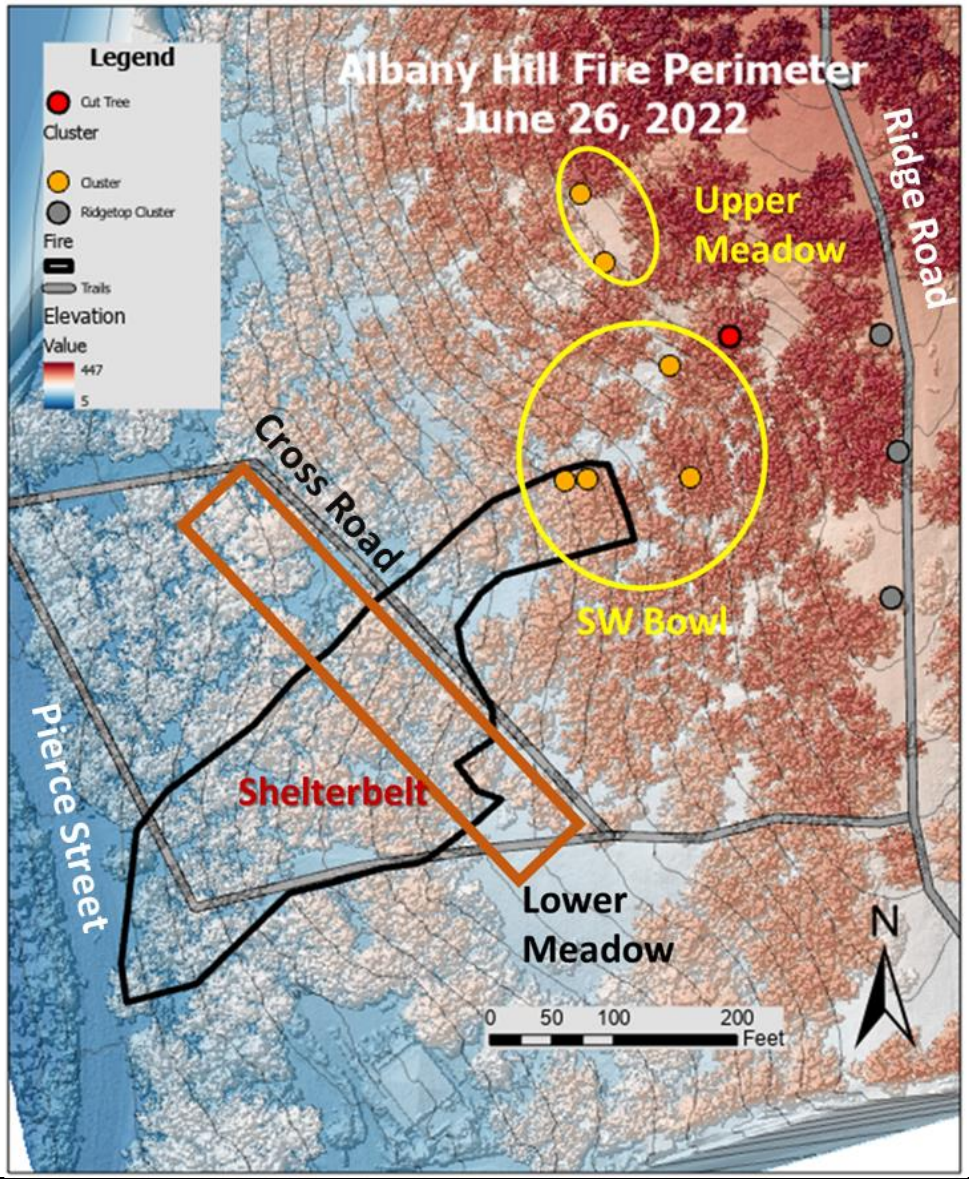
Monarch cluster near summit November 3, 2022

Fire Perimeter and Monarch Habitat (Map 1)

Key features of the fire perimeter and monarch habitat include:

1. Monarchs cluster in the "SW Bowl" and the "Upper Meadow"
2. The "Shelterbelt" provides understory and middle story wind protection.
3. The 1.4-acre fire penetrated the shelterbelt along a 150-200' front.
4. The fire jumped the crossroad and burned into the SW Bowl cluster zone in the understory, including scorching the base of two cluster trees.
5. A tree was cut down (red dot) because it caught fire

Map 1. Fire perimeter, cluster sites, and canopy elevation (blue to red gradient)



Fire impacts on Monarch Habitat - Photos

The fire penetrated the key shelterbelt below the crossroad, and damaged wind protection. A set of photos was taken on June 22, 2022. The scorched canopy (Photos 1, 2, 3, 6) will open with leaf fall, and allow more W and SW wind into the SW cluster zone at middle and overstory heights.

The understory is already open to the W of the shelterbelt (Photo 4). But the taller trees do provide important overstory wind shelter for the cluster zone upslope.

The loss of stems and understory (Photos 2, 3, 7, and 9) will allow wind to penetrate the understory of the SW cluster zone. Resprouting of these trees is unknown at this point – the shelterbelt may reform in a few years if enough trees resprout. But the small size of the stems means that they may be more vulnerable to fire. These small trees need to be examined in coming months for signs of survival (see September photos below).

The fire got into the SW cluster zone as a ground fire and scorched the trunks of two key trees (Photo 5) but did not ascend into the canopy. These trees *should not be removed* unless they die. They may pose a hazard to people on the crossroad, so access to this short stretch of trail could be limited if the risk is deemed too high.

The loss of the large tree higher on the hill that was cut down to prevent fire spread opens the sky to the NE of the SW cluster zone. However, the hill itself provides good wind shelter from this direction, so it may not be a major issue with monarchs in the cluster zone.

The Upper Meadow cluster zone does not appear to be affected by the fire.

The crossroad served as an effective fuel break, and the clear understory in the SW cluster zone limited fire impacts and afforded containment before the fire could ascend the hill. The one exception is the spotting that ignited the upper tree that needed to be cut during control efforts. The presence of fire hydrants along the crest greatly enhanced control efforts and limited damage to the monarch habitat.

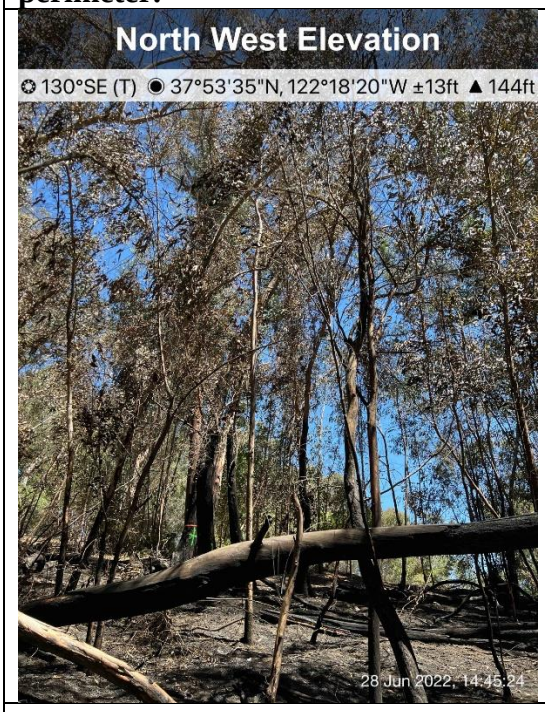
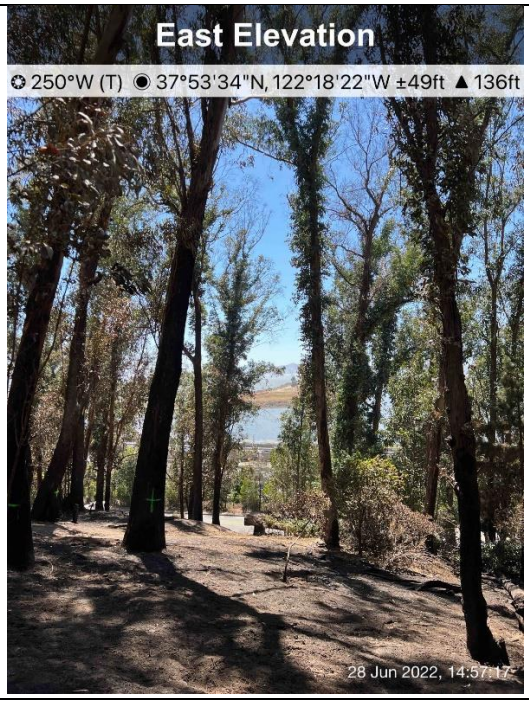
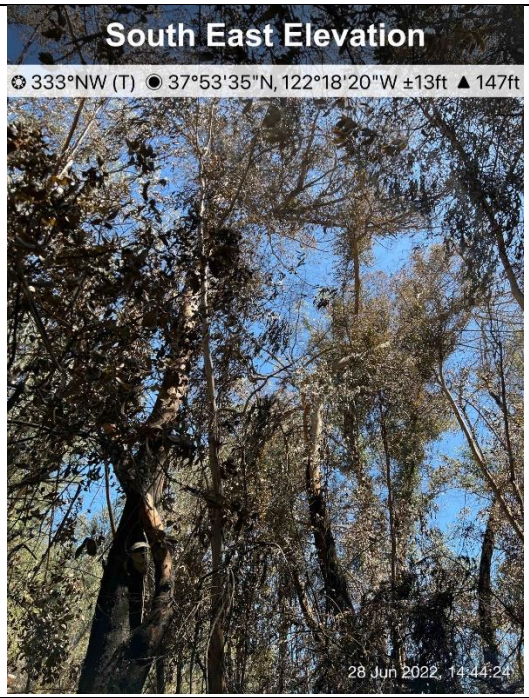
Photos taken by M. Cunningham on September 22, 2022, show some initial resprouting both from stems (Photo 10) and from basal stumps (Photo 11). Some live foliage survived and is being complemented by stump and stem resprouts (Photo 12). Much dead scorched foliage has been retained through September, and provides windbreak functions for now (Photo 13), but will eventually drop.

A more comprehensive assessment can be made after the status of scorched trees becomes more apparent and fall rains and wind lead to dead foliage dropping. Because all the fire impacts were on the 11-acre private parcel, arrangements with the City Albany need to be made for coordinated management of post-fire effects.

Post fire photos

1. SW view from cluster zone to crossroad and shelterbelt. Note scorched tree crowns in shelterbelt and scraped firebreak at lower right.

2. View N from center of fire perimeter.

3. SE view of scorched canopy and burnt understory from center of fire perimeter.	**4. W view showing open forest below shelterbelt.**
	
5. Two large trees in SW cluster zone (orange tape) that should be retained unless fire damage is too severe.	**6. SE view of scorched canopy near crossroad**
	

7. E view of burnt stems and canopy in shelterbelt. The resprouting of these trees will determine the integrity of the shelterbelt this coming monarch season. Note unburned ground in background where fire was stopped by the crossroad.

8. Hemispherical photo of cut tree near top, looking SW toward cluster zone.

9. Panorama looking SE from center of fire perimeter. Crossroad just barely visible at left lower corner of panorama.

10. Stem resprouts from small eucalyptus within the shelterbelt. October 2022 Photo by M. Cunningham

11. Basal resprouts within the burnt shelterbelt. October 2022 Photo by M. Cunningham

12. Basal and trunk resprouts, among dead small trees in shelterbelt area. October 2022 Photo by M. Cunningham

13. Dead foliage still remaining on trees in shelterbelt. October 2022 Photo by M. Cunningham

LiDAR analysis of wind shelter and ladder fuels

The LiDAR flight in February 2022 provides a 3-D map of the forest canopy at high density (~50 pts/m^2). It allows for examination of canopy structures, including canopy height, density, gaps, and importantly for this report, ladder fuels and windbreaks. This analysis of the LiDAR data focuses on delineating ladder fuels and identifying key understory and middle story areas that provide key windbreaks for the cluster zones.

The LiDAR derived map below (Map 2) shows important wind shelter zones, as the height of the 25th percentile of foliage distribution (the height below which 25% of the non-ground LiDAR reflections occur). The **thick red contour line** represents the areas where the 25th percentile is between 21' and 40' height from the ground. Areas with red contours inside the 21-40' contour have dense understory foliage where there are small eucalyptus trees, live oaks, and shrubs. This metric corresponds well to low and mid-story vegetation observed from the ground and with hemiphotos.

Note how discontinuous that contour is – gaps where the 25th percentile canopy height is greater than 40' (thin white and blue contours) have quite open understory and middle story, with most (>75%) of the canopy above 40'. A good example is the "cathedral-like" structure around the SW cluster trees.

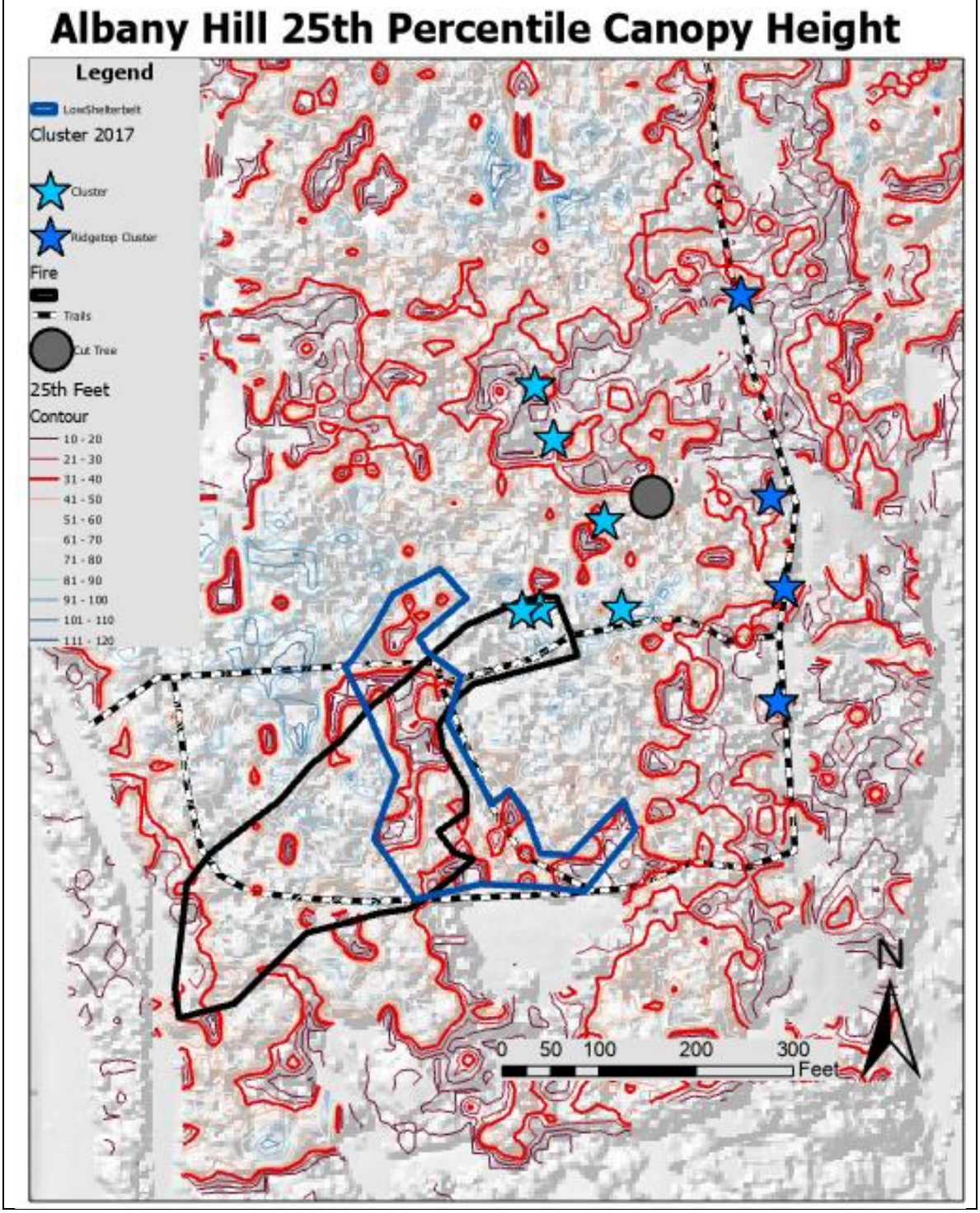
The blue line surrounding the SW Bowl indicates an outline of the main shelterbelt protecting the cluster zone from W, SW, and S winds. The area around the SW bowl had a solid shelterbelt below the crossroad extending from the ground to the canopy top as of the LiDAR flight date. The fire burned through much of that shelterbelt, stopping at the crossroad mostly except for a small finger of ground fire penetrating into the cluster zone. However, currently (as of October 2022) the shelterbelt is still functional, as scorched leaves still remain on the trees (i.e., Photo 1). One key area of shelterbelt that did not burn is at the N end of the crossroad, which provides protection from W wind penetrating along the road corridor.

Other key wind shelter spots around the SW bowl include the N edge of the SW Meadow, where a few live oaks and toyon provide lower canopy wind protection, with some gaps. S winds can penetrate through the thin row of pine trees just N of the neighborhood (see oblique view Map 3), cross the SW meadow, and enter the SW Bowl zone.

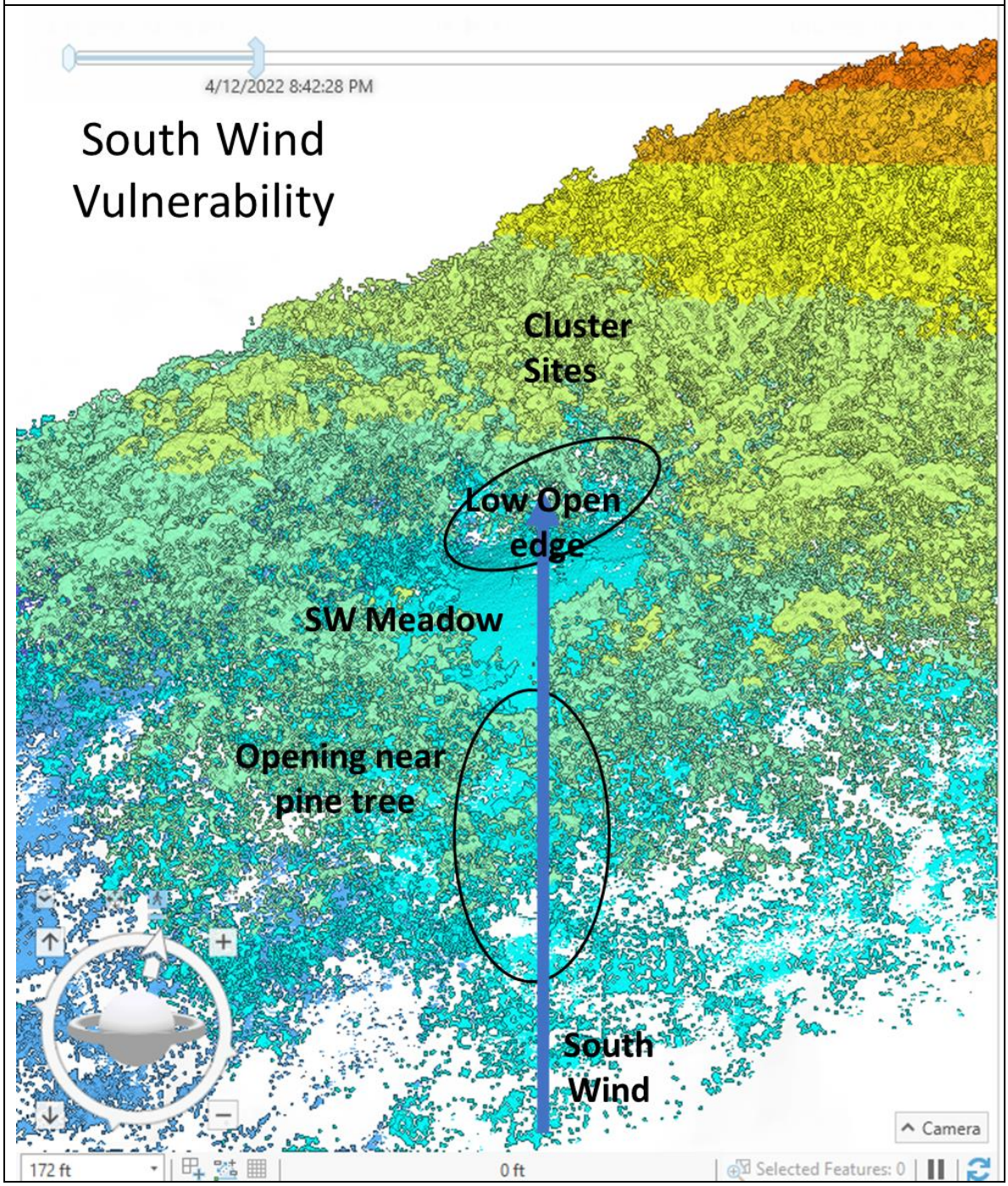
The Upper Meadow (two northernmost light blue cluster stars) is well protected by low foliage around the edges. Monarchs cluster low (10-20') on the edge trees here to be out of the wind.

The hill itself provides much of the shelter of the cluster areas from NE, E, and SE winds (see Wind Exposure section below Maps 4-6). This sheltering effect was also documented in the fire simulations (Draft Fuels Management Plan).

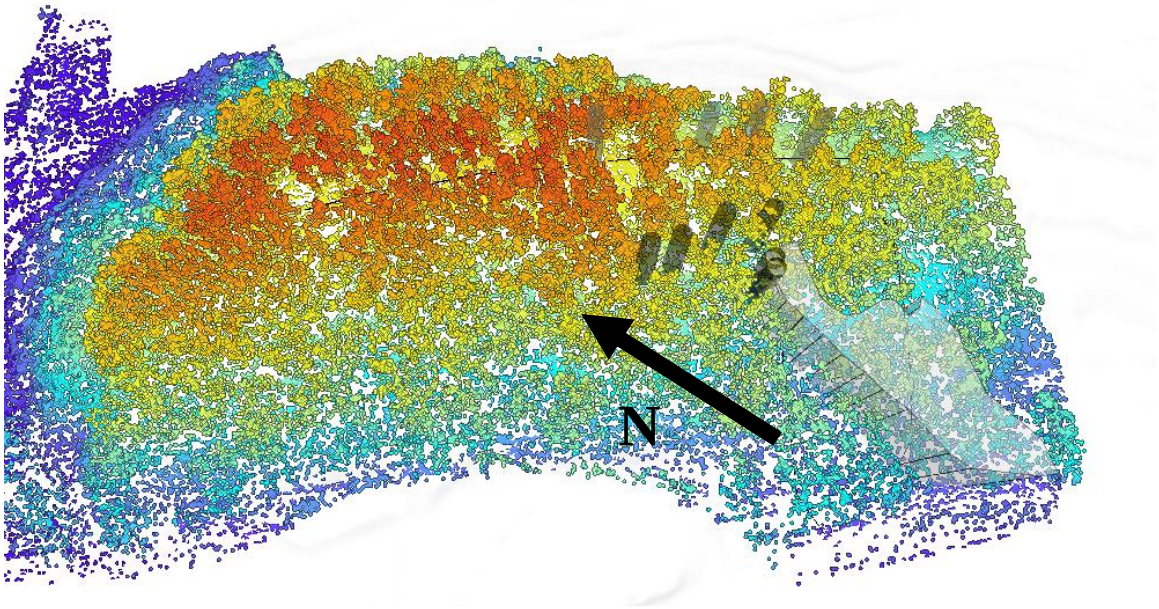
Map 2. Key wind shelter areas, represented by 25th percentile canopy height (thick red contour surrounding darker contours). Key shelterbelt area is the blue line.



Map 3A. Oblique view from S toward the SW Bowl cluster sites. Elevation coded by color.



Map 3B. Oblique view of entire Hill. Monarch cluster sites are cylinders -lighter ones along the ridgetop are the transient sites, darker ones are the sites where monarchs go following inclement weather



Paired Hemiphotos (see Appendix for Interpretation

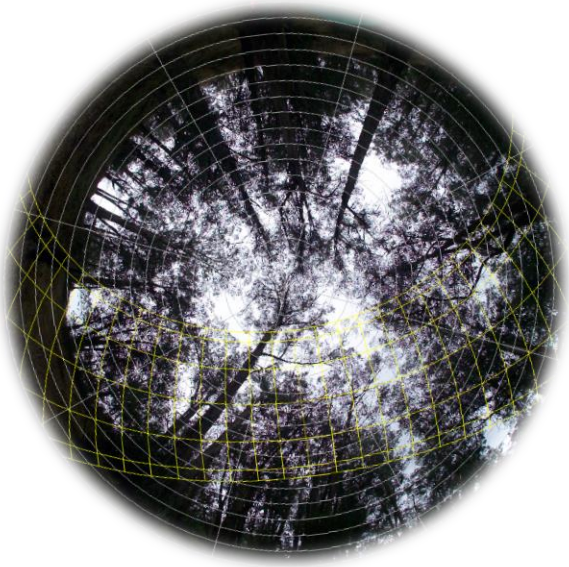
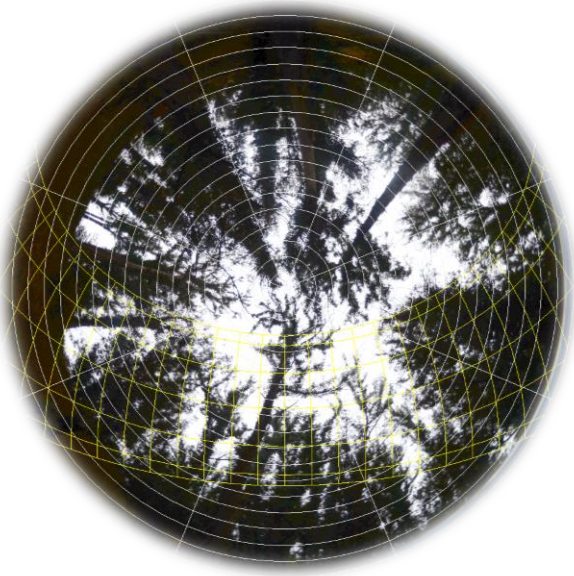
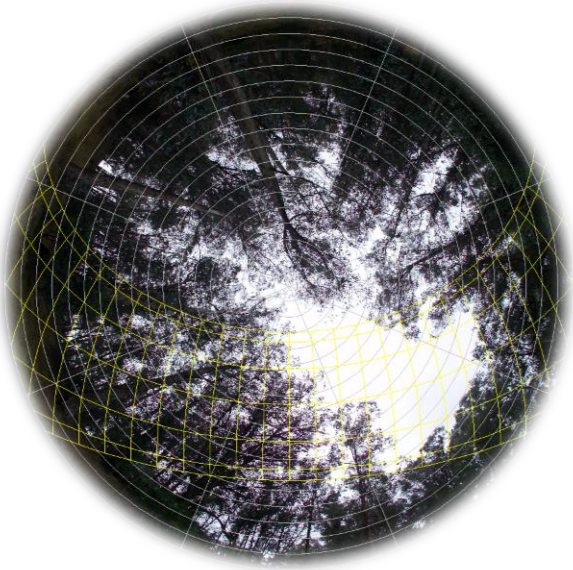
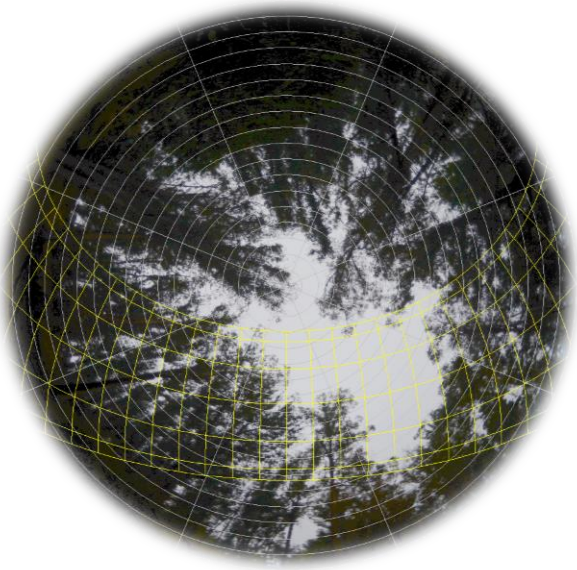
Twelve direct comparisons of hemiphotos in the same sites in 2018 and 2022 show how the forest canopy has changed with drought stress and disease. Note that exact relocation of photo sites in dense forests using GPS is problematic, so there may be some differences between the photos due to location.

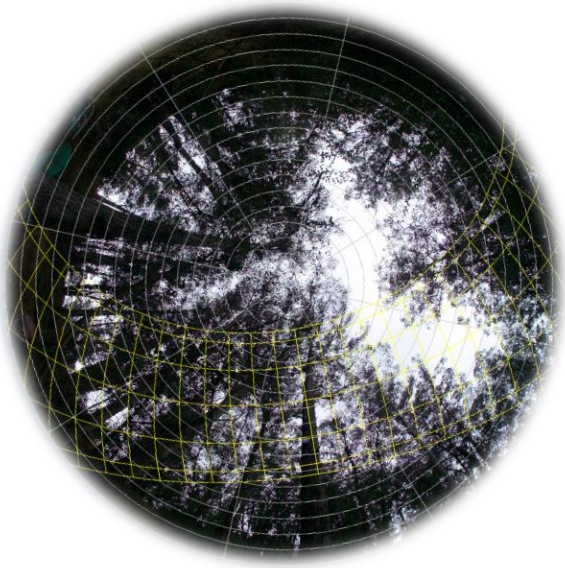
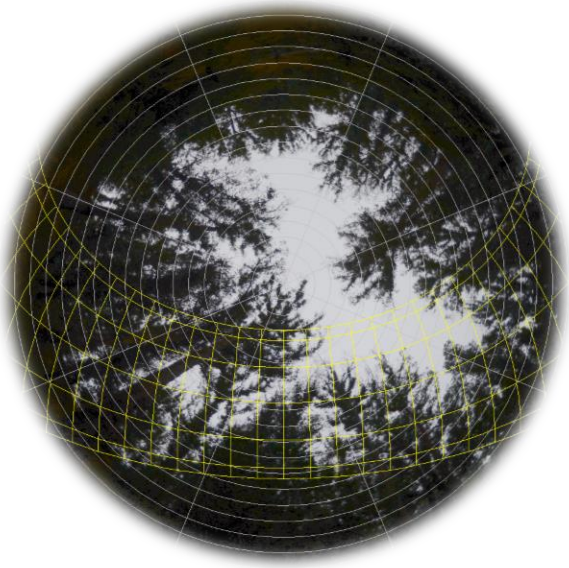
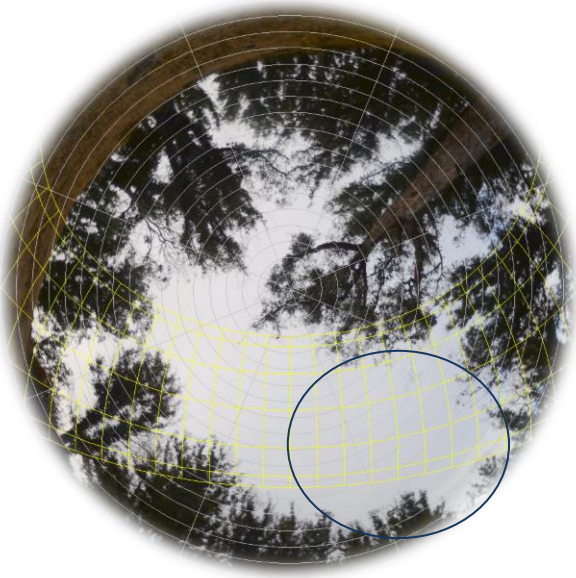
The most striking change has been the transition from branched spreading live foliage to concentrated epicormic sprouting from larger stems and branches, with bare dead branches extending outward. The result of this structural change – loss of diffuse foliage on outer branches - is that the areas of open sky are more continuous, but the general structure remains, with longer periods of direct sunlight, as opposed to dappled. There is less effect close to the horizon than overhead.

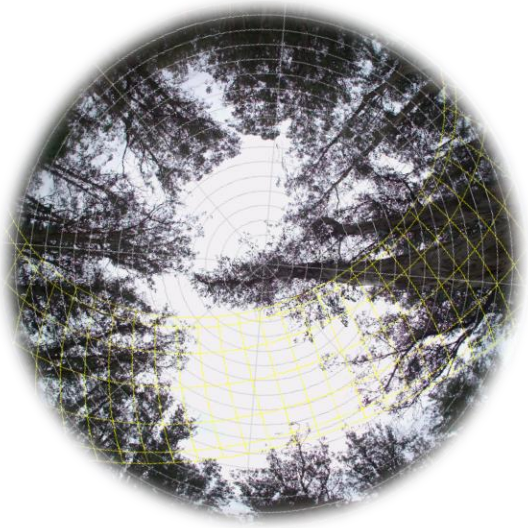
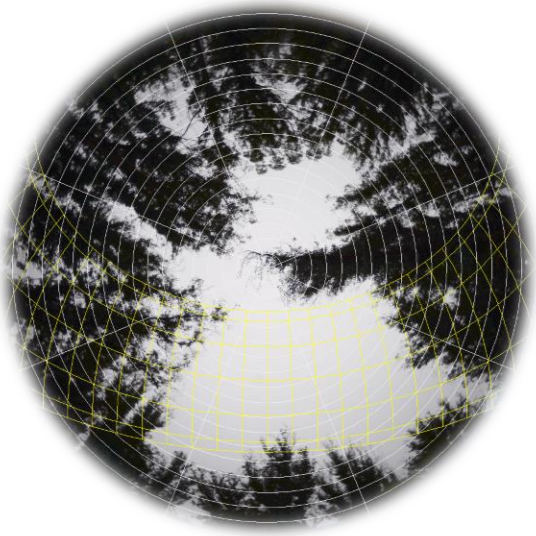
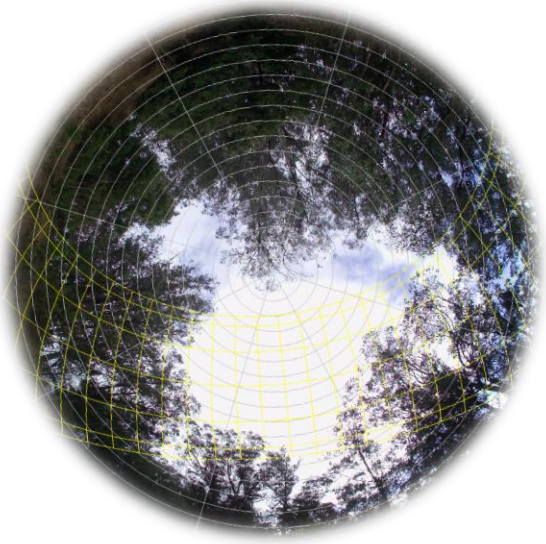
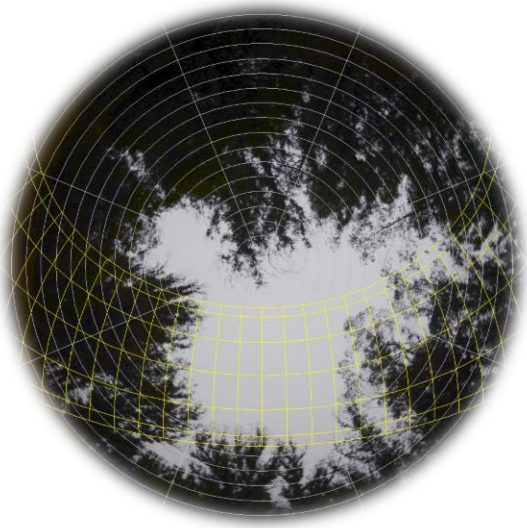
The soaking rains of October and December 2021 allowed for the recovery of the forest canopy. But this is a transient effect, as some of the epicormic sprouts will develop into longer branches. It is evidence of the resiliency of the eucalyptus forest, that such a recovery of canopy is so strong.

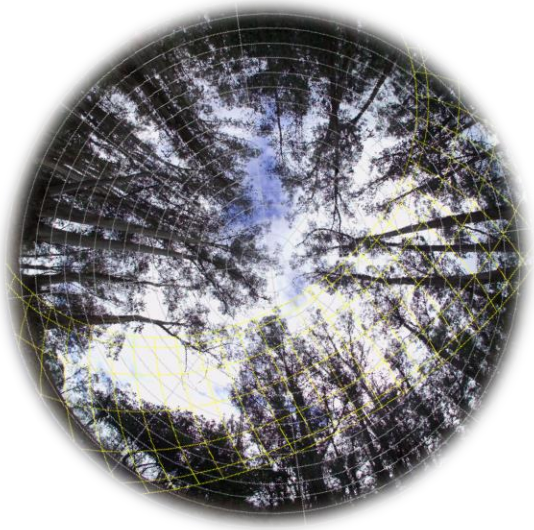
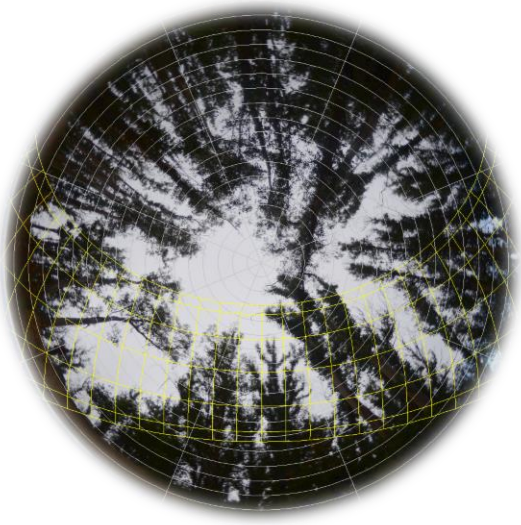
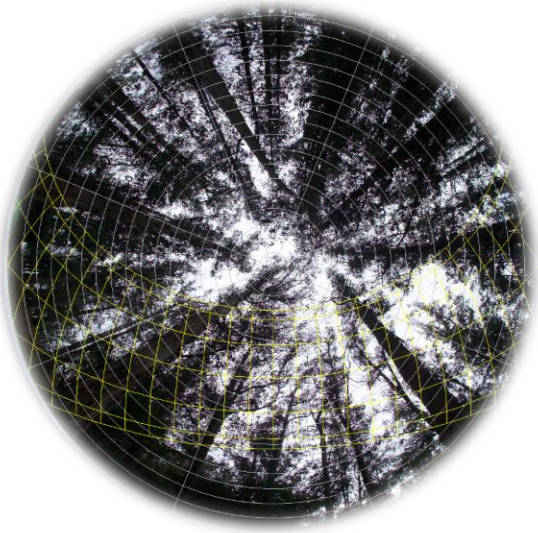
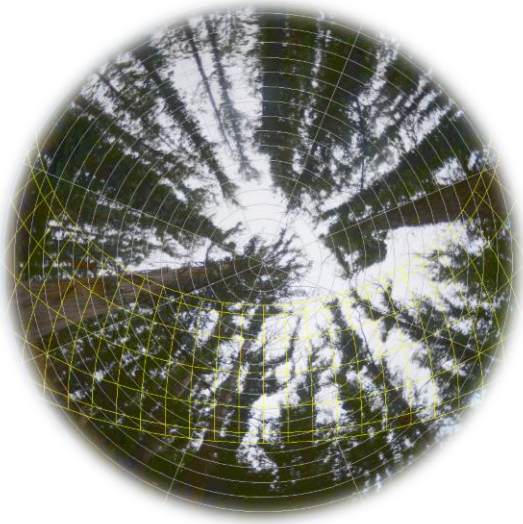
In terms of fire effects, one large tree on the upper slopes caught fire and was cut down. This tree shows prominently in Hemiphoto pairs 2403/864 and 2393/861.

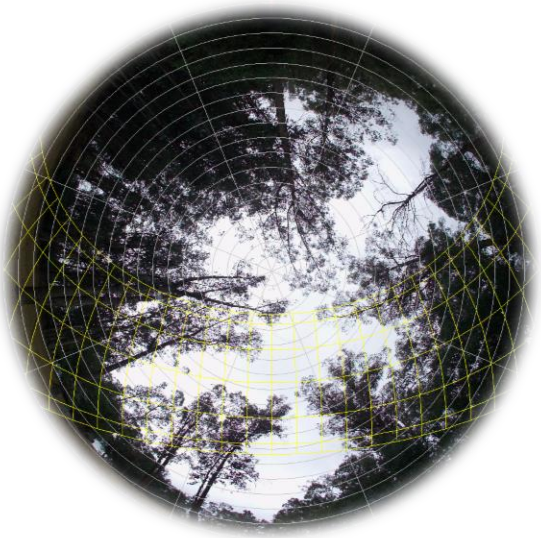
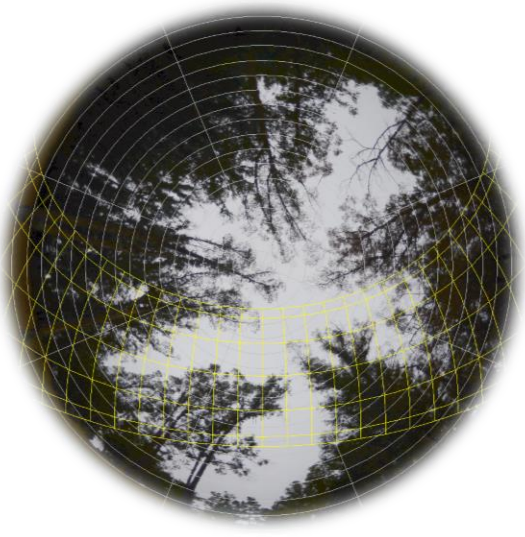
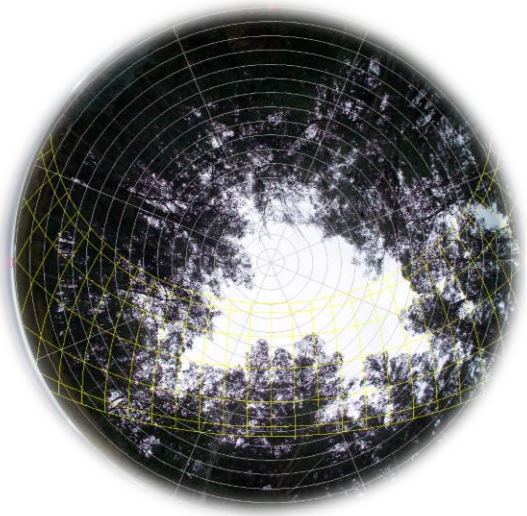
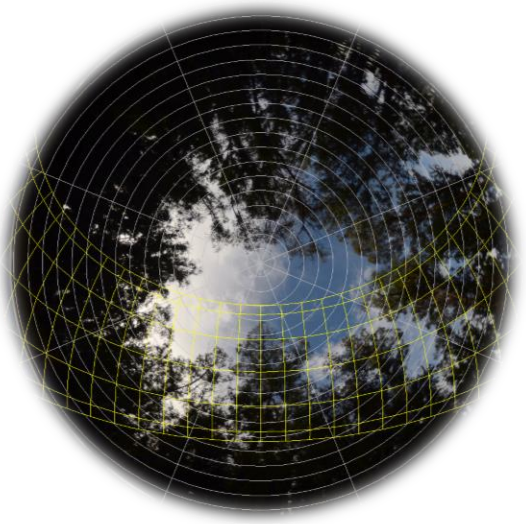
Hemiphoto Comparisons

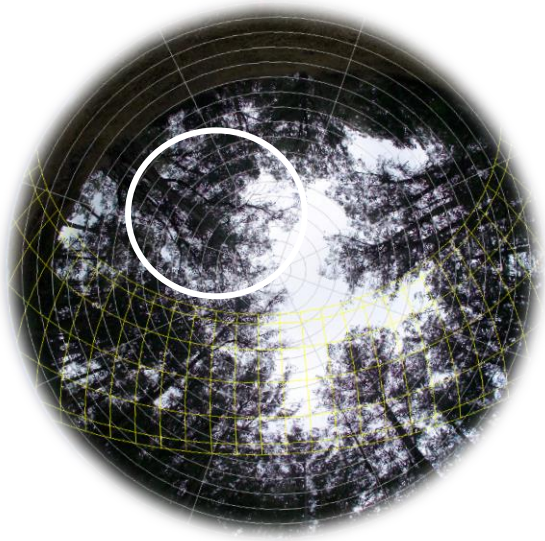
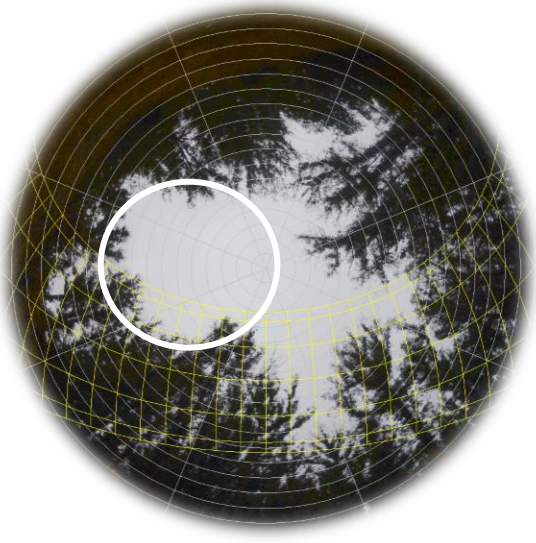
2018 Photos	2022 Photos
2018 2391 Cluster Site. Note small gap to SW that leads to the large SW meadow.	2022 858 Loss of diffuse overhead foliage, replaced with epicormic sprouting.
	
2018 2387 West of Cluster site. Large overhead gap to SW is along crossroad.	2022 852 Note loss of diffuse overhead foliage, replaced with epicormic sprouting, slightly more open to S with loss of understory but SW shelter still intact
	

2018 2392 Within lower cluster zone	2022 856 Loss of diffuse canopy and replacement with epicormic sprouts
	
2018 2403 The circled tree caught on fire and was cut down during firefighting	2022 864 Note the loss of the tree to the SSW and epicormic sprouting
	

2018 2375 Along Ridgetop, transient cluster site	2022 829 Epicormic sprouting
	
2018 2399 Upper Meadow Cluster Site	2022 835 Epicormic sprouting, little change
	

2018 2410 Near summit	2022 876 Epicormic sprouting
	
2018 2421 Dense forest N of Taft Circle	2022 885 Epicormic sprouting
	

2018 2384 Along crossroad Shelterbelt to SW	2022 848 Shelterbelt still intact
	
2018 2386 On lower road to Pierce, opening to W where road goes below arching canopies	2022 868 Little change form 2018
	

2018 2393 Cluster site in SW Bowl Circled tree caught on fire and was cut during firefighting	2022 861 Loss of large tree to ENE and epicormic sprouting
	
2018 2376 Ridgetop Cluster	2022 840 Note absence of tree from drought and disease. Loss of branch-tip foliage and epicormic sprouting
	

Wind Exposure

Wind exposure is a primary determinant of monarch habitat suitability. Two approaches are used to quantify wind exposure: 1) hemiphotos from below the canopy (Maps 4 and 5), and 2) Wind Ninja, which simulates wind over complex terrain, in this case defined by the outer canopy surface (Map 6). The WindNinja analysis, at a grid resolution of 10 meters, shows the sheltering effect of the hill itself and the outer canopy envelope, and applies only to the canopy surface, not the interior of the forest. For example, WindNinja can estimate relative wind exposure at a forest edge but cannot be applied to the understory behind the edge. Both analyses provide important insights into monarch habitat, albeit at different scales.

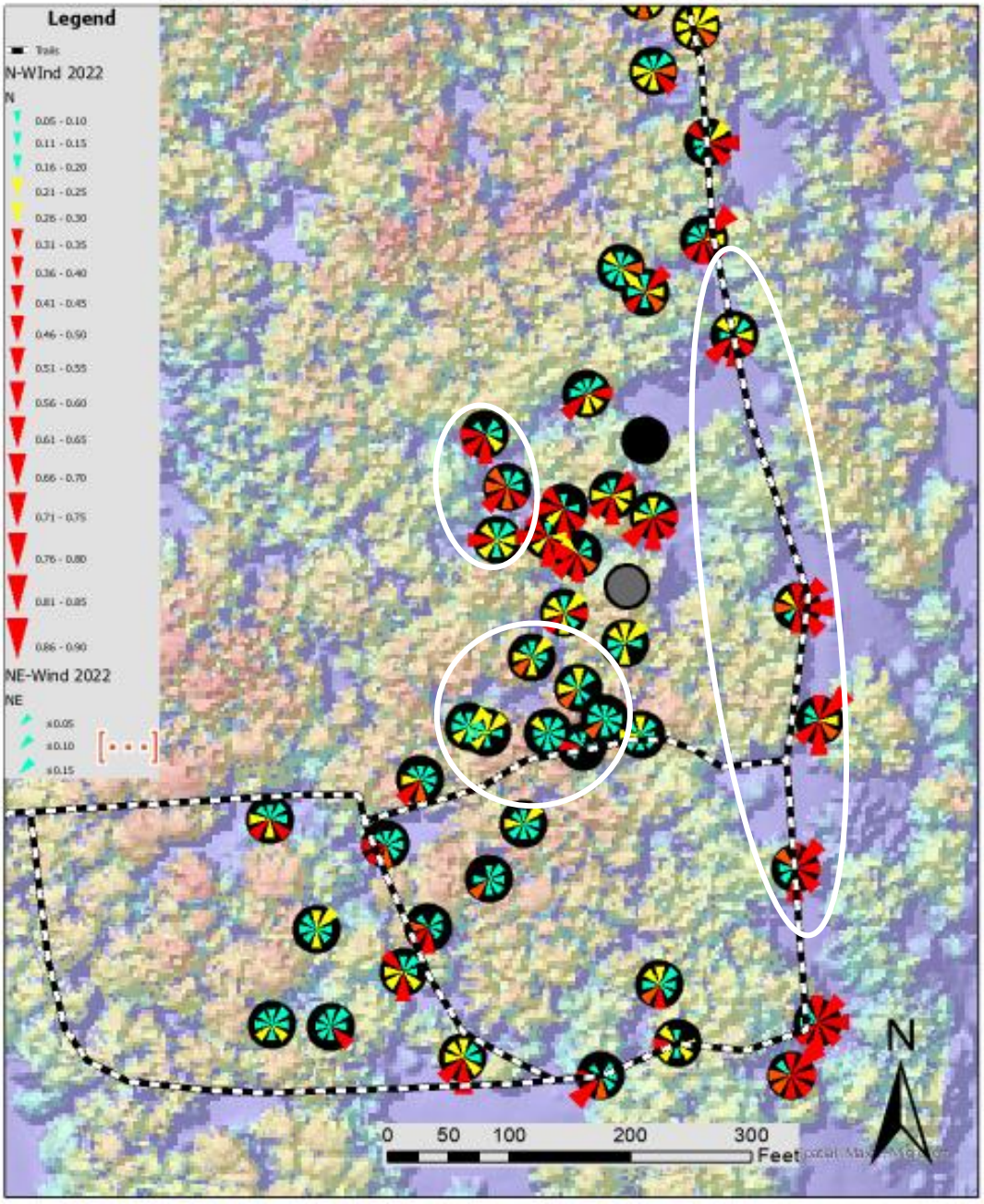
The hemiphoto analysis quantifies visible sky exposure in eight directions, as a proxy for wind penetration (see methods). Map 4 includes all the monarch cluster sites. The transient ridgetop cluster sites have high wind exposure from several directions (many large red arrows). In WindNinja, this zone has high exposure to NE, E, SE, S, and SW and lower exposure from W, NW and N. Monarchs leave these sites during and following high winds, which can come from any direction.

The SW Bowl has low wind exposure in hemiphotos from most directions (many cyan and yellow arrows). In WindNinja, the SW Bowl has low exposure from SE, E, NE, and N. and highest exposure from the SW, W, and NW. The high exposure at the outer canopy from westerly directions is ameliorated by the low exposure below the canopy.

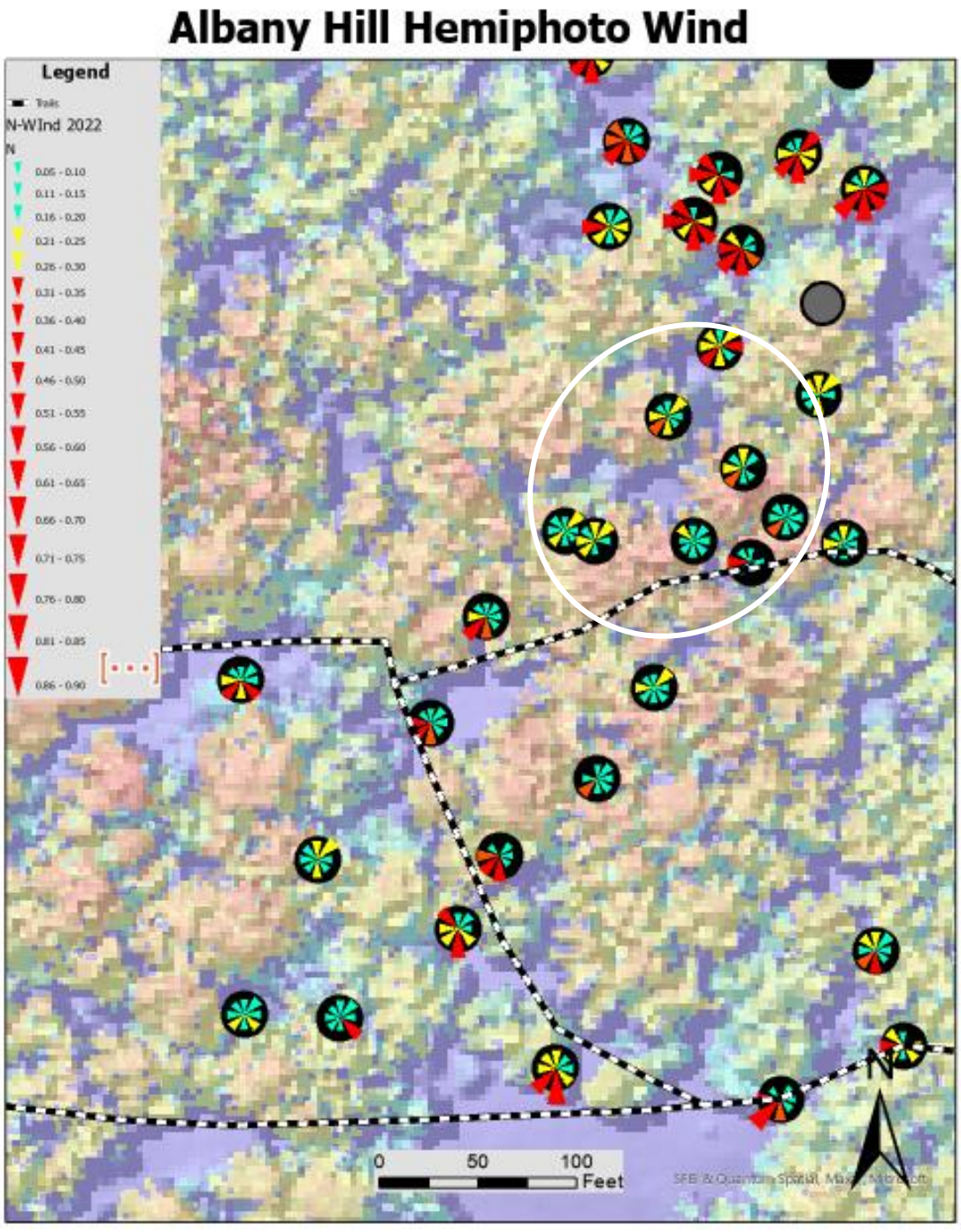
The Upper Meadow has high exposure in hemiphotos to W, SW, and S, However, the WindNinja analysis shows that this meadow is well sheltered from wind from all directions by the trees surrounding the opening (note blue spot in the center Max). Here the monarchs cluster lower to the ground (4-7 m, or 15-25 ft.) just out of the wind.

The western shelterbelt below the crossroad plays a key role in sheltering the cluster zones. The dense lower canopy prevents wind from penetrating into the SW Bowl cluster zone. The 2022 hemiphotos captured the canopy with most of the scorched leaves still on the trees (Photo 1), but those leaves will fall this winter. The temporary loss of this shelter will increase wind exposure near the ground in the cluster zone. Regrowth by basal and stem sprouts should fill in the gaps in a few years.

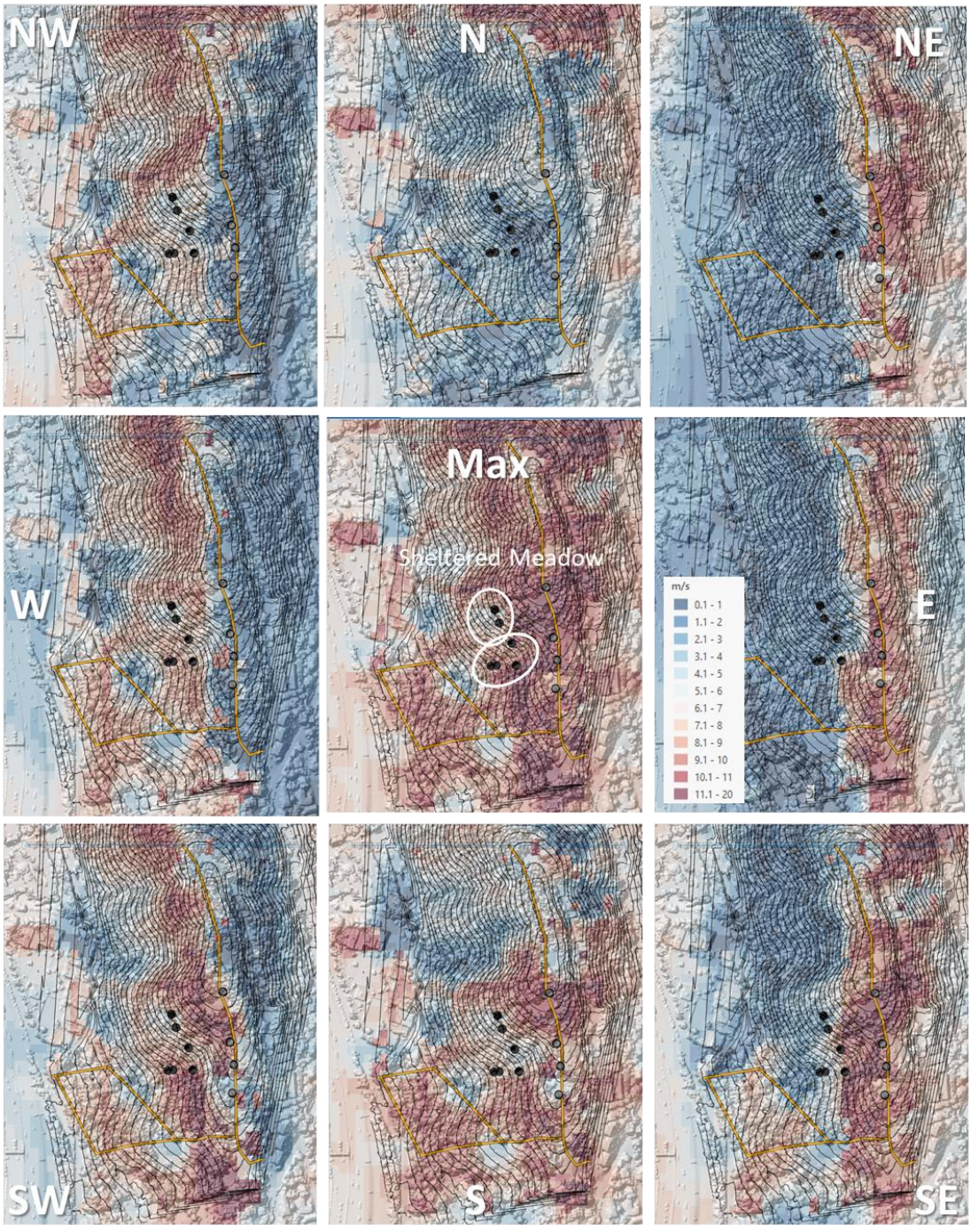
Map 4. Hemiphoto "Wind Roses" showing the direction and magnitude of visible sky in eight directions. Monarch cluster zones are in white circles. The Ridgetop cluster zone (narrow ellipse) is occupied primarily during periods of mild weather. Monarchs tend to move to the SW Bowl and Upper Meadow following stormy windy weather.



Map 5. Closeup of the SW Bowl cluster zone. Note the predominance of cyan color in wind roses, which indicates that this area is the wind sheltered from most directions and monarchs do not have to move far to find a sheltered roost.



Map 6. Relative wind exposure at outer canopy from WindNinja, using a 10 m/s (22 mph) wind from eight directions. Red is exposed, white intermediate, and blue is sheltered.

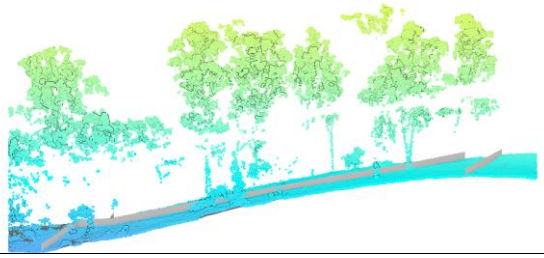
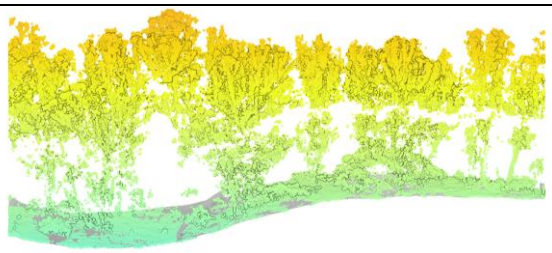
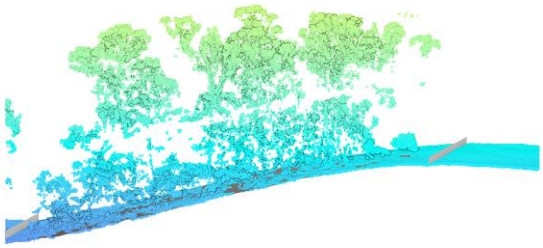
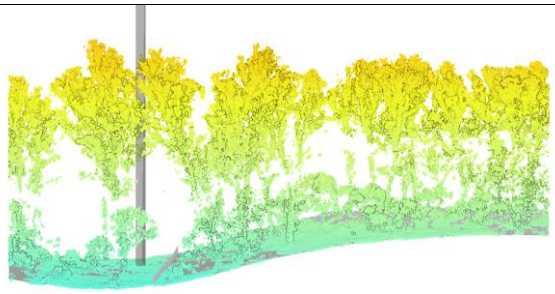
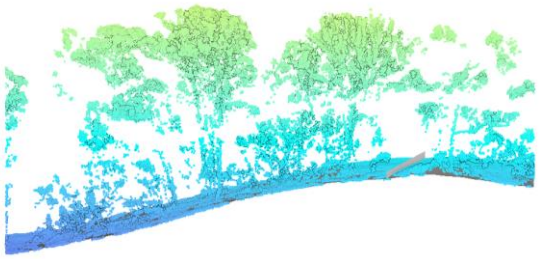
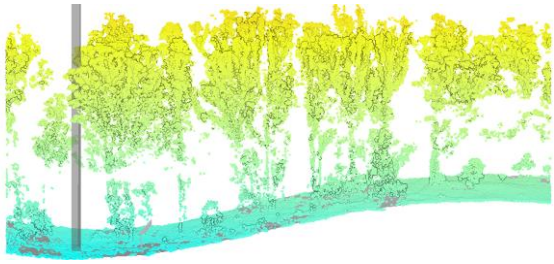
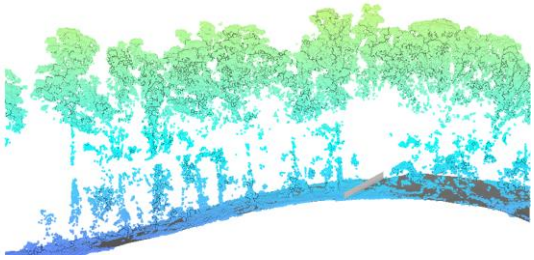
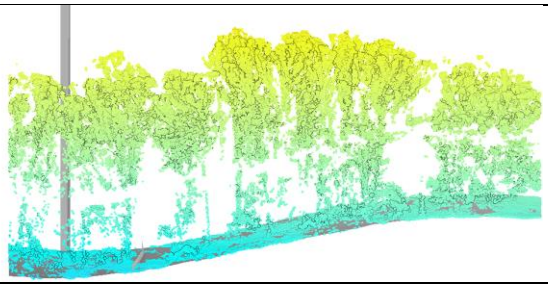
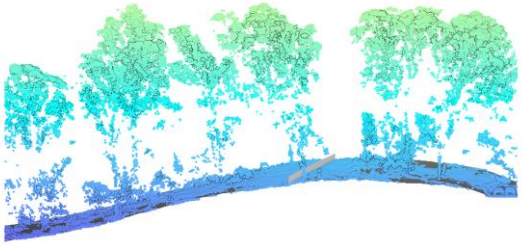
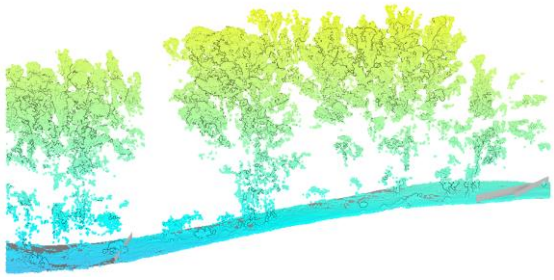


50-foot-wide profiles from base of Albany Hill to Summit, through the SW Bowl Cluster Zone

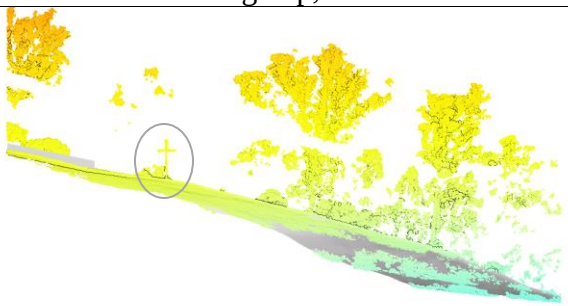
The following array of images shows 50’ wide slices (profiles) of forest structure starting near the base of Albany Hill and progressing through the shelterbelt, crossroad, SW Bowl, up to and over the ridgetop. These are pre-fire profiles. They are organized so that the bottom of the hill near Pierce Street is in the lower left, and the profiles progress up the page by 50’ increments, then skip to the lower right, and repeat the 50’ increments.

At the base of the hill, there is an open understory. It becomes denser 50’ up the slope, and the main shelterbelt is between 100 and 150’. Much of this area burned (i.e., Photo 1). The crossroad is at 200’ (note grey line) with the open understory that acted as a fuel break. Progressing further upslope (250’ bottom of second column), the open understory and “cathedral-like” structure is apparent. At 300’, 350’, and 400’, the grey columns are the observed cluster sites. The understory becomes denser at 400’ and 450’.

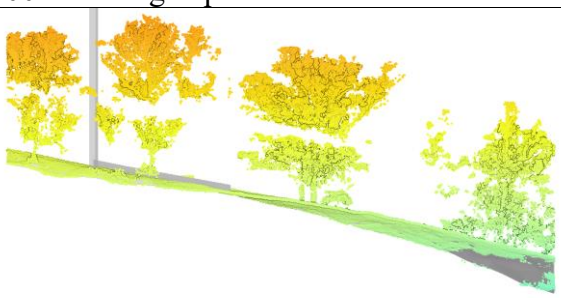
Moving to the next array, the forest opens up at 500’, and a ridgetop cluster site along the road is shown (grey column). The understory opens along the ridgetop road (550’ and 600’), and another ridgetop cluster site appears at 600’. The final slice at 650’ shows the cross (pale yellow) in the large opening, as well as some denser understory SE of the cross.

Array 1 – 50’ wide cross sections of the Albany Hill forest	
200’ Crossroad, open understory	**450’ Above Cluster Zone**
	
150’ Shelterbelt	**400’ Cluster Zone**
	
100’ Shelterbelt	**350’ Cluster Zone**
	
50’, denser understory	**300’ In SW Bowl cluster zone**
	
Near Base of Hill, open understory	**250’ Above Crossroad, open understory**
	

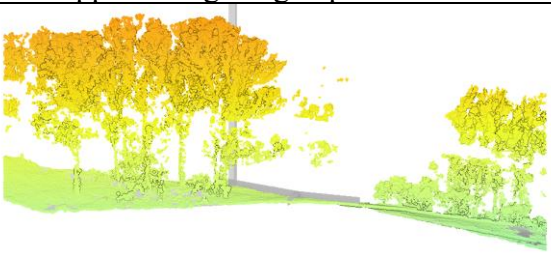
650’ Just east of ridgetop, note cross in oval



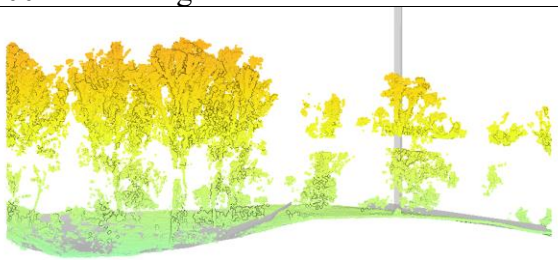
600’ On Ridgetop



550’ Approaching Ridgetop



500’ Ascending hill

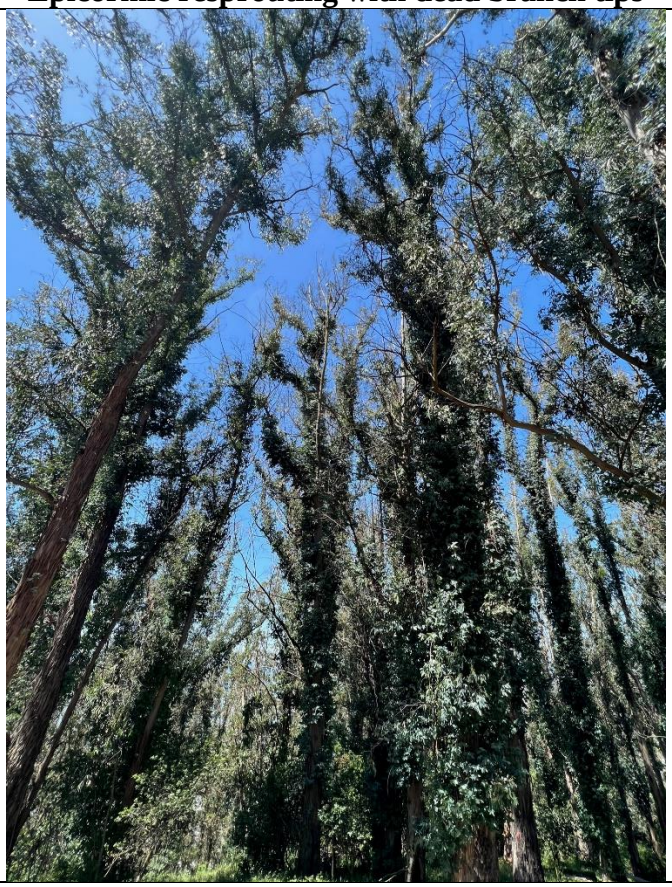


NDVI (Normalized Difference Vegetation Index)

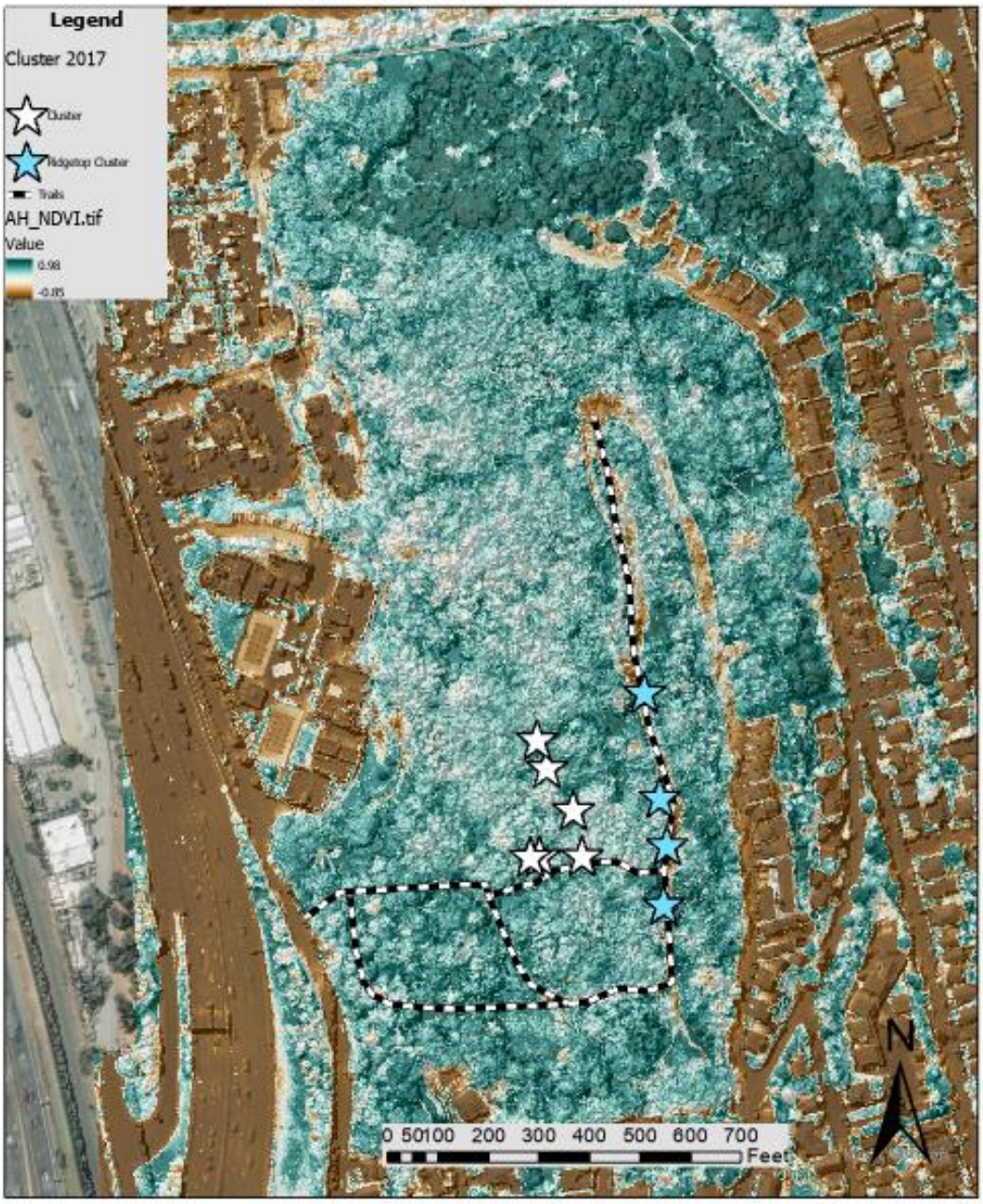
The drone LiDAR flight also included multispectral imagery, and NDVI was calculated as a measure of canopy density/health (Map 7). Key features include:

1. The brown areas are non-vegetated surfaces like pavement and roofs. The areas of bare soils along the ridgetop trail can be seen.
2. The live oak forests on the north side of Albany Hill are the darker blue green (high NDVI) which indicates dense green canopies.
3. The variety of NDVI within the blue gum forests shows thinning canopies from dieback (white and small patches of light brown) with healthier canopies and live oaks/acacias having higher NDVI.
4. The lower slopes generally have higher NDVI than the upper slopes, because of flow of water downslope and thicker soils. Qualitatively, the worst dieback was observed on the ridgetop and upper slopes, where soils are thinner.
5. The imagery was taken in February 2022, when grasses were bright green, so the meadows do not stand out like they would in summer.
6. The blue gum canopies had extensive epicormic resprouting following the soaking rains in October and December 2021, so much of the dieback noted in 2021was ameliorated (photo below).

Epicormic resprouting with dead branch tips

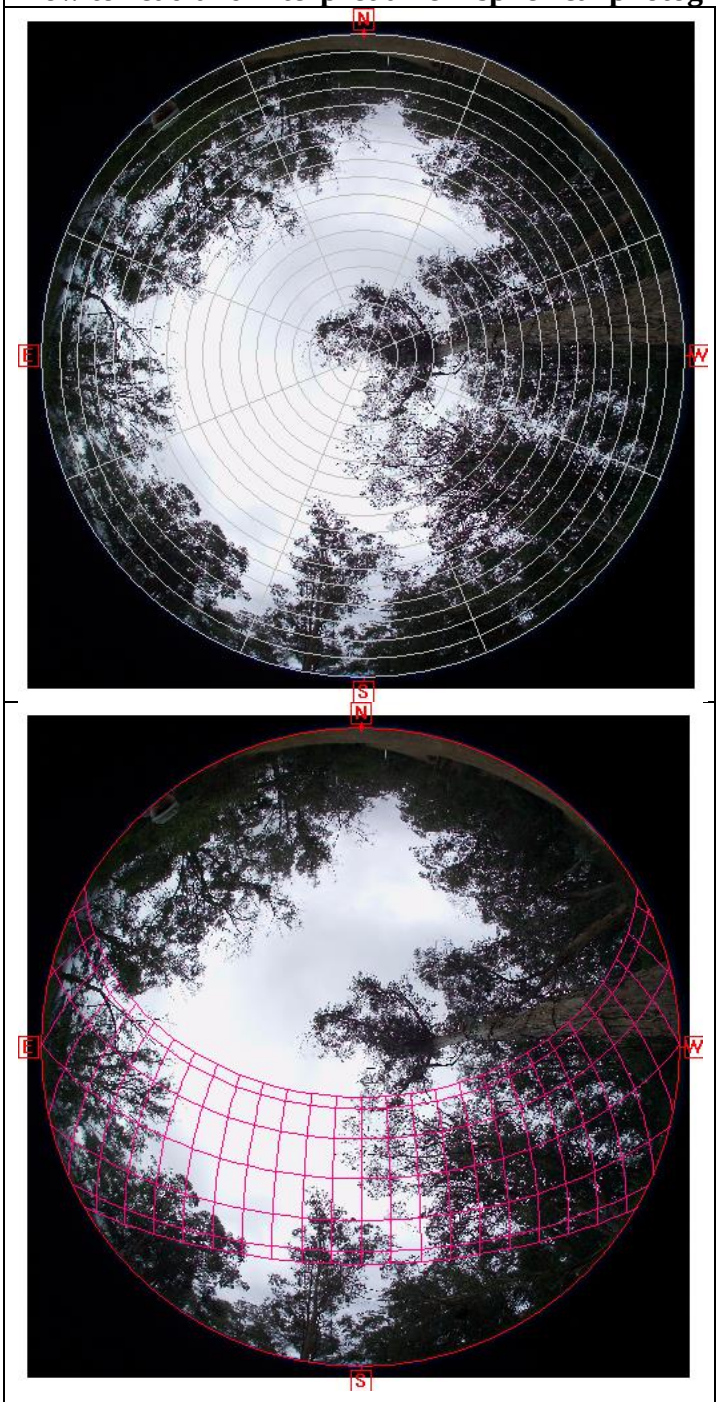


Map 7. NDVI (greenness, a measure of canopy density/health)



Appendix: Hemiphoto Interpretation

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	

Appendix: Cluster Sites

Cluster_Type	Latitude	Longitude
Ridgetop Cluster	37.894551	-122.304542
Ridgetop Cluster	37.893979	-122.304441
Ridgetop Cluster	37.89372	-122.304394
Ridgetop Cluster	37.893397	-122.304421
Cluster	37.893666	-122.305268
Cluster	37.893663	-122.305332
Cluster	37.893665	-122.304977
Cluster	37.893915	-122.305036
Cluster	37.894147	-122.305215
Cluster	37.894299	-122.30528