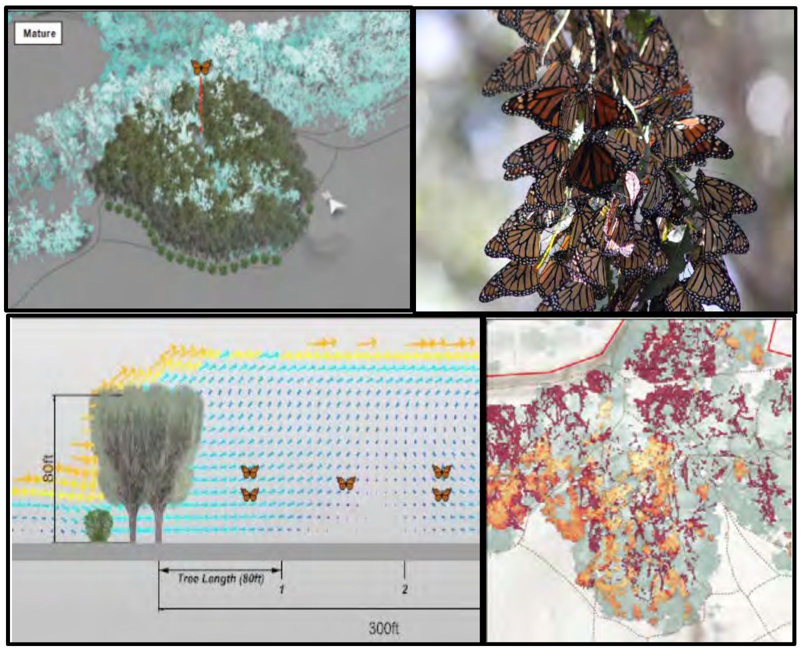
Appendix D

Ellwood Mesa/Sperling Preserve Open Space Monarch Butterfly Overwintering Habitat Analysis and Recommendations for Restoration Report

Ellwood Mesa/Sperling Preserve Open Space

Monarch Butterfly Overwintering Habitat Analysis and Recommendations For Restoration

Goleta, California



Prepared for

George Thomson, Parks & Open Space Manager
CITY OF GOLETA – PUBLIC WORKS DEPARTMENT
130 Cremona Drive
Goleta, CA 93117

by

ALTHOUSE AND MEADE, INC.
BIOLOGICAL AND ENVIRONMENTAL SERVICES
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626

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Technical Report Contributors

Kyle Nessen
TIU Program Manager
Althouse and Meade, Inc.
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626
kylen@althouseandmeade.com

Charis van der Heide
Senior Biologist
Althouse and Meade, Inc.
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626
charisvdh@althouseandmeade.com

Corbin Matley
GIS Analyst
Althouse and Meade, Inc.
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626
corbinm@althouseandmeade.com

Stu Weiss, PhD
Principal Scientist
Creekside Science
P.O. Box 1553
Los Gatos, CA 95031
(605) 269-2876
stu@creeksidescience.com

LynneDee Althouse
Principal Scientist
Althouse and Meade, Inc.
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626
lynnedee@althouseandmeade.com

NV5 (formerly Quantum) Geospatial
[LiDAR data collectors]
Andrew Brenner, Ph.D.
Senior Program Director
734-680-6424
Andrew.Brenner@NV5.com

In memory of

Daniel E. Meade, PhD.

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1 EXECUTIVE SUMMARY

The City of Goleta's Ellwood Mesa/Sperling Preserve Open Space (Ellwood Mesa) is an important and widely recognized overwintering site for monarch butterflies (*Danaus plexippus*). Historically, tens and hundreds of thousands of monarch butterflies utilized the forest in the winter months for the overwintering phase of their migration. Recently, tree health and the condition of the overwintering habitat dramatically declined, and monarch roosting sites are threatened. The City of Goleta is committed to restoration and management of the Ellwood Mesa forest for the benefit of monarch butterflies and other sensitive wildlife.

Restoration of monarch overwintering habitat is challenging because of the time it takes for trees to establish and mature. Our common goal for the Ellwood Mesa/Sperling Preserve Open Space is to maximize the probability that monarchs will continue to use the forest of Ellwood Mesa as overwintering grounds for many decades into the future.

Our technical studies provide the basis for implementation of the Monarch Butterfly Habitat Management Plan (MBHMP) relative to monarch overwintering biology and habitat needs. We report on five years of studies. Our work is extensive and rigorous to ensure the best restoration effort can be implemented and to address concerns of community members.

In this report, we present the information about the history of the Ellwood Mesa and the influence of Ellwood Cooper in the original establishment of the eucalyptus tree forest, in Section 2. We summarize the historic land swap that preserved the land of Ellwood Mesa in perpetuity in Section 2.1.

In Section 3, we explore the features of monarch butterfly overwintering habitat and biology. Monarchs roost at overwintering sites along the California coast between October and March. They seek wind-sheltered areas with a precise microclimate to support their survival through the winter and protect them from inclement weather. This habitat often has a dense wall of foliage from ground to canopy top with an open interior that receives a combination of full direct and dappled insolation (sunlight) and full shade. We discuss the importance of eucalyptus trees for the creation of this habitat in Section 3.2.

To select the best trees for our restoration efforts at Ellwood Mesa, we examine and evaluate the characteristics of 29 species of native trees, eucalyptus trees and other non-native trees for their usefulness in monarch overwintering habitat and their usefulness in restoration efforts in Section 3.3. Of the species considered for restoration at Ellwood Mesa, the following species are selected for their individual characteristics to improve the forest for overwintering monarchs: blue gum eucalyptus (*Eucalyptus globulus*), karri (*Eucalyptus diversicolor*), toyon (*Heteromeles arbutifolia*), red ironbark (*Eucalyptus sideroxylon*), coast live oak (*Quercus agrifolia*), western sycamore (*Platanus racemosa*), California bay laurel (*Umbellularia californica*), and Fremont cottonwood (*Populus fremontii*).

The Ellwood Mesa is an urban forest dominated by a mix of eucalyptus species and native trees that holds six monarch overwintering sites. Monarch butterfly surveys and counts have been conducted at the Ellwood Mesa for many years. Peak population counts were recorded for Ellwood Main (Goleta Butterfly Grove) since 1989 and counts for the Western Monarch Thanksgiving Count began in 1997. We present this data in Section 4.1. A graph of total population of western monarchs and the total population in Santa Barbara County alongside the yearly Thanksgiving Counts at Ellwood Main in Section 4.2 shows how monarch numbers at Ellwood Main continue to decline relative to California's population.

In Section 4.4, we discuss the unprecedented drought in California during 2012-2016 and the impact this had on the forest conditions at Ellwood Mesa. Forests exist in a dynamic equilibrium with available site water by growing more in wetter years and dying back in dry periods. A sustainable density of trees at a site result from a dynamic process. During wet periods, Ellwood Mesa experiences high growth and high tree mortality during and after the drought. Loss of trees and canopy cover during the past decade opened Ellwood's overwintering sites to increased wind exposure. At Ellwood Main, the depth of wind shelter diminished with mass mortality, leaving "thin green lines" of remaining live trees that provide very limited wind shelter. The forest's critical redundancy in wind shelter disappeared. We illustrate the dramatic extent of tree mortality in a series of figures with LiDAR (laser imaging, detection, and ranging) data.

In Section 5, we examine the status of monarch butterfly overwintering habitat at Ellwood Mesa and describe the myriad studies and research we conducted to better understand the habitat. We gathered data using direct observations, hemispherical photography, LiDAR, arboriculture and wind modeling. We examined these data for each monarch overwintering location: Ellwood Mesa: Ellwood Main, Ellwood West, Ellwood East, Ellwood North (North and Central), and Ellwood Ironbark. (Detailed analysis for monarch locations at Sandpiper and Ocean Meadows will be included in a later update.) Our site-specific detailed analyses include descriptions of current conditions using observations from hemispherical photographs for the Visible Sky, proportion of potential annual insolation, and monthly potential direct insolation. Each site analysis includes a detailed map of vulnerabilities and a list of our site-specific recommendations for habitat restoration that would reduce identified vulnerabilities and improve habitat conditions.

In Section 6, we present our recommendations for restoration of Ellwood Mesa as a whole. The first step is to perform deferred maintenance of the trees with strategic fuel management, surgically remove dead standing and downed trees, and clear debris to prepare planting areas. The second step is to restore wind protection around monarch roosting locations: protect existing trees (Section 6.2.1), install our recommended double wind row design (Section 6.2.3), and implement planting areas in prescribed areas (Section 6.2.1 to 6.2.10). Section 6.2.4, presents results of the wind modeling on our planting designs at Ellwood Main that illustrate expected success of improved habitat for roosting monarchs.

2 INTRODUCTION

Monarch butterfly migration is an amazing natural phenomenon worthy of conservation. Every year, monarchs migrate in massive numbers to overwintering sites in California to wait out the winter months. Overwintering habitat in coastal California is critical to this migration, providing the genetic source for the following year's migratory population. The City of Goleta's Ellwood Mesa/Sperling Preserve Open Space (Ellwood Mesa) is an important and widely recognized overwintering site where visitors delight at the sight of monarchs aggregating in the eucalyptus groves. Until recently, Ellwood Mesa supported many thousand monarchs that enveloped and draped over eucalyptus branches through winter months. Relatively rapid loss of eucalyptus trees reduced wind buffers and live branches necessary to protect overwintering monarch butterflies.

Overwintering sites are under threat from a variety of sources including urbanization, fire, drought and pests. Historically, Santa Barbara County provides an important area for overwintering monarchs with approximately 25% of the overwintering sites in California. The Ellwood Main (Monarch Butterfly Grove) has attracted some of the highest monarch counts in the state. Unfortunately, the quality of the habitat at Ellwood Main is declining. Before 2012, the monarch population at Ellwood Main fluctuated between 2 – 25% of the western population during the Thanksgiving Count with an average of 11%. Starting in 2013, the Ellwood Main portion of the western monarch population fell to 1% and has fluctuated between 0 – 2.3% with an average of 1% (Xerces Society 2023).

Blue gum (*Eucalyptus globulus*) trees comprise the dominant tree taxon for Ellwood Mesa's monarch butterfly habitat with six historic monarch overwintering locations—Ellwood Main being the largest and most well-known (Figure 1 and Figure 2). By 2016, the blue gums on Ellwood Mesa began dying off in massive numbers. This die-off creates a substantial risk for fire, injury to park goers, and degraded monarch clustering habitat. As roosting and wind buffer trees died, monarchs changed their roosting behavior, and in 2016 monarchs aggregated in higher numbers at sites adjacent to Ellwood Main (see monarch numbers Section 4).

The 2019 Monarch Butterfly Habitat Management Plan for Ellwood Mesa (MBHMP; Rincon) outlines 22 Programs to guide the maintenance and management of the monarch butterfly overwintering habitat on Ellwood Mesa. Recommended actions in the MBHMP include wildfire fuels reduction, tree maintenance, tree and nectar plant installation, and continued monitoring of monarch numbers and habitat health.

In response to public concerns about how the plan would be implemented, we conducted a series of technical and scientific studies of Ellwood Mesa eucalyptus groves. The purpose of the studies is to better understand monarch and wildlife habitat, inform forest management, and address habitat risks associated with proposed actions. Results of these studies detail conditions, past and present, in the Ellwood eucalyptus grove to guide restoration and habitat enhancement for monarch butterflies now and for decades to come.

Monarch restoration is particularly challenging because of the long-time horizons involved with tree growth. This technical report summarizes our investigations and recommendations. Our work is extensive and rigorous to ensure the best restoration effort can be implemented and to address concerns of community members and to facilitate timely recovery of monarch aggregation sites.

Our common goal with advocates of Ellwood Mesa/Sperling Preserve Open Space is to maximize the probability that monarchs will continue to use the forest of Ellwood Mesa as overwintering grounds for many decades into the future. We recognize that this goal is challenging due to tree growth rates, and the time required to provide optimal habitat benefits.

2.1 History of Ellwood Mesa – 1800s to Present

Ellwood Mesa was first planted with 150,000 blue gum eucalyptus trees in 1876 by Ellwood Cooper (Farmer 2013). Since World War II, Ellwood Mesa has been managed as a wood lot by Mr. Cooper, his horticultural successors, and by Goleta residents. Our earliest records of monarch butterflies using Ellwood Mesa as aggregation habitat is from the 1960's. Residents shared stories of riding horses during aggregation season and their horses would be covered by monarch butterflies seeking the nutrient-rich sweat of the horses.

The Ellwood Mesa is now managed by the City of Goleta after an innovative land swap and fund-raising effort in 2005 that preserved the land in perpetuity. The City of Goleta was incorporated in February 2002 and fundraising for the land swap began in January 2003 by the Trust for Public Lands and Friends of Ellwood Coast. The Ellwood-Devereux Coast Open Space and Habitat Management Plan was drafted by August 2003. The Trust for Public Lands achieved the fund-raising goal of $20.4 million in December 2004. Meanwhile, the Comstock Homes and City coastal access parking lot submitted their application to the California Coastal Commission in August 2004 and their application was approved in January 2005, providing opportunity to conserve most of the mesa's monarch butterfly habitat. In February 2005, the City of Goleta closed escrow on the ownership of Ellwood Mesa.

After acquisition, the City of Goleta implemented a hands-off approach to forest management of the eucalyptus grove at Ellwood Mesa. The City adopted the Ellwood-Devereux Coast Open Space and Habitat Management Plan (OSHMP) in 2004 that focused on broad management goals for maintaining the habitat for the monarch butterflies. For years, the City's opinion was that the forest is a natural and self-sustaining habitat that should be left alone.

The City hired Daniel E. Meade, Ph.D. with Althouse & Meade, Inc in 2010 to develop a Monarch Butterfly Habitat Management Plan for Ellwood Mesa (MBHMP). Several revisions were drafted while the needs of the habitat and the status of the trees continued to change and require additional sections in the MBHMP to address the growing list of issues.

Unfortunately, while the MBHMP was still under development, the region and state of California experienced an extreme 5-year drought (2012-2016). The drought led to widespread forest dieback that degraded monarch butterfly habitat throughout the grove, a condition emphasized by a dramatic decline of monarch population numbers across the six aggregation sites on the mesa.

In response to the declining tree health, a tree health survey was conducted in 2017 which identified over 1,400 standing dead and dying trees in the eucalyptus forest at Ellwood Mesa. The Public Works Director suggested removing these trees immediately with an emergency permit. This proposal was met with harsh public backlash based on concerns about large-scale tree removal in and around the aggregation sites without the MBHMP in place to protect and restore monarch habitat. The City Council responded to community concerns by approving the removal of only those trees that posed a threat to public safety and directing the completion of the MBHMP. The City then prepared several in-depth scientific studies to understand the forest habitat. The goal of the technical investigations was to understand grove complexity and recommend management actions that would protect and restore forest elements important to monarch butterflies.

The City received a state grant for $3.9 million for the implementation of the MBHMP in 2018. The MBHMP was adopted by the City of Goleta in March 2019. From 2019 until the present, the City is in the process of preparing permits and design plans for the approval from the many agencies with jurisdiction over the Ellwood Mesa land and habitat.

Figure 1. General Location of Ellwood Mesa

Legend

★ Project Location

Goleta Monarch Butterfly Groveat Ellwood Mesa
Map Center: 34.49408°N 119.8682°W
Goleta, Santa Barbara County

N

0 5 10 Miles

USGS Quadrangles: Dos Pueblos Canyon, Goleta

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Map Updated:
February 14, 2023 01:25 PM by CDM

Figure 2. Ellwood Mesa Project Boundaries and Monarch Roosting Sites

Legend

MBHMP Coverage Area

Ellwood Mesa Open Space

N

0 500 1,000 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42151°N 119.89267°W
Goleta, Santa Barbara County

Imagery Source: USDA NAIP, 06/20/2022

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Map Updated:
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3 MONARCH BUTTERFLY OVERWINTERING HABITAT AND BIOLOGY

Overwintering monarchs are butterflies that migrate from inland summer breeding sites in Western North America in search of groves of trees in mild coastal climates where freezes rarely occur for the winter (Pelton et al. 2016, Xerces Society 2017a). Within those groves, they seek wind-sheltered areas which require a dense wall of foliage from ground to canopy top in the windward direction or sheltering hillslopes. Overwintering monarchs prefer microsites that receive a combination of full direct and dappled insolation (sunlight) for basking, but also have shaded areas for resting at cool temperatures. Large areas of deep shade are rarely occupied for long. Forests can be either too open, or too dense for cluster sites (Weiss et al. 1991).

Monarchs adjust their micro-distribution among trees and branches as winds and insolation shift, and will completely abandon sites if the microclimate, primarily wind, exceeds their tolerance. Winds greater than 2 m/s (5.2 mph) at ground level appear to be a limit for cluster sites (Leong 1990, Leong et al. 1991, Leong 2016). When weather is mild, monarchs will use a wide variety of sites and have an expansive micro-distribution. When storms approach, with the strongest winds from the SE, monarchs concentrate in the most SE-wind-sheltered spots. As the front passes, winds shift though S, SW, W, and NW and monarchs may readjust their cluster sites when they can fly again. But strong winds are possible from all directions, including dry N, NE, and E winds, so wind shelter over the entire 360° circle needs to be available somewhere in a site. It takes a delicate balance between dense canopy cover and more open areas to attract and retain monarchs, as they dynamically "crowd source the microclimate."

Dense perimeter trees and/or sheltering topography for wind protection in all directions, with an interior canopy gap for a varied insolation environment, is an ideal habitat configuration. Some viewers fondly consider this a "cathedral" arrangement of forest canopy surrounding a central opening.

3.1 Features of Overwintering Monarch Habitat

Across the monarchs' overwintering range there are similarities in their preferred habitat. Key elements of overwintering monarch habitat include:

1) Location within a mild coastal climate, where freezing is unlikely, and high temperatures are moderate so that monarchs can conserve their fat reserves and remain in reproductive diapause. These conditions are found along the immediate coast from Mendocino to Baja and near San Francisco Bay.
2) Trees on which to form clusters. Monarchs cluster on many tree species ranging from sparse Torrey pines, various eucalyptus species, dense live oaks, to broadleaf sycamores.
3) Most importantly, wind shelter from many, if not all directions. Monarchs will leave sites when the wind at ground level exceeds <2 m/s (5.2 mph, Leong 1990, Leong et al. 1991, Leong 2016). Topography can contribute to wind shelter, in addition to the key role of trees.
4) Canopy gaps that allow sunlight (insolation) into the grove. A mix of full sun for several hours, dappled light, and deeper shade within a small area is ideal.
5) Many sites, but not all, have a "cathedral" structure, with a large empty space above a clearing, often created by a stream or gully surrounded by tall trees. Monarchs can fly

freely in the open interior space and the surrounding trees provide a varied insolation environment within short distances.

A permanent overwintering site supports monarchs through the entire October-March overwintering season and must have all these elements within a compact area to do so. A transitory or autumnal site supports monarchs for a short time at the start of the season (October, November, December). Transitory sites often have several of these elements but are lacking key elements to offer the full spectrum of protection for monarchs through the entire overwintering season.

Monarchs are opportunistic creatures. The migrating population finds overwintering sites by exploring almost every grove of trees along the coast at some point during the migration. Early in the season when weather is mild, butterflies are widely scattered. As storms blow into California, the monarchs remain at sites that provide suitable wind shelter and insolation and leave sites that do not. As they fly from grove to grove, they use the presence of other monarchs as a cue that a site is suitable – they are very skilled at finding each other. The net result is that they dynamically accumulate at the suitable sites and abandon unsuitable sites as seasonal weather proceeds.

The same basic mechanism works within a grove as monarchs choose microsites for clustering. Every cluster is in a dynamic equilibrium between monarchs staying, leaving, and arriving. Monarchs will stay in place if conditions are suitable for their immediate physiological state. Sometimes clusters break up almost instantaneously if a burst of wind occurs during good flight conditions. Other times, a wind shift will cause butterflies to move. High winds can drive monarchs completely from overwintering groves. At night, or if it is too cool and/or cloudy for flight, then high winds can dislodge monarchs, who fall to the ground where they are vulnerable to predation and perhaps freezing. “Sunburst” behavior occurs when sunlight strikes a cluster and many monarchs warm and take flight. Monarchs also take flight to find nectar, water, or mates depending on their physiological needs affected by warm temperatures and the time of the season.

When a monarch decides where to land, the presence of other clustering monarchs is the best cue that it is a good site. The individual decisions of hundreds or thousands of butterflies in an overwintering aggregation create a dynamic micro-distribution as they “crowdsource the microclimate.”

The forest canopy filters outside weather according to its fine scale structure. Trees attenuate wind according to foliage density, and multiple layers of branches and leaves can create calm conditions even during storm winds. But small gaps and wind tunnels can allow wind to exceed critical thresholds in the interior of the grove. The cumulative loss of trees and branches - whether from drought, windfall, pests, disease or human cutting - can open a formerly wind sheltered stand or weaken multiple lines of shelter and increase vulnerability to further loss.

3.2 The Importance of Eucalyptus Trees

Eucalyptus trees are important to monarch overwintering sites because they grow taller than most native trees and provide suitable branching and canopy structure to sustain overwintering monarch aggregations (Meade et al. 2018, Meade et al. 2019, Meade et al. 2023, Griffiths and Villablanca 2015, Longcore, Rich, and Weiss 2020). This technical report supports and encourages the presence and growth of eucalyptus trees for the benefit of overwintering monarchs.

Blue gum eucalyptus trees were introduced to California in the late 1800's from Tasmania and have since naturalized throughout the state. The intensity of the invasiveness of this species is under much debate. Blue gums can exhibit invasiveness and negative environmental impacts in some areas, but these are poorly represented in scientific journals. Thus, in 2015, California Invasive Plant Council (Cal-IPC) conducted a review of the literature and concluded that the data warranted the blue gum be resigned as "limited" invasive status from the previous "moderate" status (Wolf and Johnson 2014, Wolf and DiTomaso 2016, Cal-IPC 2023). Spread of blue gums is typically limited to expansion along the periphery of an existing population, especially in coastal areas in riparian habitat (Lopez 2015). In this case, limited status represents the widespread distribution of blue gums throughout the state and identifies that significant ecological impacts are limited to specific regions and there is minimal or no impact in other areas (Cal-IPC 2023). Wolf and DiTomaso note that blue gums alter fire regime by accumulation of significantly higher fuel loads than native woodlands (Wolf and DiTomaso 2016, CAL-IPC 2015).

Blue gum resprouts readily when cut, grazed, or burned. It coppices readily from stumps of all sizes and ages when the tree is damaged. If the tree is cut down, lignotubers become active and each bud produces a shoot bearing foliage. Such shoots are commonly known as "sucker growth" or coppice shoots, and a large number are usually formed (Skolmen and Ledig 1990, Bean and Russo 2014).

Contrary to popular opinion, there is no scientific evidence that blue gum eucalyptus trees produce an allelopathic effect to inhibit the growth of understory vegetation (Nelson et al. 2016). Nelson's study conducted at California Polytechnic State University, showed that germination and early seedling growth of five California native plants were not inhibited by blue gum eucalyptus chemical extracts. It is likely that any noticeable decrease of understory vegetation under eucalyptus trees is caused by the accumulation of fallen leaves, bark, and branches, and low rate of decomposition. Many native plants are regularly observed growing and thriving in gaps under eucalyptus tree canopies at monarch overwintering sites throughout the state.

Additionally, eucalyptus trees support a diversity of fauna. A 2015 study of eucalyptus woodlands in central California found that non-native eucalyptus and native oak groves had very similar bird community composition, species richness, and abundance (Fork et al., 2015). The study also reported similar abundance and richness of non-natives in eucalyptus versus oak woodlands and thus no evidence of ''invasional meltdown." Invasional meltdown was initially described in 1999 as that case where invasive species foster the spread and establishment of other non-native and/or invasive species (Simberloff and Von Holle 1999).

3.3 Tree Species Consideration and Selection

Overwintering monarchs have been observed roosting in many different species of trees and shrubs and the species of tree vary across their overwintering range in California (Xerces Society 2023). The paper *Monarch Butterfly Habitat on the Razor's Edge - Native and Non-native Vegetation in California and Occam's Razor* (2023) examined the characteristics of 29 species and their usefulness in monarch overwintering restoration efforts in Santa Barbara County (included in Appendix D).

Of the 130 overwintering sites in Santa Barbara County, 96 are dominated by eucalyptus (2 of which are eucalyptus and non-natives), 10 are mixed eucalyptus and California native trees, 9 sites are eucalyptus with local California native trees, 9 sites are California native trees, and 6 sites are local Santa Barbara County native trees (Meade et al. 2023). Eucalyptus trees are either the primary vegetation, or a significant contributor to the creation of monarch butterfly aggregation sites in Santa Barbara County in 88% percent of known or potential aggregation sites.

The Meade et al. 2023 paper evaluates native trees, eucalyptus species, and several other non-native trees that all have at least one record of monarchs using them as an aggregation tree (Xerces Society 2023). The paper concludes that several species of eucalyptus trees are the reliable choice for restoration when the goal is creating protective monarch butterfly aggregation habitat. Choices for native trees in Santa Barbara County are limited and are not sufficient for forming the typical structure of a monarch butterfly aggregation site with a flight area encircled by substantial, tall trees that filter light, buffer wind and ameliorate temperatures and humidity (Wenner 1987, Leong 1990, Weiss et al. 1991, Calvert 1991, Meade 1999, Leong 2016). The structures of a eucalyptus grove generally provide better protection from wind and rain for a longer period through the overwintering season than sycamore, oak, cottonwood, and willow habitats.

We've given these 29 tree species a rank based on the tree rating analysis that was conducted in the Meade et al. 2023 paper. This ranking system assigns Very High, High and Moderate labels to the tree species in order of their rating. This ranking relates to their usefulness in the restoration efforts of monarch butterfly overwintering habitat, all things considered.

The three highest ranked trees from the evaluation are three eucalyptus tree species and are given a Very High ranking label. These three trees are commonly found at aggregation sites and are naturalized in California: red iron bark gum *(Eucalyptus sideroxylon),* blue gum *(E. globulus)*, and river red gum *(E. camaldulensis).* The next grouping of ranked trees are given a High ranking label and are six species that create suitable aggregation habitat for the duration of the overwintering season: lemon scented gum *(Corymbia citriodora),* red flowering gum *(Corymbia ficifolia)*, toyon *(Heteromeles arbutifolia)*, karri *(E. diversicolor)*, Monterey cypress *(Hesperocyparis macrocarpa)*, and sugar gum *(Eucalyptus cladocalyx)*. All the trees with lower ratings are given the ranking label of Moderate and would provide additional habitat benefits by increasing diversity and wind shelter to an aggregation grove in association with the nine higher ranked species: Bishop pine *(Pinus muricata)*, silver wattle *(Acacia dealbata),* Canary Island pine *(Pinus canariensis),* holly-leaf cherry *(Prunus ilicifolia* ssp. *ilicifolia)*, Monterey pine *(Pinus radiata)*, Torrey pine *(Pinus torreyana ssp. torreyana)*, coast redwood *(Sequoia sempervirens)*, evergreen ash *(Fraxinus uhdei)*, cork oak *(Quercus suber)*, blackwood *(Acacia melanoxylon)*, California bay laurel *(Umbellularia californica)*, western sycamore *(Platanus racemosa)*, Fremont cottonwood *(Populus fremontii)*, coast live oak *(Quercus agrifolia)*, grand fir *(Abies grandis)*, arroyo willow *(Salix lasiolepis)*, Douglas fir *(Pseudotsuga menziesii)*, monkey-puzzle *(Araucaria Araucana)*, dawn redwood *(Metasequoia glyptostroboides)*, and black cottonwood *(Populus trichocarpa)*.

We explore the characteristics of five *Eucalyptus* species in Table 1 and list their rank (from Section 3.3), propensity to spread into wildlands (Invasiveness), distribution in Australia from tropical to Mediterranean (Natural Habitat), and on their height. The species include red river gum (*E. camaldulensis*), sugar gum (*E. cladocalyx*), karri (*E. diversicolor*), blue gum *(E.*

globulus), and red ironbark gum (*E. sideroxylon*). In Table 2, we list the leaf characteristics of these same five eucalyptus species.

TABLE 1. RANKING OF FIVE EUCALYPTUS SPECIES

Eucalyptus Species	Rank	Invasive/ Naturalized Lignotuber[1]	Natural Habitat	Height & Leaves
Red River Gum ***(E. camaldulensis)***  (Photo UFEI 2023)	Very High	Invasive. Lignotuber sometimes present	Near seasonal water	<25 m
Sugar Gum *(E. cladocalyx)*  (photo EUCID 2020)	High	Naturalized. No lignotuber—has epicormic buds[2] on stem	Mediterranean (S. Australia)	10 – 20 m

[1] Lignotuber is a basal woody swelling that holds a large number of dormant buds in a protected position along with carbohydrates and other nutrients (Bortoloto et al. 2020).

[2] Epicormic bud will form shoots arising spontaneously from adventitious or dormant buds on stems or branches of woody plants, often following exposure to increased light levels or fire (Helms 1998).

Eucalyptus Species	Rank	Invasive/ Naturalized Lignotuber[1]	Natural Habitat	Height & Leaves
Karri *(E. diversicolor)*  (Photo UFEI 2023)	High	Not Naturalized. No lignotuber—has epicormic buds on stem	Mediterranean (SW of Western Australia)	90 m
Blue Gum (E. globulus)  (Photo UFEI 2023)	Very high	Very naturalized. Forms lignotuber.	Southeastern Australia with uniform climate/rainfall	<60 m
Red Ironbark Gum *(E. sideroxylon)*  (Photo UFEI 2023)	Very high	Reproduces occasionally (uncommon naturalized). Forms lignotuber.	Eastern Australia (wet summer)	7 – 25 m

TABLE 2. LEAF CHARACTERISTICS OF FIVE EUCALYPTUS SPECIES

Eucalyptus Species	Leaf Characteristics (EUCLID 2020)
Red River Gum ***(E. camaldulensis)***  © N Parks Flora&FaunaWeb	alternate, petiole 0.7-3 cm long; blade lanceolate or broadly so or falcate, 8-23 cm long, 1-4.2 cm wide, base tapering to petiole, concolorous, dull, bluish or blue-green, rarely green, or slightly glaucous, side-veins about 45° or more to midrib, venation usually sparsely to moderately reticulate, intramarginal vein parallel to and well removed from margin, oil glands numerous, island[3], rarely obscure. [leaf description for ssp. *arida*]
Sugar Gum ***(E. cladocalyx)***  (Photo by John Rawlings)	alternate, petiole 0.9–2.7 cm long; blade slightly falcate to lanceolate, 6.5–17 cm long, 1.2–4 cm wide, base usually tapering to petiole, strongly discolorous, glossy, darker green on upper side, paler below, side-veins at an acute or wider angle, densely to very densely reticulate, intramarginal vein parallel to and well removed from margin, oil glands small, obscure.
Karri ***(E. diversicolor)*** 	alternate, petioles 1–2 cm long; blade lanceolate, 7–13.5 cm long, 1.5–3.7 cm wide, base tapering or oblique, margin entire or subcrenulate, apex a drip-tip, discolorous, dark green and glossy above, paler below, penniveined, reticulation dense, intramarginal vein close to margin, oil glands mostly island, yellow.

[3] "island" in this context means the leaf oil glands occur in the center of the smallest unreticulated areas (areole) of the leaf, as opposed to intersectional oil glands that occur at the intersections of the veinlets.

Eucalyptus Species (Photo from lucidcentral.org)	Leaf Characteristics (EUCLID 2020)
Blue Gum *(E. globulus)*  From *Trees of Stanford and Environs,* *Ronald Bracewell*	alternate, petiole 2–3.5 cm long; blade lanceolate to falcate, 12–30 cm long, 1.7–3 cm wide, glossy, green, side-veins greater than 45° to midrib, densely reticulate, intramarginal vein parallel to and well removed from margin, oil glands island and intersectional.
Red Iron Bark Gum ***(E. sideroxylon)***  © Ron Vanderhoff	alternate, petiole 0.5–2.5 cm long; blade lanceolate, 5–14 cm long, 1–4 cm wide, base tapering to petiole, concolorous, dull, green to blue-green, grey-green, grey or glaucous, side-veins at an acute or wider angle to midrib, moderately to densely reticulate, intramarginal vein parallel to and just within margin or well removed from it, oil glands island and intersectional.

3.4 Tree Species for Restoration of Ellwood Mesa

Of the species considered for restoration at Ellwood Mesa, the following species have risen to the top of the list and are selected for their individual characteristics to improve the forest for overwintering monarchs:

<u>Blue gum (*Eucalyptus globulus*)</u>

The blue gum eucalyptus (*Eucalyptus globulus*) is an evergreen tree with a max height of 50 m (165 ft). This species is well documented to provide suitable overwintering habitat for monarch butterflies in California (Meade et al. 2018, 2023). This species is native to the wet regions of Tasmania, and it has a medium water use rating (UFEI 2023). The blue gum has week branch strength and sheds bark and branches generously. Therefore, a healthy and sustainable blue gum forests require regular maintenance and management.

The blue gum eucalyptus tree is well established in the forest on Ellwood Mesa and functions as the dominant tree in the structure of the monarch aggregation habitat. Although the blue gum trees have experienced die-off from the extreme drought in the forest at higher rates compared to other eucalyptus species on the mesa, the species remains an extremely valuable element of the forest for monarch butterflies.

We recommend protecting and supporting the live blue gum trees, encouraging blue gum saplings and resprouts to flourish in the forest, and adding additional plantings of this species as the need arises to improve coverage in the monarch roost sites. In Phase 1 of the implementation of the MBHMP, blue gum trees will be planted to replaced dead and dying monarch roost trees in the monarch aggregation sites on Ellwood Mesa. See Section 6.2 for planting details.

Karri (Eucalyptus *diversicolor*)

The karri (*Eucalyptus diversicolor*) tree is native to Southwestern Western Australia and is often used as a windbreak and shade tree (Photo 1). It is the tallest tree in Western Australia with a max height of 64 m (210 ft). Its leaves are spear-shaped and similar to the sickle shape of the blue gum. The karri tree has medium branch strength and smooth bark that sheds less than blue gum trees. The karri tree has a low water use rating, compared with the medium of the blue gum, meaning that it is more tolerant to drought stress (UFEI 2023).

Photo 1. Karri. EUCLID 2020.

The karri tree is known to occur in the Goleta/Santa Barbara area. The book *Trees of Santa Barbara*" documents the occurrence of karri trees “along the west side of Sheffield Drive north of the intersection with San Leandro Lane." (p. 282 in Muller et al. 2005). This location is at the base of Ortega Hill which is a known monarch overwintering site. Karri trees in this location are part of the canopy of eucalyptus trees that may influence the wind protection to the Ortega Hill site, this is also known as the shelter zone for the site.

Of the *Eucalyptus* taxa found in aggregation sites, the karri tree is the only one considered not naturalized or is not found as a garden escape in California. The other four species in Table 1 are known to reseed into natural lands. The Australian Native Plants Society does not consider Karri to be an invasive risk in the wild in Australia (ANPSA 2023). Dr. Matt Ritter did not even consider it for inclusion in the Manual of California Vegetation because it is not found as a garden escape in California (Jepson Flora Project 2023; Ritter and Yost 2009; personal communication 2/10/2023 with LynneDee Althouse). It is Southwestern Australia's tallest tree with smooth, deciduous bark that changes color as it ages (EUCLID 2020).

Based on its characteristics and expert opinion, we are including the karri tree in the planting plans and restoration actions at Ellwood Mesa. While the blue gum is intended to remain the dominant tree at the monarch roost sites, the karri tree will strengthen the forest by adding diversity and structure. Our intention is to build a more drought resilient forest with the addition of the karri tree. See Section 6.2 for planting details.

Toyon (Heteromeles *arbutifolia*)

Toyon (*Heteromeles arbutifolia*) is an evergreen shrub and native the western part of California and the Sierra foothills. This perennial shrub is drought-tolerant and common in coastal sage scrub and chaparral plant communities (CNPS 2023). Toyon grows well in the understory of eucalyptus forests and is present on the Ellwood Mesa, see Photo 2.

Toyon shrubs grow to a mature height of 1.8 to 9 m (6 to 30 ft) (UFEI 2023). The evergreen and perennial characteristics of this species make it well suited to provide wind shelter to the monarch aggregation habitats. Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2023).

We are proposing to plant toyon around the existing monarch overwintering sites to strengthen the wind shelter zones and build a more drought resilient forest. See Section 6.2 for planting details.

Photo 2. Toyon shrub well established outside of eucalyptus grove at Ellwood Mesa.

Red ironbark (*Eucalyptus sideroxylon*)

Red ironbark (*Eucalyptus sideroxylon*) trees are the dominant species in the southern section of the Ellwood North area and some are growing on the eastern edge of Ellwood West along Santa Barbara Shores access road, see on Figure 2.

Red ironbark is native to Eastern Australia and has max tree height of 27 m (90 ft). Its leaves are spear-shaped and similar to the sickle shape of the blue gum. The red ironbark has medium branch strength and furrowed black or red bark that does not shed like blue gum trees. This tree has a low water use rating, compared with the medium of the blue gum, meaning that it is more tolerant to drought stress (UFEI 2023). Evidence of its higher drought tolerance was apparent during the 2012-2016 drought; no red ironbark trees succumbed to the drought conditions at Ellwood Mesa while many blue gum trees are drought stressed, as shown in Photo 3.

Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2018 and 2023). The red ironbark tree has pink to red flowers which bloom in fall, winter, spring and offers a nectar source for the overwintering monarchs (UFEI 2023).

We are proposing to plant red ironbark around the existing monarch overwintering sites to strengthen the wind shelter zones and build a more drought resilient forest. See Section 6.2 for planting details.

Photo 3. Red ironbark trees in the southern section of Ellwood North are green and healthy (on the right) while the blue gum trees (on the left) are drought stressed.

Coast live oak (*Quercus* agrifolia)

The coast live oak is native to central and southern California and is present in the Ellwood Mesa forest in the under and middle story among the eucalyptus trees. This evergreen tree has high wildlife value and is important to the California landscape. This oak has a max tree height of 21 m (70 ft) and given enough time this tree can develop a large spreading canopy often wider that its height (UFEI 2023). Coast live oak has a low water use rating and strong branch strength (UFEI 2023).

Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2018 and 2023). We are proposing planting this tree in the wind shelter zone on the Ellwood Mesa to improve the monarch habitat and add wildlife value.

Western sycamore (*Platanus racemosa*)

The western sycamore is a deciduous, California native riparian tree (UFEI 2023). This species is common along creeks and drainages in California and is present along Devereux Creek and other drainages on the Ellwood Mesa. This tree has a maximum height of 24 m (80 ft) and can have a canopy width between 6-15 m (20-50 ft). The western sycamore has a high water use rating and is tolerant of extreme heat and wind with medium branch strength (UFEI 2023).

Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2018 and 2023). Its deciduous nature causes this tree to offer decreased wind protection for monarchs by December or January as its leaves fall. This species is proposed for planting near Ellwood Main along Devereux Creek to close the wind vulnerability from the north.

California bay laurel (*Umbellularia californica*)

California bay laurel (*Umbellularia californica*) has a native range from southwestern Oregon to Baja California (UFEI 2023). It is an evergreen tree and is commonly associated riparian habitats, oak woodlands, and mixed-evergreen forests. This species has a maximum height of 22.8 m (75 ft) and can be as wide as it is tall (UFEI 2023).

Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2018 and 2023). This species is proposed for planting near Ellwood Main along Devereux Creek to close the wind vulnerability from the north.

Fremont Cottonwood (*Populus fremontii*)

Fremont Cottonwood (*Populus fremontii*) is a deciduous, California native riparian tree (UFEI 2023). This tree has a maximum height of 24 m (80 ft) and can have a canopy width between 9-15 m (30-50 ft). This species has a high water use rating and weak branch strength (UFEI 2023).

Monarchs are known to roost on this species in Santa Barbara County (Xerces Society 2023, Meade et al. 2018 and 2023). This species is proposed for planting near Ellwood Main along Devereux Creek to close the wind vulnerability from the north.

4 ELLWOOD MESA BACKGROUND

The Ellwood Mesa is an urban forest dominated by a mix of eucalyptus species and native trees. The eucalyptus forest on the Ellwood Mesa holds six monarch overwintering sites (Calvert 1991, Nagano and Sakai 1987, Meade 1999). These overwintering sites are scattered through the forest, as shown on Figure 2.

4.1 Monarchs at Ellwood Mesa

Monarch butterfly surveys and counts have been conducted at the Ellwood Mesa for many years. Peak population counts were recorded for Ellwood Main (Goleta Butterfly Grove) since 1989 and counts for the Western Monarch Thanksgiving Count began in 1997. Monarch aggregation locations are shown on Figure 2. The counts follow the Xerces Society's protocol for estimating number of monarch butterflies, the Step-by-Step Western Monarch Thanksgiving Count Monitoring Guide (The Xerces Society 2017b).

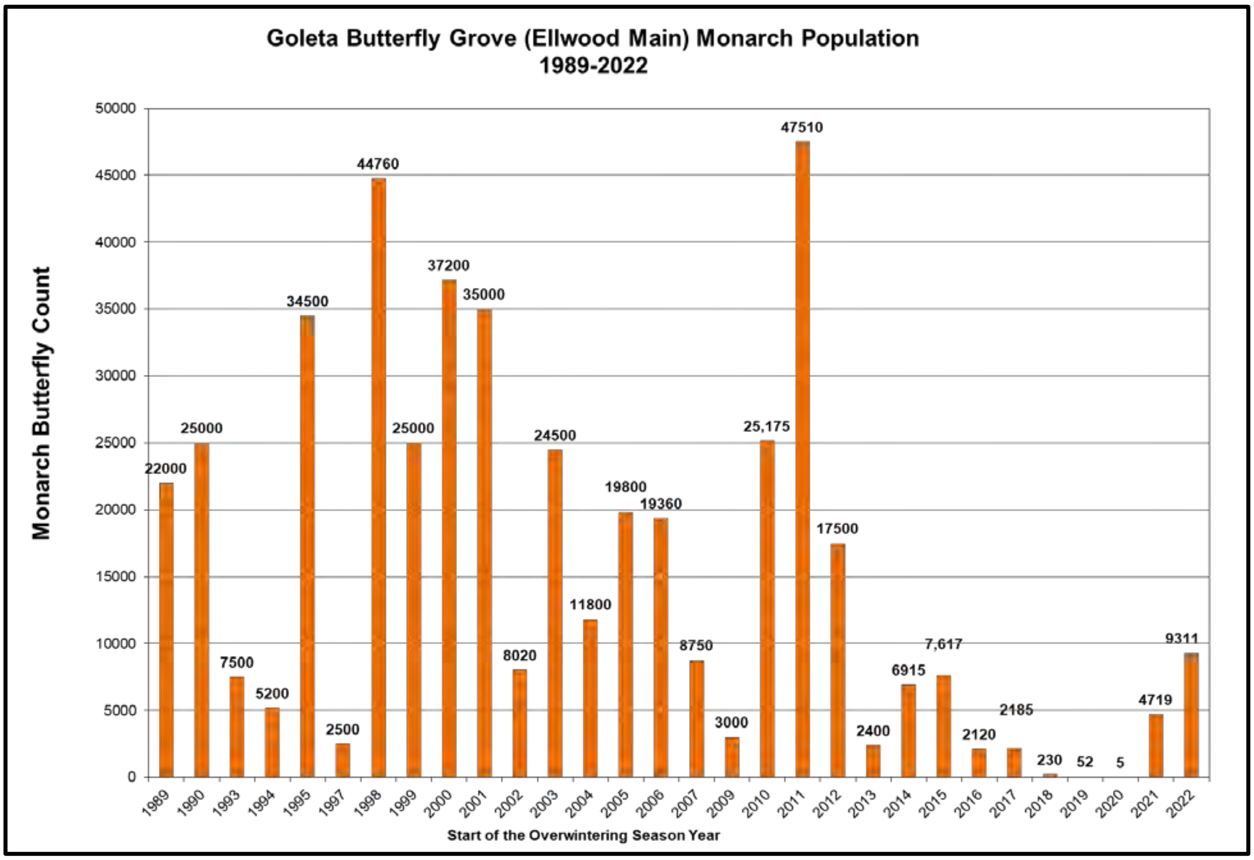
The monarch population at Ellwood Main (Goleta Butterfly Grove) fluctuates greatly from year to year, as shown in Graph 1. The highest monarch population at Ellwood Main was recorded at 47,510 in 2011 and the lowest was 5 in 2020. These fluctuations are natural and expected for insect populations (Xerces Society 2021).

We assume that monarch butterflies vote on suitable overwintering habitat with their presence. Monarch butterflies select preferable and suitable habitat and show us these locations with their numbers. There is a direct relationship between suitable habitat and monarch counts. In a year with a decent population abundance to span the entire distribution of overwintering sites, we can assume that the sites with suitable and protective habitat will have higher monarch butterfly counts relative to those sites with less suitable and poorly protective habitat. Thusly, the decline of habitat quality can be shown in the relative decline of monarch numbers at a site over time.

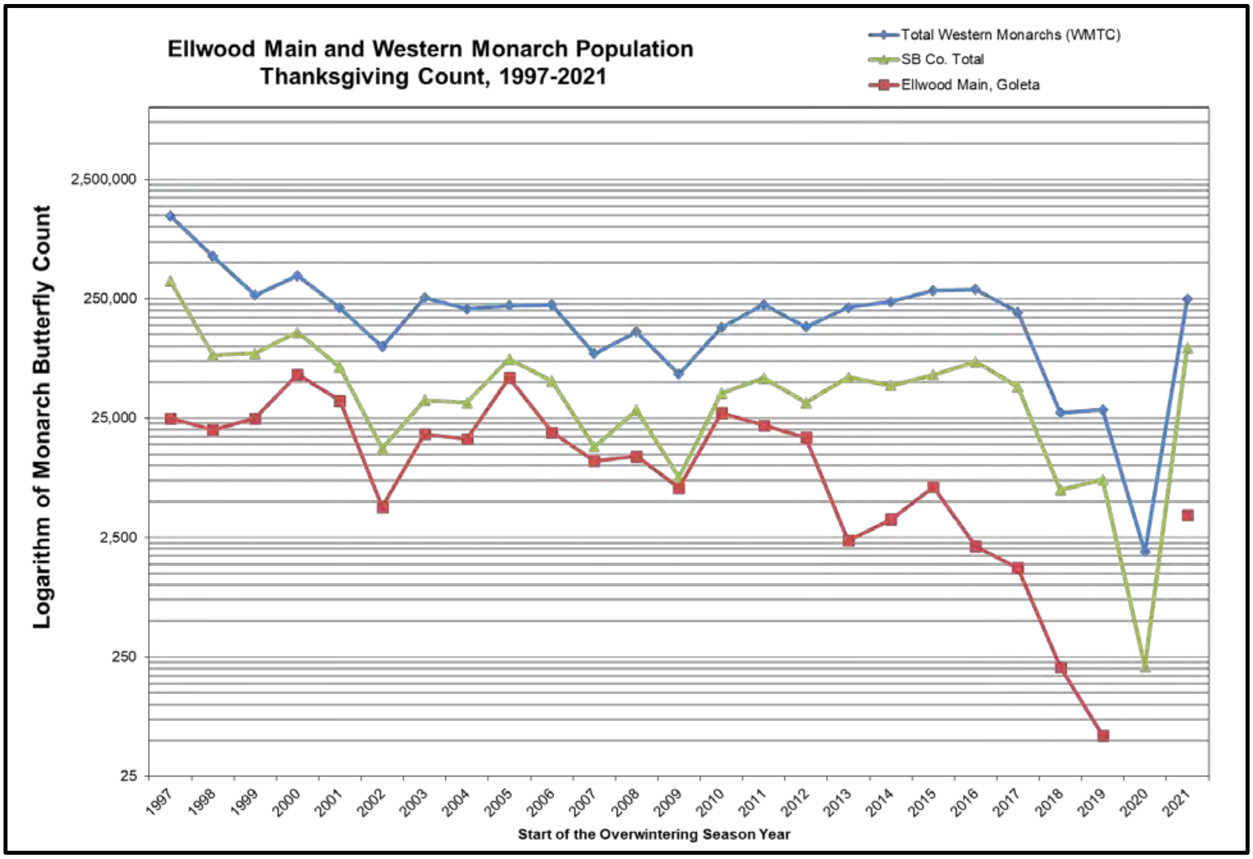
4.2 Ellwood Mesa Monarchs Relative to the Western Population

When we graph the total population of western monarchs and the total population in Santa Barbara County alongside the yearly Thanksgiving Counts at Ellwood Main, we begin to see how the monarch numbers at Ellwood Main are declining relative to the larger populations, and thusly we can see the decline of the habitat at Ellwood Main. Graph 2 shows these population numbers on the logarithmic base 10 scale. Logarithmic scale is helpful for visualizing the growth and decline in populations and natural systems. In Graph 2, we can see how the total populations of western monarchs in California and Santa Barbara County are closely linked with the monarch numbers at Ellwood Main and the fluctuations are parallel from 1997 until 2010. In 2011, the monarch numbers at Ellwood Main start to decline while the western and Santa Barbara County populations follow a similar upwards and fluctuating trend. The monarch numbers at Ellwood decline drastically in the years 2013 and 2016 which the populations of western monarchs and the Santa Barbara County showed an increase. One explanation for this incongruity is the decline of the habitat quality because of the drought discussed in Section 4.4.

In addition to the Western Monarch Thanksgiving Counts, the City of Goleta conducts monarch counts at the six known aggregation sites every two weeks during the overwintering period, October 1st through March 15th. In 2019, the city included habitat-wide surveys for monarchs potentially roosting outside of the six known sites and two sites were added in 2019 after this effort. These data show us how the monarchs are utilizing the sites every two weeks and we can infer habitat value from this numbers. In the 2015-2016 season (Graph 3), the monarchs maintained a consistent presence at Ellwood Main through the season and remained at Ellwood Main until mid-February. In the 2021-2022 season (Graph 4), the monarchs were present at Ellwood East in greater numbers than at Ellwood Main and my mid-January they had abandoned Ellwood Main in favor of Ellwood East. In the 2022-2023 season (Graph 5), we see that the monarchs were present at Ellwood Main and Ellwood East, and they had abandoned both sites by mid-January, likely because of the severe storms that occurred along the central coast in late December 2022 and early January 2023. This shows that the Ellwood Main habitat has declined to the point where it is no longer suitable habitat to protect monarchs from severe storms through January.

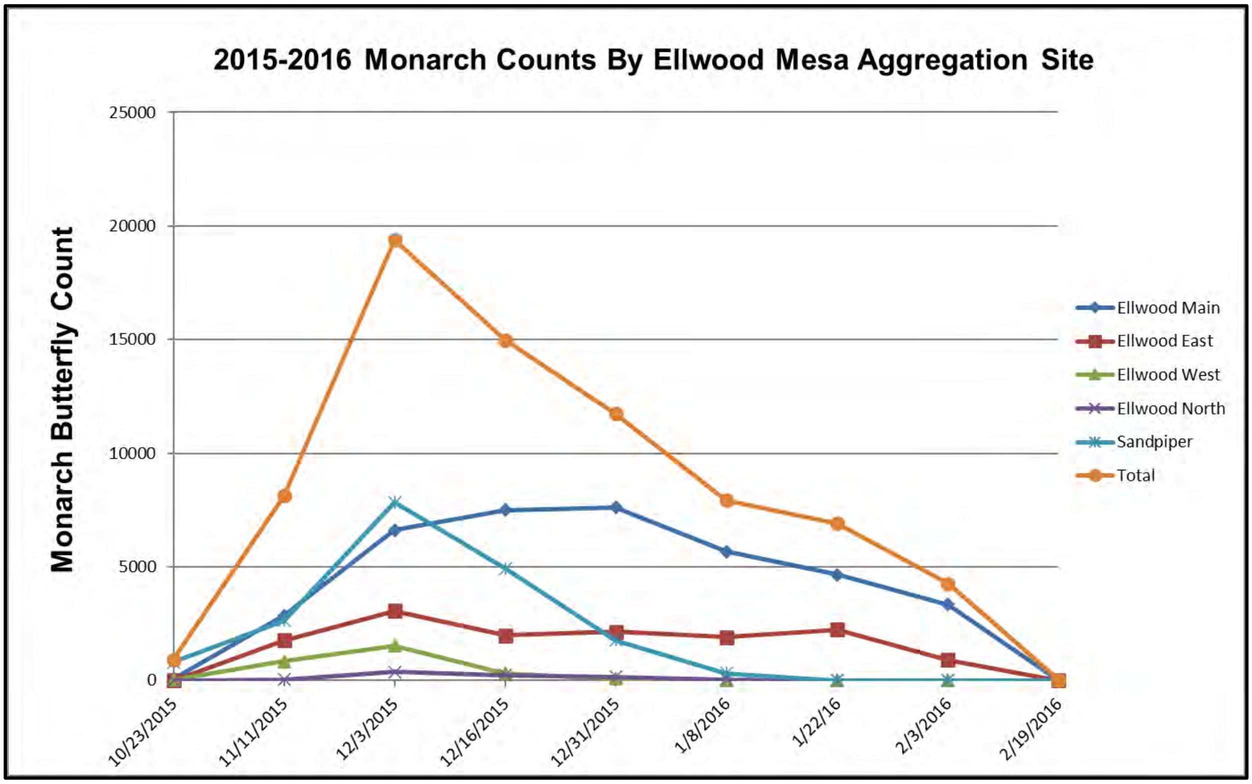


GRAPH 1. PEAK MONARCH POPULATION AT ELLWOOD MAIN FROM 1989 TO 2022
Data from Althouse and Meade Inc and Rincon Consultants Inc.



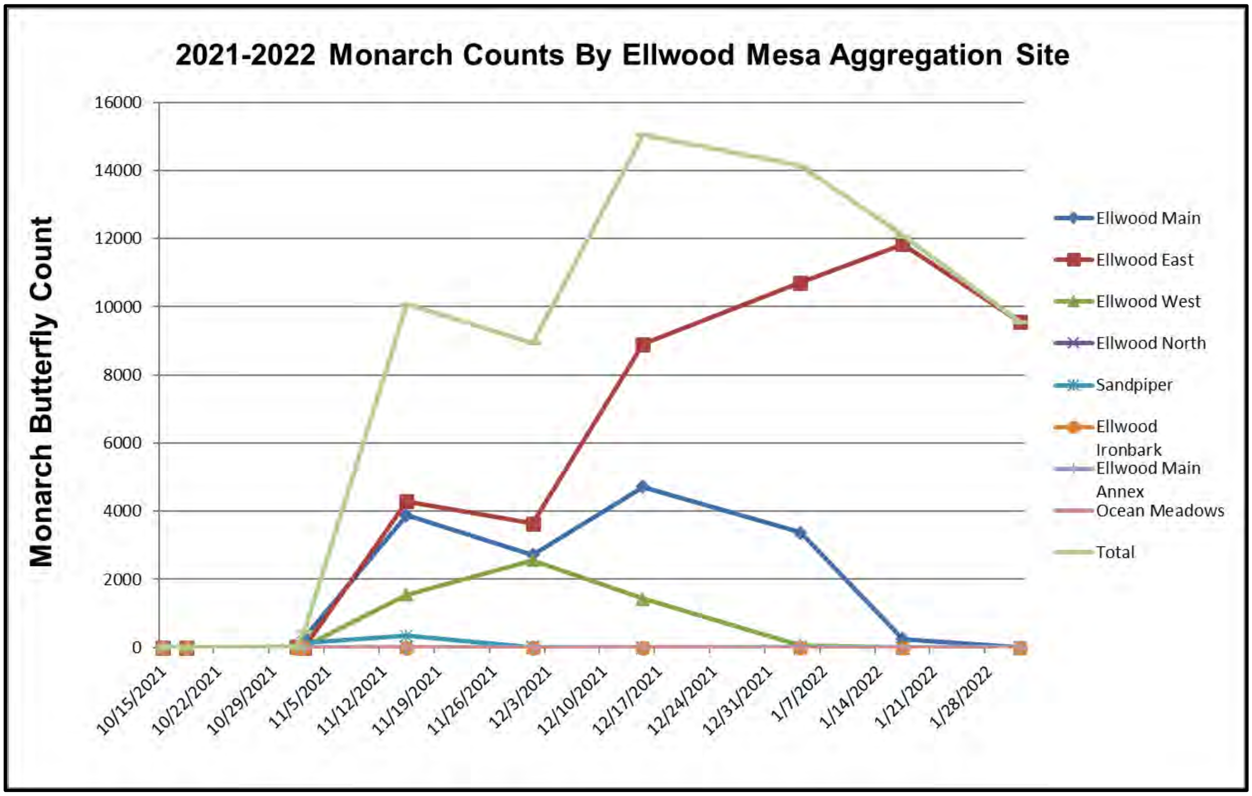
GRAPH 2. TOTALS OF WESTERN MONARCH POPULATION, SANTA BARBARA COUNTY MONARCH POPULATION, AND MONARCHS AT ELLWOOD MAIN IN LOGARITHMIC SCALE

Data source: Xerces Society for Invertebrate Conservation 2023.



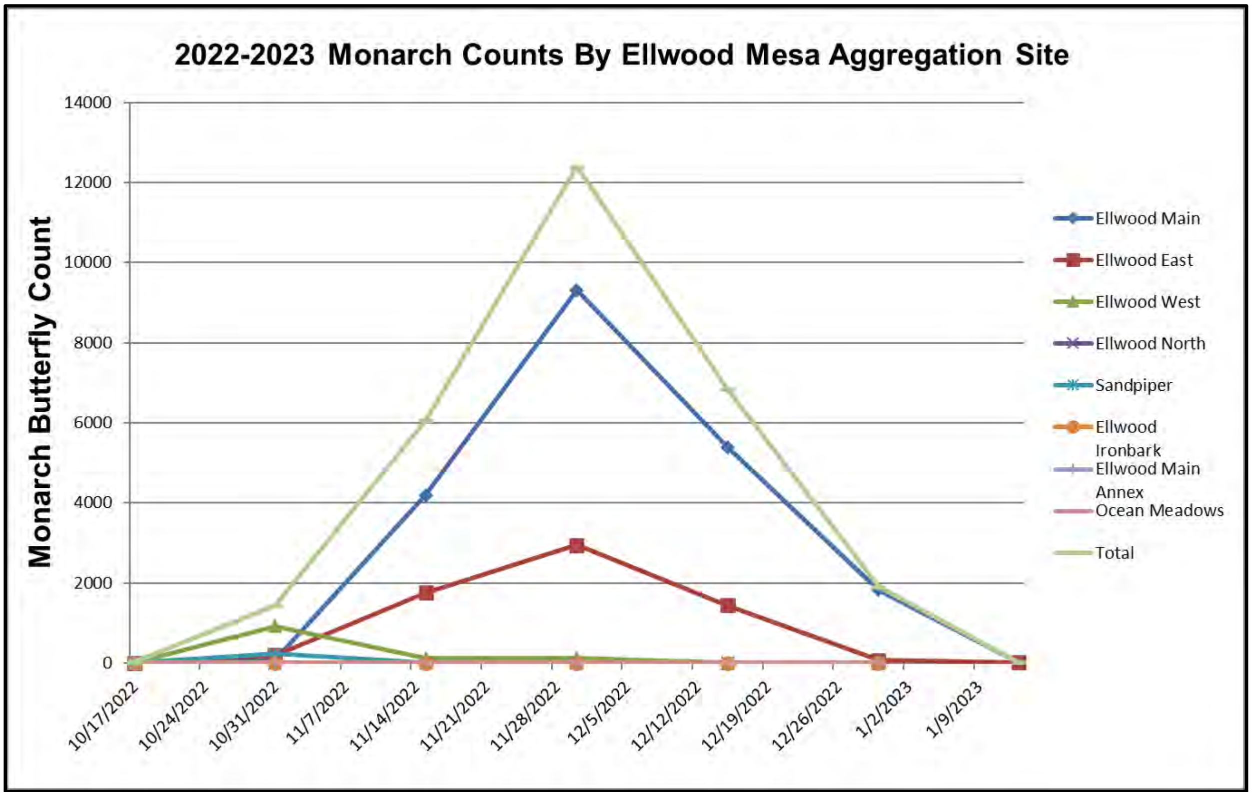
GRAPH 3. MONARCH COUNTS AT ELLWOOD MESA, 2015-2016 SEASON

Data from Althouse and Meade Inc and Rincon Consultants Inc.



GRAPH 4. MONARCH COUNTS AT ELLWOOD MESA, 2021-2022 SEASON

Data from Rincon Consultants Inc.



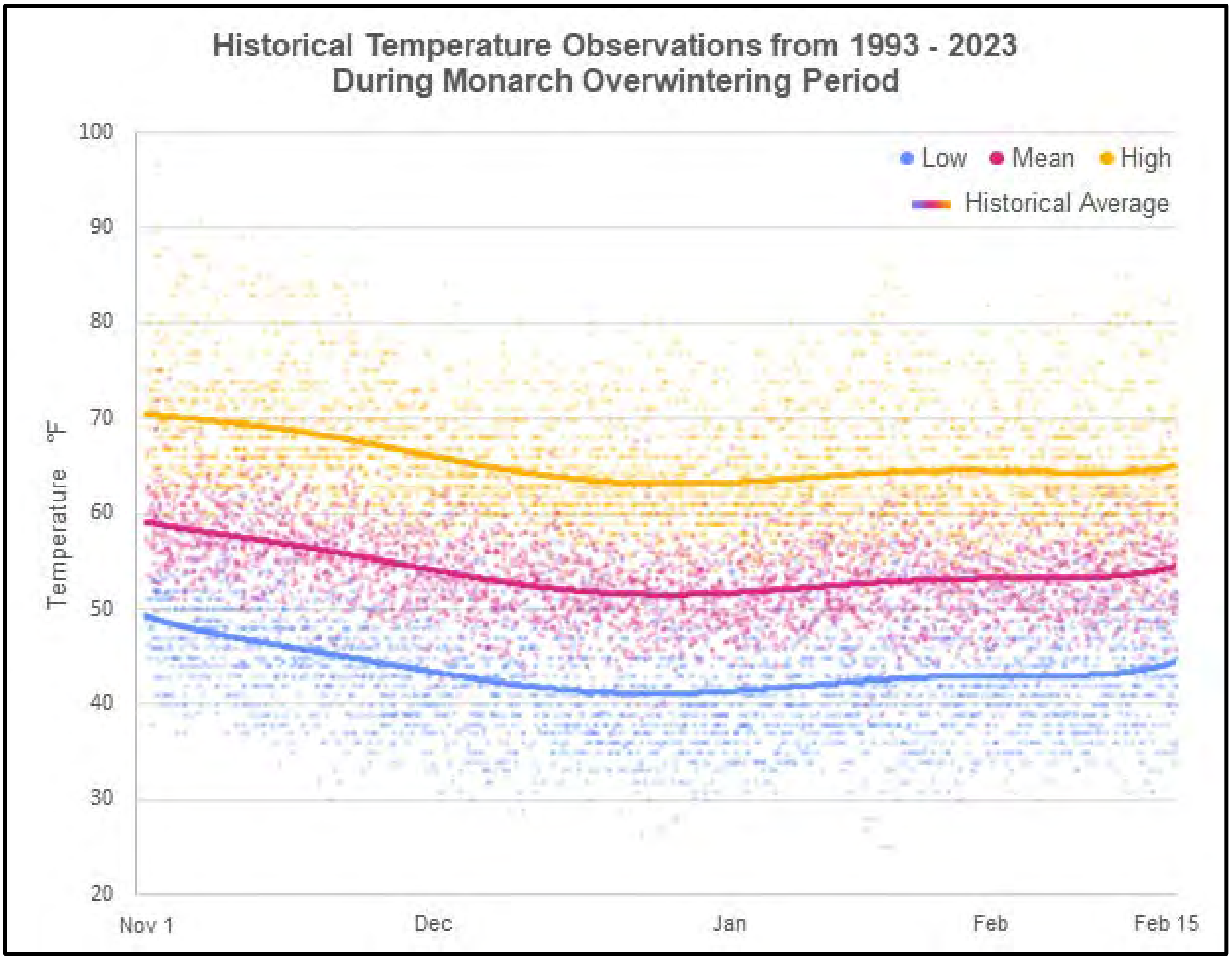
GRAPH 5. MONARCH COUNTS AT ELLWOOD MESA, 2022-2023 SEASON
Data from Rincon Consultants Inc.

4.3 Climate and topography at Ellwood Mesa

Ellwood Mesa has a Mediterranean climate, characterized by mild temperatures year-round. During the winter months when monarchs roost at Ellwood Mesa, temperature lows range from low to high 40 degrees Fahrenheit, highs from mid to high 60's, and mean temperature ranges from low to high 50's (Graph 6). Events outside this range are possible any time during the overwintering period, however, with a handful of uncharacteristically warm or cold days. November has the bulk of warmer than average days, occasionally exceeding 80 degrees. Only two days in the last thirty years were daytime highs above 90 degrees. Conversely, temperature lows can often go below 40 degrees, with a handful of incidents below 30 degrees (Graph 6).

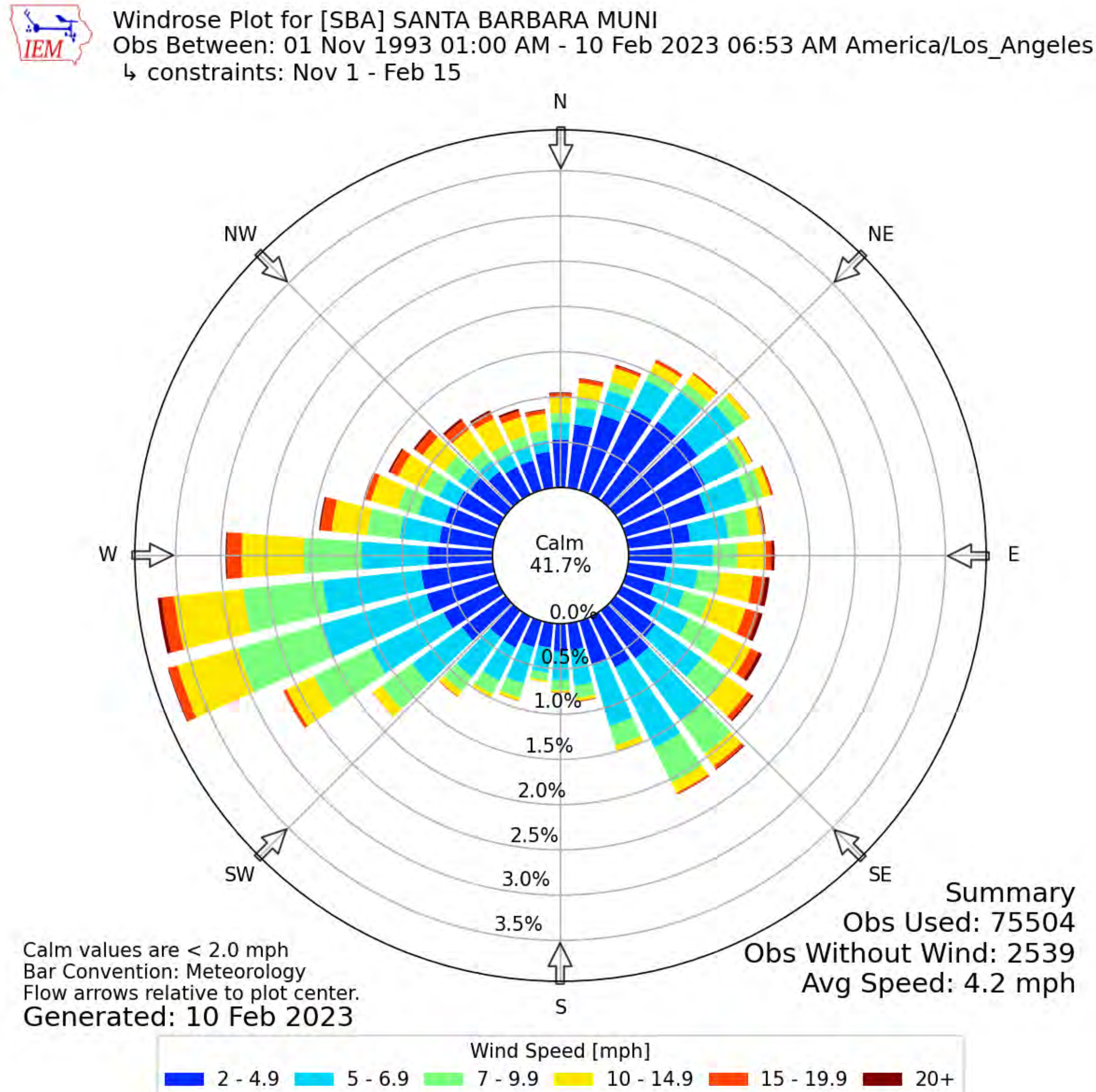
Wind conditions at Ellwood Mesa are generally suitable for monarch butterflies, with the majority of wind observations under 10 mph (blue, teal, and green areas in Graph 7). However, winter storms periodically bring strong winds throughout the overwintering period. These storms most frequently come from the southwest which bring wind speeds up to 30mph and heavy rain. While less common, all directions have records of strong storm events, particularly from the northeast and southeast (Graph 7).

The Ellwood Mesa contains topographic features that provide conditions supportive of the microclimate needs of migratory monarch butterflies. Overwintering monarch butterflies tend to cluster in specific areas where cold air is allowed to sink and drain away from the aggregation area. This mechanism allows for a warmer and better regulated microclimate to persist within the aggregation site. The low-lying channels formed by Deveraux creek allow for this removal of cold air at each of the show aggregation sites (Figure 3).



GRAPH 6. HISTORICAL TEMPERATURE OBSERVATIONS FROM 1993 – 2023

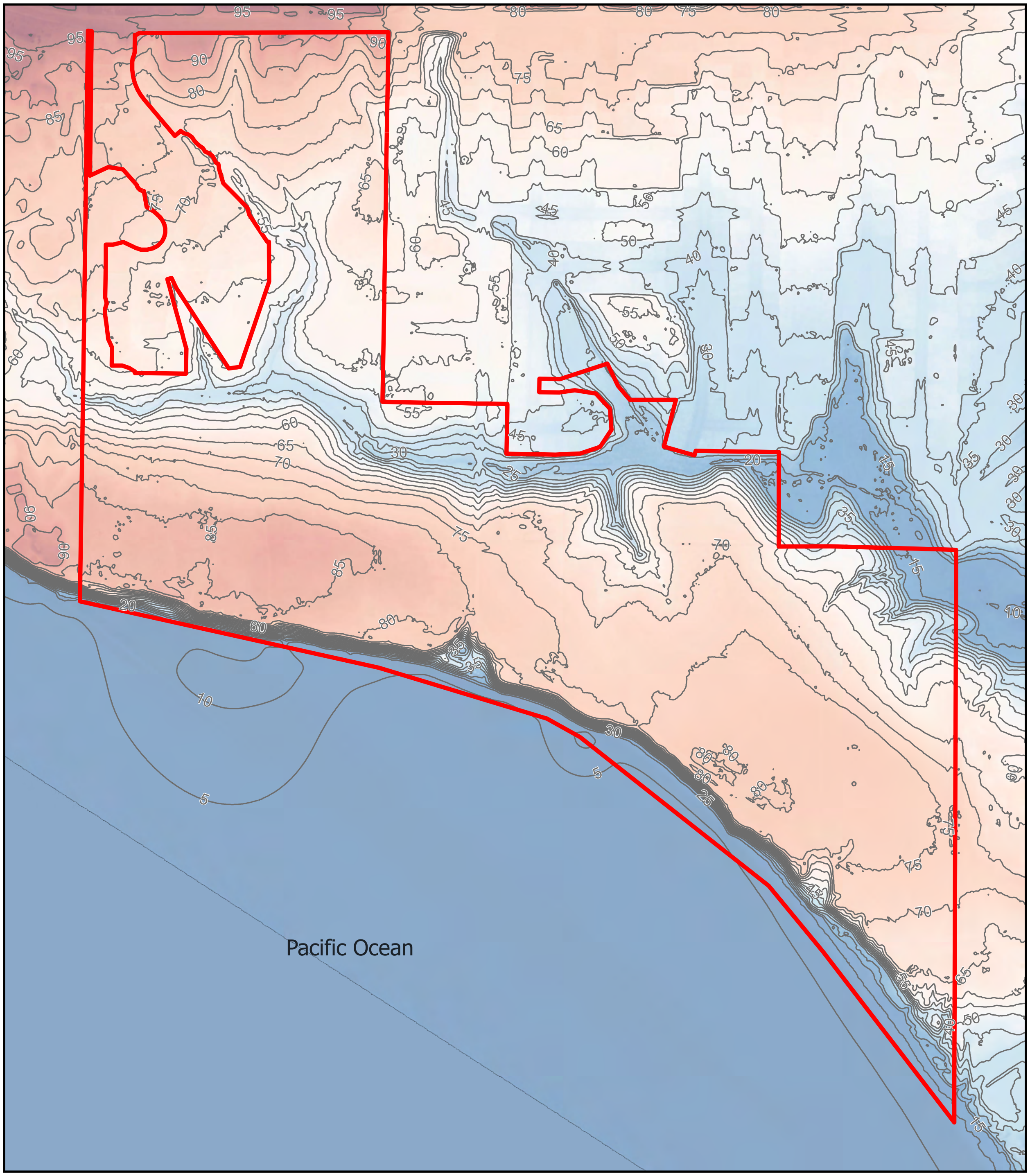
Data is during the monarch overwintering period. Temperature extremes and mean are plotted by date for each year. Averages for each temperature category are plotted across the time range.



GRAPH 7. WIND OBSERVATIONS FROM 1993 – 2023

Data is during the monarch overwintering period.

Figure 3. Ellwood Mesa Topography



Legend

Ellwood Mesa Open Space

Countour interval = 5 feet

Elevation

100

0

N

0 500 1,000 US Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42151°N 119.89267°W
Goleta, Santa Barbara County

Elevation data: 2018 USGS LiDAR

ALTHOUSE AND MEADE, INC.
BIOLOGICAL AND ENVIRONMENTAL SERVICES

Map Updated:
February 28, 2023 05:00 PM by CDM

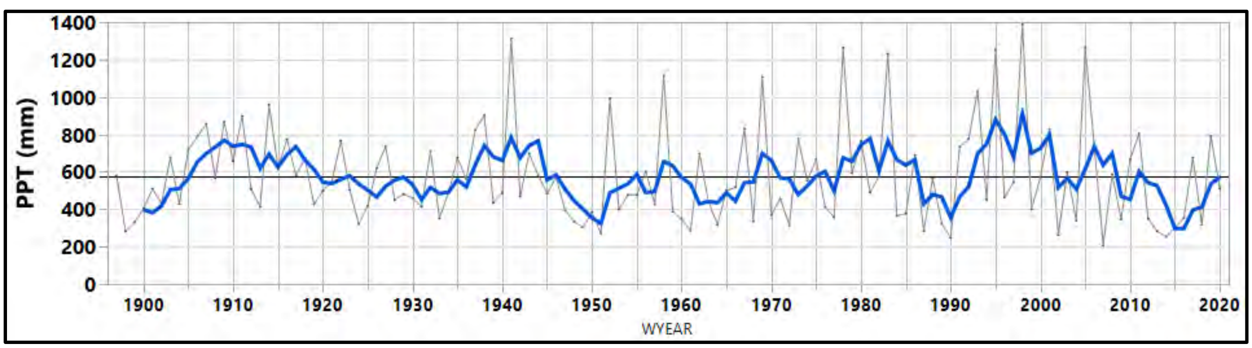
4.4 The 2012 – 2016 Drought: Unprecedented Event

4.4.1 Impacts of Drought on the Ellwood Forests

Forests exist in a dynamic equilibrium with available site water – growing more in wetter years and dying back in dry periods. The sustainable density of trees at a site results from dynamic processes. The first response to drought conditions is reduced annual growth, followed by loss of leaves and branches, and eventually death of entire trees as competition below ground for limited water pushes trees over their tolerances (Metcalfe et al. 1990, McJannet and Vertessy 2001). Insects and disease also can thrive under water stressed conditions, hastening tree mortality. For example, the eucalyptus long-horned borer (*Phoracantha* spp.) can more readily spread when trees do not have sufficient water to produce sap to repel the growing beetle grubs below the bark layer.

The Ellwood forests were established in the late 19th Century, during a relatively wet period. The tree spacing was typically around 2 meters (6'). The trees grew well in the mild climate and developed into the dense forests we associate with Ellwood. The monarchs occupied the suitable microclimatic niches – wind-sheltered gaps in the canopy (see Section 3.1) – as they developed across topography and by the recruitment and mortality of trees. For many decades, the forest was managed as a woodlot, where a certain amount of live and dead wood was removed, which maintained a sustainable forest density.

A historical reconstruction of the climate and water balance at Ellwood allows the current crisis to be put in perspective. The long-term (1895-present) precipitation (PPT) records by water year (October 1- September 30) for Ellwood shows high interannual variability, typical of the California climate (Graph 8). Mean PPT was close to 600 mm (23"). Maximum PPT was >1200 mm (47") in 1941 and 1998, and minimum PPT was <250 mm (7.9") in 1990 and 2007. Notable multi-year periods of low precipitation included the late-1920s and early-1930s, the late-1940s and early-1950s, the late 1980s-early 1990s, and 2012-2016.

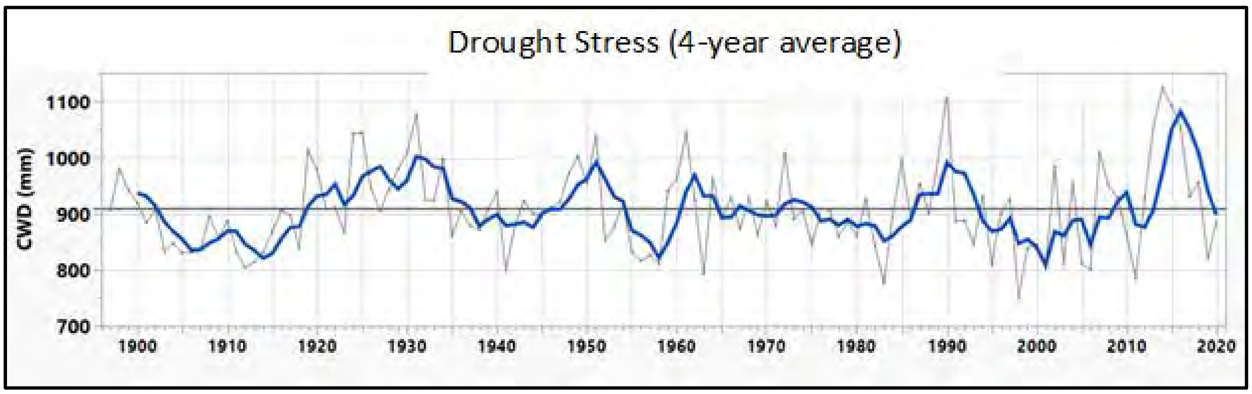


GRAPH 8. ANNUAL PRECIPITATION AT ELLWOOD MESA (OCT. 1 – SEPT. 30)
Long-Term Average=576 mm (22.7", Horizontal Line)

Annual precipitation (PPT) is not the only driver of drought – evaporative demand over the dry season, driven largely by temperature and the last date of soaking rains, depletes soil moisture until the rains return in fall. A water balance model, the Basin Characterization Model (Flint et al. 2021), keeps track of PPT, soil storage, and outputs including evapotranspiration, recharge, and runoff. Drought intensity is characterized by "Climatic Water Deficit" (CWD), which integrates precipitation, evaporative demand (PET), and soil moisture storage monthly into a single number for the water year. The calculation is for a standardized site with available soil water capacity of 451 mm (17”), the Ellwood monthly climate, and occupied by a blue gum forest. This is a consistent measure of annual and multi-year CWD that characterizes the overall intensity of drought on the soil type mapped at Ellwood. It does not account for microsite differences in soil depth and topography (to be discussed later).

A single year of drought stress rarely has strong lasting effects. Some leaf fall in evergreen trees may be observed. Cumulative stress over several years leads to widespread forest decline with loss of entire branches and trees (Metcalfe et al. 1990, McJannet and Vertessy 2001).

Annual CWD values are shown in Graph 9 as the thin grey line. Mean CWD was approx. 900 mm (35”) – Mediterranean climates have relatively high CWD because of the summer dry season, but the vegetation is adapted to these average levels. Maximum annual CWD was >1100 mm (43”) in 1990 and 2014, and minimum CWD was <800 mm (31”) in 1963, 1983, and 1998. The 4-year running average is shown as the thicker blue line. The multi-year droughts in the 1920s and 1930s, 1940s, and from 1987- 1990 peaked at 1000 mm (39”). There was some observable canopy die off by the early 1990s, but was largely restricted to high branches (S.B. Weiss and D. E. Meade, pers. observ.). But these branches resprouted during the relative wet period in the 1990s and 2000s.



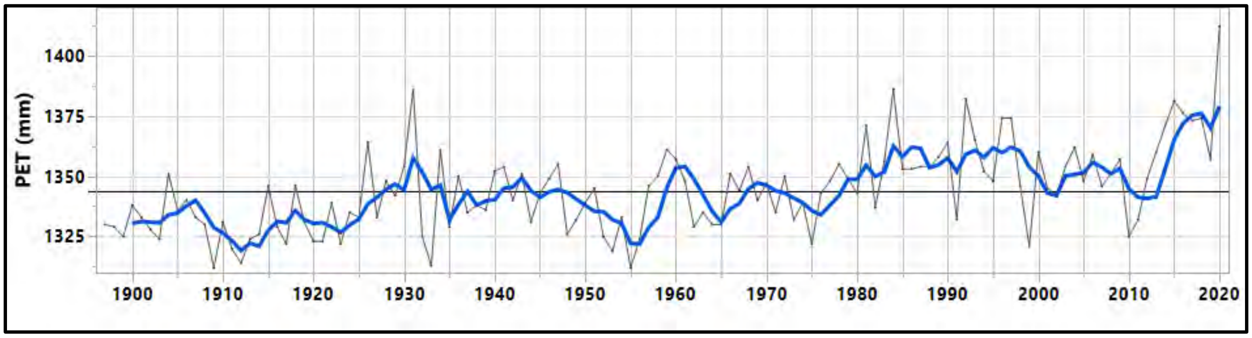
GRAPH 9. ANNUAL CLIMATIC WATER DEFICIT AND 4-YEAR RUNNING AVERAGE

A measure of annual Climatic Water Deficit (CWD) (grey line) and 4-year running average (thick blue line) at Ellwood Mesa. Long-term average = 907 mm (35.7”, Horizontal Line).

The other side of the equation is high productivity periods, characterized by low CWD and high PET. Notable periods of high forest productivity include 1905-1918, 1954-1959, and 1993-2005. The last high productivity period set up the catastrophic response to the recent drought, as trees grew according to site water availability with no removal of live biomass.

At the end of the latest drought from 2012-2016, CWD peaked at a 4-year average of 1081 mm (43”), nearly 100 mm greater than the historical highs in 1931 and 1990. The 2012-2015 California drought was not only the most severe in 1,200 years, but it also “has an almost incalculable return period and is completely without precedent” (Robeson 2015). Unlike much of California, Santa Barbara County received relatively little rain in 2016, extending the drought one more year.

The most important long-term climate trend at Ellwood Mesa has been an increase in evaporative demand – annual potential evapotranspiration (Graph 10). PET is a multiplicative function of air temperature and solar radiation, and accounts for summer fog. The long-term trend is driven by increasing air temperature, especially during the dry season. PET has increased by 50 mm (2”) since 1900, with the sharpest increase since 2013. In 2020, PET hit an unprecedented 1412 mm (56”); however, the resultant CWD was not excessive because Mar-Apr rainfall was 285 mm (11”) which saturated the soils at the beginning of the dry season. In contrast, in 2013 and 2015, the rains stopped early (January) so the CWD accumulated over an extended dry season. These examples highlight how the timing of precipitation is an important component of annual CWD.



GRAPH 10. ANNUAL POTENTIAL EVAPOTRANSPIRATION

A measure of evaporative demand (grey line) and 4-year running average (thick blue line) at Ellwood Mesa. Long-term average = 1344 mm (53-inch, horizontal line).

4.4.2 Tree Mortality

The impact of this unprecedented drought on Ellwood has been mass mortality of blue gums across much of the site (Photo 4 and Photo 5). As discussed elsewhere, Ellwood is too arid for blue gums to thrive over the long term – the tree comes from Tasmania and southeast Australia where there is regular summer rainfall. The whole tree mortality was exacerbated by the uncontrolled growth of dense stands during the wet periods in the 1990s and 2000s, after woodlot management ceased. The blue gums have “self-thinned” to restore some balance between forest density and water availability. The other eucalyptus species present at Ellwood, especially red ironbark, have not suffered drought mortality.

The extent of the tree mortality is captured in the LiDAR map of dead standing and downed wood (Figure 5 - Figure 12) (LiDAR is explained in Section 5.1.3). The figures show large swaths of the forest died off. We estimate that there was approximately 360,797cubic feet of dead standing and downed wood across the entire forest as of 2021 with major mortality hotspots in Ellwood North, Ellwood West, and parts of Ellwood Main (maps). Total volumes of dead standing and downed wood by monarch site area (Figure 4) is presented in Table 3.

TABLE 3. VOLUME OF DEAD STANDING AND DOWNED WOOD BY MONARCH SITE AREAS

Name of Monarch Site Area	Monarch Site Area Size (ac)	Volume of Dead standing and Dead downed Wood (cubic feet)	Number of Dump Trucks
Ellwood Main	13.86	95,377	252
Ellwood West	6.74	58,079	154
Ellwood East	8.33	32,802	87
Ellwood North	10.81	95,280	252
Ellwood Ironbark	8.14	66,652	176
Sandpiper	3.04	6,699	18
Ocean Meadows	2.09	5,908	16
Totals	53.01	360,797	954

4.4.3 Effects of Tree Mortality on Monarch Habitat

The loss of trees and canopy cover has opened the overwintering sites to increased wind exposure. At Ellwood Main, the depth of wind shelter has diminished with the mass mortality, so that there are “thin green lines” of remaining live trees to provide wind shelter from various directions. Critical redundancy in wind shelter is gone. The west-southwest exposure has opened into a wind gap. The dead trees tend to be on the convex shoulder of the drainage, where the soils are thin, and water drains away. Downslope, where soils are thicker and some water drains in from the slopes above, fewer trees have died, and the remaining row of live trees provide the last line of wind shelter for the cluster zone. On the southeast side, the outer edge row of trees is still intact, but the interior trees have died. The loss of trees north of the cluster zone, some still standing as of 2023, has opened that direction to more wind, and the cluster trees themselves provide the remaining shelter from the northwest, north, and northeast winds.

At Ellwood West and Ellwood East, the topography – the rise from Deveraux Creek to the mesa – has ameliorated the loss of tree canopy to the south. The cluster sites close to the riparian zone, in the flat or just up the slope, and the mesa, with an elevation difference of approximately 12 m (40’), provides additional shelter from SE, S, and SW winds. Shelter from E and W winds are provided by the great depth of forest cover along the riparian corridor, and these trees are relatively well watered and less susceptible to drought (although there have been individual trees that have died or uprooted).

Figure 4. Dead Wood Volume Zones

Legend

Dead Wood Volume Zones

Monarch Roosting Site

N

0 500 1,000 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42491°N 119.89278°W
Goleta, Santa Barbara

Imagery Source: USDA NAIP, 06/20/2022

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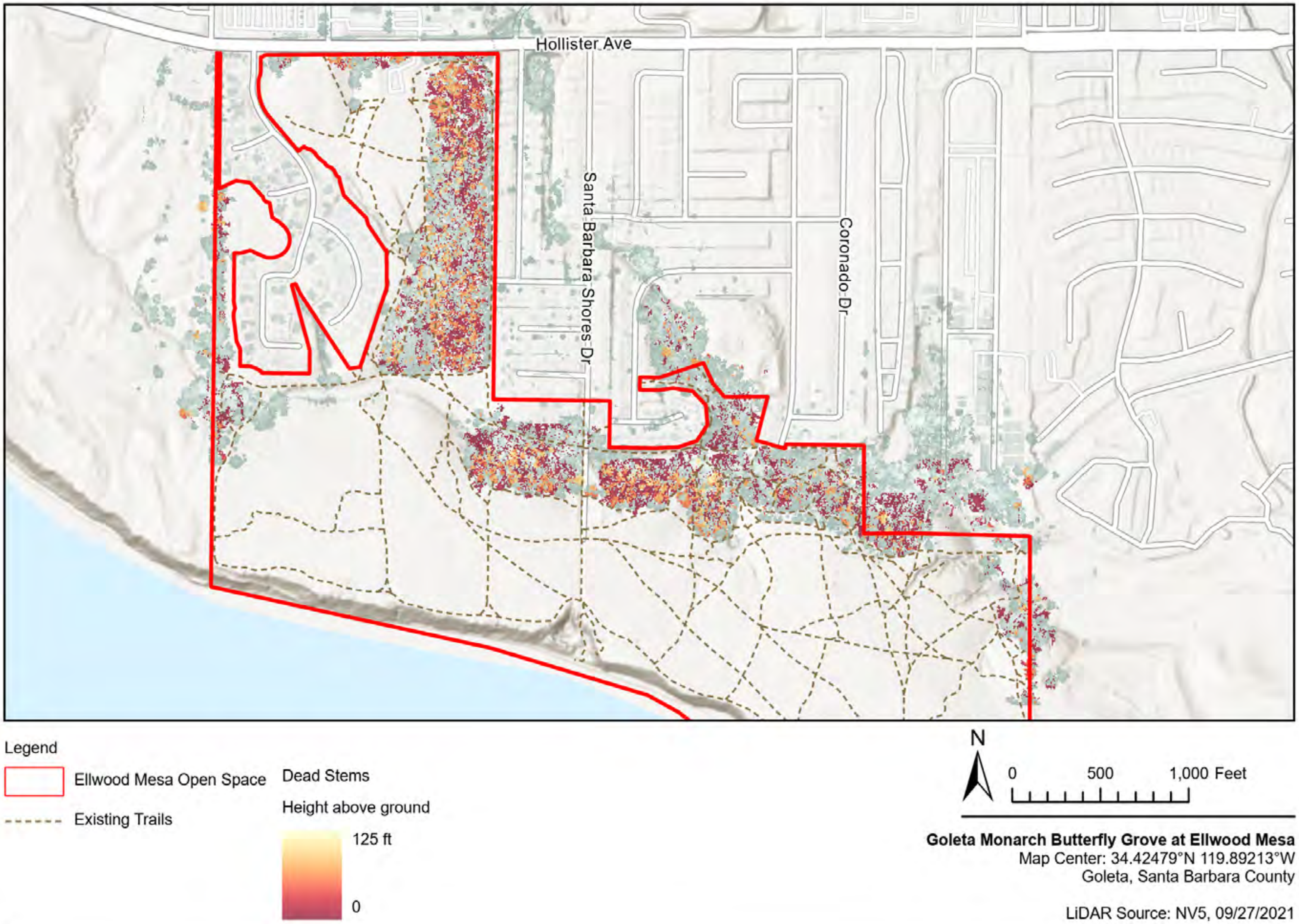
Map Updated:
February 28, 2023 12:28 PM by CDM

Figure 5. Classified Dead Wood - Overview



Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42479°N 119.89213°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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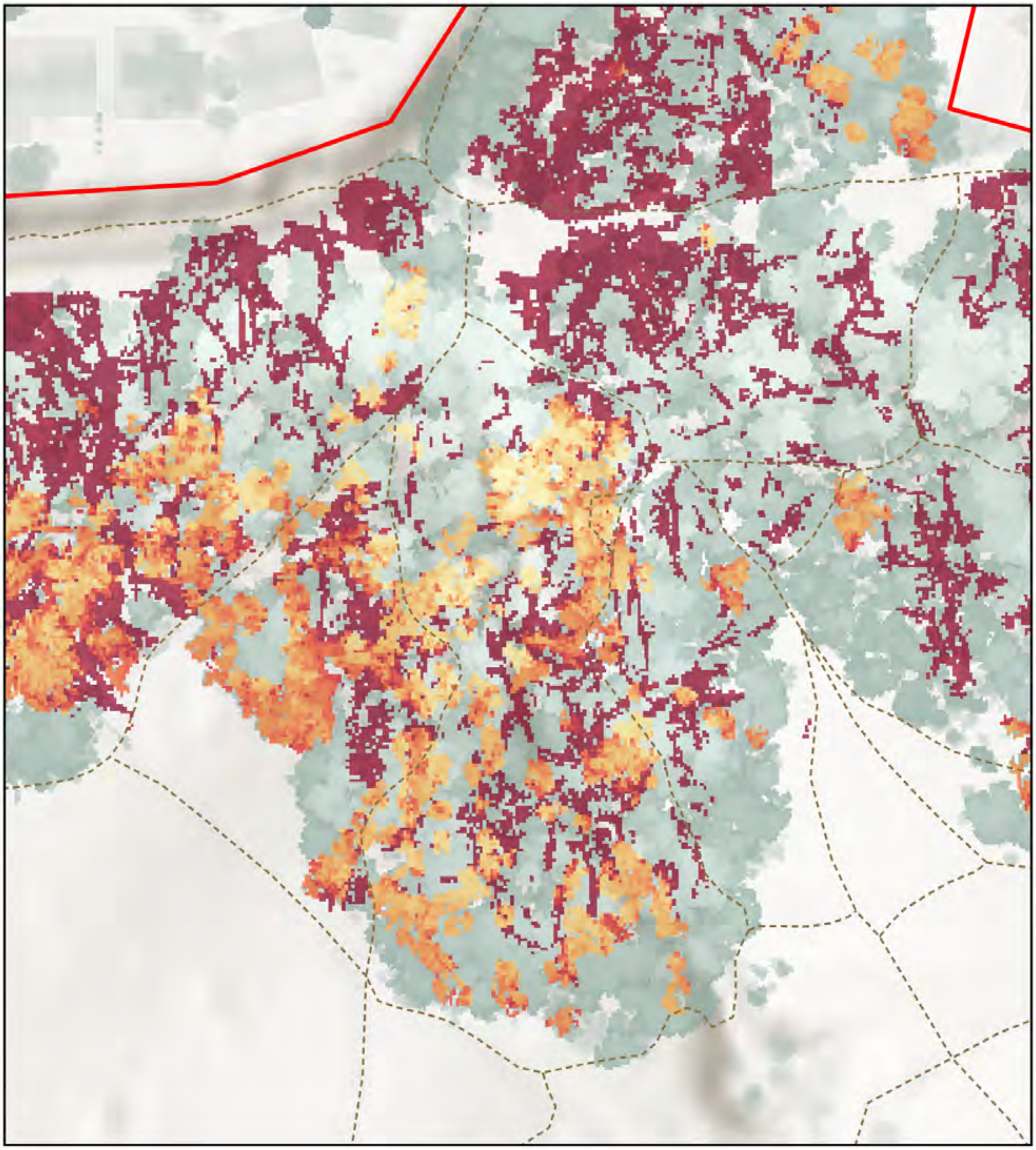
Map Updated:
February 21, 2023 01:33 PM by KRN

Figure 6. Classified Dead Wood - Ellwood Main



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 50 100 Feet

Goleta Monarch Butterfly Grove
at Ellwood Mesa
Map Center: 34.42283°N 119.89096°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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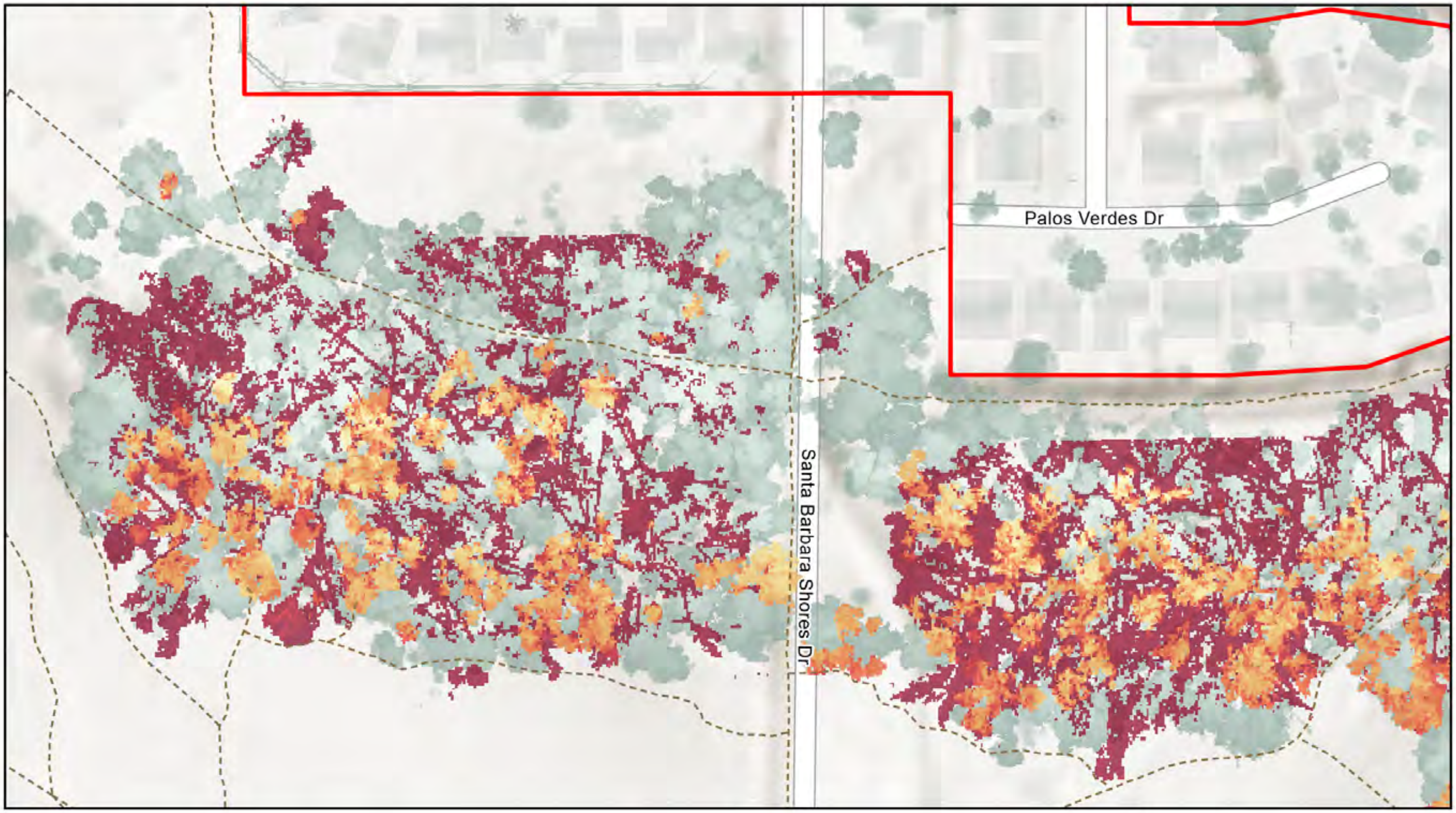
Map Updated:
February 21, 2023 01:35 PM by KRN

Figure 7. Classified Dead Wood - Ellwood West



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42338°N 119.89355°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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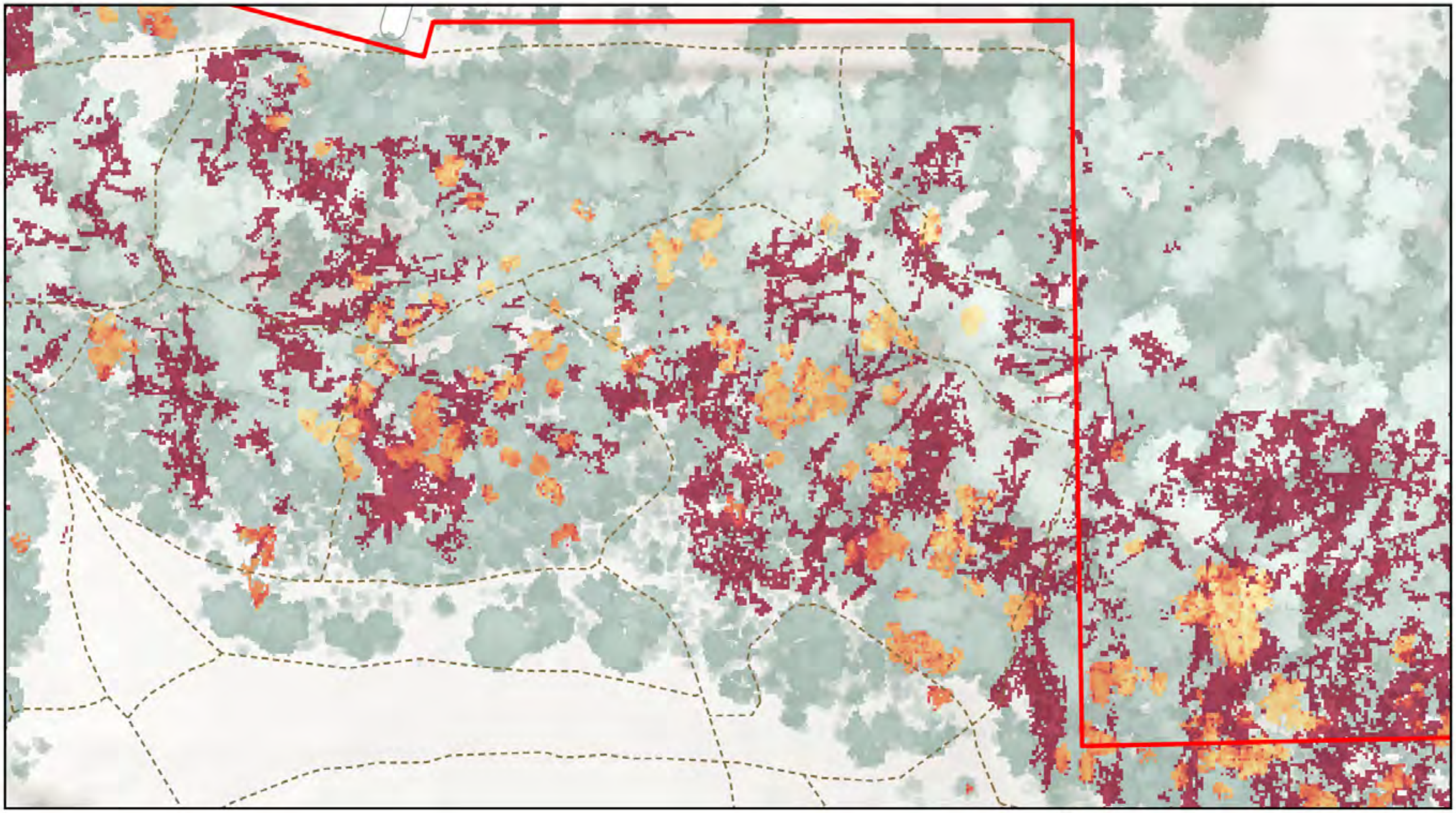
Map Updated:
February 21, 2023 01:36 PM by KRN

Figure 8. Classified Dead Wood - Ellwood East



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42283°N 119.88886°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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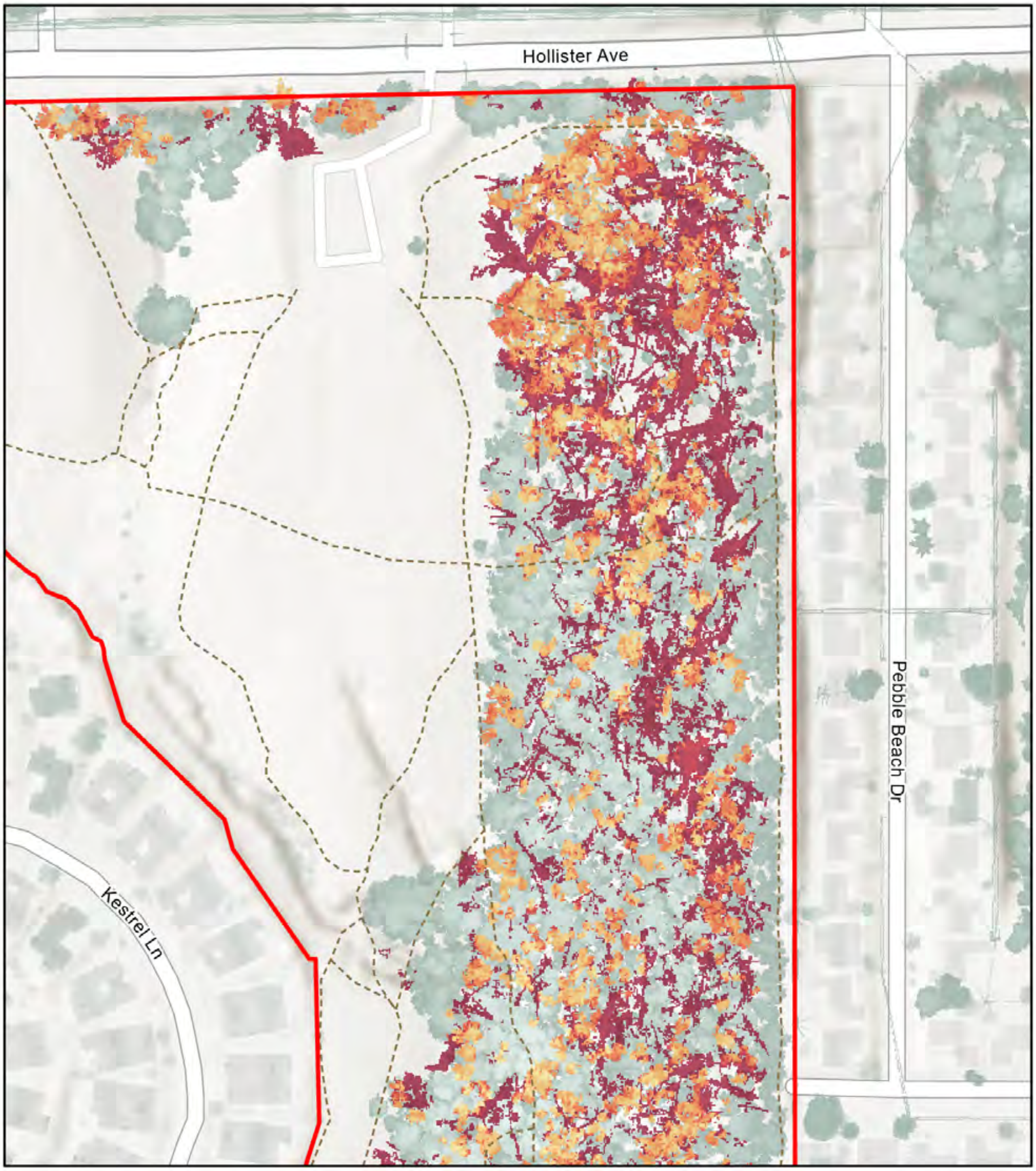
Map Updated:
February 21, 2023 01:36 PM by KRN

Figure 9. Classified Dead Wood - Ellwood North



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.4278°N 119.89625°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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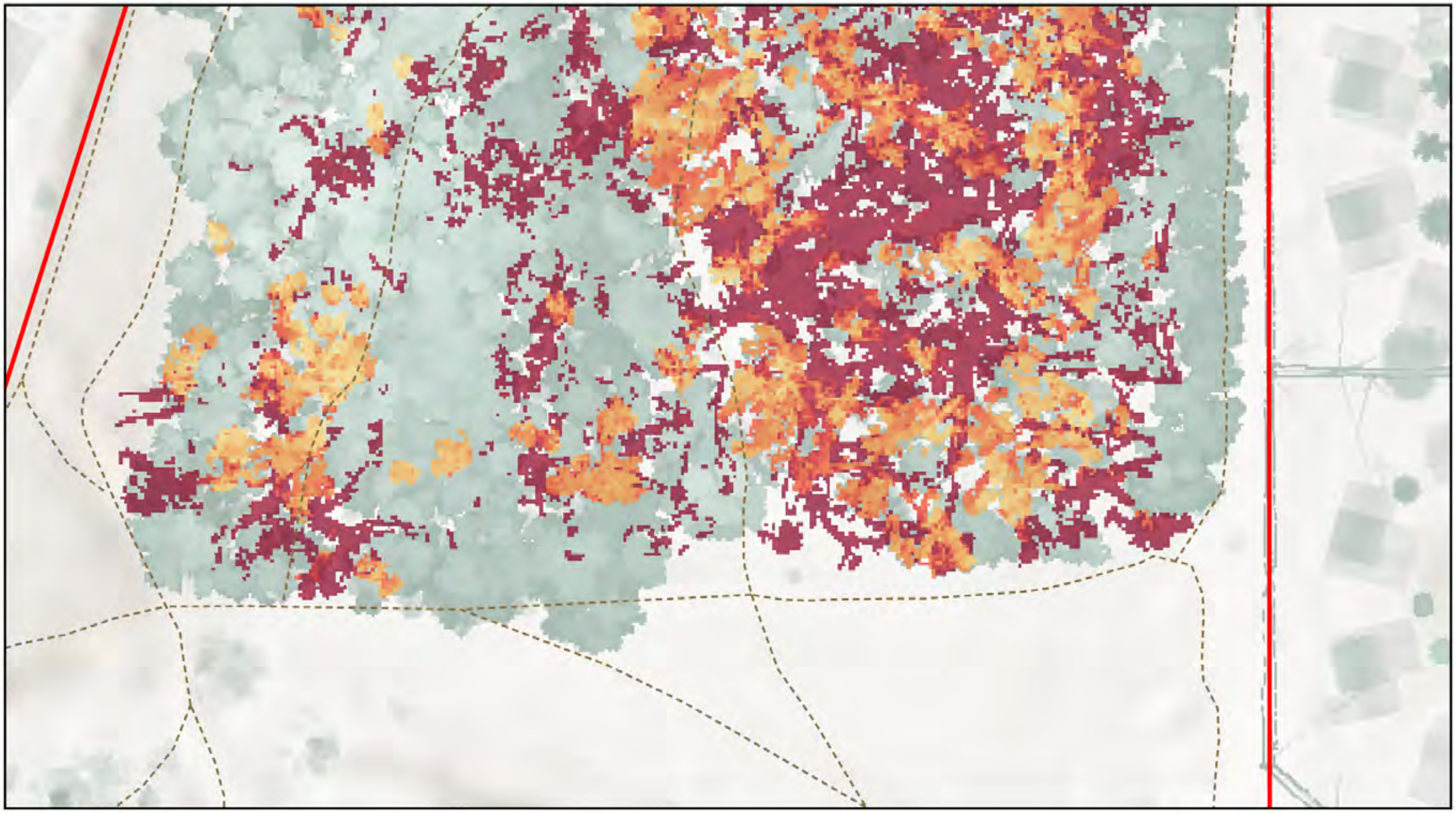
February 21, 2023 01:36 PM by KRN

Figure 10. Classified Dead Wood - Ellwood Ironbark



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 50 100 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42486°N 119.89609°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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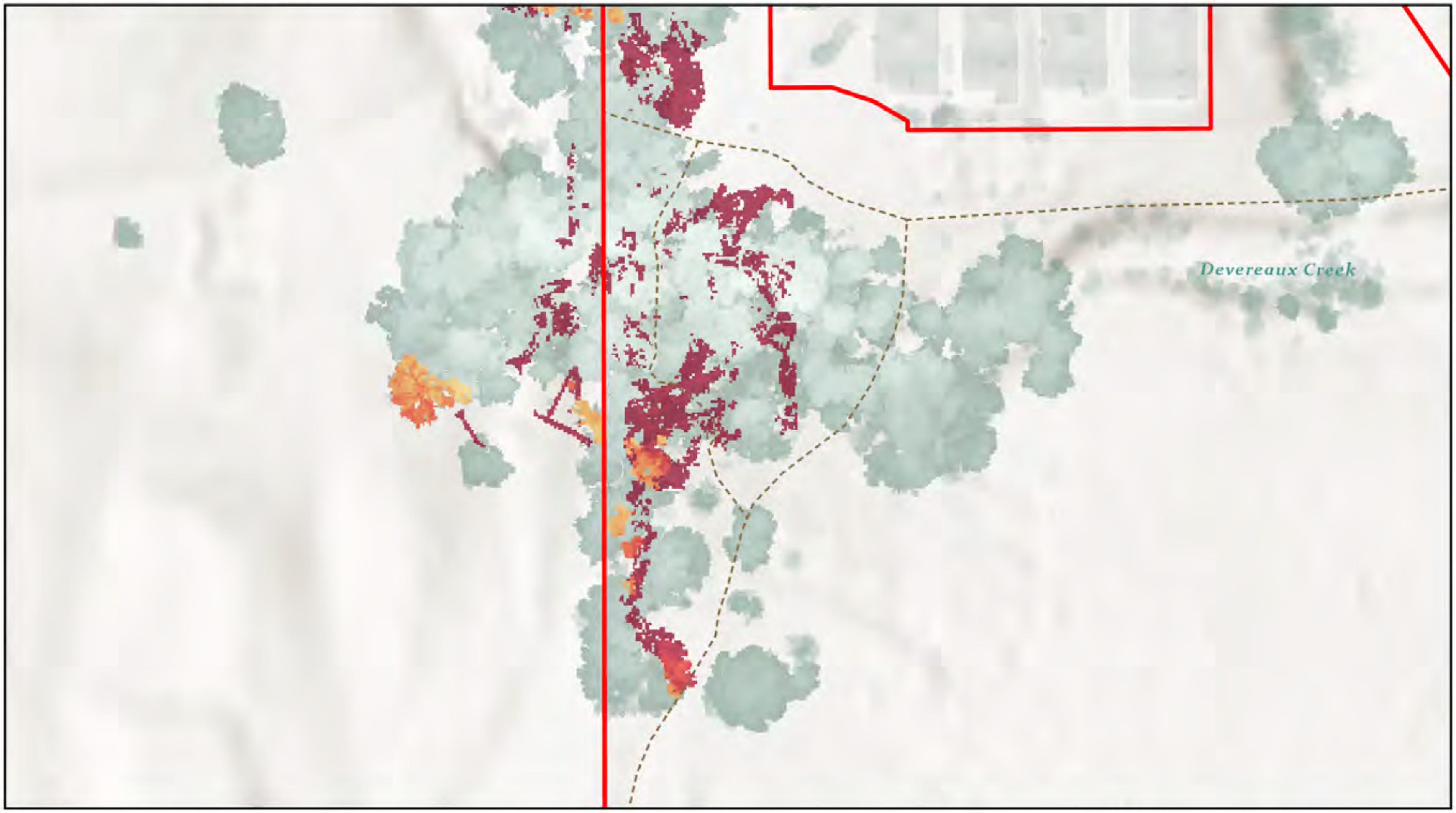
Map Updated:
February 21, 2023 01:37 PM by KRN

Figure 11. Classified Dead Wood - Sandpiper



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42385°N 119.89995°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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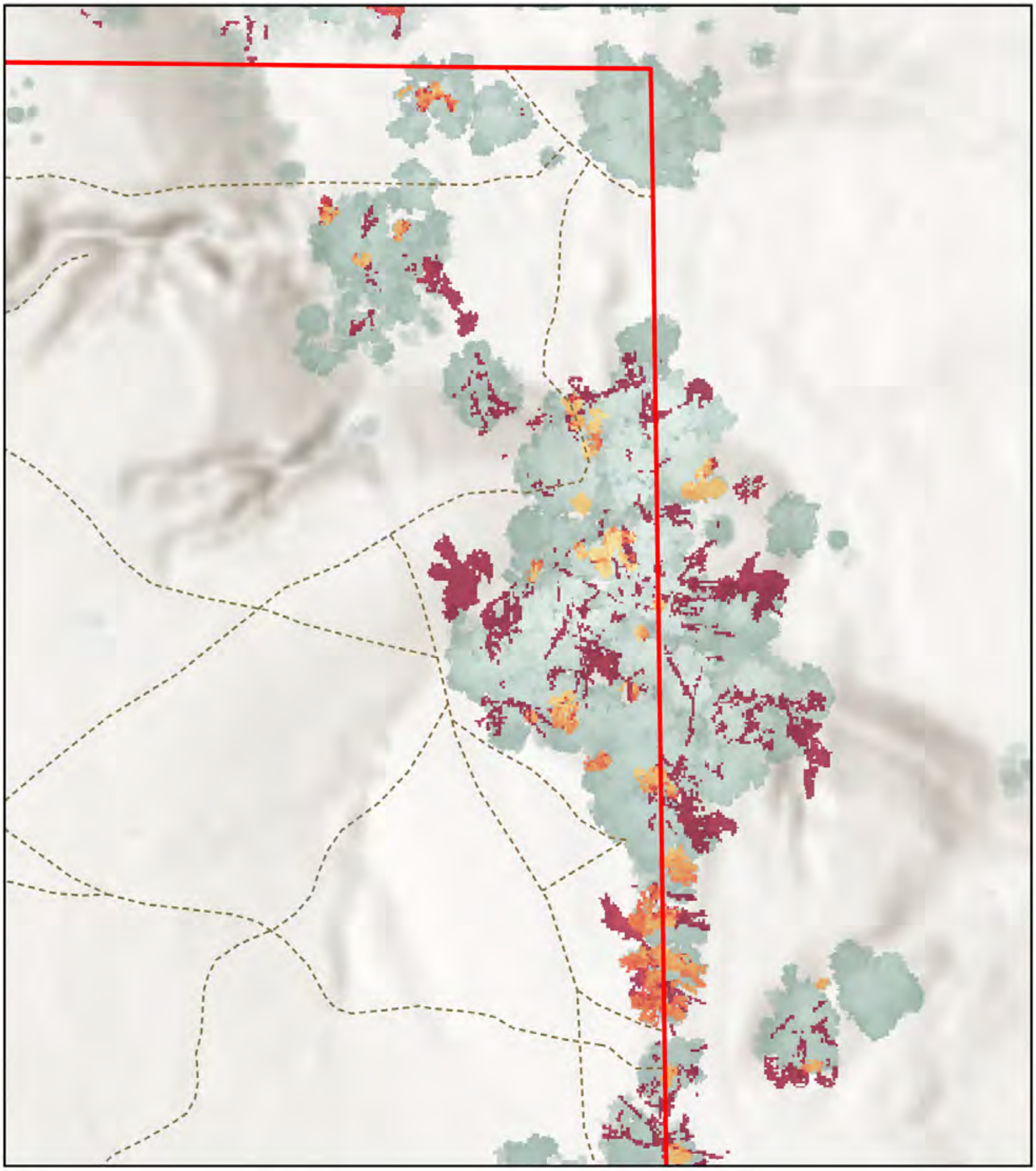
Map Updated:
February 21, 2023 01:37 PM by KRN

Figure 12. Classified Dead Wood - Ocean Meadows



Legend

Ellwood Mesa Open Space

Existing Trails

Dead Stems

Height above ground

125 ft

0

N

0 75 150 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa

Map Center: 34.42098°N 119.8853°W

Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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Map Updated:
February 21, 2023 01:38 PM by KRN

Photo 4. Mass mortality of blue gums at Ellwood North, view towards the east.

Photo 5. Mass mortality of blue gums at Ellwood Main, at viewing area looking southwest.

5 STATUS OF THE HABITAT AT ELLWOOD MESA

Professional experience integrates the technical analyses into a coherent assessment and plan that maximizes chance of success, if adopted and executed. Since 1989, the core scientists on this team have worked on dozens of formal and informal monarch habitat assessments/plans and have seen a full gamut of site characteristics, monarch behavior, and management successes and failures.

5.1 Overview of Methods

We are applying this best available science to diagnosing and restoring the monarch habitat at Ellwood Mesa. The tools we use to assess and manage overwintering sites include:

1) Direct observations
2) Hemispherical photography
3) LiDAR
4) Forestry
5) Wind modeling

These are methods that are used to quantify the amount of canopy and openness in the canopy in order to then infer the prevalence of wind and intensity of light. These techniques encompass the best available science, bolstered by collective decades of monarch experience at Ellwood Mesa and dozens of sites from Sonoma to San Diego.

5.1.1 Direct Observation

The direct observations of monarch distribution and abundance allows the butterflies to tell us what they like and do not like. The Western Monarch Thanksgiving Counts document numbers in late-November and early-December, and the New Year's Counts document numbers at a subset of sites in early-January. The difference between the two counts reflects site suitability in the face of whatever weather occurred between the counts. With strong storms, monarchs leave some sites completely, do a partial exodus, and many sites decline with ongoing mortality. Often, a large storm will reshuffle monarch distributions among close sites, or sites tens of kilometers away. In other years conditions are mild and little change in distribution occurs, only some mortality. In California as a whole, the change from Thanksgiving to New Year's ranged from –35 to –49 % but varied greatly from site to site and region to region.

Finer temporal resolution of monitoring (1-2 weeks, or even close to daily) reveals responses to individual weather events especially when the cluster locations are closely tracked by tree, branch, and height. Wind vulnerabilities become apparent when movements are linked to individual storms or storm sequences, and we can often observe the fine-scale shelter provided by individual branches. Also, monarchs prefer different insolation regimes at different times of the year conditional to wind, seeking afternoon sun after a day flying, or morning sun when early activity.

Direct observation of wind, temperature, and insolation can be valuable, but have limits. Spot observations can map instantaneous conditions across an entire site and have proven invaluable (Leong 1990, Leong et al. 1991). Continuous observations by automated equipment are limited to a few sites in any given grove.

5.1.2 Hemispherical Photography

Hemispherical photography (hemiphotos) is a well-developed technique for analyzing canopy structure at overwintering sites (Weiss et al. 1991). A 180 degree “fisheye” image pointed upward allows precise determination of canopy gaps, and their directional impacts on light and wind is determined by specialized image analysis software, such as Hemiview. The methodology for the hemispherical photography is included in Appendix A.

Canopy gaps along sunpaths allow for fine-scale estimation of monthly and half-hourly insolation, and gaps in different wind directions that are produced. These “site factors” can be mapped as points or as interpolated surfaces. The point data are presented as color-coded circles for ISFU (Visible Sky), DSFU (proportion of potential annual insolation), and monthly potential direct insolation.

The first-order approximation of wind penetration from hemiphotos is “directional exposure:” the proportion of open sky in 8 different directions. “Wind roses” for hemiphotos are created from different sized wedges in 8 directions that correspond to the proportion of open sky in that 45° sky sector. Low elevation angles are more highly weighted than overhead the hemispherical view (greater proportion of the hemisphere at low elevation angles). Hemiphotos are labeled for directional exposure with the wind rose below the photo number. The wind rose wedges are color coded: red is > 0.30 and indicates too much exposure, yellow is between 0.20 -0.30 which is marginal, and blue is < 0.20 which is generally well-sheltered.

At Ellwood Main, a dense enough array was taken so that interpolated surfaces could be generated in ArcGIS using the Geostatistical Analyst. The chosen technique (Thin Plate Spline) that is an exact interpolator – the surface goes through each observation, and directional bias (i.e., upwind/downwind) can also be considered.

More detailed methodology is included in Appendix A.

5.1.3 LiDAR

LiDAR is the newest tool for evaluating monarch sites, developed since 2019. A laser scanner, from drone or airplane, is flown over a site and the 3-D “point cloud” of reflections captures the fine-scale canopy structures across entire sites and adjacent areas. Lidar is an acronym of "light detection and ranging", a method for determining ranges by targeting a surface with a laser and measuring the time for the reflected light to return to the receiver. The full analysis report with methodology is included in Appendix G.

5.1.4 Arboriculture

Professional arborists were employed to assess current conditions and tree health and make recommendations for future maintenance. The foundational knowledge arborists provide is important to our understanding of forest dynamics and our ability to manage them into the future. In 2017 and 2018, an ISA Certified Arborist (Cory Meyer) assessed trees throughout Ellwood Mesa by documenting tree genus and species, diameter at breast height (DBH), tree height, canopy spread, health, and environmental conditions. Diameter was measured in Standard American English (SAE) units by running a Starrett 530JT-50 diameter tape measure around the trunk at breast height. Visual inspections were used to estimate canopy height and spread, health, structure (e.g., direction of lean), and defects. Notes were taken for environmental or site conditions, tree structural problems, or possible diseases and pests.

5.1.5 Wind Model

Recent software advances allow computational fluid dynamics to be applied to LiDAR point clouds to model wind within forest canopies. We applied Rhinoceros 3D 7 (McNeel et. al. 2010) with Eddy3D (a plugin for Rhino 7 that uses OpenFOAM), Volvox (Zwierzycki 2016), Lands Design (Asuni 2022). We created a 3-D map of wind speeds at fine scales, allowing for more detailed assessments than those based on inferred wind from canopy gaps. Detailed wind modeling methods are provided in Appendix B.

The effects of both proposed and existing forest management, such as planting shelterbelts, or the loss of trees, as well as the effects of nearby buildings were simulated to understand how wind dynamics are affected by various structure types and heights.

More detailed methodology is included in Appendix B.

5.2 Ellwood Main

Ellwood Main is a stand of primarily blue gums surrounding a north-south running side gully of Deveraux Creek. The core stand extends approximately 140 m (460 ft) north-south from Deveraux Creek to the end of the gully, and approximately 125 m (410 ft) east-west. Some outlying stands north across Deveraux Creek and east and west of the core stand provide outer wind shelter. The main cluster sites occupy approximately 30 m (100 ft) over the gully, starting approximately 30 m (100 ft) from the creek channel. Tree heights are up to 40 m (130 ft).

The stand of trees has a cathedral structure and the elongated north-south gap over the gully allows substantial insolation into the cluster sites. The trees on the shoulders of the gully and extending onto the mesa top provided multiple layers of shelter from southerly, easterly, and westerly winds. The south, west, and east edges of the stand are characterized by dense stands of saplings and pole-sized trees. Trees between the cluster site and Deveraux Creek and the trees north of the creek provided shelter from northerly winds. The gully itself provides a cold moist air pool at night and in the morning.

The combination of these features made Ellwood Main a premiere overwintering site that has attracted and maintained large numbers of monarchs thorough entire overwintering season for decades. In recent years, monarchs have utilized the trees along the gully for roosting and their cluster locations span the 100 m area, as shown on Figure 13.

The recent mass mortality of blue gums has greatly weakened the wind shelter for the monarch roosting areas. To visualize the canopy of Ellwood Main, we created a dissection of the profile of Ellwood Main in 25 m slices, shown in Figure 14. The profile starts on the north bank of Deveraux Creek and progresses due south through the cluster zones to the south end of the stand of trees. The V-shape is the north-south gully through Ellwood Main. Table 4 gives a description of each slice of the profile.

Figure 13. Monarch Observations - Ellwood Main

Legend

Ellwood Mesa Open Space Boundary

Monarch Cluster Observations by year

- 2022
- 2021
- 2020
- 2019

N

0 50 100 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42283°N 119.89096°W
Goleta, Santa Barbara County

Imagery Source: NV5,10/29/2021

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Map Updated:
February 21, 2023 04:02 PM by CDM

FIGURE 14. A PROFILE THROUGH ELLWOOD MAIN: ANATOMY OF A MAJOR AGGREGATION SITE

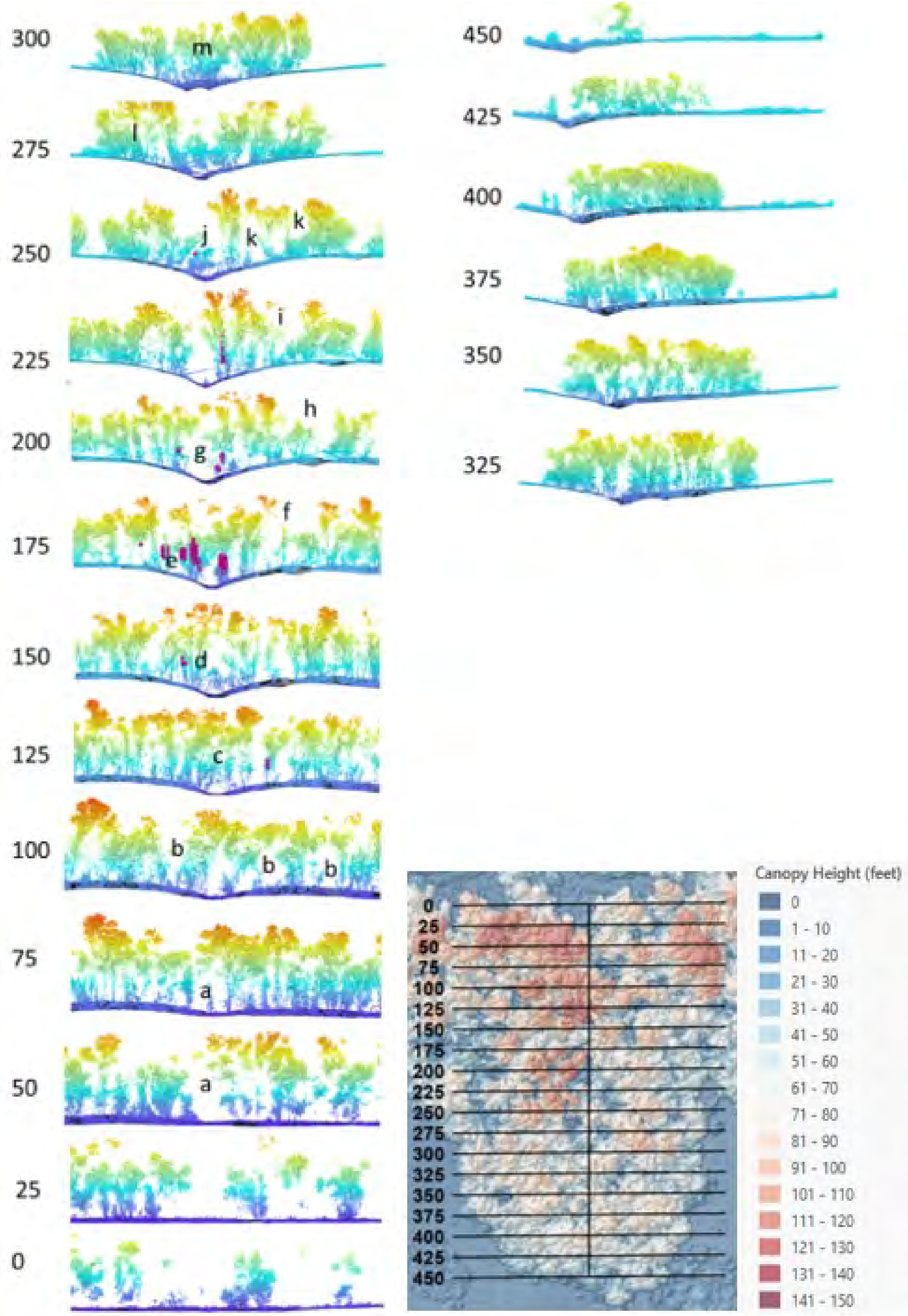


TABLE 4. DESCRIPTION OF ELLWOOD MESA CANOPY SLICES

Images of this Slices are shown in Figure 14.

Location	Description
0	North bank of Deveraux Creek, scattered trees
25	Creek Channel
50	South bank
75	Opening above gully [a], south-edge of riparian zone with tall dense trees
100	Openings east and west away from gully [b]
125	First small clusters on west bank (purple dots), substantial north wind shelter across gully [c]
150	Small clusters on east bank, immediate north wind shelter major cluster zone [d]
175	Major cluster zone. Mainly on east bank or bottom of gully. Viewing area on east bank [e]. West opening [f] is a major tree mortality zone (Photo) that opened a west-southwest wind vulnerability.
200	Cathedral structure apparent over gully [g], clusters are low. Large west-opening continues south [h]
225	Most southerly stack of clusters, on west bank. Large west opening continues [i]
250	Short south-wind shelter across gully [j], interior gaps to west of gully [k]
275	Tall canopy on east and west banks of gully [l]
300	Taller south-wind shelter across entire gully [m]
325-340	The stand narrows and densifies and the gully emerges east of the stand

Note: 25 ft slices were created in ARCGIS Scene, starting on the north bank of Deveraux Creek, and progressing due south through the cluster zones and to the south end of the stand. The V-shape is the north-south gully.

5.2.1 Historical Conditions at Ellwood Main: Hemiphotos 1990, 1998, and 2021

In January 1990, a 100 m transect was set up along the Ellwood Main gully, with hemiphotos taken every 10 m (Weiss et al. 1991). The transect was resampled in 1998 and in 2021, allowing for a quantitative comparison of site factors over time that document change in the canopy structure and habitat suitability for the monarchs.

The array of hemiphotos (Figure 15) shows the main cluster zone at Ellwood Main, at 60 m and 70 m along the gully, with hemiphotos taken in 1990, 1998, and 2021. In 1990, the forest had experienced 4 intense drought years so was relatively open with loss of tall branches and foliage. During the wet 1990s, the forest grew vigorously. By 2021, further drought had thinned the forest, and large numbers of whole trees died.

At 70 m, the canopy filled in from south through north-west between 1990 and 1998, primarily from south through north-west, while it opened to the north. By 2021, more openings appeared to the south, southwest, west, and northwest, and an overhead tree to the southeast died. But the tree almost due east filled in over that time. A similar pattern is seen at 60 m.

The major site factors (Table 5) show trends of key "site factors" across all three dates. ISFU[4] (fraction of visible sky in all directions) varies from 0.11-0.16 in the photos, and ranges by 0.03 through time at each site. ISFU increased from 1998 to 2021 at 60 m but decreased from 0.13 to 0.11 at 70 m over that period. ISFC[5] (visible sky corrected to a horizontal surface) is higher than ISFU and ISFU/ISFC ratio has a narrow range from 1.5-1.6, indicating that the canopy is relatively more open overhead than around the edges, i.e., the sites are in a substantial overhead gap. The Direct Site Factor Uncorrected (DSFU) is the fraction of potential annual insolation uncorrected for receiving surface – basically how open the canopy is along all of the yearly sunpaths. The DSFU values, and visual inspection, indicate that the sites are open enough toward the S that full or dappled sunlight is received several hours each day.

TABLE 5. MAJOR SITE FACTORS AT TWO HEMIPHOTO SITES IN CLUSTER ZONE FOR 1990, 1998, AND 2021

Site Factor	60m			70m		
	1990	1998	2021	1990	1998	2021
ISFU	0.15	0.13	0.16	0.14	0.13	0.11
ISFC	0.23	0.20	0.25	0.22	0.20	0.17
ISFU/ISFC	1.50	1.60	1.60	1.50	1.50	1.50
DSFU	0.23	0.15	0.28	0.20	0.15	0.17

The graphic assessment of canopy gaps is shown as polar plots in Figure 16 and Figure 17. The figures show directional exposure in 8 directions and show some complex behavior of the canopy gaps over time and space. For example, at 60 m north-exposure decreased from 1990/1998 to 2021; i.e., the canopy filled in in that direction. In contrast, at 70 m north-exposure remained relatively constant. At 60 m, south- and southwest-exposure decreased from 1990 to

[4] ISFU = Indirect Site Factor Uncorrected: the overall proportion of sky visible.

[5] ISFC = Indirect Site Factor Cosign corrected to a horizontal surface.

1998, then increased by 2021, reflecting the many trees that died from 1998 to 2021 in that sector. At 70 m, south-exposure decreased from 1990 to 1998, and slightly increased by 2021. And southwest-exposure decreased from 1991 to 1998 and increased back in 2021. Many more changes can be observed.

The differences between sites only 10 meters apart show that monarchs can move short distances to reduce wind exposure. For example, moving from 60 m to 70 m reduces south-exposure from 0.28 to 0.13, but moving to 80 m increases south-exposure to 0.25. The same move reduces southeast-exposure from 0.26 to 0.18 and to 0.11.

The main conclusion from this historical comparison is that the patterns of sky exposure in the cluster zone have shifted through time, to be expected in a complex dynamic forest. Throughout the 1990s and 2000s, Ellwood Main supported permanent season-long monarch aggregations, indicating that the site factors observed in 1991 and 1998 were well within the tolerance range and could protect monarchs from the most intense winter storms. The degradation of the forest starting in the mid-2010s has reduced the multiple layers of wind shelter, thereby increasing wind vulnerabilities, leaving “thin, green lines” as the remaining wind shelter.

As of 2021, the cluster zone remains relatively well-sheltered from most directions, but significant gaps have formed especially to the west and southwest. By 2021, the site factors in the cluster zone were suitable when monarchs arrived, and they remained at the site until strong windstorms exceed a threshold between 25 and 30 mph, as occurred in December 2021 and December 2022. As such, Ellwood Main may be acting as an “ecological trap,” attracting monarchs early in the season but leaving them vulnerable to strong storms that can be expected each year (as shown on the wind rose in Graph 7 in Section 4.3).

FIGURE 15. HEMIPHOTOS FROM THREE YEARS BETWEEN 1990 AND 2021 AT 60 AND 70 METERS INTO THE ELLWOOD MAIN GROVE

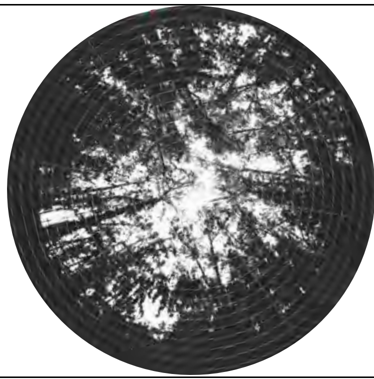
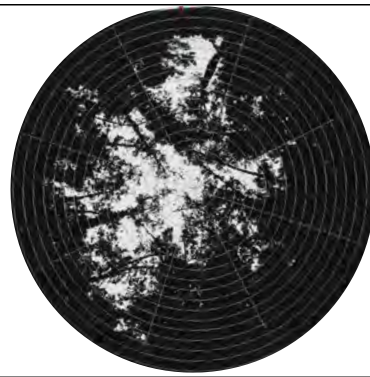
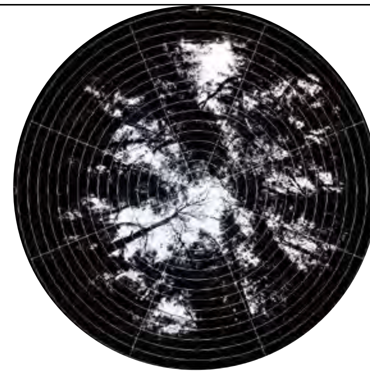
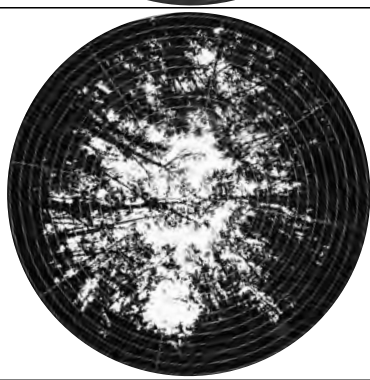
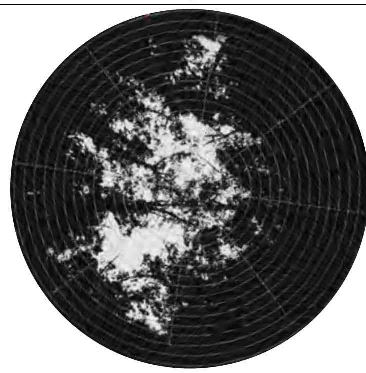
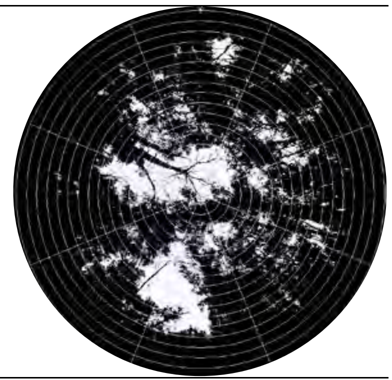
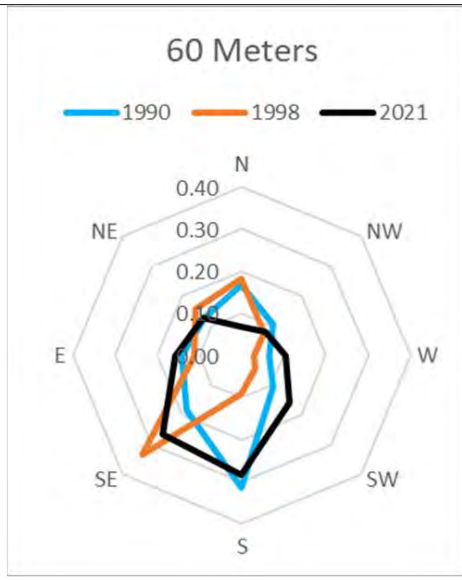
			
	1990	**1998**	**2021**
70			
60			

FIGURE 16. GRAPHIC ASSESSMENT OF CANOPY GAPS OBSERVED IN THE HEMIPHOTOS EACH OF THREE YEARS



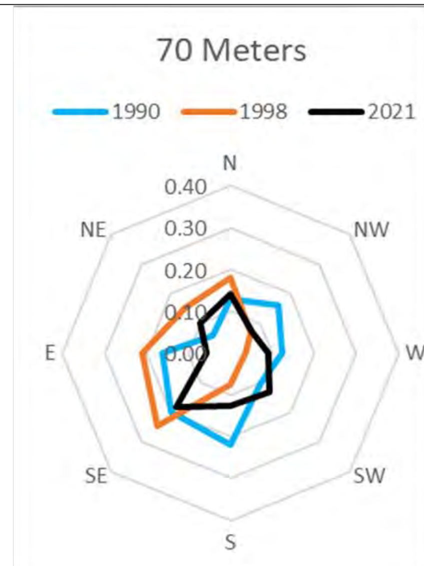
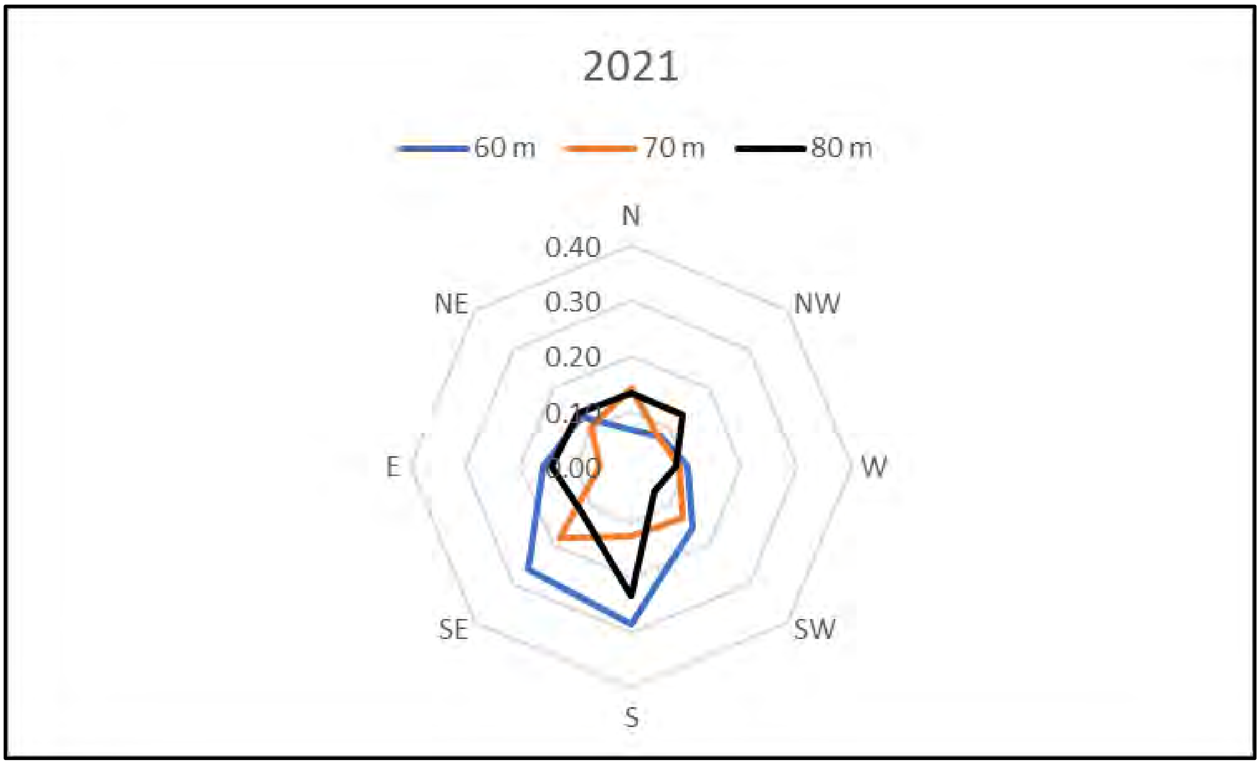


FIGURE 17. GRAPHIC ASSESSMENT OF 2021 DIRECTIONAL EXPOSURE AT THREE LOCATIONS 10 METERS APART IN THE CLUSTER ZONE



5.2.2 Current Conditions at Ellwood Main

At Elwood Main, hemiphotos were taken at 10 m (33 ft) increments along the gully bottom (recreating the 1990 and 1998 transects, see historical conditions in Section 5.2.1), and at 10 m increments along the trails on the east-side and west-side, and a few at the canopy edges. Photo locations are shown in Figure 18, overlaid onto the maps of standing and downed dead wood, and a color infrared (CIR) image with live canopy as bright red. The cluster zone of 2021 and 2022 is in the white oval.

5.2.2.1 Visible sky

The point map of Visible Sky (ISFU) at Ellwood Main (Figure 19) shows that the cluster zone is in the range of 0.125-0.20. The northern part is slightly more closed. Areas 20+ meters south of the cluster zone are less open, < 0.125. The ranges reported in Table 6 are from the four hemiphotos that overlap within the cluster zone oval.

5.2.2.2 Directional exposure

The maximum directional exposure and wind roses (Figure 19) show how exposure decreases from the edge (red) into the interior (yellow through blue), and there are "wind tunnels" where a bulge or streak of red or yellow extend into the interior. The individual wind roses show which and how many directions are vulnerable. Maximum directional exposure shows that much of the northern half of Ellwood main has marginal (yellow) exposure from one or more directions. The only 360° sheltered areas in the grove are in the southern half, but those areas have too much canopy cover and lack sufficient insolation.

Directional exposure (Figure 20) shows an array of 8 directions. The penetration of wind into the grove is illustrated as the gradient from red (>0.30) at the edge, through yellow (0.20-0.30), and into blue (<0.20). Descriptions of key features from each direction are in Table 6. Note some extremely sharp gradients near the gully transect; these are the "thin green lines" of remaining live foliage that are the last live shelter for the cluster zone.

The most vulnerable directions in the cluster zone are W, SW, S, SE. The depth of wind shelter in these directions has been compromised by the tree mortality in the interior, extending all the way to the edge in the southwest gap (see Figure 18 for dead trees) – prior to the mortality, many more trees provided redundant wind shelter in these areas. The thin green lines of live trees that provides the critical wind shelter are just below the E-trail and along the SE edge. The high S-exposure is a natural consequence of the cathedral structure over the gully and is also what allow insolation into the cluster zone (see below). Monarchs could move about 10 m north along the gully axis, cluster behind some branches, and reduce their S-exposure. But then they will increase their N exposure. The N-exposure in the cluster zone is attenuated by the remaining thin green line running E-W across the gully just N of the cluster zone. N-exposure has increased from tree mortality and canopy thinning.

The array of photos around the primary cluster zone (Figure 21) shows these structures from the ground. Each photo is discussed in Table 7.

5.2.2.3 Insolation

Maps of ground-level DSFU (Figure 22) show that the cluster zone is in a higher insolation belt (white. 0.23-0.29) running E-W across the gully. Other parts of the grove (the gully floor N of the cluster zone) are deeply shaded all year long (darker blue, < 0.13). Note that DSFU assess all sunpaths through the year and includes the high sun angles of summer (see Methods). But DSFU is relevant as an approximate measure of southern sunpath exposure higher in the canopy, i.e., the values for summer from ground level are relevant for winter values higher in the canopy.

The point maps of monthly insolation at ground level show that the cluster zone is in a higher Oct- Feb insolation area compared with areas further south, the result of the elongated gap over the gully that creates the cathedral structure. The gap can be clearly seen in Photos 314 and 315 (Figure 21). Insolation in the cluster zone decreases from October to December and increases again through February (a natural consequence of seasonal sun angles). In October. most of the forest floor is not in deep shade, but the deepest shade (darkest blue) increases in November and December, especially in the southern interior of the grove. By December, the ground-level shade extends to the S end of the cluster zone. The S-edges receive nearly all potential radiation (reds).

An array of hemiphotos around the primary cluster zone show some of the canopy structures described above (Figure 21). The descriptions (Table 7) include presence of gaps and thin green lines in various directions.

5.2.2.4 Ellwood Main Summary of Findings

Between the LiDAR, current and historical hemiphotos, and experience, we have a comprehensive view of current conditions at Ellwood Main. The key southwest, south-southeast and north vulnerabilities are presented as oblique LiDAR views with hemiphotos from below (Figure 23 - Figure 25). If the darker blues (ground) are visible, it means that a deep canopy gap exists in that view. Accompanying hemiphotos give the view from the ground inside the grove.

Key conclusions and observations include:

1. The primary cluster zone has relatively higher insolation than surrounding areas, created by the cathedral structure and elongated gap over the gully.
2. The primary cluster zone has low directional exposure from most sides, but with moderate wind vulnerabilities from SW, S, SE, and N.
3. Mass tree mortality has opened the canopy, leaving only thin green lines of live trees in key directions as the remaining wind shelter. Gaps in those lines create specific vulnerabilities shown in Figure 23 - Figure 25.
4. Even where some wind shelter remains, redundancy in wind shelter has been lost.
5. Monarchs were attracted to Ellwood Main in October and November 2021 and 2022, but then abandoned the site following strong storms, confirming substantial loss of wind shelter.
6. Further tree mortality and treefall will reduce remaining wind shelter.
7. Some vulnerabilities are compensated by short movements (10-20 meters) to other trees/branches, but then wind shifts can drive monarchs back to original cluster sites.
8. Many standing dead trees threaten nearby cluster and windbreak trees.

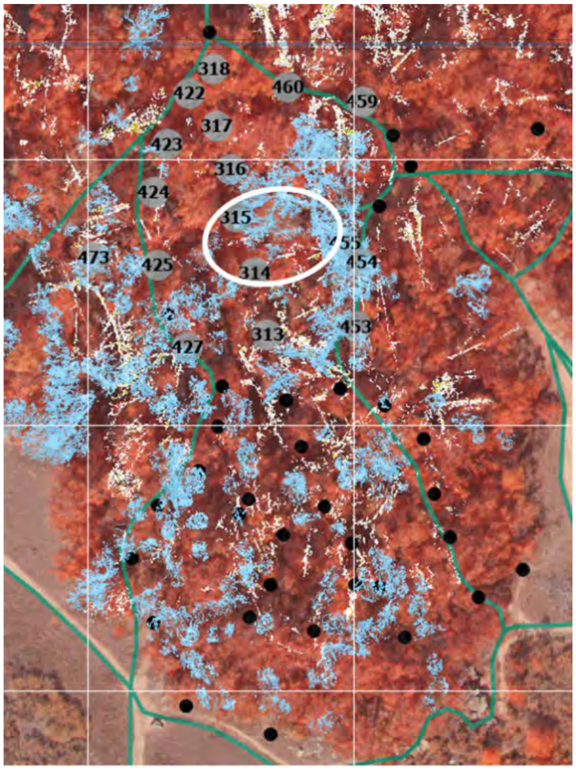
The restoration recommendations (Figure 26) show the primary cluster zone, the main dieback zones, and the vulnerabilities described above.

5.2.3 Recommendations for Ellwood Main Restoration Actions

The following are our recommendations for the restoration of Ellwood Main and correspond with Figure 26:

- Replace/replant dead monarch aggregation trees with blue gum eucalyptus.
- Encourage the recruitment and establishment of blue gum saplings and existing trees.
- Retain tall trees north of creek for north-northwest shelter.
- Be very surgical with fuels reduction in areas 18A-B-C-D.
- Fuel reduction areas 21B-C and 22A are important northeast shelter trees.
- Remove standing dead trees (shown in black on Figure 26).
- Remove high fraction of downed wood, especially finer fuels <10 inches diameter that prevent new growth.
- Separate large logs on the forest floor as practical.
- Plant shelterbelts of red ironbark on open edges, or inside behind the first row of blue gums.
- Fill the west gap with red ironbark (white oval on Figure 26).
- Plant karri (*E. diversicolor*) within interior of grove around the aggregation area for tall canopy and wind shelter trees.
- Plant California bay trees along the south side of Devereaux Creek.

FIGURE 18. HEMIPHOTOS TRANSECT LOCATIONS AT ELLWOOD MAIN



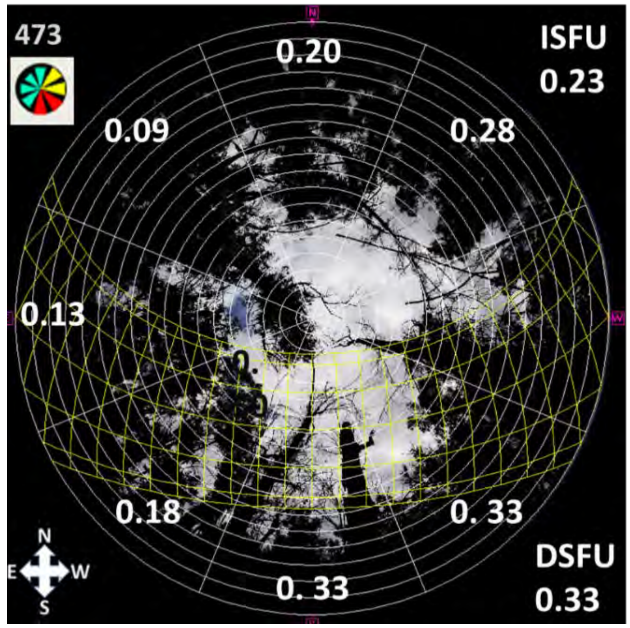


Photo locations on left, on top of a CIR image and dead standing (blue) and dead downed (white) wood. Example photograph (473) in high mortality zone with directional exposure in each octant, as a reference. Maximun expoure to S, SW, and W, lowest NE. Monthly sunpaths are in yellow, from December (most southerly) through June (nearly overhead at noon). The most southern 3 bands are the overwintgering season (Oct-Dec-Feb). Many dead standing trees in photo. Gap to W is same as in Photo 6 taken from outside forest.

Photo 6. Dead snag in west gap at Ellwood Main taken from the outside of the canopy (Photo by Stu Weiss).

FIGURE 19. VISIBLE SKY

Green is in the most frequent zone (0.15-0.30) of overwintering microsites, blue is too closed (<0.15), and white-red is too open (>0.30). For Directional Exposure blue is low exposure (<0.20), yellows are marginal (0.20-0.30, and red is high (>0.30).

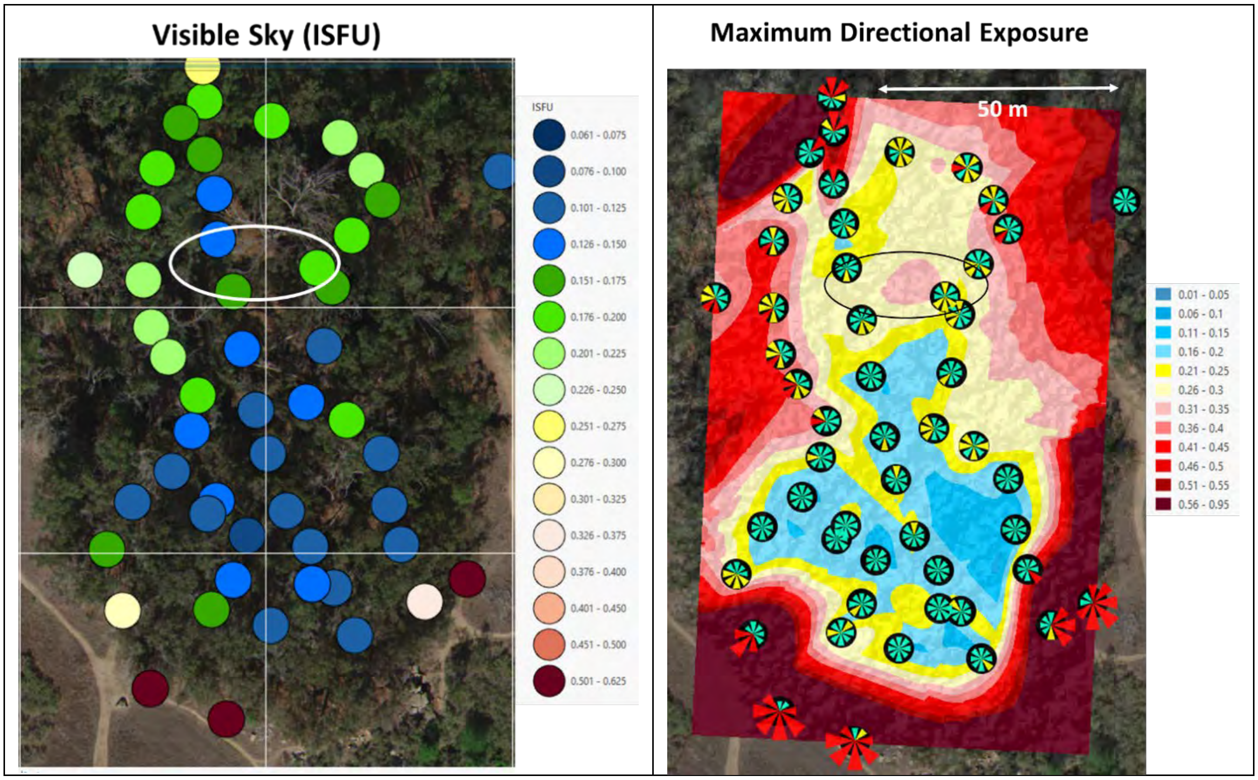


FIGURE 20. DIRECTIONAL EXPOSURE FROM 8 DIRECTIONS

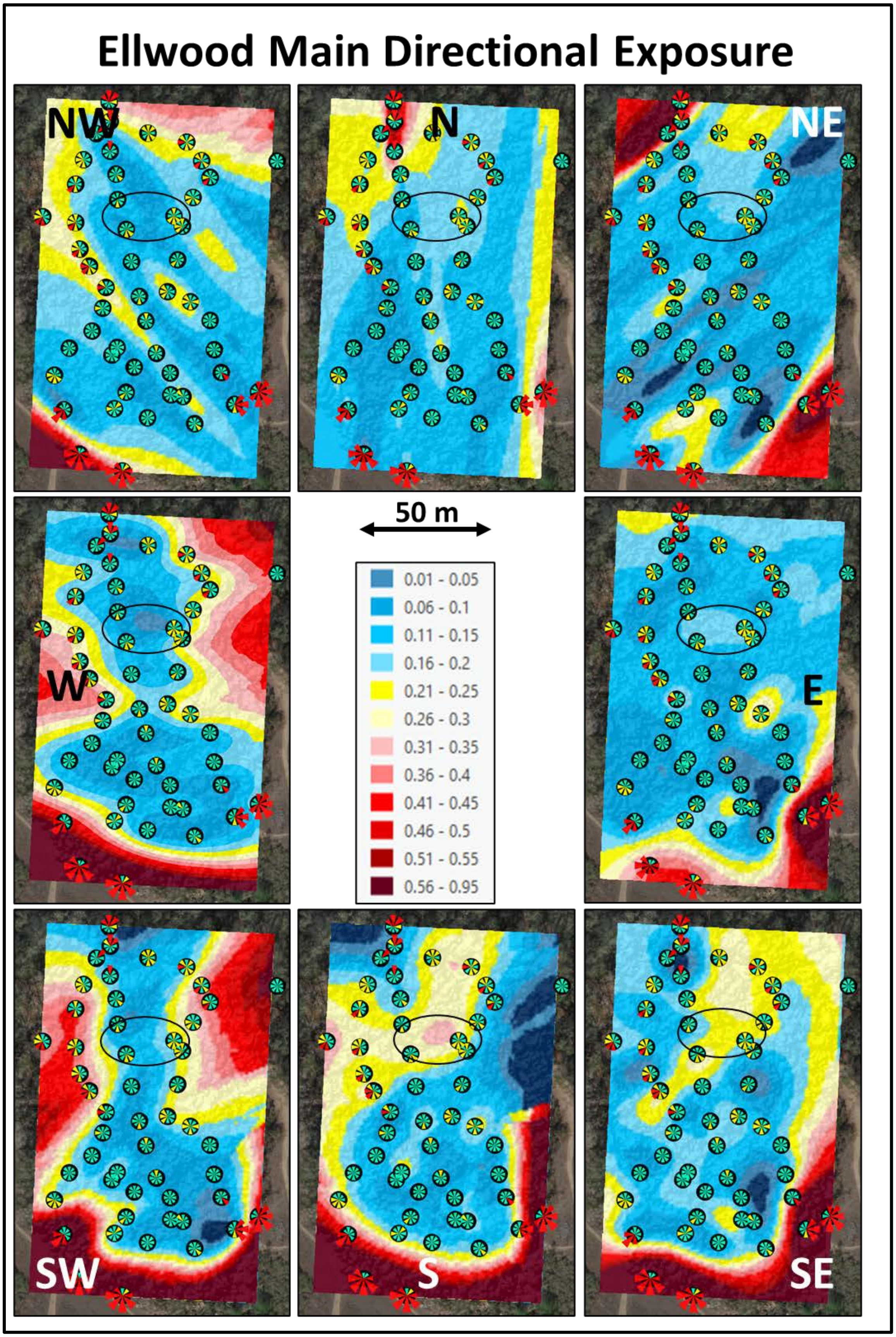


TABLE 6. DETAILS OF 4 HEMIPHOTOS WITHIN PRIMARY CLUSTER ZONE

Direction	Cluster Zone	Comments on pattern
NW	0.06-0.15	Penetration into the southern section of the grove through tree mortality zone on W side.
N	0.13-0.21	Small patch >0.20, high penetration into zone from gap to north (red), attenuated 10 m N of cluster zone by a thin green line E-W across gully (drawn in)
NE	0.13-0.19	Moderate penetration (yellow) on N-border, and high (red) in NW corner
E	0.08-0.16	Patch of moderate (yellow) exposure in interior on E-side, SE of cluster zone. Thin green line of live trees along SE and E border,
SE	0.13-0.28	Much of cluster zone is > 0.20, storm wind direction. The SE edge is a thin green line with high mortality in the interior, gaps in this dense edge would have disproportionate effects.
S	0.15-0.28	Highest interpolated exposure (0.32) in center of cluster zone, reduced to 0.05 past N-end of zone behind live trees. 0.2-0.25 within the W tree mortality patch. This is a natural consequence of the position of the clusters at the N-end of an elongated gap over the gully (cathedral structure).
SW	0.07-0.30	Penetration into high mortality zone (red), rapid attenuation at W-side of cluster zone, thin green line below trail (drawn in). Highest exposure at E end of cluster zone on E shoulder of gully
W	0.07-0.24	Penetration into high mortality zone(red), thin green line below trail (drawn in), higher exposure (yellow) on far E side of cluster zone on E shoulder of gully

TABLE 7. DESCRIPTIONS OF HEMIPHOTOS IN FIGURE 21

Photo	Comments
318	End of gully at Deveraux creek. Large opening to N, dense canopy to S blocks insolation.
317	10 m S of 317, opening appears smaller, some dappled insolation from S
316	N-end of main cluster zone, small gap N, some gaps SW and W, dappled insolation. Dead tree to SE.
315	Main cluster area, thin green line between here and 424/425, blocking W and SW. S gap for direct insolation mid-day. Dead tree to NE.
314	Large gap S, some gaps SW. Thin green line W to 425 427, full mid-day, dappled afternoon insolation
423	W-shoulder of gully, gap to NE and SW. insolation in afternoon, Thin green line to E toward 317
424	Large gap SW (mortality zone w/ dead trees). Thin green line E to 316
425	Large gap SW w/ dead trees, low exposure elsewhere Thin green line to 315 and 314
427	Large gap S and SW w/ dead trees, direct insolation late-morning to mid-afternoon.
460	Dappled insolation late morning
459	Gap to NE, direct insolation mid-day.
455	Viewing area, few large gaps dappled light early afternoon
454	Viewing area, large gap SSW, direct insolation for 2 hrs.
453	Gap to SW across gully to high mortality zone

FIGURE 21. ELLWOOD MAIN CORE HEMIPHOTO EXAMPLES

Photo locations above, note that east and west are reversed in upward looking hemiphotos. Discussion of photos in Table 7.

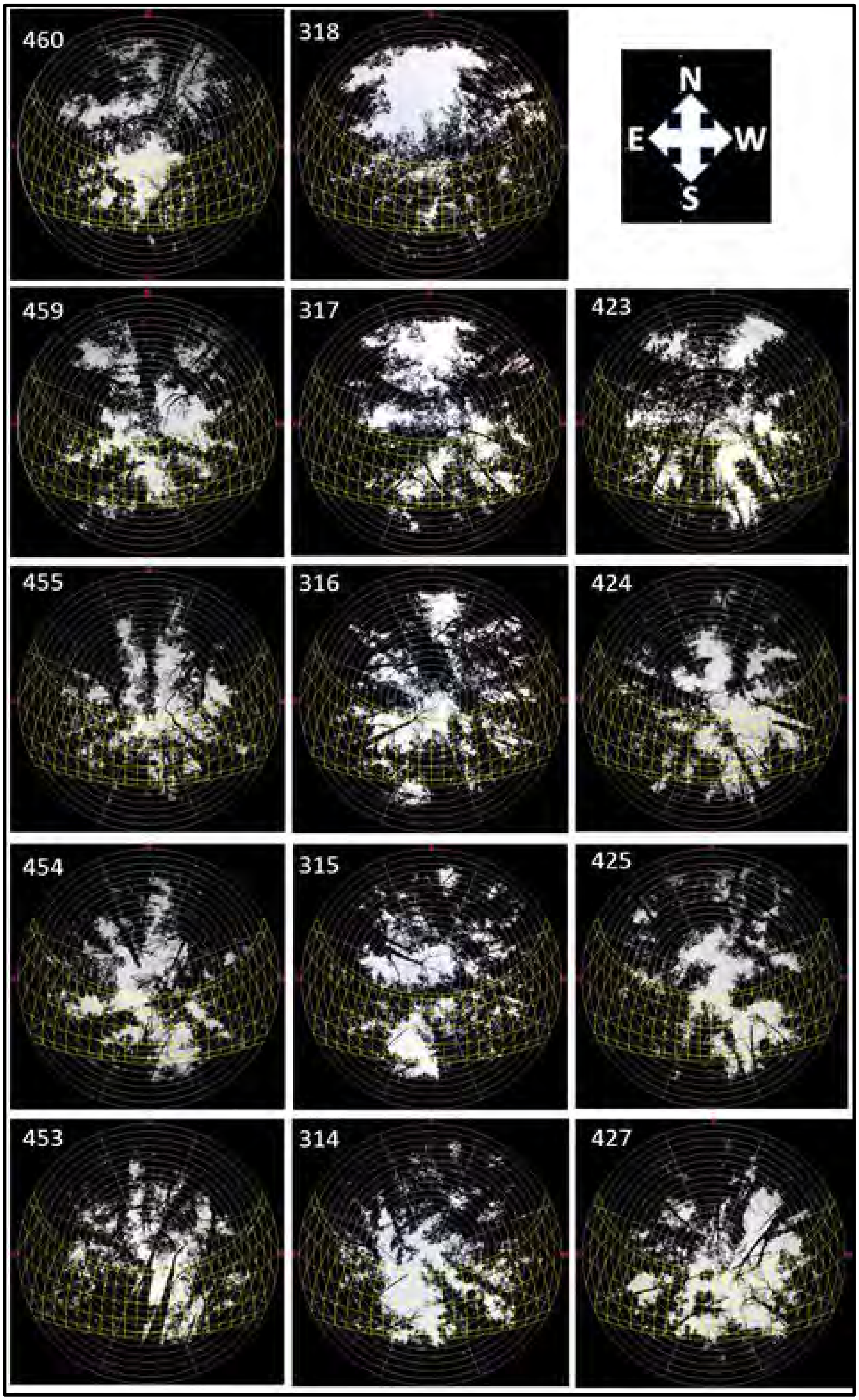


FIGURE 22. INSOLATION AT HEMIPHOTO SITES

Upper legend only applies to DSFU

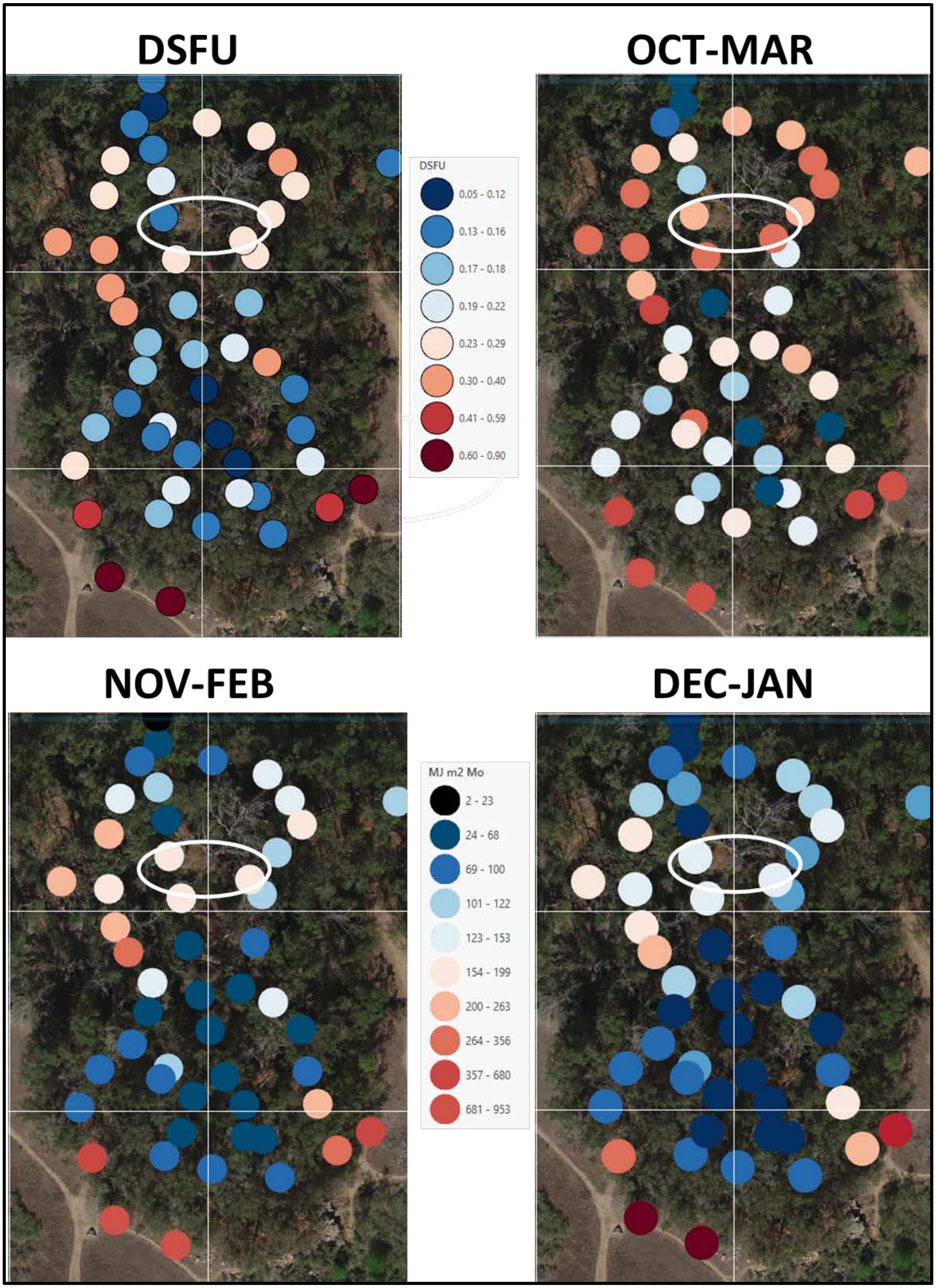


FIGURE 23. OBLIQUE LIDAR VIEW FROM SOUTH WITH EXAMPLE HEMIPHOTO

Dead standing trees in northeast sector and protruding into south gap.

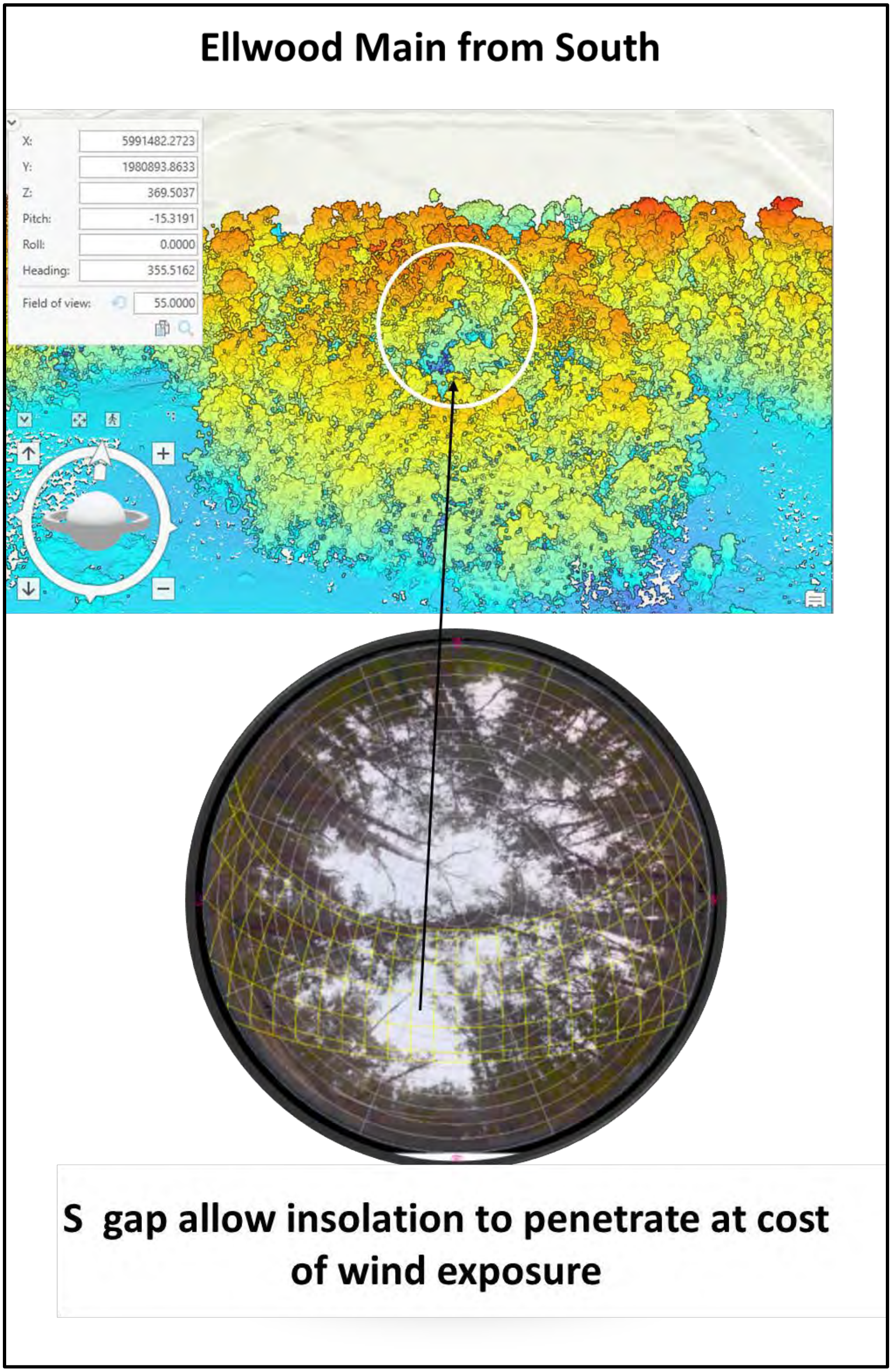


FIGURE 24. OBLIQUE LIDAR VIEW FROM SOUTHWEST WITH EXAMPLE HEMIPHOTO
Thin green line is at top of photo between the photo and the cluster zone.

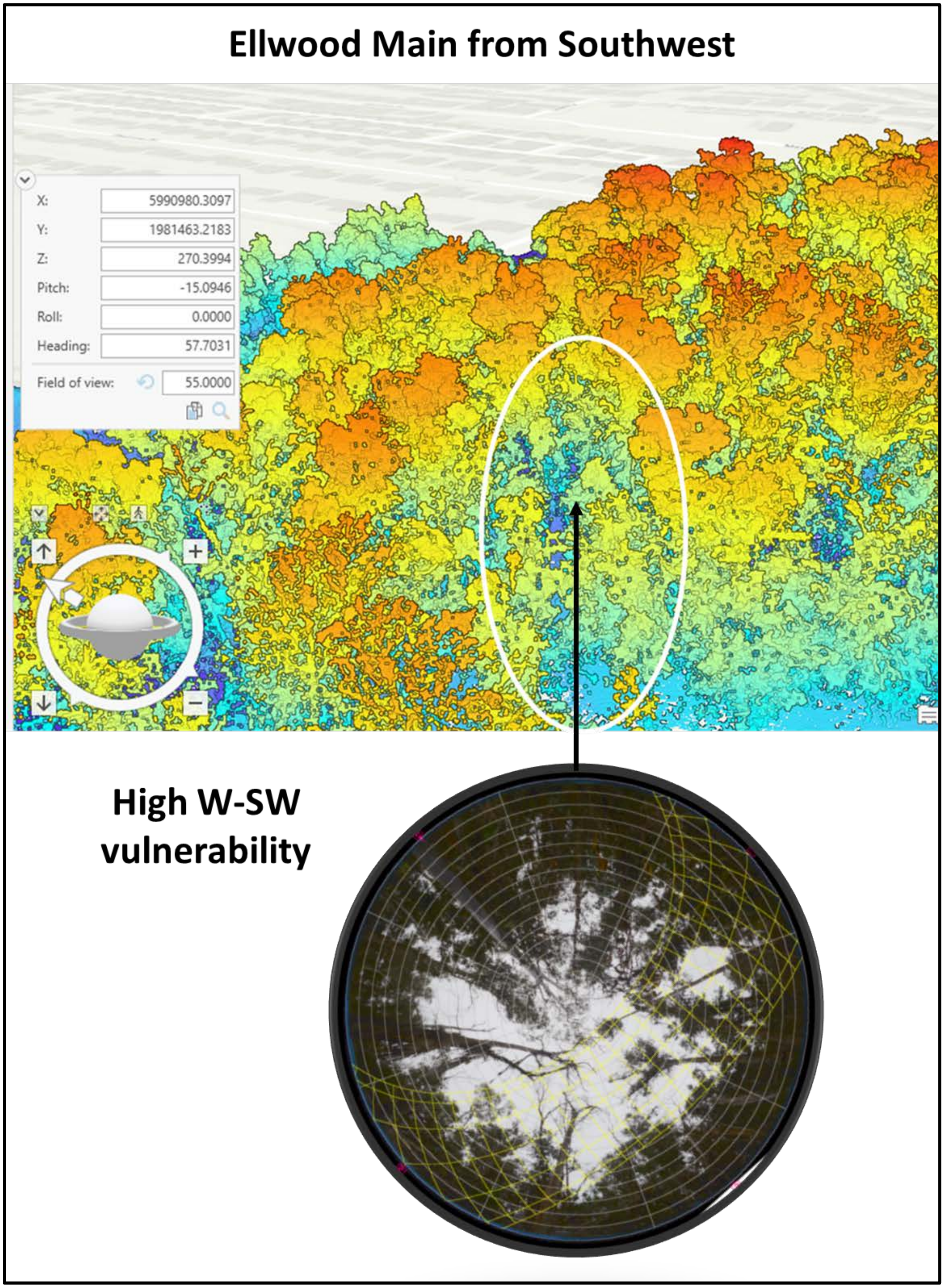


FIGURE 25. OBLIQUE LIDAR VIEW FROM N, WITH TWO HEMIPHOTOS ALONG GULLY

90m and 70m with thin green line of remaining wind shelter in between the photos.

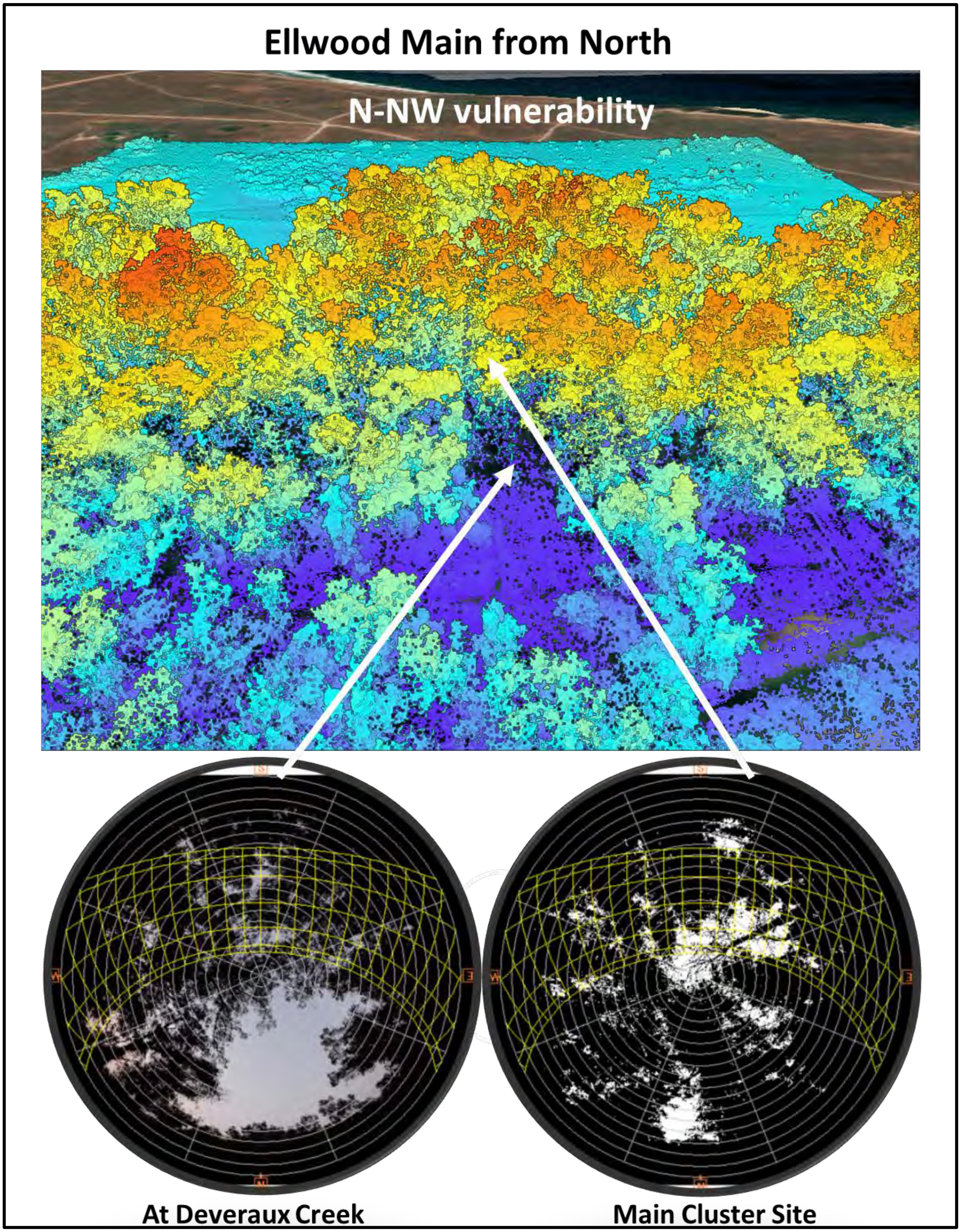


FIGURE 26. ELLWOOD MAIN VULNERABILITIES AND RECOMMENDATIONS FOR RESTORATION

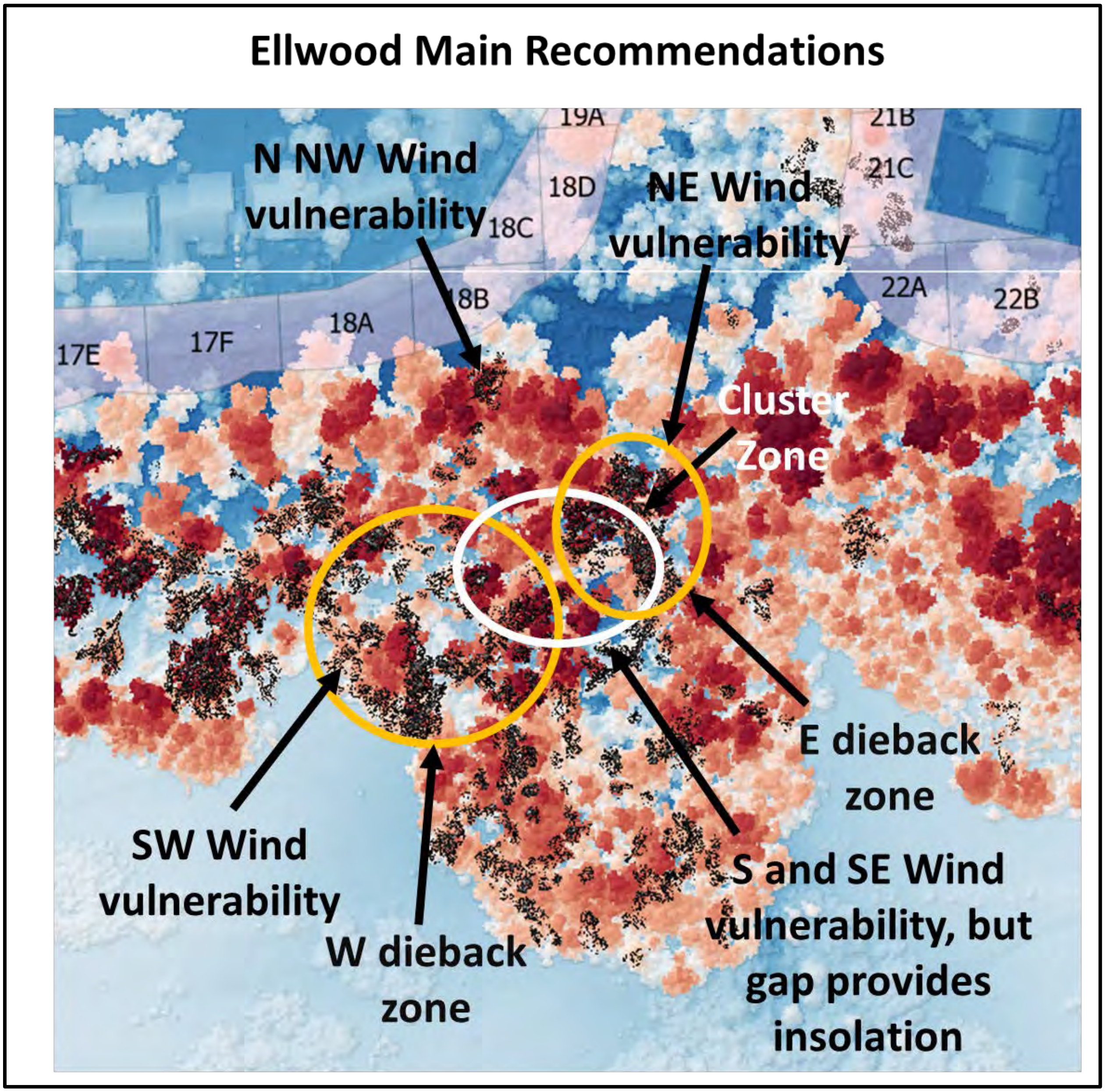
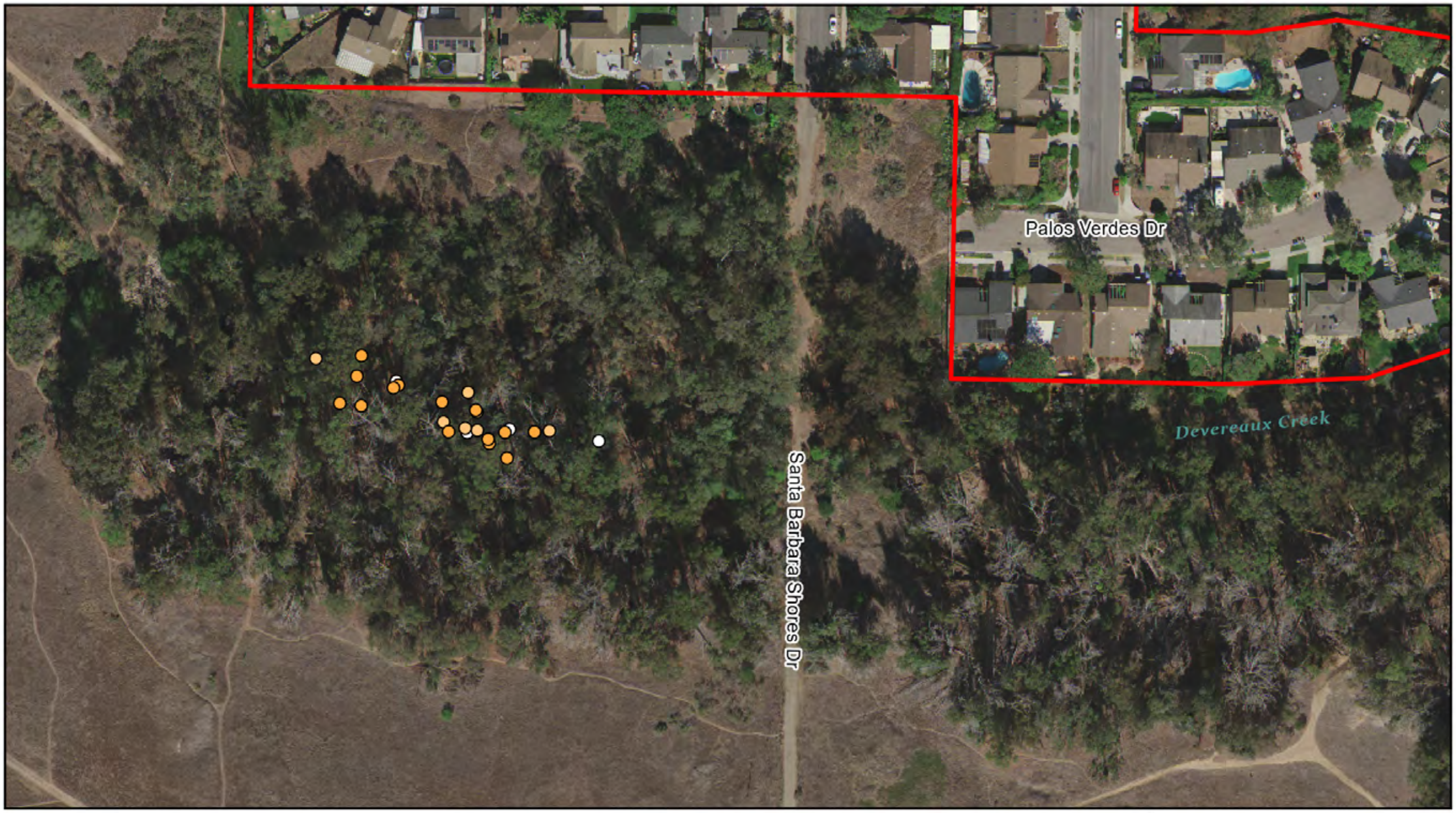


Figure 27. Monarch Observations - Ellwood West



Legend

Ellwood Mesa Open Space Boundary

Monarch Cluster Observations by year

- 2022
- 2021
- 2019

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42338°N 119.89355°W
Goleta, Santa Barbara County

LiDAR Source: NV5,10/29/2021

Althouse and Meade, Inc.
Biological and Environmental Services

Map Updated:
February 21, 2023 04:07 PM by CDM

5.3 Ellwood West

5.3.1 Current Conditions at Ellwood West

A similar set of hemiphoto and LiDAR analyses were applied to Ellwood West. Ellwood West has been a subsidiary overwintering site, sometime supporting a large fraction of butterflies at Ellwood Mesa as a whole, but in recent years has been occupied early in the overwintering season, and then largely abandoned.

The monarchs roost at Ellwood West in a cathedral opening along Deveraux Creek, shown in Figure 27. From the center of the Ellwood West site, the Mesa rises approx. 12 m (40 ft) in elevation to the south, with forest edges approx. 65 m (213 ft) south and approx. 65 m (213 ft) north, and the neighborhood border approx. 90 m (295 ft) north. There has been massive tree mortality in this area (Figure 28). Many trees south of the creek on the slope have recently died and are still standing, and much dead wood lies on the forest floor. In recent seasons, the monarchs began roosting in small open areas on the slope south of the creek, however these roosts are temporary given the loss of protective canopy.

A transect of hemiphotos at 10 m spacing was taken through the historical cluster zone extending along the creek (Figure 28A). Four example hemiphotos (Figure 28B) illustrate key features of the cluster zone. Photos 217 and 218 are in the most recent cluster zone and are at the east end of the transect. Photo 214 is in the center, and 212 is at the west end. These sites have maximum directional exposure to the east. The hemiphotos in Figure 28B show how most of the sunpaths are covered by foliage, leading to low insolation.

In general, the canopy is closed at Ellwood West, with ISFU < 0.15 across the transect (range 0.10 to 0.14), see Table 8. DSFU is low (0.11-0.19) as well – the rise of the Mesa adds to the effective height of trees along the sunpaths. While some sites receive substantial insolation in October, by December much of the transect is in deep shade (darker blues in Figure 29). The maximum directional exposure in the two cluster sites is east (0.24 to 0.29) (yellow wedges, also see Table 8). In the middle of the transect, there is a site with high E-exposure (0.31), and one site with moderate NE exposure (0.22).

TABLE 8. EXAMPLE HEMIPHOTO DATA AND COMMENTS AT ELLWOOD WEST

Photo	Cluster	ISFU	DSFU	Max Exposure	Comments
418	Current	0.14	0.17	0.24 E	East end of transect
417	Current	0.12	0.16	0.29 E	Dead canopy visible ENE
412	Historic	0.13	0.19	0.26 W	West end of transect
414	Historic	0.14	0.19	0.22 NE	Dead standing visible SE

Ellwood West tends to be abandoned mid-season. Early in the 2022 season (Oct 31), Ellwood West attracted 924 monarchs (out of 1431 at Ellwood, 65%), but numbers fell to 120-130 (1-2%) through November, and the site was largely abandoned by Dec 15. In 2021, Ellwood West supported 2,564 butterflies (29% of the overall Ellwood Mesa aggregation) on Dec 1, but only 3 were observed by Jan 4, 2022.

The low insolation and east exposure may be factors in the relative low use of Ellwood West by December, and the abandonment by mid-season. The east exposure may be a problem during storms, east is a common wind direction with occasionally strong winds (see Section 4.3). By December, all the hemiphoto sites are quite dark at ground level, so the site may just be unattractive for monarchs in mid-winter. Some thought should be given to opening the overhead canopy, once the dead standing wood is cleared, but a detailed study is desirable for removing more than the standing dead trees.

Prior to the mortality of so many trees on the slope, the site was undoubtedly even more shaded. Sealing up the southern edge with a double ironbark row would ensure wind shelter along the Mesa edge (Figure 31), but minimally affecting insolation. Sealing up the northern exposure would reinforce the thin green line between the trail and the edge. And, selectively planting tall growing eucalyptus east of the cluster site would address the east-wind vulnerability.

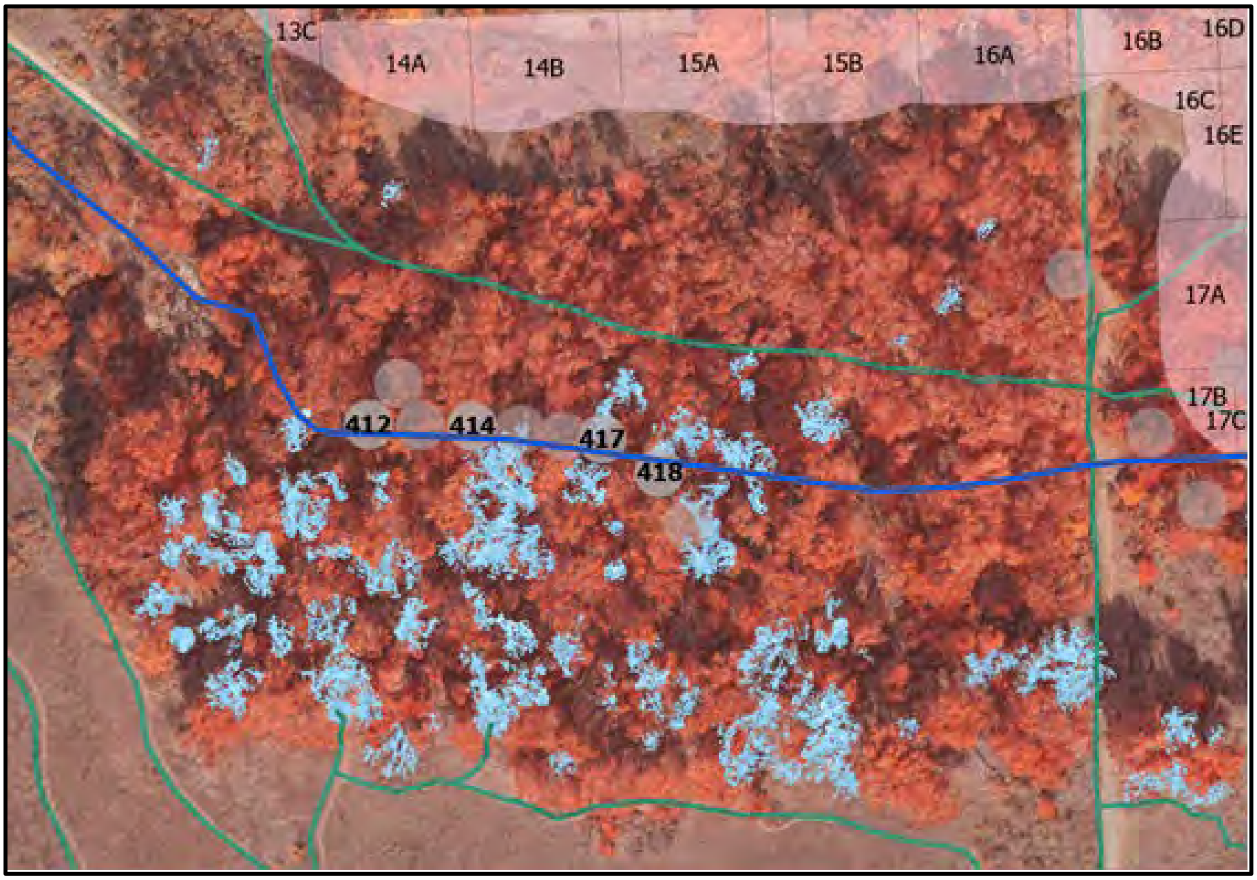
5.3.2 Recommendations for Ellwood West Restoration Actions

The following are our recommendations for the restoration of Ellwood West:

- Replace/replant dead monarch aggregation trees with blue gum eucalyptus.
- Encourage the recruitment and establishment of blue gum saplings and existing trees.
- Removal dead standing trees (black in Figure 31)
- Remove high fraction of downed wood, especially finer fuels <10 inches diameter that prevent new growth.
- Separate large logs on the forest floor as practical.
- Plant red ironbark trees in the openings on south-edge.
- Plant ironbark/karri (*E. diversicolor*) between Santa Barbara Shore Drive and cluster zone to address east wind vulnerability.
- Plant double ironbark row on north-side.
- Plant low density karri (*E. diversicolor*) within tree mortality zones to diversify canopy and add to the wind shelter zone.
- Plant native trees in riparian zone along Devereux Creek, do not fill in the open interior under monarch roost trees to maintain cathedral structure.
- Plant understory native shrubs and oaks
- Once dead wood removed, consider opening the overhead canopy after additional study.

FIGURE 28A. HEMIPHOTO TRANSECT LOCATIONS AT ELLWOOD WEST

In map with 50 m grid, CIR and dead trees, trails (green line), Devereux Creek (blue line), grey polygons (fuel management treatment areas).



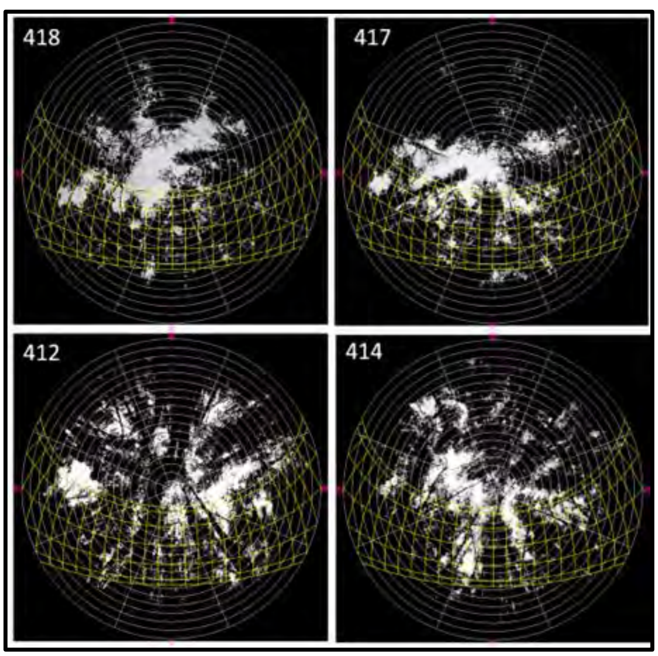


FIGURE 28B. EXAMPLE HEMIPHOTOS AT ELLWOOD WEST

Photos 418 and 417 are the cluster site.

FIGURE 29. POINT MAPS OF HEMIPHOTO RESULTS AT ELLWOOD WEST

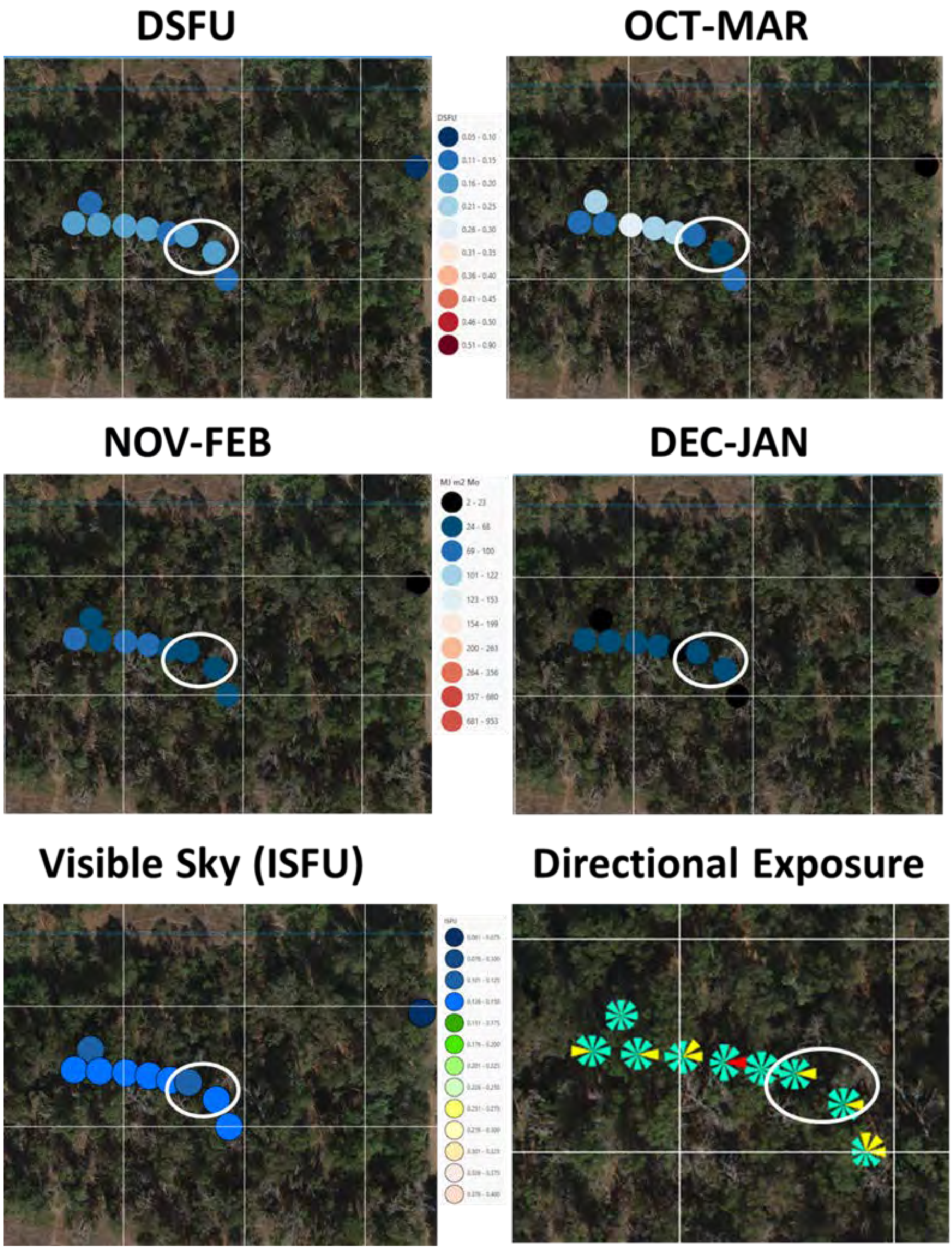
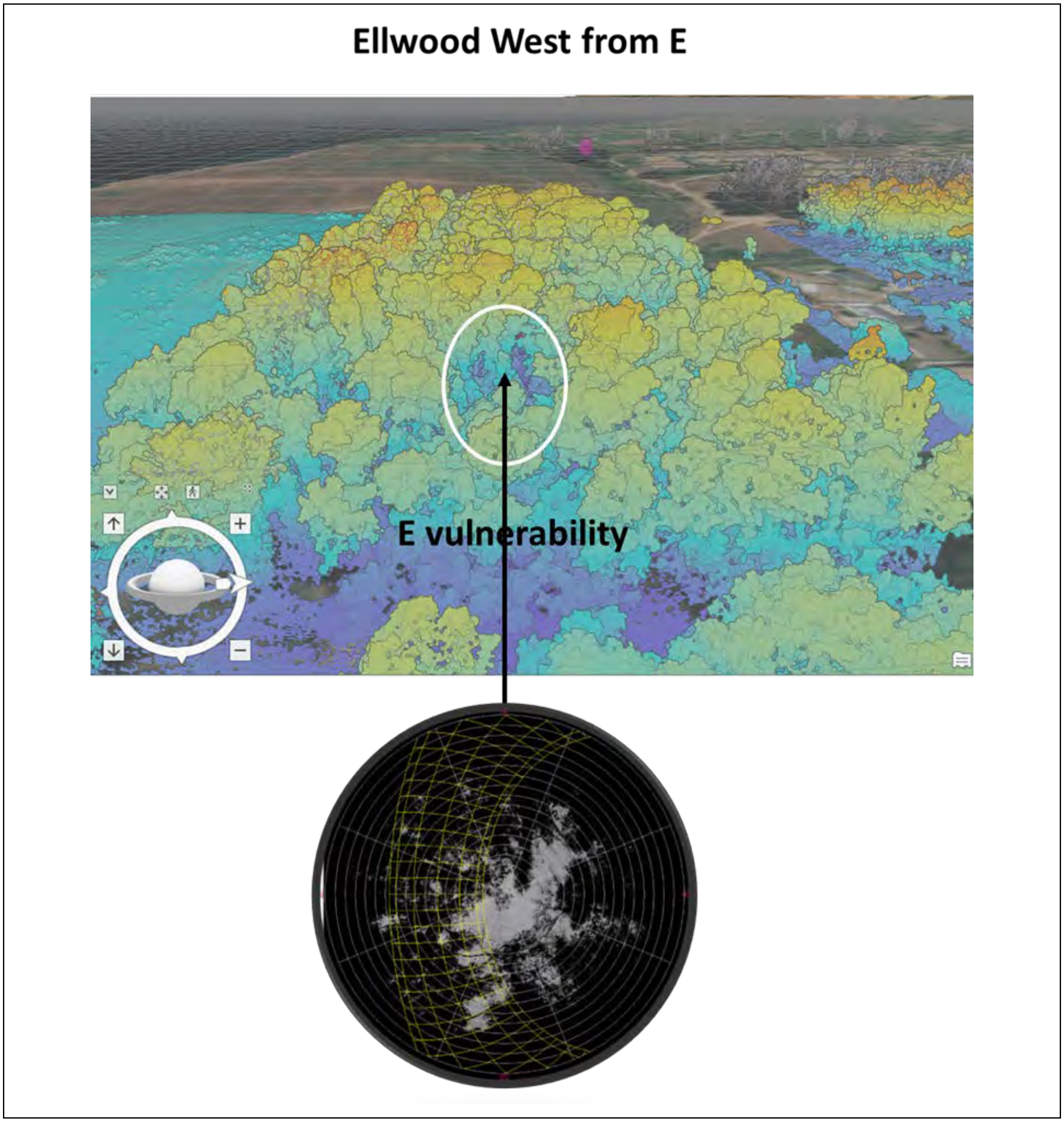


FIGURE 30. OBLIQUE VIEW ELLWOOD WEST VULNERABILITIES



Descriptive comments about Figure 30 of Ellwood West:

- Black dots are historical cluster sites, E end of transect occupied in 2021 and 2022.
- Cathedral structure along creek.
- The hillslope to the Mesa provides intrinsic wind shelter. Reduces impact of tree mortality.
- E and N wind vulnerabilities, thin green line N of trail
- Fuels management – only 17A, B, and C (shown on Figure 31) have potential impacts, but far from cluster zone, stand of red ironbark. Other fuel grid cells along N-edge do not have tall trees.

FIGURE 31. ELLWOOD WEST VULNERABILITIES AND RECOMMENDATIONS FOR RESTORATION

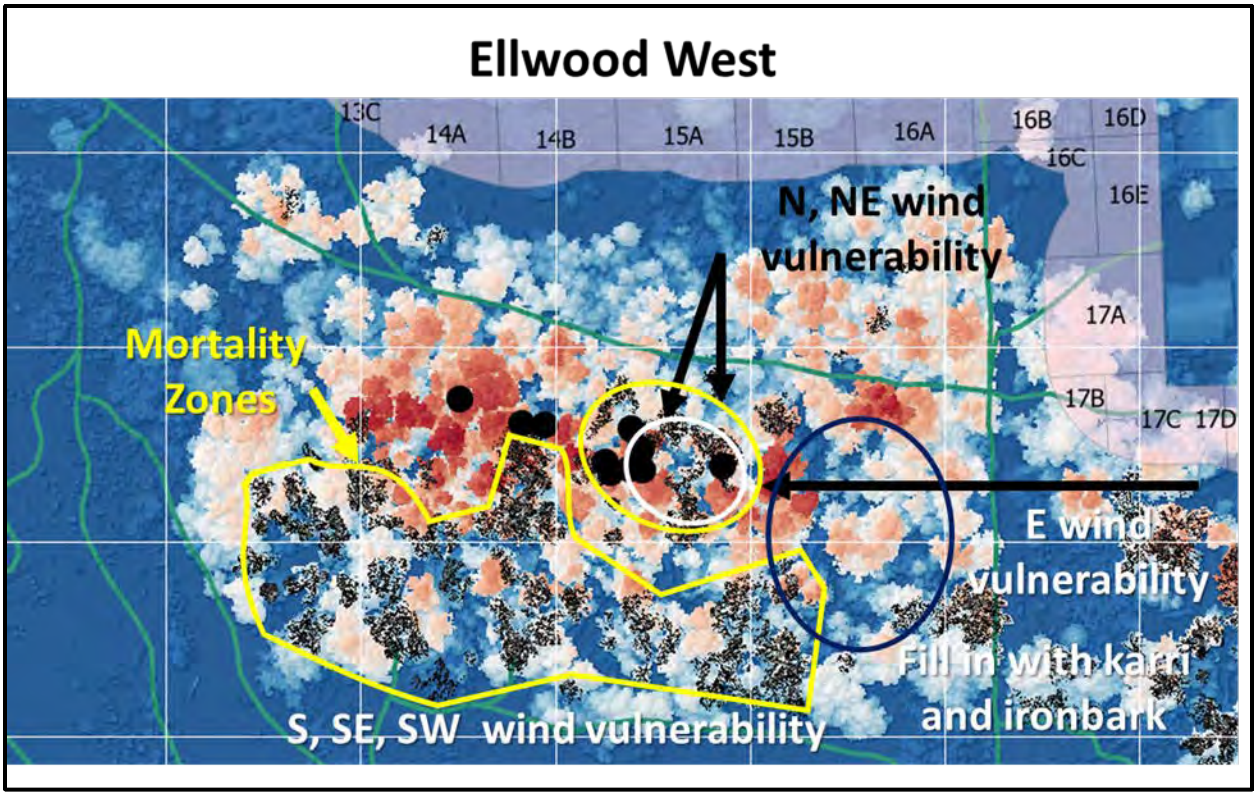


Figure 32. Monarch Observations - Ellwood East

Legend

Ellwood Mesa Open Space Boundary

Monarch Cluster Observations by year

- 2022
- 2021
- 2020
- 2019

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42283°N 119.88886°W
Goleta, Santa Barbara County

Imagery Source: NV5, 10/29/2021

ALTHOUSE AND MEADE, INC.
BIOLOGICAL AND ENVIRONMENTAL SERVICES

Map Updated:
February 28, 2023 05:04 PM by CDM

5.4 Ellwood East

5.4.1 Current Conditions at Ellwood East

Ellwood East is in the eastern portion of the eucalyptus stand on Ellwood Mesa, south of Deveraux Creek in a topographic bowl at the base of the Mesa slope. The bowl wraps around from east to south and southwest and rises approximately 12 m (40 ft). The bowl itself provides some intrinsic wind shelter from east through southwest. Monarchs historically clustered along a 80 m (260 ft.) stretch in the bottomland flat, shown in Figure 32. In 2021, monarchs clustered 10-15 m south of the previous cluster zone at the very base of the Mesa slope. The Ellwood East stand has several species of eucalyptus in addition to blue gums – red river gums (*E. camaldulensis*), and a small stand of red ironbark at the Mesa rim.

The bottomland flat is occupied by numerous non-native, evergreen ash (*Fraxinus uhdei*) trees, some of which are >30 m (100 ft.) tall. A stand of evergreen ash is present in the western side of the bottomland flat, west of the historical cluster zone, and monarchs also roosted in these trees in 2021-2022 season. The edge of the forest at the Mesa rim consists of small dense trees on highly compacted soils, with many small gaps that lead to the larger trees on the slope. Substantial mortality of blue gum on the Mesa slope and in the flat opened the forest and dead downed wood (especially large trunks) is strewn across the forest floor.

Ellwood East has been heavily used in recent years (see Section 4.1 and Appendix C). In 2021-2022, monarchs abruptly abandoned Ellwood Main in late December, and many moved to Ellwood East for the remainder of the season. A similar, less abrupt movement from Ellwood Main to Ellwood East occurred in 2022-2023. But unlike 2022, Ellwood East was abandoned as monarch numbers at Ellwood crashed following a series of intense winter storms in late-December and early-January (see Section 4.1 and Appendix C).

A transect of hemiphotos spaced ~10 m (33 ft.) apart was taken northwest to southeast through the historical cluster zone (Figure 33A). Another set of hemiphotos was taken in a 2021 cluster area, slightly up the Mesa slope. Some photo data are presented in Table 9. Photos 702, 709, and 708 are in the slope cluster zone (Figure 33B). The Mesa slope rises to the S. Photo 702 is well sheltered from all directions, Photos 708 and 709 have gaps to the NE and SW. All three photos receive some dappled light at ground level for a few hours during the overwintering season. Photo 707 is upslope from the cluster zone, and a substantial gap appears to the SSW – note that there is only one clump of trees in the SE octant. This is the area of substantial tree mortality. Photos 468 and 462 are along the historical cluster zone; 468 has a large overhead gap and moderate N and NW exposure.

The point maps of hemiphoto data (Ellwood East has relatively high overall canopy cover. ISFU ranges from 0.075 to 0.15. The DSFU map shows a higher insolation (0.16-0.25) zone on the slope, and the monthly insolation is higher in the slope area. S, SW, and W exposure increase on the slope (Figure 34). One slope site (Photo 708) has high NE exposure. The E end of the lower transect has moderate NW and N exposure, and one site in the middle of the transect has high E exposure. The outlying hemiphoto site to the SW is in the ironbark stand and has all around low directional exposure.

TABLE 9. EXAMPLE HEMIPHOTO DATA AND COMMENTS AT ELLWOOD EAST

Photo	Cluster	ISFU	DSFU	Max Exposure	Comments
702	Cluster	0.10	0.14	0.14 E	2021 slope location
708	Cluster	0.12	0.14	0.34 NE	2021 slope location
709	Cluster	0.11	0.12	0.25 N	2021 slope location
707	Upslope	0.12	0.25	0.24 S	Upslope above cluster zone
468	Cluster	0.14	0.13	0.28 NW	East-end of zone
462	Cluster	0.12	0.16	0.27 N	West-end of zone

Overall Ellwood East has an array of microsites that provide moderate insolation and low directional exposure within short distances within the site. The shift to the 2021 cluster sites appears to be driven by insolation, but moving farther up the slope would increase wind exposure.

Ellwood East combines generally low directional exposure with higher insolation on the slope. The extensive drought mortality of blue gums (dieback zones) on the slope has opened the forest, allowing insolation to penetrate at the cost of increasing SE-S-SW wind vulnerabilities. Planting a red ironbark shelterbelt along the rim, where soils become deep enough to support larger trees (north of the stunted stands that occupy the compacted soils), will address this vulnerability. The sheltering effect of the windbreak at the Mesa rim will extend across the entire cluster zone. A healthy stand of ironbark already occupies part of the Mesa rim.

The forest on the slope has self-thinned to a more sustainable density of blue gums. Removing fine fuels and dispersing large fallen trunks will prepare the slope for new plantings of native understory shrubs and oaks, as well as a few karri (*E. diversicolor*), near the top of the slope to diversify the canopy. But planting tall trees on the mid- and lower slope would reduce insolation at the base of the slope so should be mostly avoided.

On the northern edge, the fuels management grid cells 23A, 24A, and 24B are sensitive areas and maintaining the taller vertical structure is imperative. Closer to the cluster zone, canopy gaps that create N and NW vulnerabilities can be closed by large trees. Riparian restoration along Deveraux Creek can establish sycamores, cottonwoods, and willows on that stretch, once the ash trees are selectively removed. Adding California bay to the mix would provide an evergreen species. Between the riparian zone and the cluster zone, planting well-spaced tall eucalyptus, especially karri (*E. diversicolor*), will eventually fill these gaps – the trees should grow well on the bottomland soils.

These recommendations consider the whole site with regard to monarch habitat. However, the cluster site is bisected by a property line – City of Goleta owns the western section, and the Rancho Estates owns the eastern section. We recommend that actions – primarily the rim ironbark shelterbelt - be taken on the Goleta property now and that the other actions in the bottomland be taken with permission from property owner.

5.4.2 Recommendations for Ellwood East Restoration Actions

The following are our recommendations for the restoration of Ellwood East and corresponds with Figure 39:

- Replace/replant dead monarch aggregation trees with blue gum eucalyptus.
- Encourage the recruitment and establishment of blue gum saplings and existing trees.
- Fuel treatment grids 23B, 24A, 24B are most sensitive and include riparian corridor (blue line in Figure 35)
- Remove most dead standing trees (shown in black in Figure 35)
- Remove high fraction of downed wood, especially finer fuels <10 inches diameter that prevent new growth.
- Remove accumulated small (<10 in.) branches for fuel reduction. Raking out the accumulated debris.
- Separate large logs on the forest floor as practical.
- Plant an ironbark shelterbelt along the crest of the Mesa slope (thick blue line in Figure 35) in an arc from southwest to south to southeast. The western part on Goleta property can be planting now, the south and southeast sections depend on agreement with the adjacent property.
- Plant red ironbark and karri (*E. diversicolor*) within orange oval north of cluster zone to address north-northwest vulnerability.
- Manage blue gums at current drought-thinned density on slope above cluster zone.
- Fill in understory on slope with coast live oaks, toyons and other native shrubs.

FIGURE 33A. HEMIPHOTOS TRANSECT LOCATIONS AT ELLWOOD EAST

Dead standing (blue) and downed (yellow) shown over a color infrared photo. White oval is the cluster zone over the last decade.

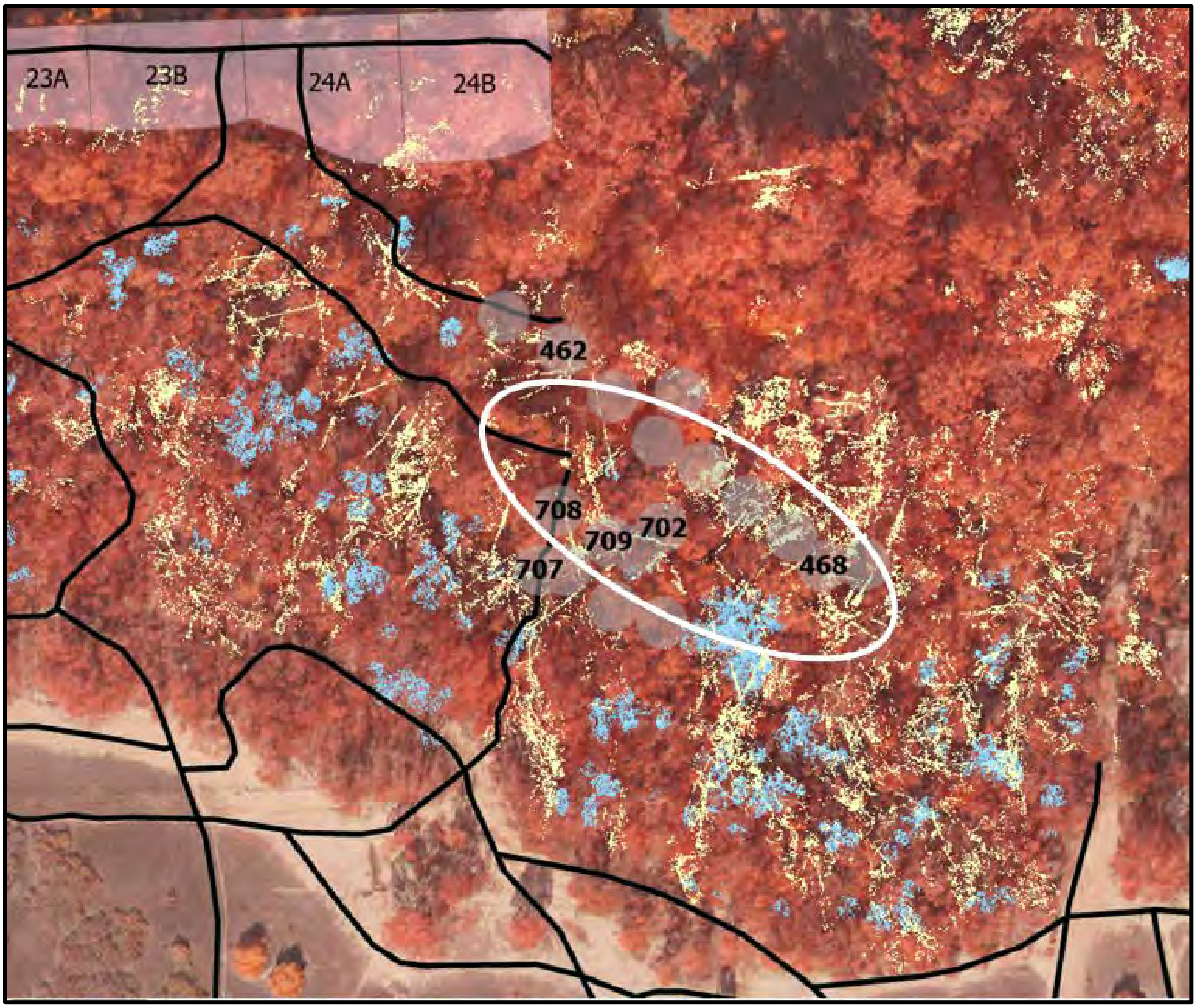


FIGURE 33B. EXAMPLE HEMIPHOTOS FOR ELLWOOD EAST

Hemiphotos 702,708,709, and 468 are in the cluster zone.

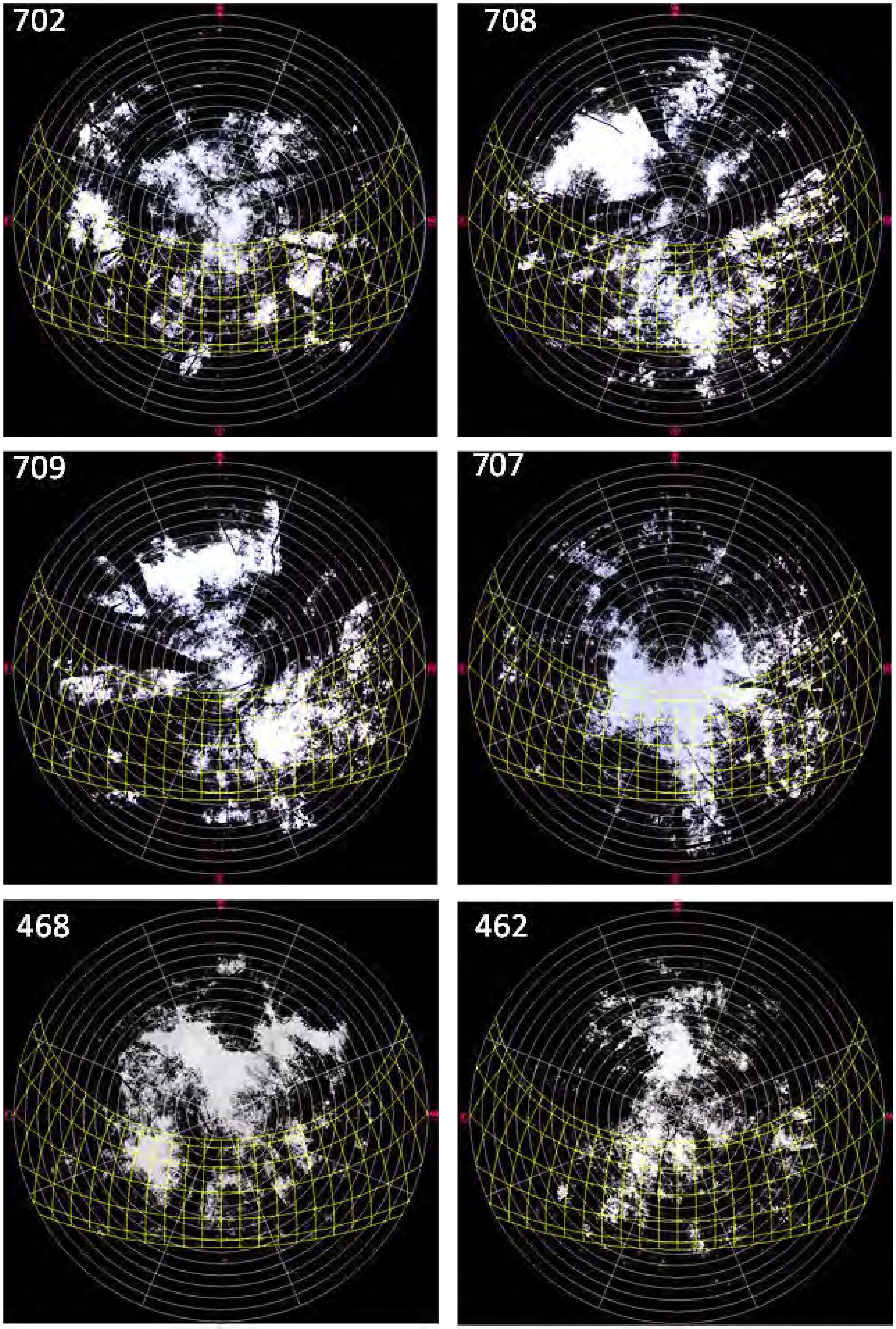


FIGURE 34. POINT MAPS OF HEMIPHOTO RESULTS AT ELLWOOD EAST

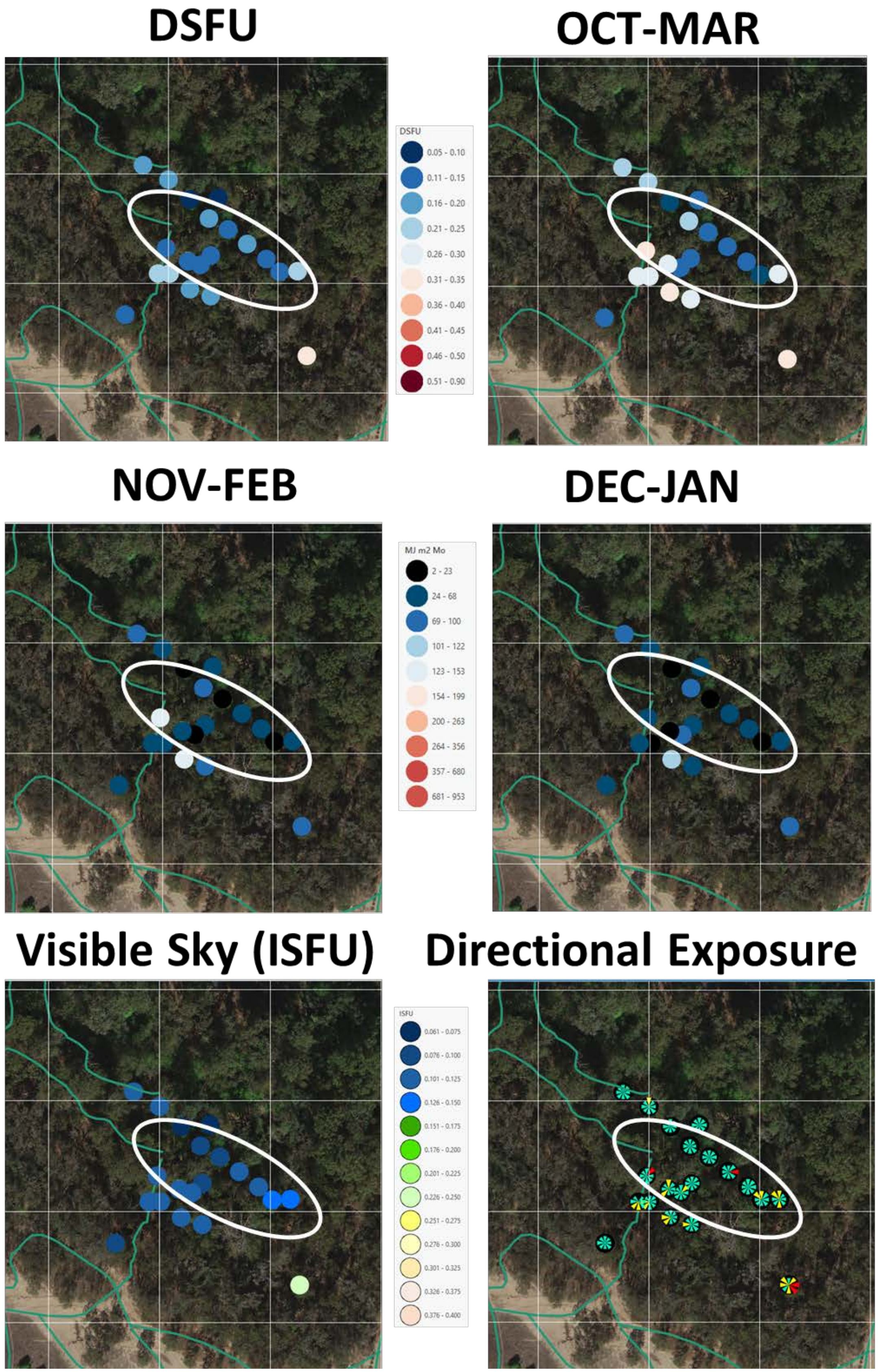


FIGURE 35. ELLWOOD EAST VULNERABILITIES AND RECOMMENDATIONS FOR RESTORATION
Cluster sites are small white circles within the larger ellipse.

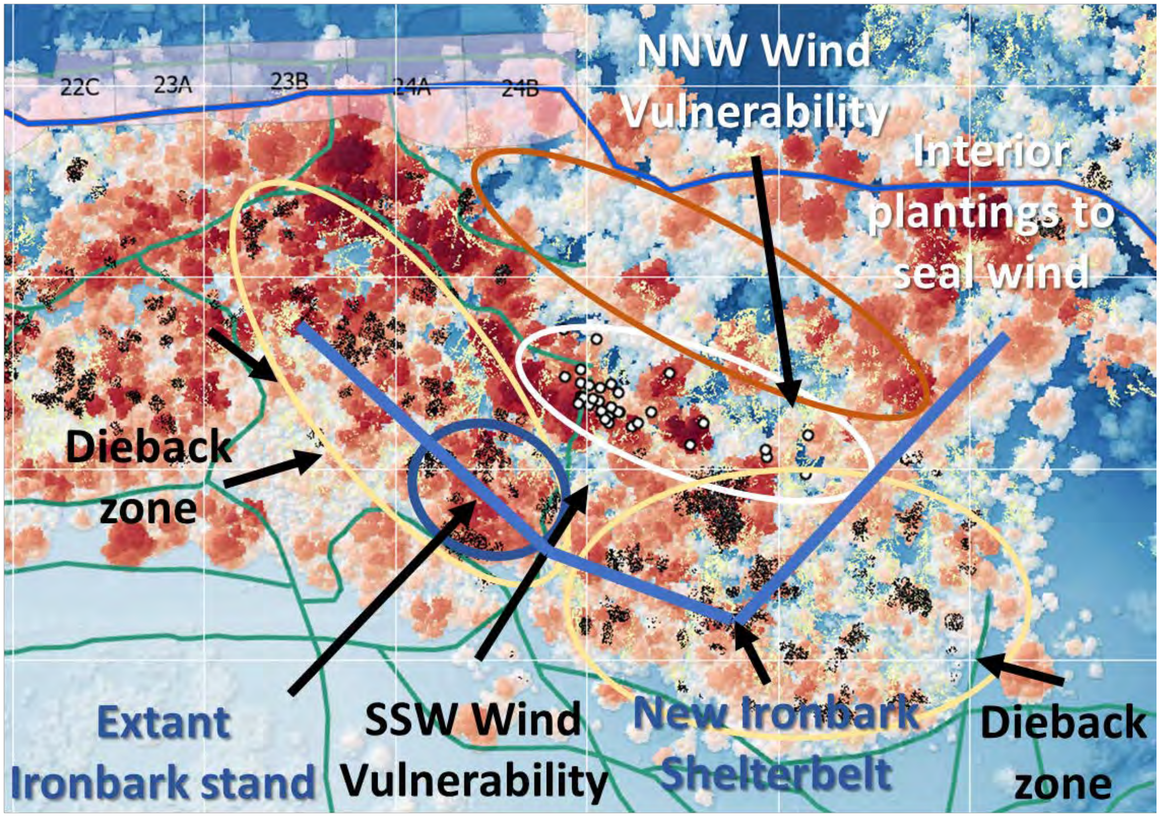


Figure 36. Monarch Observations - Ellwood North

Legend

Ellwood Mesa Open Space Boundary

Monarch Cluster Observations by year

○ 2019

Aggregation Sites

Primary

Historic

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.4278°N 119.89625°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 10/29/2021

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Map Updated:
April 21, 2023 12:53 PM by CDM

5.5 Ellwood North

Ellwood North is a large rectangle of eucalyptus forest. Monarchs have aggregated historically in the northern portion of this area and more recently closer to the center of the area, as shown on Figure 36. We have examined both locations and refer to them as Ellwood North-North (the northern location) and Ellwood North-Central (the central location).

5.5.1 Current Conditions at Ellwood North-Central

Ellwood North-Central (NC) is the area south of the cross trail in Ellwood North and has the most current potential for cluster sites within Ellwood North area. Monarch clusters greater than 20 individuals were last observed during the 2017-2018 season. Since then, only single butterflies or groups of a few individuals have utilized the Ellwood NC site, see Figure 36 and Appendix C for monarch count data. The entire Ellwood North has experienced the most tree mortality, especially north of the cross trail in Ellwood North-North (NN). There are substantial areas of tree mortality within Ellwood NC, especially along the cross trail, but also scattered within the forest.

Photo 481 is located closest to the last historical cluster site and is approx. 33 m (108 ft.) south of the cross trail in an area that has not suffered as much tree mortality as further north, shown in Figure 37 A and B. This site is more exposed to the northwest (0.27 DSFU) than is optimal, see the data from the hemiphotos in Table 10. Photo 345 is located along the cross trail and clearly shows the extensive tree mortality to the north. Photo 342 is located along the inner edge of the eastern 100 ft fuels management buffer and is an example of the type of gaps along that edge that create wind vulnerabilities – in this case the key direction is southeast (0.36 DSFU).

TABLE 10. EXAMPLE HEMIPHOTO DATA AND COMMENTS AT ELLWOOD NORTH-CENTRAL

Photo	Cluster	ISFU	DSFU	Max Exposure	Comments
481	Historic	0.18	0.27	0.27 NW	Near center of cluster zone
345	Historic	0.22	0.25	0.33 NW	North-edge along trail, dead trees N
342	Shelter zone	0.21	0.32	0.36 SE	West-edge at 100’ fuels border
350	Shelter zone	25	0.21	0.49 W	West-edge

Unlike the other sites (Ellwood Main, West, and East) Ellwood North-Central does not have an obvious cathedral structure over a creek or gully. The historical cluster sites have been in small gaps in the forest. Overall ISFU within the cluster zone ranges from 0.13 to 0.23 (Figure 38). DSFU ranges from 0.19 to 0.30, indicating good exposure to insolation on an annual basis. In October and November, strong insolation (white/red) penetrates to the forest floor at several sites within the cluster zone. Directional exposure is varied, but most sites have one or more directions with excessive exposure; a few sites have low or moderate exposure in all directions.

Sites like Photo 481 appear suitable for clustering. But few monarchs appear or stay in Ellwood North (any part of it) and it has always been a secondary site among the Ellwood complex.

The main vulnerabilities at Ellwood North-Central are northeast, north, and northwest wind penetrating through the mortality zone north of the cross trail. The trail itself creates east and west vulnerability at either end. Mismanagement of the fuels buffer zone to the east could open the forest to northeast, east, and southeast winds.

Removal of the dead standing trees is a high priority. Management of the downed fuels – removal of finer fuels (less than approx. 10-inch diameter) and spreading out of the large, downed trunks will prepare the ground for plantings. The main plantings to address the wind vulnerabilities are to seal up the edge just south of the cross trail with a red ironbark shelterbelt (double row), establish an inner red ironbark shelterbelt on the east side at the 100 ft fuel management line, and establish an inner red ironbark shelterbelt along the west side. In the interior of the forest, it will be important to maintain the existing blue gum trees, encourage blue gum saplings, and plant some well-spaced karri (*E. diversicolor*) to add diversity. There is sufficient depth of forest south of the cluster zone for wind shelter. Maintenance of some gaps within the sheltered area may be necessary in the long term.

The vulnerability of the blue gum forest in Ellwood North in general to drought resulted from tight spacing (approx. 6 ft.) of trees, and exuberant growth of coppiced (multi trunk) trees during wet periods. When the 2012-2016 drought intensified, these areas were primed for mass mortality because of the dense growth, thinner soils, and upland topographic position. The forest has thinned to a density commensurate with the drought intensity, so future management should aim to avoid densification of the blue gums. There is plenty of room in the understory for native shrubs (toyon grows well in this area) and live oak trees.

5.5.2 Recommendations for Ellwood North-Central Restoration Actions

The following are our recommendations for the restoration of Ellwood North-Central and corresponds with Figure 39:

- Replace/replant dead monarch aggregation trees with blue gum eucalyptus.
- Encourage the recruitment and establishment of blue gum saplings and existing trees.
- Fuels management (10 A, B, C, 11A, B) is very sensitive area.
- Removal of most dead standing trees (shown in black in Figure 39)
- Remove high fraction of downed wood, especially finer fuels <10 inches diameter that prevent new growth.
- Separate large logs on the forest floor as practical.
- Plant shelterbelts at 100’ limit of fuels management grid. Multistoried with red ironbark as canopy and understory native shrubs and oaks
- Reinforce western edge shelterbelt as needed.
- Reinforce northern edge (just south of cross trail) with double ironbark row.
- Plant karri (*E. diversicolor*) within interior to diversify the overstory.
- Maintain lower density of blue gums established after drought.

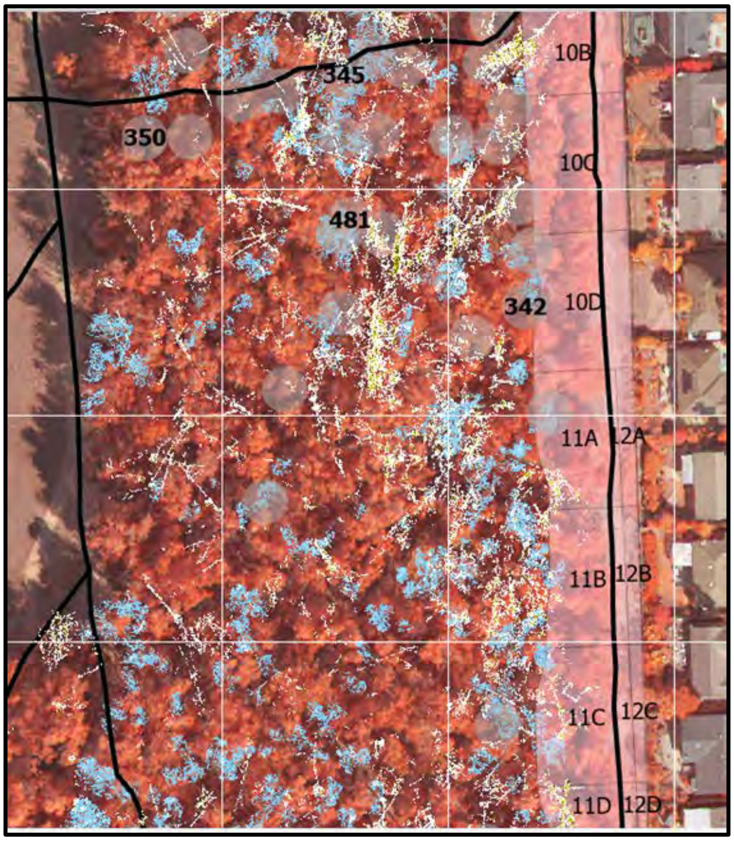


FIGURE 37A. HEMIPHOTO TRANSECT LOCATIONS AT ELLWOOD NORTH CENTRAL

Map with 50 m Grid. Dead standing (blue) and Downed (yellow) shown over a color infrared photo. Lighter shaded grids are fuel management areas.

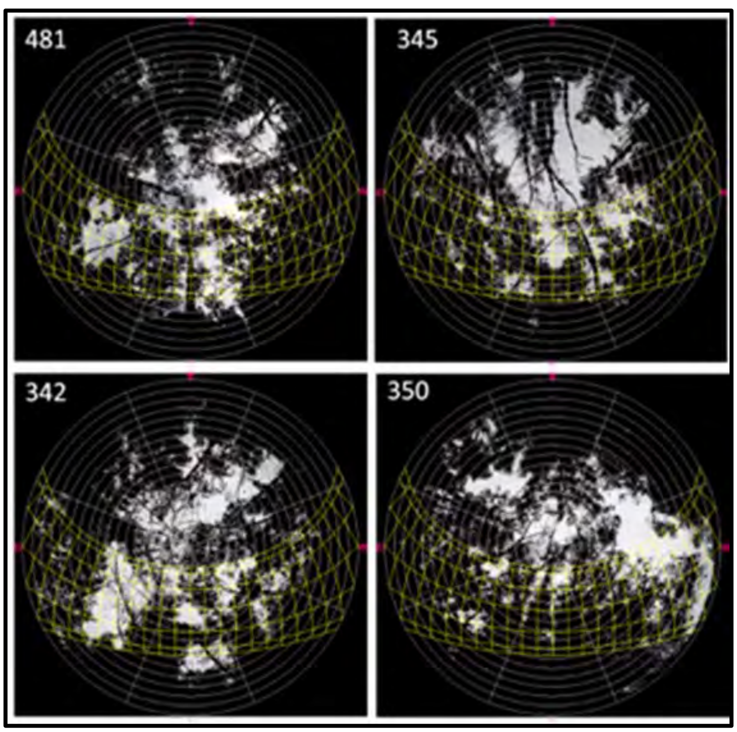


FIGURE 37B. EXAMPLE HEMIPHOTOS AT ELLWOOD NORTH CENTRAL

FIGURE 38. POINT MAPS OF HEMIPHOTO RESULTS AT ELLWOOD NORTH-CENTRAL

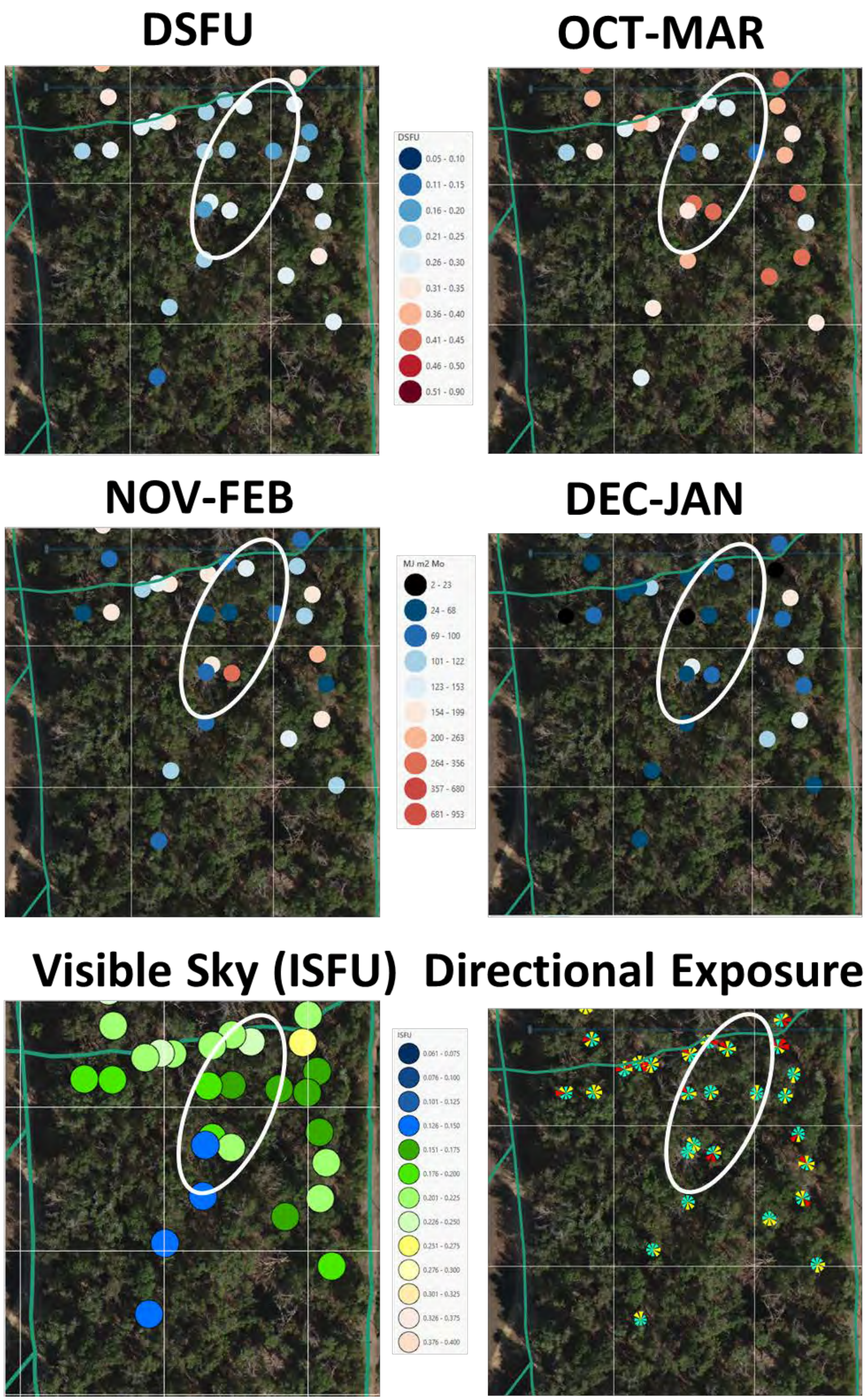
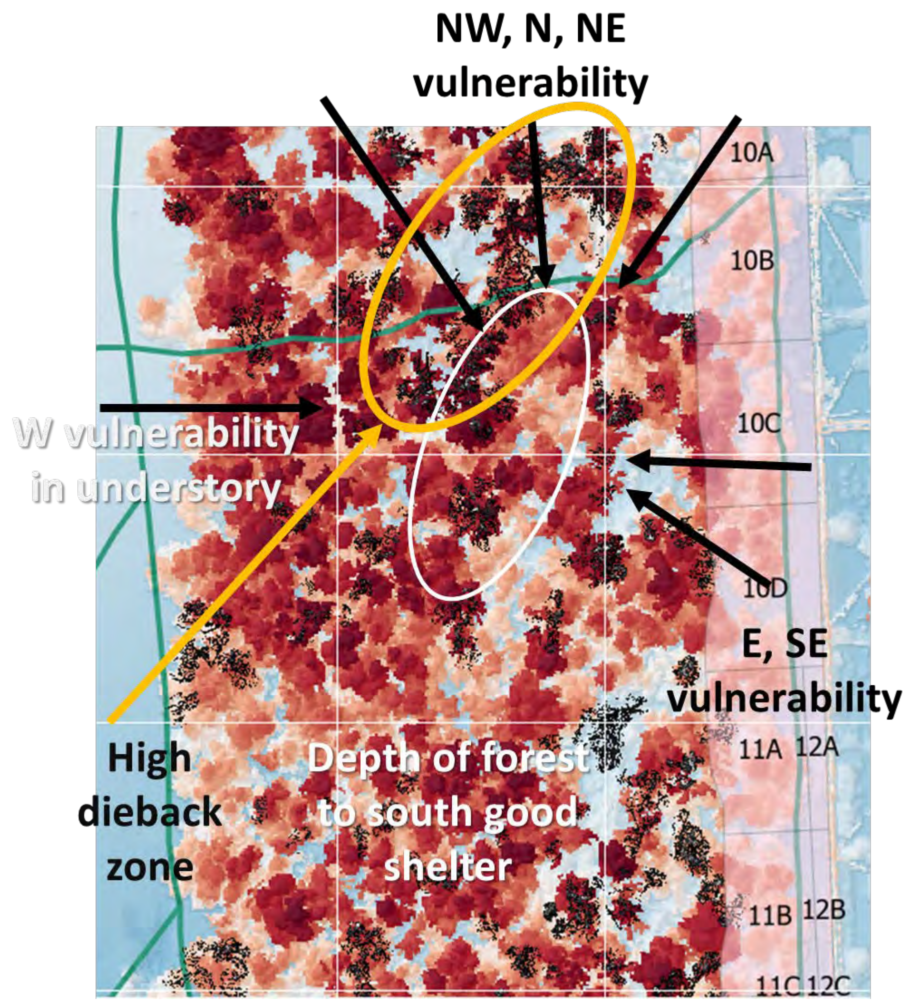


FIGURE 39. ELLWOOD NORTH-CENTRAL VULNERABILITIES AND RECOMMENDATIONS FOR RESTORATION



5.5.3 Current Conditions at Ellwood North-North

Ellwood North-North (NN) is the area north of the cross trail in Ellwood North and is one of the epicenters of tree mortality (Figure 40A). Monarchs were last observed roosting north of the cross trail over 10 years ago, see Figure 36 and Appendix C for monarch count data. Ellwood North-North has lost virtually all habitat value for overwintering monarchs that once clustered in the southern part of this zone because the forest has opened to the point where wind vulnerabilities from most directions are widespread. Because of this, Ellwood North-North has a lower potential to become overwintering habitat and is therefore a lower priority for restoration; the adjacent area at Ellwood North-Central has much higher restoration potential. The Ellwood North-North area has better nectar habitat potential and can be managed with an open eucalyptus overstory with a diverse native understory, including nectar plants in open areas.

Hemiphotos were taken primarily along the east and west edges, and along the cross trail at the south end of this area. Four examples are shown in Figure 40B with dead standing trees (blue) and downed trees (yellow) shown over a color infrared (CIR) photo; note the dead standing trees in Photos 356 and 362. Photo 332 is in the middle of a large clearing. There are wind vulnerabilities in many directions in these photos.

The point maps of the hemiphoto results show the openness of the canopy at site, see Figure 40B and Figure 41. The majority of the ISFU values are above 0.30 (shown in white-red), except at the southern boundary along the cross-trail (which is considered more deeply in Ellwood North-Central account). There is high annual insolation (DSFU), again except for the denser forest along the cross trail and very high insolation at ground level October-February throughout the site, with a few exceptions. All of these results point to a very open site with very little habitat suitability for overwintering monarchs. Directional Exposure is high in most direction at most sites (red wedges predominate), again only at the cross trail are there less exposed sites, see values in Table 11.

TABLE 11. EXAMPLE HEMIPHOTO DATA AND COMMENTS AT ELLWOOD NORTH-NORTH

Photo	Site	ISFU	DSFU	Max Exposure	Comments
332	Shelter zone	0.46	0.64	0.58 N	Near center of stand
333	Shelter zone	0.41	0.70	0.60 W	On east-end, at 100’ fuels border
356	Shelter zone	0.32	0.41	0.52 N	Near west-edge
362	Shelter zone	0.25	0.19	0.42 NE	Northwest section

No detailed vulnerability map was produced because there are so many vulnerabilities that can be seen in the point maps in Figure 41. Widespread tree plantings for monarchs at this site should be delayed until the other higher priority sites are planted. The recommended plantings of an ironbark shelterbelt south of the cross trail are primarily for Ellwood North-Central. Nectar plants in the understory at Ellwood North-North could help attract butterflies to Ellwood North-Central.

A limited area within this site could be designed with a circular shelterbelt to create a wind-protected gap, but that detailed design should wait until Phase 2.

5.5.4 Recommendations for Ellwood North-North Restoration Actions

The following are our recommendations for the restoration of Ellwood North-North:

- Replace/replant dead monarch aggregation trees with blue gum eucalyptus.
- Encourage the recruitment and establishment of blue gum saplings and existing trees.
- Fuels management (9A, B, C, D, 10A on Figure 40A) are less sensitive than in other fuel management areas.
- Removal of most dead standing trees
- Remove high fraction of downed wood, especially finer fuels less than 10-inches diameter that prevent openings for plantings and new growth.
- Separate large logs on the forest floor as practical.
- Ellwood North-North is an excellent place to practice wood removal because it is not a high sensitivity area.
- Plant native shrubs and forbs, with nectar plants in sunny interior areas. Take advantage of some swales where goldenrods (*Solidago* sp.) are already established as a native fall-blooming nectar source.
- Nectar plants at Ellwood North-North would help attract butterflies that might cluster at Ellwood North-Central.

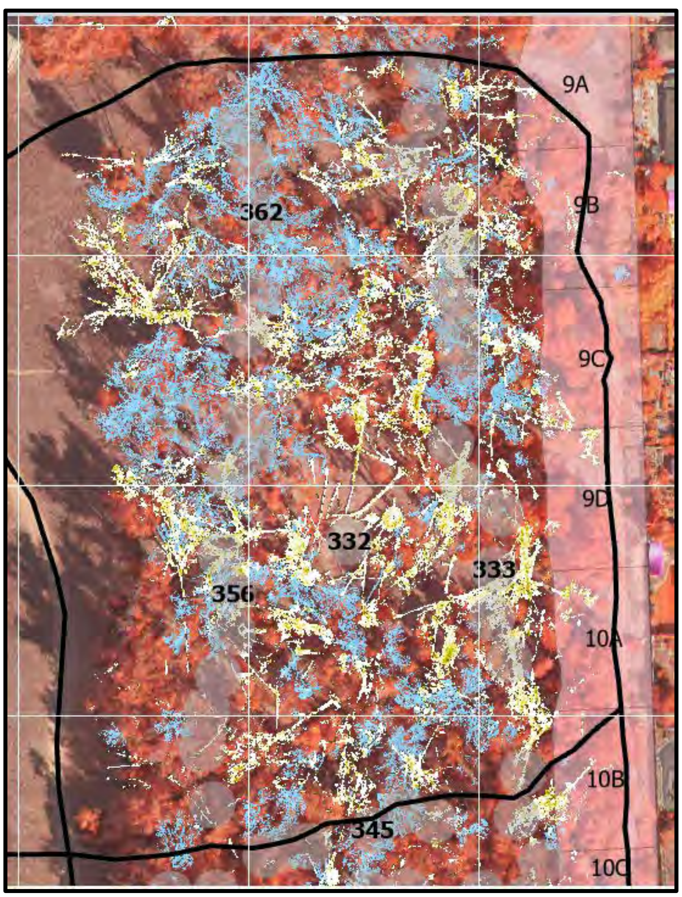


FIGURE 40A. HEMIPHOTO TRANSECT LOCATIONS AT ELLWOOD NORTH-NORTH

Hemiphoto is shown over a color infrared photo. Map with 50 m Grid. Dead standing trees are indicated in blue and downed trees are indicated in yellow.

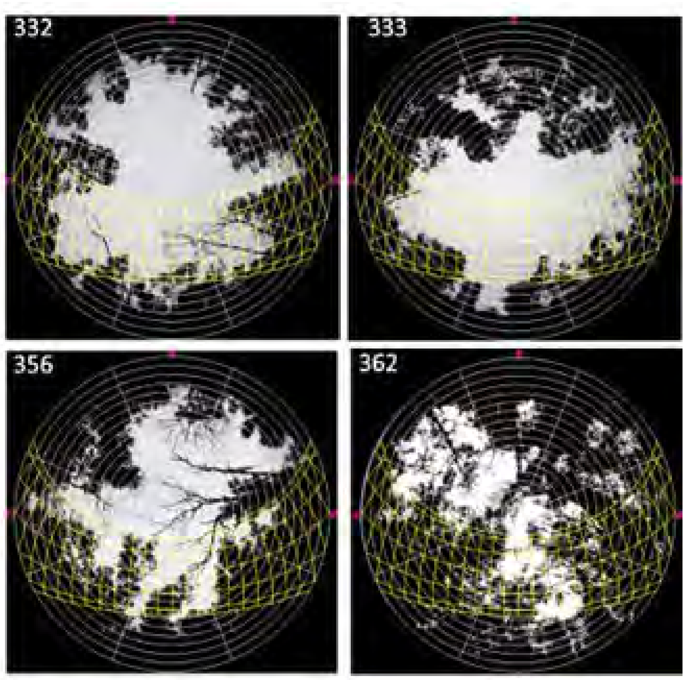


FIGURE 40B. EXAMPLE HEMIPHOTOS AT ELLWOOD NORTH-NORTH

FIGURE 41. POINT MAPS OF HEMIPHOTO RESULTS AT ELLWOOD NORTH-NORTH

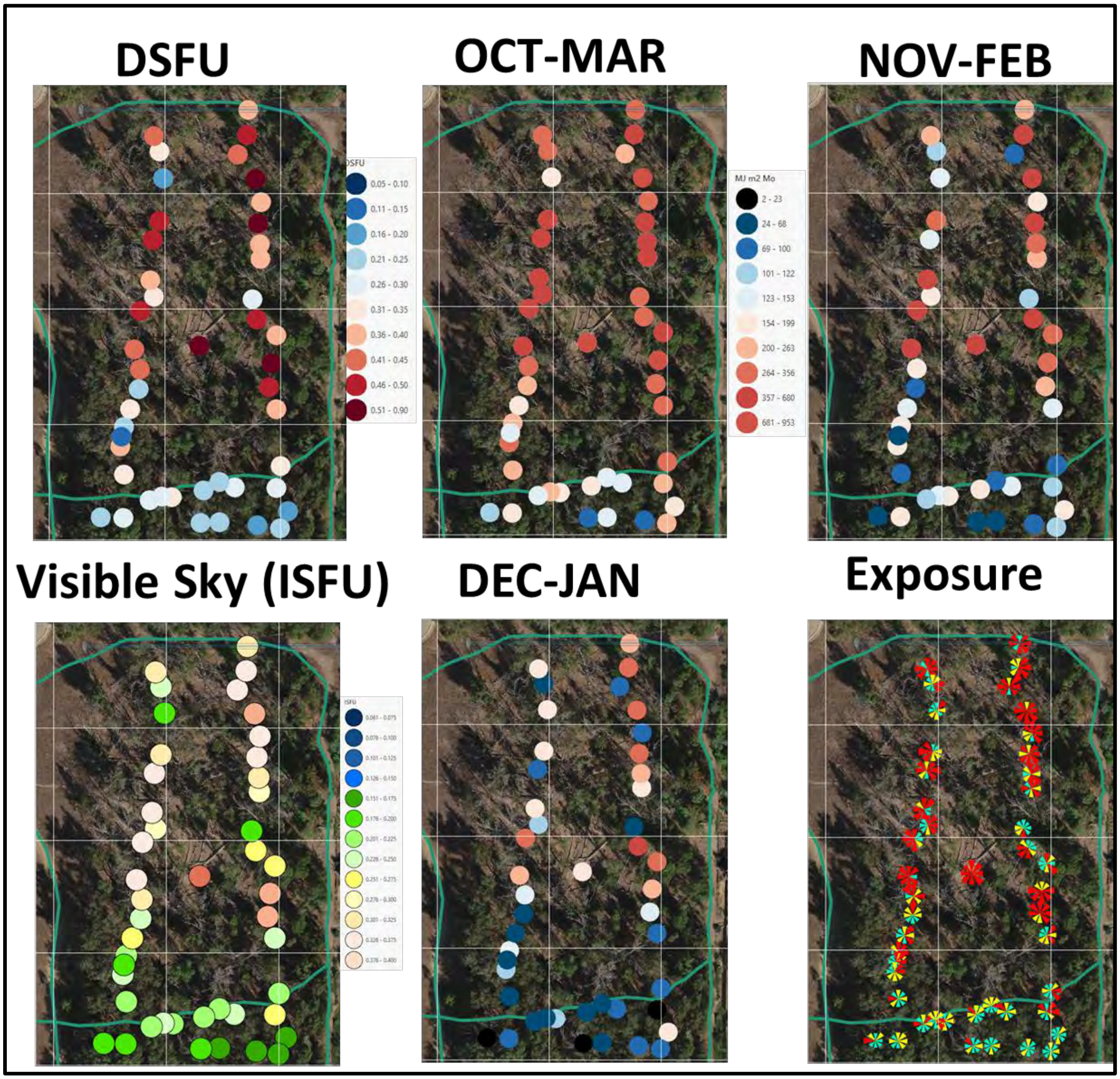


Figure 42. Monarch Observations - Ellwood Ironbark

Legend

Ellwood Mesa Open Space Boundary

Monarch Cluster Observations by year

○ 2019

N

0 50 100 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42486°N 119.89609°W
Goleta, Santa Barbara County

Imagery Source: NV5, 10/29/2021

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Map Updated:
April 21, 2023 12:54 PM by CDM

5.6 Ellwood Ironbark

5.6.1 Current Conditions at Ellwood Ironbark

The Ellwood Ironbark area is at the southwest corner of Ellwood North. A stand of red ironbark (*Eucalyptus sideroxylon*) is between a grove of blue gums along the drainage channel to the west, and a stand of blue gums to the east (Figure 43A). A few monarch observations were recorded in 2019, see Figure 42 and Appendix C for monarch count data. The area east of the major trail suffered massive tree mortality. All the dead standing trees (shown in blue) and downed trees (shown in yellow) in the map are blue gums; no whole-tree ironbark mortality was noted. The red ironbark trees are planted close together (3-6 ft), and many stumps have multiple stems and form very dense stands that are highly effective at blocking the wind. But the dense canopy blocks insolation, except in narrow gaps along trails (Photos 393 and 394, Figure 43B). There is a double row of ironbarks running east-west at the south end of the stand, with a narrow trail on the north-side. Photo 387 shows how effective this double row is for reducing south exposure, as well as the narrow east-west gap along the trail. The interior is very dark (Photos 393 and 394), and Photo 394 shows an elongated gap along the narrow north-south trail through this area. Along the drainage in the blue gums, dead standing trees are visible to the southwest (Photo 400) and the elongated gap along the creek runs southwest to northeast. Table 12 shows the ISFU and DSFU values and comments for the four example hemispherical photos.

Hemiphotos were taken in 3 transects, shown in Figure 44. One transect ran east-west along a narrow trail behind a double row. A second transect ran north-south through the ironbark stand along a narrow trail. The third transect ran along the drainage bottom toward the west end. The hemiphoto point maps show that the interior is very dark. ISFU values are all less than 0.125, and some less than 0.10 (Figure 44). There is a relatively higher insolation site just south of the proposed gap, a result of the narrow north-south trail. The south-edge transect shows higher ISFU and insolation at the west and east ends, where the trail opens. The interior has low directional exposure in nearly all directions (note the preponderance of blue wedges along the north-south trail). The low south exposure along the east-west trail is the basis for proposing a double row of red ironbarks as the basic shelterbelt design. Note that exposure is high (red) at the ends of this trail where it opens, and moderate (yellow) at 20 m (70 ft) into the stand along the trail. This pattern emphasizes that trail openings need to be carefully designed to avoid wind tunnel effects. The transect along the drainage channel has one site in the optimal ISFU range (shown in green) but that site has moderate to high southwest, south, and west exposure. The sites farther south have lower ISFU, as well as moderate south exposure. This drainage channel site has only a thin green line west of the channel to provide shelter.

TABLE 12. EXAMPLE HEMIPHOTO DATA AND COMMENTS AT ELLWOOD IRONBARK

Photo	Cluster	ISFU	DSFU	Max Exposure	Comments
393	Shelter zone	0.10	0.16	0.20 S	W side of proposed opening
394	Shelter zone	0.08	0.14	0.60 W	S of proposed opening
387	Shelter zone	0.12	0.19	0.20 W	S-edge interior
400	Shelter zone	0.12	0.23	0.23 W	Along drainage channel

5.6.2 Recommendations for the Creation of a New Site at Ellwood Ironbark

The major recommendation for Ellwood Ironbark is the creation of a new gap in the well-protected interior of the ironbark stand where insolation is currently too low to be suitable for roosting monarchs. In 2022, Weiss and a crew from Rincon Consultants tagged 17 trees for potential removal to initialize a gap that is approximately 10 x 15 m (33 by 50 ft). This is viewed as an experiment – the effects on canopy cover and insolation will be evaluated and further removal considered. Such gap creation has been executed at 3 other sites – Monarch Lane (Los Osos, SLO County) in the 1990s, Point Pinole (Richmond, Contra Costa County) and Andrew Molera State Park (Big Sur, Monterey County), both in 2022. At Monarch Lane, the monarchs use the gap, and it has been successful over time in providing a wind-sheltered, high insolation site.

As part of the gap creation, another recommendation is to fill in the forest just to the east with red ironbark and karri, as replacements for the dead trees and to bolster wind shelter from that direction. This is consistent with some previous mitigation requirements that are described in the planting plan.

The following are our recommendations for the restoration of Ellwood Ironbark:

- Remove most dead standing trees (shown in black in Figure 45)
- Remove high fraction of downed wood, especially finer fuels <10 inches diameter that prevent new growth.
- Remove some accumulated litter within ironbark stand for fuel reduction.
- Separate large logs on the forest floor as practical.
- Create a small gap as indicated, removal of ~17 trees initially.
- Maintain the double wind row of ironbark trees for a wind shelter zone.
- Plant ironbark and karri (*E. diversicolor*) within blue circle for wind shelter.
- Maintain lower density of blue gums established after drought.
- Manage massive dieback zone for native understory, live oaks.

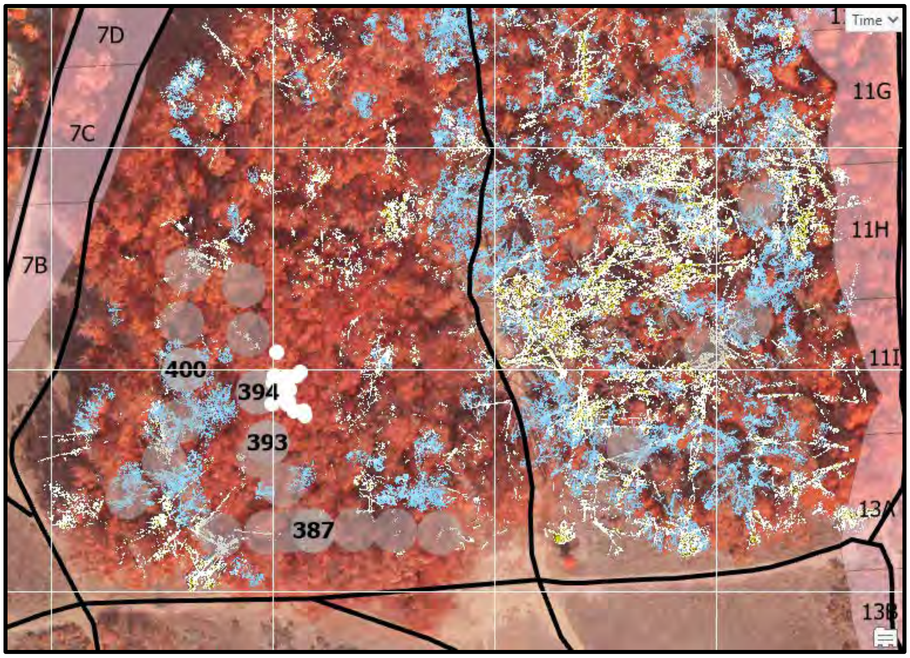


FIGURE 43A. HEMIPHOTO TRANSECT LOCATIONS AT ELLWOOD IRONBARK

Dead standing (blue) and downed (yellow) shown over a color infrared photo. The bright white dots are the locations of trees marked for potential removal to create a hospitable gap for monarchs.

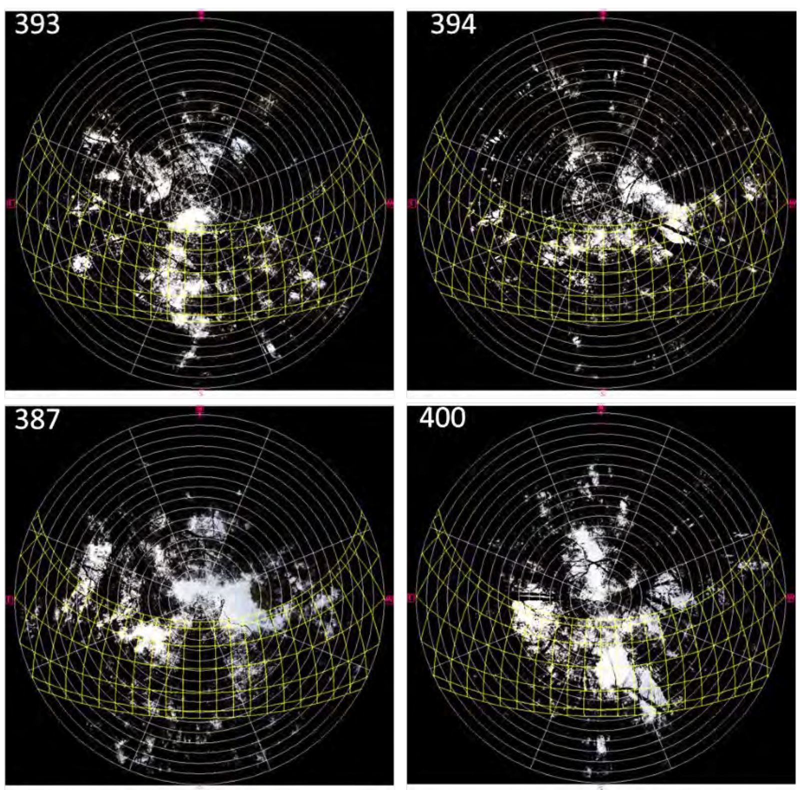


FIGURE 43B. EXAMPLE HEMIPHOTOS AT ELLWOOD IRONBARK

FIGURE 44. POINT MAPS OF HEMIPHOTO RESULTS AT ELLWOOD IRONBARK

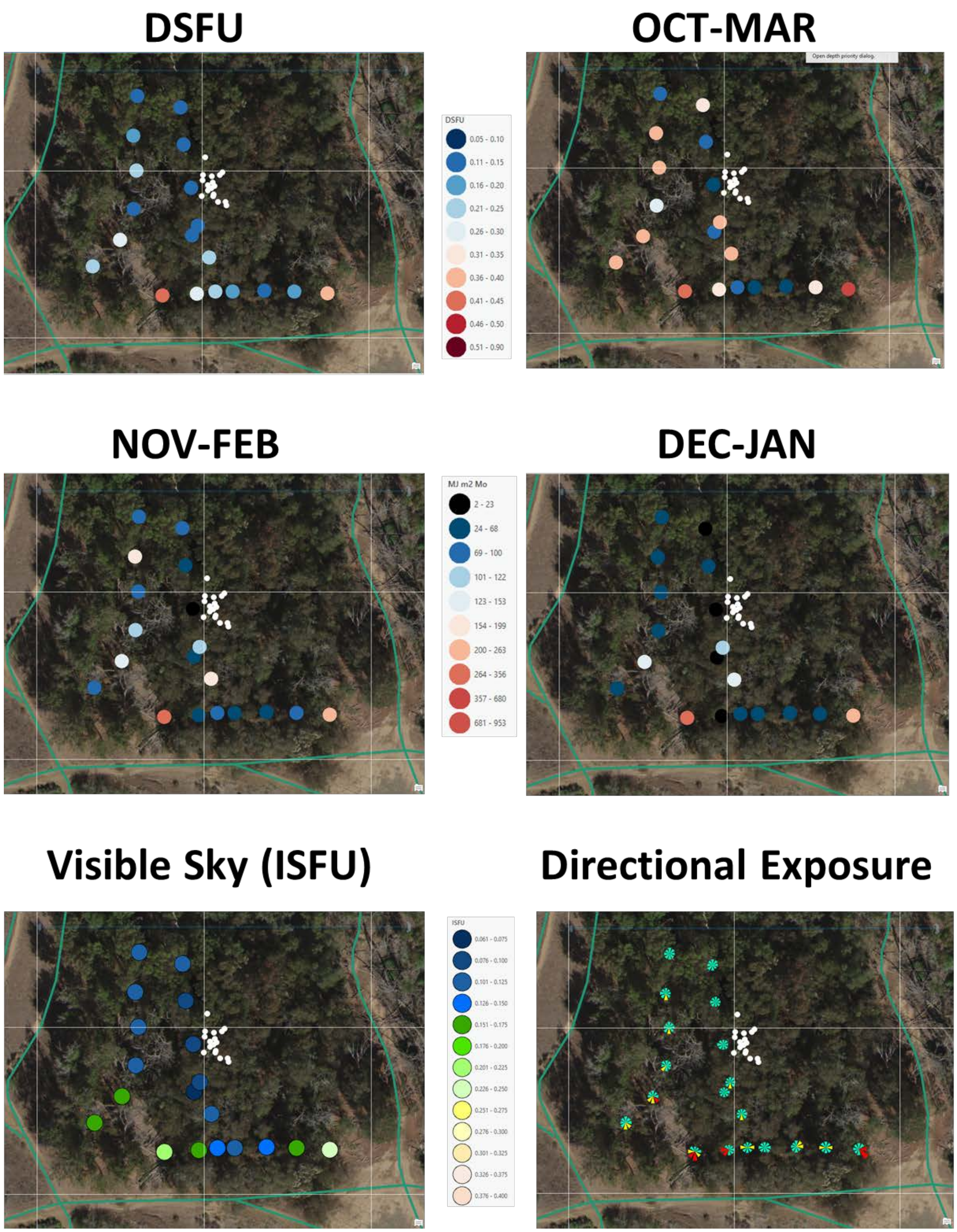
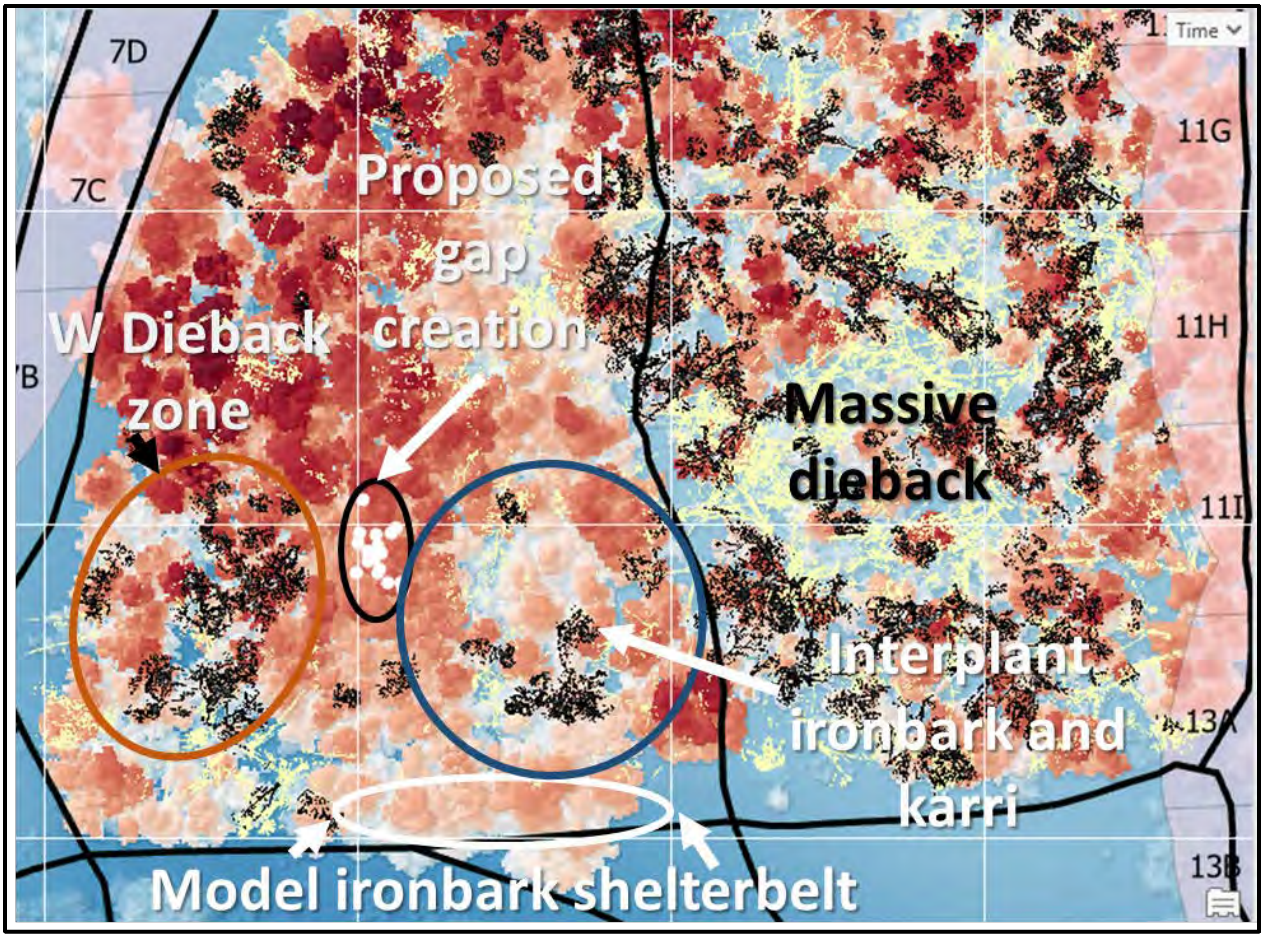


FIGURE 45. ELLWOOD IRONBARK RECOMMENDATIONS



5.7 Sandpiper

Restoration of the Sandpiper monarch site will be included in MBHMP Implementation Phase 2. We will discuss analysis and restoration recommendations in a future update for future reference and planning.

5.8 Ocean Meadows

Restoration of the Ocean Meadows monarch site will be included in MBHMP Implementation Phase 2. We will discuss analysis and restoration recommendations in a future update for future reference and planning.

5.9 Extent of Forest Death

Comparative photographs from 2011 and 2017 illustrate the significant canopy loss throughout the eucalyptus forest at Ellwood Mesa (Photos 7-16) (Meade et al. 2017). The 2011 photos show the tree canopy during conditions with plentiful rainfall and extensive growth. The 2017 photos show the same location after several years of extended drought. Thick canopies are present in the 2011 photos, while dead trees and/or sparce trees with epicormic growth are visible in the 2017 photos.

A health assessment was conducted in 2017 on the trees in the five monarch aggregation sites (Meade et al. 2017). The assessment assigned a health rating to each tree: 0 - dead, 1 - dying or hazard tree (should be removed), 2 - distressed trees, poor structure and health (some may need to be removed depending on their importance to aggregation site), 3 - tree with decent structure and health (should remain), 4 - tree with good structure and overall health (should remain; Table 13).

TABLE 13. RESULTS OF 2017 TREE HEALTH ASSESSMENT AT ELLWOOD MESA

	North	West	Main	East	Sandpiper
Total trees assessed	94	54	184	33	47
Health rating (Average)	1.6	1.75	1.6	1.75	2.55
Dead (0)	22 (23%)	5 (9%)	32 (17%)	3 (9%)	0
Remove (0-1)	34 (36%)	10 (19%)	63 (34%)	8 (24%)	0
Dead or distressed (0-2)	73 (78%)	49 (91%)	165 (90%)	28 (84%)	23 (49%)
Height of dead trees (Average)	65 ft.	70 ft.	67 ft.	67 ft.	n/a

Data source: Meade et al. 2017

Photo 7. Ellwood North monarch roost location, 2011 (photo by Daniel E. Meade).

Photo 8. Ellwood North monarch roost location, 2017 (photo by Daniel E. Meade).

Photo 9. Viewing area at Ellwood Main, 2011 (photo by Daniel E. Meade).

Photo 10. Viewing area at Ellwood Main, 2017 (photo by Daniel E. Meade).

Photo 11. Monarch clusters at Ellwood Main, 2011 (photo by Daniel E. Meade).

Photo 12. Monarch clusters at Ellwood Main, 2017 (photo by Daniel E. Meade).


Photo 13. Trail to bluffs east of Ellwood Main, 2011 (photos by Daniel E. Meade).


Photo 14. Trail to bluffs east of Ellwood Main, 2017 (right) (photos by Daniel E. Meade).


Photo 15. Trail to bluffs west of Ellwood Main, 2011 (photo by Daniel E. Meade).


Photo 16. Trail to bluffs west of Ellwood Main, 2017 (photo by Daniel E. Meade).

5.10 Wind and Monarch Movement between Ellwood Aggregation Sites

Overwintering monarch butterflies require specific habitat conditions that offer them buffering potential from negative wind and temperature effects. Cool moist air that is sheltered from strong winds offer ideal habitat. Such conditions have historically been met in Ellwood Mesa, however, widespread forest dieback has jeopardized ideal habitat conditions and now pose a threat to overwintering monarch populations.

In Santa Barbara California, monarchs can typically be found in overwintering mode from October-February. In these months, warmed air escaping from the land interior means that the prevailing winds tend to blow from the north and/or east. Winds coming off the ocean, that blow from the south and/or west, tend to be cooler.

In the 2021/2022 season, overwintering sites were subject to strong and prolonged wind events from the east/southeast between December 13-14 in 2021. This event lasted for around 36 hours, and although average wind speed was only around 15 mph, wind gusts averaged 27 mph for up to 16 hours. These winds did not however, result in notable alterations to temperature and humidity. In the same season, at midnight on January 21, an unusual wind blew in from the northeast at 18 mph. This relatively isolated event increased the temperature by 15 degrees and decreased humidity by over 50%.

In the 2022/2023 season, overwintering sites were subject to strong and prolonged wind events from east/southeast between January 4-5. This event lasted for up to 40 hours but was especially severe between 8pm (Jan 4) – 5am (Jan 5). In these 9 hours, the average wind speed was around 16 mph, and gusts averaged 30 mph, with some gusting up to 38 mph. Temperature and humidity did not appear to be affected by this wind event. However, on January 22-23, unusual north/northeast winds blew throughout the night with gusts up to 29 mph. The winds appeared to keep the temperature elevated and humidity low throughout the night. Upon cessation of the winds around 4am (Jan 23), the temperature quickly dropped, and humidity increased.

The winter months in Ellwood generally have tame winds, and although events of extended duration and gust strength, or of unusually warmth and dryness are infrequent, they appear to occur with some regularity from season-to-season. Historically, the topography of Ellwood, and habitat structure provided by eucalyptus and other trees have allowed some buffering capacity for the monarch butterflies.

Monarchs are sensitive to dehydration and seek areas of high humidity where available. They will avoid warm temperatures and seek the protection of cool moist post of air pools in the forest interior, where microsite conditions buffer them from warm dry air blowing from inland. Monarchs are also sensitive to the cold and may freeze under certain conditions. If situations allow, monarchs may move around their roosting trees to find areas most suited to their needs. However, the level of forest degradation that we currently see has little buffering capacity and now may be incapable of protecting monarch populations from large weather fluctuations.

Wind data is included in Appendix E.

6 RECOMMENDATIONS

6.1 Perform Deferred Maintenance

6.1.1 Strategic Fuel Reduction

The City of Goleta prepared the Community Wildfire Protection Plan (CWPP) in 2012 and acquired a Cal Fire grant to fund the implementation of the fuel reduction strategy in 2022. The goal of the CWPP is to minimize the risk of wildland fire to life, homes and infrastructure, and natural resources. Our habitat analysis supports the recommendation to remove dead wood and downed debris outlined in the CWPP. The removal of dead wood and downed debris will reduce the fire risk to the forest, and this is crucial for the protection and longevity of the monarch habitat at Ellwood Mesa.

Dr Daniel E. Meade and Dr. Stu Weiss prepared a letter report titled “Dead wood removal and monarch butterfly habitat effects” dated March 9, 2022, which is included in Appendix F. This letter emphasizes the importance for the management of monarch overwintering habitat and the removal of dead standing and downed wood. The Xerces Society guidelines for managing monarch groves stress the importance of removing hazard trees and felled debris (The Xerces Society 2017a). The 1993 Monarch conservation and management guidelines similarly state the importance of removing hazardous trees and the forest floor should be maintained to prevent the accumulation of dead plant materials (Bell et al. 1993).

The Meade and Weiss 2022 letter continues to explain that historically, Ellwood forests were managed to remove dead wood and maintain healthy stands of trees through normal forestry practices (Santos 1997, Meade personal observation). Failure to manage a grove results in over recruitment of trees during periods of higher rainfall and then death of trees during times of water stress (droughts). Appropriately managing tree density based on water demand creates a more stable grove and is a fundamental tenet of forestry management, even for groves managed for wildlife (Grebner et al. 2021, Taylor 2018).

The accumulation of bark and dead wood on the ground and leaning into the tree canopy creates a major fire hazard to monarch habitats (Xerces Society 2017a). Ignition from campfires and other human sources can feed on ground debris and quickly escalate into a catastrophic fire event. This risk can be managed by reducing fuel load through removal of dead branches, trunks and highly flammable vegetation that can create fire ladders into the forest crown. The Ellwood groves, once managed for wood production, now present a tangle of downed wood, dead leaning trunks, and over abundant understory shrubs. The City of Goleta Community Wildfire Protection Plan (2012) provides management recommendations to reduce, “potential fire intensity, rate of spread, and severity of effects” (pg. 58). Management prescriptions in the CWPP when implemented will help to protect life, property, and natural resources including monarch butterfly habitat.

The presence of large quantity of dead wood at Ellwood results in:

- Increased wind penetration and speed at aggregation locations due to downed trees,
- Higher tree-fall risk to remaining live trees,
- Reduction in shade at aggregation sites,
- Loss of cover for butterflies from predators,
- Poor recruitment and growth of replacement trees,

- Increased wildfire risk - intensification of fires and a fire ladder to canopy, and
- Public safety hazard from dead standing and leaning trees and ground debris.

Removal of dead wood from the Ellwood forests and monarch groves will have positive effects for monarch butterflies. The benefits include:

- Removal and replacement of dead trees will increase humidity and shade and boost protection of monarchs as they grow to maturity in the next decade.
- Removal of downed trees and branches eliminates debris tangles that interfere with recruitment of saplings and growth of trees with good form.
- Space for planting trees and shrubs will be opened by removing dead wood.
- Removal of leaning dead trees and branch and debris tangles will improve patrolling and clustering habitat for monarch butterflies.
- Reduction of hazards for visitors to the grove
- Preservation of habitat by reducing intensity and rate of spread of fires.

Maps showing the abundance of dead wood is shown in Figure 5 - Figure 12 in Section 4.4.2.

6.1.2 Prepare Restoration Areas

Removing the standing dead trees and downed wood, discussed in Section 6.1.1, will open up space for new plantings. Downed wood on the forest floor takes up a large area and we would have difficulty finding available open ground for new plantings. Photo 17 shows the grandeur of the downed wood in the Ellwood Mesa forest. After the removal is conducted, care may be necessary to prepare the recommended areas for plantings. These actions may include removing litter, removing non-native and invasive weeds, and smoothing out disturbed soil surface.

Eucalyptus debris does not break down as quickly as native vegetation and bark debris that accumulates on the ground retains nutrients and can inhibit new growth. Fallen blue gum eucalyptus trees decompose very slowly (DiTomaso et al. 2013), especially in dry climates. The high level of phenolics in eucalyptus inhibits fungi from breaking down the wood and allows accumulation of fire fuel (Reid et al. 2005). Chipping will aid the release of nutrients from woody debris by converting coarse wood to fine pieces (Russell et al. 2015). Mulching around new forest plantings can increase planting survival and growth rate (Cahill et al. 2005, Chalker-Scott 2007).

Photo 17. Extensive area with mass of dead, downed trees (Photo by Kyle Nessen).

6.2 Restore Aggregation Trees and Wind Protection

After the dead standing trees are removed, the restoration of the monarch aggregation locations and the surrounding wind protection zones is crucial for the longevity of the monarch habitat.

6.2.1 Restore Aggregation Trees

The monarchs have chosen specific recurring locations in Ellwood Mesa and the trees they return to year after year are very important for their overwintering roosting success. In areas where the monarch aggregation trees have died and have been removed, we recommend replacing these trees with blue gum eucalyptus plantings. Specific locations of these aggregation tree replacement plantings should be identified by a monarch butterfly biologist on the ground. Care should be taken to retain and protect the integrity of the open interior within the monarch aggregation sites.

6.2.2 Protect and Support Existing Live Trees

The existing tree canopy is vital to the continued health of the Ellwood Mesa forest for overwintering monarchs. We recommend encouraging seedlings and saplings, especially of blue gum eucalyptus trees, within the monarch aggregation sites. This will require the removal of dead and downed wood for fuel management to be conducted carefully to avoid unintentional impacts to existing young trees and clearing away the debris around seedlings and saplings. We recommend consultation with an arborist to explore methods of irrigation and fertilization to maximum the survival of existing trees.

6.2.3 Double Wind Row Design

The wind vulnerabilities throughout the Ellwood Mesa require reinforcement in order to provide adequate wind protection and maintain suitable wind speeds in monarch butterfly aggregation areas. Reinforcement of these areas is determined by the distribution and density of the existing foliage and the terrain around the aggregation sites, and the characteristics of species included in the reinforcement.

We designed a layout of tree planting that includes two rows of red ironbark with a row of toyon in front of it. This layout is referred to as the ‘double row’. The intention of the design is that the red ironbark will provide most of the wind protection while the toyon plugs any gaps in the lower canopy. This will create a continuous wall of canopy from the ground to the top of the canopy and thus a solid wall of wind protection. The red ironbark is spaced out with 20 feet between each tree’s center, one row staggered from the other, with toyon also spaced 20 feet from one another in a row 40 feet in front of the back row of red ironbark (Figure 47). The 20-foot spacing is intended to limit competition amongst trees in the double row, allowing for sufficient resources to grow to the desired mature size. This design can be used in areas where existing foliage and terrain are the thinnest, requiring substantial reinforcement to maintain suitable aggregation site conditions.

Red ironbark is favorable for the design because of its observed success on Ellwood Mesa, drought tolerance, fast growth rate, dense canopy, and mature canopy height of approximately 80 ft (approx. 24 m). Toyon is a favorable compliment to red ironbark because it is also established on Ellwood Mesa and grows to a mature height of 20 ft (6 m), which covers areas in red ironbark’s lower canopy that naturally thin in maturity.

To quantify the wind protection provided by this design we simulated an ideal version of the layout in an isolated environment. We simulated the effects of winds encountering the double row head on and the resulting wind shadow on the leeward side of the double row (Figure 46). We ran iterations of this test with the double row plants at three different ages and thus heights: early establishment, intermediate, and mature (Table 14).

TABLE 14. DOUBLE ROW GROWTH CHART

Species Height	Early Establishment	Intermediate	Maturity
Red ironbark	10 ft (3.05 m)	40 ft (12.2 m)	82 ft (25 m)
Toyon	3.3 ft (1 m)	6.6 ft (2 m)	20 ft (6 m)

Figure 46. Ideal Double Wind Row Simulation

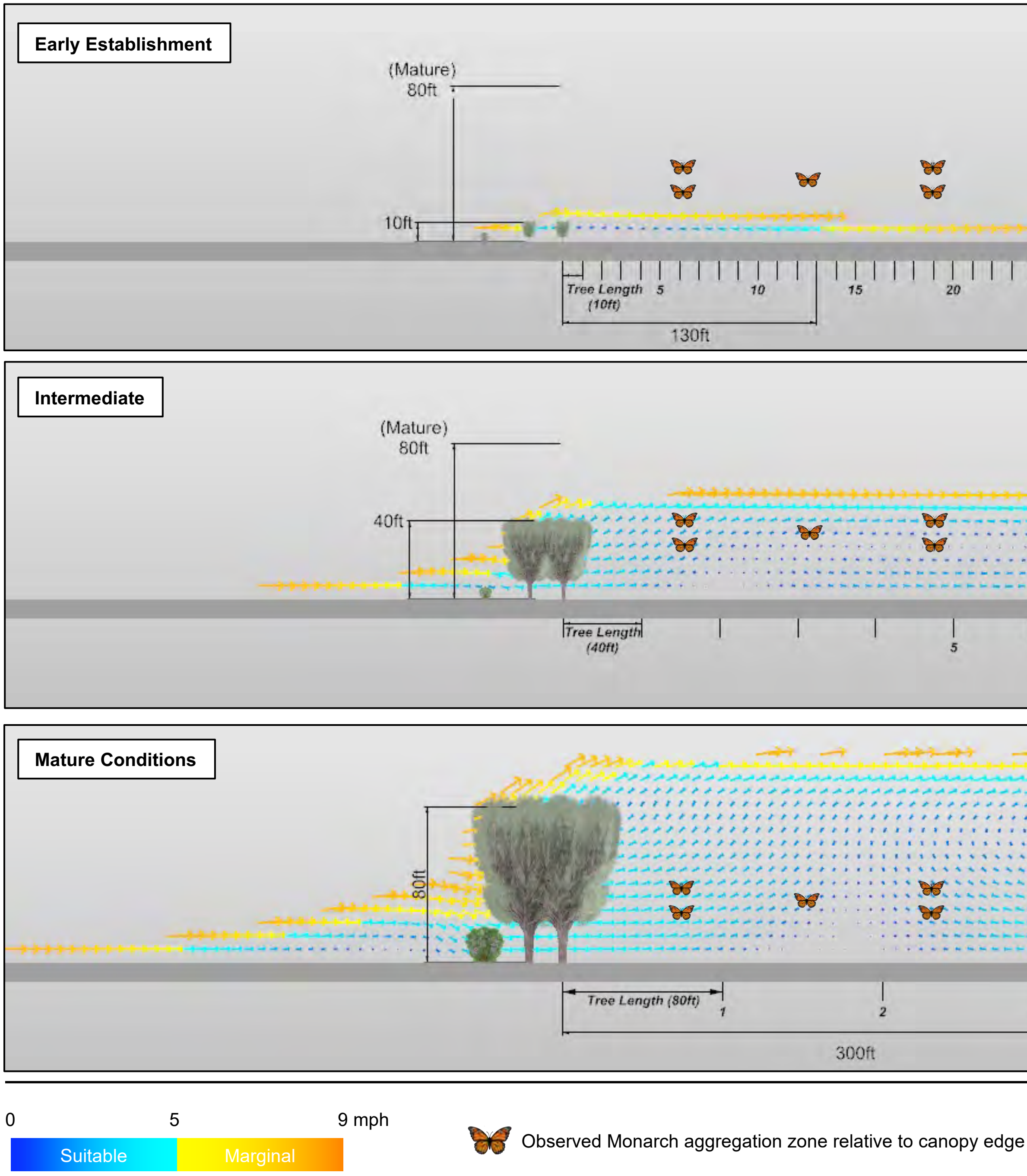


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Figure 47. Double Row Layout

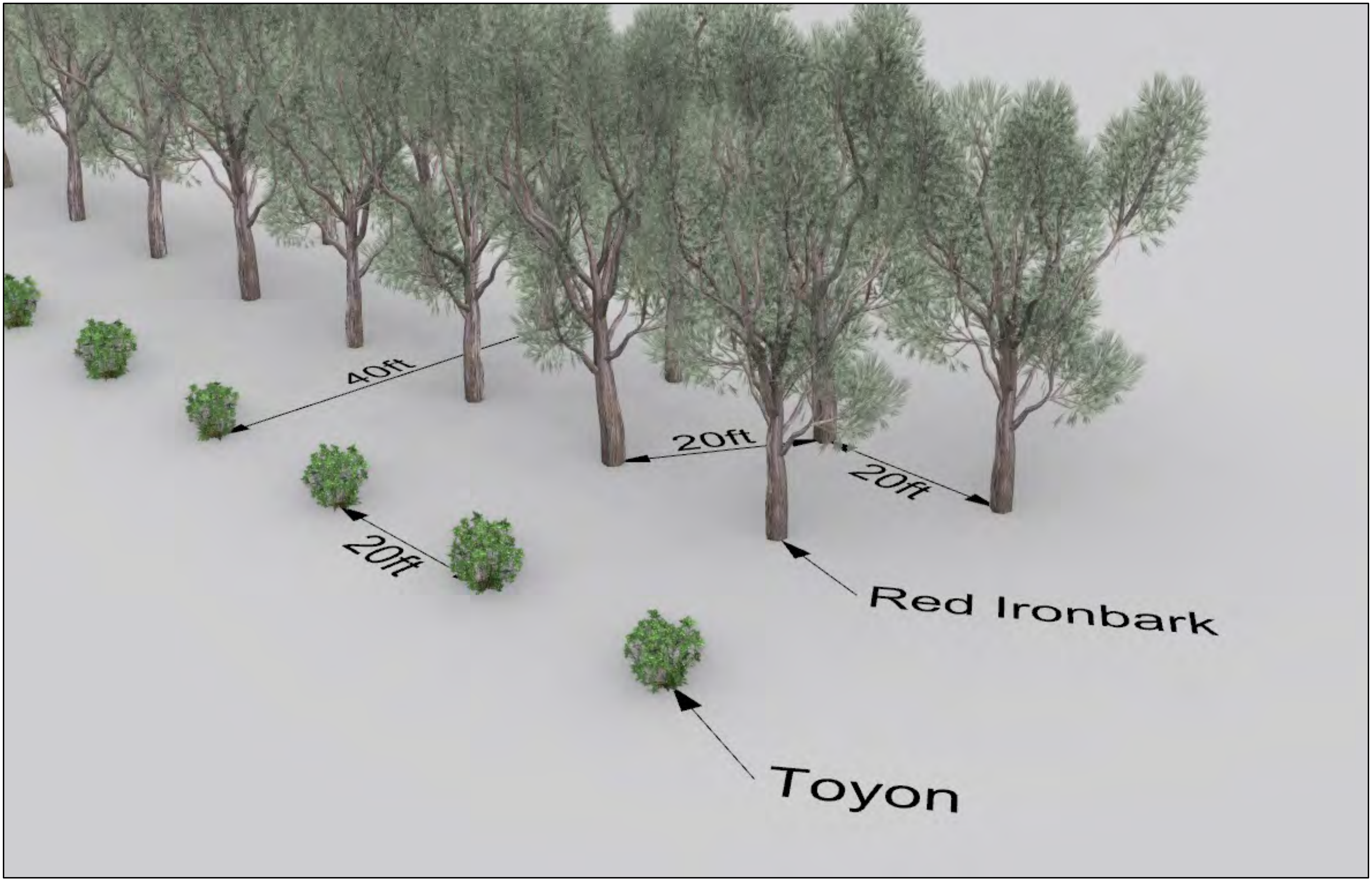
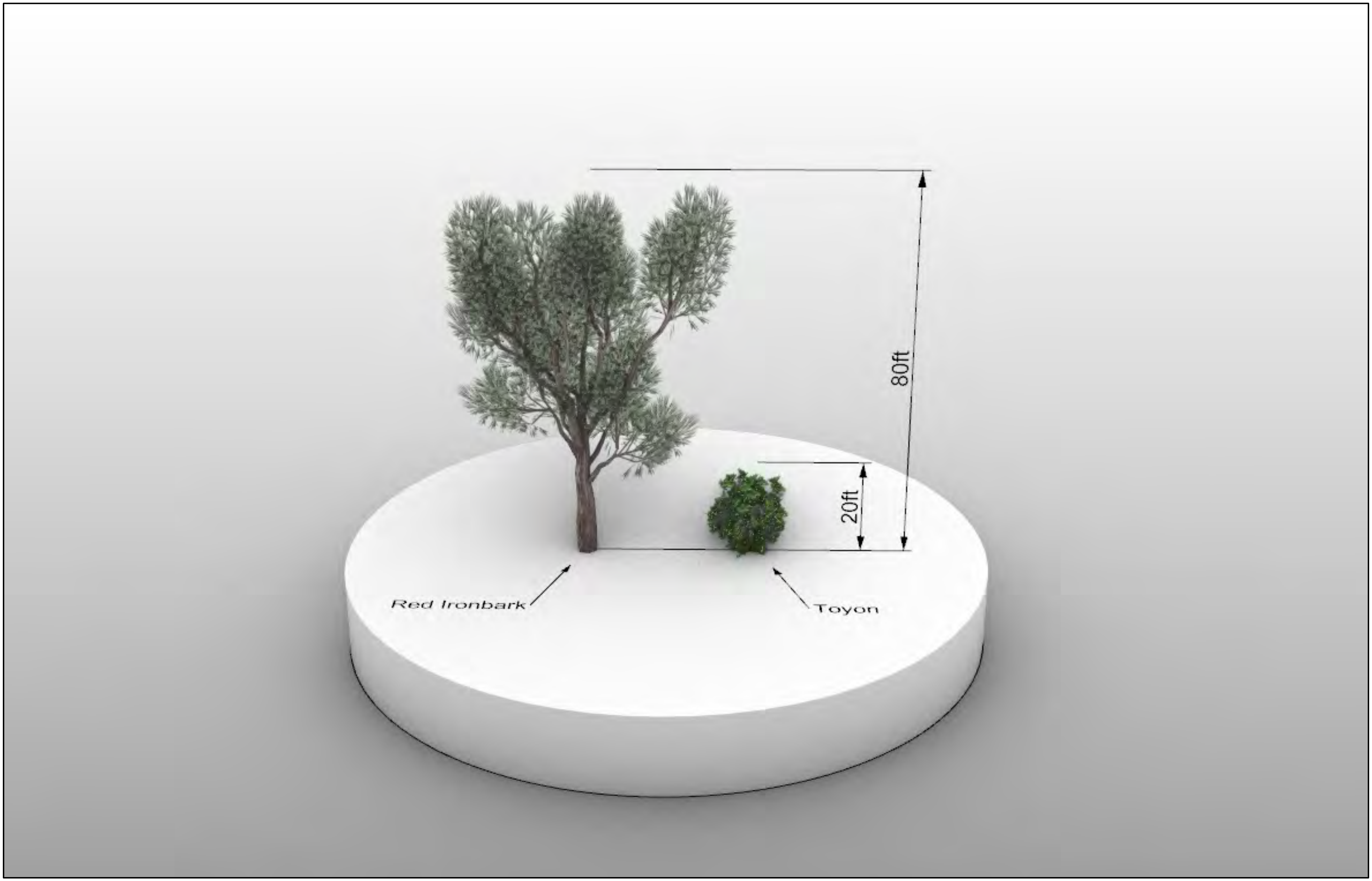


Figure 48. Double Row Species Models



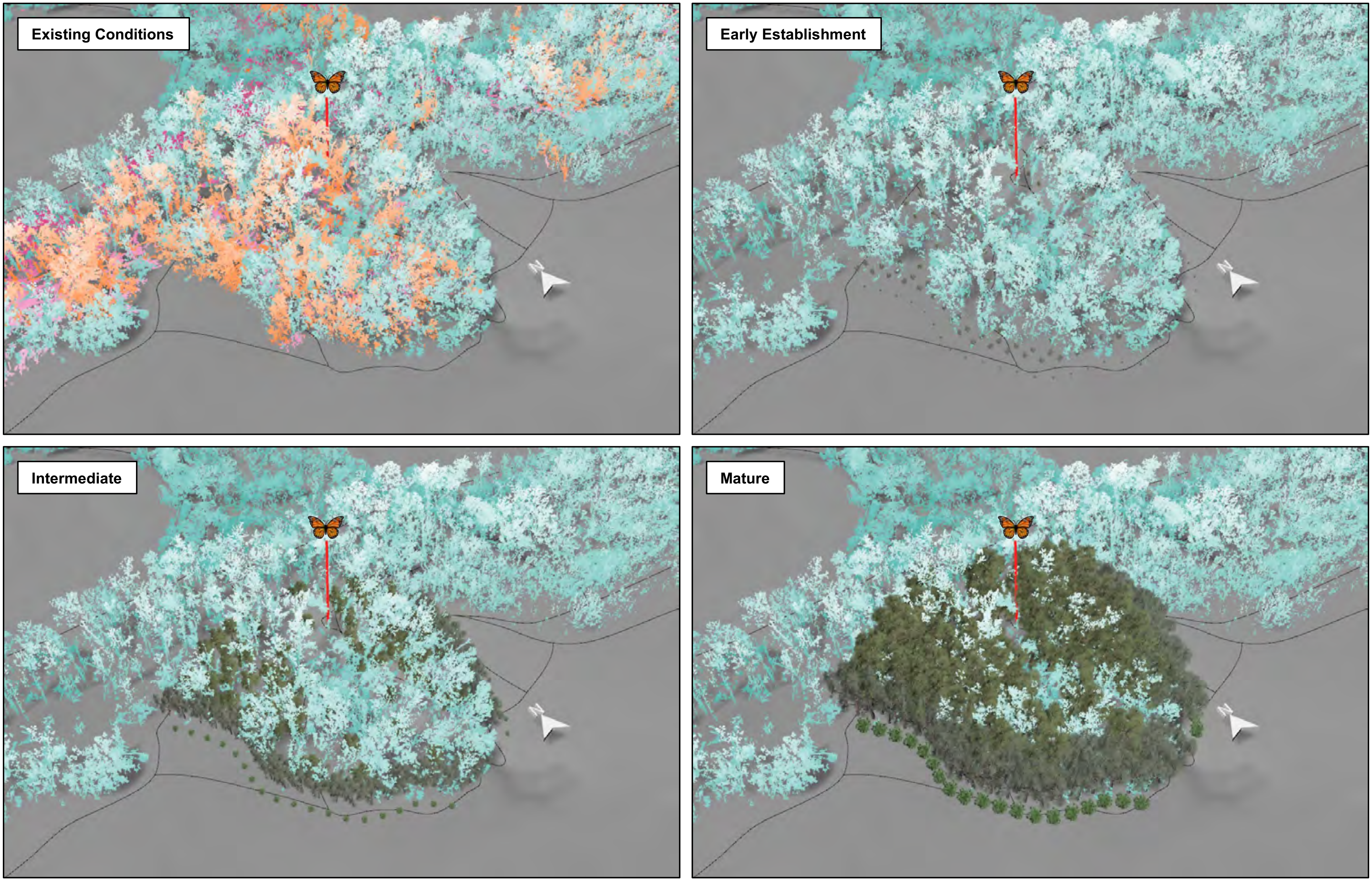
6.2.4 Wind Modeling at Ellwood Main

We conducted simulations of microclimate wind conditions at Ellwood Main during a southwest storm event in order to assess the efficacy of our restoration plans. We evaluated four scenarios: Existing Conditions, Early Establishment, Intermediate Conditions, and Mature Conditions (see Figure 49). Existing scenarios included three stem categories (living, standing dead, and dead downed), as well as vegetation not classified as stems (See Figure 50). All other scenarios included only living stems (See Appendix B for more details). The Early Establishment scenario represented 0-5 years after planting, when trees are allowed to grow to 10 ft in height and dead wood has been removed to make space for new plantings. Intermediate Conditions scenario is when trees reach 40 ft in height, approximately 10-15 years after planting. Finally, Mature Conditions are when tree heights have reached existing conditions and replaced lost forest canopy.

Figure 51, Figure 52, and Figure 53 shows wind conditions within the monarch clustering area for the four simulated scenarios. Existing conditions show mostly marginal conditions with some pockets of favorable wind speeds. Early Establishment, however, reveals a decrease in habitat quality primarily due to the removal of standing dead wood. While this result is not ideal in the near term, any protection from dead standing wood is temporary and poses a safety risk to hikers and remaining living trees. Any restoration plantings will also be inhibited by existing dead wood, and inevitable felling could damage newly planted trees. Thus, we recommend removing the dead wood now so that we can address the issues previously mentioned and begin restoring Ellwood Main for the long-term management of monarch butterfly habitat. See Section 5.10 for a discussion on the adaptability of monarch butterflies and how they have historically used other parts of the forest when conditions have turned unfavorable at Ellwood Main.

Intermediate Conditions show when wind favorability meets or exceeds Current Conditions within the clustering area, as well as an improvement in habitat quality along the eastern edge of Ellwood Main. Finally, at Mature Conditions, the clustering area is almost entirely in suitable wind conditions, suggesting that when fully implemented, restoration activities will improve habitat conditions for monarch butterflies for many decades to come.

Figure 49. Wind Modeling Scenarios



Monarch viewing area

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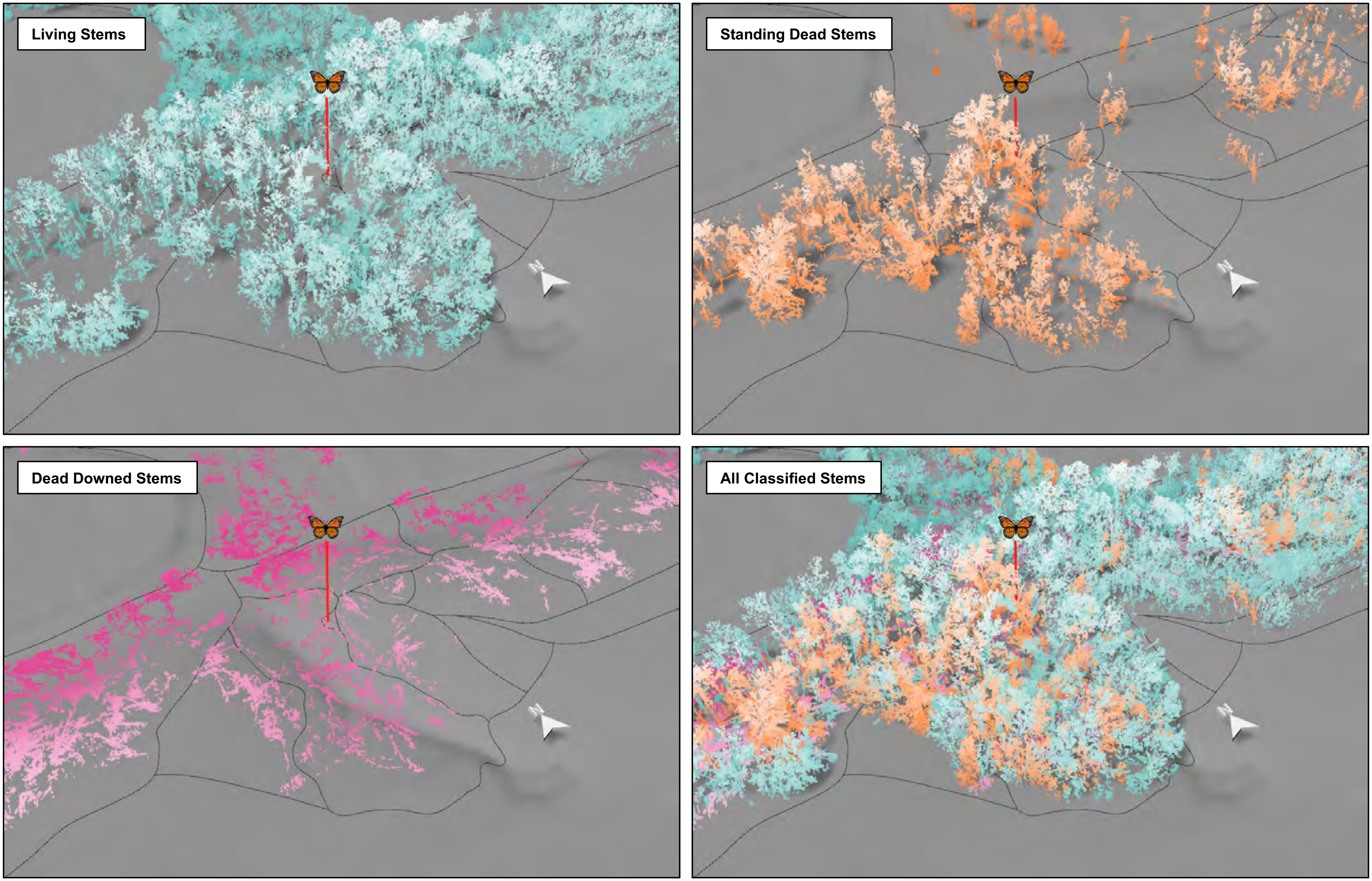
Figure 50. Existing Conditions Classified Stems



Monarch viewing area

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Figure 51. Above Ground Wind Conditions (30 ft)

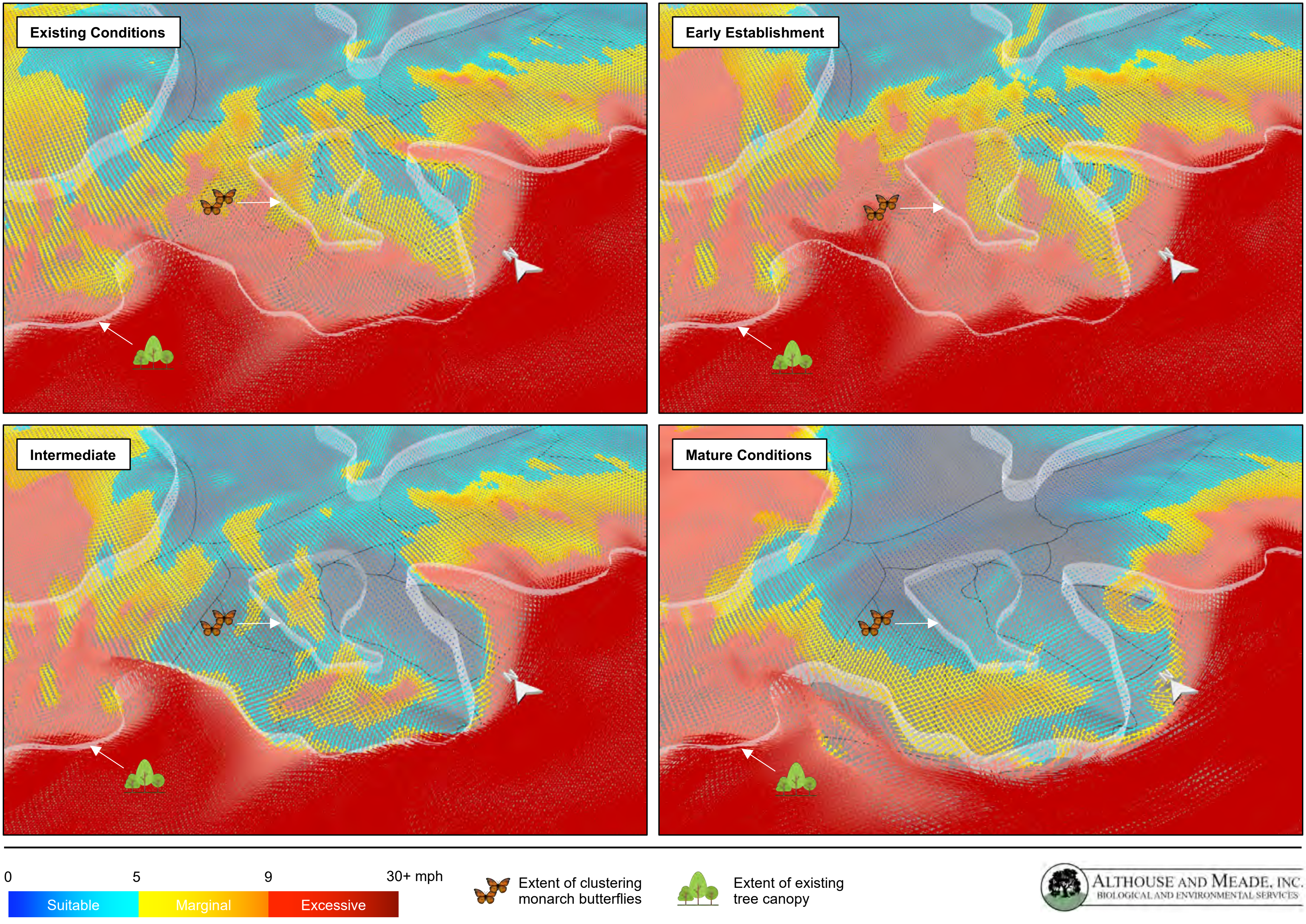

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Figure 52. Wind Conditions within Clustering Area

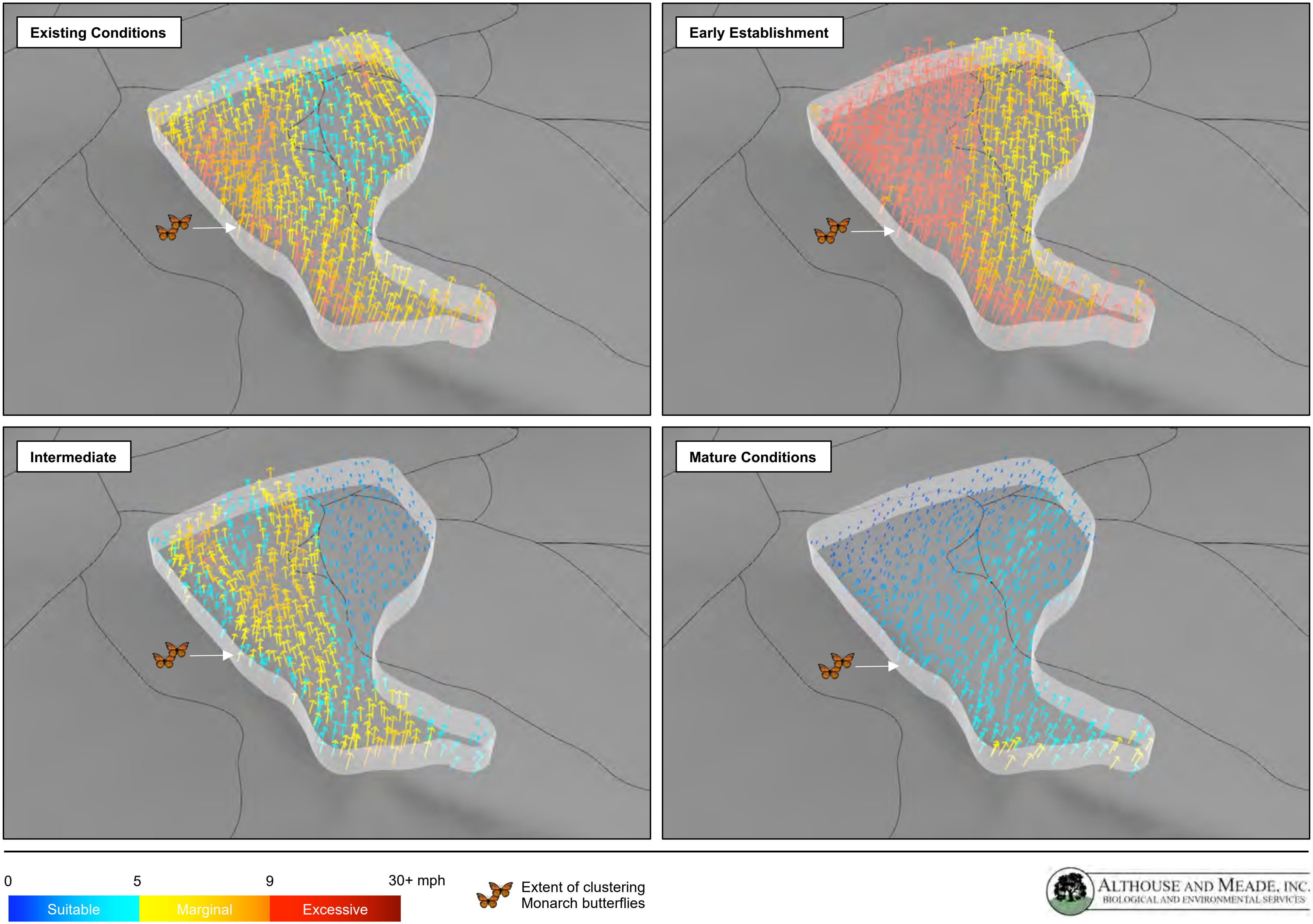

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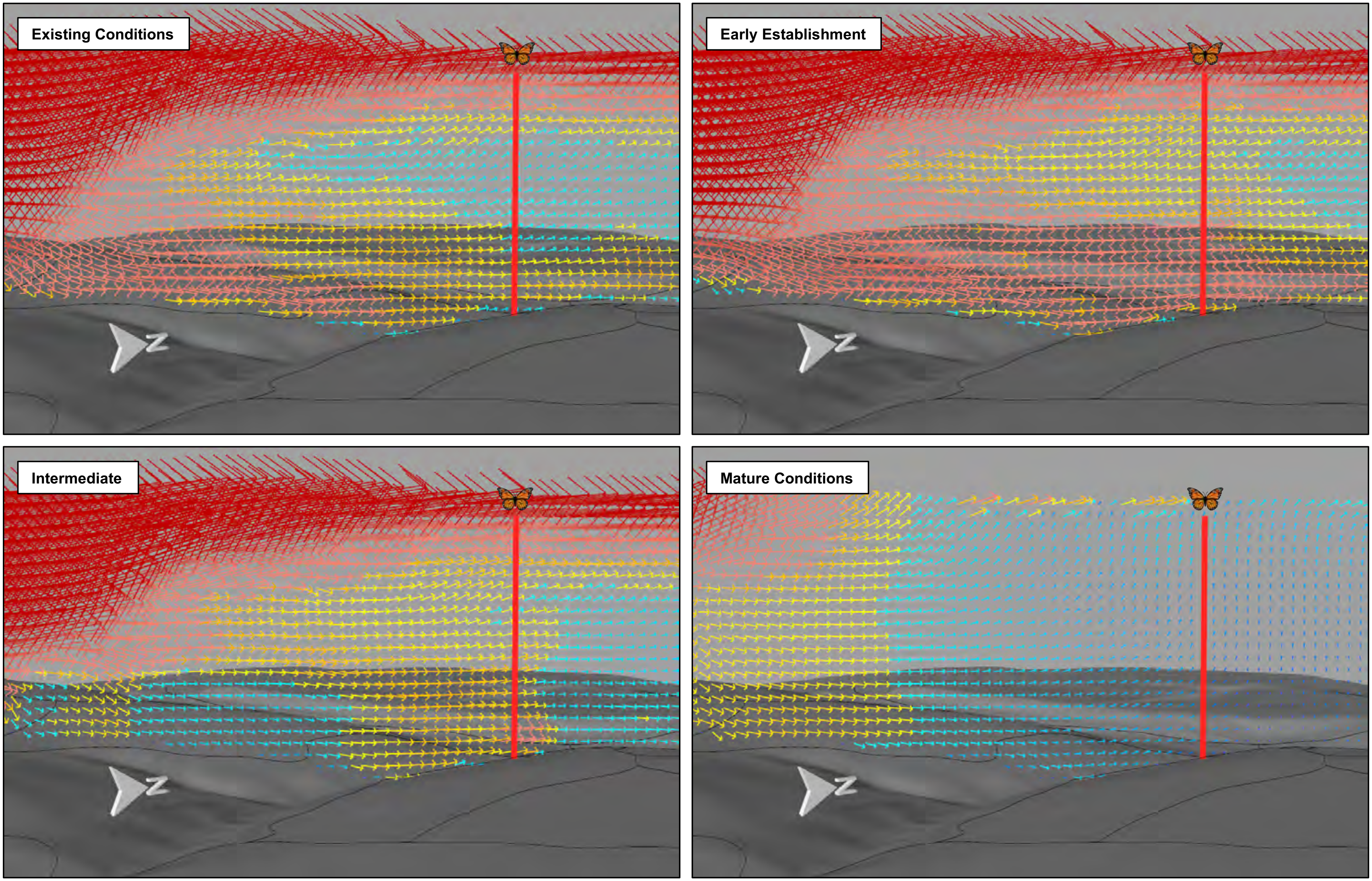
Figure 53. Vertical Profile of Wind Conditions at Viewing Area



0 5 9 30+ mph

Suitable | Marginal | Excessive

Monarch viewing area

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6.2.5 Ellwood Main Prescriptions

To address the vulnerabilities identified in this report (See section 5.2), additional tree planting is recommended around Ellwood Main. Figure 54 shows specific planting areas and outlines the recommended species and spacing of these trees.

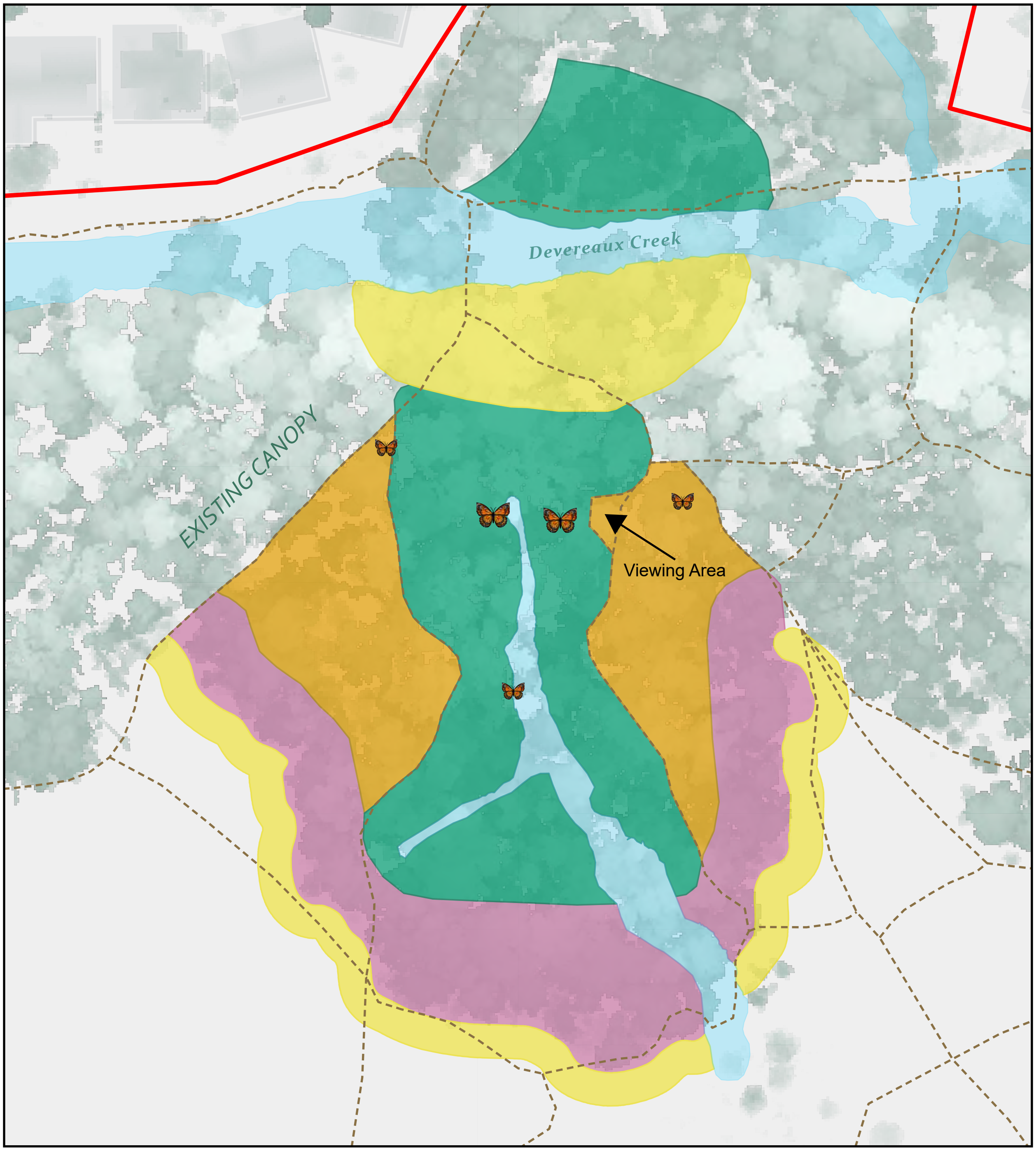
Along the southern edge of Ellwood Main, a double row planting of red ironbark (*Eucalyptus sideroxylon*) should be implemented within the boundaries of the existing canopy. Tree planting should generally follow the design outlined in Section 6.2.3; however, conditions on the ground will determine final planting locations and deviations from the idealized plan. Outside the southern existing canopy, toyons (*Heteromeles arbutifolia*) should be planted roughly 20 ft apart to act as an understory buffer as the red iron bark grow out. Inside the double wind row and edge of canopy, karri (*Eucalyptus diversicolor*) should be planted to replace blue gum loss. This species has been identified as having several advantages in this environment (See section 3.4 for additional details).

The monarch aggregation trees are blue gum (*Eucalyptus globulus*) trees along the west and east slopes of the gully at Ellwood Main. Several of the recurring aggregation blue gum trees have died and the loss of roosting substrate is substantial. These aggregation trees should be replaced with blue gum eucalyptus trees in similar locations along the west and east slopes and the blue gums should be planted at 20 ft spacing. Along the higher slopes of Ellwood Main that occur outside of the recurring aggregation trees, karri should be planted at 50 ft spacing. Wherever possible, blue gum regrowth should be encouraged, and planting should consider this potential. This is shown in the Sparse Planting polygon on Figure 54.

North of the Ellwood Main and adjacent to Devereux Creek, several native species should be planted, specifically sycamore (*Platanus racemosa*), California bay laurel (*Umbellularia californica*), and cottonwood (*Populus fremontii*), to seal the north gap vulnerability. In areas of fuel removal along the neighborhood boundary, special care should be taken around existing large trees that provide critical protection. Across the creek, karri should be planted at 40 ft spacing.

Finally, in the grove west of Ellwood Main, blue gum regrowth should be encouraged where possible and karri and blue gum should be planted to fill in gaps. Planting should be no closer than 50 ft apart. Separate fallen logs where applicable, and remove high fraction of downed wood, especially finer fuels that are less than 10 inches in diameter.

Figure 54. Prescribed Tree Planting Areas - Ellwood Main



Legend

- Ellwood Mesa Open Space
- Jurisdictional Wetlands
- Existing Trails

Aggregation Sites

- Primary
- Secondary

Prescription Areas

- Double Wind Row
- Inner Windbreak
- Native Windbreak
- Sparse Planting

N

0 50 100 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42283°N 119.89096°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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Map Updated:
May 02, 2023 12:04 PM by KRN

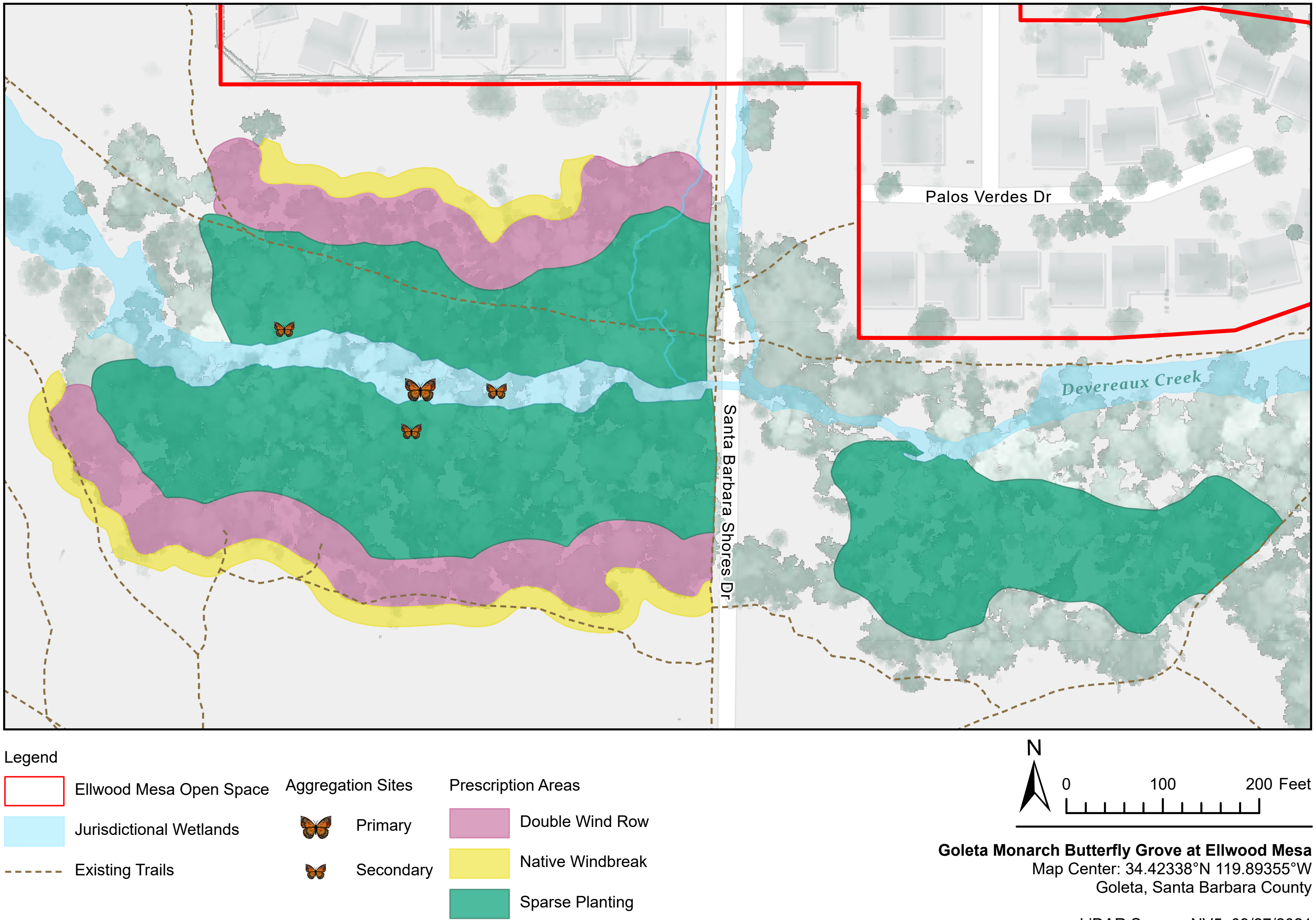
6.2.6 Ellwood West Prescriptions

The Ellwood West aggregation site sits above Devereux Creek and is composed of blue gum trees to the north and south of the creek. Due to extensive die-off, particularly on the south side of Devereux Creek, there are now vulnerabilities in wind protection. To remedy this, we recommend removing the existing dead wood, replacing dead aggregation trees with blue gum, and planting karri sparsely to fill in the area surrounding the aggregation trees. Tree planting should be 50 ft spacing where large gaps in the canopy exist. Finer fuels, less than 10 inches in diameter, should be removed to promote new growth. Existing blue gum eucalyptus regeneration should also be encouraged wherever possible.

At the edge of canopy, double wind rows are recommended for the north and south face of Ellwood West. On the north face, coast live oaks (*Quercus agrifolia*) and toyons are encouraged outside of existing canopy at approximately 20 ft spacing. On the south face, only toyons are recommended outside of existing canopy, also at 20 ft spacing. East of Santa Barbara Shores trailhead, we recommend maintaining the density of existing red iron bark stand with karri.

Along Devereux Creek, native trees should be planted but not within 50ft of monarch aggregation trees. Care should be take to protect and maintain the open interior along the creek near the monarch aggregation trees. All plantings shall stay out of jurisdictional wetland delineations. Specific planting areas and recommendations are detailed in Figure 55.

Figure 55. Prescribed Tree Planting Areas - Ellwood West



Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42338°N 119.89355°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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Map Updated:
May 02, 2023 12:04 PM by KRN

6.2.7 Ellwood North Prescriptions

Based on our analysis of Ellwood North, we recommend a significant restoration effort to restore Ellwood North to its historic overwintering conditions. Fuel management in the area is less sensitive, and removal of dead standing, dead downed, especially finer fuels, is recommended wherever practical. Separate large logs and remove fine fuels as needed. Ellwood North is an excellent opportunity to refine fuel management within the groves as it currently offers the least habitat quality for overwintering monarchs.

Along the western face, we recommend a double row windbreak spanning approximately 1,200 ft. Plantings should include red iron bark within existing eucalyptus canopy where space exists, and oaks and toyon outside of eucalyptus canopy.

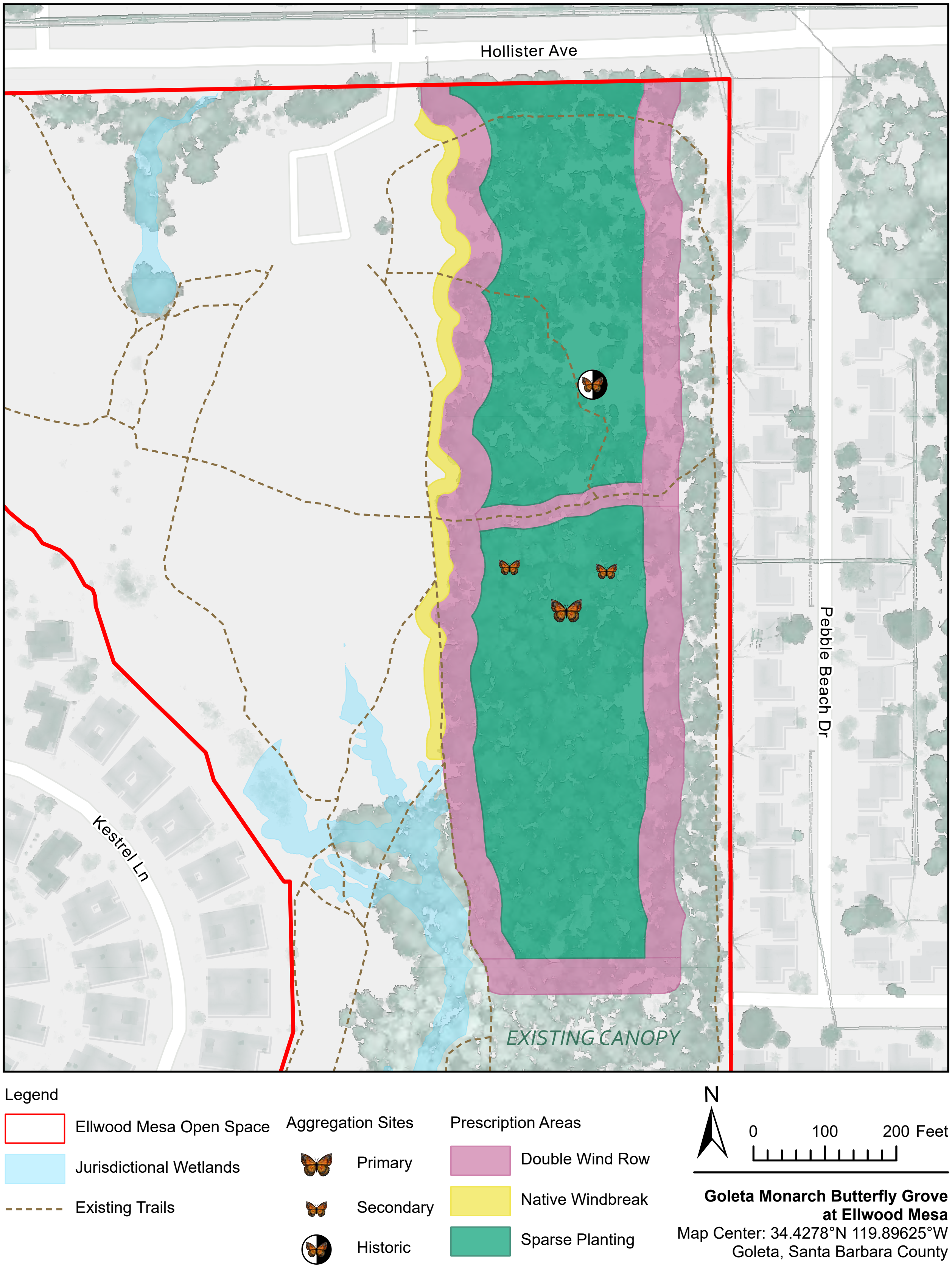
Along the eastern face, a double wind row as described above is recommended for the northern half, beginning at the trail that bisects the habitat from west to east. South of the trail on the eastern side, we recommend planting karri and red iron bark to close the wind vulnerabilities. Toyons and oaks are recommended outside of existing canopy as described in the double row design. All plantings on the eastern side of Ellwood North shall occur outside the 100ft fire safety perimeter.

Along the bisecting trail mentioned previously and the similar trail further south, we recommend planting red iron bark carefully placed at the direction of restoration experts to fill gaps.

In the interior spaces created by the windbreaks, replace dead monarch aggregation trees with blue gum eucalyptus and create or retain open interiors. Sparsely planted karri trees are recommended where canopy is thin. Plantings should be no closer than 50ft. Wherever possible, existing blue gum eucalyptus regeneration should be encouraged, as well as natives such as coast live oak and toyon. Interior open spaces should encourage native forbs and nectaring plants. Encourage existing plants where available, such as (*Solidago* sp.).

See Figure 56 for specific planting area recommendations.

Figure 56. Prescribed Tree Planting Areas - Ellwood North



Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.4278°N 119.89625°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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Map Updated:
April 21, 2023 12:45 PM by KRN

6.2.8 Ellwood East Prescriptions

We recommend replacement of dead monarch aggregation trees with blue gum eucalyptus. Existing live trees should be supported, and regeneration should be encouraged. We suggest planting karri sparsely around the monarch aggregation trees, no closer than 50ft apart in these areas. Additionally, we recommend planting a double wind row of red ironbark on the south side of the eucalyptus canopy to close the south wind vulnerability and planting red ironbark and karri north of Devereux Creek to address the north-northwest wind vulnerability. Coast live oaks, toyons and other native shrubs can be used to fill in the understory.

All fuel treatment should take careful consideration on the north side of Devereux Creek and along neighborhood boundary. Remove dead standing wood and reduce fuels on the ground wherever practical. Because Ellwood East aggregation sites only partially occur on city property, restoration activities are limited to the western extent.

See Figure 57 for specific areas where planting is recommended.

See Section 5.4 for a full description of the current status of Ellwood East and identified vulnerabilities.

6.2.9 Ellwood Ironbark Prescriptions

See Section 5.6 for a full description of the current status of Ellwood Ironbark Site.

6.2.10 Sandpiper Prescriptions

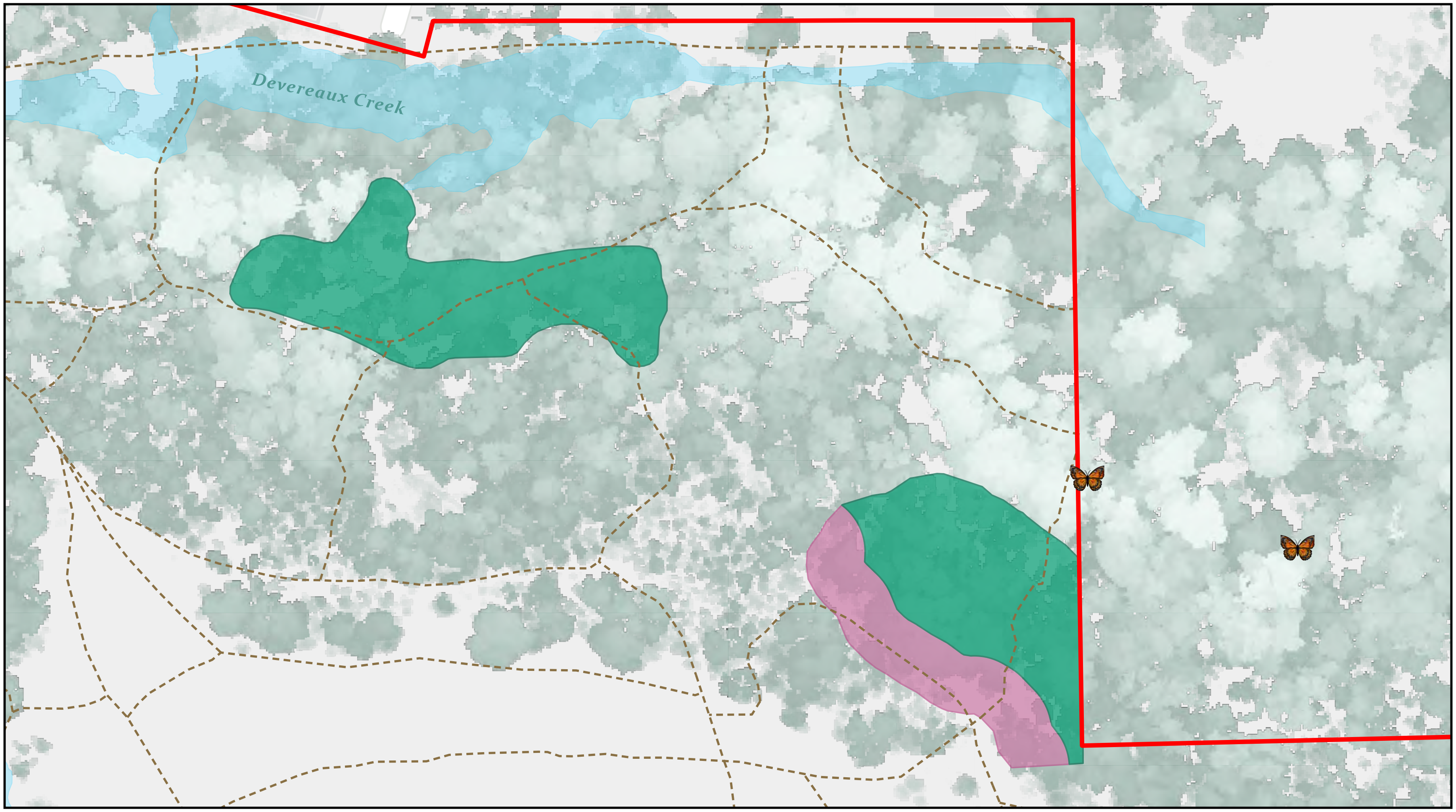
The restoration of the Sandpiper site will be addressed further in Phase 2 of the Implementation. To inform restoration efforts, a double wind row with red ironbark should be planted along the trail on the north side of Devereux Creek. Native trees, such as oak and toyons can be planted to reinforce the boundary. On the south side of the creek where the two trails converge, additional red ironbark planting is recommended, along with native trees and shrubs.

The most important area of restoration is along the western boundary of Ellwood Mesa and Sandpiper Golf Course. Loss of trees has resulted in significant vulnerabilities to wind protection. We recommend planting red ironbark along the western boundary of Ellwood Mesa and work with Sand Piper Golf Course to plant additional trees for greater resiliency. We recommend that dead monarch aggregation trees be replaced with blue gum eucalyptus and the existing blue gum should be supported and regeneration encouraged.

Fuel management should focus on removing dead downed wood and reducing fuel loads. Large logs can be left on site but moved as practical to allow for tree planting. Fine fuels (less than 10 inches in diameter) shall be either mulched or removed from site.

See Figure 59 for recommended planting areas.

Figure 57. Prescribed Tree Planting Areas - Ellwood East



Legend

- Ellwood Mesa Open Space
- Jurisdictional Wetlands
- Existing Trails

Aggregation Sites

- Primary

Prescription Areas

- Double Wind Row
- Sparse Planting

N

0 100 200 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42283°N 119.88886°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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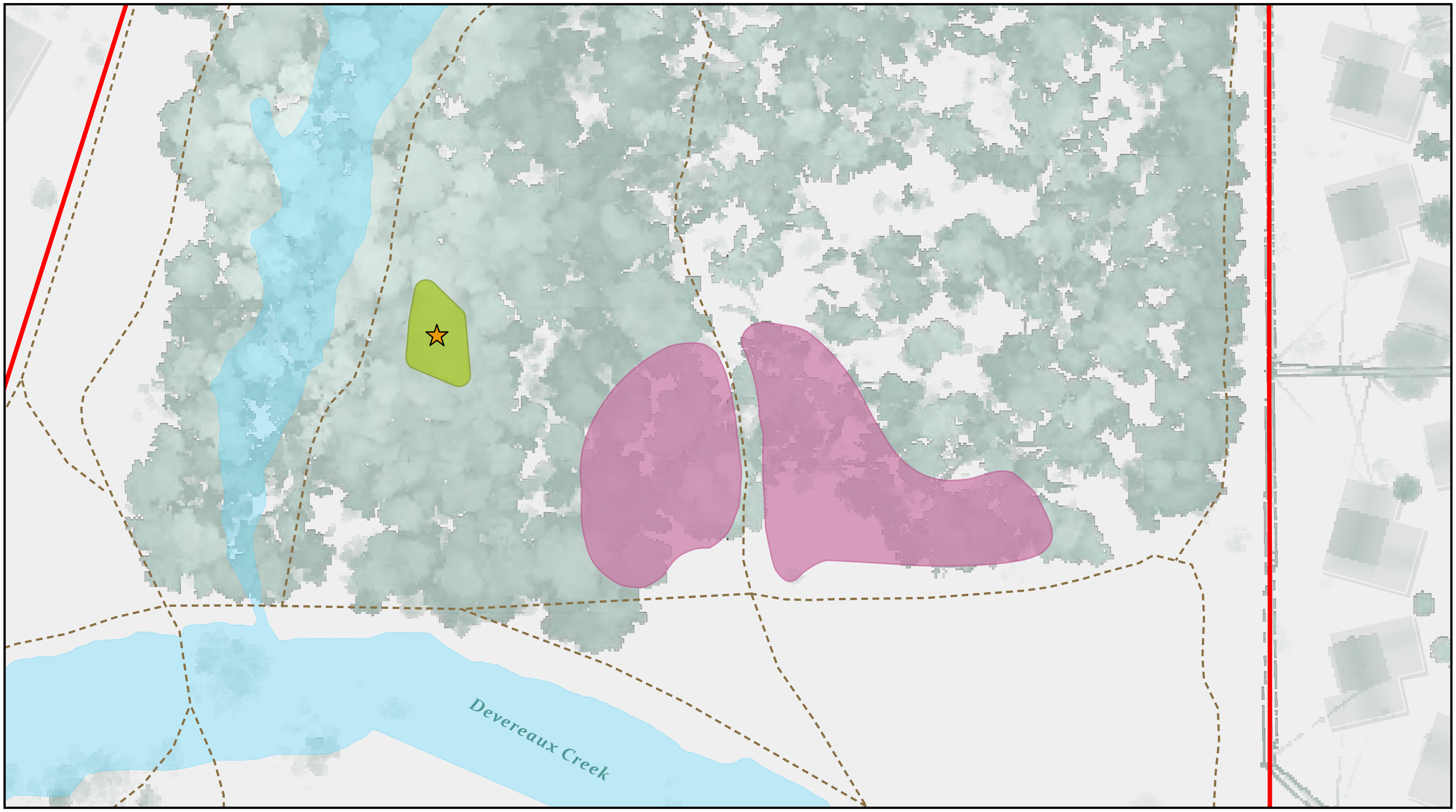
Map Updated:
April 21, 2023 12:46 PM by KRN

Figure 58. Prescribed Tree Planting Areas - Ellwood Ironbark



Legend

- Ellwood Mesa Open Space
- Jurisdictional Wetlands
- Existing Trails

Aggregation Sites

- Proposed

Prescription Areas

- Double Wind Row
- Selective Tree Thinning

N

0 50 100 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42486°N 119.89609°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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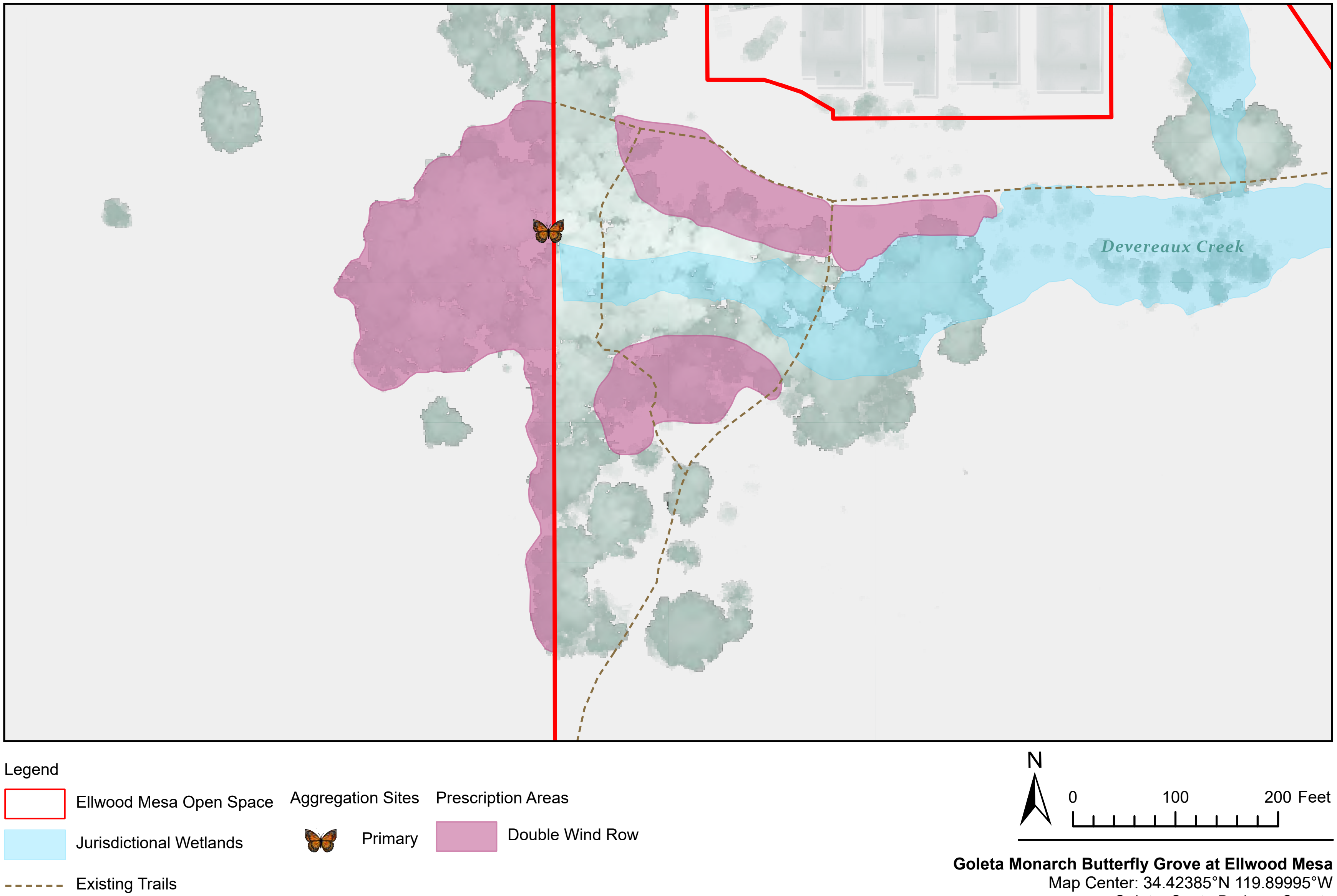
Map Updated:
April 21, 2023 12:47 PM by KRN

Figure 59. Prescribed Tree Planting Areas - Sandpiper



Goleta Monarch Butterfly Grove at Ellwood Mesa
Map Center: 34.42385°N 119.89995°W
Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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Map Updated:
April 21, 2023 12:49 PM by KRN

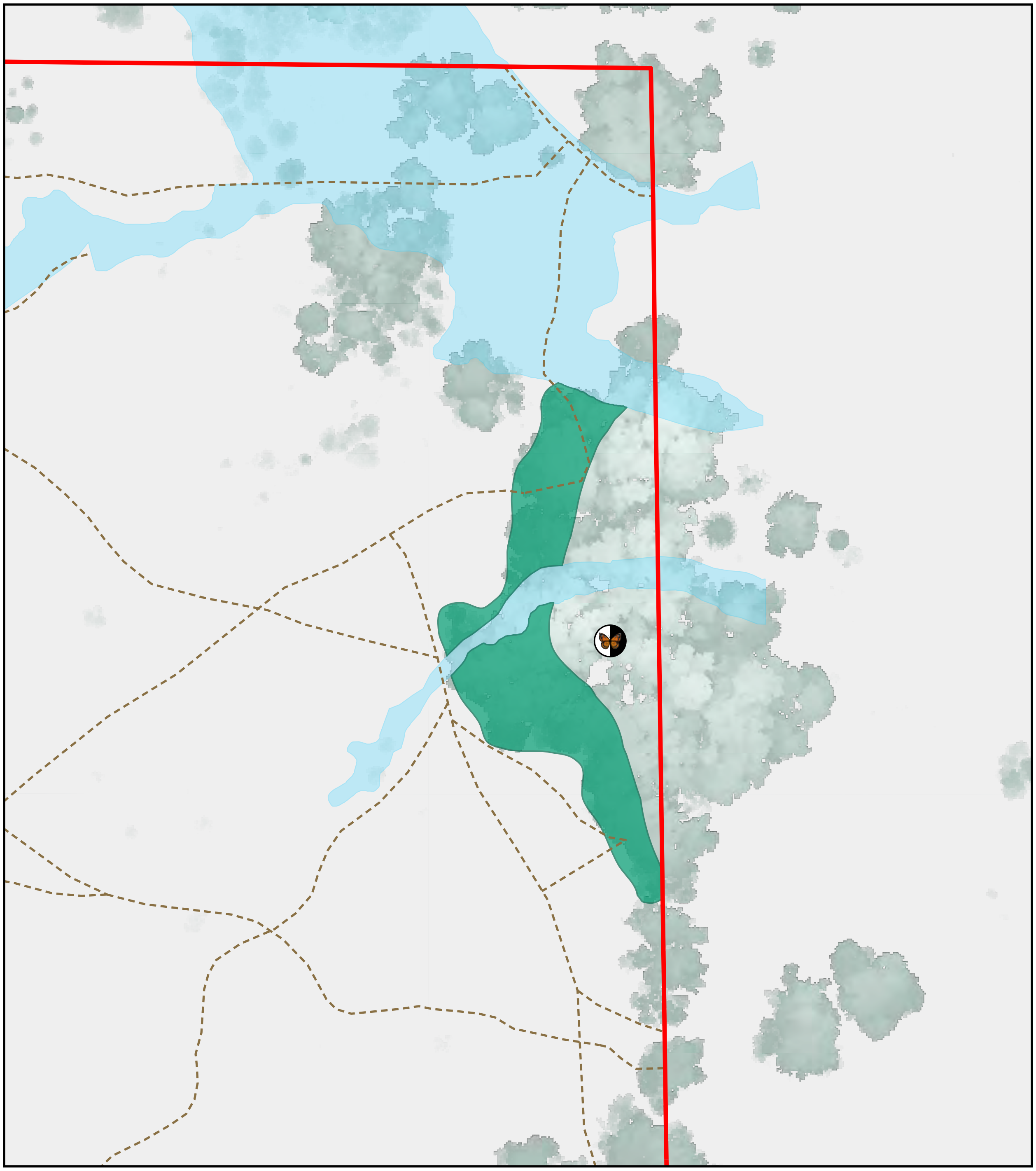
6.2.11 Ocean Meadows Prescriptions

The restoration of the Sandpiper site will be addressed further in Phase 2 of the Implementation. To inform restoration efforts, tree planting shall focus on the western side of the aggregation site that occurs on Ellwood Mesa. We recommend filling holes on outer edge of canopy with red ironbark where necessary. Encourage regeneration of existing blue gums where possible and use native trees and shrubs within and outside the existing canopy to reinforce wind protection. Planting shall not occur in jurisdictional wetlands.

Fuel management should focus on removing dead downed wood and reducing fuel loads. Large logs can be left on site but moved as practical to allow for tree planting. Fine fuels (less than 10 inches in diameter) shall be either mulched or removed from site.

See Figure 60 for tree planting locations.

Figure 60. Prescribed Tree Planting Areas - Ocean Meadows



Legend

Ellwood Mesa Open Space

Jurisdictional Wetlands

Existing Trails

Aggregation Sites

Historic

Prescription Areas

Sparse Planting

N

0 75 150 Feet

Goleta Monarch Butterfly Grove at Ellwood Mesa

Map Center: 34.42098°N 119.8853°W

Goleta, Santa Barbara County

LiDAR Source: NV5, 09/27/2021

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BIOLOGICAL AND ENVIRONMENTAL SERVICES

Map Updated:
April 21, 2023 12:49 PM by KRN

7 DISCUSSION

The multi-generational journey of monarch butterflies is one of the most famous examples of migration in the animal kingdom (National Geographic Society 2022). Every year, monarch butterflies in western North America travel up to thousands of miles from their summer breeding grounds to gather in dense clusters along the California coast. One of the best places to view this natural phenomenon was Goleta Monarch Butterfly Grove at Ellwood Mesa, a widely recognized site of importance for overwintering butterflies. For decades, residents and visitors enjoyed the opportunity of observing the butterflies up close and in tremendous numbers, evoking feelings of appreciation and fostering calls for conservation.

Historically, the eucalyptus groves at Ellwood Mesa created ideal habitat conditions for monarchs. Large trees with varied canopies allow for "dappled light," where monarch butterflies can seek either shade or sun to moderate their body temperature throughout the day. Dense foliage acts to increase humidity within the grove, slowing the rate of desiccation of the butterflies and reducing the need for them to seek out water. During strong storm events, the trees provide critical wind protection that would otherwise cause butterfly mortality. This extensive forest was, at one time, the largest plantation in California (Farmer 2013), leading to numerous named overwintering sites both presently and historically.

Until the 1990s, Ellwood Mesa was actively managed through forestry practices, such as felling dead trees, harvesting firewood, and thinning live branches (Santos 1997). However, when the City of Goleta acquired the property in 2005, forestry activities ceased, leaving the grove largely unmanaged. Since then, periods of wet and dry seasons have caused stretches of growth and dieback of the forest canopy. The most significant of these periods was between 2012 and 2016, when unprecedented drought conditions led to a dramatic loss of trees throughout the Mesa. Thousands of trees died and remain on site today. Deferred maintenance of dead and downed wood at Ellwood Mesa create imminent danger to human safety, neighboring homes, and monarch overwintering habitat. High fuel loads present an extreme fire hazard while standing dead trees pose a risk to the thousands of hikers who visit this area each year. Additionally, fallen wood inhibits restoration activities, and risk of tree fall from standing dead trees threaten live trees and future planting efforts.

Our findings document that the loss eucalyptus trees at Ellwood Mesa caused a marked decline in the quality of overwintering monarch habitat. At all aggregation sites, reduced canopy cover corresponded with fewer overwintering monarchs, as well as increased instability in movement between sites - indicating a heightened vulnerability to adverse weather conditions.

To restore habitat quality, we recommend first strategic removal of existing fuel loads around identified aggregation sites. Second, we recommend planting additional trees and encourage regeneration of existing blue gums (*Eucalyptus globulus*) wherever possible. We recommend strategic removal of dead wood, removal of ground fuels, and planting of specific species in designed and tested configurations. Chipping and mulching downed wood and planting new trees will all aid in the process of restoring a healthy forest and ensuring resilient wind protection zones.

For an effective wind break along the periphery of the existing canopy, we propose a new tree planting design—the double wind row—with drought-resistant red ironbark (*Eucalyptus sideroxylon*). Within the interior of the groves and where blue gum regeneration is not present, we recommend planting karri (*Eucalyptus diversicolor*). This species of eucalyptus is comparable in size and structure to blue gum and has two distinct advantages: it is adapted to Mediterranean climates, and does not reproduce spontaneously in California, mitigating invasive potential that blue gums bring. While we recognize blue gums characterize much of Ellwood Mesa, they were overwhelmingly impacted by the 2012-2016 drought. A diversity of tree species will minimize the potential of a future mass die-off.

Trees are our best tool for restoring monarch overwintering habitat. In arid southern California, eucalyptus species are especially useful for their ability to grow large quickly. Unfortunately, given the imperiled state of monarch populations, the time window for restoration through trial and error is gone and the time for iteration is minimal. time to act is now to address this challenge, our wind simulations informed our planting designs for Ellwood Mesa to ensure new trees and shrubs, when mature, will offer sufficient wind protection. Although our simulations are specific to Ellwood Mesa, our planting principles can be applied to other overwintering sites in California. Ultimately, we hope this report serves as a starting point for land managers seeking to restore damaged overwintering monarch habitat.

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9 APPENDICES

Appendix A. Hemispherical Photography Methods

Appendix B. Wind Modelling Methods

Appendix C. Ellwood Mesa Monarch Counts 2015-2023

Appendix D. Monarch Butterfly Habitat on the Razor's Edge

Appendix E. Ellwood Wind Data

Appendix F. Dead Wood Removal and Monarch Butterfly Habitat Effects

Appendix G. Ellwood Monarch Butterfly Habitat Characterization Report

APPENDIX A. HEMISPHERICAL PHOTOGRAPHY METHODS

Hemispherical photographs were collected at Ellwood Main/ Goleta Butterfly Grove in the 1990, 1998, and 2021 by Dr. Stu Weiss.

Hemispherical photography has been a standard method for assessing forest canopy structure at monarch overwintering sites (Weiss et al. 1991, Weiss and Murphy 1992, Weiss 1998, Weiss 2011, Weiss 2016). Photographs are taken using a Nikkor 8mm lens on a Nixon D610 camera body, mounted on self-leveling gimbals so that the photograph is pointed straight up at the zenith. A compass is used to orient to north. The hemispherical photo point locations cover the habitat contributing to protection of monarch clustering locations. Photos taken at these points were used to produce a hemiphoto that shows the interpolated exposure from 8 different directions and the maximum exposure from all directions.

Photographs are analyzed with Hemiview 2.0 software (Delta-T Devices). The photographs are aligned, and a gray-scale threshold is interactively selected to differentiate sky from obstructions. Photographs are best taken under uniform overcast conditions, or at sunrise or sunset, when there is no direct illumination of the canopy (which can be brighter than the sky).

Hemiview overlays a “sky grid” (gray) that divides the upward hemisphere into 5° zenith angle increments (18 total = 90°) and 45° azimuth wedges centered on the eight cardinal directions. The fraction of open sky in each segment is calculated and weighted by the geometry of the segment depending on the analysis. Hemiview also overlays a “sun grid” (yellow) based on site latitude, with monthly increments through the year, and half-hourly increments over the day. The December 21 sunpath (winter solstice) is the lowest path, the middle path is March 21, and the highest path is June 21. The fraction of open sky in each of the segments is calculated, and the specified solar model is used to calculate insolation. Here, the units are MJ m-1 month-1, which is directly proportional to the LiDAR derived watt-hours m-2 d-1.

An example photograph, taken in the cluster site, shows both grids. The following “site factors” are extracted:

(1) ISFU – Indirect Site Factor Uncorrected, the fraction of visible sky in all directions.

(2) DSFU – Direct Site Factor Uncorrected, the fraction of potential radiation across all months.

(3) October, 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.

Reading a Hemispherical Photograph

The important thing to look at in the photographs is the amount of open sky in various sectors – in the 8 cardinal 45° compass directions (azimuth) and in the various elevation angle bands. Note how much larger the area of each sector is near the horizon. For wind at ground level, the most important sectors are the first 10° above the horizon. However, as one ascends in height, the higher elevation angle sectors become more important. WSF uses visible sky in the entire 45° sector as an approximation, one that provides a good measure of relative wind exposure. The basic relationship is monotonic – more open sky equals more wind exposure.

The sun paths are divided into monthly bands going east to west (left to right) across the photo, divided into half-hour time slices. Fully shaded is when a sector is totally blocked, dappled light of varying intensities is where many small holes in the canopy are visible, and full sun when the sky is open. Apparent sunpaths are quite sensitive to the height of observation – sites that are completely shaded at ground level may be in bright sun 20 ft up in the canopy, depending on the exact configuration of branches and canopy gaps.

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APPENDIX B. WIND MODELLING METHODS

To assess changes in sheltering dynamics around monarch aggregation sites, we modeled existing and proposed wind conditions using microclimate airflow simulations.

A three-dimensional model of Ellwood Main was created in Rhinoceros 3D 7 (McNeel et. al. 2010) using LiDAR data collected by NV5 on September 27, 2021. Three categories of tree stems were classified and used in the model: living stems, standing dead stems, and dead downed stems (See Appendix G for additional details). All additional points were classified as vegetation. Point clouds were converted to a voxel volume by using the plugin, Volvox (Zwierzycki 2016). All stem categories were 0.25 m sized voxels, while vegetation was 1 m. Vegetation voxels were modeled as a momentum sink, using the default "dense" settings. Stems were also modeled as momentum sinks, but used high values (LAI = 50) to approximate a solid object. Terrain within the model was derived from classified ground points and converted to a 3D solid object.

Proposed restoration tree plantings were added using the landscape architecture plugin, Lands Design (Asuni 2022). The location of trees was directed from our proposed double row planting scheme and input from monarch restoration experts. Three scenarios were simulated: early establishment, minimum viable tree height, and maturity. Early establishment represents the first five years of planting where trees reach a height of 3.05 m (10 ft). Minimum viable tree height represents the first ten to fifteen years after planting where trees reach a height of 12.2 m (40 ft). This threshold was determined iteratively though multiple simulation runs at various heights. Maturity represents after thirty years or more of growth where trees reach a height of 24.4 - 30 m (80 - 100 ft). Tree object geometry was simplified for simulation runs and treated as momentum sinks, using the default "dense" setting. Only living stem and vegetation voxels were included in proposed simulations, as dead wood is proposed to be removed.

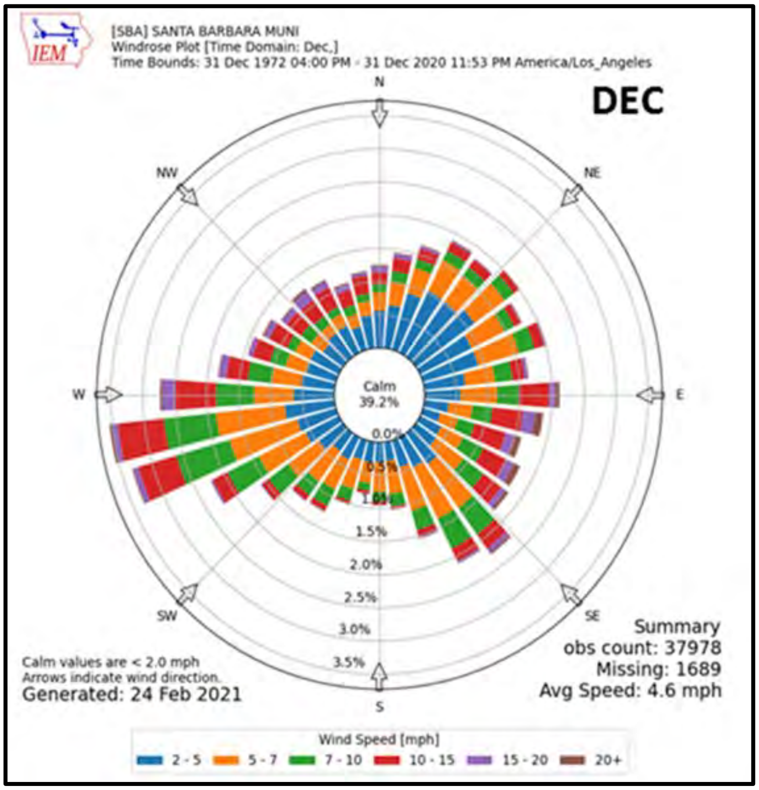
An additional simulation was conducted to test the effect of our double-wind row design in isolation. Using the same set of tree species and modeling specifications as used at Ellwood Main, a 274 m (900 ft) idealized double wind row was simulated in perfectly flat terrain. Model geometry was simplified identically as performed in Ellwood Main simulations.

All simulated conditions were modeled using Eddy3D, a plugin for Rhino 7 that uses OpenFOAM, a computational fluid dynamic simulator, to model microclimate conditions (Weller et. al. 1998). An atmospheric flow boundary condition, informed by weather data collected at Santa Barbara Municipal Airport, was used for all models. Turbulence parameters used the kOmegaSST model. Relaxation factors and solution and control algorithms were both set to robust. The model treated trees as momentum sinks, using the default "dense tree" Darcy-Forcheimer coefficients. Models were allowed to run for 3,000 iterations. All residuals (Ux, Uy, Uz, omega, k) did not exceed 10^{-4}, except for p, which approached this value.

All scenarios used storm conditions of 12 m/s (27 mph) as the model input, which have been observed in all directions (Exhibit 1). We chose a southwest wind at Ellwood Main because those are the most frequent storms and also subject to some of the most severe dieback in existing canopy.

Modeling dynamic systems is challenging, even in tightly controlled environments. A large natural system, such as a grove of eucalyptus trees found within Ellwood Mesa, is subject to some inaccuracy. However, modeling all conditions using identical parameters allows us to explore how proposed restoration efforts will vary from existing conditions.

Exhibit 1. Santa Barbara Airport Wind Rose December 1972-2020 shows strong winds from all directions.



Reference:

Asuni CAD. 2022. Lands Design, Version 5.6.2.7780. Barcelona, Spain.

APPENDIX C. ELLWOOD MESA MONARCH COUNTS 2015-2023

Ellwood Mesa Biweekly Monarch Population Data by Season

Data sources: Althouse and Meade Inc. and Rincon Consultants Inc.

2015-2016	10/23/15	11/11/15	12/3/15	12/16/15	12/31/15	1/8/16	1/22/16	2/3/16	2/19/16
Ellwood Main	72	2,852	6,610	7,505	7,617	5,680	4,654	3,335	0
Ellwood East	8	1,763	3,065	1,991	2,134	1,900	2,246	910	8
Ellwood West	37	840	1,525	322	75	7	0	0	0
Ellwood North	4	41	379	225	148	45	0	4	3
Sandpiper	795	2,626	7,823	4,932	1,770	306	2	2	4
Total	916	8,122	19,402	14,975	11,744	7,938	6,902	4,251	15

2016-2017	10/5/16	11/14/16	12/2/16	1/7/17	2/1/17	3/1/17
Ellwood Main	13	1,365	2,120	123	0	11
Ellwood East	5	1,175	1,200	2,670	20	8
Ellwood West	4	1,920	1,730	1,145	527	5
Ellwood North	10	25	1,580	1,490	453	15
Sandpiper	90	3,051	4,495	2,860	858	2
Total	122	7,536	11,125	8,288	1,858	41

2017-2018	10/24/17	11/9/17	11/30/17	1/8/18	1/13/18	1/23/18	2/8/18
Ellwood Main	120	829	1,390	2,185	1,510	1,680	192
Ellwood East	39	479	610	0	3	7	3
Ellwood West	117	825	2,537	120	2	3	0
Ellwood North	4	0	100	1	21	1,534	376
Sandpiper	156	771	2,407	0	0	0	0
Total	436	2,904	7,044	2,306	1,536	3,224	571

2018-2019	10/13/18	10/25/18	11/8/18	11/25/18	12/13/18	1/4/19	1/17/19
Ellwood Main	0	11	11	205	230	170	0
Ellwood East	0	0	1	0	0	0	0
Ellwood West	0	5	7	1	0	0	0
Ellwood North	0	3	0	0	1	0	2
Sandpiper	2	3	8	1	0	0	0
Total	2	22	27	207	231	170	2

2019-2020	10/10/19	10/24/19	11/7/19	11/19/19	12/5/19	12/19/19	1/2/20	1/16/20	1/30/20	2/14/20	2/28/20	3/12/20
Ellwood Main	0	8	66	52	2	1	1	0	2	0	1	0
Ellwood East	1	2	4	55	52	13	7	0	0	0	0	0
Ellwood West	0	5	2	44	15	2	1	0	0	0	4	0
Ellwood North	3	2	2	8	1	0	3	0	2	0	0	0
Sandpiper	9	22	18	89	40	0	2	0	3	2	5	0
Ellwood Ironbark	0	0	0	4	0	0	0	0	1	0	3	0
Ellwood Main Annex	0	0	0	19	1	0	0	0	0	0	5	0
Ocean Meadows	0	0	0	0	0	0	0	0	0	0	0	0
Total	13	39	92	271	111	16	14	0	8	2	18	0

2020-2021	10/15/20	10/29/20	11/12/20	11/25/20	12/15/20	12/27/20	1/13/21	1/26/21	2/15/21	2/25/21	3/17/21	3/31/21
Ellwood Main	0	3	5	0	0	0	0	0	0	0	0	0
Ellwood East	0	2	3	0	0	0	0	0	0	0	0	0
Ellwood West	0	0	0	0	0	0	0	0	0	0	0	0
Ellwood North	0	1	2	0	0	0	0	0	0	0	0	0
Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0
Ellwood Ironbark	0	0	0	0	0	0	0	0	0	0	0	0
Ellwood Main Annex	0	0	0	0	0	0	0	0	0	0	0	0
Ocean Meadows	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	6	10	0	0	0	0	0	0	0	0	0

2021-2022	10/15/21	10/18/21	11/1/21	11/2/21	11/15/21	12/1/21	12/15/21	1/4/22	1/17/22	2/1/22
Ellwood Main	0	0	6	295	3,874	2,719	4,719	3,378	250	0
Ellwood East	0	0	18	0	4,292	3,645	8,900	10,714	11,840	9,555
Ellwood West	1	0	0	36	1,551	2,564	1,435	50	3	0
Ellwood North	6	0	0	14	6	3	0	0	0	0
Sandpiper	18	0	0	129	346	5	0	0	0	0
Ellwood Ironbark	3	0	0	0	0	0	0	0	0	0
Ellwood Main Annex	0	0	0	0	0	0	0	0	0	0
Ocean Meadows	0	1	0	0	1	0	1	0	0	0
Total	28	1	24	474	10,070	8,936	15,055	14,142	12,093	9,555

2022-2023	10/17/22	10/31/22	11/15/22	11/30/22	12/15/22	12/30/22	1/13/23
Ellwood Main	11	73	4,188	9,311	5,394	1,833	6
Ellwood East	3	202	1,756	2,946	1,443	78	12
Ellwood West	0	924	120	130	7	0	0
Ellwood North	0	3	0	0	0	0	0
Sandpiper	9	228	0	0	0	0	0
Ellwood Ironbark	0	1	0	0	0	0	0
Ellwood Main Annex	0	0	0	0	0	0	0
Ocean Meadows	0	0	0	0	0	0	0
Total	23	1,431	6,064	12,387	6,844	1,911	18

Western Monarch Population Data

Data source: Xerces Society 2023

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
Total Western Monarchs (WMTC)	1,235,490	564,349	267,574	390,057	209,570	99,353	254,378	205,085	218,679
SB Co. Total	354,300	84,309	87,138	131,266	67,078	13,922	35,324	33,598	78,319
Ellwood Main, Goleta	25,000	20,000	25,000	58,000	35,000	4,500	18,400	16,680	54,700

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total Western Monarchs (WMTC)	221,058	86,437	131,889	58,468	143,204	222,525	144,812	211,275	234,731
SB Co. Total	50,853	14,430	29,230	8,000	40,518	54,260	33,621	54,980	46,916
Ellwood Main, Goleta	19,000	11,000	12,000	6,500	27,600	21,800	17,150	2,355	3,543

Year	2015	2016	2017	2018	2019	2020	2021
Total Western Monarchs (WMTC)	292,888	298,464	192,624	27,721	29,436	1,899	247,246
SB Co. Total	57,782	74,060	45,868	6,287	7,665	208	97,025
Ellwood Main, Goleta	6,610	2,120	1,390	205	55	0	3,874

APPENDIX D. MONARCH BUTTERFLY HABITAT ON THE RAZOR'S EDGE

Native and Non-native Vegetation in California and Occam's Razor, 2023

Monarch Butterfly Habitat on the Razor's Edge: Native and Non-native Vegetation in California and Occam's Razor

Daniel E. Meade, Jessica Griffiths, Charis van der Heide

for

City of Goleta, Santa Barbara County, California

Prepared for

George Thomson, Parks & Open Space Manager
City of Goleta – Public Works Department
130 Cremona Drive
Goleta, CA 93117

by

ALTHOUSE AND MEADE, INC.
BIOLOGICAL AND ENVIRONMENTAL SERVICES
1650 Ramada Drive, Suite 180
Paso Robles, CA 93446
(805) 237-9626

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Production Note: This is updated from the original version completed in April 2019 with Daniel E. Meade, Jessica Griffiths, and Charis van der Heide as the original authors. Charis van der Heide completed this revision following the passing of Dr. Daniel E. Meade on November 26, 2022.

Charis van der Heide may be reached at: charisvdh@althouseandmeade.com

Jessica Griffiths may be reached at: Jessica.L.Griffiths@gmail.com

Cover Page: Clustering Monarchs taken by Charis van der Heide on November 19, 2022.

1 INTRODUCTION

Conservation biologists and land managers face a dilemma prescribing effective, proven, conservative recommendations to restore western monarch butterfly aggregation sites (Lane 1993). In sites where monarchs aggregate in trees native to their location, such as Monterey pines (*Pinus radiata*) in Monterey, this question is beginning to be answered in favor of native trees when both native trees and eucalyptus are present (Griffiths and Villablanca 2015). But, in areas where native trees are absent from most monarch butterfly aggregation sites, such as Santa Barbara County, the question of what to plant in aggregation sites in need of restoration is more complicated. This pertains specifically to eucalyptus trees that are the subject of a long and sometimes bitter controversy in California regarding whether to keep or replace eucalyptus trees with native vegetation (Bell et al. 1993, Santos 1997, Farmer 2013, Marris 2016, St. George 2016, Longcore et al. 2020).

There are only four tree species native to Santa Barbara County's coastal habitats with suitable size and structure to be considered for protecting monarch aggregations from inclement weather: western sycamore (*Platanus racemosa*), Fremont cottonwood (*Populus fremontii*), arroyo willow (*Salix lasiolepsis*), and coast live oak (*Quercus agrifolia*). Black cottonwood (*Populus balsamifera* subsp. *trichocarpa*) occur in some south coast riparian corridors. White alder trees (*Alnus rhombifolia*) are confined to higher elevations on the south coast in or near streams with abundant water. All except one of these trees, coast live oak, are deciduous and provide reduced protection from wind and storms once their leaves fall. Coast live oak does not have a columnar growth form that creates usable aggregation spaces. No aggregation sites are known in oak woodlands. A few native shrubs such as toyon (*Heteromeles arbutifolia*), California bay (*Umbellularia californica*), and holly-leafed cherry (*Prunus illicifolia*), expand the possible plant palette for roosting monarchs, but do not provide the tall canopy cover necessary at sites where monarchs aggregate. Therefore, choices for native trees are limited and are not sufficient for forming the typical structure of a monarch butterfly aggregation site with a flight area encircled by substantial, tall trees that filter light, buffer wind and ameliorate temperatures and humidity (Wenner 1987, Leong 1990, Weiss et al. 1991, Calvert 1991, Meade 1999, Leong 2016).

1.1 Purpose

Scientific problem-solving employs the principle of Occam's razor, or parsimony. This fundamental heuristic, or way of discovering something, is summarized as, "simpler solutions are more likely to be correct than complex ones" (attributed to William of Occam). When attempting to determine what causes monarchs to aggregate at a site, the simplest approach would be to examine the aggregation sites as a whole. The most easily observable feature of overwintering sites is the tree species they are comprised of. The structure of an overwintering site (i.e. the trees) directly influences the myriad other factors that cause monarchs to select a site, e.g. temperature, wind speed, humidity, and light. Thus, we can look at overall habitat preference using the composition of tree species and not all the other factors that may generate that preference. Although many factors may be involved in how monarch butterflies choose an aggregation site, a simple test of monarch habitat preference is to observe where they aggregate and note the tree composition of those sites. The trees present at a chosen aggregation site inform what works at aggregation sites. Additionally, if native tree habitats are present in the vicinity of aggregation sites, we could assess whether those native tree habitats are used preferentially to non-native tree habitats. Our immediate goal must be to recover and enhance protection for monarchs at overwintering sites to the best of our ability given what we have learned about the characteristics of overwintering sites during the peak of the western monarch population.

2 SANTA BARBARA COUNTY HABITATS

2.1 Background

In Santa Barbara County there are 114 locations named as monarch butterfly aggregation sites by the Xerces Society (Xerces Society 2023). Another source, the 2018 report *Monarch Butterfly Overwintering Sites, Santa Barbara County, California* (Meade, Griffiths, van der Heide, and Villablanca 2018) documented 117 monarch butterfly aggregation sites, and inspected a total of 130 potential or known aggregation sites in Santa Barbara County. This study relied on previous work (Meade 1999, Calvert 1991) and the Xerces Society Monarch Overwintering Sites database for site locations along with additional potential sites added by the study investigators. These 130 sites are grouped into 5 categories based on what tree species the monarchs roost on at each site, listed in Table 1 Of the 130 sites investigated, 96 are dominated by eucalyptus (2 of which are eucalyptus and non-natives), 10 are mixed eucalyptus and California native trees, 9 sites are eucalyptus with local California native trees, 9 sites are California native trees, and 6 sites are local California native trees (only trees native to Santa Barbara County). Eucalyptus trees are either the primary vegetation, or a significant contributor to the creation of monarch butterfly aggregation sites in Santa Barbara County in 88% percent of known or potential aggregation sites.

TABLE 1. NUMBER OF AGGREGATION SITES BASED ON TREE SPECIES-COMPOSITION CATEGORIES

Category Number	Tree Composition Label	Tree Species	Count
1	Eucalyptus and other non-native trees	Blue gum, red iron bark, silver wattle, evergreen ash	97
2	Eucalyptus and California native trees	Monterey cypress, Monterey pine, coast redwood	9
3	Eucalyptus and Santa Barbara native trees	Eucalyptus trees and coast live oak, western sycamore, arroyo willow, California bay laurel	9
4	California native trees	Monterey cypress, Monterey pine, coast redwood	9
5	Santa Barbara native trees	Coast live oak, western sycamore, arroyo willow, California bay laurel	6
Total number of aggregation sites			130

2.2 Data Analysis

Analysis of data from the Santa Barbara County study of monarch abundance across these 5 tree categories by month shows that 92-99% of the monarch population in Santa Barbara County aggregated at sites with eucalyptus compared to sites with only native vegetation (Figure **1**). About 8% of the monarch population roosted at sites with native trees (combining the California and local native categories) in the early overwintering season and this number decreased to less than 1% in the later months of the overwintering season. Sites with only Santa Barbara County local native trees were utilized by 1% of the monarch population at peak use (data from Meade et al. 2018). This result raises the question of whether monarchs have a choice between eucalyptus and native trees for overwintering aggregations. If eucalyptus and native trees are equally available, monarchs may be preferentially choosing to aggregate in eucalyptus. However, if eucalyptus is more abundant and therefore more available than suitable native tree habitat, the monarchs may be aggregating in eucalyptus because they do not have a choice.

This data on a logarithmic scale presented in **Error! Reference source not found.** shows more detail into the behavior of the monarchs through the season. Like the stacked bar graph in Figure **1**, the logarithm scaled data in **Error! Reference source not found.** shows the monarchs use sites in the eucalyptus only group (Category 1) more than the other groups. The logarithm scale graph shows the monarchs used the categories 3 and 4 almost identically and they were present at sites in category 2 slightly more than categories 3 and 4 in the winter months of December and January. Sites with only species native to Santa Barbara County were utilized by the fewest monarchs in the fall months with a steep decline of utilization in January when the monarchs abandoned those sites for the season.

FIGURE 1. MONARCH BUTTERFLY USE OF SITES IN 5 TREE COMPOSITION CATEGORIES IN SANTA BARBARA COUNTY BY MONTH IN BAR GRAPH

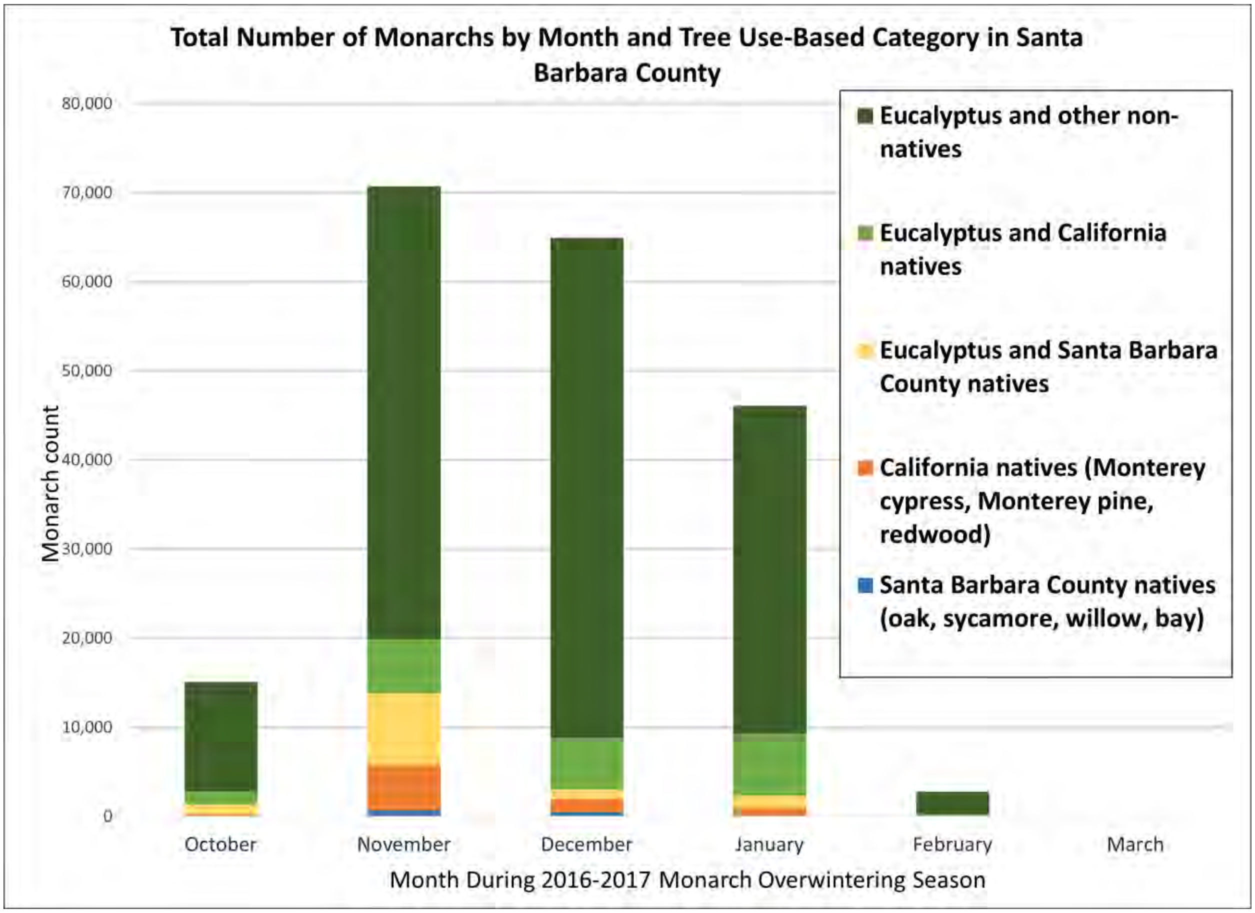
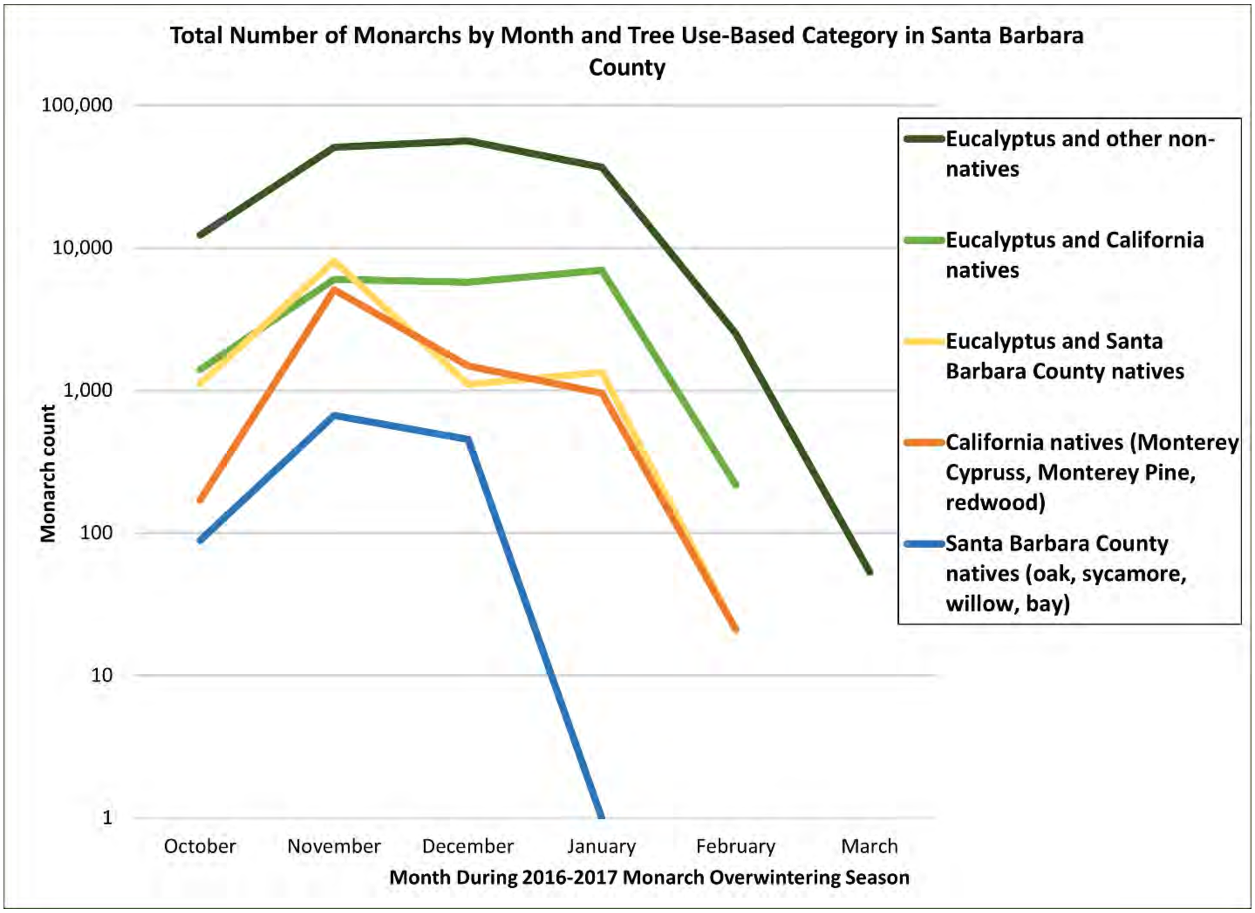


FIGURE 2. MONARCH BUTTERFLY USE OF SITES IN FIVE TREE COMPOSITION CATEGORIES IN SANTA BARBARA COUNTY BY MONTH IN LOGARITHMS



2.3 Tree and Habitat Choices

To explore this idea of tree choice by monarch butterflies, we examined locations with native trees along the south coast of Santa Barbara County. Criteria for consideration include well-established native trees, locations near the coast, and sites of similar elevation within one mile of known aggregations. At least 17 locations of these native riparian habitats are in proximity to known eucalyptus dominated monarch aggregation sites, yet no records of aggregating monarch butterflies occur for these native areas (Table 2). These native riparian habitats are within ½ mile or less of known monarch aggregation sites with a range of nearly adjacent (e.g. Rincon Creek) to a distance of less than ½ mile (e.g. Garrapata Creek). Choice is available for monarch butterflies between eucalyptus tree stands and native riparian vegetation habitats.

TABLE 2. SANTA BARBARA COUNTY SOUTH COAST LOCATIONS WITH ABUNDANT NATIVE VEGETATION, NO ROOSTING MONARCHS, AND NEAREST KNOWN MONARCH BUTTERFLY AGGREGATIONS

Location	Native vegetation	Nearest monarch aggregation (Name and Site Number)**	Distance to native tree habitat (ft)
Rincon Creek	willow, cottonwood, sycamore, oak	Rincon Canyon, Site 118	200
Rincon Creek	willow, cottonwood, sycamore, oak	6765 Rincon Road, Site 102	1,200
Carpinteria Creek	sycamore, willow, cottonwood	Carpinteria Creek*, Site 99	400
Arroyo Paredon	sycamore, willow, oak	Padaro Lane sites	900
Garapata Creek	sycamore, coast live oak riparian forest	Lambert Road, Site 95	2,100
Toro Canyon Creek	oak, sycamore	Lambert Road, Site 95	1,100
Romero Creek	sycamore, oak, willow	Ortega Hill, Site 92	650
San Ysidro Creek	sycamore, willow, oak	Crane School, Site 90	600
Arroyo Burro Creek	willow, sycamore	Arroyo Burro Canyon, Site 82	900
Atascadero Creek	sycamore, willow	Atascadero Creek, Site 78 (historic location)	250
San Jose Creek	willow, cottonwood, sycamore	Elks Grove*, Site 76	1,500
Bell Canyon	sycamore, willow, cottonwood, oak	Bell Canyon, Site 58	1,000
Tecolote Canyon	willow, oak	Tocolote Canyon, Site 57	1,400
Gato Canyon	sycamore, oak	Arroyo west of Gato Canyon, Site 53	1,600
El Capitan Canyon	sycamore, oak, pine, cottonwood	El Capitan State Park, Site 52	750
Honda Canyon	sycamore, willow, cottonwood	Arroyo Hondo, Site 110	100
Gaviota Creek	willow, cottonwood	Gaviota Beach Road, Site 109	250

oak = coast live oak (Quercus agrifolia)

willow = arroyo willow (Salix lasiolepsis)

cottonwood = Fremont cottonwood (Populus fremontii)

sycamore = western sycamore (Platanus racemosa)

**Some native trees occur at the aggregation site and support clusters, however the site is protected by large blue gum eucalyptus.*

***Site names and numbers correspond with Meade et al 2018.*

There are nine south coast sites where monarch butterfly aggregations were observed clustering on native trees. These sites include: Canada Refugio (Site 49), El Rancho Refugio (Site 101), Corral Canyon (Site 51), Elks Grove (Site 76), Los Carneros Creek (Site 71), Carpinteria Creek (Site 99), Maria Ygnacio Creek at La Ramada Road (Site 115), Padaro Lane (Site 119), and Stow Grove County Park (Site 75).

Five of these sites are closely associated with eucalyptus. Carpinteria Creek and Elks Grove have large blue gum eucalyptus trees that provide shade and weather protection for the site. At those two sites, monarch butterflies cluster on both eucalyptus and native trees that overhang the creek. At Rincon Creek, native sycamore, willow, and oak trees line the drainage adjacent to eucalyptus, and yet monarch butterflies chose to aggregate in the one stand of eucalyptus trees along the creek channel. At one time monarchs also aggregated at a eucalyptus row on Rincon Road (since removed). At Los Carneros Creek, monarchs have been observed clustering on oak branches over the creek and on eucalyptus trees that protect the site and line the creek bank.

The remaining four of these sites are not associated with eucalyptus trees: Canada Refugio, El Rancho Refugio, Corral Canyon, and Stow Grove County Park. Canada Refugio and El Rancho Refugio, which each held about 3,000 butterflies in 1998, had a high count of 7 and 75 respectively in October 2016. El Rancho Refugio site is adjacent to a lemon orchard where up to 12,000 butterflies were observed in native willow and cottonwood vegetation on January 6, 1990 (Calvert 1991). Calvert (1991) considered the location to be a nectaring bivouac for lemon blossoms. This site is in a relatively protected canyon, and native vegetation is still present. Corral Canyon held an autumnal aggregation of 637 monarchs in 2016 and 1,425 butterflies in November 2017. These sites were then abandoned during the winter. The Stow Grove site is one of only two locations in the County where monarchs aggregated on redwood trees, holding 100 butterflies in 1999. Drought severely damaged the redwoods, and only 3 butterflies were observed there in fall 2017.

These site-specific observations together with the monthly analysis shown in Figure **1** show us that butterflies can use south coast native stands of vegetation as aggregation sites; however, they support low numbers of monarchs in the fall and not through the overwintering period. The use of habitat dominated by eucalyptus is likely a matter of preference as well as availability.

2.4 Tree Characteristics

To evaluate candidates for restoration planting, we compiled a list of characteristics of trees native to California and species known at monarch aggregation sites. We used records in the Xerces Society's database and site descriptions (Lane 1993, Meade 1999, Meade et al. 2018, Xerces Society 2023). The list of species and the compilation of characteristics are shown in Attachment A. We used tree character information from the Urban Forest Ecosystems Tree Detail list (Urban Forest Ecosystems Institute 2023), Calscape (California Native Plant Society 2023), and Cal-IPC Inventory (Cal-IPC 2023) databases, along with our observations and information from an analysis of aggregation habitats (Meade et al. 2018). Ratings are assigned based on characteristics that are directly related to forming suitable aggregations sites for monarch butterflies along south coast sites in Santa Barbara County. A higher rating score indicates a species better suited for use in monarch butterfly site restoration. Characters are summed for each species providing a comparative rating among species, shown in Table 3. The highest rated species are three eucalyptus trees commonly found at aggregation sites: red iron bark gum, blue gum, and river red gum. The next six species are trees that create suitable aggregation habitat for the duration of the overwintering season: lemon scented gum, red flowering gum, toyon, karri, Monterey cypress, and sugar gum. All the trees with lower ratings would provide additional habitat benefits by increasing diversity and wind shelter to an aggregation grove in associate with the nine higher ranked species: Bishop pine, silver wattle, Canary Island pine, holly-leaf cherry, Monterey pine, Torrey pine, coast redwood, evergreen ash, cork oak, blackwood, California bay laurel, western sycamore, Fremont cottonwood, coast live oak, grand fir, arroyo willow, Douglas fir, monkey-puzzle, dawn redwood, and black cottonwood.

TABLE 3. TREE SPECIES BY OVERALL MATRIX SCORE

Species	Common Name	Overall Score
Eucalyptus sideroxylon	Red iron bark gum	62.0
Eucalyptus globulus	Blue gum	61.0
Eucalyptus camaldulensis	River red gum	59.0
Corymbia citriodora	Lemon scented gum	56.0
Corymbia ficifolia	Red flowering gum	56.0
Heteromeles arbutifolia	Toyon	56.0
Eucalyptus diversicolor	karri	55.0
Hesperocyparis macrocarpa	Monterey cypress	54.0
Eucalyptus cladocalyx	Sugar gum	53.0
Pinus muricata	Bishop pine	51.0
Acacia dealbata	silver wattle	50.0
Pinus canariensis	Canary Island pine	50.0
Prunus illicifolia	Holly-leaf cherry	50.0
Pinus radiata	Monterey pine	49.0
Pinus torreyana	Torrey pine	49.0
Sequoia sempervirens	Coast redwood	48.0
Fraxinus uhdei	Evergreen ash	47.0
Quercus suber	Cork oak	47.0
Acacia melanoxylon	Blackwood	46.0
Umbellularia californica	California bay laurel	45.0
Platanus racemosa	Western sycamore	44.0
Populus fremontii	Fremont cottonwood	44.0
Quercus agrifolia	Coast live oak	44.0
Abies grandis	Grand fir	43.0
Salix lasiolepsis	Arroyo willow	43.0
Pseudotsuga menziesii	Douglas fir	42.0

Species	Common Name	Overall Score
Araucaria araucana	Monkey-puzzle	40.0
Metasequoia glyptostoboides	Dawn Redwood	34.0
Populus trichocarpa	Black cottonwood	34.0

3 CONCLUSION

Why are so few monarch butterfly aggregations in south Santa Barbara County in native vegetation, even though native vegetation is present near or adjacent to eucalyptus dominated aggregation sites? The simplest conclusion based on observation is that in this area of California, eucalyptus trees provide better shelter for monarch butterfly overwintering aggregations than do native plant habitats. The butterflies have shown us their preference when a choice is available and when we consider growth forms and attributes of tree choices available. Tree species with a structure most likely to provide protection added with a history of monarch's behavior explains what might continue to work. Eucalyptus grove structures often provide better protection from wind and rain than sycamore, oak, cottonwood, and willow habitats.

The recovery of the western monarch butterfly population will depend on action at every stage of their migration and life cycle. Restoration and enhancement of monarch overwintering sites is an important part of that recovery (Xerces Society 2019). When creating a protective aggregation habitat is the goal, eucalyptus trees remain a reliable choice for restoration. Monarchs have shown their preference for sites with eucalyptus trees in Santa Barbara County. Using the species most likely to provide the best protection for aggregating monarchs seems the most reasonable approach to the pressing conservation question of what species to plant in Santa Barbara County south coast monarch restoration sites.

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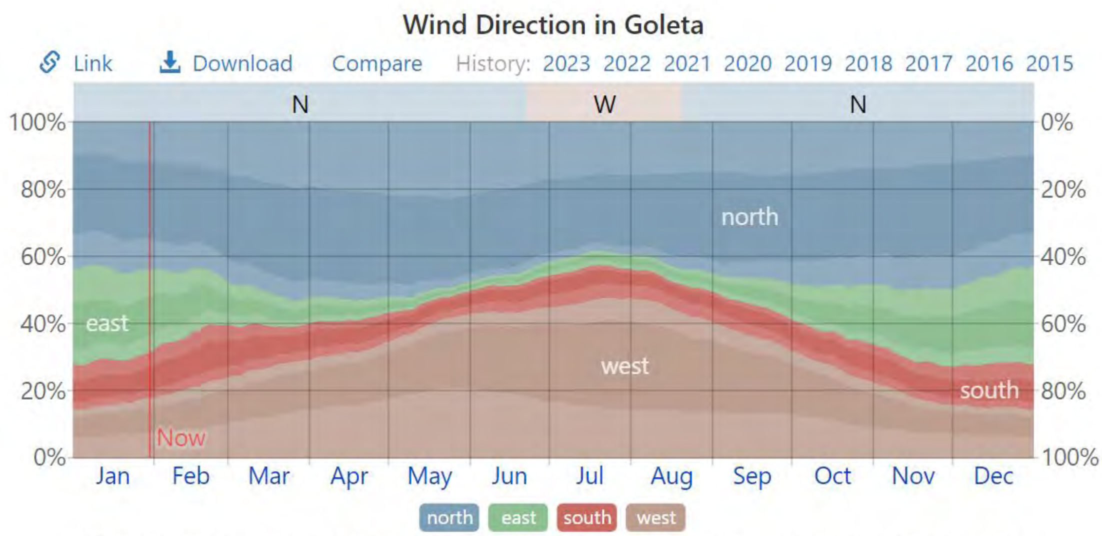
ATTACHMENT A. TREE COMPARISON FOR CHARACTERISTICS IMPORTANT TO MONARCH BUTTERFLY AGGREGATION SITES

Species	Common Name	Nativeness	Percentage of Monarch Use in SB Co	Used by Roosting Monarchs in California	Nectar value	Growth Form	Height (m)	Canopy/wind protection factor	Ease of care	Water require-ment (Drought Tolerance)	Branch Strength	Life Span	Growth Rate	Climate change Resilience	Potential for success at Ellwood North site	Cal-IPC invasive level	Overall Score
Abies grandis	Grand fir	3	0	1	0	5	5	5	4	1	3	5	4	1	1	5	43.0
Acacia dealbata	silver wattle	0	1	4	3	5	4	5	5	4	1	3	5	4	4	2	50.0
Acacia melanoxylon	Blackwood	1	0	3	2	4	3	3	5	5	1	3	5	4	4	3	46.0
Araucaria araucana	Monkey-puzzle	1	0	1	0	5	5	2	4	1	3	5	3	2	3	5	40.0
Corymbia citriodora	Lemon scented gum	1	1	3	5	5	5	3	4	5	3	3	5	4	4	5	56.0
Corymbia ficifolia	Red flowering gum	1	2	4	5	5	3	2	5	5	3	3	3	5	5	5	56.0
Eucalyptus camaldulensis	River red gum	0	4	5	5	5	5	3	5	5	4	3	5	3	4	3	59.0
Eucalyptus cladocalyx	sugargum	0	1	4	3	4	4	3	5	4	3	5	5	4	4	4	53.0
Eucalyptus diversicolor	karri	0	0	1	4	5	5	5	5	4	3	5	5	4	4	5	55.0
Eucalyptus globulus	Blue gum	0	5	5	5	5	5	5	5	4	2	5	5	3	4	3	61.0
Eucalyptus sideroxylon	Red iron bark gum	0	3	5	5	5	4	4	5	5	3	3	5	5	5	5	62.0
Fraxinus uhdei	evergreen ash	1	1	5	1	5	4	5	5	1	2	3	5	3	1	5	47.0
Hesperocyparis macrocarpa	Monterey cypress	3	2	4	0	5	4	5	4	3	4	3	5	3	4	5	54.0
Heteromeles arbutifolia	Toyon	5	2	5	2	3	1	5	5	5	3	3	3	4	5	5	56.0
Metasequoia glyptostoboides	Dawn Redwood	2	0	1	0	1	4	2	3	1	3	5	5	1	1	5	34.0
Pinus canariensis	Canary Island pine	2	1	3	0	5	4	5	4	5	3	3	5	4	1	5	50.0
Pinus muricata	Bishop pine	4	1	4	0	5	4	5	4	4	3	3	5	1	3	5	51.0
Pinus radiata	Monterey pine	3	2	3	0	5	5	5	4	1	2	3	5	3	3	5	49.0
Pinus torreyana	Torrey pine	3	0	1	0	4	5	5	4	4	3	5	5	3	2	5	49.0
Platanus racemosa	Western sycamore	5	1	4	0	1	4	3	3	1	3	5	5	2	2	5	44.0
Populus fremontii	Fremont cottonwood	5	1	4	2	1	4	4	5	1	1	3	5	2	1	5	44.0
Populus trichocarpa	Black cottonwood	5	1	1	0	1	4	3	5	2	1	3	3	2	1	5	37.0
Prunus illicifolia	Hollyleaf cherry	5	0	1	5	5	1	2	5	4	3	3	4	3	4	5	50.0
Pseudotsuga menziesii	Douglas fir	3	0	1	0	4	5	5	5	1	3	5	3	1	1	5	42.0
Quercus agrifolia	Coast live oak	5	1	2	0	4	2	2	5	3	2	5	2	3	3	5	44.0
Quercus suber	Cork oak	0	0	1	0	4	4	5	4	5	4	5	3	4	3	5	47.0
Salix lasiolepsis	Arroyo willow	5	1	4	3	1	2	5	5	1	1	1	5	2	2	5	43.0
Sequoia sempervirens	Coast redwood	3	1	5	0	4	5	3	4	1	5	5	5	1	1	5	48.0
Umbellularia californica	California bay laurel	5	1	2	2	2	1	2	5	4	5	5	2	2	2	5	45.0

Ratings Broken Down for each column	Rating Scale	Nativeness	Percentage of Monarch Use in SB Co	Used by Roosting Monarchs in California	Nectar value	Growth Form	Height (m)	Canopy/wind protection factor	Ease of care	Water require-ment (Drought Tolerance)	Branch Strength	Life Span	Growth Rate	Climate change Resilience	Potential for success at Ellwood North site	Cal-IPC invasive level
	5	Goleta	75-100%	Goleta	Nectar available over winter	Evergreen, spreading	35 m and up	Full canopy	Easy	Extremely Low	Strong	Greater than 150 years	Fast/ 36 in. per year	High	High	Not rated
	4	Santa Barbara County	50-74%	Santa Barbara Co	Some nectar available overwinter	Evergreen columnar	15-35 m	Top only	Moderately Easy	Very Low	Strong-medium	n/a		Good	Good	watch/alert
	3	South and Central California	25-49%	Monterey Co south	Limited nectar available	Evergreen, shrub	10-15 m	Top only sparce	Moderate	Moderate	Medium	50 to 150 years.	Moderate, 24 in. per year	Medium	Medium	limited
	2	West Coast	5-24%	California	Nectar out of season	Sub-tree	5-10 m	Sparce canopy	Moderately High	High	Medium-weak	n/a		Question-able	Question-able	moderate
	1	North America	1-5%	Limited records	Poor nectar	Winter deciduous	0-5 m	No canopy	High	Very High	weak	Less than 50 years	less than 12 inches per year	n/a	Low	high
	0	Another continent	0%	No Records	No Nectar	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

APPENDIX E. ELLWOOD WIND DATA



The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph*. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).*

Source: https://weatherspark.com/y/1430/Average-Weather-in-Goleta-California-United-States-Year-Round

November 2021 – January 2022 – Daily Wind

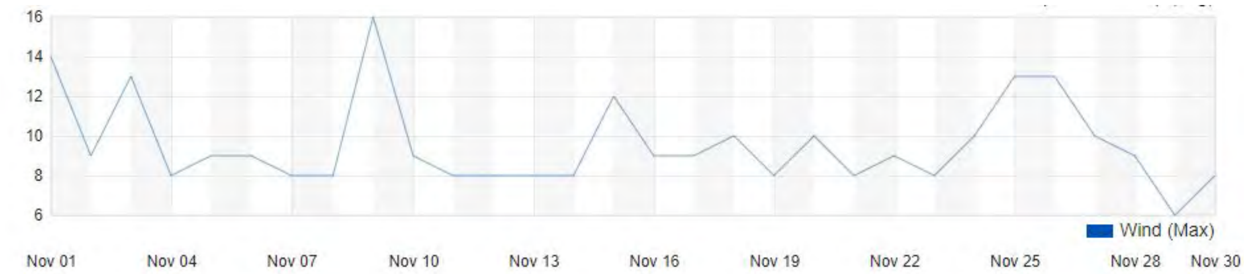


FIGURE 1. NOVEMBER 2021

Nov 9th – W 12-16 mph (3:30PM-5PM)
Nov 25th – W/SW 12-13 mph (12PM-3PM) / Gust of 25 mph (4am), variable direction

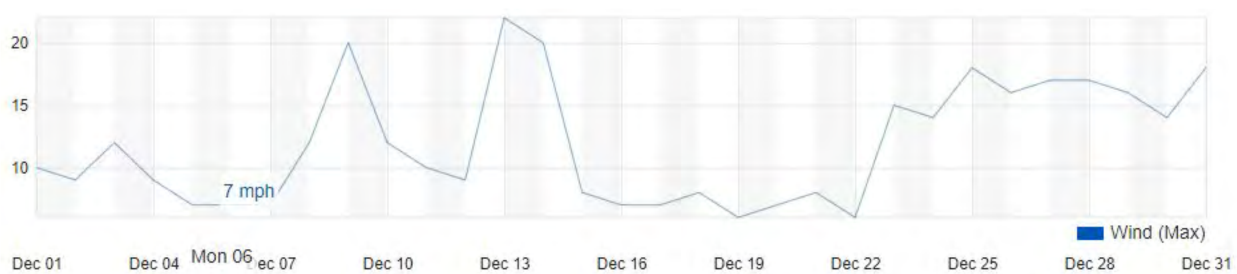


FIGURE 2. DECEMBER 2021

Dec 9th – W/NW - 12-20 mph (12pm-4pm) / Gusts 18-25 mph (12pm-4pm)
Dec 13th – E/SE - 13-22 mph (9am-11pm) / Gusts – 18-23 mph early in the day, 23-29 mph (9pm-11pm)
Dec 14th – E/SE - 13-20 mph (12am-3am) / Gusts 18-28 mph (12am-3am)
– W/NW – 12-17 mph (8am-9pm) / Gusts 20-24 mph (8am-9pm)
Dec 23-31 – Average wind – 6 mph variable direction / Gusts 22-26 mph (Large gusts mostly W/NW/SW)

FIGURE 3. JANUARY 2022

Jan 21st – NE – 18 mph (11pm)

TABLE 1. JANUARY 21ST – JAN 22ND 2022- NE WIND AT MIDNIGHT

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
5:53 PM	54 °F	51 °F	90 %	CALM	0 mph	0 mph	29.94 in	0.0 in	Fair
6:53 PM	53 °F	49 °F	86 %	N	3 mph	0 mph	29.96 in	0.0 in	Fair
7:53 PM	51 °F	45 °F	80 %	SSE	7 mph	0 mph	29.96 in	0.0 in	Fair
8:53 PM	51 °F	44 °F	77 %	N	5 mph	0 mph	29.97 in	0.0 in	Fair
9:53 PM	48 °F	41 °F	77 %	NNE	3 mph	0 mph	29.99 in	0.0 in	Fair
10:53 PM	46 °F	39 °F	76 %	CALM	0 mph	0 mph	30.01 in	0.0 in	Fair
11:53 PM	61 °F	31 °F	32 %	NNE	18 mph	0 mph	29.99 in	0.0 in	Fair
12:53 AM	57 °F	37 °F	47 %	SE	5 mph	0 mph	29.98 in	0.0 in	Fair
1:53 AM	47 °F	35 °F	63 %	N	6 mph	0 mph	30.00 in	0.0 in	Fair
2:53 AM	46 °F	34 °F	63 %	CALM	0 mph	0 mph	29.99 in	0.0 in	Fair
3:53 AM	45 °F	34 °F	65 %	NNE	6 mph	0 mph	29.98 in	0.0 in	Fair
4:53 AM	45 °F	33 °F	63 %	CALM	0 mph	0 mph	29.98 in	0.0 in	Fair
5:53 AM	38 °F	31 °F	76 %	CALM	0 mph	0 mph	29.99 in	0.0 in	Fair
6:53 AM	39 °F	32 °F	76 %	CALM	0 mph	0 mph	30.01 in	0.0 in	Fair
7:53 AM	41 °F	33 °F	73 %	CALM	0 mph	0 mph	30.04 in	0.0 in	Fair
8:53 AM	53 °F	36 °F	52 %	NE	3 mph	0 mph	30.06 in	0.0 in	Fair
9:53 AM	63 °F	38 °F	40 %	CALM	0 mph	0 mph	30.07 in	0.0 in	Fair
10:53 AM	65 °F	38 °F	37 %	SSW	7 mph	0 mph	30.07 in	0.0 in	Fair

November 2022 – January 2023 – Daily Wind

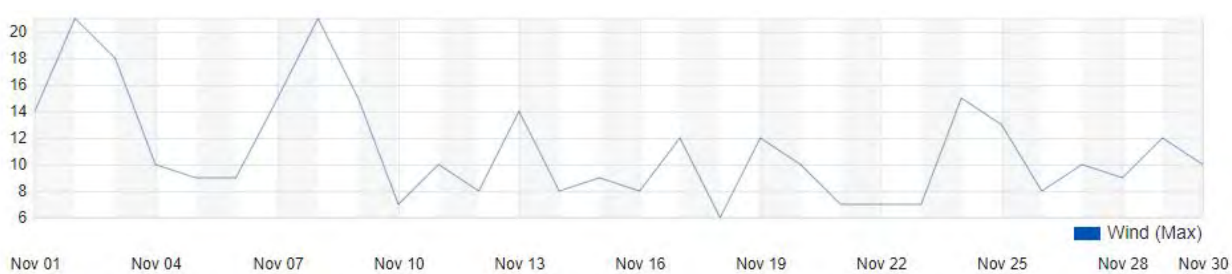


FIGURE 4. NOVEMBER 2022

Nov 2nd – W/NW - 13-21 mph (6am-10pm) / Gusts 21-31 mph (*especially strong @ 10am-4pm)
Nov 3rd – W/NW/NE - 10-18 mph (2am-7pm) / Gusts 22-28 mph (8am-2pm)
Nov 7th – E/SE - 10-15 mph (9am-2pm)
Nov 8th – E/SE - 12-21 mph (7am-1pm) / Gusts 22-29 mph (10am-12pm)
Nov 9th - W/SW 13-15 mph (1pm-4pm) / Gust 23 mph (1pm)

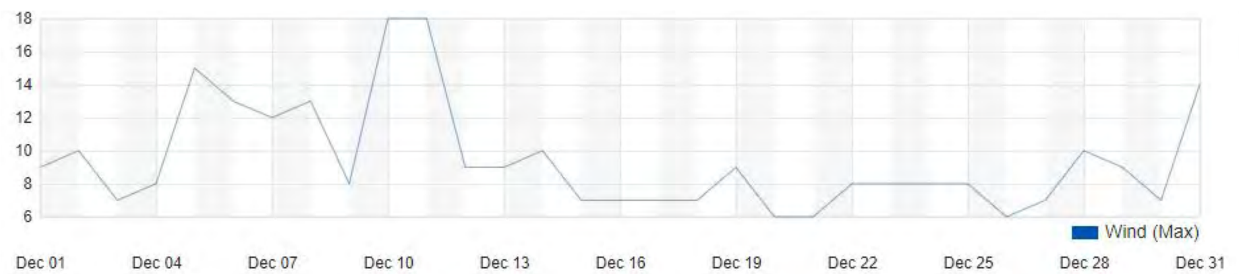


FIGURE 5. DECEMBER 2022

Dec 10th – E/SE - 10-18 mph (1pm-11pm) / Gusts 22-26 ((9pm-11pm)
Dec 11th – S/SW/W/NW – 10-18 mph (12am-4pm) / Gusts - S/SW 20-28 mph(12am-2am) – N/NW 21-25 mph (12pm-4pm)

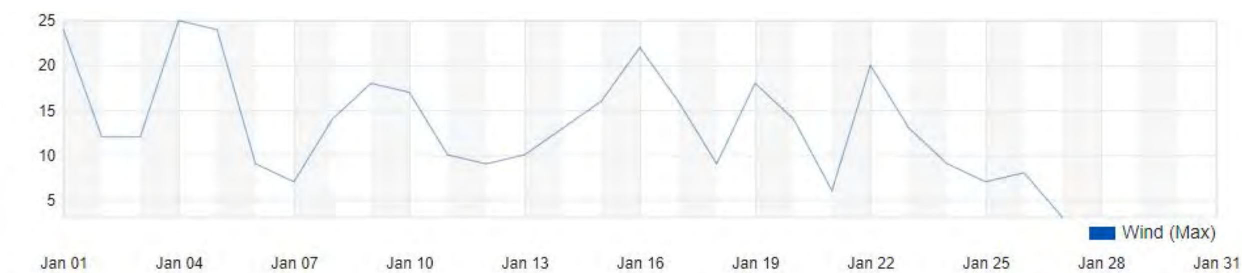


FIGURE 6. JANUARY 2023

Jan 1st - W/NW 13-24 mph (12am-7pm) / Gusts 17-33 (12am-7pm, *especially strong from 8am – 7pm)
Jan 4th - E/SE 12-25mph (12am-11pm) / Gusts 22-38 mph (5am-11pm, *especially strong from 6pm-11pm)
Jan 5th - E/SE 12-24 mph (12am-3pm) / Gusts 22-33 mph (12am-3pm, *especially strong from 12am-5am)
Jan 16 - NE/E/SE/SW/W/NW 12-22mph (12am-8pm) / Gusts 16-28 (Sporadic throughout the day)
Jan 22 -W/SW/NW/W/NE 12-20 (4pm-11pm) / Gust 20 (3pm) & 29 mph (7pm)

TABLE 2. JAN 15TH – 16TH – E/NE WINDS THROUGHOUT THE NIGHT

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
1:53 PM	57 °F	50 °F	77 %	CALM	0 mph	0 mph	29.79 in	0.0 in	Cloudy
2:53 PM	57 °F	50 °F	77 %	CALM	0 mph	0 mph	29.78 in	0.0 in	Light Rain
3:33 PM	56 °F	52 °F	87 %	CALM	0 mph	0 mph	29.76 in	0.0 in	Light Rain
3:53 PM	56 °F	51 °F	84 %	ESE	5 mph	0 mph	29.77 in	0.1 in	Rain
4:53 PM	52 °F	48 °F	86 %	ENE	5 mph	0 mph	29.76 in	0.2 in	Light Rain
5:53 PM	53 °F	49 °F	86 %	E	3 mph	0 mph	29.77 in	0.0 in	Light Rain
6:53 PM	52 °F	48 °F	86 %	E	7 mph	0 mph	29.76 in	0.0 in	Light Rain
7:53 PM	52 °F	49 °F	89 %	E	13 mph	0 mph	29.74 in	0.0 in	Light Rain
8:53 PM	52 °F	48 °F	86 %	E	15 mph	0 mph	29.73 in	0.0 in	Light Rain
9:53 PM	52 °F	48 °F	86 %	E	16 mph	0 mph	29.70 in	0.0 in	Light Rain
10:53 PM	52 °F	48 °F	86 %	E	14 mph	0 mph	29.66 in	0.0 in	Light Rain
11:53 PM	53 °F	49 °F	86 %	E	14 mph	20 mph	29.65 in	0.1 in	Light Rain
12:51 AM	54 °F	50 °F	88 %	E	20 mph	25 mph	29.62 in	0.0 in	Light Rain
12:53 AM	54 °F	50 °F	86 %	E	21 mph	25 mph	29.63 in	0.0 in	Light Rain
1:53 AM	55 °F	50 °F	83 %	ENE	8 mph	0 mph	29.61 in	0.0 in	Cloudy
2:04 AM	55 °F	50 °F	83 %	E	13 mph	0 mph	29.61 in	0.0 in	Cloudy
2:53 AM	56 °F	50 °F	80 %	E	12 mph	18 mph	29.60 in	0.0 in	Light Rain
3:36 AM	55 °F	51 °F	86 %	CALM	0 mph	0 mph	29.60 in	0.1 in	Rain
3:43 AM	55 °F	51 °F	86 %	E	6 mph	0 mph	29.60 in	0.1 in	Light Rain
3:53 AM	55 °F	51 °F	86 %	E	9 mph	0 mph	29.60 in	0.1 in	Light Rain
4:15 AM	55 °F	52 °F	89 %	NNW	7 mph	0 mph	29.61 in	0.0 in	Light Rain
4:19 AM	55 °F	52 °F	89 %	CALM	0 mph	0 mph	29.61 in	0.0 in	Rain

TABLE 3. JANUARY 22ND – 23RD – N/NE WINDS THROUGHOUT THE NIGHT

12:53 PM	66 °F	38 °F	36 %	WSW	12 mph	0 mph	29.90 in	0.0 in	Fair
1:53 PM	69 °F	33 °F	26 %	W	10 mph	0 mph	29.86 in	0.0 in	Fair
2:53 PM	69 °F	31 °F	24 %	NNE	8 mph	20 mph	29.86 in	0.0 in	Fair
3:53 PM	66 °F	27 °F	23 %	N	12 mph	0 mph	29.86 in	0.0 in	Fair
4:53 PM	63 °F	27 °F	26 %	NNW	12 mph	0 mph	29.87 in	0.0 in	Fair
5:53 PM	59 °F	26 °F	28 %	NE	14 mph	0 mph	29.89 in	0.0 in	Fair
6:53 PM	57 °F	25 °F	29 %	NNE	20 mph	29 mph	29.91 in	0.0 in	Fair
7:53 PM	54 °F	27 °F	35 %	NNE	16 mph	0 mph	29.92 in	0.0 in	Fair
8:53 PM	53 °F	28 °F	38 %	NE	12 mph	0 mph	29.94 in	0.0 in	Fair
9:44 PM	55 °F	29 °F	37 %	NNE	10 mph	0 mph	29.96 in	0.0 in	Fair
9:53 PM	54 °F	30 °F	40 %	N	10 mph	0 mph	29.96 in	0.0 in	Fair
10:53 PM	55 °F	29 °F	37 %	NNE	15 mph	0 mph	29.95 in	0.0 in	Fair
11:53 PM	52 °F	30 °F	43 %	ENE	7 mph	0 mph	29.97 in	0.0 in	Fair

Example Santa Ana wind events – October 2007, December 2017

TABLE 4. OCTOBER 21ST 2007

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
10:53 PM	67 °F	29 °F	24 %	ENE	15 mph	24 mph	29.87 in	0.0 in	Cloudy
11:53 PM	68 °F	29 °F	23 %	NE	21 mph	26 mph	29.86 in	0.0 in	Cloudy / Windy
12:53 AM	68 °F	29 °F	23 %	NNE	13 mph	0 mph	29.87 in	0.0 in	Cloudy
1:09 AM	66 °F	28 °F	24 %	CALM	0 mph	0 mph	29.88 in	0.0 in	Cloudy
1:53 AM	63 °F	31 °F	30 %	WNW	8 mph	18 mph	29.88 in	0.0 in	Cloudy
2:53 AM	61 °F	0 °F	34 %	NNW	7 mph	0 mph	29.88 in	0.0 in	Mostly Cloudy
3:13 AM	57 °F	0 °F	38 %	S	3 mph	0 mph	29.88 in	0.0 in	Partly Cloudy
3:30 AM	57 °F	34 °F	41 %	SE	3 mph	0 mph	29.89 in	0.0 in	Mostly Cloudy
3:53 AM	57 °F	35 °F	44 %	CALM	0 mph	0 mph	29.89 in	0.0 in	Mostly Cloudy
4:01 AM	57 °F	36 °F	44 %	CALM	0 mph	0 mph	29.89 in	0.0 in	Partly Cloudy
4:53 AM	50 °F	35 °F	57 %	CALM	0 mph	0 mph	29.91 in	0.0 in	Fair
5:53 AM	52 °F	35 °F	53 %	CALM	0 mph	0 mph	29.93 in	0.0 in	Fair
6:53 AM	50 °F	35 °F	57 %	CALM	0 mph	0 mph	29.97 in	0.0 in	Fair
7:53 AM	62 °F	35 °F	37 %	CALM	0 mph	0 mph	30.00 in	0.0 in	Fair
8:53 AM	69 °F	35 °F	29 %	CALM	0 mph	0 mph	30.01 in	0.0 in	Fair
9:53 AM	69 °F	36 °F	30 %	WSW	9 mph	0 mph	30.02 in	0.0 in	Fair
10:53 AM	72 °F	36 °F	27 %	VAR	6 mph	0 mph	30.03 in	0.0 in	Fair
11:53 AM	74 °F	30 °F	20 %	W	10 mph	0 mph	30.03 in	0.0 in	Fair
12:53 PM	74 °F	28 °F	18 %	W	12 mph	0 mph	30.01 in	0.0 in	Fair
1:53 PM	76 °F	25 °F	15 %	WNW	8 mph	0 mph	30.01 in	0.0 in	Fair
2:53 PM	76 °F	25 °F	15 %	WNW	10 mph	0 mph	30.01 in	0.0 in	Fair
3:53 PM	75 °F	28 °F	18 %	WSW	8 mph	0 mph	30.02 in	0.0 in	Fair
4:53 PM	70 °F	24 °F	18 %	WNW	8 mph	0 mph	30.03 in	0.0 in	Fair

TABLE 5. DEC 16TH 2017 – SANTA ANA WIND DRIVEN FIRE EVENT

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	54 °F	51 °F	90 %	E	7 mph	0 mph	29.84 in	0.0 in	Smoke
1:53 AM	59 °F	44 °F	58 %	E	6 mph	0 mph	29.79 in	0.0 in	Smoke
2:53 AM	54 °F	48 °F	80 %	CALM	0 mph	0 mph	29.80 in	0.0 in	Smoke
3:53 AM	51 °F	43 °F	74 %	WNW	13 mph	0 mph	29.77 in	0.0 in	Smoke
4:53 AM	51 °F	46 °F	83 %	E	3 mph	0 mph	29.72 in	0.0 in	Smoke
5:53 AM	45 °F	41 °F	86 %	CALM	0 mph	0 mph	29.71 in	0.0 in	Smoke
6:53 AM	55 °F	40 °F	57 %	NNE	18 mph	24 mph	29.69 in	0.0 in	Smoke
7:53 AM	57 °F	38 °F	49 %	NNE	10 mph	0 mph	29.69 in	0.0 in	Smoke
8:53 AM	59 °F	39 °F	48 %	CALM	0 mph	0 mph	29.70 in	0.0 in	Smoke
9:53 AM	66 °F	34 °F	30 %	CALM	0 mph	0 mph	29.70 in	0.0 in	Smoke
10:53 AM	67 °F	38 °F	34 %	S	8 mph	0 mph	29.70 in	0.0 in	Smoke
11:53 AM	68 °F	35 °F	30 %	VAR	3 mph	0 mph	29.67 in	0.0 in	Smoke
12:53 PM	68 °F	40 °F	36 %	S	6 mph	0 mph	29.66 in	0.0 in	Smoke
1:53 PM	65 °F	47 °F	52 %	SSE	5 mph	0 mph	29.66 in	0.0 in	Smoke
2:53 PM	64 °F	46 °F	52 %	ESE	6 mph	0 mph	29.66 in	0.0 in	Smoke
3:53 PM	62 °F	44 °F	52 %	CALM	0 mph	0 mph	29.66 in	0.0 in	Smoke
4:53 PM	63 °F	29 °F	28 %	NNE	7 mph	0 mph	29.68 in	0.0 in	Smoke
5:53 PM	64 °F	26 °F	24 %	N	10 mph	0 mph	29.70 in	0.0 in	Smoke
6:53 PM	60 °F	26 °F	27 %	NE	3 mph	0 mph	29.73 in	0.0 in	Smoke
7:53 PM	57 °F	33 °F	40 %	VAR	5 mph	0 mph	29.74 in	0.0 in	Smoke
8:53 PM	58 °F	26 °F	30 %	CALM	0 mph	0 mph	29.76 in	0.0 in	Smoke
9:53 PM	57 °F	27 °F	32 %	NE	3 mph	0 mph	29.77 in	0.0 in	Smoke
10:53 PM	47 °F	27 °F	46 %	WNW	7 mph	0 mph	29.79 in	0.0 in	Smoke
11:53 PM	47 °F	28 °F	48 %	CALM	0 mph	0 mph	29.80 in	0.0 in	Smoke

TABLE 6. DEC 20TH 2017 – POSSIBLE SANTA ANA WIND EVENT

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	44 °F	43 °F	96 %	N	5 mph	0 mph	30.14 in	0.0 in	Partly Cloudy
1:53 AM	44 °F	43 °F	96 %	CALM	0 mph	0 mph	30.13 in	0.0 in	Fair
2:53 AM	42 °F	42 °F	100 %	NNW	3 mph	0 mph	30.14 in	0.0 in	Partly Cloudy
3:53 AM	40 °F	40 °F	100 %	CALM	0 mph	0 mph	30.13 in	0.0 in	Mostly Cloudy
4:34 AM	43 °F	41 °F	93 %	CALM	0 mph	0 mph	30.12 in	0.0 in	Cloudy
4:53 AM	42 °F	40 °F	92 %	W	3 mph	0 mph	30.12 in	0.0 in	Cloudy
5:29 AM	44 °F	41 °F	89 %	CALM	0 mph	0 mph	30.11 in	0.0 in	Partly Cloudy
5:53 AM	43 °F	41 °F	93 %	CALM	0 mph	0 mph	30.12 in	0.0 in	Partly Cloudy
6:53 AM	42 °F	40 °F	92 %	CALM	0 mph	0 mph	30.12 in	0.0 in	Partly Cloudy
7:53 AM	46 °F	44 °F	93 %	CALM	0 mph	0 mph	30.12 in	0.0 in	Mostly Cloudy
8:53 AM	50 °F	45 °F	83 %	CALM	0 mph	0 mph	30.14 in	0.0 in	Cloudy
9:53 AM	57 °F	47 °F	69 %	VAR	3 mph	0 mph	30.14 in	0.0 in	Partly Cloudy
10:53 AM	59 °F	48 °F	67 %	S	6 mph	0 mph	30.12 in	0.0 in	Mostly Cloudy
11:53 AM	61 °F	47 °F	60 %	VAR	3 mph	0 mph	30.08 in	0.0 in	Fair
12:53 PM	64 °F	48 °F	56 %	WSW	20 mph	30 mph	30.04 in	0.0 in	Partly Cloudy
1:53 PM	63 °F	47 °F	56 %	W	16 mph	24 mph	30.01 in	0.0 in	Mostly Cloudy
2:53 PM	63 °F	46 °F	54 %	WNW	20 mph	26 mph	29.99 in	0.0 in	Fair
3:53 PM	58 °F	43 °F	58 %	W	16 mph	26 mph	29.96 in	0.0 in	Fair
4:53 PM	58 °F	36 °F	44 %	NW	10 mph	0 mph	29.97 in	0.0 in	Partly Cloudy
5:52 PM	57 °F	30 °F	36 %	N	12 mph	25 mph	29.99 in	0.0 in	Fair
6:53 PM	55 °F	24 °F	30 %	N	9 mph	0 mph	30.01 in	0.0 in	Partly Cloudy
7:53 PM	53 °F	22 °F	30 %	NNE	13 mph	0 mph	30.04 in	0.0 in	Fair
8:53 PM	55 °F	20 °F	25 %	N	12 mph	29 mph	30.04 in	0.0 in	Fair
9:53 PM	52 °F	18 °F	26 %	N	8 mph	0 mph	30.06 in	0.0 in	Fair
10:53 PM	52 °F	19 °F	27 %	VAR	3 mph	0 mph	30.07 in	0.0 in	Fair
11:53 PM	42 °F	23 °F	47 %	N	5 mph	0 mph	30.07 in	0.0 in	Fair

APPENDIX F. DEAD WOOD REMOVAL AND MONARCH BUTTERFLY HABITAT EFFECTS

Dead wood removal and monarch butterfly habitat effects

March 9, 2022

TO: George Thomson
Parks & Open Space Manager
City of Goleta - Public Works Department

FROM: Dr. Daniel Meade, Principal Scientist, Althouse and Meade, Inc.
Dr. Stu Weiss, Chief Scientist, Creekside Science

Removal of dead downed wood and dead standing trees benefits monarch butterfly habitat and forest health. Forest habitat is best for monarch butterflies when it provides a balance between cover and room for flight. Wind shelter by a dense outer screen of trees is critical. Inside that screen, dappled light is key to monarch aggregation locations. Very dense canopies from overcrowded trees or open canopies from death of trees are not suitable as monarch aggregation habitat.

The Xerces Society guidelines for managing monarch groves (The Xerces Society 2017) suggests that even very important trees (VITs), "…that are also hazard trees should be replaced." (pg. 14). "Completely dead trees and branches generally do not contribute to monarch habitat and are a potential liability. Felled debris from diseased and infected trees should be removed from the habitat to eliminate host material." (pg. 19). "Standing dead trees generally do not contribute to monarch habitat and are a hazard to people and other trees." (pg.25).

The 1993 Monarch conservation and management guidelines (Bell et al. 1993) state, "Theauthors recognize the importance of removing hazardous trees from forests." (Recommendation 18). And "Understory levels should be managed to prevent a localizedbuildup of dead plant materials." (Recommendation 30).

Monarch Habitat

In our experience of visiting scores of monarch butterfly aggregation sites during more than 30 years of observation, monarch butterflies prefer to aggregate in locations with a wind protection buffer surrounding a more open center that allows access and patrolling space for flying butterflies. Monarchs leave roosts subject to disruptive wind (Leong 2016) for protected locations that provide dappled light and ameliorate temperature and humidity extremes.

Monarch aggregation habitats often have low to moderate densities of ground vegetation with an open mid story within the wind protected area. Several famous monarch butterfly aggregation sites, such as Pismo Beach and Pacific Grove have highly managed understories free of downed wood. The relatively clear floors in those groves include wide walking paths thatare not detrimental to monarch aggregations that form in the surrounding trees.

In Ellwood, monarchs have sought out wind-sheltered gaps in the forest to form their aggregations. Ellwood Main prior to the recent drought die-off was the exemplar of an aggregation site with a “Cathedral” structure consisting of an open understory, minimal ground cover, and a high vertical open space encompassed by protective trees. Surrounding slopes contributed to wind shelter and tall canopy trees formerly provided ideal dappled light and room to fly. The northern entrance to the aggregation site remained open and thicker vegetation around the edges of the site provided excellent wind buffering. The drought die-off of trees changed the site and where protective trees stood west and east of the grove, tangles of dead fallen wood and standing dead stems occupy the space and allow wind to penetrate far deeper into the grove than previously. Within the aggregation site, standing dead trees place other treesat risk, and downed trees and debris interfere with recruitment of replacement trees. Ellwood Main no longer provides the excellent aggregation habitat as in past years.

Monarchs are often observed flying through stands of trees investigating habitat. This behaviorcan lead them to aggregations. Groves where trees are too dense, or where debris and tanglesof dead wood block patrolling areas, reduce access and increase effort to locate suitable roosting locations.

Historically, Ellwood forests were managed to remove dead wood and maintain healthy standsof trees through normal forestry practices (Santos 1997, Meade personal observation). Failure to manage a grove results in over recruitment of trees during periods of higher rainfall and then death of trees during times of water stress (droughts). Appropriately managing tree density based on water demand creates a more stable grove and is a fundamental tenet of forestry management, even for groves managed for wildlife (Grebner et al. 2021, Taylor 2018).

Eucalyptus does not break down as quickly as native vegetation and wood and bark debris that accumulates on the ground retains nutrients and can inhibit new growth. Fallen blue gum eucalyptus trees decompose very slowly (DiTomaso et al. 2013), especially in dry climates. Thehigh level of phenolics in eucalyptus inhibits fungi from breaking down the wood and allows accumulation of fire fuel (Reid et al.2005). Chipping will aid the release of nutrients from woodydebris by converting coarse wood to fine pieces (Russell et al. 2015). Mulching around new forest plantings can increase planting survival and growth rate (Cahill et al. 2005, Chalker-Scott2007).

Wildfire Risk

Accumulation of bark and dead wood on the ground and leaning into the tree canopy creates a major fire hazard to monarch habitats (Xerces 2017). Ignition from camp fires and other human sources can feed on ground debris and quickly escalate into a catastrophic fire event. This risk can be managed by reducing fuel load through removal of dead branches, trunks and highly flammable vegetation that can create fire ladders into the forest crown. The Ellwood groves, once managed for wood production, now present a tangle of downed wood, dead leaning trunks and over abundant understory shrubs. The City of Goleta Community Wildfire Protection Plan (2012) provides management recommendations to reduce, “potential fire intensity, rate of spread, and severity of effects.” (pg 58). Management prescriptions in the CWPP when implemented will help to protect life, property, and natural resources including monarch butterflyhabitat.

The presence of large quantity of dead wood at Ellwood results in:

- Increased wind penetration and speed at aggregation locations due to downed trees.
- Higher risk to remaining live trees
- Reduction in shade at aggregation sites
- Loss of cover for butterflies from predators
- Poor recruitment and growth of replacement trees
- Increased wildfire risk - intensification of fires and a fire ladder to canopy
- Public safety hazard from dead standing and leaning trees and ground debris

Removal of dead wood from the Ellwood forests and monarch groves will have positive effects for monarch butterflies.

- Removal and replacement of dead trees will increase humidity and shade and boost protection of monarchs.
- Removal of downed trees and branches eliminates debris tangles that interfere with recruitment of saplings and growth of trees with good form.
- Space for planting trees will be opened by removing dead wood.
- Removal of leaning dead trees and branch and debris tangles will improve patrolling and clustering habitat for monarch butterflies.
- Reduction of hazards for visitors to the grove
- Preserve habitat by reducing intensity and rate of spread of fires.

Photo 1 shows the dead stand along the trail that runs west of the gully at Ellwood Main. Large tangles of fallen trees lie among the standing dead, and the canopy is very open.

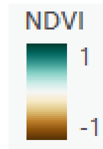
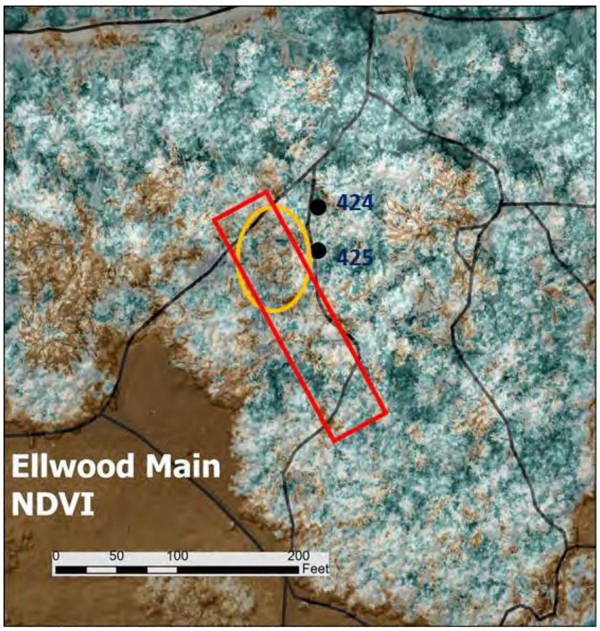
The hemispherical photographs (hemiphotos) below show some of the impacts of tree mortalityon the effectiveness of windbreaks. Photo 2 was taken near the same site as Photo 1 above. The hemiphoto is taken straight up - the horizon is at the circular edge, and the zenith is the center of the circle. North is at the top of the photograph, and east and west are reversed froma map view because the photograph is looking upward. The opening in the orange circle in the SW direction is where many trees died (the site in Photo1), allowing wind to penetrate well intothe aggregation site. The dead standing trees block only a tiny fraction of the sky compared with the live trees in other directions. Photo 3 was taken 10 meters south of Photo 2, showing the same wind shelter gap, which affects a large area downwind. In this case, the loss of shelter against prevailing SW winds has degraded the quality of Ellwood Main.

Photo 2

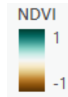
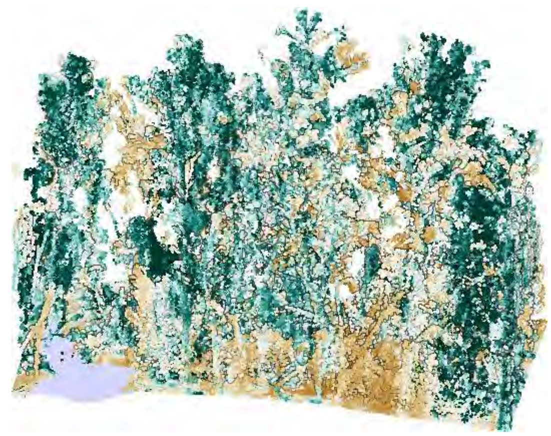
Photo 3

The map below shows a measure of canopy greenness (Normalized Difference Vegetation Index, NDVI) where the blue-green shows healthy foliage and the brown shows dead canopy (and brown grass outside of the forest). Note how much of the canopy around Ellwood Main has died, leaving dead standing trees, and large piles of downed wood.

The orange circle is the gap in Photos 1-3., which leaves the aggregation area to the east of the photograph sites (424 and 425) vulnerable to prevailing SW winds. Note also the numerous dead tree crowns throughout Ellwood Main, and the particularly large dead area at the western edge of the map, which is shown from the ground in Photo 4.

Normalized DIfference Vegetation Index (NDVI) map of Ellwood Main. Blue-green is live foliage (high NDVI) and brown is dead trunks, branches, and grass.	
Map 1 	Photo 4 

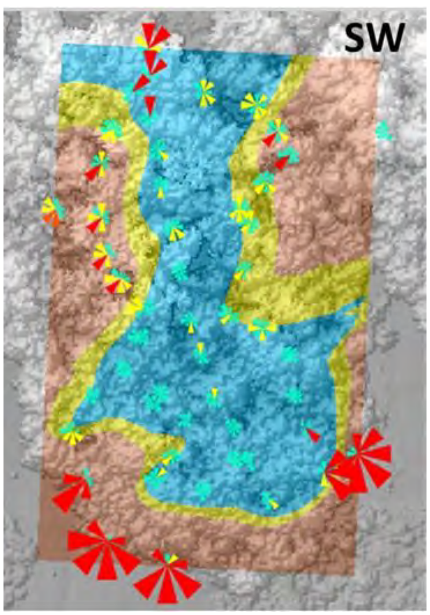
Below is a profile of forest, with the same NDVI color scale as Map 1, taken along the west edge of Ellwood Main (red rectangle). The small dip at the left is the road from the mesa going down to Deveraux Creek. The large masses of brown dead trees stand out, with a particularly dense mass of dead trees at the center-right. The oblique view gives some sense of the depth of the dead zone. All of the dead standing material will eventually fall to the ground, further opening up the canopy to wind.

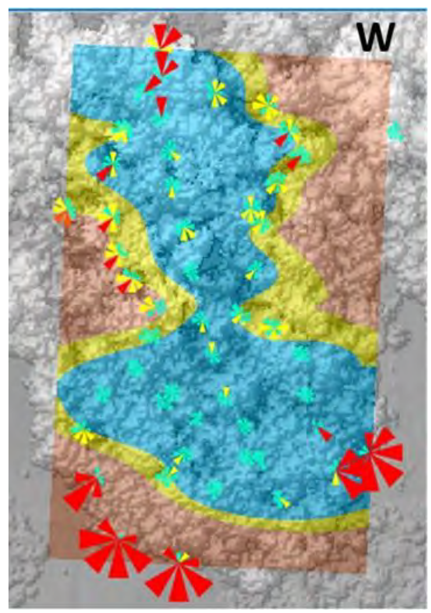
Profile view west side Ellwood Main 	Oblique view west side Ellwood Main
	

Maps of wind exposure

The map below shows “wind roses” of the exposure from eight cardinal directions, with size of the arrow being proportional to the fraction of open sky in that direction. The arrows are color coded where blue is well-sheltered (<0.20), yellow is marginal (0.20-0.30) and red is high exposure (>0.30). The same colors are used for the interpolated surfaces of SW wind (left) and W wind (right).

The increased wind penetration into the western edge, caused by the tree deaths, is apparent in the red and yellow intrusions. Sealing up this edge will greatly increase habitat suitability within Ellwood Main.





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APPENDIX G. ELLWOOD MONARCH BUTTERFLY HABITAT CHARACTERIZATION REPORT

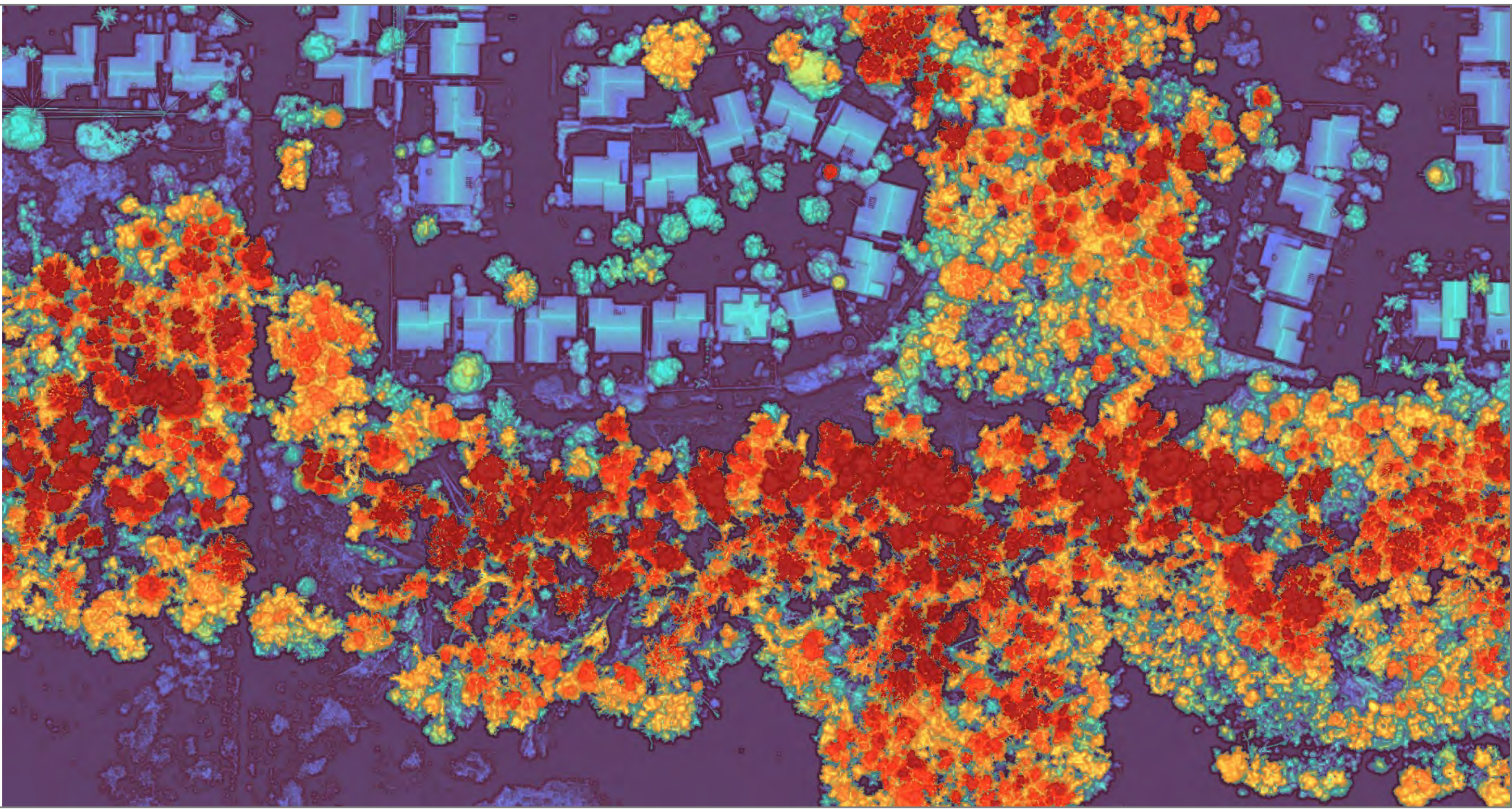
Prepared by NV5 dated October 24, 2022

ELLWOOD MESA MONARCH BUTTERFLY HABITAT CHARACTERIZATION

October 24, 2022

Prepared For:

Althouse and Meade, Inc.
Dan Meade
1602 Spring St
Paso Robles, CA 93446
dan@althouseandmeade.com



1100 NE Circle Blvd
Suite 126
Corvallis, OR 97330

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1.0 INTRODUCTION

In June 2020, NV5 Geospatial (NV5G) was contracted by Althouse and Meade, Inc. to collect high density Light Detection and Ranging (lidar) and multispectral orthoimagery data for the fall of 2021 across the Ellwood Mesa site in Goleta, California. Site characterization products were then developed to support planning, management, and future analysis of the Ellwood Mesa site using the lidar, imagery, and field data provided by Stu Weiss of Creekside Science.

The Ellwood Mesa Monarch Butterfly Habitat Characterization Project was undertaken using an experimental approach that would allow for the design of custom deliverables to meet the needs of various stakeholders involved in the project. By working with Stu Weiss of Creekside Science and Althouse and Meade, Inc. a suite of analytical datasets was outlined to support the characterization of monarch butterfly habitat and management of the Ellwood Mesa project area. An important outcome for this project was to create analytical products that would support the rehabilitation of the eucalyptus grove and site management to mitigate wildfire risk for nearby structures. To support these efforts, deliverable datasets were designed to leverage the three-dimensional nature of a lidar point cloud to identify the presence of vegetation and dead material in different height strata throughout the project area. The three primary deliverables designed for this project are lidar point density profiles for ladder fuels assessment, standing dead and downed woody debris classification, and simulated fisheye photos from the lidar point cloud. These datasets were identified as being more valuable to the characterization of monarch butterfly habitat and site management than the tree and canopy metric deliverables originally outlined in the project proposal.

This report accompanies the delivered lidar data, imagery, and analytical products. It documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including lidar accuracy and density. Acquisition dates and acreage are shown in Table 1, the projection information for the project is shown in Table 2, a complete list of contracted deliverables provided to Althouse and Meade, Inc. and Creekside Science is shown in Table 3 and Table 4, and the project area of interest (AOI) is shown in Figure 1.

Table 1: Acquisition dates, acreage, and data types collected on the Ellwood site

Project Site	Contracted Acres	Buffered Acres	Acquisition Dates	Data Type
Ellwood	230	270	09/27/2021	Lidar
Ellwood	230	270	10/29/2021	5 band (Red, Green, Blue, Near Infrared, Red Edge) Digital Imagery

Table 2: Deliverable product projection information.

Projections	EPSG	Horizontal Datum	Vertical Datum	Units
California zone 5	6424	NAD83(2011)	NAVD88 (GEOID18)	US Survey Feet

Table 3: Lidar and imagery products delivered for the Ellwood site.

Product Type	File Type	Product Details
Points	LAS v 1.4 (*.las, *.laz)	All Classified Returns
Vectors	Shapefiles (*.shp)	• Project Area of Interest • Lidar Tile Index • Ground Survey Data
Rasters	GeoTiffs (*.tif)	• Bare Earth Digital Elevation Model (DEM) – 1.5 ft resolution • Highest Hit Digital Surface Model (DSM) – 1.5 ft resolution • Normalized Digital Surface Model (nDSM) – 1.5 ft resolution • Intensity Raster – 0.25 ft resolution
Digital Imagery	GeoTiffs (*.tif)	9.75 cm Orthophotography • 5 spectral bands (RGB, NIR, Red Edge)

Table 4: Analytical products delivered for the Ellwood site.

Product Type	File Type	Product Details
Points	LAS v 1.4 (*.las)	Height Normalized Point Cloud with Custom Classification • Standing dead wood (64), downed woody debris (65), tree stems (67), ground (2), and unclassified (1).
Vectors	Shapefiles (*.shp)	• Point Density Profiles Summarized to 100 ft x 100 ft Ladder Fuel Grid • Adjusted Plot Locations
Rasters	GeoTiffs (*.tif)	• Point Density Profiles – 1 meter resolution • Dead Material Volume Rasters o Standing Dead Wood – 6-inch and 12-inch voxel o Downed Woody Debris – 6-inch and 12-inch voxel
Tables	Comma Separated Values (*.csv)	Point Density Profiles Summarized to 100 ft x 100 ft Ladder Fuel Grid
Images	JPEG (*.jpeg)	Simulated Fisheye Photos from Lidar Point Cloud • Adjusted plot locations with points of view (POV) located 1.75, 5, and 10 meters above ground • Historic Monarch cluster locations with POV located at 5-foot intervals for the range of heights measured for each Monarch cluster.

Figure 1: Location map of the Ellwood 2021 site in California.

2.0 ACQUISITION

2.1 PLANNING

In preparation for data collection, NV5 Geospatial reviewed the project area and developed a specialized flight plan to ensure complete coverage of the Ellwood Mesa lidar study area at the target point density of ≥50.0 points/m². Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flight were continuously monitored due to their potential impact on the daily success of airborne and ground operations. In addition, logistical considerations including private property access and potential air space restrictions were reviewed.

2.2 AIRBORNE SURVEY

2.2.1 Lidar

The lidar survey was accomplished using a Riegl VUX-1UAV system mounted on an DJI Matrice 600 Unmanned Aerial Vehicle (UAV) (Figure 2). Table 5 summarizes the settings used to yield an average pulse density of ≥50 pulses/m² over the Ellwood Mesa project area. The Riegl VUX-1UAV laser system can record 8 range measurements (returns) per pulse at 122 meters nominal terrain height. It is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the lidar sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset.

Figure 2: NV5 Geospatial's DJI M600 with Riegl VUX-1LR LiDAR Scanner.

Table 5: Lidar specifications and survey settings

Lidar Survey Settings & Specifications	Details
Acquisition Dates	September 27, 2021
Aircraft Used	DJI Matrice 600
Sensor	Riegl
Laser	VUX-1UAV
Maximum Returns	8
Resolution/Density	Average 50 pulses/m^2
Survey Altitude (AGL)	122 m
Survey speed	15 knots
Field of View	90º
Mirror Scan Rate	78.5 Lines Per Second
Target Pulse Rate	820 kHz
Pulse Length	3 ns
Laser Pulse Footprint Diameter	6.1 cm
Central Wavelength	1064 nm
Pulse Mode	Multiple Times Around (MTA)
Beam Divergence	0.5 mrad
Swath Width	244 m
Swath Overlap	50%
Intensity	16-bit
Accuracy	RMSEZ ≤ 10 cm

All areas were surveyed with an opposing flight line side-lap of ≥50% (≥100% overlap) in order to reduce laser shadowing and increase surface laser painting. To accurately solve for laser point position (geographic coordinates x, y and z), the positional coordinates of the airborne sensor and the attitude of the aircraft were recorded continuously throughout the lidar data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.

2.2.2 Digital Imagery

Imagery was collected using a Micasense Red Edge-MX digital mapping camera (Table 6). The Red Edge –MX is a global shutter multispectral camera manufactured by Micasense. The system is mounted fixed to the UAS platform and collects multispectral imagery and Downwelling Light Sensor (DLS) data.

Table 6: Camera manufacturer's specifications.

Camera Specification	Details
Equipment	Micasense Red Edge-MX
Focal Length	5.4 mm
Data Format	Blue, Green, Red, NIR, Red Edge
Pixel Size	8 cm @ 120 m
Image Size	1,280 x 960 pixels
Frame Rate	1 Hz
HFOV	47.2°

For the Ellwood Mesa site, images were collected in five spectral bands (red, green, blue, NIR, and Red Edge) with 90% along track overlap and 75% sidelap between frames. The acquisition flight parameters were designed to yield a native pixel resolution of ≤ 10 cm. Orthophoto specifications particular to the Ellwood Mesa project are in Table 7.

Table 7: Project-specific orthophoto specifications.

Orthophoto Specification	Details
Equipment	Micasense Red Edge - MX
Spectral Bands	Blue, Green, Red, NIR, Red Edge
Ground Sampling Distance (GSD)	9.4 cm pixel size
Along Track Overlap	≥90%
Cross Track Overlap	≥75%
Above Ground Level (AGL)	122 meters
GPS PDOP	≤3.0
GPS Satellite Constellation	≥6
Image	8-bit GeoTiff

2.3 GROUND SURVEY

Ground control surveys, including monumentation, aerial targets and ground survey points (GSPs) were conducted to support the airborne acquisition. Ground control data were used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final lidar data and orthoimagery products.

2.3.1 Base Stations

Base stations were utilized for collection of ground survey points using real time kinematic (RTK) and static survey techniques. Base station locations (Table 8) were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage.

Table 8: Base station position for the Ellwood acquisition. Coordinates are on the NAD83 datum.

Monument ID	Latitude	Longitude	Ellipsoid (meters)
1000	34° 25' 16.71413"	-119° 53' 48.47240"	-9.868

NV5 Geospatial utilized static Global Navigation Satellite System (GNSS) data collected at 1 Hz recording frequency for each base station. During post-processing, the static GNSS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS[1]) for precise positioning. Multiple sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy.
Ground control was collected using real time kinematic (RTK) survey techniques. For RTK surveys, a roving receiver receives corrections from a nearby base station via radio, enabling rapid collection of points with relative errors less than 1.5 cm horizontal and 2.0 cm vertical. RTK surveys record data while stationary for at least thirty, one-second epochs for aerial targets and five, one-second epochs for GSPs. All aerial targets were calculated by taking the average of two independent thirty, one-second epochs. All GSP measurements were made during periods with a Position Dilution of

[1] OPUS is a free service provided by the National Geodetic Survey to process corrected monument positions. http://www.ngs.noaa.gov/OPUS.

Precision (PDOP) of ≤ 3.0 with at least six satellites in view of the stationary and roving receivers. See Table 9 for Trimble unit specifications.

2.3.2 Ground Survey Points (GSPs)

GSPs were collected in areas where good satellite visibility was achieved on paved roads and other hard surfaces such as gravel or packed dirt roads. GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads due to the increased noise seen in the laser returns over these surfaces. GSPs were collected within as many flightlines as possible; however, the distribution of GSPs depended on ground access constraints and monument locations and may not be equitably distributed throughout the study area (Figure 3).

2.3.3 Air Targets

Ground survey data were collected by NV5 Geospatial to adjust aircraft positional and attitude data and to perform an accuracy assessment of final orthophoto products. NV5 Geospatial collected hard surface air targets typically on high visibility road markings or temporary white vinyl chevrons. Air target points were surveyed throughout the Ellwood Mesa study area, prior to imagery acquisition, using RTK techniques (Figure 3). Hard surface points consisted of high contrast, road markings such as stop bars, turn arrows, or cement corners. Typically, each corner of the road marking or temporary air target panel was surveyed, in this way only one point was used for aerial triangulation while the remaining points were used for quality assurance purposes.

Table 9: NV5 Geospatial ground survey equipment identification.

Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R10	Integrated Antenna	TRMR10 NONE	Rover

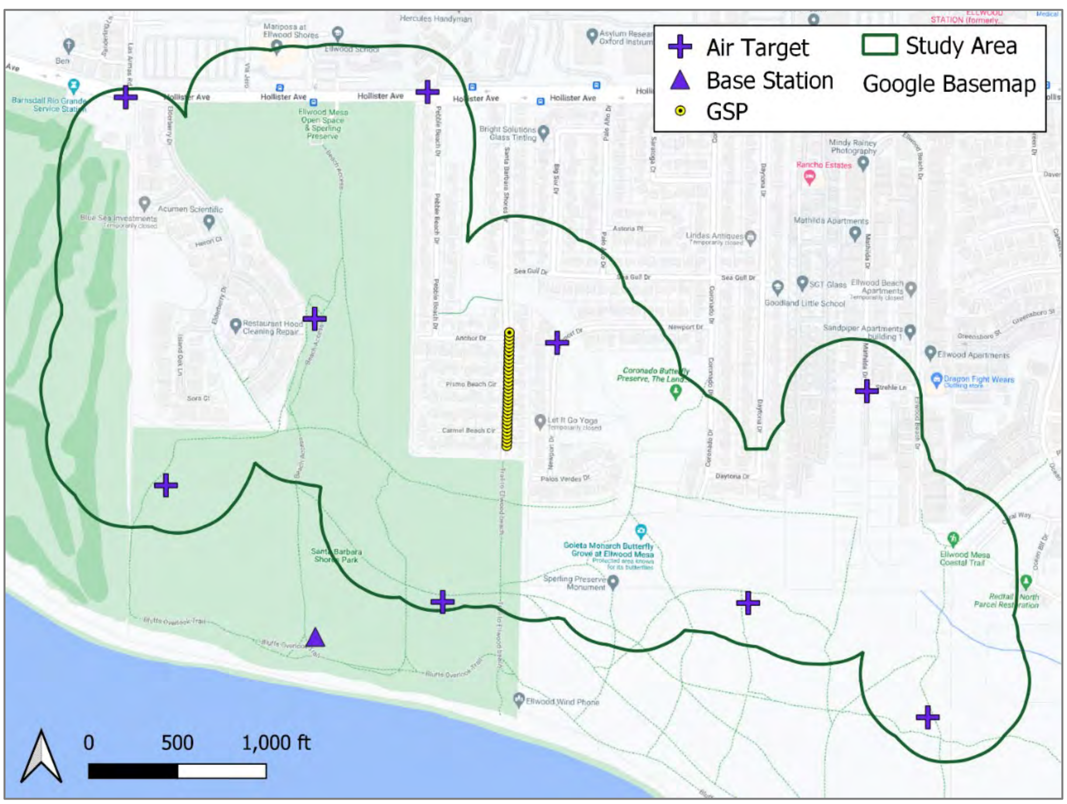


Figure 3: Ground survey location map.

3.0 LIDAR AND IMAGERY PROCESSING

3.1 LIDAR DATA

Upon completion of data acquisition, NV5 Geospatial processing staff initiated a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks included GPS control computations, smoothed best estimate trajectory (SBET) calculations, kinematic corrections, calculation of laser point position, sensor, and data calibration for optimal relative and absolute accuracy, and lidar point classification (Table 10). Processing methodologies were tailored for the landscape. Figure 4 shows a cross section of the lidar acquired in the Ellwood Mesa project area.

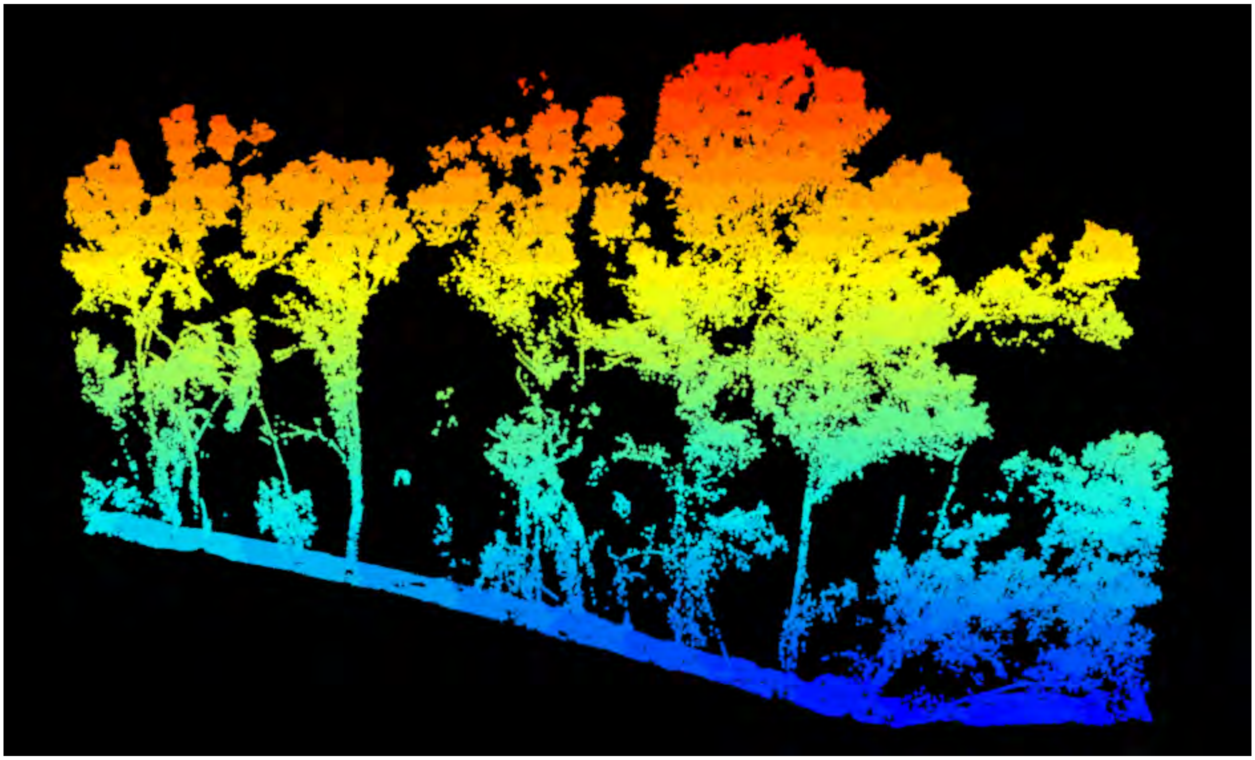


Figure 4: Cross section of the lidar point cloud in Ellwood.

Table 10: ASPRS LAS classification standards applied to the Ellwood dataset.

Classification Number	Classification Name	Classification Description
1	Default/Unclassified	Laser returns that are not included in the ground class, composed of vegetation and anthropogenic features
2	Ground	Laser returns that are determined to be ground using automated and manual cleaning algorithms

3.2 DIGITAL IMAGERY

To produce a normalized multispectral orthomosaic in post-processing it was necessary to take radiance images of a calibration panel with known spectral reflectance in each of the collected spectral bands. These images are then used for spectral reflectance calibration, which normalizes the radiance values across all acquired imagery and calculates resulting reflectance values for each image.

Images of each spectral band were matched to their respective camera station and composited into stacked 5 band images. In Agisoft Metashape, these images were then adjusted and orthorectified using the Lidar-derived ground model to remove displacement effects from topographic relief inherent in the imagery. The resulting orthos were mosaicked and exported. The final mosaic was inspected and edited for seam cutlines across above ground features such as buildings and other man-made features.

4.0 ACQUISITION RESULTS AND ACCURACY ASSESSMENT

4.1 LIDAR DENSITY

The acquisition parameters were designed to acquire an average first-return density of 50 points/m^2. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in first return density analysis. Some types of surfaces (e.g., breaks in terrain, water, and steep slopes) may have returned fewer pulses than originally emitted by the laser. First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas, the highest feature could be a tree, building or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The density of ground-classified lidar returns was also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may penetrate the canopy, resulting in lower ground density.

The average first-return density of lidar data for the Ellwood Mesa project was 277.81 points/m^2 (Table 11). The statistical distribution of first return densities per 1 meter x 1 meter cell are portrayed in Figure 5.

Table 11: Average lidar point densities.

Classification	Point Density
First-Return	277.81 points/m^2

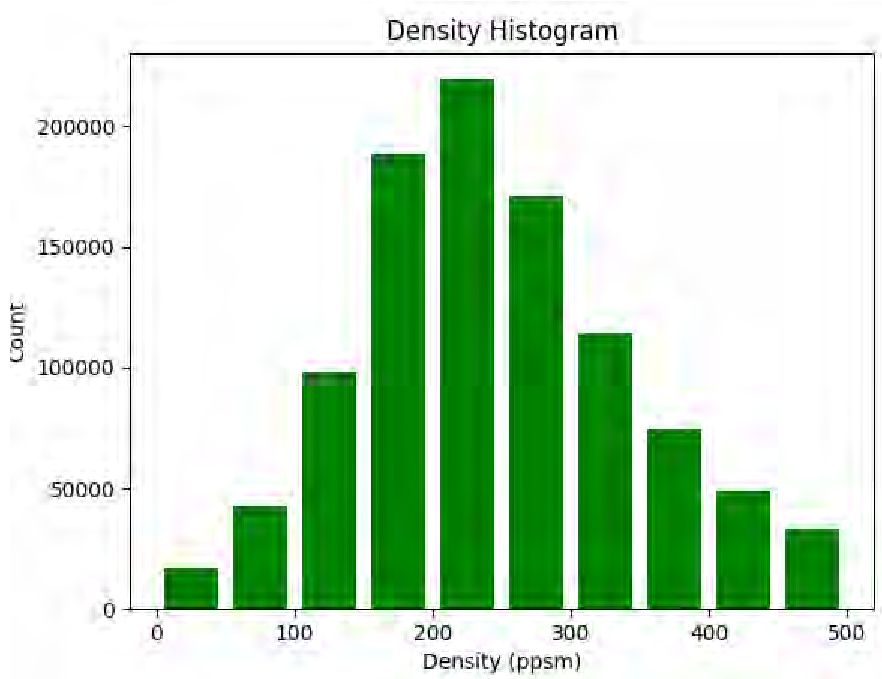


Figure 5: Frequency distribution of first return point density values per 1 x 1 meter cell.

4.2 LIDAR ACCURACY ASSESSMENTS

The accuracy of the lidar data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Acquisition Accuracy Controls for further information on sources of error and operational measures used to improve relative accuracy.

4.2.1 Lidar Non-Vegetated Vertical Accuracy

Absolute accuracy was assessed using Non-Vegetated Vertical Accuracy (NVA) reporting designed to meet guidelines presented in the FGDC National Standard for Spatial Data Accuracy[2]. NVA compares known ground check point data that were withheld from the calibration and post-processing of the lidar point cloud to the triangulated surface generated by the classified lidar point cloud as well as the derived gridded bare earth DEM. NVA is a measure of the accuracy of lidar point data in open areas where the lidar system has a high probability of measuring the ground surface and is evaluated at the 95% confidence interval (1.96 * RMSE), as shown in Table 12.

The mean and standard deviation (sigma σ) of divergence of the ground surface model from quality assurance point coordinates are also considered during accuracy assessment. These statistics assume the error for x, y and z is normally distributed, and therefore the skew and kurtosis of distributions are also considered when evaluating error statistics. For the Ellwood Mesa survey, 41 ground check points were withheld from the calibration and post processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.078 feet compared to classified LAS, and 0.066 feet as compared to the bare earth DEM, with 95% confidence (Figure 6, Figure 7).

Table 12: Absolute accuracy results.

	NVA, as compared to classified LAS	NVA, as compared to bare earth DEM
Sample	41 points	41 points
95% Confidence (1.96*RMSE)	0.078 ft	0.066 ft
Average	-0.015 ft	-0.013 ft
Median	-0.017 ft	-0.012 ft
RMSE	0.040 ft	0.033 ft

[2] Federal Geographic Data Committee, ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA EDITION 1, Version 1.0, NOVEMBER 2014. https://www.asprs.org/a/society/committees/standards/Positional_Accuracy_Standards.pdf.

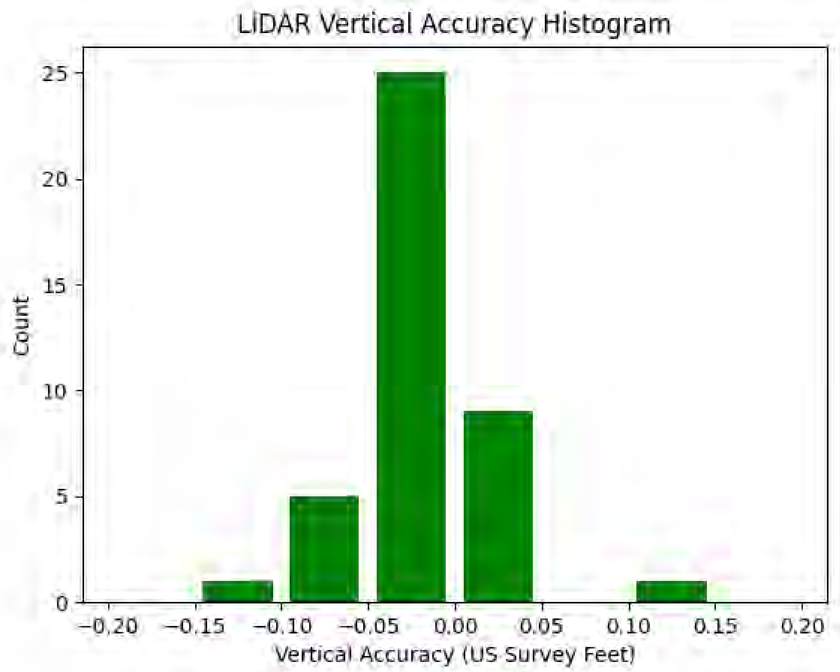


Figure 6: Frequency histogram for lidar classified LAS deviation from ground check point values (NVA).

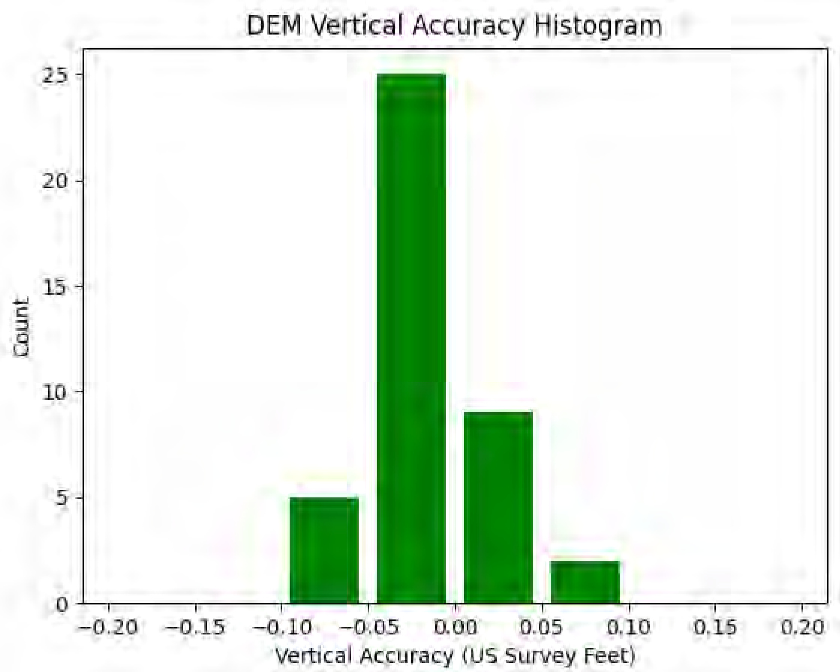


Figure 7: Frequency histogram for the lidar bare earth DEM surface deviation from ground check point values (NVA)

4.2.2 Lidar Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the Ellwood Mesa Lidar project was 0.079 feet (0.024 meters) (Table 13, Figure 8).

Table 13: Relative accuracy results

Relative Accuracy	
Sample	17 surfaces
Average	0.001 ft
Median	0.001 ft
RMSE	0.083 ft
Total Compared Points	6,465,865

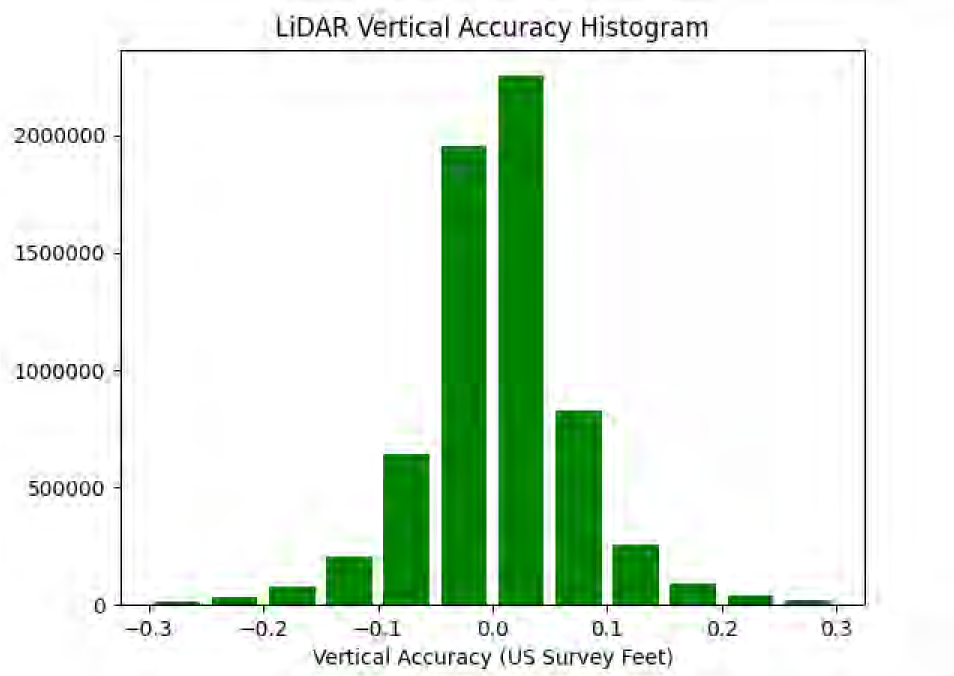


Figure 8: Frequency plot for relative vertical accuracy between flight lines

4.2.3 Lidar Horizontal Accuracy

Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95 percent of the time. Based on a flying altitude of 122 meters, an IMU error of 0.016 decimal degrees, and a GNSS positional error of 0.019 meters, this project was compiled to meet 0.36 feet (0.11 m) horizontal accuracy at the 95% confidence level (Table 14).

Table 14: Lidar horizontal accuracy.

Unit	RMSEr	ACCr
Feet	0.21 ft	0.36 ft
Meter	0.06 m	0.11 m

4.3 ORTHOPHOTO ACCURACY

Image accuracy was assessed using the air target points from the aerial triangulation procedure. Image accuracy results are shown in Figure 9 and Table 15.

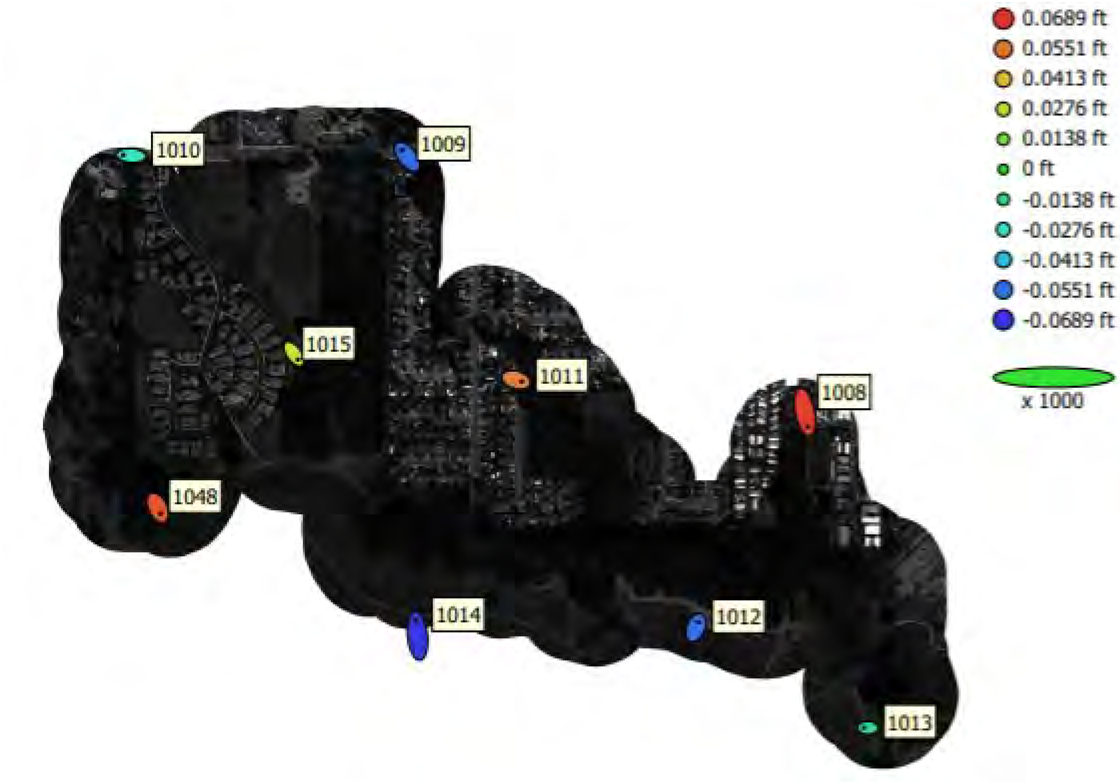


Figure 9: Map of orthophoto accuracy assessments.

Table 15: Orthophotography accuracy statistics for Ellwood Mesa.

Count	X Error (ft)	Y Error (ft)	Z Error (ft)	XY Error (ft)	Total (ft)
9	0.0541056	0.0969402	0.0521177	0.111017	0.122642

4.3.1 Ground Control

Air target points from the aerial triangulation adjustment are listed with their location and residuals in Table 16.

Table 16: Location of air target check points withheld from aerial triangulation adjustment.

Label	X Error (ft)	Y Error (ft)	Z Error (ft)	Total (ft)	Image (pix)
1008	0.035652	-0.176307	0.0661093	0.191639	6.390 (17)
1009	-0.0633332	0.0813204	-0.0578349	0.11819	10.845 (8)
1010	-0.0950713	0.00616302	-0.028731	0.0995088	6.922 (8)
1011	0.070953	-0.0208685	0.0536556	0.0913714	5.937 (11)
1012	0.0282189	0.0662476	-0.0564813	0.0915161	26.104 (9)
1013	-0.046341	0.00135106	-0.0213413	0.0510369	29.024 (8)
1014	-0.0175511	0.178497	-0.0674167	0.19161	23.088 (8)
1015	0.0499553	-0.0690696	0.0321876	0.0911163	7.289 (8)
1048	0.0352748	-0.0733733	0.0616433	0.102117	16.989 (8)
Total	0.0541056	0.0969402	0.0521177	0.122642	16.189

4.3.2 Anomalies and Misfits

No anomalies or misfits detected.

4.4 ACQUISITION ACCURACY CONTROLS

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data were tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

Table 17: Lidar accuracy error sources and solutions.

Type of Error	Source	Post Processing Solution
GPS (Static/Kinematic)	Long Base Lines	None
GPS (Static/Kinematic)	Poor Satellite Constellation	None
GPS (Static/Kinematic)	Poor Antenna Visibility	Reduce Visibility Mask
Relative Accuracy	Poor System Calibration	Recalibrate IMU and sensor offsets/settings
Relative Accuracy	Inaccurate System	None
Laser Noise	Poor Laser Timing	None
Laser Noise	Poor Laser Reception	None
Laser Noise	Poor Laser Power	None
Laser Noise	Irregular Laser Shape	None

Operational measures taken to improve relative accuracy:

Low Flight Altitude: Terrain following was employed to maintain a constant above ground level (AGL). Laser horizontal errors are a function of flight altitude above ground (about 1/3000th AGL flight altitude).

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±45^{o} from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day. During all flight times, a dual frequency DGPS base station recording at 1 second epochs was utilized and a maximum baseline length between the aircraft and the control points was less than 13 nm at all times.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flight lines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flight line coincides with the swath edge portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flight Lines: All overlapping flight lines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

5.0 ANALYTICAL METHODOLOGY

The goal of the analytical portion of this project is to create lidar derived products that support the management of the Ellwood Mesa eucalyptus stand and the characterization of monarch butterfly habitat within the project area. Three products were identified and designed to meet these needs: lidar point density profiles for ladder fuel management, standing dead and downed woody debris identification to guide dead material removal and plan replanting, and simulated fisheye photos from the lidar point cloud to support monarch habitat characterization throughout the eucalyptus stand.

5.1 LIDAR POINT DENSITY PROFILES

To assess the prevalence and location of ladder fuels along the boundary of the eucalyptus grove and the nearby structures in the Ellwood Mesa site, point density profiles were generated from the lidar point cloud. Point density profiles highlight the location of dominant, subdominant, and understory vegetation by dividing the above ground space within the AOI into height profiles or slices and measuring the number of lidar returns within each profile. The density profiles generated for this project can be used to map ladder fuels near buildings as well as clumps and gaps of canopy cover within the eucalyptus grove.

Prior to generating the point density profiles, the point cloud was height normalized. Height normalization creates a point cloud where all ground returns have an elevation of 0 and the elevation of all features captured in the point cloud have heights relative to ground level. The height normalized point cloud was then filtered to remove ground classified points and sliced into 1-meter tall height slices (or profiles). The percentage of points within the profile range compared to the total number of points within the pixel footprint were summarized by pixel. Functionally this is a representation of the relative point density within each 1-meter voxel that covers the area of interest. This dataset shows where returns are located within the specified height ranges so that ladder fuels can be identified or gaps in forest cover can be targeted for planting.

5.1.1 Products

A 37-layer raster product (at 1-meter resolution) was needed to fully characterize the height variability in the point cloud. Each layer, one through thirty-seven, was populated with a percentage of the total points captured in that 1-meter cube (or voxel) relative to all returns present in its respective vertical point cloud column. A refined area of interest was used in the ladder fuels assessment to target areas that are close to structures and require management to reduce wildfire risk. The ladder fuels AOI is shown in Figure 10. Each point density profile raster was summarized to the gridded polygons of the ladder fuels AOI to represent the mean point density of each polygon for all 37 density profiles (Figure 11). The summarized ladder fuels AOI can be used to identify regions of the AOI that may need management for fire risk.

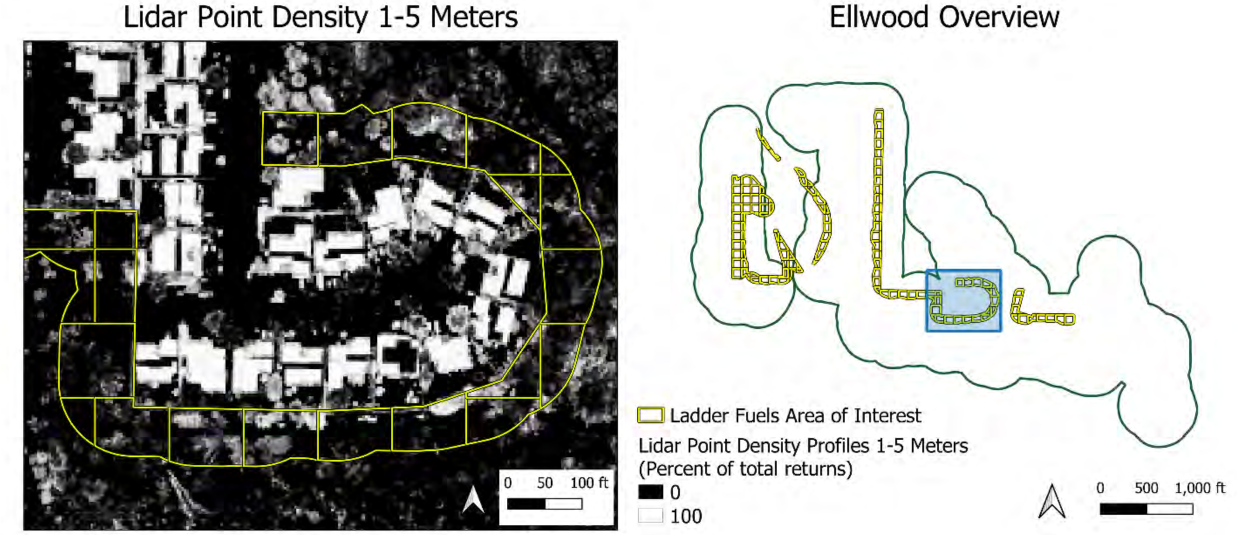


Figure 10: [Left] Demonstration of lidar point density percentage from 1-5 meters above ground. Houses, shrubs, leaning eucalyptus stems, and the lower levels of the tree canopy are visible in this map. [Right] Ladder fuels AOI within the Ellwood project area.

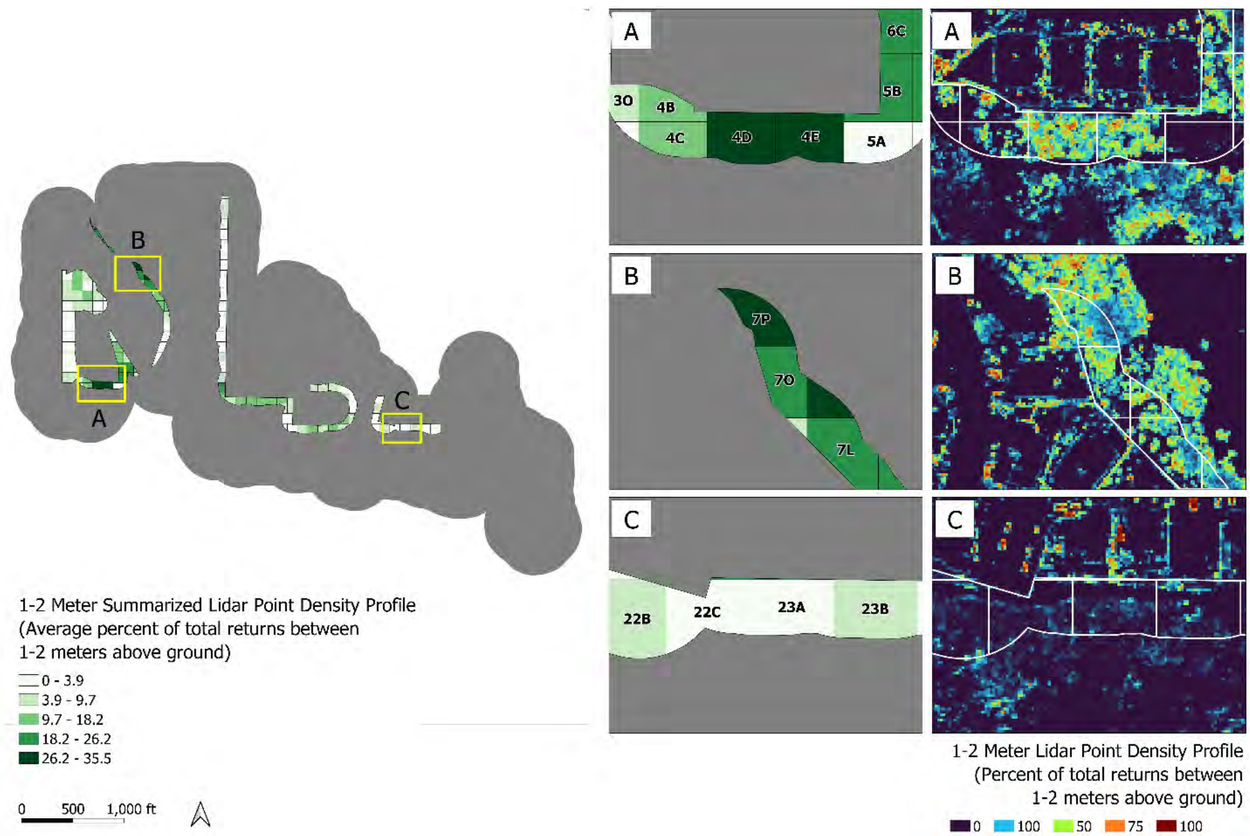


Figure 11: Summarized ladder fuels AOI showing average lidar point density for the 1-2 meter profile.

The lidar point density deliverable dataset allows a user to peel back layers of the point cloud to identify where ladder fuels may be present within the forest. Figure 12 provides a comparison between the canopy height model and the individual density profiles to demonstrate the concept of looking through the canopy to the inner layers of the point cloud. In the map shown at the top of Figure 12 the canopy height model showcases the upper canopy layers, rooftops, and exposed ground locations. A canopy height model shows a surface model of the highest returns captured in the height normalized point cloud. The first density profile layer (second from the top in Figure 12) represents the proportion of lidar returns present from 0-1 meter above ground and excludes lidar returns that are classified as ground. This layer shows where low lying vegetation is present and shows values near 100 in regions where no lidar points are obscured by taller features like houses or canopy. The next two density profile layers shown in Figure 12 demonstrate where lidar point returns are located for the 1-2 meter profile and the 2-3 meter profile, respectively. In the 1-2 meter profile, returns from fences, shrubs, and leaning debris are visible. In the 2-3 meter profile, returns begin to capture roof edges and taller shrub features. Figure 13 shows an overview of the point density profile rasters for the lowest six point density profile layers (0-1 meters, 1-2 meters, 2-3 meters, 4-5 meters, and 5-6 meters).

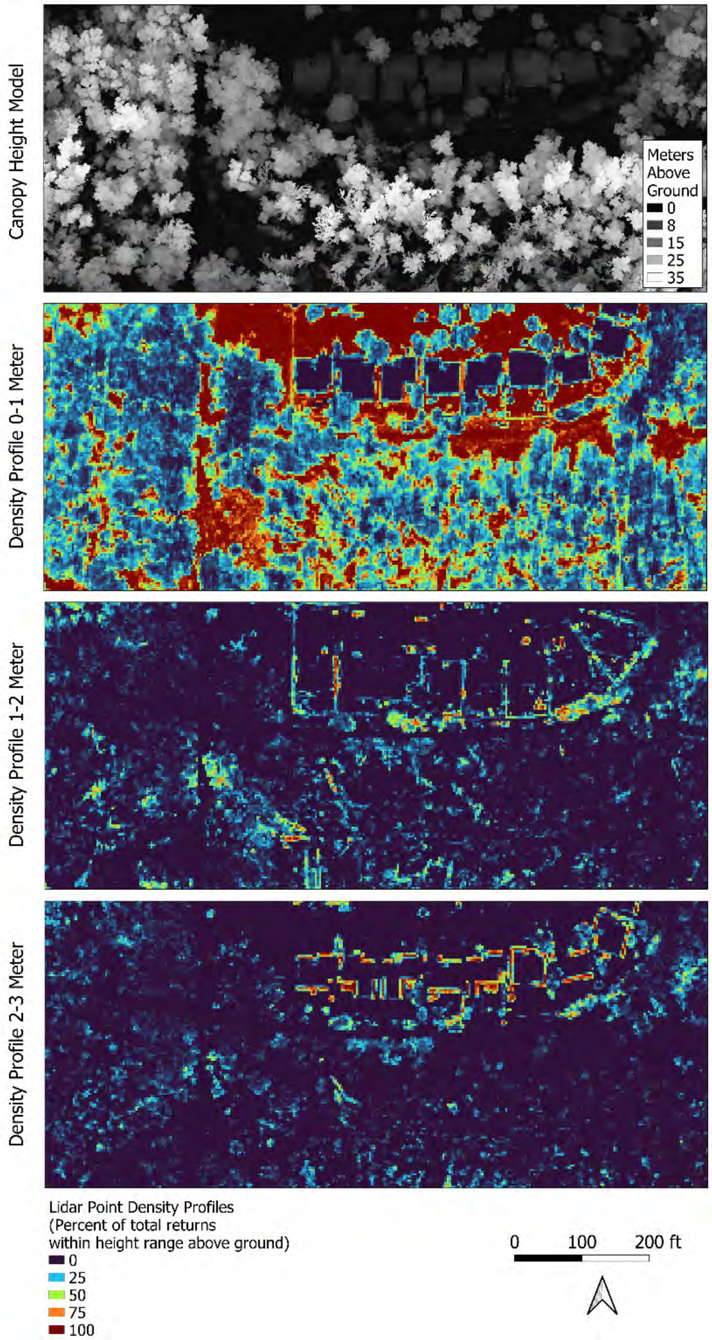


Figure 12: Map displaying lidar point density profiles for an example region of Ellwood. Top to bottom: Canopy Height Model shows a surface model of the highest returns captured in the height normalized point cloud. The density profiles from 0-1 meters above ground, 1-2 meters above ground, and 2-3 meters above ground, respectively.

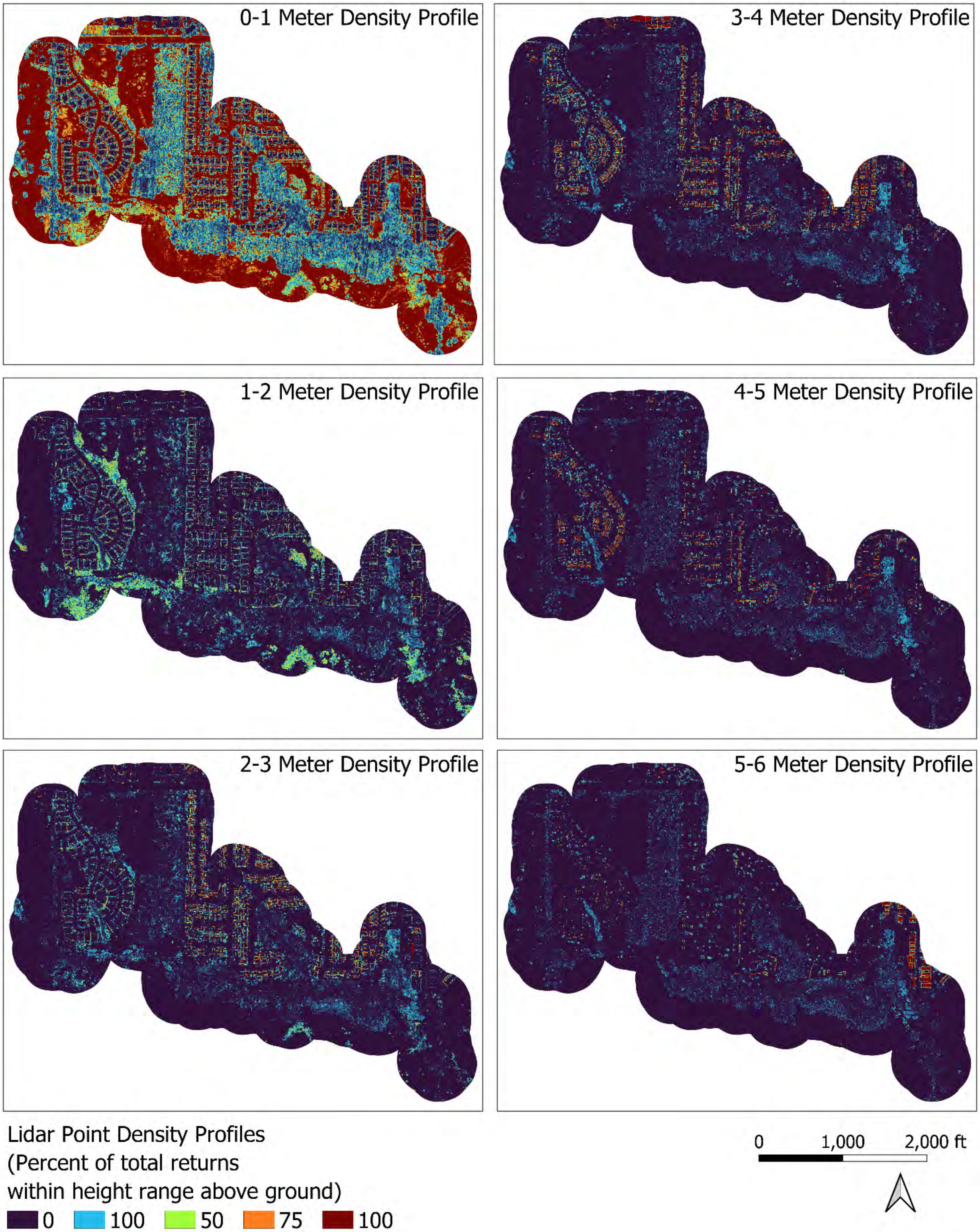


Figure 13: Overview of lidar point density profile rasters for the Ellwood Mesa AOI. Top to bottom and left to right: 0-1 meter density profile, 1-2 meter density profile, 2-3 meter density profile, 3-4 meter density profile, 4-5 meter density profile, and 5-6 meter density profile.

5.2 STANDING DEAD AND DOWNED WOODY DEBRIS CLASSIFICATION

Standing dead trees and downed woody debris were identified in this project to support forest rehabilitation, fire risk mitigation, maintenance, and safety within the Ellwood project area. Deliverable products related to the identification of dead material within the AOI were designed to provide mapped locations and volume estimates of dead material to aid in the planning and execution of hazard removal.

The standing dead and downed woody debris classification was implemented using imagery and lidar derived inputs in three main phases: an intermediate classification of woody material lidar returns, spectral classification of standing dead trees, and a threshold-based classification of downed woody debris with manual review. Downed woody debris is considered to be dead tree material within 0.5-3.5 feet (approximately 0.15-1 meters) above ground level. Any dead material identified higher than 3.5 feet above ground level was considered to be standing dead material.

5.2.1 Woody Material Identification

A preliminary step involved in the classification of the lidar point cloud for standing and downed dead material was a filtering process used to isolate woody material lidar returns, such as tree stems and branches. The lidar point cloud was filtered using non-ground lidar returns, lidar return intensity, and eigen values relating each point to its five nearest neighbors. Lidar returns identified as woody material in this process were classified as class 67. Standing dead material and downed woody debris were classified from this subset of woody material classified points. The woody material filtering procedure was very influential in the classification of standing dead and downed trees because it reduced the false positive classification of leafy material near dead trees.

The woody material class (67) is considered an intermediate classification because it was not manually edited or evaluated after assignment. The classification procedure was tuned to the specific attributes of the Ellwood lidar dataset and is expected to contain false positive and false negative classifications. The woody material classification was retained in the final deliverable dataset to support future analysis by the client, and it should be evaluated for appropriateness of use prior to inclusion in any additional work.

5.2.2 Standing Dead

The standing dead classification was focused on identifying and quantifying the volume of standing dead trees. To perform the standing dead classification, a model was trained to identify dead trees represented in the orthoimagery. Dead trees were identified as lacking green and leafy material. They are characterized by exposed branches and light and brown colored returns from the stem and branch structures. The full spectrum of potential tree health statuses were not considered in this process, a binary live or dead classification scheme was used.

Spectral training points were selected by a photo interpreter and used to build a random forest model. The five imagery bands (R, G, B, NIR, Red edge) and additional spectral indices were incorporated as predictor variables. Once the model was applied across the area of interest, the results were vectorized, manually reviewed, and edited where necessary. Upon finalization of the two-dimensional standing dead vector layer, the classification was applied to the lidar point cloud, converting any points greater than 3.5 feet above ground and classified as 67 into class 65: standing dead material. Figure 14 shows a map of standing dead features identified in the orthoimagery and Figure 15 shows a map of the identified standing dead trees within the Ellwood Mesa project area.

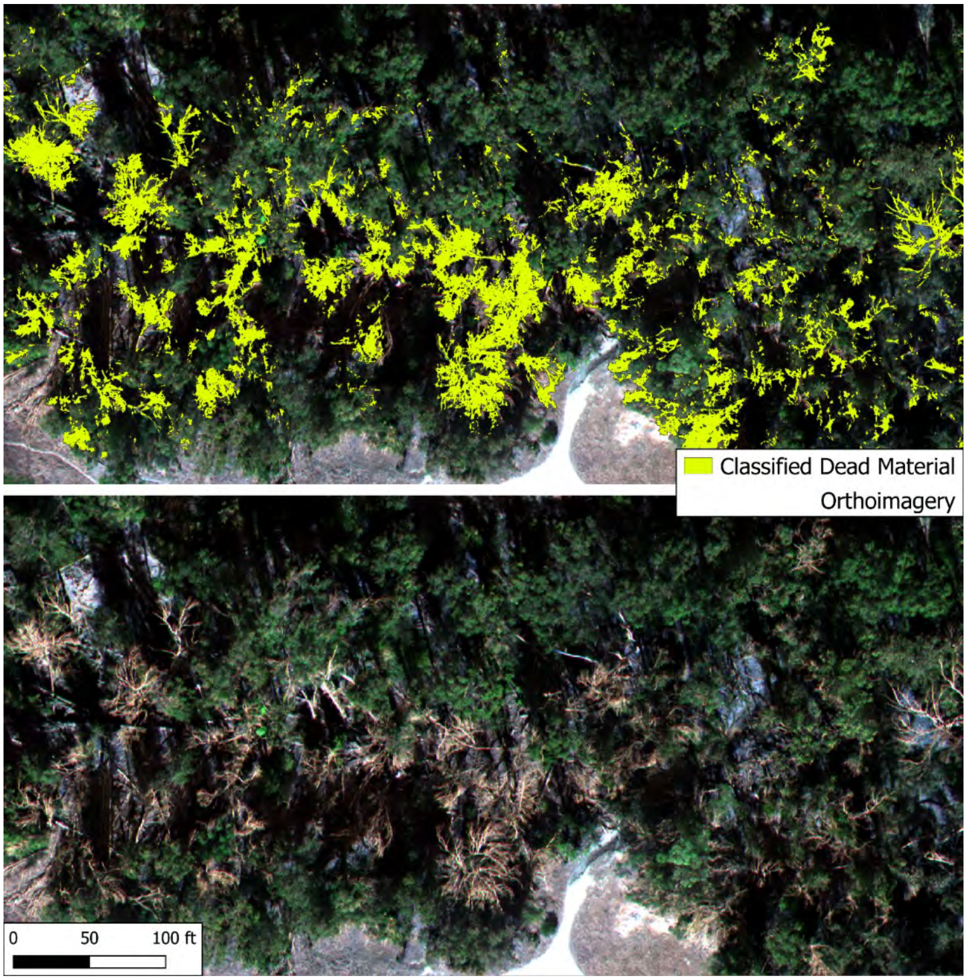


Figure 14: Example of dead trees identified in the orthoimagery.

Standing Dead Trees in Ellwood Mesa

Figure 15: Mapped results of the identified standing dead trees within the Ellwood area of interest.

5.2.3 Downed Woody Debris

The process for classifying downed woody debris was built upon the woody material classification described in Section 5.2.1. After the lidar point cloud was processed to identify woody material, all woody material returns (class 67) between 0.5 feet and 3.5 feet above the ground were reclassified as downed woody debris (class 64). The regions of classified downed woody debris were then extracted and manually edited. Manual review of the downed woody debris classification focused on reducing the false positive classification of shrubs and bushes and filling in gaps of downed stems and branches. Fine resolution vegetation density profiles were used to aid in the digitization of downed woody debris to visualize the forest floor through the canopy. The edited downed woody debris identification layer was then applied to lidar returns between 0.5 and 3.5 feet tall to create the final downed woody debris classification (class 64). Figure 16 shows a map of the identified downed woody debris within the Ellwood Mesa project area.

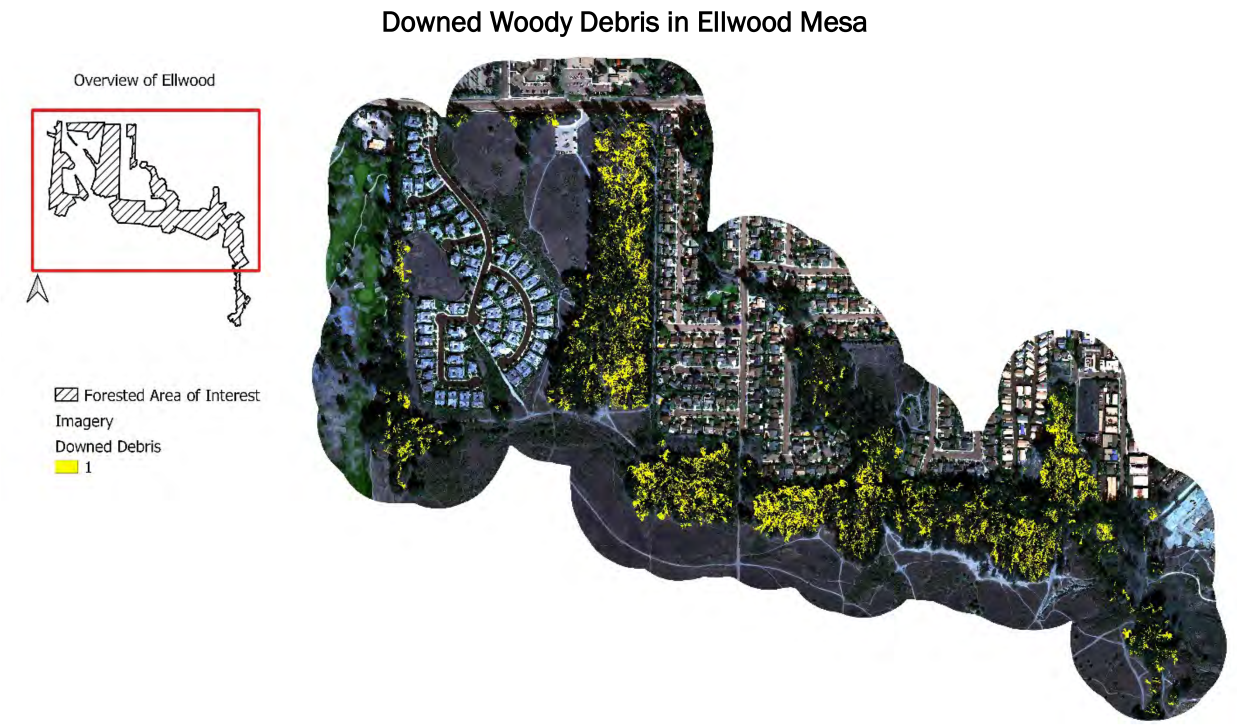


Figure 16: Mapped results of the identified downed woody debris within the Ellwood area of interest.

5.2.4 Dead Material Volume Estimates

Dead material volume estimates were generated from the classified lidar point cloud using voxels to estimate the area occupied by standing dead trees or downed woody debris. Voxelization of the lidar point cloud converts the point returns into 3-dimensional cubes of a user defined size. Multiple lidar returns can occupy one voxel, and all points are represented by a voxel. A six-inch voxel size was used for volume estimation for the Ellwood project because it created realistic visualizations of the point cloud that did not overinflate the areas represented by the stems in this forest. Figure 17 shows examples of the voxelized downed woody debris for a lidar tile to highlight the impact of voxel size on the overall volume estimate. A 12-inch voxel size creates a wood volume model treats every stem as at least 12 inches in diameter. This is not realistic for the eucalyptus trees within the Ellwood project area.

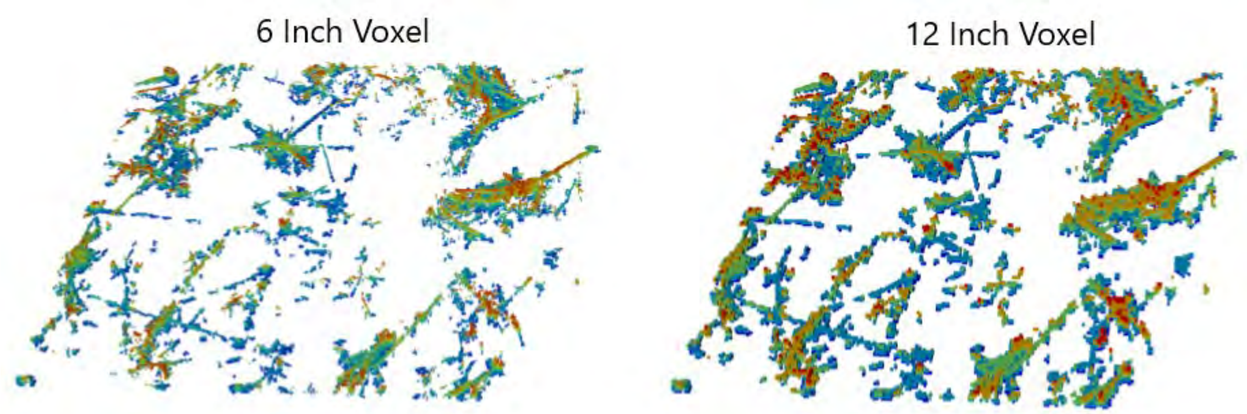


Figure 17: Voxel representations of classified downed woody debris for a lidar tile. A six-inch voxel size is shown on the left and a 12-inch voxel size is shown on the right. Voxel visualizations are colored by elevation above ground. Cool colors represent features closer to ground level, while warmer colors represent features farther from the ground.

5.2.5 Products

The primary deliverable products for this dead wood classification analysis are geospatial rasters representing the mapped location and voxel count of the downed woody debris and standing dead tree classifications. A raster format was chosen to offer flexible visualization of the project results and the potential for custom summarization of specific areas of interest within the larger project area. To calculate the volume of standing dead or downed woody debris for a specific region of Ellwood, the sum of the pixel values within that geographic region (the total number of classified voxels) should be calculated and multiplied by 0.125 to measure the cubic footage of dead material (either standing dead or downed woody debris depending on which raster is being summarized). The total volume of standing dead trees within the Ellwood project area is estimated to be 222,953 cubic feet and the total volume of downed woody debris within the Ellwood project area is estimated to be 207,252 cubic feet. Figure 18, Figure 19, Figure 20, and Figure 21 show examples of the raster-based dead wood volume deliverables created for the Ellwood project area.

Figure 18: Standing dead volume raster for an example region of Ellwood. The raster visualization is colored by the number of voxels representing standing dead material within a given pixel footprint.

Figure 19: Downed woody debris volume raster for an example region of Ellwood. The raster visualization is colored by the number of voxels representing standing dead material within a given pixel footprint.

Figure 20: Standing dead volume raster for an example region of Ellwood. The raster visualization is colored by the number of voxels representing standing dead material within a given pixel footprint.

Figure 21: Downed woody debris volume raster for an example region of Ellwood. The raster visualization is colored by the number of voxels representing standing dead material within a given pixel footprint.

The downed woody debris and standing dead tree raster products were generated from the classified and voxelized point cloud results. To support further modeling and analysis in the Ellwood Mesa project area the classified lidar point cloud was also delivered to the client. The classification scheme for the delivered point cloud is outlined in Table 18. Class 67 was used as an intermediate classification for identifying woody material (as outlined in Section 5.2.1). However, it was not specifically tuned for accuracy beyond its needs for the dead material classification and should be evaluated for appropriateness of use prior to inclusion in any additional analyses. Figure 22 shows an example tile of the classified point cloud displaying only the standing dead and downed woody debris for a particularly unhealthy region of the project area.

Table 18: Las classification scheme.

Classification	Definition
1	Unclassified Points
2	Ground
64	Standing Dead (Z > 3.5 ft)
65	Downed Dead (Z <= 3.5 ft)
67	Woody Returns

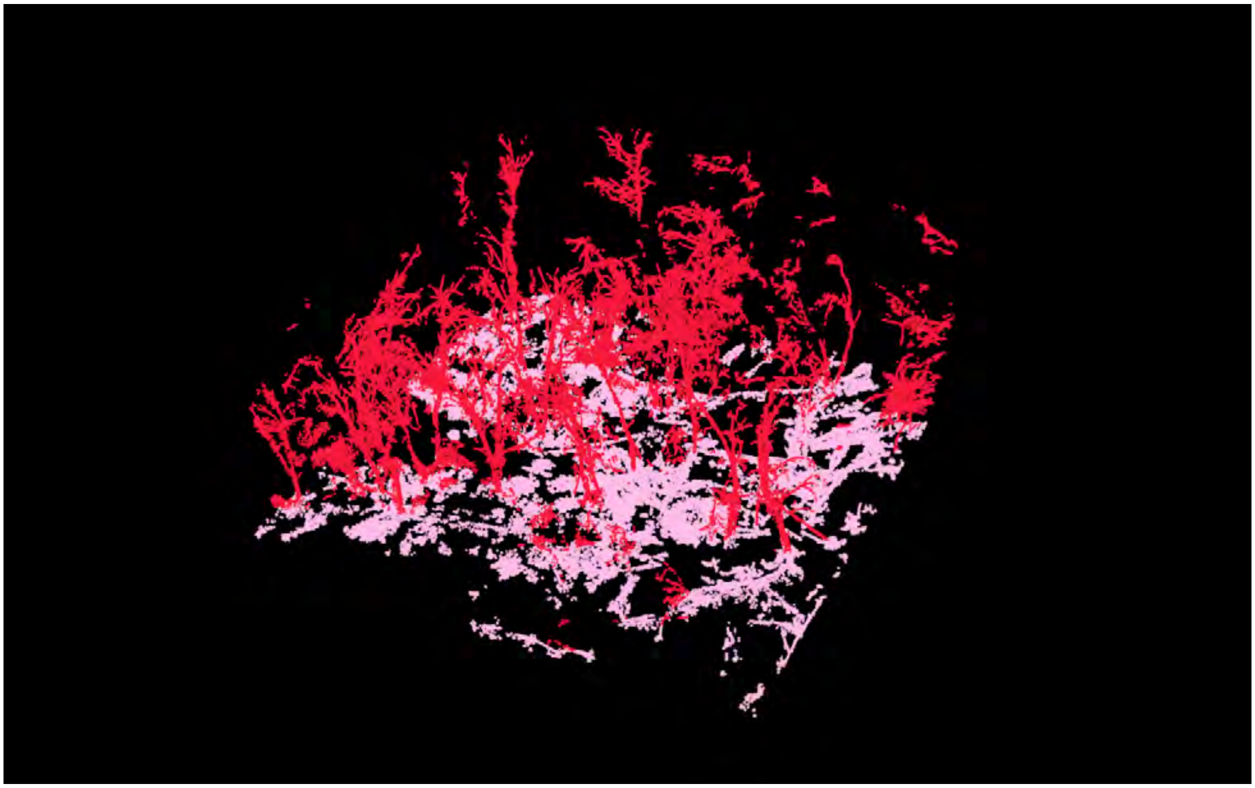


Figure 22: Example image of the classified lidar point cloud showing the identified standing dead material and downed woody debris for a particular unhealthy region of the Ellwood project area.

5.3 FISHEYE PHOTO SIMULATION FROM THE LIDAR POINT CLOUD

Simulated fisheye photos were targeted as deliverables for this project in order to supplement field collected photos and support seamless quantification of solar exposure and potential wind penetration within the Ellwood eucalyptus stand. Historically, monarch habitat suitability has been assessed at this site and others using fisheye photos processed with Hemiview software to characterize the canopy gap fraction and quantity and quality of light penetration into the canopy. Appropriate wind shelter and solar exposure are important elements of quality monarch habitat. Exhaustive fisheye photography field campaigns are limited by resource availability and by the physical limitations of camera placement positions. Simulated photos allow the photo point of view to be placed anywhere in x, y, and z space within the project area. This creates the potential for photos to be simulated in the middle of the canopy at monarch cluster locations or throughout the canopy to measure how canopy closure changes at different heights above ground. NV5G's current investigation into simulated fisheye photos from a lidar point cloud is being complemented by an investigation into drone spherical photography by Althouse and Meade, Inc.

Fisheye photographs were collected and provided to NV5G by the client in designated field plots across the Ellwood project area. Photos were taken on a tripod approximately 5 feet tall and image locations were recorded using GPS. For each of the field photos, a lidar derived simulated photo was created to facilitate comparison and evaluation of performance for the simulated photos. A prerequisite to simulating the fisheye photo in each plot, was to adjust for GPS error and ensure that photo locations were geolocated accurately and that features in the lidar matched with features captured in the field photographs.

5.3.1 Plot Adjustments

Thirty field plots were collected throughout the Ellwood project area by Stu Weiss, Creekside Science, and his team. For each plot, the plot center was flagged 2 meters south of a central reference tree and its GPS location was recorded. Then dominant trees within a 1/10th acre plot were selected and their distance and azimuth from plot center were measured. Additional information about these trees was also recorded, such as diameter at breast height, species, total height, crown condition, and health. A fisheye photo was also collected at each plot center location.

Manual adjustment of the plot geolocation was necessary to align the field collected data to the features captured in the lidar point cloud. Plot adjustment corrects for GPS error that occurs during field collection and allows for precise alignment of lidar derived products with features on the ground. To perform plot adjustments, the 3-5 dominant reference trees collected for each plot were projected around the plot center using the measured distances and azimuths to create tree constellations. The tree constellations were then used to perform plot location adjustments by matching the arrangement and heights of reference trees to features seen in the lidar point cloud. Plot adjustments were tested by simulating fisheye photos at the adjusted locations and visually comparing the simulated photos with photos captured in the field. The same forest features (presence or absence of trees and patterns of view to sky) are expected to be seen in both the field and simulated photographs. Table 19 contains the plot adjustment changelog with the calculated bearings and distances of each plot adjustment. The most extreme adjustment in terms of distance moved was approximately 50 feet (Plot Number 5), however average adjustments were roughly 17 feet. Five of the thirty reference plots could not be confidently matched with the lidar features. Plots typically could not be aligned with the point cloud features due to high forest density in the region the plot was taken, or due to a small number of reference trees collected. In these cases, the reference tree patterns and heights were not unique enough to identify within the point cloud data.

Table 19: Plot adjustment change log. Bearings are recorded in degrees from North and distances are recorded in feet to match the project projection units.

Plot Number	Bearing (degrees)	Distance (feet)	Comment
1	58	17.7	-
2	345	0.89	-
3	64	4.83	-
4	184	9.69	-
5	199	57.46	-
6	180	3.77	-
7	328	20.02	-
8	244	30.05	-
9	114	13.63	-
10	149	4.66	-
11	198	27.25	-
12	213	12.04	-

Plot Number	Bearing (degrees)	Distance (feet)	Comment
13	199	7.02	-
14	220	7.73	-
15	43	33.45	-
16	120	33.35	-
17	16	20.62	-
18	190	12.47	-
19	181	26.75	-
20	22	10.46	Unable to confidently match plot with point cloud features
21	309	24.84	Unable to confidently match plot with point cloud features
22	153	4.31	-
23	44	11.75	-
24	205	2.08	Unable to confidently match plot with point cloud features
25	200	3.79	Unable to confidently match plot with point cloud features
26	168	18.78	-
27	198	29.48	-
28	180	7.09	-
29	350	29.16	-
30	97	15	Unable to confidently match plot with point cloud features

5.3.2 Photo Simulation

Simulated fisheye photos were created from the lidar point cloud by spherically projecting the point cloud, converting the points to voxels, flattening the image, and enforcing its orientation. Simulated photos were designed to contain equiangular distortion and a 180-degree viewing angle that matches the lens information provided by Stu Weiss, Creekside Science. The fisheye photo simulation procedure is built around the location of the target point of view. The point of view represents the simulated camera location and can be placed anywhere within the point cloud along the x, y, and z axes. For a given point of view, a subset of the full point cloud is extracted with the point of view at its center. Equiangular distortion of the simulated image is achieved by projecting the target point cloud to a sphere (Figure 23 and Figure 24A). The 180-degree viewing angle is achieved by cropping the projected point cloud at a height equal to the sphere's center location (the location of the point of view) (Figure 24B). The upper hemisphere of the point cloud is then rotated and aligned so that the point of view is rendered looking up to the sky with North at the top of the simulated image. The point cloud is then voxelized in order to determine which pixels of the simulated photo are blocked by forest features and which have a clear view to sky (Figure 24C).

Figure 23: An example of a point cloud projected to a sphere. The yellow sphere located in the center of the unmodified point cloud (left) represents the center of the sphere and the point of view for the simulated photo.

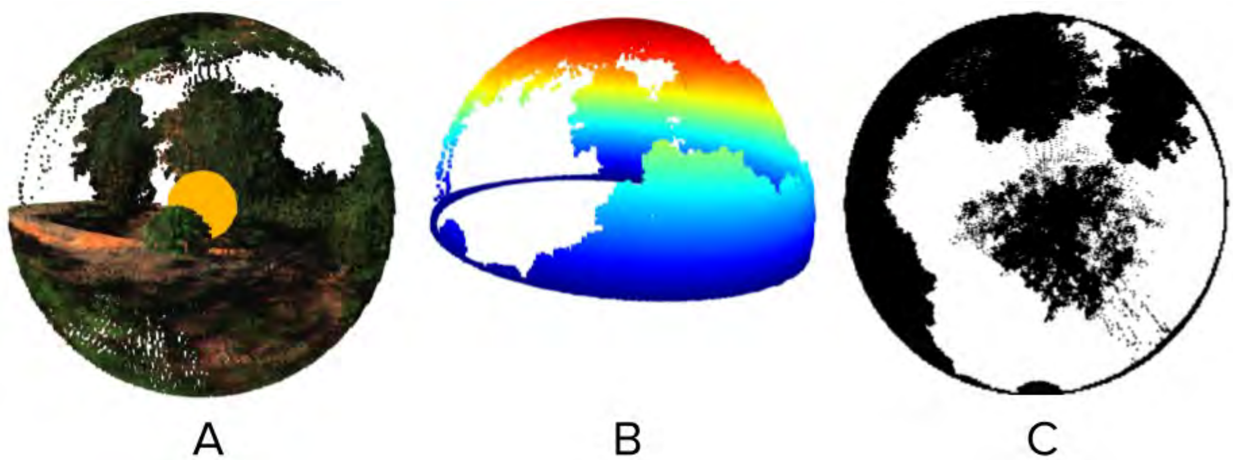


Figure 24: (A) Projected Point Cloud: An example of a point cloud projected to a sphere. The small yellow sphere located in the center of the projected point cloud represents the center of the projection sphere and the point of view for the simulated photo. (B) Cropped Projected Point Cloud: The projected point cloud cropped at the height of the point of view. (C) Point of View Enforced Simulated Photo: The cropped point cloud is viewed from below and the orientation of the photo is enforced to ensure that North is on top.

Point cloud projection and voxelization parameters were tested by simulating fisheye photos with varying tile sizes, radii for spherical projection, and voxel sizing. A sphere radius of 400 feet with a voxel size of 2 feet was selected to most closely approximate the look and feel of field photographs based on visual interpretation (Figure 25). In order to balance memory limitations and feature inclusion, a lidar tile size of 400 feet was selected as the input data extent for each simulated photograph. Figure 26 demonstrates examples of three different tile sizes that were tested for this project. As the tile size increases, more distant features are included in the simulated photo and the number of lidar points used to build the image increases. As a result, more pixels of the fisheye photo along the image perimeter are obscured. This effect is demonstrated by the increase in dark pixels along the bottom left of each simulated photo shown in Figure 26 where tile size increases by 200 feet in each simulation from left to right.

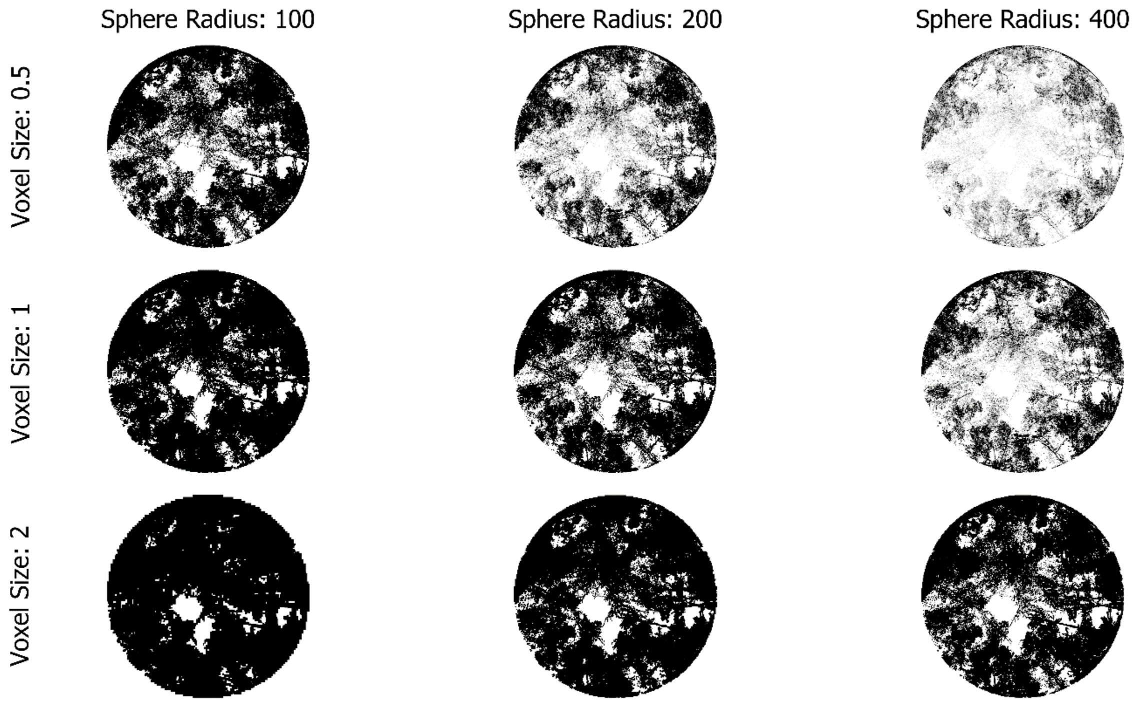


Figure 25: Image matrix showing various sphere radius and voxel size pairs. The selected parameters with the best look and feel compared to field photographs was a 400 foot radius and 2 foot voxel size (shown in the bottom right).

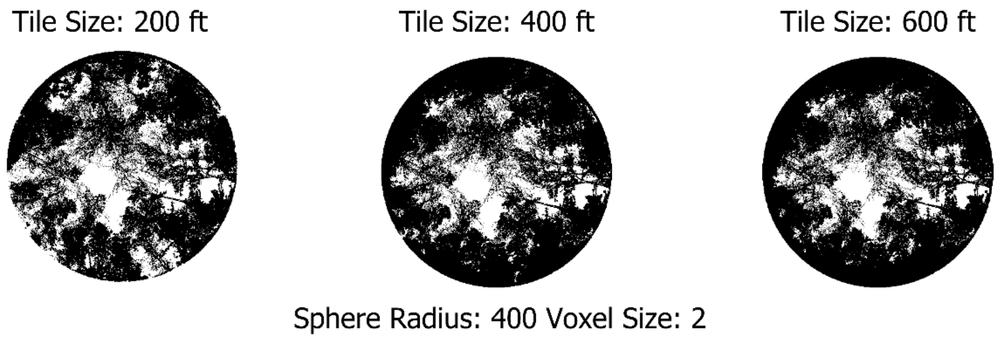


Figure 26: Image matrix showing how the input data tile size changes the resulting simulated image. A tile size of 400 feet was selected to balance the inclusion of features represented in the image and memory limitations.

5.3.3 Products

Products created during the fisheye photo simulation procedure include jpeg images representing simulated hemispherical photography with a 180-degree viewing angle and equiangular distortion. Fisheye photos were simulated from the lidar point cloud at multiple locations throughout the Ellwood project area. Photos were simulated in a location that matched each field plot center with a point of view at 1.75 meters above ground, 5 meters above ground, and 10 meters above ground. Photos were also simulated at all historical monarch cluster locations the client had documented. Monarch cluster photos were simulated with points of view between 20 and 60 feet above ground depending on the recorded height of the monarch cluster.

5.3.3.1 Fisheyes for Field Plots

Fisheye photos were simulated at each field plot center at multiple points of view (POV).

- POV 1.75 meters above ground – 30 photos

- POV 5 meters above ground – 30 photos
- POV 10 meters above ground – 30 photos

Deliverable images are named by plot number, tile size, sphere radius, and voxel size (EX: ‘P01_400ft_400_v2.jpeg’= Plot #1, 400 ft tile size, 400 ft sphere radius, 2ft voxel). The folders indicate their height above ground (EX: ‘Fisheyes_01_75_meters’ indicates 1.75 meters above ground). Table 20 contains a comparison of the fisheye photographs collected in the field and those simulated using the lidar point cloud.

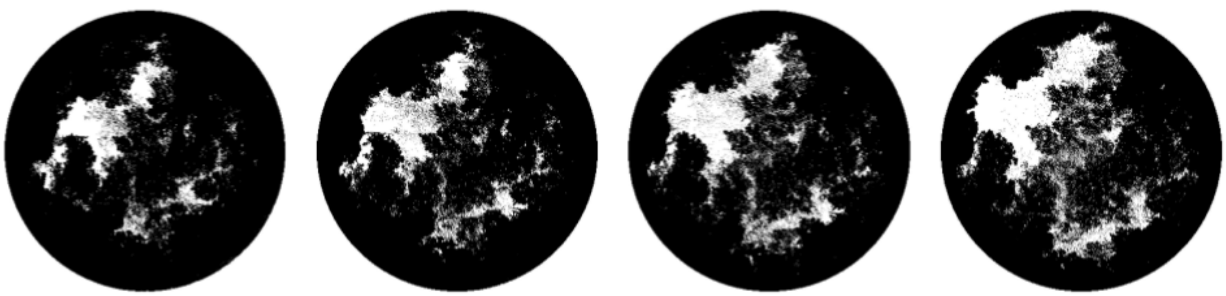
Some features are represented differently between the field and simulated images. For example, powerlines and sparsely leaved branches at the top of the canopy block more view to sky in the simulated photos than the field photos. Additionally, due to a lack of lidar point density in the lower regions of the forest, primarily on stems, the eucalyptus trunks that block light very definitively in the field photos are less present or missing in the simulated fisheye photos.

5.3.3.2 Fisheyes for Monarch Cluster Locations

Fisheye photos simulated from the lidar point cloud at points of view (POV) determined by the attributed height of monarch cluster points.

- When the attributed height of the cluster point was represented by a range, a fisheye photo was generated at each 5-foot interval between the minimum and maximum height listed.

Files are named by their cluster GlobalID and height above ground (EX: ‘0a8017df-eebe-456d-8d75-030427c9a047__25ft.jepg’ represents a cluster captured with a point of view 25 feet above ground).



20 ft | 30 ft | 40 ft | 50 ft

Figure 27: Examples of simulated fisheye photos centered on a historic monarch cluster site and moving upwards through the canopy. Left to right images show the camera point of view situated 20 feet, 30 feet, 40 feet, and 50ft above the ground.

6.0 DISCUSSION

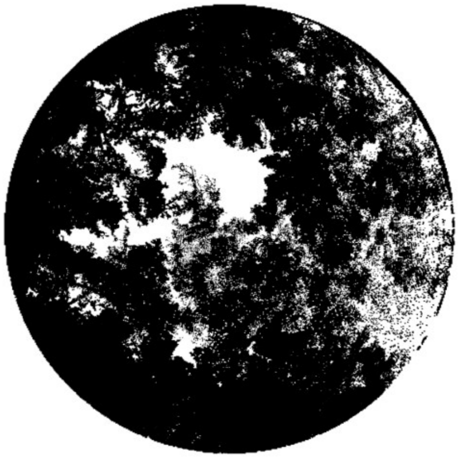
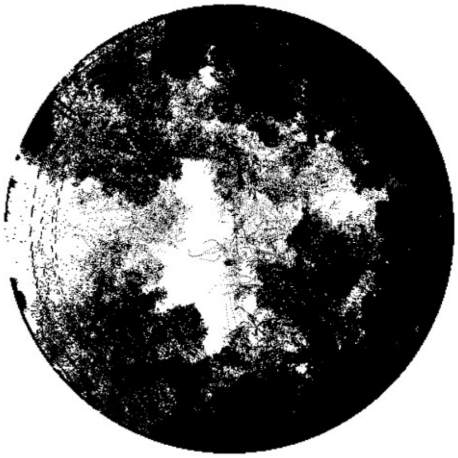
The data created as a part of the Ellwood Mesa Monarch Butterfly Habitat Characterization project will facilitate a fine-scale analysis of the eucalyptus grove used as a monarch over-wintering site. The point density rasters, dead debris classification, and fisheye photo simulations will support the assessment, planning, and management of forest rehabilitation. These data will also support future analytical work and provide a baseline for assessing change over time with the collection of future lidar datasets.

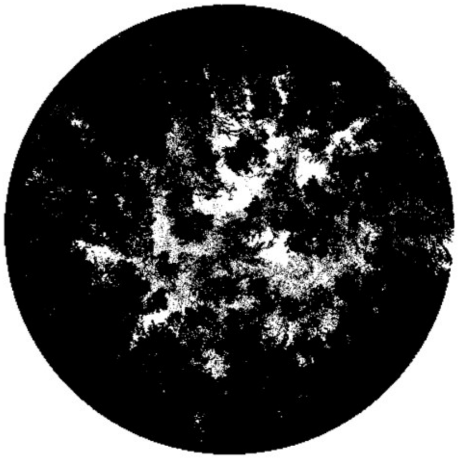
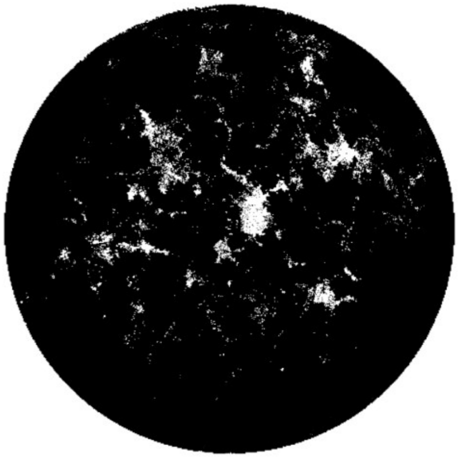
The work done for this project has explored a variety of methods for transforming and analyzing lidar and imagery collected across the Ellwood Mesa project area. The deliverable dataset demonstrates the high level of flexibility and analytical opportunity that comes with a high-density three-dimensional dataset. A key achievement of this project was the development of a method for simulating fisheye photographs from lidar point clouds. However, the simulated fisheye photos should be evaluated for classification accuracy once the fisheye photos captured in the field have been processed into classified images. The relationship between simulated fisheye photos and field-collected photos needs to be established so that analysts can appropriately interpret and understand the gap fraction and solar exposure values calculated from a simulated photo. Additionally, the relationship between wind and solar exposure measured from fisheye photos and other lidar-derived indices should be explored to support smooth interpolation of monarch habitat characteristics across the project area. Future work could expand upon the methods developed in this project to create datasets that are planning-ready and would require fewer client-side analytical resources. One opportunity to stream-line data analysis is to investigate the capacity for open source software to programmatically analyze simulated fisheye photos. This would allow for the provision of simulated fisheye photos set at any desired point of view and processed information regarding canopy gap fraction and solar exposure potential at each location.

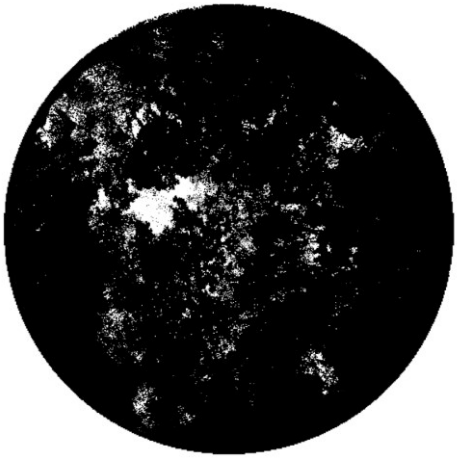
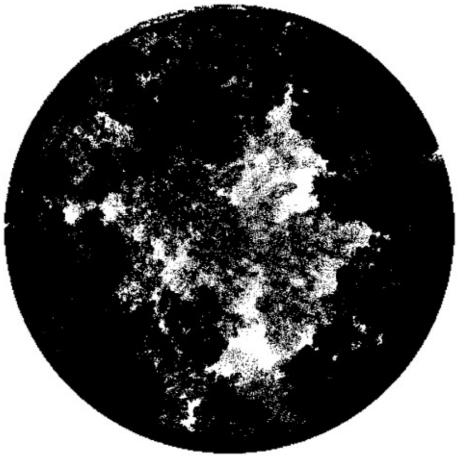
A future area of investigation is to understand whether similar products and results can be generated with lower density lidar. The UAS collected lidar had excellent canopy penetration and high first return densities (average 277.81 points/m^2) creating an ideal foundation for analytical work. Future efforts should study the capabilities of downed woody debris detection and fisheye photo simulation using lower density lidar datasets.

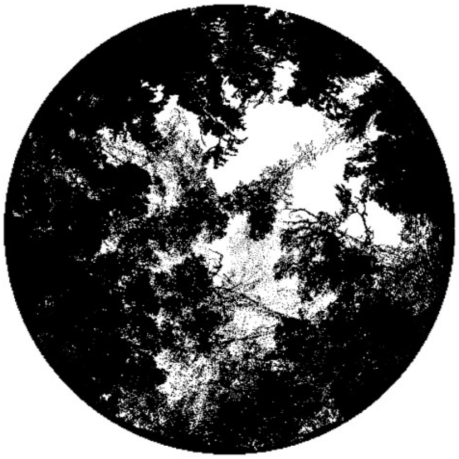
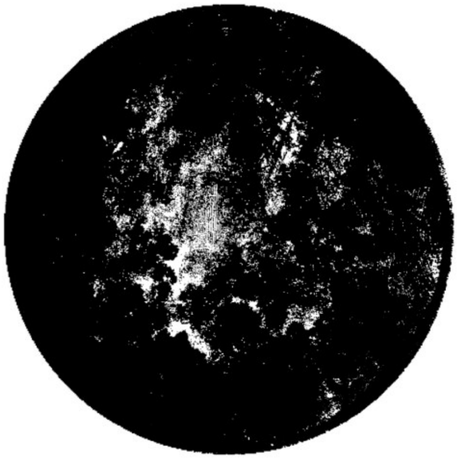
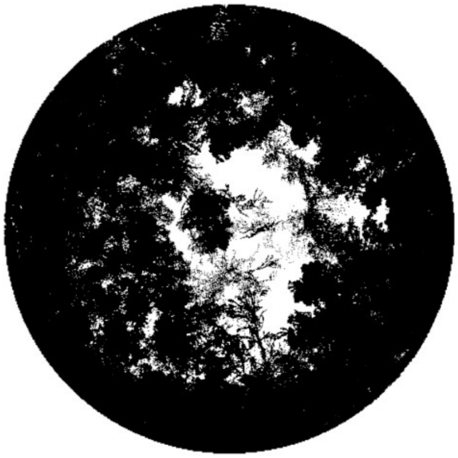
7.0 FISHEYE PLOT PHOTO COMPARISON

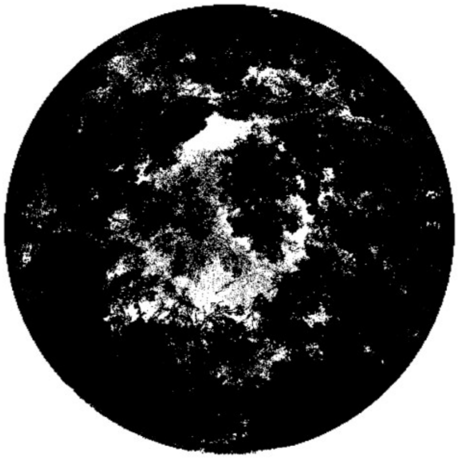
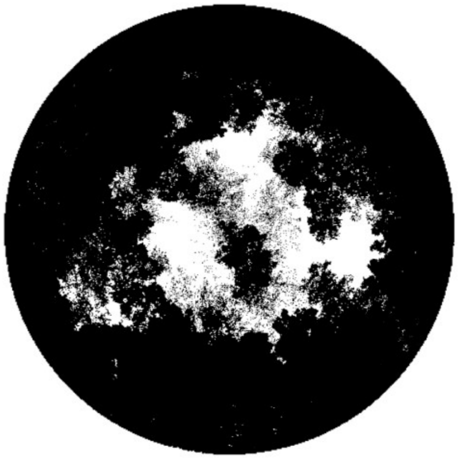
Table 20: Field photo and simulated fisheye photo comparison. Simulated fisheyes are generated from the lidar point cloud at 1.75-meter height above ground. The asterisk (*) on a plot number indicates that a confident plot geolocation adjustment could not be made and that there is not confidence in the simulated fisheye results.

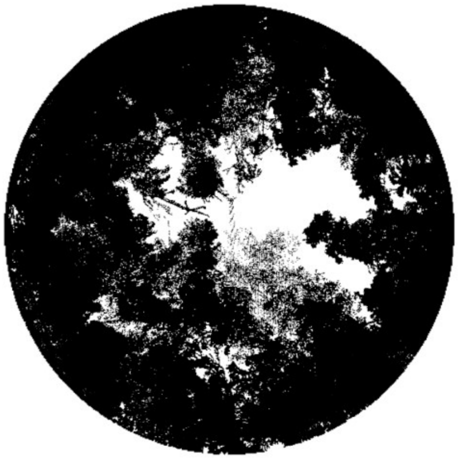
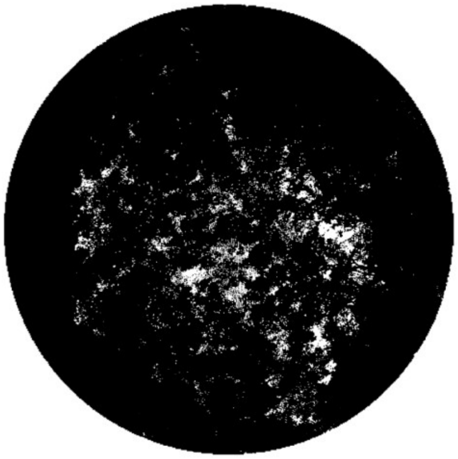
Plot Number	Field Photo	Simulated Fisheye Photo
1		
2		
3		

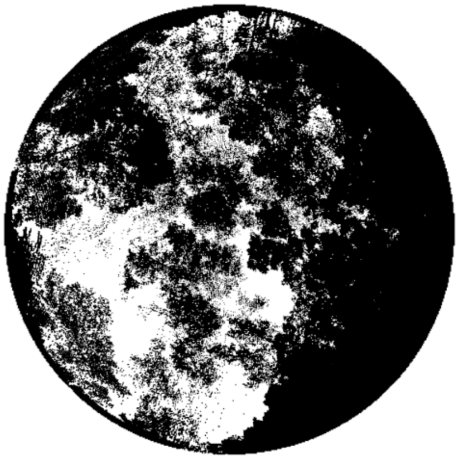
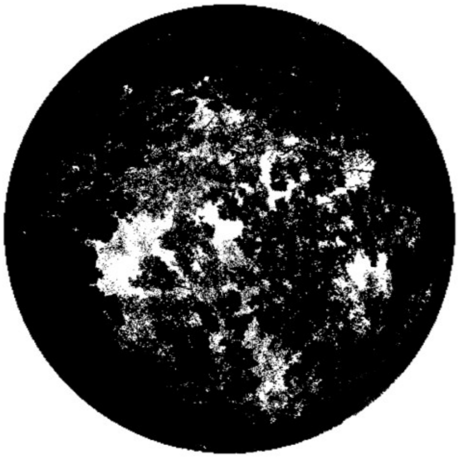
Plot Number	Field Photo	Simulated Fisheye Photo
4		
5		
6		

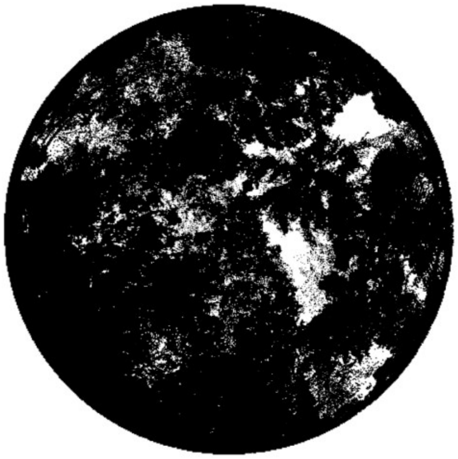
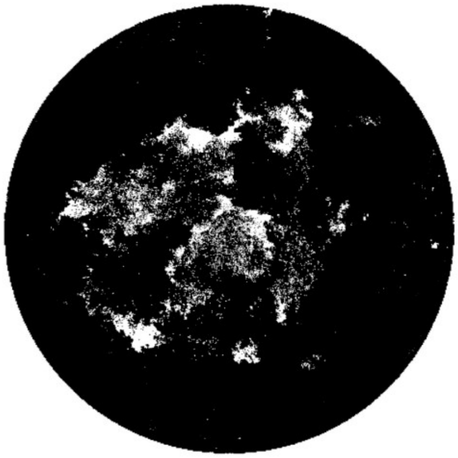
Plot Number	Field Photo	Simulated Fisheye Photo
7		
8		
9		

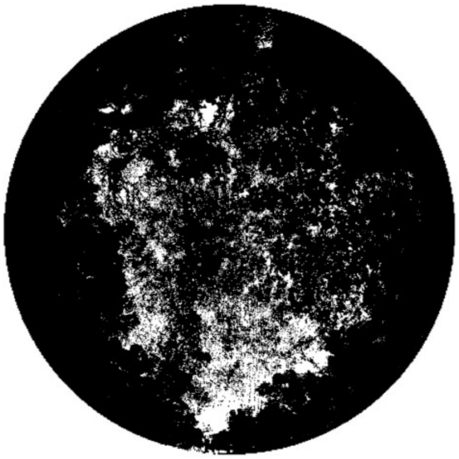
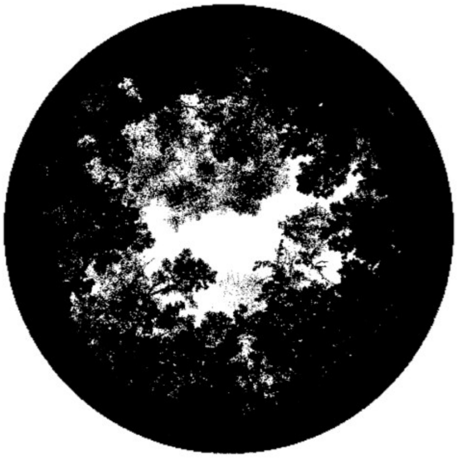
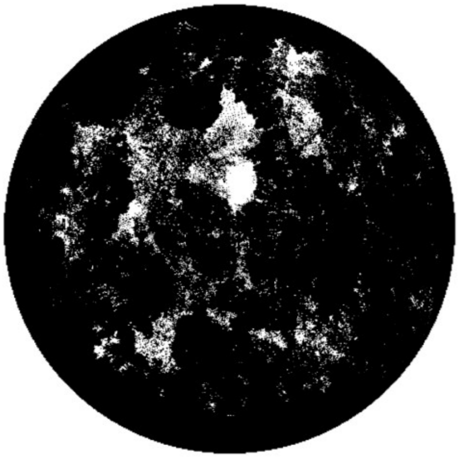
Plot Number	Field Photo	Simulated Fisheye Photo
10		
11		
12		

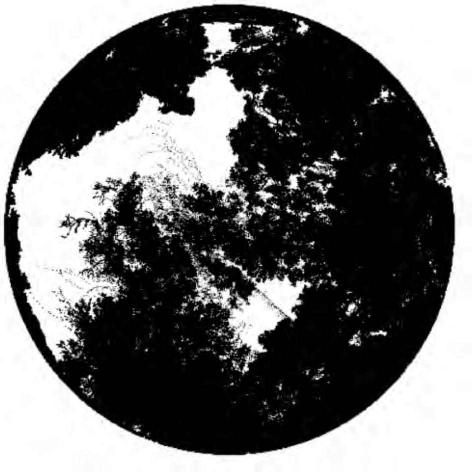
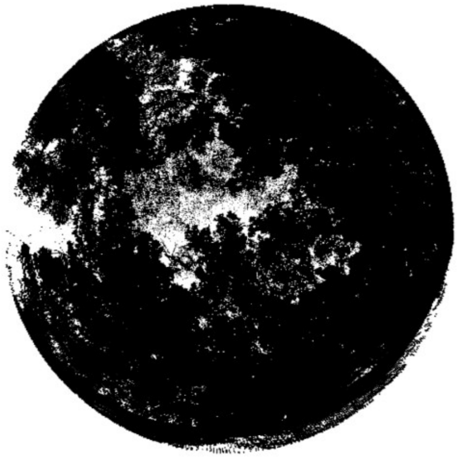
Plot Number	Field Photo	Simulated Fisheye Photo
13		
14		
15		

Plot Number	Field Photo	Simulated Fisheye Photo
16		
17		
18		

Plot Number	Field Photo	Simulated Fisheye Photo
19		
20*		
21*		

Plot Number	Field Photo	Simulated Fisheye Photo
22		
23		
24*		

Plot Number	Field Photo	Simulated Fisheye Photo
25*		
26		
27		

Plot Number	Field Photo	Simulated Fisheye Photo
28		
29		
30*		

8.0 GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set, based on the FGDC standards for Non-vegetated Vertical Accuracy (NVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> Absolute Accuracy: The vertical accuracy of lidar data is described as the mean and standard deviation (sigma σ) of divergence of lidar point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics.
>
> Relative Accuracy: Relative accuracy refers to the internal consistency of the data set; i.e., the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the lidar system is well calibrated, the line-to-line divergence is low (<10 cm).
>
> Root Mean Square Error (RMSE): A statistic used to approximate the difference between real-world points and the lidar points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

Data Density: A common measure of lidar resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from surveyed points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

Overlap: The area shared between flight lines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

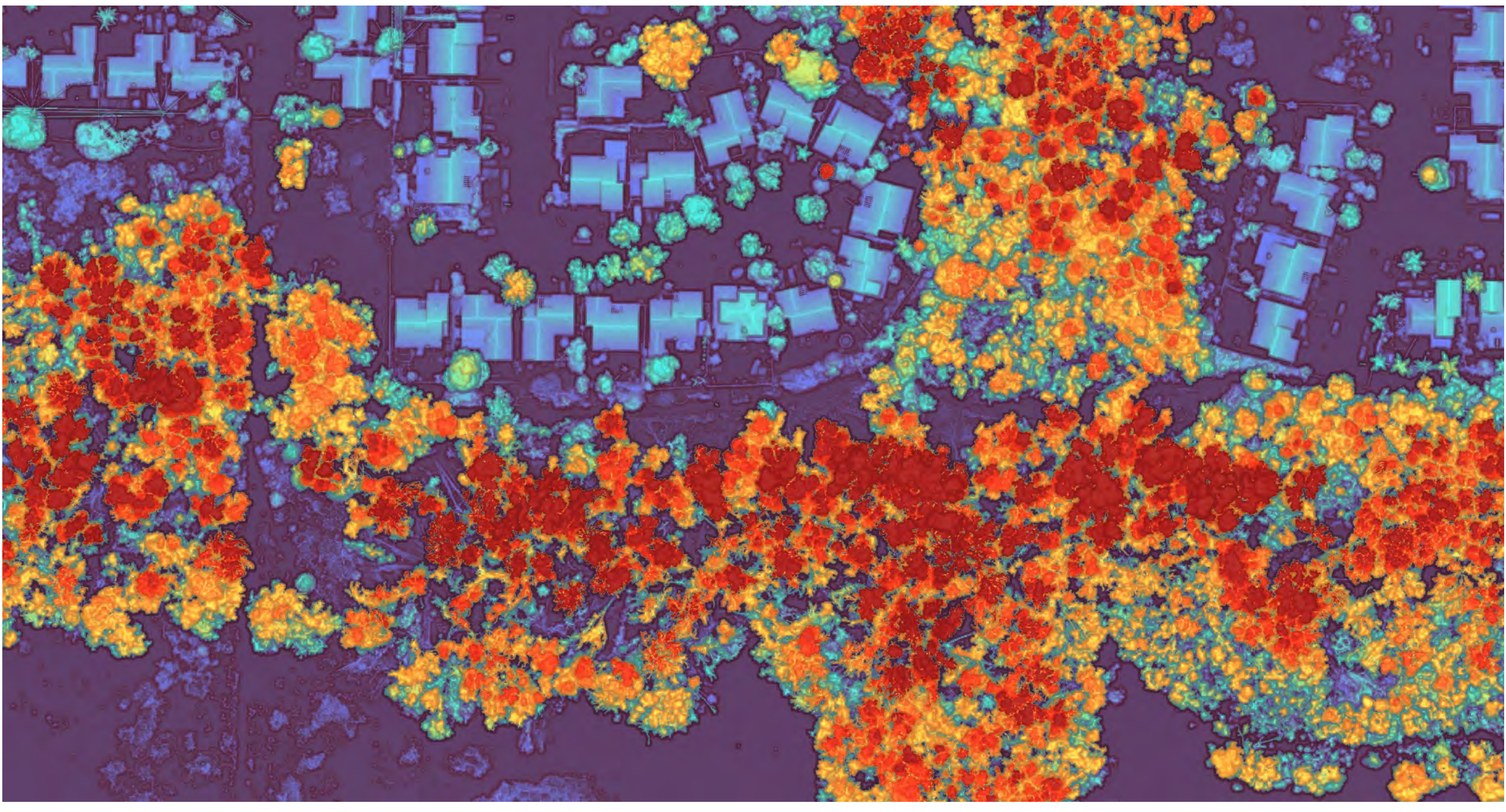
Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echoes) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native Lidar Density: The number of pulses emitted by the lidar system, commonly expressed as pulses per square meter.



NV5 GEOSPATIAL

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