Protecting California's Butterfly Groves

Management Guidelines for Monarch Butterfly Overwintering Habitat

XERCES SOCIETY
for Invertebrate Conservation

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The Xerces Society for Invertebrate Conservation is a nonprofit organization that protects wildlife through the conservation of invertebrates and their habitat. Established in 1971, the Society is a trusted source for science-based information and advice. Our conservation team draws together experts from the fields of habitat restoration, entomology, botany, farming, and conservation biology with a single focus: protecting the life that sustains us.

Portland, Oregon
www.xerces.org

Creekside Center for Earth Observation was founded in 2006 by Drs. Stuart B. Weiss and Paul M. Rich to apply the latest science and technology to address challenging conservation problems. We specialize in experimental design, field measurement, and quantitative analysis. We subscribe to the worldview of Aldo Leopold, who expounded a "land ethic" in which the basic ethical considerations given to human beings are expanded to include the natural world around us. As such, while our work is founded in science, it is also rooted in a deep philosophical commitment to achieve and maintain ecosystem health, preserve vital ecosystem functions, protect rare and endangered species, and expand consciousness about conservation through education and outreach.

Menlo Park, California
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Front Cover Photograph
Overwintering monarchs clustering in a Monterey pine at a site in California. Photo: The Xerces Society / Carly Voight.

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Executive Summary

Every year, hundreds of thousands of monarch butterflies spend the winter in groves of trees along coastal California. However, their numbers have declined by over 95% since the 1980s and the migratory population is at a high risk of extinction. In the 1980s, about 10 million monarchs overwintered in coastal California, while in 2016 fewer than 300,000 were counted. While researchers are still evaluating what may have caused the long term population trend of monarchs in California, the declines that have been observed may be attributable to:

- **Loss of milkweed and nectar plants** due to herbicide use, urban and agricultural development, and long-term drought (which may be linked to climate change),
- **Loss and degradation of overwintering groves** due to development and grove senescence, and
- **Other stressors** such as disease, insecticides, and impacts of climate change.

Monarchs are especially vulnerable during the overwintering stage because so many animals are concentrated in a few locations. They have very specific overwintering habitat requirements and will only utilize tree groves that provide suitable environmental conditions, which include high humidity, dappled sunlight, a nearby water source, and protection from high winds, storms, and fluctuating temperatures. These butterfly groves are part of a dynamic ecosystem, and active management of groves is often required to maintain the environmental conditions that monarchs require to survive over the long term. Loss of trees and branches due to aging, storms, pests, and disease; tree and branch removal; and human visitors can all contribute to changes in the microclimate of overwintering groves, potentially resulting in unsuitable monarch habitat.

This document is intended to serve as a guide for land managers and landowners who wish to implement management actions to protect, improve, and restore monarch overwintering habitat. As all overwintering sites are unique, detailed site-specific guidelines should be developed for each overwintering site following the recommendations in this document, and if possible, in consultation with a monarch habitat specialist and a certified arborist.

The following five steps will guide you in developing a site-specific management plan.

1. Become Familiar with Monarch Overwintering Habitat Requirements and Characteristics

Monarchs are thought to select sites based on:

- protection from high wind and storms;
- absence of freezing temperatures;
- presence of spatially variable light including a mix of full sun, shade and dappled sunlight;
- presence of high humidity; and
- availability of water.

2. Create an Initial Monarch Overwintering Habitat Boundary Map

Use aerial imagery to produce a base map of the overwintering site. Monarch habitat includes cluster trees and the features that provide important windbreaks, encompassing trees well outside the main

grove. Use observations and consult with Xerces Society staff or a local monarch expert to determine where monarchs have overwintered at your site in the past to refine the habitat boundary and focus survey efforts.

3. Conduct a Habitat Site Assessment and Monitor During the Overwintering Season

Habitat site assessment should include identification and mapping of:

- property lines and locations of cluster trees and surrounding trees,
- very important trees and saplings, and
- hazard trees.

Monitoring for microclimate and monarchs should include:

- evaluation of wind exposure of cluster trees,
- assessment of solar radiation patterns and dappled sunlight availability, and
- counts of monarch abundance at regular intervals throughout the overwintering season (October to March).

4. Revise the Monarch Overwintering Habitat Boundary Map

Revise the habitat boundary map after each season of monitoring based on the habitat site assessment and monitoring data.

5. Develop an Adaptive Management Plan

A site specific management plan that includes the principles of adaptive management may include:

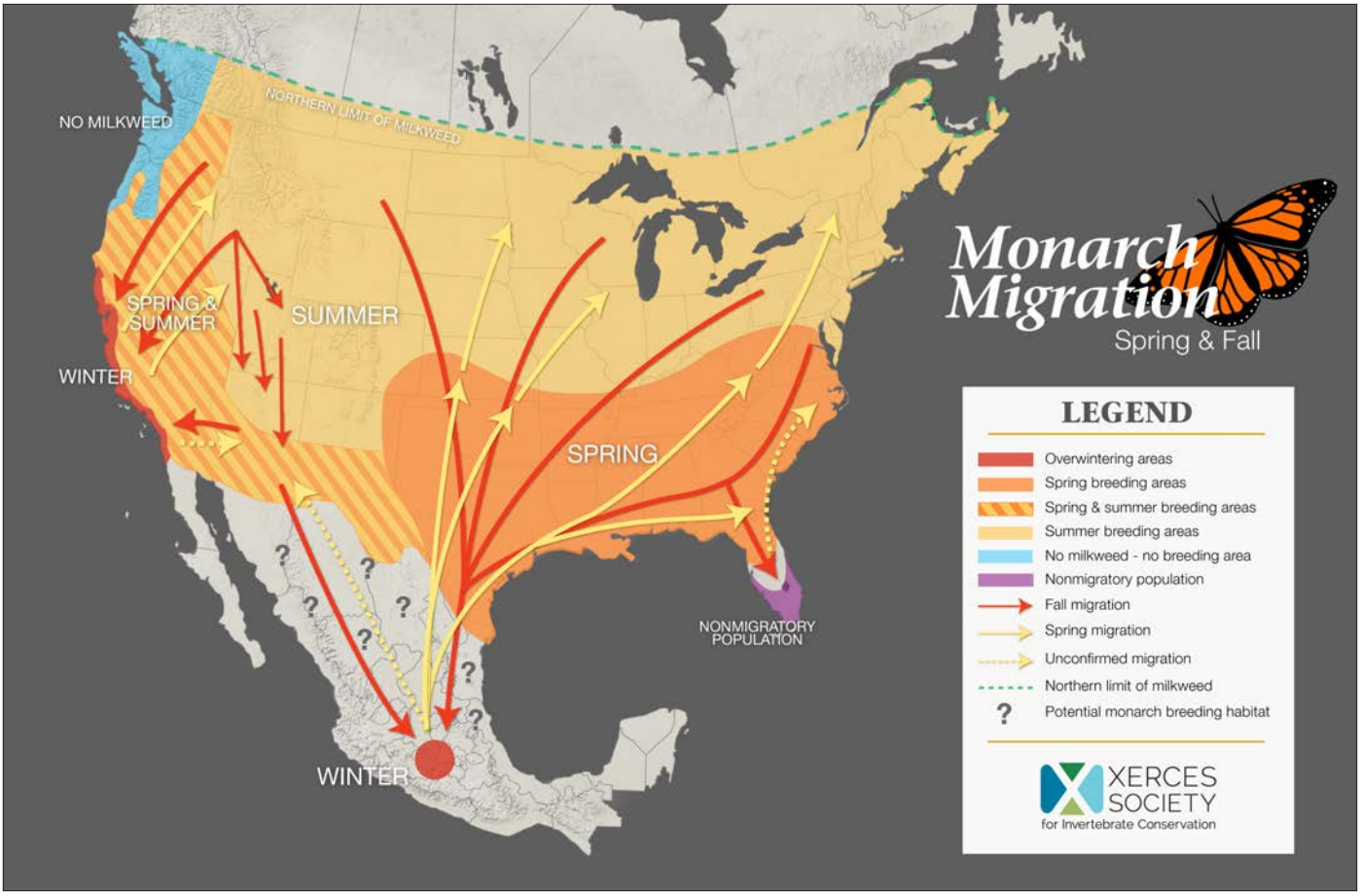
- recommendations for trimming or removing select trees or branches for hazard reduction and increasing sun exposure,
- developing and implementing a long-term tree planting strategy,
- planting fall- and winter-blooming nectar flowers,
- reducing or altering pesticide use,
- implementing erosion control measures,
- minimizing the negative impacts of public access by planning trail locations, installing signage, and/or providing staff or docents, and
- involving stakeholders and adjacent landowners in the decision making process.

Monarchs shelter on the underside of a Monterey cypress branch. (Photograph: The Xerces Society / Carly Voight.)

Introduction

Every fall, hundreds of thousands of monarchs arrive at forested groves along the California coast and aggregate en masse. This seemingly impressive number is just a small fraction of the more than 10 million butterflies that have congregated in the past. A long-term citizen monitoring effort, the Xerces Society Western Monarch Thanksgiving Count (Monroe et al. 2017), has provided annual estimates of the number of monarchs overwintering at 300 coastal California sites since 1997. Data from the Thanksgiving Count and historical data show a population decline of over 95% since the 1980s and the migratory population is at a high risk of extinction. In the 1980s, about 10 million monarchs overwintered in coastal California, while in 2016 fewer than 300,000 were counted (Schultz et al. 2017). While climatic factors such as rainfall and drought may explain much of the interannual variation in monarch numbers (Stevens and Frey 2010; Espeset et al. 2016), loss or degradation of habitat including breeding and overwintering habitat are persistent factors that likely are also contributing to long-term declines in the species' ability to survive and reproduce (Pelton et al. 2016). In California, active management of monarch overwintering sites is an important component of monarch conservation.

Figure 1. Migration routes, breeding areas, and overwintering areas of monarchs in North America.



Biology and Conservation of Western Monarchs

Biology and Life History of Monarchs in Western North America

The monarch butterfly (*Danaus plexippus plexippus*) is renowned for its long-distance seasonal migration and its spectacular winter gatherings in central Mexico's oyamel fir forests and along the California coast. In western North America, monarch overwintering sites are distributed along the California coast from Mendocino County to the Mexican border, and south into Baja California, Mexico (Xerces Society Western Monarch Overwintering Site Database 2017). Each spring, monarchs depart these sites and spread out across the Californian interior and the western U.S., sometimes reaching as far north as British Columbia.

After mating, female monarchs lay their eggs on milkweed plants (*Asclepias* spp.). Several generations of adult butterflies are produced throughout the spring, summer, and fall. Each autumn, the last generation of monarch butterflies migrates to overwintering habitat. It was formerly thought that monarchs west of the Rocky Mountains would only migrate to California overwintering sites, and those east of the Rocky Mountains would only migrate to sites in Mexico. Tagging studies (Morris et al. 2015) by citizen scientists, however, have shown that monarchs in western North America migrate to both Mexico and California, and genetic research (Lyons et al. 2012) confirms that eastern and western monarchs comprise a single population (Brower and Pyle 2004).

Monarchs generally begin to arrive at the California coast in mid-October (Hill et al. 1976) but may arrive as early as September (Leong 1990a). They form dense groups on the branches, leaves, and occasionally, trunks of trees. Trees that support these large groups of monarchs are called cluster trees. While a few monarchs will attempt to mate during the winter, most overwintering monarchs are in a state of reproductive dormancy called reproductive diapause (Herman 1981), and remain in this state until February or March. In the spring, monarchs leave overwintering sites and return to their spring and summer breeding grounds.

Overwintering monarchs have very specific microclimatic requirements, such as protection from wind and storms, absence of freezing temperatures, exposure to dappled sunlight, presence of high humidity, and availability of water (Chaplin and Wells 1982; Calvert and Cohen 1983; Masters et al. 1988; Anderson and Brower 1996; Leong 1999). Monarchs use nectar for energy, storing the calories obtained as lipids. The presence of fall- or winter-blooming flowers at overwintering sites may be important to maintain lipid reserves required for the spring migration (Tuskes and Brower 1978).

Conservation and Management of Monarch Overwintering Habitat

The historical composition of vegetation on the California coast differed from the contemporary composition, and groves of native trees presumably hosted dense monarch aggregations (Lane 1984, 1993). Today, monarch overwintering habitat in California is directly threatened by urban and suburban development, and to a lesser extent, agricultural development. Habitat alterations such as tree trimming

or tree removal as well as natural factors such as fire, severe storms, and disease or senescence of trees, can alter the structure and microclimate of an overwintering site and reduce its suitability for monarchs (Sakai and Calvert 1991; Commission for Environmental Cooperation 2008).

Housing development is a major cause of overwintering site loss. A statewide report published in 1991 documented 38 overwintering sites that had been lost or destroyed; 16 of these were lost to housing developments (Sakai and Calvert 1991). In the 1990s, an additional 11 overwintering sites were lost to development (Meade 1999), and there are seven more that have been destroyed due to development since the late 1990s, including one in 2016 (Xerces Society Western Monarch Overwintering Sites Database 2017). In recent years, advocates seeking to protect overwintering sites have contacted the Xerces Society to report that additional sites are slated for development (SJ, personal observation). Anecdotal reports suggest that overwintering sites have also been lost due to tree cutting or trimming (Sakai and Calvert 1991), or that the monarch population has declined after tree trimming, although this assertion can be difficult to demonstrate (see discussion in Villablanca 2010).

At present, the dominant trees on most overwintering sites are nonnative blue gum (*Eucalyptus globulus*) or red river gum eucalyptus (*E. camaldulensis*), although many sites also contain Monterey pine (*Pinus radiata*), Monterey cypress (*Cupressus macrocarpa*), western sycamore (*Platanus racemosa*), and other native trees (Xerces Society Western Monarch Overwintering Site Database 2017). Eucalyptus are exotic invasive species and have been shown to reduce biodiversity (Bossard et al. 2000). Removal of eucalyptus is often a restoration goal in natural areas, and conflicts can emerge between monarch habitat conservation and eucalyptus removal. Recent studies suggest that monarchs do not prefer eucalyptus trees to native tree species (Griffiths and Villablanca 2015), so restoration of overwintering sites with native tree species should be the long-term aim. This work, however, can take decades because many of California's native conifers are relatively slow-growing. Consequently, removing eucalyptus at overwintering sites should be done in phases while native trees are planted so that viable monarch habitat will be continually present (Lane 1993).

Many monarch overwintering sites also contain aging or diseased trees. For example, Monterey pine is affected by pitch canker (*Fusarium circinatum*), a fungus that causes swollen lesions that girdle branches, trunks, and exposed roots. The disease was first observed in California in Santa Cruz County in 1986 and has since spread to many coastal counties (Winkler et al. 2003). As aging or diseased trees lose limbs or die, sites can become less suitable for monarchs and pose a public safety hazard. To reduce safety hazards, land managers prune aging or diseased trees which may result in microclimatic changes that make a site unsuitable for overwintering monarchs.

The planning and implementation of long-term management of monarch groves is critical to maintaining sufficient, viable overwintering monarch habitat in coastal California.

(Opposite) California's butterfly groves are diverse in location and varied in character. Despite their differences, they have one thing in common: they each provide just the right conditions to sustain clusters of monarch butterflies through the winter months. Their care and management is essential to maintain the phenomenon of migrating butterflies. (Photographs: The Xerces Society / Carly Voight.)

Developing a Site-Specific Management Plan

The most vulnerable element of the monarch annual cycle may be the overwintering stage (Pyle and Monroe 2004). Protection and active, careful management of overwintering habitat are critical to supporting the migratory phenomenon and conserving the species. In this section, guidance is provided as five steps to consider in developing a site specific management plan for California overwintering groves:

1) Become familiar with monarch overwintering habitat requirements and characteristics.
2) Create an initial monarch overwintering habitat boundary map.
3) Conduct a habitat site assessment and monitor during the overwintering season.
4) Revise the monarch overwintering habitat boundary map.
5) Develop an adaptive management plan and continue to monitor and refine over time.

Step 1
Become Familiar with Monarch Overwintering Habitat Requirements and Characteristics

The mild conditions at forested groves along the California coast provide the microclimate that monarchs require to survive the winter in western North America. The majority of these sites are within 1.5 miles (about 2.4 km) from the Pacific Ocean or San Francisco Bay (Leong et al. 2004), and these water bodies moderate temperature fluctuations (Chaplin and Wells 1982). The suitability of habitat for overwintering monarchs is likely also influenced by landscape- and site-level characteristics that create very specific environmental conditions. These conditions include: protection from winds and storms, absence of freezing temperatures, exposure to dappled sunlight, high humidity, and access to nectar and water. Monarch habitat encompasses the cluster trees that monarchs roost on, as well as surrounding trees that influence the microclimate of the grove (Leong 1989; Leong et al. 1991).

Monarch behavior is influenced by conditions within the region and individual sites. The distribution of butterflies among overwintering sites in California changes from year to year and from month to month (Leong 1989, 1990b; Leong et al. 1991). Migrating monarchs that reach the coast in October roost in groves that offer a wide range of conditions. As the rainy season brings strong winds and cooler temperatures, monarchs frequently leave sites that do not provide enough shelter, and remain at sites that do. Monarchs are likely attracted to the presence of other monarchs as an indicator of site quality, so that occupied sites attract wandering monarchs that have left unsuitable sites. Monarchs may use a given site only in the fall, but in years with mild weather, they may occupy the site throughout the fall and winter. Monarchs may also use certain sites in northern California in the fall temporarily on their way to central or southern California sites for the winter.

Knowledge of the habitat conditions that monarch butterflies require and the forest characteristics that determine these conditions is essential for managing or restoring overwintering habitat. Details of

The suitability of a grove for overwintering monarchs is influenced by many factors, including shelter from wind and storms and the right amount of sunlight for the butterflies to maintain body temperature. Even seemingly small things such as a tree branch at the correct height and angle can be significant. (Photograph: The Xerces Society / Carly Voight.)

monarch habitat requirements are provided below to aid in the development of management plans at overwintering sites.

Landscape Topography

Local landscape topography contributes to the microclimatic characteristics of overwintering habitat. Most sites occur at low elevations (below 300 feet [90 m]) and sometimes can be found in shallow canyons or gullies (Lane 1993). Many groves occur on slopes that are oriented to the south, southwest, or west, which likely offer the most favorable solar radiation exposure and wind shelter (Leong et al. 2004).

Shelter from Storms and Prevailing Winds

Strong winds or rain dislodge monarch clusters, and batter individuals, and can be lethal to the butterflies (Calvert and Cohen 1983). Monarchs that have been blown off trees can die of exposure and become susceptible to ground predators, such as wasps and ants. Forest groves that provide the best wind protection for monarchs have areas that are free from strong, sustaining winds of 4.5 mph (2 m/s) or greater, in at least a portion of the site (Leong 1990a; Leong et al. 1991). Winter storms along the California coast can produce southerly winds of >56 mph (25 m/s) and pose the greatest risk to successful overwintering.

Wind may drive much of the short-term movement of monarchs within a site. For example, if a cluster site is exposed to storm winds from the southeast, it may drive monarchs to seek cluster trees

away from the winds in more sheltered areas. When the prevailing northwest winds return after the passage of the storm, monarchs may return to the original cluster sites (Leong 1990a). Strong winds may drive monarchs completely from some sites; after a December 1995 storm with hurricane force winds, the Monarch Grove Sanctuary in Pacific Grove was abandoned, perhaps due to the storm (Weiss 1998). Trees, especially when growing in high density, act as a shelter and slow near-surface winds. Isolated trees provide less of a shelter effect because the wind wraps around them (Weiss and Luth 2002).

Temperature and Humidity

The survival and behavior of monarchs are influenced by both temperature and humidity. Freezing temperatures can be lethal to monarchs (Calvert and Cohen 1983). Generally, monarchs can only crawl when the temperature is between 39° and 55° F (4° and 12.7° C) (Anderson and Brower 1996) and they are only able to fly when temperatures reach 54.9° F (12.7° C) or greater (Chaplin and Wells 1982; Masters et al. 1988). However, monarchs require mild daytime temperatures to conserve their fat reserves throughout the overwintering season (Chaplin and Wells 1982). Monarchs also require high humidity; low humidity can cause desiccation and lead to death (Chaplin and Wells 1982; Masters et al. 1988).

Monarchs appear to adjust their distribution within an overwintering site as temperature conditions vary throughout the winter months (Leong et al. 1991). The butterflies will only cluster in deeply shaded areas if the area is warmer than approximately 55° F (Leong 1999). Near the ground, temperatures are cooler at night and warmer in the day. Monarchs cluster closer to the ground at warmer, more southerly sites, and higher in the canopy at cooler, more northerly sites. The height at which monarchs cluster may be a function of the level to which cold air reaches at night (Tuskes and Brower 1978). Thus, the presence of branches at different heights that can be used for clustering is an important structural component of overwintering habitat.

Features that make a good monarch grove include shelter from storms and winds, a choice of roosting branches, dappled sunlight, a water source, and nectar plants that bloom in fall and winter. (Photographs: top and middle, The Xerces Society / Carly Voight; bottom, Matthew Shepherd.)

Solar Radiation

Solar radiation entering the grove is an important component of monarch overwintering habitat. Full sunlight allows for rapid warming to increase activity levels and flight temperatures, even under cool air temperatures (<50° F [10° C]) (Chaplin and Wells 1982; Masters 1993). Dappled sunlight provides options for flight or rest, and shade provides the coolest conditions for maintaining fat reserves. Monarchs generally cluster in areas that receive dappled sunlight in the late morning and early afternoon (Leong et al. 1991). The sunlight warms the butterflies, enabling them to fly to nectar sources to refuel their energy and lipid reserves. If a cluster area remains shady throughout the day, the monarchs' internal temperature may remain too low for them to fly. Conversely, if a cluster area is in direct sunlight, monarchs may overheat, which increases fat depletion (Chaplin and Wells 1982).

There may be predictable seasonal patterns in the distribution of clusters within a site, as sun angles and the needs of the monarchs change through the season. In mid-winter, when there is less need for activity, sites that remain sheltered, shaded, and cool may be preferred. However, once mating begins in February, there may be a preference for sites with early morning sun exposure.

The amount of solar radiation reaching the monarchs through the day and through the overwintering season is determined by canopy density. Larger canopy gaps provide longer periods of solar radiation, whereas a single layer of branches and foliage can produce dappled or filtered light. Solar radiation is greatly influenced by fine-scale gap patterns in the canopy and can, therefore, be highly variable from point to point within a grove. A single branch can make a large local difference, and small differences in height or horizontal position can create high variability in solar radiation.

Suitable overwintering habitat will have small canopy gaps that allow dappled sunlight and contain areas with larger gaps that allow for sunning and nectaring. The overwintering habitat as a whole must be dense enough to provide protection from strong winds and winter storms, yet also contain canopy gaps (Leong 1990a; Leong et al. 1991; Weiss et al. 1991).

Water

Water is another basic habitat requirement of monarchs. Most overwintering sites in California exist adjacent to natural water courses (Lane 1993; Xerces Society Western Monarch Overwintering Sites Database 2017). Water can be obtained from dew in open areas, local mud puddles, and sluggish streams, as well as from flowering plants in the form of nectar (Leong 1989; Leong et al. 1991; Weiss et al. 1991). While monarchs are generally inactive on rainy, windy, and cold days, they will fly from the clusters on sunny, warm days to obtain water necessary to sustain them throughout the winter (Frey et al. 1992; Leong 2003). Water sources close to cluster trees allow monarchs to conserve their fat reserves because they fly shorter distances to reach this essential resource (Masters et al. 1988; Wells et al. 1990). Also, water sources should be in direct or dappled sunlight as monarchs will not readily fly into shaded areas except under relatively warm air temperatures (Leong 2003).

Fall- and Winter-Blooming Nectar Plants

Monarchs in California use up approximately half of their lipid reserves during the overwintering period, and their ability to migrate in the spring may depend upon the amount of nectar that they consume during the winter (Tuskes and Brower 1978). It has also been suggested that abundant nectar sources contribute to the formation of temporary autumnal monarch aggregations, and that reduced nectar availability may cause the dispersion of these aggregations (Lane 1993).

Sunny areas with abundant nectar plants that bloom in the late fall, winter, and early spring form an important component of monarch overwintering habitat. In particular, blue gum eucalyptus blooms in early winter and provides copious nectar. Ensuring that a variety of nectar plants grow near the grove

provides choices for the monarchs through the overwintering season. A list of recommended monarch nectar plants native to California and commercially available can be found in Appendix A (page 28).

Forest Structure

The forest canopy of a monarch overwintering habitat serves as both "a thermal blanket and a rain umbrella" (Anderson and Brower 1996) because it provides protection from temperature extremes, high winds, and heavy rains during storms. By filtering wind, light, heat, and moisture, the canopy creates conditions within the overwintering groves that are calmer, darker, more humid, cooler in the day, and warmer at night as compared to those on the outside (Geiger 1965). Overhead branches are particularly important for protecting monarchs from heavy rainstorms, although wind-driven rain can come from many angles. Most high-quality monarch sites fall within a relatively narrow range (15–25%) of overall canopy openness (Weiss et al. 1991).

Monarch habitat includes the trees that provide important windbreaks, sometimes encompassing trees (and on occasion, structures) well outside the main grove. Wind exposure is determined by canopy density and canopy height. Denser canopies block the wind more effectively, whereas large tree gaps can funnel winds into groves.

Understory Structure

Monarchs overwintering sites often have a moderate level of ground vegetation and detritus, such as branches or shed tree bark. These elements provide a substrate upon which monarchs can crawl on if they are dislodged by the wind from cluster trees on cold or cloudy days. If a site lacks sufficient ground vegetation, monarchs may die from freezing ground temperatures or by being eaten by predators. Conversely, excessive ground vegetation may impede a monarch's ability to freely fly in the forest understory.

Step 2
Create an Initial Monarch Overwintering Habitat Boundary Map

Develop a Base Map

Begin with an aerial image of your grove and the vicinity using available photographs (e.g., GIS or Google Earth) to create a base map. Monarch overwintering habitat encompasses not only the trees upon which monarchs cluster, but also surrounding trees and grove features that create the habitat characteristics described in Step 1. An overwintering site may include cluster trees, trees that provide windbreaks and dappled light, buildings or objects that provide windbreaks, flowering nectar plants, ground vegetation, and water sources (Leong 2003; Weiss 1998, 2011). Trees or structures that provide windbreaks can be located more than 110 yards (100 m) from what may appear to be the habitat boundary (Weiss 1998). You will need to use your best judgment in determining which trees and features may provide windbreaks until you have completed at least one season of monitoring.

Consult with the Xerces Society or a Local Monarch Expert

If you are conducting an assessment for the first time, past records of monarch presence or behavior will be valuable to focus monitoring efforts. Individuals involved in the Xerces Society's Western Monarch Thanksgiving Count and organizations such as Monarch Alert have been monitoring monarchs at scores of sites and may have records of monarchs at your site or other site-specific information. Contact the Xerces Society at monarchs@xerces.org for more information about long-term monitoring of specific overwintering sites.

Step 3
Conduct a Habitat Site Assessment and Monitor During the Overwintering Season

Information gathered during a habitat site assessment and by monitoring through the overwintering season will provide the necessary data to inform management decisions. Evaluating a site should consist of both a habitat site assessment to help you identify important trees, hazards, and other areas used by overwintering monarchs, monitoring of microclimate variables that contribute to habitat suitability, and conducting a monarch count. Ideally, monitoring should be conducted at least twice a month during the overwintering season (October to March), as monarchs often move within the grove in response to changing conditions.

Aerial photography is easily available (for example, from Google Earth) and will make a good foundation for mapping the boundary of a site as well as the location of significant trees and other habitat components.

Habitat Site Assessment

Begin with aerial imagery of the grove. A map of property lines and tree locations is essential. This map can be made using GIS, triangulation with measuring tapes (50–100m long), or more sophisticated surveying equipment. Note that most GPS units, even high end models, may perform poorly in dense forests; in this case, a static map is extremely useful.

Identify Cluster Trees

Observe the use of trees by clustering monarchs and note the height and aspect (cardinal direction) of the branches being used. Record the location and species of these trees and note if monarch clusters are shifting vertically or between trees over the season.

Identify "Very Important Trees" (VITs)

While all trees may play some role in creating suitable habitat, there may be a limited number of trees that play key roles, such as cluster sites or trees that provide storm wind protection. The loss of such trees will seriously compromise the integrity of the overwintering habitat. Identifying these trees or groups of trees will help to prioritize tree management objectives. Initially, this will include all cluster trees and surrounding trees that provide appropriate shade or protection from the predominant wind directions. (Storm winds typically come from the southeast, south, or southwest. During non-storm periods, the winds are predominantly from the west and northwest.)

Identify "Very Important Saplings" (VISs)

These are smaller trees that are in key locations and which may grow to replace larger VITs. Note the tree species to predict how the tree's anticipated height and branching structure will affect the microhabitat characteristics nearby. If useful, you can classify the saplings' current heights to track changes over time. Suggested height classes are 3–10 ft., 10–30 ft., 30–100 ft., and >100ft. (1–3 m, 3–10m 10–30m, >30 m). Also note if there are no saplings present which are poised to replace a VIT and thus planting in the near future may be necessary.

The site assessment should identify and map all features of significance for the butterflies and site management. Significant trees can be those that provide shelter or roosting branches, but also those that create hazards or need replacing. (Photograph: The Xerces Society / Carly Voight.)

Identify Hazard Trees

A certified arborist should evaluate the health of trees at the overwintering site to determine which trees are in danger of losing limbs or falling. Obvious hazard trees should be identified, as well as trees that are infected by pests or pathogens and may become hazards in the near future. The location of all hazard trees should be mapped. Hazard trees should also be evaluated for "targets" (e.g., paths, other trees, structures) should they shed branches or fall. VITs that are also hazard trees should be replaced.

Tracking Important Trees

After mapping the location and species of the important trees (cluster trees, VITs, VISs, and hazard trees), marking key trees with tags or a unique identifier on a map is useful for tracking the trees into the future. Proper identification also helps ensure that cluster trees, VITs, or VISs are not misidentified and accidently trimmed or removed. If there are many small trees or clustered re-sprouts, then groups of trees rather than individuals can be defined by a single identifier. Physically marking trees or identifying them clearly on a static map may be very important for finding them again in the grove as GPS units may perform poorly under a tree canopy.

Identify Nectaring, Sunning, and Water Areas

Walk through the habitat and take note of any areas that monarchs use for nectaring, water consumption, or sunning. Record any species of flowering plants that are in bloom during the overwintering period, in particular, any that are used by monarchs for nectaring. Mark all documented and potential foraging, water, and sunning locations on your map.

Record Microclimate Variables

By using simple tools such as a compass, pocket weather meter, and standard digital camera, coupled with basic mapping, you can document differences in variables such as wind and light exposure that determine site suitability and areas which may require management to improve conditions for monarchs.

Wind Exposure

Classify the wind profile of the site by measuring the wind direction and speed with a pocket weather meter (several brands are readily available) and the compass at many points throughout the grove. Wind measurements should be done during periods of sustained winds. Baseline measurements in open areas outside the grove, coupled with interior grove measurements, allow an estimate of wind attenuation. Hourly wind data from a local weather station, if available, can supplement your measurements. Wind measurements should be taken in multiple areas in the grove close to cluster trees and in nearby areas

which do not host monarchs, as well as outside the grove. Comparing these measurements will allow you to better understand where wind protection may be insufficient outside of the cluster area. If a recent event (e.g., storm, tree removal) has made the area with clustering monarchs susceptible to high winds or storm winds, planting fast-growing trees and shrubs—or even transplanting mature trees—may be imperative to close the gap. Creating a wind profile also helps identify which lines of trees are contributing the most to wind protection of the grove and should be labeled as VITs and/or which areas may require additional plantings to increase redundancy in wind protection.

Solar Radiation

Examine the pattern of light through the day and identify those trees that are providing shade to cluster trees. This can be achieved using photographs of the canopy and ground and/or by using a light meter. Also, evaluate the amount of dappled sunlight that clusters on trees receive throughout the course of the day, and especially early morning and late afternoon. Observations in early November and in late December will be sufficient to represent the majority of the overwintering season (since the sun tracks in early November are the same as in late February). Take note if areas of the grove are allowing or blocking too much sunlight (consideration of the differences between ground level measurements and cluster heights are essential). These may be areas which would benefit from select limb thinning or additional tree planting.

Temperature and Relative Humidity

Record the temperature and humidity of the interior of the grove, near the cluster tree(s). These data can be collected with a pocket weather meter or a continuous microclimate recorder. Compare these measurements to other areas of the grove unoccupied by monarchs and outside of the grove. Colder and drier areas of the grove may benefit from management to make the microclimate conditions more suitable for clusters, such as additional tree planting.

Developing a basic wind and solar radiation profile of a monarch overwintering site can be achieved using the methods described above, and for many overwintering sites, these methods may be sufficient to plan beneficial management action. Site managers with the resources to undertake more advanced monitoring of site conditions should consider consulting with a monarch habitat expert to assess their site's conditions and needs in greater detail. Contact monarchs@xerces.org for recommendations of individuals and organizations in your area.

Two approaches to assess monarch habitat suitability in greater detail are profiled below:

- **Develop a detailed microclimate profile**: Utilize systematic wind, temperature, and humidity monitoring over the course of the overwintering season to map the microclimate profile of the site over time (see Leong et al. 1991). Combining this map with your knowledge of monarch habitat requirements and monarch movement will reveal when and where site conditions are unsuitable for clustering within the grove.
- **Utilize hemispherical photography and detailed tree mapping**: Together, these methods allow an assessment of canopy structure, and its effects on wind, solar radiation, and monarch habitat in a high degree of detail (Weiss et al. 1991, 2012; Weiss 1998, 2011). For example, data from this approach can identify areas of the grove which may receive excessive indirect and direct solar radiation throughout the season and may benefit from additional tree planting.

Conduct a Monarch Count

Observations of monarch distribution and abundance in a grove are critical to understanding site suitability—the vulnerabilities of a site are expressed by the movements of monarchs themselves. Monitoring should be done as frequently as possible during the overwintering season to capture changing distributions through the season and in response to storm events. Monitors should record the number of monarchs present and, to get an accurate estimate, counts should be done in the morning (before monarchs become active) or late afternoon/evening (after they have settled for the night). During the middle of the day, observations of monarchs sunning and nectaring can be made to identify habitats that are utilized for these activities. The monarchs' duration of occupancy (e.g., October to March) should be noted.

The Xerces Society, Monarch Alert, and others provide training on counting clustering monarchs. Land managers can contact these organizations for guidance in establishing a local monitoring program. They may be able to provide training to land management staff or initiate contacts between landowners and trained volunteer citizen scientists to monitor the site. Additional information on monitoring monarch clusters and data sheets are available online from the Western Monarch Count Resource Center, www.westernmonarchcount.org.

Step 4
Revise the Monarch Overwintering Habitat Boundary Map

Once you have completed at least one season of monitoring, revise your initial monarch overwintering habitat boundary map. Three seasons of monitoring are ideal, although often not realistic (Leong 2003). Incorporate information from the habitat site assessment, including the trees you mapped and water or nectar sources that may not have been apparent early in the season. Use data from your wind exposure evaluations to determine if additional features in the landscape act as wind buffers. If so, redraw your boundary to include these features. If the monarchs used different cluster trees throughout the season, make sure to also note this on your map.

Based on the temperature, humidity, wind, and solar radiation data you collected, highlight areas of the grove on the map which are currently unsuitable or marginally suitable for monarchs. These are areas which may benefit from active management such as tree thinning to open up the canopy or tree planting to provide additional wind/storm protection or to replace/expand the current cluster trees as the grove ages.

Figure 2 offers an example of an overwintering habitat boundary map including specific cluster trees, windbreaks, and areas targeted for active management.

Step 5
Develop an Adaptive Management Plan

A site-specific management plan should be developed using an adaptive management model (Figure 3). Adaptive management is a process that involves the continuous refinement and improvment of future management practices by learning from the outcomes of previous actions. Under this model, management regimes are designed and implemented in order to achieve stated objectives. Results are assessed through monitoring, and information gained is used to assess and adjust the management plan.

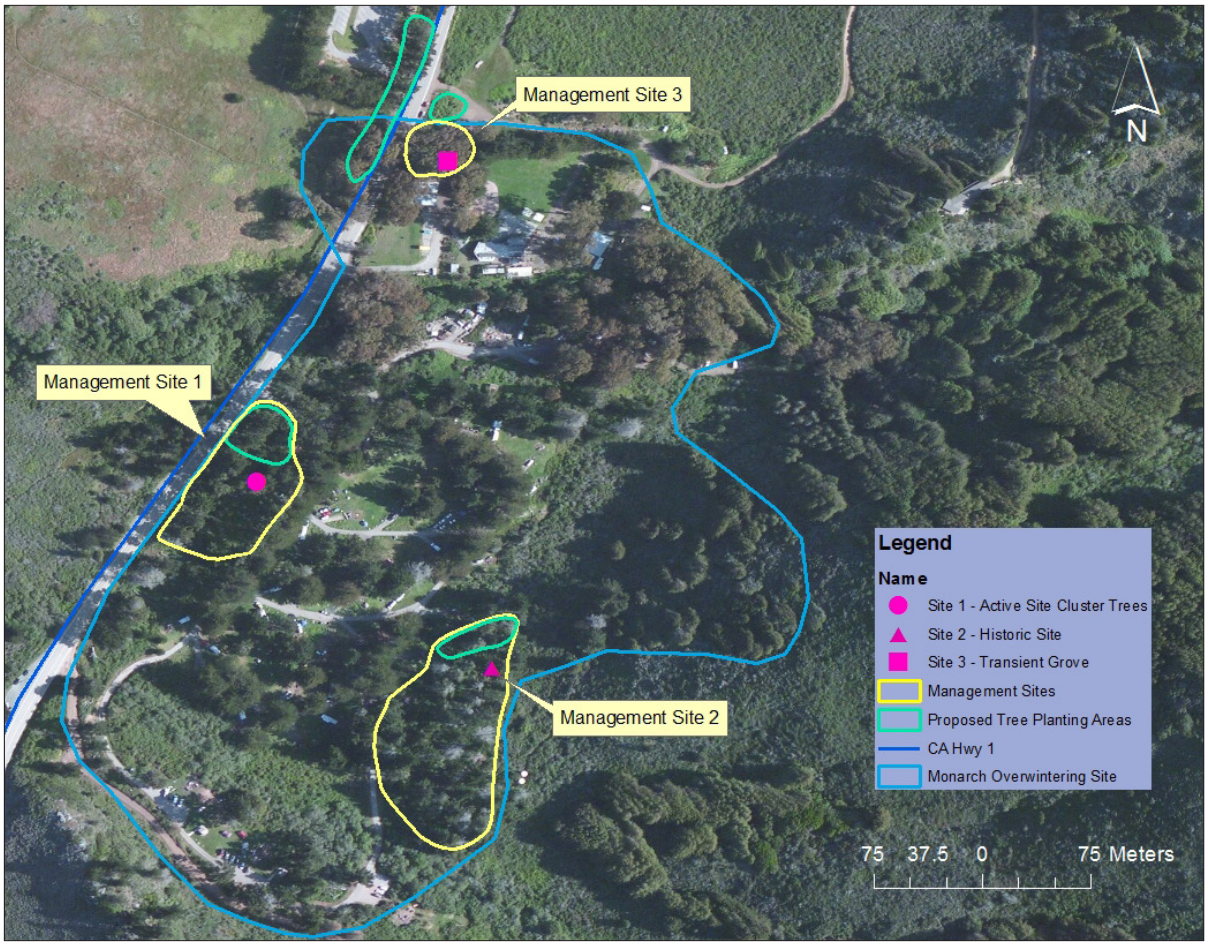


Figure 2. Aerial image of the Plaskett Creek Campground, Los Padres National Forest, showing key features of the monarch butterfly overwintering habitat, including overall boundary, clustering trees, and areas for future tree planting.

The following key elements should be included in an adaptive management plan:

- Assess the habitat to determine the existing environmental conditions at an overwintering site (See Step 3, above).
- Identify goals and objectives, and specific management actions to meet them, and set a timeline for accomplishing these actions.
- Implement management actions and grove modifications.
- Routinely monitor monarch abundance, roosting location, and microclimatic variables (See Step 3, above).
- Evaluate the information obtained from monitoring to determine the effectiveness of the management actions.
- Adjust and improve the management plan and specific actions based upon the evaluation of implemented grove modifications.

Many sites are on publicly owned or managed land. For those, a predictable annual cycle of meetings allowing for appropriate stakeholder and public input to proposed management actions is highly recommended. For all sites, both public and private, good record keeping is valuable for building institutional memory, because the adaptive management process can take decades and personnel may come and go during that time or site ownership may change.

As you develop your adaptive management plan, keep in mind that monarch abundance at a site is likely influenced by a variety of different factors (including region-wide milkweed availability and quality in breeding areas, overwintering habitat availability and quality, and climate), and monitoring yearly monarch abundance will not necessarily tell you if you have been successful at managing or restoring monarch habitat. Keeping track of the overall monarch numbers in California, and within your region, via the Xerces Society Western Monarch Thanksgiving Count and the New Year's Count (www.westernmonarchcount.org), provides a context for local fluctuations. Routine monitoring of microclimatic variables, such as temperature, wind speed and direction, solar radiation, and nectar plant availability, both before and after implementing management actions, will allow you to evaluate the effectiveness of your activities in creating an overwintering habitat that is suitable for monarchs. In addition, trees that have been identified as providing an important function to the overwintering site (e.g., contributing to a windbreak) should be periodically assessed for pests and diseases. The earlier that hazard trees are identified, the earlier they can be replaced.

Patience is critical in the adaptive management process. As discussed in chapter 4, newly planted trees can take a decade or more to reach heights where they provide wind shelter and affect the light environment. Short-term impacts of hazard branch and tree removal may be ameliorated in subsequent years by growth responses of remaining trees, especially eucalyptus that can develop new branches to take advantage of increased light availability.

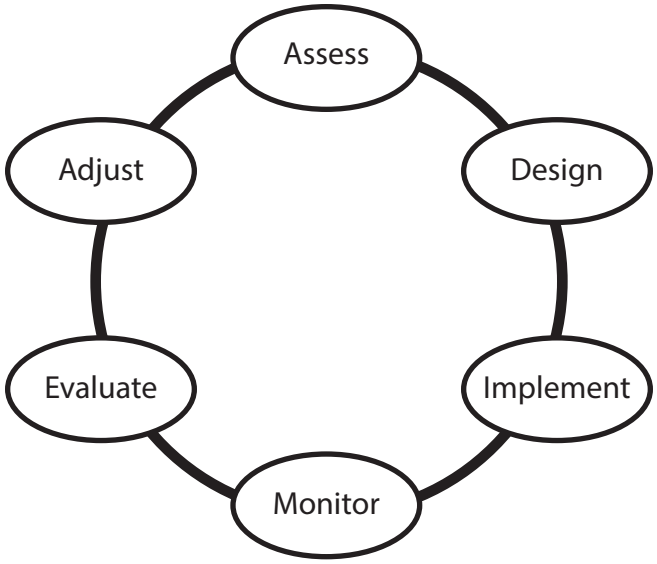


Figure 3. The adaptive management cycle (adapted from Elzinga et al. 1998).

Considerations to Include in a Management Plan

Since every overwintering habitat is unique, different management strategies and actions will be necessary for each site. Any management modifications should be based on at least one seasonal assessment of the microclimatic conditions and biological characteristics of the habitat. For example, if the habitat assessment indicates that the grove is aging and no longer provides sufficient wind shelter, additional trees should be planted at precise locations to provide a windbreak.

The following recommendations are general management modifications or actions that land managers can implement to manage and restore their monarch overwintering habitat.

Tree Management

Remove or Trim Hazard Trees When Necessary

If hazard trees are identified during the habitat site assessment, consider removing or trimming them. Hazard has two components: the likelihood of structural failure, such as a limb falling or an entire tree collapsing, and the "target" should failure occur. Targets include viewing areas, paths, structures, and other trees. Consult with a monarch habitat specialist and certified arborist before cutting or trimming any trees within the overwintering habitat; contact monarchs@xerces.org for recommendations of individuals and organizations in your area. Unless there is an immediate danger, these activities should only occur when monarchs are not present (usually between April and August). A tree planting strategy should be developed to replace any function such as wind protection that is lost or significantly diminished when trees or branches are removed (see "Plant Native Trees" below).

Old trees within monarch groves that are open to the public may need to be periodically trimmed or cut for safety reasons. These trees can shed branches, become diseased, or deteriorate with old age, and falling trees and branches can injure and kill people. Obvious hazards include standing dead trees and dead branches that could fall onto trails or observation areas. Completely dead trees and branches generally do not contribute to monarch habitat and are a major potential liability. Felled debris from diseased and infected trees should be removed from the habitat to eliminate host material.

If the habitat site assessment indicates that trees are affected by pests or pathogens, integrated pest management can be utilized to control pests without harming monarchs or other wildlife. The use of systemic insecticides at overwintering sites is strongly discouraged because they are toxic to butterflies and persistent in the environment.

Remove or Trim Select Trees to Create Appropriate Solar Radiation Pattern

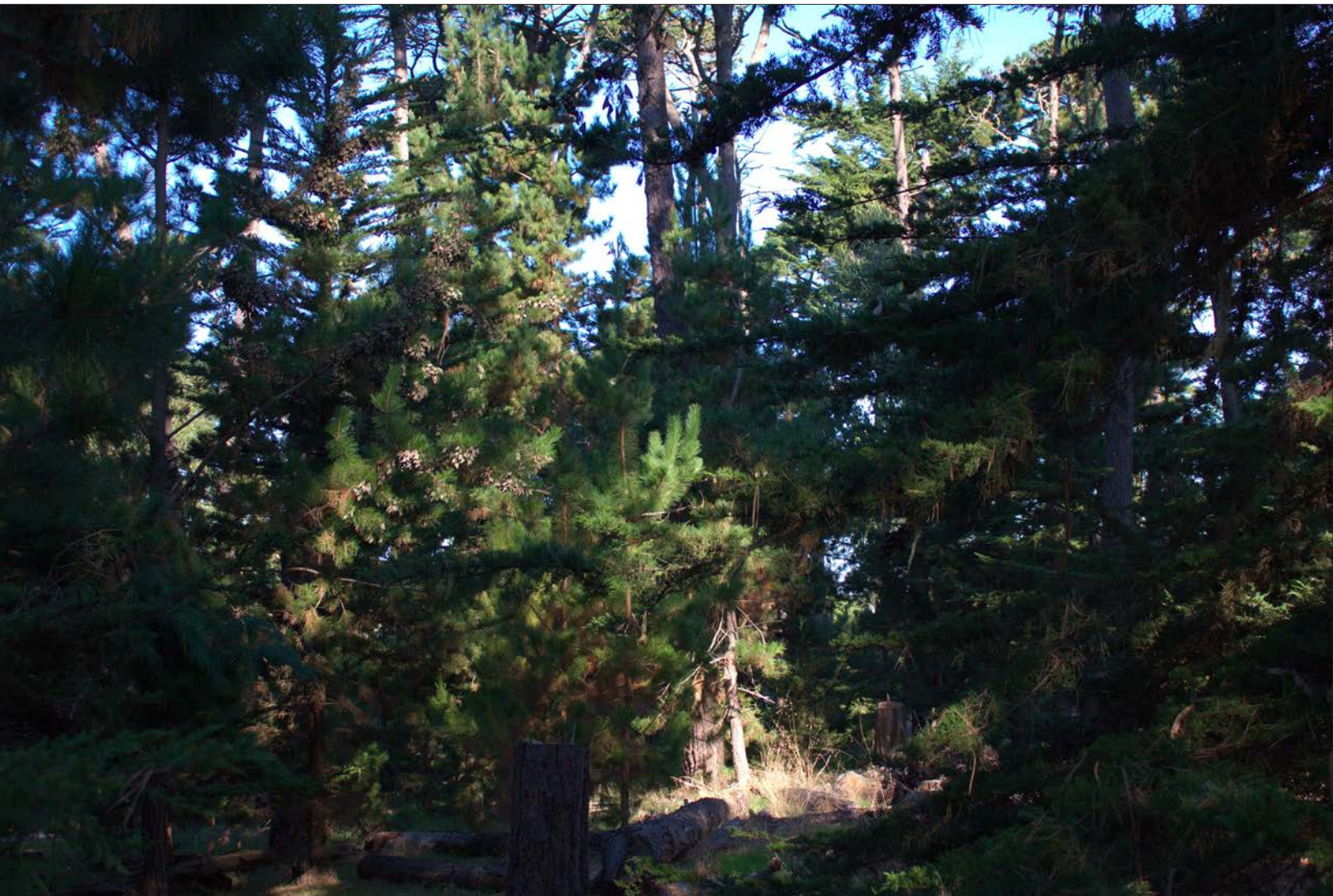
Branches or trees can be selectively removed if the habitat site assessment indicates that the monarch site does not provide adequate dappled sunlight (Weiss et al. 2012). The removal should only occur if suitable wind protection can still be maintained at the site. Additionally, some areas of shade should be retained to create a heterogeneous habitat that provides access to areas with full sun, dappled sunlight, and shade. Trees or branches should only be removed after careful thought and planning to address the potential positive and negative impacts of tree removal (Weiss 1998, 2011).

Develop a Long-Term Tree Planting Strategy

New trees could be planted to replace removed, old, or lost trees and also to provide additional wind protection. The appropriate action will be guided by conclusions from the habitat site assessment. Because it takes decades for new trees to grow and replace the function of lost trees, a plan should be developed to plant replacement trees long before old trees die or lose their ability to provide suitable microclimatic conditions. It is critically important to anticipate forest dynamics over several decades (Weiss 1998, 2011; Leong 1999). In areas where no saplings exist, new trees should be planted (Weiss and Luth 2002). Anticipate that these new plantings will take 15–30+ years to reach functional heights. Stands of the same age should be avoided and therefore plantings should be planned at appropriate intervals over time (Weiss 1998). In cases where there is an immediate need to fill a gap in an overwintering site, managers may consider excavating and relocating already established young conifers from other areas to the desired location. However, this option may be much more costly than planting saplings. If removal of nonnative trees is a goal, planting native trees many years before eucalyptus removal is necessary. Include overstory species (conifers) and mid-story trees (oaks, or delayed plantings of conifers) that can fill gaps when the lower branches of overstory conifers senesce. Tree planting and removal strategies should be designed to maintain or increase the size of the habitat and to ensure a balanced ratio of saplings to mature trees and sufficient density of the upper and lower forest layers (Janecki et al. 2004).

Take care to plant trees where they will provide the wind protection necessary for monarchs but not where they will cast shade over areas of dappled sunlight. If the monarch cluster is located far from the

Hundreds of monarchs cluster on the smaller trees in a sunlit opening. Ensuring suitable conditions are retained within this grove necessitates a long-term tree management plan that addresses trimming of branches or entire trees to remove hazards or provide adequate levels of sunlight, maintaining a windbreak against winter storms, and replacement of nonnative species. (Photograph: The Xerces Society / Carly Voight.)



newly planted trees, light infiltration may not be a concern and it may be best for the windbreak to be composed of tall trees that create a dense mid-story and understory.

Ideally, trees should be planted in the fall, after the first heavy rains (Weiss 1998). Two new trees should be planted for each removed tree, since not all saplings survive to maturity and trees can be thinned as needed. Eventual spacing of trees should be on the order of 10–20 ft. (3–6 m) so that they will not be overcrowded. To provide suitable wind protection, multiple rows of trees can be planted and trees can be offset by +/- 3 ft. (1 m) within the rows to avoid straight lines of trees (Weiss and Luth 2002). Irrigation of new plantings may be needed during the first two years to ensure survival of plantings and avoid stressing trees, but irrigation beyond should not be necessary beyond that period, except perhaps, during extreme drought. If the area is frequented by deer, deer-edible tree species should be protected (Weiss 1998).

Plant Native Trees

The Xerces Society recommends planting trees that are native to your geographic region. Recent studies suggest that monarchs do not have a preference for eucalyptus trees (Griffiths and Villablanca 2015), and that they may shift to native trees during adverse weather conditions. Ideally, restoration plantings at overwintering sites would consist of only native tree species. If this is not possible, ensure native trees are included in any planting plan.

Below are descriptions of a variety of tree species that monarchs utilize at overwintering sites, the advantages and disadvantages of using these species in restoration projects, and some insight into their management. The best option may be to plant a diversity of tree species at an overwintering site to create the variety of microhabitats that monarchs require and, potentially, to deter pests and pathogens (Weiss and Rich 2008).

Native Tree Species

Monterey Cypress (*Cupressus macrocarpa*)

Monterey cypress is one of the most desirable trees to plant at monarch groves. It is native only to the Monterey Peninsula and produces thick foliage on sturdy limbs that are able to buffer gusty winds and storms (Leong 2003). At groves which contain both cypress and eucalyptus, such as Lighthouse Field State Beach in Santa Cruz, monarchs apparently prefer Monterey cypress to nonnative eucalyptus during windy and stormy conditions (J. Dayton, unpublished data). This is perhaps because Monterey cypress has less flexible limbs and smaller scale-like leaves than eucalyptus, which may provide clustering monarchs with increased stability during strong wind events (J. Dayton, personal communication) as well as more shelter.

Careful placement of this tree is important. Its dense growth can obstruct light and prevent monarchs from receiving sufficient dappled sunlight if placed in inappropriate areas.

One disadvantage of Monterey cypress is that it is slow growing. It should be planted either well before hazard or aging trees are removed or in conjunction with a fast growing tree (Weiss 1998), such as Monterey pine or eucalyptus. As with most monarch grove trees, hazard management is required for old Monterey cypress since trees become frail with age. It also does not quickly regenerate new growth if trimmed (Leong 2003). Lower branches are lost with age and do not regenerate, leaving large open areas under the upper tree crown, so establishment of a mid-story of younger conifers or perhaps oaks is necessary.

Monterey Pine (*Pinus radiata*)

Monterey pine is also native to the Monterey Peninsula and was among the trees used by monarchs when butterfly groves were first recorded in that area in the 1800s (Lane 1993; Brower 1995). Additionally, it is a fast growing tree and can live up to 100 years. As with Monterey cypress, monarchs apparently prefer Monterey pine to eucalyptus during windy conditions at sites that contain both species (J. Dayton, personal communication). Monterey pine produces excellent wind shelter foliage at many heights well into the middle years (ca. 50 years old) of its lifespan. Like Monterey cypress, Monterey pine loses foliage and branches in the middlestory and understory as it matures (Weiss 1998, 2011). They do not produce new branches quickly when cut and frequently die when the top of the tree is cut (Leong 2003).

Fast-growing Monterey pine provides monarchs with excellent wind shelter. Unfortunately, it is prone to pitch canker fungus. (Photograph: The Xerces Society / Carly Voight.)

The major disadvantage to planting Monterey pine is that it can develop pitch canker fungus (Weiss 1998). Monterey pine found at many overwintering sites have developed this disease (Xerces Society Western Monarch Overwintering Site Database 2017) and mortality rates can be quite high. Generally, Monterey pine develops pitch canker during its mature years, but younger trees can also exhibit symptoms. Recent research indicates that approximately 10% of Monterey pines are at least somewhat resistant to pitch canker and will not sustain serious damage from this disease, although resistant varieties are not yet commercially available (Camilli et al. 2013). When available, resistant Monterey pines could be planted for revegetation efforts.

Coast Redwood (*Sequoia sempervirens*)

Coast redwood is native to the northern and central California coast, from Del Norte to Monterey counties. Since it produces dense foliage and grows rapidly, coast redwood provides excellent wind shelter at monarch sites. Similar to Monterey cypress and Monterey pine, monarchs apparently prefer coast redwood to eucalyptus during windy conditions at sites that contain both trees (Monarch Alert, unpublished data). Redwoods may not be appropriate for sites very close to the Pacific coast as they cannot tolerate direct exposure to ocean winds (Weiss 1998).

Coast Live Oak (*Quercus agrifolia*)

Coast live oak is native to western California, from Mendocino County to the southern border. Although coast live oaks are generally not used as cluster trees, they can be an important component of monarch groves. Their dense understory growth primarily serves as low- and mid-level windbreak, especially as other tree species lose understory branches. For this reason, the coast live oak may be a suitable tree species to plant at aging overwintering habitats. Usually they are unable to offer adequate

shelter from upper winds since they are not tall enough (Weiss 1998; Weiss and Luth 2002). These shorter trees can be planted in a matrix among taller trees to provide heterogeneity of wind shelter and ample solar radiation (Weiss and Rich 2008). They are fire resistant and can lessen the hazard of a potential fire, especially at sites containing eucalyptus (Weiss 1998). One disadvantage to using this tree in restoration efforts is that they are relatively slow growing (Weiss and Rich 2008).

Douglas-Fir (*Pseudotsuga menzesii*)
Another tree species that provides an effective windbreak at overwintering habitats is Douglas-fir. This tree is broadly distributed in western North America, and is native to the northern California coast, as well as isolated areas of the central and southern California coast. Douglas-fir is relatively fast growing, making it a good choice for restoration efforts. Although it can develop pitch canker, it is less susceptible to this disease than Monterey pine.

Other Natives
Monarchs have also been documented using western sycamore (*Platanus racemosa*) and bishop pine (*Pinus muricata*). These both may be options for improving tree diversity in groves.

Nonnative Tree Species

Blue Gum (*Eucalyptus globulus*), Red River Gum (*Eucalyptus camaldulensis*), and Other Eucalyptus Species
Blue gum, red river gum, and other eucalyptus species produce durable limbs and dense foliage that are readily used by monarchs. They grow quickly and regenerate rapidly after trimming. They also produce winter flowers, which provide a nectar source for monarchs (Weiss 1998; Weiss and Rich 2008; Leong 2003). Many species of eucalyptus of varying stature will grow in coastal California and a list of some potential species is provided by Weiss and Rich (2008).

The majority of California monarch overwintering sites are dominated by eucalyptus. This is likely due to its high relative abundance on the California coast, rather than preference by monarchs. Recent research by Griffiths and Villablanca (2015) indicates that monarchs do not prefer eucalyptus over native tree species. Despite its use for overwintering, eucalyptus is an invasive exotic species that was introduced to California in 1853 from Australia (Butterfield 1935). It can rapidly spread and encroach on native plant species, reducing biodiversity (Bossard et al. 2000).

Decomposers native to California are typically unable to process fallen eucalyptus leaves and shed bark strips, creating a thick layer on the forest floor—up to four feet deep in extreme cases—that native plants can seldom infiltrate (del Moral and Muller 1970). In addition, this leaf and bark litter leaches allelopathic compounds into the soil, preventing the establishment of native plant species in the forest understory and reducing plant species diversity (Bossard et al. 2000; del Moral and Muller 1970). The presence of eucalyptus groves also affect bird species diversity, with negative impacts on cavity nesters, warblers, and vireos (Sax 2002; Suddjian 2004).

Eucalyptus species are prone to acquire pests such as eucalyptus leaf beetle (*Chrysophtharta* sp.), eucalyptus lerp psyllids (*Glycaspis brimblecombei* and *Blastopsylla occidentalis*), or eucalyptus longhorn borer (*Phorocantha semipunctata*) (Weiss 1998; Leong 2003; Janecki et al. 2004). Many overwintering sites that contain eucalyptus have been critically affected by these pests (Xerces Society Western Monarch Overwintering Site Database 2017). Pest pressure, combined with stressors such as drought, make eucalyptus prone to developing unstable limbs that can fall and injure people. This abundance of downed branches, foliage, and shed bark strips can pose a major fire hazard (Weiss 1998; Leong 2003).


The presence of eucalyptus trees in groves presents managers with something of a conundrum. Nonnative eucalyptus species support fewer native birds and insects than native tree species, and the leaf litter and shed bark suppresses plant growth below the trees. Many of California's butterfly groves are dominated by eucalyptus, however, and the trees are used by monarchs. (Photographs: The Xerces Society / Carly Voight.)

The continued existence of the monarch overwintering phenomenon in California in the short term, however, may depend on maintaining certain groves of eucalyptus with the appropriate physical structure and microclimate. Although it is preferable to plant only native trees at monarch sites, it may not be possible. For example, if the site is composed exclusively of eucalyptus, a complete conversion to native tree species within a short time period is not feasible without negatively affecting the grove's microclimatic conditions. Also, since eucalyptus are fast-growing species, it may be necessary to plant them to provide an immediate replacement for trees unexpectedly lost from a fire, windthrow, or unplanned hazard tree removal. In these instances, it is recommended that a mixture of eucalyptus and natives be planted. A long-term plan should be developed to restore the grove with native trees as eucalyptus trees age and senesce.

The concept of managing a nonnative species for the benefit of a desirable native species has been difficult for many to grasp, and polarization of views has made management decisions contentious in many cases. A compromise is necessary to make decisions that benefit both the monarchs and the surrounding native habitats. The following guidelines for eucalyptus management are offered:

- If the site is dominated by one species of eucalyptus—this is typically blue gum (*E. globulus*)—consideration should be given to diversifying the stand with other species, such as Monterey pine and Monterey cypress, and even other eucalyptus species. Single species stands are vulnerable to pests and diseases.
- The least desirable variety of blue gum is *E. globulus* variety 'compacta.' This variety does not provide appropriate branch structure for clustering monarchs, nor does it allow for sufficient dappled sunlight (Weiss 1998). It is highly recommended that this is not planted.
- Delineate a distinct footprint for eucalyptus and establish a clear boundary beyond which all

spreading eucalyptus will be controlled. Every 3 to 5 years, find and pull seedlings and/or saplings to prevent invasion of adjacent habitats.

- Standing dead trees generally do not contribute to monarch habitat and are a hazard to people and other trees. These can be removed when monarchs are not present (April to August). All tree removal work should be done carefully and under supervision to avoid impacts on adjacent live trees. As described above, identification of hazards by a professional arborist is essential and human safety should always come first.
- Eucalyptus forests can build up large amounts of fuel and pose fire hazards. Fuel management at and beyond the edges of groves is critical and is the first option to be pursued as opposed to working the interior of the groves. All activities regarding fuel management should be conducted in conjunction with local fire agencies. The role of "ladder fuels" in fire behavior creates potential conflicts with wind protection; disrupting multi-storied forest structures that provide wind shelter should be avoided within the core footprint of a monarch site. As with hazard branches and trees, these decisions need to be made on a case-by-case basis and alternatives to large-scale removal and trimming should be considered.
- In the interior of groves, and especially near the cluster sites themselves, small downed branches, low-growing vegetation, and shed bark provides substrates for monarchs to climb off the ground and recover from being dislodged from clusters. Full removal of ground litter to bare earth is not recommended in and near cluster sites.
- Some management of eucalyptus duff and debris can encourage establishment of an understory. Native shrubs such as toyon, as well as nonnative annual grasses and some forbs, can establish and thrive.

Shrub and Forb Management

Plant Native Fall- and Winter-Blooming Flowers to Provide Nectar

Fall- and winter-blooming flowers should be maintained or planted at overwintering sites to provide nectar sources. Monarchs use nectar for energy, and store the calories obtained as lipids, which may contribute to their ability to fly great distances as spring migrants (Tuskes and Brower 1978). Nectar species should be planted in open areas that have ample sunlight between the hours of 9:00 a.m. and 2:00 p.m., as the butterflies will not readily nectar in shaded areas. Furthermore, the closer the nectar plants are to the cluster trees, the better. Monarchs that forage for nectar far from the cluster trees expend more of their energy and fat reserves and are more vulnerable to predators (Leong 2003). Nectar plants should be located within the habitat or within a quarter-mile of the cluster trees.

Appendix A (page 28) provides a list of native plants that bloom in the fall, winter, or early spring and that grow along the California coastline between Mendocino and San Diego counties. These flowers are known to be visited by monarchs. Xerces Society recommends planting only native species and selecting from nurseries plants which have not been treated with systemic insecticides.

Do Not Plant Milkweed at Overwintering Sites

The majority of monarchs spend the winter in reproductive diapause (Herman 1981) until February or March when breeding resumes. Monarchs require milkweed for egg laying and larval development, but historic records suggest that milkweed was largely absent from most coastal areas of California (Xerces

Society Western Milkweed and Monarch Occurrence Database 2017). There is some evidence of milkweed historically growing along parts of southern California's coast and in the East Bay of San Francisco, but not in central and northern coastal California. Planting milkweed outside of its historic range and close to overwintering sites may encourage monarchs to continue breeding and laying eggs during the winter. Until additional research results are available, the Xerces Society recommends a precautionary approach: Do not plant milkweed near overwintering sites (generally within 5–10 miles) in those parts of coastal California where it did not historically occur.

Xerces Society opposes the planting of nonnative tropical milkweed (*Asclepias curassavica*) because its evergreen nature is associated with higher infection loads of the monarch parasite OE (*Ophryocystis elektroscirrha*), both in California and the Gulf Coast (Altizer et al. 2015; Satterfield et al. 2015, 2016).

Milkweed, such as woollypod milkweed (*Asclepias eriocarpa*) shown here, is necessary for monarch caterpillars. It should not be planted within 5–10 miles of a known overwintering grove (Photograph: The Xerces Society / Scott Hoffman Black.)

Minimize or Eliminate Pesticide Use

Refrain from using insecticides and herbicides at overwintering sites because they may negatively impact butterflies or nectar plants. Of particular concern are systemic insecticides because of their lethal and sublethal effects on monarch caterpillars (Pecenka and Lundgren 2015; Krischik et al. 2015) and their persistence in the environment (Hopwood et al. 2016). If pesticides are used, it is best to apply the chemicals when monarchs are not present in the habitat (from April to August) and the lowest amount and least toxic chemicals should be employed.

Visitor Management

Publicly accessible sites that host overwintering monarchs can provide important educational and scientific research opportunities, but such sites may be vulnerable to impacts from even the most well-intentioned visitors. Site management should balance public access with protection of overwintering monarchs and their habitat. The following recommendations will help to minimize the negative impacts.

Plan Trails to Avoid Interfering with Monarch Habitat

Designated trails help prevent trampling of grounded monarchs and vegetation and help prevent soil compaction and erosion. A trail system should be limited, such as an in-and-out trail to a viewing area or a loop trail to allow access to the butterfly area with minimal damage to the habitat. Using trail markers such as posts or cones or moveable fencing may be sufficient and allow the markers to be easily moved as the monarchs move during and between overwintering seasons. In some groves, boardwalks

may be useful to cater to high visitor numbers, although there is the risk that monarchs will move out of view from permanent facilities as microclimate conditions within the grove change over time. Trails should not be paved as this may increase the temperature in the delicate microclimate; wood chips or similar materials have fewer impacts. Motor vehicles should not be allowed in monarch habitat when monarchs are present.

Protect Public Access Overwintering Sites with a Staff or Docent Presence

A staff or docent presence at public overwintering habitats can help protect monarchs and their habitat from disturbance as well as educating visitors about monarchs and their conservation. Staff and docents can remind tourists to only walk on the designated trails and discourage inappropriate collecting or dislodging of monarchs. If a public site is unable to hire staff or enlist help from docents, appropriate interpretative signs can help educate visitors about the needs of the overwintering monarchs. Railings and signs placed along trails can prevent erosion and keep tourists at a distance from monarchs.

Erosion Prevention and Control Measures

Erosion, which can lead to runoff and pollution, is a serious problem at several monarch overwintering sites. Erosion can be caused by soil compaction from foot or bicycle traffic. Trail planning (see above) can prevent this problem. In some cases, run off of toxic oils and other materials and erosion can be caused by increases in paved roads, parking lots, and other impervious surfaces nearby. One option for minimizing this issue is to divert stormwater runoff by surface grading to impede the pooling of water within the grove. If the monarch site is located in a residential area, street water runoff may also be re-routed to storm drains although this can cause issues if the storm drains discharge into nearby creeks. Sedges (*Carex* spp.) and rushes (*Juncus* spp.) can be planted to control erosion, as can grasses such as fescue (*Festuca* spp.) (Janecki et al. 2004).

Involve Adjacent Landowners and Stakeholders

The successful conservation or restoration of overwintering habitat is contingent upon the involvement of land managers as well as adjacent landowners. If possible, tree cover should be maintained in areas surrounding the overwintering site and the area should be managed as one unit. As previously mentioned, windbreak trees can be located a considerable distance from the monarch habitat. Adjacent landowners should be aware of monarch habitat requirements and encouraged to implement management which benefits the site such as the proper removal of hazard trees and planting new trees to replace removed trees. This requires the coordination and cooperation of all surrounding landowners in management plans. Ideally, all stakeholders are included in management planning, implementation, and monitoring. In addition, funding may be more available for management and monitoring projects that are implemented with a collaborative or community approach (Weiss and Luth 2002; Janecki et al. 2004).

Additional Guidance

Information about the legal status of monarch butterflies and their habitat is available through the International Environmental Law Project and the Xerces Society (IELP 2012). Additional guidance focused on managing monarch overwintering habitat in California can be found in Bell et al. (1993) and Leong (2016).

Appendix A: Recommended Nectar Plants for Monarchs

Note: All species in this list are native to California, commercially available, and monarch butterflies have been documented visiting the flowers.

Form	Bloom Period	Common name	Species name	Flower Color
	Sp = spring, Su = summer, Fa = fall, Wi = winter			
Herb	Sp–Fa	Coastal sand verbena	*Abronia latifolia*	Yellow
Herb	Su–Fa	California goldenrod	*Solidago velutina* ssp. *californica*	Yellow
Herb	Su–Fa	Common sandaster	*Corethrogyne filaginifolia*	Yellow/purple
Herb	Su–Fa	Dunn's lobelia	*Lobelia dunnii* var. *serrata*	Purple
Herb	Su–Fa	Roughleaf aster	*Eurybia radulina*	Purple
Herb	Su–Fa	Sweetscent	*Pluchea odorata*	Pink/purple
Herb	Su–Fa	Western goldentop	*Euthamia occidentalis*	Yellow
Herb	Wi–Sp	Bluedicks	*Dichelostemma capitatum*	Purple
Herb	Wi–Su	Seaside fleabane	*Erigeron glaucus*	Purple
Shrub	Sp–Su	Black sage	*Salvia mellifera*	Blue/purple
Shrub	Sp–Su	Blueblossom	*Ceanothus thyrsiflorus*	Blue
Shrub	Sp–Fa	Dune ragwort	*Senecio blochmaniae*	Yellow
Shrub	Su–Fa	California broomsage	*Lepidospartum squamatum*	Yellow
Shrub	Su–Fa	Saltmarsh baccharis	*Baccharis douglasii*	White
Shrub	Fa	California goldenbush	*Ericameria ericoides*	Yellow
Shrub	Fa–Wi	Coyotebrush	*Baccharis pilularis*	Yellow/white
Shrub	Fa–Su	Bladderpod spiderflower	*Cleome isomeris*	Yellow
Shrub	Wi	Desertbroom	*Baccharis sarothroides*	Pink/white
Tree	Wi–Sp	Arroyo willow	*Salix lasiolepis*	Yellow/white
Tree	Wi–Sp	Hollyleaf cherry	*Prunus ilicifolia*	Yellow/white
Shrub	Wi–Sp	Morro manzanita	*Arctostaphylos morroensis*	Pink/white
Shrub	Wi–Sp	Refugio manzanita	*Arctostaphylos refugioensis*	White
Shrub	Wi–Sp	Sugar sumac	*Rhus integrifolia*	Pink
Shrub	Wi–Su	California brittlebush	*Encelia californica*	Yellow

Height	Water Needs	Notes
Maximum, in feet.	Low, Medium, or High	All species are perennials. Monarchs are typically present in coastal California from September through March, but can be found year-round in some parts of the region.
1	L/M	Tolerates salt spray and prefers sandy soils; can bloom year-round.
3	L	Important late-season forage for bees, butterflies, wasps, beetles, and more.
3	L/M	Host plant for Gabb's checkerspot (*Chlosyne gabbii*)
2	H	Excellent butterfly plant.
2	M	High drought tolerance once established.
3	L	Mostly coastal, brackish plant. Can tolerate saline sites.
6	M/H	Wetland-riparian.
3	L	Attracts other bees, butterflies, and hummingbirds. An early spring bloomer.
2	L/M	A great butterfly plant.
6	L	Important butterfly and hummingbird plant. Quail eat the seeds.
15	L	Amazing pollinator plant. Host plant to many butterfly species. Birds will eat the seeds.
3	L/M	Limited distribution.
6	L/M	Can be used in restoration and stream stabilization projects.
3	M/H	Important nectar source for many species of wasps, butterflies, and flies.
3	L/M	Great late season nectar source for bees and butterflies.
8	L	Easy to grow and extremely drought-tolerant. Attractive to many insects.
4	L	Tolerates salt spray. Also attracts bees.
10	L	Can be used for streambank stabilization.
20	H	Tolerates sand and seasonal flooding; good for erosion control. Important wildlife plant.
14	L	Fruits eaten by many birds and small mammals.
20	L	Limited distribution. On CA rare/threatened/endangered list.
7	L	Limited distribution. On CA rare/threatened/endangered list.
8	L/M	Good for erosion control on coastal bluffs. Fruits are eaten by birds and other wildlife.
4	L/M	Tolerates salt spray. Can be used to stabilize slopes. Good bee and butterfly plant.

Literature Cited

Altizer, S., K. A. Hobson, A. K. Davis, J. C. De Roode, and L. I. Wassenaar. 2015. Do healthy monarchs migrate farther? Tracking natal origins of parasitized vs. uninfected monarch butterflies overwintering in Mexico. *PloS One* 10(11):e0141371.

Anderson, J. B., and L. P. Brower. 1996. Freeze-protection of overwintering monarch butterflies in Mexico: critical role of the forest as a blanket and an umbrella. *Ecological Entomology* 21:107–116.

Bell, E., L. Brower, W. H. Calvert, J. Dayton, D. Frey, K. Leong, D. Murphy, R. M. Pyle, W. Sakai, K. B. Snow, and S. Weiss. 1993. *Conservation and Management Guidelines for Preserving the Monarch Butterfly Migration and Monarch Overwintering Habitat in California*. Portland, OR: The Xerces Society.

Bossard, C. C., J. M. Randall, and M. C. Hoshovsky. 2000. *Invasive Plants of California's Wildlands*. Berkeley: University of California Press. (The complete text is available online, at http://cal-ipc.org/ip/management/ipcw/online.php [accessed May 31, 2017].)

Brower, L. P. 1995. Understanding and misunderstanding the migration of the monarch butterfly (Nymphalidae) in North America: 1857-1995. *Journal of the Lepidopterists' Society* 49:304–85.

Brower, L. P., and R. M. Pyle. 2004. The Interchange of migratory monarchs between Mexico and the western United States, and the importance of floral corridors to the fall and spring migrations. In *Conserving Migratory Pollinators and Nectar Corridors in Western North America*, edited by G. Nabhan, 144–166. Tucson: University of Arizona Press and the Arizona-Sonora Desert Museum.

Butterfield, H. M. 1935. The introduction of *Eucalyptus* into California. *Madroño* 3:149–154

Calvert, W., and J. Cohen. 1983. The adaptive significance of crawling up onto foliage for the survival of grounded overwintering monarch butterflies (*Danaus plexippus*) in Mexico. *Ecological Entomology* 8:471–474.

Camilli, K. S., J. Marshall, D. Owen, T. Gordon, and D. Wood. 2013. *Tree Notes: Pitch Canker Disease in California*. Sacramento: California Department of Forestry and Fire Protection. Available online: http://ufei.calpoly.edu/pitch_canker/publications.lasso (accessed May 31, 2017).

Chaplin, S., and P. Wells. 1982. Energy reserves and metabolic expenditures of monarch butterflies overwintering in southern California. *Ecological Entomology* 7:249–256.

Commission for Environmental Cooperation. 2008. *North American Monarch Conservation Plan*. Montréal: Communications Dept. of the CEC Secretariat. Available from http://purl.access.gpo.gov/GPO/LPS96018 (accessed May 31, 2017).

del Moral, R., and C. H. Muller. 1970. The allelopathic effects of *Eucalyptus camaldulensis*. *American Midland Naturalist* 83:254–282.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. *Measuring and Monitoring Plant Populations. BLM Technical Reference. 1730-1*. 477 pp. Washington, D.C.: Bureau of Land Management. Available at https://www.blm.gov/nstc/library/pdf/MeasAndMon.pdf (accessed May 31, 2017).

Espeset, A. E., J. G. Harrison, A. M. Shapiro, C. C. Nice, J. H. Thorne, D. P. Waetjen, J. A. Fordyce, and M. L. Forister. 2016. Understanding a migratory species in a changing world: climatic effects and demographic declines in the western monarch revealed by four decades of intensive monitoring. *Oecologia* 181:819 doi:10.1007/s00442-016-3600-y.

Frey, D., K. L. H. Leong, D. Fredericks, and S. Raskowistz. 1992. Clustering patterns of monarch butterflies (Lepidoptera: Danaidae) at two California central coast overwintering sites. *Annals of the Entomological Society of America* 85:148–153.

Geiger, R. 1965. *The Climate Near the Ground*. 611+xiv pp. Cambridge, MA: Harvard University Press.

Griffiths, J., and F. Villablanca. 2015. Managing monarch butterfly overwintering groves: making room among the eucalyptus. *California Fish and Game* 101(1):40–50.

Herman, W. S. 1981. Studies on the adult reproductive diapause of the monarch butterfly, *Danaus plexippus*. *Biological Bulletin* 160:89–106.

Hill, H., A. Wenner, and P. Wells. 1976. Reproductive behavior in an overwintering aggregation of monarch butterflies. *American Midland Naturalist* 95:10–19.

Hopwood, J., A. Code, M. Vaughan, D. Biddinger, M. Shepherd, S. H. Black. E. Lee-Mäder, and C. Mazzacano. 2016. *How Neonicotinoids Can Kill Bees: The Science Behind the Role These Insecticides Play in Harming Bees*. 2nd Ed. 76 pp. Portland, OR: The Xerces Society for Invertebrate Conservation.

[IELP 2012] International Environmental Law Project and The Xerces Society for Invertebrate Conservation. 2012. *The Legal Status of Monarch Butterflies in California*. Available at http://www.xerces.org/wp-content/uploads/

2008/09/legal-status-of-california-monarchs.pdf (accessed May 31, 2017).

[Janecki et al 2004] Joni L. Janecki & Associates, Inc., Boone/Low Consulting Architects, Barrie Coate Consulting Arborist, Entomological Consulting Services, LTD, and John Dayton Consulting Biologist. 2004. "Management Plan for the Monarch Butterfly Habitat at Moran Lake County Park." Report submitted to the Santa Cruz County Department of Parks, Open Space and Cultural Services.

Krischik, V., M. Rogers, G. Gupta, and A. Varshney. 2015. Soil-applied imidacloprid translocates to ornamental flowers and reduces survival of adult *Coleomegilla maculata*, *Harmonia axyridis*, and *Hippodamia convergens* lady beetles, and larval *Danaus plexippus* and *Vanessa cardui* butterflies. *PLoS One* 10(3):e0119133.

Lane, J. 1984. The status of monarch butterfly overwintering sites in Alta California. *Atala* 9:17–20.

Lane, J. 1993. Overwintering monarch butterflies in California: Past and present. In *Biology and Conservation of the Monarch Butterfly*, edited by S. B. Malcolm and M. P. Zalucki, 335–344. Los Angeles: Natural History Museum of Los Angeles County.

Leong, K. L. H. 1989. Final Report: Monarch Lane Butterfly Study.

Leong, K. L. H. 1990a. "Monarch Butterfly Overwintering Study of the California Central Coast: 1988-89 & 1989-90 Winters. Report to the USFWS Sacramento Field Office." San Luis Obispo: California Polytechnic State University.

Leong, K. L. H. 1990b. Microenvironmental factors associated with the winter habitat of the monarch butterfly (Lepidoptera: Danaidae) in central California. *Annals of the Entomological Society of America* 83:907–910.

Leong, K. L. H. 1999. Restoration of an overwintering grove in Los Osos, San Luis Obispo County, California. In *1997 North American Conference on the Monarch Butterfly*, edited by J. Hoth, L. Merino, K. Oberhauser, I. Pisanty, S. Price, and T. Wilkinson, 221–218.

Leong, K. L. H. 2003. "Purple Gate Winter Site Study." Report to Marin County Community Development Agency, San Rafael, CA.

Leong, K. L. H., D. Frey, G. Brenner, S. Baker, and D. Fox. 1991. Use of multivariate analyses to characterize the monarch butterfly (Lepidoptera: Danaidae) winter habitat. *Annals of the Entomological Society of America* 84:263–267.

Leong, K. L. H., W. H. Sakai, W. Bremer, D. Feuerstein, and G. Yoshimura. 2004. Analysis of the pattern of distribution and abundance of monarch overwintering sites along the California coastline. In T*he Monarch Butterfly: Biology and Conservation*, edited by K. Oberhauser and M. Solensky, 177–185. Ithaca: Cornell University Press.

Lyons, J. I., A. A. Pierce, S. M. Barribeau, E. D. Sternberg, A. J. Mongue, and J. C. de Roode. 2012. Lack of genetic differentiation between monarch butterflies with divergent migration destinations. *Molecular Ecology* 21:3433–3444.

Masters, A. R., S. B. Malcolm, and L. P. Brower. 1988. Monarch butterfly (*Danaus plexippus*) thermoregulatory behavior and adaptations for overwintering in Mexico. *Ecology* 69:458–467.

Masters, A. R. 1993. Temperature and thermoregulation in the monarch butterfly. In *Biology and Conservation of the Monarch Butterfly*, edited by S. B. Malcolm and M. P. Zalucki, 147–156. Los Angeles: Natural History Museum of Los Angeles County.

Meade, D. E. 1999. "Monarch Butterfly Overwintering Sites in Santa Barbara County California." 114 pp. Paso Robles, CA: Althouse and Meade, Inc.

Monroe, M., E. Pelton, S. McKnight, C. Fallon, D. Frey, and S. Stevens. 2017. "Western Monarch Thanksgiving Count Data from 1997–2016." Available from http://www.westernmonarchcount.org/data/ (accessed May 31, 2017).

Morris, G., C. Kline, and S. M. Morris. 2015. Status of *Danaus plexippus* population in Arizona. *Journal of the Lepidopterists' Society* 69(2):91–97.

Pecenka, J. R., and J. G. Lundgren. 2015. Non-target effects of clothianidin on monarch butterflies. *Science of Nature* 102:19. doi:10.1007/s00114-015-1270-y.

Pelton, E., S. Jepsen, C. Schultz, C. Fallon, and S. H. Black. 2016. *State of the Monarch Butterfly Overwintering Sites in California*. 40+vi pp. Portland, OR: The Xerces Society for Invertebrate Conservation. (Available online at www.xerces.org)

Pyle, R. M., and M. Monroe. 2004. Conservation of western monarchs. *Wings. Essays on Invertebrate Conservation* 27:13–17.

Sakai, W. H., and W. C. Calvert. 1991. "Statewide monarch butterfly management plan for the state of California Department of Parks and Recreation. Final Report, June 1991." Interagency Agreement No. 88-11-050 between California Department of Parks and Recreation and Santa Monica College. 160 pp. Sacramento: California Department of Parks and Recreation.

Satterfield, D. A., J. C. Maerz, and S. Altizer. 2015. Loss of migratory behaviour increases infection risk for a butterfly host. *Proceedings of the Royal Society B* 282:20141734.

Satterfield, D. A., F. X. Villablanca, J. C. Maerz, and S. Altizer. 2016. Migratory monarchs wintering in California experience low infection risk compared to monarchs breeding year-round on non-native milkweed. *Integrative and Comparative Biology* 56(2):343–352.

Sax, D. F. 2002. Equal diversity in disparate species assemblages: A comparison of native and exotic woodlands in California. *Global Ecology & Biogeography* 11:49–57.

Schultz, C. B., L. M. Brown, E. Pelton, and E. E. Crone. 2017.

Citizen science monitoring demonstrates dramatic declines of monarch butterflies in western North America. *Biological Conservation* doi:10.1016/j.biocon.2017.08.019.

Stevens, S., and D. Frey. 2010. Host plant pattern and variation in climate predict the location of natal grounds for migratory monarch butterflies in western North America. *Journal of Insect Conservation* 14:731–744.

Suddjian, D. L. 2004. "Birds and *Eucalyptus* on the central California coast: A love-hate relationship." David L. Suddjian, Biological Consulting. A paper presented at Ecology and Impacts of Blue Gum Eucalyptus in Coastal California, June 3, 2004.

Tuskes, P. M., and L. P. Brower. 1978. Overwintering ecology of the monarch butterfly, *Danaus plexippus* L., in California. *Ecological Entomology* 3:141–153.

Villablanca, F. 2010. "Monarch Alert Annual Report: Overwintering Population 2009-2010." Available at http://monarchalert.calpoly.edu/pdf/Monarch-Alert-Report-2010.pdf (accessed May 31, 2017).

Weiss, S. B. 1998. "Habitat Suitability, Restoration, and Vegetation Management at Monarch Grove Sanctuary, Pacific Grove, California." Report to Thomas Reid Associates, Palo Alto, CA, by the Creekside Center for Earth Observation (Menlo Park, CA).

Weiss, S. B. 2011. "Management Plan for Monarch Grove Sanctuary: Site Assessment and Initial Recommendations." Report to City of Pacific Grove, CA, by the Creekside Center for Earth Observation (Menlo Park, CA).

Weiss, S. B., and D. C. Luth. 2002. "Assessment of Overwintering Monarch Butterfly Habitat at Cooper Grove (Andrew Molera State Park, Monterey County, CA) Using Hemispherical Photography." Menlo Park, CA: Creekside Center for Earth Observation.

Weiss, S. B., L. Naumovich, and C. Niederer. 2012. "Rob Hill Monarch Habitat. Site Assessment and Initial Recommendations." Report to Presidio Trust, San Francisco, CA, by the Creekside Center for Earth Observation (Menlo Park, CA).

Weiss, S. B., and P. M. Rich. 2008. "Recommendations for Restoration of Monarch Butterfly Winter Habitat at Norma B. Gibbs Park, Huntington Beach, CA." Menlo Park, CA: Creekside Center for Earth Observation.

Weiss, S. B., P. M. Rich, D. D. Murphy, W. H. Calvert, and P. R. Ehrlich. 1991. Forest canopy structure at overwintering monarch butterfly sites: measurements with hemispherical photography. *Conservation Biology* 5:165–175.

Wells, H., P. H. Wells, and P. Cook. 1990. The importance of overwinter aggregation for reproductive success of monarch butterfly. *Journal of Theoretical Biology* 147:115–131.

Winkler, K., T. R. Gordon, A. J. Storer, and D. L. Wood. 2003. *Pitch Canker. Integrated Pest Management for Gardeners and Landscape Professionals. Cooperative Extension Publication 74107*. 5 pp. Davis: University of California.

Xerces Society Western Milkweed and Monarch Occurrence Database. The Xerces Society for Invertebrate Conservation. 2017.

Xerces Society Western Monarch Overwintering Site Database. The Xerces Society for Invertebrate Conservation. 2017.

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