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Nearly all California monarch overwintering groves require non-native trees

TRAVIS LONGCORE,[1,2*] CATHERINE RICH,[2] AND STUART B. WEISS[3]

[1] *University of California, Los Angeles, Institute of the Environment and Sustainability, 300 La Kretz Hall, Los Angeles, CA 90095, USA*

[2] *The Urban Wildlands Group, P.O. Box 24020, Los Angeles, CA 90024, USA*

[3] *Creekside Center for Earth Observation, Menlo Park, CA 94025, USA*

**Corresponding Author: longcore@ucla.edu*

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Monarch butterflies (*Danaus plexippus*) are in steep decline and threatened by loss of breeding habitat, loss of wintering habitat, pesticide use, and climate change (Pelton et al. 2019; Schultz et al. 2017). The population that winters along the coast of California has declined 97% since the 1980s (Pelton et al. 2019) and Schultz et al. (2017) conclude that this population, or at least the overwintering phenomenon, is at a high risk of extinction within 50 years. Factors associated with this decline include land use most strongly, encompassing increasing use of pesticides (e.g., glyphosate herbicide and neonicotinoid insecticides) and coastal development, and then less so climate, which remains a looming threat (Crone et al. 2019; Espeset et al. 2016). Historically, the largest threat to overwintering groves was development (Lane 1981[1984]) but recent analysis of overwintering survival (Pelton et al. 2019) suggests that grove quality itself is also in decline through senescence (Pelton et al. 2016). Protecting and managing wintering habitat is a top conservation priority (Pelton et al. 2019; Western Monarch Working Group 2018).

Preferred winter roosting habitat for monarchs in California is made up of groves of trees that provide particular microclimatic conditions that protect the butterflies from winter storms (Leong 2016; Leong et al. 1991; Weiss et al. 1991). Overwintering groves can provide suitable microclimates with different tree densities, species composition, and topography (Leong et al. 2004), but essential features, including a windbreak to protect against winter storms and a range of sunlight from full to filtered to shaded, must be present (Leong 1990). At nearly every overwintering site on the current landscape, those conditions are created by exotic trees, and in particular by eucalyptus species (Bell et al. 1993; Leong 1990; Nagano and Lane 1985; Nagano and Sakai 1987; Pelton et al. 2016). This need for the structural properties provided by eucalyptus has long been known by California monarch experts (Bell et al. 1993):

> Conflict between Monarch habitat conservation and Eucalyptus removal for native revegetation arises when the tree removal occurs in proximity to a Monarch overwintering habitat. Since the entire grove of trees serves as Monarch habitat, even selective tree removal around the margins of groves may have adverse effects on the habitat. At a time when current political and development pressures imperil Monarch habitats statewide, the butterflies cannot afford to lose these prime Eucalyptus habitats to a political battle between native and non-native species. Some native plant advocates assert the Monarchs will go elsewhere if their Eucalyptus habitats are destroyed. But the decline of Monarch populations in areas where Eucalyptus groves were developed suggests otherwise.

This statement is still true today, and managers should not hesitate to use eucalyptus species thoughtfully to create and maintain overwintering habitat for monarch butterflies. To do otherwise would threaten the mass overwintering of monarchs in California. Our reasons for this assessment follow.

With few exceptions, the overwintering monarch phenomenon in California is dependent on non-native trees, particularly eucalyptus planted in the mild coastal zone. Only a handful of extant sites are made up predominantly of native trees (Fiscalini Ranch Preserve in Cambria, Point Lobos State Natural Preserve, George Washington Park in Pacific Grove; Pelton et al. 2016). The monarchs have made their choice, and we have to work with that choice for effective conservation and management. The success of these overwintering sites in attracting and retaining monarchs is a function of appropriate microclimate. Groves must provide good shelter from wind and a varied light environment ranging from full sun to deep shade. The structure of groves, not the species composition, is the primary determinant of microclimate.

The only areas where truly native trees could be used are the few native Monterey pine (*Pinus radiata*) and Monterey cypress (*Cupressus macrocarpa*) forests in the Monterey Peninsula–Point Lobos area, Cambria, and Año Nuevo (Griffin and Critchfield 1972; Lane 1981[1984]). It is possible that scattered small monarch aggregations were found on native oaks (*Quercus agrifolia*) and sycamores (*Platanus racemosa*) in coastal locations to the south historically, but only a few sites have been documented (Nagano and Lane 1985). After eucalyptus trees were introduced in the 1850s (Butterfield 1935), they expanded the distribution of suitable monarch overwintering conditions while the extent of native conifers was reduced through development and disease (Millar 1998). Today, monarch overwintering groves are predominantly composed of eucalyptus trees, even within the range of the two native roost tree species. Outside that narrow Central Coast region, overwintering sites are created by eucalyptus species (Pelton et al. 2016). Even Monarch Grove Sanctuary in Pacific Grove, one of the premier overwintering sites, is utterly reliant on eucalyptus trees despite its location within the native Monterey pine forest.

Eucalyptus species have proven to be excellent for providing the necessary grove structure. The variability of growth forms within and between species and their rapid growth make for a more resilient grove. For example, eucalyptus will respond to canopy openings by pushing out epicormic branches, sealing up the edges of groves against the wind. Understory recruitment, stump sprouting/coppice behavior, and fire recovery can be rapid. In addition, blue gum eucalyptus (*Eucalyptus globulus*) come into flower in January, providing copious nectar resources.

Pine and cypress have issues that reduce their utility in developing overwintering habitat today. Monterey pines are not reliable for long-term habitat because of pine pitch

canker mortality. Monterey cypress grow more slowly than eucalyptus. Both Monterey pine and Monterey cypress lose their lower branches as they mature, hence middlestory and understory trees are critical for wind shelter, especially at the edges of groves. These trees are susceptible to drought, especially south of their narrow natural ranges, based on interpretation of their history (Millar 1999).

Trees where monarchs are found aggregated during the winter (cluster trees) are only a small component of the habitat; trees providing wind shelter, often well away from the cluster trees, are absolutely critical. While monarchs may have some preference for clustering on pines and cypress *when available* (Griffiths and Villablanca 2015), this observation does not indicate that native trees alone are superior, or even adequate, to produce monarch overwintering habitat throughout the California coast.

Until now, persistence of suitable monarch habitat has largely been an accident. Forest dynamics within planted groves have produced light gaps with adequate wind shelter. Explicit management of groves *within a specified footprint*, including deliberate planting of eucalyptus, will be required going forward. While blue gum eucalyptus is currently the dominant species in most monarch groves, diversifying to other eucalyptus species is desirable to create resiliency against pests, diseases, and drought. These principles have been applied at Monarch Grove Sanctuary in Pacific Grove, with success in establishing critical wind shelter, are being applied at several other sites including Ardenwood Regional Park (Fremont, Alameda County) and Gibbs Park (Huntington Beach, Orange County), and are being considered in site management plans that are being developed as of 2020 (S. Weiss, personal observation).

Not all recent guidelines have been as clear about the utility of eucalyptus in creating habitat conditions needed for monarch overwintering. In 2012, The Xerces Society introduced a new position on overwintering habitat, stating that, "As eucalyptus trees age and become decadent, a long-term plan should be developed to restore a monarch grove to provide habitat with native trees" (Xerces Society Policy on Eucalyptus Management at Monarch Overwintering Sites, 2012). In 2017, guidelines for wintering site management were issued, which articulated a preference for planting "only native tree species" and gave a rationale (Jepsen et al. 2017):

> 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.

We would emphatically state that restoration plantings of only native trees, especially for windbreak functions, will not provide monarch overwintering habitat except in extraordinarily limited circumstances. Despite some caveats in the recommendations, these particular statements of preference for "only native species" have been, in our experience, seized upon by some stakeholders as a rationale to block or reduce the use of eucalyptus in overwintering site management. This unfortunate outcome has been reinforced by a rigid preference to promote only native plant species in conservation practice. For example, California State Parks has strong policies favoring the removal of exotic plant species, which leads to a presumption that eucalyptus should be removed and concomitant resistance to planting eucalyptus within the context of management of monarch overwintering sites (see Califor-

nia State Parks Department Operations Manual, Policy 0310.7.2 Removal of Established Populations of Exotic Plants).

We agree that some plantings of native trees could be included, especially as potential cluster trees to give fine-scale alternatives to the monarchs, but the options for creating effective long-term windbreaks with only locally native trees are extremely limited beyond a small area on the Central Coast. The promotion of locally native trees as alternatives to non-native trees in producing necessary microclimatic conditions for winter roosts is not supported by the history of monarchs in California or by the Griffiths and Villablanca (2015) study cited by Jepsen et al. (2017) in support of such a proposition. Griffiths and Villablanca (2015) looked at roost choice within the zone protected from wind and exposed to enough filtered sunlight. They did not investigate the attributes of the trees that created this area, which Leong calls the "cluster arena" (K. Leong, California Polytechnic State University, San Luis Obispo, personal communication). Within the cluster arena, Griffiths and Villablanca (2015) showed that monarchs used native trees more as roosts during some periods and eucalyptus trees more as roosts during other periods. Their results do not support a conclusion that replacing all trees at those overwintering sites with native species would preserve the microclimate, and the study was not designed so that it could support that conclusion. Similar results have been found at Monarch Grove Sanctuary in Pacific Grove over longer time periods (Weiss 2019). Furthermore, it is not possible to extrapolate from the Griffiths and Villablanca (2015) study to locations without native conifer species (e.g., any location farther south). Indeed, they admonish in their discussion, "This recommendation [to use native conifers] would not be appropriate for Southern California since we have not evaluated data from that region and because the native conifers are not suited to that climatic region."

We also concur that eucalyptus groves that support monarch overwintering must be managed to preclude the spread of trees into habitat outside the area needed for the grove. Issues of eucalyptus management are discussed in the Xerces guidelines (Jepsen et al. 2017).

The coastal monarch overwintering phenomenon in California expanded with the planting of eucalyptus and, in that sense, it is an unnatural situation, but eucalyptus has sustained the population, which might otherwise have been extirpated by development. The historic range of native coastal conifer forest has been dramatically reduced, and examples of groves of all-native trees supporting substantial monarch overwintering numbers outside the natural ranges of Monterey pine and Monterey cypress are limited to a few examples in well-sheltered riparian zones (see site descriptions in Pelton et al. 2016). Monarchs responded to a landscape dramatically altered by human activity and took advantage of the microclimate of eucalyptus groves as their native conifer groves were decimated. If we want the western monarch population to survive, we should not hesitate to plant eucalyptus trees (of several species depending on site characteristics) as part of well-formulated and long-term management plans for overwintering sites,

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