



State of the Monarch Butterfly Overwintering Sites in California

Report to the U.S. Fish and Wildlife Service
by the Xerces Society for Invertebrate Conservation



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Cover photographs

Front: Overwintering cluster of monarchs in Monterey cypress at Pismo Beach State Park. (Photograph: The Xerces Society/Carly Voight.)

Back: Overwintering cluster of monarchs in eucalyptus. (Photograph: The Xerces Society/Candace Fallon.)

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Monarch butterflies cluster on a Monterey pine in the Point Lobos State Natural Reserve, Monterey County. The site is ranked number 31 in the Top 50 list of overwintering sites in California in greatest need of management attention. (Photo: The Xerces Society/Carly Voight.)



Executive Summary

Monarchs spread across North America in the spring and summer, relying on milkweed for larval development and nectar plants for fuel. Each fall, the last generation of adults migrates to overwintering sites. While the migration pathways of monarchs in the interior West are still poorly understood, a portion of western monarchs migrate to coastal California, which hosts hundreds of overwintering sites along a 1,000-kilometer (620-mile) stretch from Mendocino County to Baja California, Mexico. Monarchs have been found clustering at more than four hundred sites that provide suitable microhabitat conditions, including protection from wind and freezing temperatures. However, overwintering habitat continues to be lost to development and the senescence of groves. While monarchs face multiple stressors, such as breeding habitat loss and pesticide use, loss of overwintering habitat may also be an important driver of population decline. This report summarizes existing information about western overwintering monarch population trends and identifies the highest priority overwintering sites for active management and protection.

A concerted effort to obtain population estimates at western overwintering sites began in 1997 through the Western Monarch Thanksgiving Count (WMTC), a citizen-science based effort now coordinated by the Xerces Society and Mia Monroe. These data show that western overwintering monarchs have undergone a significant population decline from over 1.2 million monarchs counted in 1997 to 292,674 monarchs in 2015. Through analyses that account for differences between sites and in effort over time, we estimate that the population has declined 74% since the late 1990s, which is similar to the decline in the eastern monarch population overwintering in central Mexico.

Of the more than four hundred current and historic overwintering sites in California, a Top 50 list prioritizes sites for protection and active management. Twenty-five of the Top 50 sites are profiled with a basic site description and information about site-specific conservation issues. Sites have been ranked based on quantitative measures. The highest ranking is given to sites which have undergone the greatest declines, yet still host the largest proportion of the remaining western overwintering population. These sites demand the most urgent attention from land managers and policy makers. The top ten highest priority sites are 1) Pismo Beach (San Luis Obispo County); 2) Private Site 2732 (Santa Barbara County); 3) Private Site 2920 (Monterey County); 4) Ellwood Main (Santa Barbara County); 5) Morro Bay Golf Course (San Luis Obispo County); 6) Pacific Grove Sanctuary (Monterey County); 7) Lighthouse Field State Beach (Santa Cruz County); 8) San Leandro Golf Course (Alameda County); 9) Moran Lake (Santa Cruz County); and 10) Pecho Road, Los Oso (San Luis Obispo County).

Management action and protection of overwintering sites is a necessary component of recovering the western monarch population. In addition to prioritizing the Top 50 sites, this report identifies knowledge gaps and provides management recommendations to inform conservation efforts. We intend for this report to be used by land managers, restoration practitioners, researchers, and policy makers to understand the current state of overwintering sites in California, and to begin to identify actions that can contribute to sustaining monarchs for future generations.



To complete their annual cycle, monarchs require different plants, sometimes hundreds of miles apart. In the spring and summer breeding range, milkweeds are the essential host plant for caterpillars (above left). During the fall migration, adults are fueled by late-blooming flowers (above right). During the winter, they cluster in groves along the Pacific Coast (below). (Photographs: [above left] The Xerces Society/Scott Hoffman Black; [above right] Carly & Art/WikiMedia Commons; and [below] The Xerces Society/Candace Fallon.



Life History of the Western Monarch

Life cycle

Female monarchs (*Danaus plexippus plexippus*) lay eggs singly on milkweed (*Asclepias* spp.), which the larvae rely upon for energy and protective cardenolides. The larvae develop through five instars before forming a chrysalis and pupating into an adult butterfly. During the spring and summer, an adult monarch spends its 2–5 week lifespan mating and nectaring on flowers, with females searching for milkweed upon which to lay their eggs. Multiple generations are produced over the spring and summer, with the fall generation migrating to overwintering sites and living for 6–9 months.

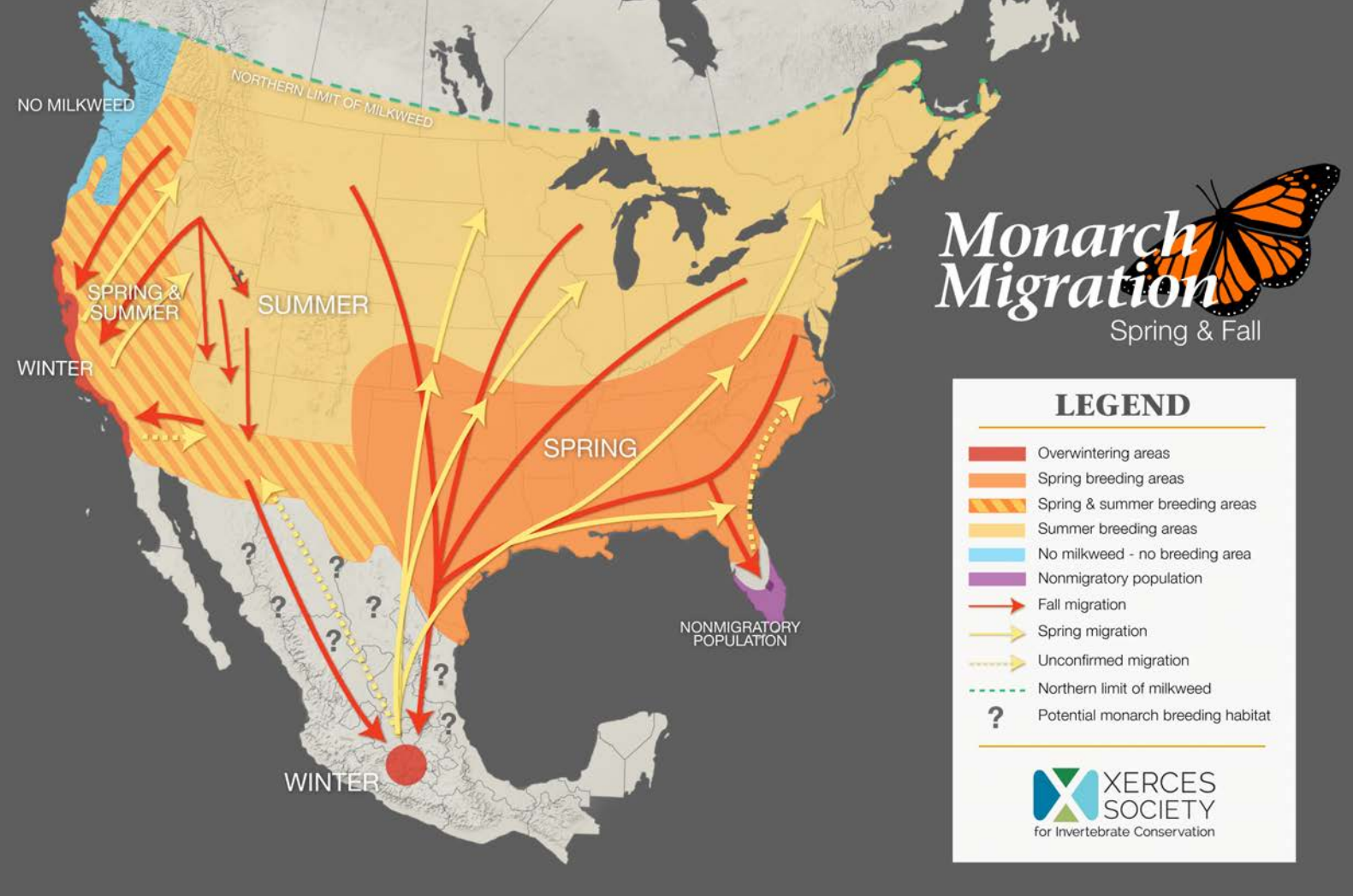
Migration and overwintering behavior

Monarchs begin to arrive at overwintering sites along the Pacific coast in September and the first half of October (Hill et al. 1976; Leong 1990), forming fall aggregations. By mid-November, they have formed more stable aggregations that persist through January or into February. The butterflies cluster in dense groups on the branches, leaves, and occasionally, the trunks of trees. The adults usually remain in reproductive diapause throughout the winter (Herman 1981) and activity is limited to occasional sunning, rehydrating, and nectaring. In February and March, the surviving monarchs breed at the overwintering site before dispersing.

Monarchs aggregate in clusters at sites scattered along 1,000 km (620 miles) of the Pacific coast from California's Mendocino County to Baja California, Mexico (Lane 1993; Leong et al. 2004; Jepsen and Black 2015). Small aggregations inland from the coast have been reported in Inyo County and Kern County in California (Xerces Society Western Monarch Overwintering Sites Database 2016) and in Arizona, where a maximum of 45 butterflies per site have been reported (Morris et al. 2015). The distribution of monarchs among overwintering sites changes over the season and annually, based on regional and individual site conditions (Leong 1990).

Older migration models assumed that monarchs west of the Rocky Mountains overwinter on the Pacific coast while monarchs east of the Rockies migrate to central Mexico. Tagging efforts have shown that wild monarchs tagged in Oregon (Pyle 2015) and Nevada (Southwest Monarch Study 2016) migrate to the California coast, and as well as some monarchs in Washington (Pyle 1999; Pyle 2015), Idaho (Pyle 1999), and Arizona (Morris et al. 2015). Additionally, a recent isotopic study at four overwintering sites suggests that the natal origin of a large proportion of the overwintering monarchs is from coastal Southern California and Oregon, Washington, and Idaho (Yang et al. 2015).

However, the Continental Divide has proven to be more permeable than originally thought. An early eastern vs. western population migration model was built upon very limited evidence (Pyle 1999;



Brower and Pyle 2004), and we now know that there is significant interchange between monarchs in the eastern and western United States (Pyle 2015). Monarchs tagged in Idaho (Pyle 1999) and Washington (David James, Dplex listserv) have been recovered in Utah as well as California, suggesting a second, south-easterly migration route and recently, monarchs tagged in Arizona have been recovered in central and western Mexico, as well as coastal California (Morris et al. 2015). Furthermore, genetic studies have concluded that the western and eastern populations are not genetically distinct (Lyons et al. 2012; Zahn et al. 2014). These findings support hypotheses that some portion of western monarchs travel to Mexico for the winter (Pyle 1999; Brower & Pyle 2004; Dingle et al. 2005), some portion of eastern monarchs travel to the western United States after overwintering in central Mexico (Brower & Pyle 2004; Vandenbosch 2007), and/or there is interbreeding of eastern and western monarchs during the breeding season, likely in the Intermountain West. The relative rate of exchange between the eastern and western populations is currently unknown and isotopic studies have generally omitted isoscapes on either side of the Continental Divide (Wassenaar and Hobson 1998; Yang et al. 2015). Hence, while population trends at California overwintering sites provide an index of the western population, they do not represent the entire western population.

Overwintering habitat requirements

Coastal California provides the mild climatic conditions that monarchs need to survive the winter in western North America. The majority of overwintering sites are located within 2.4 km (1.5 miles) of the Pacific Ocean or San Francisco Bay (Leong et al. 2004) which moderates temperatures (Chaplin and Wells 1982). Sites are typically found at low elevations (60–90 m [200–300 feet]) and situated on slopes oriented to the south, southwest, or west which provide the most solar radiation (Leong et al. 2004) or in shallow canyons or gullies (Lane 1993).

Monarchs require very specific microclimatic conditions at overwintering sites including dappled sunlight, high humidity, fresh water, and an absence of freezing temperatures or high winds (Chaplin and Wells 1982; Calvert and Cohen 1983; Masters et al. 1988; Anderson and Brower 1996; Leong 1999). Fall- or winter-blooming flowers provide nectar which may be needed to maintain lipid levels necessary for spring migration (Tuskes and Brower 1978).

Suitable microclimate conditions are often found at sites consisting of roost trees, in which monarchs cluster, surrounded by a larger grove or windrow of trees. The trees most commonly used for roosting are the nonnative blue gum eucalyptus (*Eucalyptus globulus*) and the native Monterey pine (*Pinus radiata*) and Monterey cypress (*Cupressus macrocarpa*) (Xerces Society Western Monarch Overwintering Sites Database 2016). Clusters are also found on nonnative red gum eucalyptus (*Eucalyptus camadulensis*), and the native western sycamore (*Platanus racemosa*), coast redwood (*Sequoia sempervirens*), coast live oak (*Quercus agrifolia*), and others (Xerces Society Western Monarch Overwintering Sites Database 2016). Although it was historically assumed that monarchs preferred to overwinter in nonnative eucalyptus rather than native tree species, recent research has demonstrated that monarchs do not prefer eucalyptus trees, and actually use native tree species more than would be expected, given the low density of native trees relative to eucalyptus in many groves (Griffiths and Villablanca 2015).

Overwintering Population Trends

Description of data

The Xerces Society's Western Monarch Overwintering Sites Database is the most comprehensive database of California overwintering site locations and population trends. The database was created by combining long-term monitoring data from the Western Monarch Thanksgiving Count, monarch overwintering site occurrences in the California Department of Fish and Wildlife's California Natural Diversity Database (CNDDDB), and information from a variety of unpublished reports, personal communications, and published literature. Ongoing data sharing between Xerces and CNDDDB occurs, and the database is frequently updated. The database includes sites identified by historical records, original site surveys (e.g., Nagano and Lane 1985; Sakai and Calvert 1991; Meade 1999), ongoing data collection as part of the annual Western Monarch Thanksgiving Count, and focused survey efforts by Xerces staff after identifying information gaps. It also includes information such as site location, habitat quality, conservation issues, and land ownership information.

As of June 2016, the database contains 400+ overwintering sites which are known to have hosted monarchs in California with over 4,400 count records stretching back to 1970. An additional 70+ sites have been anecdotally reported as cluster sites by landowners or historical records, but have not been verified by counts. More than thirty sites have been added to the database in the last five years due to Xerces Society staff survey effort and growing volunteer participation in the Western Monarch Thanksgiving Count (WMTC).

The WMTC was started in 1997 by three individuals, Dennis Frey, Mia Monroe, and David Marriott, to provide a standardized method of collecting monarch abundance estimates. The WMTC greatly increased the quality and quantity of data available to track the trends of the Western overwintering monarch population. Each year, during a three-week period centered on Thanksgiving, monarch experts and citizen scientists fan out across coastal California to count clustered monarchs using a standard protocol (available at westernmonarchcount.org). The number of sites visited each year has varied between 76 and 188 sites based on volunteer effort. An additional five sites in Baja California, Mexico, were monitored during the early years of the WMTC and five sites in Arizona have been added in recent years due to the participation of the Southwest Monarch Study program. While survey efforts are not exhaustive, the majority of known, large overwintering sites are included in the count. The standardized counts of the WMTC allow comparisons between years and sites and provide an estimate of the size of the monarch population that overwinters in western North America.

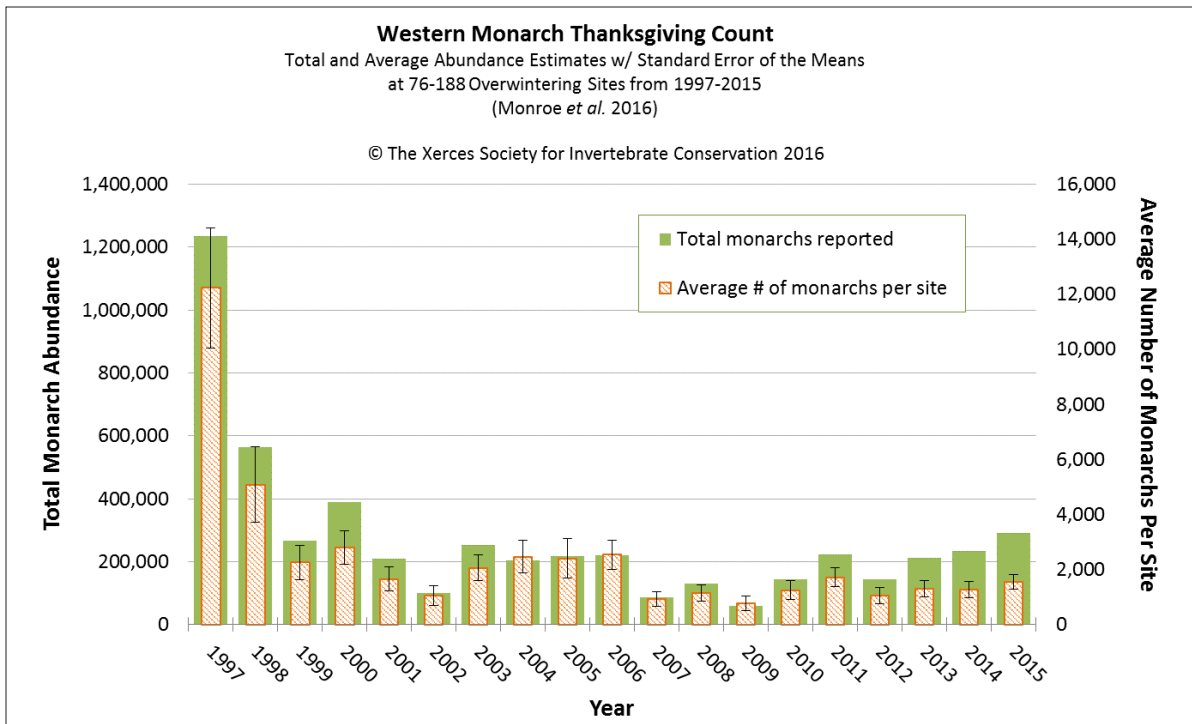


Figure 1. Total abundance and average number of butterflies per site (with standard error of means) calculated from data gathered during the Western Monarch Thanksgiving Count, 1997–2015.

Population estimates before 1997

Western overwintering monarch populations have been declining since regular monitoring began in 1997, but older data indicates the downward trend may have started even earlier. In 1991, 200,000 butterflies were observed at Pismo Beach (San Luis Obispo County) and clusters of more than 100,000 butterflies were observed at five other sites in the 1980s and 1990s. Since 1997, no site has hosted over 100,000 monarchs. Clusters of more than 10,000 butterflies were documented at 90 sites between 1970 and 1997, but in 2015, only seven sites had clusters this large (Xerces Society Western Monarch Overwintering Sites Database 2016).

A major survey effort in 1990 by Sakai and Calvert (1991) provided count estimates at a large number of overwintering sites, including 24 which were later included in the Western Monarch Thanksgiving Count. Monarch abundance in 1990 was comparable to that in the late 1990s at these sites, suggesting the late 1990s were not unusually high monarch years. Due to the limited data availability of standardized estimates of the western monarch population in other years, analyses of long-term population trends prior to 1997 are limited.

Recent population trends

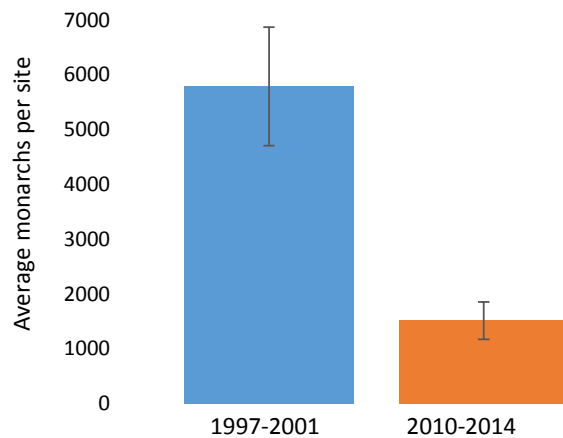
Several methods have been used to quantify changes in the western monarch overwintering population size. In 1997, a total of 1.2 million monarchs were observed overwintering along the Pacific coast. In 2015, the number of monarchs was 292,674. A comparison of the average number of monarchs per site shows that the 2015 count total is 35% below the 19-year annual average. Using the long-term average as the yardstick, in the past five years western monarch counts have fluctuated between 35% and 59% below average. Hence, a 40–50% decline has been generally cited (e.g., Center for Biological Diversity et al. 2014; Jepsen et al. 2015).

Using the long-term average as the yardstick has been widely used to describe declines in the eastern overwintering population as well, and while useful and straightforward, insect populations are characterized by a high degree of variability from year to year and site to site. Spatial or temporal averages do not reflect the inherent variability in population dynamics that influence long-term trends (Fagan et al. 2001; Schultz and Hammond 2003). For example, the central Mexico overwintering population in 2013 was 90% below the 20-year average, whereas high numbers of monarchs in 2015 puts the population just 32% below the 22-year average. Still, the long-term trend of Mexican overwintering monarchs is demonstrably downward.

To overcome the limitations of this method, the Xerces Society has undertaken more robust analyses to model overall trends while accounting for differences in survey effort over time and variability between sites. These new analyses of the WMTC data (below) estimate the western overwintering population has undergone a 74% decline since 1997–2001 (Analysis 1) and an average decline of 12% per year (Analysis 2). All statistical analyses were performed using R (R Development Core Team 2015).

Analysis 1: Before-and-after site comparison

One hundred fifteen overwintering sites have at least two years of count data in the period 1997–2001 and at least two years of count data in the period 2010–2014. Using the average monarch count for each site over each 5-year time period minimizes the influence that any one year has on the analysis. A paired t-test shows a significant decline between the two time periods ($t = 5.098$, $df = 114$, $p\text{-value} < 0.0001$). This before-and-after site comparison analysis shows a 74% decline since 1997–2001.

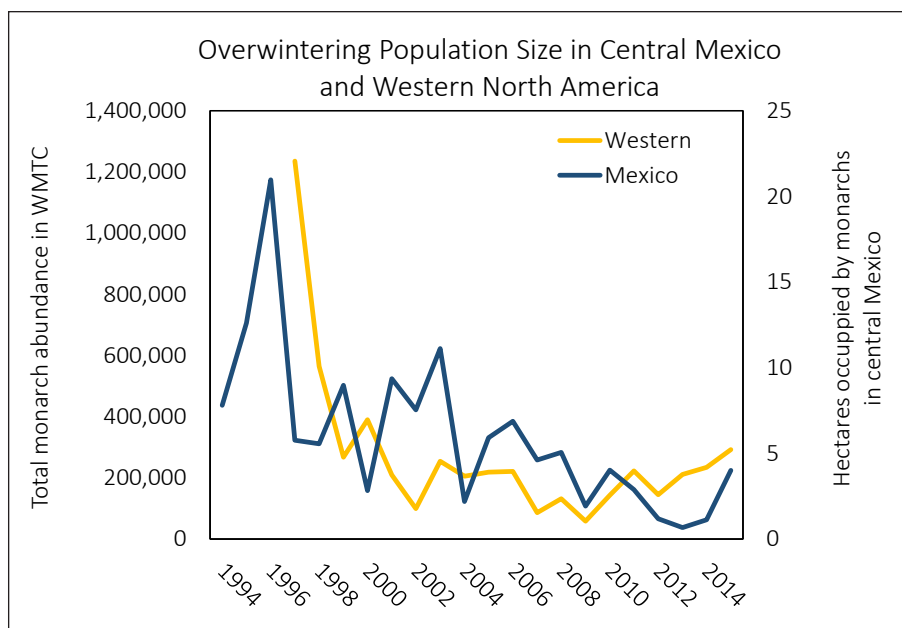


Analysis 2: Mixed model analysis

Population trends across the 1997–2015 WMTC data were analyzed using a general linear mixed model (lme4 package in R; Bates et al. 2015). The number of monarchs counted was natural log transformed and the model included site as a random effect and fixed effects of Year and Year x Site interaction, with the latter included to account for autocorrelation in the data. The analysis shows that the data fit a logarithmic trend of a 12% average decline in the population per year.

Comparing California and central Mexico overwintering populations

The eastern monarch population migrates in astonishing numbers to the oyamel fir forests of central Mexico. However, eastern overwintering numbers have also undergone a significant decline in abundance since the 1990s (Brower et al. 2012; Center for Biological Diversity et al. 2014) and recent analyses have determined that the Eastern overwintering population of monarch butterflies in central Mexico is highly vulnerable to extinction (Jepsen et al. 2015; Semmens et al. 2016). Due to the massive numbers of monarchs which cluster in the forests of central Mexico, yearly monarch abundance is determined by measuring the total area occupied by the butterflies. The area occupied in central Mexico is modeled at 84% below the 1996 population maximum (Semmens et al. 2016). While calculated differently, the 74% decline from the 1997–2001 population average at California overwintering sites (documented in this report) is similarly severe.



Priority Overwintering Sites

California overwintering sites by county

The table below presents an overview of the 400+ known monarch overwintering sites, organized by county and occupancy status. “Active sites” are those where monarchs have been observed clustering at least once during surveys done between 2010 and the present. “Failed to find” are sites where monarchs have not been observed clustering during surveys done since 2010. “Unknown status” denotes sites which have not been visited during a monitoring survey since 2010, but were verified as cluster sites in a pre-2010 monarch count.

County	Total Number of Sites	Occupancy Status		
		Active sites	Failed to find	Unknown status
Mendocino	3	2	1	0
Sonoma	15	3	2	10
Marin	21	10	4	7
Solano	3	0	1	2
Contra Costa	2	1	1	0
Alameda	11	10	0	1
San Francisco	13	10	0	3
San Mateo	14	3	3	8
Santa Cruz	19	13	1	5
Monterey	25	15	3	7
San Luis Obispo	54	39	6	9
Santa Barbara	130	61	20	49
Inyo	3	0	0	3
Ventura	12	11	0	1
Los Angeles	39	13	4	22
Orange	20	11	1	8
San Diego	28	19	6	3
Total Sites	412	221	53	138

Top 50 priority sites list

A list of the fifty overwintering sites in greatest need of attention was developed to help land managers, policy makers, communities, and others make decisions about which sites are most critical for protection and active management when resources are limited. The Top 50 sites are listed on the next page, with short profiles of the twenty-five sites in greatest need of attention on the pages that follow.

The ranking of the Top 50 priority overwintering sites was generated by multiplying two factors: 1) the percent decline in a site's population from its 1997–2001 count average to 2010–2014 count average and 2) the proportion of the remaining total population in 2010–2014 at the site. Sites in which the monarch populations have undergone the greatest declines, yet host the largest proportion of the remaining population have the highest ranking. Sites that lacked sufficient count information (not monitored in 1997–2001 or 2010–2014) or that have been recently discovered were excluded, as a ranking could not be calculated. Management and protection decisions should also be based on criteria such as severity of development pressures, grove structural diversity, level of tree senescence or other site threats, but comprehensive information on these threats at many sites is currently lacking, so this information was not used in the ranking process.

The Top 50 priority sites are spread across twelve California counties stretching the length of the Pacific coast from Sonoma to San Diego counties. Twenty of the sites are located in two counties, Santa Barbara and San Luis Obispo, which represent the core of the monarchs overwintering range along the Pacific coast. More than half of the Top 50 sites are publicly owned: twelve are located within California state parks, five are located on city property, two on Department of Defense property, two within the East Bay Regional Parks District, and at least six others are owned by county, state, university, or federal entities. Of the sites located on private property, most are in residential areas, although three are located on golf courses, and three on oil or natural gas facilities.



Figure 2. Locations of the Top 50 priority monarch overwintering sites in California. (Priority sites are orange, other sites white.)

Top 50 Priority Sites

Rank	Xerces Database ID#	County	Site Name	Current Population (2010–2014 average)	Decline (from 1997–2001 average)
1	3060	San Luis Obispo	Pismo Beach State Park	25,494	64.8%
2	2732	Santa Barbara	Private Site 2732	12,686	67.6 %
3	2920	Monterey	Private Site 2920	16,362	48.7 %
4	2751	Santa Barbara	Ellwood Main	12,142	58.0 %
5	3056	San Luis Obispo	Morro Bay Golf Course	11,306	61.2 %
6	2935	Monterey	Pacific Grove Sanctuary	11,914	51.8 %
7	3000	Santa Cruz	Lighthouse Field State Beach	7,360	83.6 %
8	2833	Alameda	San Leandro Golf Course	5,350	63.0 %
9	2983	Santa Cruz	Moran Lake	3,915	74.7 %
10	3043	San Luis Obispo	Pecho Road, Los Oso	4,321	64.3 %
11	2998	Santa Cruz	Natural Bridges State Park	2,760	95.1 %
12	3142	Ventura	Arrundel Barranca, Ventura	2,716	82.5 %
13	2765	Santa Barbara	Atascadero Creek	5,138	42.6 %
14	2799	Santa Barbara	Carpinteria Creek	2,445	75.1 %
15	2712	Santa Barbara	Vandenberg AFB, Spring Canyon	1,760	82.0 %
16	2699	Santa Barbara	Vandenberg AFB, Tangair Rd.	2,067	67.8 %
17	2831	Alameda	Ardenwood Historic Farm	1,837	72.4 %
18	3140	Ventura	Vista Del Mar, North Ventura	1,250	94.6 %
19	3151	Ventura	Harbor Boulevard, Ventura	967	87.2 %
20	2800	Santa Barbara	Chevron Park	1,100	74.5 %
21	3051	San Luis Obispo	Toro Creek, South of Cayucos	926	79.4 %
22	3055	San Luis Obispo	Morro Bay State Park	1,095	64.0 %
23	3070	San Luis Obispo	Villa Creek, North of Cayucos	787	85.3 %
24	3058	San Luis Obispo	Montana De Oro State Park	683	97.5 %
25	2755	Santa Barbara	Devereaux School	748	71.4 %

Note: A site is named as numbers only if it is sensitive to public disturbance and/or at the explicit request of the private landowner.

Rank	Xerces Database ID#	County	Site Name	Current Population (2010–2014 average)	Decline (from 1997–2001 average)
26	2832	Alameda	Chuck Corica Golf Course	1,459	31.3 %
27	3057	San Luis Obispo	Eagle Rock, Morro Bay	788	52.7 %
28	2941	Monterey	Plaskett Creek Campground, Los Padres National Forest	430	96.3 %
29	2883	Los Angeles	Busch Dr. & Pacific Coast Hwy., Malibu	417	91.2 %
30	3093	San Luis Obispo	San Luis Obispo Cemetery	337	81.6 %
31	3186	Monterey	Point Lobos State Natural Reserve	287	91.8 %
32	2903	Marin	Stinson Beach	261	98.7 %
33	2986	Santa Cruz	New Brighton/Potbelly, Aptos	394	61.7 %
34	3150	Ventura	Taylor Ranch, North Ventura	250	94.0 %
35	2899	Marin	Purple Gate, Bolinas	233	98.8 %
36	3053	San Luis Obispo	Monarch Lane, Los Osos	202	91.1 %
37	2841	Contra Costa	Point Pinole	197	86.1 %
38	2830	Alameda	Albany Hill	389	33.1 %
39	3121	Sonoma	Bodega Dunes Campground	124	86.8 %
40	2924	Monterey	Andrew Molera State Park	2,176	4.8 %
41	2857	Los Angeles	Encinal Canyon, Malibu	97	96.1 %
42	2909	Marin	Fort Baker, GGNRA	102	89.0 %
43	2980	Orange	Sundance Drive, Costa Mesa	87	91.3 %
44	2949	Orange	San Clemente State Park	61	96.4 %
45	2749	Santa Barbara	Ellwood North	58	98.3 %
46	3054	San Luis Obispo	Sweet Springs, Los Osos	386	13.4 %
47	3149	Ventura	Pt. Mugu State Park	46	97.9 %
48	3031	San Diego	UCSD Coast Site, Azul Street	41	92.6 %
49	3181	Los Angeles	Woodlawn Cemetery	44	83.5 %
50	2855	Los Angeles	Leo Carrillo State Beach, Malibu	35	97.0 %

Profiles of 25 Highest Priority Overwintering Sites

Below are brief profiles of the 25 highest priority sites. Each profile includes the ownership, population trends, and conservation issues that have been identified. Site profiles are based on information contained in the Xerces Society Western Monarch Overwintering Sites Database, reports from previous studies (e.g., Sakai and Calvert 1991), and habitat assessments completed by Xerces biologists and WMTC volunteer monitors. Site profiles are based on the most recent available information. However, not all sites have been assessed comprehensively and conservation issues may be incomplete or unknown. Conservation issues are presented for the purpose of identifying common conservation challenges for overwintering sites and recognized site-specific concerns, but are not comprehensive. In addition, many overwintering site managers are actively addressing site-specific threats, and these activities are not captured in these summaries. If you have additional information about conservation issues at these sites, please email it to wmtc@xerces.org.

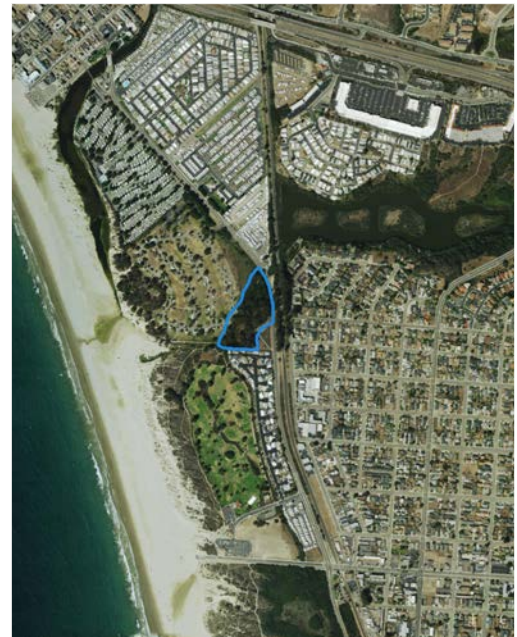
1. Pismo Beach State Park

County: San Luis Obispo
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 65%
Peak (1990): 200,000
Most recent (2015): 28,073

This site contains ~11% of the overwintering population in California.

Site Description: Grove along creek includes eucalyptus and Monterey cypress cluster trees. Non-cluster tree species include blue gum, Monterey pine, Monterey cypress, and willow (*Salix* spp.). Nectar species include dune groundsel/ragwort (*Senecio blochmaniae*), mock heather (*Ericameria ericoides*), crisp dune mint (*Monardella crispera*), nightshade (*Solanum* spp.) and common deerweed (*Lotus scoparius*).

Conservation Issues: Unknown



2. Private Site 2732

(No aerial image is provided to maintain privacy of landowner.)

County: Santa Barbara

Ownership: Private

Population: Decline from 1997–2001 average: 68%
Peak (1998): 150,000
Most recent (2013): 10,777

Site Description: Large grove of mixed-age blue gum eucalyptus along a dry creek drainage. Nectar species include Aster (*Aster* spp.), willow (*Salix* spp.) and coyote brush (*Baccharis* spp.).

Conservation Issues: Site is largely unprotected from vandalism. Trees are senescing and stressed from Eucalyptus leaf beetle infestation and there is evidence of fire-killed trees. Erosion may be limiting plant regeneration and threatening cluster trees.

3. Private Site 2920

(No aerial image is provided to maintain privacy of landowner.)

County: Monterey

Ownership: Private

Population: Decline from 1997–2001 average: 49%
Peak (1996): 75,000
Most recent (2015): 5,202

Site Description: A large, planted coast redwood tree surrounded by blue gum eucalyptus, Monterey pine, Monterey cypress, and palms. Site is a facility consisting of buildings within a natural area landscape. Nectar species include nonnative English ivy (*Hedera helix*).

Conservation Issues: Tree trimming and removal may threaten the site.

4. Ellwood Main

County: Santa Barbara
Ownership: Public (City of Goleta)
Population: Decline from 1997–2001 average: 58%
Peak (1990): 129,000
Most recent (2015): 6,610

Site Description: Site is part of a complex of overwintering sites located along a drainage extending northward from the coastal bluff, which forms a gully through a dense grove of eucalyptus. The gully is primarily dry and connects to Devereaux Creek which runs east/west across the Ellwood Mesa. The eucalyptus grove is part of a thick band of eucalyptus trees running parallel to Devereaux Creek. Monarchs roost on either side of the gully or directly above on overhanging branches in a cathedral-like opening. Devereaux Creek provides a fresh water source in wet winters. Nectar sources include coyote brush (*Baccharis* spp.) on the coastal bluff, herbaceous species along Devereaux Creek, and numerous ornamental plants at the nearby residences.

Conservation Issues: Nearby development may negatively affect this site. High levels of human visitation may have caused erosion and damage to understory. The eucalyptus trees in the grove are significantly drought-stressed and the canopy is becoming increasingly open as trees and branches fall.



5. Morro Bay Golf Course

County: San Luis Obispo
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 61%
Peak population in 1998: 110,500
Most recent (2015): 13,492

Site Description: Groves of Monterey pine, eucalyptus, Monterey cypress, and other tree species on a golf course. Nectar species include coyote brush (*Baccharis* spp.).

Conservation Issues: The Monterey pines on the site have pitch canker and some trees have been removed or trimmed because of the disease. Monterey cypress and redwood were planted in their place. However, additional tree planting may be needed.

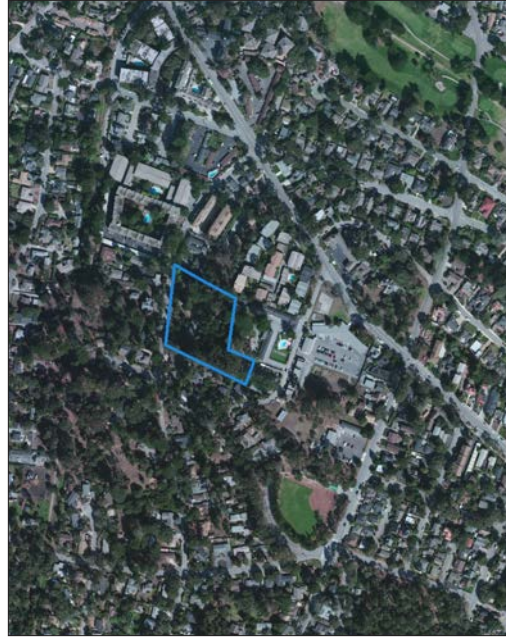


6. Pacific Grove Sanctuary

County: Monterey
Ownership: Public (City of Pacific Grove)
Population: Decline from 1997–2001 average: 52%
Peak (1997): 45,000
Most recent (2015): 11,472

Site Description: Grove in a residential area dominated by Monterey pine; cypress and eucalyptus tree species are also present. Nectar species include native coyote bush (*Baccharis* spp.) and many nonnative species.

Conservation Issues: This site has been the focus of active restoration for many years including native tree plantings, which have since been occupied by overwintering monarchs, and nectar plants.

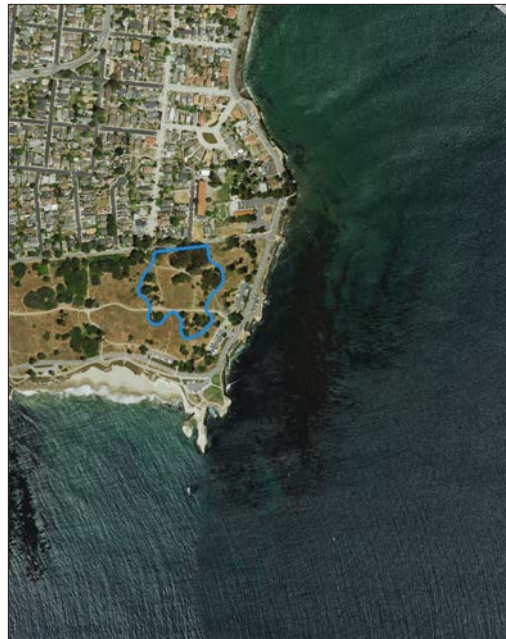


7. Lighthouse Field State Beach

County: Santa Cruz
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 84%
Peak (1997): 70,000
Most recent (2015): 12,000

Site Description: Eucalyptus and Monterey cypress remain from old plantings on an originally treeless coastal terrace between a residential area and the ocean. Other trees nearby include Monterey pine and willows. Nectar species include nonnative ice plant (family Aizoaceae), *Oxalis* spp., mustard and radish (family Brassicaceae), and *Prunus* spp.

Conservation Issues: The grove is small, and some of the eucalyptus trees are senescing or have been trimmed for safety reasons or due to storm damage. Much of the downed wood remains on site and may be harboring tree pests. Eucalyptus beetle infestation and drought are also negatively affecting the eucalyptus. There is limited regeneration of trees outside the cluster area to provide wind protection, especially from storms. Pitch canker is present in the Monterey pines on site. Human use of the area is high and symbolic fencing offers only minimal protection to the cluster trees.



8. San Leandro Golf Course

County: Alameda
Ownership: Private (American Golf Corporation)
Population: Decline from 1997–2001 average: 63%
Peak (1998): 31,000
Most recent (2015): 12,864

Site Description: Windrow of eucalyptus on a golf course surrounded by residential housing and parkland. Monarchs cluster on blue gum eucalyptus; non-cluster tree species include coast redwood.

Conservation Issues: Development has been planned for the adjacent San Leandro Marina and this development may negatively impact the site.

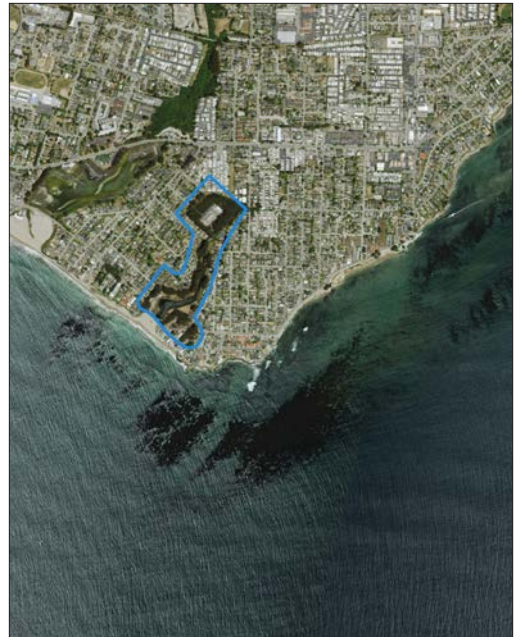


9. Moran Lake

County: Santa Cruz
Ownership: Public (County of Santa Cruz).
A portion of site is privately owned.
Population: Decline from 1997–2001 average: 75%
Peak (1997): 70,000
Most recent (2015): 5,800

Site Description: A dense stand of eucalyptus and pine with native species in the wind break near a creek and surrounding a water treatment plant. Non-cluster tree species include blue gum, coast redwood, Monterey cypress, Monterey pine. Nectar species include nonnative ivy.

Conservation Issues: This site has undergone tree trimming and removal in some areas, but vegetation in other areas may be growing too densely to provide ideal microclimate conditions for clustering monarchs. Unrestricted human use of the site has resulted in at least one fire in recent years. Runoff and erosion may also limit tree and nectar plant regeneration.



10. Pecho Road, Los Oso

County: San Luis Obispo
Ownership: Private
Population: Decline from 1997–2001 average: 64%
Peak (1998): 50,000
Most recent (2015): 9,232

Site Description: Eucalyptus grove bordered by roads on three sides. Eucalyptus trees planted in tightly packed rows with little to no understory. Grove is located on five residential lots, three of which have residences. Nectar sources are located in home gardens.

Conservation Issues: Drought stress on eucalyptus trees has resulted in several dead and dying trees. There is potential development risk on the two residential lots that are currently undeveloped.



11. Natural Bridges State Park

County: Santa Cruz
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 95%
Peak (1997): 120,000
Most recent (2015): 8,000

Site description: Eucalyptus grove in a ravine surrounded by coastal prairie. A nearby freshwater pond provides a water source for monarchs. Other tree species present include Monterey cypress and Monterey pine. Nectar species include nonnative English ivy (*Hedera helix*). Wooden boardwalks and interpretative signage have been added in recent years to direct park visitors.

Conservation Issues: The eucalyptus grove is senescing, and the Monterey pines, which provide wind protection, may be affected by pitch canker.

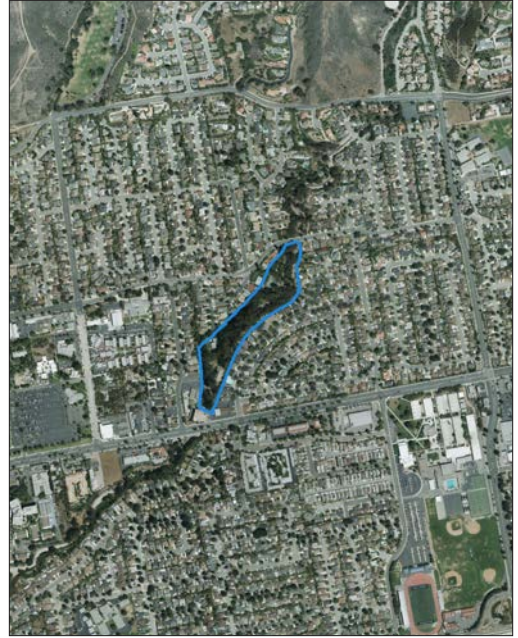


12. Arrundel Barranca

- County:** Ventura
- Ownership:** Mixed public–private ownership. Site boundaries are undefined, but likely intersect private residential land and county land, including flood control basins and channels owned by Ventura County Flood Control District.
- Population:** Decline from 1997–2001 average: 83%
Peak (1997–98): 40,000
Most recent (2015): 835

Site Description: Concrete-lined channel bordered on either side by eucalyptus windrows.

Conservation Issues: Unknown



13. Atascadero Creek

- County:** Santa Barbara
- Ownership:** Private
- Population:** Decline from 1997–2001 average: 43%
Peak (1996): 70,000
Most recent (2015): 3,795

Site Description: Eucalyptus grove lines both sides of a perimeter road on the northern edge of a natural gas industrial facility. A road runs through a thick grove of eucalyptus. Monarchs cluster on branches extending towards the road on both sides. Atascadero Creek parallels the road to the north, providing a fresh water source, and to the south are agricultural fields and the natural gas facility. Nectar species include nonnative German ivy (*Senecio mikanioides*) and weedy herbaceous species along the roadsides.

Conservation Issues: Unknown



14. Carpinteria Creek

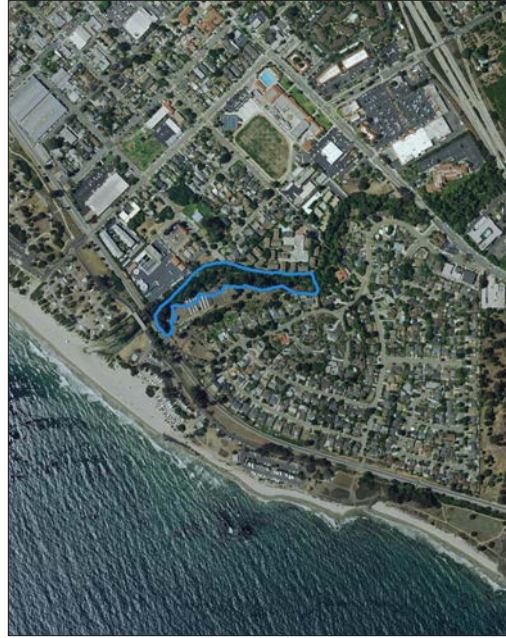
County: Santa Barbara

Ownership: Private

Population: Decline from 1997–2001 average: 71%
Peak (1997): 50,000
Most recent (2015): 4,110

Site Description: Grove including arroyo willows (*Salix lasiolepis*), western sycamore, blue gum eucalyptus, cottonwoods (*Populus* spp.), alders, and coast live oak on both banks of Carpinteria Creek, immediately south of an apartment complex. Monarchs have been documented clustering on almost every tree species at the site, sometimes only a few feet off the ground. Mature sycamore trees overhang the creek from north and south banks. Scattered mature blue gum eucalyptus are located on the south bank. Understory on both sides of the creek consists of arroyo willow trees and shrubs, nonnative shrubs, and annual grasses and forbs. A footpath runs parallel to the creek, on top of the north bank. Nectar sources include assorted native and nonnative weedy herbaceous species along the creek banks.

Conservation Issues: There is unrestricted public access, but human visitation to the site is probably low. The development risk is unknown.



15. Vandenberg AFB, Spring Canyon

County: Santa Barbara

Ownership: Public (Department of Defense)
No public access

Population: Decline from 1997–2001 average: 82%
Peak (1997): 50,000
Most recent (2015): 8,625

Site Description: Blue gum eucalyptus and Monterey cypress grove along a dry creek bed. Nectar species include California blackberry (*Rubus ursinus*), mustard (family Brassicaceae) and coyote brush (*Baccharis* spp.).

Conservation Issues: The grove is drought stressed.



16. Vandenberg AFB, Tangair Road

County: Santa Barbara
Ownership: Public (Department of Defense).
No public access
Population: Decline from 1997–2001 average: 68%
Peak (1997): 25,500
Most recent (2015): 2,860

Site Description: Large, medium-density mixed-age grove of blue gum eucalyptus growing on flat terrain. Nectar species include coyote brush (*Baccharis* spp.) and nonnative ice plant (family Aizoaceae).

Conservation Issues: The eucalyptus trees are drought stressed and the grove is located in a high fire risk area.



17. Ardenwood Historic Farm

County: Alameda
Ownership: Public (Eastbay Regional Parks District)
Population: Decline from 1997–2001 average: 72%
Peak (1997): 25,000
Most recent (2015): 2,409

Site Description: Blue gum eucalyptus plantation within a working farm and park landscape with a residential neighborhood bordering the grove on the northwest and a park-run railroad to the southeast. Additional eucalyptus species and other tree species are present at the far west and east ends of the grove. Nectar plants include *Oxalis* spp. and other plants in the ornamental gardens on the site.

Conservation Issues: Eucalyptus trees are suffering from drought and pest pressure from the eucalyptus leaf beetle, lerp psyllid, and longhorned borer. Sections of the grove are senescing and some trees have been lost or cut for safety reasons. Human visitation is high, but managed by staff.



18. Vista Del Mar, North Ventura

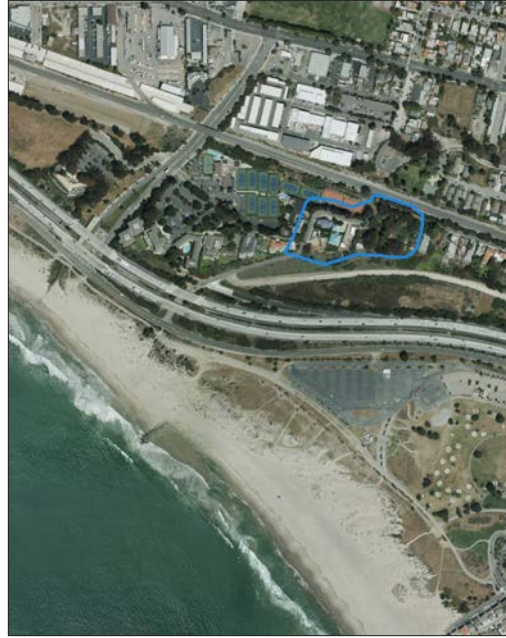
County: Ventura

Ownership: Mixed ownership

Population: Decline from 1997–2001 average: 95%
Peak (1997): 47,500
Most recent (2014): 2,500

Site Description: Grove surrounded by residential development and sports facilities. Tree species include pines, eucalyptus, cypress, and cheesewood (*Pittosporum* spp.).

Conservation Issues: Unknown



19. Harbor Boulevard

County: Ventura

Ownership: Mixed public–private ownership

Population: Decline from 1997–2001 average: 87%
Peak (1998): 30,000
Most recent (2014): 975

Site Description: Eucalyptus grove near agricultural fields, undeveloped land, and residential neighborhoods.

Conservation Issues: Trees have been pruned and a subset of trees have been removed in recent years. Regeneration was noted in a 2014 assessment of the site.



20. Chevron Park

County: Santa Barbara

Ownership: Private

Population: Decline from 1997–2001 average: 75%
Peak (1996): 45,000
Most recent (2013): 0

Site Description: Grove of eucalyptus and Monterey pine between a subdivision and former industrial facilities. Non-cluster tree species include western sycamore and coast live oak.

Conservation Issues: Monterey pines show signs of pitch canker.



21. Toro Creek, South of Cayucos

County: San Luis Obispo

Ownership: Private

Population: Decline from 1997–2001 average: 79%
Peak (1990): 26,000
Most recent (2015): 1,699

Site Description: Grove along a creek consisting of eucalyptus and western sycamore cluster trees and non-cluster trees including coast live oak and western sycamore. Nectar species include nonnative German ivy (*Senecio mikanioides*).

Conservation Issues: Unknown



22. Morro Bay State Park

County: San Luis Obispo
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 64%
Peak (1988): 30,000
Most recent (2015): 4,441

Site Description: Eucalyptus grove near a campground within the park. Nectar species include coyote brush (*Baccharis* spp.).

Conservation Issues: Unknown



23. Villa Creek, North of Cayucos

County: San Luis Obispo
Ownership: Private
Population: Decline from 1997–2001 average: 85%
Peak (1996): 16,000
Most recent (2015): 171

Site Description: Blue gum eucalyptus grove in the flood plain of Villa Creek.

Conservation Issues: Eucalyptus trees show signs of pest pressure from the eucalyptus leaf beetle. Wind protection of cluster trees from the north may be inadequate.



24. Montana De Oro State Park

County: San Luis Obispo
Ownership: Public (California Department of Parks and Recreation)
Population: Decline from 1997–2001 average: 98%
Peak (1998): 80,000
Most recent (2015): 2,105

Site Description: Grove of eucalyptus along a drainage.

Conservation Issues: Unknown



25. Devereaux School

County: Santa Barbara
Ownership: Public (University of California)
Population: Decline from 1997–2001 average: 71%
Peak (2000): 7,320
Most recent (2015): 1,307

Site Description: Grove of eucalyptus and willows surrounding a drainage connected to Devereaux Slough. Cluster tree species include blue gum eucalyptus, Monterey cypress, and willows. These are surrounded by a row of eucalyptus that extends around the east, west, and south sides. Grove is open to the north where small drainage connects to larger branch of the slough. Nectar species include plants in the genus *Baccharis*. Poison oak (*Toxicodendron diversilobum*) is present on the western slope of the drainage.

Conservation Issues: The drainage is surrounded by parking lots, school buildings, and an access road. The site may be impacted by vehicular traffic and landscape activities.



Conservation Issues

Monarch butterfly populations in North America face multiple stressors and may be limited by the availability of breeding habitat, fall and winter nectar resources, and overwintering habitat as well as pesticides, natural enemies, and climate change.

The loss of breeding habitat in the Midwest has been identified as an important driver of the eastern population's decline since the late 1990s (Pleasants and Oberhauser 2012; Flockhart et al. 2015). Breeding habitat loss refers to the decline in milkweed abundance in Midwestern agricultural fields linked to the increased adoption of genetically modified corn and soy and related increased use of the herbicide glyphosate (Hartzler 2010; Pleasants and Oberhauser 2012). However, the relative importance of milkweed, compared with other drivers such as fall nectar or overwintering habitat availability is an area of active research and debate (e.g., Davis and Dyer 2015; Dyer and Forister 2016; Inamine et al. 2016; Pleasants et al. 2016). This question is particularly poorly understood in the western states, where glyphosate use has also increased over the past two decades but the severity of milkweed loss is unclear.

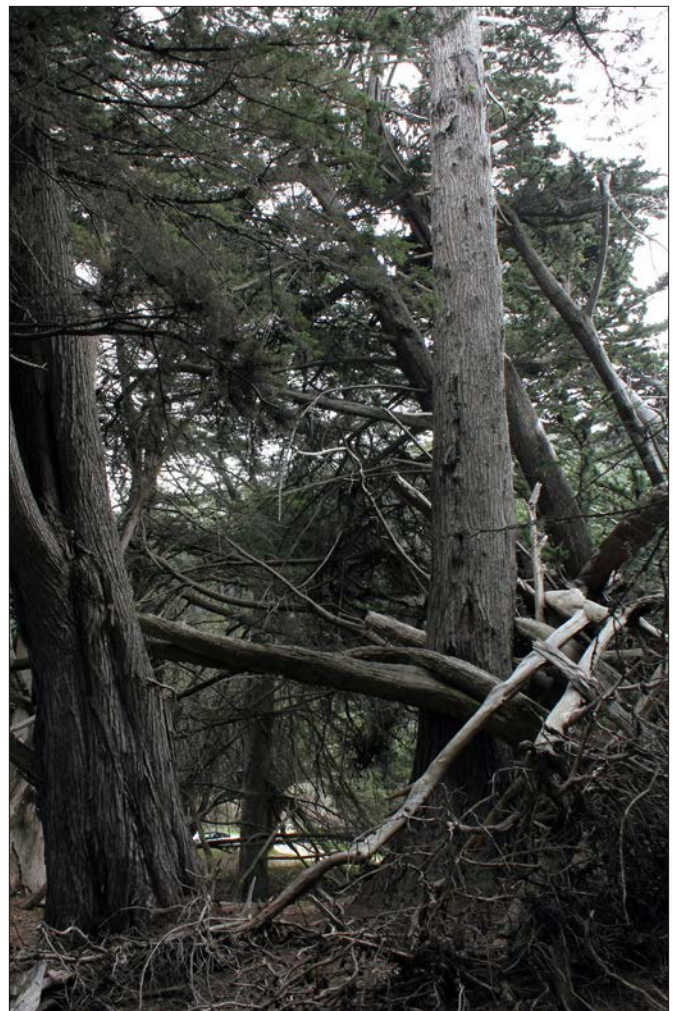
Besides loss of breeding habitat, monarchs are directly impacted by insecticides such as neonicotinoids (Krischik et al. 2015; Pecenka and Lundgren 2015) which have increased in use in agriculture, plant nurseries, and in urban and suburban landscapes since the late 1990s (USGS NAWQA 2016). Herbicides such as glyphosate may also be limiting nectar plant availability for breeding and migrating adult monarchs across their range. Monarch fitness and mortality are naturally regulated by predators, pathogens, and parasites. The best studied of these is the protozoan parasite *Ophryocystis elektroscirrha* (OE), which may negatively impact migratory success (Altizer et al. 2015). Climate change may also be affecting monarchs by increasing the severity and intensity of drought, which has been suggested as a major driver of monarch populations in the West (Stevens and Frey 2010). Another important factor that may influence monarch population size, and the focus of this report, is the availability and quality of overwintering habitat (Jepsen & Black 2015; Jepsen et al. 2015).

The importance of overwintering survival to the population

The monarch's life history trait to congregate in restricted geographic areas may make the species more vulnerable to stochastic events than other broadly distributed species. The short-term effects of mortality events at overwintering sites can be severe, such as the single winter storm in Mexico in January 2002 that caused an estimated 500 million monarchs to perish (Brower et al. 2004). In 2015, the entire overwintering population consisted of only 150 million monarchs and a winter storm in March 2016 may have killed millions of monarchs overwintering in Mexico, but the impact of that event on the population may never be fully known.

Monarchs in coastal California overwinter at more sites than their counterparts in central Mexico, and thus it is less likely for a stochastic event, destruction, or degradation of a single site to have a large impact on the overall population. However, overwintering has been posited as the most vulnerable element of the western monarch's annual cycle (Pyle and Monroe 2004) and loss of overwintering habitat may be an important driver of population decline (Jepsen & Black 2015; Espeset et al. 2016). Overwintering habitat is also crucial for the continuity of the migratory phenomenon. Clustering of monarchs in large numbers (up to 11% of the overwintering population in a single site) in the western U.S. means that an event such as a winter storm or fire in an overwintering site can have an outsized effect on the next spring's population because a notable percentage of the population can be impacted. Additionally, without sufficient high-quality overwintering habitat, monarchs may be forced to utilize sites with poor microclimatic conditions and inadequate wind protection. At these poor-quality sites, monarchs may incur higher mortality or reduced fitness because of storms and severe weather.

The overwintering groves in California are under pressure from several threats, including encroaching development (left) and aging and diseased trees (right). The overwintering sites need thoughtful management to ensure that they can continue to play an essential role in the monarch's annual cycle. (Photographs: The Xerces Society/Carly Voight.)



Threats to California overwintering habitat

Development

Development is a major cause of overwintering habitat loss and degradation; California has undergone and continues to face development pressure of varying severity along its coast. In highly urban areas such as the San Francisco Bay and Los Angeles, land conversion is extreme and can lead to complete destruction of suitable overwintering habitat. The destruction of 38 overwintering sites prior to 1990 was documented in a California statewide report (Sakai and Calvert 1991), and the destruction of 11 additional sites in the 1990s was documented in a 1999 Santa Barbara county report (Meade 1999). Six additional sites are known to have become unsuitable for monarchs since the late 1990s (Xerces Society Western Monarch Overwintering Sites Database 2016). The majority of sites were made unsuitable for monarch overwintering when urban development replaced the cluster trees. Encroaching development can also degrade overwintering sites by limiting grove size and tree regeneration and altering microclimatic conditions, but the severity of these effects on individual sites is unknown.

Grove senescence, pests, and disease

The impact of and interaction between grove senescence, pests, and disease reduce habitat quality for monarchs and is the most commonly noted conservation issue at California overwintering sites (Xerces Society Western Monarch Overwintering Sites Database 2016). Many groves are dominated by one or a few tree species, especially blue gum eucalyptus, and all of the trees on a site may be of a similar age class. Without tree planting or management to encourage regeneration, low diversity groves may senesce and eventually become uninhabitable for monarchs as microclimate conditions deteriorate. Senescing groves are also especially vulnerable to the negative impacts of diseases (e.g., pitch canker) and pests (e.g., eucalyptus leaf beetle [family Chrysomelidae]). The continuing drought in California has exacerbated these stressors at many overwintering locations, which can result in limb or tree failure, sometimes throughout an entire grove. Stressed blue gum eucalyptus may also cease flowering, eliminating the main source of nectar available to monarchs during the overwintering season at some sites. Additionally, downed trunks and limbs often attract and harbor pests (e.g., eucalyptus longhorned beetle [family Cerambycidae]), creating a feedback cycle which further stresses the grove.

Inappropriate site management

Silviculture management

Inappropriate tree removal and tree trimming can adversely affect the quality of overwintering sites by reducing wind protection and altering microclimate conditions. Severe alteration of a grove can make monarch clusters more vulnerable during storm events. These practices are especially problematic at small groves, where removal of a key individual tree or windrow may render the site unsuitable for monarchs.



The nonnative blue gum eucalyptus has become an important tree for clustering monarchs. Careful management of aging trees is needed to maintain suitability of a site for monarchs. (Photograph: The Xerces Society/Candace Fallon.)

Blue gum eucalyptus

Blue gum eucalyptus was introduced from Australia to California in the 1850s (Butterfield 1935), a time of expanded European settlement, and actively planted on farms and in parks. The species is now abundant along the California coast and may form dense groves, in large part because its leaves contain allelopathic compounds which inhibit regeneration of other plants. Despite the fact that monarchs do not prefer nonnative eucalyptus to native conifers (Griffiths and Villablanca 2015), blue gum is now the dominant tree in most of the California overwintering sites. The trees are not long lived and are prone to disease and herbivory. In addition, many sites have management goals to remove eucalyptus and trim trees considered to be fire or public safety hazards. Together, these pressures can put overwintering sites at risk. The Xerces Society recommends incorporating native tree species such as Monterey cypress into monarch overwintering sites to diversify eucalyptus groves.

Milkweed and overwintering sites

The majority of monarchs spend the winter in reproductive diapause (Herman 1981) until breeding resumes in February or March. 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 2016). Planting milkweed outside of its historic range and close to overwintering sites may encourage monarchs to continue breeding and laying eggs during the winter. Of particular concern is tropical milkweed (*Asclepias curassavica*); monarchs that reproduce in winter on tropical milkweed in coastal areas of California and along the Gulf Coast have higher loads of the parasite OE, which may inhibit successful monarch migration in the eastern United States. (Altizer et al. 2015; Satterfield et al. 2015, 2016). The Xerces Society recommends a precautionary approach: Do not plant milkweed close to overwintering sites (generally within 5–10 miles) in those parts of coastal California where it did not historically occur. In addition, the Xerces Society recommends against planting of tropical milkweed anywhere because of its potential to increase parasite infection in monarchs.

Public access to overwintering sites

Allowing public access to overwintering sites is valuable from an education and scientific perspective, but must be balanced with protection of overwintering monarchs and their habitat. Recreational use of overwintering sites can indirectly harm monarchs by having a negative impact on habitat quality and

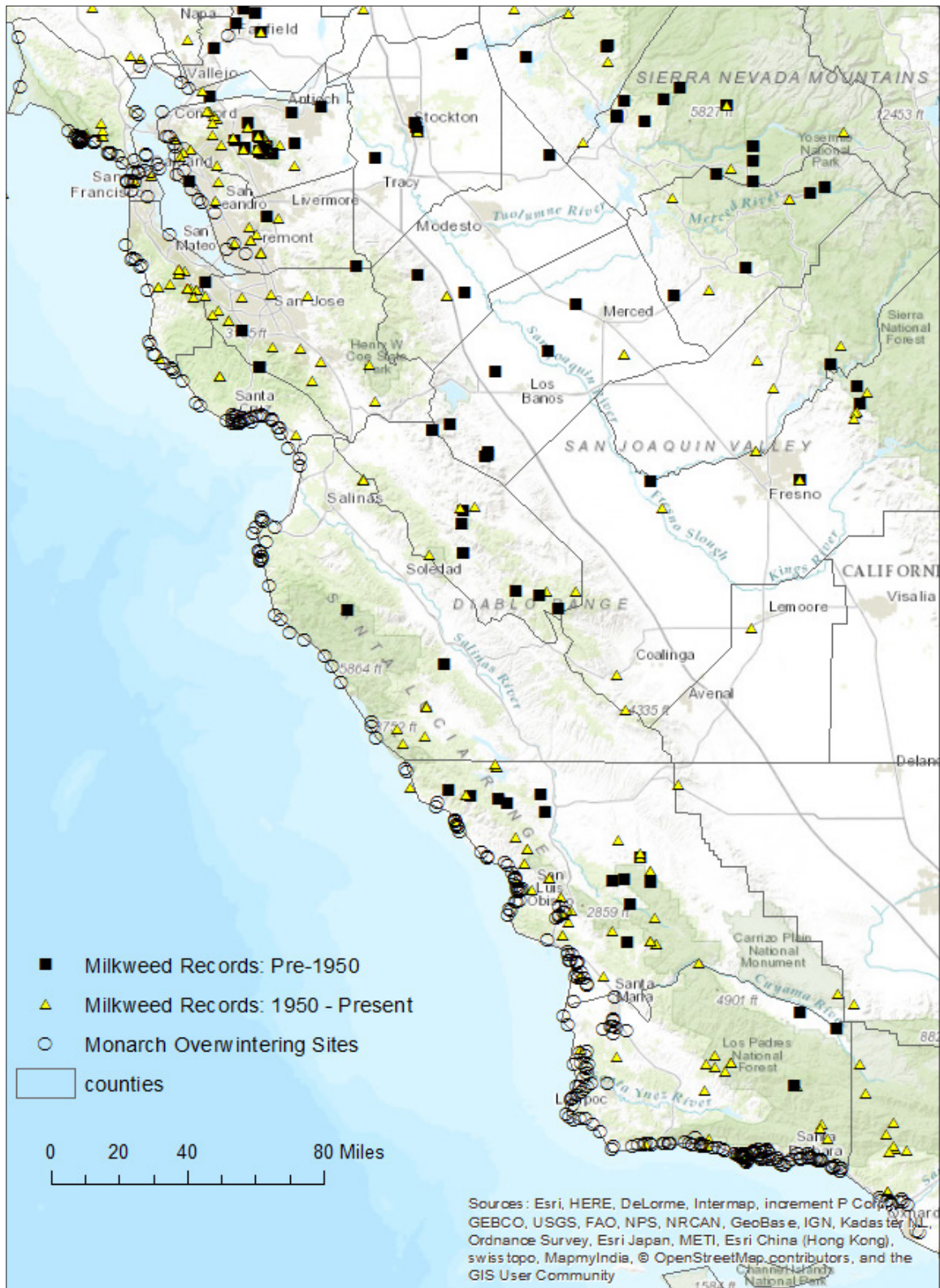


Figure 3. Locations of historical and recent records of milkweed occurrence in relation to monarch overwintering sites in California. The presence of milkweed close to overwintering sites may be altering monarch breeding patterns.

directly affect monarchs through disturbance. High pedestrian traffic can cause erosion and limit natural regeneration of nectar plants and trees. At overwintering sites in urban areas, human habitation and the associated risk of uncontrolled fire can threaten groves. Collection of large numbers of monarchs for commercial rearing or other purposes may also be detrimental to monarch populations. The Xerces Society recommends a balanced approach to providing access to monarchs for education, tagging, and other research studies. Fencing, designated trails, interpretative signage and the presence of docents or other staff can limit the negative effects of high human visitation.

Legal status and protection

A petition was submitted to the U.S. Fish and Wildlife Service in 2014 by the Center for Biological Diversity, the Center for Food Safety, the Xerces Society, and Dr. Lincoln Brower,

requesting that the monarch butterfly be listed as a threatened species under the federal Endangered Species Act. The petition is currently under review by USFWS after a positive 90-day finding. In California, Oregon, Washington, and Idaho, the butterfly is designated as a Species of Greatest Conservation Need which allows state agencies greater ability to work on the butterfly's conservation. A full summary of the species status in California can be found in "The Legal Status of Monarch Butterflies in California" (International Environmental Law Project and the Xerces Society 2012).

Overwintering sites have mixed levels of protection depending upon site ownership. On non-military federal and state lands, monarch overwintering sites are protected from almost all development and non-scientific collection, but there are not restrictions on habitat modification by land managers. Federal military lands have restrictions in place for monarch overwintering sites but are largely non-binding. City and county ordinances create a patchwork of protection and most ordinances are inadequate to protect sites from development or monarchs from collection. Many overwintering sites fall within the "coastal zone" as defined by the federal Coastal Zone Management Act of 1972 and a subset of these sites are designated as environmentally sensitive habitat areas (ESHAs) which "shall be protected against any significant disruption of habitat values." Collectively, these laws do not offer comprehensive or consistent protection for monarchs or their overwintering habitat in California.



Overwintering monarchs are a remarkable phenomenon that can attract significant public interest. Providing facilities such as boardwalks and trails within overwintering groves can reduce potential disturbance to the habitat. (Photograph: The Xerces Society/Carly Voight.)

Taking Action

Knowledge gaps

Documenting changes in the western monarch population and determining the effectiveness of recovery efforts requires long-term monitoring at overwintering sites. The Western Monarch Thanksgiving Count (WMTC) is the most comprehensive survey of overwintering populations in California and currently provides the most robust index of the western monarch population. The data from the WMTC has been used in at least seven scientific publications or book chapters (Frey and Schaffner 2004; Koenig 2006; Vandenbosch 2007; Stevens and Frey 2010; Griffiths and Villablanca 2015; Jepsen and Black 2015; Espeset et al. 2016). The WMTC is volunteer based, and while many dedicated volunteers and regional coordinators contribute hundreds of hours to the count each year, crucial data gaps remain. About one third of the 400+ known overwintering sites have not been monitored in the past five years and other sites are inconsistently monitored (only 111 sites have been monitored 10 of the 19 years of monitoring). Increased outreach activities such as workshops to recruit and train new volunteers are needed to help fill critical gaps in the WMTC. Additionally, a comprehensive statewide survey of overwintering sites could supplement the WMTC and resolve site status questions.

In addition to annual population estimates, many questions remain about western monarch overwintering biology, habitat needs, and population dynamics. The prevalence of winter breeding and the interactions between tropical milkweed, OE, and winter breeding are areas of active investigation in California (by Monarch Health and Monarch Alert). A better understanding of the parameters such as wind protection and forest structure that make overwintering habitat suitable for monarchs, could improve restoration and management recommendations and aid in prioritizing where actions would be most effective on the landscape. Other questions in need of additional research include determining the impact of tree disease and pests on grove health, the prevalence of bird and rodent predation on overwintering monarchs, and population dynamics over the season as monarchs move between sites.

The relative importance of the western monarch population to the entire North American monarch population remains poorly understood and has been the focus of few studies. However, successful conservation of the North American monarch population relies on understanding migratory monarchs' natal origins and basic biology across its range, including in the western United States. Further research could focus on improving our understanding of migratory monarchs' natal origins through the use of isotopic analyses which include all of North America in its isoscapes. Increased monitoring and tagging of monarchs in the central U.S. and interior West (e.g., Montana, Colorado, etc.), perhaps through improved outreach to citizen scientists, would improve our knowledge of migration paths of western monarchs.

Management recommendations

The majority of overwintering sites would benefit from active management to address issues of grove senescence, disease and pest infestations, and ensure tree regeneration or replacement. Other management considerations include minimizing negative impacts of public access by adding trails and fencing (or symbolic fencing) to reduce erosion and disturbance to the butterflies, signage for education, and, if feasible, a docent or staff presence during peak winter months for both outreach and protection of the site.

Best management practices for monarch overwintering habitat management include developing a site-specific adaptive management plan which consists of:

- ⇒ identifying where monarchs cluster and important wind break features in the surrounding landscape;
- ⇒ measuring wind, temperature, humidity, and sun exposure throughout the grove area to determine where additional tree planting or tree trimming would benefit or harm the site's suitability for monarchs;
- ⇒ monitoring monarchs' use of the site during the overwintering season (October to February), including cluster trees and areas used for sunning, nectaring, and imbibing water;
- ⇒ scheduling management action outside of the overwintering season to minimize impacts on clustering monarchs;
- ⇒ ensuring management action that does occur does not negatively impact trees used by monarchs or buffer trees; and
- ⇒ monitoring of site conditions and monarchs' use of the site and subsequent adaptation of the site management plan.

Management actions at an overwintering site should take place only after monitoring for an entire overwintering season (and ideally after multiple years of monitoring) to determine where monarchs move within the grove and surrounding habitat over the season. Before any modifications are made to monarch cluster trees, consultation with a monarch expert and an arborist or forestry professional is recommended. Management of overwintering groves and surrounding wind break features should continue to be monitored and adjusted in accordance with an adaptive management framework as the microhabitat conditions of a grove will change as trees grow and senesce.

(Opposite—Photograph: The Xerces Society/Candace Fallon.)



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