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Sarina Jepsen, Dale F. Schweitzer, Bruce Young, Nicole Sears,
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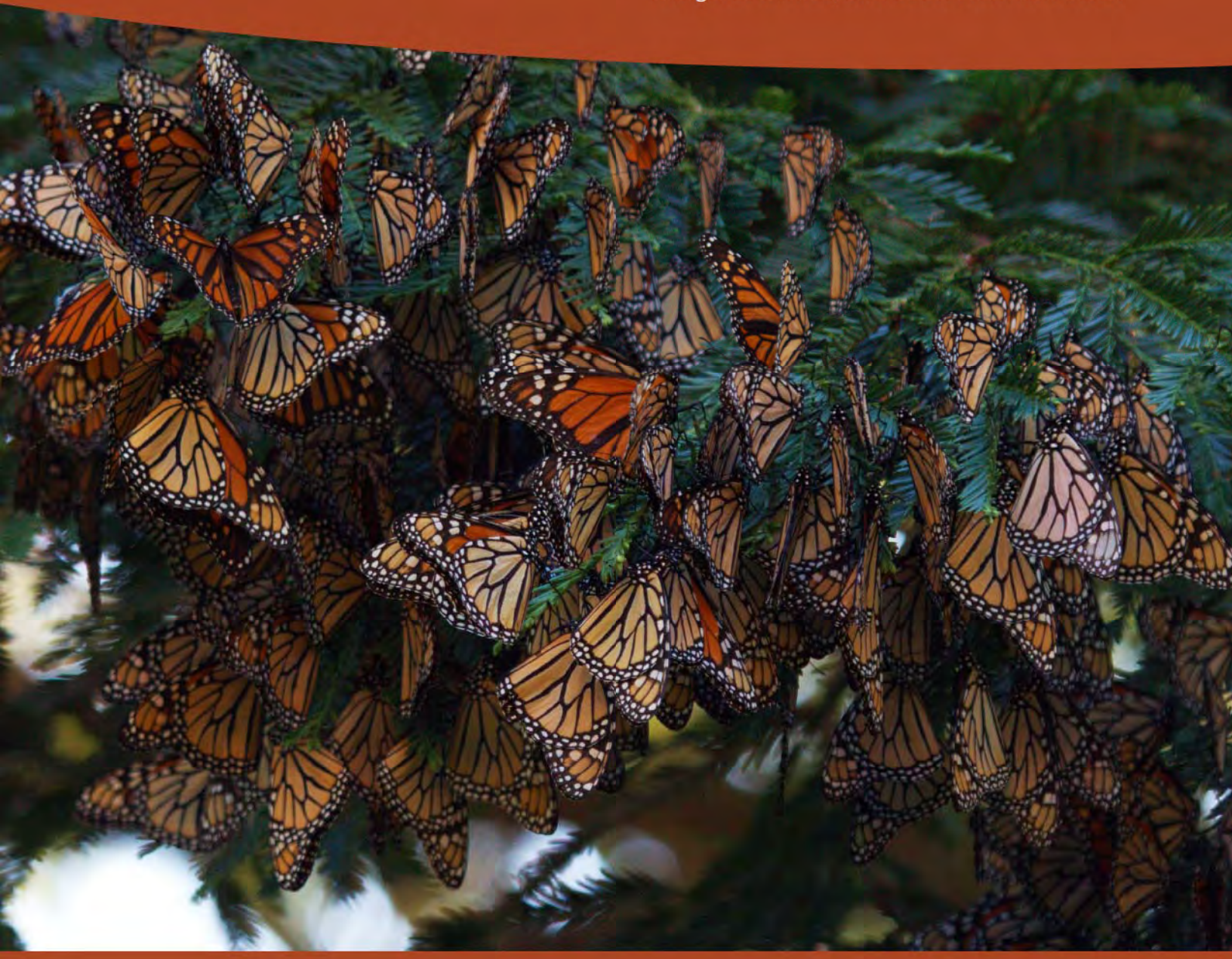

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Prepared for the U.S. Forest Service by:

NatureServe
Arlington, Virginia

and

The Xerces Society for Invertebrate Conservation
Portland, Oregon

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Front Cover Photograph

Overwintering monarchs clustering in a coast redwood tree at a site in California. Photo: Carly Voight/ The Xerces Society.

Contents

Executive Summary

The monarch (*Danaus plexippus*) is one of the best known butterflies in North America. This familiar orange-and-black butterfly occurs in a variety of habitats, including rangelands, farms, riparian areas, deserts, prairies, meadows, open forests, woodlands, cities, gardens, and roadsides, where it searches for milkweed, its host plant. The species is widespread in the conterminous United States, except for the high Rockies, and in southern Canada. Each fall, monarchs that breed east of the Rockies undertake a vast fall migration to forests in the mountains of central Mexico, whereas western monarchs generally undergo a shorter migration to coastal California (though some western monarchs migrate to Mexico).

The monarch population has recently declined to a fraction of its previous size. In the 1990s, estimates of up to one billion monarchs made the epic flight each fall from the northern plains of the U.S. and Canada to sites in the oyamel fir forests northwest of Mexico City, and more than one million monarchs overwintered in forested groves on the California coast. In the winter of 2013–2014, estimates from overwintering sites in Mexico suggest that only about 33 million monarchs overwintered, representing a 90% drop from the 20-year average. As of 2014, the western monarch population had declined by an estimated 50% from the long term average. These declines are so severe that a group of biologists has petitioned the U.S. Fish and Wildlife Service to list the North American monarch as a threatened species under the U.S. Endangered Species Act (Center for Biological Diversity et al. 2014).

Using population abundance, trend, and threat data, we employ the NatureServe conservation status assessment methodology (Master et al. 2012) to determine the level of imperilment for the eastern and western monarch populations, the entire subspecies (*Danaus plexippus plexippus*) that includes these two populations, as well as the global monarch population (*Danaus plexippus*). As a species, the monarch is apparently secure (Table 1). Across the range of the species, populations in many places where it is not strongly migratory or is nonnative remain apparently stable such that the species is not in immediate danger of extinction. However, the subspecies occurring in North America and the two North America populations are threatened. The recent, rapid decline and widespread threats to the eastern monarch population qualify it as critically imperiled. The western population, with a slightly slower rate of decline and less widespread threats is categorized as vulnerable to imperiled. Thus despite the species as a whole being apparently secure, the two major populations at the heart of the range are now threatened with extinction. The subspecies that includes these two populations, *Danaus plexippus plexippus*, is also vulnerable to extinction.

Three factors appear most important to explain the decline of eastern monarchs: loss of milkweed breeding habitat due to increased use of herbicides on genetically modified herbicide-resistant cropland and land conversion, logging at overwintering sites, and climate change and extreme weather. In addition, natural enemies such as diseases, predators, and parasites, as well as insecticides used in agricultural areas may also contribute to the decline.

In this report, we briefly summarize the monarch's North American distribution, life history, population, current conservation status, and potential causes of decline. In addition, we include a set of breeding and overwintering habitat management recommendations. This report aims to inform government agencies charged with biodiversity protection, as well as conservation organizations and the public in general about the threats to and current conservation status of this much-loved, iconic insect.

Monarch butterfly nectaring on butterfly weed.
(Photograph: Bryan E. Reynolds.)

Ecology of the Monarch Butterfly

Distribution

North America forms the core of the monarch's distribution but the overall range extends through Central America and the Caribbean to South America. Monarchs also occur in Hawaii, Australia, and several Pacific islands, as well as parts of Asia, Africa, and southern Europe (Zhan et al. 2014). Several populations outside of the Americas appear to be nonnative, originating from introductions that are thought to have occurred in the 1800s (Vane-Wright 1993), but Zhan et al. (2014) suggests that introductions may have occurred much earlier. Although the precise population size of many island and non-American populations is unknown, native North American monarchs probably represent the vast majority of the total global population. The North American migratory population is genetically distinct from non-migratory monarch populations (Zhan et al. 2014). While small-scale movements and winter roosting have been noted in Australia, only the North American populations are known to be strongly migratory.

Life History

Life Cycle

The monarch, as with all butterflies and moths, undergoes complete metamorphosis comprised of four stages: egg, larva (caterpillar), pupa (chrysalis), and adult. This cycle is completed in approximately 30 days. Eggs are laid on milkweed leaves and after 3–5 days the caterpillar hatches. It will eat milkweed as it grows and molts. Over a period of 10 to 14 days, the caterpillar undergoes five instars, the period of time between each molt, after which it will pupate and spend 9 to 14 days as a chrysalis (pupa). When fully developed, the adult butterfly will emerge from the pupal case, pump fluid from its body into its wings, and fly off to search for nectar, mate, and (if female) lay its own eggs. In the summer, adults live 2–6 weeks. Migrating monarchs live all winter, approximately 6–9 months.

Diet

Monarch larvae feed exclusively on plant species in the subfamily Asclepiadoideae. In North America, 27 different milkweed species in the genus *Asclepias*, as well as a few species in closely related genera, have been recorded as larval food plants (Malcolm and Brower 1986). Milkweeds used by monarchs grow in rangelands, agricultural areas, riparian habitats, wetlands, deserts, prairies, meadows, open forests, woodlands, and roadsides. They are also extensively grown in gardens. In the eastern U.S., the broadly distributed *Asclepias syriaca* (common milkweed) is a commonly used monarch larval food plant, and in the southern U.S., species such as *A. asperula* ssp. *capricornu* (antelope horns), *A. viridis* (green milkweed), and *A. humistrata* (pinewoods milkweed) are important host plants for monarchs.

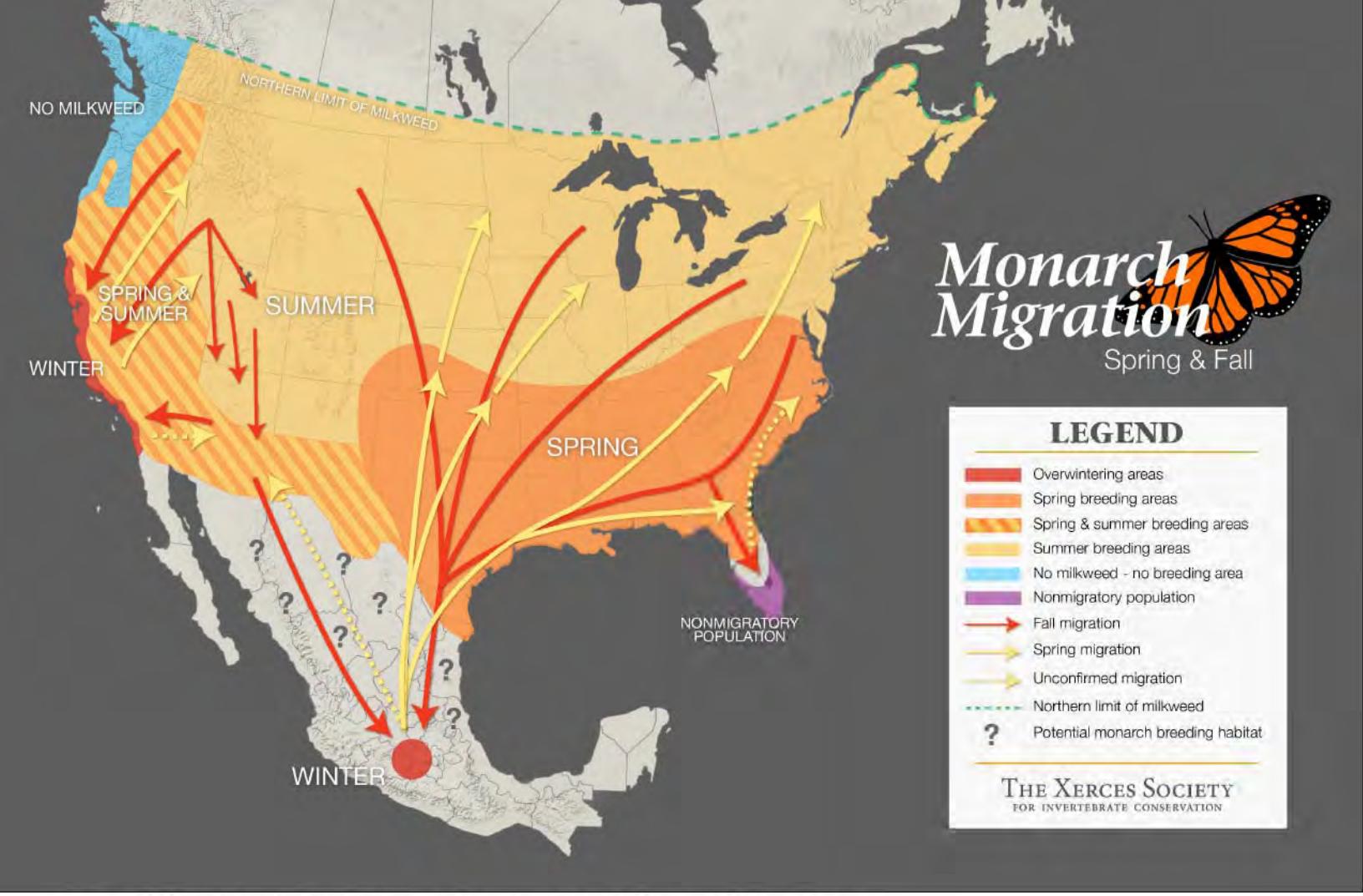


Figure 1. Migration routes, breeding areas, and overwintering areas of monarchs in North America.

In the western U.S., the broadly distributed *A. fascicularis* (narrow-leaved milkweed) and *A. speciosa* (showy milkweed) are two commonly used species. Monarch caterpillars sequester cardenolides (cardiac glycosides) from milkweed, making them toxic to predators as both caterpillars and adults. To fuel their migration, monarchs forage from a wide variety of plant species for nectar, which they convert into lipids (Brower et al. 2006). Monarchs metabolize these lipid reserves as an energy source for winter survival (Tuskes and Brower 1978; Alonso-Mejia et al. 1997).

Breeding and Migration

Eastern North America

The life history of the monarch in North America revolves around its unusual migratory life cycle. In eastern North America, monarchs migrate each autumn to central Mexico where they overwinter as reproductively inactive adults in dense clusters on oyamel fir (*Abies religiosa*) trees in cool, high-elevation forests. Monarchs that survive the winter fly north in spring. When they reach areas with milkweed they mate and lay eggs. Their offspring move further north and successive generations populate virtually

the entire eastern U.S. by June or July. For example, most monarchs reaching the Midwest in April and May developed a few weeks earlier in Texas (Flockhart et al. 2013). Monarchs emerging as adults in late summer in North America east of the Rockies migrate south to Mexico and repeat the cycle. Although many butterflies, moths, and other insects migrate, the monarch migration appears to be unique in the dramatic differences between the sizes of the breeding range (over one million square kilometers [390,000 square miles]) and the wintering area (a few hectares [acres]).

Decades of tagging studies and citizen science efforts have helped to uncover the migratory pathways of the monarch. To date, about 1.1 million monarchs have been tagged in the eastern U.S., and 12,000–14,000 of these have been recovered at the Mexican wintering sites (Brindza et al. 2008). Monarch observations from throughout the breeding range have contributed essential information about the route that monarchs use in their spring and fall migrations (Figure 1). During this migration, monarchs use internal sun and magnetic compasses to guide their flight to their wintering grounds (Perez et al. 1997; Guerra et al. 2014).

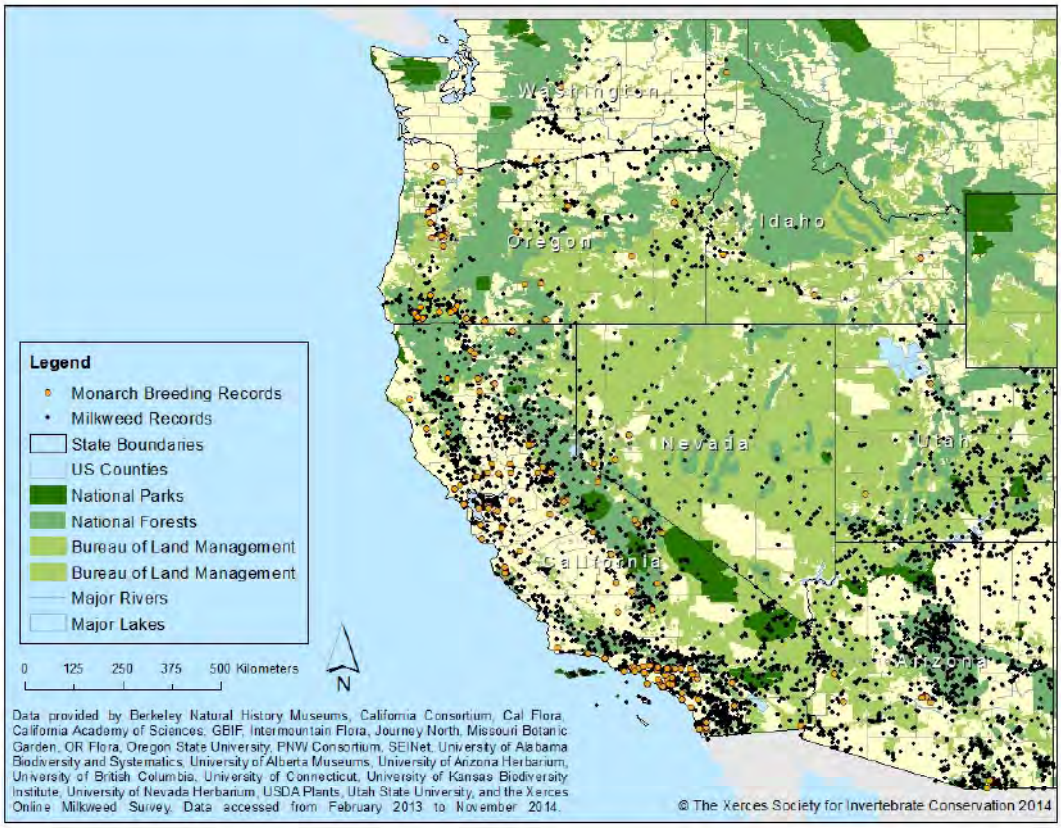
Stable isotope analysis and citizen scientist observations demonstrated that the U.S. Corn Belt is the most important natal area for monarchs (Flockhart et al. 2013). Monarchs migrating south along the Atlantic coast appear to be less likely to reach Mexico than those migrating down the Piedmont or west of the Appalachian Mountains (Brindza et al. 2008). The coastal route may be more hazardous due to over-water crossings at Delaware Bay, Chesapeake Bay, and other major inlets and the likelihood of being blown out to sea. Alternatively, monarchs migrating along the coast may be in a less optimal physical condition (Brindza et al. 2008).

Western North America

Monarchs generally begin to arrive at overwintering sites along the California coast in mid-October (Hill et al. 1976) but may arrive as early as September (Leong 1990). They form dense groups on the branches, leaves, and occasionally, trunks of trees. While a few monarchs will attempt to mate throughout the winter, most overwintering monarchs are in reproductive diapause (Herman 1981) and remain in this state until late-February or March. Each spring, monarchs leave their overwintering habitat and spread out across interior California and several western states, including Nevada, Arizona, Utah, Oregon, and Washington (Dingle et al. 2005). Breeding habitat in California is characterized by the presence of early spring milkweeds (Wenner and Harris 1993). As monarchs breed and disperse, they produce multiple generations during the spring and summer. Monarchs are most abundant in the Great Basin from June to August, and still occur in the Great Basin in September and, to a lesser extent, October (Dingle et al. 2005).

The precise locations that are most important for monarch breeding in the western U.S. are unknown, although a model by Stevens and Frey (2010) identifies probable breeding habitat in most of California, western Nevada, Arizona, and isolated regions of Oregon, Washington, Utah, and Idaho. A compilation of monarch specimen records from various museums and private collections by Dingle et al. (2005) illustrates that numerous monarchs have been collected from California, Nevada, and Oregon, and to a lesser extent from Washington, Arizona, and Utah during the summer breeding season. A database of milkweed and monarch breeding records compiled by the Xerces Society from online herbaria, scientific literature, and a survey of land managers, lepidopterists, monarch enthusiasts, and others reveals numerous monarch breeding observations from California, Oregon and Arizona (Figure 2).

Figure 2. Documented locations of milkweed and breeding monarchs in the western United States. Records for Montana and Wyoming are not shown.



Dingle et al. (2005) suggest that monarchs in the western U.S. primarily occur along rivers, and observational data suggests that autumn migrants follow river corridors (e.g., Pyle 1999).

Monarch populations that overwinter in Mexico have some interchange with those that overwinter in California (Brower and Pyle 2004; Dingle et al. 2005), although the amount of interchange is unknown. Recent recoveries of monarchs that were tagged in Arizona from both Mexico and coastal California provide evidence to support this model (Southwest Monarch Study 2015). Microsatellite genetic analyses have demonstrated that the western and eastern monarch populations are panmictic (Lyons et al. 2012), further supporting the contention that the two populations interchange.

Overwintering

Eastern North America

The eastern North American population overwinters in Mexico at 19 sites in the states of Michoacan and Mexico at elevations between 2,900 and 3,300 meters (9,500 to 10,800 feet). Monarchs arrive between October and December. With reduced metabolic rates in the cold climate, monarchs live off of their lipid reserves and do not feed again until February.

Monarchs fill the air and cluster in the trees of this Mexican over-wintering site. (Photograph: hspauldi, Wikimedia Commons.)

Recent observations indicate that only seven sites are still active, and that 88% of individuals were concentrated in two colonies in the winter of 2013–2014 (Vidal and Rendon-Salinas 2014). These two colonies together occupy less than one hectare (2.5 acres) of forest.

Some East Coast monarchs migrate in the fall to southern Florida, as well as Cuba and other Caribbean islands, where they apparently merge into resident nonmigratory populations (Zhan et al. 2014). Although some individuals reproduce, they die within a month and do not return north.

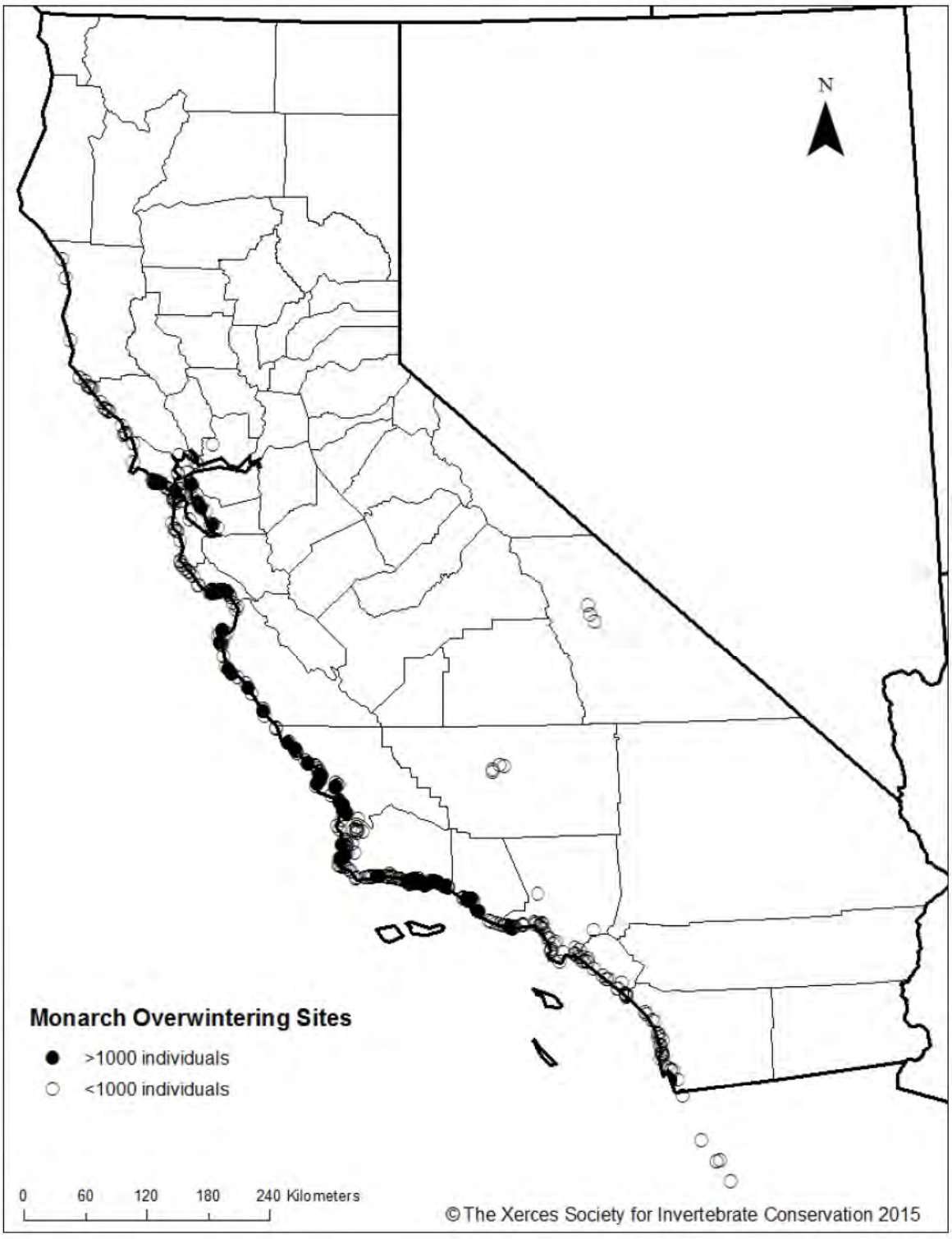
A few North American monarchs stop their fall migration in Texas and the Gulf coast. Virtually all die during winters with one or more exceptionally cold nights, but in less severe winters they produce one or more generations of offspring using introduced tropical milkweeds, while nectaring on garden flowers. Currently, biologists are uncertain whether some individuals remain reproductively inactive, successfully overwinter, and migrate north in the spring, thus contributing to the next generation population in eastern North America, or whether any that emerge on the Gulf coast or Texas in late winter join the spring migration (Howard et al. 2010).

Western North America

In the western U.S., monarchs have historically aggregated in the fall and winter at more than 450 wooded sites scattered along 1,000 km (620 miles) of the Pacific coast from California's Mendocino County to Baja California, Mexico (Figure 3) (Lane 1993; Leong et al. 2004; Jepsen and Black, in press). The monarch's overwintering range has contracted in recent years (Griffiths and Villablanca 2014), and monarchs are rarely found overwintering in the far northern or southern extremes of their overwintering range. Similar to the Mexican overwintering sites, monarchs return to many of the same locations in California year after year. Western monarch overwintering locations include sites that host small or large monarch clusters; are current, historic, or of unknown status; and host monarchs very temporarily (transitory) or throughout much of the fall and winter (climax) (Jepsen and Black, in press). In fall 2013, only 34 sites hosted more than 1,000 monarchs (Xerces Society monarch overwintering sites database). The mild environmental 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 at low elevations (below 60–90 meters [200–300 feet]), within 2.4 km (1.5 miles) of the Pacific Ocean or San Francisco Bay (Leong et al. 2004), where these water bodies moderate temperature fluctuations (Chaplin and Wells 1982), and 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).

At present, most overwintering sites in California are dominated by one of two nonnative species of eucalyptus, blue gum (*Eucalyptus globulus*) and red gum (*E. camaldulensis*). Both were introduced from Australia in 1853 (Butterfield 1935), and are now recognized as invasive species. However, many sites also contain native trees such as Monterey pine (*Pinus radiata*), Monterey cypress (*Cupressus macrocarpa*), western sycamore (*Platanus racemosa*), coast redwood (*Sequoia sempervirens*), coast live oak (*Quercus agrifolia*), and other natives (Jepsen and Black, in press). Recent research demonstrates that monarchs do not prefer eucalyptus trees. In fact, they use native tree species more than might be expected by the low density of native trees relative to eucalyptus in many overwintering groves (Griffiths and Villablanca, in press).

Figure 3. Distribution of current and historic monarch overwintering sites in California. Filled circles represent sites that have hosted more than 1,000 monarchs in the past decade. (From Jepsen and Black, in press.)



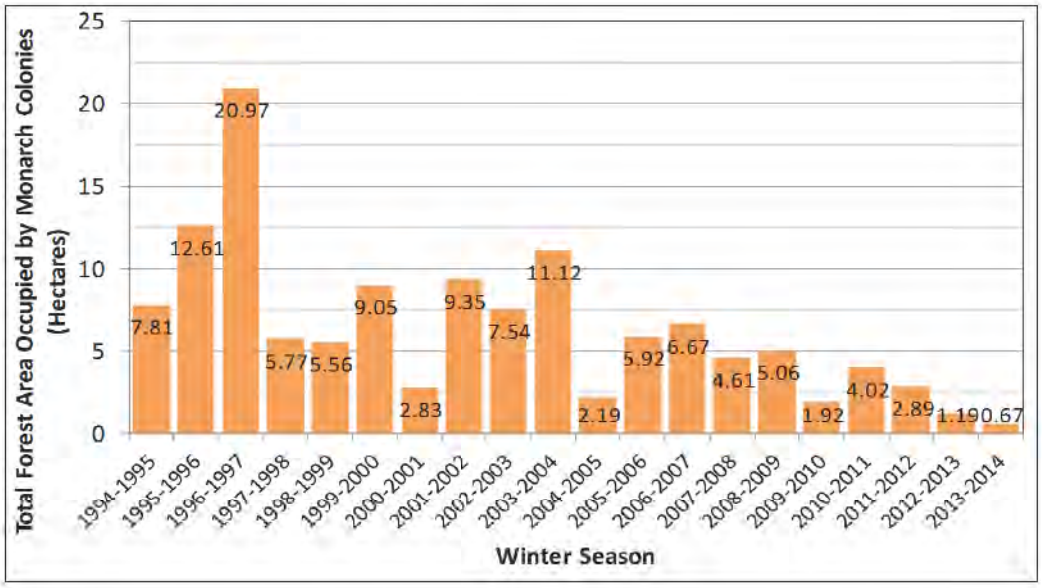
Population

Eastern North America

Due to the difficulties in counting a widespread butterfly, the best available population size estimate for the eastern population is the number of individuals at the overwintering sites. Based on recapture rates, the late summer breeding population is considerably larger than the number reaching the overwintering sites in Mexico, as most individuals fail to reach Mexico and therefore do not contribute to the next generation in the spring (Brindza et al. 2008). The number of monarchs that overwinter in Mexico has been extrapolated from the combined area of overwintering sites (Brower et al. 2012b), assuming that approximately 50 million monarchs occur per hectare (Slayback et al. 2007). Using this estimate, the area covered by the overwintering sites represents an annual average of 463 million monarchs from 1994 to 2003. The highest population estimate was for the winter of 1996–97, with more than one billion individuals spread among twelve sites. In 2011, 2012, and 2013, annual estimates dropped to 144.5 million, 59.5 million and 33.5 million individuals, respectively (data from World Wildlife Fund–Mexico and MBBR in Butler 2014). Data from these wintering site counts show a significant decline from 1994 to 2013 (Vidal and Rendon-Salinas 2014) (Figure 4). The last estimate, in 2013, was exceptionally low at 0.67 hectares (1.65 acres) occupied, which represents a 90% decline from the 1994–2013 average.

In contrast to the overwintering population estimates, a 19-year count of monarchs migrating through Cape May, New Jersey, in the fall showed no directional trend (Walton et al. 2005; Davis 2012). If few Atlantic coast migrants reach Mexico, then the observation of no change in numbers at Cape May supports the argument that the Mexican overwintering decline is primarily due to smaller populations in the Midwest (Pleasants and Oberhauser 2012; Flockhart et al. 2015). In addition, observations of migrants at Peninsula Point, Michigan, near the northern edge of the species' range, are stable (Meitner et al. 2004; Davis 2012).

Figure 4. Area of Mexican overwintering sites occupied by monarchs. (Courtesy Monarch Joint Venture; data from World Wildlife Fund–Mexico and MBBR.)



Eastern monarch populations have been estimated systematically only since 1994. Researchers speculate that monarch populations were likely higher in the two centuries prior to 1994, although historical estimates are unavailable (Vidal and Rendon-Salinas 2014). Numbers might have peaked in the nineteenth century, after European settlement (which created extensive disturbed habitats favored by common milkweeds) but before the near elimination of tall grass prairie. During this period, milkweed was likely common in prairies and agricultural lands, providing an abundant food source for monarch reproduction.

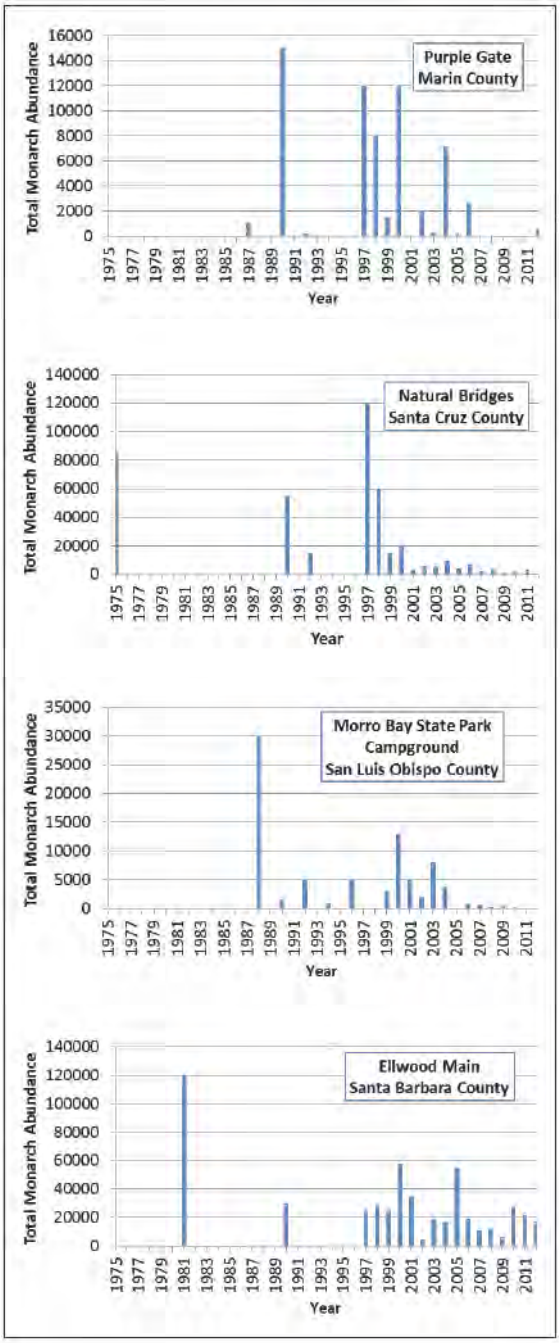
Western North America

In contrast to the millions of monarchs that overwinter in Mexico, less than one million monarchs currently overwinter in California. In the past ten years, only 83 of the 478 recorded monarch overwintering locations in California have hosted more than 1,000 monarchs (Figure 5). In the fall of 2013, only 34 sites hosted more than 1,000 monarchs. Smaller aggregations of monarchs consisting of tens to hundreds of butterflies have been reported from Arizona and southeastern California (Monroe et al. 2015, Jepsen and Black, in press).

Prior to monitoring efforts that began in the 1980s, the historic distribution and size of the western monarch population was largely unknown. There are early accounts of overwintering masses of monarchs from Monterey, California, in 1869 and 1873, and from Santa Cruz in 1888 (Lane 1993; Brower 1995). Estimates of the historical California overwintering population size range from 1 to 10 million (Nagano and Lane 1985; Nagano and Freese 1987). Leong et al. (2004) used data from the California Natural Diversity Database (CNDDB) from 1990 to 2000 to estimate the maximum number of overwintering monarchs for a single season to be more than 2.3 million. Available historical estimates from a few overwintering sites suggest that the monarch population was larger prior to the onset of large-scale yearly monitoring that began in 1997 (Figure 5).

In 1997, there were more than 1.2 million monarchs overwintering in California (or an average of 12,232 monarchs per site), but by 2014 there were only about 234,000 monarchs counted (an average of 1,268 monarchs per site), representing a decline of 81% from the 1997 high and a 48% decline from the 18-year average (Monroe et al. 2015) (Figure 6). An analysis of 17 western monarch overwintering sites that have been monitored every year

Figure 5. Monarch population estimates from November 1 to December 15 at four sites: Purple Gate (Marin County), Natural Bridges (Santa Cruz County), Morro Bay State Park Campground (San Luis Obispo County), and Ellwood Main (Santa Barbara County) (Monroe et al. 2015; Jepsen and Black, in press).



between 1997 and 2013 reveals that there has been a statistically significant population decline of 10.6 percent per year (Griffiths and Villablanca 2014). Figure 7 shows the number of overwintering monarchs counted at 15 sites during the Western Monarch Thanksgiving Count since 1997. Survey data also show that the range has contracted, with significantly more sites declining at the southern and northern extremes than at the center of the monarch's winter range (Griffiths and Villablanca 2014).

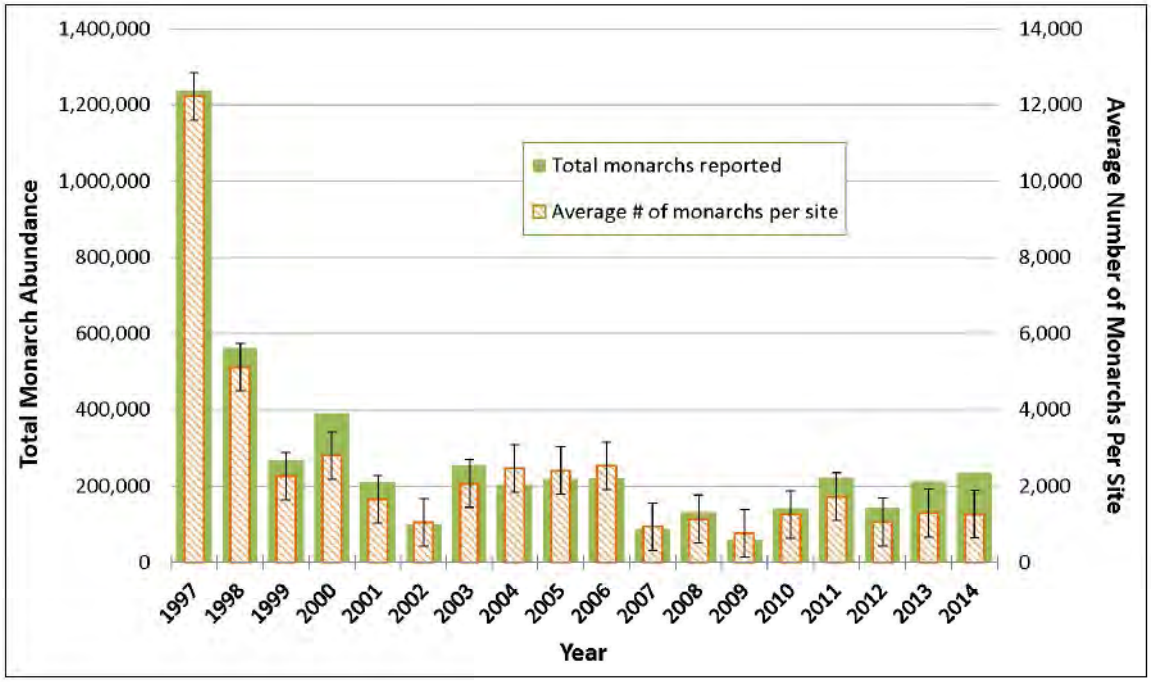


Figure 6. Western Monarch Thanksgiving Count total and average abundance estimates with standard error of the means at 76–185 overwintering sites from 1997–2014 (Monroe et al. 2015).

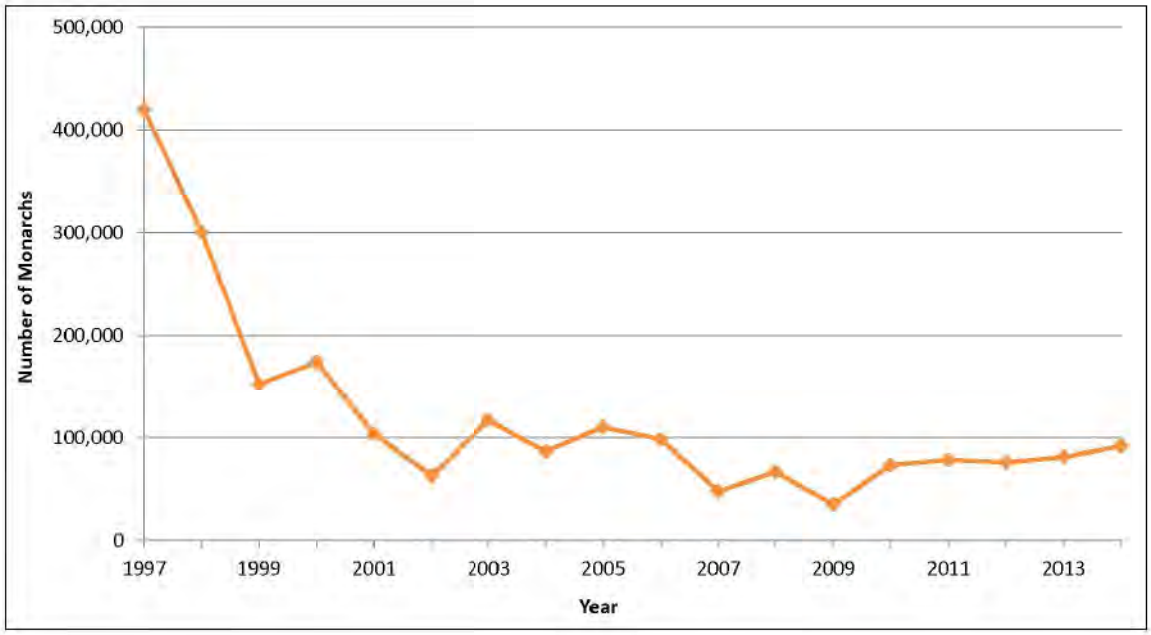


Figure 7. The number of monarchs counted at 15 overwintering sites during the Western Monarch Thanksgiving Count from 1997–2014 (Monroe et al. 2015).

Monarch cluster in a tree at a California overwintering site. (Photograph: Carly Voight/The Xerces Society.)

Conservation Status

To determine the conservation status of the monarch, we assessed the species as a whole, the subspecies that occurs in North America, and the eastern and western populations using the NatureServe conservation status methodology. This approach, which uses ten factors that consider rarity, threats, and population trends, is widely used in North America to assess species, subspecies, varieties, and populations for extinction risk (Master et al. 2012). The system ranks living taxa on a seven-point scale: GX (full species) or TX (subspecies, varieties, or populations) denotes extinct; GH or TH, possibly extinct, e.g., known only from historical records; G1 or T1, critically imperiled; G2 or T2, imperiled; G3 or T3, vulnerable; G4 or T4, apparently secure; G5 or T5, secure. If ranking factor data are imprecisely known, range ranks that span two or mare categories are used. The actual values applied to each ranking factor for monarchs are provided in Table 1.

As a species, the monarch is apparently secure (Table 1). Populations in many places across the range of the species where it is not strongly migratory or nonnative remain apparently stable such that the species is not in immediate danger of extinction. However, the subspecies occurring in North America and the two North America populations are threatened. The recent, rapid decline and widespread threats to the eastern monarch population qualify it as critically imperiled. The western population, with a slightly slower rate of decline and less widespread threats is categorized as vulnerable to imperiled. Thus despite the species as a whole being apparently secure, the two major populations at the heart of the range are now threatened with extinction. The subspecies that includes these two populations, *Danaus plexippus plexippus*, is also vulnerable to extinction.

Potential Causes of Decline

Three factors appear most important to explain the decline of eastern monarchs: loss of milkweed breeding habitat due to increased use of herbicides on genetically modified herbicide-resistant cropland and land conversion, logging at overwintering sites, and climate change and extreme weather (Brower et al. 2012a). In addition, natural enemies such as diseases, predators, and parasites, as well as insecticides used in agricultural areas may also contribute.

The factors that influence monarch population dynamics in the western U.S. are still not completely understood. Increasing drought frequency has been hypothesized to be an important cause of decline (Stevens and Frey 2010). Western monarch populations may also be influenced by the loss of milkweed and changes in the amount and quality of overwintering sites, but the relative contribution of each of these factors has not been studied. Other potential threats to western monarchs include disease, parasitism, predation, and pesticide use.

Table 1. Conservation status factor scoring for the monarch butterfly

Factor Category	Status Factor or Documentation Field (See note below)	*Danaus plexippus* (Monarch)	*Danaus plexippus plexippus* (Monarch)	*Danaus plexippus plexippus* (Western North America: California Overwintering Population)	*Danaus plexippus plexippus* (Eastern North America: Mexican Overwintering Population)
Rarity	Range Extent	>2,500,000 km² (greater than 1,000,000 square miles) (H)	200,000–2,500,000 km² (about 80,000–1,000,000 square miles) (G)	250–5,000 km² (about 100–2,000 square miles) (CD)	250–20,000 km² (about 100–8,000 square miles) (CE)
	Area of Occupancy	(No data)	(No data)	26-500 (4-km² grid cells) (EF)	6-125 (4-km² grid cells) (DE)
	Population	>1,000,000 individuals (H)	>1,000,000 individuals (H)	10,000–1,000,000 individuals (FG)	>1,000,000 individuals (H)
	Number of Occurrences	>300 (E)	81 to >300 (DE)	21–80 (C)	6–20 (B)
	Number of Occurrences or Percent Area with Good Viability/ Ecological Integrity	(No data)	(No data)	Few to some (4–40) (CD)	None to few (0–12) (AC)
	Environmental Specificity	(No data)	(No data)	(No data)	Very narrow. Specialist or community with key requirements scarce. (A)
Trends	Long-term Trend	Decline of 30–70% (DE)	Decline of 70–90% (BC)	Decline of >90% (A)	Decline of >80% (AB)
	Short-term Trend	Decline of 30–70% (DE)	Decline of 70–90% (BC)	Decline of 30–70% (DE)	Decline of >80% (AB)
Threats	Threats	Medium (C)	Medium (C)	Medium–low (CD)	Medium (C)
	Intrinsic Vulnerability	(No data)	(No data)	Moderately vulnerable (B)	Highly vulnerable (A)
N/A	Conservation Status Rank	G4 (Apparently secure)	G4T3 (Vulnerable)	G4T2T3 (Vulnerable to imperiled)	G4T1 (Critically imperiled)
N/A	Status Factor Author	Schweitzer, D. F., Jepsen, S.	Schweitzer, D. F., Jepsen, S.	Schweitzer, D. F., Jepsen, S., Ormes, M., and Sears, N.	Schweitzer, D. F., Jepsen, S., Hatfield R., Black, S., Ormes, M. and Sears, N.
N/A	Conservation Status Rank Date	12/31/2014	1/6/2015	12/31/2014	12/31/2014

NOTE: Ten factors are used to assess conservation status, grouped into three categories, rarity, trends, and threats. Each factor is represented by at least two types of data fields; a coded letter value field (with associated words or short phrases) and a text comment field. The coded values can be expressed as either a single capital letter (e.g., A, B) or as combinations to indicate an estimated range of uncertainty (e.g., AB, DE). In this table the short phrases are followed by the corresponding letter value (in parentheses). See Master et al. (2012) for a detailed description of each factor, including the lists of break points for each status factor field.

In many regions, the abundance and extent of milkweed has been greatly reduced and it has been pushed into the margins. (Photograph: Jennifer Hopwood, The Xerces Society.)

Clean farming technology has led to the elimination of milkweed in crop fields. (Photograph: iStock.com/BanksPhotos.)

Loss of Milkweed

Eastern North America

Milkweed has undergone a massive decline and suffered from substantial habitat reduction in the central U.S. (Commission for Environmental Cooperation 2008; Brower et al. 2012a; Miller et al. 2012; Pleasants and Oberhauser 2012; Flockhart et al. 2013, 2015; Center for Biological Diversity et al. 2014). The loss of milkweed has occurred as a result of two changes in agricultural practices: 1) widespread adoption of genetically modified, herbicide-tolerant corn and soybeans—often referred to as "Roundup-ready" crops—and use of the herbicide glyphosate on these crops; and 2) placing more than 10 million additional hectares (25 million acres) into production of mostly herbicide-tolerant corn since 2007. Pleasants and Oberhauser (2012) found an 81% decline in milkweeds in Midwestern agricultural lands in the past decade, coincident with an increase in the use of the herbicide glyphosate on genetically modified, herbicide-tolerant corn and soy crops. They argue that the loss of milkweeds from agricultural areas is a major contributor to the monarch population decline observed at overwintering sites. Additional threats to milkweed habitat include excessive roadside mowing, development, reforestation (at least in the eastern U.S.), and insecticide use (Oberhauser et al. 2006; Oberhauser et al. 2009) for mosquito control.

Western North America

Little is known about the current or historic abundance of milkweed—nor of the trends—within the range of the western monarch population. Anecdotal reports suggest that roadside maintenance practices may contribute to a loss of milkweed. Milkweed growing within agricultural settings may be subject to extensive herbicide use, as has been documented in the Midwest (Pleasants and Oberhauser 2012). Cotton crops that have been genetically modified to tolerate glyphosate are abundant in some important western monarch breeding areas, such as parts of Arizona and central and southern California, but the

abundance of milkweed in cotton crops prior to the introduction of glysophate-tolerant cotton is not known. Glyphosate is the most commonly used (as measured by cumulative area treated) pesticide in California, where it is applied most extensively to cotton, alfalfa, almonds, and wine grapes (California Department of Pesticide Regulation 2014). The herbicide is also used widely in eastern Washington and northeastern Oregon (USGS 2014), areas where monarchs are known to breed.

Degradation of Overwintering Habitat

Eastern North America

Monarchs require relatively dense and mature canopy cover from conifer forests both to lessen the impact from extreme cold and storms and to maintain a cool temperature to conserve their stored lipids. The Monarch Butterfly Biosphere Reserve (MBBR) in Mexico is comprised of a core area of more than 13,000 hectares (32,000 acres) and a buffer area of more than 42,000 hectares (104,000 acres). Deforestation between 1971 and 1999 was substantial, and small-scale logging continued from 2002 to 2012 (Brower et al. 2012a, Vidal et al. 2014). Illegal logging within the MBBR may be ongoing, and certainly poses a future threat to monarchs (Vidal et al. 2014; L. Brower, pers. comm.). Lastly, the impact of past logging within the core and buffer areas of the MBBR may still be negatively affecting monarchs because of the degradation of the habitat that took place in the past.

Western North America

Pyle and Monroe (2004) suggested that the most vulnerable element of the monarch annual cycle is the overwintering stage. Monarch overwintering habitat in California is directly threatened by urban development, and to a lesser extent by other types of development. Habitat alteration, such as tree trimming or tree removal, and natural factors such as fire, severe storms, or diseases 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).

More than two decades ago, a California statewide report documented the loss or destruction of 38 overwintering sites, 16 of which were lost to housing developments (Sakai and Calvert 1991). During the 1990s, housing developments replaced 11 additional monarch overwintering sites (Meade 1999). Since 2012, one of the authors (SJ) has learned of three additional California overwintering sites that may be replaced by housing developments. The Xerces Society's database of monarch overwintering sites currently lists 62 sites that have been made unsuitable for monarchs, but many of those localities need to be monitored to determine whether monarchs have returned and to evaluate the condition of the habitat.

Many monarch overwintering sites contain aging or diseased trees, such as Monterey pines infected with pitch canker (the fungus *Fusarium circinatum*). Anecdotal reports, such as those from Pacific Grove, suggest that overwintering sites have been lost due to tree cutting or trimming to remove diseased trees or limbs (Sakai and Calvert 1991), or that monarchs have declined after tree trimming, although this latter assertion can be difficult to demonstrate (Villablanca 2010).

Climate Change and Severe Weather

Eastern North America

Climate change in the Mexican overwintering areas is expected to become a serious threat in the next few decades. Although mortality due to extreme cold weather will likely become less common with a warming climate (Flockhart et al. 2015), precipitation associated with winter storms may increase and would therefore increase mortality (Oberhauser and Peterson 2003). Winter storms can have severe impacts on overwintering monarchs. A particularly cold storm in January 2002 killed an estimated 450–500 million individuals.

Projected climate change in central Mexico will make some if not all current winter habitats unsuitable (Oberhauser and Peterson 2003; Saenz-Romero et al. 2012). It will be important that new habitats become available relatively quickly, probably at higher elevations, if current habitats become unsuitable due to climate change. However, forests outside the Monarch Butterfly Biosphere Reserve have mostly been lost and would require decades for regeneration. Current overwintering sites are already at high elevation, and presumably, less habitat will be available if monarchs are forced to move even higher.

A warmer climate in eastern North America could potentially increase the suitability of northern latitudes for breeding in summer, especially if warming also allowed adults to reach these areas earlier than they do now. Increased high temperatures in the southern, especially southwestern, part of the current breeding range could mean that region becomes less suitable. The net impact of shifting the primary breeding region northward, or of simply expanding it if the southern boundary remains unchanged, is difficult to predict although it would certainly lengthen an already long and hazardous migration.

Hotter temperatures in the monarch's summer breeding range could theoretically create physiologically

Neglect and disease of trees within California overwintering sites can result in fallen branches and trees, opening gaps in the canopy that leave butterflies more exposed to winter storms. (Photograph: Carly Voight, The Xerces Society.)

intolerable conditions for monarchs (Batalden et al. 2007). Monarch caterpillars in most of the current range already experience stressful temperatures of greater than 29°C (84°F). Climate change will increase exposure to such temperatures, but the extent to which the higher temperatures pose a mortality risk is unknown. While continuous exposure to 36°C (99°F) is lethal, York and Oberhauser (2002) found very little difference in survival or body mass for larvae reared for six or twelve hours daily at 36°C alternating with 27°C (81°F), compared to controls at 27°C. These experimental conditions are hotter than currently experienced in the summer breeding range, suggesting that the hotter temperatures brought on by climate change may not be a limiting factor.

Unresolved questions about how climate change may influence monarchs in the breeding range include:

- Whether the frequency and extent of lethally high temperatures will increase.
- The extent of increase in summer die back of milkweeds in parts of the breeding range where suitable foliage now remains available all summer.
- The importance of microhabitat refugia (such as ditches and wetlands) where milkweeds do not die back.
- How rapidly milkweeds can spread northward, mostly in Canada, as the climate warms.

Western North America

Increasing drought conditions associated with ongoing climate change may be the most likely cause of decreases in monarch population size reflected in the 1998–2007 Western Monarch Thanksgiving Count data (Stevens and Frey 2010). The severity of the drought in key monarch breeding states (California, Arizona, Nevada, and Oregon) explained the variation in monarch abundance during that time period. This correlation may be explained by a multi-year drought reducing the diversity of milkweed and monarch nectar sources at a landscape scale (Stevens and Frey 2010). Future climate scenarios predict that drought severity in arid and semi-arid mid-latitude areas of temperate western North America will increase, suggesting that the population decline is likely to continue (Stevens and Frey 2010 and references therein).

Pathogens and Parasites

The best-known monarch parasite is the native protozoan *Ophryocistis elektroscirrha* (OE). Adults that are heavily infected with this parasite are less fecund, less mobile, more sensitive to desiccation, shorter-lived, and less fit for long migration than uninfected adults (Altizer and Oberhauser 1999; Altizer 2001). Exceptionally heavy infection is lethal at or before adult eclosion. The OE–monarch interaction has become a well-studied host–parasite system (e.g., Sternberg et al. 2013; Hall et al. 2014). The rate of heavy infestation has remained relatively steady at about 8% in eastern monarchs from the late 1960s into the late 1990s, but is higher in western and non-migratory Florida populations (Altizer et al. 2014b). A parasitic infection may explain an observed decline in the proportion of females in the population, which in turn may contribute to the overall population decline (Davis and Rendon-Salinas 2010).

Pesticides

As described above, increased use of the herbicide glyphosate and its detrimental effect on milkweed is almost certainly playing a significant role in the monarch population decline. This impact is magnified as huge amounts of habitat have been—and continue to be—converted to glyphosate-impacted croplands.

Many insecticides used in agriculture and residential yards and gardens are lethal to monarchs. Specifically, use of pesticides containing neonicotinoids has increased substantially. The increased use and spread of these potent, in some cases persistent, biocides within the monarch's breeding habitat likely impacts monarchs (Center for Biological Diversity et al. 2014; Pisa et al. 2015). Numerous studies and reviews have found neonicotinoid contamination in soil (Sanchez-Bayo 2014; Pisa et al. 2015) and water (Hladik et al. 2014) to be widespread, and not limited to the immediate vicinity of croplands. The chemicals are taken up by plants and can become incorporated into plant tissues including pollen and nectar. Milkweeds growing in contaminated soils may contain neonicotinoids, which may occur in sublethal or lethal concentrations for monarch caterpillars that eat them (Center for Biological Diversity et al. 2014). However, the impact of neonicotinoids on monarchs is not known.

Habitat restoration on a massive scale, particularly of areas rich in milkweed and other native flowers, is needed to provide monarchs with breeding grounds, as well as support them as they migrate in search of overwintering sites. (Photograph: Jennifer Hopwood, The Xerces Society.)

Conservation and Management

The North American Monarch Conservation Plan (Commission for Environmental Cooperation 2008) provides a framework for monarch breeding and overwintering habitat management and restoration. This plan guides many current monarch conservation efforts, including those of the Monarch Joint Venture, a consortium of public and private entities that are working to protect the monarch migration across the lower 48 United States.

Breeding Habitat Management and Restoration

Restoring milkweed breeding habitat is the most important monarch conservation and management need, although a Herculean effort will be required to recover monarchs to anything close to pre-2004 levels (Commission for Environmental Cooperation 2008; Butler 2014). The core of any such effort would be planting tens of millions of milkweeds in places suitable for monarchs, especially in the key breeding areas of the Midwest and Central United States. Milkweed planting efforts are underway but have not yet reached the scale that is needed to recover the monarch migration.

In the eastern U.S., the most important areas to preserve and restore include the spring breeding range in Texas, Oklahoma, Missouri, and Arkansas, and summer breeding areas in the Midwest (Illinois, Indiana, Iowa, Minnesota, Michigan, Wisconsin, and Ohio). In the western U.S., key breeding areas include California, Nevada, and Arizona, as well as parts of Utah, Oregon, Washington, and Idaho.

Federal agencies are currently collaborating with monarch scientists to develop plans for monarch habitat recovery. For example, the U.S. Geological Survey is developing a model to determine how much breeding habitat will be needed to support a monarch population that can withstand poor weather conditions and predation at overwintering sites. Preliminary estimates suggest that between 600,000 and 3.24 million hectares (1.5–8 million acres) of additional habitat will need to be restored.

In addition to milkweed, monarch butterflies also require nectar plants that are in bloom during the times when they are present. Nectar plants that are attractive to monarchs and available during the fall migration to overwintering sites may be especially important, and large-scale plantings of such plant material should be included in monarch conservation planning.

Native species of milkweed and monarch nectar plants that are produced from locally or regionally sourced seeds should be used in restoration efforts. However, in many cases, locally appropriate milkweed seed sources are not yet commercially available and require development (Borders and Lee-Mäder 2014). The use of tropical milkweed is not recommended due to concerns about the potential spread of the OE disease (see MJV 2014, and discussion below).

Restoration plans should also consider surrounding land use. Planting milkweed or nectar plants in soils that are contaminated with neonicotinoids could render nectar and foliage toxic to adults and larvae, respectively. In addition, nursery stock purchased for restoration projects may contain these biocides (Friends of the Earth 2014). However, the presence of neonicotinoids in milkweeds growing near agricultural areas has not been documented and the impact of these compounds on monarchs remains to be investigated.

Protection of existing monarch breeding habitat is another essential component of recovering the monarch population. To begin this process, important breeding locations need to be identified and current management practices that affect these areas should be evaluated. In prioritizing these areas, one should consider where conservation opportunities exist.

Public lands that may already provide habitat for breeding or migrating monarchs include national wildlife refuges and national parks, as well as other federal lands managed by the Forest Service, Bureau of Land Management, Department of Defense, and the Federal Highway Administration. There are also opportunities at the state and county levels through land owned or managed by parks, transportation, and natural resources agencies. Managers of these lands should consider incorporating monarch conservation into existing management practices.

On private lands, opportunities exist for restoring monarch habitat through Farm Bill programs, including the Environmental Quality Incentive Program, Conservation Stewardship Program, Conservation Reserve Program, Wetlands Reserve Program, and others. The Conservation Reserve Program can incentivize milkweed restoration on private agricultural lands, and the Conservation Stewardship Program can incentivize the protection of milkweed resources on private ranchlands. In addition to these federal habitat-restoration programs, many public education campaigns exist that promote voluntary monarch habitat enhancement among private landowners.

Overwintering Site Management

Mexico

After the overwintering areas in Mexico were discovered in 1976, protecting these forests from logging was considered the top conservation need. The small size of the scattered overwintering roosts made them vulnerable to logging or other disturbances. While logging has been substantially reduced in recent years within the core area of the Monarch Butterfly Biosphere Reserve (Vidal and Rendon-Salinas, 2014), it remains a conservation concern (L. Brower, pers. comm.).

The spectacle of tens of millions of monarchs packed into a few hectares of trees has since spawned substantial local winter ecotourism and national and local efforts to protect the sites. Vidal and Rendon-Salinas (2014) report from direct observation that poorly managed tourism has some level of negative impact by disturbing the roosting adults, causing them to waste energy by flying to another tree. This practice could be easily remedied, for example by educating guides to lead less interruptive tours.

California

Overwintering monarchs have very specific microclimatic habitat requirements, such as protection from wind and storms, absence of freezing temperatures, exposure to dappled sunlight, and presence of high humidity (Chaplin and Wells 1982; Masters et al. 1988; Leong 1999). Active management of monarch overwintering sites is an important component of monarch conservation in the western U.S. Historically, the composition of vegetation on the California coast differed from the contemporary composition, and groves of native trees presumably hosted dense monarch aggregations in the past (Lane 1984, 1993). Recent studies suggest that monarchs do not prefer *Eucalyptus* trees. They use native tree

species more than might be expected, given the low density of native trees relative to *Eucalyptus* in many overwintering groves (Griffiths and Villablanca, in press). However, restoration of overwintering sites with native tree species can take decades because many of California's native conifers are relatively slow-growing. Eucalyptus trees should therefore be removed in phases while native trees are planted to ensure that mature trees are continually present (Lane 1993).

Managers of overwintering sites should use the following steps to develop a monarch habitat management plan for their particular site:

- Become familiar with monarch overwintering habitat requirements and characteristics.
- Define the monarch habitat boundary.
- Conduct a monarch habitat assessment.
- Develop a monitoring plan.
- Develop a management plan that includes the principles of adaptive management.

Management considerations include using appropriate methods when removing or trimming hazard trees, creating areas with dappled sunlight at an overwintering site, developing a long-term tree planting strategy, and planting fall- and winter-blooming nectar plants.

Disease Concerns

Release of Captive-Reared Monarchs

Concerns that the release of commercially reared monarch butterflies may spread disease, introduce unhelpful genetic traits to wild monarchs, or interrupt scientist's ability to understand monarch biogeography have been voiced by numerous authors (Pyle 2010; Pyle et al. 2010; Boppré and Vane-Wright 2012; Altizer et al. 2014a). It is not possible to evaluate the impact of commercial monarch releases on wild monarchs without understanding the scale of the commercial monarch breeding industry. The number of commercially raised monarchs that are released into the environment each year is unknown, although a recent survey of most of the butterfly breeders suggests that no more than 250,000 monarch adults are sold for the purpose of releases in the U.S. annually (T. Villareal, pers. comm.). However, an unknown number of commercially raised monarchs in other life stages (eggs, larvae, or pupae) are sold, and once they reach adulthood, an unknown proportion of those animals are released into the environment. Once the scale of commercial rearing is understood, government agencies can assess the need for regulation to prevent undesired outcomes of these releases.

Photograph: cincooldesigns/Wikimedia Commons

Tropical Milkweed and Unnatural Overwintering

The widespread planting and establishment of the nonnative tropical milkweed (*Asclepias curassavica*) may promote increased OE infection in wild, migratory monarchs. Whereas most native milkweed species die back in the winter, tropical milkweed does not. The winter persistence of tropical milkweed along the Gulf Coast and perhaps southern California allows monarchs to breed throughout the winter. Winter breeding adults on the Gulf Coast are infected with much higher levels of OE than migrants, leading to the possibility that the disease could spread to migratory monarchs (Altizer et al. 2014a). The Monarch Joint Venture recommends against planting tropical milkweed beyond latitude 28° north, the level of Orlando, Florida (Altizer et al. 2014a). If managers wish to maintain patches of tropical milkweed but avoid encouraging unnatural winter breeding and/or eliminate most OE spores, tropical milkweeds can be cut back to the ground before winter, which makes them unavailable for breeding monarchs until they re-sprout in the spring.

Citizen-Science Monitoring Programs

A variety of programs engage citizen scientists in monitoring monarchs during their migratory, breeding, and overwintering seasons (Oberhauser et al., in press). Monarch-focused citizen science programs include Correo Real, Journey North, Monarch Alert, Monarch Health, the Monarch Larval Monitoring Project, the Monarch Monitoring Project, Monarch Watch, the Southwest Monarch Study, the Western Monarch Thanksgiving Count, and World Wildlife Fund–Mexico's surveys of the Monarch Butterfly Biosphere Reserve. In addition, other butterfly programs gathering data on a broad variety of species allow individuals to contribute data on monarchs, including the North American Butterfly Association's Fourth of July count, statewide butterfly monitoring networks, and online projects such as eButterfly and Butterflies and Moths of North America. Despite the diversity of existing programs, efforts are still needed to monitor the monarch migration in key regions, such as areas of Kansas, Missouri, Arkansas, and Oklahoma directly south of the monarch's core breeding area and in Texas (Davis 2012).

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