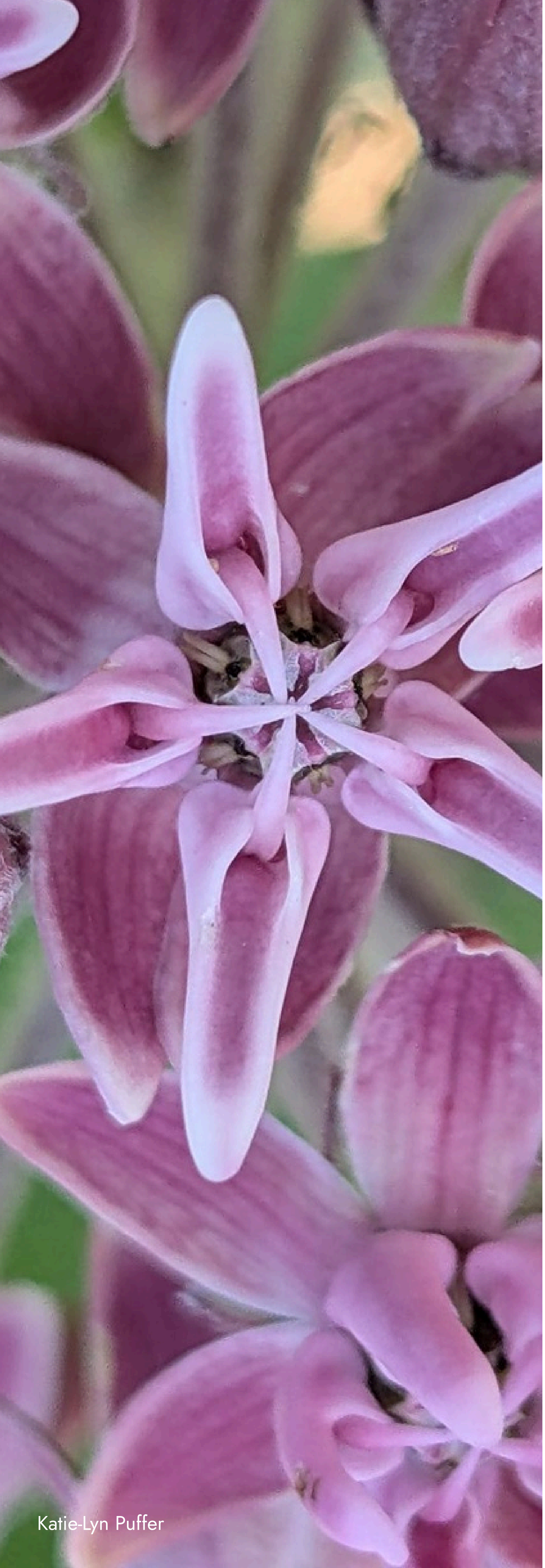
2025 MONARCH RESEARCH REVIEW

Prepared by

Monarch Joint Venture

www.monarchjointventure.org



The Monarch Joint Venture's Mission

is to protect monarchs and their migration by collaborating with partners to deliver habitat conservation, education, and science across the monarch range.

Contents

EXECUTIVE SUMMARY

In 2025, 85 studies and reports added to our collective knowledge of monarch ecology, conservation, and management. From explorations of brain neurons to international collaborations, these works demonstrate the value that the monarch butterfly provides to our understanding of the natural and societal world. Simultaneously, this work also emphasizes the value that the conservation community offers to the North American monarch population itself. For the third year in a row, the eastern monarch population has grown (2.93 ha), yet this is still less than half of the target for this population. Similarly, the western monarch's overwintering population rose to 12,260 individuals, far short of the 500,000 target. These increases, and the research herein, demonstrate the potential for the monarch's recovery under favorable conditions.

At a high level, favorable conditions for monarchs necessitate support across the full annual cycle. On the breeding grounds, this year's studies show that monarchs benefit from a diversity of milkweed species not just across geographies, but throughout the season as their oviposition preferences and larval survival shift. We learn that the U.S. Department of Agriculture's Conservation Reserve Program prairie strips abound with wildflowers relative to some other land use types, and milkweed embedded in a diverse wildflower matrix like this can be preferred by ovipositing monarchs. Once again, research supports the importance of fall nectar resources for migrating monarchs. On the eastern overwintering grounds, favorable conditions, i.e., intact oyamel forests, are most successfully achieved when the local communities are not only considered but directly engaged.

Diving deeper into the spatial context, this year's research stresses the importance of strategically targeting monarch conservation across regions and scales. Breeding areas in the far north of the eastern breeding range contributed 30-55% of the Mexican overwintering population in 2019-2021, a much higher proportion than previously estimated. Near the eastern seaboard, roosts closer to the coasts are at greater risk of loss than those inland, and very few roots occur on protected lands regardless of proximity to the coast. Urban gardens can be especially attractive to monarchs when they are well-maintained, even if they are smaller than other habitat patches in the landscape. In the West, monarch larvae are more common in shaded areas during the summer, and high temperatures make them more likely to "drop" off the milkweed in response to stressors such as predators.

At even finer scales, plant traits, microclimates, and management practices may impact monarch behavior and survival. We learned that eastern overwintering monarchs must be exposed to cold temperatures for several weeks in order to reverse their flight orientation back north—and thus, a warming climate may negatively affect monarchs' navigational abilities. However, if migration is lost from a population, the chromosomes responsible for it persist in the population and could be re-expressed under the right conditions. Host plant species and time of year interact to create shifting windows of opportunity for monarch success: monarch larvae survival can be higher on narrowleaf milkweed (*Asclepias fascicularis*) than showy milkweed (*A. speciosa*) in the West, but only during certain times of the year.

Finally, this year's research situates monarch conservation within broader ecological and social contexts. Butterfly populations across the United States have declined by 22% over the past two decades, reflecting widespread pressures from habitat loss, pesticides, and climate change. Although the monarch's breeding population did not decline quite as dramatically as other species in that study, the research in this year's review demonstrates that monarchs face similar pressures as other declining butterflies. Yet, alongside these challenges are clear signals of progress and opportunity. Public willingness to support conservation remains strong, particularly when efforts are tangible, accessible, and, as one study demonstrates, when there is an "attractive" species ambassador like the monarch. So add a beautiful native plant or sign to your yard, gift a friend or community leader a native plant plug (rather than a seed; read on to find out why!), and learn even more about creating favorable conditions not just for monarchs, but for the community of conservation around this species.

PURPOSE & METHODS

The Monarch Joint Venture (MJV) organized this annual research review to keep its partner organizations, network, and monarch enthusiasts abreast of the latest monarch conservation research. MJV staff, partners, and other contributors summarized 85 individual papers, and MJV staff compiled and condensed key takeaways. The set of papers summarized in this review include peer-reviewed research (primary research, review papers, and opinion/commentaries) and 4 technical reports. We selected articles that were published from January to December 2025 that were searchable by the terms "*Danaus plexippus*," "*Asclepias*," "monarch butterfly," "milkweed," and "pollinator conservation." Papers were limited to those directly related or highly relevant to monarch and milkweed research and conservation advancements. We did not include papers that studied milkweed as an invasive species outside the North American monarch range. We also included papers with 2026 citations that were made available in 2025. Our representation and summarization of the research by staff and partner reviewers is not intended to evaluate the integrity of the science or endorse the findings.

NAVIGATING THE REVIEW

The review is organized into four sections that include several topical subsections: **I)** Advances in Partnership, Engagement, and Technology, **II)** Monarch Ecology, **III)** Habitat, and **IV)** Threats & Stressors. Within each subsection is a high-level overview of the research findings followed by a short summary of each paper. Paper citations and links to their abstracts (and full text, if open access) are provided at the end of the review. **Papers that used data from community science projects are denoted with a magnifying glass 🔎 icon.**

REVIEWERS

Reviewers include the following MJV contributors and staff: Claire Beck, Alex Carroll, Ryan Drum, Sarah Gomes Swanson, Rebeca Gutierrez-Moreno, Mykayla Hagaman, John Harkness, James Hart, Alexa Koch, Cory Kragness, Becca Krasky, Laura Lukens, Kailey Meacham, Natalie Melkonoff, Elisha Mueller, Karen Oberhauser, Clarissa Ortega, Luis Osorio, Mandy Pearson, Kim Pegram, Danielle Rutkowski, Jennifer Thieme, Jenna Totz, Angelarose Vaccaro, Katie Van Dame, Josiah Velner, and Lucas Zilverberg. Thank you to the many volunteers who helped make this possible!

RESEARCH REVIEW

I. Advances in Partnership, Engagement, and Technology

a. Policy, Collaboration, & Education

Public support and engagement are crucial to conserving monarch butterflies. Members of the public are more willing to protect species that they find attractive and more likely to plant free milkweed plants than free wildflower seed packets. For outreach events, seed paper is proposed as a more effective alternative to seed balls. A trinational analysis indicates that urgent collaborative action across Canada, the United States, and Mexico is key to preserving monarch butterfly populations, and restoring milkweed habitat in the central U.S. is the most cost-effective action.

Prokop et al. (2025) assessed willingness of the public to protect plants and pollinators, including monarchs, based on their perceived attractiveness. Volunteers in Slovakia responded to an online questionnaire about their preferences for different living organisms. Participants were shown images of plants alone, pollinators alone, and plant and pollinators together and asked to rate each organism's attractiveness and whether it should be protected by law. Participants had higher willingness to protect plants when they were presented alongside their associated pollinators, and on average they were more willing to protect organisms that they found more attractive. Monarchs were one of the species that received high attractiveness ratings with respondents more willing to protect their associated plant species.

Through their work at the Oklahoma City Zoo and Botanical Garden, **Geest and Snyder (2026)** tracked the outcome of milkweed plant and wildflower seed packet giveaways by emailing visitors who received free plant materials. They studied whether people who received free milkweed plants, wildflower seed packets, and/or grow bags actually used them. They also assessed participants' knowledge of monarch biology and ability to identify monarch butterflies and caterpillars. They found that while milkweed plants were much more expensive than seed packets, recipients of milkweed plants were significantly more likely to actually plant their milkweed than recipients of wildflower seed packets. 96% of people who responded to the survey and received milkweed plants planted their milkweed compared to 46% of respondents who received wildflower seed packets.

Seed balls are a popular public outreach activity to engage the public in monarch conservation. **Donahey and Fisher (2025)** compared three seeding methods: seed balls, seed paper, and bare seed to determine if seed balls are an effective method for growing milkweed. They embedded common milkweed (*Asclepias syriaca*) or butterfly milkweed (*A. tuberosa*) seeds in a mixture of clay and compost, and they tested both stratified and unstratified seed. The bare seed and seed paper had higher milkweed germination rates

(90-94%) than the seed balls (32%) for both milkweed species. The authors noted that the balls of clay were still intact after 30 days whereas the seed paper degraded, and they recommend seed paper as a more effective outreach tool.

Flockhart et al. (2025) developed a dynamic full-annual-cycle matrix population model to identify optimal conservation strategies (investment allocations) for the eastern monarch population. Their analysis, based on a 5-year, $150 million budget scenario, suggests that immediate, coordinated conservation actions across Canada, the US, and Mexico will significantly outperform uncoordinated or single-nation efforts in achieving three key objectives: maximizing population viability, reaching the target overwintering population size (6 ha in Mexico), and maximizing overall population size. They recommend restoration of milkweed habitat in the central US as the most cost-effective and impactful action, particularly in the early years of implementation. Their results underscore the urgency of initiating collaborative, strategically timed habitat restoration, especially in breeding regions, to reverse population declines and avoid extinction risks.

b. Research Methods & Technology

Recent research provides new tools to monitor monarchs and their habitat. Drone surveys may be an effective method for mapping milkweed, and a new migration model can help predict monarch migration patterns and navigational strategies.

To advance plant monitoring methods, **Bakacsy and Zakar (2025)** tested the ability of drone imagery to map invasive common milkweed (*Asclepias syriaca*) across a site in the sand grasslands of Hungary. They compared aerial survey results with ground-based surveys and found that, although ground surveys detected slightly more milkweed shoots, shoot counts were highly correlated between the two methods. These results demonstrate that drone imagery can effectively assess milkweed distribution in areas where the species is morphologically distinct from surrounding vegetation. Similarly, **Pringle et al. (2025)** used drones and vehicle-mounted cameras combined with machine learning models to map milkweed along roadsides in Nevada. They found that drones detected narrowleaf milkweed (*A. fascicularis*) and showy milkweed (*A. speciosa*) with 90% accuracy, and vehicle-mounted cameras detected the milkweed with 86-93% accuracy. These new technologies could drastically reduce field labor while maintaining mapping accuracy and be used by departments of transportation to inform roadside management and fulfill monitoring requirements for the Monarch Candidate Conservation Agreement with Assurances (CCAA).

🔎 Modeling the paths of migratory species is difficult, especially for monarch butterflies. **Kendzel et al. (2025)** developed a new model that could be used to predict the distribution of migratory species and incorporate available data on the species. They then tested several model variations on the western monarch population and compared model results to real monarch sighting data from the community science program iNaturalist. The real-life monarch observations had a similar distribution to the vector navigation model, which assumes that butterflies continue in a constant direction throughout their migration. The best monarch models also included elevation as a predictor of migration routes; mountains are considered barriers to insect migration.

II. Monarch Ecology

a. Monarch Physiology

Research on monarch physiology continues to improve our understanding of monarch navigational systems, foraging behaviors, and toxin sequestration. Changing environments may pose a threat to monarch navigation since temperature is key to flight orientation during spring migration. Research identified genes associated with circadian rhythms, neurons associated with motion and color detection, and a brain region that may be unique to monarchs. Metabolic processes improve longevity in overwintering monarchs compared to short-lived summer individuals, and monarchs sequester toxins within minutes of milkweed consumption. These studies highlight the importance of ongoing research to better understand and protect monarch butterflies.

Lepidoptera exhibit many spatial orientation behaviors to forage, migrate, find mates—basically to do everything they need to survive. **Grob et al. (2025)** reviewed the wide variety of neural mechanisms and environmental cues used by lepidopterans, including monarchs, as they move through the world. They also reviewed the threats to orientation ability posed by environmental stressors like habitat loss, pesticide use, climate change, light pollution, and electromagnetic noise. The environments that lepidopterans have adapted to over millions of years are changing, and the authors argue that resulting declines in orientation success are likely to interfere with their dispersal, mating, host-plant selection, and migration behavior. Individuals may become disoriented and lose time and energy needed for foraging, reproduction, and survival. They encourage both monitoring and experimental studies to document how orientation failures scale up to affect lepidopteran populations, and thus their roles as pollinators and key players in trophic networks.

For navigation during migration, monarchs mainly use a sun compass. However, on overcast days, they rely on the earth's magnetic field for navigation. In addition to indicating direction, the earth's geomagnetic field may act like a map and give geographic clues about location. **Shively-Moore et al. (2025)** simulated the magnetic field at monarch overwintering sites in Mexico and locations farther north and south. When monarchs experienced magnetic fields similar to sites past their overwintering grounds, they did not change their flight direction. This indicates that they use the magnetic field only to determine their flight direction. However, when exposed to cold temperatures for 24 days, the monarchs reversed direction and oriented north, which suggests that temperature helps monarchs orient for spring migration. The authors noted that a warming climate could negatively affect monarch navigational abilities.

Two studies explored timekeeping in monarchs and other lepidopterans. **Gkanias and Webb (2025)** tested two models by which insects might utilize a time-compensated signal to navigate. They proposed a basic model, which uses time of day, and a complete model, which additionally uses time of year and geomagnetic inclination. Their results demonstrate the basic model is often sufficient to demonstrate behavior of foraging and migrating insects, although the complete model is more adaptable to a wider variety of locations. **Li et al. (2025)** identified conserved genes in monarchs and a nocturnal lepidopteran species that regulate circadian rhythm, and they point to different metabolic patterns that may help explain differences in diurnal and nocturnal lepidopterans.

While many researchers have studied delayed reproductive maturity (i.e., reproductive diapause) monarchs, few have studied how post-diapause individuals, which remigrate north in the spring, are different from individuals that have never been in diapause, such as summer breeding individuals. Diapause is environmentally induced and enables insects to withstand adverse environmental conditions. **Stratton and Green (2025)** reared monarchs under different conditions, either autumn light and temperature conditions (diapause inducing) or summer conditions (non-diapause development). Post-diapause individuals, the ones reared under fall conditions, retained diapause maintenance processes, like altered protein production, mitochondrial metabolism, and lipid regulation. They also showed enhanced stress response and other mechanisms that promote longevity. The authors concluded that diapause history probably impacts monarch re-migration ability.

Two studies looked closely at monarch brains. **Supple et al. (2026)** studied brain response to color and motion by comparing monarchs to the blue-wave butterfly (*Myscelia cyaniris*). They presented moving patterns to the butterflies and studied their brain response to different colors and patterns. They found that wide-field descending neurons, which focus on a large area, were tuned to a wide spectrum of colors. In contrast, target selective descending neurons, which are used for tracking small objects, were tuned to a narrow color range: blue in the blue-wave butterfly and red in monarchs. They hypothesized that this part of the brain is used to track individuals of the same species, perhaps for mating or territorial displays. **Adden et al. (2025)** compared brain size and structure across 15 Lepidoptera species to better understand if behavioral traits, such as migratory behavior, were linked to brain structure. They created 3D brain reconstructions and found three brain areas that were larger in migratory species than non-migratory ones. They also noted that monarch butterflies have a unique brain region, the optic glomerular complex, a specialized visual-processing center that could aid in navigation.

Assadia and Green (2025) examined the attraction of monarch butterflies to the *Lantana camara* flower. They found that the evolved attraction is innately visual and not a learned behavior. Monarch attractions were guided by visual cues at short range, but olfactory cues drew a sustained attraction that grew stronger over time.

Many people know that monarchs are distasteful because they sequester toxins from milkweed. They also might think viceroy butterflies (*Limenitis archippus*) mimic monarchs to avoid being eaten, but the two are Mullerian mimics because they are both distasteful. Another pair of mimics, the pipevine swallowtail (*Battus philenor*) and red-spotted purple (*L. arthemis astyanax*), are Batesian mimics; only the swallowtail is toxic. Ecologists predict that mimic species should emerge seasonally after their models, so predators have time to learn to avoid eating them. **Robinson et al. (2025)** tested this prediction using iNaturalist occurrence data to estimate the seasonal timing of first appearance. As predicted, red-spotted purples emerge after pipevine swallowtails throughout their range. Monarchs, which are generally considered to be more toxic than viceroys, appeared before viceroys in most of the range, although this order switches in the very northern part of their study area. The authors speculated that viceroys might be educating birds about viceroy and monarch toxicity in the early part of the northern flight season.

Betz et al. (2025) investigated toxin sequestration in monarchs through feeding trials. They found that monarch larvae rapidly sequester cardenolide toxins from the milkweed they eat; cardenolides were present in body tissue within one minute of ingestion. Cardenolides provide protection against predators, but most of the toxins stored in the larval cuticle were left behind when monarchs metamorphosed from a fifth instar to pupa. When monarch adults first emerged from the chrysalis, they relocated cardenolides from the gut to their wings.

b. Migration & Movement

Migration and movement research on monarch butterflies continues to expand our understanding of the genetic, physiological, and environmental factors that shape migratory behavior and success. Recent studies highlight how ancestral genetic variation, geographic differences in breeding origin, nutrient allocation, and roosting habitat availability all influence migration outcomes. Together, this work shows that monarch migration is shaped by processes operating from genes to landscapes, with important implications for long-term conservation.

Recent studies highlight how both geographic origin and nutrient allocation shape monarch butterfly migration success. Stable hydrogen isotope analyses of wings and lipids from 2019–2021 reveal that monarchs migrating from northern breeding regions contribute 30–55% of overwintering populations in Mexico, a far higher proportion than previously recognized. This underscores the importance of northern production zones and the value of annual isotope monitoring **(Hobson et al., 2025)**. Research on lipid metabolism found that monarchs reared under migratory (fall) conditions conserved essential fatty acids more effectively than those under reproductive (summer) conditions, reflecting physiological adaptations to the energetic demands of long-distance flight. Adult nectar sources also influenced lipid synthesis and quality, with stopover frequency and nectar composition affecting fuel reserves. The authors suggested that nectar availability along the fall migration route may be especially important to maintain fuel reserves since monarchs do not stockpile lipids before migration **(Anparasan et al., 2025)**. These studies emphasize how both landscape level production zones and fine scale nutritional ecology are critical to sustaining monarch populations across their annual cycle.

🔎 **Boxler et al. (2026)** utilized a species distribution model (SDM) to predict the locations of important roosting habitat for the southward migration of the eastern population of monarch butterflies, focused on the Atlantic seaboard and Appalachia. They then evaluated habitat vulnerability and conservation status of these locations. Using the conservation planning software Zonation, they concluded that coastal areas along the Atlantic Coast of the U.S. were at greatest risk of losing roosting habitat, due to the combination of sea level rise and coastal development.

In one population of monarch butterflies in Queensland, Australia, migratory behavior re-emerged in monarch butterflies after more than 90 years of non-migration. Using genomic analyses, **Hemstrom et al. (2025)** identified a gene (Karst) on Chromosome 29 that is associated with reproductive diapause initiation, a trait that is closely tied to migratory behavior. Variation in the Karst gene was also found at low frequencies in North American monarchs, which suggests that the gene is ancestral and has been maintained through population bottlenecks during monarchs' Pacific expansion. The findings suggest that the genetic variation that enables migration can persist for hundreds of generations, even in non-migratory populations, and it offers hope that migration loss may be reversible on relatively short evolutionary timescales.

c. Population Dynamics

Research has shown a significant decline in butterfly populations across the U.S., particularly in the arid Southwest. This is mainly due to habitat loss, pesticides, and climate change. While many species are struggling, monarch trends remain varied and uncertain. As temperatures rise, pollinators are shifting their ranges northward, which is actually expanding the potential suitable habitat for several species, including the monarch. Community science data helps document monarch trends in the Pacific Northwest, an understudied region.

🔍 **Edwards et al. (2025)** found that butterfly populations across the contiguous U.S. declined by 1.3% annually from 2000 to 2020, totaling a 22% loss. Declines were seen in all regions, especially the arid Southwest, due to threats like climate change, habitat loss, and pesticide use. Monarch populations, however, showed varying trends by region, for an overall "uncertain" trend classification. 🔍 **Schultz et al. (2025)** provide useful visualizations of these population changes and steps for enhancing pollinator habitat in many land use types. Both papers emphasize habitat loss, pesticide use, and climate change as key drivers of pollinator population decline including monarch butterflies. Notably, climate change is also shifting pollinator distributions across North America. 🔍 **Hanberry (2025)** found that mean annual temperature was the strongest predictor of pollinator distributions, with pollinator distribution centers generally shifting 357 miles north. This shifting towards north may give pollinators, including monarchs more potential suitable habitat in the future.

🔍 Using 13 years of community science data, **James and James (2026)** found that monarch observations in the Pacific Northwest during the breeding season followed similar trends to the western overwintering population. Monarch observations peaked in 2017 and 2022 and dipped between those years. Community science records are a valuable source of data in this understudied region, and monarchs were observed along the coast of Washington and British Columbia, which is outside the monarch range shown in most distribution maps.

d. Growth & Survival

Two studies address the effects of heat on western monarchs. Monarch larvae are often found in shaded areas, are more likely to defensively drop from plants under high heat, and—during late summer—survive better on narrowleaf milkweed (*Asclepias fascicularis*) than showy milkweed (*A. speciosa*). Tropical milkweed (*A. curassavica*) enables monarch development outside the normal temperature conditions.

Boone et al. (2025) and **Singh and Yang (2025)** explored different components of how heat impacts monarch behavior and demographics in the western U.S. Both studies, via observational or experimental work, showed that monarch larvae are more common in shaded areas during the summer season, especially as temperature increases. Larvae were more likely to defensively "drop" from leaves at very high and low temperatures; this posed the greatest survival risk for small larvae in high heat (i.e., over 40 °C). Monarchs feeding on narrowleaf milkweed had a higher larvae survival in late summer than those feeding on showy milkweed. Thus, Boone et al. recommend including narrowleaf milkweed in western monarch breeding habitat plantings where showy milkweed also occurs.

Unlike native milkweeds, which senesce in late fall and help trigger migration, non-native tropical milkweed remains green year-round in some locations. **DuBose et al. (2025)** compared larval and pupal success rates between captive monarchs reared on tropical milkweed and native swamp milkweed (*A. incarnata*) during summer and fall. While developmental success was similar in summer, monarchs raised on the non-native milkweed had significantly higher success in the fall and continued developing despite low temperatures typically thought to inhibit growth. These findings suggest non-native milkweeds may disrupt monarchs' seasonal life cycle.

III. Habitat

a. Breeding & Migration Habitat

To conserve monarchs, it is important to conduct habitat management activities when monarchs are not breeding. In Canada, agricultural lands are important targets for increasing common milkweed. Two studies provide recommendations to improve habitat on Conservation Reserve Program (CRP) land. Site preparation is important, and diverse seed mixes planted during the dormant season have the highest success. Restorations should include diverse plant families to support a range of pollinators, and asters may be good species for restoration in arid regions. Cattle can generally avoid eating milkweed in the field, but it can be toxic if included in hay mixes.

🔎 **Fyson et al. (2025)** and 🔎 **Mitchell et al. (2025)** provide insights into monarch conservation across North America, highlighting ecological patterns and practical management strategies. Fyson et al. used community science data to characterize monarch breeding across the U.S. and Canada, identifying four patterns: year-round, spring-only, summer, and disjunct. Breeding timing shifted later at higher latitudes, with additional longitudinal and topographic variation. The study emphasized that mowing and maintenance should be planned in a timely manner to avoid peak breeding while considering milkweed life cycles and other insect communities. Mitchell et al. focused on Canada, estimating a 61% increase in common milkweed (*Asclepias syriaca*) stems is needed to meet recovery targets. Agricultural lands are key but vulnerable, while wetlands and riparian zones are disproportionately valuable. Both studies underscore the importance of adaptive management that integrates breeding phenology, habitat management, and habitat restoration.

Jackson and Meissen (2025) assessed the quality of CRP acres for monarch habitat and considered how to best establish new habitat and augment existing CRP acres. CRP acres enrolled in conservation practice CP25 had milkweed abundances on par with existing conservation grasslands. In new CRP establishments, seed mixes with high forb and graminoid diversity planted during the dormant season had the best establishment of quality monarch habitat. To augment existing acres, they recommend that only low-quality habitat should be enhanced, and seeding efforts should focus on spring/fall blooming nectar plants and milkweed species that do not self-colonize. In sites dominated by cool-season grasses, spraying herbicide twice during the early growing season before seeding was the most cost-effective method for successful establishment. However, recolonization of cool-season grasses happened rapidly within two years post-treatment.

Bistline-East et al. (2025) compared the abundance of planted and volunteer flowering vegetation in managed and unmanaged pollinator habitat sites in agricultural areas, with a specific focus on sites enrolled in the CRP as pollinator habitat (CP42) in Indiana. They did not find significantly higher floral or pollinator abundance in CP42 sites compared to non-CP42 sites, and the type of site management did not have a significant impact on plant or insect variables. The authors acknowledged that these results may be due in part to a small sample size (14 sites). Weedy, volunteer plant species that are not especially attractive to pollinators strongly impacted the planted habitat sites, reducing the impact of seeding. These results underscore the need for sufficient seeding rates and disturbance (tillage, burning, mowing, herbicide spraying) to establish the target plant species and reduce weeds when creating pollinator habitat.

Souther et al. (2026) grew and evaluated six different dryland native forbs, including horsetail milkweed (*A. subverticillata*), in the Colorado Plateau to assess their potential for seed production and restoration. Horsetail milkweed produced few seeds, which is a challenge for plant propagation efforts, but it attracted a unique set of pollinators. The authors recommend three aster-family species, spreading fleabane (*Erigeron divergens*), hoary aster (*Dieteria canescens*), and hairy false goldenaster (*Heterotheca villosa*) as strong candidates for restorations in arid conditions, but they noted that a diversity of plant families are necessary to support the maximum number of insect species.

Walck et al. (2025) documented cattle deaths caused by milkweed contamination in hay. Determining the cause of death in cattle can be difficult, but in this case, a combination of evidence led to the conclusion that milkweed was responsible. The cattle showed clinical symptoms matching known signs of cardenolide toxicity, milkweed was abundant in the hayfield, and DNA metabarcoding of rumen contents detected milkweed at levels consistent with a lethal dose. Together, these findings confirmed milkweed as the cause of death. Cattle foraging on milkweed is usually not a concern since it is unpalatable, but if there is not enough forage, they may eat it. In this case, milkweed was mixed in the hay feed, and cattle cannot easily tell what is palatable in dried form. The authors recommend that producers avoid haying fields with abundant milkweed, control milkweed in hay fields, make sure proper forage is available when grazing cattle, and focus monarch habitat efforts in fields not used for hay production.

b. Overwintering Habitat

Forests in the Monarch Butterfly Biosphere Reserve (MBBR) are under increasing pressure from land-use change, bark beetle outbreaks, climate change, and avocado farming. Substantial loss of oyamel fir forest has occurred since the 1970s, with some places more impacted than others. Conservation is most effective when community needs are considered; additionally, new technology offers a non-lethal way to measure tree biomass (e.g., estimating carbon storage). Breeding monarchs are found in the San Francisco Bay Area, California, very near overwintering grounds.

At a large scale, **Palacios-Carrillo et al. (2025)** analyzed satellite images to quantify forest cover change in the MBBR. They documented 6,389 ha of forest loss from 1994 to 2023, including a 9% reduction of sacred (oyamel) fir forest (1,772 ha). They also recognized small increases in forest cover from oak forests and pine forests, which increased 5-7% in some time periods. However, they suggest caution interpreting this as a positive finding, since these forests are secondary growth after the loss of the primary cover. More locally, **López-García et al. (2025)** studied the effectiveness of forest conservation on communal lands within a specific watershed in the MBBR, La Hacienda. Finding a 43% reduction in essential fir forest between 1971 and 2021, they attributed this partially to the MBBR's failure to account for the location and opinions of local communities. For example, excluding tourism opportunities or core zone status from some forests ultimately resulted in significant forest removal. The authors suggest incorporating community needs and local engagement to increase the chances of forest recovery.

Two studies explored the land-use and management pressures facing the MBBR forests. **Sáenz-Ceja and Pérez-Salicrup (2025)** found that avocado farming has expanded quickly since 2006, with 1,345 ha now inside the reserve, mostly replacing traditional cropland and to a lesser extent, pine-oak forests. Climate change is expected to make even more high-elevation land suitable for avocados, which could push farming further into the forest areas important to monarchs. **Gómez-Pineda et al. (2025)** studied efforts to bark beetles, a pest that can weaken trees in the overwintering grounds. The MBBR straddles two states, Michoacán and Estado de Mexico, and the authors found that bark beetle outbreaks and tree removal varied between the states, primarily because of differences in rules and decisions about when to log infected trees and what is considered an outbreak.

Hernández-Moreno et al. (2025) tested a way to measure tree size and weight without cutting trees down, using a ground-based laser scanner (TLS) and a simple math formula. When tested on oyamel firs (*Abies religiosa*) and smooth-bark Mexican pine (*Pinus pseudostrobus*) in the MBBR, this new method was efficient and accurate relative to two standard destructive measurements of tree volume. This new method is especially useful to assess forest growth in protected areas like the MBBR, where cutting trees is restricted.

In the San Francisco Bay area, milkweed and breeding monarchs were found very near to an overwintering site. **James et al. (2025)** categorized this as the first documentation of North American reproductive monarchs coexisting with non-reproductive, overwintering monarchs. The authors propose that this is a good thing for conservation since it shows the adaptability of monarchs to undertake two life strategies within the same area, and these events will become more common with climate change.

c. Urban Gardens & Landscapes

Urban gardens can provide important islands of pollinator habitat within an inhospitable landscape. Two studies looked at the genetics of insects and milkweed and found that urbanization generally did not impact genetic drift and gene flow of common milkweed, monarchs, or other insects in the studied areas. Other studies addressed the relationship between urban pollinator gardens and monarch migration in California and the impacts of aphid populations and habitat maintenance on monarch utilization of habitat in Chicago, Illinois and Ontario, Canada. All three of these studies found that urban pollinator gardens provide benefits to monarch butterflies, particularly when that habitat is well-maintained.

Two studies demonstrated the important role of urban milkweed gardens in supporting monarch butterflies and other specialist herbivores. **Quiroz et al. (2025)** found that monarchs readily oviposit on common milkweed stems with high aphid densities in Chicago gardens. This was a surprising result since previous research has suggested that monarchs avoid aphid-infested milkweed. The authors hypothesize that oviposition behavior may differ based on the milkweed or aphid species, and the study indicates that urban milkweeds remain valuable habitat despite the presence of other herbivores. Similarly, 🔎 **Gillies et al. (2026)** showed that maintained urban gardens had higher occupancy of monarchs, leaf miners, and aphids compared to naturally occurring stands (e.g., unmaintained vacant lots), driven by plant traits such as taller stems and more leaves. Stand size influenced occupancy for some herbivores but not monarchs, emphasizing that garden quality, rather than sheer size, promotes herbivore presence.

Together, these studies highlight that urban gardening can enhance habitat quality, bolster monarch populations, and support specialized herbivore communities, making it a practical conservation strategy in urban landscapes.

Miles et al. (2025) examined genetic patterns in monarchs, beetles, and weevils across 100 urban and rural sites in northern California. Despite urbanization reducing weevil abundance, gene flow and genetic drift were largely unaffected in all species. Monarchs were equally abundant in both habitats, likely due to their strong dispersal ability. The findings suggest that urbanization has not affected genetic diversity in monarchs. Comparably, a study of common milkweed (*Asclepias syriaca*) across urban–rural habitats in Toronto examined how urbanization affects the genetic structure of *A. syriaca* across 124 sites. **Breitbart et al. (2025)** found no significant genetic differences, with all plants belonging to a single genetic population. This demonstrates that urbanization had little effect on genetic diversity and suggests that common milkweed is similarly affected by both urban and rural human-impacted environments, in contrast to natural habitats. Together, these studies provide evidence that urbanization is not harming genetic diversity in monarchs or their host plants.

Erickson et al. (2025) examined whether urban pollinator gardens in the Bay Area, California are acting as an ecological trap for migratory monarch butterflies by attracting, but not sufficiently supporting, individuals from the migratory population. In 2022 and 2023, they conducted monthly monarch and milkweed surveys along urban streets to determine whether the population of non-migrating monarchs draws from the migratory population. The authors did not find an influx of monarch butterflies from the migratory population into winter-breeding populations in urban gardens. The non-migratory population increased in the summer months, suggesting that they are reproducing independently rather than being sustained by annual influx from the migratory population. The findings suggest that urban gardens are not negatively affecting the migratory population in the Bay Area.

d. Habitat Selection & Use

Recent papers examined monarch habitat use and selection patterns. Nectar resources are more limited in southern states during the fall migratory window; monarch usage of prairie strips may be higher during fall migration due to the floral resources that they provide. When examining managed rangelands, butterfly abundance and diversity are positively correlated with increased forb cover. Monarchs show some preferences towards certain species of milkweed; however, these preferences are dynamic throughout the breeding season. Non-native nectar sources are well-integrated into butterfly diets.

Multiple papers explored monarch preferences in habitat use, with a focus on the Great Plains region. **Damiano and Perkins (2025)** investigated oviposition preferences among native milkweed, reaffirming the results of previous studies that suggest a preference for swamp milkweed (*Asclepias incarnata*) and common milkweed (*A. syriaca*). Usage seemed to shift throughout the breeding season, with *A. syriaca* more popular during the early season but preference for *A. incarnata* later in the year. Looking at floral resource availability, 🔎 **Spaeth et al. (2025)** examined the density and richness of monarch preferred nectar plants during the autumn migration. They drew attention to low densities of native nectar resources in southern reaches of the migratory pathway as a potential contributing factor to monarch decline. However, **Pekos et al. (2025)** concluded that non-native nectar sources are also well integrated into butterfly diets and may provide important additional sources of nectar in times of year when native resources are limited. Additional research is needed to fully understand how nonnative nectar sources contribute specifically to the fall migratory period.

Harris et al. (2025) studied monarch egg abundance in patches of swamp milkweed and common milkweed surrounded by different landscape characteristics. They found that monarch egg-laying preferences and survival on different milkweed species varied from year-to-year and season-to-season. More eggs were found when plants were surrounded by wildflowers instead of grass. Surprisingly, monarch eggs were more likely to be present on plants with oleander aphids. The presence of ladybird beetles, a generalist predator, did not influence monarch egg presence. When designing monarch habitat, the authors recommend planting more than one species of milkweed within a matrix of wildflowers, and close to a wooded tree line. Their results indicate that management for aphids is not necessary.

Stephenson et al. (2025) compared monarch use and breeding habitat qualities of prairie strips and linear grassy features in Iowa. Although common milkweed was more abundant in linear grassy features, prairie strips had four times as many flowering plant species and five times as many blooms. Adult monarch presence was significantly higher in prairie strips, indicating a positive association between floral resources in prairie strips and adult monarch presence, especially during the fall migratory window. There was no significant difference in egg abundance, but further research is needed to assess larval survival in prairie strips.

Tronstad et al. (2025) surveyed adult butterflies across eastern Wyoming, focusing on the monarch and regal fritillary (*Argynnis idalia*), to establish baseline abundance, richness, and habitat use. Butterfly abundance and richness were higher at sites with low wind, greater forb cover, and less bare ground. In total, they observed 31 monarchs at 22 sites. A Species Distribution Model (SDM) predicted that suitable monarch habitat occurs across most of Wyoming, especially in warmer and wetter areas with low sagebrush cover. Although Wyoming is at the edge of the monarch and regal fritillary range, these findings indicate that properly managed grasslands may provide suitable habitat for both species.

e. Habitat Establishment & Management

Proper management is key for creating and maintaining monarch habitat. Burning and grazing reduce thatch and increase milkweed abundance. When restoring sandhill milkweed (*Asclepias humistrata*), seeding in deep containers improves root growth, and PVC pipes improve plant survival after transplanting. Treating seeds with gibberellic acid and hydrogen peroxide improves germination rates for dormant native species.

Johnson et al. (2025) examined the relationship between invasive grass abundance, fire, grazing, and milkweed. Increased buildup of thatch from invasive Kentucky bluegrass and smooth brome caused a decrease in abundance of milkweed stems, while burning and grazing decreased thatch depth and increased the abundance of milkweed. Grazing post-fire had initial benefits for milkweed production since cattle grazed heavily on the high-nutrient vegetation that emerged immediately after burning. However, the benefits to milkweed decreased over time as grazing pressure decreased.

Two studies assessed the best methods for restoring sandhill milkweed in coastal dune habitats. **Campbell-Martínez et al. (2025a)** experimented with production containers, substrates, and hydrogel to improve planting protocols. *A. humistrata* survival was similar in four substrate types, which included both industry standard substrate mix and three perlite-free mixes. However, tall tree tubes with deep soil greatly improved survival compared to standard 32-cell trays (77% versus 32%) since the tall tubes allowed better root formation. Hydrogel application during planting did not improve survival. **Campbell-Martínez et al. (2025b)** studied *A. humistrata* seedling recruitment in coastal dune systems in the Bon Secour National Wildlife refuge in Alabama. After 52 weeks, the highest seedling survival was in open areas where plants were protected with a PVC pipe and seeds had been covered with sand during planting.

Ermiş et al. (2026) compared multiple methods to improve germination rates for pollinator plants, including 3 milkweed species. Seeds treated with gibberellic acid (GA3) in a 20/30 °C temperature regime had the highest germination rate and speed. In further tests, they found that a combination of gibberellic acid and hydrogen peroxide (H_2O_2) produced the best germination rates for common milkweed (*A. syriaca*), swamp milkweed (*A. incarnata*), and several other species. The addition of non-ionic surfactants did not provide additional benefits and sometimes increased mold growth. The *Asclepias* species tolerated a range of soil moisture conditions, with the highest germination at 42% to 92% soil moisture.

f. Milkweed Ecology

Milkweed growth, reproduction, and ecological interactions are shaped by seed source, genetics, and biotic relationships. Common milkweed (*Asclepias syriaca*) plants flower later in the season and receive more pollinator visits if sourced from a more southerly location. In the West, larger showy milkweed (*A. speciosa*) seeds germinate early and produce taller plants. Protecting seed pods increases seed recovery for early-season western milkweeds. Rush milkweed (*A. subulata*) exhibits two bloom periods (spring and late fall), and its primary pollinators are spider wasps (*Pepsis* spp.). Herbivory affects floral trains and plant chemistry, and arbuscular mycorrhizal fungi benefit *A. syriaca* but not some other non-milkweed native plants. Finally, a new species (*A. tonkawae*) is proposed in Texas, distinct from *A. tomentosa* populations in Florida and Carolinas.

Finch et al. (2025) used common milkweed to test the impacts of latitudinal seed source on flowering phenology, floral visitation, plant size, and reproduction in Chicago, Illinois over the course of three years. Understanding the effect of seed sources on multiple aspects of plant ecology is important to fostering the best possible restoration outcome for habitat, especially under future climatic conditions. The authors gathered seeds from wild common milkweed plants across a north-south gradient in Minnesota, Illinois, and Missouri. The plants from the southern seed source exhibited later flowering, longer flowering period, taller plant height, and greater floral visitation. The authors suggested that a mix of seed sources for restoration may be best to achieve a longer overall bloom period, and introduction of southern seed sources could assist in adaptation to changing climates.

Both **Dallabetta et al. (2025)** and 🔎 **MacArthur-Waltz et al. (2025)** examined how intrinsic (germination timing) and extrinsic factors (temperature and precipitation) shape trait variation and reproductive timing of milkweeds important to western monarchs. Dallabetta et al. found that larger showy milkweed seeds germinated more quickly, and that these earlier-germinating seeds grew taller overall. Leaf area was greater in late-germinating seeds during late July but was otherwise unassociated with germination date. MacArthur-Waltz et al. studied five California milkweed species, *A. californica*, *A. cordifolia*, *A. fascicularis*, *A. eriocarpa*, and *A. speciosa*, using over 16,000 citizen science observations from iNaturalist. They found that warmer springs tended to accelerate growth and flowering, especially for early-season species (*A. californica* and *A. cordifolia*), while wetter years delayed growth, particularly for late-season species (*A. fascicularis*, *A. eriocarpa*, and *A. speciosa*). Water availability also influences reproduction: late-season species were more likely to flower and produce seeds in cooler, wetter years, whereas early-season species were less affected by precipitation. Together, these studies highlight that both environmental and developmental factors can influence milkweed availability for the western monarch population.

Planting early-season milkweed such as California milkweed (*A. californica*) and heartleaf milkweed (*A. cordifolia*) has been identified as a key conservation technique to support the western monarch population. **Landis et al. (2025)** investigated ways to increase the seed availability of these species for plant nurseries. The authors identified stands of milkweed in the wild, protected the seed pods until harvest, and shipped them to a seed extractor for cleaning and testing. Unprotected seeds that fell to the ground were frequently damaged by rodents, their preferred seed bag was the nylon "try-on-socks" typically available in shoe stores, and this collection method can greatly increase seed availability for native plant nurseries and local seed production gardens.

Two studies explored the distribution and ecological interactions of specific milkweed species. 🔎 **Alvarado-Cárdenas et al. (2025)** used herbarium collections and community science observations to study the biology of rush milkweed. This species was found from 0-1600 meters in elevation and was widely distributed in the Mojave and Sonoran Deserts. These generally leafless plants bloomed in association with regional rainfall peaks (March - May and November - January), and their main potential pollinators during the spring peak are Hymenoptera, especially spider wasps. **Ehlert et al. (2025)** documented Welsh's milkweed (*A. welshii*) as a monarch host plant for the first time in published literature. They also intentionally summarize historic gray literature findings in conjunction with their own to make historic findings more accessible. This includes Morrison bumblebee (*Bombus morrisoni*), oleander aphids (*Aphis nerii*), and western small milkweed bugs (*Lygaeus kalmii kalmii*) feeding on the milkweed species.

Two papers investigated the effects of herbivory on milkweed and their microbial communities. Herbivory may change how plants invest their resources, whether in reproduction or defense. **Aguirre et al. (2025)** simulated herbivory on common milkweed and found that herbivory altered the composition of scent compounds (volatile organic compounds) and changed some floral characteristics, such as increasing the diameter of individual flowers, but it did not affect the total size of the inflorescence. Milkweed plants produce defensive compounds (cardenolides) in response to herbivory, and some microbes can produce enzymes that break down these compounds. **Hansen and Enders (2025)** tested three milkweed species to determine how monarch herbivory impacted the diversity, composition, and function of their microbiomes. Surprisingly, they found an inverse relationship between the toxicity of the milkweed plant and the microbial enzymes that could break down those compounds. Butterfly milkweed (*A. tuberosa*) produces minimal cardenolides, but its microbial community had the most detoxification enzymes. They also noted that the microbial community in the roots (rhizosphere) had more diverse genes than the leaf (phyllosphere) microbe community.

Delavaux et al. (2025) explored the effects of arbuscular mycorrhizal fungi (AMF) on several native tallgrass prairie species, including common milkweed. AMF can improve their host plant's growth through nutrient exchange and pest protection. The authors studied each species' response to AMF and how this related to the benefits of mycorrhizal-induced resistance (MIR) to pathogens and mycorrhizal growth response (MGR) based on both pathogen and mycorrhizal origin. AMF inoculation resulted in higher MIR (i.e., improved pathogen resistance) and MGR (i.e., improved growth) in common milkweed. This trend was opposite or absent for two other native, early successional species, dogbane (*Apocynum cannabinum*) and Canada goldenrod (*Solidago canadensis*). This research highlights the important, but nuanced, relationship between AMF and native plant health in restoration ecology.

Two studies used genetic analyses to investigate milkweed species dynamics. Tuba milkweed (*A. tomentosa*) is a rare milkweed that has three geographically separate populations, in Texas, Florida, and the Carolinas. However, **Duran et al. (2025)** discovered that the Texas population is genetically distinct and has unique floral morphology. The authors propose that the Texas population should be considered a new species, *A. tonkawae*. The plants have a narrow range and grow on acidic sands, and they would likely be considered critically imperiled, both globally and within the state of Texas. While Duran et al. suggest splitting one species into two, **Andreev et al. (2025)** examined hybridization between two species. Showy milkweed is common in the western U.S., and common milkweed is abundant in the East, and. Their ranges overlap in the Great Plains., and Andreev et al. found genetic and morphological evidence that the two species hybridize. The genetic data did not indicate that the two species are merging into one, and the authors suggested that climate adaptations are keeping them separate since common milkweed is better adapted to wetter climates whereas showy milkweed tolerates periods of drought. Genetic evidence indicates that the two species first diverged 1.3 million years ago then came back into contact 9,400 years ago after the glaciers receded.

IV. Threats & Stressors

a. Pesticides, Toxins, & Heavy Metals

Pesticides are ubiquitous, both in agricultural and urban areas, and they can have detrimental effects on monarchs. A recent synthesis of pesticide research demonstrates varying effects of pesticides on monarchs. Monarchs killed at an overwintering site in California contained up to 15 different pesticides, and plants across genera contain a cocktail of pesticides. The neonicotinoid clothianidin increases milkweed growth and body mass in monarch larvae but decreases adult fitness. Lead decreases wing size in monarchs and other butterflies. Mosquito sprays can reach toxic levels in urban yards. These studies emphasize the need for increased data on pesticide applications, the interactions between pesticides, and their toxicity for Lepidoptera.

McCulloch et al. (2025) synthesized 29 studies on grassland management and pesticide effects on monarch growth, survival, and reproduction. The review focused on papers published since the 2020 U.S. Fish and Wildlife Service Species Status Assessment. They found only two papers that studied the direct effects of management on monarch fitness or survival, which highlights a major knowledge gap. Of the 27 papers on pesticides, 18 documented negative effects of pesticides on monarchs, and one had positive effects. Most of the studies were lab trials, so field studies and research on the interactions between various pesticides are avenues for further research. The authors concluded that pesticides pose a clear threat to monarch development and survival, both through acute and chronic exposure, and that future monarch conservation will need to address the issue of widespread pesticide exposure in addition to adding and restoring monarch habitat.

Two observational studies demonstrate the ubiquity of pesticides in urban environments. Cibotti et al. (2025b) measured pesticide levels in 10 monarch butterflies from a 2024 die-off event at a 2-acre overwintering site in Pacific Grove, CA. They found 15 pesticides in the monarchs, with an average of 7 per butterfly. Three neurotoxic pyrethroids (bifenthrin, cypermethrin, and permethrin) were found in almost all of the samples at levels close to the lethal concentration for monarchs or other butterfly species. Sublethal concentrations of the other 12 pesticides in combination may also have contributed to mortality. No specific pesticide application could be implicated, but it was more likely residential or commercial than agricultural. The authors recommend that pesticide use should be restricted around sensitive overwintering sites. Dittemore et al. (2025) measured pesticide levels in 19 genera of plants at 24 sites in Sacramento, CA, and Albuquerque, NM. They found a total of 47 different pesticides in 314 of 336 plants sampled, with a median of 3 and maximum of 18 in any one plant. Agricultural drift and residential application were both considered potential sources. Two pesticides, chlorantraniliprole and azoxystrobin, were found in 71 plants at levels that have lethal effects on monarch larvae or sublethal effects on monarch adults. 38 of the pesticides have little or no published data on effects on lepidopterans. Both authors recommend more control and reporting of pesticide application in urban areas.

Two papers tested the effects of clothianidin, a neonicotinoid seed treatment, on monarch development. Cibotti et al. (2025a) tested the effects of clothianidin on common milkweed (*Asclepias syriaca*) chemical defenses and caterpillar feeding and growth. Monarchs that fed on clothianidin-treated milkweed had lower flight metabolic rates as adults, especially males, which suggests that the insecticide had sublethal effects. In contrast, Cibotti et al. (2025c) found that clothianidin had a beneficial effect on milkweed plant growth and development. They used field-realistic concentrations and included greenhouse and open field experiments. Monarch butterflies had no oviposition preference between clothianidin-treated and control plants, and monarch larvae on clothianidin-treated plants had higher body mass.

Kemmerling et al. (2025) quantified lead levels in 22 butterfly species, including monarchs, collected in an urban environment. Across all species, wing size decreased with increasing lead exposure, which indicates stress during larval development and could affect migratory ability. However, brain mass and egg number were not affected. Soil and air, but not host plants, were the main sources of lead exposure.

Adult mosquito sprays reduce pest species, but they may negatively affect beneficial insects such as monarchs. In **Anderson et al. (2025)**, 19 volunteers in three states used silicone bands to assess adult mosquito sprays in urban yards. They compared two types of adult mosquito treatment, barrier sprays by private companies and ultra-low volume (ULV) sprays by mosquito control districts. They detected 21 compounds in the sprays, including 12 insecticides and 8 fungicides. The barrier sprays by hired companies, which are designed to last on vegetation for several weeks, had higher pesticide richness and amounts of pyrethroids. Although there is little toxicology data on monarchs, two yards had bifenthrin concentrations high enough to kill monarch fifth-instar larvae, and there was also evidence of insecticide sprays drifting into neighboring yards.

b. Climate Change

In the eastern monarch population, spring arrival times have not shifted earlier in response to warming temperatures, but peak abundance has shifted later. Habitat fragmentation exacerbates phenological mismatch with host plants. Warming temperatures disrupt reproductive diapause and elevate overwintering mortality risks. Climate change may alter the distribution of monarchs. In contrast to long-term temperature changes, short-term heat waves synchronize milkweed development. Together, these five studies converged on the theme that climate-driven temperature changes pose serious, multifaceted threats to monarch butterflies and their milkweed host plants.

Debinski et al. (2025) combined long-term monarch abundance and milkweed phenology data with experiments manipulating monarch arrival time to test for phenological mismatch and its effects on monarch development. Seventeen years of surveys in Iowa (2003–2017) showed no shift in monarch arrival dates, although peak abundance occurred 9 days later and summer population growth declined. Herbarium records of common milkweed (*Asclepias syriaca*) (1970–2018) from Iowa, Wisconsin, and Minnesota showed stable flowering onset, providing no evidence of mismatch with monarchs. In experimental trials, larval survival was highest when release coincided with the average natural arrival date, lower when release was delayed by two weeks, and lowest when advanced by two weeks. These results suggest that earlier monarch arrival would be costly to monarchs, but field data indicate that arrival timing has not changed.

Drawing on landscape and observational data across North America, **Harsh (2025)** demonstrated that climate warming shifts monarch breeding phenology in ways that risk mismatches with host plants, compounded by habitat fragmentation. The structure and diversity of landscapes all contribute to the success of monarch populations. Fragmented or simplified landscapes amplify the negative impacts of climate warming and thus contribute to population declines. This paper underscores that both gradual warming and discrete extreme heat events can threaten monarchs at multiple life stages. The author recommends maintaining diverse and well-connected habitats across multiple land-cover types to support monarchs.

Using a controlled laboratory experiment with wild-caught Oklahoma migrants, **Rich et al. (2025)** found that warmer migratory temperatures disrupted reproductive diapause, increased male mortality, and elevated overwintering mortality risk, with reproductive development and OE parasite burden as the strongest predictors of death.

Ragab et al. (2025) evaluated how future climate change may alter the global distribution of monarch butterflies under multiple emission scenarios. Using climate projections models, they assessed habitat suitability for near-term (2021–2040) and long-term futures (2041–2060) under both high and low emissions pathways. Annual precipitation, land cover, and altitude were the most influential factors shaping monarch distribution. These findings highlight the need for adaptive, region-specific conservation strategies, including habitat restoration, and protection of overwintering sites.

Working in an experimental Michigan common garden, **Cope and Wetzel (2025)** showed that heat waves delay and synchronize milkweed development, reduce arthropod species richness, and suppress herbivory from arthropods indirectly through plant-mediated effects. They noted that heat waves and gradual warming produced opposite effects.

c. Predators & Parasites

Monarch butterflies face several interacting pressures from predators, parasites, and environmental conditions. Predation patterns vary by habitat and season, with insects being the most common predators, and rural areas experiencing higher attack rates overall. Western yellowjackets can cause high mortality in western overwintering monarchs. Disease risk from the parasite *Ophryocystis elektroscirrha* (OE) depends heavily on environmental conditions: group feeding can reduce individual infection risk, while warmer temperatures can make OE infection of monarch butterflies more harmful and remove the disease-reducing benefits of tropical milkweed. Monarchs are generally more susceptible to infection than queen butterflies, and *Ophryocystis* parasites have existed across a wide range of species, locations, and time periods. OE life cycles are more complex than previously recognized. Overall, monarch health is shaped by a combination of ecological interactions and environmental conditions.

To study predation, **Baker (2025)** placed clay models that looked like late-stage monarch caterpillars on milkweed plants in urban, suburban, and rural areas in Kentucky and Ohio. They checked for bite marks to determine the predator: insects, birds, or mammals. Insects were the most common predators, especially in rural areas, and their attacks increased through the summer before dropping off in late summer and fall. Bird attacks were most frequent in spring and again in early fall, while mammals rarely attacked. Overall, more predation happened in rural than urban areas. The study shows that using artificial caterpillars can be a helpful, non-lethal way to study predator activity, although the results should be interpreted cautiously since these are clay models and may not represent real-world predation on monarch larvae. The findings highlight that predation pressure on monarchs may vary by habitat and season, which could inform habitat restoration and management efforts.

When overwintering populations of monarch butterflies in California are large, predator-inflicted losses upon butterfly numbers from organisms such as birds, small mammals, and arthropods are minimal. If the butterfly populations are small, monarch butterfly losses are more important. **Magor and James (2025)** studied the effects of the western yellowjacket (*Vespula pensylvanica*) as a predator upon overwintering monarch butterflies at a site in Santa Cruz, CA from October to December 2024. They conducted weekly surveys on dead monarchs underneath the clusters and observed behaviors before and after wasp attacks. In early December, wasps killed 68 monarchs, which represented 4.5% of the butterflies at the overwintering site. The authors recommend the use of wasp management practices such as wasp traps or nest destruction to protect small populations of overwintering monarchs from wasp predation.

Monarch disease risk from the protozoan parasite OE is strongly influenced by environmental conditions. **Majewska et al. (2025)** showed that monarch caterpillars feeding in groups on contaminated milkweed had a lower chance of becoming infected and carried fewer parasites than monarchs feeding alone. This is due to “foraging dilution,” where shared feeding removes OE spores from the environment. However, population-level modeling suggested that increased survival under crowding may still lead to higher overall infection rates. **Ragonese et al. (2025)** found that warmer temperatures made OE infections more harmful to monarchs and removed the tolerance to OE that several other studies had previously demonstrated under standard temperatures, even though the plants themselves were more nutritious with warmer temperatures (lower C:N ratio). These studies highlight that the dynamic between monarchs, milkweed, and OE are shaped by complex mechanisms, highlighting the need for further research into how climate change will affect monarchs and their habitat.

Müller-Theissen et al. (2025b) performed cross-infection experiments between monarchs and queen butterflies *(Danaus gilippus*). Monarchs were highly susceptible to both parasites from their own species and those from queens (100% and 82%

respectively). In contrast, queens were susceptible almost exclusively to parasites from their own species. The results suggest that queens are both more tolerant and more resistant to parasites, countering the initial hypothesis that queens would have a reduced ability to tolerate infection due to investing in greater immune defense.

Müller-Theissen et al. (2025a) also used museum specimens to determine whether *Ophryocystis* parasites infect butterfly species beyond monarchs and queens. The authors sampled 10 genera of milkweed butterflies, which included 61 different species and 2727 individual samples from five continents. They documented the first *Ophryocystis* infection in Jamaican monarchs (*D. cleophile*) and found infected specimens dating back as far as 1909. Despite a close relationship and geographic overlap, they did not find infections in South American monarchs (*D. erippus*) and soldiers (*D. eresimus*). This suggests that factors other than relatedness or geographic range may influence parasite occurrences.

Parasites are classified as "complex" if they have multiple hosts during their life cycles. OE uses only one host, monarch butterflies, so it has a "simple" life cycle. However, **DuBose and de Roode (2025)** challenge this binary classification. They studied functional differences in OE during different life stages of their host, from 3rd instar caterpillars to adults, using mRNA sequencing. They found major differences in gene expression in OE at different monarch life stages, which suggests that OE specializes in different tasks during each life stage of its host. OE has a more complicated life cycle than previously recognized since it changes activity to align with its metamorphosizing host.

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Clara Jordan

How You Can Support Monarchs

Create habitat. Plant milkweed and other native flowering plants. Visit the Monarch Joint Venture's Create Habitat page for recommendations on how to create a pollinator-friendly garden.

Report observations. Participate in community science projects, such as tagging or habitat monitoring.

Educate others. The MJV offers monthly webinars, a variety of free educational resources for teachers, and resources to advocate and take leadership on monarch conservation in your community.

Make connections. Consider the circles of people and groups in your life and invite them to connect with the MJV and our growing partner network.

Share our work. Share the work of the MJV with your friends and family. You can share a video that provides an overview of our work, a post on Facebook, a photo on Instagram, or a post on LinkedIn.

Contribute financially. Donate today and help ensure that resources are available to help the MJV and other conservation-focused organizations implement the science-based recommendations in the Monarch Conservation Implementation Framework.

Walk, run, hike, or paddle. As an individual or with a team, participate in Miles for Monarchs to help raise funds and awareness for monarch conservation.

MONARCH JOINT VENTURE