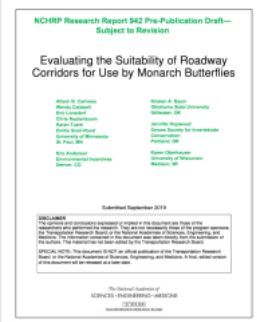

Evaluating the Suitability of Roadway Corridors for Use by Monarch Butterflies (2020)

DETAILS

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The roles of the authors were as follows. Alison Cariveau (Monarch Joint Venture; MJV) led the project overall and was lead author for the report. Karen Oberhauser was the original Principal Investigator at the University of Minnesota; when KO moved to University of Wisconsin, Emilie Snell-Rood became Principal Investigator at the University of Minnesota. Wendy Caldwell oversaw the project for MJV and provided feedback and guidance throughout the project. Kristen Baum (Oklahoma State University) was involved in the design of the Rapid Assessment protocol and led the field testing in Oklahoma. Erik Anderson (Environmental Incentives) was involved in the design of the Habitat Calculator, conducted user interviews, and created the manager workflow diagram. Eric Lonsdorf and Chris Nootenboom (Institute on the Environment, University of Minnesota) developed the Landscape Prioritization Model and authored the chapter and user guide. Karen Tuerk (MJV) designed and completed all of the programming for the Monarch Habitat Evaluator in Survey123, wrote the user guide, and was GIS specialist for the project. Jennifer Hopwood (Xerces Society for Invertebrate Conservation) co-led the best management practices and decision support team with Alison Cariveau and authored Frequently Asked Questions, Monarchs, Herbicides, and Weeds, and a set of regionally specific milkweed identification handouts.

CONTENTS

SUMMARY

Overview

This project examined the potential for roadway corridors to provide habitat for monarch butterflies and developed tools for roadside managers to optimize potential habitat for monarch butterflies in their road rights-of-way. We developed the following products through the project, all of which are available to interested departments of transportation:

- **Product A:** A Landscape Prioritization Model for Roadside Habitat for Monarchs to assist roadside managers with identifying locations that are both compatible with their road and ROW maintenance objectives and ranked in suitability for monarch habitat conservation. The national GIS model can be enhanced with state or more local information to further refine prioritization of sites.

- **Product B:** A Rapid Assessment of Roadside Habitat for Monarchs protocol enables roadside managers to quickly survey a roadside area to evaluate the current status of the habitat quality for monarchs. The assessment focuses on functional components of monarch habitat: breeding habitat, foraging habitat, threats and landscape context, and roadside vegetation management practices. Data are entered into Esri Survey123, software used by most state transportation authorities, the survey may be customized by each state, and results are easily tracked and summarized within each state department of transportation.

- **Product C:** The Roadside Monarch Habitat Calculator transforms Rapid Assessment data into monarch habitat quality scores, metrics that can be used to compare sites within a road system or state and inform land managers of needed conservation actions. Data gathered in this assessment create an adaptive management feedback loop in order to track success of efforts through time and improve future conservation practices. The functional components of the rapid assessment are combined into one monarch habitat quality score but also reported independently to inform adaptive management.

- **Product D**: Decision support tools for roadside managers were developed to help align road authority objectives and regulations with conservation goals in a way that is economically and environmentally additive. A survey of roadside management entities across the U.S. helped identify areas where roadside management objectives and barriers intersect with conservation objectives, and findings were used to inform the tools developed through this project to ensure the tools were adopted by and useful to road authorities. Online and print materials were also developed to support land managers in their conservation-oriented decisions, including a decision tree, milkweed guides, a weed and herbicide resource sheet, and a set of frequently asked questions.

Products A through D are available online (https://monarchjointventure.org/roadsidehabitat) for departments of transportation who want to learn more about the habitat in the road corridors they manage. We published the tools in Esri products that are readily in use by most transportation departments. Products B and C are combined into a Roadside Monarch Habitat Evaluator module that may be customized by each state for its use. Managers may then view their site data and habitat scores in a spatial map layout or in a spreadsheet depending on their information needs.

Findings

In our survey of roadside managers as well as by interactions with transportation professionals throughout the project, we found a high degree of interest and dedication to providing pollinator and monarch habitat along roadways. Our investigations indicated that variable amounts of knowledge and time that could be

allocated to pollinator work. Funds for pollinator work are generally extremely limited, so cost-savings from altered management is an important topic. We found tremendous variation in the reported use of key management techniques including mowing and herbicide application, indicating opportunities for alteration in the area of vegetation management.

In our field trials, we found high quality monarch breeding habitat in roadside rights-of-way areas. Field studies in Minnesota and Oklahoma showed high levels of milkweed and monarch use of milkweed in roadside rights-of-way, as well as nectar plants. We also found concurrence between our Rapid Assessment of Roadside Habitat for Monarchs to another more intensive monarch habitat monitoring protocol.

Our study addressed the question of whether habitat along roads is suitable for monarch butterflies. Our research including data collected in this project suggests that roadsides are promising habitat for monarchs. With respect to host plants, over half of randomly selected roadsides contain milkweed and surveys detailed in this report highlight densities over 2000 stems of milkweed per mile. Roadside sites also include a variety of nectar plants beneficial not only to monarchs but to a diversity of pollinators.

We reviewed risks to monarchs and their habitat in roadside corridors, including impacts of vegetation management, particularly mowing that is required for maintenance of safety standards. While mowing for traffic visibility kills some monarch larvae, it also maintains open roadside habitat favorable for monarchs, can be used to control invasive and undesirable plant species, and milkweed re-growth is heavily used by egg-laying monarchs. Roads also present danger of traffic collisions for monarchs, although these effects appear to be more concentrated in particular funnel areas during migration. Monarchs in roadside rights-of-way may also experience increased exposure to road salts, heavy metals, and insecticides applied to nearby agricultural or developed areas any of which could present risks to monarch survival and development. However, current research, although still unpublished, suggests that the majority of roadside milkweed is of suitable nutritional quality for monarchs (i.e., not toxic). Roadside sodium and heavy metals (especially zinc) vary with traffic volume and distance from road. Most metal levels are below what is toxic for monarchs. While sodium levels do reach toxic levels, this seems to be limited to milkweeds along the highest traffic roads and in the buffer zones that are often mowed just adjacent to the road. Screens for pesticides do find residues on at least a quarter of roadside milkweeds, however, the majority of the chemicals that show up in these screens are fungicides and herbicides. Current work is clarifying the presence of sublethal levels of neonicitinoids. Taken together, this work in progress suggests that most roadside milkweed, especially along the majority of roads (which are moderate to low traffic volume) harbor milkweed of suitable nutritional quality for monarchs.

In summary, threats along roadway corridors exist for monarchs and other pollinators, but in the context of the amount of habitat needed for recovery of sustainable populations, roadsides are of vital importance. As detailed in this report, we have developed tools including a landscape model and a habitat calculator to to assist managers in understanding the habitat they manage and improving their ability to enhance these habitats through adaptive management.

The Landscape Prioritization Model developed in this project is the first of its kind at this scale. It provides a transportation manager the ability to evaluate the landscape in their state with regard to areas where diverse roadside habitat could complement already existing natural habitats or where high-quality roadside plantings might create a corridor of suitable habitat where there is otherwise very little. In addition, this model depicts roads and their associated hazards in a way that helps managers to think about the importance of traffic volume, traffic speed, and right-of-way width, all factors that can potentially affect the roadside environment for monarchs. Together, this landscape information and road metrics inform managers' understanding of their road systems in a novel way.

The Rapid Assessment of Roadside Habitat for Monarchs is a way for transportation managers to readily assess the habitat currently in their rights-of-way, and to track it through time. While many land management entities often lack time and capacity to conduct habitat assessment work, this tool was designed to be quick and easy to implement with different skill levels and also feeds into broader scale monarch and habitat monitoring initiatives and tracking efforts. Tracking and evaluating monarch habitat projects using the Rapid Assessment creates a feedback loop of information that will tell rights-of-way managers the baseline quality of their site, as well as continued tracking of how the project is doing. In turn, this will provide a valuable data set that will improve the seed mix design and habitat management practices implemented by the land management authority as they learn what is performing well, and what may not be. Not only will this reduce costs over time, but if applied in an adaptive management framework, the quality of the habitats for monarchs and pollinators should also improve (or minimally be sustained) over time.

The Roadside Monarch Habitat Calculator provides managers an easy way to interpret breakdown of the functional components of the habitat. Using data collected through the Rapid Assessment, it provides users with scores about how a particular project or site area is performing in the areas of monarch breeding habitat, foraging, landscape context and threats, and management. The scores for each of these components are combined into an overall score, but also presented independently such that a land manager can pinpoint specific problem areas that could be improved on that site. For example, if the breeding habitat score for a site is low, this means that it is lacking sufficient milkweed host plants for monarchs. Actions to increase the milkweed density at that site could improve the habitat score over time. The Calculator also provides a reportable metric that can be used in internal or external reporting. These scores can be viewed in an online map or spreadsheet format.

We provided several types of decision support tools in response to the needs of the roadside management community. We recognized that there were several information needs, including guidance on mowing, herbicide applications, milkweed identification, and native seed guides (including milkweed). We identified some resources that were currently available and linked to them in our online manager toolbox. We developed several other materials that were not yet in existence. We developed regionally appropriate Milkweed Guides, single-sheet handouts that may be given to road management crews to help them to identify milkweed growing in their roadside corridors and choose appropriate management actions, such as avoiding the application of herbicide to milkweed and planning mowing activity to avoid when monarchs are breeding in their locality. We developed a Monarch Butterflies, Weeds, and Herbicides resource sheet. Recognizing that road managers operate within single states, we have that facilitated information sharing across states, including case studies. We have also developed a set of frequently asked questions and answers to optimizing information sharing about best practices

Future Research Needs

There are several gaps in our knowledge where expert opinion was used to develop the project tools. To improve the tools over time, we've identified the following research priorities:

- Exploration of how field level habitat quality values (such as derived from the habitat calculator) and use of roadside areas by monarchs relate to the landscape factors depicted in the Landscape Prioritization Model.
- Milkweed and nectar plant abundance in various land-use types and regions of the US, and how these values relate to the habitat quality within road rights-of-ways in various regions
- Response of milkweeds, nectar plants, and monarch eggs and larvae to management practices, including mowing and haying at various times of year

- Differences in utilization of various species of milkweed by monarchs in roadside areas
- Quantification of traffic collisions (adult mortality) in relation to production of monarchs in roadside habitat (and in relation to traffic volume, speed, and surrounding habitat type)
- Chemical exposure risks to monarchs in highly agricultural or heavy traffic areas, e.g., >30,000 cars a day typical of highly urbanized areas (pesticides and vehicle/road chemical runoff/drift)
- Effective treatments of invasive species to enhance future restoration activities
- Economic studies on the short-, mid-, and long-range costs of implementing monarch/pollinator programs within a roadside management entity, which may be influenced by the upcoming proposed listing decision by USFWS for species listing under the Endangered Species Act
- Assessing the value of roadsides as important habitat corridors in "habitat deserts," such as areas in the Midwest that are dominated by agriculture

Recommendations

- We recommend that roadside management authorities use the landscape prioritization model to identify areas for monarch breeding habitat restoration or improved management where fewer threats to monarchs are posed.
- We recommend that roadside managers assess their roadside rights-of-way with the Rapid Assessment protocol to gain valuable information about the roadside areas they manage. This could take the form of an inventory of the habitat they manage, to find out the proportion of areas that provide high quality habitat, or to estimate the milkweed density their road system provides, or other similar objectives. Managers also may wish to compare the habitat characteristics for areas under different management regimes, such as modified mowing practices, or areas that have been restored with a particular seed mix. For all pre-, post-, and long-term restoration or improved management projects, assessment of the habitat builds a base of information that can be used in an adaptive management framework to improve benefit to monarchs and pollinators and cost-effectiveness of conservation practices.
- The habitat quality scores generated automatically by the habitat calculator may be used to identify high quality sites and sites where habitat could be improved.
- We encourage departments of transportation to use the decision support tools and best management practices information made available through our website to support their monarch conservation efforts. Educational objectives can be built into roadside management programs to engage diverse stakeholders, train management staff about how to properly maintain diverse native plant communities, and to increase awareness about monarch and pollinator conservation needs.

Conclusions

Land use changes have caused dramatic losses of habitat for monarchs across much of their breeding and migratory range. Roadside habitats provide a unique opportunity to influence habitat availability on a large scale (number of acres) and in distribution across the landscape. In some urbanized and agricultural parts of the monarch range, roadside habitats are a primary source of breeding habitat, and therefore increasing the abundance and quality of those critical areas is an important contribution to a larger strategy to conserve monarchs, other pollinators, other wildlife species, and to provide other important ecological services. It is possible that in these "habitat deserts" roadsides may act as important corridors or refuge areas during migration.

We have developed an initial set of tools and decision support mechanisms to support roadside managers in these efforts. This project reflects partnership between conservation organizations, universities, and roadside authorities to enhance the objectives of all parties by developing and improving strategies for monarch conservation. An 'all hands on deck' approach to conservation is needed to protect monarch butterflies, and this work assists transportation authorities in pursuing opportunities to implement proactive

and voluntary approaches to provide pollinator habitat in roadway corridors. In doing so, transportation agencies can also appeal to the growing public attention and calls for monarch and pollinator conservation.

Opportunities

Moving forward, we would like to pursue implementation to more widely promote the findings of this project through a) a well-designed, interactive website tailored to the needs of roadside managers, b) trainings in how to use the tools created, c) scientific writing regarding the outcomes of our field research, and d) more outreach and public relations around best management practices, case studies, and sharing of successes across states. This work has also highlighted opportunities for future research and assessment. For instance, future research needs have highlighted knowledge gaps with respect to mowing, adult mortality from collisions and the value of roadside corridors isolated from core habitat – all research topics that would benefit from agency-university interaction and collaboration. Our work has also identified a need for integrating our recommendation tools with the budget and labor needs of individual transportation agencies – for instance, determining the optimal course of action based on habitat calculator scores will depend on the agency. An agency with a low budget may invest in preserving the highest value roadsides, while an agency with a modest budget for restoration may invest in roadsides with high potential value, but current low to moderate habitat. As agencies begin to use these tools, there are many opportunities for assessment and refinement of the tools and recommendations.

This project has also created several opportunities with respect to broader conservation goals. First, while we have focused on monarchs, this species serves as a flagship species for many other species, both plant and animal, that support natural ecological functions. Preserving monarch habitat, and associated nectar plants and host plants (which are a great nectar plant for many insect pollinators) no doubt has beneficial impacts on hundreds of other species. This is particularly important given recent outcries of a pending "insect apocalypse" as negative effects of pesticide use, habitat destruction and climate change are leading to precipitous declines across over 40% of insect species (Sanchez-Bayo and Wychhuys 2019). Second, while this work has focused on roadside rights-of-way, many of the tools and recommendations are relevant to other types of rights-of-way. Rights-of-way alongside railroads, power lines, and gas lines also present valuable opportunities for habitat as they can act as habitat corridors and cover millions of acres across the country. There is overlap between outcomes of this project and management decisions related to mowing, landscape context, invasive species control, collisions, chemical exposure, and prioritization of sites for restoration. We hope that some of the general lessons learned in roadside management for monarchs can also be applied to conservation opportunities in other rights-of-way.

CHAPTER 1

Background

Monarch Butterflies and Pollinators

Globally, numerous insect species, including many pollinators, have experienced steep population declines (Beismeijer et al. 2006, Potts et al. 2010, Powney et al. 2019, Cameron et al. 2011, Goulson et al. 2015). In the United States, twenty-six butterfly and skipper species and eight bee species are currently listed as threatened or endangered under the U.S. Endangered Species Act (https://ecos.fws.gov/). The decline in pollinator numbers, their importance to natural and agricultural ecosystems, and the need for coordinated action to address this decline with expanded efforts to reverse pollinator losses was highlighted in a 2014 Presidential Memorandum (White House 2014).

The monarch butterfly (*Danaus plexippus*) is an iconic species garnering admiration and concern by residents throughout North America. Monarchs exhibit one of the most spectacular animal migrations (Urquhart 1976, Brower 1977). East of the Rocky Mountains in North America, monarchs migrate up to 4,500 km each fall to overwinter in high-altitude fir forests in central Mexico. West of the Rockies, monarchs overwinter in groves along the California coast. In spring, monarchs return to their breeding grounds, with several generations moving and breeding across most of North America throughout the summer. Migrating and breeding butterflies rely on nectar sources for food; to reproduce monarchs depend solely on larval host plants in the milkweed subfamily (primarily *Asclepias* spp.).

North American monarch populations have declined over the past two decades, an estimated 80% for the eastern population (Brower et al. 2012, Vidal and Rendón-Salinas 2014, Semmens et al. 2016) and 90% for the western population (Shultz et al. 2017; west of the Rocky Mountains), motivating range-wide conservation efforts. The United States, Mexico, and Canada have pledged to reverse declines by improving and expanding habitat (CEC 2008, Pollinator Health Task Force 2015). In 2014, the monarch was petitioned for listing under the U.S. Endangered Species Act. Among multiple factors including climate change, exposure to pesticides and other toxins, invasive species, disease, and predation (Stenoien et al. 2017, Malcolm 2018), habitat loss is implicated as a primary driver of the population decline (Flockhart et al. 2015, Thogmartin et al. 2017a, Thogmartin et al. 2017b). Two important components in monarch habitat are nectar sources for adult monarchs, provided by a wide variety of blooming plants that benefit pollinators in general, and plants for larval development, provided by plants in the milkweed subfamily (Apocynaceae: Asclepiadoideae). Demographic models of the North American eastern monarch population indicate that the breeding season is likely the phase of the monarch life cycle that contributes most to population dynamics (Flockhart et al. 2015, Oberhauser et al. 2017) and loss of milkweed in the core of its breeding range is implicated in the population declines (Pleasants and Oberhauser 2013, Pleasants 2017, Stenoien et al. 2018, Thogmartin et al. 2017a, Thogmartin et al. 2017b, Zaya et al. 2017). This has led to the goal of adding 1.3-1.6 billion stems of milkweed in the United States to increase the monarch population to sustainable levels (Pleasants 2017, Thogmartin 2017a). To reach this goal, habitat conservation is needed across all land use sectors (e.g., agriculture, developed areas, rights-of-way), not just in lands set aside for conservation (Thogmartin et al. 2017b).

Suitability of Roadside Rights-of-way as Habitat for Monarchs

Rights-of-way along roads, railways, and power corridors represent a vast opportunity to restore, enhance, and manage habitat for monarchs and other pollinators. There are over 1.2 million miles of roadsides in the US (Federal Highway Administration 2014), representing approximately 17 million acres of habitat (Ament et al. 2014); in some areas, roadsides comprise the only land easily available as a source of monarch habitat. In contrast to many other land-use types such as agriculture and developed areas, rights-of-way management priorities are largely compatible with providing pollinator habitat. Rights-of-way may provide suitable pollinator habitat if managed in ways that promote and maintain host and nectar plants (Munguira and Thomas 1992, Ries et al. 2001, Saarinen et al. 2005, Hopwood 2008, Skorka et al. 2013, Halbritter et al. 2015). Enhancing milkweed numbers in roadsides could significantly contribute to the goal of adding 1.3 – 1.6 billion milkweed stems and improve the accessibility of breeding habitat throughout the landscape. In addition, increasing flowering plants resources supports adult monarchs during both breeding and migration seasons.

Several studies have shown that roadsides can provide beneficial breeding and foraging habitat to monarchs and other pollinators (Ries et al. 2001, Saarinen et al. 2005, Hopwood 2008, Mueller and Baum 2014, Hanley & Wilkins 2015, Hopwood et al. 2015). Roadsides can also increase connectivity between larger habitat patches, which is likely to lead to increased monarch reproduction (Zalucki & Lammers 2010, Zalucki et al. 2015, Grant et al. 2018). However, there are risks associated with roads, including impacts of vegetation management, particularly mowing at times when monarch eggs and larvae are present (Monarch Joint Venture 2019). Mowing may be conducted for safety reasons, such as the regular mowing of the clear zone. While mowing for traffic visibility kills some monarch larvae, it also maintains open roadside habitat favorable for monarchs, and milkweed re-growth is heavily used by egg-laying monarchs (Alcock et al. 2016, Baum and Mueller 2015, Fischer et al. 2015, Haan and Landis 2019, Knight et al. 2019). Mowing is also used to control invasive species Invasives such as wild parsnip (*Pastinaca sativa*), Johnsongrass (*Sorghum halepense*), Phragmites (*Phragmites australis australis*), and sericea lespedeza (*Lespedeza cuneata*) can take over roadsides, often outcompeting the plant species needed by monarchs and other pollinators; control of these invasives often require mowing or herbicide treatments that have negative short-term consequences, but could prove beneficial (if invasives are controlled) over the long term.

Roads also present dangers to butterflies and pollinators (Munoz et al. 2015) including traffic collisions (Skorka et al. 2013, McKenna et al. 2001, Keilsohn et al. 2018), although these effects are likely to be more detrimental in areas of concentrated use during migration (Kantola et al. 2019, Tracy et al. 2019). Monarchs in roadside rights-of-way may also experience increased exposure to road salts (Snell-Rood et al. 2014), heavy metals (Lagerwerff & Specht 1970, Jaradat & Momani 1999), and insecticides applied to nearby agricultural or developed areas (Krischik et al. 2007, Hopwood et al. 2015, Mogren et al. 2016, Xu et al. 2016), any of which could present risks to monarch survival and development.

While roadsides include host plants and nectar plants for monarchs, concern exists that these plants may have less suitable nutritional quality for monarchs, given insecticide spillover from adjacent agriculture and runoff of heavy metals and salts from the road itself. Current research, although still unpublished, suggests that the majority of roadside milkweed is of suitable nutritional quality for monarchs (i.e., not toxic). Roadside sodium and heavy metals (especially zinc) vary with traffic volume and distance from road. Most metal levels are below what is toxic for monarchs. While sodium levels do reach toxic levels, this seems to be limited to milkweeds along the highest traffic roads and in the buffer zones that are often mowed just adjacent to the road. Screens for pesticides do find residues on at least a quarter of roadside milkweeds, however, the majority of the chemicals that show up in these screens are fungicides and herbicides. Current work is clarifying the presence of sublethal levels of neonicitinoids. Taken together, this work in progress suggests that most roadside milkweed, especially along the majority of roads (which are moderate to low traffic volume) harbor milkweed of suitable nutritional quality for monarchs.

In summary, threats along roadway corridors exist for monarchs and other pollinators, but in the context of the amount of habitat needed for recovery of sustainable populations, roadsides are of vital importance. As detailed in this report, we have developed tools including a landscape model and a habitat calculator to quantify variation in roadside habitat quality for monarchs and to assist managers in enhancing the value of these potential habitats.

Opportunities for Monarch Habitat in Roadside Rights-of-Ways

A growing number of transportation agencies have implemented pollinator habitat programs (e.g., Iowa Living Roadway Trust Fund, Illinois DOT Monarch Program, Monarch Highway, Ohio Pollinator Habitat Initiative; Figure 1 and Figure 2). In addition to these exemplary programs, we are finding great interest on the part of many other transportation authorities in providing monarch habitat in their roadways, through groups such as the Rights-of-Way as Habitat Working Group, facilitated through the Energy Resources Center (University of Illinois-Chicago). An example of this high level of interest is that more than thirty transportation and energy sector rights-of-way management entities are engaging voluntarily in the design of a Monarch Candidate Conservation Agreement with Assurances. This is a formal agreement between the U.S. Fish & Wildlife Service (USFWS) and land managers to engage in important conservation actions for the monarch butterfly (Cardo 2019). Another example of interest in the monarch butterfly is the participation by many state departments of transportation in the Mid-American Monarch Conservation Plan written by the Midwest Association of Fish and Wildlife Agencies (MAFWA 2018).

Figure 1. Examples of signs along roadways indicating pollinator projects in transportation rights-of-way.

There are several information needs associated with the interest in developing monarch habitat pollinator and butterfly habitat, from several states. Roadside managers need information to decide where to invest limited resources for maintaining and developing additional monarch habitat. Identifying and selecting priority candidate roadsides for conservation action requires consideration of more criteria than risks or benefits of immediate roadside features such as traffic volume, toxin levels, plant diversity, and habitat width. The value of roadside habitat to monarchs is also determined by the broader landscape context at local, regional, and national scales. For example, at the local level, proximity to arable fields could increase exposure to agricultural chemicals, but this risk might be counterbalanced by an overall lack of monarch habitat at a regional scale if roadsides are the only available habitat (even sub-optimal habitat can be better than no habitat).

. Thus, a nuanced understanding of how habitat availability, connectivity, and other abiotic and biotic factors can interact across local to regional to national scales is germane to effective monarch conservation. Managers who have a limited budget for investing in the creation or restoration of monarch habitat would like to know where and how to make the greatest impact per dollar spent. Determining where and how to augment habitat for monarchs in roadsides requires weighing environmental, logistical, and financial factors at multiple landscape scales, while also considering motorist safety concerns.

Figure 2. A roadside restoration project in Illinois, Illinois Department of Transportation (photo courtesy of Jack Pizzo).

Roadside habitat managers also need information about existing habitat within their roadside rights-of-way. Critical information about the availability of milkweeds and nectar plants within rights-of-way habitats is largely missing (but see Hartzler and Buhler 2000, Kasten et al. 2016, Pitman et al. 2018), both generally and specifically within roadside management authorities. In addition, there are no publicly available methods for managers to collect data for such habitat assessments.

Comparing roadside areas with scores would enable managers to use data to learn more about how various management actions affect the extent and quality of monarch habitat within their jurisdictions. For instance, mowing is needed to maintain safety strips along road margins and is used to control woody and invasive species. However, frequently mowed areas can have fewer species of blooming nectar plants (Halbritter et al. 2015). Many roadside management authorities are implementing reduced mowing practices particularly when monarchs are breeding in their regions to protect habitat for monarchs and other pollinators. These managers are interested in assessing the habitat characteristics created by such programs.

Providing roadside pollinator habitat, either through the creation of new habitat or support of existing habitat, requires identification of optimal best management practices to benefit monarchs, while reducing other impacts from invasive species, and minimizing costs. Historically and currently, roadside best management practices (BMPs) seek to optimize driver safety by providing obstacle-free visual corridors and unimpeded drainage. Roadsides are also managed for aesthetic appeal. Thus, wildlife habitat accommodations must be considered alongside safety requirements and aesthetic expectations (e.g. mowed vegetation). Best management practices have been developed for pollinator habitat in roadside rights-of-way (Hopwood et al. 2015, Hopwood et al. 2016a,b), and in this project we tailor those recommendations as needed for monarch butterflies, and make connections between these best management practices and the other tools for roadside managers.

Finally, roadside managers must consider the costs of different conservation actions and the scale at which they can be implemented. Selecting management practices that optimize positive impact over the largest priority areas requires assessment tools and consideration of multiple cost-benefit scenarios. For

example, a State DOT might assess roadsides for potential monarch habitat and identify some that fall into priority monarch conservation areas and pose minimal local risks to monarchs, but that currently have poor quality habitat. The DOT could then restore monarch habitat on these sites. Where this habitat is created, it might benefit monarchs, but because of the expense, the DOT might be unable to restore habitat on a broader scale, limiting overall benefits. On the other hand, the DOT might allocate funds or modify management practices to enhance existing habitat. Lower costs might allow for enhancements at a broader scale, with a larger net benefit to monarchs. Some DOTs have noted cost savings by reducing routine mowing of the entire ROW (but this is not always the case as other forms of weed control may be needed for instance). Reduced mowing (beyond the safety zone) can allow more wildflowers to bloom (e.g. Halbritter et al. 2015), which can benefit monarchs. For example, limiting mowing (beyond the safety/clear zone) to once a growing season (rather than the standard seven times), in the fall, along a stretch of highway I-10 in Madison County, Florida, reduced mowing costs by $1000 per mile and significantly increased wildflower abundance and diversity (Norcini 2014).

Tools for Roadside Managers

In this project, we developed a tool set to help rights-of-way managers to develop, assess, and manage monarch habitat. Work was focused on four main Products.

Product A: Landscape Prioritization Model for Roadside Habitat for Monarchs

The Landscape Prioritization Model for Roadside Habitat for Monarchs is a computer-based model that helps roadside rights-of-way managers to visualize roads in their state relative to landscape-scale factors that influence monarch habitat quality. When roadside managers are determining where to invest in creating monarch habitat in the roadside right-of-way, the Landscape Prioritization Model provides information about the surrounding landscape that may be used to rank roadsides according to their context. The model is a way to visualize various habitat functions in the landscape and could be used to target particular areas or set up a sampling scheme. It may be used to describe different settings into which restoration or habitat development practices could be implemented. The model uses publicly available national landcover, cropland, and road datasets in a Esri Geographic Information System (GIS). The latter requires an ArcGIS for Desktop Basic license with the Spatial Analyst extension. The model provides options for customization with more specific data. It is designed to be run at the state scale, and then managers may examine roadsides at the state, county, road system, or bioregional scale within states.

Product B: Rapid Assessment of Roadside Habitat for Monarchs

The Rapid Assessment of Roadside Habitat for Monarchs is a quick and simple data collection tool for roadside vegetation managers or other transportation professionals to assess current monarch habitat in their roadside rights-of-way. This tool enables managers to complete a brief (less than 20 min) survey on a mobile data collection device such as a tablet or smartphone or on paper, at specific locations or locations selected in a systematic (e.g., every ½ mile along a stretch) or random way to represent the road system of interest. The Rapid Assessment focuses on plants that provide monarch habitat (milkweed for reproduction and nectar plants for foraging), as well as threats and management in the right-of-way. Rapid Assessment data collected in Esri Survey123 directly feed into the Roadside Monarch Habitat Calculator to give Monarch Habitat Quality Scores for comparing sites across the assessed locations. These protocols may also be employed after management to assess effectiveness of conservation actions and over years to track the persistence of habitat through time.

Product C: Roadside Monarch Habitat Calculator

The Roadside Monarch Habitat Calculator is a data-driven scoring system that rates sites for their habitat quality for monarchs. This product can be used to evaluate existing roadside habitat quality for monarchs and also to evaluate the effectiveness of management actions after their employment. The calculator incorporates four functional components of habitat: breeding habitat (milkweed), foraging habitat (nectar plants), threats and context (roads, invasive species, and adjacent land use), and management (mowing and herbicide use). Each assessed site is given a Monarch Habitat Quality Score, which enables managers to compare sites within their state or road system. Managers can also view component scores for the four main functional components. The tool uses data collected in the Rapid Assessment; calculations are done automatically in Survey123, and results may be viewed in spreadsheet or map formats.

Product D: Best Management Practices and Decision Support

Decision support is a theme that weaves throughout our project. It drives the production of all of the products. We are focused on helping managers make decisions about habitat installation and management, as well as communications with their staff and public about these decisions.

Based upon information derived in the Landscape Prioritization Model or the Roadside Monarch Habitat Calculator on a given roadside's habitat score, context-specific management recommendations are needed to guide selection of best management actions to enhance and maintain habitat for monarchs and mitigate threats. While general guidelines for managing roadside habitat for pollinators are available, this information is often not accessible to roadside management practitioners. Based on our first annual meeting, we built a logical prototype of user-defined objectives and management actions. We developed that into a decision-support tree representing various decisions managers can make that affect their ability to provide monarch habitat in their rights-of-way. This can be used to orient managers to appropriate resources supporting each decision. Surveys, interviews, and webinars have provided information for us to share back out in web-based resources. Through a gap analysis, we identified areas where more decision support information was needed. For these areas, we developed simple, easy to read resources for print or web access, including an herbicide fact sheet, regional milkweed guides, and comprehensive list of frequently asked questions.

Tool Use Scenarios, Interactions between the Products

The Landscape Prioritization Model may be used to locate sampling areas for a manager who would like to sample roadside habitats with the Rapid Assessment. One could select roadsides representing low and high potential for habitat development according to the landscape model, and then sample randomly or systematically among them. Or, if one were interested in planting a high diversity monarch-friendly seed mix in one of several construction zones, then one could assess areas that appeared to be in close proximity to other habitat areas, or conversely to place habitat in an area where there appears to be a need for a patch of connecting habitat, consulting the best management practices provided through the project.

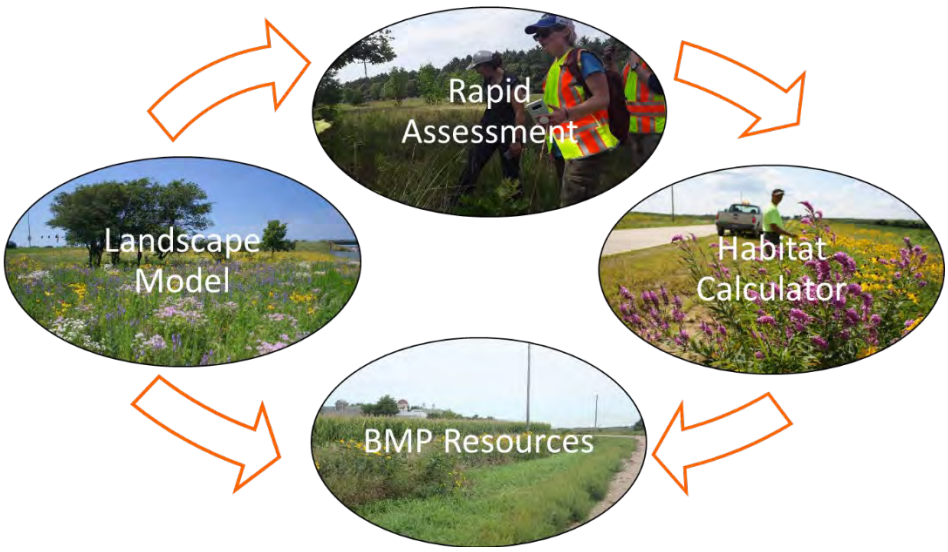

Figure 3. Schematic indicating relationship between components in this project.

Below is a flow chart (Figure 4) illustrating how the Rapid Assessment, Habitat Calculator, and Best Management Practices relate to one another. Secondly a schematic representation of the workflow process a manager might use in developing monarch habitat within their roadside corridors, using decision-support tools developed in this project (Figure 5; see Appendix A for full-sized .pdf).

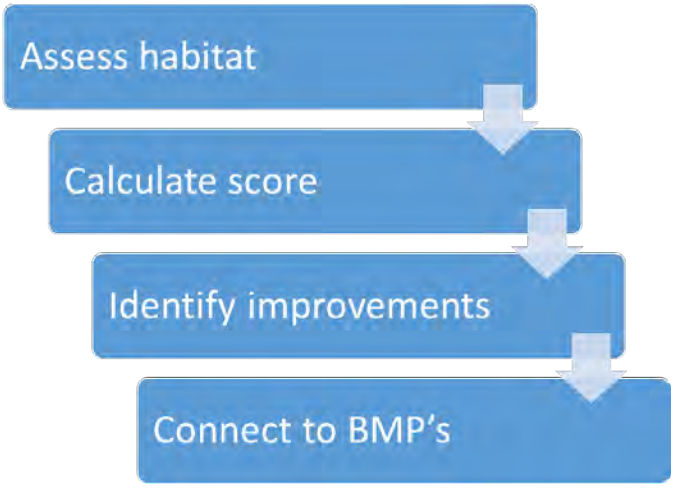

Figure 4. Flowchart illustrating the relationship among project elements: habitat assessment, habitat calculation and best management practices.

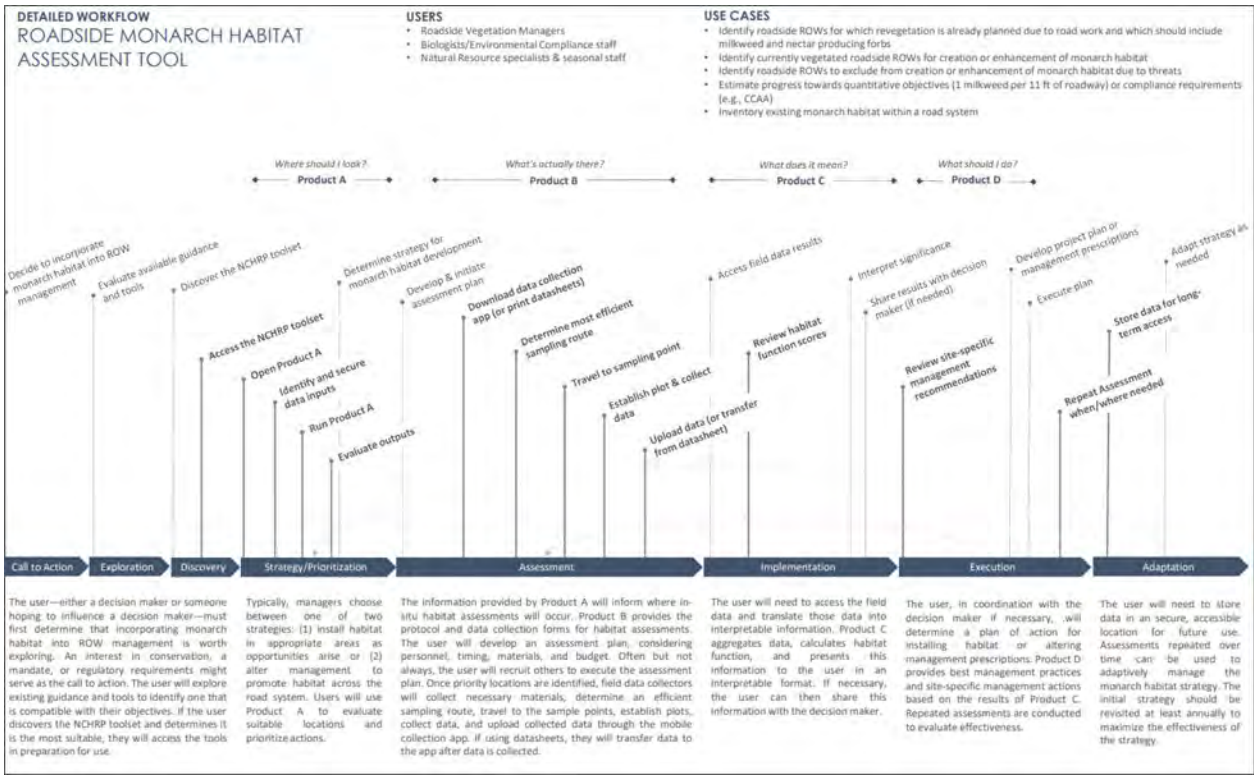

Figure 5. Workflow diagram illustrating how a manager may assess roadsides using tools developed in this project. See Appendix A for full .pdf.

CHAPTER 2

General Research Approach

Meetings

We held two Project Annual Meetings. First was the kick-off meeting (April 2017) with the Research Team and several advisors, incorporating both in-person and call-in participation. In March 2018, we held an Annual Meeting with the Research Team, Research Advisors, and Advisory Panel. We had in-person participation from 25 attendees and an additional 6 people calling in. In each of the Annual meetings we determined priorities for the next year of the project.

We also attended various professional meetings throughout the course of the project, where we have presented our ongoing work and engaged in outreach. Participation in meetings put us into communication with transportation departments, environmental organizations, and academics, giving us invaluable input to the project. We attended meetings of The Rights-of-Way as Habitat Working Group, a forum that meets twice a year, bringing together professionals from the transportation and energy sectors who share an interest in managing rights-of-way for habitat. Many of the participants in this group are focused on providing pollinator habitat, particularly for the monarch butterfly, in part because of its pending status under the Endangered Species Act. Here are some specific meetings where we spoke about this project:

- Wendy Caldwell – presented preliminary project details at the Rights-of-Way as Habitat Working Group – May 2017
- Alison Cariveau – included project within the Monarch Science Update at the Minnesota Pollinator Summit – September 2017
- Emilie Snell-Rood – "Potential for adaptation of pollinators to roadside habitats: effects of sodium and heavy metals." (related project), in a symposium on "Behavioral and physiological adaptation to urban environments." Society for Integrative and Comparative Biology - January 2018
- Alison Cariveau – "Monarchs and Roadsides: A Research Update" - the Rights-of-Way as Habitat Working Group – April 2018
- Jennifer Hopwood – "Merging Roadside Management and Pollinator Conservation"- AASHTO Committee on Maintenance Annual Meeting - July 2018
- Lauren Agnew (graduate student, Snell-Rood lab) spoke on the "Nutrition of roadside plants for pollinators" (related project) at the Minnesota Pollinator Summit – September 2018
- Alison Cariveau – "Roadside Habitat for Monarchs: Tools for Managers" – presentation at the Monarch Joint Venture Annual Meeting – November 2018
- Tim Mitchell (postdoc, Snell-Rood lab) spoke on the "Nutrition of roadside plants for pollinators" (related project) - University of Minnesota Center for Transportation Research Annual meeting - November 2018
- Jamie Pavona (Delaware Department of Transportation) – poster "Monarch Butterfly Rapid Assessment on Delaware's Roadsides" - Transportation Research Board meeting – January 2019
- Jennifer Hopwood included project in Best Management Practices for Pollinators training - Colorado Department of Transportation - May 2019

Webinars

Throughout the course of the project, we have engaged with our Advisory Council, Research Team, and a growing number of interested parties, particularly state departments of transportation through several webinars. These were opportunities to share progress on the project and to obtain feedback on various components of our work. We gave three webinars about the project:

- Project Update Webinar – October 2018
- Landscape Prioritization Model – May 17, 2019
- Roadside Monarch Habitat Evaluator – May 28, 2019

Survey of Transportation Managers

To guide the design of this project, we surveyed transportation managers to learn about their interest in pollinator habitat programs, their information needs, and the personnel resources that may be dedicated to habitat assessment. We created a 30-question survey about desired management tools in Qualtrics that we distributed to a network of roadside management authority representatives via email. (The survey was reviewed by the Institutional Review Board at the University of Minnesota and determined not to constitute human subjects research, therefore not requiring IRB approval.) The survey included questions about existing pollinator habitat programs and what types of information would be helpful for planning or implementing these programs. We included questions about the availability of data about factors that could influence pollinator habitat quality, including noxious weeds, salt applications, mowing regimes, and herbicide applications. We also inquired about their interest in tracking management practices. The survey captured information about personnel resources available for conducting habitat assessments, including the number of people and number of days they could spend assessing habitat, and the expected skill levels of the personnel relative to assessing habitat. Answers were mostly categorical with some free response. Results from the Survey are reported in Chapter 6.

User Profile Interviews

We became interested in gaining more in-depth information from managers who were already involved in pollinator habitat management within rights-of-way. We selected several managers to interview to learn about their data and decision support needs to augment the more general information we gained from our Qualtrics survey. We were also interested in fine-tuning the design of the Rapid Assessment and Habitat Calculator. In the winter of 2018, we interviewed four roadside managers with the following profiles:

- **Rob Roman** (Roadside Manager, Engineering & Secondary Road Dept., Linn County, IA) - Piloting a program to identify 1,000 miles of roadside for establishment and management of milkweed habitat.
- **Kayti Ewing** (Botanist, Environmental Division, Arkansas DOT) -Maintains 1,000 miles of 'wildflower routes', consults with landowners to install pollinator habitat on adjacent roadsides through the 'Operation Wildflower' program, and is working with District staff to identify areas where they can plant pollinator habitat and mow only once in the fall. Also working towards a CCAA with the USFWS.
- **Dan MacSwain** (Natural Resources Coordinator, Washington County, MN) - Negotiated a new rule to limit mowing/haying of roadsides in the county by adjacent landowners. Consults with engineers on seed mixes and revegetation designs.
- **Stephanie Dobbs** (Roadside Manager, Illinois DOT) - Implementing a reduced mowing program along roadside rights-of-way statewide. Planning to actively manage and monitor the center median of I-39 for monarch habitat to meet CCAA requirements.

Reviewing Existing Tools and Protocols

When developing the Rapid Assessment protocol, we reviewed existing assessment tools and monitoring programs. There are no other published rapid assessment methodologies for monarchs or for pollinators in roadsides. The most similar protocol was the Monarch Habitat Quantification Tool (Environmental Defense Fund et al. 2017), which is not rapid (i.e., requires a substantial time commitment), but can be used in roadsides. It includes milkweed and nectar plant quantification but does not contain other factors that we determined to be important in rating the suitability of monarch habitat in roadside rights-of-way, including the management factors of mowing, and pesticide application as well as threats from invasive non-native plant species. We reviewed pollinator scorecards and pollinator habitat rating systems (Table 1). We conducted our review in collaboration with the Rights-of-Way as Habitat Working Group (Energy Resources Center, University of Illinois-Chicago; http://www.erc.uic.edu/biofuels-bioenergy/pollinator-habitat/rights-of-way-as-habitat/), Metrics and Targets Taskforce (A. Cariveau, co-chair). We also sought consistency with large-scale monarch monitoring programs: Monarch Larva Monitoring Project (www.mlmp.org), and the Integrated Monarch Monitoring Program (IMMP; www.monarchjointventure.org/IMMP; Cariveau et al. 2019).

We began by reviewing the Environmental Defense Fund's Monarch Habitat Quantification Tool (HQT; Environmental Defense Fund et al. 2017, Anderson et al. 2017). The HQT describes habitat quality, including threats, based on the best available science regarding species' habitat needs, combined with habitat quantity to compute "functional acres." The purpose of the HQT was specifically to support the rating of habitat enrolled in the Monarch Exchange. While our project intent is quite different, the process of assembling a habitat quality calculation tool is very similar. Our intent is to provide roadside rights-of-way managers with the ability to score areas within their rights-of-way in terms of habitat quality for monarchs. In our interviews with transportation managers and background research, we identified important factors in roadside rights-of-way that were not incorporated in the HQT. In particular, the HQT does not include measures related to road characteristics, threats by invasive non-native plant species (weeds), or mowing and herbicide application practices that are commonly applied in the roadside corridor. Therefore, we designed a data collection protocol, the Rapid Assessment, that would provide data for all these categories (see Table 1), and then designed the Monarch Habitat Quality Calculator to seamlessly incorporate these data inputs.

Table 1. Pollinator or Monarch Habitat Assessment tools reviewed.

Name of Assessment Tool	Name of Organization
Solar Site Pollinator Habitat Assessment Form for Project Planning	Minnesota Board of Water & Soil Resources
Monarch Breeding Habitat Assessment Tool	University of Minnesota Monarch Lab
Pollinator Habitat Site Evaluation Rubric	Pollinator Partnership
Native Bee Conservation Pollinator Habitat Assessment Form and Guide	The Xerces Society for Invertebrate Conservation
Pollinator Habitat Assessment Form	American Transmission Company
Solar Site Pollinator Habitat Planning and Assessment Form (For site and seed mix planning/designing)	Pollinator-Friendly Solar Initiative of Vermont
Rusty Patched Bumble Bee Habitat Assessment Form and Guide	The Xerces Society for Invertebrate Conservation
Idaho Pollinator Habitat Assessment Form	The Xerces Society for Invertebrate Conservation

Farm Management Assessment Guide	Bee Better Certified- Xerces Society for Invertebrate Conservation
Monarch Habitat Quantification Tool	Environmental Defense Fund, Environmental Incentives, University of Minnesota Monarch Lab
The Pollinator Site Value Index (PSVI)	Hubert A. Allen, Jr. Michael R. Haggie, and Richard A. Johnstone
Application for Pollinator Friendly Garden Certification	Penn State College of Agricultural Sciences- Center for Pollinator Research
2018 Project Scoring Sheet- Pollinators	Wildlife Habitat Council

Expert User Testing

To further refine our tools, we knew it would be important to engage directly with several state departments of transportation to verify the Landscape Prioritization Model and field-test the Rapid Assessment and Habitat Calculator.

We worked with representative users from the Illinois, Minnesota, and Wisconsin Departments of Transportation. We arranged times to visit in person during the summer of 2018 (Figure 6). These visits entailed first a demonstration of the Landscape Prioritization Model for their state, and then selecting sites to field test the Rapid Assessment protocols. We selected high quality sites, such as prairie remnants, as well as sites where restoration activities had been completed, to gain further feedback and refine the protocols and range of data that would be encountered. We then went into the field with DOT teams to collect data using the Rapid Assessment, and then those data were put through the Habitat Calculator. These same states were also asked to download and run the scripts for assembling and running the Landscape Prioritization Model for their states within their state GIS system.

In addition to these visits, we engaged significantly with the state of Delaware, who completed a statewide inventory of monarch habitat in their state-managed roadside rights-of-way in 2018. We cooperated by providing the Landscape Prioritization Model, Rapid Assessment, and prototype of the Habitat Calculator. They successfully profiled more than 100 sites and presented their findings at the National Meeting of Transportation Managers in January 2019.

Field-testing with Biotechnician Crews

We employed field crews in Minnesota and Oklahoma to inform protocol development for the Rapid Assessment tool, to provide data inputs to calibrate the Habitat Calculator, and finally to test the final version of the Rapid Assessment and Habitat Calculator in 2018. Field study objectives included:

- learn about the feasibility and challenges in running the protocol
- record how long it took to conduct surveys
- obtain data to calibrate the Habitat Calculator
- collect monarch use data and compare it to habitat data

- validate data collected by these methods by comparing data collected by other protocols
- learn about the importance of landscape in the quality of habitat and the use by monarchs

To calibrate the Rapid Assessment protocol, we collected data from the same roadside sites using both our Rapid Assessment protocol and other more intensive protocols. In Minnesota, at a subset of sites, we took data using the Integrated Monarch Monitoring Program protocol for comparison to the Rapid Assessment methodology. Specifically, we compared results from the Rapid Assessment to those from the IMMP for milkweed densities, nectar plant species richness, and monarch observations (eggs and larvae). We were interested in whether both protocols yielded similar estimates for these key metrics, and in the correlation of measures from the two protocols. In Oklahoma, additional and comparative data were collected according to protocols of the Oklahoma State University research team (Baum, unpublished data). Between 2017 and 2018, modifications were incorporated to the Rapid Assessment protocol, based on feedback from the field experience, examination of the data collected, input from advisors to the project, and additional input from roadside vegetation managers through the survey. More about the data collected in field work is detailed in Chapter 4.

Figure 6. Conducting User-Testing of the Rapid Assessment with the Wisconsin Department of Transportation

We developed the *Roadside Monarch Habitat Calculator* in parallel with the Rapid Assessment. We designed the Habitat Calculator in the Esri Surveys123 environment as many departments of transportation already use Esri products, and programming may be done to automatically calculate from data from the *Rapid Assessment of Roadside Habitat for Monarchs* to generate a *Monarch Habitat Quality Score* for each assessed right-of-way site. Based on factors thought to be important in defining monarch habitat quality along roads, we group data measures under four functional components of habitat: breeding, foraging, landscape context and threats, and management. Function and measure weights were determined by the project work team through meetings and discussions regarding the relative importance of various habitat components. For each measure represented in the calculator, we developed point distributions (0-100 for each measure) to correspond with various levels in the scores. The development of scoring for each functional area is explained in Chapter 5.

CHAPTER 3

Product A: Landscape Prioritization Model for Roadside Habitat for Monarchs

Introduction

Roadside rights-of-way represent potential monarch habitat but not all areas are likely to be equal in terms of potential suitability for developing or maintaining monarch habitat. When managers are posed with options about where to focus limited resources for higher quality pollinator seed mixes, or where to adopt alternative management strategies designed to enhance monarch habitat, determining which roadsides are best for monarch conservation is a priority. Our objective was to develop a standardized roadside prioritization tool that helps state DoT's determine where to allocate effort towards monarch conservation.

The main purpose of the model is to provide DoT managers with a roadside monarch habitat suitability index to identify roadsides with the greatest potential to contribute monarch habitat and that they can use to compare and prioritize roadsides within a given area. Additionally, they may be able to locate areas where roadside habitat may complement high functioning surrounding habitats, or, conversely, to identify places where roadside habitat could be developed as a habitat corridor in areas where the landscape is providing little monarch habitat. If managers are interested in surveying existing habitat in their roadside rights-of-way, they could use the tool to select sample locations across the spectrum of roadside suitability index values. Finally, if the tool were used in conjunction with manual surveys of rights-of-way with the Rapid Assessment of Roadside Habitat for Monarchs tool, it could help target roads with high suitability index values but low actual habitat quality scores for enhancement through altered management.

This Landscape Prioritization Tool creates a suitability index using Esri ArcGIS software, widely used within the transportation management community. The tool integrates two sources of data: nationally available standard land cover data that are translated into monarch habitat and potential pesticide risk and roads data that are used to evaluate the roadside characteristics. Figure 7 illustrates the conceptual structure of the suitability index. Habitat for monarchs is a determined by potential for roadside to provide milkweed and nectar plants and augment adjacent habitat and increase connectivity in the landscape. Risks are determined by the potential exposure to chemicals from traffic and adjacent land use and risk of collision by cars. Here we describe each of those components and how the model integrates them to create the overall suitability index.

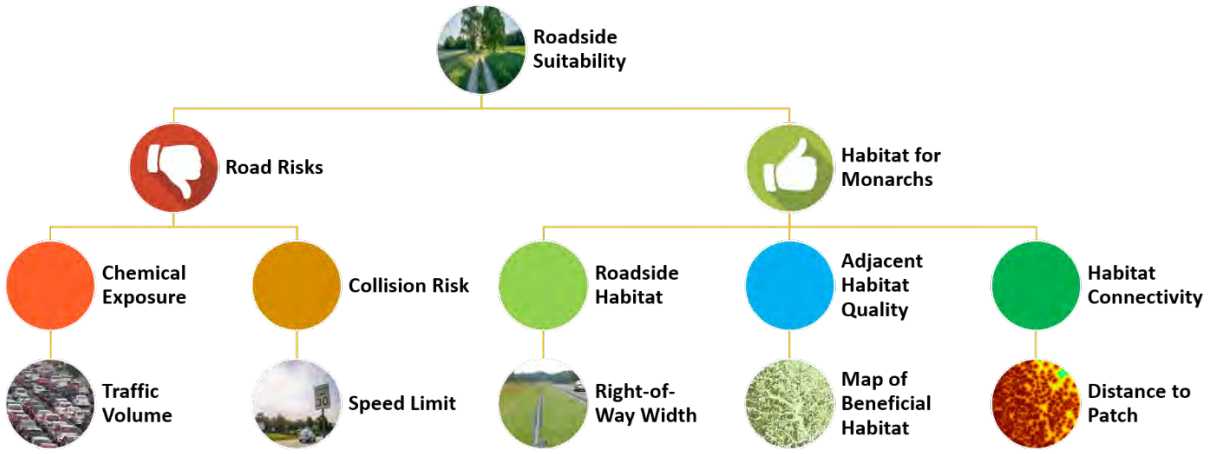

Figure 7. Logical structure and components of the roadside suitability index for monarchs.

Habitat Modelling

Monarchs require two types of resources, one for breeding and one for foraging, during the annual life cycle. Specifically, monarchs require milkweed plants for reproduction and nectar sources for foraging. The model uses land cover data and translates different cover types into milkweed density and nectar quality. We combined these two metrics in addition to potential exposure to pesticides to determine the overall quality of habitat for monarchs. While our goal is to develop a tool that can be used across the country, we could find no single land cover layer that could be used across the full range of the monarch range. Instead we developed separate approaches for the different ecoregions of the monarch (Figure 8): the northern core, the southern core and the western regions.

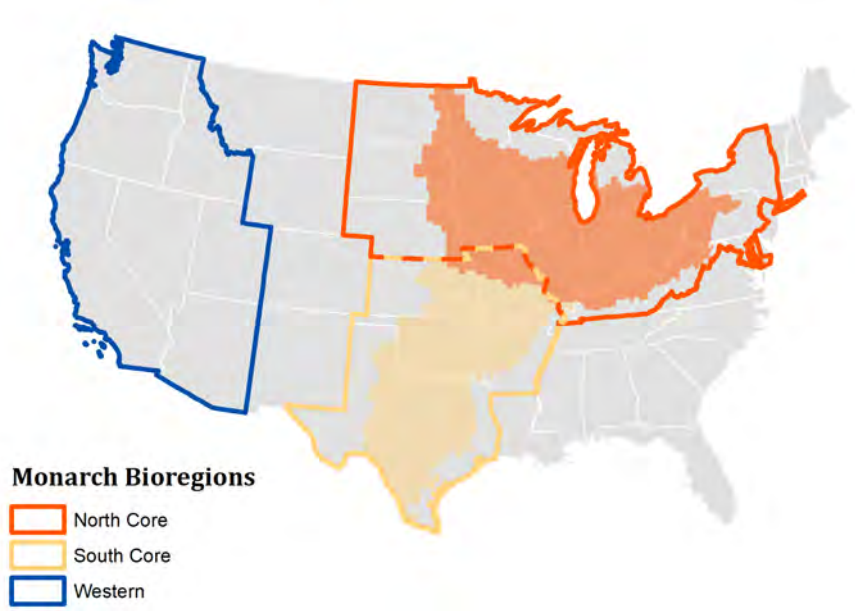

Figure 8. Monarch bioregions in our model, derived from Anderson et al. 2017 and Dilts et al. 2018.

Milkweed suitability

The ecoregions differ in how estimates for milkweed density are generated but estimates for nectar and pesticide exposure are the same across the ecoregions. In predicting milkweed stem density in the North Core, we used the USDA Cropland Data Layer (CDL) and, following work by Thogmartin et al. (2017), reclassified each land cover into an estimated milkweed stem density (Table 2, from Thogmartin et al. 2017). Thogmartin et al. (2017) used expert judgment to estimate how many milkweed stems would be expected to be found on different land cover types within the north core. The CDL classification for land cover works well in areas with mainly agricultural lands but not as well in areas dominated by pasture lands as the classification scheme does not differentiate pasture from grasslands or adequately capture variation in grasslands, e.g. the habitat within the south core. We are working to identify more appropriate land cover and then a reclassification scheme so that the same approach can be applied to the south core.

For the North Core, modelled milkweed stem density was converted to a **Milkweed Quality** map using a formula derived from Kasten et al. 2016 and Anderson et al. 2017 (Eq. 1, where M_i=milkweed quality on site i and m_{ij} =milkweed stem density per acre for site i from cover type j).

$$M_i = 1 - \frac{2}{1 + \exp\left(6 * \frac{m_{ij}}{2000}\right)} \quad (1)$$

The equation was based on the relationship between the per acre density of native milkweed stem and observed immature monarchs (eggs and larvae) on over 1000 randomly selected 50-meter swaths of habitat along roadsides in Illinois, Iowa, Minnesota, South Dakota, and Wisconsin (Kasten et al. 2016; Figure 9).

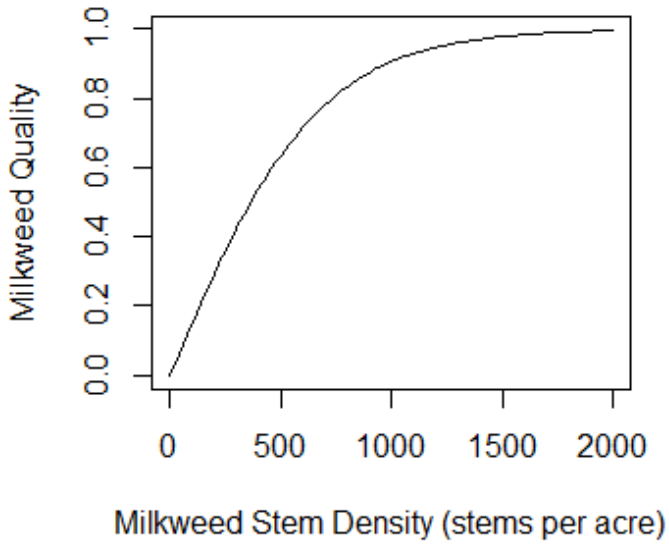

Figure 9. A representation of milkweed quality for breeding in relation to milkweed stem density (based on Kasten et al. 2016).

For the Western region, we use a separate milkweed habitat suitability map developed by Dilts et al. (2018) that uses observed milkweed data input into a habitat niche model. Their niche model replaces the expert judgment reclassification approach used for the used in the North Core model.

Nectar availability

We also used the USDA Cropland Data Layer (CDL) to predict nectar resources by reclassifying each land cover into an estimated nectar suitability, following work by Koh et al. (2016; Table 2). Koh et al. (2016) used expert judgment to estimate the suitability of floral resources for bees on different land cover types across the conterminous US using the CDL. When monarchs are stopping to forage, rather than travel for migration, they've been found to travel up to about 240 meters (Zalucki et al. 2016). We estimated **Nectar Availability** by calculating the average nectar suitability index within a 240 meter foraging radius.

We integrated nectar and milkweed suitabilities to develop an overall habitat quality map such that potential habitat quality on site *i*, q_i is:

$$q_i = M_i * N_i \quad (2)$$

where M is milkweed quality and N is nectar availability.

Pesticide exposure (E_i)

Pesticides, defined here as any chemicals added to control weeds, pests or fungi on agricultural lands, can potentially reduce nearby monarch habitat quality through unintended movement of applied chemicals. Based on the USDA Natural Resources Conservation Service's Monarch Butterfly Wildlife Habitat Evaluation Guide (USDA 2018), any habitat within 100ft (~30 meters) of a pesticide source has reduced habitat potential. While we know pesticide application and unintended drift is highly variable across crops and conditions during application, we wanted to minimize the risk of exposure in these areas. Thus, we predicted the potential source of pesticides as any cover type that is agricultural (Table 2). We assumed that the potential exposure and negative impact on habitat declined with distance.

As the CDL raster is at a 30m resolution, we used a conservative estimate of 60m (two CDL cells) was chosen to represent potential range of drift exposure. We assumed that if habitat was part of an agricultural land such that the raster cell is expected to have some milkweed and nectar sources, then exposure on site *i*, E_i, was 1, if monarch habitat was 30 meters away, i.e. a neighboring raster cell, then the exposure is 0.6, if habitat was 60 meters away, then exposure was 0.2 and 0 otherwise. A Euclidean distance function was used to calculate drift distance, to account for distance along diagonal cells.

Overall habitat quality (H_i)

Potential landscape habitat and exposure were combined to create an overall **Habitat Quality** index, and we assume that as potential exposure to pesticides on site i, E_i, increases the overall quality of a site should decrease. However, we also assume that pesticide drift does not fully remove habitat such that monarch habitat quality on site i, H_i, is:

$$H_i = q_i * \left(1 - \frac{E_i}{2}\right) \quad (3)$$

This function indicates that perfect monarch habitat would receive a score of 1 and terrible habitat would receive a score of 0.

Core habitat

The overall habitat quality index provides a potential suitability index for monarchs but does not indicate the type of habitat that would support a thriving monarch population. Thus we wanted to provide a

prediction of where potential "core" patches might be, patches that would represent areas of breeding monarchs. We took a conservative approach by assuming that core monarch areas are places that have suitability index score, H_i, of 0.95 or higher. The decision support tool generates core monarch habitat polygons and determines the distance to the nearest core patch. If important monarch areas are known, it would allow a DoT manager to load their own patches.

Roadside Potential

The second component of the roadside monarch habitat model is the roadside characteristics. The goal of this component is to apply conceptual logic about roads that maximize the potential benefits of creating habitat along roadsides while minimizing risks to monarchs.

Benefits

Our team identified three types of benefits: 1) direct habitat along a roadside; 2) the potential to augment habitat next to the road; and 3) the potential to connect to core habitat patches in the landscape.

Potential roadside habitat (A_i)

Here, we made the simple assumption that as the width of roadside rights-of-way (edge of pavement to the edge of DoT-managed area) increases, the potential habitat area increases. We not are aware of studies that precisely examine how rights-of-way (ROW) width affects monarch habitat use so instead apply our goal to minimize the risk associated with roadside habitat and the assumption that wider ROWs have the potential to provide habitat farther from traffic. We sought to capture the expected range of potential widths by using google earth to estimate the width of ROWs. With this approach we developed a relationship between roadside width of site i, w_i, and the potential habitat area along road i, A_i (Equation 4; Figure 10):

$$A_i = 1 - \frac{2}{1+\exp\left(\frac{w_i}{40}\right)} \qquad (4)$$

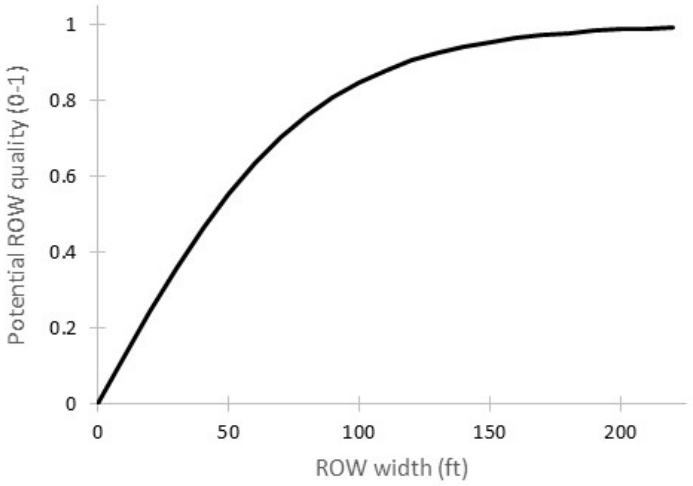

Figure 10. A representation of potential ROW habitat quality in relation to ROW width

Augmenting adjacent habitat (Q_i)

Roadside habitat has the potential to increase existing adjacent habitat and we assumed that as the quality of the adjacent increased the greater the benefit of the roadside habitat. We represented the quality of adjacent habitat around roadside *i*, Q_i, by calculating the average beneficial habitat within a radius of 120 meters, a distance derived from the single maximum step distance from Zalucki et al.'s (2016) paper on monarch movement.

Roadside connectivity (D_i)

Our research team suggested that roadsides that could provide additional supporting monarch habitat if they were closer to core habitat patches, such that the value of creating or maintaining monarch habitat would decrease as the distance to core habitat patches increases. Monarch movement studies by Zalucki et al. (2016) and Grant et al. (2018) suggest benefits would become negligible beyond about 9 miles (15 km). Using this logic, we created a distance decay function that is scaled from 0 to 1 and represents the benefit of connecting core patches from roadside habitat *i* to a core patch, D_i:

$$D_i = \frac{1.03}{1+0.9994^{\left(3.4 - d_{ij}\right)}}, \qquad (5)$$

where d_{ij} is the distance in miles between roadside habitat *i* and the nearest core patch *j* (Figure 11).

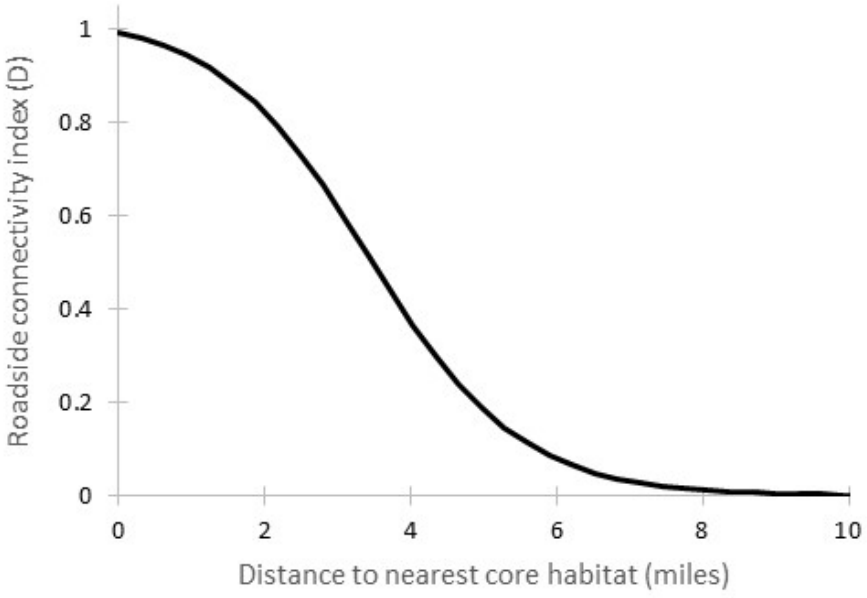

Figure 11. A model of a Roadside Connectivity Index relative to miles to nearest core habitat area

Risks

We identified two types of risks of roadsides – collision with vehicles and exposure to chemicals associated with roads.

Vehicle collision risk (V_i)

High quality habitat along roads can be beneficial but they could also bring monarchs close to vehicles and lead to mortality from collisions with cars. We assumed that as traffic volume increases, the risk of being hit also increases and that this risk is mediated by the speed limit of the road. McKenna et al. (2001) found that roadside mortality was higher with intermediate speed limits (between 15 and 55 mph). At slow speeds, monarchs can avoid cars and at higher speeds, the aerodynamics appear to push the monarch out of the way. We represent this logic by creating two relationships with traffic volume along roadside i, t_i, one for intermediate speeds and one with slow or fast speeds. We also assumed that collision risk along roadside i, V_i, increases with traffic volume (McKenna et al. 2001, Skorka et al. 2013, Soluk et a. 2011, Martin et al. 2018) up to an annual average daily traffic (AADT) of 26,000 where risk is maximized:

$$V_i = \begin{cases} \theta * \frac{t_i}{26000}, & t_i < 26{,}000 \\ \theta, & t_i \geq 26{,}000 \end{cases} \qquad (6)$$

$$\text{where: } \theta = \begin{cases} 1, & 15 < l_i < 55 \\ 0.8, & else \end{cases}$$

where l_i represents the speed limit (MPH) along roadside i.

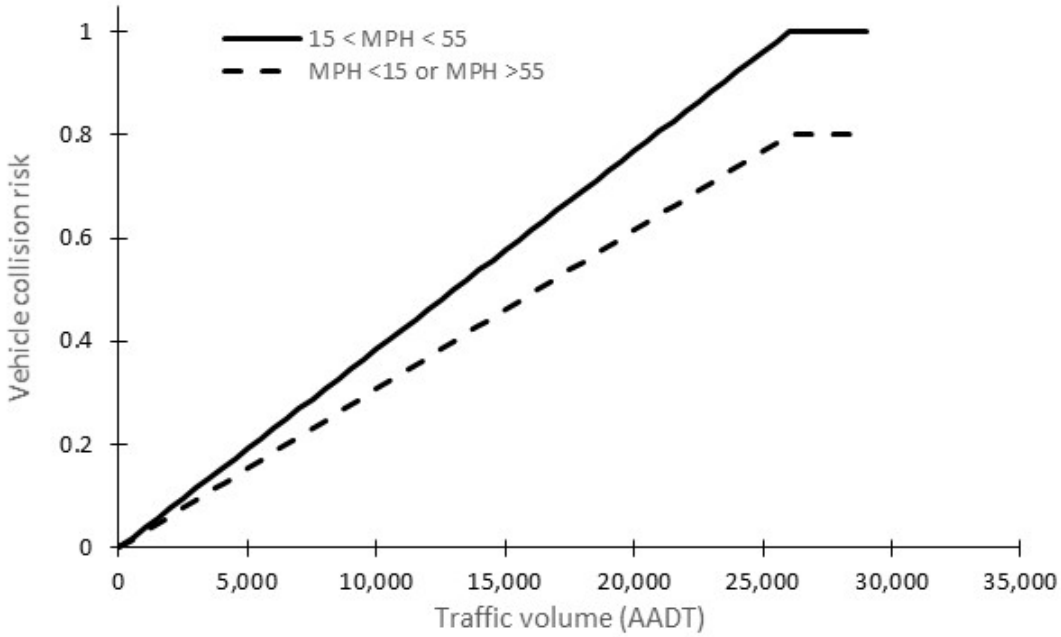

Figure 12. A model of vehicle collision risk relative to traffic volume

Chemical exposure from cars (C_i)

Emissions from cars have chemicals that could be toxic to insects (Bukowiecki et al. 2010, Carrero et al. 2013, Wang et al. 2014) so we included an additional risk to monarchs as a function of traffic volume. In addition, runoff from car wear-and-tear and road salt application creates additional chemical risks along high traffic roads (Snell-Rood et al. 2014, Lagerwerff & Specht 1970, Jaradat & Momani 1999). We assumed that as traffic volume increases, the potential exposure to chemicals that could be detrimental to monarchs foraging along roadside i, C_i, also increases:

$$C_i = \frac{t_i}{\max(t_i)}, \qquad (7)$$

where t_i is the average annual daily traffic along roadside I and the maximum value references the maximum traffic volume for the area of analysis, likely a state. This means the index will be scaled from 0 to 1, where 0 would be no traffic and 1 would be along the road with the highest traffic volume in the area of analysis.

Roadside suitability overall

Overall roadside suitability (R_i): We determined the overall Roadside Suitability Index by taking the average of the components of the habitat and roadside potential metrics separately and then weighting the two major factors (habitat and roadside potential) to calculate on overall weighted average. Our experts felt that the habitat factors were more important for the overall weighting than the roadside risks such that the overall roadside habitat suitability index for monarchs at road segment *i*, R_i, is:

$$R_i = \left(\frac{Q_i + D_i + A_i}{3}\right) * \frac{2}{3} - \left(\frac{C_i + V_i}{2}\right) * \frac{1}{3} \qquad (8)$$

where the first term represents the three components of the habitat quality metrics and the second term represents the two components of roadside potential.

Data sources

We used the U.S. Geological Survey's National Transportation Dataset (NTD) as the basis for all roadside analyses as it provides a standard source across the country. The National Map Feature Road Class (TNMFRC) attribute field in the NTD was used to predict right-of-way width, traffic volume, and speed limit (Table 1). We assumed that right-of-way width and speed limits are likely to be predicted by road type but we also recognize that they are likely to vary state to state (AASTHO 2001). We made the general assumption that traffic volume and roadside width increase with increasing road type, i.e. county roads have lower traffic volume and smaller roadsides than interstate highways (Table 2). We recognize that there is likely substantial variation in the observed data (Setton et al. 2005), however, so these are meant to be exploratory assessments. The tool allows users to override the basic reclassification of NTD road type by providing optional inputs if state-specific data are available. The NTD values remained the default coverage, replaced by the user-inputted roads only for overlapping coverage.

Table 2. Reclassification of NTD's TNMFRC field into ROW width, traffic volume, and speed limit.

TNMFRC (Road Classification)	Generalized Road Characteristics		
	Right-of-way Width (ft)	Traffic Volume (AADT)	Speed Limit (mph)
Controlled-access Highway	400	26000	75
Secondary Highway or Major Connecting Road	100	15000	55
Local Connecting Road	75	5000	45
Local Road	40	2600	25
Ramp	50	15000	45
4WD	20	1000	45
Ferry Route; Tunnel; Unknown	NA	NA	NA

Discussion

The national scale Landscape Prioritization Tool is designed to give transportation managers insight into which roadsides within a given area have the greatest potential to contribute to monarch habitat, whether through connectivity to other core areas, or because they are more suitable from a risk mitigation standpoint. Built with Esri ArcGIS software to foster usability, the tool combines national-level datasets, published literature, and expert opinion into a model that estimates monarch habitat quality across the entire landscape and relates those estimates to individual roadsides. The final output, a map of potential roadside suitability for monarch habitat, can be used by departments of transportation to optimally allocate habitat maintenance and restoration funds with the study area, or as the basis for more intensive roadside assessments such as those detailed later in this report. The landscape prioritization of roadside suitability tool provides information about the context in which roadside habitat exists. Further exploration about whether field level habitat quality values (such as derived from the habitat calculator) and monarch use relate to the landscape factors depicted in the model. Further research into the risks from roads (e.g., chemicals and collisions) could be structured using a sampling design from the landscape prioritization tool. The model provides road managers supplemental information to make decisions at scales ranging from individual counties to entire states.

CHAPTER 4

Product B: Rapid Assessment of Roadside Habitat for Monarchs

Background

The protocol includes information on road type, adjacent land use, management practices, forb species richness and percent cover, noxious weed presence and percent cover, and milkweed species richness and abundance (Table 3; field data sheet and protocol instructions provided in Supplemental Materials). We developed both a paper data sheet and an electronic data form that could be filled using a tablet or smartphone in the field.

Table 3. Habitat components (and data collected) for roadside right-of-way habitats using the Rapid Assessment.

Habitat Component	Significance	Measure	Categories
Road	Exposure to collisions, road salt, and chemicals from cars	Road Type	2 lane, 4 lane, > 4 lane
Landscape	Exposure to pesticides, proximity to existing habitat	Adjacent Land Use Type (within 100 ft)	CROP[1], HCR, DEV, HDE, WOOD, DIV, NDI, WET
Milkweed	Required host plants for monarch eggs and larvae	Milkweed Abundance (count plants or choose category)	0, 1-5, 6-10, 11-25, 26-50, 51-250, > 250
	Species richness may increase seasonal availability	Milkweed Number of Species	
Nectar	Required for adult monarch foraging	Potential Blooming Nectar Plant[2] (PBNP) % Cover	0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, >75%
	Species richness increases seasonal availability of nectar	PBNP Number of Species	
	Native species may have higher resilience, sustainability, and provide habitat to pollinators and other native organisms	Native PBNP Number of Species	
Weeds[3]	Threatens native milkweed and nectar plants; may require management that could temporarily remove habitat	Weed % Cover	0%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, >75%

	Greater species richness of weeds may require more and/or multiple control effort (s)	Weed Number of Species	
Herbicide Use	frequency of use	Herbicide use on site	none, spot treat noxious weeds, spot treat woody species, treat grass to stimulate forbs, broadleaf applied in clear zone 1x/yr; broadleaf applied in clear zone >1x/yr; broadleaf applied throughout the ROW[4]
Mowing	Mowing, at least temporarily, reduces nectar availability and destroys eggs and larvae; the width of frequently mowed areas impacts the amount of available habitat	Mowed width (ft)	
	Frequent mowing of the full width of the ROW reduces nectar availability and survival of egg and larval monarchs	Frequency of mowing full ROW width	never, every few years, 1x/yr, 2x/yr, >2x/yr, don't know
1. CROP=cropland, no barrier; HCR=Crop with woody barrier or hedgerow; DEV=Developed, lawn, or paved; HDE=Developed with woody barrier or hedgerow; DIV=Diverse grassland/natural habitat; NDI=Not diverse grassland with few forbs; WOOD=Woody habitat; WET=Wetland habitat 2. Potential Blooming Nectar Plants (PBNP) are forbs and shrubs that can provide nectar for monarchs or other pollinators, whether or not blooming on the survey date			
3. Weeds we define to be of management interest by the transportation authority; may include noxious weeds and other invasive species under active surveillance or management. 4. ROW = right-of-way			

The Rapid Assessment was designed in Survey123 for ArcGIS (Esri), which affords several benefits for roadside management authorities. States or other entities can collect, manage, and view their own datasets using their own Esri Enterprise account. The *Rapid Assessment* is installed within each agency's ArcGIS Online platform. It comes pre-populated with a comprehensive nectar plant list for their state (derived from the U.S. Department of Agriculture Plants database). Then managers may customize their assessment by selecting the noxious weeds they wish to track and set default answers regarding herbicide use and mowing practices, if desired. Within their own Survey123 website, transportation managers can view site locations, field data, and monarch habitat quality scores derived from data collected using the Rapid Assessments.

The electronic form of the Rapid Assessment provides the field user advantages such as the ability to automatically record the location, date, and time of the assessment. The survey also provides features such as a searchable drop-down list of plant species that enables one to type in letters from either the common name or the Latin name to select the species. There are also choices based on genera, such as "Solidago/goldenrod species" to lump plant species that are difficult to distinguish. The assessment is flexible in that observers may also tally plant types they cannot identify and choose to estimate milkweed plant abundance in categories rather than count individual plants (e.g., depending on the abundance of the milkweed and time constraints). We incorporated several factors identified as important to roadside managers, including the need to assess sites quickly and once per growing or monarch breeding season, the

ability to specify weeds of local or state importance, and the ability to specify the width of the area to be surveyed with regard to mowed areas, which we describe subsequently.

Given the strong preference of roadside managers for a protocol that could adequately characterize the habitat quality of a site in a single visit per year, we required a proxy for the availability of nectar throughout the growing season. We defined a term "Potentially Blooming Nectar Plants" (hereafter 'nectar plants') to describe forbs and shrubs that could provide nectar to pollinators (e.g., excluding grasses), whether or not blooming on the date of assessment. This broad categorization encompasses plants that may provide nectar, regardless of their nativity or the amount or quality of nectar they may provide. The number of nectar plant species may be important because a greater number of species may represent a greater number of bloom times and thereby provision nectar for a greater proportion of a season of monarch use or use by other pollinators. We identified plants to species when possible, and also estimated the aerial percent cover of nectar plants as a group. To make the protocol usable for people with varying skills in identifying plants to species, we included an option for tallying unidentified types of plants.

To accommodate variation in the list of invasive species, weeds, or non-native species of management concern from state to state, we created a customizable weed list. When transportation managers initially set up the protocol for their organization, they can populate a custom list of weed species they want to include in the assessment. Weeds of interest can be specified for each field assessment if important weed species vary across the jurisdiction. Observers will then report whenever those species are present on the assessment areas and estimate aerial cover for those species as a group to describe their prevalence.

Our survey of roadside managers indicated that the frequency and widths of mowing in the rights-of-way were highly variable; mowing the full right-of-way width was done multiple times per growing season to sometimes only once every several years. Some mow a safety strip (e.g., first 10-12 feet) monthly during the growing season, while others mow the strip only once per year (and some donot mow from May-July for wildlife and pollinators). Furthermore, some roadside managers expressed interest in using the Rapid Assessment to gain information about the effects of their mowing practices on pollinator habitat. Mowing is needed to maintain safety strips along the road margins, and also may be used to control woody and invasive species beyond the safety strip. Reduced mowing during the monarch breeding season is recommended to reduce direct mortality for monarch eggs and caterpillars and to preserve more plant blooms as nectar sources (Monarch Joint Venture 2017). Reduced mowing also can be associated with greater species richness of blooming nectar plants (Halbritter et al. 2015). However, mowing can also stimulate growth of new milkweed leaves preferred by egg-laying monarchs (Alcock et al. 2016, Baum and Mueller 2015, Fischer et al. 2015). In 2017, we collected data across the entire right-of-way. In 2018, after recognizing how difficult it is to assess vegetation in safety strips if they are frequently mowed (e.g., monthly or more), we collected data from the unmowed area. Ultimately, to accommodate regional variation in mowing practices, we allow managers or surveyors to choose whether to conduct their assessments in full rights-of-way, unmowed areas, or in mowed and unmowed areas separately.

Finally, because some departments of transportation were interested in monarch breeding activity in their roadside areas, we included optional data fields for recording monarch eggs, larvae, and adults. This section also includes a place to record the species and number of milkweed plants searched.

Rapid Assessment Protocol

Rapid Assessments are completed for a 45.7 m (150 ft) length of roadway, implemented at random locations or systematically (e.g., every mile or ten miles) in a road system (see protocol in Supplemental Materials). They may be combined to depict average conditions or to compare habitat quality among sites. Alternatively, sites may be selected because they are of interest to the observer, such as construction, restoration, or remnant native habitat areas. Upon arrival at a location of interest, the observer walks parallel to the road, toward traffic, pacing the 150 ft distance (Figure 13). Next, the width of the vegetated right-of-way (perpendicular to the road) is estimated (e.g., paced). These two distances bound the rectangular assessment area that extends from the road to the back of the right-of-way. The observer walks back through the right-of-way to the starting point, systematically zigzagging back and forth throughout the roadside habitat, while recording data. The observer records the number of milkweed plants by species, where stems separated by soil are counted as plants regardless of whether they are clonal or genetic individuals (following Kasten et al. 2016 and CEC 2017), the species or number of nectar plants (also notes for each species if it is blooming or not), and the presence of weeds (as defined by their roadside organization).

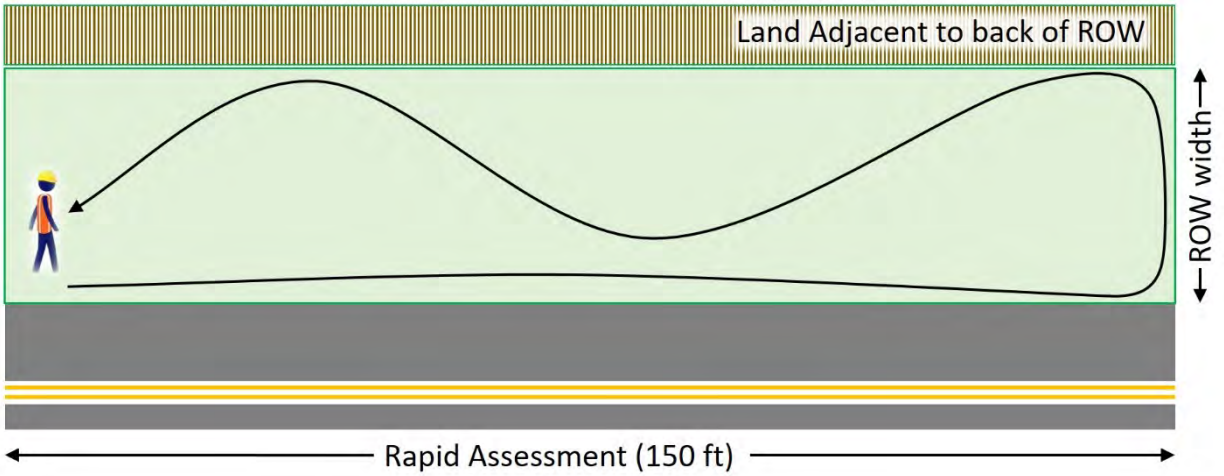

Figure 13. Depiction of a Rapid Assessment, showing how an observer moves from a starting point 150 ft along a roadside, systematically zig-zagging throughout the right-of-way to characterize habitat conditions.

Percent aerial cover is also estimated by classes for nectar plant species collectively and for weeds of concern. The observer records the dominant adjacent land use and mowing and herbicide application information. As an option, observers may examine milkweed plants by species for monarch eggs and larvae, recording the number of plants searched, and number of eggs and larvae detected. To maintain efficiency when milkweed is abundant, observers may choose to monitor every 2nd, 3rd, or 5th milkweed plant encountered to gain a sample size of 50-100 milkweed plants searched.

Integrated Monarch Monitoring Program Methods

IMMP sampling employs a total of 100 quadrats placed along ten transects arrayed diagonally from the road edge to the back of the right-of-way along a 400-500 m length of roadway (see Figure 13). Transects are 50 m in length and quadrats are placed every 5 m (however, in 2017, we placed quadrats every 2 m along 25 m transects, with 25 m between each transect). Quadrats consist of a 1.0 m by 0.5 m sampling frame placed to either side of the transect line for a 2.0 m by 0.5 m or 1 m2 quadrat area. Within each quadrat, observers count milkweed plants (same definition as above) to estimate milkweed density (milkweed plants/ha). All blooming plants are identified to species and assigned to the first subplot (area

within the quadrat) in which they occur (first 0.5 x 0.5 m, 1.0 x 0.5 m, or 2.0 x 0.5 m) to generate a frequency score (proportion of subplots occupied; not presented in this paper). Plants that are not blooming on the date of the assessment are not recorded.

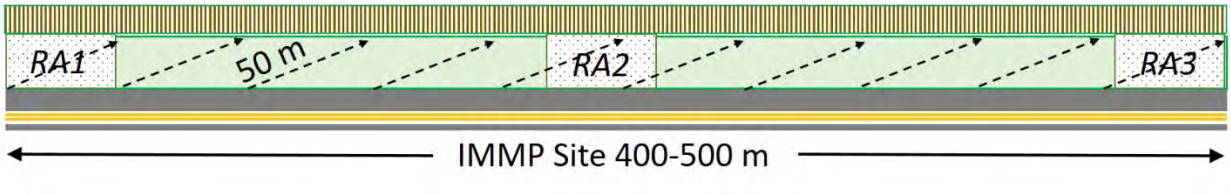

Figure 14. Overlay of Rapid Assessment (RA) and Integrated Monarch Monitoring Program (IMMP) for the comparison of protocols. The IMMP uses ten 50 m long transects arrayed diagonally 400 – 500 m along the roadway. In our comparison trials, 2-4 Rapid Assessments were completed for each IMMP site, typically established at the ends and middle of each IMMP site.

To account for the different sizes of the survey areas for each protocol, at each of these sites we completed one IMMP survey and typically three Rapid Assessments spaced 200-250 m apart within the footprint of the IMMP site (Figure 14). One site in 2017 had four Rapid Assessments and one site had only two; in 2018 three sites had only two Rapid Assessments.

Field Trials

The Rapid Assessment was tested in Minnesota and Oklahoma. In Minnesota we collected comparative data to allow the Rapid Assessment to be compared to the Integrative Monarch Monitoring Program, and to address specific questions about the interaction between landscape and roadside habitat and use by monarchs. In Oklahoma we focused on conducting a statewide survey, including evaluating the contributions of single or clustered sites.

Minnesota – Protocol Comparison

For 2017 field trials, we chose 14 sites from a set of randomly selected roadside sites in Minnesota that had been surveyed for milkweed and monarchs in 2015 (Figure 15; Kasten et al. 2016). We selected sites that contained milkweed in 2015. In 2018, we selected 15 new sites through the IMMP, which uses generalized random tessellated stratified sampling (GRTS) to identify random 10 x 10 km blocks and random point locations within them stratified by land use sector and prioritized to accommodate for variable inclusion probability (Cariveau et al. 2019). Sites in 2018 were randomly selected using the GRTS list of point locations; 13 sites were within the 15 highest ranked blocks in Minnesota (with vegetated roadsides at least 4 m wide) plus two additional sites within the 25 highest ranked blocks, for a total of 15 sites. Sites in both years represented variation in roadway types (except freeways which were excluded due to safety concerns).

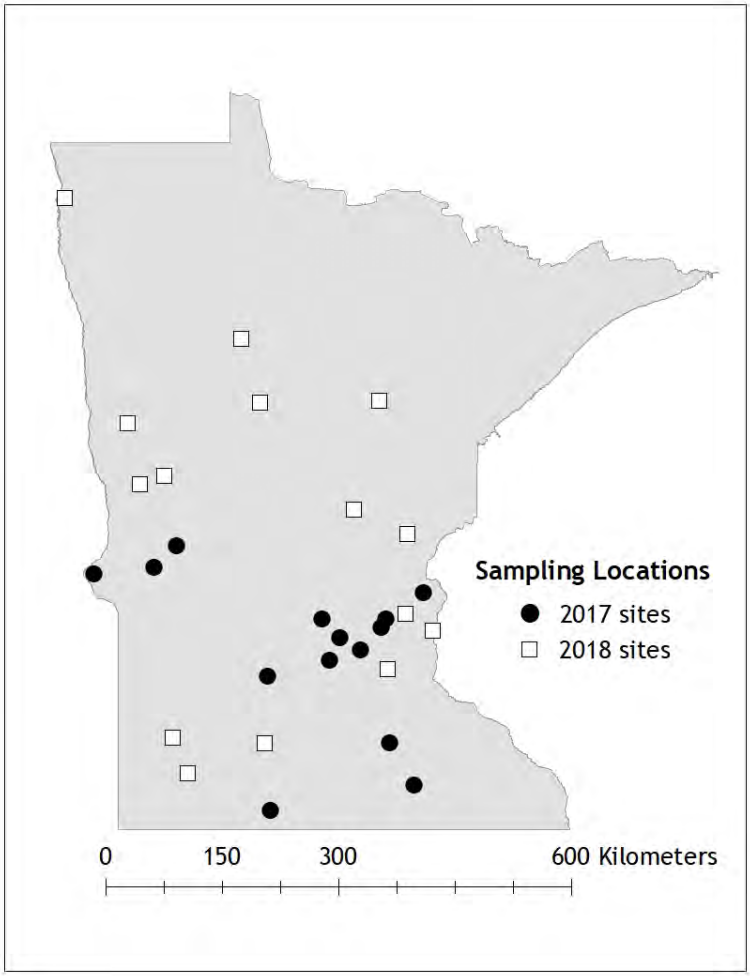

Figure 15. 29 field sampling locations in Minnesota where Rapid Assessments and Integrated Monarch Monitoring Program protocols were compared.

Minnesota - Broadscale Surveys

After refining the protocols based on the 2017 season, in 2018 we sent a field crew to locations throughout Minnesota to run Rapid Assessments. We had four primary objectives in the 2018 season.

Our primary objective was to determine how the habitat quality scores would be distributed through the Rapid Assessment protocol. To augment the Minnesota surveys, we also field-tested the protocol in several states and in cooperation with departments of transportation in order to incorporate their reviews.

We also addressed research questions regarding the interaction between landscape and roadside habitat and use by monarchs as follows:

- On sites that are adjacent to natural lands (i.e., not developed, not agriculture), and closer to habitat core areas,
  - Is milkweed more abundant?
  - Are the metrics representing nectar plants (potentially blooming plant species richness, native species richness, cover by potentially blooming plants, or blooming cover) higher?

  - Is cover by noxious weeds lower?
  - Is monarch use greater? In terms of distance to habitat core areas, does use of sites differ among close, near, and far?
- For all four metrics above, can we see any differences when comparing sites adjacent to developed, agricultural, and natural land-use types?
- Are density of milkweed or nectar plant indices inversely related to percent cover by noxious weeds?
- Are habitat calculator scores correlated to scores from the Landscape Prioritization Model?

We created a stratified-random process for selecting field sites to address questions about the relative importance of landscape context vs on-site vegetation characteristics in terms of predicting milkweed availability and breeding use by monarchs. We drew a sample of 15 sites in each of the categories below (36 categories) for a total of 520 samples. The sample of random sites was selected from a factorial of these types of roads:

- Road types / ROW widths
  - Local (2 lane; < 10 m wide)
  - Moderate (2-4 lane; 10-20 m wide)
  - Interstate (4+ lanes; > 20 m wide) – subject to permissions
- Adjacent Land Use:
  - cropland
  - developed
  - grassland
  - wooded
- Distance from Core Habitat Areas
  - Mainland (Adjacent to Core, within 1 km of core)
  - Stepping Stone (intermediate distance from Core Area)
  - Island (isolated from core area by at least 10 or 15 km)

Core metrics were: milkweed density, nectar plant species richness, % cover by potentially blooming plants, % area covered by blooms, % cover by native blooming plants; % cover by noxious weeds, and use by monarchs.

Statistical Analyses

We calculated milkweed plants/ha based on the number of milkweed plants counted (all species combined) and the area searched at each site and converted to hectares. For the IMMP, the area searched was 100 m2 based on the 100 1 m2 quadrats. For the Rapid Assessment, the area searched was estimated as 45.7 m (the length of the plot) multiplied by the right-of-way width.

We present monarchs/plant as the sum of all monarch eggs and larvae observed, divided by the number of milkweed plants searched. For the IMMP protocol, the number of milkweed plants searched differed from the number of milkweed plants in the density estimate, because observers could search additional milkweed plants between the quadrats to look for monarch eggs and larvae. We focused analyses on sites with at least 10 milkweed plants to ensure robustness of our density statistics (larvae/plant). We also estimated monarchs/ha by multiplying the average number of monarchs/plant times the average number of milkweed plants/ha using the IMMP method.

We present number of blooming species to represent species richness of blooming plants as an index of nectar resource availability. For the IMMP protocol, this is a list of all blooming species encountered in the quadrats. For Rapid Assessments, in 2017, we listed all of the blooming plant species encountered; in 2018,

we identified all of the potentially blooming nectar plants and noted whether or not plants were blooming. Here we present the blooming subset in comparison to the IMMP data. The nectar plant species lists across the several Rapid Assessments (RA) for each IMMP site were combined in two ways. First, the number of blooming species was determined for each RA, and then the number averaged across the several RA for each IMMP survey location; we call this RA averaged. Second, because of known relationships between species richness and area, we also depict the number of blooming species determined when summing the species across the RAs for each IMMP site (removing duplicates), which we call RA summed.

We computed statistics using R version 3.5.1 (R Core Team 2018). For milkweed plants/ha, and monarchs/plant, we compared the mean of the 2-4 Rapid Assessments to the IMMP measure for each site. To determine if protocol type had a significant effect on response variables, we ran generalized linear mixed models with year and protocol type as fixed effects and site as a random effect for each of the response variables of milkweed density, monarchs/plant, and number of blooming species ('nlme' package; Pinheiro et al. 2018). We report an interaction term for year and protocol type when significant. The sample size was 113 visits to 29 sites for the plant data; because we found no milkweed plants during 17 visits, the model for monarchs per plant contained 96 visits to 29 sites. For number of blooming species, we compared the estimates by the IMMP protocol to the RA averaged and RA summed in a generalized linear mixed model with year and protocol type as fixed effects, site as a random effect, and a year by protocol type interaction effect. For clarity, we also compare the numbers of blooming species by the IMMP protocol to the RA averaged and RA summed for each year separately. We also compared the mean of the Rapid Assessments per IMMP site to the IMMP measure with a Kendall Rank Correlation for each of the same response variables. We plotted data in Excel and ggplot2 (Wickham 2016).

Field Trials - Oklahoma

From 28 May through 18 June 2018, we visited 143 sites across Oklahoma with every ecoregion represented (Figure 16). The selected sites were a subset of those from a 2016 statewide milkweed survey. At each site either a single survey was conducted (73 sites) or three surveys were conducted approximately 500m apart (70 sites). We revisited a subset of sites in the Cross Timbers and Southern Great Plains ecoregions in July and August 2018. This subset consisted of 9 sites with three surveys and 11 sites with single surveys for a total of 38 surveys.

At each site we implemented the Rapid Assessment protocol, which included recording information about road type, mowed width, ROW width, and adjacent land use. We also estimated overall forb cover, flowering plant cover, and noxious weed cover based on the following categories: <5%, 5-25%, 26-50%, 51-75%, 76-95%, or >96%. The number of milkweed plants was also estimated in categories, including 0, 0-10, 11-50, 51-100, 101-500, or >500 plants for each species present at a site. We also recorded all forbs present at a site and indicated if they were flowering or not.

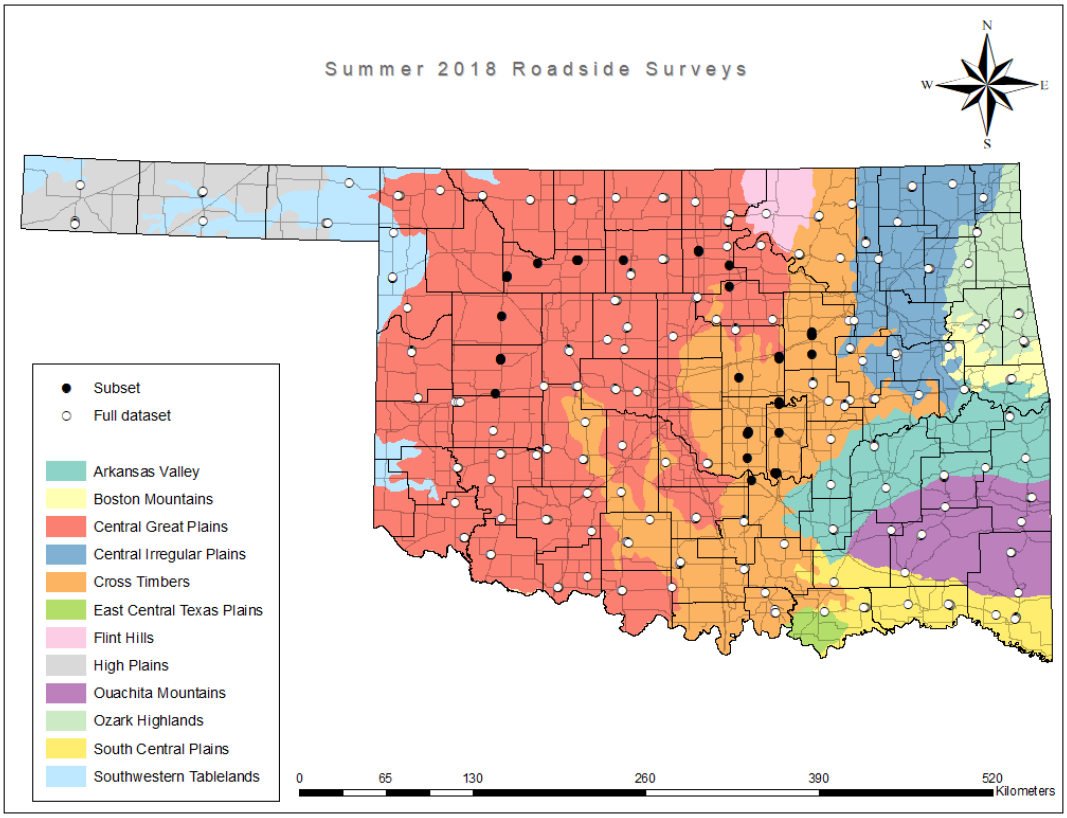

Figure 16. Map of Oklahoma with 143 visited sites indicated by the white and black circles. Sites were visited from 28 May through 18 June 2018. All 12 ecoregions, represented by color, were sampled in the full dataset. Solid black circles indicate a subset of 20 sites revisited in July and August 2018 within the Cross Timbers and Central Great Plains ecoregions.

The total time to complete a single survey, without including travel time, averaged 9 minutes (range: 0-39 min) (Figure 17a). The total time to complete a set of three surveys (located approximately 500m apart), including travel time between sites, averaged 45 min (or 15 min per single survey; range: 27-88 min). The average ROW width (calculated as mowed width (i.e., safety zone width) + ROW width) was smaller for 2 lane roads (10.5-201 ft; safety zone: 16.5 ft) than 4 lane roads (17-348 ft; safety zone: 20.7 ft) (Figure 17b).

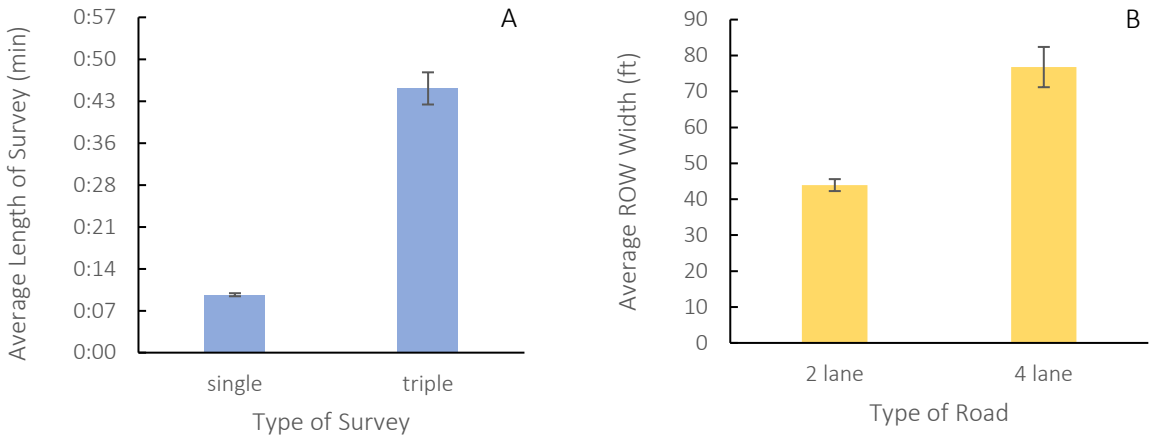

Figure 17. A) Average amount of time (min) to complete a single survey and triple surveys (located approximately 500m apart). B) Average ROW width (ft) for 2 lane roads and 4 lane roads.

Seven species of milkweed were recorded during surveys with green antelopehorn (*Asclepias viridis*) being the most common (40.93% of sites) (Figure 18). Clasping milkweed (*A. amplexicaulis*) and Englemann's milkweed (*A. englemanniana*) were the least commonly encountered milkweed species (present in <1% of surveys). No milkweed plants were observed in 53.74% of surveys.

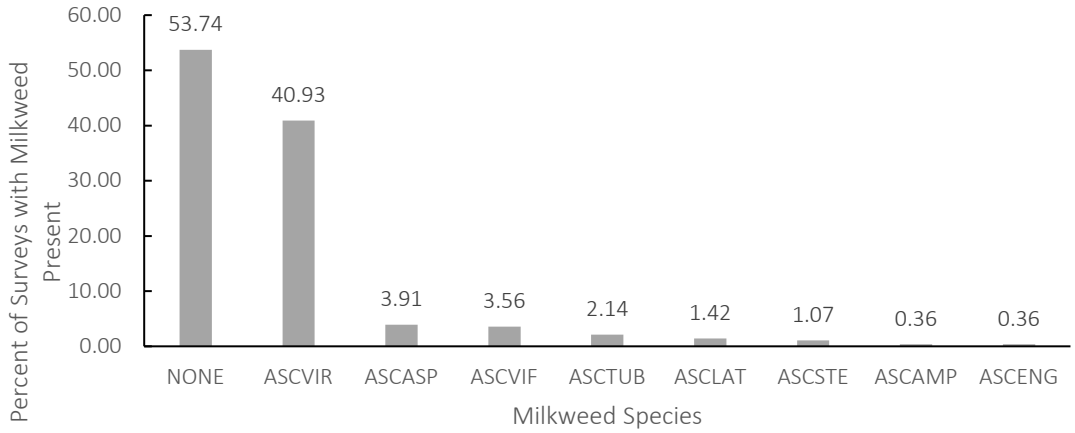

Figure 18. Percent of surveys with milkweed species present, by milkweed species. Milkweed codes are defined in Table 3.

Table 4. Milkweed species encountered during surveys with common names and codes.

Species	Common name	Code
Asclepias viridis	green antelopehorn	ASCVIR
Asclepias asperula	spider milkweed (antelopehorns)	ASCASP
Asclepias viridiflora	green comet milkweed	ASCVIF
Asclepias tuberosa	butterfly milkweed	ASCTUB
Asclepias latifolia	broadleaf milkweed	ASCLAT
Asclepias stenophylla	slimleaf milkweed	ASCSTE

Asclepias amplexicaulis	clasping or blunt leaved	ASCAMP
Asclepias engelmanniana	Engelmann's milkweed	ASCENG

Milkweed species richness was highest in roadsides adjacent to diverse grasslands and lowest in roadsides adjacent to cropland regardless of road type (Figure 19). However, the difference in species richness between the highest and lowest sites was only one additional species. When comparing the number of milkweed species observed among triple surveys, 40 sites had a different number of milkweed species among surveys, while only 8 sites had the same number of milkweed species among surveys. Thus, conducting triple compared to single surveys increased the number of milkweed species observed in approximately 83% sites.

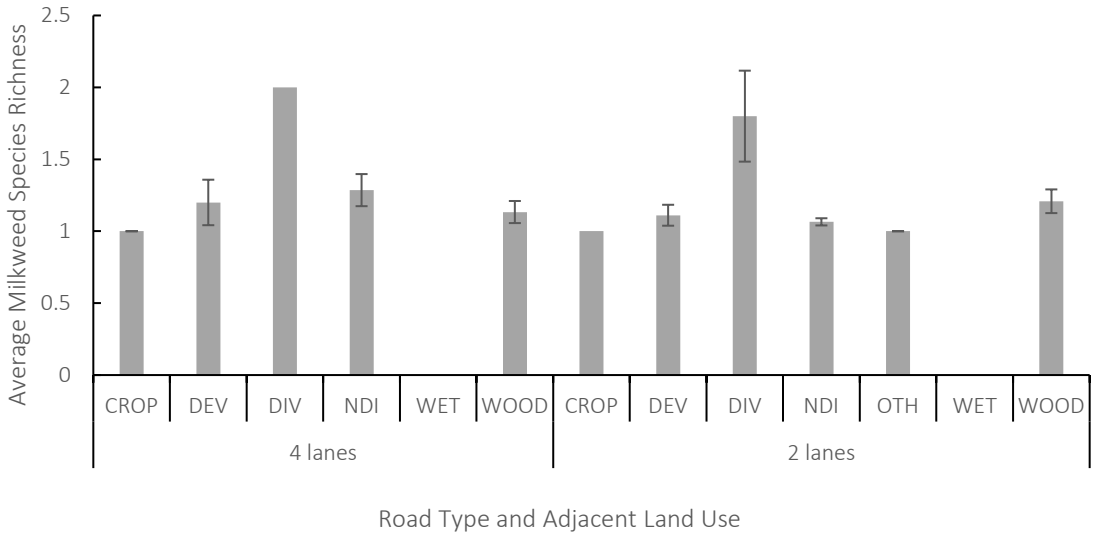

Figure 19. Average milkweed species richness by adjacent land use and road type. CROP= agricultural land, DEV= developed/industrialized land, DIV= diverse forb grassland, NDI= non-diverse forb grassland, WET= wetlands and/or water bodies, WOOD= prominently wooded/forested areas, OTH= other or not recorded.

Average forb species richness ranged from 7.5-14 species. The most common forb species encountered during surveys were fleabane species (*Erigeron* spp.) followed by green antelopehorn (*A. viridis*) (Table 5). Four non-native forb species were frequently recorded, including annual yellow sweetclover (*Melilotus indicus*), yellow salsify (*Tragopogon dubius*), prickly lettuce (*Lactuca serriola*), and curly dock (*Rumex crispus*).

Table 5. The most frequently encountered forb species during surveys. The native status of each forb is included.

# Survey Locations	Code | forb species | common name	Native?
126	Other - *Erigeron* spp.| fleabanes	Yes
114	ASVI2| *Asclepias viridis* | green antelopehorn	Yes
99	MEIN2| *Melilotus indicus* | annual yellow sweetclover	No

95	ACHIL| *Achillea* | yarrow	
92	Other - *Cirsium* spp. | thistles	
83	MINU6| *Mimosa nuttallii* | Nuttall's sensitive-briar	Yes
80	TRDU| *Tragopogon dubius* | yellow salsify	No
78	DAPU3| *Daucus pusillus* | American wild carrot	Yes
75	LASE| *Lactuca serriola* | prickly lettuce	No
74	COCA5| *Conyza canadensis* | Canadian horseweed	Yes
72	SOEL| *Solanum elaeagnifolium* | silverleaf nightshade	Yes
71	Unknown	
61	RUHI2| *Rudbeckia hirta* | blackeyed Susan	Yes
58	Other - *Plantago* spp. | plantains	
54	RUCR| *Rumex crispus* | curly dock	No
51	SOLAN| *Solanum* | nightshade	
50	HELIA3| *Helianthus* | sunflower	Yes

Field Surveys with Multiple Protocols

In 2017, 14 sites were assessed between June 29 and August 22. All sites were located along paved roads, eleven along 2-lane roads, and three along 4-lane roads. Eight sites were adjacent to cropland, with two sites each by woodland, grassland, and developed land. Right-of-way widths from the Rapid Assessments varied from 3 m to 21.5 m (mean = 12.35 m, standard deviation (SD) = 3.71); widths were not recorded by the IMMP protocol in 2017.

In 2018, 15 sites were surveyed between July 23 and August 29; all sampled sites were along 2 lane roads; 12 were paved; 3 were dirt/gravel. In 2018, adjacent land uses included: cropland (7), woodland (3), grassland (2), and wetland (3). The widths of the rights-of-way by Rapid Assessments varied from 5 to 52 m (mean = 14.07, SD = 12.79). The average width of the rights-of-way in 2018 recorded by the IMMP was 9.43 m (SD = 3.70, range 3.5–19.5 m).

Single Rapid Assessments took an average of 22 minutes in 2017 (SD = 15 min; range 4 – 88 min) and 20 minutes in 2018 (SD = 12 min; range 5 – 59 min). IMMP visits took 134 minutes on average (SD = 67 min; range 68 – 345 min) in 2017 and 167 minutes in 2018 (SD = 56 min; range 92– 274 min). Variation in the duration of visits was likely related to the number of nectar plant species present and the number of milkweed plants counted and examined for monarch eggs and larvae.

Milkweed density

We detected milkweed at all sites in 2017 and 14 of the 15 sites (93%) in 2018 using the IMMP protocol. The vast majority of milkweed was *Asclepias syriaca* (common milkweed; 96%); other species were *A. incarnata* (swamp milkweed, 3%), *A. verticillata* (whorled milkweed, 0.69%), *A. sullivantii* (Sullivant's milkweed, 0.2%), and *A. tuberosa* (butterfly weed, 0.01%). The mean milkweed density for all species of milkweed combined using the IMMP protocol was 1242 plants/ha (SD=1303) in 2017, 2807 plants/ha (SD=4864) in 2018, and for both years combined: 2052 plants/ha (SD = 3639; median = 800; range 0 – 18000) (Figure 20a). Averaging the Rapid Assessments per site, the mean milkweed density for all species of milkweed across sites in 2017 was 1508 plants/ha (SD=2082), 1545 plants/ha (SD=2377) in 2018, and 1527 plants/ha for years combined (SD = 2199; median = 625; range 0 – 8966). Milkweed density did not vary with year ($t_{27}=0.415$, $p=0.681$) or survey type ($t_{83} = -0.639$; $p=0.524$, $df=83$). Milkweed density as

estimated by the two protocols was correlated (Kendall's rank correlation tau = 0.568, z=4.257, df=27, p<0.001; see Figure 21).

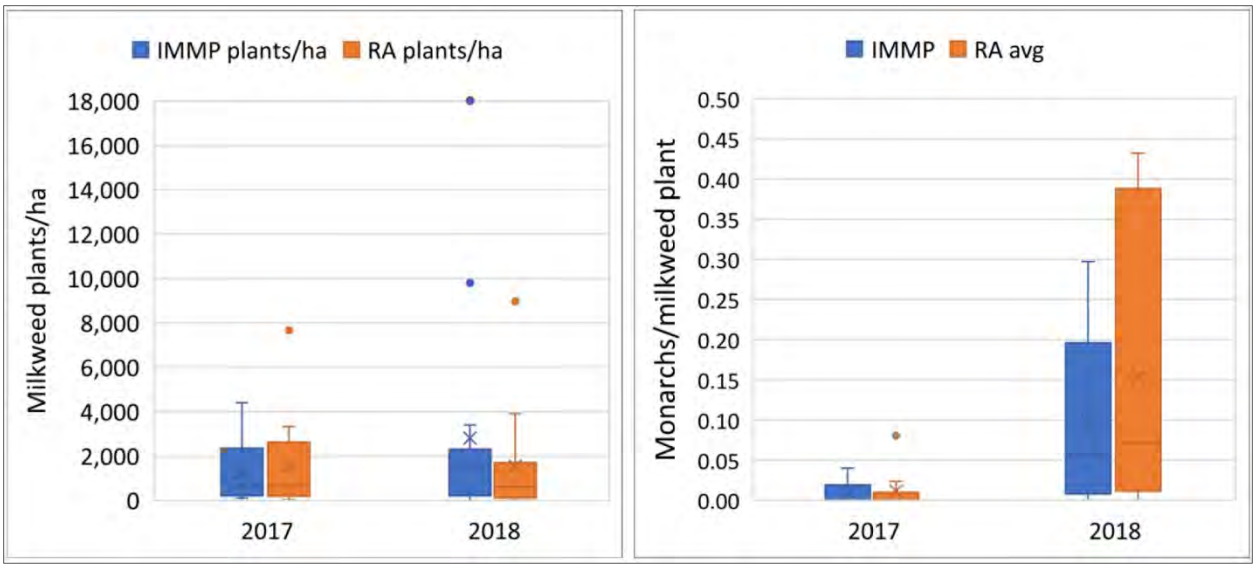

Figure 20. A) Mean milkweed density (plants/ha) and B) mean monarch eggs and larvae per milkweed plant with two sampling methodologies, IMMP and averaged values for 2-4 Rapid Assessments. Mean values are indicated by the 'x'; median values by a horizontal line, boxes indicate 25 and 75% quartiles, bars indicate the upper and lower quartiles, and outliers more than 1.5 the 75% quartile are depicted by dots.

Monarch eggs and larvae

The mean number of milkweed plants searched for monarch eggs and larvae in 2017 was 40.93 (SD = 47.66) with the IMMP and 76.11 (SD = 91.15) with the Rapid Assessment (RA) (Figure 20b). In 2018 the mean number of milkweed plants searched for monarch eggs and larvae was 113 (SD = 134.48) with the IMMP and 36.27 (SD = 44.38) with the RA. In 2017, using the IMMP method, monarch eggs or larvae were found at 6 of 14 sites (43%); with the RA monarch eggs or larvae were found at 7 of 14 sites (50%). In 2018, using the IMMP method or the Rapid Assessment, monarch eggs or larvae were found in 11 of 15 sites (73%), or in 11 of 14 sites containing milkweed (79%). If considering Rapid Assessments independently from one another, then in 2017, monarch eggs or larvae were found in 11 of 42 (26%) Rapid Assessments or 11 of 37 (30%) sites with milkweed. In 2018, monarch eggs or larvae were found in 19 of 42 (45%) Rapid Assessments or 19 of 30 (63%) sites with milkweed.

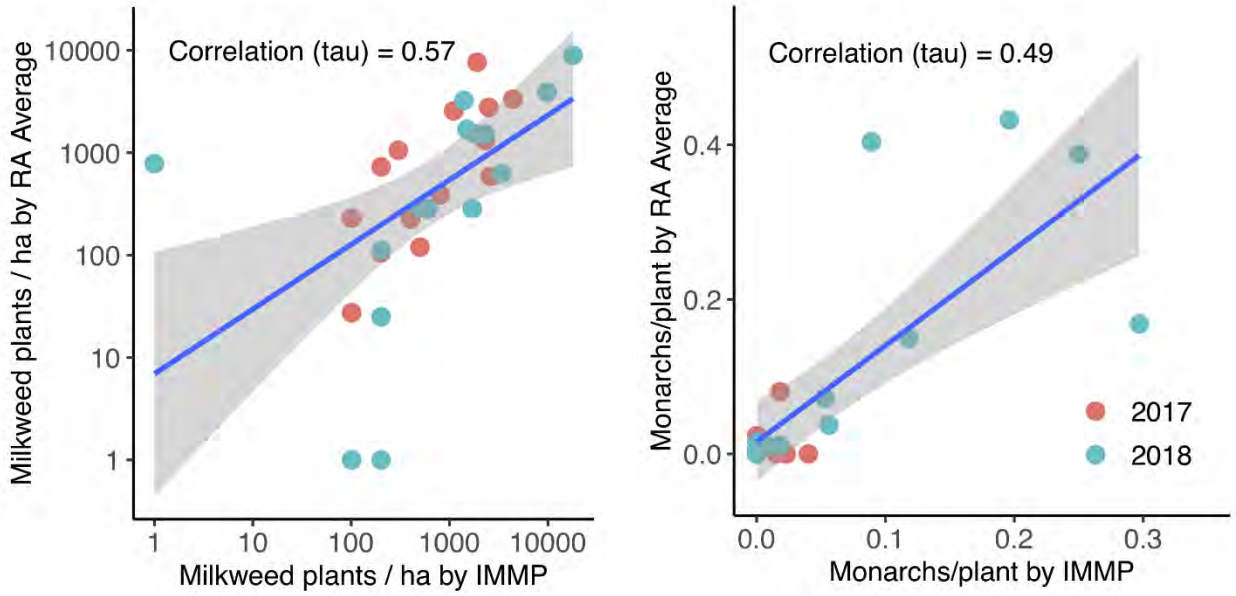

Figure 21. A) Comparison of milkweed density (milkweed plants/ha), log_{10} transformed, for sites monitored in 2017 (red) and 2018 (blue), using the IMMP and Rapid Assessment (RA) averaged for each site. 95%CI indicated in gray. B) Monarch eggs and larvae per milkweed plant searched (monarchs/plant), log_{10} transformed, for sites monitored in 2017 (red) and 2018 (blue), same two methodologies.

When restricting our analysis to sites with at least ten milkweed plants examined by each protocol (10 sites), in 2017 monarch egg or larvae were found at 40% of the sites with the IMMP protocol and 50% with the RA protocol (summed per site). In 2018 (n=11 sites with at least 10 milkweed plants examined by each protocol) monarch eggs or larvae were found at 82% of the sites with the IMMP protocol and 91% with the RA. In 2017, monarchs/plant with the IMMP protocol was 0.010 (SD =0.014) and 0.011 (SD = 0.025) with the Rapid Assessment. In 2018, the mean number of monarchs/plant was 0.099 (SD = 0.105) with the IMMP and 0.153 (SD = 0.173) with the RA. For monarchs/plant, year was a significant factor (t_{27}=2.373, p=0.025) with more eggs and larvae found in 2018 than 2017, but protocol type did not have a significant effect on monarch density (t66= 0.118; p=0.906). Monarchs/plant measured with the two protocols were correlated (Kendall's rank correlation tau = 0.489, z = 2.71, p= 0.007; see Figure 21B). An estimate of the average number of monarch eggs and larvae per ha, using the overall IMMP mean was 115 monarchs/ha (2052 plants/ha*0.056 monarchs/plant) across both years. For 2017, the estimate was 12 monarchs/ha (1242*.01) and for 2018, 253 monarchs/ha (2807*.09).

Blooming nectar plants

The average number of blooming species per site in 2017 was 6.71 (SD=4.50, range 1–18) with the IMMP protocol, 6.72 (SD=2.56, range 1–12.33) with RA averaged, and 12.14 (SD=4.45, range=5-19) with RA summed (Figure 22). In 2018, the average number of blooming species per site was 10.40 (SD=6.40, range=1-23) with the IMMP protocol, 6.57 (SD=2.85, range 2 – 11.33) with RA averaged, and 12.00 (SD=5.35, range=1-20) with RA summed.

Comparing the number of blooming species by IMMP to the Rapid Assessments (taking each RA independently as in milkweed and monarch analyses), the significance of the factors in the model was as

follows: year (t_{27}=2.33, p=0.027), protocol type (t_{82}= -0.047; p=0.963), and protocol type by year interaction (t_{82}= -2.86; p=0.005). In 2017, the number of blooming species estimated by IMMP did not differ from the RA averaged (t_{26}=0.007, p=0.995), but was lower than the RA summed (t_{26}=6.247, p<0.001). In 2018, for the same comparison, IMMP results did not differ from RA summed (t_{28}=1.532, p=0.136), but were higher than RA averaged (t_{28}=-3.463, p=0.002).

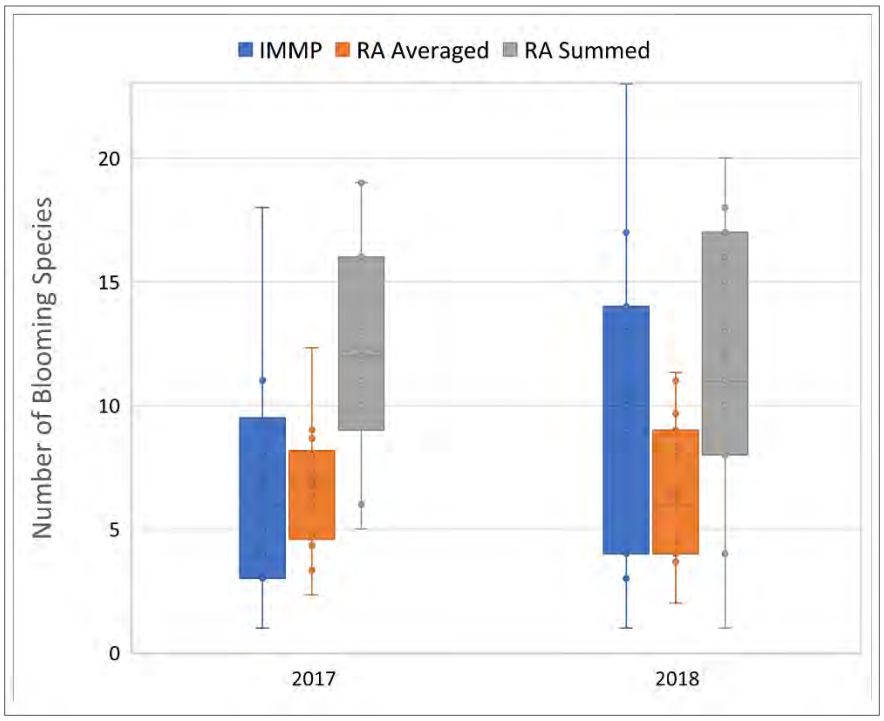

Figure 22. Mean number of blooming species as estimated by IMMP, averaging across Rapid Assessments (RA averaged) per IMMP site, and summing across RA per IMMP site. Mean values are indicated by the 'x'; median values by a horizontal line, boxes indicate 25 and 75% quartiles, and bars indicate the upper and lower quartiles.

In 2017, the number of blooming species by IMMP protocol was correlated with RA averaged (Kendall's tau=0.457, z=2.22, p=0.027) and RA summed (Kendall's tau=0.568, z=2.684, p=0.007; Figure 23a). In 2018, the number of blooming species by IMMP protocol was correlated with RA averaged (Kendall's tau=0.617, z=3.105, p=0.002) and RA summed (Kendall's tau=0.596, z=2.967, p=0.003; Figure 23b).

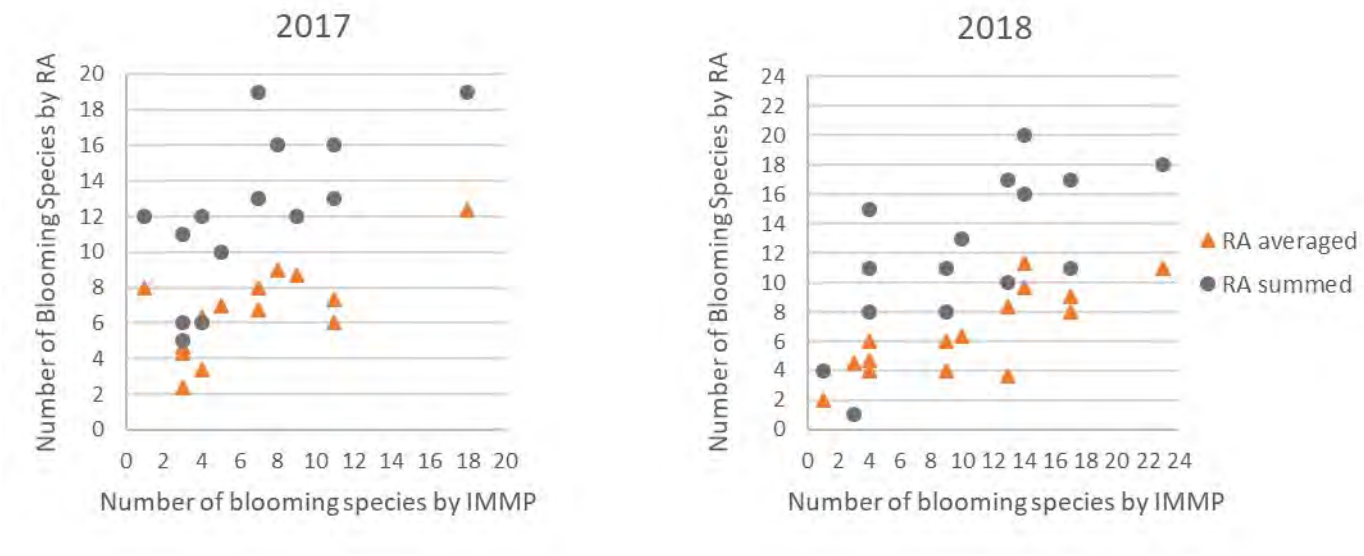

Figure 23. Number of blooming plant species in 2017 (A) and 2018 (B) comparing data by RA averaged (in orange) or RA summed (in gray), compared to the number derived from the IMMP for each site.

Discussion

We designed and tested a Rapid Assessment protocol for monarch habitat within roadside rights-of-way. While other monarch monitoring programs exist, none were developed for ready application in the roadside rights-of-way context. Our results suggest that the Rapid Assessment provides a standardized, rapid, accurate way to describe habitat conditions for monarch butterflies in roadside rights-of-way.

We sought input from roadside vegetation managers through a survey, semi-structured interviews, and by observing representative users apply the protocol in the field. The survey and interviews provided insights into important considerations for design of the protocol and identified constraints facing roadside vegetation managers. Many managers have pollinator programs and were interested in information on the distribution of potential monarch habitat as well as ways to assess the current quality of their roadsides as monarch habitat. Furthermore, many (but not all) managers indicated that they could provide staff to assess habitat conditions, and that their staff could learn to identify key habitat features, including milkweed species and noxious weeds. However, the amount of time they could dedicate to habitat assessments was limited. Observations of representative users in field visits supported refinement of the protocol by uncovering common mistakes and suggesting ways of customizing the protocol for users with differing abilities and roadside management authorities with differing needs. We used this information to design a habitat assessment protocol that would meet the needs of roadside managers.

Through the course of developing the Rapid Assessment, including field visits with state departments of transportation, we learned that meeting the wide range of needs of departments of transportation required a flexible survey design. Departments differ in their capacities to identify vegetation. For instance, some field staff are knowledgeable about vegetation and would like to quantify not only the number of nectar plant species present but also how many are native. Others are only able to quantify numbers of plants that look distinct from one another without identifying them all to species. We developed a convenient plant lookup table from which a surveyor can pick plants by either common or Latin names and simply tally unknown types. Departments differ also in the tracking of noxious weeds, from no tracking to extensive lists of

species that differ state to state and sometimes by counties or bioregions within states. Therefore, when setting up their survey, road management entities also can include a custom list of species they wish to track. Additionally, they can enter default values regarding management practices of herbicide (type, targets, and frequency of application) and mowing – or these may be left to vary by site.

The Rapid Assessment focuses observers on a small area along the roadway (150 ft, which may easily be paced); within each area the observer counts milkweed plants and types of nectar plants, and estimates cover of nectar plants and noxious weeds. The protocol may be conducted across particular areas (e.g., where a pollinator planting was installed or where construction is planned) or repeated at intervals along a roadway to depict the conditions in that area (e.g., once per ½ mile for 10 miles). It should be noted that it is important for managers to conduct assessments at pre-selected random or systematic (e.g., every 1/2 mile) locations if they wish to effectively characterize larger areas without being biased by sampling in locations where habitat conditions are known to be high.

Because managers indicated that only a limited number of days and people would be available for assessments, we designed a survey to be conducted once per growing season. To accommodate the single yearly sample, we created the term "potentially blooming nectar plants" to represent all of the plants that could provide nectar for monarchs and other pollinators, regardless of whether they were blooming on the date of the survey (and without information regarding nectar quality or quantity). This is consistent with a pollinator scorecard being designed by the Rights-of-way as Habitat Working Group of the Energy Resource Center at the University of Illinois-Chicago (A. Cariveau personal communication). Because it is generally more difficult to identify plants if they are not blooming, we recommend that surveys be conducted in peak blooming season within the period(s) of time when monarchs are present, to facilitate identification, or at least differentiation, of species (usually mid-to late-summer).

The Rapid Assessment protocol was well received by state departments of transportation for simplicity in implementation, without the need for measuring tapes or other sampling gear. While estimating distances will introduce variation into the areas measured, it is likely to be small relative to the inherent variability in the distribution of milkweed and nectar plants in roadside habitats. All of the departments of transportation that provided input use Esri software and many employ data collection tablets in the field for other projects, and in many cases already use Survey123. As an indication of the interest in this project, personnel at the Delaware Department of Transportation implemented the Rapid Assessment at nearly 100 locations in summer 2018 to learn about monarch habitat along their roadways.

We evaluated the efficiency and efficacy of the protocol by comparing time requirements and parameter estimates obtained through the Rapid Assessment with those required and obtained through the Integrated Monarch Monitoring Program, a similar but more rigorous protocol. We sought to determine whether a more rapid assessment, necessary given constraints on time and funding, could characterize the quality of monarch habitat sufficiently to meet the needs and objectives of roadside vegetation managers. The IMMP employs a more rigorous sampling protocol that provides additional data, particularly regarding nectar plants frequency and diversity. This highly repeatable protocol is stronger for objectives of the IMMP, such as tracking changes in habitats throughout seasons and across years and for comparing monarch habitat quality and use across land use sectors. However, our results suggest that for assessing and comparing rights-of-way habitat, the rapid assessment produces sufficiently accurate results for the purposes of roadside habitat restoration and management.

We found the Rapid Assessment to be efficient; the two-person field crew completed assessments in an average of 21 minutes, including time spent looking for monarch eggs and larvae. The Rapid Assessment was significantly more efficient than the IMMP even when repeating the protocol three times over the footprint of the IMMP (sum of 62 min as compared to an average duration of 2 ½ hours). The Rapid

Assessments may be spread out further, enabling managers to sample from a larger landscape more readily, and in one day a crew could complete 10-20 assessments. Experienced crews, after learning how to identify the plants in the rights-of-way, are expected to be faster than employees who are conducting assessments for the first time. However, observers typically become faster through practice, and we expect most transportation entities to focus on habitat assessment rather than to systematically look for monarch eggs and larvae, which would make the surveys even faster.

There may be concerns about whether road crews could effectively collect the data required for the Rapid Assessment. However, several other monitoring programs, such as the Monarch Larva Monitoring Project and the IMMP have success in citizen scientists collecting similar data.

The Rapid Assessment was effective for measuring milkweed density and monarch eggs and larvae per plant. When averaging Rapid Assessments, milkweed density estimates and monarch eggs and larvae per plant were not statistically different than those derived by the IMMP protocol, and the estimates by the two methods were moderately correlated across sites (tau = 0.568, 0.489, respectively; Figure 5). Milkweed is patchily distributed across the landscape, and the spatial distribution of quadrats sampled with the IMMP protocol was more reliable for detection of milkweed than a single Rapid Assessment, although milkweed detection was similar when combining the several Rapid Assessments per site. Also, it is likely that the use of quadrats in the IMMP provided more accurate estimates of milkweed density by focusing observer attention into small areas, but the estimates obtained by the Rapid Assessment were similar and highly correlated. Averaging parameter estimates for multiple Rapid Assessments generally yielded more consistent results than any single Rapid Assessment from sites, suggesting that combining multiple Rapid Assessments to characterize areas is preferred over single samples.

Numbers of species of blooming nectar plants also were highly correlated between survey protocol types (tau = 0.457 – 0.617, depending on the comparison; Figure 7). A greater number of nectar plant species was detected when summing results across the Rapid Assessments per site (excluding duplicates) than by a single Rapid Assessment, due to variation in species composition across the area. These results suggest that completing multiple Rapid Assessments along a roadway will yield better results than single samples in depicting nectar plant availability. We also noted differences between years in numbers of blooming species. Using the IMMP protocol and data summed across Rapid Assessments, the average number of blooming plants in 2018 was higher than in 2017, which may have been due to different sampling locations in each year and the particular composition of the flora at the sites sampled. However, the number of nectar plants estimated by the Rapid Assessment averaged across sites was not similarly higher in 2018. It is possible that in these locations blooming plants were patchily distributed across sites, such that in at least one of the three Rapid Assessments the blooming species richness was very low (e.g., grass-dominated), thus decreasing the estimate of species richness when averaging as compared to the IMMP.

The high milkweed density documented in this study in Minnesota (2052 plants/ha by the IMMP method (834 plants/ac); 1527 plants/ha (620 plants/ac) by Rapid Assessment) confirm that roadside rights-of-way can provide significant amounts of breeding habitat for monarchs (Kasten et al. 2016). The 2017 estimate could have been inflated due to the fact that we selected sites from a set that contained milkweed in a prior study, but the 2018 average milkweed density was higher and these sites were selected through a random process. These milkweed densities are higher than other studies in the upper Midwest (508 plants/ha, Kasten et al. 2016; 141 plants/ha, as converted from Hartzler and Buhler 2000 in Thogmartin et al. 2017b and used to estimate levels in current roadside rights-of-way). However, our sample size was small and we did not sample all types of roads, such as those in developed areas that do not typically provide habitat or those that appeared to be less than 4 m wide when reviewed online. Overall estimates of habitat availability must take into account different roadway types and potential variation by region; data collected from more locations will greatly assist in ongoing assessments of monarch habitat availability.

The levels of monarch use for reproduction suggest these roadways are serving a significant function for breeding habitat. The per plant density of monarch eggs and larvae ranged from 0.01 monarchs/plant in 2017 to 0.099 in 2018 (IMMP protocol), bracketing the 0.059 reported for roadsides by Kasten et al. (2016) and 0.043 eggs/plant reported by Nail et al. (2015; from Monarch Larva Monitoring Project data from non-roadside areas, primarily gardens). We detected a strong difference among years in monarch abundance, which is not surprising given high inter-annual variation in monarch numbers (Thogmartin et al. 2017a). This suggests that if monarch use is a primary focus for a roadside manager, collecting data in more than one year (and comparing across sites within the same year(s) would be advisable. Repeat surveys within a year would also greatly improve information about monarch use.

The presence of late instar larvae indicate that monarchs can develop in these habitats. Providing more milkweed dispersed across the landscape may improve monarch larval survival in lower density patches of milkweed (Zalucki and Kitching 1982), and having access to milkweed across the landscape should increase the number of eggs females lay (Zalucki and Lammers 2010, Grant et al. 2018, Zalucki et al. 2016). However, monarch eggs and larvae sustain high levels of mortality due to predation, weather, disease, and other factors (Nail et al. 2015). And, roadside areas may support lower densities of monarchs than adjoining agricultural habitats (Pitman et al. 2018), although it is not known if these patterns reflect differences in habitat quality or other factors, such as behavioral responses to linear landscape features. Therefore, more information about the survival of monarch eggs and larvae in roadside habitats compared to other habitat types will be highly informative in assessing the relative benefits of roadside habitat for producing monarchs.

While our results and a handful of previous studies highlight the promise of roadsides as monarch habitats, these areas also bring a suite of threats to monarchs and other pollinators including collisions with vehicles and chemical inputs (Skorka et al. 2013, Keilsohn et al. 2018, Pitman et al. 2018, Snell-Rood et al. 2014). However, larger butterflies such as monarchs may sustain a lower rate of mortality from car collisions than smaller butterflies (Skorka et al. 2013). Furthermore, mortality from cars is lower in roadside habitats with certain characteristics, such as greater plant species richness (Ries et al. 2001, Skorka et al. 2013). The width of the right-of-way habitat as well as the composition of adjacent lands also may affect collision mortality rates, such that wider habitats with greater access to adjoining habitats may reduce collision mortality (Munguira and Thomas 1992, Skorka et al. 2013, but see Saarinen et al. 2005). Chemicals, including sodium and heavy metal run-off from roadways, are incorporated into roadside vegetation (Snell-Rood et al. 2014, Munoz et al. 2015). These chemicals could affect the development of monarch eggs and larvae or even affect adults through contamination of nectar resources. Further study of roadside areas to profile monarch egg and larval survival as well as chemical or traffic-induced mortality would allow better understanding of how roadside habitats perform as monarch breeding areas.

Roadside management authorities are becoming aware of the impact of management policies on roadside habitat, and exemplary programs with deferred mowing, re-establishment of native plants, control of noxious weeds, and integrated vegetation management occur around the country. While providing protocols for the assessment of pollinator habitat in rights-of-way is an important first step, additional work is needed to interpret the resulting data in the context of pollinator habitat quality. We are developing a Roadside Monarch Habitat Quality Calculator to score monarch habitat quality for sites assessed by the Rapid Assessment protocol. Additional challenges include balancing the multiple management needs for rights-of-way and communicating the benefits of native, uncut vegetation to shift public preferences for well-manicured turf grass along roadways.

Because of the importance of the breeding season to the monarch annual cycle (Oberhauser et al. 2017), the strong connection between habitat loss in the core of the eastern population's breeding range and low monarch numbers (Thogmartin et al. 2017a), and use of roadsides for monarch breeding (Kasten et al.

2016), roadside restoration and management is promising for monarch conservation. Furthermore, roadside areas managed for monarch habitat provide native plants that could benefit other wildlife, such as small mammals, birds, pollinators and other beneficial insects. Ongoing communication and research around the potential conservation benefits of well managed roadside rights-of-way will be highly beneficial.

Important findings from our work include the high level of interest and motivation within departments of transportation for providing habitat for monarchs. We were impressed by the number of interested departments as well as the number who are implementing exemplary practices. Our survey revealed the needs for simple ways to assess habitat both in the landscape setting as well as at the level of the vegetation present. Communication tools are also highly valued by transportation administrators who are not experts in the area of monarch habitat development, and who interface with varied audiences, from high level management, to vegetation management crews, to the public.

CHAPTER 5

Product C: Roadside Monarch Habitat Quality Calculator

Background

The *Roadside Monarch Habitat Calculator* uses data from the *Rapid Assessment of Roadside Habitat for Monarchs* to generate a *Monarch Habitat Quality Score* for each assessed right-of-way site. Managers may wish to use Monarch Habitat Quality Scores to compare sites under different management schemes (e.g., reduced mowing, weed control), in different bio-regions (e.g., prairie, woodland), or for different road types. The calculator groups the data measures under four functional components of habitat: breeding, foraging, landscape context and threats, and management (see Table 6).

Table 6. Roadside Monarch Habitat Calculator functional components, measures, and weights.

Functional Component	Measure	Function Weight	Weight within Function	Measure Weight
Breeding	Milkweed Abundance (*density; plants/ac*)	30%	80%	24%
	Milkweed # Species		20%	6%
Adult Foraging	Potential Nectar Plants: % Cover	25%	50%	12.5%
	Potential Nectar Plants: # Species		30%	7.5%
	Potential Nectar Plants: # Native Species		20%	5%
Context /Threats	Adjacent Land Use Type	25%	30%	7.5%
	Road Type		35%	8.75%
	Weeds: % Cover		20%	5%
	Weeds: # Species		15%	3.75%
Management	Herbicide Application Practices	20%	40%	8%
	Frequency of Full Width Mow		30%	6%
	Width of Mow: proportion of ROW Width		30%	6%
Total		100%	100%	100%

Methods

We based the calculator on the Environmental Defense Fund's Monarch Habitat Quantification Tool (HQT; Environmental Defense Fund et al. 2017, Anderson et al. 2017). However, in our interviews with transportation managers and background research, we identified a number of important factors in roadside rights-of-way that were not incorporated in the HQT. In particular, the HQT does not include measures related to road characteristics, threats by invasive non-native plant species (weeds), or mowing and herbicide application practices that are commonly applied in the roadside corridor. Therefore, we designed a data collection protocol, the Rapid Assessment, that would provide data for all these categories (see Table 1), and then designed the Monarch Habitat Quality Calculator to incorporate these data inputs.

In designing the Rapid Assessment and Habitat Calculator, we reviewed other pollinator rating systems in collaboration with the Rights-of-Way as Habitat Working Group (Energy Resources Center, University of Illinois-Chicago; http://www.erc.uic.edu/biofuels-bioenergy/pollinator-habitat/rights-of-way-as-habitat/), Metrics and Targets Taskforce (A. Cariveau, co-chair; see listing in Table 1, Chapter 2).

Function and measure weights were determined by the project work team through meetings and discussions regarding the relative importance of various habitat components. For each measure represented in the calculator, we developed point distributions (0-100 for each measure) to correspond with various levels in the scores. The development of scoring for each functional area we explain in the following sections.

Each of the functional components is weighted within the full score (Function Weight), and measures are then weighted within each functional component (Weight within Function). Multiplying the Function Weight by the Weight within Function determines the weight of the measure in the total score (Measure Weight). For example, within the functional component of breeding (Function Weight 30%), the measure of milkweed density (Weight within Function 80%) represents 24% (30% x 80%) of the overall Quality Score (when scored maximally, generates 24 points for the Quality Score).

Monarch Breeding Habitat

Milkweed Abundance

Monarchs require milkweed plants (primarily in the genus *Asclepias*; 76 species in the U.S.) for their larvae to develop. Sites with more milkweed plants provide more habitat for reproduction and therefore receive a higher score. Smaller sites with fewer milkweed plants may support higher densities of eggs per plant (Stenoien et al. 2015). Nail et al. (2015) found that monarch egg survival was higher in sites that had more milkweed plants, but that there was a negative effect of per-plant larvae density. Also, it is thought that higher rates of predation and parasitism are encountered in higher density patches of milkweed (Zalucki and Kitching 1982, Bartel et al. 2011, Stenoien et al. 2016, Pitman et al. 2017). Based on modeling that takes into account behaviors of monarchs looking to lay eggs, it appears that lower density milkweed spread out across the landscape will benefit monarch reproduction more than fewer higher density patches of milkweed (Grant et al. 2018). Taking all of these studies together, we would expect an increase in breeding habitat quality with an increase in milkweed plant densities, but only to a point, after which the effect declines or plateaus.

There are a few studies explicitly relating monarch reproduction to the density of milkweed (milkweed plants or stems per unit area). Studies such as the Monarch Larva Monitoring Project have data regarding monarchs per milkweed plant, but only recently began collecting data on site level milkweed density. A study by Kasten et al. (2016) in MN, SD, IA, WI, and IL found that milkweed density was the strongest predictor of density of monarch eggs and larvae, with an increase in immature monarchs leveling off above

0.6 milkweeds per square meter (2428 plants or stems/acre). However, it should be noted that milkweed abundance was rarely observed at this level, with the median count of 0.0036 plants/m^2 (14 plants/acre) and mean of 0.0508 plants/m^2 (206 plants/acre). Thogmartin et al. (2017), based on their review of the literature, suggested that mean milkweed density for primary (larger) roadside rights-of-way is 57.15 plants/acre, with an amended (when habitat is enhanced) density of 100.02 plant/acre.

Points assigned for milkweed densities followed Kasten et. al. 2016 and the Milkweed Density Suitability Index of the HQT (Anderson et al. 2017). In the HQT, 2000 stems/acre was determined to be the highest desirable level and the curve was generated with this equation: 1-(2/(1+EXP(6*(I2/2000)) (see Figure 9 in Chapter 3).

In the Rapid Assessment, surveyors either count the number of milkweed plants within the survey area or use abundance categories of 0, 1-5, 6-10, 11-25, 26-50, 51-250, >250. The calculator then divided the number of plants (or the used the midpoint of the abundance category; 300 for the highest category) by the size of the survey area to generate milkweed density in plants/acre. Then, we assign points according to the midpoint of these milkweed densities (0, 1-50, 51-100, 101-200, 201-500, 501-1000, 1001-2000, > 2000) as in Figure 24.

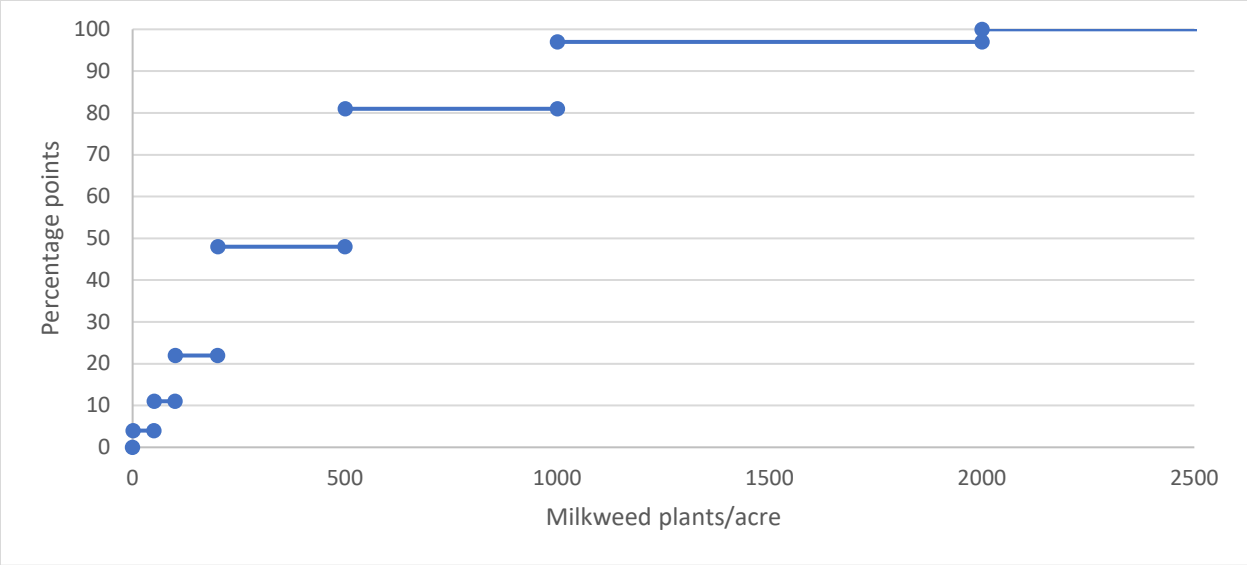

Figure 24. Milkweed abundance point curve based on values calculated from data from the Rapid Assessment.

Milkweed Species Composition

The number of milkweed species present at a site is a factor that can enhance habitat quality. Having more than one milkweed species available at a site may increase the period of the year when milkweed is available to monarchs for oviposition and for nectar, as milkweed species when found together often are offset in the timing of their peak blooms (personal communication, Bill Handel, retired, Illinois Natural History Survey). Also, in trials, monarchs lay more eggs when they encounter a mix of milkweed species rather than the same number of plants of one species on which to lay their eggs (Pocius et al. 2018), although they reproduce successfully on all of the milkweed species tested (Pocius et al. 2017). Therefore, for providing blooms throughout a longer period and for providing more options to ovipositing monarchs, sites with more than one species of milkweed are ranked higher in quality. We assigned points such that surveys

with 1 milkweed species received 2 points, 2 milkweed species gave 4 points, and 3 or more milkweed species gave the maximum of six points.

Adult Monarch Foraging Habitat

Nectar Plant Abundance

Adult monarchs require nectar from flowering forbs and shrubs for feeding during their reproductive and migratory phases. It is widely recognized that nectar sources are important and may be limiting for monarchs, with particular concern about availability of nectar in early spring and during the fall migration period (see Malcolm 2018). In addition, a variety of other pollinators including wild bees rely on floral resources (nectar and pollen), many of which are only in flight for a short time of the year. Best management practices for providing nectar resources for monarchs and other pollinators typically recommend providing blooming native plants during each season of spring, summer, and fall, to ensure availability of floral resources when needed by these various species and life stages.

Roadside vegetation managers are typically limited to visiting sites once per monarch season (i.e. once a year in the northern part of the breeding range, twice a year in the southern parts or the breeding range). Therefore we defined a term that might characterize the potential for a site to provide flowers, "Potentially Blooming Nectar Plants" (hereafter, Nectar Plants) as species of forbs (e.g., herbaceous plants that are not grasses) and blooming shrubs that may provide nectar resources, whether or not they are blooming at the time of the survey. For these plants we estimate their aerial cover on the site, in the categories of none, <5%, 5-9%, 10-25%, 26-50%, 51-75%, > 75%. These cover classes were derived from classic Daubenmire cover classes (<5%, 5-25%, 26-50%, 51-75%, 76-95%, > 95%; Daubenmire 1959), with the following modifications. We added a 'zero' category for places where no nectar plants were found and consolidated the highest two categories into one '>75%' category for simplification and because we did not encounter any instances of '>95%' in the field in 2017-2018. We also added a category from 6-9% to better distinguish among sites and to correspond with a minimum threshold value of 10% cover by Nectar Plants included in the draft Candidate Conservation Agreement with Assurances for the monarch as developed by the Rights-of-Way as Habitat Working Group of the Energy Resources Center at University of Illinois-Chicago.

We considered assigning points according to the midpoints of the cover class values (Figure 25). However, because these values are small for the lower cover classes, and because this factor is only a small weight among other factors (12.5% of total score), we found that this did not distinguish well among sites with different cover classes of nectar plants. To better reflect the scoring levels for this component, we assigned points with greater spread among the lower cover classes such that each increase among cover classes added at least one point when considering the final point contributions (Figure 26). Also, based on expert opinion, we chose to score the highest two cover categories the same, as forbs are not expected to grow in such high relative abundance in grassland areas, and our team of experts felt that anything above 50% should be given full points.

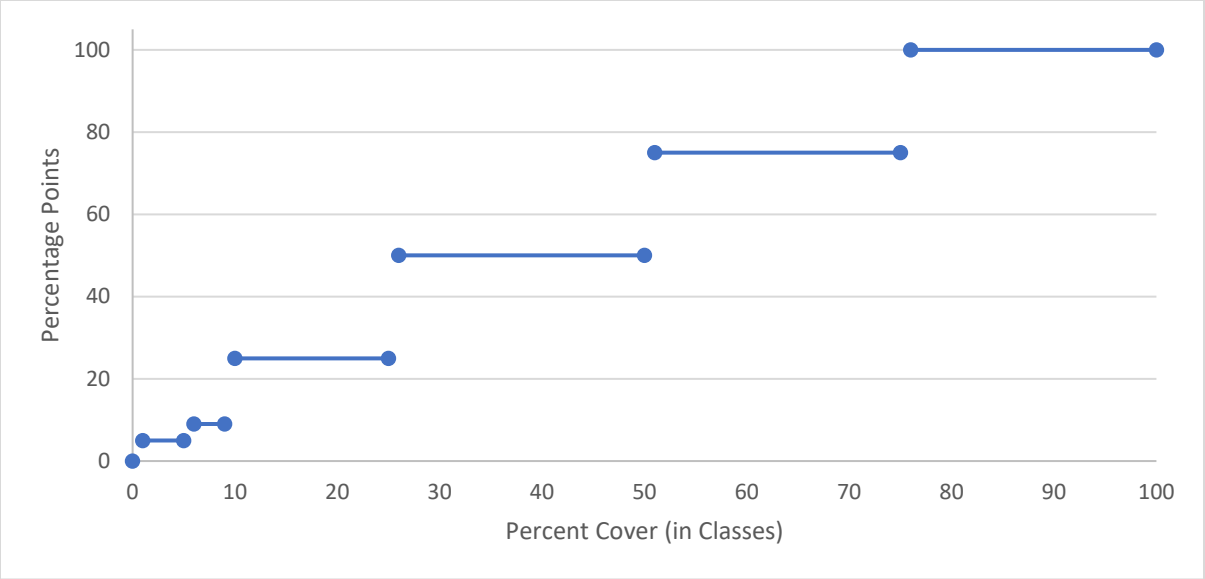

Figure 25. Rejected point curve where points were given in proportion to midpoint of cover class for Potential Blooming Nectar Plants.

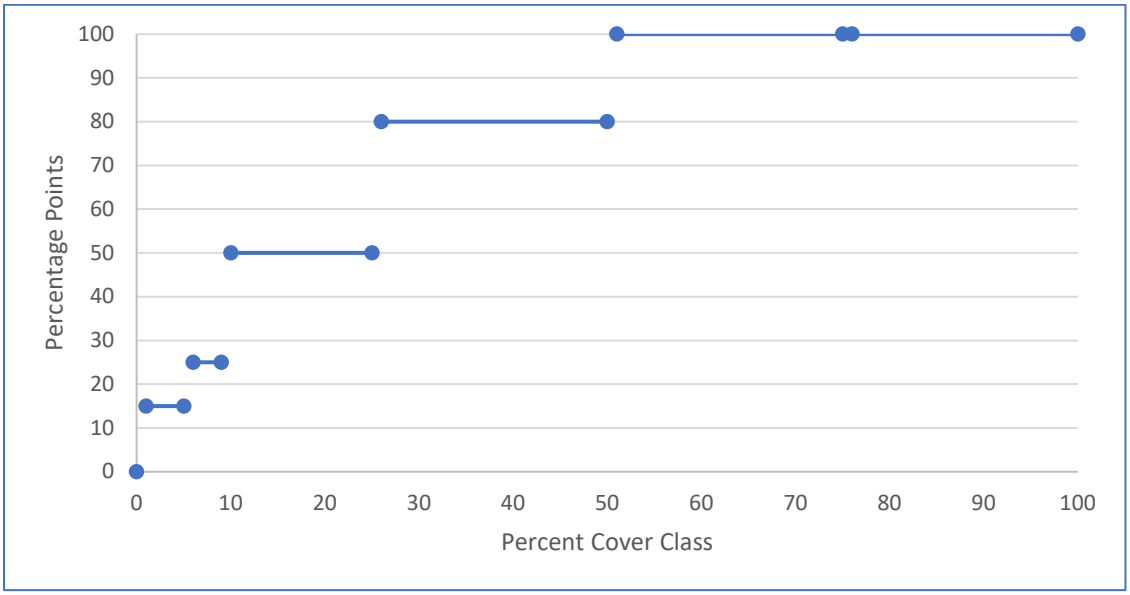

Figure 26. Adopted set of percentage points assigned to various cover class midpoints for Potentially Blooming Nectar Plants, providing better distinctions among sites with different cover classes in the lower part of the range.

Nectar Plants: number of species

Having a variety of blooming species with different blooming periods such that a site provides nectar through the season when monarchs may be present is optimal. This follows the recommendations set forth in many management guidelines for pollinator habitat. Thus, we award greater points to sites where there are greater numbers of species of Potentially Blooming Nectar Plants (Figure 27). Surveyors recording the

number of distinct types of nectar plants they see creates a relative index across all sites surveyed in a similar fashion with regard to blooming plant richness.

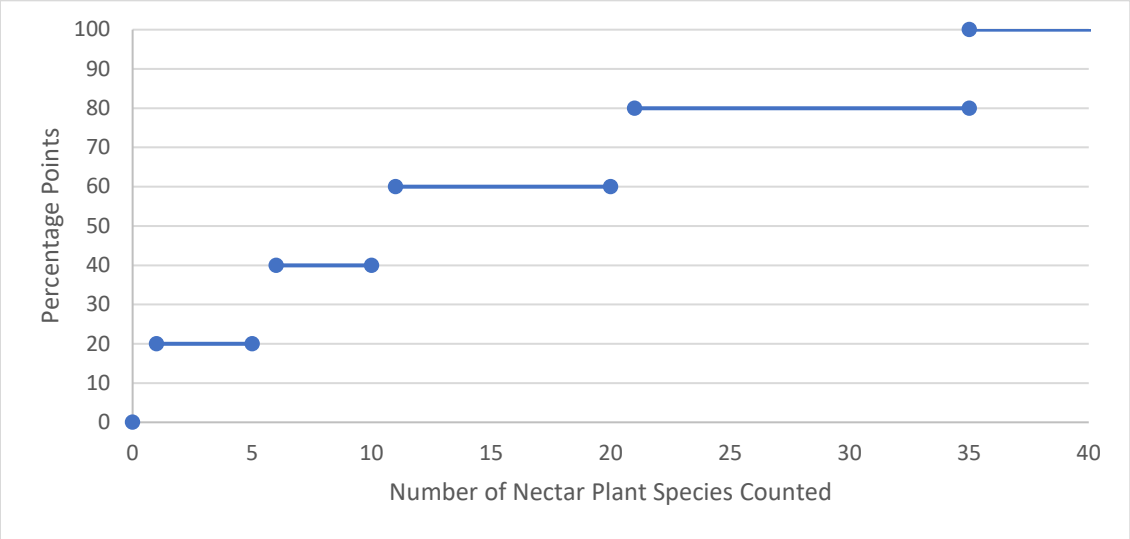

Figure 27. Points awarded for various numbers of Potentially Blooming Nectar Species.

Nectar Plants: number of native species

A roadside manager may prefer to grow plant species native to their area, because of the benefits they have in providing habitat for other species, such as wild bees or butterflies that may rely on particular species as a host plant or for nectar or pollen during limited flight times. Many native plants are perennials with strong root systems effective at soil stabilization and in the right combinations, these native plantings can be resilient against invasion by weed species and require less maintenance than traditional plantings of ornamental flowers or turfgrass.

As a matter of background, in EDF's HQT, only native plants are counted in their nectar plant scoring system; a site with only non-native species would receive a zero score for nectar sources. Experts agree that there are great benefits provided by native species, however, they acknowledge that non-native flowers also may provide nectaring resources. Therefore, we decided to make points for native species additive to those determined by the full count of Potentially Blooming Nectar Species. In this way, we acknowledge that some non-native plants can provide nectaring habitat, while also giving additional credit to sites where native plants are provided. Figure 28 depicts the scoring curve developed for number of native nectar species. We based the levels from the numbers of plants reported in the statewide field testing in Minnesota and Oklahoma.

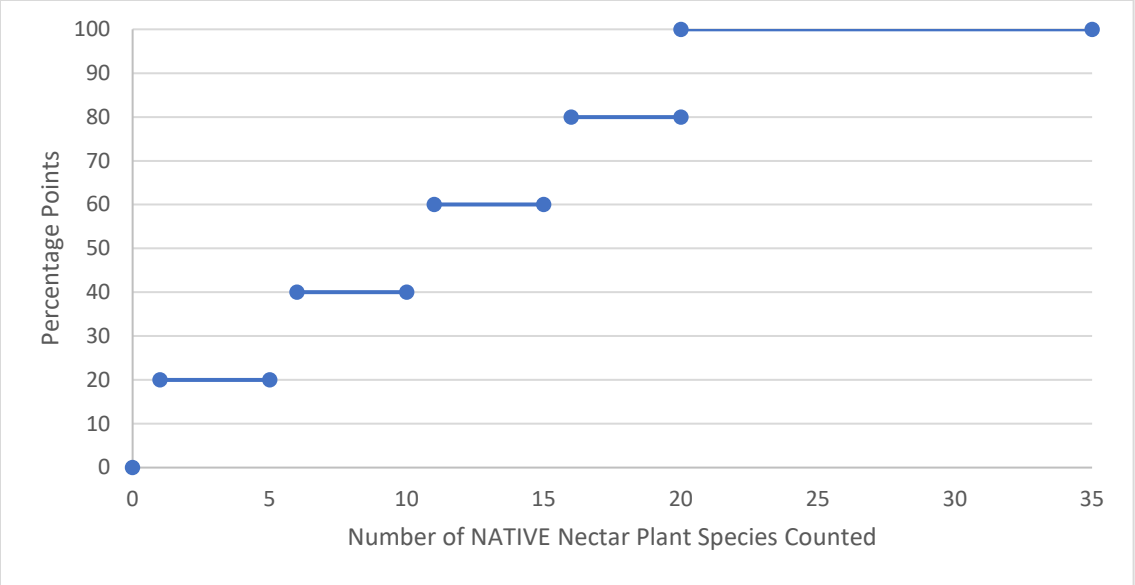

Figure 28. Points awarded for numbers of Native Nectar Plant Species counted in each Rapid Assessment.

Context/Threats

In the Context / Threats component we consider three factors: adjacent land use, road characteristics, and presence of noxious weeds. We will discuss each of these areas in turn.

Adjacent Land Use

Adjacent land use may affect the suitability of monarch habitat in two primary ways. We noted adjacent land uses in the field when conducting the Rapid Assessment. While this could have been brought in from the Landscape Prioritization Model, we found that the scale of the national datasets was often inaccurate at the local scale, so the on-the-ground notation of adjacent land use was more accurate.

First, adjacent land use may bring the risk of pesticide (herbicide, fungicide, or insecticide) drift from agricultural or developed areas. The extent of drift is highly variable according to application practices and weather conditions during application (primarily wind speed and direction). The HQT and NRCS recommend a monarch habitat buffer distance of at least 100 feet from the edge of fields where insecticides are applied, or for there to be a woody barrier (such as a hedgerow) in place. Xerces Society suggests a buffer distance of 60 ft for aerial insecticidal spray applications, or 125 ft for neonicotinoid applications, including treated seeds (Hopwood et al. 2018), or for there to be a barrier, such as woody vegetation. We assume that the risk or likelihood of pesticide exposure is highest near agricultural fields and developed areas with no buffer, and therefore these locations receive the lowest ranking in the calculator. Sites bordered by woody barriers and neighboring agricultural and developed areas are ranked higher, and the highest ranking is attributed to those that neighbor wooded or grassland areas (Table 7).

Table 7. Adjacent Land-use Categories and Associated Point Scores

Adjacent Land-use Category	Points
Cropland	10
Cropland with Hedgerow or other woody barrier	50
Developed	25
Developed with hedgerow or other woody barrier	50
Woodland or Forest	75
Diverse Grassland (contains native species including forbs)	100
Not Diverse Grassland/Open space/idle ground	50
Wetland	75

Secondly, adjacent land use may affect the suitability of the habitat by attracting monarchs to the area. Areas that are adjacent to natural vegetation containing nectar resources, such as nature reserves, are predicted to have the highest suitability, followed by less diverse grasslands and developed areas. Woodlands and agricultural fields are thought to have the lowest value as adjacent habitat. In one study, butterfly abundance was lowest in roadsides adjacent to woodlands and greatest near grasslands (Kasten et al. 2016). In another study, insect mortality was lower when adjacent to woodlands and increased along roadways with vegetated medians (Keilsohn et al. 2018).

Roads as Sources of Chemical Inputs and Vehicular Collisions

Roads pose two main threats to monarchs: an influx of chemicals from vehicles and road maintenance (e.g., application of road salts) into the plant material consumed by larval monarchs, and adult butterfly collisions with vehicles. As a proxy for speed limit and traffic volume for each road, we categorized roads into 2-lane, 4-lane, and greater than 4-lane. We then ascribed low, higher, and highest in terms of both speed limit and traffic volume to these road types.

Roads bring an influx of chemicals from vehicle wear-and-tear, exhaust emissions, and from the application of road salts (e.g., Lagerwerff & Specht 1970, Jaradat & Momani 1999). These chemicals can be consumed by monarchs when they are taken up by milkweeds (heavy metals, sodium) or deposited on the plant surface (residues from exhaust). High levels of sodium, metals such as zinc and lead, or exhaust emissions can have lethal or sub-lethal effects on roadside monarchs. For this study, we assume that larger roads with more traffic lanes bring greater chemical inputs. Therefore, relative to chemical inputs, we give a higher habitat quality rank to roads with 2 lanes, followed by 4 lanes, followed by roads with greater than 4 lanes. Preliminary results from the Snell-Rood lab support the idea that sodium and zinc content of roadside milkweeds scales with traffic intensity (Mitchell et al. in prep).

Risk of collision with moving vehicles is a threat that has been studied for butterflies in general as well as recently specifically with regard to monarchs. Limited research on traffic volume indicates that butterfly mortality increases with traffic volume to a point, but there appears to be an avoidance effect on roadways with the highest traffic volume. Therefore, relative to potential vehicular collisions, smaller, slower roads are best, but moderate traffic levels would rank worse than the highest traffic volumes.

We coded 2-lane roads as best (100 points), and we ranked moderate and high-speed and volume roads the same at 50 points, due to the conflicting predictions for the two factors above.

Noxious weeds

Invasive plants, non-native species, or noxious weeds, have not been documented as having a direct effect on the quality of monarch habitat, but due to their propensity for dominating areas and becoming monocultures, we know that the potential exists for them to displace a diversity of native nectar plants and milkweeds. We view the threat of noxious weeds in two ways.

First, they may directly replace native vegetation that is more beneficial to monarchs, particularly over the long term. This would be true for an area that is invaded by a species that does not supply nectar, such as any number of invasive grasses. However, some invasive species are utilized as nectar sources by monarchs. Although this would seem to benefit adult monarchs, the tendency to grow as a monoculture results in a highly synchronized bloom time, reducing the ability for the site to provide nectar throughout the season of monarch activity and potentially reducing the availability of milkweed.

The second way in which noxious weeds could threaten monarch habitat is through management actions that are performed to reduce weed infestation, such as repeated mowing and/or treatment with herbicide. Because the goal of this management is to improve habitat, those negative effects are short-term, for one to several growing seasons while the weeds are actively managed. In many cases the habitat quality will be greatly improved after treatment, particularly when enhanced by seeding or other restoration measures.

To rank weeds in our model, we faced a difficulty in that managers in different locations, particularly in different states, had distinct lists of weeds they were trying to control. Some departments of transportation aggressively track all species on their noxious weed lists, while in other states this is not practical. Because the effect of weeds is driven largely by the management actions needed to control them, our team decided to have the list of weeds be self-defined by each management entity. Therefore, we enable managers when setting up the Rapid Assessment to specify the species of plants that they are concerned about, that they are actively working to control. Then these are noted if present or not during Rapid Assessments. The measures we include in the Calculator are percent cover estimated across the survey area and the number of species present (Table 8).

Table 8. Weed metric levels and points

Metric	Level	Points
Weeds – Percent Cover	0%	100
	1-5%	80
	6-10%	60
	11-25%	40
	26-50%	20
	51-75%	20
	>75%	0
Weeds – Number of Species	*0	100
	*1	75
	*2	50
	*3-4	25
	5+	0

Management

Vegetation management in roadsides is essential to operations for safety, aesthetics, and stewardship. We wanted to include management within the calculator to illustrate how changes in management can be expected to affect habitat quality for monarchs. We include two common management actions that may have great impacts on monarch butterfly habitat: herbicide use and mowing.

Herbicide application

Herbicide is applied in many ROW contexts, primarily for the control of invasive species, which may be grasses, forbs, or woody species. A variety of herbicide types are used and are applied in different ways, for different target vegetation, different management objectives, at different times of year, differently by bioregion, etc. These sources of variation make it difficult to score in a national protocol. However, it is an important factor, so we created a descriptive scale that can be applied in many situations (Table 9) and weighted it fairly low (8% of total). Also, we developed a Best Management Practices support document about the use of Herbicides in Roadside Habitats for Monarchs (see Appendix F).

Table 9. Management factors and point assignments.

Metric	Level	Points
Herbicide Application	none	100
	against noxious weeds only; applied only as needed (with plan, spot treatment)	100
	against weedy grasses to stimulate forbs	100
	broadleaf applied in clear zone 1 x /yr	75
	broadleaf applied in clear zone at > 1 x /yr	50
	broadleaf applied throughout ROW 1 x year	0
Frequency of Full Width Mow	Never	100
	Every few years	90
	1x/yr	90
	2x/yr	50
	3x/yr	25
	>3x/yr	0
Width of Mow as Proportion of ROW Width	no mowing	100
	less than a third of the ROW width is mowed	75
	between 1/3 and 2/3 of the ROW is mowed	50
	greater than 2/3 of the ROW width is mowed	25
	ROW entirely mowed	0

Mowing

Mowing is a necessary tool in ROW management, for providing safe sightlines along roadways and also for managing undesirable woody or weedy vegetation. Mowing can provide both negative and positive effects on monarch habitat depending on timing, condition of the habitat, and time scale of consideration. Please see the Mowing and Management: Best Management for Monarchs handout (Monarch Joint Venture 2019; https://monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf). We noted

great variation in our survey of roadside managers when we asked about the frequency of mowing the safety strip, as well as the full ROW width including the back-slope. There has been more interest building on the topic of reducing mowing, and it is being implemented in the mowing policy for some departments of transportation (such as the state of Illinois).

Mowing can have negative effects, including:

- removes flowers that provide nectar (Halbritter et al. 2015)
- cuts down milkweed used by larval monarchs (and assumed to destroy most larvae and eggs)
- can spread weed seeds (e.g., wild parsnip, personal communication, Christa Schaefer, WISCDOT)

Mowing can have positive effects, such as:

- provides good visibility and safe areas for emergency exit from the roadway
- can stimulate the ability for nectar producing forbs to compete with grasses
- if done early enough in the growing season, stimulates regrowth of milkweed, providing more tender (and likely nitrogen-rich) leaves farther into the season (Fischer et al. 2015, Baum and Mueller 2015, Alcock et al. 2016, Haan and Landis 2019),
- in milkweed, single mowing in early or peak growing season can reduce predators of monarchs (Haan and Landis 2019)
- removes woody vegetation which often provides fewer nectar resources that non-woody dominated areas (but not always)
- can be used to control some weeds that may reduce habitat quality due to encroachment, benefits more likely to be seen particularly over the long term
- removal of plants adjacent to roadsides which may have higher levels of chemicals from road run-off (e.g., for both sodium and zinc, Mitchell et al. in prep)

To create a simple index of mowing intensity, we combined one temporal factor and one spatial factor. For the temporal component, we asked managers to report the frequency with which they typically mowed the full width of the right-of-way. For the spatial component, we used the observed width of the mowed area during our field visit (typically this is the backslope, but sometimes is the entire area, or sometimes the entire area has been mowed (to less than 10 inches; see Rapid Assessment protocol). Together, these two factors serve as a surrogate for mowing pressure (see points allocated, Table 7).

Running the Calculator

Information about how to install the proper software, collect data, and retrieve data are provided in the *User Guide to the Roadside Monarch Habitat Evaluator* (Appendix D).

Field testing the Calculator

To validate the calculator, we processed data from field surveys in Minnesota and Oklahoma in 2018. We used the data collected to make small changes to the calculations. In Minnesota we ran the calculator on 298 sites. In Oklahoma the sample size was 282 sites.

Results

Minnesota

In Minnesota, the overall mean Monarch Habitat Quality Score was 52.36 (standard deviation = 13.57, minimum = 20, maximum = 88; for 298 random sites; see Figure 29). We also depict the distribution of values for the breeding component score (Figure 30) and the foraging component score (Figure 31). See Figure 32 for a geographic representation of the site locations and overall habitat quality scores.

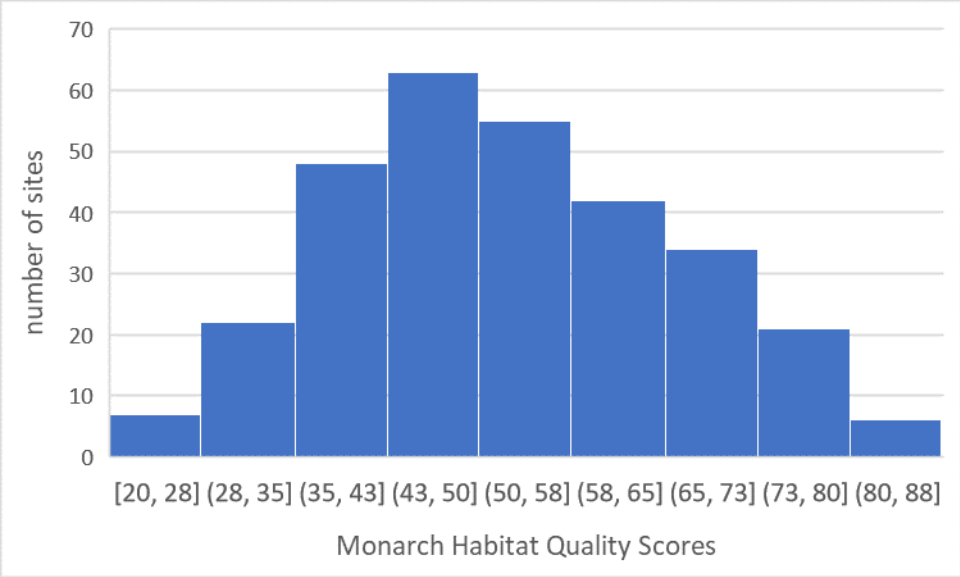

Figure 29. Histogram depicting the distribution of Monarch Habitat Quality Scores for 298 randomly located roadside sites in Minnesota, sampled once during the summer of 2018.

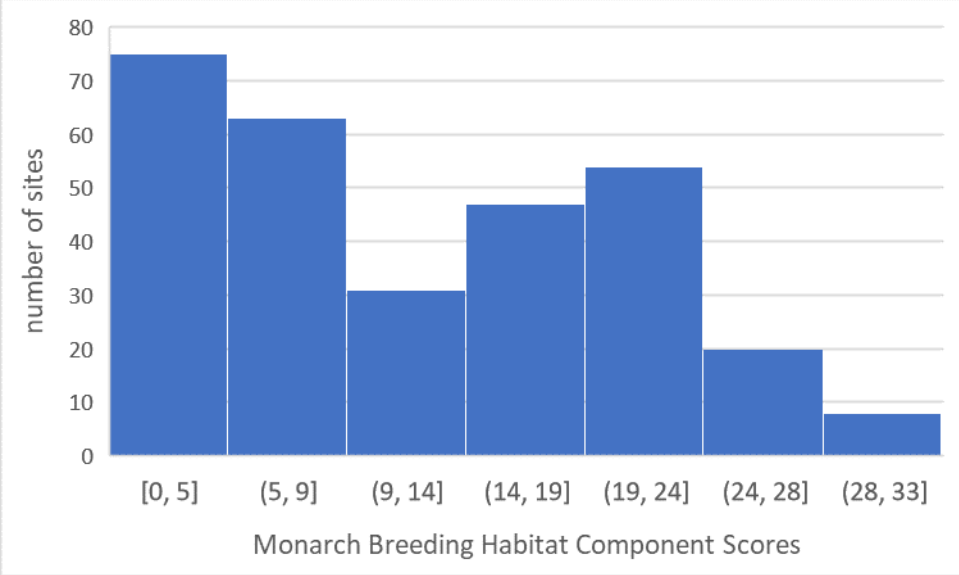

Figure 30. Histogram depicting the distribution of Monarch Breeding Habitat Component Scores for 298 randomly located roadside sites in Minnesota, sampled once during the summer of 2018. The left-biased curve is indicative of many sites that did not contain milkweed (n=74).

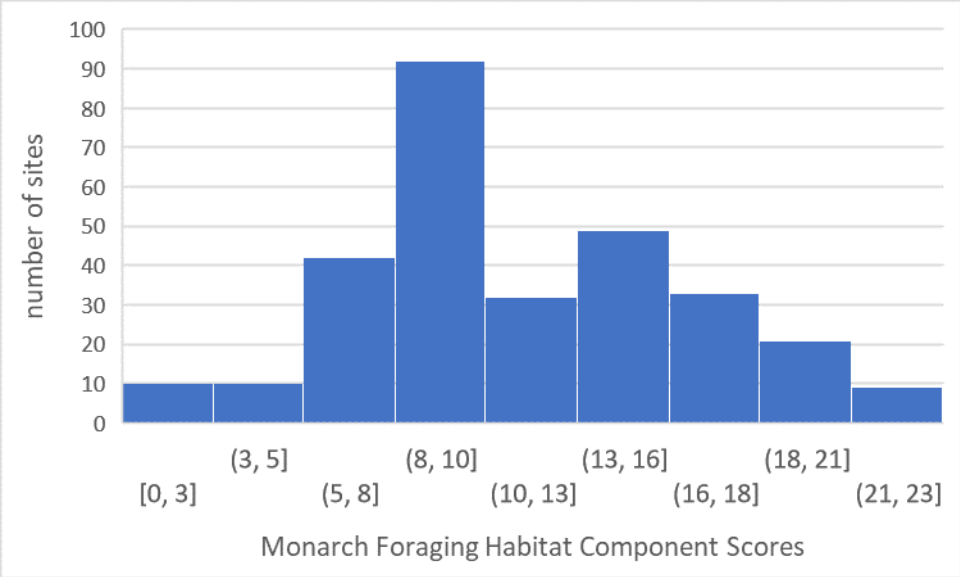

Figure 31. Histogram depicting the distribution of Monarch Foraging Habitat Component Subscores for 298 randomly located roadside sites in Minnesota, sampled once during the summer of 2018.

Summary statistics for all of the component sub-scores were as follows (Table 10).

Table 10. Summary statistics for component scores within the monarch habitat quality scores for 298 random roadside locations in Minnesota surveyed in 2018.

	Breeding	Foraging	Threats	Weeds	Management
mean	11.546	11.295	10.941	6.921	4.339
SD	9.012	4.906	3.002	1.164	1.452
minimum	0	0	4.375	2.125	0
model maximum	30	25	16.250	8.750	20
field maximum*	30	22.938	16.250	8.750	6

*The maximum for management that was recorded in the field was 6 points, based upon the proportion of the area that was mowed. We were lacking data regarding mowing frequency and herbicide application practices because we were not within the managing transportation department.

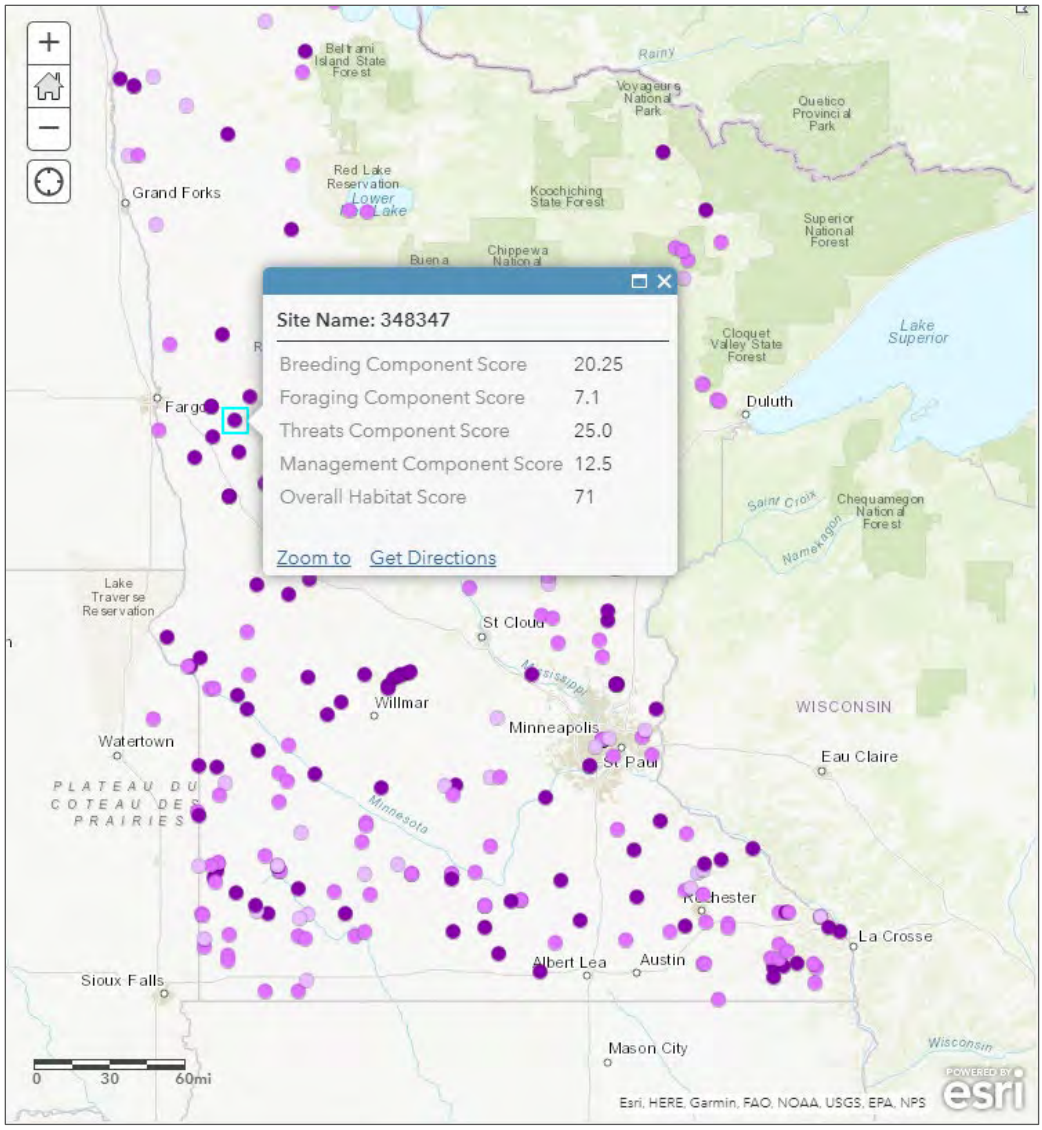

Figure 32. Monarch Habitat Quality Scores for 298 sites visited in Minnesota in 2018.

Oklahoma

In Oklahoma, the mean overall habitat quality score was 37.64 (st dev = 10.38; min 14.75, max 72.75; see Figure 32. See Figure 33 for the histogram of breeding habitat component scores and Figure 34 for nectar plant component scores.

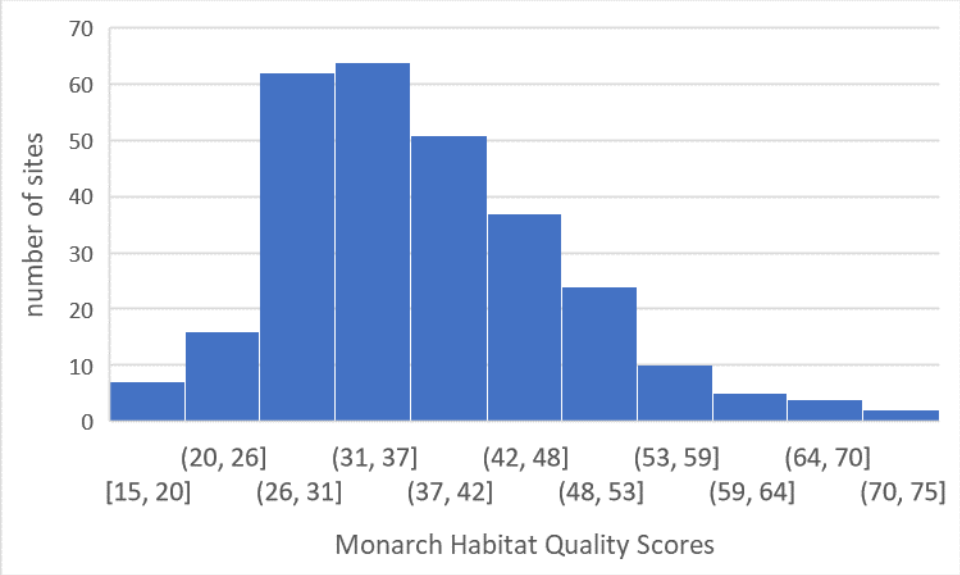

Figure 32. Monarch Habitat Quality Scores for all site visits in Oklahoma, first visits (May 28 - June 18, 2018; n=282).

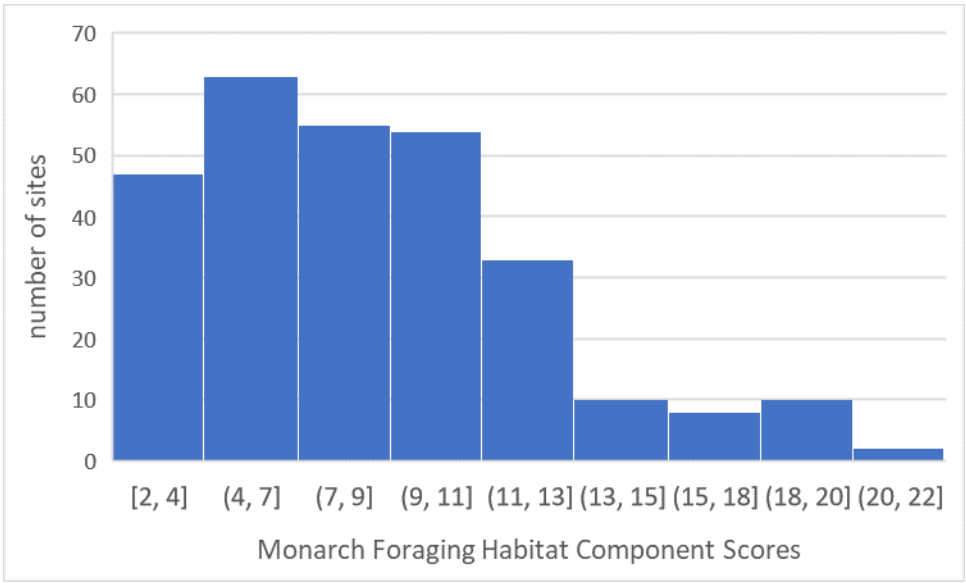

Figure 33. Histogram depicting the distribution of Monarch Breeding Habitat Component Scores for 282 sites in Oklahoma, sampled once during the summer of 2018. The left-biased curve is indicative of many sites that did not contain milkweed (n=150).

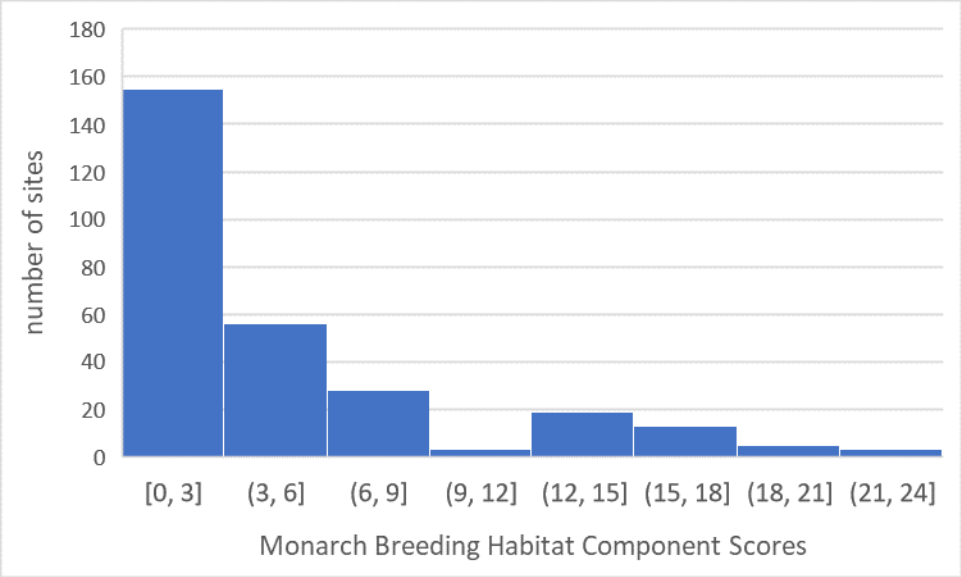

Figure 34. Histogram depicting the distribution of Monarch Foraging Habitat Component Sub-scores for 282 roadside sites in Oklahoma, sampled once early in the summer of 2018.

A summary of all of the primary habitat component scores is presented in Table 11.

Table 11. Summary statistics for component scores within the monarch habitat quality scores for 283 first visits to Oklahoma sites surveyed in 2018.

	Breeding	Foraging	Threats	Weeds	Management
mean	4.162	8.321	9.945	6.512	3.431
SD	5.580	4.091	2.970	2.053	0.866
minimum	0	2.25	4.375	1.875	1.5
model maximum	24	21	16.25	8.75	4.5
field maximum*	30	25	16.25	8.75	20

*The maximum for management that was recorded in the field was 4.5 points, based upon the proportion of the area that was mowed. We were lacking data regarding mowing frequency and herbicide application practices because we were not within the managing transportation department.

Discussion

Additional research regarding preference, use by, and survival on different species of milkweed in roadside rights-of-way is needed to improve the milkweed component of the Habitat Calculator. Since monarchs successfully reproduce on many different milkweed species (Pocius et al. 2018), but milkweed species vary significantly in stature and biomass, it is likely that the quantity of milkweed consumed by larvae for each species may vary as well. For example, more stems of smaller-statured milkweeds like *Asclepias verticillata* (whorled milkweed) may be necessary for monarchs to develop to maturity. The Thogmartin et al. (2018) All Hands on Deck model that drives national, state, and sector based goals was restricted to common milkweed (*A. syriaca)*, and therefore, there is growing interest among researchers to

further define optimal densities for other species of milkweed which vary greatly in size, number of stems, and biomass. In addition, because of this focus on common milkweed, many recent articles define 'plants' synonymously with 'stems,' due to the rhizomatous nature of *A. syriaca* (which makes them impossible to distinguish above ground). For species that grow in clumps, like *A. tuberosa*, the number of stems per plant can vary widely, and there is more to be learned about how this variation affects monarch density or use of that plant. The Habitat Calculator could be updated as new species-specific information becomes available.

Knowledge of the availability and species-specific value of nectar resources for monarchs is also limited. In future versions of the Habitat Calculator, the scoring for nectar plant species could be weighted toward plants considered to be particularly good nectar sources for monarchs as new research becomes available. Some efforts to list preferred or particularly beneficial plants have been made which could serve as a starting point for developing more robust research studies and updating tools like the Habitat Calculator. The NRCS published an in-depth set of regionally specific guides, entitled *Important Plants and Plant Lists of the Monarch Butterfly* (NRCS 2018; https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207). The NRCS list of plants used by monarchs gives a rating of 'very high' for plant species 'reported to be of superlative use by the monarch' or for 'plants mentioned in multiple sources as providing nectar to monarchs' (NRCS 2018). Monarchs appear to prefer large flowers in the aster family or those with upright floral displays such as the gayfeathers (*Liatris* sp.) (NRCS 2018). A second set of quick guides was developed, also regionally, called *Monarch Nectar Plants*, by the Xerces Society, Monarch Joint Venture, and the National Wildlife Federation (https://xerces.org/monarch-nectar-plants/) with funding from the USDA Natural Resources Conservation Service (NRCS) and Monarch Joint Venture.

Landscape context, while an important part of valuing a potential habitat area, is often not within the land manager's control. While it could be considered low hanging fruit to always prioritize areas that are in areas that pose less potential risk, it is also important to make efforts to mitigate risk and in other areas to distribute more habitat across the landscape. Through education and outreach to surrounding landowners and land managers, this Calculator and other associated tools serve an important role in engaging the surrounding community to improve practices for monarchs, pollinators, and greater environmental benefit.

Our field trials identified a number of sites with high quality habitat for monarchs. Interestingly, the overall scores are distributed more as a bell-shaped curve, suggesting that most sites are at least decent habitat and have potential to be high-quality habitat (rather than a skew towards lower scores). While this method clearly identifies the top roadside sites with current quality habitat for monarchs, it is less clear what the "minimum" score is for monarch "success." Additional field research that considers factors such as survival of monarch larvae on roadsides can help to determine the range of scores that need minimal investment apart from protection versus the range of scores that would benefit from restoration. This may also depend on the resources available to invest in restoration – for instance, roadside managers with moderate resources may choose to protect sites with scores of 80-100 and invest in restoration of sites with scores of 60-80.

Future research may also consider interactions between the "bottom-up" approach that combines assessment of existing roadside quality with the "top-down" approach of the landscape prioritization model that uses higher level data to predict potential roadsides. For instance, regions with high potential identified through the landscape prioritization model and median scores from the habitat calculator may represent the best potential sites for restoration.

CHAPTER 6

Product D: Best Management Strategies and Decision Support

Survey of Transportation Managers

Methods

We created a survey with 28 questions using Qualtrics, which we emailed in the fall of 2017 to a list of approximately 50 project contacts, including representatives from many transportation authorities, primarily states. We asked that these professionals share the survey with colleagues to increase participation in the survey. We also asked specifically for email addresses of contacts they felt could contribute additional information to our study (e.g., GIS managers) which grew our contact list to over 130 professionals.

To introduce the survey, we included this text: "The Monarch Joint Venture, with funding from the National Cooperative Highway Research Program, is developing tools for managers of roadside rights-of-way to provide habitat for monarch butterflies. These tools include 1) models for where to place or maintain habitat, 2) field assessment techniques, 3) habitat quantification tools, and 4) forums for selecting best management practices. We have a few questions for you as a transportation professional that will help us to design these conservation tools." The survey questions are listed below.

Survey Questions

Overview

1. Name, email address, organization, state
2. What geographical jurisdiction best describes your work? (state, larger than state, smaller than state)
3. Does your organization provide habitat for pollinators, such as flower plantings, on some of your road right-of-ways?
4. Give a brief description of your organization's habitat program for pollinators or monarchs.
5. What best characterizes how your organization currently determines where to put habitat plantings? (work in GIS, have a process but it does not use GIS, we do not have a standard process)
6. Which of these would be helpful to your program? (guidance where to install habitat plantings or manage current habitat, tools for monitoring vegetation to assess habitat quality, both, other (write in available)

Geographical

7. What road length unit would be most useful in a model that helps roadside managers identify better places to develop monarch habitat along roadways? (1/4 mile, ½ mile, 1 mile, 5 miles, 10 miles +)
8. Does your organization have any maps of levels of winter salt application on various roadways? (yes, no, in development, no, n/a, I don't know but you could contact (write-in))
9. Does your organization have a map of where noxious weeds occur within the roadside right-of-ways? (yes, no, in development, no, n/a, I don't know but you could contact (write-in))

Rights-of-Way Width

10. Are you familiar with the widths of the roadside rights-of-way in your jurisdiction?
    - If yes, continue through next questions
    - If no, skip forward
11. Can you estimate the width of the roadside habitat on these road types? Please estimate the distance from paved edge to right-of-way edge, on one side of road, in feet.
    - Interstate and other large highways and freeways
    - State or smaller highway
    - County or moderate roadway
    - Local road

Field Assessment

12. For field visits to assess good potential sites identified in the habitat model, what length of road would it make the most sense to evaluate in a visit? (less than ¼ mile, 1/4 mile, ½ mile, 1 mile, 5 miles, 10 miles +)
13. Do you direct or manage a roadside management crew?
    - If yes, continue through next questions
    - If no, skip forward
14. Would you have personnel or interns who could conduct field assessments of potential monarch habitat in the roadside corridor? (yes, no, maybe)
15. How many people would you have who could conduct field assessments of potential roadside monarch habitat? (1, 2-4, 5-9, 10+)
16. How many days do you estimate these people might be able to assess habitat? (1-5 days/yr, 6-10 days/yr, ½ day/week, 1 day/week, 1 day/month)
17. Would your crew be able to identify noxious weeds that require management? (yes, no, maybe)
18. Would your crew be able to learn how to identify milkweed plants that are important to monarchs? (yes, no, maybe)
19. If your crew was assessing a site for its suitability for development into monarch habitat, how long could they spend assessing the site? (< 30 minutes, 30-60 min., 1-3 hours, 4-6 hours, 6 hr +)
20. If your crew was monitoring existing pollinator plantings to assess the quality of the habitat for monarchs, how much time could be spent per site? (< 30 minutes, 30-60 min., 1-3 hours, 4-6 hours, 6 hr +)

Management Questions

21. Do you manage noxious weeds along your roadways?
    - If yes, continue through next questions

- If no, skip forward

22. Can you briefly describe the approach or techniques employed in your jurisdiction in controlling noxious weeds?
23. If there is a guidance document, can you provide the link to that?
24. Can you estimate what percentage of the roadways in your jurisdiction are managed for noxious weeds? (< 5%, 5-25%, 51-75%, >75%)
25. Can you answer questions about roadside mowing practices in your area?
    - If yes, continue through next questions
    - If no, skip forward
26. Is there a consistent mowing schedule throughout your jurisdiction or does it vary among road types or vegetation types? (yes; no, it varies by region; no, it varies by road type; no, it varies by county; no, it varies by more than one factor)
27. How frequently are the interior edges (to maintain sight-lines) of the roadways mowed? (monthly or more during growing season, every 6-8 weeks during growing season, other (write-in))
28. How frequently are the entire widths of the right-of-ways mowed? (3+ times per year, 1-2 times per year, once every 2 years, once every several years, typically not needed, other (write-in))

Open Input

What guidelines or products would you find most helpful? (a model of where habitat may exist for monarchs, a model of where it may be good to develop for monarchs, field protocols for managers to assess field habitat, a habitat calculator to depict habitat quality for monarchs, information about best management practices for monarchs, other (write-in))
Please share any comments or questions about the project.

Survey Results

We received 79 responses to the survey; the majority of respondents represented states (58%) followed by counties (25%), 8% were regional or national, 9% were local, and 5% were other entities. Survey respondents represented 19 states: Arizona, Arkansas, California, Illinois, Indiana, Iowa, Kansas, Maryland, Michigan, Minnesota, Nebraska, New Hampshire, Ohio, Oklahoma, South Dakota, Texas, Virginia, Washington, and Wisconsin. Because we ask questions in a variety of different topical areas that may match up differently to areas of expertise, we made answering questions optional; thus, the number of respondents varied across questions.

Nearly three-fourths (74%) of the states represented indicated that they had a pollinator program (14 states). Many programs indicated that they were planting prairie or wildflowers in the ROWs, also in rest areas, some programs augment with milkweed, some programs cited outreach components, and also vegetation management, mostly in the form of altered herbicide treatments and mowing schedules.

We asked if managers would like guidance about where to install or manage monarch habitat, tools for monitoring that habitat, or both. Of 33 respondents to this question, 39% wanted monitoring methods, 12% indicated that the planning information would be most valuable, and 39% wanted both (9% had other answers).

When asked about “how your organization currently determines where to manage pollinator habitat or put habitat plantings,” the greatest number of respondents indicated that they did not have a standardized process (36%), 25% said they have a process that does not use GIS, and 17% indicated that they used GIS in this process.

We asked managers to indicate which length of road would be most relevant for their planning purposes (for focus of our GIS prioritization tool). We found responses varied quite heavily, from ¼ mile to ten miles or more (see Figure 36).

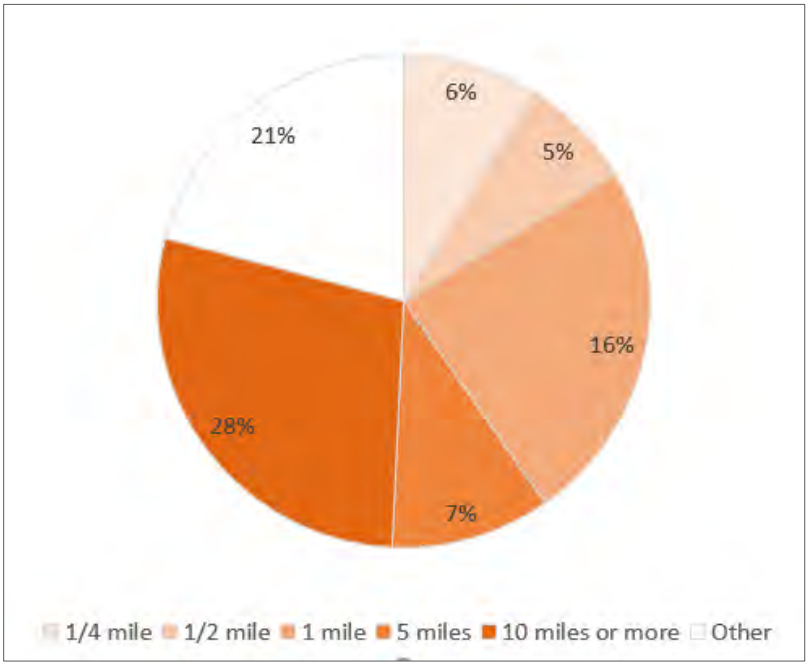

Figure 36. Variety of responses in the scale of road miles that managers thought might be an appropriate length for assessing in GIS (n=67).

We asked about the availability of GIS data regarding the application of road salt. While the greatest number of respondents indicated that they did not have this information, positive responses came from these six states: Arizona, California, Iowa, Maryland, Michigan, and Minnesota.

Similarly, we found that while many respondents (47%) did not have a map of noxious weeds within their rights-of-way, we had 15 positive responses and 7 indicated "maybe". Respondents in these six states indicated that they had maps of noxious weeds: California, Iowa, Maryland, Michigan, Minnesota, and Washington.

Most respondents did not have a map indicating rights-of-way widths for various road types, but a few states indicated that they did: California, Iowa, Minnesota, South Dakota, and Virginia. Road managers also offered estimates of the widths of the rights-of-way (one side of road, from road edge to vegetation edge) for various road types (data available on request).

When we asked if personnel or interns could be made available to conduct field assessments of potential monarch habitat in the roadside corridor, 22% indicated yes, 52% indicated maybe, and 26% indicated no. Most respondents (50%) indicated they would expect to be able to have 2-4 people who could conduct field assessments, 31% indicated they could have one person available, and 19% thought they could have a team of 5 of more people. Most respondents (41%) thought the field team would be available 1-5 days/year, 22% thought 6-10 days a year; other responses were ½ day a week, 1 day a week, and 1 day a month (3 responses for each).

When asked "how long your field crew could spend assessing potential habitat sites," most indicated less than 30 minutes (n = 53; see Figure 36). Answers to 'how long your field crew could spend monitoring existing habitat" were very similar.

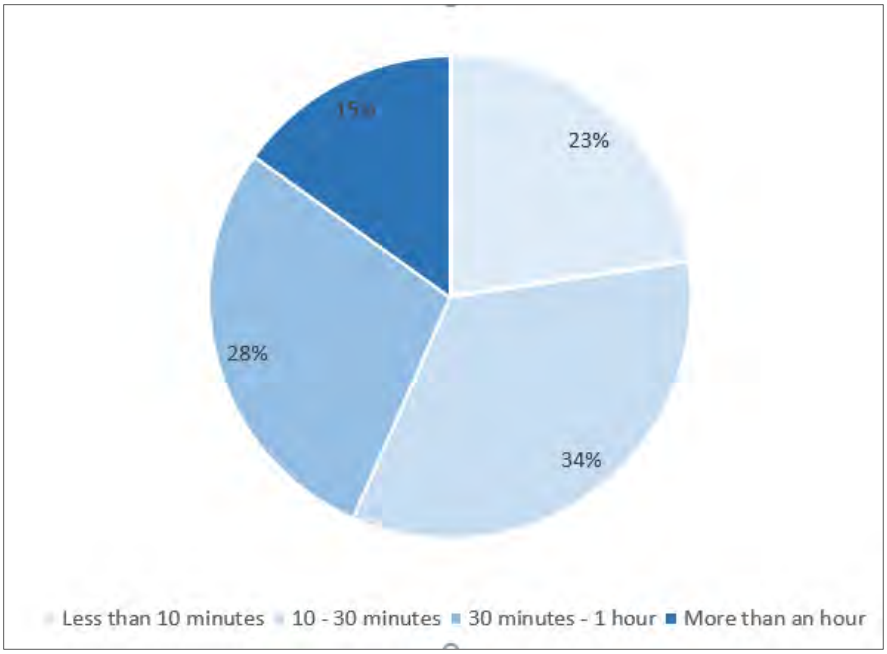

Figure 37. Amount of time managers indicated that their field crew could spend assessing each potential habitat site (n=53).

We asked about the skills of their potential field crews. Most thought that their crews would be able to identify noxious weeds that require management (56% yes, 34% probably yes, 9% no; 32 respondents). Similarly, when we asked if they would be able to identify milkweed plants, all but one respondent thought this would be possible (97% yes; n = 32).

Answers to additional questions about capacity for field work and management practices are presented in Table 12 below.

Table 12. Responses by roadside managers to a subset of the survey questions we asked regarding roadside vegetation assessment and management.

Question	Survey Results			
Do respondents have personnel/interns that could conduct field assessments? (n=46)	Yes	No	Maybe	
	22%	26%	52%	
How many days per year could their field crew(s) allocate to habitat assessment? (n=32)	10+	6 to 10	1 to 5	Other
	9%	31%	50%	9%
	Definitely yes		Probably yes	

Could field crews identify weeds requiring management? (n=32)	56%		34%	
Could field crews identify milkweed? (n=32)	Definitely yes		Probably yes	
	66%		31%	
Appropriate length of right-of-way for field visits? (n=64)	5+ miles	1 mile	0.5 miles	≤0.25 mi
	25%	30%	22%	22%
How much time could be spent monitoring a specific site? (n=52)	1+ hours	30-60 min	10-30 min	<10 min
	15%	28%	34%	23%
Do respondents manage noxious weeds? (n=63)	Yes			
	71%			
Is there a consistent mowing regime in their jurisdiction? (n=42)	No, due to factors such as region, road type, etc.			
	79%			
Frequency of mowing the safety zone during the growing season (n=42)	Monthly	Every 6-8 weeks	Other	
	17%	26%	57%	
Frequency of mowing the full width of the right-of-way during the growing season (n=42)	3+ times per year	1-2 times/yr	Once every 2-5 years	Typically not needed	Other
	5%	36%	24%	29%	7%

When we asked "Can you estimate in what percentage of the roadways in your jurisdiction there are weeds actively being managed for noxious weeds?" we found responses highly variable (see Figure 38; n = 48).

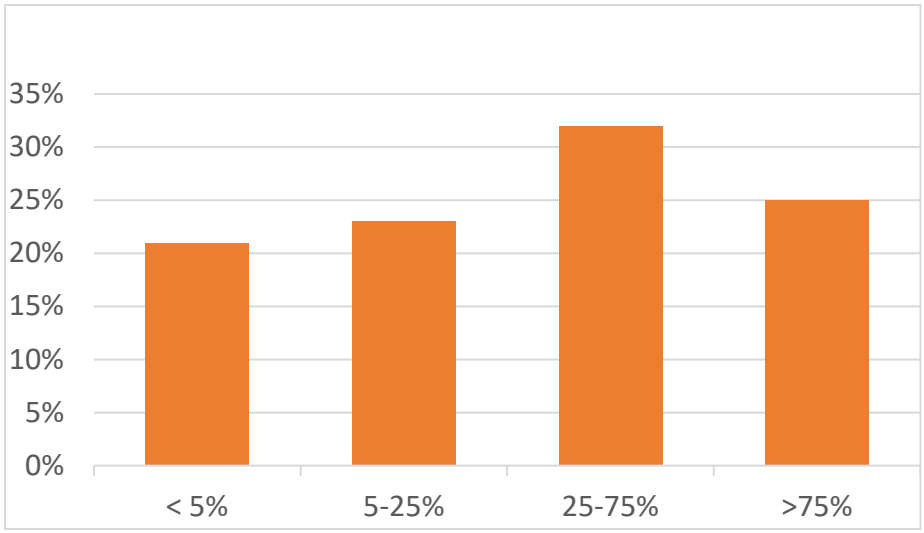

Figure 38. Estimated percent of roadway in their jurisdiction treated for noxious weeds.

We asked about typical mowing frequencies, first how often the safety zones or sight-lines were mowed per season. Responses were monthly or more (17%), every 6-8 weeks (26%), other (57%) (n = 42). We then asked about the frequency by which they mowed the full width of the right-of-way (Figure 39).

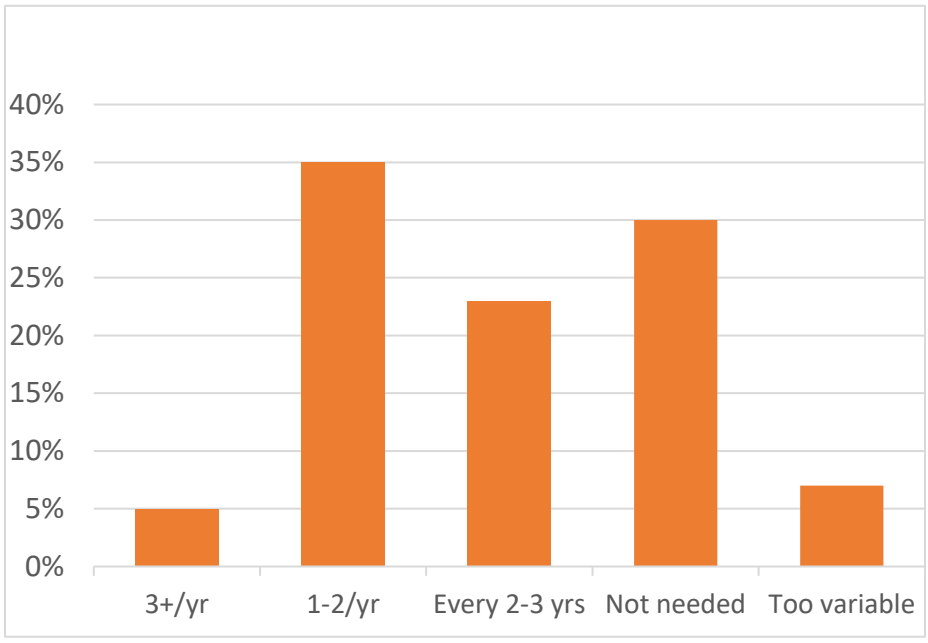

Figure 39. Variety in answers regarding the frequency with which they mow the full width of the rights-of-way.

Comments we received in the survey indicated a concern among respondents about a lack of time or funding for field assessments. Similarly, there were also needs for funds to plant milkweed and other beneficial nectar species in their habitat restorations. Another comment indicated that more work was

needed in improving the public perception of deferred mowing and other integrated vegetation management techniques to benefit pollinator habitat and the cost-savings that it provides.

Survey Conclusions

From this survey, we gathered valuable data to guide design of the decision support tools in our project and gained many valuable project contacts that will continue to provide value to this ongoing work. We gained insights into the interests, capacity, and needs of transportation managers. We learned that many managers were interested in tools for assessing where to put habitat, as well as tools for assessing existing habitat. It is feasible for departments of transportation to assess habitat in the field (with a preference for surveys to be quick), and to develop habitat, although time and funding were often cited as limiting factors.

Hearing directly from roadside managers and other transportation professionals bridged our understanding in what barriers and limitations prevent widespread adoption in restoring native plant vegetation in roadside areas. Through asking targeted questions about decision making processes, we were able to tailor our discussions and tool development in a way that will make them more useful to roadside management entities. Understanding the time and capacity limitations that they face also emphasized for us the importance of the quick nature of the assessment tools we developed through this project. Robust scientific datasets come at the cost of a lot of time in the field and biological expertise often not encountered in roadside management entities, so we paired our robust monarch monitoring program experts with the project team to simplify tools that yield valuable information but are easier and faster to implement than the more robust program protocols.

User Profile Interviews

Methods

To gain more in-depth information from managers who were already involved in pollinator habitat management within rights-of-way, we conducted interviews to learn about their information and decision support needs to augment the more general information we gained from our Qualtrics survey. We interviewed four roadside managers with the following profiles:

- **Rob Roman** (Roadside Manager, Engineering & Secondary Road Dept., Linn County, IA) - Piloting a program to identify 1,000 miles of roadside for establishment and management of milkweed habitat.
- **Kayti Ewing** (Botanist, Environmental Division, Arkansas DOT) -Maintains 1,000 miles of ‘wildflower routes’, consults with landowners to install pollinator habitat on adjacent roadsides through the ‘Operation Wildflower’ program, and is working with District staff to identify areas where they can plant pollinator habitat and mow only once in the fall. Also working towards a CCAA with the USFWS.
- **Dan MacSwain** (Natural Resources Coordinator, Washington County, MN) - Negotiated a new rule to limit mowing/haying of roadsides in the county by adjacent landowners. Consults with engineers on seed mixes and revegetation designs.
- **Stephanie Dobbs** (Roadside Manager, Illinois DOT) - Implementing a reduced mowing program in roadside rights-of-way statewide. Planning to actively manage and monitor the center median of I-39 for monarch habitat to meet CCAA requirements.

Findings

We identified two distinct strategies for installing and managing milkweed in roadside rights-of-way:

- **'Special Status' Areas** – areas with unique conservation value are set aside and afforded special management, such as reduced mowing.
  - **Arkansas DOT:** Wildflower Routes and Operation Wildflower areas
  - **Linn County, IA:** 1,000 miles of milkweed pilot

- **Broad Management Prescriptions** – new management regimes are adopted for entire road systems or components thereof to promote milkweed and pollinator habitat.
  - **Illinois DOT:** reduced mowing along I-39 center median
  - **Washington County, MN:** new haying/mowing restrictions

Our findings included the following:

- Almost every interviewee had conducted an inventory of roadsides at some point. Some 30 years ago, some last year. In all but one case, the inventory was conducted via 'window inventory' (i.e., from the vehicle).
- Only one interviewee had conducted any quantitative monitoring (Stephanie Dobbs, ILDOT), however she was very clear that she did not expect other roadside managers to do the same. Those who are participating in the energy and transportation CCAA do expect some monitoring requirement.
- GIS-based data management is increasingly common. Most departments are porting their paper data to a GIS, however most feel they are 'behind' in the effort. In MN, they have used the Collector app to inventory weeds; in AR, crews have and use tablets in the field; in IL, the Collector app has also been used this year for a couple applications.
- Most interviewees had set targets in terms of milkweed plants/stems or wanted to know how many additional milkweed plants/stems resulted from changes to management.
- Areas with 'bare dirt opportunities' are the easiest to target for milkweed and forb seeding, which are more common in populous or economically developing areas. Prepping sites specifically for monarch is time intensive and costly.

Habitat Calculator Use Scenarios

The following capture how respondents indicated that they thought the habitat calculator could be used:

- Identify roadside ROWs for which revegetation is already planned due to road work and which should include milkweed and nectar producing forbs

- Identify currently vegetated roadside ROWs for creation or enhancement of monarch habitat

- Identify roadside ROWs to exclude from creation or enhancement of monarch habitat due to threats

- Estimate progress towards program goals (1 milkweed per 11 ft of roadway) or compliance requirement (CCAA)

- Inventory existing monarch habitat within road system

Most Common Users

We were able to profile two types of users for the habitat calculator tool.

- **Common:** Individual or small team of DOT staff (e.g., any roadway authority, including state, county, or municipal) with a dedicated window of time (1-5 days per year) to inventory and monitor potential or existing monarch habitats within the road system under their authority.

- Roadside Vegetation Managers
- Biologists in Environmental Compliance department
- Natural Resource program interns

– **Less Common:** roadside crew members on contract or under direct employment of a DOT during routine maintenance activities.
  - Mowing personnel
  - Herbicide applicators

Decision Support Tree

At the first and second team meetings, we built and refined a decision support tree that represents decisions roadside managers often make. Below are simplified figures (Figures 40, 41, and 42) that reference a more complex decision tree that is difficult to represent in print format. Also refer to Figure 5 (in Chapter 1 and Appendix A) that depicts a manager's workflow in regard to decision making regarding rights-of-way conservation.

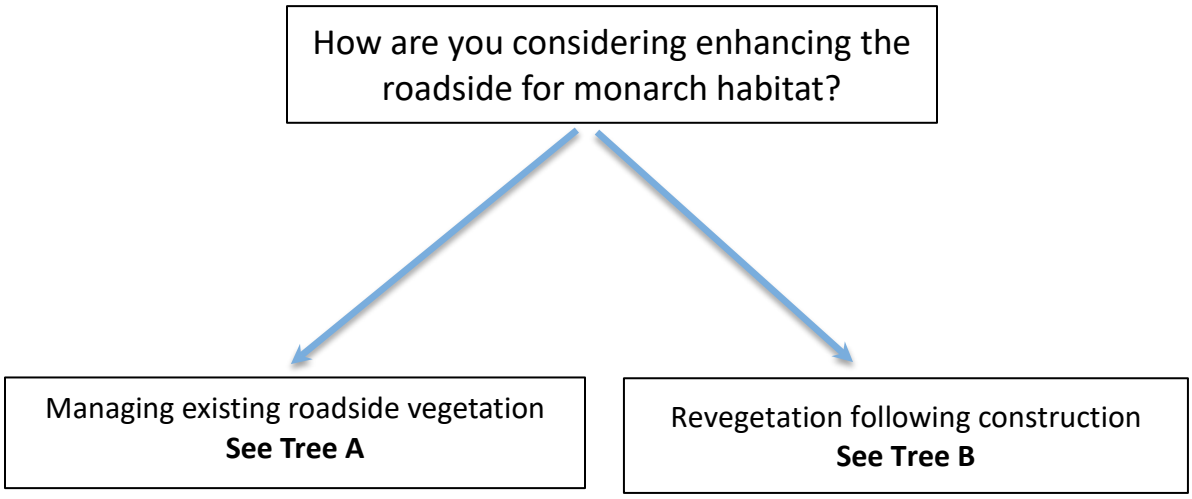

Figure 40. General Schematic of Decision Support: Best Management Practices for Monarchs

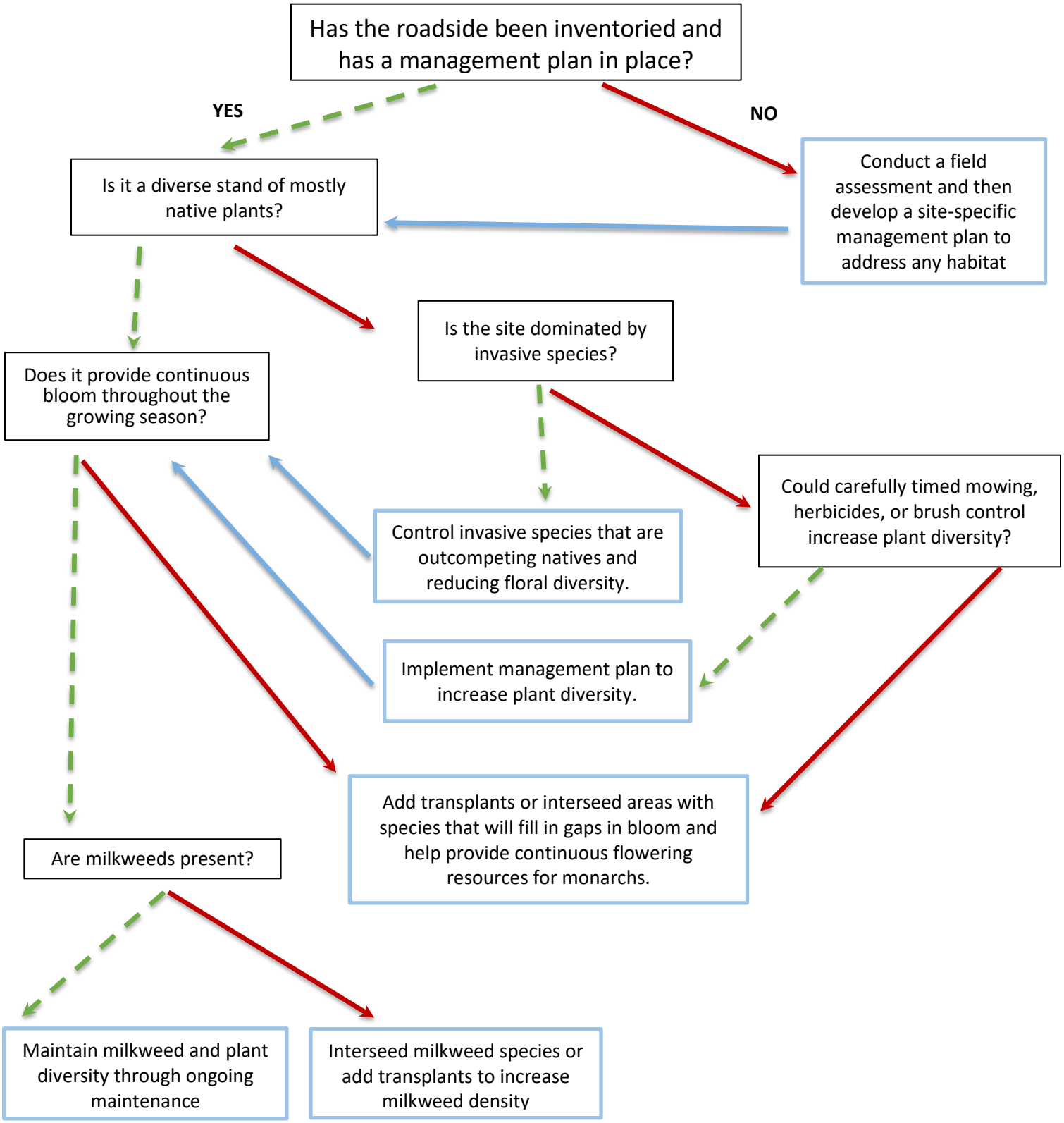

Figure 41. Decision Support Tree A. Best Management Practices for Monarchs: Managing Existing Vegetation

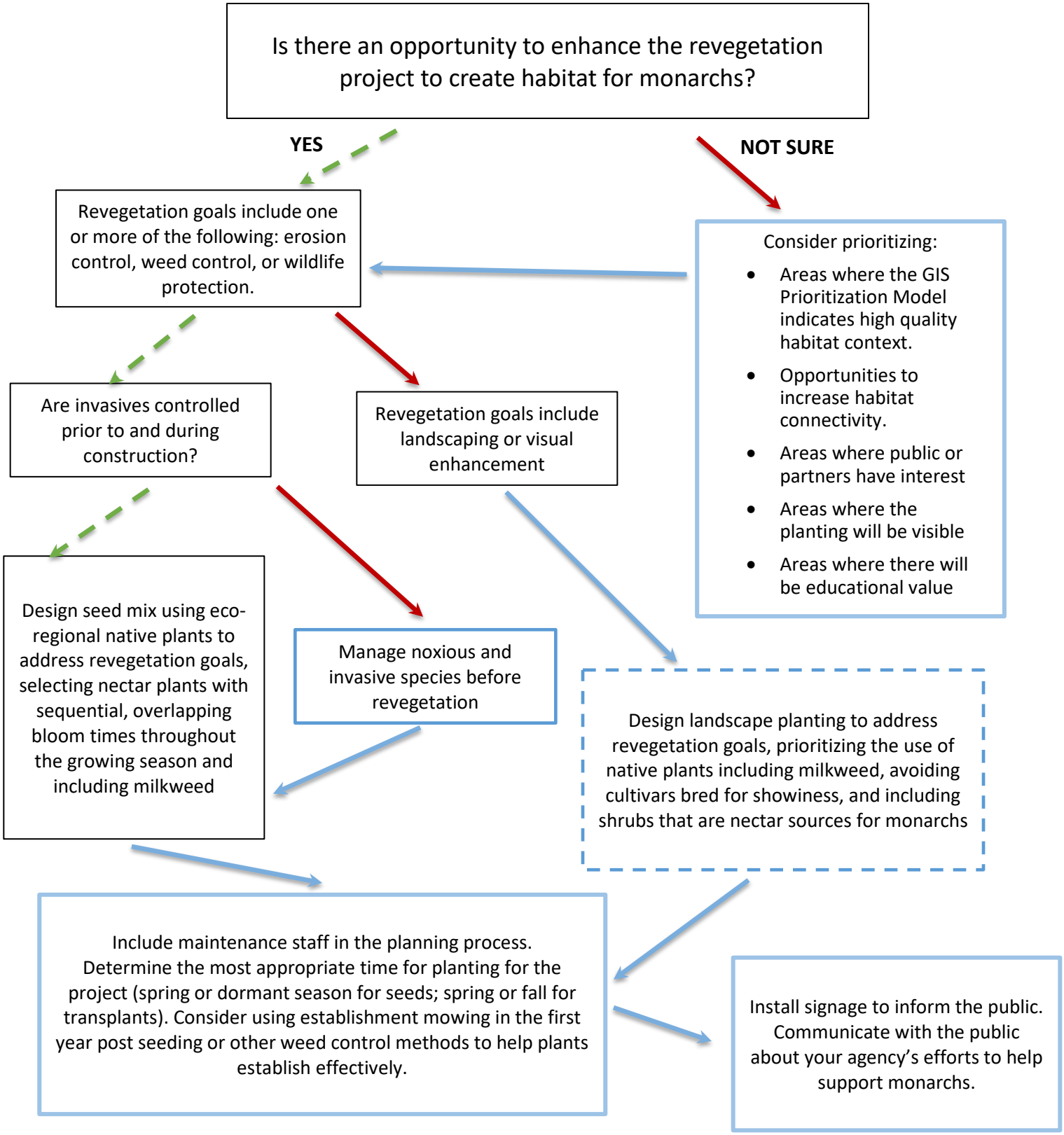

Figure 42. Decision Support Tree B. Best Management Practices for Monarchs: Revegetation

Decision Support Materials

For each part of the decision tree, we identified pertinent materials for the decision. We wanted information that could be easily accessible to a manager, something brief yet informative, providing links to additional information if more detail was desired. On a website, links to appropriate existing materials can be made. For example, if considering mowing as a management practice, one can consult the Mowing and Management: Best Practices for Monarchs handout written by Monarch Joint Venture (https://monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf). In other cases, when our team discussed the topic, we could not identify existing material that would be useful. Those were topics then that we prioritized for development within our team. Together these will complement existing resources. Our vision is to provide these materials via a website, but we have not yet had the capacity to design the website.

Existing resources

Nectar Plant Guides

There are many native species that can be planted on roadsides to support monarchs. We have produced recognition guides that highlight the most common milkweed species along roadsides. The Xerces Society has also produced lists of monarch nectar plants for each region of the lower 48 states. These fact sheets are available at: http://xerces.org/monarch-nectar-plants. Additionally, the USDA's Natural Resources Conservation Service (NRCS) has produced monarch nectar plant guides for 5 regions of the country (and many state NRCS offices have developed lists for their state). The five regional guides are available at: www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207

Locating Plant Materials

- The Xerces Society's Milkweed Seed Finder provides a search tool for locating commercially available native milkweed seed sources by species and state. Available at: http://xerces.org/milkweed-seed-finder
- Monarch Watch's (www.monarchwatch.org) Milkweed Market Vendors provides a map of native milkweed vendors across the country.
- The Xerces Society's Pollinator Resource Center provides region-specific information about native plant nurseries.

Best Management Practices

For detailed information on best management practices for monarchs and other pollinators on rights-of-way, consult:

- The Federal Highway Administration's Roadside Best Management Practices that Benefit Pollinators handbook: www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_landscapes.
- Additional guidance is found here:
- www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_roadsides.aspx

Revegetation Guidance

- Visit nativerevegetation.org to find:

- **Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat.** This report offers an integrated approach to facilitate the successful establishment of native plants and pollinator habitats along roadsides and other areas of disturbance associated with road modifications. The report takes practitioners through a comprehensive process of initiation, planning, implementation, monitoring and operations & maintenance of a roadside revegetation project with native plants for creating pollinator habitats, and describes adapting/improving processes for future projects. The comprehensive 500+ page online report offers an integrated approach to facilitate the successful establishment of native plants and pollinator habitat along roadsides and other areas of disturbance associated with road modifications. A primer and resource library accompanies the report. Available at: www.nativerevegetation.org/learn/manual_2017
- Consult the Ecoregional Revegetation Assistant Tool, an online map-based tool to help practitioners to select native plants suitable for revegetation of a site by using filters for needed plant attributes, including such as soil type, moisture needs, salt tolerance, and nectar plants for monarchs. www.nativerevegetation.org/era

Case Studies

- Examples of State DOT practices that support pollinators and monarchs can be found through Federal Highway Administration's Environmental Toolkit for Pollinators: www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx
- Additional case studies have been collected on the Roadside Habitat for Monarchs webpage: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies

New Materials Developed

Series of Frequently Asked Questions (FAQ's): Managing Roadside Habitat for Monarchs

Based on a need identified from DOTs, we compiled a list of frequently asked questions (FAQ's) and answers to explain how monarchs use roadsides. These science-based explanations can be used by DOTs when interacting with the public about roadside management or revegetation practices to support monarchs. We intend these questions to be made available through the project's website, where they will be easily accessible and can be 'living documents' that may be updated as more information becomes available.

Roadside Habitat for Monarchs

Frequently Asked Questions: Monarchs and Roadsides

Monarch Butterflies and Roadsides

How does roadside vegetation support monarchs?

Milkweed on roadsides is readily used by adult monarchs who seek out milkweed stems and leaves to lay their eggs on and nectar on milkweed flowers. Monarch larvae, or caterpillars, eat the leaves of many different species of milkweeds that grow in roadside areas. Roadsides can also provide diverse nectar sources which fuel adult flight, breeding, migration, and overwintering. *Sources: Kasten et al. 2016; Pitman et al. 2018*

Which types of roadside vegetation support monarchs?

Adult monarchs feed on nectar from a variety of blooming plants, including wildflowers and shrubs and monarch caterpillars consume milkweed. Roadsides with diverse, flowering vegetation provide habitat for monarchs during breeding and migration. For example, fall-blooming flowers can be especially important to migrating monarchs, which need large quantities of nectar to generate the fat reserves that enable them to complete their long-distance migration to overwintering grounds and survive winter. *Sources: Cariveau et al. in review; Western Monarch Milkweed Mapper 2019*

Do monarchs reproduce on roadsides?

Yes. Monarchs use milkweed on roadsides for reproduction—eggs, caterpillars, chrysalises, and adults are all observed. Studies and monitoring efforts in the Midwest, Southern Plains, West, and other areas have documented monarch's use of roadsides for reproduction. *Sources: Mueller & Baum 2014; Kasten et al. 2016; Pitman et al. 2018; Western Monarch Milkweed Mapper 2019; Cariveau et al. in review*

Are there tools available for roadside managers to monitor milkweeds and/or monarchs on roadsides?

Yes, a rapid field assessment for milkweeds can be found on the *Roadside Habitat for Monarchs* website: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies. Another option is the national Integrated Monarch Monitoring Program (https://monarchjointventure.org/IMMP), which compares monarch habitat and use across different land-use types, including roadsides. This program is more quantitative and may be more rigorous when comparing different habitat types or regions across time.

Does roadside vegetation that supports monarch butterflies also support pollinators and other beneficial insects?

Yes! Roadside vegetation that supports monarchs also supports a wide range of insects, including butterflies, bees, flies, wasps, beetles, and more. Roadsides with diverse, flowering vegetation can serve as foraging habitat, provide a place to breed, nest, or overwinter, and help pollinators and other insects to move through landscapes by linking fragmented habitats.
Sources: Dirig and Cryan 1991; Munguira and Thomas 1992; Ries et al. 2001; Saarinen et al. 2005; Hopwood 2008; Schaffers et al. 2012.

Does monarch-friendly roadside vegetation provide any advantages to adjacent landowners?

Yes, habitat on roadsides can help maintain healthy ecosystems and provide ecological services, such as crop pollination or crop pest suppression. Habitat increases the diversity and stability of the pollinator community, and when on or near farms, habitat can improve pollination and increase crop yields. Roadside habitat also supports the beneficial insects that are predators of crop pests and contribute to natural pest control. In addition, roadside habitat can provide other ecological benefits that can translate to advantages to adjacent landowners, including reducing soil loss and water runoff, increasing water filtration and carbon sequestration, and supporting grassland birds. *Sources: Mader et al. 2014; Morandin and Winston 2006; Morandin and Kremen 2013; Varchola and Dunn 1999; Losey and Vaughan 2003; Harrison 2014.*

Threats to Monarchs associated with Roads

Are monarchs killed by collisions with vehicles?

Yes, like many other animals and pollinators, monarch butterflies are killed by vehicles on roads. Few studies have estimated monarch mortality due to vehicles, but those that have note that the greatest risk for monarch collisions is during fall migration. Researchers in Illinois estimated that up to 500,000 monarchs were killed during the fall migration in the state; researchers in Texas estimated 1-3 million monarchs killed during the fall migration. Other studies in Mexico have estimated millions of monarchs killed on roadsides as the population's migration concentrates closer to the overwintering sites. However, roadsides are also very productive habitat for monarch reproduction and in many locations, the numbers of monarchs produced on roadsides likely outweighs the numbers killed by vehicles, though studies are needed on this topic. Additional surveys are also needed for estimating variation in monarch road mortality across seasons, and identifying and better understanding potential roadkill hotspots.*Sources: McKenna et al. 2001; Munoz et al. 2015; Kantola et al. 2019*

If roadsides have higher quality monarch habitat, will that increase collisions of monarchs with cars?

No studies have examined this with monarch butterflies specifically, but research involving other butterfly species suggests that more diverse roadside habitat and roadsides with less frequent mowing are associated with reduced butterfly mortality, perhaps because butterflies are better able to find resources within the roadside habitat and are less pressured to cross the road in search of additional habitat. This research suggests that, rather than luring butterflies to areas where they are killed by vehicles more frequently, roadsides with high quality habitat actually reduces butterfly mortality compared with grassy, low diversity roadsides. *Sources: Munguira and Thomas 1992; Ries et al. 2001; Skórka et al. 2013.*

Do vehicle collisions with monarch butterflies increase during migration, and is there any way to prevent roadkill?

Data are limited, but it appears that more monarchs are killed due to vehicle collisions during fall migration compared to other parts of their migratory cycle. In Illinois, monarch mortality due to vehicles peaked during fall migration. In Texas, when monarchs funnel through the state on their way to overwintering grounds in Mexico, researchers found hotspots of mortality due to vehicle collisions. Roadkill hotspots were in less densely populated areas and sites with a more arid

climate. The researchers suggest that migrating monarchs may spend more time flying lower to the ground during the afternoon in desert areas to seek shelter from the heat and may need to search more for nectar sources. Similar results have been found from studies in northern Mexico. Potential mitigation strategies for reducing monarch roadkill on recurring hotspots in Texas and Mexico are under investigation.*Sources: McKenna et al. 2001; Kantola et al. 2019*

Does roadside runoff, including heavy metal deposition and road salt deposition, affect monarchs and milkweeds?

Studies have shown that roadsides can suffer from heavy metal accumulation from car wear-and-tear and residual leaded gasoline emissions. In northern states, sodium from road salt application can accumulate along roadsides, and exhaust emissions can elevate levels of nitrogen. These chemicals can make their way into the leaves and nectar of plants growing next to the road. Studies to date suggest that toxic levels of metals, sodium, and other roadside pollutants are most worrisome along very high traffic volume roads, and just adjacent to the roadside. If we can prioritize restorations along low- or medium-traffic volume roads, and keep a mowed buffer adjacent to the roadside, we can likely avoid negative effects of roadside toxins on milkweed and monarchs. *Sources: Snell-Rood et al. 2014; Snell-Rood in prep*

Milkweeds on Roadsides

What milkweeds are most common on roadsides?

The answer to this question depends on what part of the country you are in. There are over 70 species of milkweeds native to the United States, but none of them occur in every state. To help roadside managers and others recognize milkweeds in their regions, we have developed milkweed recognition guides for 16 regions of the lower 48 states, found here: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies

How do I know if there is milkweed on my roadsides? / How can roadside managers recognize milkweeds?

We have created recognition guides to help you to recognize the milkweed species that are most common on roadsides in your area, found here: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies

Most milkweeds have milky sap, so if you see a plant that looks like one of those in the guide to your region and milky sap oozes from the plant after breaking a leaf or stem, this is an indicator that you might be looking at a milkweed (though there are a few other types of plants, such as dogbane and spurges, which also have milky sap). Most milkweeds also have distinctive star shaped flowers that cluster together at the top of the plants. Then, when flowering is done, most milkweeds produce seed pods that open up to release brown seeds with white fluff attached (the fluff helps those seeds travel on the wind). There are a variety of factors (height, leaf shape, leaf arrangement, flower color, etc.) to help one distinguish among the different milkweed species—or even to recognize dried milkweed stems in the fall and winter. Additionally, some milkweed species are only found in certain soils. If you are seeking information beyond what is found in the recognition fact sheets, see Milkweeds: A Conservation Practitioner's Guide for more about milkweeds. *Sources: Borders and Lee-Mader 2014*

Are milkweeds in roadsides likely to spread to adjacent land and become weeds?

Although milkweed, the common name for plants in the genus *Asclepias*, implies that the plants are indeed weeds, milkweeds are a diverse group of native wildflowers that are not listed as noxious weeds at either the state or the federal level in the United States. Milkweeds may have been perceived as weeds historically because a few species (out of the 70+ species in the U.S.) will readily colonize disturbed areas.

These species tend to reproduce vegetatively (in addition to reproduction by seed), sending up new shoots from roots that spread outward from the parent plant. This clonal reproduction allows their populations to expand over time, and plants may spread out of their original area. Common milkweed (*Asclepias syriaca*) exhibits the highest degree of clonal reproduction, and vegetative growth also occurs to a lesser degree in horsetail milkweed (*A. subverticillata*), narrowleaf milkweed (*A. fascicularis*), plains milkweed (*A. pumila*), prairie milkweed (*A. sullivantii*), showy milkweed (*A. speciosa*), and whorled milkweed (*A. verticillata*). Despite the vegetative growth, many of these species are unlikely to create an ongoing and unmanageable weed problem for roadside managers (or adjacent landowners, other land managers, homeowners, etc.). *Sources: Borders and Lee-Mader 2014*

Are milkweeds in roadsides a concern for grazing animals on adjacent land?

Milkweed species present in roadsides are unlikely to be a threat to livestock on adjacent property. Very few milkweed species will spread from their planting site. If milkweeds are present in pastures or rangelands, most livestock take care to avoid them. Although milkweeds are toxic, livestock generally find them highly unpalatable. Poisoning events are rare—but not unheard of--, possibly because livestock must consume a large amount of milkweed to become sick or die. An average cow weighing roughly 1,200 lbs would need to eat 12 lbs or more (1-2% of their body weight) of dried milkweed on average to die. Milkweed poisoning typically only occurs when livestock are confined to a barren paddock with no alternate food sources or when hungry animals are released into milkweed patches. However, there are two species, western whorled milkweed (*A. subverticillata*) and narrowleaf milkweed (*A. fascicularis*) which have been reported as especially problematic for cattle and sheep, likely because of their growth forms and thin stems and leaves which are easily tangled in grasses and thus difficult for grazing animals to separate out. It is also important to note that the palatability of milkweed increases when it is dry. If adjacent landowners are haying the roadside, it is best to avoid haying areas where concentrations of milkweed are high. *Sources: Panter et al. 2011; Burrows and Tyrl 2007; DiTomaso and Healy 2007; Schultz 2003; Malcolm 1991; Kingsbury 1964; Fleming 1920*

Are milkweeds in roadsides that are hayed by adjacent landowners a risk to livestock?

The palatability of milkweed increases when it is dry and so it is more likely that livestock will be sickened or even die from consuming dried milkweed in great enough quantities than fresh milkweed. If adjacent landowners are haying the roadside, it is best to avoid haying areas where concentrations of milkweed are high. However, large quantities of milkweed need to be ingested in order to cause harm. For example, an average cow weighing roughly 1,200 lbs would need to eat 12 lbs or more (1-2% of their body weight) of dried milkweed on average to die. The toxicity of milkweed varies by species and cardenolide concentrations (as well as local growing conditions); some species are generally of very low risk to livestock (e.g., butterfly milkweed, *A. tuberosa*) while others are consistently quite high (e.g., woollypod milkweed, *A. eriocarpa*).*Sources: Burrows and Tyrl 2007; DiTomaso and Healy 2007; Schultz 2003; Malcolm 1991; Kingsbury 1964; Fleming 1920*

How do milkweeds support pollinators or beneficial insects?

Besides providing food for monarch caterpillars and adults, milkweeds support a wide range of pollinators and beneficial insect species. Milkweed flowers are a high quality nectar source for pollinators such as bees, butterflies, wasps, beetles, flies, and more. Milkweeds also attract a wide range of insects that contribute to crop pest control, and some producers (e.g. vineyards in the Pacific Northwest) have begun to integrate milkweeds into their agricultural system in order to attract these important insects and support biological control. Milkweed leaves, stems, and roots support insect herbivores such as other lepidoptera (butterfly and moth) species, wasps, flies, beetles, true bugs, and more. Milkweed "silk" (the fibers attached to the seeds and help the seeds catch the wind) can be used for nesting materials by vertebrates such as birds and small mammals.*Sources: Tilman and Carpenter 2014; Borders and Lee-Mader 2014; James et al. 2016*

What times of the year are milkweeds most readily observed in roadsides?

In all of the lower 48 states, the majority of milkweed species will be observable during the growing season. The months during which you can most readily observe milkweeds depend somewhat on where you are. In much of the northern half of the country, the best months to see milkweeds on roadsides are from July to August. However, in Texas and southern Oklahoma, green antelopehorn and spider milkweed emerge in March, and are extremely important in that they help sustain the first generation of monarchs produced in the U.S. each year. Interestingly, in those two states, it can be difficult to find milkweeds in midsummer, as some of the most abundant milkweed species go dormant then; milkweeds can become abundant again in late summer or fall when conditions are more favorable. In the Desert Southwest, there are some native milkweeds that remain green during the late fall and winter. The same is true in the southeastern coastal plain with regards to a wetland species, aquatic milkweed (*Asclepias perennis*), which can be found along roadsides in winter in eastern TX (and presumably in other places along the Gulf Coast that have warm winters).

How can roadside managers share information about the occurrence of milkweeds and monarchs in roadsides to improve understanding of habitat conservation?

Set up a survey of monarch habitat and monarchs in your road system using the Roadside Habitat for Monarchs Rapid Assessment and Habitat Calculator (https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies) and then share findings at statewide and regional meetings, such as the Rights-of-Way as Habitat Working Group meeting.

Designate a staff member as point person for milkweeds and monarchs who can answer questions and be a liaison between roadside managers, administration, state monarch efforts, and conservation organizations.

In your local, regional, or state jurisdiction, include milkweed and/or monarch sightings and location maps to the list of communications and reports that are shared among staff.

Add milkweed and monarch sightings to community science portals: Journey North (all of US; https://journeynorth.org) and/or the Western Monarch Milkweed Mapper (western US; www.monarchmilkweedmapper.org/).

Roadside Management for Monarchs

How can roadside vegetation inventories benefit monarchs?

A roadside vegetation inventory involves mapping the composition and condition of current roadside vegetation, including native, invasive, and noxious weeds. Such inventories can inform management plans that can benefit monarchs in a number of ways:

- Identification of remnant habitat can allow roadside managers to make informed decisions about how to manage remnant habitat to maintain and improve it, to help sensitive plant species survive and sustain habitat for monarchs and other wildlife.
- Roadside inventories can also be used to map out existing weed issues and identify emerging weed problems. Those data can then be used to help target management operations and to evaluate the effectiveness of weed management techniques.
- Inventories may be used to learn about the effects of management strategies across different management areas.
- Finally, inventories can help identify opportunities for future monarch-friendly revegetation efforts.

How can a roadside manager assess the value of roadside vegetation for monarchs?

A habitat assessment tool for monarchs can be found on the *Roadside Habitat for Monarchs* project website: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies

How does roadside mowing impact monarch caterpillars and adults?

Mowing during the growing season affects monarchs by removing nectar sources and reducing milkweed availability (but see milkweed stimulation question below), and can result in direct mortality of butterfly eggs, larvae, and sometimes adults. For these reasons, mowing can set back monarch breeding temporarily and can remove nectar sources needed during monarch migration. (In some regions, mowing can stimulate milkweed regrowth, and monarchs prefer to oviposit on mown milkweed when both mowed and unmowed plants are available; see "Could roadside mowing stimulate milkweed" question below.) In general, it is preferable to mow when monarchs are not present; however, there may be circumstances when mowing when monarchs are present is more beneficial to the long-term quality of habitat for monarchs. See the Monarch Joint Venture handout "Mowing and Management: Best Practices for Monarchs" for more information, including management windows. *Sources: Morris 2000; Johst et al. 2006; Noordijk et al. 2009; Kayser 2014, Thomas 1984; Wynhoff 1998; Humbert et al. 2010; Kayser 2014*

When should roadsides be mowed to reduce impacts to monarchs?

It is best to mow when monarchs are not present (see management window map below). Based on the best available data for when and where monarchs breed, Monarch Joint Venture and Xerces Society have developed regionally-appropriate monarch breeding habitat management windows. These windows are periods when management activities are least likely to have negative effects on monarchs—especially immature monarchs.

The exact timing of monarch breeding may vary from year to year and site to site (but try consulting a website such as JourneyNorth or Western Monarch Milkweed Mapper to see when monarchs are reported in your area)—and these windows may be revised in the future as we learn more. This is especially true for areas where few data are currently available on the timing of monarch breeding, such as the states that straddle the continental divide. Also, as long as milkweed is present in the landscape during the breeding season, there is a chance that monarchs are also there and that management actions could result in monarch mortality. As every year and site are slightly different, it is useful to survey milkweed plants for immature stages of monarchs prior to mowing. This is time consuming but is especially helpful if the management timing falls on the cusp of the recommended window for your region or if it has been an early spring/late fall year (see Figure 43).

Could roadside mowing stimulate milkweed growth and support monarch breeding?

Limited research in eastern North America has shown that spring or summer mowing can promote new growth and extend the availability of milkweed plants for monarch breeding. Mowing may stimulate growth of some milkweed species, particularly those that spread through rhizomes like common milkweed (*A. syriaca*) and showy milkweed (*A. 80aturali*). Summer (June or July) mowing in Michigan resulted in more monarch eggs on regenerated stems than unmowed stems. Summer (July) mowing and burning can increase

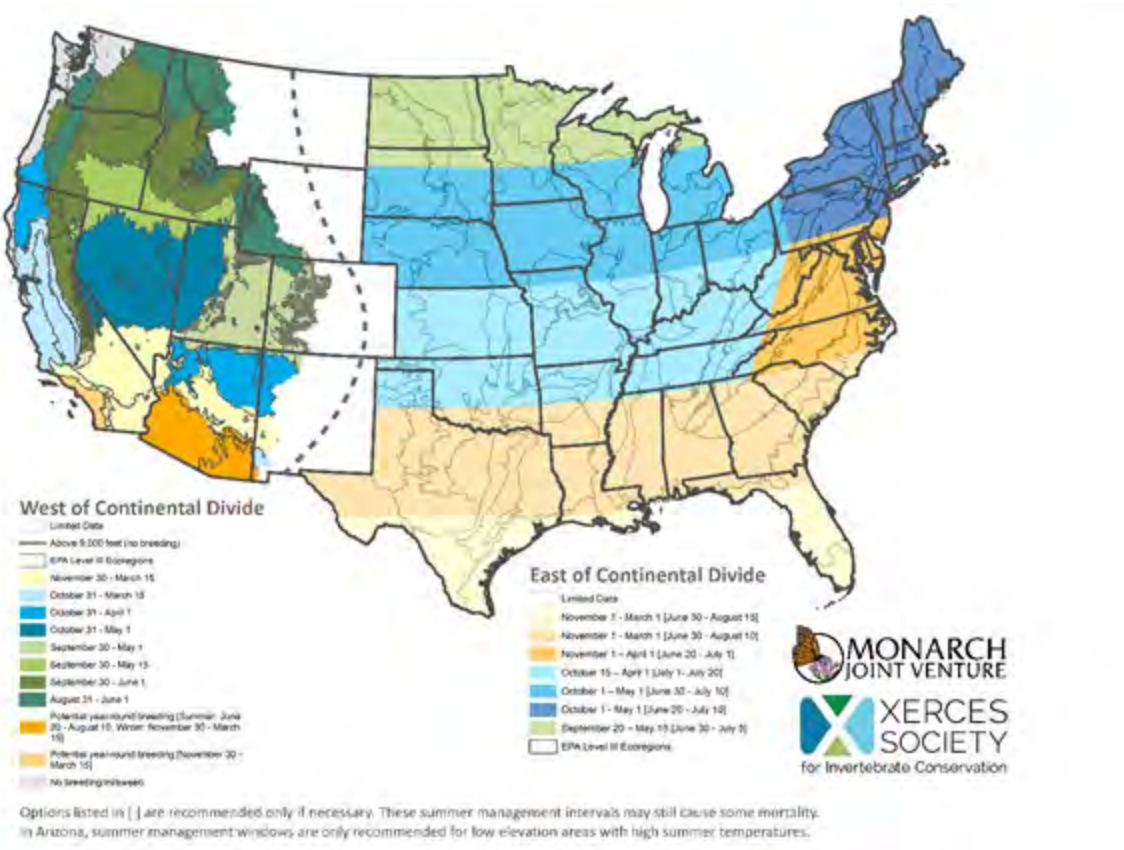

Figure 43. Map depicting best time windows for management actions that may affect monarch breeding habitat (from the MJV 'Mowing and Management: Best Practices for Monarchs' handout).

green antelopehorn milkweed (*A. viridis*) availability in the late summer and early fall in the Southern Great Plains, whereas in areas without mowing, the milkweed has senesced by August. In the West, showy milkweed will regrow after summer mowing and continue to support monarch breeding (Stephanie McKnight, personal observation). However, more research is needed in other areas to determine the optimal timing and frequency of mowing that promotes not only milkweed but also nectar plants. It is also unknown if the benefit of additional milkweed availability in the fall outweighs the costs of the larval mortality caused by summer mowing. The benefits are likely greater in areas that primarily have breeding monarchs in the spring and fall and where the dominant species of milkweed spread by rhizomes.*Sources: Alcock et al. 2016; Baum and Mueller, 2015; Bhowick 1994; Haan and Landis 2019; Fischer et al. 2014*

How does roadside mowing impact nectar plant abundance and diversity?

Frequent roadside mowing beyond the safety zone can reduce native plant species diversity and abundance and may also favor the development of grasses over herbaceous plant species, which can indirectly affect monarchs and other pollinators. However, moderate mowing levels—such as twice per season or less (it varies by region)—have been shown by multiple studies to increase plant species diversity in grassland habitats. Other studies suggest that a single mowing during the growing season or in the fall is more beneficial for floral diversity compared to two or more mowings in a year. It should be cautioned that spring or summer mowing, while potentially beneficial to plant diversity in some locations, can lead to direct mortality of monarchs and other pollinators. However, there may be circumstances when mowing

when monarchs are present is more beneficial to the long-term quality of habitat for monarchs.*Sources: Parr and Way, 1988; Williams et al., 2007; Mader et al., 2011;Forman, 2003; Noordijk, et al. 2009; Entsminger et al., 2017; Valtonen et al., 2007*

How does herbicide use on roadsides impact monarchs?

Noxious and invasive weeds can degrade habitat for monarchs by displacing valuable nectar plants and milkweed. Herbicides are a tool employed by many transportation departments to control noxious and invasive weeds, encroaching woody vegetation, or vegetation that exceeds maximum height specifications in safety zones on roadsides. However, herbicide use can have non-target effects that reduce the quality of roadside habitat for monarchs by removing flowering plants and milkweed plants and may also have some direct negative impacts on pollinators themselves. Following best management practices for use of herbicides in relation to pollinators and other wildlife will assist managers in minimizing adverse effects on monarchs. A fact sheet on this topic summarizes recommended practices and can be found on the Roadside Habitat for Monarchs website: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies. *Sources: Russell and Schultz 2014*

Does reduced roadside mowing increase vehicle collisions with deer or other large mammals?

Frequency of mowing of the entire roadside does not appear to influence rates of deer–vehicle crashes. In fact, deer may actually prefer some roadsides that are mowed more frequently because mowing can increase the palatability of some plants. A strip of vegetation adjacent to the pavement, often referred to as the clear or safety zone, that is mowed regularly, while allowing the rest of the roadside grow to a reasonable height, can help maintain visibility for drivers and prevent deer–vehicle crashes. Driver safety may increase with the presence of wildflowers and diverse vegetation by reducing monotony on roadsides, which improves driver awareness. *Sources: Mastro et al. 2008; Barnum and Alt 2013; Guyton et al. 2014.*

Are there other advantages to reducing mowing and herbicide use beyond helping pollinators?

Often there are cost savings associated with reduced mowing and efficient herbicide use. There are also many ecological benefits, including reduced carbon emissions, reduced herbicide runoff, and improved habitat for small wildlife such as grassland birds. *Sources: Harrison 2014*

What are some roadside mowing strategies that roadside managers have used to support monarchs?

Illinois DOT has reduced mowing of roadsides beyond the 15’ safety zone in many areas, mowing different sections of the right-of-way once a growing season rather than mowing the entire right-of-way.

Texas DOT manages right-of-ways for the protection of wildflowers and pollinators. Mowing operations start after the spring flowers have bloomed and set seed, usually around June. This is the best time for the mowing operation and by this time the monarchs are out of the state. Mowing at this time opens the canopy for warm season species, and TxDOT sets all mowers to 7 inches to ensure less damage to warm season plants. TxDOT also conducts a fall mowing operation that opens up the canopy so the cool season flowers have room to germinate and establish for the following year. TxDOT also sets aside as much right of way as possible in non-mowed areas. These areas are great for wildlife habitat and fall blooming nectar plants such as Maximillian Sunflower, Goldenrod and Gayfeather.

Case studies are available at the Federal Highway Administration’s Pollinators page in their Environmental Review Toolkit (Select the State DOT Pollinator-Friendly Practices and Information tab): www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx

How do non-native and/or invasive plants in roadsides affect milkweeds and monarchs?

Invasive plants on roadsides can greatly reduce the abundance of milkweeds by outcompeting them for water, light, space, and nutrients, and thereby limit the reproductive potential of monarchs. Invasive plants can also outcompete the wildflowers that serve as nectar sources for monarch adults. By reducing the abundance and diversity of milkweeds and nectar sources, invasive plants reduce the food supply for adult monarchs, leading to reduced monarch abundance.

How can the transfer of seeds on mowing equipment affect roadside habitat for monarchs?

Mower decks (above and underneath), the area around the gear box, as well as blades and shafts can transfer the seeds of noxious and invasive weeds, species that can seriously degrade vegetation quality and diversity once they invade new sites. Adult monarchs rely on diverse sources of nectar throughout the breeding season as well as during migration. If invasive species become dominant, this can reduce the diversity of native plants available to provide nectar throughout the entire growing season. Preventing the spread of weed seed can help to reduce new invasions.

How does haying of roadsides affect monarchs and milkweeds?

Annual haying at the right time can benefit herbaceous roadside plant communities by suppressing the growth/encroachment of woody vegetation and reduce competition from tall grasses, allowing flowering plants to thrive. However, it can have negative effects on monarchs by abruptly removing milkweed and flowers at a site and destroying immobile eggs and larvae. To provide refuges for monarchs, harvest hay in strips or patches, instead of harvesting hay from an entire site. Cut hay at a high height (8–12”), so that some wildflowers can recover and go on to flower later in the season. Varying the season of haying from year to year may increase overall plant diversity. *Sources: Feber et al. 1996, Foster et al. 2009*

What impact does fire (either prescribed burns or wildfire) have on roadside monarchs and milkweeds?

Prescribed fire is an important management tool; if carefully implemented, fire can be used to control unwanted woody vegetation and some invasive plants, stimulate wildflowers in fire-adapted plant communities, and reduce plant litter buildup that can suppress nectar resources for pollinators such as the monarch. The response of adult monarchs has been reported to be positively correlated with the post-fire availability of nectar resources, with significantly more monarchs using burned areas compared to unburned areas, especially during the first growing season after a fire. Burns (either prescribed or wild) during the growing season may stimulate growth of certain milkweeds, depending on the region (e.g. In Oklahoma, researchers found that summer prescribed fire stimulated resprouting of *A. viridis*). However, implementing fire during the monarch breeding season can directly kill monarch eggs, larvae, and pupae, and temporarily remove nectar and host plant resources for adult monarch butterflies. Adjusting the timing of prescribed fire to occur outside the monarch breeding and migration season can reduce the impacts to monarchs. Implementing fire in the early spring before monarchs arrive to a region, in late fall after monarch migration is complete, or in the winter will have the least direct impacts on the butterfly. However, in some regions and under some circumstances, the long-term benefits to vegetation management or plant diversity of using prescribed fire while monarchs are present may outweigh the short-term costs. *Sources: Rudolph and Ely, 2006; Vogel et al., 2007; Baum and Sharber, 2012; Moranz et al., 2012.*

Revegetation

What kinds of plants can be planted on roadsides to support monarchs?

In each region, there are many native species that can be planted on roadsides to support monarchs. We have produced recognition guides that highlight the most common milkweed species along roadsides. The Xerces Society has also produced lists of monarch nectar plants for each region of the lower 48 states. These fact sheets are available at: https://xerces.org/monarch-nectar-plants

The USDA's Natural Resources Conservation Service (NRCS) has produced monarch nectar plant guides for 5 regions of the country (and many of the state NRCS offices have developed lists for their state). The five regional guides are available at:

http://nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207

What plants do monarchs use as nectar sources?

Documented nectar plants for monarchs are summarized in these regional lists (https://xerces.org/monarch-nectar-plants), but additional studies will likely increase our knowledge of the plants they use. Although they are known to nectar on a wide variety of plants (and thus are considered nectar plant generalists), there are many plant species that they rarely or never visit, and a smaller number of plant species that they strongly prefer. For example, many milkweed species, in addition to providing food for caterpillars, are also preferred nectar sources. Until we know more about monarch nectar preferences, you can refer to the regional monarch nectar plant lists that the Xerces Society in collaboration with Monarch Joint Venture or the NRCS have developed for each region of the lower 48 states.

These plant lists are available at:

https://xerces.org/monarch-nectar-plants

www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207

www.calflora.org/app/ipl?list_id=px771&incvar=t

When revegetating roadsides, how can planners consider the needs of monarchs?

Include wildflowers or shrubs that are nectar sources for monarchs. Include species that bloom in spring, species that bloom in summer, and species that bloom in fall so nectar is available throughout monarch breeding and migration periods. Monarch nectar plant lists are available at: https://xerces.org/monarch-nectar-plants

www.nrcs.usda.gov/wps/portal/nrcs/detail/national/plantsanimals/pollinate/?cid=nrcseprd402207

Include native milkweed species in seed mixes or in landscape plantings. In regions where milkweed is difficult to establish from seed (e.g. California), using transplants may be a more cost effective way to establish milkweed in roadside habitat. For a directory of sources of milkweed seed, visit https://xerces.org/milkweed-seed-finder.

What are some general guidelines for designing seed mixes or landscape plans for roadsides that can support monarchs?

- Include a diversity of plants; diverse communities are better able to prevent erosion, resist weeds, help with water infiltration, and are aesthetically pleasing.
- Include species that can fill different roles. Cool season grasses green up early in the spring and can provide erosion control from late winter into early summer, while warm-season grasses provide erosion control as they grow through the warm summer months and into the fall. Legumes can fix nitrogen and improve soil health. Annual forbs will establish quickly to provide attractive vegetative cover, erosion control, and nectar for monarchs during the time it takes for longer lived perennial forbs to establish.
- Avoid taller herbaceous plants in areas where lines of sight could be blocked, such as intersections and other safety zones.
- In areas with snow and ice, species to be planted close to the road should have some level of salt tolerance to reduce damage from road salt applications.

- Include species adapted for the soil conditions present at the roadside site (e.g., use moisture-tolerating species for wet ditches), or, if seed mixes cannot be context-specific, include species adapted to a wide range of growing conditions.
- Focus on wildflowers that establish easily and are relatively inexpensive, but also include some species that are harder to establish and may be a bit more expensive to increase the aesthetics of the planting and the value of the habitat to monarchs.
- To achieve high plant diversity and long-term stability of a stand of vegetation intended for erosion control, a minimum of 25% of the seed mix should be wildflowers, but 50% results in a considerably more diverse planting. In highly visible areas, seed mixes for showy plantings should include greater than 50% wildflower component.
- Check erosion control mulches, seed laboratory reports and legal seed labels of the planting stock. Mulches, seed and other planting stock should be free of noxious weeds, invasive/introduced species and other crop components.
- Where available and economical, native plants and seed should be procured from local ecotype providers. Local ecotype plant materials are adapted to the local climatic conditions and will generally establish well and will have bloom times in sync with the presence of monarchs and other pollinators. Some cultivars have been bred for a particular trait such as showiness and may have little to no pollen and nectar and therefore little value to monarchs.

  Sources: Lippit et al. 1994; Hopwood et al. 2015

Why use native plants in new roadside plantings, if they are more expensive than nonnative species?

In addition to their value to pollinators, there are many advantages of using native plants to stabilize roadsides. Native grasses and flowers are best adapted to local growing conditions, require minimal inputs for establishment, and are able to tolerate extreme weather events such as drought. Native plants in roadsides are less likely than many nonnative plants to become weed issues and encroach on adjacent land. The root systems of native plants can increase water infiltration, which reduces runoff and water pollution and keeps our waters cleaner. A diverse native plant community can reduce soil erosion and resist weed invasions, which can reduce maintenance costs. Although native plants may cost more upfront, they can provide cost savings over time. Native plants can be aesthetically pleasing during the growing season while also acting as snow fences in the winter, trapping and preventing snow from blowing across roads. Roadsides with a diverse assemblage of plants sequester more carbon than weedy or species poor habitats. Native plant communities also support more birds, pollinators, and other wildlife. The use of native plants in roadsides can provide ecological benefits to the surrounding landscape. *Sources: Cramer 1991; Bugg et al. 1997; Harper-Lore and Wilson 2000; Johnson 2000; Ries et al. 2001; Quales 2003; Blumenthal et al. 2005; Tilman et al. 2006; Tallamy and Shropshire 2009; Williams et al. 2011; Harrison 2014; Harper-Lore et al. 2014.*

What should planners consider when selecting sites for roadside plantings that support monarchs?

When thinking about where to prioritize plantings that support monarchs, planners should consider the surrounding landscape, existing weed pressure, width of site, visibility to the public and potential for community engagement. Considerations include:

- Prioritize sites that are unlikely to undergo construction within 10-15 years following establishment of vegetation to ensure the long-term persistence of the plantings and to protect the investments of cost and time.
- Focus efforts on the widest roadsides to maximize potential habitat.
- Prioritize sites that connect other existing habitat within the landscape.
- Sites with high weed pressure may be challenging to return to native vegetation; DOTs that have limited experience with native plant revegetation may want to begin revegetation efforts on sites with low weed pressure.
- If a project goal is to highlight the value of DOT rights-of-way, sites planted with showy wildflowers to benefit monarchs and pollinators should be located in areas that are visible to the public, such as rest areas, or sites near farms that could benefit from the pollination services the roadside habitat

would help to support (e.g., roadside sites near almond orchards in California). Public education and perception of the planting is important. Visible plantings may make surrounding landowners more aware of the importance of roadside habitat, which may decrease landowner spraying, mowing, or haying of the roadside. Signage can also be a valuable tool for educating community members.

What kinds of tools are available to guide or inform decisions of planners?

A habitat prioritization modelling tool and a decision tree is available through the Roadside Habitat for Monarchs project website: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies.

Ecoregional Revegetation Assistant Tool

A map-based tool to aid practitioners when selecting native plants for restoration and pollinator habitat enhancement. The map can be searched by US Environmental Protection Agency (EPA) Level III Ecoregions, as well as by state. The database includes plant attributes such as soil type, moisture needs, palatability, salt tolerance, and value to pollinators, including nectar plants for monarchs. The plant species found within an ecoregion can be filtered by attributes, and a list of workhorse plant species can also be generated. This is part of a collaboration between the Federal Highway Administration, US Forest Service, WSP, and Xerces Society. This tool can help practitioners to select native plants suitable for revegetation of a site by using filters for needed plant attributes, including value to pollinators. The tool is available at www.nativerevegetation.org/era.

Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat

This report offers an integrated approach to facilitate the successful establishment of native plants and pollinator habitats along roadsides and other areas of disturbance associated with road modifications. The report takes practitioners through a comprehensive process of initiation, planning, implementation, monitoring and operations & maintenance of a roadside revegetation project with native plants for creating pollinator habitats, and describes adapting/improving processes for future projects.

The comprehensive 500+ page online report offers an integrated approach to facilitate the successful establishment of native plants and pollinator habitat along roadsides and other areas of disturbance associated with road modifications. A primer and resource library accompanies the report. Available at: www.nativerevegetation.org/learn.

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Best Management Practice Guide: Herbicides, Weeds, and Monarchs

This guide is intended to fill a gap that practitioners noted, an overview of the impacts of herbicides on monarchs and how herbicides can be used to improve monarch habitat on roadsides. Please see Appendix E for a formatted version.

Roadsides as Habitat for Monarchs

Monarch Butterflies, Weeds, and Herbicides

Monarch butterflies are in decline in North America, and restoring monarch habitat, including roadsides, is important to the species' recovery[1]. Monarch caterpillars require milkweed (primarily in the genus *Asclepias*) to complete their development. A diversity of milkweed species are found on roadsides[2,3], and monarchs lay their eggs readily on milkweed plants in roadsides[4] and consume nectar from milkweed flowers.

Roadsides provide more than just milkweed; they can also provide diverse nectar sources to feed adult monarchs and other pollinators. Nectar fuels adult monarchs in their breeding, migration, and overwintering. Adult monarchs feed on nectar from a variety of blooming plants, including wildflowers and shrubs, throughout the growing season. Spring flowers support monarchs as they leave their overwintering grounds to breed, and summer flowers support several generations of breeding monarchs. Fall-blooming flowers are also important, as monarchs migrating to overwintering grounds require lots of nectar to build fat reserves to support their long-distance flights and sustain them through the winter.

Noxious and invasive weeds can degrade habitat for monarchs by displacing valuable nectar plants and milkweed. Herbicides are a tool employed by many transportation departments and other land managers to control noxious and invasive weeds or encroaching woody vegetation. However, some herbicide uses have non-target effects that reduce the quality of roadside habitat for monarchs by removing flowering plants and milkweed plants or reducing plant diversity over time. This guide highlights best management practices to reduce the impacts of herbicides on monarchs.

Best Management Practices

Roadside managers and other vegetation managers can reduce the impacts of herbicide use on monarch butterflies by:

1) using herbicides within an integrated approach that incorporates a range of methods to prevent and manage weeds and non-compatible vegetation,

2) limiting nonselective broadcast applications, which can damage host or nectar plants,

3) using herbicides as efficiently as possible to reduce the amount applied,

4) reducing off-site movement of herbicides, and

5) limiting direct exposure of monarchs to herbicides when possible.

Specific management practices to reduce risk to monarchs from herbicide applications include:

Applicator Training

- Train staff and contractors to distinguish noxious and invasive weeds and encroaching woody vegetation from similar species to reduce unintended damage to nontarget plants. For instance, training may help crews to distinguish the invasive Canada thistle (*Cirsium arvense*) from the native tall thistle (*Cirsium altissimum)*, an important fall blooming native nectar plant for migrating monarchs in the central states.
- Train applicators in herbicide application techniques that reduce damage to nontarget plants. Create specifications that would hold contractors accountable to using proper techniques.

Assessment

- Inventory roadside vegetation regularly to identify emerging noxious and invasive weed issues or encroaching woody vegetation. Early detection of weeds can result in improved control and may reduce the amount of herbicide needed overall.
- Document desirable plants that may be present, such as native nectar plants and milkweeds.

Planning

- Use herbicides within an integrated vegetation management plan. Evaluate the range of management techniques (e.g., chemical, cultural, biological, physical, and mechanical) in order to select the most effective, feasible, and least harmful weed management method(s) that can increase or conserve the abundance and diversity of blooming plants.
- Prioritize selective herbicides—those formulated to control specific weeds or groups of weeds—whenever possible, to reduce damage to nontarget plants.
- If using nonselective herbicides--products that are broad-spectrum and kill or damage a wide range of plants—use direct or targeted application methods or apply when desirable plants are dormant. If possible, avoid applications when monarchs are present (Use on-site scouting as well as expected windows of monarch activity, found here: https://monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf.).
- Coordinate spray operations with mowing crews to enhance weed control. For example, it may improve control to treat mature weeds when they are actively growing, shortly after mowing.
- Choose and calibrate equipment with drift management in mind. Use nozzles that produce larger droplets that are less likely to drift off target. Calibrate equipment regularly to avoid over-application.
- Select herbicides with low volatility when feasible to reduce the off-target movement of herbicide vapors. Do not apply herbicides when temperatures are high (see label for more information) or during temperature inversions, when herbicides are more likely to volatilize.
- Use appropriate drift control agents.
- Prioritize the use of formulations that are jointly terrestrial and aquatic-approved, and that have lower residual activity and shorter half-life, when possible, in order to minimize potential impacts on the environment following application.
- Select adjuvants—products added to a spray solution to enhance performance of post-emergence herbicides—that are terrestrial and aquatic-approved, and compatible with the selected herbicide formulation.

Herbicide Applications

- Always apply herbicides according to label directions and use the minimum application rate that will effectively control the weed.
- Apply herbicides at the stage of growth when the weed is most vulnerable and the application likely to be most successful. This will be the seedling or rosette stage for some weeds. Consider the mode of action of the herbicide and the application technique when determining timing of application. For example, when using a systemic herbicide, treat perennial weeds in the late summer and fall, when perennials begin to move sugars down to their roots, so that the herbicide will be translocated to vegetative reproductive structures where it will be most effective at controlling the plant.
- When possible, treat plants before they convert from vegetative phase to floral phase and bloom; this will reduce the weed seed bank (reservoir of weed seeds in the soil). If weeds are treated just before bloom or after seed set, their populations may persist in future years. Treatment of weeds during their vegetative phase also reduce exposure of adult monarchs to herbicides and adjuvants.
- Apply herbicide sprays when weather conditions will minimize drift. Avoid applications when wind speeds are greater than 10 mph. Avoid applications during a temperature inversion (when warmer air above traps cooler air near the ground); these conditions cause herbicides and other pesticides to linger in the air, where they can move long distances offsite with any air movement. No wind or wind speed below 2 mph suggests a possible inversion.
- Make direct, selective applications to target plants to avoid weakening nontarget species. Target weeds or non-compatible species using spot treatment applications made with a backpack sprayer, weed wiper, or similar technology. Use highly targeted applications to cut stems, stumps, or underneath bark. Limit the use of broadcast treatments or pellet dispersal only for dense infestations of weeds or non-compatible vegetation, or for safety zone or guardrail treatments.
- Use an approved marker dye with spot treatments or cut stem/stump treatments to allow the applicator to know the target has already been treated and the extent of target coverage. Spray dyes reduce likelihood of an accidental retreatment or missing treatment of a target weed.

Post-Treatment

- Keep records of locations where herbicides are applied. Records on the plants treated, application method, type and amount of herbicides used, and dates of application can help to evaluate the effectiveness of treatments over time and can be useful when adjusting management decisions. Your state agency charged with education or regulation of pesticide use will have example application record keeping forms that can be used. Multiple seasons of herbicide applications or other weed control methods may be needed to fully control an invasive species.
- Follow label directions and standard practices when rinsing or cleaning spray equipment in between work sessions; incomplete removal of a prior herbicide mix can have detrimental impacts to the next treatment area.
- Rinse off, or otherwise clean mower decks (upper and undersides), deflectors, gear box housing, and mower blades and shafts, between sites to avoid transferring weed seeds. This is especially important after mowing an area known to contain noxious or invasive weed species.
- After treating a dense infestation, consider seeding or replanting the area if necessary (e.g. if the seed bank was depleted of desirable species). Plant with desirable, competitive native species to reduce the need to re-treat the area. Always make sure that seed and vegetative planting stock is free of weed species.
- After treatment, monitor resulting conditions and outcomes to evaluate the effectiveness of management practices on target plants and any effects on nontarget plants. If desired conditions were not produced or if site conditions change, adapt management practices accordingly.

Monarch use of noxious or invasive weeds - sidebar

Adult monarchs feed on nectar from a variety of blooming plants, including some noxious weeds or invasive non-native plants (such as Canada thistle, *Cirsium arvense*). However, if invasive species become dominant, this can reduce the diversity of other plants available to provide nectar throughout the season. For example, if Canada thistle is the only flowering plant present in a stretch of roadside, monarchs will only have nectar available to them from that single species which blooms during a small portion of the growing season, rather than a diverse patch of vegetation that could provide nectar from spring through fall. Hence, managing invasive plants will generally increase the abundance and diversity of plants that support monarchs and pollinators throughout the growing season.

In highly degraded landscapes where native nectar sources are scarce, the large-scale removal of the noxious or invasive species may cause a short-term reduction in nectar for monarchs. In these circumstances, reseed with native blooming plants that are attractive to monarchs, known to compete well with weeds, and bloom within the first few years of planting in your seed mix. In time, these species and other native perennial plants should deter recolonization of invasive plants and provide a haven for monarchs and pollinators.

Toxicity of herbicides to monarchs - sidebar

Although herbicides are formulated to kill plants and do not target insects, recent research indicates that some herbicides may be toxic to butterflies, particularly when ingested by caterpillars eating treated plants. Often, the herbicides are not immediately lethal but still have negative effects such as reducing butterfly size, weight, development rates, and survival[5, 6, 7, 8]. These sublethal effects may reduce butterfly populations over time[6]. These studies did not focus on monarchs and further research into the effects of commonly used herbicides, tank mixes, surfactants and other inert ingredients in formulated products on monarchs is needed.

Until more is known, we recommend a cautious approach when applying herbicides to milkweed where monarch caterpillars are present. Avoiding direct applications to milkweed plants when feasible, for example, can reduce direct herbicide exposure to monarchs.

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Resources

- Monarch Joint Venture: Roadsides as Habitat for Monarchs: https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies
- Xerces Society: Regional guides to monarch nectar plants: https://xerces.org/monarch-nectar-plants/
- Federal Highway Administration: Environmental Toolkit Review: Pollinators: https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx

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Regional Milkweed Identification Field Sheets

A diversity of milkweed species can be found growing on roadsides. Milkweeds can occur within intact natural plant communities on roadsides and several species can also colonize highly disturbed roadsides. Vegetation management that allows milkweeds to persist can support monarchs. These regional guides are intended to help roadside managers recognize the most common native species found on roadsides. Formatted to include photos of key features and county level distributions, these short recognition guides highlight the most common species on roadsides within the region. We created 16 regional roadside milkweed recognition fact sheets (found in Appendix F):

- Milkweeds of Arkansas, Louisiana, and Mississippi
- Milkweeds of Arizona and New Mexico
- Milkweeds of California
- Milkweeds of Colorado
- Milkweeds of Florida
- Milkweeds of the Great Lakes
- Milkweeds of Iowa and Minnesota
- Milkweeds of Kansas and Missouri
- Milkweeds of the Mid-Atlantic
- Milkweeds of Montana and Wyoming
- Milkweeds of Nebraska, North Dakota and South Dakota
- Milkweeds of the Northeast
- Milkweeds of Nevada and Utah
- Milkweeds of the Northwest
- Milkweeds of Oklahoma and Texas
- Milkweeds of the Southeast

Discussion

Roadside managers are already responsible for maintaining vegetation along our roadways. This vegetation serves many functions, but its value to pollinators is often not the first priority. With proper educational tools and training to support roadside maintenance decisions, there are opportunities to make adjustments from small tweaks in mowing timing or frequency to larger scale restoration or planting initiatives. The various products that we've developed through this project help managers to identify the best areas for habitat projects and to assess the conditions of those habitats for monarchs. To supplement these tools, we sought to provide descriptive answers to commonly encountered questions, to provide educational materials on different species of milkweeds and nectar resources, the potential impacts and best practices for herbicide use in roadside areas, and to guide decisions through a series of simple questions. These tools provide a good start for promotion to DOTs throughout the U.S. and will inform future educational and decision support tools that would benefit roadside managers.

We intend to make these resources accessible through the project web page and to begin promoting them to our list of project contacts. Ultimately, having an easily accessible and navigable website to share these tools in various fashions will benefit the project greatly.

CHAPTER 7

Conclusions and Suggested Research

The products developed through this project serve as an important foundation for rights-of-way conservation activities that have multiple benefits. Not only do well-informed conservation projects benefit monarchs and other pollinators, they provide a suite of environmental benefits (e.g., water filtration, carbon storage) and can improve cost-savings (in some but not all cases) for rights-of-way long term management activities. The charismatic and familiar monarch butterfly serves as a flagship species for pollinator conservation, and gives rights-of-way entities opportunities to engage a diverse array of stakeholders who are invested in not only restoring monarch numbers to sustainable levels, but also mitigating many other environmental and economic issues.

Roadsides provide promising monarch habitat as they frequently contain nectar and host plants, but present a range of risks, including pesticide spillover, vehicle collisions, contaminant runoff, and non-native vegetation. This project sought to maximize the potential of roadside restorations for monarchs by developing three tools targeted to roadside managers across the United States, including a) a GIS-based landscape prioritization model, customizable to each state, that identifies roadsides with the greatest potential for monarch conservation, b) methods for assessing the quality of a given roadside for monarchs through rapid assessment, c) putting the assessment data through a "habitat calculator," and c) a series of best management recommendations.

The Landscape Prioritization Model developed in this project is the first of its kind at this scale. It provides a transportation manager the ability to evaluate the landscape in their state with regard to areas where diverse roadside habitat could complement already existing natural habitats or where high-quality roadside plantings might create a corridor of suitable habitat where there is otherwise very little. In addition, this model depicts roads and their associated hazards in a way that helps managers to think about the importance of traffic volume, traffic speed, and right-of-way width, all factors that can potentially affect the roadside environment for monarchs. Together, this landscape information and road metrics inform managers' understanding of their road systems in a novel way.

The Rapid Assessment is a way for transportation managers to readily assess the habitat currently in their rights-of-way, and to track it through time. While many land management entities often lack time and capacity to conduct habitat assessment work, this tool was designed to be quick and easy to implement with different skill levels and also feeds into broader scale monarch and habitat monitoring initiatives and tracking efforts. Tracking and evaluating monarch habitat projects using the Rapid Assessment creates a feedback loop of information that will tell rights-of-way managers the baseline quality of their site, as well as continued tracking of how the project is doing. In turn, this will provide a valuable data set that will improve the seed mix design and habitat management practices implemented by the land management authority as they learn what is performing well, and what may not be. Not only will this reduce costs over time, but if applied in an adaptive management framework, the quality of the habitats for monarchs and pollinators should also improve (or minimally be sustained) over time.

The Habitat Calculator provides managers an easy to interpret breakdown of the functional components of the habitat. Using data collected through the Rapid Assessment, it provides users with scores about how

a particular project or site area is performing in the areas of monarch breeding habitat, foraging, landscape context and threats, and management. The scores for each of these components are combined into an overall score, but also presented independently such that a land manager can pinpoint specific problem areas that could be improved on that site. For example, if the breeding habitat score for a site is low, this means that it is lacking sufficient milkweed host plants for monarchs. Actions to increase the milkweed density at that site could improve the habitat score over time. The Calculator also provides a reportable metric that can be used in internal or external reporting.

We provided several types of decision support tools in response to the needs of the roadside management community. We recognized that there were several information needs, including guidance on mowing, herbicide applications, milkweed identification, and native seed guides (including milkweed). We identified some resources that were currently available and linked to them in our online manager toolbox. We developed several other materials that were not yet in existence. We developed regionally appropriate Milkweed Guides, single-sheet handouts that may be given to road management crews to help them to identify milkweed growing in their roadside corridors and choose appropriate management actions, such as avoiding the application of herbicide to milkweed and planning mowing activity to avoid when monarchs are breeding in their locality. We developed a Monarch Butterflies, Weeds, and Herbicides resource sheet. Recognizing that road managers operate within single states, we have that facilitated information sharing across states, including case studies. We have also developed a set of frequently asked questions and answers to optimize information sharing about best practices.

This work has highlighted several opportunities and needs for future research. There are several gaps in our knowledge where expert opinion was used to develop the project tools. We've identified the following research priorities:

- Exploration of how field level habitat quality values (such as derived from the habitat calculator) and use of roadside areas by monarchs relate to the landscape factors depicted in the Landscape Prioritization Model.
- Milkweed and nectar plant abundance in various land-use types and regions of the US, and how these values relate to the habitat quality within road rights-of-ways in various regions
- Response of milkweeds, nectar plants, and monarch eggs and larvae to management practices, including mowing and haying at various times of year
- Differences in utilization of various species of milkweed by monarchs in roadside areas
- Quantification of traffic collisions (adult mortality) in relation to production of monarchs in roadside habitat (and in relation to traffic volume, speed, and surrounding habitat type)
- Chemical exposure risks to monarchs in highly agricultural or heavy traffic areas, e.g., >30,000 cars a day typical of highly urbanized areas (pesticides and vehicle/road chemical runoff/drift)
- Effective treatments of invasive species to enhance future restoration activities
- Economic studies on the short-, mid-, and long-range costs of implementing monarch/pollinator programs within a roadside management entity, which may be influenced by the upcoming proposed listing decision by USFWS for species listing under the Endangered Species Act
- Assessing the value of roadsides as important habitat corridors in "habitat deserts," such as areas in the Midwest that are dominated by agriculture

We also need more detailed information about the recruitment of monarchs from roadside sites (e.g., from egg to adult) and the mortality associated with traffic collisions for adult monarchs. Additional research into the effects of pesticide drift into roadway corridors near agricultural fields is an ongoing (yet difficult) research need. Another area of future research includes longitudinal studies that document various management steps for revegetation. Many managers have reported that sometimes high diversity pollinator plantings are very successful, while other times invasive plants take over and the project is less successful.

Published documentation of well-designed studies will help roadside managers determine which practices over what time scales are most successful.

As deliverables emerged from our project, it became apparent that we would need a website to house the toolbox and provide support to roadside managers interested in providing habitat for monarchs. We plan to seek implementation funds to further develop such a website, along with additional communication about the tools developed here, perhaps at regional meetings. For states to fully implement the tools may require additional training (online or in-person) for department of transportation personnel and ongoing technical support to revise and maintain the tools.

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ACRONYMS

AP: Advisory Panel
BMPs: Best Management Practices
DOT: Department of Transportation
EDF: Environmental Defense Fund
EI: Environmental Incentives
HQT: Habitat Quantification Tool
HSI: Habitat Suitability Index
IUCN: International Union for Conservation of Nature
MCSP: Monarch Conservation Science Partnership
MJV: Monarch Joint Venture
NCHRP: National Cooperative Highway Research Program
NRCS: Natural Resources Conservation Service
OSU: Oklahoma State University
ROW: Right-of-Way
RT: Research Team
UMN: University of Minnesota
USDA: United States Department of Agriculture
USGS: United States Geological Survey
WHEG: Wildlife Habitat Evaluation Guide

APPENDIX A.

Manager Workflow Diagram: Use of Roadside Habitat for Monarchs Decision Support Tools

DETAILED WORKFLOW

ROADSIDE MONARCH HABITAT ASSESSMENT TOOL

USERS

- Roadside Vegetation Managers
- Biologists/Environmental Compliance staff
- Natural Resource specialists & seasonal staff

USE CASES

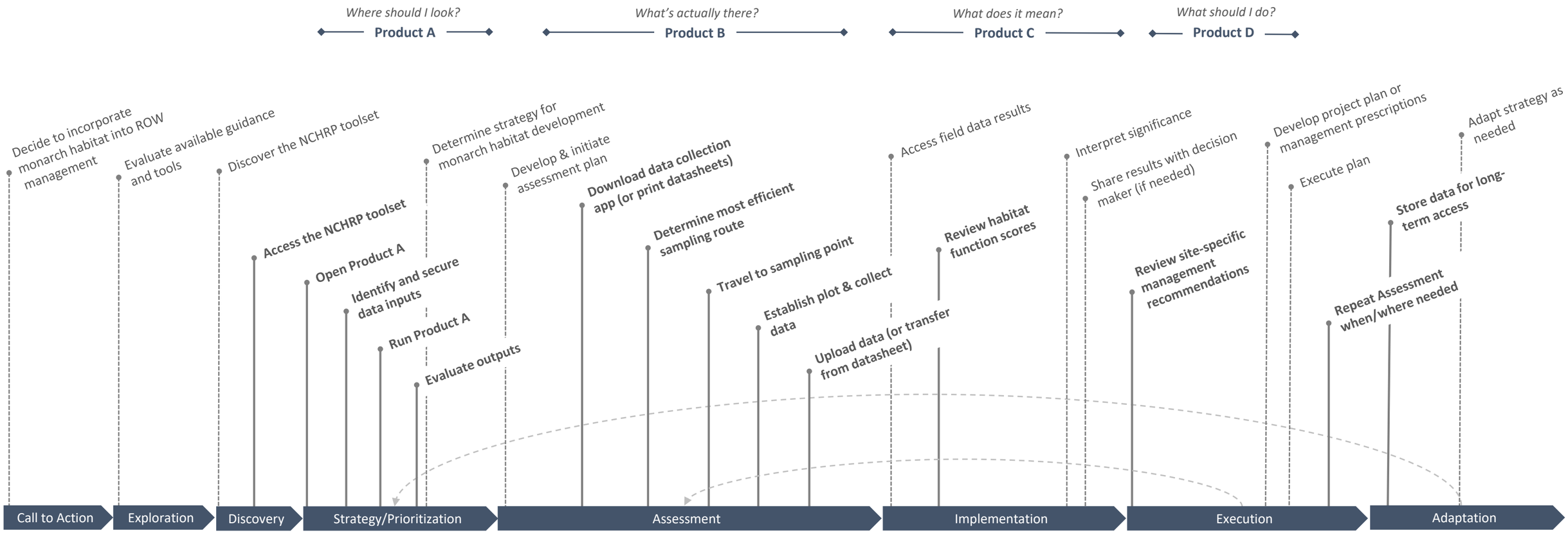
- Identify roadside ROWs for which revegetation is already planned due to road work and which should include milkweed and nectar producing forbs
- Identify currently vegetated roadside ROWs for creation or enhancement of monarch habitat
- Identify roadside ROWs to exclude from creation or enhancement of monarch habitat due to threats
- Estimate progress towards quantitative objectives (1 milkweed per 11 ft of roadway) or compliance requirements (e.g., CCAA)
- Inventory existing monarch habitat within a road system

Where should I look? — **Product A**

What's actually there? — **Product B**

What does it mean? — **Product C**

What should I do? — **Product D**



The user—either a decision maker or someone hoping to influence a decision maker—must first determine that incorporating monarch habitat into ROW management is worth exploring. An interest in conservation, a mandate, or regulatory requirements might serve as the call to action. The user will explore existing guidance and tools to identify one that is compatible with their objectives. If the user discovers the NCHRP toolset and determines it is the most suitable, they will access the tools in preparation for use.

Typically, managers choose between one of two strategies: (1) install habitat in appropriate areas as opportunities arise or (2) alter management to promote habitat across the road system. Users will use Product A to evaluate suitable locations and prioritize actions.

The information provided by Product A will inform where in-situ habitat assessments will occur. Product B provides the protocol and data collection forms for habitat assessments. The user will develop an assessment plan, considering personnel, timing, materials, and budget. Often but not always, the user will recruit others to execute the assessment plan. Once priority locations are identified, field data collectors will collect necessary materials, determine an efficient sampling route, travel to the sample points, establish plots, collect data, and upload collected data through the mobile collection app. If using datasheets, they will transfer data to the app after data is collected.

The user will need to access the field data and translate those data into interpretable information. Product C aggregates data, calculates habitat function, and presents this information to the user in an interpretable format. If necessary, the user can then share this information with the decision maker.

The user, in coordination with the decision maker if necessary, .will determine a plan of action for installing habitat or altering management prescriptions. Product D provides best management practices and site-specific management actions based on the results of Product C. Repeated assessments are conducted to evaluate effectiveness.

The user will need to store data in an secure, accessible location for future use. Assessments repeated over time can be used to adaptively manage the monarch habitat strategy. The initial strategy should be revisited at least annually to maximize the effectiveness of the strategy.

APPENDIX B.

User Guide for the Landscape Prioritization Model for Roadside Habitat for Monarchs

Landscape Prioritization Model

Roadside Habitat for Monarchs

Model Overview

The *Landscape Prioritization Model of Roadside Habitat for Monarch*s analyses and combines factors related to monarch habitat suitability along roadways. The model helps roadside rights-of-way managers assess how the roads in their state relate to landscape-scale factors affecting monarch habitat quality.

The Landscape Prioritization Model may be used in several ways:

- To locate areas where roadside habitat may complement high functioning surrounding habitats.
- To identify places where roadside habitat could be developed as a habitat corridor in areas where the landscape is providing little monarch habitat.
- To compare roadsides within a given area using the roadside suitability index.
- To select sample locations for surveys of monarch habitat within roadside rights-of-ways, across the spectrum of roadside suitability index values.
- If used in conjunction with manual surveys of rights-of-way with the *Rapid Assessment of Roadside Habitat for Monarchs* tool, the model can help target roads with high suitability index values but low actual habitat quality scores for enhancement through altered management.

The model is downloaded as a .zip drive containing the model's code and relevant source data. To open the model, the user must access the uncompressed folder in ArcGIS and open the ArcGIS Python Toolbox within. **The user must provide the land-cover (USDA Cropland Data Layer) and road data layers (USGS National Roads Dataset), as well as a study area of interest, as specified in the Model User-Interface section below.** The user can substitute state-specific road data for traffic volume, right-of-way (ROW) width, and speed limits to improve the model's accuracy by replacing the generalized metrics derived from the USGS National Roads Dataset.

ArcGIS Licensing

The model requires an **ArcGIS for Desktop Basic** license with the **Spatial Analyst** extension.

Downloaded Files

Source_Files: A folder containing the required source data (ArcGIS Layer files for cartographic consistency) and back-up python code for the model.

Monarch Roadside Suitability.pyt: The ArcGIS Python Toolbox containing the *Landscape Prioritization Model of Roadside Habitat for Monarch*s interface and code. Open the folder in ArcGIS to access the tool.

Graphical Abstract

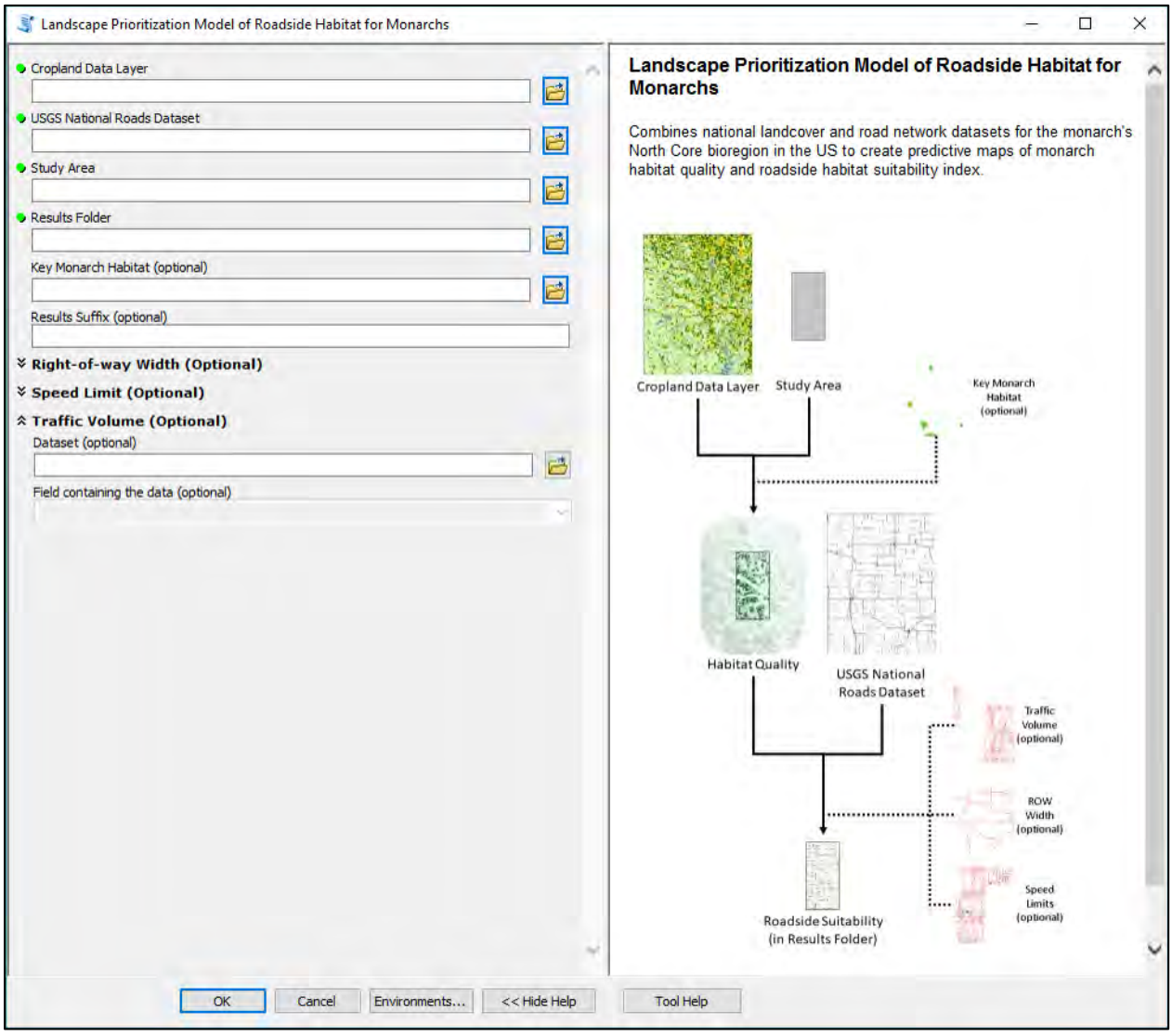


Figure 1. Graphical abstract of the Landscape Prioritization Model

Model User-Interface

Inputs

Cropland Data Layer: The raster dataset containing the USDA Cropland Data Layer, downloadable from the USDA National Agricultural Statistics Service website: https://www.nass.usda.gov/Research_and_Science/Cropland/Release/index.php

USGS National Roads Dataset: A Shapefile or ArcGIS Feature Class containing the USGS National Transportation Map's road layer, downloadable on a state-by-state basis from the USGS National Map website: https://prd-tnm.s3.amazonaws.com/index.html?prefix=StagedProducts/Tran/GDB/ National coverage is available via ftp here: ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Tran/Shape/

Study Area: A Shapefile or ArcGIS Feature Class denoting the full extent of the study area, typically a state or county.

Results Folder: Folder location where the model will deposit results. Also acts as the working folder for any intermediate data created during the modeling process, all of which is subsequently deleted upon model completion.

Key Monarch Habitat (optional): A Shapefile or ArcGIS Feature Class featuring areas of known high-quality monarch habitat (e.g. conservation areas, habitat reserves, etc.).

Results Suffix (optional): A text suffix appended to all files generated by the model. Used to distinguish results from different runs of the model in the same folder.

Traffic Volume (optional):

- **Dataset (optional):** A Shapefile or ArcGIS Feature Class of roads in the study area, containing data on Average Annual Daily Traffic volumes (number of cars per day).
- **Field containing the data (required if using Traffic Volume data):** The relevant data field in the Traffic Volume dataset.

Speed Limit (optional):

- **Dataset (optional):** A Shapefile or ArcGIS Feature Class of roads in the study area, containing data on speed limits (miles-per-hour).
- **Field containing the data (required if using Speed Limit data):** The relevant data field in the Speed Limit dataset.

Right-of-Way Width (optional):

- **Dataset (optional):** A Shapefile or ArcGIS Feature Class of roads in the study area, containing data on roadside right-of-way widths (feet).
- **Field containing the data (required if using Right-of-Way Width data):** The relevant data field in the Right-of-Way Width dataset.

Outputs

ArcMap Layer Files:

Roadside Suitability.lyr: A map of roads in the study area and their predicted roadside monarch habitat suitability from 0 (low-quality) to 1 (high-quality)

Patch Habitat.lyr: A map of predicted high quality monarch habitat 'patches'

Habitat Quality.lyr: A map of landscape-scale predicted monarch habitat quality from 0 (low-quality) to 1 (high-quality)

Nectar Availability.lyr: A map of predicted monarch-specific nectar availability from 0 (low availability) to 1 (high availability)

Milkweed Quality.lyr: A map of predicted monarch-specific milkweed quality from 0 (low-quality) to 1 (high-quality)
Pesticide Exposure.lyr: A map of predicted pesticide exposure risk from 0 (low-risk) to 1 (high-risk)
Landcover.lyr: A map of the underlying land use/land cover data for the study area.

Other Files:
Results.gdb: An ESRI File GeoDatabase containing the source data for the layer files (see above).
Default.gdb: A vestige of the modeling process, an ESRI File GeoDatabase containing nothing.

Methodology Overview

Summary

There are two distinct parts to this model, (1) predicting landscape-scale monarch habitat quality and (2) assessing roadsides for monarch habitat suitability based on a combination of road- and landscape-derived attributes. The habitat model is built from national land-cover data to highlight areas likely to provide high quality monarch habitat: where milkweed (host plants) and blooming plants (nectar sources) are likely to be abundant with a low likelihood of exposure to herbicides or insecticides. The habitat model then interacts with road data layers containing specific relevant attributes: potential roadside habitat area as determined by roadside right-of-way width, chemical exposure from traffic volume, and the threat of vehicular collision based on traffic volume and speed. Together these habitat- and road-based metrics combine into a single index of 'roadside suitability'—the predicted habitat value of each road segment within the given landscape. The model can run at any spatial scale (e.g., state, county) within its specified ecological zone (e.g. North Core, South Core, or Western states, see Fig. 2). The model outputs a map of the 'roadside suitability' index as well as the habitat quality across the landscape (see Fig. 1). The model does not incorporate field data and may or may not predict well the actual field conditions within the right-of-way; to find out what habitat values exist on the ground in the rights-of-way, field data may be collected by the *Rapid Assessment of Roadside Habitat for Monarchs* tool.

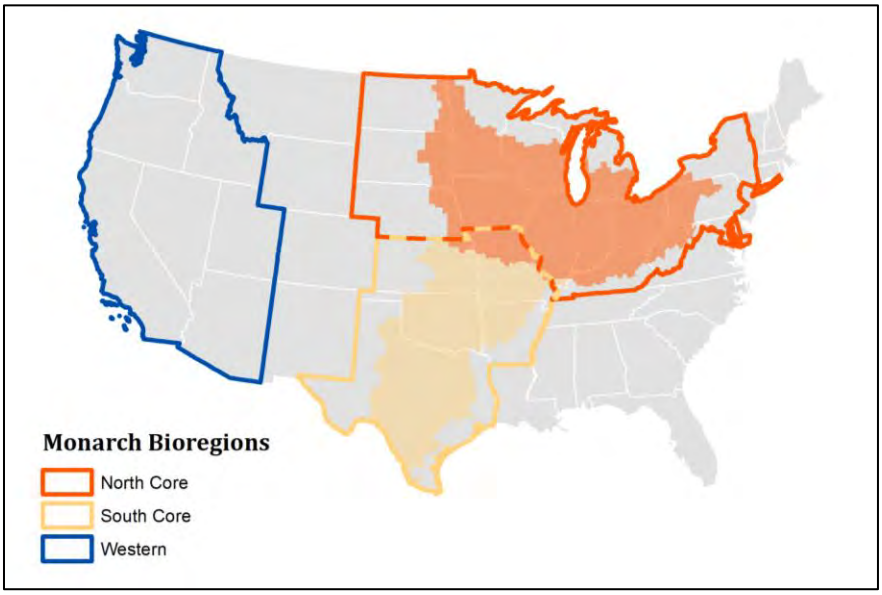


Figure 2. Monarch bioregions

Habitat Quality

Maps of nectar availability, milkweed quality, and pesticide exposure are derived from the USDA Cropland Data Layer using data and equations from a variety of monarch ecological literature (see 'Methodology' file for more detailed information). The associated reclassification table is within the Source_Files folder. These three maps are combined to create an overall habitat quality map. If the user provides data on Key Monarch Habitat (see Model User-Interface above), the model increases the habitat quality in those areas. Habitat 'patches'—areas of exceptional habitat quality—are selected from this map.

Two of these habitat-based maps are used in predicting roadside suitability: (1) the distance of a given roadside to the nearest high quality habitat patch and (2) the 'adjacent' habitat quality, meaning the average habitat quality score (excluding pesticide exposure) within 120m of the roadside.

Roadside Suitability

Roads in the study area are derived from the USGS National Transportation Dataset. The 'classification' of these roads (e.g. highway, local road, etc.) translate to monarch-relevant metrics:

- roadside right-of-way width: predicts potential roadside habitat area
- traffic volume: predicts roadside chemical exposure risk (and see below)
- speed limit: combined with traffic volume, predicts monarch-vehicular collision risk

These metrics act as baseline datasets. The user may provide more specific maps of right-of-way width, traffic volume, and speed limits, which will replace the baseline datasets wherever they overlap. For instance, users can provide an incomplete map of traffic volume and still retain the baseline data from the National Transportation Dataset for the incomplete areas.

These roadside metrics each predict potential risks or benefits to monarch butterflies. Wide right-of-ways equate to higher potential roadside habitat area within the roadside buffer strips. Higher traffic volumes can lead to increased risk of roadside chemical exposure, and also higher vehicular collision risk in areas with speed limits between 15 and 55mph.

For computational efficiency, the road data are converted into raster format before introducing the landscape-scale habitat metrics. Once converted, each section of road is analyzed for the two key metrics of the nearby habitat (distance to the nearest high quality habitat patch, adjacent habitat quality). Finally, for each section of road, the three road-derived metrics (potential roadside habitat area, roadside chemical exposure risk, monarch-vehicular collision risk) and two habitat-derived metrics are combined into the single roadside suitability index, using a weighted average approach that weights habitat benefits (potential roadside habitat area, distance to the nearest high quality habitat patch, adjacent habitat quality) higher than roadside risks (chemical exposure risk, vehicular collision risk).

APPENDIX C.

Rapid Assessment of Roadside Habitat for Monarchs: Field Protocol and Datasheet

Rapid Assessment Field Protocol and Datasheet

Roadside Habitat for Monarchs

Introduction

The Field Protocol for Rapid Assessment of Roadside Habitat for Monarchs (*Rapid Assessment*) is a quick and simple way for roadside vegetation managers or other transportation professionals to determine if a roadway is currently providing monarch habitat.

The Rapid Assessment focuses on plants that provide monarch habitat, including *nectar plants* (wildflowers and flowering shrubs) that provide nutrition for adult monarchs throughout their breeding and migration periods, and *milkweed plants*, which are required by monarchs to reproduce, the only type of plant on which their eggs and larvae can develop.

Managers may use either a paper data form or a tablet or smart phone using Esri Survey 123 to collect data where they wish to know about current monarch habitat conditions. They may use GIS tools to choose sites for assessment or they may have areas of interest, such as where they are planning road development projects. Data gathered by this Rapid Assessment feed into a Monarch Habitat Calculator for Roadsides, which creates a score for each location, considering surrounding context (road and adjacent land) and current vegetation to rank its potential for providing monarch habitat.

This protocol was developed as part of the project "Evaluating the Suitability of Roadway Corridors for Use by Monarch Butterflies," led by the Monarch Joint Venture and funded by the National Cooperative Highway Research Program of the Transportation Research Board (Project 20-119). Other components of the project were a GIS Monarch Habitat Landscape Prioritization Model and a Monarch Habitat Calculator for Roadsides (both of which may be used with the Rapid Assessment) and best management practice decision support information (see website[1]).

The *Rapid Assessment* is a quick way to assess monarch habitat. If more detailed habitat assessment is desired, such as to track the quality of a restoration area through time, the national *Integrated Monarch Monitoring Program*[2] (IMMP) protocol may be more appropriate. The IMMP assesses habitat along approximately 0.3 mile length of road with ten diagonal 164 ft (50 m) transects sampled with 1 m^2 quadrats. The IMMP includes options for monitoring adult, egg, and larval monarch stages. In addition to roadsides, data are collected from several other key land use types and contribute to a national database.

How to do a Rapid Assessment

A Rapid Assessment usually takes less than 20 minutes. Once arriving at a desired sampling location in the roadside right-of-way (ROW), observers mark their starting location and then walk a 150 ft (45.7 m) length parallel to the road, toward traffic, making a rectangular study area that extends from the road to

[1] https://monarchjointventure.org/our-work/projects/roadsides-as-habitat-for-monarch-butterflies
[2] https://monarchjointventure.org/IMMP

the back of the ROW (which will be estimated or measured; Figure 1). During or before the first assessment, observers should stretch out a measuring tape to find out how many steps it takes to go 150 ft; once calibrated, observers can pace this distance for future assessments. Observers will then walk perpendicular to the road to the back of the right-of-way to estimate the width of the vegetation and the width that is mowed (if any). (Managers or observers will choose whether their assessments will encompass the entire right-of-way or if they will focus their assessment on the unmowed area (e.g. beyond the safety strip).) Next, observers walk back through the ROW back to the starting point, zig-zagging back and forth through the width of the roadside habitat, recording the blooming nectar plants, milkweed, and noxious weed species that they find. Alternatively, if the ROW is wider than 30 ft (9.1 m), or if the habitat is very dense with nectar plant types or milkweed, observers may choose to walk back and forth across the ROW in smaller sections. For instance, an observer could walk parallel to the road in one direction (moving back and forth within a 10-30 ft swath), then move over and walk back in the opposite direction surveying the next 10-30 ft of width (adding a pass for each 10-30 ft of ROW width). The goal is to see the plants throughout the width of the vegetated right of way; depending on the width of the site and the type of vegetation present, observers may choose the best way to move through the area.

List of Items to Bring to Field

1. Permit/permission for use of the roadside right-of-way from proper authority
2. Safety clothing (Type 3 vest in some states), helmet (in some states or if desired)
3. Revolving or flashing light for top of car
4. Datasheets, clipboard, pen/pencil -OR- mobile device for data collection
5. GPS unit, GPS enabled tablet, or smartphone
*6. Measuring tape (for ROW width)**
7. Clicker counter (for tallying milkweed)*
*8. Milkweed identification sheets or plant guidebook**
*9. Monarch identification sheets**
10. Hand lens or magnifying glass (for looking for monarch eggs)*

**Optional items*

Where to do Rapid Assessments

Rapid Assessments are best repeated at consistent intervals throughout a ROW of interest. One recommendation would be to sample every 3/10th of a mile, such that 3 to 4 assessments are done for each mile of roadway, and the assessments would be combined to characterize the stretch as a whole. For much larger areas, assessments would be further spaced apart. Depending on the type of habitat encountered, greater or fewer stops may be needed to characterize a ROW. After several assessments have been done, a manager may determine if the stretch of road should be treated all as one or if there are features within the site, such as a patch of noxious weeds, that require the site be assessed in smaller units.

Data Collection

On each Rapid Assessment, record the **Observer, Date, Time Start, Time End**. Date and time will be auto-filled if using Survey 123.

Site Description Information

- **Road/Site Name:** such as county road or highway number, or experimental plot #, to facilitate recognizing the site for future reference or management discussions. This name or code should be unique to the site.
- **Latitude and Longitude**: record your starting location (latitude and longitude). This will be automatically filled using Survey 123 (but make sure the location error is less than 50 m). When using a paper form, observers can drop a pin into a mapping application on their smartphone, and then record the location onto the data sheet.
- **Road type**: 2 lane, 4 lane, or > 4 lane (count lanes for both directions)
- **Full ROW width:** Measure or estimate the average width (in feet, perpendicular to road) of the vegetated ROW, from barren shoulder edge to the backside of the ROW (sometimes this is signed or fenced, usually where the land use changes) along the 150 ft length and *including mowed areas*. If highly variable, estimate a few times and enter the average. If there is no apparent ROW edge, use 100 or 150 ft width.
- **Mowed width:** measure or estimate average width of mowed area perpendicular to road along the 150 ft length. This may correspond to the 'safety strip' area or it may be the full width or it may be absent (be sure to record "0" if none of the area appears to be mowed). If highly variable, estimate a few times and provide the average.
- **Area you are assessing:** designate the area to be assessed –the full width of the ROW or only the unmowed area. Alternatively, choose to separately record data for the unmowed and mowed areas (using an optional reverse side of the paper sheet). It is best to stay consistent across multiple Rapid Assessments.
- ***Optional: Mowed height****: measure or estimate height of mowed vegetation above ground level in inches.*
- **Site notes.** Note landmarks, known management practices, conditions, etc. On smaller roads where the GPS location may be ambiguous, note which side of road is sampled.

Adjacent Land Use

Record the land use type directly adjacent to the ROW that borders the majority of the length of the 150 ft survey length. We distinguish adjacent land types with or without a vegetated or other barrier that could disrupt drift of chemical applications from adjacent lands, such as hedgerows, trees, or solid fences (rather than wire or crosspost) as follows:

- CROP= Cropland with no barrier (see barrier definition above)
- HCR= Cropland with barrier
- DEV=Developed (e.g., pavement, buildings, lawn, landscaping) with no barrier
- HDE=Developed (e.g., pavement, buildings, lawn, landscaping, etc.) with barrier
- DIV= Diverse grassland/natural habitat (such as a native grassland or prairie remnant, wildlife

area, etc.)

- NDI= open space/non-diverse grasslands (e.g., heavily grazed land, hayfields, recreational fields). *Please note that conservation (e.g. CRP) fields could be either DIV or NDI; if bunchgrasses and forbs are present, use DIV; if one grass dominates, use NDI.*
- WOOD= Woody or brush-dominated habitat
- WET= Wetland
- OTH = Other, write in another land type of interest

Management Information

Management practices influence habitat quality. When setting up the survey in Esri, managers will list the noxious weeds or invasive species that they wish to be included in assessments. In addition, for herbicide and mowing questions, managers may pre-set default answers, which may be overwritten in the field if conditions deviate. Observers choose from the following:

- **Type of Herbicide Application**
  - none
  - spot treat noxious weeds
  - spot treat woody species
  - treat grass to stimulate forbs
  - broadleaf applied in clear zone 1x/year
  - broadleaf applied in clear zone >1x/year
  - broadleaf applied throughout the ROW
  - don’t know

- **Frequency the Full ROW Width is Mowed**
  - never (or only very rarely if needed)
  - every few years (typically, or as needed)
  - once a year
  - twice a year
  - more than twice a year
  - don’t know

Weeds: Noxious Weeds and Other Invasives of Management Concern

Noxious weeds or other invasive species may threaten monarch habitat quality by requiring treatment or if they outcompete nectar plants and milkweed. First, when setting up the survey, managers will list the species of noxious weeds or other invasive plant species of management concern to their roadside authority and which they would like their field surveyors to note. These are the weed species to be recorded during the Rapid Assessment.

- **List** the noxious weeds or invasive plants (from the list of weeds species for your roadside agency) that are present in the assessment area.

- **Percent aerial cover**, estimate for the weeds as a group, from the following categories:
    - None
    - Less than 5%
    - 5-9%
    - 10-25%
    - 26-50%
    - 51-75%
    - Greater than 75%

Potential Blooming Nectar Plants

Many roadside managers wish to characterize sites in a single visit per year, but what is needed is information regarding the availability of nectar for monarchs throughout the year. Therefore, we collect information for all "*Potentially Blooming Nectar Plants*," wildflowers (forbs) and flowering shrubs (i.e., excluding grasses) that could provide nectar to pollinators, regardless of whether or not those plants are blooming on the date of assessment (and regardless of their nativity or the quality or quantity of nectar they provide). Surveyors also record which species are blooming and not blooming, so that if a manager wishes to focus solely on blooming plants that option is available. The *number of species* may be important because a greater number of species may represent a greater number of bloom times and thereby provide nectar for a greater proportion of a season of monarch use. The *amount of cover* by blooming plants as opposed to grasses or weeds is an index to the amount of nectar that may be provided for an assessment area.

- **List:** Identify and record as many different Potentially Blooming Nectar Plant species as you can, marking 'blooming' for each species if the plant is blooming anywhere in the plot. In Survey 123, you can begin typing either a common or latin name and then you can select a species from the list. There are also options for some plant genera, such as "*Solidago* sp; unknown goldenrod."
- **Unknowns:** Then tally the number of additional types that you cannot identify, (also noting which are blooming). ***Alternatively, for surveyors who have not been trained in plant identification, just list the number of different types, blooming and not, without identifying them.***
- **Percent cover:** Estimate the percent of area covered by nectar plants, including forbs and shrubs that have already or not yet bloomed, in the following categories:
    - None
    - Less than 5%
    - 5-9%
    - 10-25%
    - 26-50%
    - 51-75%
    - Greater than 75%

Milkweed

Because milkweed is required for monarch reproduction, the species and number of milkweed plants is important. Estimating the number of milkweed plants in the assessment area makes it possible to estimate the milkweed density, an important metric in monarch habitat descriptions. In addition to *Asclepias* species, include also honeyvine, *Cynanchum laeve.* When tallying or estimating, count a plant as a single stem (e.g., common milkweed, *Asclepias syriaca,* ignoring possible below ground connections); or a plant may be multiple stems originating from the same central location in the soil (e.g., green antelope horn, *A. asperula*, or butterfly weed, *A. tuberosa*, see photo). For honeyvine, it will likely be necessary to estimate number of plants. ***Note that it is important to mark "none" for any survey for which no milkweed are found.***

- **Species:** Identify milkweeds by species, using reference sheets for your area as needed.
- **Plant Tally:** Tally the number of plants per species within the assessment area.
- **-OR- Estimate Categorical Abundance:** Estimate number of milkweed plants, by species, in the following categories: none, 1-5, 6-10, 11-25, 26-50, 51-250, >250 plants.

Example of multi-stemmed milkweed, Asclepias tuberosa, butterfly weed. Count 1 plant. (Photo: University of Maryland

Monarchs (Optional):

If interested in whether sites are being used by monarchs, observers may record adults seen and look on milkweed plants for eggs and larvae (caterpillars). These activities are optional, as it is important to learn how to recognize monarchs from other species and differentiate eggs from other insect eggs and milkweed latex bubbles (see photos below). If managers are interested in comparing the number of eggs and larvae across sites, it is important to check each plant thoroughly and carefully track the number of plants that are examined. If a site has too many milkweed to check individually, observers may search every several plants.

Monarch egg on a milkweed leaf, little more than 1 mm tall. Note upright, oblong, slightly pointed shape (*Photo: Lynda Andrews*)

Close-up of monarch egg — Note pointed shape, glossy off-white color and vertical ridges (*Photo: Michelle Solensky*)

Monarch egg (left; off-white) and latex drop (right; bright white, spherical) *(Photo: Anurag Agrawal)*

Monarch caterpillars, 1st (smallest) through 5th (largest) instars (*Photo: Monarch Lab*)

Beware of mimics that may be in your area. Monarch (top left), Viceroy (bottom left), Queen (right) (*Courtesy of Journey North*)

Rapid Assessment of Roadside Habitat for Monarchs

Site/Road Name:	Date:	Start Time:	End Time:	Observer(s)	
Latitude (digital, 8 digits)			Full ROW width (ft):	Mow width (ft): *(0 if unmowed)*	Mow Ht (in): *optional*
Longitude (digital, 8 digits)			Area you are assessing: ❑full-width (regardless of mow) ❑unmowed area		
Road Type: ❑2 lane ❑4 lane ❑> 4 lane			❑unmowed & mowed areas separately (*use back*)		
Site Notes (e.g. side of road, management, landmark):					# Adult monarchs:

Adjacent Land Use within 100 ft of ROW (choose one):		
❑CROP=Cropland, no barrier	❑ DEV=Developed, lawn, paved	❑ WOOD=Woody habitat
❑ HCR=Crop with wood barrier/hedgerow	❑ HDE=Developed, woody /hedgerow	❑ WET=Wetland habitat
❑ DIV=Diverse grassland/natural habitat	❑NDI= Not diverse grassland, few forbs	❑ OTHER=

Management
Herbicide: ❑ never ❑ spot treat noxious weeds ❑ spot treat woody spp ❑ treat grass to stimulate forbs
❑ broadleaf in clear zone 1x/yr ❑ broadleaf in clear zone >1x/yr ❑ broadleaf throughout ROW ❑ don't know
Full Width Mowing Frequency: ❑never ❑every few years ❑ 1x/yr ❑ 2x/yr ❑ >2x/yr ❑ don't know

Potential Blooming Nectar Plants (*forbs + flowering shrubs*)		**Weeds**
Blooming:	*Not Blooming:*	*List Species:*
Tally unknowns:		
Unknown Notes:		

Percent Cover	
Potential Nectar Plants: ❑none ❑< 5% ❑5-9% ❑10-25% ❑26-50% ❑51-75% ❑> 75%	**Weeds**: ❑none ❑< 5% ❑5-9% ❑10-25% ❑26-50% ❑51-75% ❑> 75%

Milkweed (*Tally preferred or Categorize*)		
Species	Plant Tally	Categorical Abundance
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250

Monarchs *(optional)*			
Milkweed Sp.:	# Searched:	# eggs:	# caterpillars:
Milkweed Sp.:	# Searched:	# eggs:	# caterpillars:
Other Pollinator or Habitat notes:			

Rapid Assessment of Roadside Habitat for Monarchs

If assessing the MOWED area for comparison, enter data here:

Site/Road Name:		
Potential Nectar Plants (*forbs + flowering shrubs*)		**Weeds**
Blooming:	*Not Blooming:*	*List Species:*
Tally unknowns:		
Unknown Notes:		
Percent Cover		
Potential Nectar Plants: ❑none ❑< 5% ❑5-9% ❑10-25% ❑26-50% ❑51-75% ❑> 75%	**Weeds**: ❑none ❑< 5% ❑5-9% ❑10-25% ❑26-50% ❑51-75% ❑> 75%	

Milkweed (*Tally preferred or Categorize*)		
Species	Plant Tally	Categorical Abundance
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250
		❑none ❑1-5 ❑6-10 ❑11-25 ❑26-50 ❑51-250 ❑>250

Monarchs *(optional)*			
Milkweed Sp.:	# Searched:	# eggs:	# caterpillars:
Milkweed Sp.:	# Searched:	# eggs:	# caterpillars:

APPENDIX D.

User Guide for Rapid Assessment of Roadside Habitat for Monarchs and Habitat Calculator: Monarch Habitat Evaluator Tool

User Guide for the Roadside Monarch Habitat Evaluator

Monarch Joint Venture

Overview

The *Roadside Monarch Habitat Evaluator* integrates the *Rapid Assessment of Roadside Monarch Habitat* and the *Monarch Habitat Quality Calculator* in Esri *Survey123*. Roadside managers collect data from roadside rights-of-way through field visits, using the Rapid Assessment protocol (Appendix C). Rapid Assessment data are automatically processed through a calculator in *Survey123* to generate Monarch Habitat Quality Scores.

Management Application

Roadside managers will find this tool useful in addressing questions about the habitat that exists along their roads, as well as how their management actions (such as weed management or mowing regimes) affects the quality of the habitat. Questions that can be addressed include:

- How much monarch habitat exists along our roads?
- Where is the best monarch habitat in our road system?
- Which areas of poorer quality can be targeted to increase monarch habitat value?
- How do our management practices affect monarch habitat quality?

Habitat Quality

Monarch habitat along roadways may be broken down into four functional component areas (see Table 1), including breeding habitat (primarily milkweed; *Asclepias* spp) and foraging habitat for adult butterflies (flowering plants with nectar). In addition, the context of roads and their adjacent land-uses affect habitat quality in rights-of-ways. Roads bring threats of collisions with cars and exposure to chemicals; adjacent land uses also can bring threats of chemical drift, and noxious weeds and other plants also can threaten monarch habitat. Management is the final main component affecting habitat quality; variation in use of herbicides and mowing practices can impact the quality of monarch habitat as well. Please see Chapter 5 for more information.

How-to Steps

This document gives detailed steps on how to set up and use the "Habitat Evaluator" to collect roadside habitat data and how to visualize and interpret the calculated data outputs.

I. Setting up the "Roadside Monarch Habitat Evaluator"
II. Using the Survey 123 field application
III. Exploring the results

What You'll Need

- An organizational ArcGIS Online (AGOL) account.
- Staff member with a "Creator" role (publisher rights) for that AGOL account. You may need to work with your GIS office or coordinator for initial survey set-up.
- AGOL users accounts for field technicians.
- Survey Template folder: Request by filling out this form. We will send it to you via email.
- Survey 123 Connect (Esri, free download) – for project administrator/GIS personnel
- Survey 123 Field App (Esri, free download) – for field technicians

General Workflow

1) **Project Manager** – customizes the data collection form using the Survey 123 Connect software from template provided.
2) **Project Manager/GIS staff** – publishes the survey form to agency's AGOL account.
3) **Field technicians** – download the Survey 123 field app and survey form.
4) **Field technicians** – collect field data using the Survey 123 field app on a mobile device and submit data.
5) **Project Manager** – uses the Survey123 website to access database to view, query, analyze, and visualize results or download the data as a geodatabase for local use.

Table 1. Roadside Monarch Habitat Quality components, field measures, and weights.

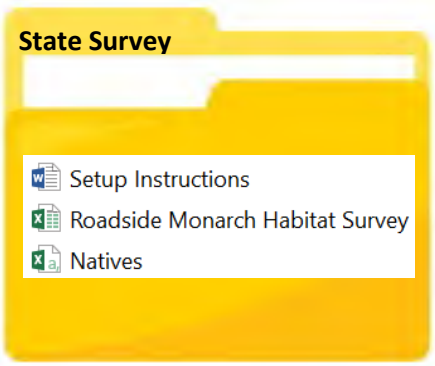
Component	Measure	Function Weight	Sub-weight	Measure Weight
Breeding	Milkweed Abundance	30%	80%	24%
	Milkweed # Species		20%	6%
Adult Foraging	Potential Nectar Plants - % Cover	25%	50%	12.5%
	Potential Nectar Plants - # Species		30%	7.5%
	Potential Nectar Plants - # NATIVE Species		20%	5%
Context	Adjacent Land Use Type	25%	30%	7.5%
/Threats	Road Type		35%	8.75%
	Weeds % Cover		20%	5%
	Weeds # Species		15%	3.75%
Management	Herbicide Application	20%	40%	8%
	Frequency of Full Width Mow		30%	6%
	Width of Mow as Proportion of ROW Width		30%	6%
	TOTAL	100%	100%	100%

I. Setting up the Roadside Monarch Habitat Evaluator

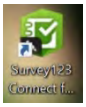
1) Download "Assessment Survey Files" and Install "Survey 123 Connect" software

a. Download the **Assessment Survey folder for your state**.
[Request by filling out this form.](#) We will send it to you via email.

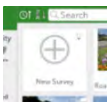
Unzip folder and save to a local drive on your computer. This folder contains three files—these setup instructions, the survey template (Roadside Monarch Habitat Survey), and a supplemental CSV (Natives).



b. Download **Survey123 Connect software**:
http://doc.arcgis.com/en/survey123/download/
Choose the download appropriate for your operating system.

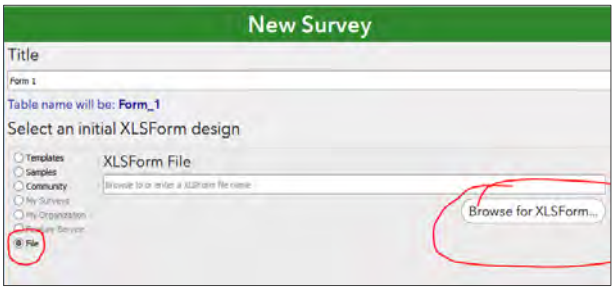
c. Install ArcGIS Connect with the installation wizard. 

d. Launch application from shortcut icon automatically placed on desktop.

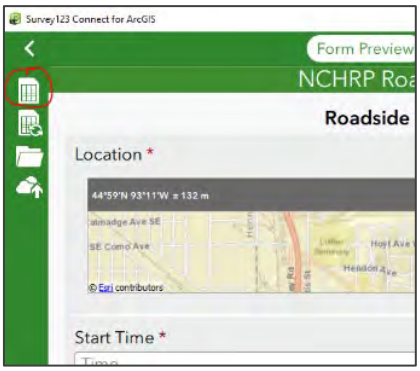
e. Click on **New Survey.** 

f. **Name the survey -** replace "Form 1" under "Title" with the name you want to appear on your assessment survey form (e.g. Roadside Habitat Assessment).

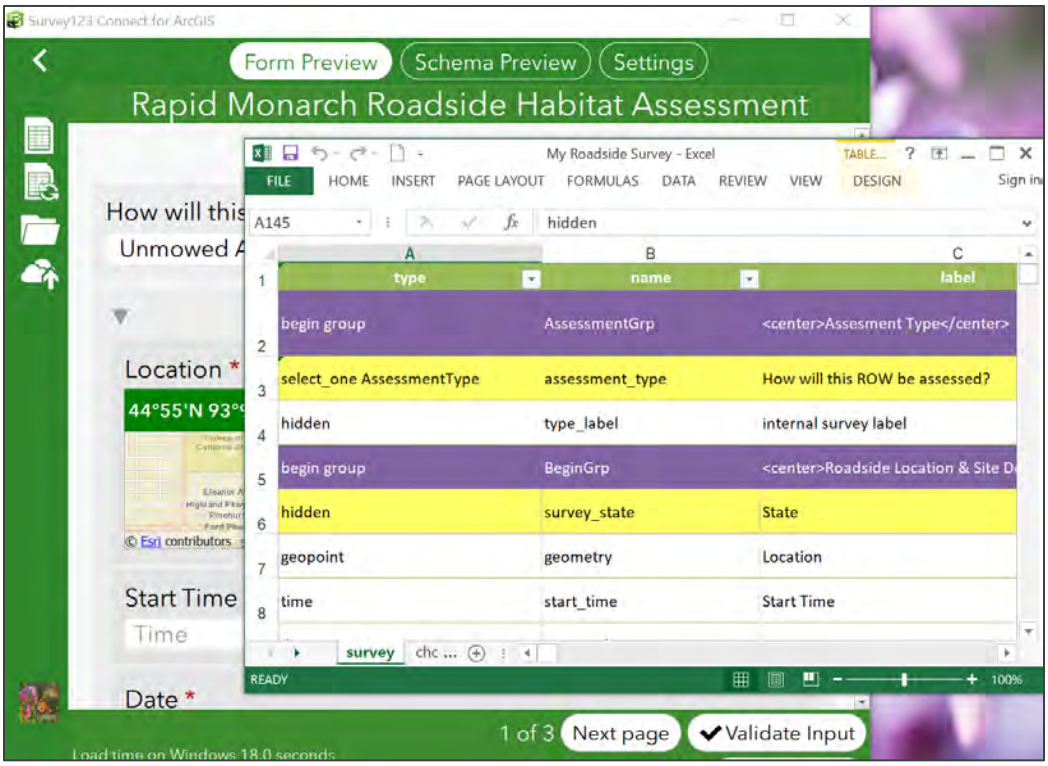
g. **Check the "File" radio button.** Then navigate to the Excel (XLS) file named "Roadside Monarch Habitat Survey" inside the template folder and hit **Open**. It will take a few moments to convert the file to your new survey form.



The Excel file (below) should open by default. If not, you can open the form in Survey 123 Connect and clicking the table icon (right).



If asked, hit **YES/CONTINUE** to update links and trust the external file.



Each **row** in the table is a field in the survey as well as in the database it creates when published. The **columns** contain various settings and coding for each field.

type – field data type

name –field name (in database)

label – what is displayed for each survey question in form

hint – information to help field technicians answer questions. p

Others: Scrolling to the right you will see many more columns that you will not need to be concerned with and should not alter. The exception being **DEFAULT.**

2) **Set Defaults**
You have the option to set some defaults to survey questions. This is most appropriate for answers that will always or usually be the same for your field technicians. Scroll to the right until you find the **default** column. Here are a couple defaults you may want to set.

a. **Assessment Type** (1st row highlighted in yellow)
Your state program may call for the collection data on the entire roadside regardless of mowing, on only the unmowed area of the roadside (most common), or on the mowed and unmowed zones of the roadside to separately for comparison.

To set one of these options as a default, put a "0" (whole site), "1" (Unmowed Area), or "2" (unmowed/mowed areas assessed separately) in the **default** column of the **assessment_type** row.

b. **State** (2nd row highlighted in yellow)
You'll see that the state default has already been set for you. This is a hidden field in the survey and exists for internal purposes related to an associated plants list. Leave this as is after making sure it is the correct state! If it is not, contact us for a new file.

c. **Survey Length** (3rd row highlighted in yellow)
You'll see that survey length has been set to 150 per protocol. This can be changed it there is a reason your state will run a different survey length. Total survey areas will adjust automatically.

d. **How are you counting milkweeds?** (4th row highlighted in yellow)
This is set to "0" (counting plants). If you want field staff only *estimate* numbers

of plants of each milkweed species they observer instead of counting each plant, change the default to "1".

e. **Are you searching for eggs and caterpillars?** (5th row highlighted in yellow) This is set to "0" (no). If you want field staff to collect data on eggs and caterpillars, change this default to "1" (yes).

Note: The second tab in the Excel file are all the choices for questions that have selection options. Use this for guidance if you need to set other defaults.

list_name	name	label
yes_no	1	Yes
yes_no	0	No
AssessmentType	0	Full Width (regardless of mow)
AssessmentType	1	Unmowed Area Only
AssessmentType	2	Unmowed and Mowed assessed separately (for comparison)
roadtype	1	>4 lanes
roadtype	2	4 lanes
roadtype	3	2 lanes
Abundance	0	None
Abundance	3	1-5
Abundance	8	6-10
Abundance	18	11-25
Abundance	38	26-50
Abundance	150	51-250
Abundance	300	>250
Landuse	CROP	Cropland, no barrier
Landuse	HCR	Cropland with woody vegetation barrier (e.g. hedgerow)
Landuse	DEV	Developed, including lawn, landscaping
Landuse	HDE	Developed with woody vegetation barrier (e.g. hedgerow)
Landuse	WOOD	Woody habitat
Landuse	DIV	Diverse grassland/natural habitat (e.g., reserve, prairie remnant
Landuse	NDI	Non-diverse grassland/Open space
Landuse	WET	Wetland habitat
MowFreq	0	Never
MowFreq	1	Every few years
MowFreq	2	Once a year
MowFreq	3	Twice a year
MowFreq	4	> Twice a year

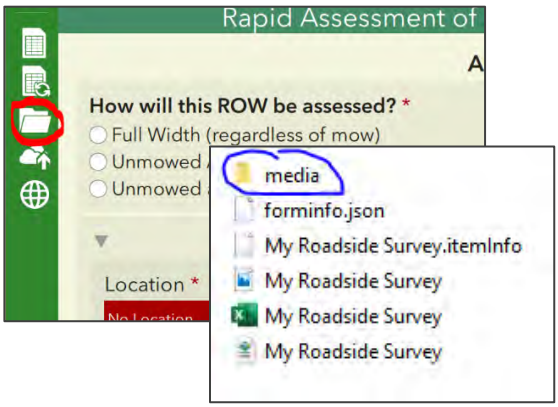
survey | choices | external_choices | setti ...

list_name – the lookup table name called to from the survey form.

name – the code that is dumped into the database when chosen in the survey.

label – what will be displayed as an answer choice in the survey.

3) **Add Native Table.**
   a. From the template folder, copy the **Natives** CSV file.
   b. Click on the folder icon in the Survey 123 Connect interface (see right) and put the Natives file inside the **media** folder.
   c. Close window.



4) **Customize plant lists**

There are three sets of plant lists, two of which you will want to configure to be specific to your state: **milkweeds** and **noxious (managed) weeds**. The third, **nectar plants**, is a comprehensive list of all forbs, vines, shrubs, and trees already specific to your state. These data were pulled from the USDA Plants Database and includes scientific name synonyms.

To view and alter milkweeds and noxious weeds, click on the **choices tab** (second tab) in the excel file and scroll down until you see the milkweed or noxious weed choices.

a. **Milkweeds**

You may leave the milkweed list as is but if you do, field technicians will have to choose from over 100 milkweed species in the survey (the survey *is responsive*; it narrows choices as any part of the name is typed, but best practice is to remove inappropriate choices). To constrain the choices to only those milkweeds that exist in your state, simple remove those rows containing plants that are not appropriate.

You may also use your own milkweed list and unique coding system. Just remember that the **name** is the code that is put into the database and the **label** is what appears in the choice dropdown list. The **list_name (Milkweeds)** should not be changed!

list_name	name	label
Milkweeds	ASCAMP	ASCAMP | Asclepias amplexicaulis | clasping or blunt leaved
Milkweeds	ASCANG	ASCANG | Asclepias angustifolia | Arizona milkweed
Milkweeds	ASCARE	ASCARE | Asclepias arenaria | sand milkweed
Milkweeds	ASCASP	ASCASP | Asclepias asperula | antelopehorns
Milkweeds	ASCBRA	ASCBRA | Asclepias brachystephana | bract milkweed
Milkweeds	ASCCAL	ASCCAL | Asclepias californica | California milkweed
Milkweeds	ASCCIN	ASCCIN | Asclepias cinerea | Carolina milkweed
Milkweeds	ASCCON	ASCCON | Asclepias connivens | largeflower milkweed
Milkweeds	ASCCOR	ASCCOR | Asclepias cordifolia | heartleaf milkweed
Milkweeds	ASCCRY	ASCCRY | Asclepias cryptoceras | pallid milkweed
Milkweeds	ASCCUR	ASCCUR | Asclepias curassavica | bloodflower
Milkweeds	ASCCUS	ASCCUS | Asclepias curtissii | Curtiss' milkweed
Milkweeds	ASCCUT	ASCCUT | Asclepias cutleri | Cutler's milkweed
Milkweeds	ASCEMO	ASCEMO | Asclepias emoryi | Emory's milkweed
Milkweeds	ASCENG	ASCENG | Asclepias engelmanniana | Engelmann's milkweed
Milkweeds	ASCERI	ASCERI | Asclepias eriocarpa | woollypod milkweed
Milkweeds	ASCERO	ASCERO | Asclepias erosa | desert milkweed
Milkweeds	ASCEXA	ASCEXA | Asclepias exaltata | poke milkweed
Milkweeds	ASCFAS	ASCFAS | Asclepias fascicularis | Mexican whorled milkweed
Milkweeds	ASCFEA	ASCFEA | Asclepias feayi | Florida milkweed
Milkweeds	ASCFRU	ASCFRU | Asclepias fruticosa | African milkweed

b. **Noxious Weeds**

Similarly, noxious weeds should be constrained to only those noxious weed species managed by your agency or state. What's currently listed in this form is all federally listed noxious weeds (pulled from the USDA Plants Database). You can create any list appropriate for your state. Feel free to change codes (**name column**) and descriptions (**label column**) but leave **list_name** as is! Just make sure the codes are all unique.

list_name	name	label
NoxWeeds	BUUM	BUUM | Butomus umbellatus | flowering rush
NoxWeeds	CACA	CACA | Cabomba caroliniana | Carolina fanwort
NoxWeeds	CAST	CAST | Callitriche stagnalis | pond water-starwort
NoxWeeds	CASE13	CASE13 | Calystegia sepium | hedge false bindweed
NoxWeeds	CASA3	CASA3 | Cannabis sativa | marijuana
NoxWeeds	CAIM	CAIM | Cardamine impatiens | narrowleaf bittercress
NoxWeeds	CADR	CADR | Cardaria draba | whitetop
NoxWeeds	CAPU6	CAPU6 | Cardaria pubescens | hairy whitetop
NoxWeeds	CAHA13	CAHA13 | Cardiospermum halicacabum | balloon vine
NoxWeeds	CARDU	CARDU | Carduus | plumeless thistle
NoxWeeds	CAAC	CAAC | Carduus acanthoides | spiny plumeless thistle
NoxWeeds	CACR2	CACR2 | Carduus crispus | curly plumeless thistle
NoxWeeds	CANU4	CANU4 | Carduus nutans | nodding plumeless thistle
NoxWeeds	CAPY2	CAPY2 | Carduus pycnocephalus | Italian plumeless thist
NoxWeeds	CATE2	CATE2 | Carduus tenuiflorus | winged plumeless thistle
NoxWeeds	CAKO2	CAKO2 | Carex kobomugi | Japanese sedge
NoxWeeds	CALA20	CALA20 | Carthamus lanatus | woolly distaff thistle
NoxWeeds	CALE52	CALE52 | Carthamus leucocaulos | whitestem distaff thi

Example: Here's a noxious weed list using common names and simple codes.

NoxWeeds	BROKNAP	Brown Knapweed
NoxWeeds	MEAKNAP	Meadow Knapweed
NoxWeeds	ORIBITT	Oriental Bittersweet
NoxWeeds	BLASWAL	Black Swallowort
NoxWeeds	COMTEAS	Common Teasel
NoxWeeds	DALTOAD	Dalmatian Toadflax
NoxWeeds	GIAHOGW	Giant Hogweed

c. **Nectar Plants**

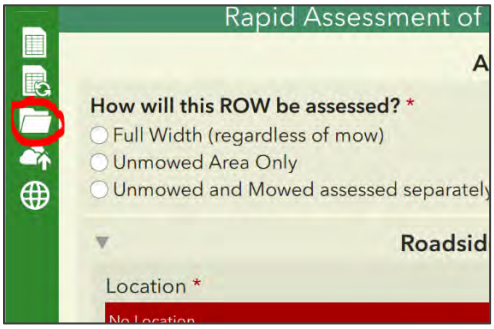
A comprehensive nectar plant list has already been populated in the **choices_external** tab for your state. This list was pulled from the USDA Plants Database at https://plants.sc.egov.usda.gov/adv_search.

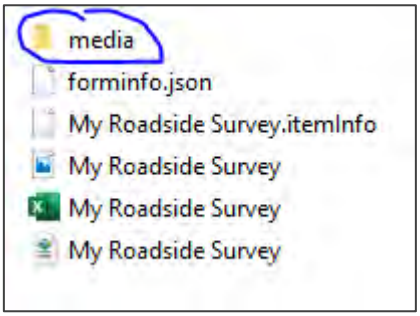
You *may* choose to substitute this list with your own state plant list replacing the **name** and **label** column or to add additional species that you discover are missing *(Note: adding choices after an initial publishing will require the form to be republished and then redownloaded by field techs for those additions to appear).*

USING YOUR OWN STATE PLANT LIST

WARNING: For **native species richness** to be calculated, if you use your own plant list, you will also need to modify the supplemental **Natives** table**.** The code for the plant in the **choices_external** (name column) table must have a corresponding code in the **Natives** table (PlantCode column) to determine nativity. Note that nativity is defined as native to the Continental U.S. and not to your state.

The Native table is the CSV file that you placed in the media folder of your survey new survey directory.

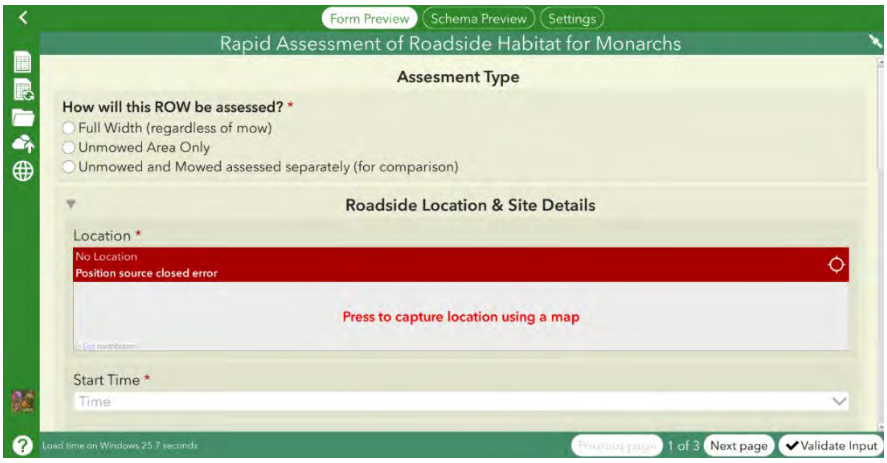




*If using your own plant list, the **native** table must have a corresponding **PlantCode** and the **Status** column populated. The status is 1=native, 0=not native.*

PlantCode	Status
ABAB	1
ABAL	1
ABAM2	1
ABAM3	1
ABAN	1
ABAR	1
ABAU	0
ABBE	1
ABBI	1
ABBO	1
ABCA	1
ABEL	1
ABELI	0

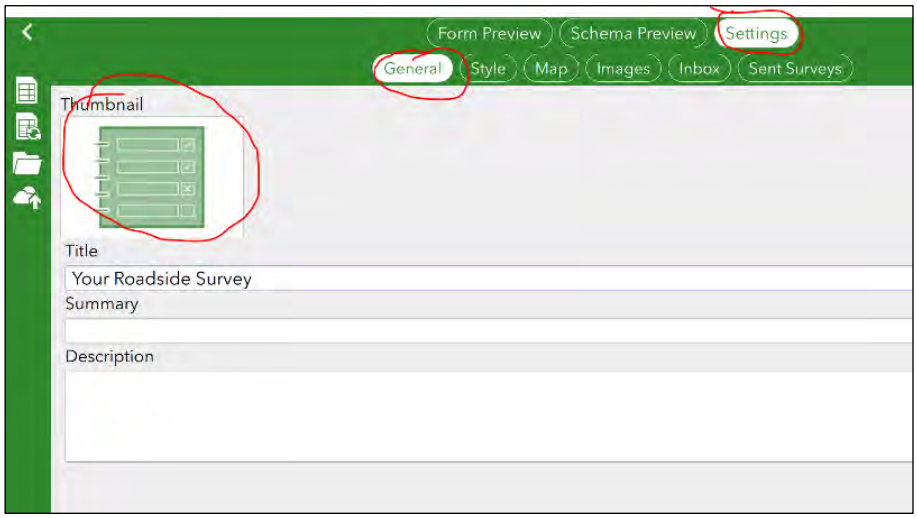
5) **Save form and view –** Once all these updates have been made, save the excel table and close it. Every time you save the table, the form will update with the changes. Review the survey to check everything look right. Test the plant dropdown lists in particular.



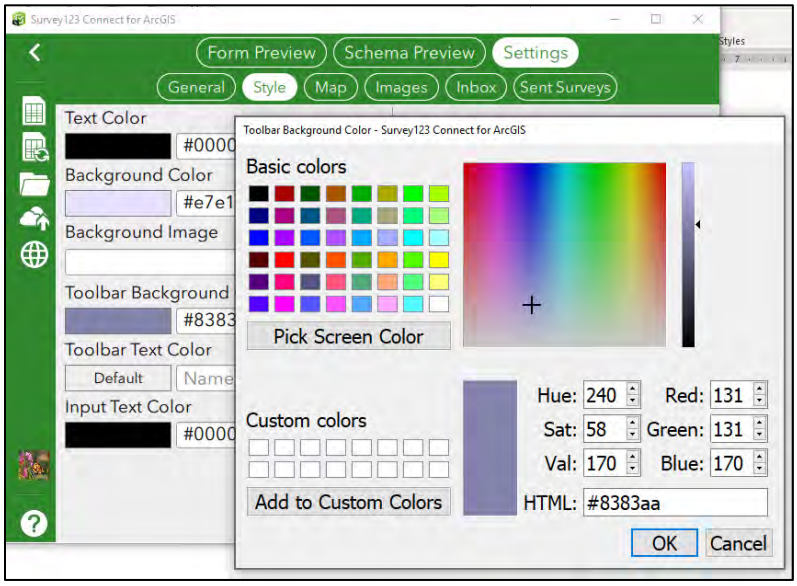
Click on **Next page** to view all 3 pages of the survey. Questions with red asterisks are mandatory. Answers to some question will trigger other questions to appear in the form so try out various scenarios.

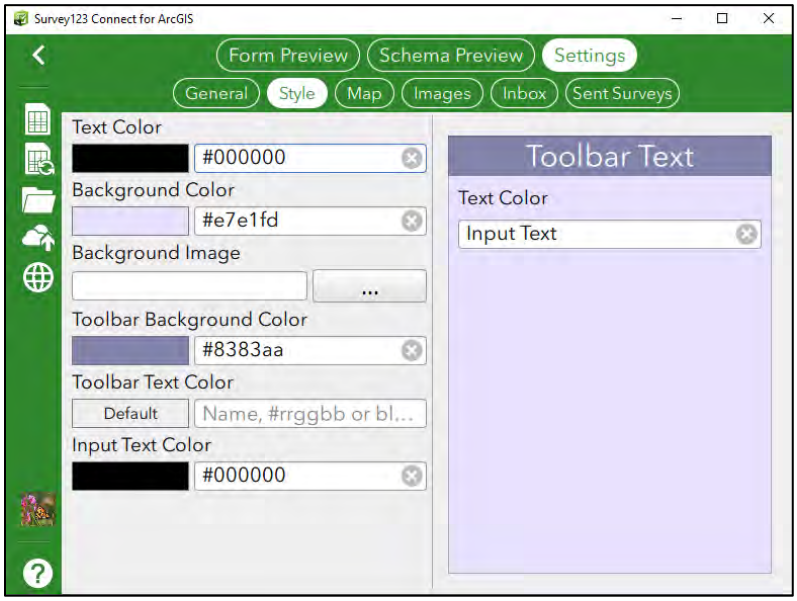
6) **Style the Survey**
To add a picture and change the look of your survey, click the **Settings** tab.

a. **Add thumbnail photo** – Under the **General** settings tab, click the thumbnail image to browse to an image file. For best results, use an image that is 600x400 pixels in size.



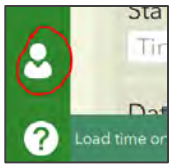
b. **Change Survey Look (optional) –** Click the **Styles** tab. Styles control the colors of basic elements in your survey.





You **do not** need to save anything when changing survey **Settings**. These components will save automatically.

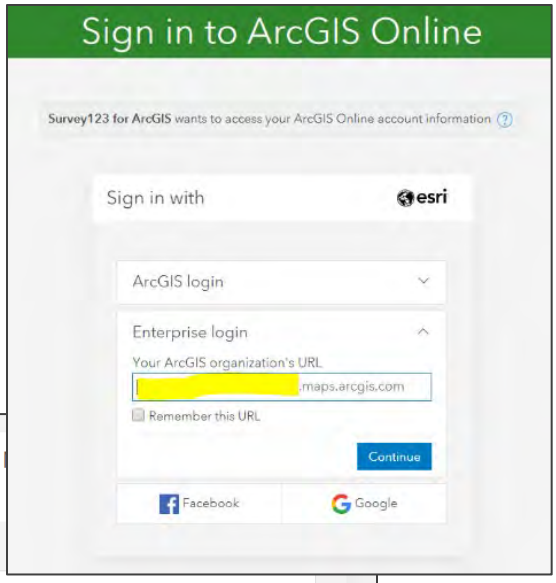
7) **Publish form up to AGOL**



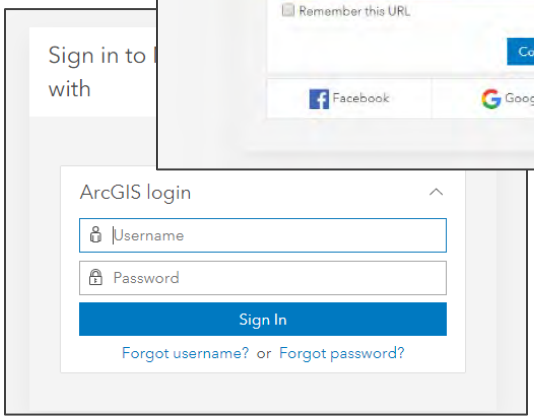
Publish the survey to your agency's AGOL account. To do this you'll need to log in using AGOL "Creator" user credentials. The act of publishing the form to your AGOL account not only prepared the survey for deployment, it creates the database to which survey data will be deposited.

a. Sign into to your agency AGOL account by clicking the person icon (bottom left corner).

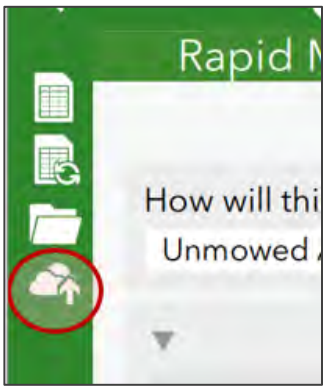
b. On the first screen, type the name of your AGOL organizational account before "**.maps.arcgis.com"**. This takes you to your organizational AGOL login screen.

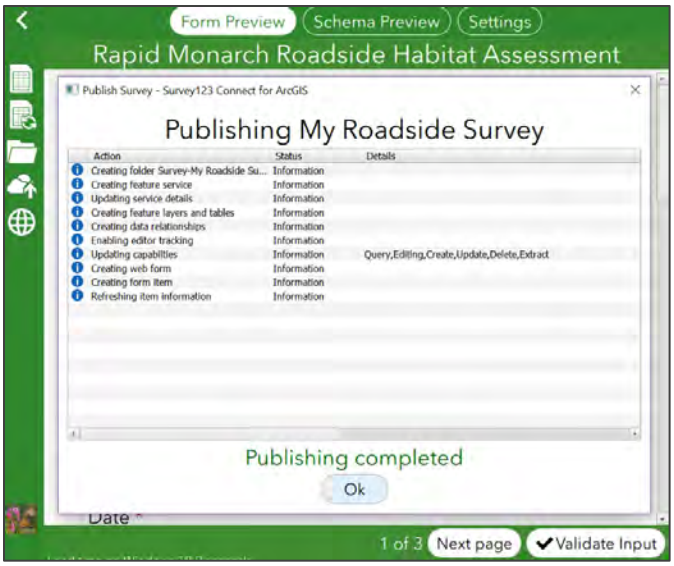


c. On the second screen log in with your "Creator user" credentials.

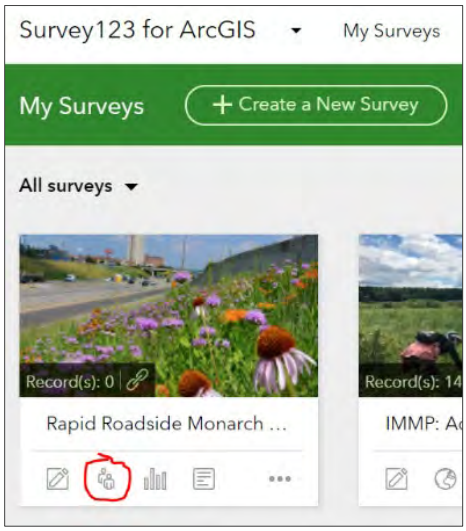


d. Click on the publish icon in Survey 123 Connect. This may take a few minutes. You'll be notified when publishing is complete.





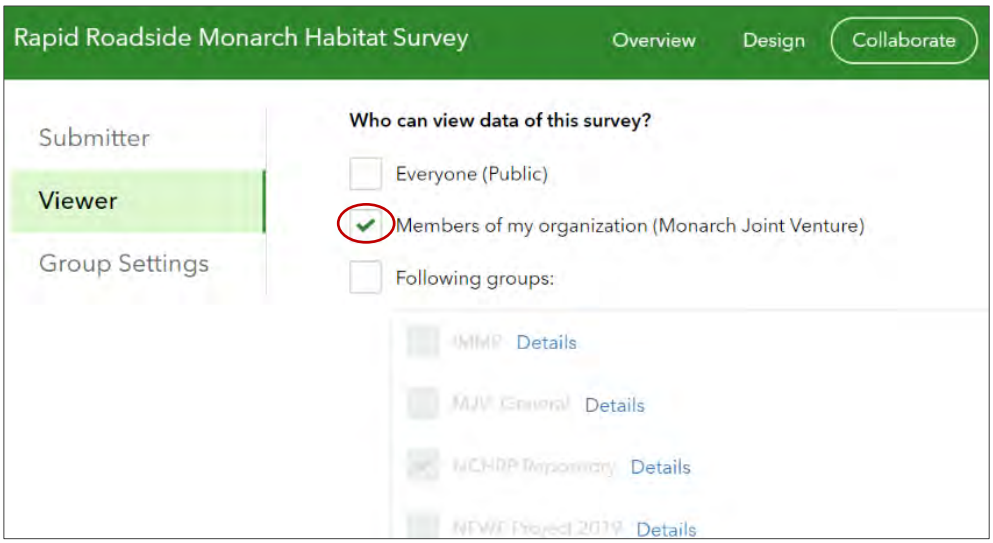
8) **Set permissions.** Before the survey can be downloaded by field technicians for use, you need to set sharing permissions.

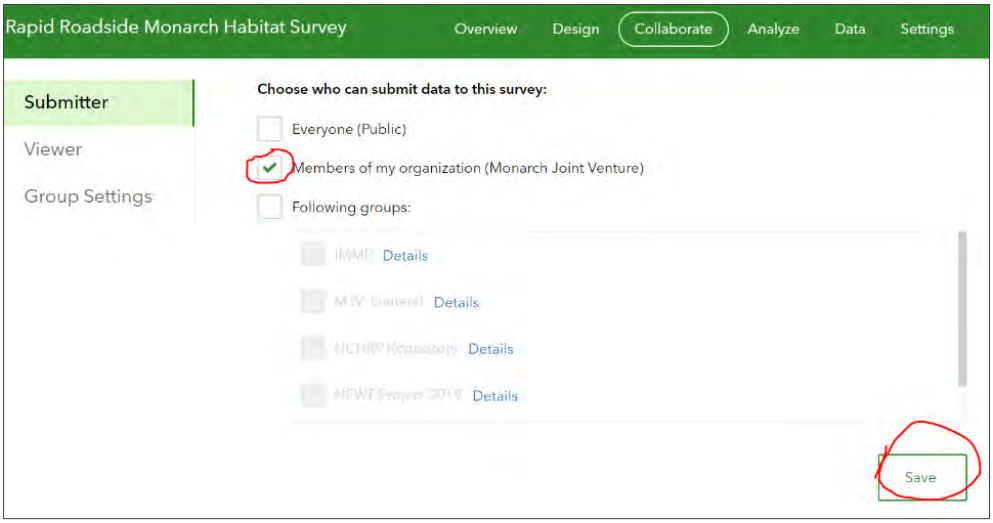


a. Go to https://survey123.arcgis.com/ and log in with the same credentials that you used to publish the form.

b. Your survey should be displayed there. Click on the **collaborate** icon (right).

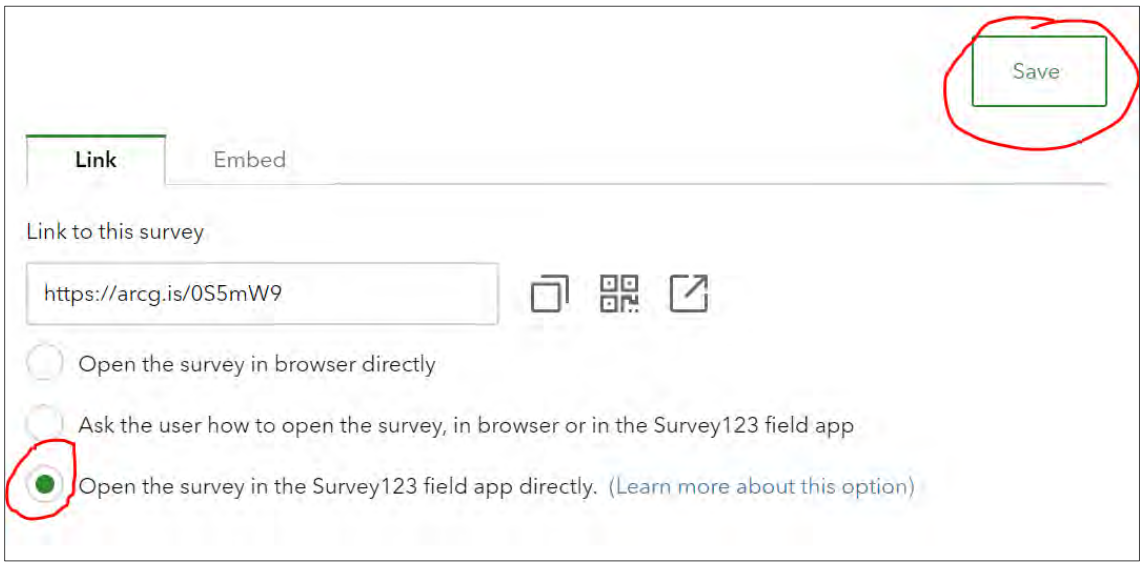
c. Set permissions under the **Submitter** AND **Viewer** tabs to "Members of my organization".





9) Finally, click on the **Submitter** tab and scroll to the bottom. Click on **"Open the survey in the Survey123 field app directly".**

   This action generates a **survey link** that you can send to field technicians. When clicking this link, the form will automatically download and open in their installed Survey123 field app.



10) **SAVE**

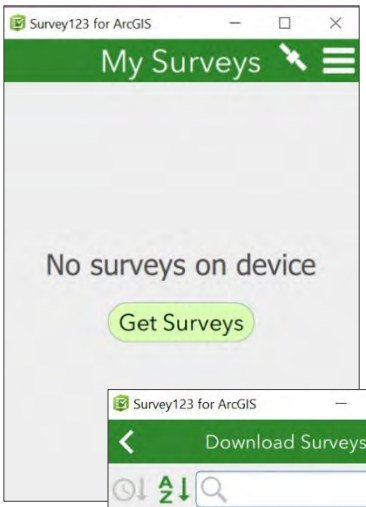
The survey now set to be deployed in the field!

II. Using the Survey 123 field application

Field staff will use a related software product called the **Survey 123 field app** (a.k.a "Survey 123 for ArcGIS") to collect the roadside habitat data to submit to the AGOL database. Your Esri/AGOL administrator will need set field staff up with user credentials for them to access survey form and submit data.

The link to the software is located at http://doc.arcgis.com/en/survey123/download/ or can be downloaded directly via the Apple or Android app store by searching on "Survey123".

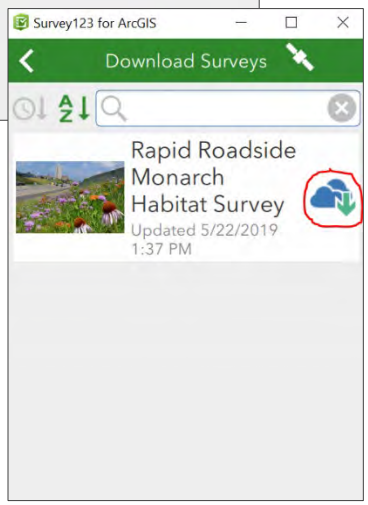
1) **Install the field application and download survey form**
    a. Download **Survey 123 field app:**
    http://doc.arcgis.com/en/survey123/download/
    Choose the download appropriate for your mobile platform.
    b. Once the Survey 123 field app is loaded, the survey form can be downloaded to it in one of two ways:
        1) Share the survey link (previous page). Once users click the link, the form will download into field app.
        2) Users sign into the AGOL account and bring the form down from the site.



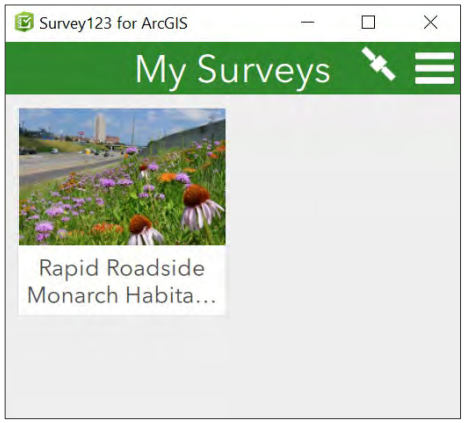
Click **Get Surveys** and sign into the organizational AGOL account with user credentials.

The survey will appear. *If your organization have many surveys available to users, you can search on the survey name to find it.*

Click the **download icon**.



Click the **back arrow** in the green header to see the downloaded form.



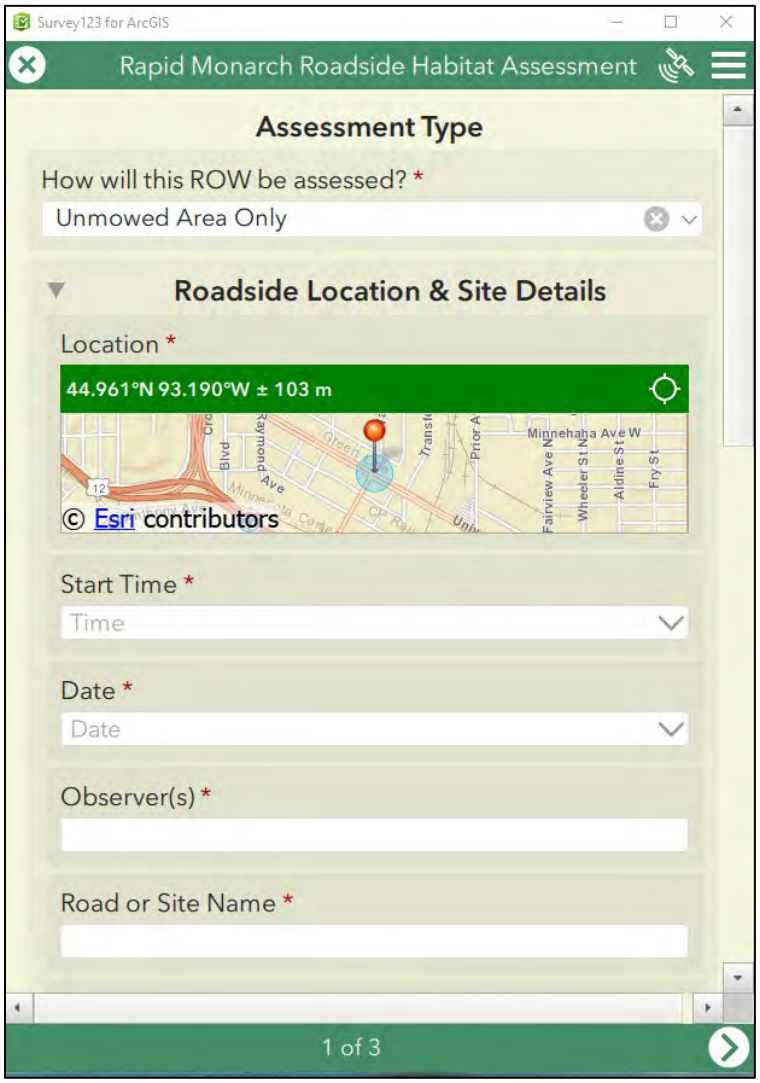
2) **Collect Data**

The survey form is now ready to go. The form can be completed, submitted, and reused over and over. An internet connection is not needed to use the survey in the field. An internet connection is only needed to download the initial form and when submitting surveys. There's an outbox feature of the app that stores completed surveys for later submission when WiFi is available.

Click on the survey and then the **collect button** launch survey.

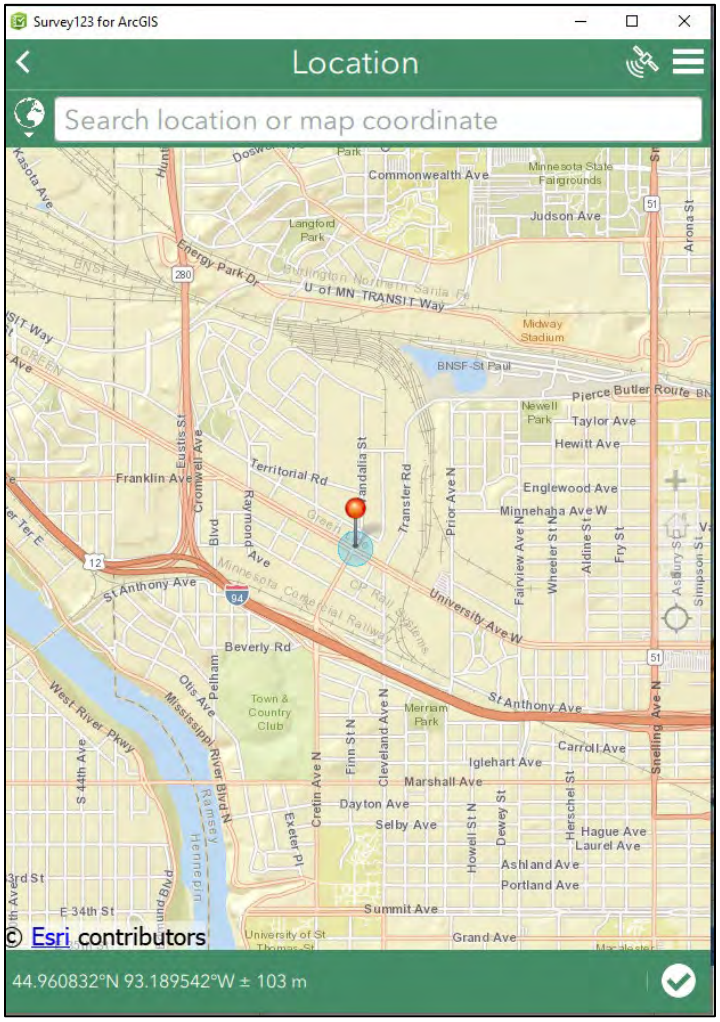
***Note**: In the instructions below, the component score to which the field contributes is listed in parenthesis after the field name.*

a. Page One: Assessment Type, Location & Site Details, Management Practices



1) **Assessment Type:** How will this ROW be assessed? (Set as a default) This should have set this as a default and will not need to be entered by field techs (see defaults section on page 5 of this guide).

2) **Location** (start point of survey): Locational service setting for the mobile device needs to be turned ON for in order to find location.



a. Click on the map to launch larger map window.

b. Wait until red pushpin appears

c. Click the check icon to capture the point.

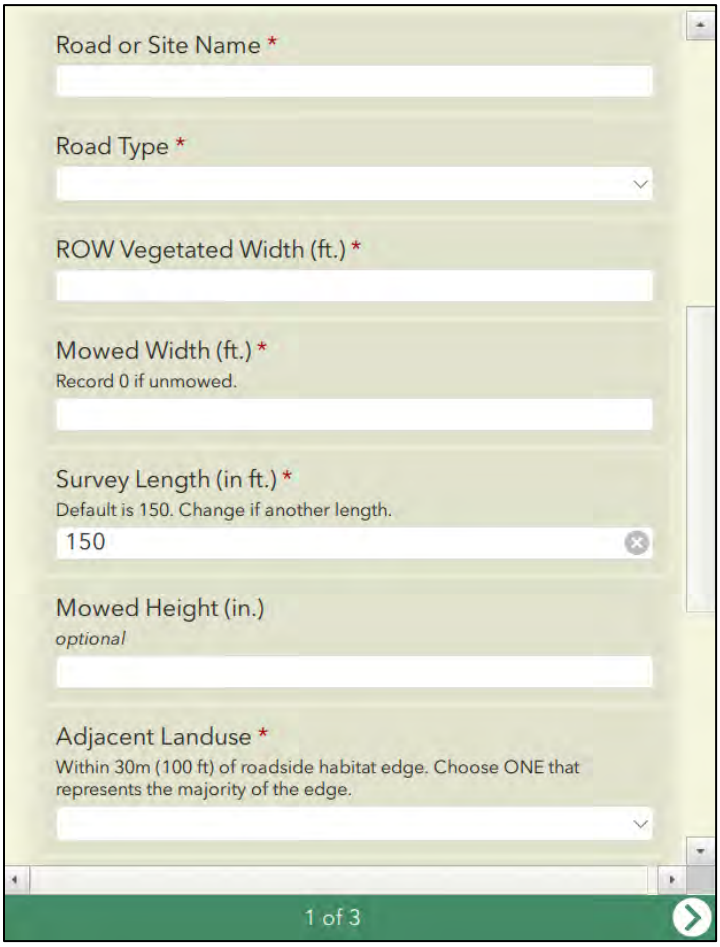
Note: If you are entering data from a paper datasheet, **enter the coordinates (latitude, longitude) manually** into the search box above the map, hit return, and then capture by clicking the check icon.

3) **Start Time**: By clicking this field, the time will autofill. (Note: If taking data on paper and entering it into the survey form after the fact, you will need to manipulate this time field).

4) **Date:** By clicking this field, the date will autofill. (Note: If taking data on paper and entering it into the survey form after the fact, you will need to manipulate this date field).

5) **Observer name(s):** Type observer name(s)

6) **Road or Site Name:** This is the site identifier**.** Type a **unique** site name or code for in this field to identify the site.



(6)

(7)

(8)

(9)

(10)

(11)

(12)

7) **Road Type** (threats): select the road type form the dropdown (2-lane, 4-lane, over 4 lanes)

8) **ROW Vegetated Width** (management): width in feet (can be decimal) of the vegetated area of the roadside.

9) **Mowed Width** (management): width in feet (can be decimal) of the mowed area of the roadside.

10) **Survey Length** (Set as a default): 150 feet by default.

11) **Mowed Height** (optional): height of the vegetation in the mowed area in inches.

12) **Adjacent Landuse** (threats)**:** What is the dominant land use directly adjacent to the roadside area you are surveying.

Cropland, no barrier
Cropland with woody vegetation barrier (e.g. hedgerow)
Developed, including lawn, landscaping
Developed with woody vegetation barrier (e.g. hedgerow)
Woody habitat
Diverse grassland/natural habitat (e.g., reserve, prairie remnant)
Non-diverse grassland/Open space
Wetland habitat
Other

(13)

(14)

Management Practices (optional): This is an optional section. While management is one of our four habitat component scores, if these data are not taken, the overall score denominator will reduce accordingly. In other words, the habitat score will not be reduced because of the lack of these data.

13) **Herbicide Application** (management): Enter the type of herbicide application. If left blank or "Don't know" is marked, this question will not be factored into the management component score since it is optional.

Never
spot treat noxious weeds only
spot treat woody species only
treat grass to stimulate forbs
broadleaf applied in clear zone 1 x /yr
broadleaf applied in clear zone > 1 x /yr
broadleaf applied throughout ROW
Don't know

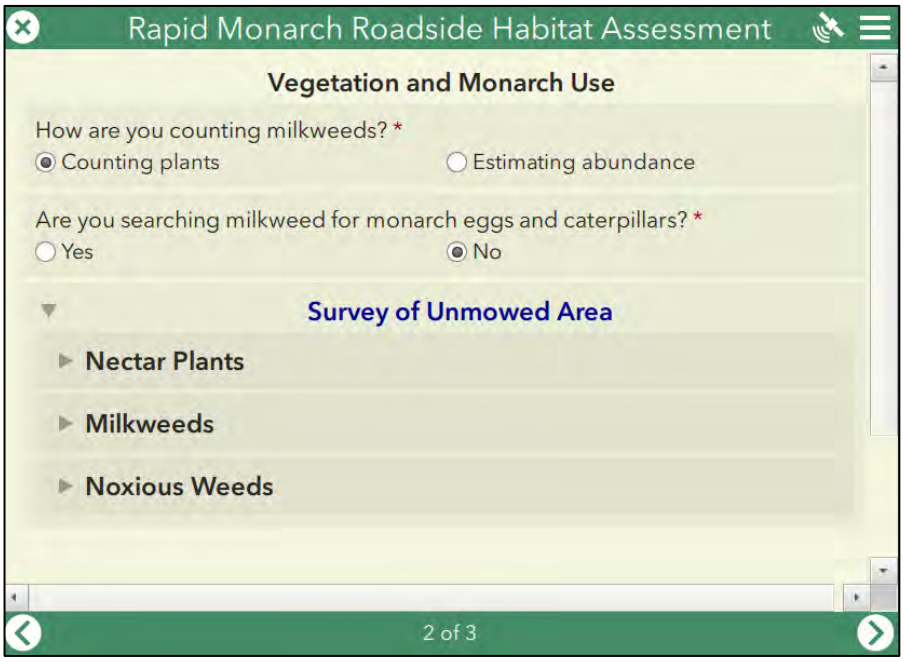
14) **Frequency of Full-Width Mowing** (management): Enter the frequency of which the full-width of this site is mowed. If left blank or "Don't know" is marked, this

question will not be factored into the management component score since it is optional.

Never
Every few years
Once a year
Twice a year
> Twice a year
Don't know

Click the arrow at the bottom of form to proceed to the next page. 

b. Page Two: Vegetation and Monarch Use



(15)

(16)

(17)

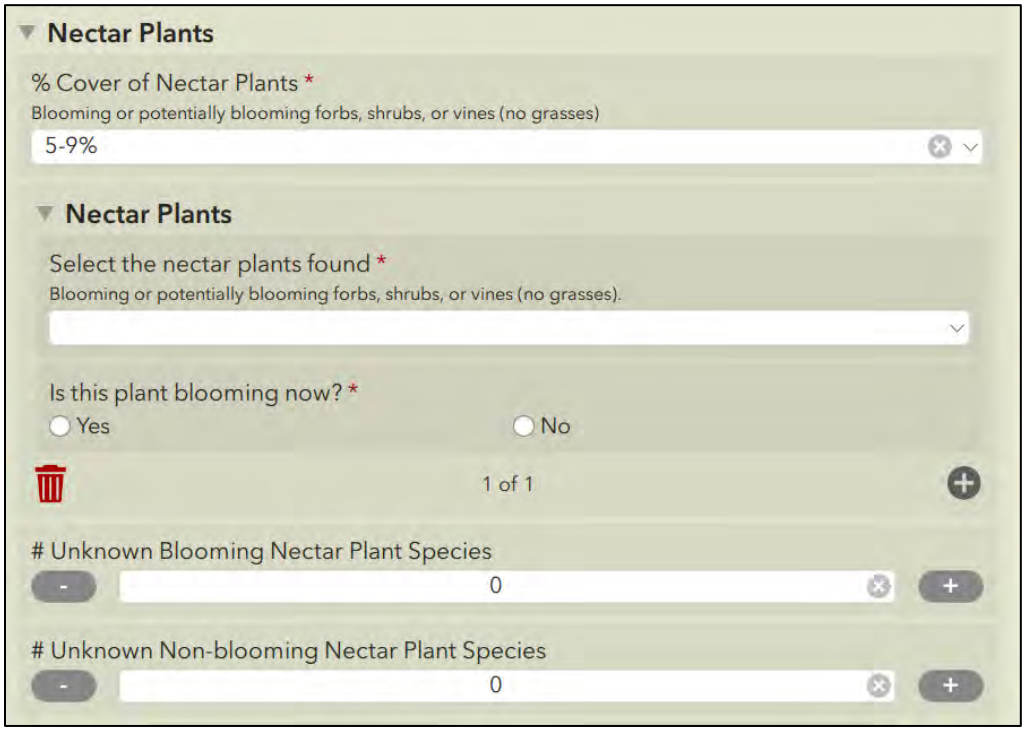
(18)

(19)

15) **How are you counting milkweeds** (Set as a default)? Counting individual plants is the default. Option for managers to set "Estimating Abundance" as the default.

16) **Are you searching to eggs and caterpillars** (Set as a default)? No by default. Option for managers to set "Yes" as the default.

17) **NECTAR PLANTS** (foraging)

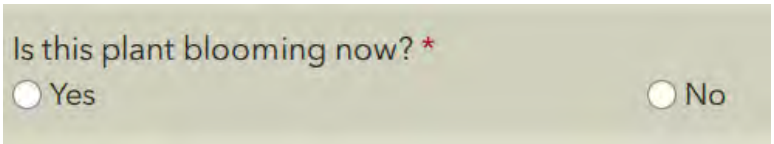


a. **% Cover of Nectar Plants –** estimate the total cover of nectar plants (blooming and non-blooming) on the site.

None
<5%
5-9%
10-25%
26-50%
51-75%
>75%

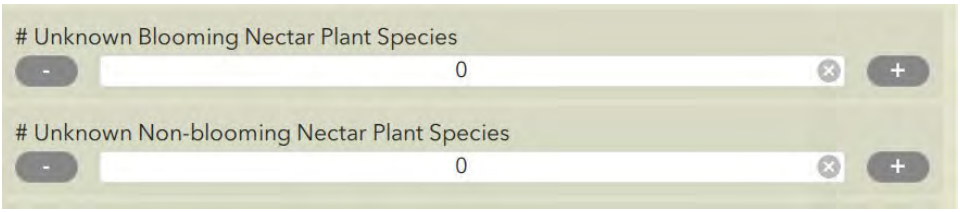
b. If any answer besides “None” is chosen, you will enter each nectar plant species identified by selecting from the dropdown list. This is an autofill list. Start typing the common or scientific name to limit choices. If you can only identify to the genus, there is a “genus sp.” choice for each (example: “Solidago sp.”). If the plant is NOT on the list, enter “Other”. You will then be able to type the name of that species into a field.

c. Mark whether the species is currently blooming or not.

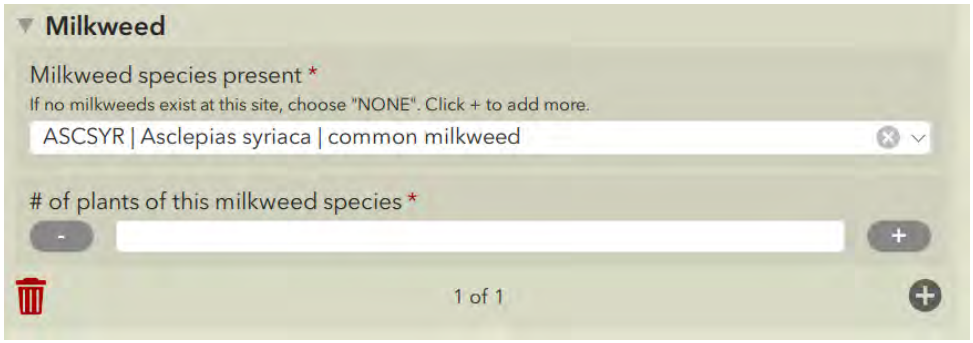


d. To add new species, click the round cross button. Repeat as often as necessary.

e. For plants that you cannot identify even to the level of genus, record each species using the tally buttons. One for species that are blooming and another for those that are not blooming. Do not double count species.



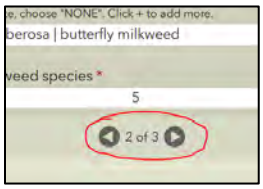
18) **MILKWEEDS** (breeding)



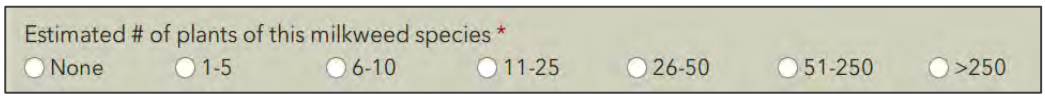
a. Choose a milkweed species observed on the site. If there are no milkweed, choose **None**. This is an autofill list. Start typing the common or scientific name to limit choices (don't bother typing full scientific name – they are nearly all asclepias!)

b. To add new milkweed species, click the round cross button. Repeat as often as necessary.

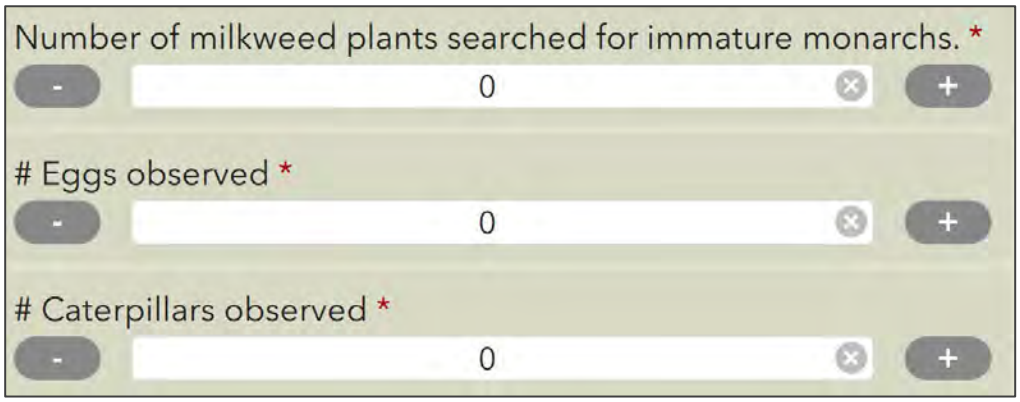
c. Keep a tally of the numbers of plants of each species. Use the back and forth arrows to toggle between species if tallying as you walk.



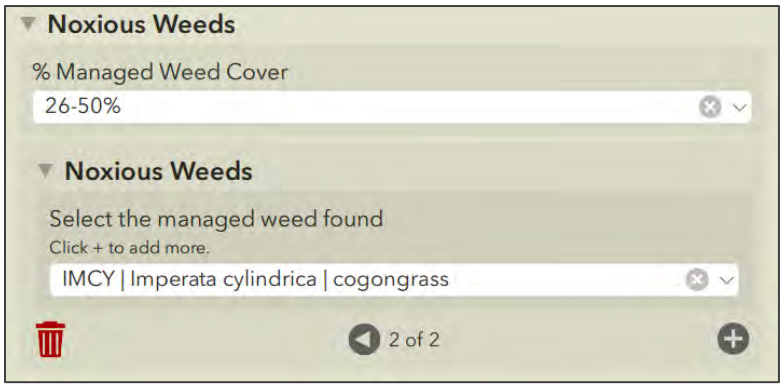
d. If you are **estimating** abundance, choose from the following categories.



e. If you are counting eggs and caterpillars, the following fields will appear. Fill out the total number of milkweed plants searched, and the number or eggs and caterpillars found.



19) **NOXIOUS WEEDS** (threats)

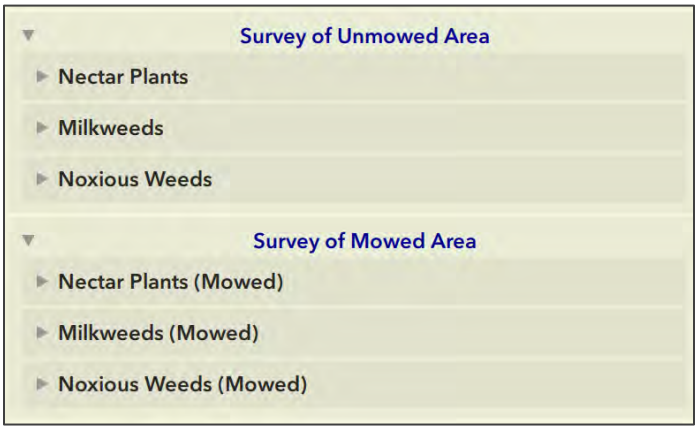


a. **% Cover of Noxious Weeds:** estimate the total cover of noxious weeds on the site. These are a set list of plants earmarked for management by your agency.

None
<5%
5-9%
10-25%
26-50%
51-75%
>75%

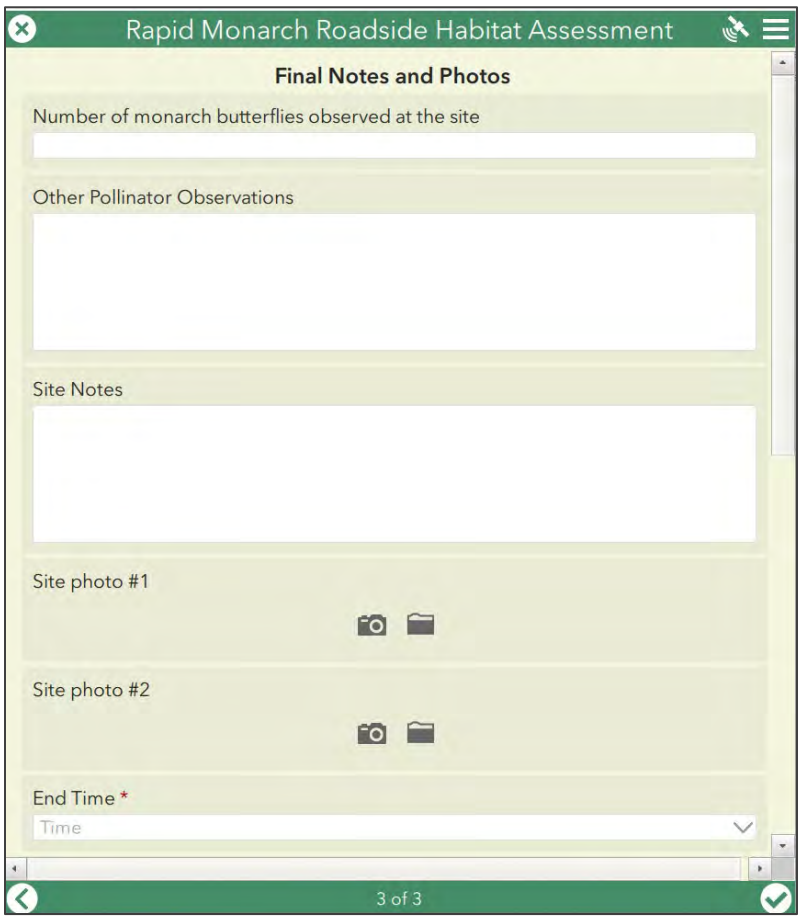
b. If any answer besides “None” is chosen, you will enter each noxious species identified here. These are a set list of plants earmarked for management by your agency that are listed in the dropdown.

NOTE: If collecting data in the unmowed and mowed sections of the roadside separately, the form will look like below. The same fields are replicated in the mowed area section for later comparison.



Click the arrow at the bottom of form to proceed to the last page.

c. Page Three: Notes and Photos



(20)

(21)

(22)

(23)

(24)

20) **Number of monarch butterflies observed** (optional): Note the number of monarch butterflies observed at this site during the survey. This does not go into any calculation. It is a general marker for presence or absence of monarchs.

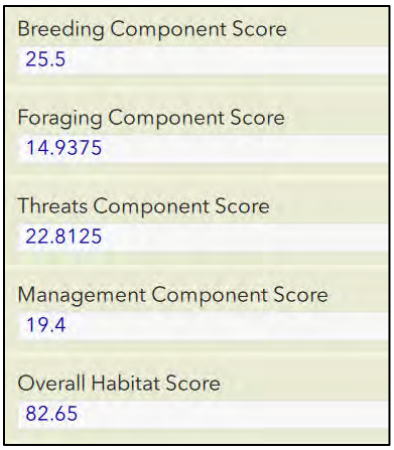
21) **Other Pollinator Observations** (optional): Any notes on other pollinator use of this site.

22) **Site Notes** (optional): Anything you would like to communicate about this site.

23) **Site Photos** (optional): Click the camera icon to take a photo from your mobile device. If entering data later, a photo can be uploaded from a file using the folder icon.

24) **End Time:** By clicking this field, the time will autofill. (Note: If taking data on paper and entering it into the survey form after the fact, you will need to manipulate this time field).

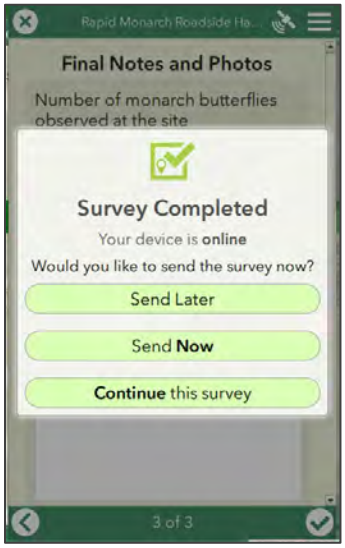
Habitat Component and Overall Habitat Score
The overall habitat score, as well as the component scores, are revealed at the end of the form. These are read-only field for your information.



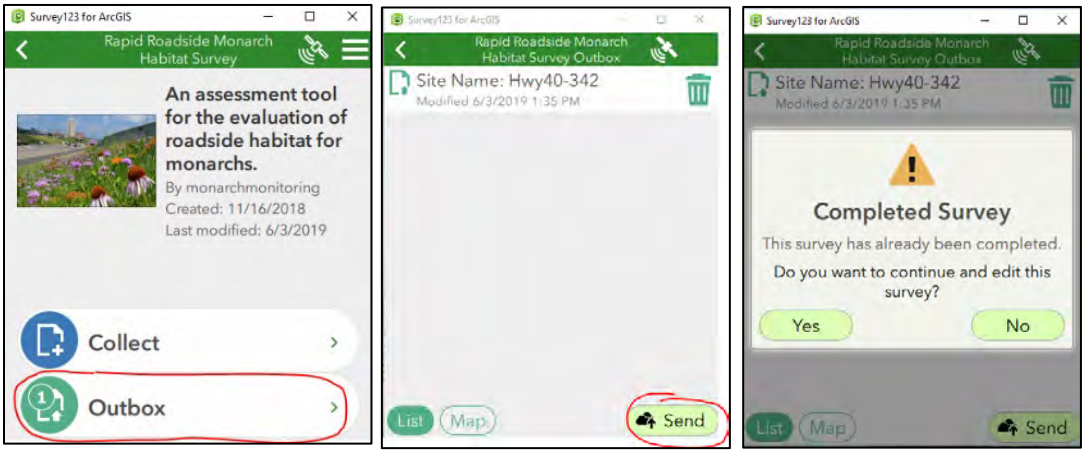
3) Submit Data
You have choices for submitting the survey data.

a. Click the check at the bottom right of page 3 of the survey. You can check whether or not you are online the **Survey Completed** header.

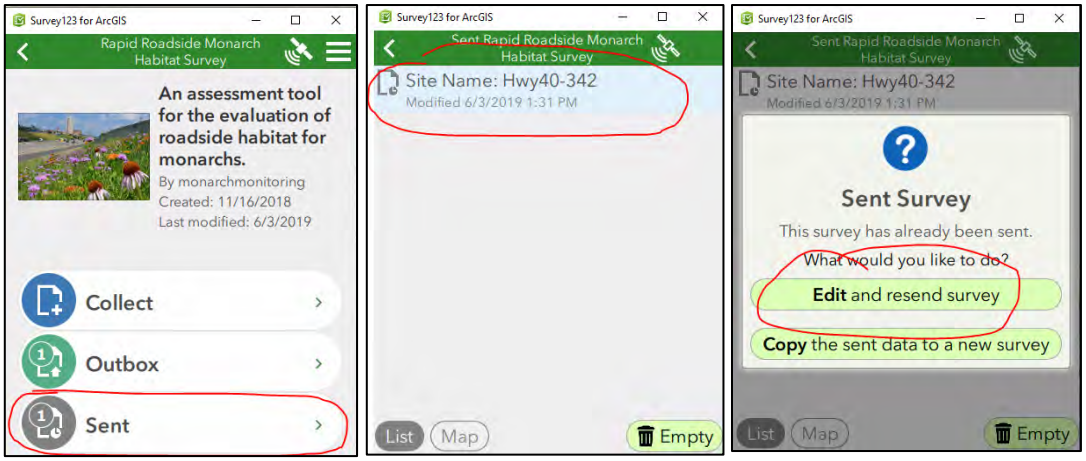
b. If you are not connected to the internet, click **Send Later**. If you are connected, you can **Send Now.** If you need to go back to the survey, click **Continue the survey**.



Send Later will store the survey in an **Outbox** for later submission. After clicking on the Outbox, hit **Send** to submit all the surveys stored there. You can also click on individual surveys to review before sending.



Send Now sends the data directly to the to the AGOL database and stores the survey in the **Sent** box. Sent surveys can be retrieved here. If you need to make changes to a submitted survey, click on it in the sent box, make corrections. And resubmit. The resubmitted survey will overwrite the original submission.

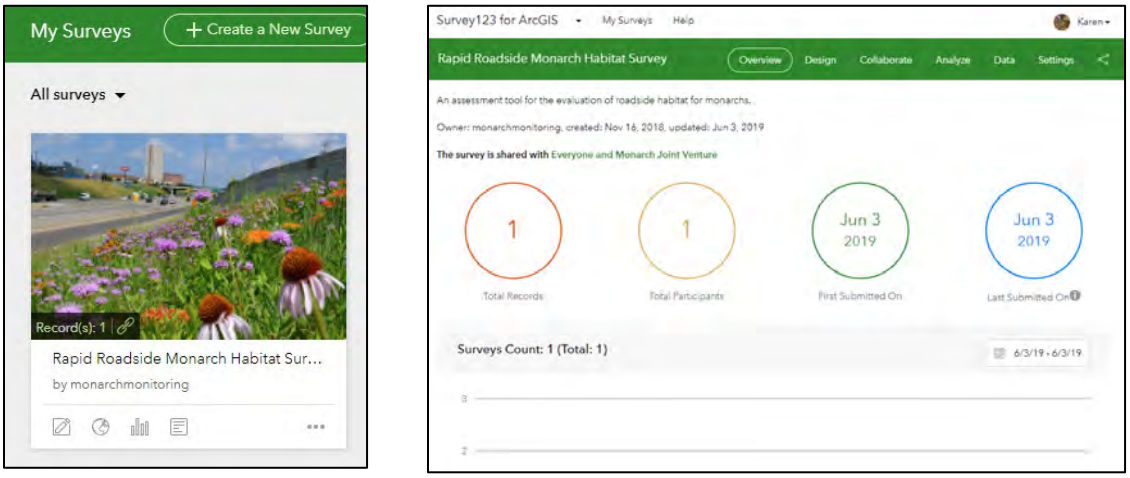


III. Exploring the Results

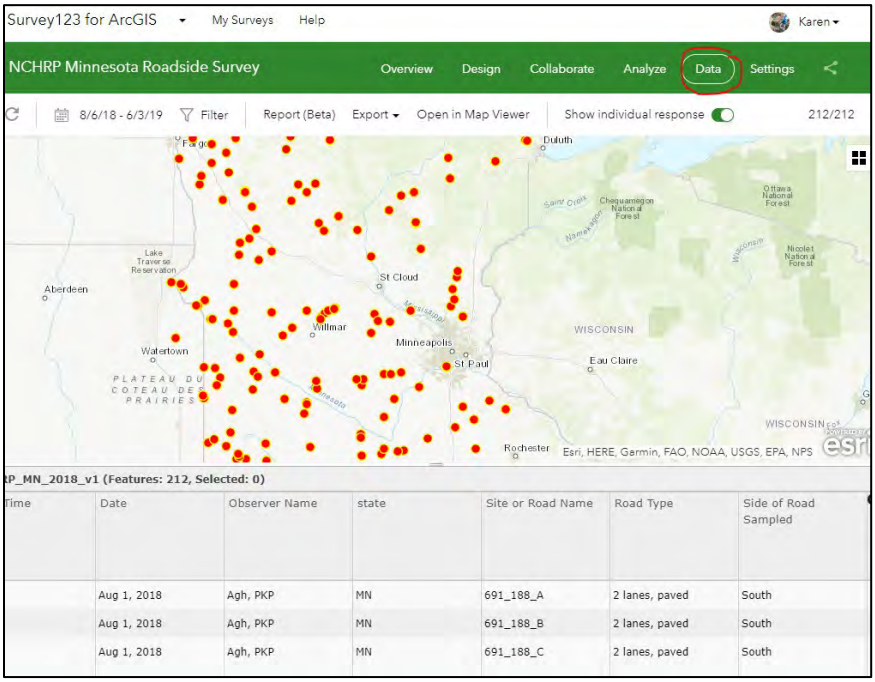
You can view, download, analyze, and visualize the survey data from the Survey123 website (a portal into your ArcGIS Online data repository).

1) Log into Survey 123 the website using your AGOL credentials.

2) Select your survey by clicking on it to launch the portal interface.

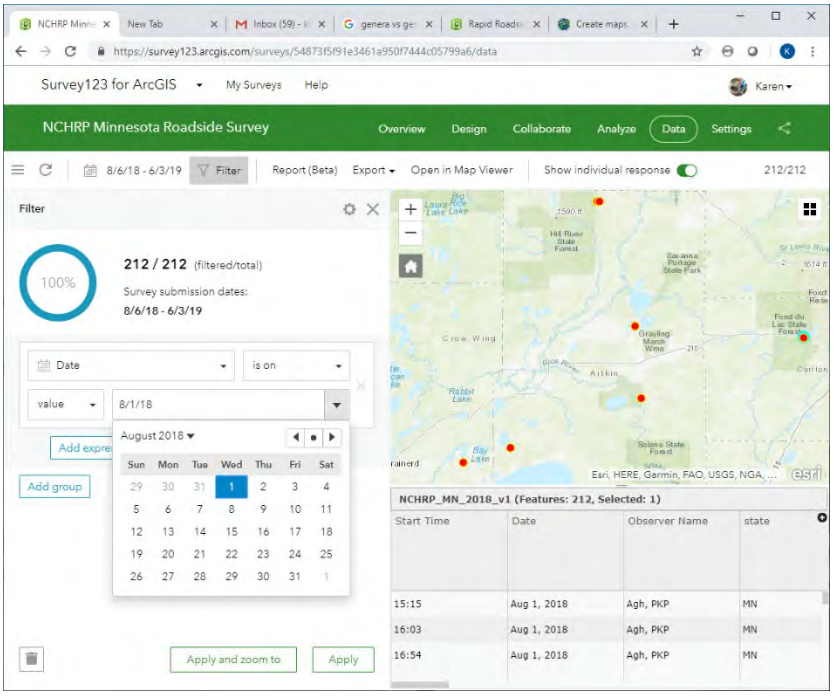


3) Click on the **Data** tab to view all records along with their locations.



On this tab you can perform many functions:

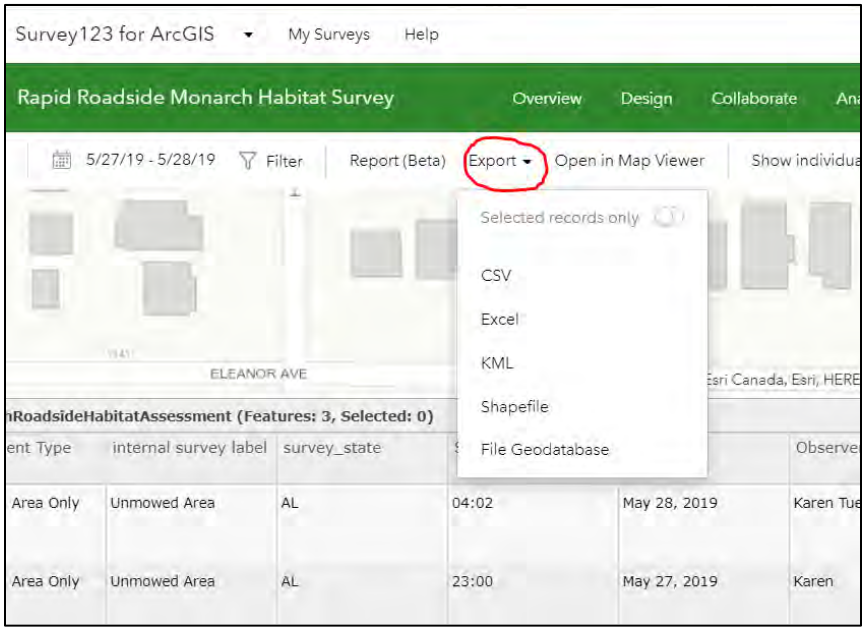
a. **Filter:** Display surveys by any field using the filter button.



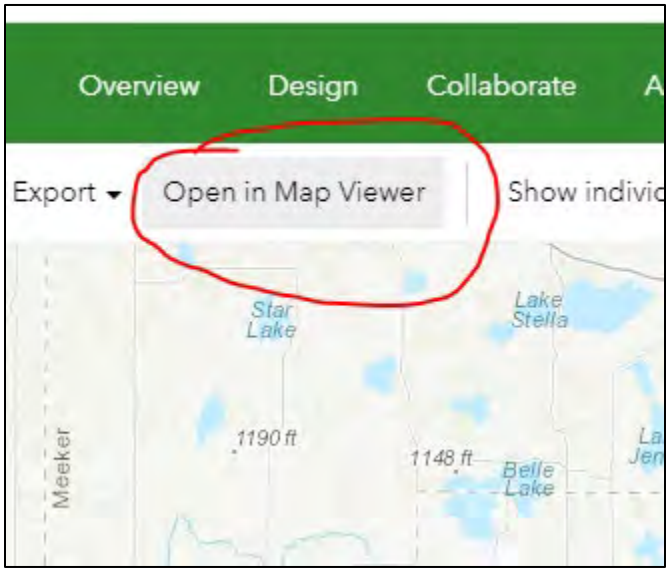
Here we are filtering our records by survey date to check out that day's submissions.

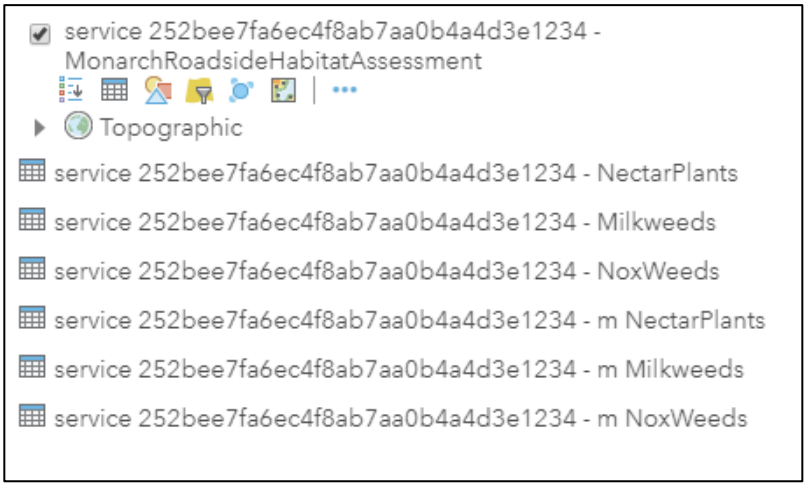
Best Practice: *It's a good idea to perform quality control on records here from time to time. If errors are discovered, field techs can resubmit corrected surveys to override results.*

b. **Export:** Full dataset (or selected subset) can be downloaded as a geodatabase or for local use with ArcGIS Desktop, or as other formats as needed.



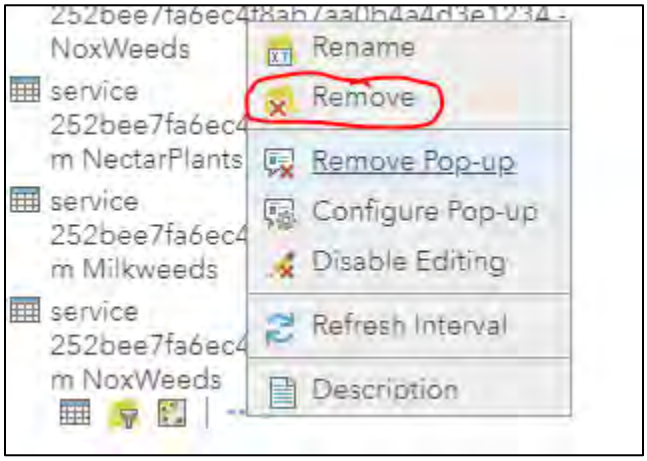
c. **Open in Map Viewer:** Visualize and share the data online by launching the Map Viewer.





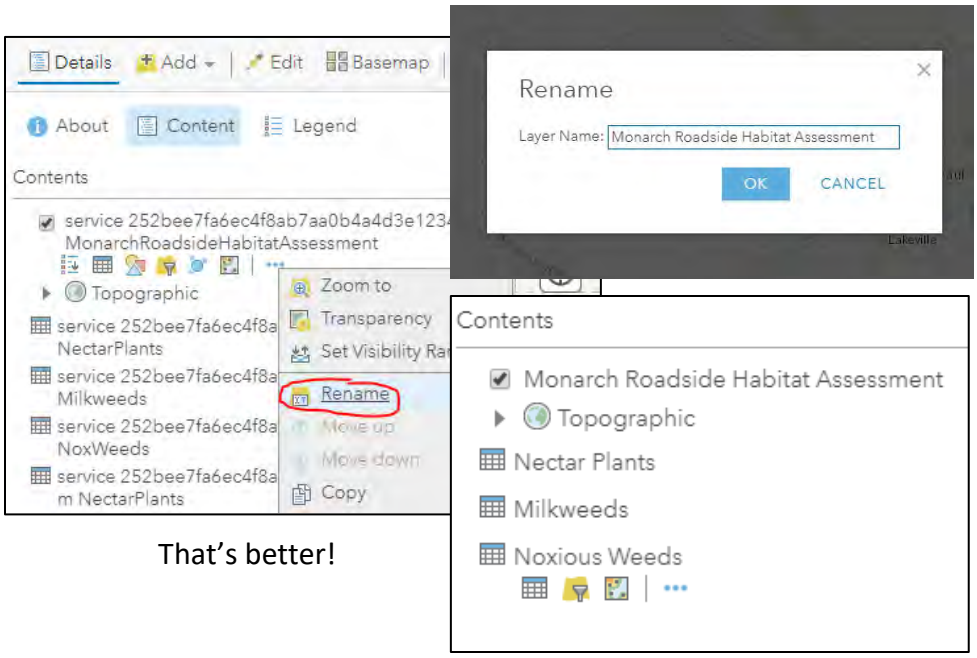
i. **Remove Tables:** You will notice the table of contents on the left has one spatial layer (**MonarchRoadsideHabitatAssessment**) and six tables (**NectarPlants**, **Milkweeds**, **NoxWeeds**, **m_NectarPlants**, **m_Milkweeds**, and **m_NoxWeeds**). The three tables preceded by **m_** are the data collected for the mowed section of the roadside (if collected separately). If your agency is not comparing mowed versus unmowed data, you can remove these three tables from the map.

1. Click on the table, then the three dots next to it. Choose **Remove.**



ii. **Change Table Names:** You will also notice the messy code preceding the table name. This is easy to change.

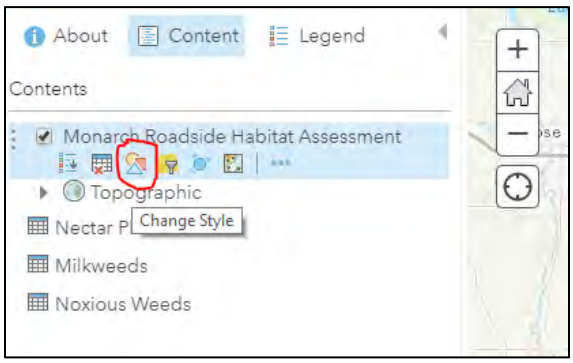
1. Again, click the three dots next to each layer or table and choose **Rename**. Delete the junk before the name or rename the layer/table something different entirely.



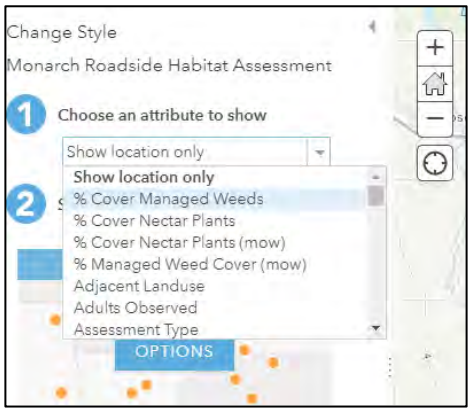
That's better!

iii. **Classify and Symbolize Data:** Now let's display the data in a more meaningful way.

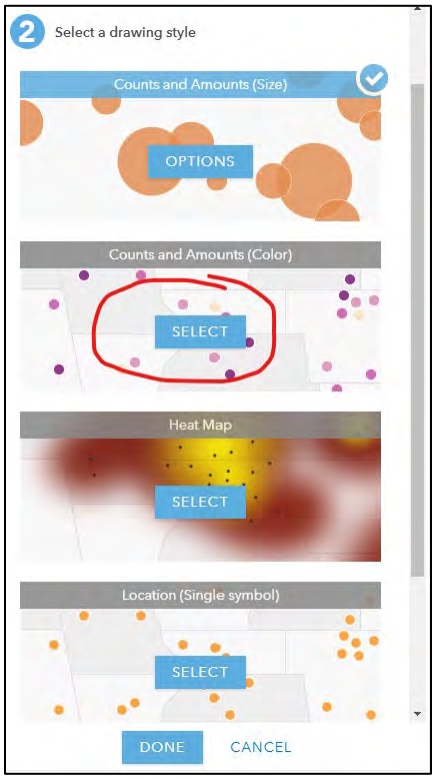
1. Click on the **spatial layer (Monarch Roadside Habitat Assessment)** tab in the Table of Contents and then the **Change Style** button.



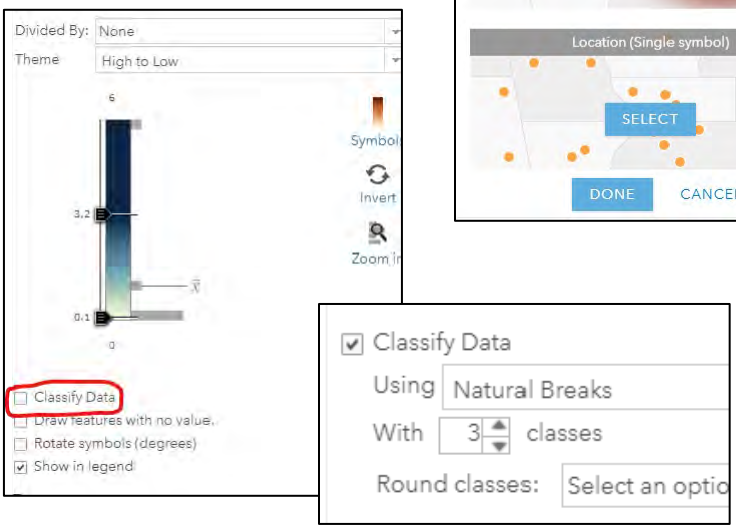
2. **Choose an attribute to show.** Here I will choose "Overall Habitat Score".



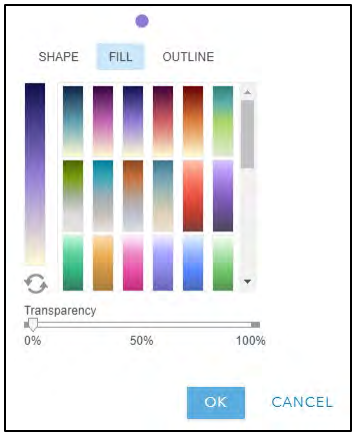
3. **Select a drawing style:** The style you pick will depend on the data you want to show. I will classify the Overall Habitat Score into three categories, so I'll choose 'Counts and Amounts (Color)". Click **Select**, then **Options**.



4. Click the "Classify Data" box. Then select the classification method, and the number of classes.

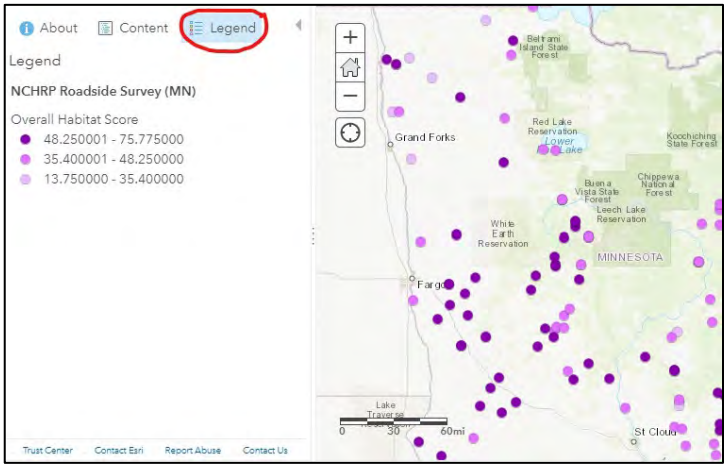


5. Click on **Symbols**
   a. **Shape tab:** make points larger or smaller.
   b. **Fill tab:** choose a color ramp for your classified data (darker should represent higher values).
   c. Hit **OK** when finished.



6. Hit **OK** at the bottom of the sidebar. And then **DONE.**

7. Click the **Legend** tab in the Table of Contents. You will then see the legend for your classified data.



iv. **Configure Popups:** When you click on a point, a pop-up screen appears. It will show ALL the fields in the table associated with the layer. Let's configure the pop-up to only show the fields we want to display.

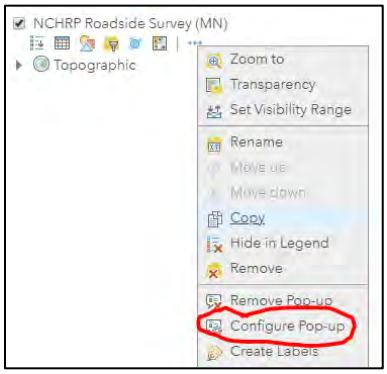
1. Click on the **Content tab.**

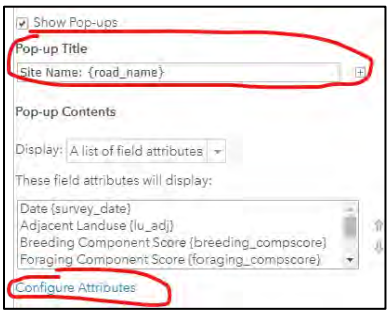
2. Click the three dots next to the layer.

3. Choose **Configure Pop-up.**

4. **Set pop-up title:** You can use a combination of type and {field names} to create a title. Click the + next to the title box to choose the field you would like to use in the title.

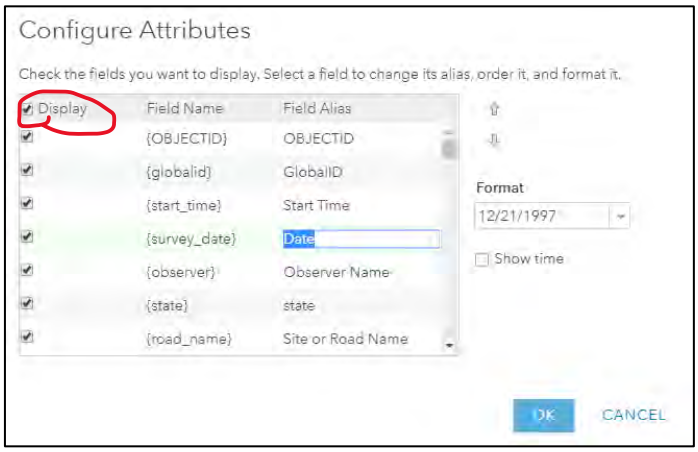
5. Click **Configure Attributes**

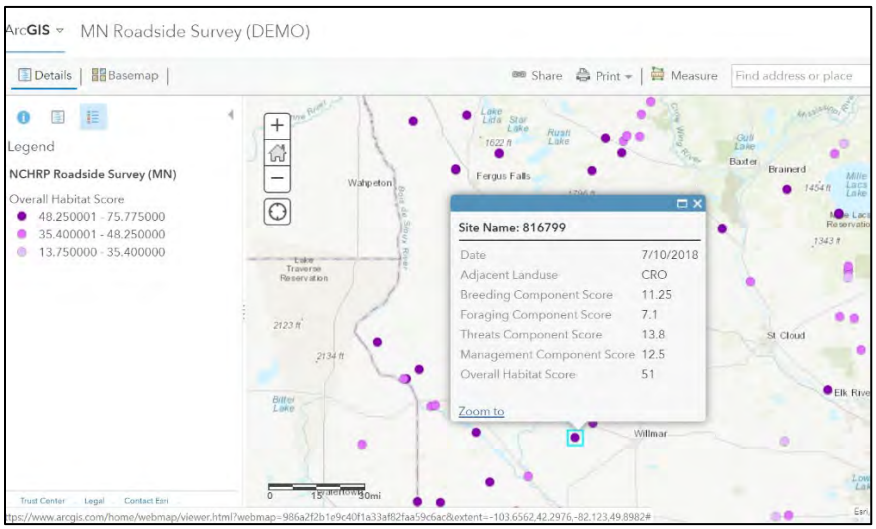




Click the **Display** checkbox to turn all fields off and then check only those you want to display.

You can click on the **Field Alias** to change the display name and format the data type (example, set decimal placements).

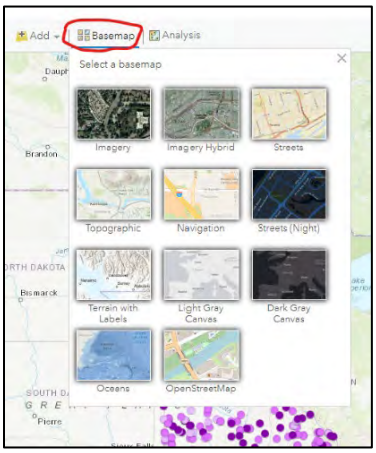


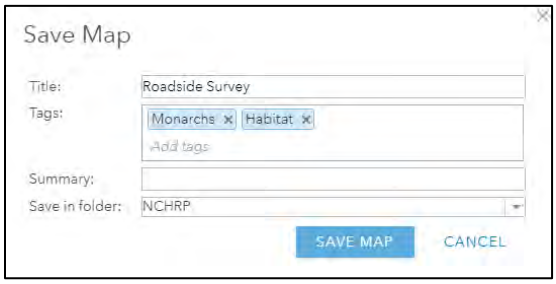


When you are finished configuring, hit **OK** in the configure box and **OK** again in the side panel. Click on a point to view the results.

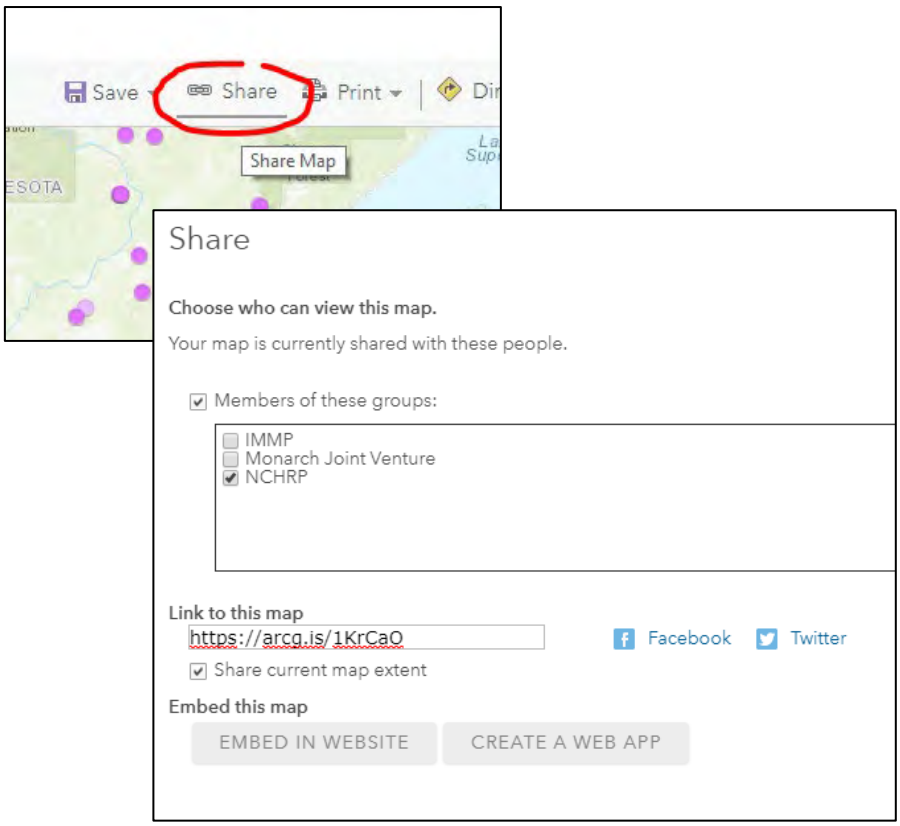
v. **Change the Basemap:** If you wish, you can change the underlying basemap.

vi. **Save the Map:** Save and name the map. The map will be stored in your AGOL contents. You will need to add a tag (example, “monarchs”) and choose a folder in which to store it.





vii. **Share Map:** We can share this map with others in our organization. Click on Share at the top of the map and choose with whom you want to share the map. Then copy the shareable link. People will have to be a member of an AGOL group to see the map unless you set all the data to "public" in the survey's **Collaborate** settings.



APPENDIX E.

Best Management Practices Resource Sheet: Monarch Butterflies, Weeds, and Herbicides

MONARCH BUTTERFLIES, WEEDS, AND HERBICIDES

Monarch butterflies are in decline in North America, and restoring monarch habitat, including roadsides, is important to the species' recovery[1]. Monarch caterpillars require milkweed (primarily in the genus *Asclepias*) to complete their development. A diversity of milkweed species is found on roadsides[2,3], and monarchs lay their eggs readily on milkweed plants in roadsides[4] and consume nectar from milkweed flowers.

Roadsides provide more than just milkweed; they can also provide diverse nectar sources to feed adult monarchs and other pollinators. Nectar fuels adult monarchs in their breeding, migration, and overwintering. Adult monarchs feed on nectar from a variety of blooming plants, including wildflowers and shrubs, throughout the growing season. Spring flowers support monarchs as they leave their overwintering grounds to breed, and summer flowers support several generations of breeding monarchs. Fall-blooming flowers are also important, as monarchs migrating to overwintering grounds require lots of nectar to build fat reserves to support their long-distance flights and sustain them through the winter.

Noxious and invasive weeds can degrade habitat for monarchs by displacing valuable nectar plants and milkweed. Herbicides are a tool employed by many transportation departments and other land managers to control noxious and invasive weeds or encroaching woody vegetation. However, some herbicide uses have nontarget effects that reduce the quality of roadside habitat for monarchs by removing flowering plants and milkweed plants or reducing plant diversity over time. This guide highlights best management practices to reduce the impacts of herbicides on monarchs.

Best Management Pratices

Roadside managers and other vegetation managers can reduce the impacts of herbicide use on monarch butterflies by:

1. using herbicides within an integrated approach that incorporates a range of methods to prevent and manage weeds and non-compatible vegetation,
2. limiting nonselective broadcast applications, which can damage host or nectar plants,
3. using herbicides as efficiently as possible to reduce the amount applied,
4. reducing off-site movement of herbicides, and
5. limiting direct exposure of monarchs to herbicides when possible.

Specific management practices to reduce risk to monarchs from herbicide applications include:

Applicator Training

- Train staff and contractors to distinguish noxious and invasive weeds and encroaching woody vegetation from similar species to reduce unintended damage to nontarget plants. For instance, training may help crews to distinguish the invasive Canada thistle (*Cirsium arvense*) from the native tall thistle (*Cirsium altissimum*), an important fall blooming native nectar plant for migrating monarchs in the central states.
- Train applicators in herbicide application techniques that reduce damage to nontarget plants.
- Create specifications that would hold contractors accountable to using proper techniques.

Assessment

- Inventory roadside vegetation regularly to identify emerging noxious and invasive weed issues or encroaching woody

vegetation. Early detection of weeds can result in improved control and may reduce the amount of herbicide needed overall.

- Document desirable plants that may be present, such as native nectar plants and milkweeds.

Milkweed (*Asclepias spp.*) growing along a roadside in Michigan. Identifying and recording the location of milkweed patches like this is a first step in ensuring that they are considered during subsequent maintenance operations. (Photo: Xerces Society / Jennifer Hopwood.)

Planning

- Use herbicides within an integrated vegetation management plan. Evaluate the range of management techniques (e.g., chemical, cultural, biological, physical, and mechanical) in order to select the most effective, feasible, and least harmful weed management method(s) that can increase or conserve the abundance and diversity of blooming plants.
- Prioritize selective herbicides—those formulated to control specific weeds or groups of weeds—whenever possible, to reduce damage to nontarget plants.
- If using nonselective herbicides—broad-spectrum products that kill or damage a wide range of plants—use direct or targeted application methods or apply when desirable plants are dormant. If possible, avoid applications during times when monarchs are present (Establish these times using on-site scouting as well as expected windows of monarch activity, found here: https://monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf.)
- Coordinate spray operations with mowing crews to enhance weed control. For example, it may improve control to treat mature weeds when they are actively growing, shortly after mowing.
- Choose and calibrate equipment with drift management in mind. Use nozzles that produce larger droplets that are less likely to drift off target. Calibrate equipment regularly to avoid over-application.
- Select herbicides with low volatility, when feasible, to reduce the off-target movement of herbicide vapors. Do not apply herbicides when temperatures are high (see label for more information) or during temperature inversions, when herbicides are more likely to volatilize.
- Use appropriate drift control agents.
- Prioritize the use of formulations that are jointly terrestrial- and aquatic-approved, and that have lower residual activity and shorter half-life, when possible, in order to minimize potential impacts on the environment following application.
- Select adjuvants—products added to a spray solution to enhance performance of post-emergence herbicides—that are terrestrial- and aquatic-approved, and compatible with the selected herbicide formulation.

Toxicity of herbicides to monarchs

Although herbicides are formulated to kill plants and do not target insects, recent research indicates that some herbicides may be toxic to butterflies, particularly when ingested by caterpillars eating treated plants. Often, the herbicides are not immediately lethal but still have negative effects such as reducing butterfly size, weight, development rates, and survival[5, 6, 7, 8]. These sublethal effects may reduce butterfly populations over time[6]. These studies did not focus on monarchs and further research into the effects of commonly used herbicides, tank mixes, surfactants and other inert ingredients in formulated products on monarchs is needed.

Until more is known, we recommend a cautious approach when applying herbicides to milkweed where monarch caterpillars are present. Avoiding direct applications to milkweed plants when feasible, for example, can reduce direct herbicide exposure to monarchs.

Herbicide Applications

- Always apply herbicides according to label directions and use the minimum application rate that will effectively control the weed.
- Apply herbicides at the stage of growth when the weed is most vulnerable and the application likely to be most successful. This will be the seedling or rosette stage for some weeds. Consider the mode of action of the herbicide and the application technique when determining timing of application. For example, when using a systemic herbicide, treat perennial weeds in the late summer and fall, when perennials begin to move sugars down to their roots, so that the herbicide will be translocated to vegetative reproductive structures where it will be most effective at controlling the plant.
- When possible, treat plants before they convert from vegetative phase to floral phase and bloom; this will reduce the weed seed bank (reservoir of weed seeds in the soil). If weeds are treated just before bloom or after seed set, their populations may persist in future years. Treatment of weeds during their vegetative phase also reduce exposure of adult monarchs to herbicides and adjuvants.
- Apply herbicide sprays when weather conditions will minimize drift. Avoid applications when wind speeds are greater than 10 mph. Avoid applications during a temperature inversion (when warmer air above traps cooler air near the ground); these conditions cause herbicides and other pesticides to linger in the air, where they can move long distances off-site with any air movement. No wind or wind speed below 2 mph suggests a possible inversion.
- Make direct, selective applications to target plants to avoid weakening nontarget species. Target weeds or non-compatible species using spot treatment applications made with a backpack sprayer, weed wiper, or similar technology. Use highly targeted applications to cut stems, stumps, or underneath bark. Limit the use of broadcast treatments or pellet dispersal only for dense infestations of weeds or non-compatible vegetation, or for safety zone or guardrail treatments.
- Use an approved marker dye with spot treatments or cut stem/stump treatments to allow the applicator to know the target has already been treated and the extent of target coverage. Spray dyes reduce likelihood of an accidental retreatment or missing treatment of a target weed.

Use of noxious or invasive weeds by monarchs

Adult monarchs feed on nectar from a variety of blooming plants, including some noxious weeds or invasive nonnative plants (such as Canada thistle, Cirsium arvense). However, if invasive species become dominant, this can reduce the diversity of other plants available to provide nectar throughout the season. For example, if Canada thistle is the only flowering plant present in a stretch of roadside, monarchs will only have nectar available to them from that single species which blooms during a small portion of the growing season, rather than a diverse patch of vegetation that could provide nectar from spring through fall. Hence, managing invasive plants will generally increase the abundance and diversity of plants that support monarchs and pollinators throughout the growing season.

In highly degraded landscapes where native nectar sources are scarce, the large-scale removal of the noxious or invasive species may cause a short-term reduction in nectar for monarchs. In these circumstances, reseed with native blooming plants that are attractive to monarchs, known to compete well with weeds, and bloom within the first few years of planting in your seed mix. In time, these species and other native perennial plants should deter recolonization of invasive plants and provide a haven for monarchs and pollinators.

Post-Treatment

- Keep records of locations where herbicides are applied. Records on the plants treated, application method, type and amount of herbicides used, and dates of application can help to evaluate the effectiveness of treatments over time and can be useful when adjusting management decisions. Your state agency charged with education or regulation of pesticide use will have example application record keeping forms that can be used. Multiple seasons of herbicide applications or other weed control methods may be needed to fully control an invasive species.
- Follow label directions and standard practices when rinsing or cleaning spray equipment in between work

sessions; incomplete removal of a prior herbicide mix can have detrimental impacts to the next treatment area.

- Rinse off, or otherwise clean mower decks (upper and undersides), deflectors, gear box housing, and mower blades and shafts, between sites to avoid transferring weed seeds. This is especially important after mowing an area known to contain noxious or invasive weed species.
- After treating a dense infestation, consider seeding or replanting the area, if necessary (e.g., if the seed bank was depleted of desirable species). Plant with desirable, competitive native species to reduce the need to re-treat the area. Always make sure that seed and vegetative planting stock is free of weed species.

Selective herbicide applications such as this treatment for Johnson grass (*Sorghum halepense*) can control the undesireable weeds while allowing milkweeds and other desireable plants to thrive. (Photograph courtesy Texas DOT.)

- After treatment, monitor resulting conditions and outcomes to evaluate the effectiveness of management practices on target plants and any effects on nontarget plants. If desired conditions were not produced or if site conditions change, adapt management practices accordingly.

Resources

Monarch Joint Venture: Roadsides as Habitat for Monarchs
https://monarchjointventure.org/roadsidehabitat

Xerces Society: Regional guides to monarch nectar plants
https://xerces.org/monarch-nectar-plants/

Federal Highway Administration: Environmental Toolkit Review: Pollinators
https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx

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8. Schultz, C.B., J. L. Zemaitis, C. C. Thomas, M. D. Bowers, and E. E. Crone. 2016. Non-target effects of grass-specific herbicides differ among species, chemicals and host plants in *Euphydryas* butterflies. *Journal of Insect Conservation* 20:867–877.

AUTHORS: Jennifer Hopwood & Emma Pelton (Xerces Society for Invertebrate Conservation); Alison Cariveau (Monarch Joint Venture). **ACKNOWLEDGMENTS**: We thank Wendy Caldwell, Aimee Code, Aaron Feggestad, Dennis Martin, Dennis Markwardt, Stephanie McKnight, Ray Moranz, Lewis Payne, Cora Lund Preston, and Michael Retterer for their review of this document. This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

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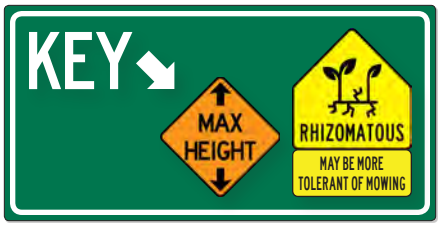
APPENDIX F.

Regionally Specific Roadside Milkweed Recognition Fact Sheets

Milkweeds of Arkansas, Louisiana, and Mississippi
Milkweeds of Arizona and New Mexico
Milkweeds of California
Milkweeds of Colorado
Milkweeds of Florida
Milkweeds of the Great Lakes
Milkweeds of Iowa and Minnesota
Milkweeds of Kansas and Missouri
Milkweeds of the Mid-Atlantic
Milkweeds of Montana and Wyoming
Milkweeds of Nebraska, North Dakota and South Dakota
Milkweeds of the Northeast
Milkweeds of Nevada and Utah
Milkweeds of the Northwest
Milkweeds of Oklahoma and Texas
Milkweeds of the Southeast

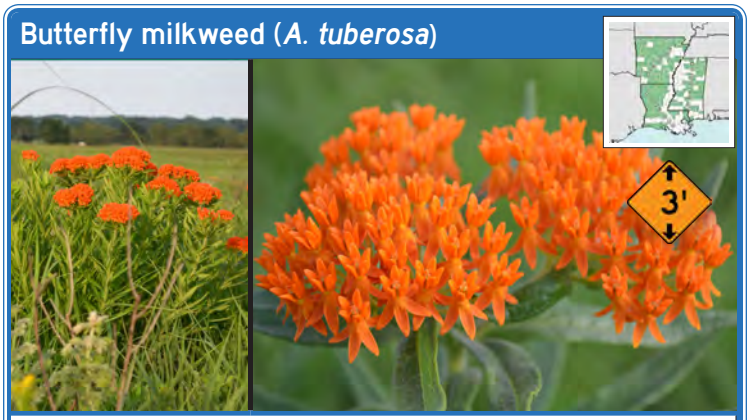
MILKWEEDS OF ARKANSAS, LOUISIANA & MISSISSIPPI

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



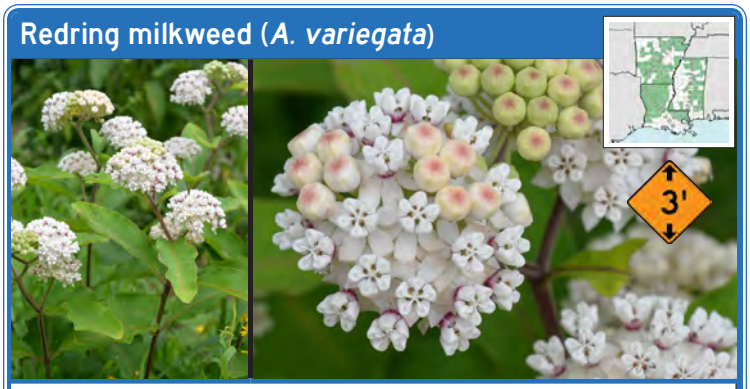
The most common milkweeds in roadsides in Arkansas, Louisiana & Mississippi (in alphabetical order):

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Prairies, old fields, open woodlands. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** May–Aug; orange to red or yellow.

Redring milkweed (*A. variegata*)

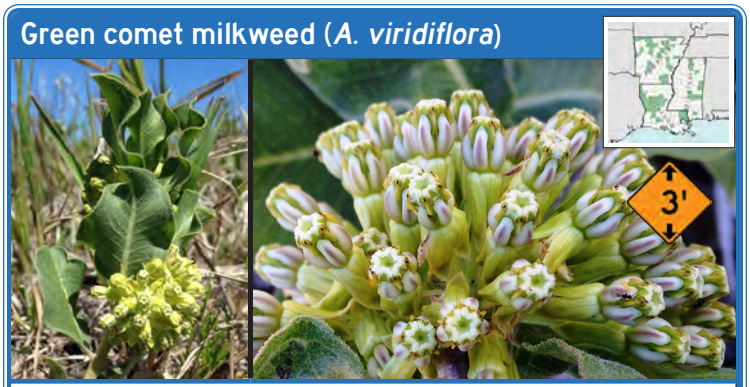


PLANT: Upright, unbranched stem; purplish-green; usually smooth. **LEAVES:** Opposite; oval-shaped; usually smooth. **HABITAT:** Savannas, rocky woodlands and edges, banks of streams; prefers some shade. **SOILS:** Sandy, rocky, loam to clay-loamy; dry–mesic. **BLOOM:** May–Jul; white to light green, with red or purple ring.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or short hairs. **HABITAT:** Prairies, open woods, fields, flood plains, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** May–Oct; white to green.

Green comet milkweed (*A. viridiflora*)



PLANT: Multiple unbranched spreading to upright stems; with short hairs. **LEAVES:** Opposite; either lance- or oval-shaped; with edges folded upward or wavy. **HABITAT:** Prairies, old fields, dunes, open woodlands. **SOILS:** Rocky or sandy, but tolerates loamy; dry–dry-mesic. **BLOOM:** Jun–Aug; light green to yellowish green.

(Continued on next page.)

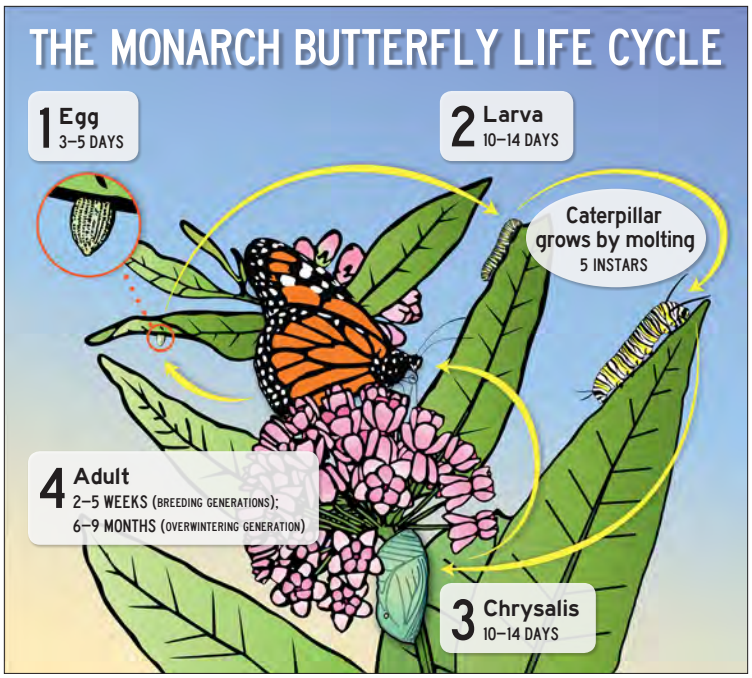
Most common milkweed species *continued*

Green antelopehorn (*A. viridis*)

PLANT: Multiple unbranched, upright stems; usually smooth. **LEAVES:** Alternate; lance- to oval-shaped with wavy margins. **HABITAT:** Upland grasslands, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry. **BLOOM:** Mar–Sep; green with touches of purple.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Mowing and Monarchs: tinyurl.com/MJV-MowingForMonarchs
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Clasping milkweed (*A. amplexicaulis*)

PLANT: Unbranched, upright stems; smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **SOILS/HABITAT:** Sandy, rocky; dry; sandhills, grasslands, savannahs. **BLOOM:** May–Jul; green with pink or purple.

Green milkweed (*A. hirtella*)

PLANT: Unbranched, upright stems; 3′ max. **LEAVES:** Alternate; long and narrow to lance-shaped; short hairs. **SOILS/HABITAT:** Sandy to rocky or clayey; dry–moist; prairies, meadows, open woods, sometimes marshes. **BLOOM:** Jun–Sep; green with purple or cream.

Aquatic milkweed (*A. perennis*)

PLANT: Multiple upright stems branching from base; dark green and hairless; 2′ max. **LEAVES:** Opposite; lance- to oval-shaped; often green all winter. **SOILS/HABITAT:** Wetland soils; ditches, streams, swamps. **BLOOM:** May–Nov; white flowers (pink-tipped when in bud).

Purple milkweed (*A. purpurascens*)

PLANT: Upright, unbranched, stout stems; smooth; 6′ max. **LEAVES:** Opposite; oval-shaped; smooth above with fine hairs below. **SOILS/HABITAT:** Loamy to clayey; mesic; prairies, meadows, woodland edges, savannas. **BLOOM:** May–Jul; dark rose to purple.

Additional milkweeds in Arkansas, Louisiana, and/or Mississippi: *Asclepias incarnata, A. lanceolata, A. longifolia, A. michauxii, A. obovata, A. oenotheroides, A. quadrifolia, A. rubra, A. stenophylla, A. syriaca.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Jennifer Hopwood, Ray Moranz, Sarah Hamilton Buxton, and Stephanie Frischie (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by Philip Barbour, USDA–NRCS. Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Mary Keim / flickr (*A. perennis*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Jerry Oldenettel / flickr (*A. verticillata, A. viridis*); Tom Potterfield / flickr (*A. purpurascens*); Karan A. Rawlins, University of Georgia / Bugwood.org (*A. variegata*); Paul Rothrock / SEINet (*A. amplexicaulis, A. hirtella*); Scott Seigfreid (*A. tuberosa*). Photographs remain under the copyright of the photographer.

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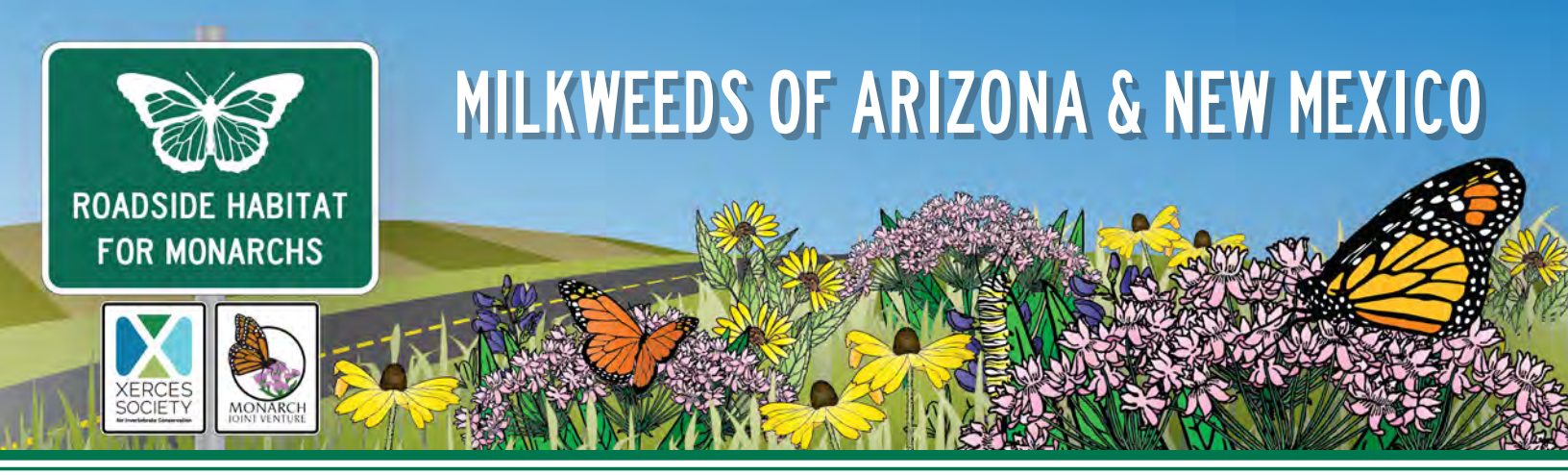
MILKWEEDS OF ARIZONA & NEW MEXICO



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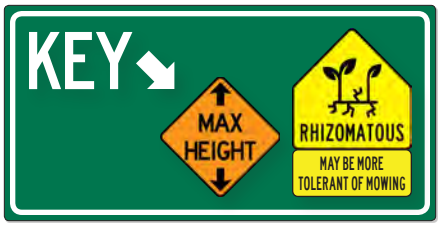
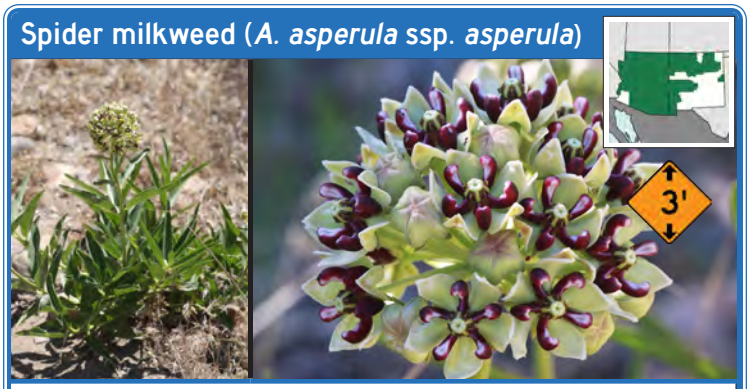


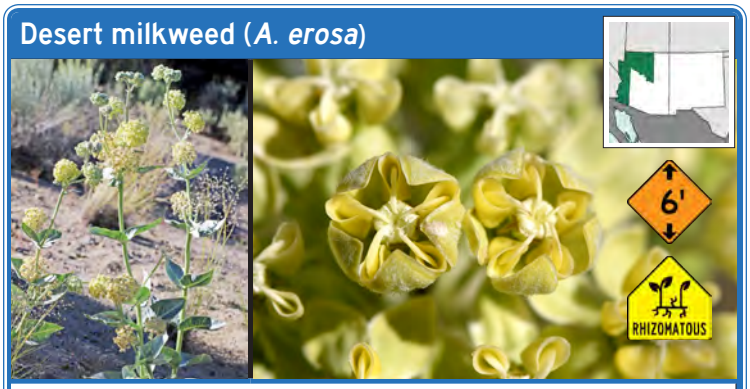
The most common milkweeds in roadsides in Arizona & New Mexico (in alphabetical order):

Spider milkweed (*A. asperula* ssp. *asperula*)



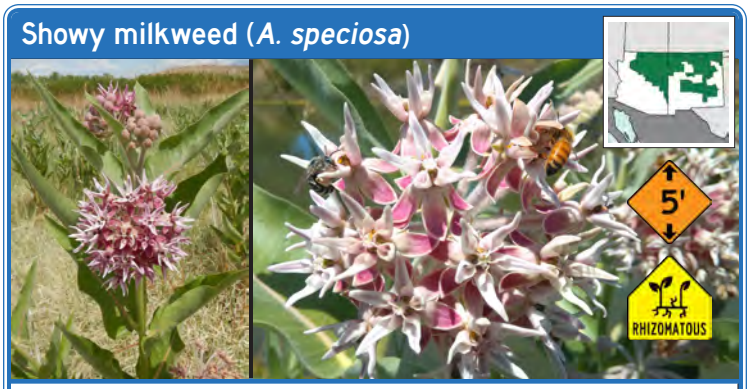
PLANT: Multiple spreading stems, unbranched to few branches; usually smooth. **LEAVES:** Alternate; lance-shaped; usually folded lengthwise. **HABITAT:** Upland grasslands, disturbed areas. **SOILS:** Sandy to clayey, gravelly and rocky limestone; dry. **BLOOM:** Apr–Jun (may have a second later bloom with rains); light green with touches of purple.

Desert milkweed (*A. erosa*)



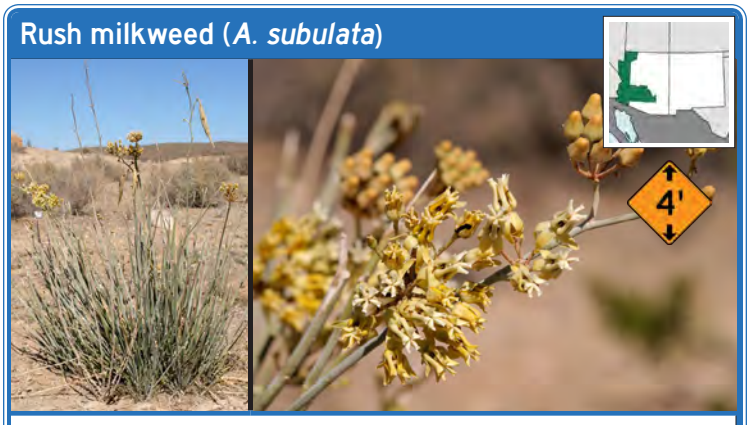
PLANT: Upright, unbranched to branched stout stems; with fine hairs; grows in clumps. **LEAVES:** Opposite; oval- to lance-shaped; smooth or with fine hairs. **HABITAT:** Washes, gulches, canyons, disturbed areas in deserts, creosote bush and sagebrush communities. **SOILS:** Sandy; dry. **BLOOM:** Apr–Oct; yellowish or cream; flower buds hairy.

Showy milkweed (*A. speciosa*)



PLANT: Stout, upright, unbranched stems; hairy. **LEAVES:** Opposite; broad and oval-shaped; hairy. **HABITAT:** Grasslands, fallow fields, disturbed areas, banks of irrigation ditches, rivers, ponds. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of American species.

Rush milkweed (*A. subulata*)



PLANT: Shrub growth form with multiple unbranched to branched stems from the base; smooth; mostly leafless. **LEAVES:** Opposite; narrow to linear; emerging after rains. **HABITAT:** Slopes, mesas, plains, desert washes. **SOILS:** Sandy, rocky; dry. **BLOOM:** Apr–Oct; whitish green with yellow.

(Continued on next page.)

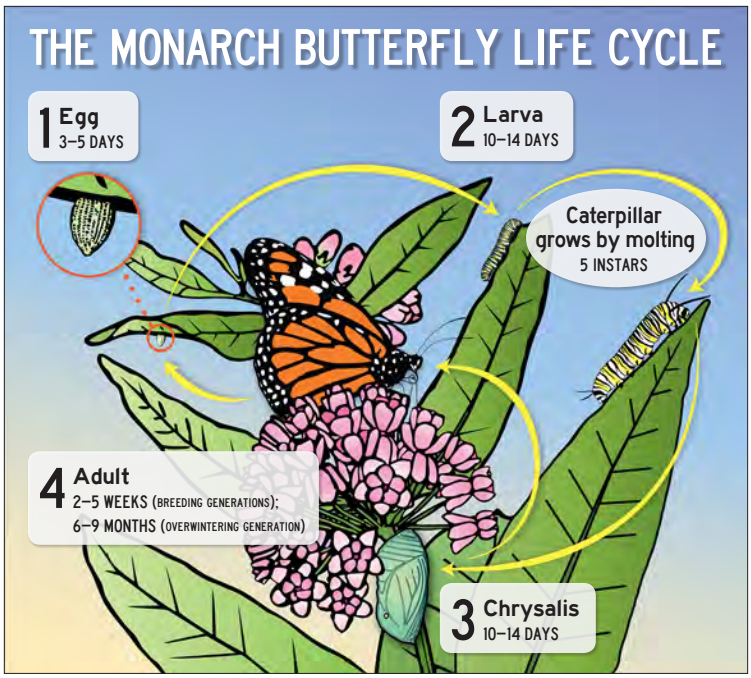
Most common milkweed species *continued*

Horsetail milkweed (*A. subverticillata*)

PLANT: Upright, branched or unbranched stems; smooth or with fine hairs. **LEAVES:** Whorled; narrow to linear; smooth. **HABITAT:** Disturbed areas, ditches, streams. **SOILS:** Sandy; moist. **BLOOM:** Jul–Aug; yellow to cream or purple.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Western Monarch Milkweed Mapper: www.monarchmilkweedmapper.org
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Bract milkweed (*A. brachystephana*)

PLANT: Upright, branched stems; with short woolly hairs, smoothes with age; 1′ max. **LEAVES:** Opposite; lance-shaped to narrow; edges folded up; woolly above, smooth below. **SOILS/HABITAT:** Sandy, rocky; dry; desert mountains, grasslands, mesas, disturbed areas. **BLOOM:** Apr–Sep; dull purple.

Engelmann's milkweed (*A. engelmanniana*)

PLANT: One to a few upright, stout stems; typically unbranched; smooth; 3′ max. **LEAVES:** Irregularly alternate; linear; smooth. **SOILS/HABITAT:** Sandy, rocky; dry; desert mountains and dry plains, grasslands, mesas, disturbed areas. **BLOOM:** Jun–Sep; green with yellow.

Broadleaf milkweed (*A. latifolia*)

PLANT: Upright, unbranched, stout stems; woolly when young to smooth with age; 2′ max. **LEAVES:** Opposite; numerous, broadly oval; woolly when young to smooth with age. **SOILS/HABITAT:** Sandy, rocky; dry; disturbed areas, grasslands. **BLOOM:** May–Aug; white to pale green.

Pineneedle milkweed (*A. linaria*)

PLANT: Shrub-like; upright stems with multiple branches; with fine hairs; 5′ max. **LEAVES:** Alternate or appearing whorled; narrow, needle-like. **SOILS/HABITAT:** Rocky; dry; slopes, mesas. **BLOOM:** Feb–Nov; white to greenish with pink or purple.

Additional milkweeds in Arizona and/or New Mexico: *Asclepias albicans, A. angustifolia, A. arenaria, A. cryptoceras, A. cutleri, A. emoryi, A. glaucescens, A. hallii, A. hypoleuca, A. incarnata, A. involucrata, A. lemmonii, A. macrosperma, A. macrotis, A. nummularia, A. nyctaginifolia, A. oenotheroides, A. pumila, A. quinquedentata, A. rusbyi, A. ruthiae, A. scaposa, A. tuberosa, A. uncialis, A. verticillata, A. viridiflora, A. welshii.*

Maps & Distribution Data:

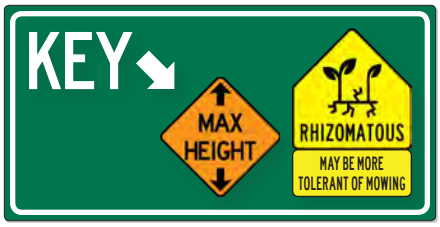
These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across both states and are found in roadsides. Less common species might not occur in both states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Stephanie McKnight and Jennifer Hopwood (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by Gail Morris (Southwest Monarch Study). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Patrick Alexander / SEINet (*A. subulata, A. brachystephana*); Frankie Coburn / SEINet (*A. linaria*); Max Licher / SEINet (*A. subverticillata, A. engelmanniana, A. latifolia*); Xerces Society / Stephanie McKnight (*A. erosa, A. speciosa*); Andrey Zharkikh / flickr (*A. a.* ssp. *asperula*).

MILKWEEDS OF CALIFORNIA

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.

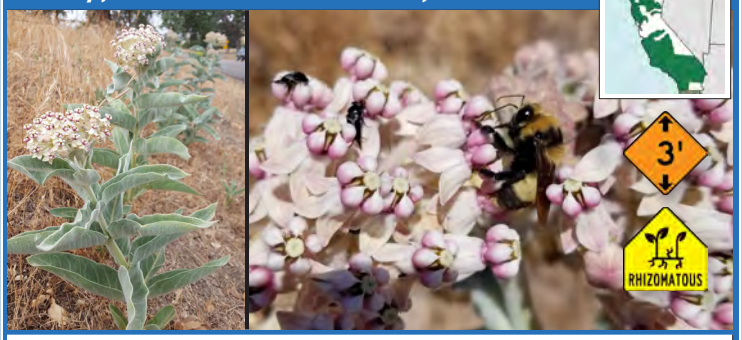


The most common milkweeds in roadsides in California (in alphabetical order):

Heartleaf milkweed (*A. cordifolia*)

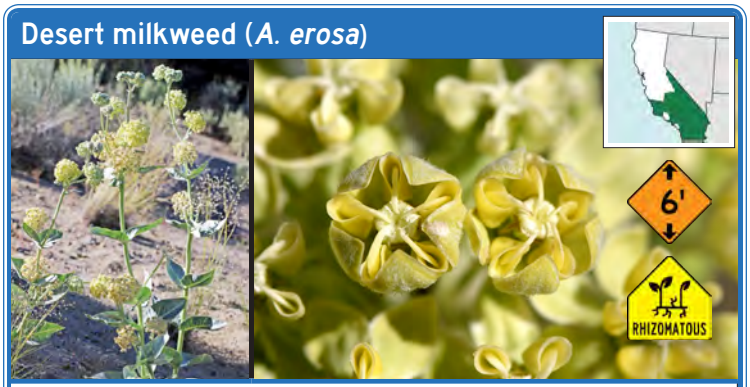
PLANT: Spreading to upright stout stems; mostly hairless. **LEAVES:** Opposite; heart- to lance-shaped; with waxy coating. **HABITAT:** Slopes and hillsides in foothill woodland, chaparral, and evergreen forest. **SOILS:** Rocky, gravelly; dry. **BLOOM:** Apr–Jul; red-purple to violet with pink or white tinges.

Woollypod milkweed (*A. eriocarpa*)



PLANT: Upright, usually unbranched stems; densely hairy but may be less so with age. **LEAVES:** Opposite; lance- to oval-shaped; may be wavy at edges; hairy but may be less so with age. **HABITAT:** Valley grassland, chaparral, foothill woodland, stream banks, disturbed areas. **SOILS:** Rocky; dry. **BLOOM:** May–Oct; cream or yellow with white or tinges of purple or pink.

Desert milkweed (*A. erosa*)



PLANT: Upright, unbranched to branched stout stems; with fine hairs; grows in clumps. **LEAVES:** Opposite; oval- to lance-shaped; smooth to with fine hairs. **HABITAT:** Washes, gulches, canyons, disturbed areas in deserts, creosote bush and sagebrush communities. **SOILS:** Sandy; dry. **BLOOM:** Apr–Oct; yellowish or cream, flower buds hairy.

Narrowleaf milkweed (*A. fascicularis*)

PLANT: Thin, upright branched stems; smooth. **LEAVES:** Opposite to whorled; narrow to lance-shaped; pointed and folded lengthwise; mostly smooth. **HABITAT:** Valley grasslands, wetland-riparian areas, open woodlands, chaparral, sagebrush, disturbed areas, banks of streams and irrigation ditches, fallow fields. **SOILS:** Sandy to clayey; dry–moist. **BLOOM:** May–Oct; dusky pink to rose with touches of white.

(Continued on next page.)

Most common milkweed species *continued*

Showy milkweed (*A. speciosa*)

PLANT: Stout, upright, unbranched stems; hairy. **LEAVES:** Opposite; broad and oval-shaped; hairy. **HABITAT:** Grasslands, fallow fields, disturbed areas, foothill woodlands, wetland-riparian areas, banks of streams, irrigation ditches, rivers, and ponds. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of American species.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Western Monarch Milkweed Mapper: www.monarchmilkweedmapper.org
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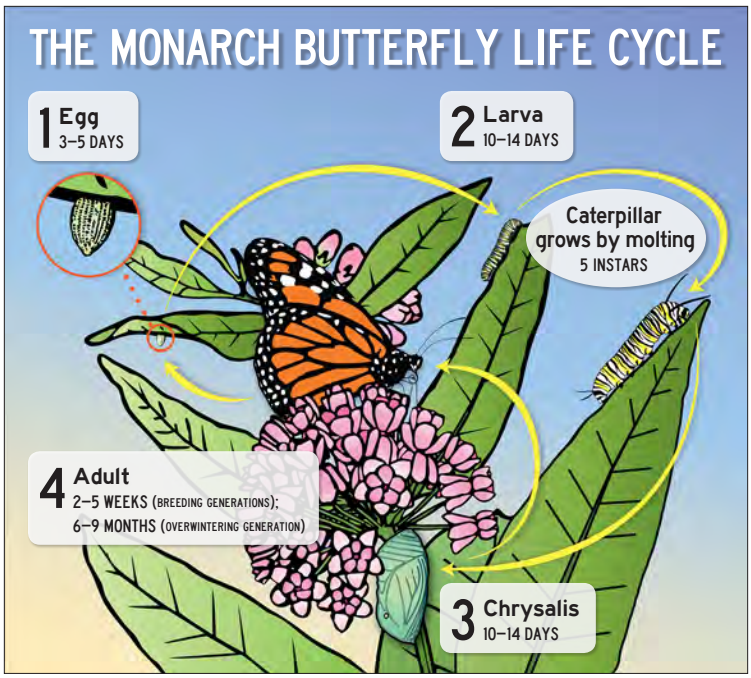


Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Whitestem milkweed (*A. albicans*)

PLANT: Shrub growth form with wand-like stems branching at tip; smooth and waxy; 10′ max. **LEAVES:** Opposite or in whorls of three; narrow to linear; shed during drought. **SOILS/HABITAT:** Rocky; dry; deserts, creosote bush scrub. **BLOOM:** Mar–Apr; yellow to white.

California milkweed (*A. californica*)

PLANT: Multiple spreading to upright stems; grow in clumps; very woolly; 3′ max. **LEAVES:** Opposite; oval-shaped; densely hairy. **SOILS/HABITAT:** Sand to clay; dry; valley grasslands, yellow pine and pinyon-juniper woods, chaparral. **BLOOM:** Apr–Jul; pink to purple; buds hairy; flowers nodding.

Rush milkweed (*A. subulata*)

PLANT: Shrub growth form; multiple unbranched to branched stems from the base; smooth; mostly leafless; 5′ max. **LEAVES:** Opposite; narrow to linear; emerging after rains. **SOILS/HABITAT:** Sandy, rocky; dry; slopes, mesas, plains, desert washes. **BLOOM:** Apr–Oct; whitish green with yellow.

Woolly milkweed (*A. vestita*)

PLANT: Stout, upright stems clustered at the base; densely hairy; 2′ max. **LEAVES:** Opposite; oval- to lance-shaped; densely hairy. **SOILS/HABITAT:** Sandy; dry; valley grassland, chaparral, foothill woodland, hillsides, canyons. **BLOOM:** Apr–Jul; yellow or pale green with white.

Additional milkweeds in California: *Asclepias asperula, A. cryptoceras, A. fruticosa, A. latifolia, A. linaria, A. nyctaginifolia, A. solanoana.*

Maps & Distribution Data:

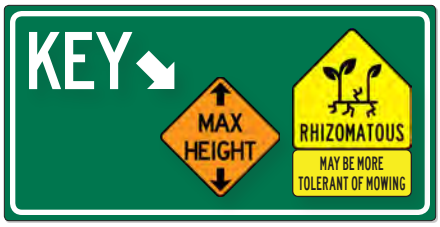
These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the state and are found in roadsides. Less common species might have a limited distribution across the state or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in the state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Stephanie McKnight, Jennifer Hopwood, Jessa Kay Cruz, and Angela Laws (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Frankie Coburn / SEINet (*A. albicans*); Professor Stephen Lynch (*A. vestita*); Xerces Society / Brianna Borders (*A. subulata*); Xerces Society / Stephanie McKnight (*A. cordifolia, A eriocarpa, A. erosa, A. fascicularis, A. speciosa*); Jordan Zylstra / Calphotos (*A. californica*). Photographs remain under the copyright of the photographer.

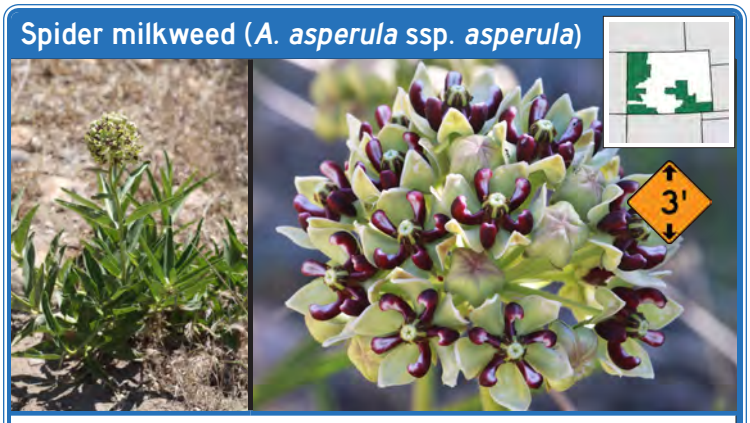
MILKWEEDS OF COLORADO

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



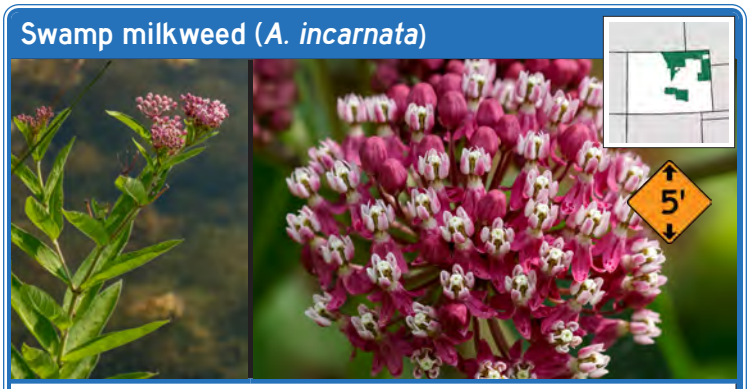
The most common milkweeds in roadsides in Colorado (in alphabetical order):

Spider milkweed (*A. asperula* ssp. *asperula*)



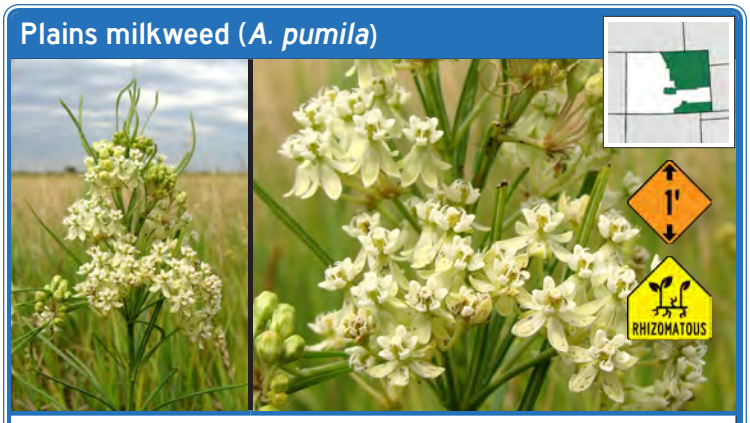
PLANT: Multiple spreading stems, unbranched to few branches; usually smooth. **LEAVES:** Alternate; lance-shaped; usually folded lengthwise. **HABITAT:** Prairie, disturbed areas. **SOILS:** Sandy, gravelly, clayey, rocky limestone; dry. **BLOOM:** Apr–Jun; light green with touches of purple.

Swamp milkweed (*A. incarnata*)



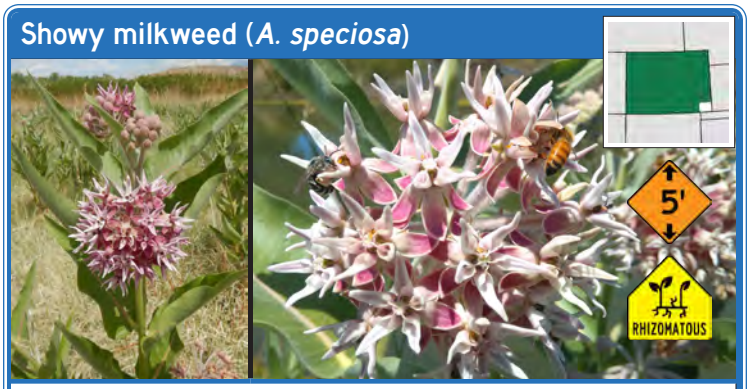
PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Grasslands and ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; wet–moist, tolerates some mesic. **BLOOM:** Jun–Sep; pink, light purple.

Plains milkweed (*A. pumila*)



PLANT: Upright, unbranched or branched stems; with fine hairs. **LEAVES:** Alternate, may appear whorled; thin and narrow; dense on stems (bottlebrush appearance). **HABITAT:** Prairies, plains, low hills. **SOILS:** Rocky, sandy; dry. **BLOOM:** Jun–Aug; white to greenish white.

Showy milkweed (*A. speciosa*)



PLANT: Stout upright, unbranched stems; hairy. **LEAVES:** Opposite; oval-shaped; hairy. **HABITAT:** Grasslands, old fields, disturbed areas, woodlands, wetlands, edges of rivers, ponds, and irrigation ditches. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of American species.

(Continued on next page.)

Most common milkweed species *continued*

Horsetail milkweed (*A. subverticillata*)

PLANT: Upright, branched or unbranched stems; smooth or with fine hairs. **LEAVES:** Whorled; narrow to linear; smooth. **HABITAT:** Ditches, stream edges, disturbed areas. **SOILS:** Sandy; moist. **BLOOM:** May–Aug; yellow to cream or purple tinges.

Additional Resources:

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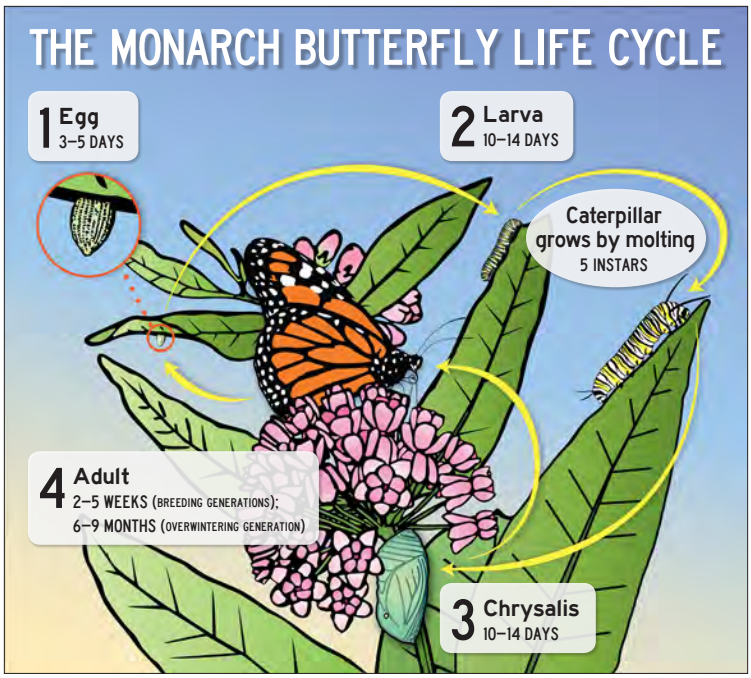

Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Hall's milkweed (*A. hallii*)

PLANT: Upright, unbranched stem or branched at base; hairy; 2′ max. **LEAVES:** Alternate to opposite; narrow oval-shaped; hairy. **SOILS/HABITAT:** Sandy, gravelly; dry; grasslands, wash-bottoms, sagebrush, woodlands. **BLOOM:** Jun–Aug; purple, pink, cream or white with green.

Broadleaf milkweed (*A. latifolia*)

PLANT: Upright, unbranched, stout stems; woolly when young to smooth with age; 2′ max. **LEAVES:** Opposite; numerous, broadly oval; woolly when young to smooth with age. **SOILS/HABITAT:** Sandy, rocky; dry; prairie, dry grasslands, slopes. **BLOOM:** May–Aug; white to pale green.

Butterfly milkweed (*A. tuberosa*)

PLANT: One to many spreading to upright stems, with short hairs; lacks milky sap, 3′ max. **LEAVES:** Alternate; lance-shaped; hairy underneath. **SOILS/HABITAT:** Sandy, loamy, rocky; dry; prairies, old fields, open woods. **BLOOM:** May–Sep; orange to red or yellow.

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, spreading to upright; with short hairs; 3′ max. **LEAVES:** Opposite; lance-shaped; with margins folded upward or wavy; with short hairs. **SOILS/HABITAT:** Sandy to loamy or rocky; dry–dry-mesic; prairies, old fields, dunes, forests. **BLOOM:** Jun–Aug; light green to yellowish green.

Additional milkweeds in Colorado: *Asclepias arenaria, A. cryptoceras, A. engelmanniana, A. involucrata, A. latifolia, A. macrotis, A. oenotheroides, A. rusbyi, A. uncialis.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the state and are found in roadsides. Less common species might have a limited distribution across the state or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in the state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

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PHOTO CREDITS: Frankie Coburn / SEINet (*A. hallii*); Max Licher / SEINet (*A. subverticillata, A. latifolia*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Tom Potterfield / flickr (*A. incarnata*); Scott Seigfreid (*A. tuberosa*); Xerces Society / Stephanie McKnight (*A. speciosa*); Xerces Society / Ray Moranz (*A. pumilla*); Andrey Zharkikh / flickr (*A. a.* ssp. *asperula*). Photographs remain under the copyright of the photographer.

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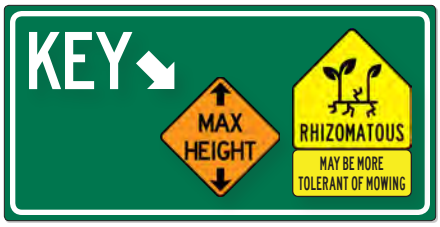
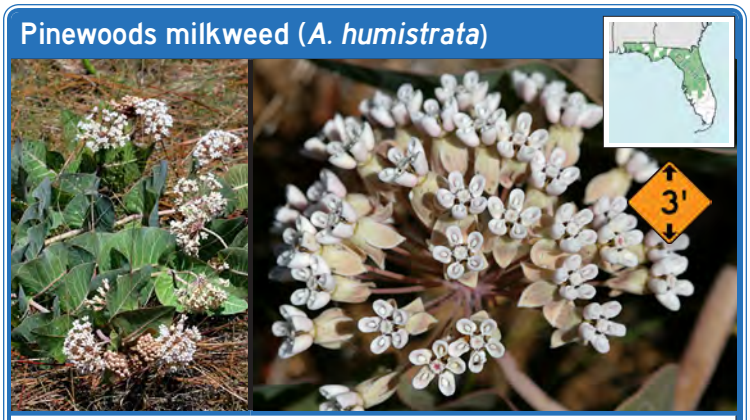
MILKWEEDS OF FLORIDA

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



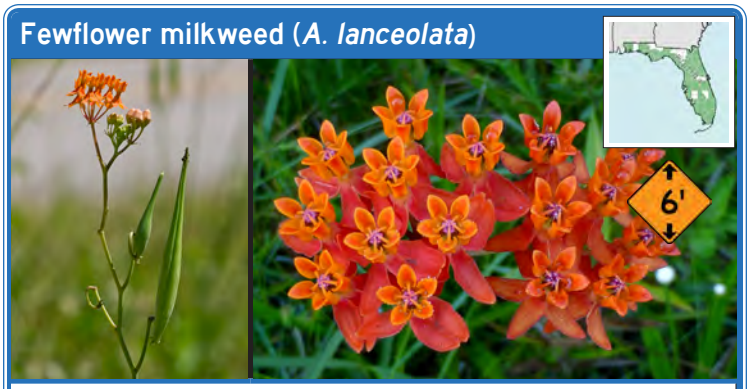
The most common milkweeds in roadsides in Florida (in alphabetical order):

Pinewoods milkweed (*A. humistrata*)



PLANT: One to multiple sprawling stems; usually smooth. **LEAVES:** Opposite; oval-shaped; bases that clasp stem; purple veins; usually smooth. **HABITAT:** Pastures, open woods, sandhills, scrubland. **SOILS:** Sandy; dry. **BLOOM:** Mar–Jun; pink to white flowers.

Fewflower milkweed (*A. lanceolata*)



PLANT: Slender unbranched stems; smooth; with few leaves or flowers. **LEAVES:** Opposite; lance-shaped or narrow; smooth. **HABITAT:** Moist grasslands and ditches, edges of ponds, lakes, streams. **SOILS:** Sandy or loamy; moist; ditches, marshes, wet pine savannas, wet prairies. **BLOOM:** May - Aug; red and orange.

Aquatic milkweed (*A. perennis*)

PLANT: One to six upright stems branching from base; dark green and hairless. **LEAVES:** Opposite; lance- to oval-shaped; often green all winter. **HABITAT:** Wet areas, ditches, streams, swamps. **SOILS:** Wetland soils. **BLOOM:** May–Nov; white flowers (with pink when in bud).

Tuba milkweed (*A. tomentosa*)

PLANT: One or two upright, unbranched stems. **LEAVES:** Opposite; elliptic; with wavy margins and velvet-like hairs. **HABITAT:** Sand dunes, pine sandhills. **SOILS:** Very well-drained sands. **BLOOM:** May–Jun; pale yellowish green.

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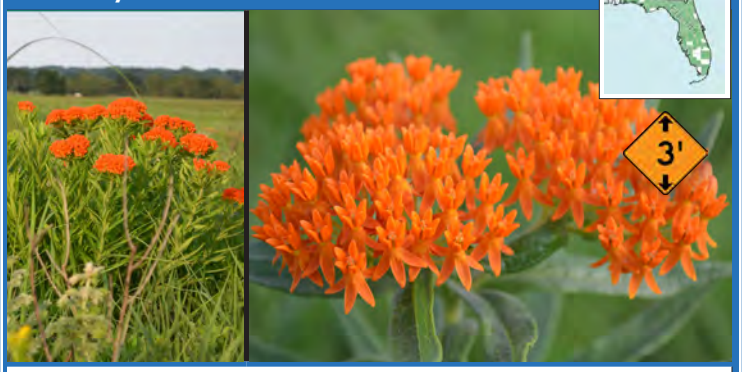
Most common milkweed species *continued*

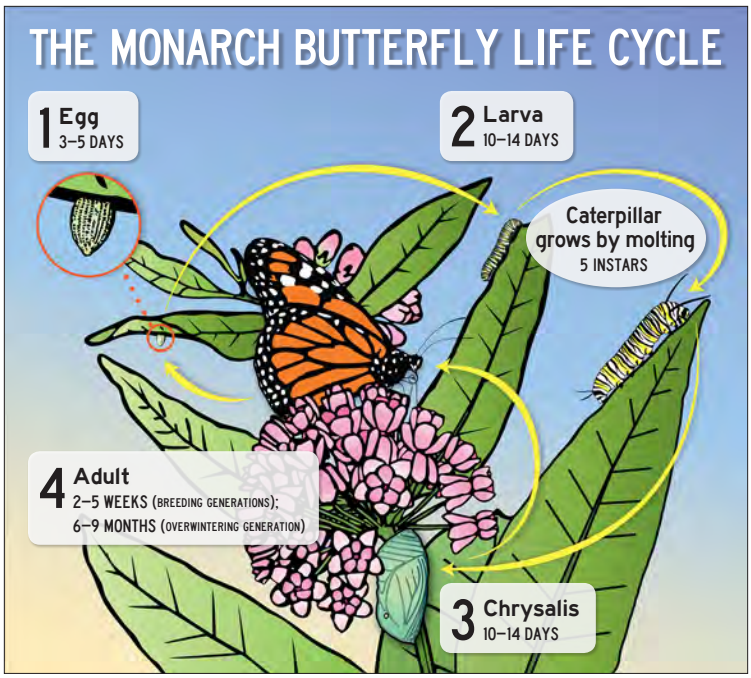
Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Sandhills, scrub, old fields. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** May–Aug; orange to red or yellow.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Mowing and Monarchs: tinyurl.com/MJV-MowingForMonarchs
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Clasping milkweed (*A. amplexicaulis*)

PLANT: Unbranched, upright stems; smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **SOILS/HABITAT:** Sandy; dry; sandhills, grasslands, savannahs. **BLOOM:** May–Jul; pink or purple with green or cream.

Swamp milkweed (*A. incarnata*)

PLANT: Multiple, upright branched stems; smooth; 6′ max. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **SOILS/HABITAT:** Silty to loamy or clayey; wet–moist; moist grasslands and pond edges. **BLOOM:** Jun–Sep; pink or pink/purple.

Longleaf milkweed (*A. longifolia*)

PLANT: Upright, unbranched slender stem; with few hairs; 3′ max. **LEAVES:** Alternate; narrow and lance-shaped; with few hairs. **SOILS/HABITAT:** Sandy to loamy or loam-clay; wet; pinelands, savannas, swamps. **BLOOM:** Jun–Sep; white and purple with green.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; 3′ max. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **SOILS/HABITAT:** Sandy, rocky, clayey; dry–mesic; grasslands, open woods, fields, flood plains. **BLOOM:** May–Oct (year-round in S. FL); white to green.

Additional milkweeds in Florida: *Asclepias cinerea, A. connivens, A. curtissii, A. feayi, A. michauxii, A. obovata, A. pedicillata, A. rubra, A. variegata, A. viridiflora, A. viridis, A. viridula.* **NOTE:** Tropical milkweed (*A. curassavica*) is non-native species frequently sold in Florida nurseries that can escape and invade native ecosystems, particularly south of Orlando. Monarch caterpillars feed on this plant, but it has been implicated in higher rates of diseased monarchs.

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the state and are found in roadsides. Less common species might have a limited distribution across the state or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in the state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

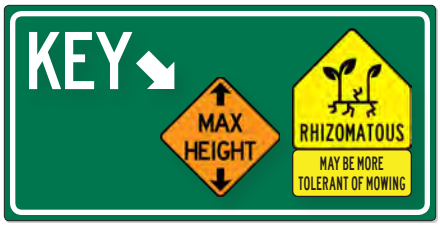
ACKNOWLEDGMENTS: Written by Ray Moranz, Jennifer Hopwood, Nancy Lee Adamson, Stephanie Frischie and (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by Scott Davis (USFWS), Jaret Daniels (University of Florida), and Mark Garland (NRCS). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine. **PHOTO CREDITS:** Patrick Coin / flickr (*A humistrata*); Eleanor Dietrich / flickr (*A. lanceolata* [right], *A. tomentosa*, *A. verticillata*); Jerry Oldenettel / flickr (*A. verticillata*); Jim Fowler (*A. longifolia, A. lanceolata* [left]); Mary Keim / flickr (*A. perennis*); Tom Potterfield / flickr (*A. incarnata*); Paul Rothrock / SEINet (*A. amplexicaulis*); Scott Seigfreid (*A. tuberosa*).

19-020_01

MILKWEEDS OF THE GREAT LAKES

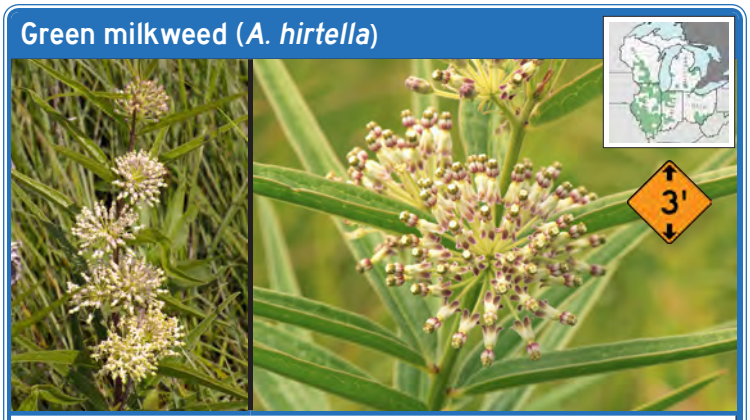
MICHIGAN, OHIO, ILLINOIS, INDIANA & WISCONSIN

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



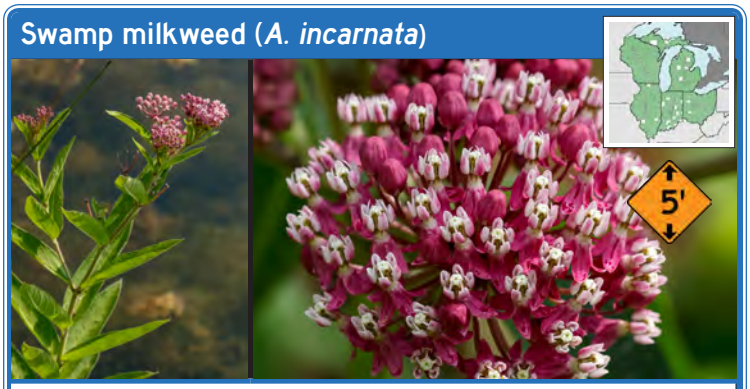
The most common milkweeds in roadsides in the Great Lakes Region (in alphabetical order):

Green milkweed (*A. hirtella*)



PLANT: Upright, unbranched stems. **LEAVES:** Alternate; long and narrow; pointed at tips; with short hairs. **HABITAT:** Prairies, meadows, open woods, disturbed areas, railways. **SOILS:** Sandy, rocky to clay; dry–wet. **BLOOM:** Jun–Aug; green with purple or cream.

Swamp milkweed (*A. incarnata*)

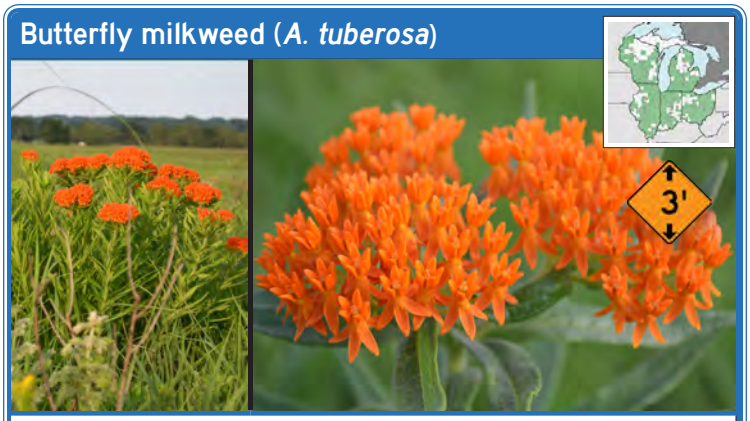


PLANT: One to many upright, branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist prairies, marshes, ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jun–Aug; pink or light purple.

Common milkweed (*A. syriaca*)

PLANT: One to many stout, upright, unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Prairies, old fields, railways, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, rocky or clayey; dry–wet. **BLOOM:** May–Aug; light purple or pink.

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Prairies, old fields, open woods. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** May–Aug; orange to red or yellow.

(Continued on next page.)

Most common milkweed species *continued*

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **HABITAT:** Prairies, open woods, fields, flood plains, glades, railways, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** May–Sep; white to green.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
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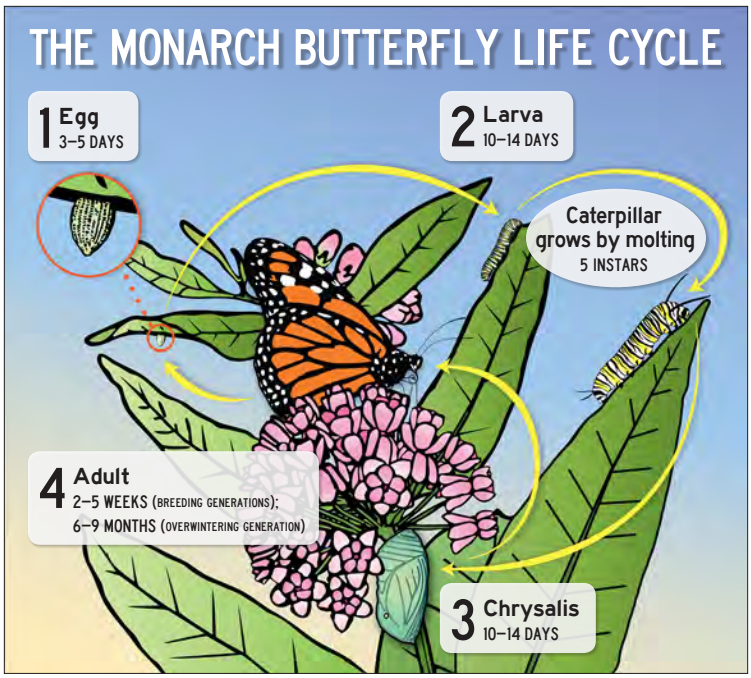


Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Clasping milkweed (*A. amplexicaulis*)

PLANT: Upright, unbranched, stems; smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **SOILS/HABITAT:** Sandy; dry; grasslands, savannas, woodland edges. **BLOOM:** Apr–Jun; pink or green with cream, sometimes purple.

Purple milkweed (*A. purpurascens*)

PLANT: Upright, unbranched, stout stems; smooth; 6′ max. **LEAVES:** Opposite; oval-shaped; smooth above with fine hairs below. **SOILS/HABITAT:** Loamy to clayey; mesic; prairies, meadows, woodland edges, savannas. **BLOOM:** May–Jul; dark rose to purple.

Prairie milkweed (*A. sullivantii*)

PLANT: Upright, unbranched, stout stems; smooth; 4′ max. **LEAVES:** Opposite; lance- to oval-shaped; very smooth. **SOILS/HABITAT:** Sandy clay or loamy; mesic–moist; prairies, wet meadows. **BLOOM:** Jun–Aug; pink with light green or purple.

Green comet milkweed (*A. viridiflora*)

PLANT: Multiple unbranched, spreading or upright stems; with short hairs; 3′ max. **LEAVES:** Opposite; lance- or oval-shaped, edges folded upward or wavy. **SOILS/HABITAT:** Sandy, rocky; dry; prairies, old fields, dunes, open woods. **BLOOM:** Jun–Jul; light to yellowish green.

Additional milkweeds in the Great Lakes region: *Asclepias exaltata, A. lanuginosa, A. quadrifolia, A. ovalifolia, A. speciosa, A. stenophylla, A. variegata.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

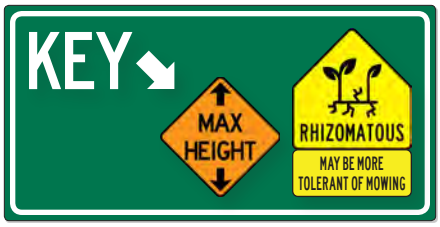
ACKNOWLEDGMENTS: Written by Jennifer Hopwood, Stephanie Frischie, and Karin Jokela (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by Dan Zay (Michigan NRCS). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Jim Fowler (*A. syriaca*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Joshua Mayer / flickr (*A. hirtella*); Jerry Oldenettel / flickr (*A. verticillata*); Tom Potterfield / flickr (*A. incarnata, A. purpurascens*); Paul Rothrock / SEINet (*A. amplexicaulis*); Scott Seigfreid (*A. tuberosa*); Xerces Society / Ray Moranz (*A. sullivantii*).

19-021_01

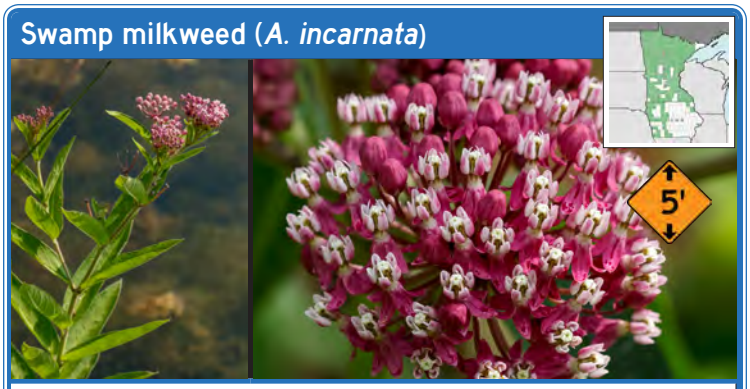
MILKWEEDS OF IOWA & MINNESOTA

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



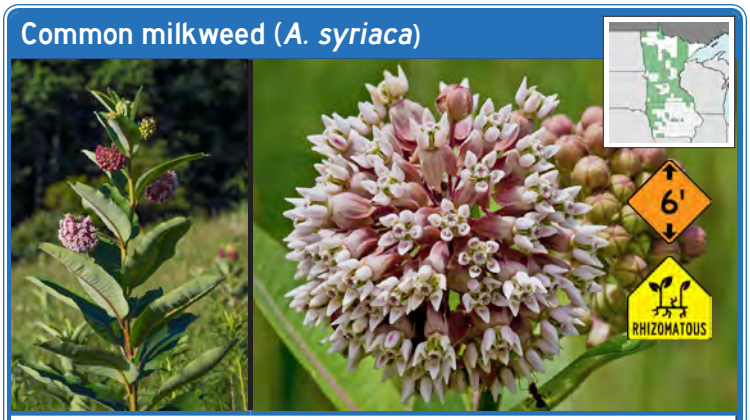
The most common milkweeds in roadsides in Iowa & Minnesota (in alphabetical order):

Swamp milkweed (*A. incarnata*)



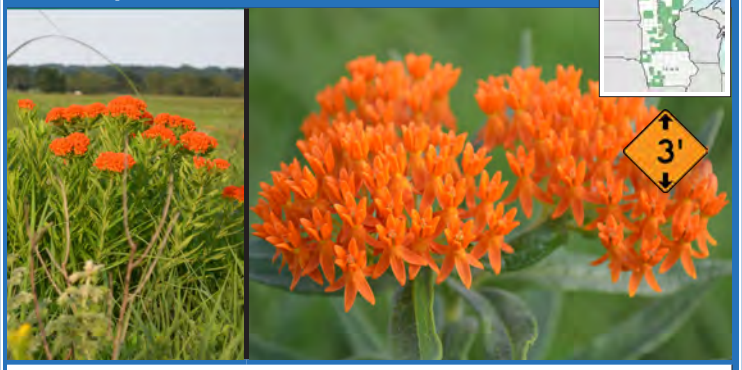
PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist prairies, marshes, ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jul–Aug; light to dark pink or rose purple.

Common milkweed (*A. syriaca*)



PLANT: One to many stout, upright, unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Prairies, old fields, railways, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, clayey or rocky; dry–wet. **BLOOM:** Jun–Aug; pink.

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Prairies, old fields, open woods. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** Jun–Aug; orange to red or yellow.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **HABITAT:** Prairies, open woods, fields, flood plains, railways. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** Jul–Sep; white to green.

(Continued on next page.)

Most common milkweed species *continued*

Green comet milkweed (*A. viridiflora*)

PLANT: Multiple unbranched spreading to upright stems; with short hairs. **LEAVES:** Opposite; either lance-shaped or oval-shaped; with edges folded upward or wavy. **HABITAT:** Prairies, old fields, dunes, openings in forests. **SOILS:** Rocky, sandy; dry–dry-mesic. **BLOOM:** Jun–Jul; light green to yellowish green.

Additional Resources:

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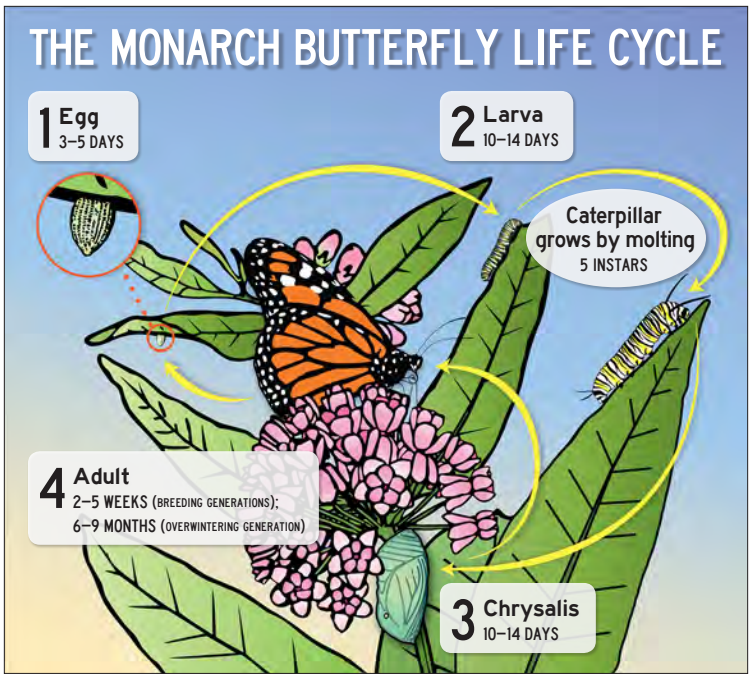

Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Green milkweed (*A. hirtella*)

PLANT: Upright, unbranched stems; 3′ max. **LEAVES:** Alternate; long and narrow to lance-shaped; with short hairs. **SOILS/HABITAT:** Sandy to rocky or clayey; prairies, open woods, disturbed areas. **BLOOM:** Jul–Aug; green with purple or cream.

Oval-leaf milkweed (*A. ovalifolia*)

PLANT: Upright, unbranched stems; with fine hairs; 2′ max. **LEAVES:** Opposite; lance-shaped to oval-shaped; fine hairs underneath. **SOILS/HABITAT:** Sandy, silty, loamy; dry; prairies, open woods. **BLOOM:** Jun–Jul; cream or white with pink or yellow.

Showy milkweed (*A. speciosa*)

PLANT: Stout upright, unbranched stems; hairy; 5′ max. **LEAVES:** Opposite; oval-shaped; hairy. **SOILS/HABITAT:** Sandy to loam; dry–moist; prairies, old fields, edges of rivers, ponds, disturbed areas. **BLOOM:** Jun–Aug; pink and cream or white; flowers are the largest of American species.

Prairie milkweed (*A. sullivantii*)

PLANT: Stout, upright, unbranched stems; smooth; 4′ max. **LEAVES:** Opposite; lance- to oval-shaped; very smooth. **SOILS/HABITAT:** Sandy, clayey, or loamy; mesic–moist; prairies, wet meadows. **BLOOM:** Jun–Aug; pink with light green or purple.

Additional milkweeds in Iowa and/or Minnesota: *Asclepias amplexicaulis, A. engelmanniana, A exaltata, A. lanuginosa, A. purpurascens, A. quadrifolia, A. stenophylla.*

Maps & Distribution Data:

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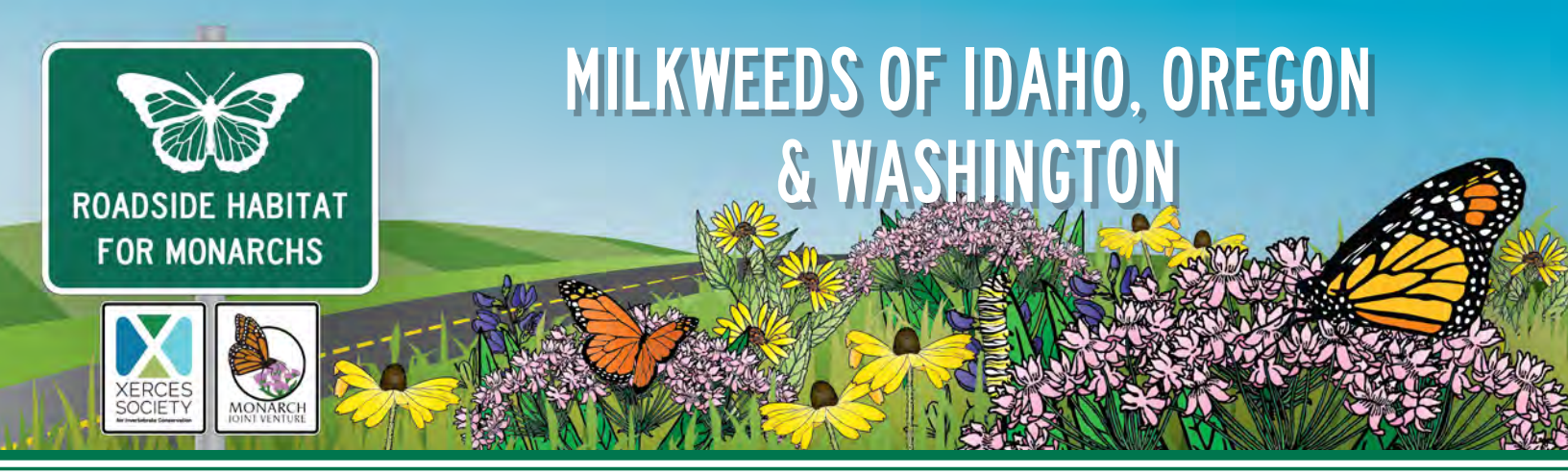
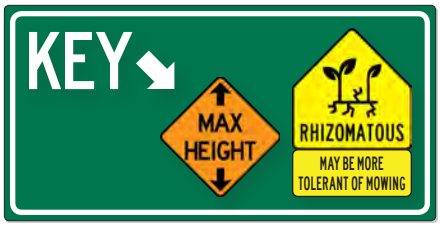


MILKWEEDS OF IDAHO, OREGON & WASHINGTON

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.

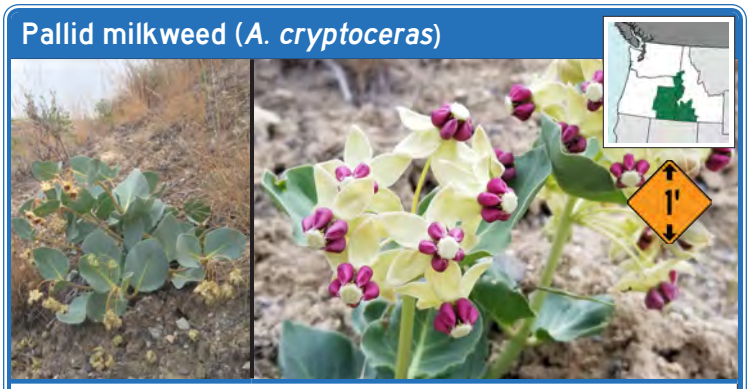


The most common milkweeds in roadsides in Idaho, Oregon & Washington (in alphabetical order):

Heartleaf milkweed (*A. cordifolia*)

PLANT: Spreading to upright stout stems; mostly hairless. **LEAVES:** Opposite heart- to lance-shaped; with waxy coating. **HABITAT:** Slopes and hillsides in woodlands, shrub steppe, chaparral, and evergreen forest (SW Oregon only). **SOILS:** Rocky, gravelly; dry. **BLOOM:** Apr–Jul; red-purple to violet with pink or white tinges.

Pallid milkweed (*A. cryptoceras*)

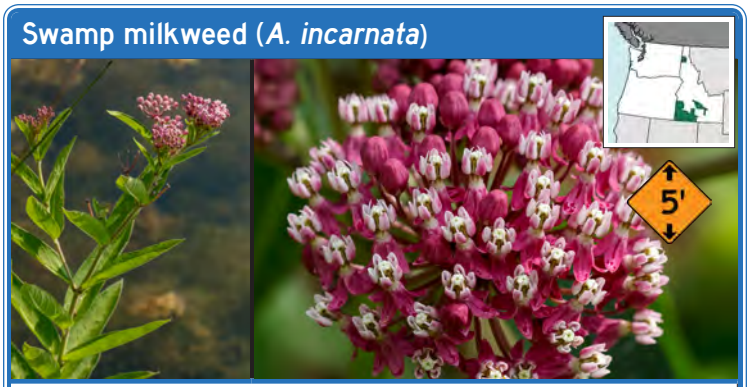


PLANT: Stout prostrate spreading stems, rarely branched; smooth. **LEAVES:** Opposite, broad oval- to heart-shaped; waxy and smooth. **HABITAT:** Desert washes, slopes, and hillsides, in pinyon-juniper woodland, sagebrush, salt desert shrublands, and aspen zones. **SOILS:** Sandy to clayey, gypsum, or serpentine; dry. **BLOOM:** Apr–Jun; greenish yellow and red or dark violet.

Narrowleaf milkweed (*A. fascicularis*)

PLANT: Thin upright branched stems; smooth. **LEAVES:** Opposite to whorled; narrow to lance-shaped; folded lengthwise; mostly smooth. **HABITAT:** Grasslands, wetland-riparian areas, chaparral, open forests, banks of streams and irrigation ditches, disturbed areas, fallow fields. **SOILS:** Sandy to clayey, tolerates saline; dry–moist. **BLOOM:** May–Oct; dusky pink to rose with touches of white.

Swamp milkweed (*A. incarnata*)



PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Grasslands and ditches, edges of ponds, lakes, streams (Idaho only). **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jun–Sep; pink, light purple.

(Continued on next page.)

Most common milkweed species *continued*

Showy milkweed (*A. speciosa*)

PLANT: Stout upright, unbranched stems; hairy. **LEAVES:** Opposite; broad and oval-shaped; hairy. **HABITAT:** Grasslands, fallow fields, disturbed areas, edges of rivers, ponds. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of American species.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Western Monarch Milkweed Mapper: www.monarchmilkweedmapper.org
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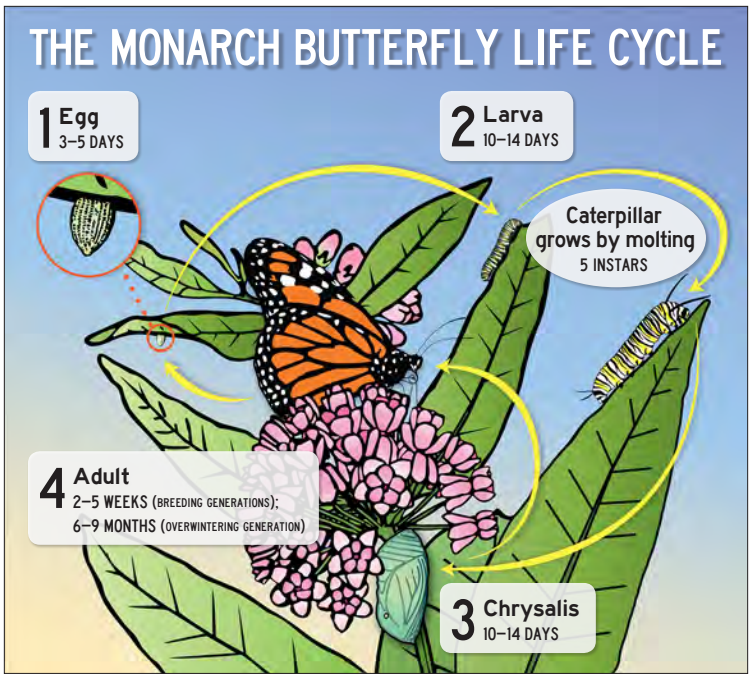


Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Other monarch nectar plants in the region:

Additional milkweeds that occur rarely in SE Idaho: *A. asperula* and *A. subverticillata*.

Note: Due to the paucity of native milkweed species in northern portions of the Pacific Northwest, monarchs are less likely to seen breeding in the region. Including high value monarch nectar plants will support adult monarchs that migrate through the region. Visit xerces.org/monarch-nectar-plants for more monarch nectar plants.

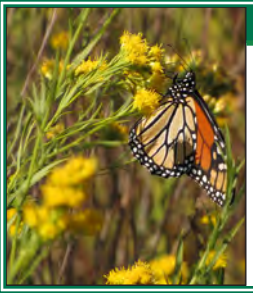
Canada goldenrod (*Solidago canadensis*)

PLANT: Slow-growing, rhizomatous perennial; 7′ max. **LEAVES:** Alternate; lance-shaped; with fine hairs. **SOILS/HABITAT:** Any; moist–wet; meadows, prairies, fallow fields, banks of rivers, streams, ditches. **BLOOM:** Jul–Oct; yellow.

Rubber rabbitbrush (*Ericamia nauseosa*)

PLANT: Shrub with erect, rubbery stems; densely hairy; 8′ max. **LEAVES:** Alternate; linear; hairy. **SOILS/HABITAT:** Any; dry; disturbed sites, roadsides, scrub, degraded grasslands, rangeland, fallow fields. **BLOOM:** Aug–Oct; yellow.

Western goldentop (*Euthamia occidentalis*)



PLANT: Rhizomatous perennial, numerous erect stems; 6′ max. **LEAVES:** Alternate; narrow, grass-like. **SOILS/HABITAT**: Loamy, sandy, clayey; wet; marshes/wetlands, meadows, grassland, scrubland, banks of rivers, streams, ditches. **BLOOM:** Jul–Sep; yellow and green.

Common sunflower (*Helianthus annuus*)

PLANT: Annual, single erect stem; coarse with rough hairs; 10′ max. **LEAVES:** Alternate; oval- to heart--shaped; with rough hairs. **SOILS/HABITAT**: Any; dry; disturbed sites, grasslands, meadows, foothills. **BLOOM:** Jul–Sep; yellow with red, orange, green, or brown.

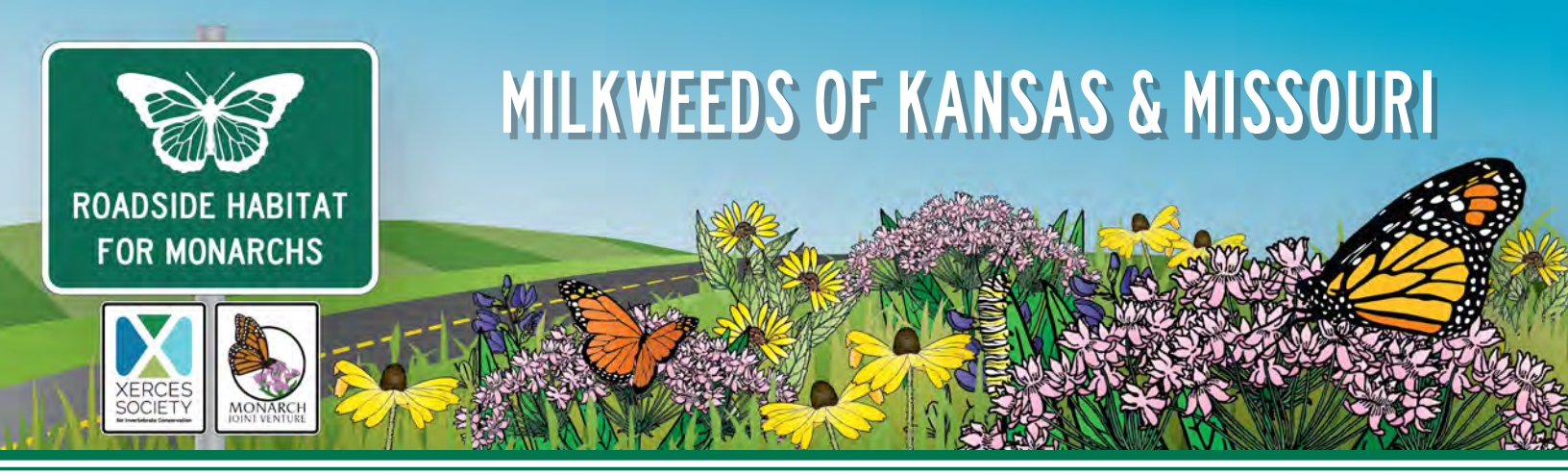
Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

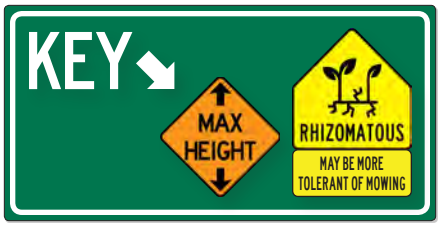
ACKNOWLEDGMENTS: Written by Stephanie McKnight, Jennifer Hopwood, and Sara Morris (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Jonathan Coffin / flickr (*Euthamia occidentalis*); Tom Potterfield / flickr (*A. incarnata*); Xerces Society / Eric Lee-Mader (*Solidago canadensis*) Xerces Society / Stephanie McKnight (*A. cordifolia, A cryptoceras, A. fascicularis, A. speciosa, Ericamia nauseosa, Helianthus annuus*).

MILKWEEDS OF KANSAS & MISSOURI

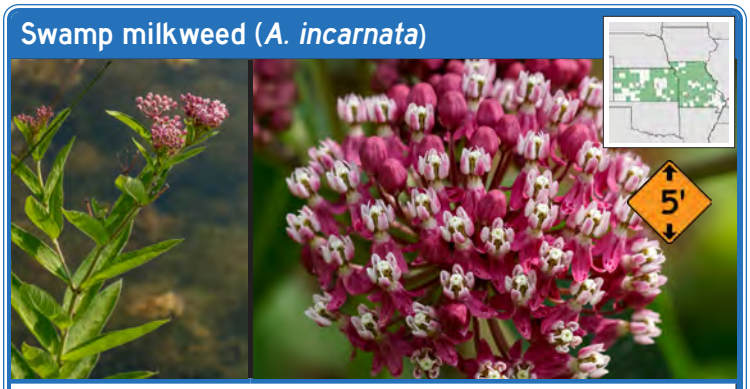


Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



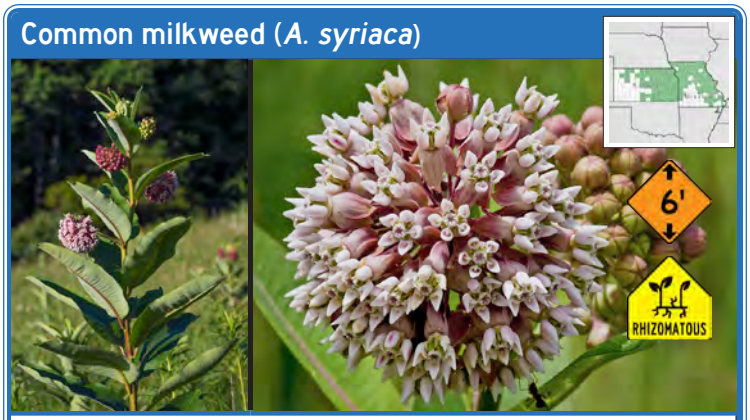
The most common milkweeds in roadsides in Kansas & Missouri (in alphabetical order):

Swamp milkweed (*A. incarnata*)



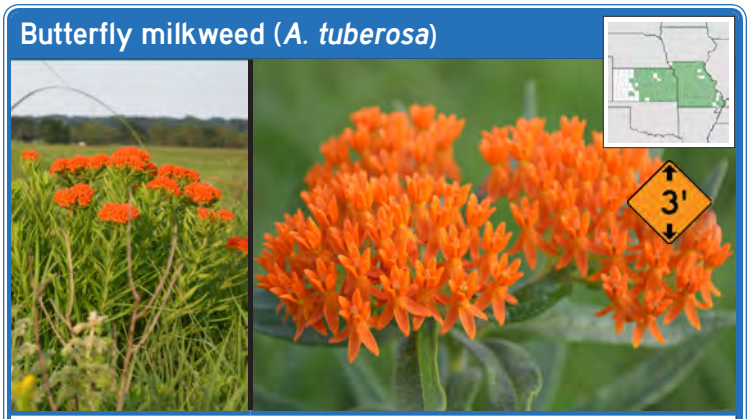
PLANT: One to many upright, branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist prairies, marshes, ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jun–Aug; light to dark pink or rose purple.

Common milkweed (*A. syriaca*)



PLANT: One to many stout, upright, unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Prairies, old fields, railways, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, clayey or rocky; dry–wet. **BLOOM:** May–Aug; pink.

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Prairies, old fields, glades, open woods. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** May–Sep; orange to red or yellow.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **HABITAT:** Prairies, open woods, fields, flood plains, glades, railways, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** May–Sep; white to green.

(Continued on next page.)

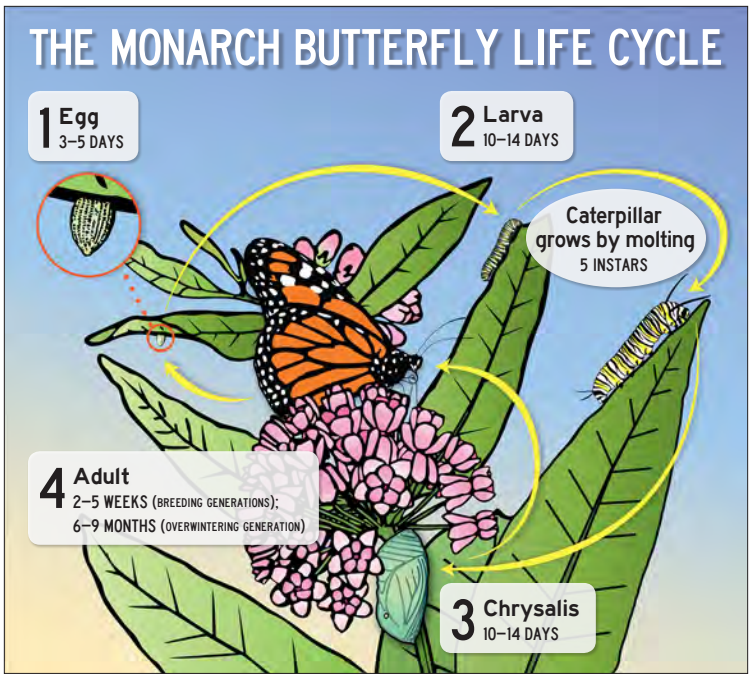
Most common milkweed species *continued*

Green antelopehorn (*A. viridis*)

PLANT: Multiple upright, unbranched stems; usually smooth. **LEAVES:** Alternate; lance- to oval-shaped; with wavy margins. **HABITAT:** Upland prairies, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry. **BLOOM:** May–Jul; green with touches of purple.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Mowing and Monarchs: tinyurl.com/MJV-MowingForMonarchs
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Green milkweed (*A. hirtella*)

PLANT: Upright, unbranched stems; 3′ max. **LEAVES:** Alternate; long and narrow to lance-shaped; with short hairs. **SOILS/HABITAT:** Sandy to rocky or clayey; dry–dry-mesic; prairies, open woods, glades, railways. **BLOOM:** May–Aug; green with purple or cream.

Slimleaf milkweed (*A. stenophylla*)

PLANT: Upright, unbranched stems; 2′ max. **LEAVES:** Alternate; very narrow to lance-shaped; folded lengthwise; with short hairs. **SOILS/HABITAT:** Sandy to rocky; dry; prairies, meadows, glades, bluffs. **BLOOM:** Jun–Aug; yellow to pale green with touches of white.

Prairie milkweed (*A. sullivantii*)

PLANT: Upright, unbranched, stout stems; smooth; 4′ max. **LEAVES:** Opposite; lance- to oval-shaped; very smooth. **SOILS/HABITAT:** Sandy clay or loamy; mesic–moist; prairies, wet meadows. **BLOOM:** Jun–Aug; pink with light green or purple.

Green comet milkweed (*A. viridiflora*)

PLANT: Spreading to upright, unbranched stems; with short hairs, 3′ max. **LEAVES:** Opposite; lance-shaped; edges folded upward or wavy; with short hairs. **SOILS/HABITAT:** Sandy to loamy or rocky; dry–dry-mesic; prairies, old fields, forests, glades. **BLOOM:** May–Aug; light to yellowish green.

Additional milkweeds in Kansas and/or Missouri: *Asclepias amplexicaulis, A. arenaria, A. asperula* ssp. *capricornu, A. engelmanniana, A. involucrata, A. lanuginosa, A. latifolia, A. meadii, A. perennis, A. pumila, A. purpurascens, A. quadrifolia, A. speciosa, A. subverticillata, A. variegata.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across both states and are found in roadsides. Less common species might not occur in both states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Jennifer Hopwood, Stephanie Frischie, and Ray Moranz (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by Craig Freeman (University of Kansas) and Carol Davit (Missouri Prairie Foundation). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTO CREDITS: Jim Fowler (*A. syriaca*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Jerry Oldenettel / flickr (*A. verticillata*); Tom Potterfield / flickr (*A. incarnata*); Paul Rothrock / SEINet (*A. hirtella*); Scott Seigfreid (*A. tuberosa*); Xerces Society / Ray Moranz (*A. stenophylla*, *A. sullivantii*).

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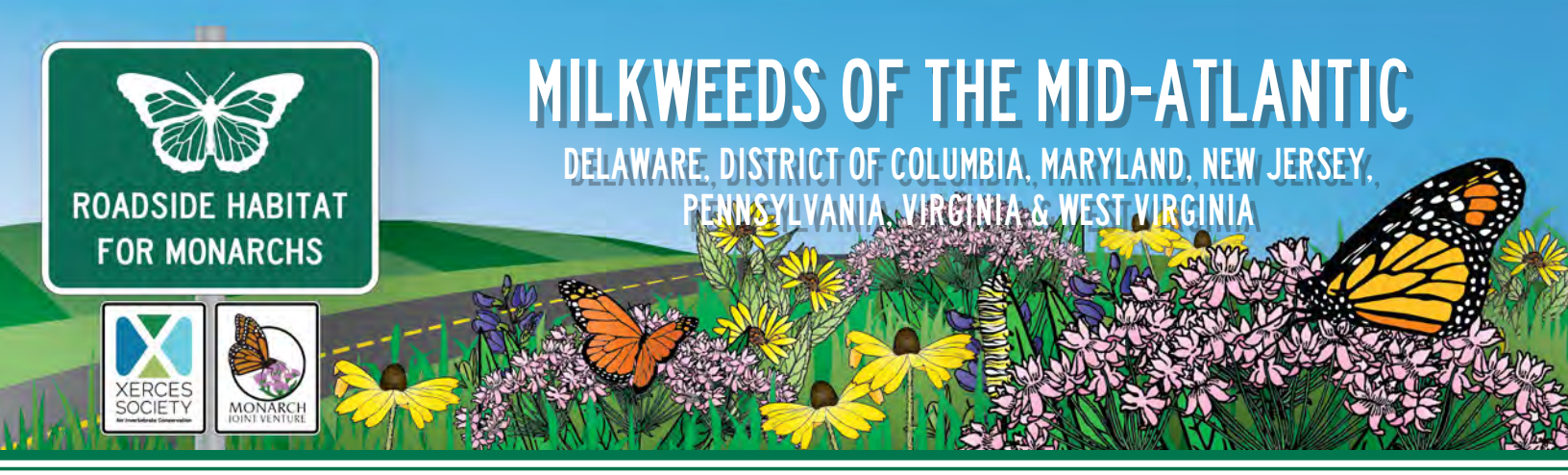
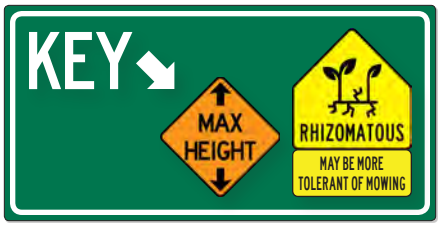


MILKWEEDS OF THE MID-ATLANTIC

DELAWARE, DISTRICT OF COLUMBIA, MARYLAND, NEW JERSEY, PENNSYLVANIA, VIRGINIA & WEST VIRGINIA

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.

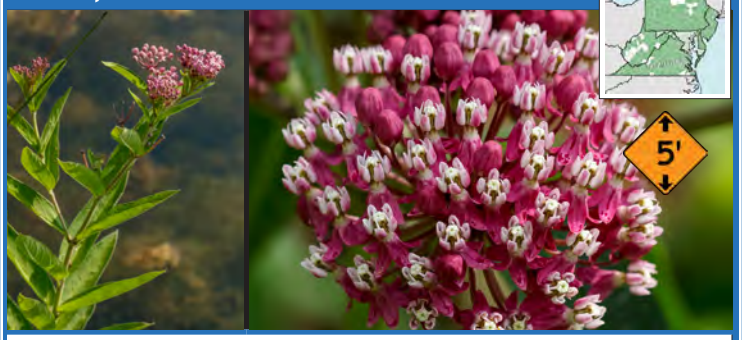


The most common milkweeds in roadsides in the Mid-Atlantic Region (in alphabetical order):

Clasping milkweed (*A. amplexicaulis*)

PLANT: Upright, unbranched stems; smooth. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **HABITAT**: Grasslands, open woodlands and edges. **SOILS:** Sandy, rocky; dry. **BLOOM:** Jun–Jul; light to dark pink with cream or light green

Swamp milkweed (*A. incarnata*)

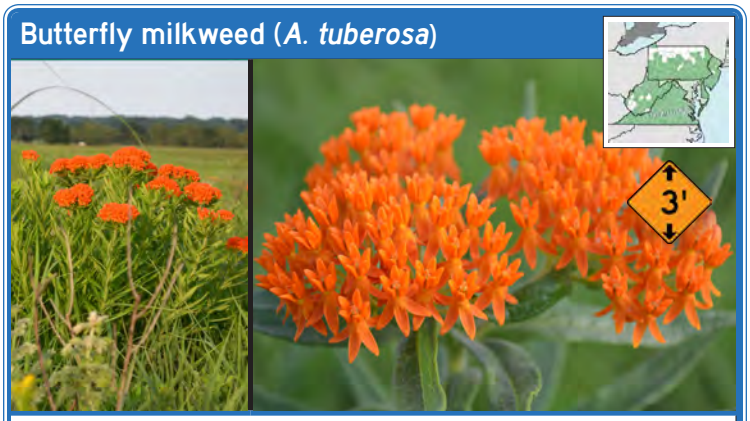


PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist grasslands and ditches, edges of ponds, swamps, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jul–Aug; light to dark pink or rose purple.

Common milkweed (*A. syriaca*)

PLANT: One to many stout, upright, unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Grasslands, old fields, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, clayey or rocky; dry–wet. **BLOOM:** Jun-Aug, light purple or pink.

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Grasslands, old fields, open woods, pine barrens, disturbed areas. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** Jun-Aug, orange to red or yellow.

(Continued on next page.)

Most common milkweed species *continued*

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **HABITAT:** Grasslands, open woods, fields, flood plains, disturbed areas. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** Jul–Sep; white to green.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
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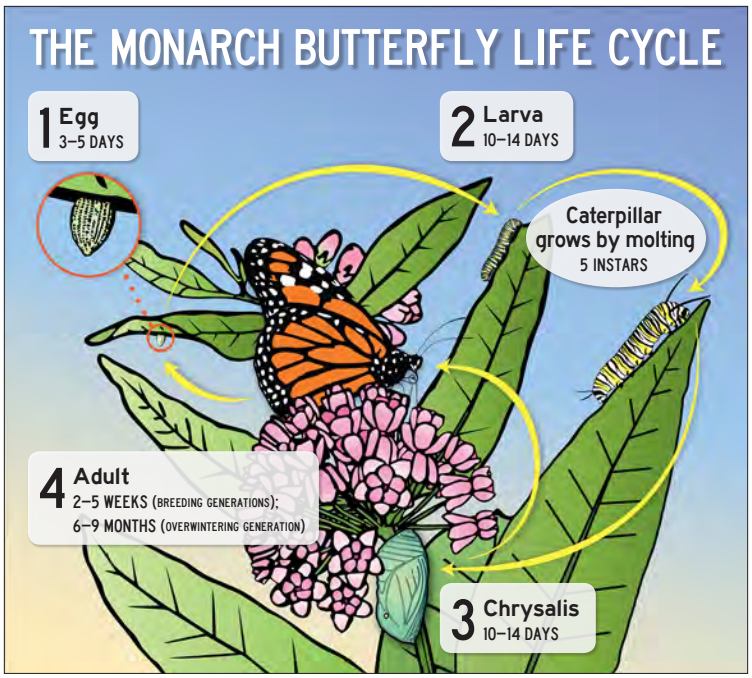

Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Purple milkweed (*A. purpurascens*)

PLANT: Upright, unbranched, stout stems; smooth; 6′ max. **LEAVES:** Opposite; oval-shaped; smooth above, with fine hairs below. **SOILS/HABITAT:** Loamy to clayey; mesic; grasslands, old fields, woodland edges, ditches. **BLOOM:** Jun–Aug; rich purple.

Fourleaf milkweed (*A. quadrifolia*)

PLANT: Upright, unbranched stems; with short hairs; 2.5′ max. **LEAVES:** Opposite (except a false whorl of four leaves in center of stem); oval-shaped; usually smooth. **SOILS/HABITAT:** Rocky, sandy to loamy; dry; woodlands or woodland edges, glades. **BLOOM:** May–Jul; white to pink.

Redring milkweed (*A. variegata*)

PLANT: Upright, unbranched stems; purplish-green; usually smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; usually smooth. **SOILS/HABITAT:** Sandy, rocky, loamy to clay-loamy; dry–mesic; savannas, woodlands and edges, banks of streams. **BLOOM:** May-Jun; white to light green, with red or purple ring.

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, upright to spreading; with short hairs; 3′ max. **LEAVES:** Opposite; lance-shaped; edges wavy or folded upward; with short hairs. **SOILS/HABITAT:** Sandy, loamy, rocky; dry–dry-mesic; grasslands, old fields, dunes, forests, glades. **BLOOM:** Jun–Sep; light to yellowish green.

Additional milkweeds in the Mid-Atlantic: *Asclepias exaltata, A. lanceolata, A. longifolia, A. rubra, A. viridis* (WV only).

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

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PHOTO CREDITS: Jim Fowler (*A. syriaca*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Jerry Oldenettel / flickr (*A. verticillata*); Tom Potterfield / flickr (*A. incarnata*); Paul Rothrock / SEINet (*A. amplexicaulis* [left]); Scott Seigfreid (*A. tuberosa*); Vern Wilkins, Indiana University / Bugwood.org (*A. quadrifolia*); Xerces Society / Nancy Lee Adamson (*A. amplexicaulis* [right]).

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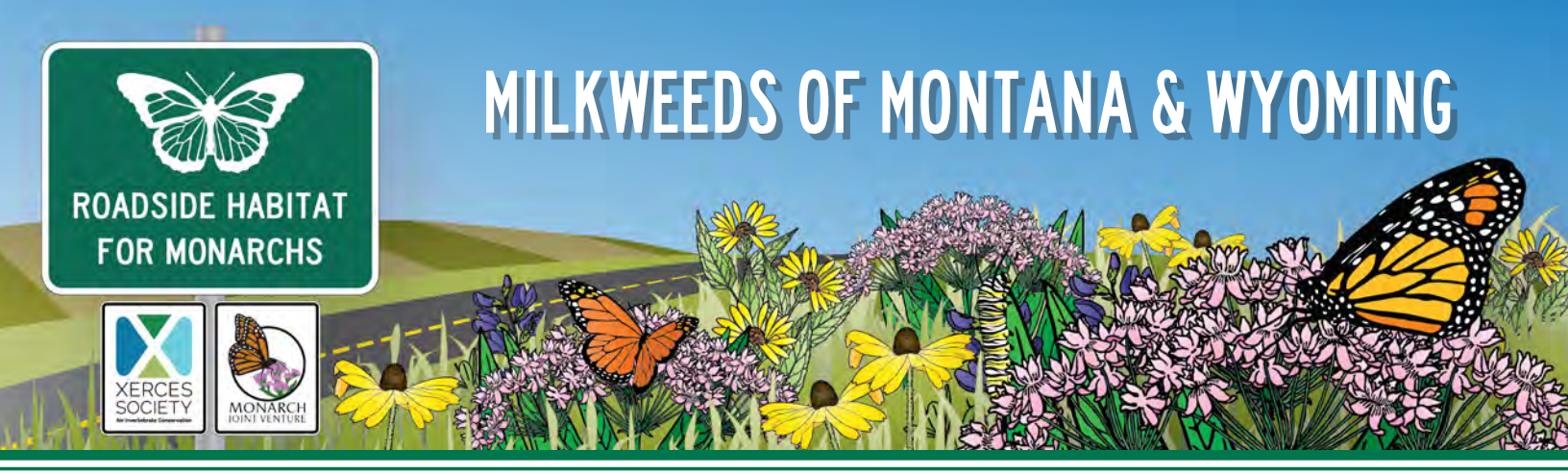
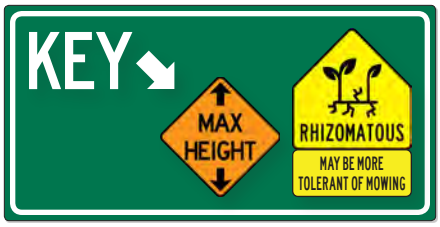


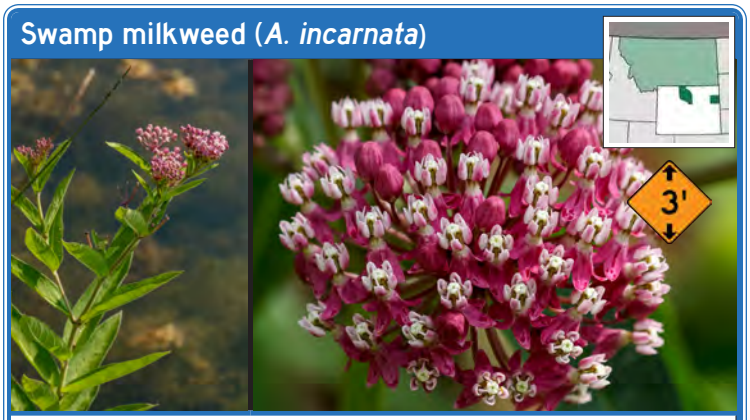
MILKWEEDS OF MONTANA & WYOMING

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



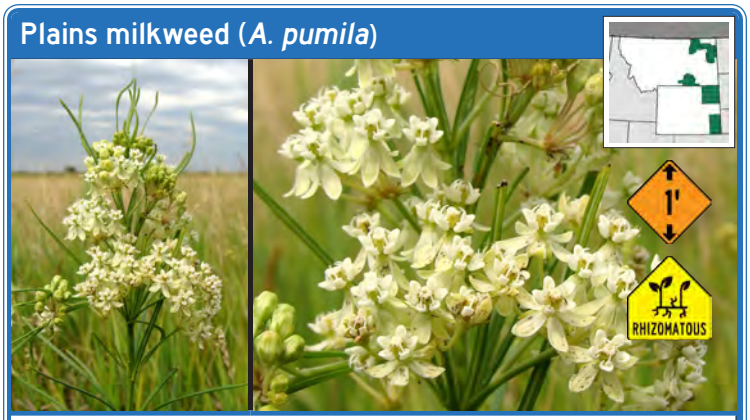
The most common milkweeds in roadsides in Montana & Wyoming (in alphabetical order):

Swamp milkweed (*A. incarnata*)



PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Wet meadows, grasslands, ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet. **BLOOM:** Jun–Jul; pink, light purple.

Plains milkweed (*A. pumila*)



PLANT: Upright, unbranched or branched stems; with fine hairs. **LEAVES:** Alternate, may appear whorled; thin and narrow; dense on stems (bottlebrush appearance). **HABITAT:** Prairies, plains, low hills. **SOILS:** Rocky, sandy, gypseous, calcareous; dry. **BLOOM:** Jun–Sep; white to pink.

Showy milkweed (*A. speciosa*)

PLANT: Stout upright, unbranched stems; hairy. **LEAVES:** Opposite; oval-shaped; hairy. **HABITAT:** Grasslands, meadows, fields, disturbed areas, edges of rivers, ponds. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of North American species.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, usually unbranched stems; sparsely hairy. **LEAVES:** Whorled; narrow to thread-like; leaf margins rolled downward; smooth or with short hairs. **HABITAT:** Grasslands, open woodlands, badlands, plains. **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** Jun–Sep; white to greenish.

(Continued on next page.)

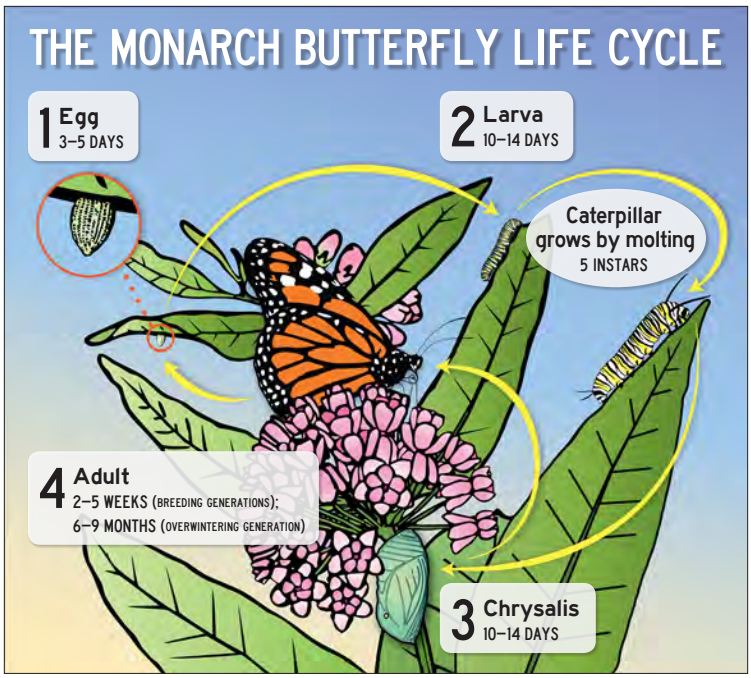
Most common milkweed species *continued*

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, spreading to upright; with short hairs; 3′ max. **LEAVES:** Opposite; lance-shaped; narrow and often with margins folded upward; with short hairs. **HABITAT:** Grasslands, plains, hills, old fields. **SOILS:** Sandy to loamy or rocky; dry–dry-mesic. **BLOOM:** Jun–Jul; light green to green.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Western Monarch Milkweed Mapper: www.monarchmilkweedmapper.org
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Hall's milkweed (*A. hallii*)

PLANT: Upright, unbranched stem or branched at base; hairy; 2′ max. **LEAVES:** Alternate to opposite; narrow oval-shaped; hairy. **SOILS/HABITAT:** Sandy, gravelly; dry; prairies, wash-bottoms, hills (Wyoming only). **BLOOM:** Jun–Aug; purple, pink, cream or white with green.

Oval-leaf milkweed (*A. ovalifolia*)

PLANT: Upright, unbranched stems; with fine hairs; 2′ max. **LEAVES:** Opposite; lance- to oval-shaped; fine hairs underneath. **SOILS/HABITAT:** Sandy, silty loam; dry; prairies, open woods. **BLOOM:** Jun–Jul; cream or white with pink or yellow.

Slimleaf milkweed (*A. stenophylla*)

PLANT: Unbranched, upright stems; 2′ max. **LEAVES:** Alternate; very narrow to lance-shaped; folded lengthwise; with short hairs. **SOILS/HABITAT:** Sandy, rocky; dry; prairies, meadows. **BLOOM:** Jun–Aug; yellow to pale green with touches of white.

Horsetail milkweed (*A. subverticillata*)

PLANT: Upright branched or unbranched stems; smooth or with fine hairs; 3′ max. **LEAVES:** Whorled; narrow; smooth. **SOILS/HABITAT:** Sandy; moist; plains, hills, disturbed areas, ditches (Wyoming only). **BLOOM:** May–Aug; yellow to cream or purple.

Additional milkweeds in Montana and Wyoming: *Asclepias arenaria, A. cryptoceras, A. engelmanniana, A. syriaca, A. uncialis.*

Maps & Distribution Data:

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PHOTO CREDITS: Frankia Coburn / SEINet (*A. hallii*); Max Licher / SEINet (*A. subverticillata*); Krista Lundgren, USFWS / flickr (*A. viridiflora, A. ovalifolia*); Jerry Oldenettel / flickr (*A. verticillata*); Tom Potterfield / flickr (*A. incarnata*); Xerces Society / Stephanie McKnight (*A. speciosa*); Xerces Society / Ray Moranz (*A. pumilla, A. stenophylla*).

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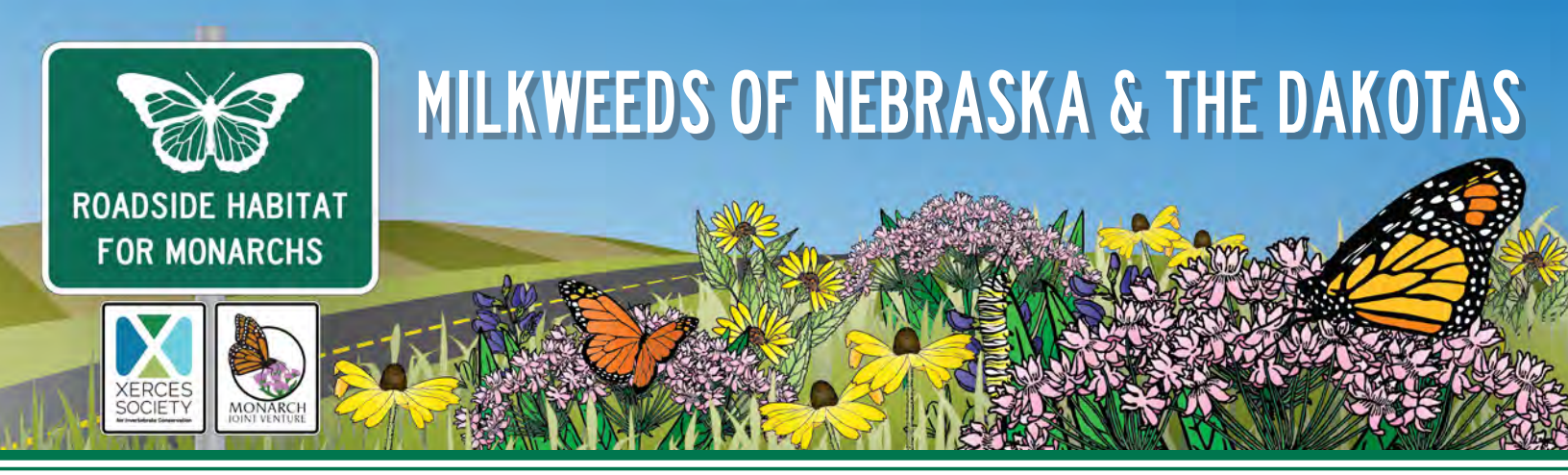
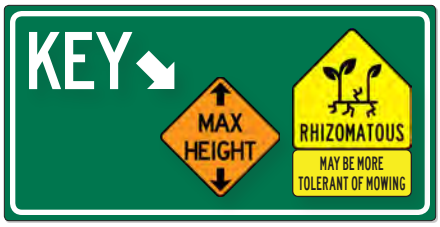
MILKWEEDS OF NEBRASKA & THE DAKOTAS

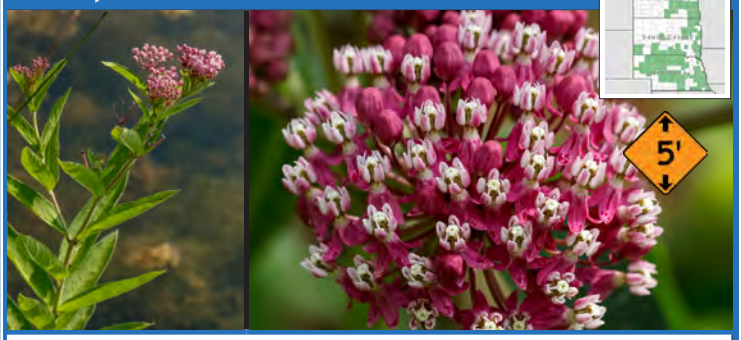


Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



The most common milkweeds in roadsides in Nebraska & The Dakotas (in alphabetical order):

Swamp milkweed (*A. incarnata*)

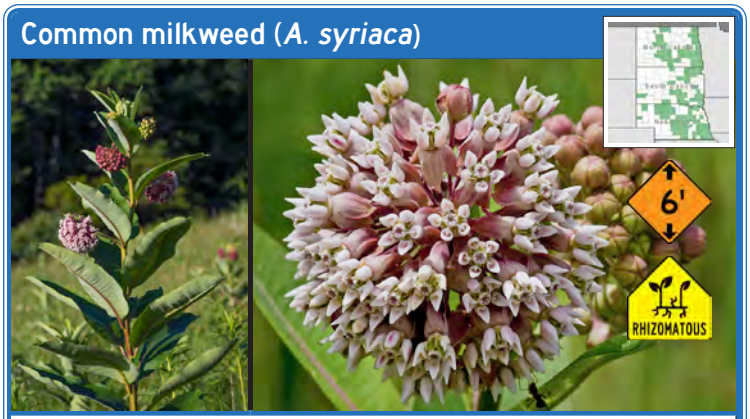


PLANT: One to many upright branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist prairies, marshes, ditches, edges of ponds, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jun–Aug; light to dark pink or rose purple.

Showy milkweed (*A. speciosa*)

PLANT: Stout upright, unbranched stems; hairy. **LEAVES:** Opposite; oval-shaped; hairy. **HABITAT:** Prairies, old fields, edges of rivers, ponds, disturbed areas. **SOILS:** Sandy to loamy; dry to slightly wet, prefers moist soils. **BLOOM:** Jun–Aug; pink and cream or white; flowers are the largest of American species.

Common milkweed (*A. syriaca*)



PLANT: One to many erect, stout unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Prairies, old fields, railways, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, clayey or rocky; dry–wet. **BLOOM:** Jun–Aug; pink.

Whorled milkweed (*A. verticillata*)

PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or with short hairs. **HABITAT:** Prairies, open woods, fields, flood plains, disturbed areas. **SOILS:** Loamy, sandy, rocky, clayey; dry–mesic. **BLOOM:** Jun–Sep; white to green.

(Continued on next page.)

Most common milkweed species *continued*

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, spreading to erect; with short hairs. **LEAVES:** Opposite; lance-shaped with edges folded upward or wavy; with short hairs. **HABITAT:** Prairies, old fields, dunes, forests. **SOILS:** Sandy to loamy or rocky; dry–dry-mesic. **BLOOM:** May–Jul; light green to yellowish green.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
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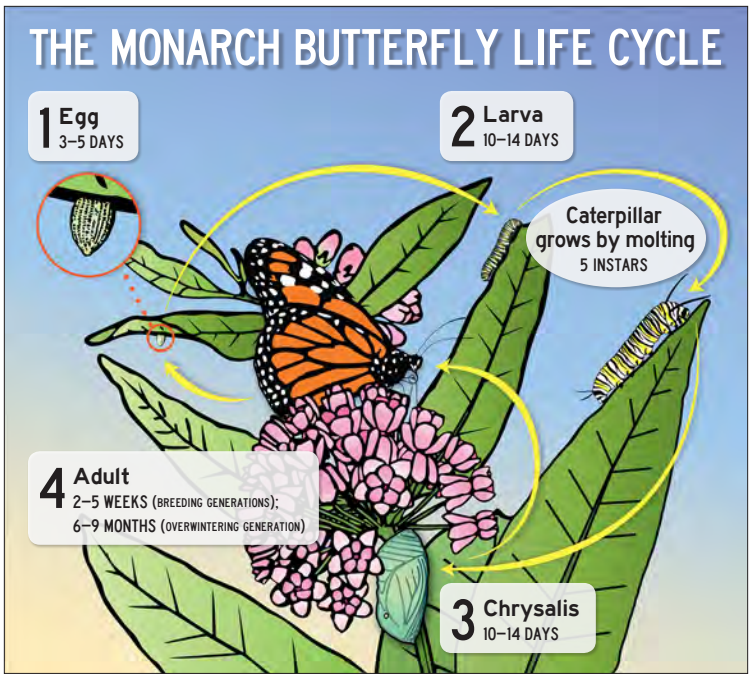


Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Sand milkweed (*A. arenaria*)

PLANT: Spreading to upright, unbranched stems; hairy; 6′ max. **LEAVES:** Opposite; broadly oval-shaped; woolly hairs. **SOILS/HABITAT:** Sandy; dry; prairies, rangeland, riverbanks, dunes. **BLOOM:** Jun–Aug; pale green, yellow or cream with tines of pink or purple.

Oval-leaf milkweed (*A. ovalifolia*)

PLANT: Upright, unbranched stems; with fine hairs; 2′ max. **LEAVES:** Opposite; lance-shaped to oval-shaped; fine hairs underneath. **SOILS/HABITAT:** Sandy, silt loam; dry; prairies, open woods. **BLOOM:** Jun–Aug; cream or white with pink or yellow.

Plains milkweed (*A. pumila*)

PLANT: Upright, unbranched to branched stems; 1′ max. **LEAVES:** Alternate; thin and narrow; dense on stems. **SOILS/HABITAT:** Sandy, clayey, rocky; dry; prairies, plains, low hills, badlands, floodplains, woods. **BLOOM:** Jul–Aug; white to greenish white.

Slimleaf milkweed (*A. stenophylla*)

PLANT: Upright, unbranched stems; 2′ max. **LEAVES:** Alternate to nearly opposite; very thin; folded lengthwise. **SOILS/HABITAT:** Sandy, rocky; dry; prairies, meadows. **BLOOM:** Jun–Aug; yellow to pale green with touches of white.

Additional milkweeds in Nebraska, North Dakota, and/or South Dakota: *Asclepias amplexicaulis, A. asperula* ssp. *capricornu, A. lanuginosa, A. latifolia, A. sullivantii, A. tuberosa, A. viridis.*

Maps & Distribution Data:

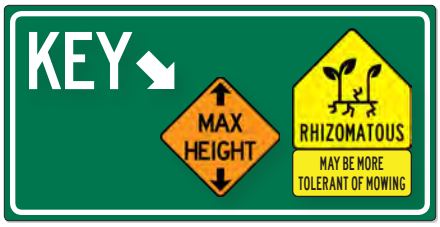
These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Jennifer Hopwood, Rae Powers, Sarah Hamilton Buxton, Stephanie Frischie (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by: Mercy Manzanares-Dinwiddie (NE Game and Parks Commission). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

PHOTOS: Jim Fowler (*A. syriaca*); Chris Helzer / The Nature Conservancy (*A. arenaria*); Krista Lundgren, USFWS / flickr (*A. viridiflora, A. ovalifolia*); Jerry Oldenettel / flickr (*A. verticillata*); Tom Potterfield / flickr (*A. incarnata*); Xerces Society / Stephanie McKnight (*A. speciosa*); Xerces Society / Ray Moranz (*A. pumilla, A. stenophylla*). Photographs remain under the copyright of the photographer.

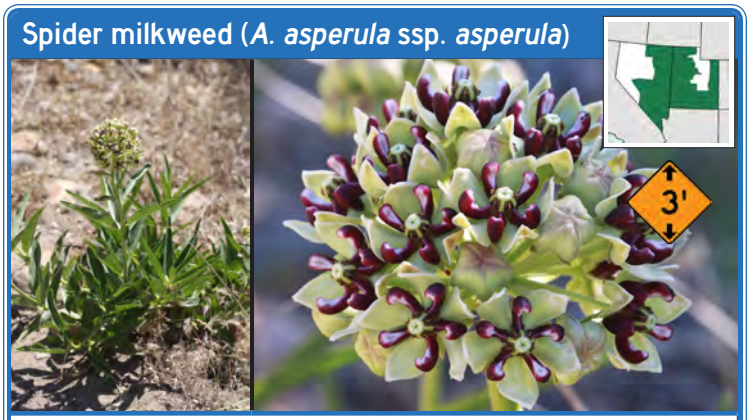
MILKWEEDS OF NEVADA & UTAH

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



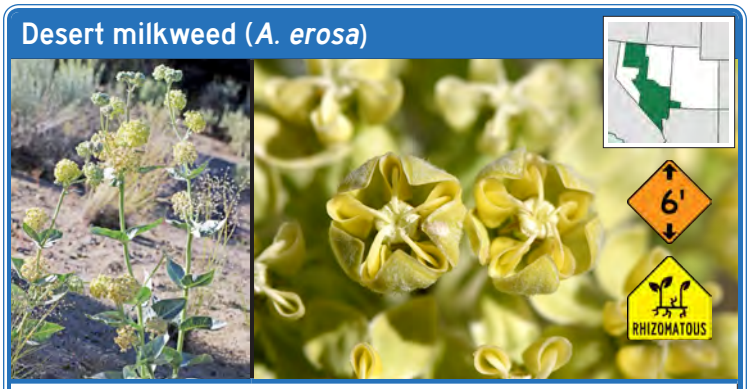
The most common milkweeds in roadsides in Nevada & Utah (in alphabetical order):

Spider milkweed (*A. asperula* ssp. *asperula*)



PLANT: Multiple spreading stems, unbranched to few branches; usually smooth. **LEAVES:** Alternate; lance-shaped; usually folded lengthwise. **HABITAT:** Grasslands, disturbed areas. **SOILS:** Clayey, gravelly, sandy, rocky limestone, dry. **BLOOM:** Apr–Jun; light green with touches of purple.

Desert milkweed (*A. erosa*)



PLANT: Upright, unbranched to branched stout stems; with fine hairs; grows in clumps. **LEAVES:** Opposite; oval- to lance-shaped; smooth to with fine hairs. **HABITAT:** Washes, gulches, canyons, disturbed areas in deserts, creosote bush and sagebrush communities. **SOILS:** Sandy; dry. **BLOOM:** Apr–Oct; yellowish or cream; flower buds are hairy.

Narrowleaf milkweed (*A. fascicularis*)

PLANT: Thin upright branched stems; smooth. **LEAVES:** Opposite to whorled; narrow to lance-shaped; folded lengthwise; mostly smooth. **HABITAT:** Grasslands, wetland-riparian areas, open woodlands, chaparral, sagebrush, disturbed areas, banks of streams and irrigation ditches, fallow fields. **SOILS:** Sandy to clayey, tolerates saline; dry–moist. **BLOOM:** May–Oct; dusky pink to rose with touches of white.

Showy milkweed (*A. speciosa*)

PLANT: Stout upright, unbranched stems; hairy. **LEAVES:** Opposite; oval-shaped; hairy. **HABITAT:** Grasslands, old fields, disturbed areas, edges of rivers, ponds. **SOILS:** Sandy to loamy; dry–moist. **BLOOM:** May–Aug; pink and cream or white; flowers are the largest of American species.

(Continued on next page.)

Most common milkweed species *continued*

Horsetail milkweed (*A. subverticillata*)

PLANT: Upright, branched or unbranched stems; smooth or with fine hairs. **LEAVES:** Whorled; narrow to needle-like; smooth. **HABITAT:** Ditches, disturbed areas, stream edges. **SOILS:** Sandy; moist. **BLOOM:** May–Aug; yellow to cream or purple.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
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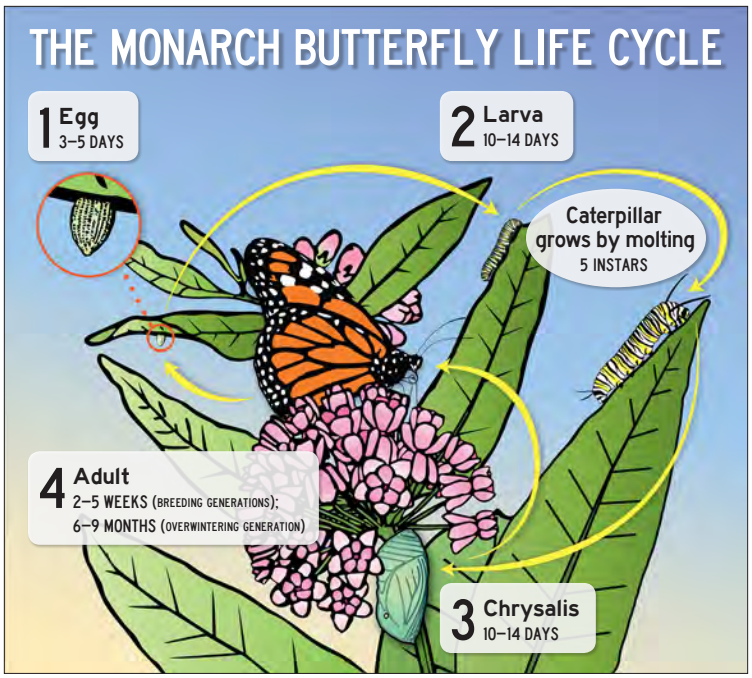


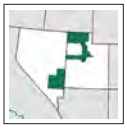
Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Pallid milkweed (*A. cryptoceras*)

PLANT: Stout, prostrate, spreading stems, rarely branched; smooth; 1′ max. **LEAVES:** Opposite; broad oval- to heart-shaped; waxy, smooth. **SOILS/HABITAT:** Sandy to clayey; dry; washes, hillsides, woodland, sagebrush, salt desert shrubland. **BLOOM:** Apr–Jun; greenish yellow and red or dark violet.

Swamp milkweed (*A. incarnata*)



PLANT: One to many upright, branched stems; smooth or with short hairs; 5′ max. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **SOILS/HABITAT:** Silty to loamy or clayey; moist–wet; grasslands, ditches, edges of ponds, lakes, streams. **BLOOM:** Jun–Sep; pink, light purple.

Utah milkweed (*A. labriformis*)

PLANT: Multiple upright, usually unbranched, stems; smooth; 1.5′ max. **LEAVES:** Opposite; lance-shaped to narrow; with a patch of coarse hairs. **SOILS/HABITAT**: Sandy; dry with moist subsoil; washes, canyons, gulches, disturbed areas, desert shrub. **BLOOM:** May–Aug; pale yellow-green to white.

Broadleaf milkweed (*A. latifolia*)

PLANT: Upright, unbranched, stout stems; woolly when young, smooth with age; 2′ max. **LEAVES:** Opposite; oval-shaped; woolly when young, smooth with age. **SOILS/HABITAT:** Sandy, clayey, rocky; dry; grasslands, chaparral, hillside woodlands, canyons. **BLOOM:** May–Aug; white to pale green.

Additional milkweeds in Nevada & Utah: *Asclepias cordifolia, A. cutleri, A. engelmanniana, A. hallii, A. involucrata, A. macrosperma, A. nyctaginifolia, A. rusbyi, A. ruthiae, A. subulata, A. syriaca, A. tuberosa, A. uncialis, A. welshii.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across both states and are found in roadsides. Less common species might not occur in both states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

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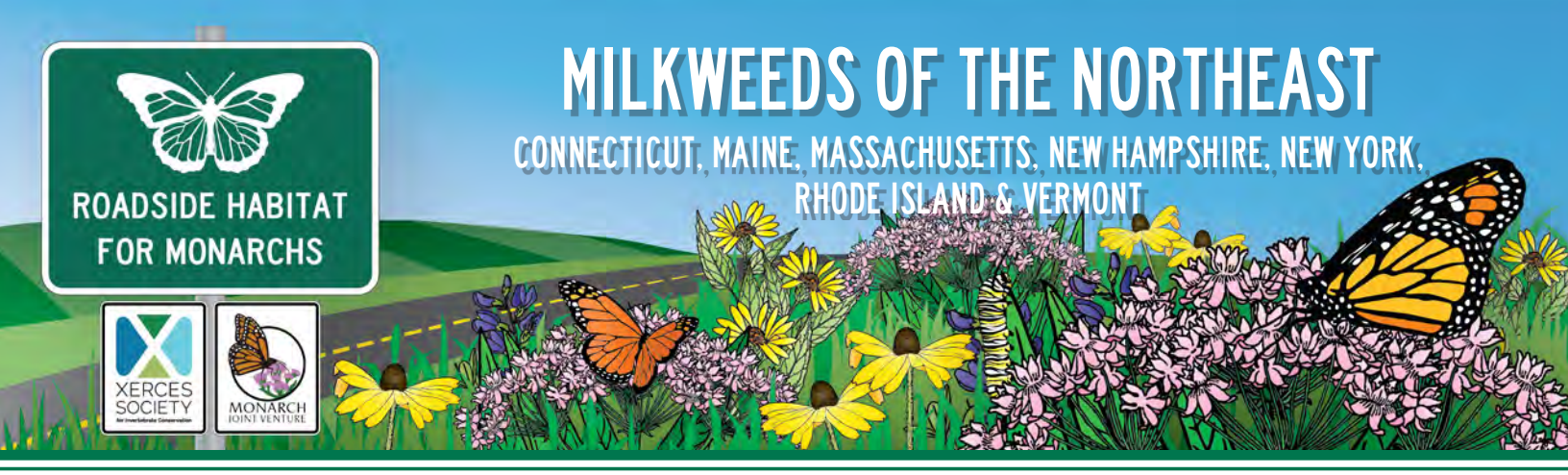
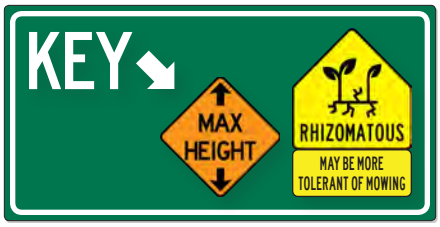
PHOTO CREDITS: Frankie Coburn / SEINet (*A. labriformis*); Max Licher / SEINet (*A. subverticillata, A. latifolia*); Tom Potterfield / flickr (*A. incarnata*); Xerces Society / Stephanie McKnight (*A. erosa, A. fascicularis, A. speciosa, A. cryptoceras*); Andrey Zharkikh / flickr (*A. a.* ssp. *asperula*). Photographs remain under the copyright of the photographer.



MILKWEEDS OF THE NORTHEAST

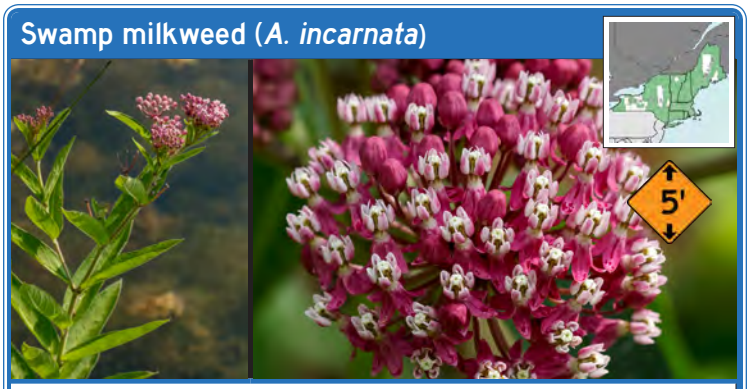
CONNECTICUT, MAINE, MASSACHUSETTS, NEW HAMPSHIRE, NEW YORK, RHODE ISLAND & VERMONT

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



The most common milkweeds in roadsides in the Northeast Region (in alphabetical order):

Swamp milkweed (*A. incarnata*)

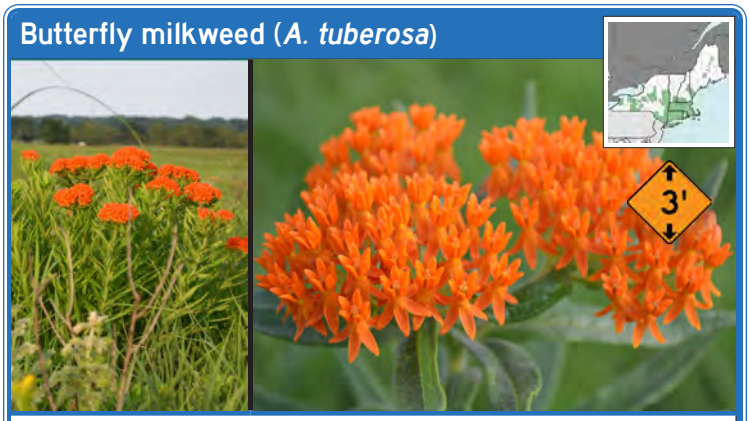


PLANT: One to many upright, branched stems; smooth or with short hairs. **LEAVES:** Opposite; lance-shaped or narrow; with few short hairs. **HABITAT:** Moist grasslands and ditches, edges of ponds, swamps, lakes, streams. **SOILS:** Silty to loamy or clayey; moist–wet, tolerates some mesic. **BLOOM:** Jul–Aug; pink or light purple.

Common milkweed (*A. syriaca*)

PLANT: One to many stout, upright, unbranched stems; usually with short dense hairs. **LEAVES:** Opposite; oval-shaped; hairy underneath. **HABITAT:** Grasslands, old fields, open woods, flood plains, disturbed areas. **SOILS:** Sandy to loamy, clayey or rocky; dry–wet. **BLOOM:** Jul–Aug; pale purple or pink.

Butterfly milkweed (*A. tuberosa*)



PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Grasslands, open woods, pine barrens. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** Jun–Jul; orange to red or yellow.

Less common roadside milkweeds:

Clasping milkweed (*A. amplexicaulis*)

PLANT: Upright, unbranched stems; smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **SOILS:** Sandy, rocky; dry. **HABITAT:** Grasslands, open woodlands and edges. **BLOOM:** Jun–Jul; light to dark pink with cream or light green.

(Continued on next page.)

Less common roadside milkweeds *continued*

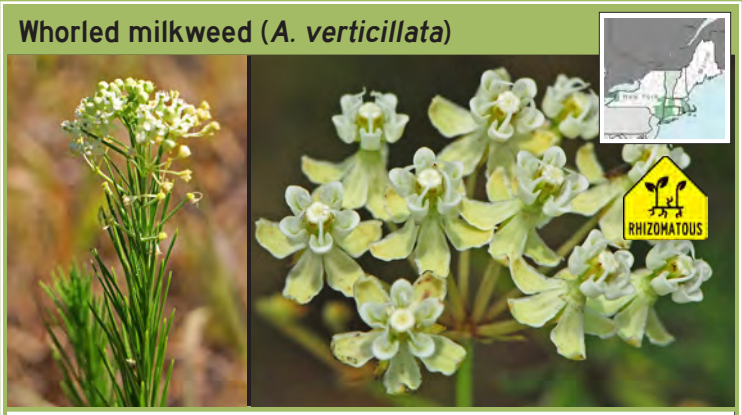
Poke milkweed (*A. exaltata*)

PLANT: Upright, unbranched stem; smooth; 6′ max. **LEAVES:** Opposite; oval-shaped; smooth. **SOILS:** Sandy, loamy; dry. **HABITAT:** Woodlands or woodland edges, dry rocky summits. **BLOOM:** Jun–Jul; green or pale purple with white or light pink; drooping.

Fourleaf milkweed (*A. quadrifolia*)

PLANT: Upright, unbranched stems; with short hairs; 2.5′ max. **LEAVES:** Opposite, except a false whorl of four leaves in center of stem; oval-shaped; usually smooth. **SOILS:** Rocky, sandy to loamy; dry. **HABITAT:** Open woodlands or woodland edges, glades. **BLOOM:** May–Jun; white to pink.

Whorled milkweed (*A. verticillata*)



PLANT: One to several upright, unbranched stems; with short hairs; 3′ max. **LEAVES:** Whorled; narrow to needle-like; smooth or short hairs. **SOILS:** Sandy, rocky, clayey; moist. **HABITAT:** Grasslands, open woods, fields, flood plains, disturbed areas. **BLOOM:** Jul-Aug; white to green.

Additional milkweeds in the Northeast: *Asclepias purpurascens, A. rubra, A. variegata, A. viridiflora.*

Additional Resources:

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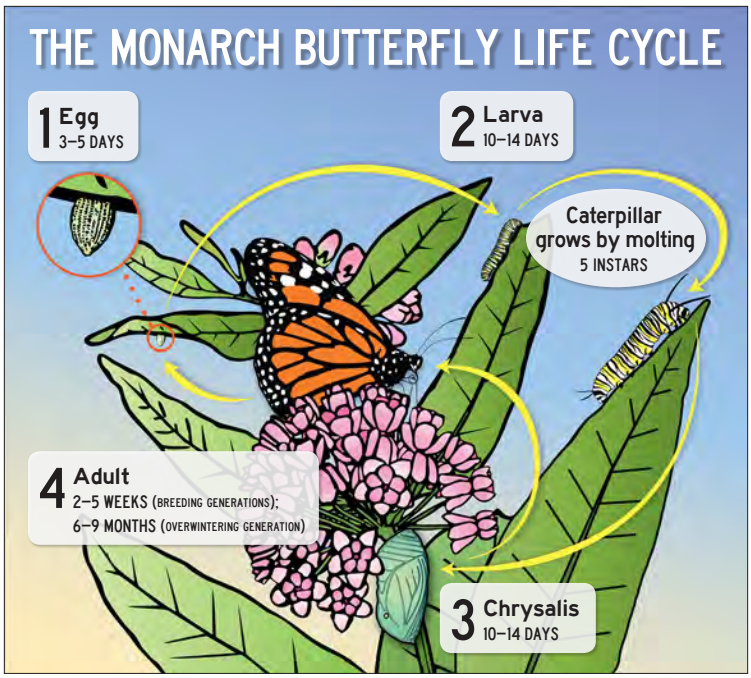

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Maps & Distribution Data:

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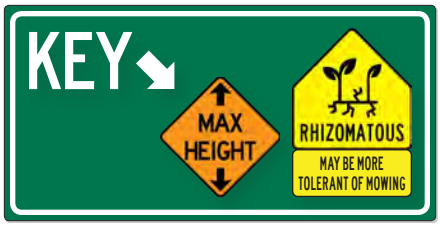
ACKNOWLEDGMENTS: Written by Jennifer Hopwood, Stephanie Frischie, Kelly Gill, Katie Hietala-Henschell, Eric Venturini, Emily May (Xerces Society), Alison Cariveau (Monarch Joint Venture). Reviewed by Steve Young (NY NHP), Shawnna Clark (USDA NRCS). Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

MILKWEEDS OF OKLAHOMA & TEXAS

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



The most common milkweeds in roadsides in Oklahoma & Texas (in alphabetical order):

Antelopehorns (*A. asperula* ssp. *capricornu*)

PLANT: Multiple spreading stems, unbranched to few branches; usually smooth. **LEAVES:** Alternate; lance-shaped; usually folded lengthwise. **HABITAT:** Prairies, disturbed areas. **SOILS:** Sandy, rocky limestone, clayey, gravelly; dry. **BLOOM:** Apr–Sep; light green with touches of purple.

Broadleaf milkweed (*A. latifolia*)

PLANT: Upright, unbranched, stout stems; woolly when young to smooth with age. **LEAVES:** Opposite; oval-shaped; woolly when young to smooth with age. **HABITAT:** Prairie, disturbed areas. **SOILS:** Sandy, clayey, rocky; dry. **BLOOM:** May–Aug; white to pale green.

Zizotes milkweed (*A. oenotheroides*)

PLANT: Spreading to upright branched stout stems; smooth. **LEAVES:** Opposite; wavy edges. **HABITAT:** Prairies, ditches, fields, dunes; may survive periodic mowing and drought. **SOILS:** Sandy, rocky; dry. **BLOOM:** Apr–Nov; green with white and/or purple.

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, spreading to erect; with short hairs. **LEAVES:** Opposite; lance- to oval-shaped with edges folded upward or wavy; with short hairs. **HABITAT:** Rocky prairies, old fields, dunes, forests, glades. **SOILS:** Sandy to loamy or rocky; dry–dry-mesic. **BLOOM:** Jun–Aug; light green to yellowish green.

(Continued on next page.)

Most common milkweed species *continued*

Green antelopehorn (*A. viridis*)

PLANT: Multiple unbranched upright stems; usually smooth. **LEAVES:** Alternate; lance-shaped to oval-shaped; with wavy margins. **HABITAT:** Upland prairies, open woods, disturbed areas. **SOILS**: Sandy, rocky, clayey; dry. **BLOOM:** Mar–Sep; green with touches of purple.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Western Monarch Milkweed Mapper: www.monarchmilkweedmapper.org
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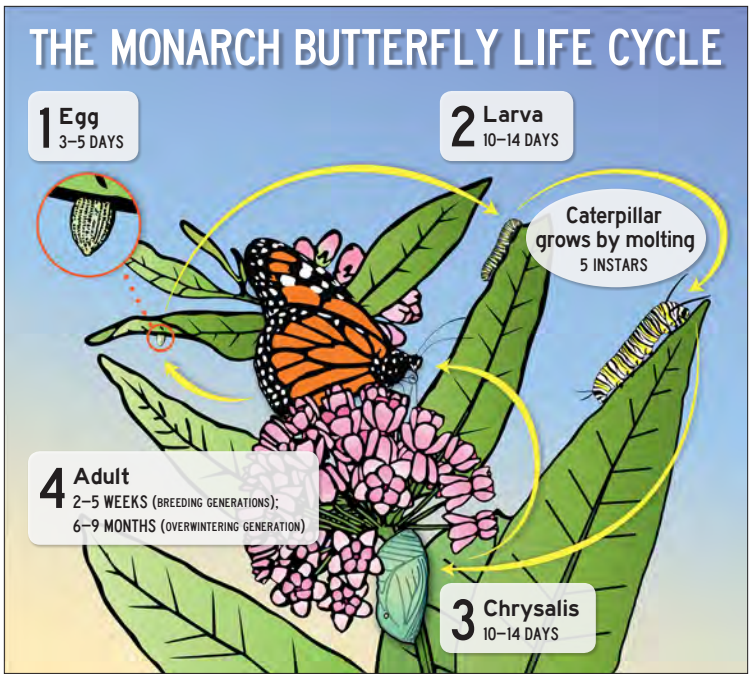

Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Clasping milkweed (*A. amplexicaulis*)

PLANT: Unbranched, upright stems; smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **SOILS/HABITAT:** Sandy; dry; grasslands, savannas, woodland edges. **BLOOM:** Apr–Jun; green with pink or purple.

Engelmann's milkweed (*A. engelmanniana*)

PLANT: One to a few upright, usually unbranched, stout stems; smooth; 3′ max. **LEAVES:** Alternate; narrow and linear; smooth. **SOILS/HABITAT:** Sandy, rocky or calcareous; dry; grasslands, savannas, woodlands, riparian areas. **BLOOM:** May–Sep; small, yellowish-green with purple.

Slimleaf milkweed (*A. stenophylla*)

PLANT: Unbranched, upright stems; 2′ max. **LEAVES:** Alternate; very narrow to lance-shaped; folded lengthwise; with short hairs. **SOILS/HABITAT:** Sandy, rocky; dry; prairies, meadows. **BLOOM:** Jun–Aug; yellow to pale green with touches of white.

Butterfly milkweed (*A. tuberosa*)

PLANT: One to many spreading to upright stems; with short hairs; no milky sap; 3′ max. **LEAVES:** Alternate; lance-shaped; hairy underneath. **SOILS/HABITAT:** Sandy, loamy, rocky; well-drained; prairies, old fields, open woods. **BLOOM:** Apr–Sep; orange to red or yellow.

Additional milkweeds in Oklahoma and/or Texas: *Asclepias arenaria, A. brachystephana, A. emoryi, A. glaucescens, A. hirtella, A. incarnata, A. involucrata, A. lanceolata, A. linearis, A. macrotis, A. nummularia, A. obovata, A. prostrata, A. perennis, A. pumila, A. purpurascens, A. rubra, A. scaposa, A. speciosa, A. sperryi, A. subverticillata, A. syriaca, A. texana, A. tomentosa, A. uncialis, A. variegata, A. verticillata.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across both states and are found in roadsides. Less common species might not occur in both states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

ACKNOWLEDGMENTS: Written by Ray Moranz, Jennifer Hopwood, and Stephanie Frischie (Xerces Society), and Alison Cariveau (Monarch Joint Venture). Reviewed by: Kristen Baum, Oklahoma State University; Jason Singhurst, Texas Parks and Wildlife Department. Design, header, and monarch life cycle by Sara Morris (Xerces Society). This work was conducted in the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Academies of Sciences, Engineering, and Medicine.

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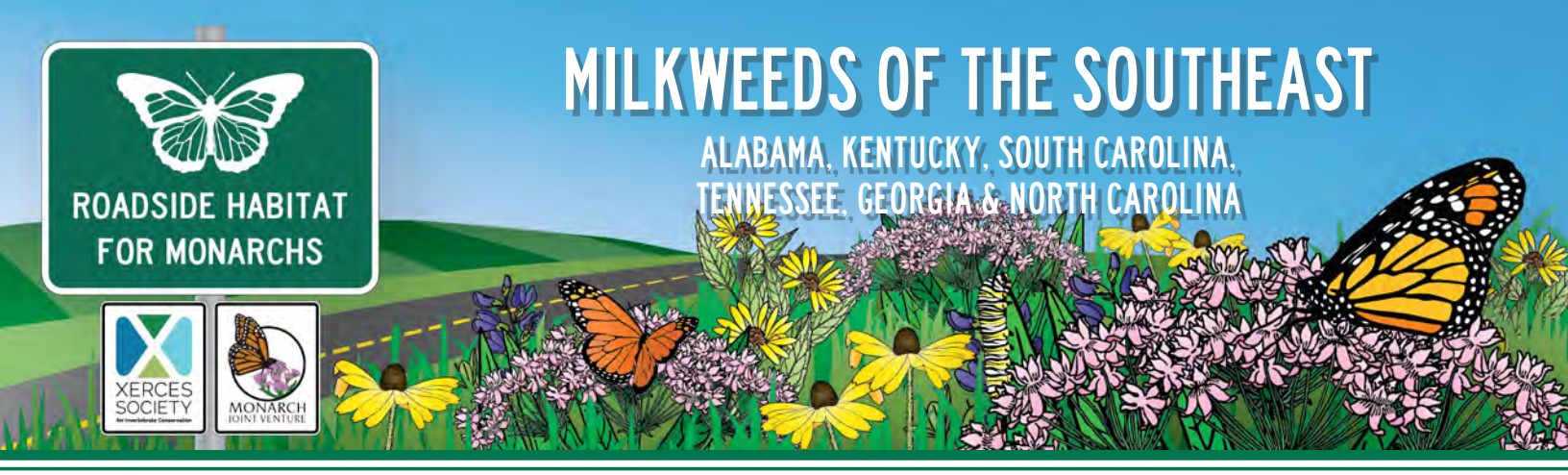
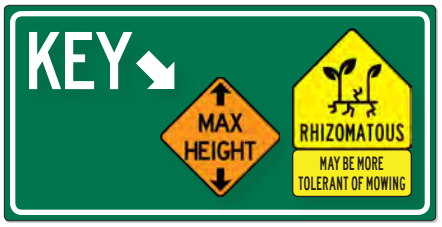


MILKWEEDS OF THE SOUTHEAST

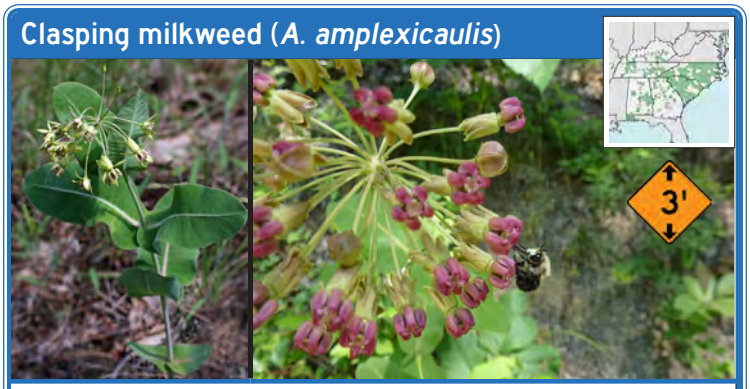
ALABAMA, KENTUCKY, SOUTH CAROLINA, TENNESSEE, GEORGIA & NORTH CAROLINA

Milkweeds (*Asclepias* spp.) are herbaceous perennial plants named for their milky sap. These plants occur in a wide range of habitats, including intact natural communities on roadsides and highly disturbed roadsides. As required host plants for monarch (*Danaus plexippus*) caterpillars, milkweeds play an essential role in the butterfly's life cycle (see reverse). Vegetation management that allows milkweeds to persist can support monarchs. This guide can help you recognize the most common native species found on roadsides in your region.



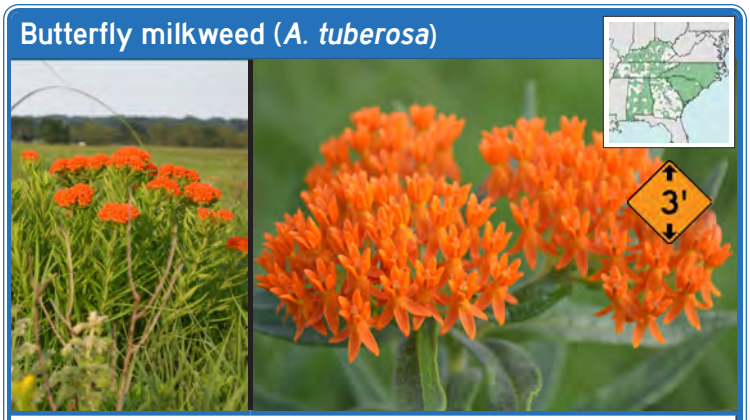
The most common milkweeds in roadsides in the Southeast Region (in alphabetical order):

Clasping milkweed (*A. amplexicaulis*)



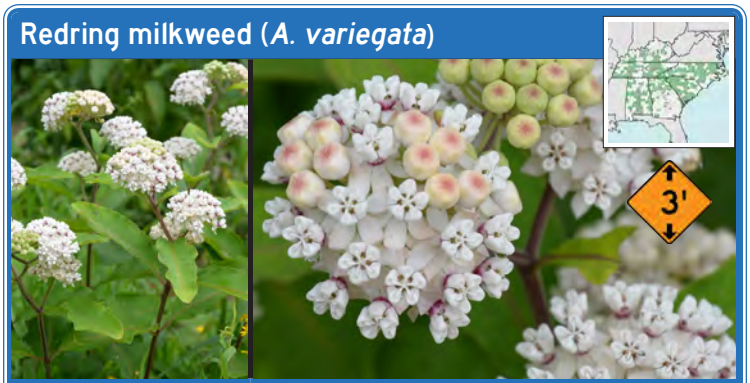
PLANT: Upright, unbranched stems; smooth. **LEAVES:** Opposite; oval-shaped; wavy margins; base of leaves clasp stem. **HABITAT:** Sandhills, grasslands, savannas, woodland edges. **SOILS:** Sandy, gravelly; dry. **BLOOM:** May–Jul; light to dark pink with cream or green; fragrance of cloves and roses.

Butterfly milkweed (*A. tuberosa*)



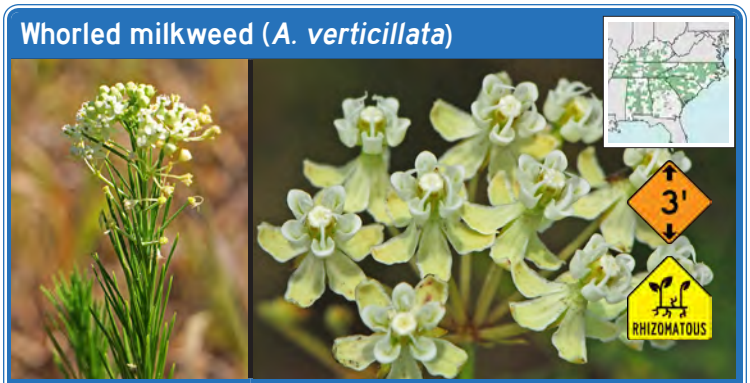
PLANT: One to many spreading to upright stems; with short hairs; lacks milky sap. **LEAVES:** Alternate; lance-shaped; hairy underneath. **HABITAT:** Grasslands, old fields, open woods, pine barrens. **SOILS:** Sandy, loamy, rocky; dry–mesic. **BLOOM:** May–Sep; orange to red or yellow.

Redring milkweed (*A. variegata*)



PLANT: Upright, unbranched stems; purplish-green; usually smooth. **LEAVES:** Opposite; oval-shaped; usually smooth. **HABITAT:** Savannas, rocky woodlands and edges, banks of streams; part shade. **SOILS:** Sandy, rocky, loamy to clay-loam; dry–mesic. **BLOOM:** May–Jul; white or cream, with red or purple ring.

Whorled milkweed (*A. verticillata*)



PLANT: One to several upright, unbranched stems; with short hairs. **LEAVES:** Whorled; narrow to needle-like; smooth or short hairs. **HABITAT:** Grasslands, open woods, disturbed areas, barrens, sandhills, rock outcrops (especially mafic rocks). **SOILS:** Sandy, rocky, clayey; dry–mesic. **BLOOM:** May–Sep; white or cream with green.

(Continued on next page.)

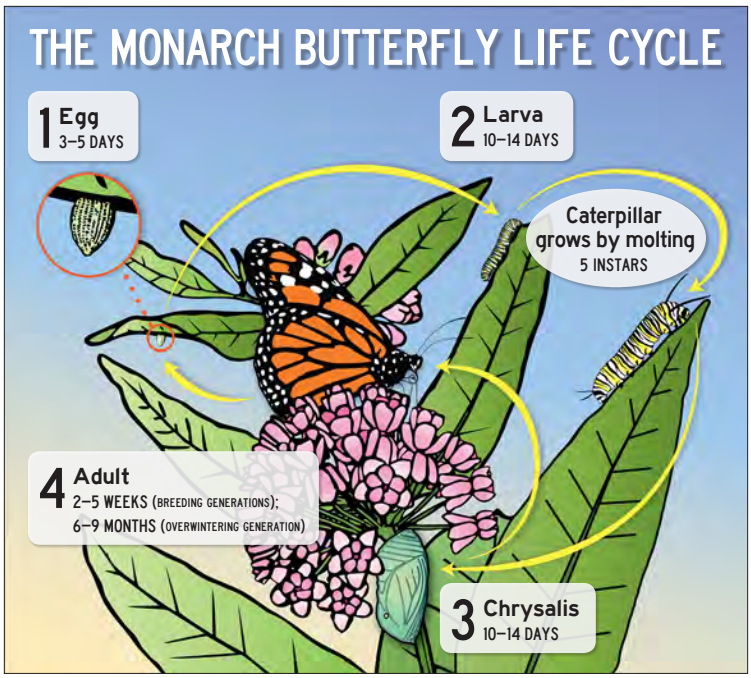
Most common milkweed species *continued*

Green comet milkweed (*A. viridiflora*)

PLANT: Unbranched stems, spreading to upright; with short hairs. **LEAVES:** Opposite; lance-shaped with edges folded upward or wavy; with short hairs. **HABITAT:** Open woodlands, woodland edges, barrens, grasslands, glades (especially over mafic or calcareous rocks). **SOILS:** Sandy to loamy or rocky; dry–dry-mesic. **BLOOM:** May–Aug; light green to yellowish green with pink.

Additional Resources:

- For more information on monarchs and roadsides, including monitoring, visit: tinyurl.com/MJV-Monarchs-Roadsides
- Mowing and Monarchs: tinyurl.com/MJV-MowingForMonarchs
- Xerces Society for Invertebrate Conservation: xerces.org
- Monarch Joint Venture: monarchjointventure.org



Multiple generations of monarchs are produced over the spring and summer, with the fall generation migrating to overwintering sites. You can monitor monarchs or milkweeds; see Additional Resources above.

Less common roadside milkweeds:

Pinewoods milkweed (*A. humistrata*)

PLANT: One to multiple sprawling stems; usually smooth; 3′ max. **LEAVES:** Opposite; oval-shaped; base of leaves clasp stem; purple veins; usually smooth. **SOILS/HABITAT:** Sandy; dry; open woods, sandhills, scrubland, pastures. **BLOOM:** Mar–Jun; pink to white flowers.

Swamp milkweed (*A. incarnata*)

PLANT: One to many upright branched stems; smooth or with short hairs; 5′ max. **LEAVES:** Opposite; lance-shaped or narrow; with sparse short hairs. **SOILS/HABITAT:** Silty, loamy, clayey; moist–wet; grasslands, ditches, edges of lakes, streams. **BLOOM:** Jul–Sep; light to dark pink or rose purple.

Longleaf milkweed (*A. longifolia*)

PLANT: Upright, unbranched slender stem; with few hairs; 3′ max. **LEAVES:** Alternate; narrow and lance-shaped; with few hairs. **SOILS/HABITAT:** Sandy to loamy or loam-clay; wet; pinelands, savannas, swamps. **BLOOM:** May–Jun; dark pink and white, tipped with green.

Common milkweed (*A. syriaca*)

PLANT: One to many stout, upright, unbranched stems; with short dense hairs; 5′ max. **LEAVES:** Opposite; oval-shaped; hairy underneath. **SOILS/HABITAT:** Sandy to loamy, clayey or rocky; dry–wet; grasslands, disturbed areas, railways, edges of lakes, ponds, streams. **BLOOM:** Jun–Aug; pink.

Additional milkweeds in the Southeast: *Asclepias cinerea, A. connivens, A. exaltata, A. hirtella, A. lanceolata, A. michauxii, A. obovata, A. pedicellata, A. perennis, A. purpurascens, A. quadrifolia, A. rubra, A. tomentosa, A. viridis, A. viridula.*

Maps & Distribution Data:

These profiles are derived from regional floras and field guides (e.g., Weakley 2019) and Woodson's *The North American Species of* Asclepias (1954). Most common species are abundant across the states and are found in roadsides. Less common species might not occur in all states, have a limited distribution across a state, or may be less common in roadsides. Additional species may be uncommon in roadsides, have a small distribution in a state or region, or are uncommon or rare. The range maps indicate counties where species have been observed (but may be incomplete), and were created by USDA-NRCS using the latest data from the USDA's PLANTS database (https://plants.sc.egov.usda.gov).

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PHOTO CREDITS: Jim Fowler (*A. syriaca, A. longifolia*); Mary Keim / flickr (*A. humistrata, A. incarnata*); Krista Lundgren, USFWS / flickr (*A. viridiflora*); Jerry Oldenettel / flickr (*A. verticillata*); Karan A. Rawlins, University of Georgia / Bugwood.org (*A. variegata*); Xerces Society / Nancy Lee Adamson (*A. amplexicaulis* [right]); Paul Rothrock / SEINet (*A. amplexicaulis* [left]); Scott Seigfreid (*A. tuberosa*).