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Pollinator Habitat Conservation Along Roadways

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Cover photo: Rusty patched bumble bee (*Bombus affinis*)
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Chapter 1 Introduction

Animal pollinators are central to human wellbeing, agricultural production, global economic health, and the viability of native plant communities and wildlife. Thirty-five percent of global crop production is dependent on pollinators, including 87 of the world's 124 most commonly cultivated crops (Klein et al. 2007). Also, many minerals, vitamins, and nutrients needed to maintain human health come from insect-pollinated crops (Eilers et al. 2011). Pollinators are essential for the reproduction of about 85 percent of all flowering plants (Ollerton et al. 2011) and are critical for wildlife food webs (Kearns et al. 1998; Summerville and Crist 2002).



Mining bees—such as this bee visiting an apple blossom—and other wild pollinators are critical for food production.

Photo Credit: Nancy Lee Adamson/Xerces Society

Insects, including bees, wasps, flies, beetles, butterflies, and moths, are the primary pollinators in much of North America (Allen-Wardell et al. 1998; Kearns 2001), yet a number of insect pollinators are in decline. Pollinators that have undergone troubling and dramatic declines over the past few decades include rare species with narrow habitat needs, as well as formerly common and widespread species like the rusty patched bumble bee (*Bombus affinis*) and the monarch butterfly (*Danaus plexippus*) (Hatfield et al. 2016; Semmens et al. 2016; Schultz et al. 2017). Factors leading to pollinator decline include habitat loss, pesticide use, diseases, parasites, climate change, and the spread of invasive species.

1.1 Why Roadsides Are Important to Pollinators

Threats to pollinators may have profound consequences for ecosystem health as well as our food systems (Kearns et al. 1998; Spira 2001; Steffan-Dewenter and Westphal 2008). Roadsides can help mitigate habitat loss for pollinators.

State departments of transportation (DOTs) manage substantial amounts of land and associated natural resources across North America, including upward of 10 million acres of roadside land in the United States (Forman et al. 2003). These acres hold the potential to create a network of habitats to support pollinators in urban and rural areas. Roadsides can provide habitat for all life stages of a diverse community of pollinators (Hopwood et al. 2015), including imperiled pollinators. Roadsides may also act as corridors for pollinators (see review in Hopwood et al. 2015), connecting remnant habitat patches and aiding pollinators to move through landscapes or expand their ranges.

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Roadsides provide monarch butterflies with food for adults as well as caterpillars.

Photo Credit: John Anderson

In some places, roadsides are home to intact native plant communities that are no longer found in surrounding lands (New et al. 2021). Searching for prairie remnants in some parts of the Corn Belt in the Midwest, for example, often requires scouring roadsides and railroad rights-of-way. In heavily altered landscapes, even those roadsides without intact native plant communities can be the only semi-natural habitat present (e.g., Brown and Sawyer 2012). For some listed or imperiled species of pollinators, roadsides include some of the last remaining patches of their habitat. Widespread species that are struggling, such as the monarch butterfly or the rusty patched bumble bee, are not completely reliant on roadsides habitat, but roadsides are still an important component of their survival (e.g., Thogmartin et al. 2017; Evans et al. 2019).

A number of state DOTs have an interest in managing roadsides to support pollinators (e.g., Hopwood et al. 2016b; National Cooperative Highway Research Program Project 25-59 Conduct of Research Report), but as more species of pollinators become listed or are being considered for listing under the Endangered Species Act (ESA), DOTs also want regulatory certainty. Currently (March 2022), there are 48 pollinating insects listed under the federal ESA (nine bees, 35 butterflies, two moths, one fly, and one beetle). This includes two species that are either a candidate species or proposed for listing, and many more species with declining populations and the potential to be listed. Figure 1-1 shows the number of species that are currently listed or a candidate for listing by region.

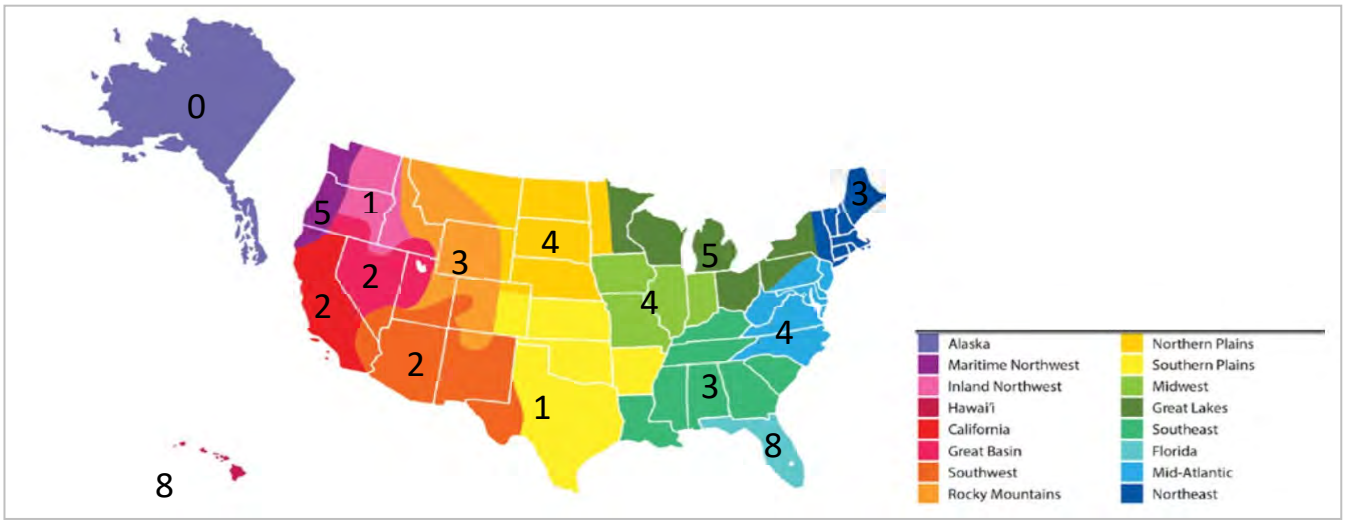


Figure 1-1. Map of the United States, with the number of pollinator species that are currently listed or candidates for listing under the Endangered Species Act (as of March 2022) within each of the 16 regions covered in these guides.

- Alaska: 0
- Maritime Northwest: 5
- Inland Northwest: 1
- Hawaii: 8
- California: 2
- Great Basin: 2
- Southwest: 2
- Rocky Mountains: 3
- Northern Plains: 4
- Southern Plains: 1
- Midwest: 4
- Great Lakes: 5
- Southeast: 3
- Florida: 8
- Mid-Atlantic: 4
- Northeast: 3

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In addition to supporting pollinators, other benefits of healthy roadside vegetation include a safe driving environment, reduced soil erosion, enhanced rainwater infiltration, improved water quality, reduced wind velocity, carbon sequestration, and habitat for a variety of wildlife, including predator and parasitoid insects that reduce crop pests.

1.2 About This Guide

This guide is intended to provide relevant guidance to rights-of-way owners and operators for roadside vegetation management practices that support pollinators, as well as strategies that are compliant with the ESA.

This guide will help DOTs and other entities that manage roadsides understand pollinators generally and imperiled pollinators specifically, and it provides information on how to manage roadsides with the goal of avoiding further declines of these important species, averting the need for them to be listed under the ESA in the future. This guide will also help DOTs make informed management decisions to coordinate ESA compliance with their operations, reduce future regulatory uncertainty, contribute to pollinator conservation and recovery, and increase awareness and the associated societal values for the ecosystem services pollinators provide for agriculture and native ecosystems alike.

This guide is one of 16 guides, one for each region identified based on ecoregions and distributions of pollinators (Figure 1-1). Each guide includes general information applicable across all 50 states as well as region-specific information developed for the habitats and pollinator species expected to occur in and adjacent to roadways of this region. The intended users of this guide are staff from transportation planning, design, construction, maintenance, and environmental disciplines, as well as communication staff.

***Listed species*:** A species listed as endangered or threatened under the federal ESA; the species has been determined to be in danger of extinction in the near or foreseeable future by the U.S. Fish and Wildlife Service.

Candidate species: A species that has been found warranted for listing under the ESA, but whose listing is precluded by higher-priority species.

Proposed species: A species that has been proposed for listing as threatened or endangered under the ESA.

Petitioned species: A species for which a petition to list the species under the ESA has been received and is being evaluated.

Imperiled species: A species that is in decline and may be in danger of extinction. This term includes species that are not legally protected under the ESA.

This guide was informed by review of scientific literature, research reports, and other relevant information, including input from transportation agency practitioners and researchers with expertise on imperiled pollinator species or roadside restoration. This input was obtained through detailed online surveys sent to leading pollinator and roadside revegetation researchers from across the United States and to DOT staff from around the country. Experts were asked to identify the relative benefit of specific conservation actions for imperiled pollinators and provide input on the opportunities for DOTs to implement practices that support pollinators. Participants included researchers from universities, state agencies, consultants, and non-governmental organizations. DOT staff were asked about current practices and potential barriers to implementing additional conservation measures. In total, 70 transportation professionals from DOTs representing agencies from 33 states responded, with 47 percent of respondents self-identifying their expertise within their agency as “Environmental,” 27 percent as “Maintenance,” 13 percent as “Landscape Architecture,” 3 percent as “Construction,” 1 percent as “Planning,” and 9 percent as “Other.”

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This guide includes eleven chapters, some of which have specific audiences and others that may be more broadly of use to transportation officials. Table 1-1 provides an overview of this guide and how it can be used.

Table 1-1. Using this guide.

Chapter	Contents
Chapter 2, Pollinator Biology and Roadsides	This chapter includes background information on pollinator biology, including: • a primer on pollinators and their habitat needs, • pollinator conservation status, and • how pollinators use roadsides.
Chapter 3, Imperiled Pollinator Profiles	This chapter includes profiles of listed, candidate, and imperiled pollinators in this region. The profiles contain: • life history information, • the current range of distribution within the region, • flight times for adults, • larval activity for management timing for butterflies and moths, • important plants, and • guidance to help integrate a species' biology into management plans.
Chapter 4, Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation	This chapter provides: • background on the ESA and • information about strategies for compliance as it relates to imperiled pollinators.
Chapter 5, Considering Imperiled Pollinators in Transportation Planning, Design, and Construction	This chapter discusses when and how pollinators need to be considered in the transportation planning, design, and construction phases of project delivery. It identifies: • opportunities to include pollinator-friendly design elements and • how project design and construction can incorporate measures to avoid and minimize potential impacts on pollinators.

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Chapter	Contents
Chapter 6, Roadside Maintenance and Vegetation Management for Pollinators	This chapter's audience is maintenance staff, planners, or those designing revegetation plans. This chapter provides: • an overview of how vegetation management practices affect pollinators and • region-specific adjustments of practices to better support imperiled pollinators.
Chapter 7, Revegetation and Pollinators: Design and Implementation	This chapter includes: • a guide on how to support imperiled pollinators through revegetation and • detailed regional plant species lists.
Chapter 8, Creating Climate-Smart Pollinator Habitat along Roadsides	This chapter explores ways to increase climate resiliency for pollinators.
Chapter 9, Surveys, Monitoring Strategies, and Habitat Assessments	Surveys can determine the presence of imperiled species, and monitoring can be used to better understand the impacts of practices on pollinators. This chapter includes: • survey and monitoring protocols and • habitat assessment tools to evaluate and prioritize habitat enhancement opportunities.
Chapter 10, Cost-Benefit Considerations for Pollinator Management on Roadsides	This chapter provides: • step-by-step processes to help DOTs make choices about actions that can support imperiled pollinators and • context for balancing the costs of conservation actions with the benefits.
Chapter 11, Communication Support	This chapter includes: • plans for communicating within DOTs as well as with the general public about how individual DOTs are supporting pollinators proactively and • links to videos, recorded presentations, a regional slide set that can be adapted for agencies, and other tools.
Chapter 12, References	This chapter includes bibliographic references for materials cited throughout the document.

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Chapter 2 Pollinator Biology and Roadsides

This chapter provides a brief background on general pollinator biology, the conservation status of pollinators, threats pollinators face, and habitat needs for different groups of pollinators. The habitat needs outlined here are the basis of conservation actions in the chapters that follow. This chapter also includes an overview of roadsides as habitat for pollinators and threats to pollinators associated with roads.

2.1 Why Are Pollinators Important?

Approximately 85 percent of the world's flowering plants depend on animals—mostly insects—to move pollen between flowers, a transfer that is essential for flowering-plant reproduction (Ollerton et al. 2011). Pollinators are critically important for the wildlife food webs that depend upon these plants (Kearns et al. 1998; Summerville and Crist 2002). Fruits, seeds, and nuts—the products of pollination—are food for many insects, birds, and mammals. Pollinators themselves are an important food source for wildlife that feed on insects for a portion or all of their diet. For example, butterfly and moth caterpillars are an important part of the diet of many young birds (Buehler et al. 2002).

Pollinators also play a significant role in agriculture. Of the world's most commonly cultivated crops, 70 percent are dependent on animal pollinators (Klein et al. 2007). Many minerals, vitamins, and nutrients such as vitamin C, calcium, and folic acid needed to maintain human health are found in crop plants that rely on pollinators (Eilers et al. 2011). In addition to production of many fruits, vegetables, spices, nuts, and seeds, pollinators are also important to forage plants like alfalfa and clover that provide feed for livestock. Pollinators contribute about $27 billion annually to the United States economy (Calderone 2012). Pollinators are essential to agricultural production and ecosystem health and are fundamental to human wellbeing.

2.2 Status of Pollinators

The great majority of pollinators in North America are insects, including bees, wasps, flies, beetles, butterflies, and moths (Allen-Wardell et al. 1998; Kearns 2001). Over the last several decades, a number of insect pollinators have steeply declined. Nearly 30 percent of all bumble bee species in North America face some degree of extinction risk (Hatfield et al. 2012), including species that were formerly among the most common (Grixti et al. 2009; Cameron et al. 2011), as do about 20 percent of butterflies (NatureServe 2018). Once common and widespread, even the iconic monarch butterfly (*Danaus plexippus*), known for its impressive long distance migration, has declined by 80 percent east of the Rocky Mountains and more than 95 percent west of the Rocky Mountains (Semmens et al. 2016; Pelton et al. 2019).

As of March, 2022, 47 pollinating insects are listed under the federal Endangered Species Act (ESA)—nine bees, 34 butterflies, two moths, one fly, and one beetle—plus two species of butterflies that are currently candidates or proposed for listing (Table 2-1).

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***Habitat Loss*:** the elimination of a habitat or transformation into another type of habitat.

***Habitat degradation*:** a decline in habitat conditions due to invasive species, pollution, development, or overutilization of natural resources.

***Habitat fragmentation*:** larger habitats are broken up into smaller patches, which may be too small to sustain populations of some species or species are unable to move between patches.

Habitat loss, degradation, and fragmentation can all lead to reductions in numbers of species and declines in populations.

There are also a number of imperiled species with declining populations, and there is a significant potential for more pollinators species to be listed in the coming years. Chapter 3, Imperiled Pollinator Profiles, includes profiles of the listed and candidate pollinators in this region, as well as other imperiled species in the region that have the potential to become listed.

Factors that contribute to insect pollinator declines include:

- the loss, degradation, and fragmentation of habitat (e.g., Kremen et al. 2002; Potts et al. 2010);
- introduced species (e.g., Memmott and Wasser 2002; Tallamy and Shropshire 2009);
- the use of pesticides (e.g., Kevan 1975, 1999; Dover et al. 1990; Baron et al. 2014);
- diseases and parasites (e.g., Altizer and Oberhauser 1999; Cameron et al. 2011; Koch and Strange 2012); and
- climate change (Forister et al. 2010; Warren et al. 2008; IPBES 2016; Glenny et al. 2018; Harvey et al. 2022).

Threats to pollinator communities affect not only pollinators themselves but also natural ecosystems and agricultural productivity.

Table 2-1. List of pollinators protected or proposed for protection by the ESA that occur in the United States as of March 2022.

Scientific name	Common name	Status	Regions Where Currently Found
	BEES		
Bombus affinis	Rusty patched bumble bee	Endangered	Great Lakes, Mid-Atlantic, Midwest, Northeast, Northern Plains, Southeast
Bombus franklini	Franklin's bumble bee	Endangered	California, Maritime Northwest
Hylaeus anthracinus	Anthricinan yellow-faced bee	Endangered	Hawaii
Hylaeus assimulans	Assimulans yellow-faced bee	Endangered	Hawaii

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Scientific name	Common name	Status	Regions Where Currently Found
Hylaeus facilis	Easy yellow-faced bee	Endangered	Hawaii
Hylaeus hilaris	Hilaris yellow-faced bee	Endangered	Hawaii
Hylaeus kuakea	Hawaiian yellow-faced bee	Endangered	Hawaii
Hylaeus longiceps	Hawaiian yellow-faced bee	Endangered	Hawaii
Hylaeus mana	Hawaiian yellow-faced bee	Endangered	Hawaii
BUTTERFLIES			
Anaea troglodyta floridalis	Florida leafwing butterfly	Endangered	Florida
Apodemia mormo langei	Lange's metalmark butterfly	Endangered	California
Boloria acrocnema	Uncompahgre fritillary butterfly	Endangered	Rocky Mountain
Callophrys mossii bayensis	San Bruno elfin butterfly	Endangered	California
Cyclargus thomasi bethunebakeri	Miami blue butterfly	Endangered	Florida
Cyclargus ammon	Nickerbean blue butterfly	Similarity of appearance to a threatened taxon	Florida
Danaus plexippus	Monarch butterfly	Candidate	Lower 48 states
Euchloe ausonides insulanus	Island marble butterfly	Endangered	Maritime Northwest
Euphilotes battoides allyni	El Segundo blue butterfly	Endangered	California
Euphilotes enoptes smithi	Smith's blue butterfly	Endangered	California

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Scientific name	Common name	Status	Regions Where Currently Found
Euphydryas editha bayensis	Bay checkerspot butterfly	Threatened	California
Euphydryas editha quino	Quino checkerspot butterfly	Endangered	California
Euphydryas editha taylori	Taylor's checkerspot butterfly	Endangered	Maritime Northwest
Glaucopsyche lygdamus palosverdesensis	Palos Verdes blue butterfly	Endangered	California
Hemiargus ceraunus antibubastus	Ceraunus blue butterfly	Similarity of appearance to a threatened taxon	Florida
Heraclides aristodemus ponceanus	Schaus swallowtail butterfly	Endangered	Florida
Hesperia dacotae	Dakota skipper	Threatened	Northern Plains
Hesperia leonardus montana	Pawnee montane skipper	Threatened	Rocky Mountains
Icaricia (Plebejus) shasta charlestonensis	Mount Charleston blue butterfly	Endangered	Southwest
Icaricia icarioides fenderi	Fender's blue butterfly	Endangered	Maritime Northwest
Icaricia icarioides missionensis	Mission blue butterfly	Endangered	California
Leptotes cassius theonus	Cassius blue butterfly	Similarity of appearance to a threatened taxon	Florida
Lycaeides argyrognomon lotis	Lotis blue butterfly	Endangered	California
Lycaeides melissa samuelis	Karner blue butterfly	Endangered	Great Lakes, Midwest, Northeast
Lycaena hermes	Hermes copper butterfly	Threatened	California

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Scientific name	Common name	Status	Regions Where Currently Found
Neonympha mitchellii francisci	Saint Francis' satyr butterfly	Endangered	Mid-Atlantic
Neonympha mitchellii	Mitchell's satyr butterfly	Endangered	Great Lakes, Midwest, Mid-Atlantic, Southeast
Oarisma poweshiek	Poweshiek skipperling	Endangered	Great Lakes, Northern Plains
Pseudocopaeodes eunus obscurus	Carson wandering skipper	Endangered	California, Great Basin
Pyrgus ruralis lagunae	Laguna Mountains skipper	Endangered	California
Speyeria callippe	Callippe silverspot butterfly	Endangered	California
Speyeria nokomis	Great Basin Silverspot	Proposed threatened	Southwest
Speyeria zerene behrensii	Behren's silverspot butterfly	Endangered	California
Speyeria zerene hippolyta	Oregon silverspot butterfly	Threatened	California, Maritime Northwest
Speyeria zerene myrtleae	Myrtle's silverspot butterfly	Endangered	California
Strymon acis bartrami	Bartram's hairstreak butterfly	Endangered	Florida
MOTHS			
Euproserpinus euterpe	Kern primrose sphinx moth	Threatened	California
Manduca blackburni	Blackburn's sphinx moth	Threatened	Hawaii
FLIES			
Rhaphiomidas terminatus abdominalis	Delhi Sands flower-loving fly	Endangered	California

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Scientific name	Common name	Status	Regions Where Currently Found
BEETLES			
Desmocerus californicus dimorphus	Valley elderberry longhorn beetle	Threatened	California

2.3 Meet the Pollinators

This guide focuses solely on invertebrate pollinators, due to their widespread importance. North America does have some vertebrate pollinators, including nectar-feeding bat species found in the southwestern United States (*Leptonycteris yerbabuenae, Choeronycteris mexicana*) and hummingbirds (family Trochilidae) (Grant 1994; Valiente-Banuet et al. 2004); those species are not covered in this guide. The primary groups of insect pollinators are bees, butterflies, and flower-visiting moths, wasps, beetles, and flies (see Figure 2-1). Bees are particularly efficient and effective pollinators because all adult females actively collect pollen to bring back to their nest to provide for their young, and bees are considered the most important group of pollinators for agricultural crops (McGregor 1976; Garibaldi et al. 2013) as well as for many wild plants in temperate climates (Michener 2007).

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Bumble bees
Order: Hymenoptera
Family: Apidae
Genus: *Bombus*
Bumble bees form annual social colonies. Queen bumble bees, mated the previous fall, start nests in spring. By mid-summer, colonies can have dozens or hundreds of workers (Figure 2-2). They nest in insulated cavities such as under clumps of bunch grass or in old rodent nests.
There are species of bumble bees that are nest parasites of other bumble bees. These cuckoo bumble bees invade an established colony, kill the queen, and lay eggs that the host colony then rears.



Ground-nesting bees
Order: Hymenoptera
Families: Andrenidae, Apidae, Colletidae, Halictidae
Most native bees live solitary lives, with each female working alone to build her nests and collect and provide food for her offspring. About 70 percent of solitary bee species nest underground, digging slender tunnels off which they build cells for each egg and its provisions.



Tunnel-nesting bees
Order: Hymenoptera
Families: Apidae, Colletidae, Halictidae, Megachilidae
Approximately 30 percent of solitary bee species nest in tunnels, inside already hollow stems or chewing into the pithy center of stems, or in existing holes, sometimes man-made. Most tunnel-nesting bees are solitary species.

Photo Credit: Jennifer Hopwood, Xerces Society

Figure 2-1. Photo gallery of the main groups of insect pollinators.

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Butterflies
Order: Lepidoptera
Families: Papilionidae, Hesperiidae, Pieridae, Lycaenidae, Nymphalidae
With their striking transformation from a chubby plant-chewing caterpillar to a delicate pupa to a graceful nectar-drinking winged adult (Figure 2-3), butterflies are some of the most beloved insects. Some species have narrow host-plant needs for their caterpillars, while others feed on a wide variety of plants.



Flower-visiting moths
Order: Lepidoptera
Families: Sphingidae, Noctuidae, Arctiidae
Moths, which are often subdued in color and tend to fly at dusk or night, are less visible than other groups, but several are important specialist pollinators of wild plants. Moths as a group form a critical food source for wildlife.



Flower-visiting flies
Order: Diptera
Families: Syrphidae, Tachinidae, others
Flower-visiting flies consume nectar and sometimes pollen. Many hover flies (in the family Syrphidae) resemble bees or wasps in coloration. Larvae of some species are voracious predators of small insects (including crop pests), like aphids.



Flower-visiting wasps
Order: Hymenoptera
Families: Sphecidae, Vespidae, Tiphiidae, Scoliidae, others
Predatory wasps, most of which are solitary, hunt for prey (including crop pests) to bring to their nest as food for their carnivorous young. They build nests in cavities or in the ground and may use pieces of grass, mud, or resin in nest construction. Adults maintain their energy by consuming nectar, and in the process may also transfer pollen between flowers.

Photo Credit: Jennifer Hopwood, Xerces Society
Figure 2-1 (continued)

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Flower-visiting beetles
Order: Coleoptera
Families: Cantharidae, Coccinellidae, Scarabaeidae, others
Flower-visiting beetles consume nectar and pollen and may also chew on flower parts. Larvae of some species are predatory, hunting other insects (including crop pests) as food, while others are herbivorous or are decomposers.

Photo Credit: Jennifer Hopwood, Xerces Society
Figure 2-1 (continued)

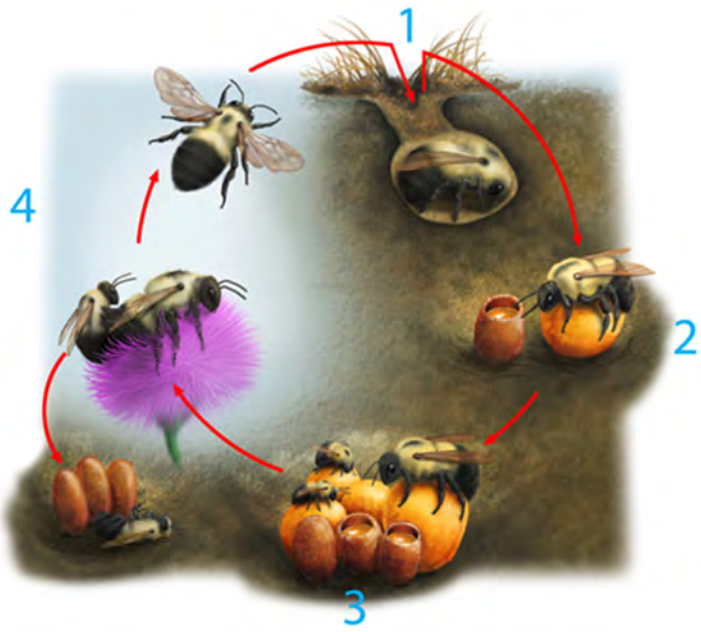


Image Credit: David Wysotski/Allure Illustration

Figure 2-2. Although most bee species native to the United States are solitary, with each female building and provisioning her own nest, bumble bees form small social colonies.

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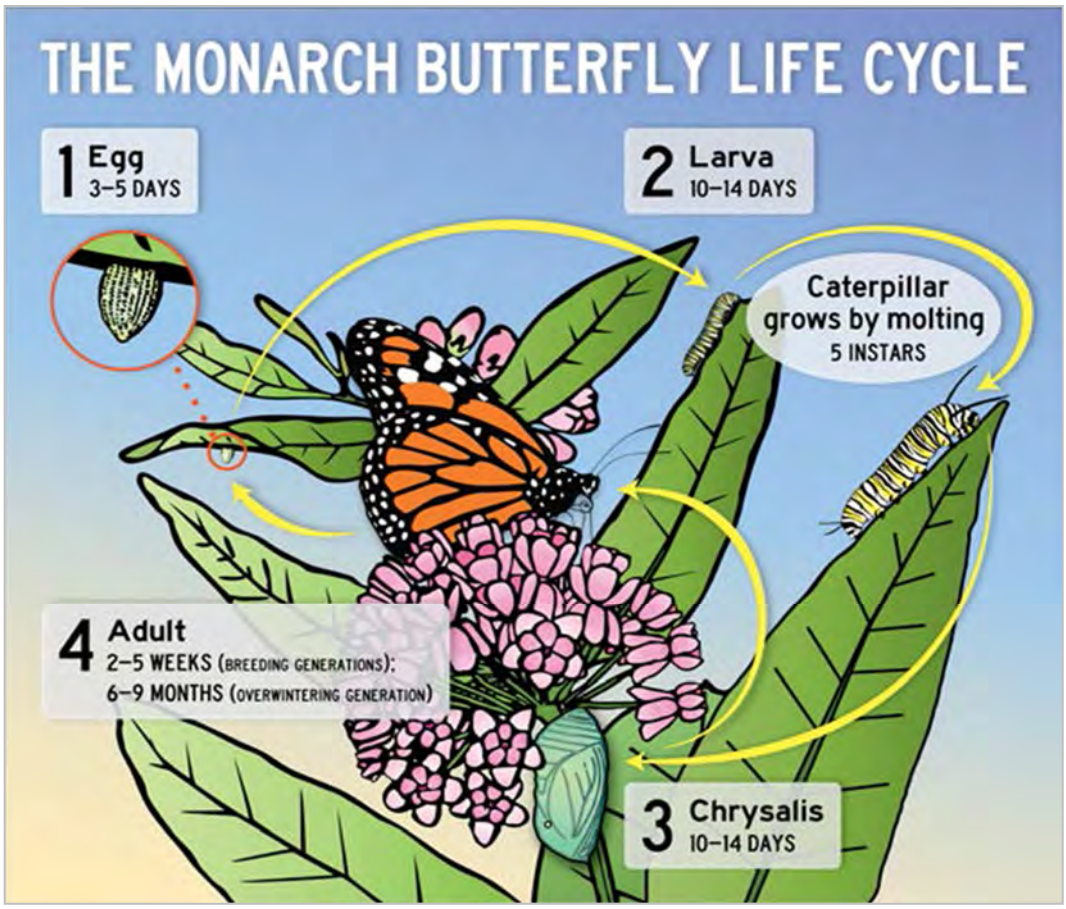


Image Credit: Sara Morris/Xerces Society.

Figure 2-3. The main groups of insect pollinators (bees, beetles, flies, moths, wasps, and butterflies, including the monarch butterfly, the life cycle shown here) all have four distinct life stages: egg, larva, pupa, and adult. These life stages, particularly the larvae and adult, may occur in different habitats.

2.3.1 Honey Bees

The western honey bee (*Apis mellifera*) is the most widely known bee species worldwide, due to its long relationship with humans. Native to Europe, Africa, and Asia, the western honey bee was first domesticated early in human history, thousands of years ago, for the harvesting of honey. Western honey bees are not native to North America; hives were first introduced by European settlers in the 1600s (Engel et al. 2009). The western honey bee lives in large social colonies (hives) of up to 20,000 individuals, with division of labor within the colony. Only the queen bee reproduces, while several generations of her daughters gather nectar and pollen to feed and rear brood and store food (honey) for the winter. Honey bees have increasingly been managed for commercial crop pollination since the 1950s, with beekeepers bringing hives temporarily to agricultural fields or orchards to increase the density of pollinators. Though western honey bees are the most important managed crop pollinator species in the United States. (Morse and Calderone 2000), the species is not the

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only pollinator involved in crop pollination. Many species of native, wild, and unmanaged bees, as well as some other insects like flower flies, play a critical role in crop pollination as well (Garibaldi et al. 2013).



Honey bees, though beloved, familiar, and important in commercial crop pollination, can transmit disease and put considerable competitive pressure on native pollinators.

Photo Credit: David Cappaert

Because honey bees are such a familiar species, they can be a way to introduce new audiences to pollination and the role pollinators play in our lives and in our world. Honey bees have frequently been in the news in recent years as colony losses are occurring at a rate that is unsustainable for beekeepers due to pathogens, pesticides, poor nutrition, and other problems associated with industrial agriculture (Shanahan 2022). However, honey bee losses are often viewed as an environmental concern, rather than an agricultural issue, in part because honey bees are not often viewed as the widely distributed livestock animal that they are. Although beekeepers are losing colonies, they are able to replace them every year and treat some of their health problems through management (though at a cost). Honey bees are still extremely numerous, with millions of hives managed by beekeepers in the United States. (National Agricultural Statistic Service, United States Department of Agriculture 2019); they are not in any danger of disappearing from the planet. Honey bees can be a "gateway species" in some instances, but concern will not always spill over to the native species that are actually in need of conservation (Geldmann and Gonzalez-Varo 2018). For this reason, it is important to recognize and emphasize that there are many pollinators other than honey bees.

Honey bees also pose potential risks to native pollinators and their associated landscapes. The foraging habits of honey bees, the amount of pollen and nectar that they consume, their interactions with native bees, and their high level of pathogen loads can all negatively affect native pollinators and plant communities. One estimate of honey bee resource use found that a standard apiary with 40 hives removes pollen that would otherwise support four million wild bees (Cane and Tepedino 2017). Honey bees put considerable competition pressure on native pollinators; for example, when honey bee densities increased, competition for floral resources forced a decline in two species of bumble bees (Thomson 2016). Competition from honey bees can also reduce wild pollinator visitation to native plants, thus reducing pollination and reproduction, while increasing the spread of some invasive flowering species that honey bees preferentially visit (Goulson 2003; Magrach et al. 2017). Honey bees can also transmit diseases to native bees through interactions on shared flowers (Singh et al. 2010; Furst et al. 2014). Pathogens are one of the several forces behind the declines of some imperiled species (e.g., rusty patched bumble bee).

Because honey bees have the potential to negatively affect native species, caution should be taken when considering the placement of honey bee hives in or near habitat that supports imperiled or listed pollinator species.

2.4 Pollinators and Roadsides

As pollinators have declined in the United States, there is increased interest in managing existing habitat or creating additional habitat to support pollinators (National Research Council 2007). Roadsides are some of the most extensive networks of linear habitats in the

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United States, and they extend across urban as well as rural landscapes. In some highly altered landscapes, roadsides are the only natural vegetation that remains (e.g., New et al. 2021). Pollinator diversity can be high in roadsides, with communities that include a significant portion of the species found in the region (Ries et al. 2001; Hopwood 2008; Noordijk et al. 2009). Roadsides can be home to rare species as well as common species (Munguira and Thomas 1992; Ries et al. 2001). They can support pollinators through a portion of their life cycle, or species may live their entire lives on roadsides. Specifically, roadsides provide pollinators with a place to find food, reproduce, and take shelter or overwinter, and they can increase habitat connectivity. In addition to supporting pollinators and flowering plants, roadsides also provide a number of other services, including support carbon sequestration; regulate air, water, and soil; enhance aesthetics and safety for drivers; and showcase regional beauty (Phillips et al. 2020).



In addition to providing pollen and nectar for adults, flowering plants that grow on roadsides can also serve as host plants for caterpillars of butterflies and moths. The common milkweed that is growing on this Maryland roadside supports monarch butterfly caterpillars.

Photo Credit: Lisa Kuder

2.4.1 Roadsides Provide Food for Pollinators

Nectar and Pollen Sources

Adults of bees, butterflies, wasps, and many species of flies, moths, and beetles feed on nectar to maintain their energy levels. Some adult beetles and flies require the protein that pollen provides in order to reproduce. Flowering plants in roadsides are important sources of nectar and pollen for pollinators that reside within the roadside habitat (e.g., Munguira and Thomas 1992) as well as those that use the roadside as a partial habitat for foraging but reproduce or overwinter elsewhere (e.g., Ouin et al. 2004).

Native plants are particularly important to pollinators. Native plants are more attractive as sources of pollen and nectar for pollinators than nonnative plants, and they support more species and more individuals, even when both plant types are present at sites (Williams et al. 2011; Morandin and Kremen 2013) because the native species of plants are those that pollinators have evolved to depend on. Some species of native plants are particularly attractive to a wide range of pollinators, offering large quantities of nectar, high-quality nectar, or pollen with high protein content. Native plants are particularly important for imperiled pollinators, which may need specific sources of pollen and nectar. Roadsides with native wildflowers support a greater number of individuals and species of butterflies and bees compared with those dominated by nonnative grass and flowers (Ries et al. 2001; Hopwood 2008).

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Host Plants

Butterflies and moths lay their eggs on plants on which their caterpillars (larvae) will feed upon after hatching; these plants are known as host plants. Some butterflies and moths have specific host-plant needs, relying on plants of a single genus or even a single species of host plant. For example, caterpillars of the Karner blue butterfly (*Lycaeides melissa samuelis*) will only survive feeding on sundial lupine (*Lupinus perennis*). Other species may exploit a wide range of plants, feeding on trees, shrubs, grasses, or wildflowers. Establishing caterpillar host plants is recognized as a way to sustain butterfly and moth populations (Croxton et al. 2005; Feber et al. 1996). Roadsides with host plants can support habitat generalist butterflies as well as habitat specialists and migrant species such as the monarch butterfly (e.g., Ries et al. 2001).

Native plants are important host plants, often preferred by butterflies and moths over nonnative species. For example, native woody plants used as ornamentals in the eastern United States support fifteen times more native butterflies and moths than do introduced species of ornamental plants (Tallamy and Shropshire 2009). Research has shown that adding nonnative plants to landscapes does not increase butterfly and moth diversity or abundance (Burghardt et al. 2010), and nonnative plants can reduce bird populations as a consequence of reduced insect availability as food (Narango et al. 2018).

Nonnative plant: A plant introduced by humans, whether on purpose or accidentally, to a new place or new habitat where it did not previously grow.

Invasive plant: A nonnative plant that establishes and grows quickly on many sites, spreading wildly and disrupting plant communities or ecosystems. Invasive plants can cause economic or environmental harm or harm to human health.

Noxious plant: A plant that can directly or indirectly injure or cause damage to crops, livestock, poultry or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment. Note: The U.S. Department of Agriculture Animal and Plant Health Inspection Service maintains a list of federally recognized noxious weeds, and each state also has its

2.4.2 Roadsides Provide Shelter and Overwintering Habitat

Woody vegetation outside of the recovery zone, such as trees and shrubs, can provide cover during the growing season that can serve as shelter for pollinators and can provide niches for overwintering. Some pollinators will overwinter under bark or in the soil just under shallow roots, or in piles of brush. Grasses can provide shelter for a variety of pollinators, most notably for butterflies on roadsides (Saarinen et al. 2005), and the root systems and grass thatch serve as overwintering habitat.

Bees and predatory wasps provide for their young by constructing and provisioning nests in which their offspring develop. Some species of bees nest underground, while others nest in tunnels or within insulated cavities (Table 2-2). Nesting is a critical factor affecting the ability of bees to persist within a site (Winfree 2010; Menz et al. 2011; Morandin and Kremen 2013).



About 70 percent of bee species in the United States nest underground. Nests may be as shallow as a few centimeters from the surface or may be as deep as three feet or more.

Photo Credit: Jennifer Hopwood, Xerces Society



Tunnel-nesting bees will build their nests in existing tunnels in hollow plant stems or old beetle borer tunnels, while others will excavate pithy stems, as seen here, to create their tunnel nest.

Photo credit: Sara Morris/Xerces Society

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Table 2-2. Nesting habitat for bees.

Bee Groups by Nesting Habit	Example Groups	Nesting Locations	Habitat Needs
Ground-nesting bees	Sweat bees, miner bees, longhorn bees	Nests are excavated in the soil, so these bees need access to the soil surface. Some species will nest in a variety of soils, while others have very specific requirements for the soil type, moisture, alkalinity, slope, and aspect (Cane 1991).	Openings in scrub or forest habitat can promote ground-nesting bees. Bunch grasses tend to offer better nesting habitat than sod-forming grass species. Roadsides with native bunch grasses have more nesting opportunities for ground-nesting bees and, consequently, a greater abundance of these bees (Hopwood 2008).
Tunnel-nesting bees	Leafcutter bees, mason bees	Nest in hollow stems or excavate pithy stems (e.g., elderberry or cane fruits) in plant or in tunnels in wood, such as abandoned beetle tunnels in logs, stumps, and snags (Michener 2007).	Where site-appropriate, planting native wildflowers with pithy stems—such as cupplant (*Silphium perfoliatum*), ironweeds (*Vernonia* spp.), and sunflowers (*Helianthus* spp.), along with shrubs such as wild rose (*Rosa* spp.), elderberry (*Sambucus* spp.), sumac (*Rhus* spp.), yucca (*Yucca* spp.), or agave (*Agave* spp.)—will provide resources for stem-nesting bees.
Cavity-nesting bees	Bumble bees	Nest in social colonies in insulated cavities, such as underneath grass clumps (Svennson et al. 2000), under the thatch of bunch grasses, in wood piles, or under rocks (Hatfield et al. 2012).	Mowing and grazing can have negative impacts on bumble bee colonies (Hatfield et al. 2012). If a colony is destroyed via mowing mid-growing season, no queens will be produced, which can lower population levels the following year.

Pollinators also need a place in which to overwinter during the dormant season. Syrphid fly species and soldier beetles overwinter in roadside soil or litter (Schaffers et al. 2012). Butterflies and moths also use roadsides as overwintering habitat (Schaffers et al. 2012), though a few species travel long distances to overwinter as adults in warmer locations (e.g., monarch butterflies).

2.4.3 Roadsides Provide Landscape Connectivity

As habitat fragmentation increases, landscape connectivity is becoming more important to the conservation of many species, including pollinators (Saunders et al. 1991; Haddad 1999; Haddad and Baum 1999). Roadsides have the potential to act as corridors—strips or patches of habitat that serve as stepping stones to connect larger patches of habitat— that facilitate movement between habitat fragments, aid in establishing or maintaining populations, and increase species diversity within isolated areas (Tewksbury et al. 2002; Ottewell et al. 2009).

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Roadsides extend across a variety of landscapes and often contain greater plant diversity than adjacent lands. The linear shape and connectivity of roadsides can help pollinators move through the landscape (Soderstrom and Hedblom 2007; Daniel-Ferreira et al. 2022a), either in search of food or in pursuit of new habitat (Lövei et al. 1998; Ries et al. 2001; Valtonen and Saarinen 2005; Hopwood et al. 2010). Additionally, several pollinator species have expanded their ranges along roadsides (Dirig and Cryan 1991; Brunzel et al. 2004). Corridors like roadsides and other linear strips of vegetation such as utility rights-of-way may enhance climate resiliency for pollinators as climate change causes shifts in species ranges. (See Chapter 8 for more information.)

Due to their mobility, pollinators have the ability to use partial habitats, habitats that may have one or more components for their survival but not all. For example, bumble bees may nest in one location but forage for food in another. Similarly, an imperiled butterfly might lay eggs on its host plant on a roadside but seek nectar elsewhere.

2.4.4 Risks to Pollinators from Roads

Roadsides present many conservation opportunities for pollinators, though roads can also pose certain risks. Roads can be a source of mortality for pollinators due to collisions with vehicles, and roadside vegetation is exposed to vehicle pollution. On roadsides, dense stands of invasive plants reduce pollinator abundance and diversity, and certain types of vegetation management can cause mortality or influence the resources available for pollinators.

Vehicle Mortality

Collisions with vehicles are a source of mortality for pollinators that use resources in roadsides as well as pollinators traveling through the landscape (McKenna et al. 2001; Baxter-Gilbert et al. 2015; Keilsohn et al. 2018). Mortality rates of butterflies using roadside vegetation range from 0.6 to 7 percent of the population of the butterflies found on the roadside (Munguira and Thomas 1992; Ries et al. 2001; Skórka et al. 2013), which is lower than the rates of butterflies killed by natural enemies like predators and parasites (Munguira and Thomas 1992). A review of studies on first instar larval Lepidopterans found high rates of mortality from natural enemies and other factors that varied widely from 40–95% (Zalucki et al. 2002).



Vehicles can be a source of mortality for pollinators; however, mortality rates tend to be lower when roadside plant diversity is high.

Photo Credit: Jeff Norcini

Some species of pollinators are more vulnerable to collisions than others due to their behavior or biology. Butterflies that mud-puddle on rural gravel roads to obtain minerals and water may have higher mortality rates (Campioni et al. 2022), while butterflies that are strong fliers appear to have lower rates of mortality than those that are not (Munguira and Thomas 1992; Ries et al. 2001; Skórka et al. 2013). However, migratory species may have increased risks due to vehicle collisions. More monarch butterflies are killed due to vehicle collisions during fall migration compared to other parts of their migratory cycle, for example (Kantola et al. 2019). As monarchs funnel through Texas on their way to overwintering grounds in Mexico, there are hotspots of mortality due to vehicle collisions. There are relatively few hotspots but those may kill approximately 2 million

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monarchs per year; hotspots occur in places that are important migratory crossing locations that are constrained to cross roads in Texas and Mexico (Kantola et al. 2019; Tracy et al. 2019; Mora Alvarez et al. 2019). Temporarily reducing traffic speed, closing outer lanes, and using netting alongside the road in mortality hotspots during key times in butterfly migration are techniques that have significantly reduced mortality rates of another migratory butterfly in Taiwan (Yang Ping-shih, personal communication.)

Traffic volume may also influence rates of mortality (Skórka et al. 2013; Daniel-Ferreira et al. 2022b). For example, queen bumble bees were more often killed on roads with higher traffic intensity, although mortality was slightly lower along roadsides with higher-quality vegetation (Daniel-Ferreira et al. 2022b). On the other hand, several studies have found that traffic volume does not consistently influence observed butterfly mortality (McKenna et al. 2001; Saarinen et al. 2005). Road width may also influence butterfly response to roads; wider roads may increase mortality rates (Skórka et al. 2013).

Additionally, vegetation quality can influence pollinator mortality; roadsides with more species of plants had fewer butterflies killed by traffic (Skórka et al. 2013; Skórka et al. 2015). Improving vegetation quality can reduce road crossings (Polic et al. 2014; Ries et al. 2011). The frequency of mowing is also linked to a higher proportion of butterflies killed on roads. Butterflies that had to disperse to find new habitat after roadsides were mowed may have had a greater likelihood of collisions with vehicles (Skórka et al. 2013). Reducing mowing during peak seasonal butterfly activity can increase butterfly numbers (Halbritter et al. 2015).

Steps to ameliorate the impacts of vehicle collisions on pollinators can include:

- increasing roadside plant diversity and
- reducing mowing beyond the mown strip in the recovery area (also known as the clear or safety zone, the band of low growing or routinely mowed vegetation directly adjacent to the pavement or shoulder where vehicles that have left the roadway can recover; Figure 2-4).

The available science indicates that the benefits of supporting pollinators on roadsides outweigh the costs (Philips et al. 2020), but, when possible, road impacts on imperiled pollinators should be mitigated to reduce threats to local populations.

Development of a landscape connectivity map may also be helpful to prioritize locations for high-quality revegetation projects with goals of supporting pollinators (see Chapter 9 for a pollinator habitat assessment guide that can be used to help prioritize locations). It is also worth considering focusing first on sites that are not in areas with a dense network of roads where habitat is fragmented, as some butterflies have decreased movement between sections of roadsides that are not connected to other roadsides (Valtonen and Saarinen 2005).

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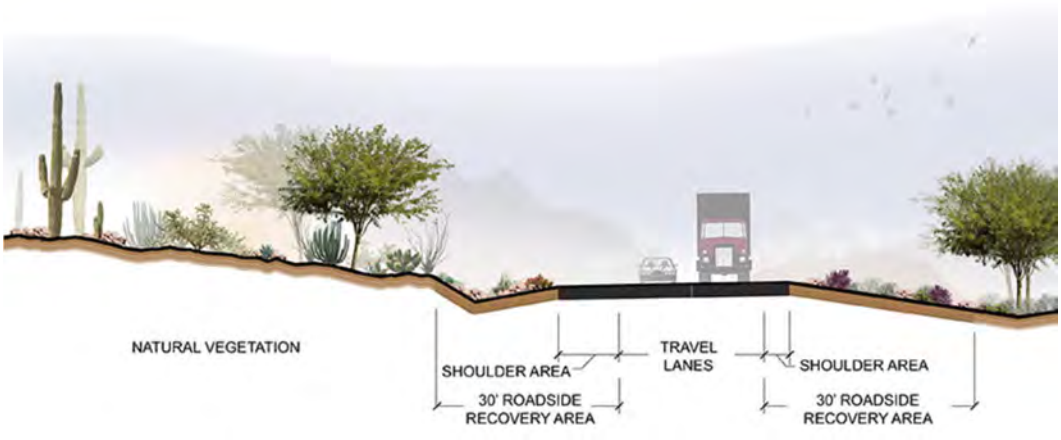


Image Credit: Arizona Department of Transportation

Figure 2-4. Recovery areas on a rural interstate road. A recovery area is free of obstruction and the width is determined by the type of road and traffic volume, as well as the slope of the embankment.

Roadside Contamination and Pollutants

Routine vehicle use and maintenance of roads contribute to roadside vegetation contamination by depositing pollutants, including vehicle exhaust and de-icing materials. Roadside soils and vegetation can be contaminated with heavy metals—such as lead, iron, zinc, copper, cadmium, and nickel—deposited from tire rubber, brake dust, and gasoline and diesel combustion products (Gjessing et al. 1984; Oberts 1986; Araratyan and Zakharyan 1988). Vehicle-derived contamination is proportional to traffic levels (Leharne et al. 1992; Mitchell et al. 2020). In general, plant and soil contamination is greatest adjacent to the road and decreases with distance from the road, usually declining significantly within 20 meters (Quarles et al. 1974; Dale and Freedman 1982; Jablonski et al. 1995; Swaileh et al. 2004). Pollen and nectar contamination is also greatest nearest to the road (Jablonski et al. 1995).



Plant diversity can reduce pollinator exposure to heavy metals. Plants such as the purple prairie clover (*Dalea purpurea*) and the yellow coneflower (*Ratibida pinnata*) growing on this Colorado roadside uptake heavy metals at different amounts.

Photo Credit: Jason Roth/CDOT

Few studies have examined the impacts of heavy metal exposure in roadsides on pollinators. One study in Minnesota found elevated levels of lead in roadside soils, but not in leaves of roadside plants, meaning pollinators would not be exposed to the elevated levels by consuming plant parts (Mitchell et al. 2020). Plants that grew closer to the road edge along busier roadsides had elevated levels of zinc in their leaves, but higher concentrations of zinc in plants did not appear to increase higher concentrations of zinc in the caterpillars that consumed the plants (Mitchell et al. 2020). In Britain, heavy metal pollution was highest and pollinator activity was reduced within 2 meters of the road (Phillips et al. 2021). Different plant species uptake heavy metals at different rates, with some taking up more (e.g., *Ratibida pinnata*) and others taking up

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smaller amounts (e.g., *Dalea purpurea*) (Emilie Snell-Rood, personal communication). Plant diversity can therefore be a buffer against heavy metal exposure.

Dry deposition of particles with nitrogen derived from fuel combustion can create a strip of "fertilized" soil along roadsides, particularly in more arid regions (Gade 2013). Busier roads are linked to increased nitrogen in roadside plants (Cape et al. 2004). Higher nitrogen content in leaves can attract insect herbivores, but it is unknown whether caterpillars are more abundant within higher nitrogen areas in roadsides.

De-icing salts used on roads alter roadside soil chemistry by increasing sodium levels in soil and plant tissues significantly (Snell-Rood et al. 2014; Mitchell et al. 2020). At high levels, salts can damage some plants (Bogemans et al. 1989), which may indirectly affect pollinators by altering or removing their food sources. Sodium levels in plants can directly affect caterpillars consuming vegetation. Varying levels of sodium in butterfly host plants can affect development of caterpillars in both positive and negative ways. Sodium is an important micronutrient for butterflies, and moderate levels of sodium can increase flight muscle and brain size of adults. However, too much sodium can be toxic (Snell-Rood et al. 2014). Soil and leaf sodium levels are higher close to the road edge and on roads with more traffic (Mitchell et al. 2020). However, sodium levels only reach lethal levels in 1 percent of roadside plants in Minnesota (Mitchell et al. 2020).

Invasive Species

Many invasive and noxious plants can be present in roadsides (Tyser and Worley 1992; Gelbard and Belnap 2003) due to favorable conditions for plant introductions and invasions (Hansen and Clevenger 2005; Von der Lippe and Kowarik 2007). Noxious and invasive plants can decrease the quality of roadside habitat for pollinators (Hopwood 2008; Valtonen et al. 2006), compete with native plants for resources, and alter habitat composition. Some cause significant reductions in the abundance and diversity of pollinators and other herbivorous insects (Samways et al. 1996; Kearns et al. 1998; Spira 2001; Memmott and Wasser 2002; Zuefle et al. 2008; Burghardt et al. 2009; Tallamy and Shropshire 2009; Wu et al. 2009; Hanula and Horn 2011; Fiedler et al. 2012). Noxious and invasive plants can spread to nearby properties and affect working lands. They can also alter wildfire cycles, increasing the frequency of burns over native vegetation (e.g., Balch et al. 2012).

A number of native insects will feed on noxious and invasive plants when few natives are available (Zuefle et al. 2008; Burghardt et al. 2009; Wu et al. 2009; Williams et al. 2011). Monarch butterflies, for example, will nectar on Canada thistle (*Cirsium arvense*). Despite potential use by pollinators, the threat that noxious and many invasive weeds pose to landowners adjacent to roadsides, to pollinators themselves, and to biodiversity overall is much greater than the benefits of using invasive species. Canada thistle, for example, only blooms for a short period of time, providing a temporary pulse of nectar, as compared to the season-long resources that would be available through a diverse plant community.

It is not realistic to remove all nonnative plant species from roadsides, nor is it always possible to remove some invasive species due to limited resources and time. State departments of transportation (DOTs) may prioritize controlling certain invasive species that are more problematic than others. However, noxious and invasive species do not need to be retained solely as a method to support pollinators.

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Vegetation Management

The management of roadside vegetation can have a significant impact on pollinators. Mowing vegetation beyond the mown strip in the recovery area multiple times a growing season, for example, can cause direct mortality to pollinators in the egg or larval stages (Humbert et al. 2010; Steidle et al. 2022); can deprive pollinators of sources of pollen, nectar, and host plants for larvae (Johst et al. 2006); and can destroy bumble bee colonies (Hatfield et al. 2012). However, the timing and frequency of mowing can be adjusted to substantially reduce the impacts on pollinators (e.g., Halbritter et al. 2015), as can adjustments to other management techniques. For additional information about vegetation management and strategies that can support pollinators, see Chapter 6, Roadside Maintenance and Vegetation Management for Pollinators.

Balancing Risks with Conservation Opportunities

There are risks to pollinators from roads, such as mortality from traffic. However, available evidence suggests that the benefits of roadsides to pollinators far outweigh the costs (Phillips et al. 2020). Roadsides often have vegetation not found in the surrounding landscape, and roadsides can be enhanced through management or revegetation to provide quality habitat for pollinators. Adjusting management of roadside vegetation can be effective, and DOTs can strategically enhance roadside vegetation across the road network to promote connectivity and prioritize sites with the greatest capacity to benefit pollinators (Phillips et al. 2020).

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Chapter 3 Imperiled Pollinator Profiles

The Northeast region, including Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and parts of New York, is home to a diverse assemblage of pollinators. In this region, there are two species listed under the federal Endangered Species Act (ESA), including the rusty patched bumble bee (*Bombus affinis*), the first bumble bee covered by the ESA, and one candidate species as of March 2022. However, there are many imperiled pollinators in this region that are not protected by the ESA. This section provides profiles of ESA-listed and -candidate pollinator species found in the Northeast region, as well as imperiled pollinators that have the potential to be listed in the future based on NatureServe rankings and expert opinion (Table 3-1). The profiles of imperiled species not listed under the ESA include two imperiled bumble bees and three imperiled butterflies. This is not an exhaustive list of all declining pollinators in the region; the focus is on species in need of conservation that have a broad distribution and those that are more likely to affect Departments of Transportation (DOTs).

An overview of the basic biology of bees, butterflies, and other insect pollinators can be found in Chapter 2. This section presents information on life history, distribution, threats, and habitat requirements for imperiled pollinators in this region. Information on known adult flight times (i.e., the breeding period) and larval active times (for butterflies and moths; larval bees live within nests) are included. The profiles also include a list of important plants that are used by each species as host plants or for pollen and/or nectar. Some of these plants are nonnative species or noxious weeds. These species are included in the profiles, as the information may be useful, but using them in revegetation efforts is not recommended (see Chapter 7 for more). Some basic conservation recommendations and information on the effects of roadside management on each species are also provided, when such information is available. Insects generally tend to be less well studied than vertebrates; therefore, very little is known about the biology and habitat requirements of some of these species. Other pollinator species may be better studied, but rigorous studies of the effects of different management practices on the species or their habitat may still be lacking. The best possible recommendations are made based on the available information. The profiles provide information on life cycles, host plants, habitat needs, and adult flight times that can be used to tailor maintenance and revegetation decisions (Chapters 6 and 7). General active times for adults and larvae are also provided. It should be noted that active times may shift regionally, such as with elevation or latitude, or from year to year with changes in climate. However, consultation with local experts, as well as biologists from state and federal agencies, is recommended to help DOTs develop meaningful management plans for species of interest in their areas, because the profiles cannot capture the site-specific nuances that should be considered.

As the profiles indicate, habitat loss is a primary driver of species' declines. Roads can be a source of habitat fragmentation (Box 5-3). However, with investments in high-quality revegetation (revegetation that prioritizes usage of native plants and high plant diversity, including an abundance of flowering plants that provide pollen and nectar or act as host plants for butterflies) where appropriate, roadsides can also provide an ideal opportunity

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to increase habitat connectivity for many species, including pollinators. It is important to note that although some of the species profiled in this section may be unlikely to use roadside habitat for breeding, individuals may still use roadside habitat for nectar or pollen or as movement corridors. Therefore, it is worthwhile to invest in high-quality habitat restoration projects along roadsides near natural areas, preserves, and populations of imperiled species. Another common threat to many imperiled butterflies in the United States is noxious and invasive plants that displace required host plants. Here again, investing in high-quality habitat restoration using native plants can benefit imperiled pollinators, even if those pollinators are not using roadside habitat, by helping to slow the spread of invasive plants into key habitat areas. This section includes profiles of pollinator species that may not occur in roadside habitat, but may be found in other DOT land holdings, such as mitigation areas.

Table 3-1. List of profiled imperiled pollinator species in the Northeast region.

Scientific Name	Common Name	Status[#]
ESA-Listed Pollinator Species		
Bombus affinis	Rusty patched bumble bee	Endangered
Danaus plexippus	Monarch butterfly	Candidate
Lycaeides melissa samuelis	Karner blue butterfly	Endangered
Declining Pollinator Species		
Bombus fervidus	Yellow bumble bee	G3G4
Bombus terricola	Yellow-banded bumble bee	G3G4
Callophrys irus	Frosted elfin butterfly	G2G3
Erynnis persius persius	Persius duskywing	G5T1T3
Hesperia leonardus	Leonard's skipper	G4

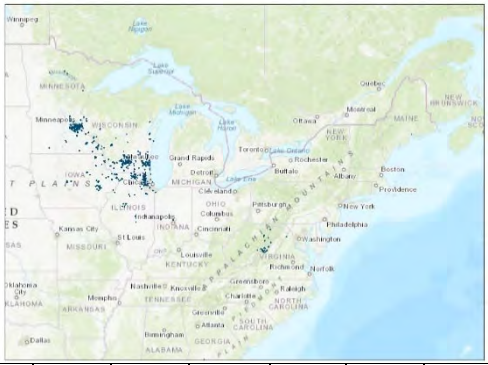
[#] Status of pollinators is either the ESA status for listed species or is taken from NatureServe (accessed March 2022) for species not listed under the ESA.

- G1: Critically Imperiled. At very high risk of extinction due to extreme rarity (often five or fewer populations), very steep declines, or other factors.
- G2: Imperiled. At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
- G3: Vulnerable. At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
- G4: Apparently Secure. Uncommon but not rare; some cause for long-term concern due to declines or other factors.
- G5: Secure. Common; widespread and abundant.
- G#G#: Range Rank. A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community.
- T#: Infraspecific Taxon (for subspecies or varieties). The status of infraspecific taxa is indicated by a "T-rank" following the species' global rank. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1.

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3.1 Rusty Patched Bumble Bee (*Bombus affinis*)





	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult												

Adult rusty patched bumble bee (top left) and known distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Rich Hatfield/The Xerces Society. Map Source: ecos.fws.gov, accessed March 2022.



Order: Hymenoptera

Family: Apidae

Status: Endangered

Distribution: Once common throughout the northeastern United States, this species has experienced severe decline in range and relative abundance. Since 1997, this species has typically been observed in very low numbers in the Midwest.

Where it occurs: forest, grassland, urban

Flight time: This species is typically active on the landscape from late April to mid-October. Between late October and early April, queens are overwintering in the ground.

How to recognize: This bumble bee has black hairs of the face and a yellow thorax with a black circle in the center. The first two segments of the abdomen are yellow; workers and males often have a rusty-colored patch on the second segment.

Body size: Large. Queens range from 12 to 23 millimeters (0.75 to 0.92 inch) and workers range from 9 to 16 millimeters (0.37 to 0.64 inch).

Habitat needs: Availability of food and nesting resources are key features in determining the success of a bumble bee colony. It is critical to maintain a bloom of floral resources throughout the spring, summer, and fall to supply bumble bees with a diversity and abundance of food.

Top reasons for decline, if known: There are multiple factors affecting bumble bee decline, including habitat loss, pesticide exposure, climate change, pathogens, and parasites, as well as the introduction of nonnative species. The greatest threat contributing to the decline of this species is likely the commercial rearing and shipping of bumble bees, which spread pathogens and parasites, and increased competition for resources.

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General conservation recommendations: Preserve, restore, and create high-quality habitat that includes suitable nesting, foraging, and overwintering sites throughout a species' range. Assess and mitigate risk of pesticide use in or near suitable habitat to avoid treating flowers in bloom or contaminating nesting and overwintering sites. Avoid the introduction of managed honey bees and managed bumble bees to areas of natural habitat to protect and minimize disease exposure.

Roadside management recommendations: Intensive mowing may deplete floral resources and potentially disturb species that have nested above ground in the roadside. Reduced mowing frequency would alleviate this problem. In areas likely to contain *B. affinis*, avoid mowing from April through October to avoid harming nests. Use a diversity of plants in revegetation to ensure multiple species are in bloom from spring through fall. Blanket spraying of herbicides can affect the health of bumble bees in the area by reducing floral resources. When managing weeds in *B. affinis* habitat, replace weeds that provide pollen and nectar with flowering plants.

A recent study of roadside mortality of bumble bee queens in Sweden found that bumble bee queens used roadsides with both high plant diversity and low plant diversity in similar proportions when looking for nests. Queen mortality increased with traffic volume but was slightly lower along roadsides with higher quality vegetation. The authors recommend improving habitat quality along roadsides, and keeping a mown buffer strip next to the road to reduce queen mortality.

Table 3-2. Plants used by bumble bees.

Species Name by Bloom Period	Common Name	Notes
Early		
Anemone spp.	Anemones	Multiple colors; perennial
Geranium maculatum	Spotted Geranium	Purple; perennial
Dicentra spp.	Bleeding hearts	White/pink; perennial
Hydrophyllum spp.	Waterleaf	White/purple; perennial
Lupinus perennis	Sundial Lupine / Wild Lupine	White/purple; perennial
Penstemon hirsutus	Hairy Beardtongue	White /purple; perennial
Tradescantia virginiana	Virginia Spiderwort	Purple; perennial
Mid		
Agastache	Giant hyssops	White/pink/purple; perennial
Baptisia australis	Blue Wild Indigo	Blue/purple; perennial
Eupatorium spp.	Snakeroots	White; perennial

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Monarda spp.	Bee balm	Pink/purple/red; perennial
Monarda fistulosa	Bee Balm / Wild Bergamot	Purple; perennial
Pycnanthemum tenuifolium	Narrowleaf Mountain Mint	White; perennial
Rudbeckia laciniata	Cutleaf Coneflower	Yellow; perennial
Veronicastrum	Veronicastrum	White/pink/blue; perennial
Late		
Cirsium discolor	Field Thistle	Pink/purple; biennial
Eutrochium spp.	Joe Pye weeds	Pink/purple; perennial
Eutrochium maculatum	Spotted Joe Pye Weed	Pink; perennial
Solidago spp.	Goldenrods	Yellow; perennial
Solidago nemoralis	Gray Goldenrod	Yellow; perennial
Symphyotrichum novae-angliae	New England Aster	Purple; perennial

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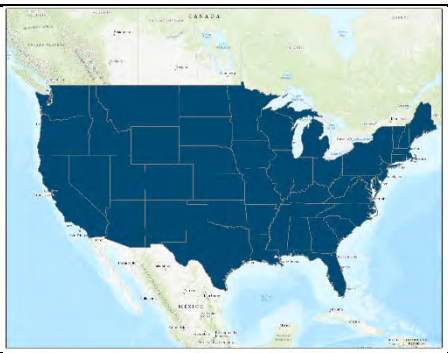
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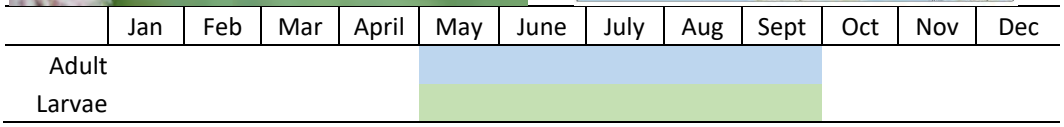
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3.2 Monarch Butterfly (*Danaus plexippus*)







Adult monarch (top left) and monarch distribution within the U.S. (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for monarchs in this region are shown in the chart (bottom). Adult and larval active times vary regionally; see figure 3-1 for regionally specific suggested management windows. Photo credit: Jennifer Hopwood.

Order: Lepidoptera

Family: Nymphalidae

Status: Candidate

Distribution: As of 150 years ago, the monarch was restricted to southern Canada, the lower 48 states, Mexico, Central America, and northwestern South America. In recent years the species has spread or been introduced to other areas including Spain, Hawaii, Australia, and New Zealand.

Where it occurs: Between May and October, it is possible to find monarchs in any county of the Northeast. These monarchs are part of the eastern population of monarchs that migrates to central Mexico in the fall.

How to recognize: Orange and black monarchs are larger than most butterflies with similar coloration. In contrast to the species that most closely resembles monarchs—viceroys—monarchs lack the black line crossing the middle of each hind wing. Behaviorally, monarchs tend to glide more than most other butterfly species. They lack the steady, rapid wingbeat of the great spangled fritillary (*Speyeria cybele*), for instance.

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Life cycle: Each year, monarchs from Mexico (and possibly from Florida and the Southeast) arrive in the Northeast in May or June, and they breed in these states until August or early September (Figure 3-1). In September and early October, they migrate southward, with numbers being particularly high at coastal sites such as Cape May, New Jersey. When breeding, females lay eggs on host plants. It is possible that small numbers of northeastern monarchs migrate in the fall to Florida or the Southeast rather than Mexico.



Monarch butterfly larvae

Photo Credit: Ray Moranz/The Xerces Society

Habitat needs: Although monarchs tend to avoid dense hardwood forests, they use most terrestrial and wetland ecosystems in the region, as long as those ecosystems have milkweeds and some nectar sources. This includes roadsides: monarchs lay eggs on the multiple milkweed species (such as *Asclepias tuberosa* and *A. syriaca*) that thrive on roadsides, as well as on *A. incarnata* that thrive in roadside ditches, marshes, and swamps.

Top reasons for decline, if known: Loss and degradation of overwintering and breeding habitat; loss of habitat via conversion to row crop agriculture and urban development; use of herbicides that kill milkweeds and nectar sources; inadequate habitat management (not enough or too much disturbance, or disturbances poorly timed); use of insecticides that kill monarchs or cause negative but sublethal effects.

General conservation recommendations: Given the migratory nature of the eastern population of the monarch, its survival is dependent on actions throughout the range of the eastern population. In the Northeast, monarchs can be helped through planting of native milkweeds and nectar sources, control of invasive species, and implementation of proper habitat management practices, including well-timed prescribed burning and mowing.

Roadside management recommendations: Frequent mowing will likely harm monarchs, especially if it occurs during their breeding season (late May through late August in most of the Northeast). Frequent mowing will also harm the plants upon which they depend. However, mowing in winter and a single mowing in mid-summer can help maintain open conditions needed for host plants and nectar sources to thrive.

Table 3-3. Plants used by monarch butterfly.

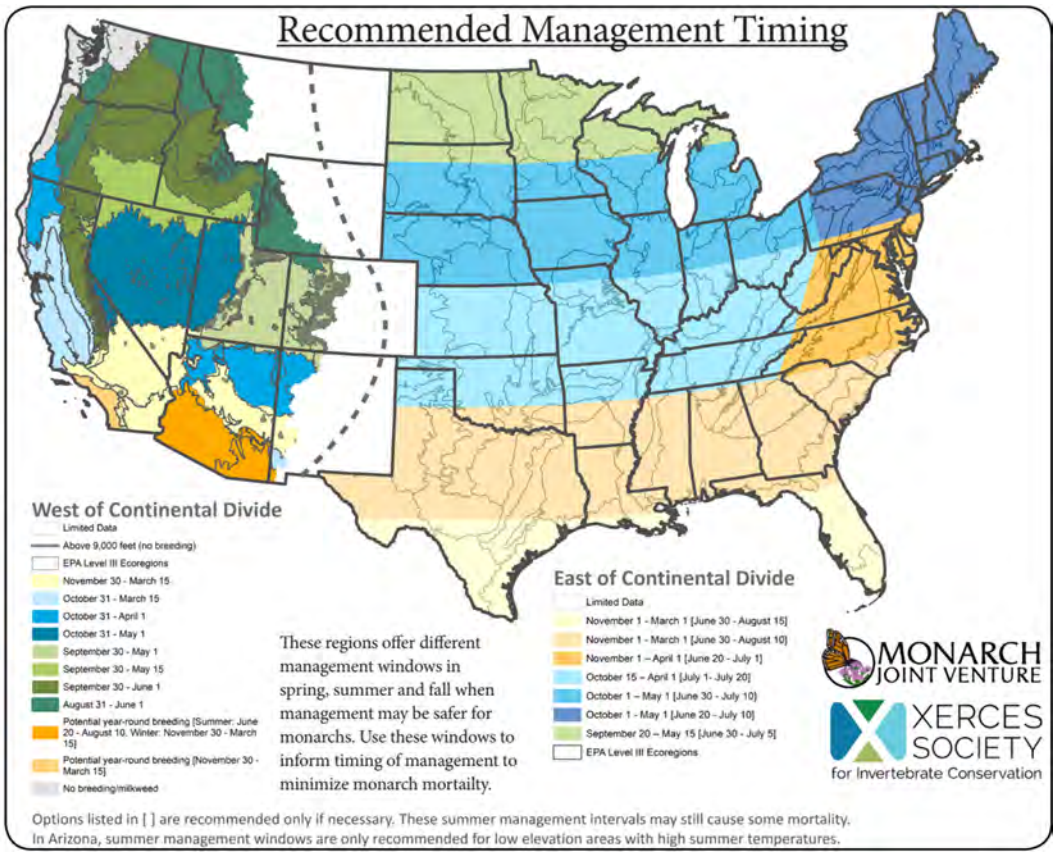
Species Name	Common Name
Larval Host Plants	
Asclepias amplexicaulis	Clasping milkweed
Asclepias exaltata	Poke milkweed
Asclepias incarnata	Swamp milkweed
Asclepias quadrifolia	Fourleaf milkweed
Asclepias syriaca	Common milkweed
Asclepias tuberosa	Butterfly milkweed

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Species Name	Common Name
Asclepias viridiflora	Green comet milkweed
Multiple other *Asclepias* spp.	Milkweeds
Nectar Plants	
Asclepias spp.	Milkweeds
Baccharis halimifolia	Eastern baccharis
Cephalanthus occidentalis	Buttonbush
Cirsium spp.	Thistles[1]
Euthamia graminifolia	Flat-top goldenrod
Eutrochium spp.	Joe Pye weeds
Liatris spp.	Blazingstars
Monarda fistulosa	Wild bergamot
Pycnanthemum spp.	Mountain mints
Solidago spp.	Goldenrods
Symphyotrichum spp.	Asters
Vernonia spp.	Ironweeds[1]

[1] This genus includes native and nonnative species; some of the nonnative species are invasive

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Taken from handout created by Monarch Joint Venture and The Xerces Society: https://monarchjointventure.org/images/uploads/documents/MowingForMonarchsUpdated.pdf.

Figure 3-1. Management timing windows for monarchs in the United States.

Roadside milkweed guides:

- Milkweeds of the Northeast: https://xerces.org/publications/fact-sheets/roadside-habitat-for-monarchs-milkweeds-of-northeast

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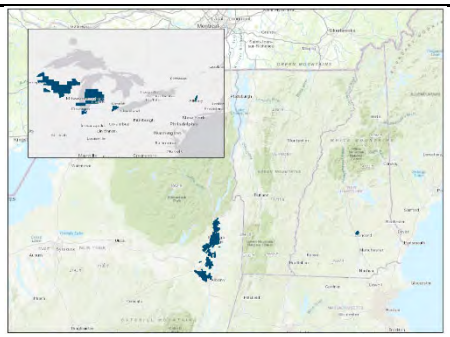
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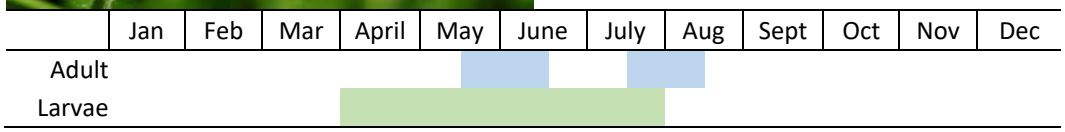
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3.3 Karner Blue Butterfly (*Lycaeides melissa samuelis*)







Adult Karner blue butterfly (top left) and known distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this this region are shown in the chart (bottom). See Life Cycle for more. Photo credit: Joel Trick/USFWS. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera

Family: Lycaenidae

Status: Endangered

Distribution: Illinois, Indiana, Michigan, Minnesota, New Hampshire, New York, Ohio, Wisconsin

Where it occurs: This species is found in openings in oak savannas, pine-oak savannas, and pine barrens. This species can also sometimes be found in sand dunes and dry prairie habitats with lupines.

How to recognize: These are small butterflies, with a wingspan of up to 1.25 inches. In males, the upper sides of the wings are blue or purplish with a black border and white fringe. In females, the upper sides of the wings are more brown and have a row of black and orange spots along the bottom of the hind wings. In both sexes, the undersides of the wings are grayish with black spots.

Life cycle: This species is bivoltine, with two generations per year. Adult flight time runs from late May to mid-June for the first generation and from mid-July through early August for the second generation. Larvae feed on lupine leaves, flowers, buds, and fruit and can be found from April through June for the first generation and from June through July for the second generation. This species overwinters in the egg stage and may be tended by ants.

Habitat needs: This species uses lupines as the host plant. Lupines are not the preferred nectar plants, but some first-generation adults will nectar from lupines. This species will take nectar from a variety of plants (Table 3-3). Lack of nectar sources in late summer can make a site unsuitable for the Karner blue. Karner blues also require sites with some shade.

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Top reasons for decline, if known: Habitat loss and fragmentation, which have led to small population sizes and greatly reduced genetic variability; habitat degradation. Climate change may play a role in current and future declines through phenological mismatches and extreme weather events.

General conservation recommendations: Protect and restore habitat. Large stretches of habitat are likely needed to save this species. Establish corridors for adults to move through and maintain forest openings for the host plant to grow in. Fire and/or mowing could be used to maintain habitat but should be done with care to avoid harming individuals and should be conducted in a way that leaves some areas unburned.

Roadside management recommendations: Avoid mowing in April through August when butterflies are active. Reduce mowing frequency outside the clear zone to increase the abundance of floral resources. Avoid using herbicide on host plants and nectar plants. Efforts should be made to control or eradicate nonnative lupines in roadside habitat where Karner blue butterflies and their native lupines occur.

Table 3-3. Plants used by Karner blue butterfly[1].

Species Name	Common Name
Larval Host Plants	
Lupinus perennis	Wild lupine
Nectar Plants	
Phlox pilosa	Prairie phlox
Coreopsis lanceolata	Sand coreopsis
Krigia biflora	False dandelion
Ceanothus americanus and other *Ceanothus* spp.	New Jersey tea
Lithospermum spp.	Stoneseeds
Arabis lyrata	Lyrate rockcress
Potentilla simplex	Common cinquefoil
Rubus spp.	Blackberry[2]
Asclepias spp.	Milkweed
Centaurea maculosa	Spotted knapweed[3]
Erigeron strigosus	Prairie fleabane
Euphorbia corollata	Flowering spurge
Melilotus alba	Sweetclover[3]
Monarda punctata	Spotted beebalm

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[1] This species specializes on wild lupine, but uses a wide variety of plants for nectar. This is a partial list of nectar plants used by this species.
[2] This genus includes native and nonnative species; some of the nonnative species are invasive.
[3] Nonnative.

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3.4 Bumble Bees: Yellow Bumble Bee (*Bombus fervidus*) and Yellow-Banded Bumble Bee (*B. terricola*)

Order: Hymenoptera

Family: Apidae

Habitat needs: Availability of food and nesting resources are key features in determining the success of a bumble bee colony. It is critical to maintain a bloom of floral resources throughout the spring, summer, and fall to supply bumble bees with a diversity and abundance of pollen and nectar, food for adults and larvae. Bumble bees nest above, on, or under the ground, utilizing pre-existing insulated cavities such as rock piles, areas of

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dense vegetation (e.g., bunch grasses), or old bird nests or mouse burrows. See Table 3-4 for a list of plants used by bumble bees.

Top reasons for decline, if known: There are multiple factors affecting bumble bee decline including habitat loss, pesticide exposure, climate change, pathogens, and parasites, as well as the introduction of nonnative bee species.

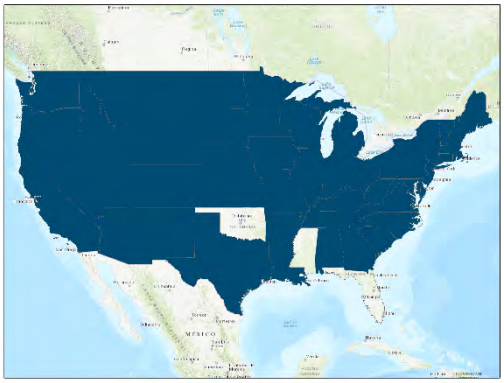
General conservation recommendations: Preserve, restore, and create high-quality habitat that includes suitable nesting, foraging, and overwintering sites throughout a species' range. Assess and mitigate risk of pesticide use in or near suitable habitat to avoid treating flowers in bloom or contaminating nesting and overwintering sites. Avoid the introduction of managed honey bees and managed bumble bees to areas of natural habitat to protect and minimize disease exposure.

Roadside management recommendations: Intensive mowing may deplete floral resources and potentially disturb species that have nested above ground in the roadside. Reduced mowing frequency would alleviate this problem. In areas with aboveground nesting species, avoid mowing during the nesting season to avoid harming nests. Use a diversity of plants in revegetation to ensure multiple species are in bloom from spring through fall. Blanket spraying of herbicides can affect the health of bumble bees in the area by reducing floral resources.

A recent study of roadside mortality of bumble bee queens in Sweden found that bumble bee queens used roadsides with both high plant diversity and low plant diversity in similar proportions when looking for nests. Queen mortality increased with traffic volume but was slightly lower along roadsides with higher quality vegetation. The authors recommend improving habitat quality along roadsides, and keeping a mown buffer strip next to the road to reduce queen mortality.

3.4.1 Yellow Bumble Bee (*Bombus fervidus*)





	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult												

Adult yellow bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Katie Lamke/The Xerces Society.

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Status: Vulnerable to apparently secure (G3G4)

Distribution: Widespread across the United States, except for the south-central and southeastern states.

Where it occurs: Grassland, urban, forest, shrubland

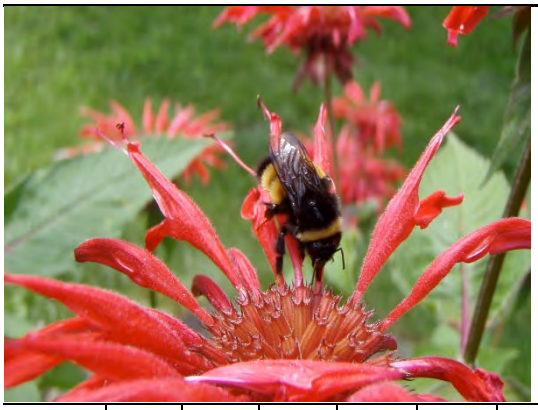
Flight time: This species is typically active on the landscape from May through September. Between late October and April, queens are overwintering in the ground.

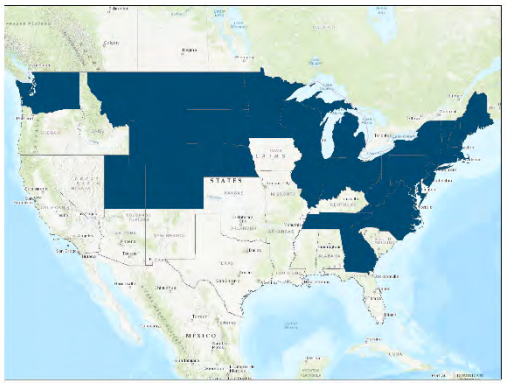
Nesting behavior: Nests on the surface or aboveground; occasionally nests underground.

How to recognize: This bumble bee has black hair on the face; a yellow thorax with a narrow, black band between the wings; and a predominantly yellow abdomen with a black posterior end. Males may have different color patterns.

Body size: Medium. Queens range from 18 to 21 millimeters (0.72 to 0.84 inch) and workers range from 11 to 17 millimeters (0.42 to 0.67 inch).

3.4.2 Yellow-banded Bumble Bee (*Bombus terricola*)





	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult												

Adult yellow-banded bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Leif Richardson.



Status: Vulnerable to apparently secure (G3G4); petitioned to be listed under the ESA, but not listed

Distribution: Northeastern half of the United States in temperate and boreal forest areas; also found at high elevations in the Appalachians and Mountain West.

Where it occurs: Woodlands, wetlands

Flight time: This species is typically active on the landscape from late May through early September. Between October and early May, queens are overwintering in the ground.

Nesting behavior: Nests underground.

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How to recognize: This bumble bee has black hair on the face and a yellow band in front of the wings on the thorax. The abdomen has a thick yellow stripe between black bands; the fifth segment near the rear usually has pale/brown hairs. Males may have different color patterns.

Body size: Medium. Queens range from 19 to 21 millimeters (0.73 to 0.84 inch) and workers range from 10 to 15 millimeters (0.39 to 0.57 inch).

3.4.3 References

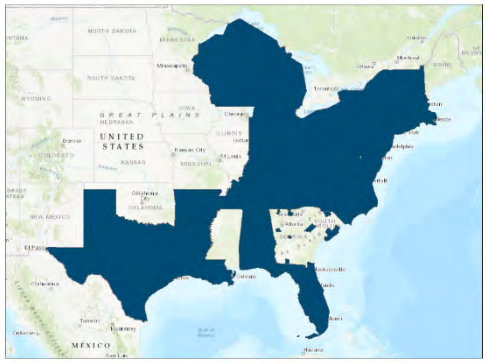
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3.5 Frosted Elfin Butterfly (*Callophrys irus*)





	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult												
Larvae												

Adult frosted elfin butterfly (top left) and known distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this this region are shown in the chart (bottom). See Life Cycle for more. Photo credit: Tom Murray/Flickr Creative Commons. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera

Family: Lycaenidae

Status: Imperiled to vulnerable (G2G3). Very rare in most of the states where it was historically found, and continuing to decline recently in most states. This species was petitioned for listing under the ESA but was not listed.

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Distribution: The historic range was from Texas east to Florida and north to Ontario and Maine. However, it is believed to have been extirpated from Illinois, Maine, and Ontario. Currently known to occur in Alabama, Arkansas, Connecticut, Delaware, Florida, Georgie, Indiana, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Vermont, Virginia, West Virginia, and Wisconsin.

Where it occurs: In the Northeast, populations remain in Massachusetts, New Hampshire, Connecticut, and Rhode Island. It occurs in open areas (e.g., savannas, woodlands, powerline rights-of-way) but only when the host plants are also present.

How to recognize: Small, brown butterfly with intricate patterns similar to congeners such as the Henry's elfin, but distinguished from them by a small, dark spot on the ventral surface near the forewing apex.

Life cycle: A single brood per year, with adults flying from mid-April through early June. Females lay eggs on the flowers and flower buds of host plants, and larvae eat those plant parts. Larvae take about 5 to 6 weeks to reach the pupal stage, which is spent under litter or just below the soil surface until they emerge as adults the next spring.

Habitat needs: Appears to require savannas and open woodlands with large populations of their host plants. *Lupinus perennis* is the primary host plant used in New Hampshire, whereas *L. perennis* and *Baptisia tinctoria* are used in Massachusetts. The host plant used in Connecticut is unknown.

Top reasons for decline, if known: Loss of habitat due to conversion of native ecosystems to urban and suburban development, row crop agriculture, and intensive forestry. Altered fire regimes are also believed to be a major cause of decline.

General conservation recommendations: Protect existing sites with habitat from conversion to other land uses. Implement good habitat management practices, including occasional well-timed prescribed burning or mowing to keep habitat open. Protect habitat from insecticides or broadcast spraying of herbicides.

Roadside management recommendations: Frequent mowing will likely harm frosted elfins and the plants upon which they depend; however, occasional mowing can help maintain the open conditions needed for host plants and nectar sources to thrive. Reduce mowing frequency beyond the clear zone and try to avoid mowing in spring through summer when adults and larvae are active. When mowing at other times of year, setting mowing height to approximately 4 inches will avoid damaging pupae at the soil surface. Avoid spraying host plants and nectar plants (Table 3-4) with herbicides.

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Table 3-4. Plants used by frosted elfin butterfly.

Species Name	Common Name
Larval Host Plants	
Baptisia tinctoria	Yellow wild indigo
Lupinus perennis	Sundial lupine
Nectar Plants	
Lupinus perennis	Sundial lupine
Viola spp.	Violets
Pycnanthemum spp.	Mountain mints
Vaccinium spp.	Blueberries
Rubus spp.	Blackberries[1]

[1] This genus includes native and nonnative species; some of the nonnative species are invasive.

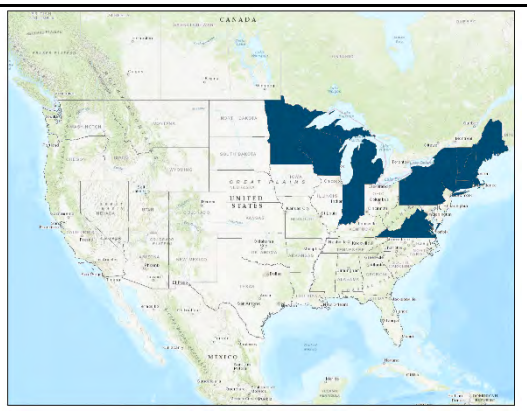
3.5.1 References

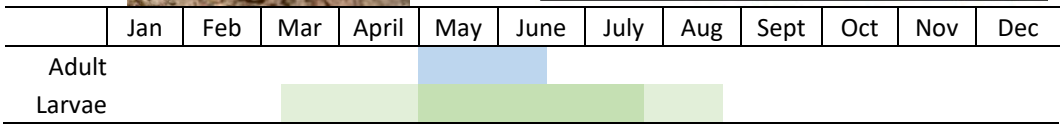
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3.6 Persius Duskywing (*Erynnis persius persius*)







Adult Persius duskywing butterfly (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this region are shown in the chart (bottom). Lighter shades indicate uncertain but likely active times. This species overwinters as larvae and pupates early in the spring (see Life Cycle for more). Photo credit: Kris Hazelbaker.

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Order: Lepidoptera

Family: Hesperiidae

Status: Secure; taxon critically imperiled to vulnerable (G5T1T3)

Distribution: Connecticut, Indiana, Maine, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, Wisconsin; presumed extirpated in Maine and possibly extirpated in Rhode Island

Where it occurs: This species occurs in a variety of open habitats, including pine barrens, oak barrens, pitch pine-scrub oak barrens, and scrubby ridgetops and in open areas under power lines.

How to recognize: A small butterfly with a wingspan of up to 1.5 inches. Like other duskywings, the wings are dark brown-black with lighter brown and gray markings on the outer half of the upper sides of the wings. In males, hind wing fringes are dark brown. This species will likely be difficult for novices to identify in the field.

Life cycle: Adult flight time occurs from early May through mid-June. Larvae feed inside of shelters they construct from silk and leaves. This species overwinters as larvae and pupates in early spring. Two primary host plants are reported (*Lupinus perennis* and *Baptisia tinctoria*; Table 3-5). Often only one or the other is available. This species may use other legumes as host plants. Nectar plants are not reported.

Habitat needs: Open, early successional habitat with abundant host plants.

Top reasons for decline, if known: Habitat degradation and alteration of natural ecological processes and disturbance regimes that maintained habitat, including loss of the primary host plant; pesticide use; habitat fragmentation.

General conservation recommendations: Manage habitat to prevent degradation and ensure that host plants are available. Do not use insecticides in areas with populations of this species. If fire is used to manage habitat, leave a portion of the area unburned to provide refugia for this species. Additional research on this species' life history is needed.

Roadside management recommendations: Mowing during April through June may reduce availability of host plants and other nectar sources. Rights-of-way may act as invasive species vectors into adjacent habitat, especially if nonnative species are used for revegetation. Avoid broadcast spraying of herbicides in areas with host plants.

Table 3-5. Plants used by Persius duskywing butterfly.

Species Name	Common Name
Larval Host Plants	
Lupinus perennis	Sundial lupine
Baptisia tinctoria	Horsefly weed/yellow wild indigo

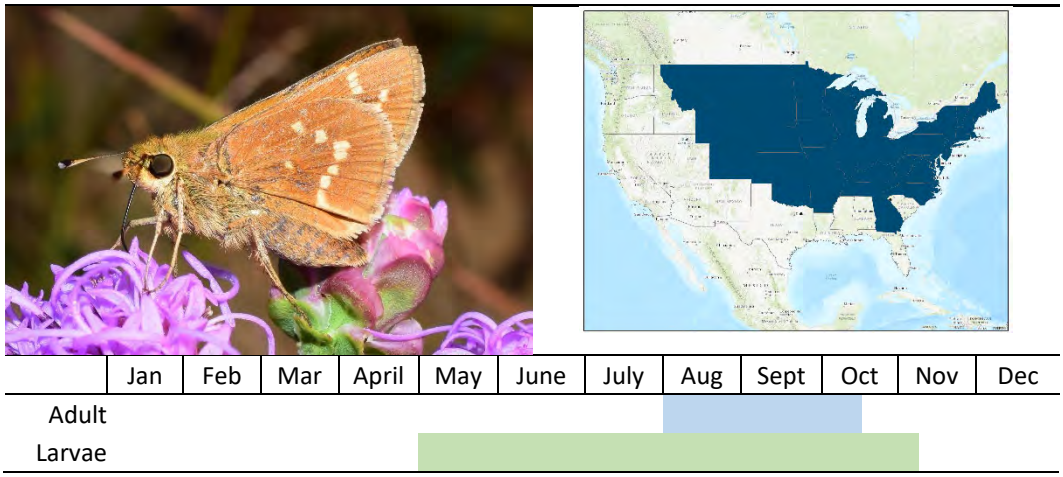
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3.7 Leonard's Skipper (*Hesperia leonardus*)



Adult Leonard's skipper (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this this region are shown in the chart (bottom). Adult flight time can vary with latitude (see Life Cycle for more). Photo credit: Chris Smith.

Order: Lepidoptera

Family: Hesperiidae

Status: Apparently secure (G4)

Distribution: This species has a broad distribution in the United States and Canada; in the United States can be found in Arkansas, Colorado, Connecticut, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Dakota, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and Wyoming

Where it occurs: Dry habitats on sand, prairie, savannas, and open woodlands. Often prefers areas with little bluestem (*Schizachyrium scoparium*) and blazing star, especially rough blazing star (*Liatris aspera*).

How to recognize: This species has a wingspan of 1.25 to 1.75 inches. The upper sides of the wings are red-orange with a black border. Undersides of the wings are reddish- to orangish-brown with whitish spots in *H. l. leonardus*. *H. l. pawnee* often has reduced (or is lacking) spots, especially in males.

Life cycle: Adult flight occurs from August through early October but may start slightly earlier or later depending on latitude. Eggs hatch after about 10 days. First and second

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instar larvae enter diapause until the next spring. Larvae use grasses as host plants, including those in Table 3-6. Like other skippers, they construct shelters for feeding. However, it is not known where the shelters are located in the canopy. Most populations have only a single generation per year.

Habitat needs: Habitat with grasses, including little bluestem and abundant floral resources, especially rough blazing star (*Liatris aspera*).

Top reasons for decline, if known: Habitat loss.

General conservation recommendations: Protect remaining habitat and increase connectivity among habitat patches. Fire can help to maintain grassland habitat over time, but this species is widely considered to be fire intolerant because even dormant-season fire causes mortality, as larvae spend the majority of their time higher up on grasses. Burning small portions of occupied habitat each year and increasing the time between burns to a minimum of 5 years can help minimize negative population-level effects. Pesticides used to control moths (*Limantria dispar*) may affect this species in open woodlands where both occur.

Roadside management recommendations: Frequent mowing can reduce floral resources, so reduce mowing frequency beyond the clear zone in areas where this species occurs. Using a higher mowing height (approximately 8 inches) may help reduce impacts on larvae and pupae, but more information on larval behavior of this species is needed. Avoid spraying host plants and nectar plants, especially *Liatris* spp. (Table 3-6), with herbicides. Increasing habitat connectivity by investing in high-quality revegetation near areas inhabited by this species will be beneficial to this species and others.

Table 3-6. Plants used by Leonard's skipper.

Species Name	Common Name
Larval Host Plants	
Schizachyrium scoparium	Little bluestem
Bouteloua gracilis	Blue grama
Agrostis spp.	Bentgrass
Nectar Plants	
Liatris aspera	Rough blazing star[1]
Liatris punctata	Blazing star[1]
Verbena spp.	Verbenas
Cirsium spp.	Thistles[3]
Aster spp.	Asters

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Species Name	Common Name
Dipsacus spp.	Teasel[2]

[1] Favored nectar source
[2] Nonnative
[3] This genus includes native and nonnative species; some of the nonnative species are invasive

3.7.1 References

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Chapter 4 Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation

4.1 Introduction

Managing roadsides to support pollinators is an important sustainability responsibility for Departments of Transportation (DOTs); however, as more species of pollinators become listed or are being considered for listing under the Endangered Species Act (ESA) of 1973 (16 U.S. Code 1531 et seq.), DOTs also want regulatory certainty. There are several ESA compliance strategies and advance planning efforts that have been successful and are available to transportation agencies interested in implementing proactive measures to aid recovery and avert listings of native pollinators. While strict avoidance of impacts on listed species is often an option for ESA compliance, avoidance can create substantial limitations on DOT operations. This chapter describes the variety of ESA compliance strategies with guidance to identify which are appropriate in different environmental and DOT operations contexts.



St. Francis' satyr is one of many pollinator species currently protected under the federal ESA.

Photo Credit: Brian Hudgens - https://en.wikipedia.org/wiki/File:Neonympha_mitchellii_francisci_individual.jpg

Consistent with ESA compliance, federal and state agencies, such as DOTs, can incorporate mitigating measures into their projects to reduce their overall negative impact on listed species and manage at-risk species that might become listed. For unavoidable impacts, a number of programs are available to project proponents, such as transportation agencies, that provide a clear regulatory pathway forward to address legal requirements of the ESA but also give them the means to be creative in the types of proactive measures put forth to recover imperiled pollinators and avert listings.

Transportation planners and managers recognize compliance with the ESA can present logistical and operational challenges. For example, a species listing leads to regulatory constraints and can often slow down project approvals and constrain construction and operational activities. When responding to the survey described in Chapter 1 (see Conduct of Research Report for full questions and summarized answers), 45 percent of 47 transportation professionals indicated they need to consult with the United States Fish and Wildlife Service (USFWS) or relevant state agency regarding federally or state-listed pollinator species at least once each year. In addition, over half of those individuals (51 percent) needed to consult five or more times a year. Furthermore, 75 percent of 48

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respondents to another question recognize the possibility that if an imperiled pollinator species became legally protected under the ESA, it would cause barriers, such as altered project timelines, increased workloads, and higher costs to their agencies.

There are a number of proactive, voluntary ESA compliance strategies from which to choose when planning transportation projects. See Figure 4-1 for assistance with understanding the relationships between identified strategies and opportunities for employing a phased approach to ESA compliance at a programmatic level. See the Evaluating ESA Compliance Approaches section for questions that can be helpful for planners and designers to ask when first evaluating different proactive approaches to addressing ESA compliance.

Although often recognized as a challenge, it is important for transportation professionals to recognize ESA compliance also presents often-overlooked opportunities for their agencies. Focused attention and well-thought-out planning and design work by planners and designers on issues tied to endangered and threatened species allow agencies to address immediate regulatory needs within their respective service areas. Additionally, up-front planning by DOTs allows the agencies to take action that pays dividends with respect to time and cost savings as workflow is improved and the number of project redesigns and modifications to operations are reduced across their larger road network. Surveyed transportation professionals recognize the cost savings that come from advance planning efforts and 81 percent of 48 respondents acknowledge the possibility of an imperiled pollinator species becoming legally protected by the ESA would motivate their agency to proactively protect pollinators in order to avert a listing. Additionally, nine transportation professionals participating in the survey recognize early adoption of compliance strategies as being good for public relations and consistent with identified sustainability goals for their respective transportation agency.

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4.2 Introduction to the ESA

The ESA is one of the most far-reaching environmental laws in the United States. Because of the number and extent of both endangered and threatened species, state DOTs will inevitably need to address compliance issues tied to listed species for some of their projects and operations.

DOTs may comply with the ESA by avoiding impacts on endangered species based on technical assistance from USFWS. If impacts on listed species (defined as *take* under the ESA) cannot be avoided, compliance commonly occurs using processes under Section 7 and Section 10 of the ESA. The Section 7 consultation process and the Section 10 permit process are the means by which take is approved under the ESA. Compliance is achieved under Section 7 when a federal nexus exists (i.e., the project requires a federal authorization apart from ESA compliance, license, or funding). In these cases, the lead federal agency is responsible for supporting consultation with USFWS. If no federal nexus exists, an incidental take permit under Section 10 is sought.

Successfully complying with the ESA requires up-front investments of time and resources, and a thoughtful and deliberate strategy. In contrast, a poorly coordinated approach to ESA compliance can result in schedule delays, cost overruns, or project failure if permit conditions are infeasible. Careful planning and a good understanding of the ESA compliance process, for both Sections 7 and 10, will help avoid these pitfalls.

ESA Section 7: The section of the ESA, as amended, outlining procedures for interagency cooperation to conserve federally listed species and designated critical habitats.

- Section 7(a)(1) requires federal agencies to use their authorities to further the conservation of listed species.
- Section 7(a)(2) requires federal agencies to consult with the Services to ensure that they are not undertaking, funding, permitting, or authorizing actions likely to jeopardize the continued existence of listed species or destroy or adversely modify critical habitat.

ESA Section 10: The section of the ESA, as amended, that provides exceptions to the taking of endangered species of fish and wildlife.

- Section 10(a)(1)(B) authorizes the Services to issue permits that allow the taking of listed species when doing so is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity.

4.2.1 ESA Overview

Congress enacted the ESA in 1973 with the intent of improving previous protective regulations by creating a more comprehensive approach that would protect not only individual species of threatened and endangered plants and animals but also their habitats and the ecosystems upon which they depend. USFWS and the National Marine Fisheries Service (NMFS; also known as National Oceanic and Atmospheric Administration Fisheries) jointly administer the ESA. NMFS has jurisdiction over listed marine species and anadromous fish, while USFWS has jurisdiction over all other listed species.

USFWS and NMFS (collectively known as the Services) maintain lists of threatened and endangered species for which the ESA provides substantial protections. In addition to administering the ESA, once a species is listed, the Services are responsible for determining whether there are areas that meet the definition of critical habitat. Critical habitat is habitat needed to support recovery of listed species; that is, specific areas within or outside of the geographical area occupied by the species at the time of listing that contain physical or biological features essential to conservation of the species and that may require special management considerations or protection. It is important to note that, given the connection between plants and pollinating insects, unlike listed animals, listed plant species are not afforded the same level of protection from take on non-federal lands under the ESA unless there is a federal nexus.

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Threatened species: Any species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Endangered species: Any species in danger of extinction throughout all or a significant portion of its range.

Section 9 of the ESA and federal regulation pursuant to Section 4(d) of the act prohibit the taking of any endangered species. Recent changes in implementation of the ESA exclude threatened species from protection from take, unless a specific 4(d) rule is promulgated.

- *Take* is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect individuals of the species, or attempt to engage in any such conduct.
- *Incidental take* is defined as take of listed species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a federal agency or applicant.
- *Harm* is defined in the ESA to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns, such as breeding, feeding, or sheltering.
- *Harass* is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns, which include, but are not limited to, breeding, feeding, or sheltering (50 Code of Federal Regulations [CFR] § 17.3).

Exceptions to these prohibitions (i.e., take authorizations) are addressed in Section 7 (for federal actions) and Section 10 (for non-federal activities) of the ESA. Issuance of an incidental take permit under Section 10 of the ESA is a federal action subject to compliance with the National Environmental Policy Act (NEPA). Note that some states (Alaska, Arizona, California, Florida, Nebraska, Ohio, Texas, and Utah as of February 2022) have NEPA Assignment where they assume federal responsibility for transportation projects for the Federal Highway Administration (FHWA). States with NEPA Assignment may use the Section 7 ESA compliance process even when no other federal nexus exists.

Since the ESA was passed in 1973, the act has seen minor revisions in 1978, 1979, 1982, and 1988 (16 U.S. Code 1531 et seq). Over the last 47 years, in addition to the revisions, various documents have been issued to guide interpretation and implementation of the ESA. Such documents have taken the form of regulations and guidance from the Services and the Council on Environmental Quality, presidential memoranda, and Secretarial Orders. ESA policy continues to evolve, with multiple recent changes to guidance, proposed regulations, and direction for ESA implementation.

4.3 ESA Compliance Options

Given their large service areas that can intersect with the range of many protected species, DOTs are commonly confronted with ESA compliance needs. While this chapter is focused on introducing transportation agencies to proactive and voluntary ESA compliance strategies typically found under Section 10 (an applicant-led process), both Section 7 (a federal agency-led process) and Section 10 processes are summarized in order to provide information on the differences between the two strategies. To facilitate consideration of ESA compliance options throughout the rest of this chapter, the primary ESA compliance strategies are summarized in Table 4-1, with the key features of each.

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Table 4-1. Permit, process, length of time to prepare, and assurances associated with voluntary ESA compliance strategies.

ESA Compliance Strategy	Permit	Process	Length of Time to Prepare*	Formal Assurances
Safe Harbor Agreement (SHA)	Enhancement-of-Survival Permit; Section 10(a)(1)(A)	SHA is prepared by the property owner(s) with the aid of USFWS.	6 to 9 months although more complex agreements are expected to take longer	Yes, property owners receive assurances they will not have to change management activities.
Recovery Crediting System (RCS)	Section 7; generated credits become the mitigation actions required for incidental take	RCS is prepared by the federal applicant and property owner(s) with USFWS determining whether a system provides a net benefit to the conservation of covered species.	Undefined	Yes, generated credits may offset either permanent or temporary impacts.
Habitat Conservation Plan (HCP)	Section 10(a)(1)(B); Incidental Take Permit	HCP is prepared by the applicant.	Undefined; typically 1 to 3 years, depending on scope of HCP	Yes, permit authorizes incidental take.
Candidate Conservation Agreement (CCA)	No permit	CCA is prepared by the applicant.	Undefined; subject to the degree of detail in CCA	No regulatory assurance is provided against the possibility that additional measures will be imposed.
Candidate Conservation Agreements with Assurances (CCAA)	Enhancement-of-Survival Permit; Section 10(a)(1)(A)	CCAA is prepared by the non-federal applicant.	6 to 9 months, although more complex agreements could take 1 to 3 years to get approved	Yes, no new restrictions or conservation obligations will be imposed on the landowner following listing.
Prelisting Conservation	Section 7 or Section 10; generated	PCA is prepared by the federal or	Undefined; PCAs are expected to	Yes, applicants are given the opportunity to have actions serve

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ESA Compliance Strategy	Permit	Process	Length of Time to Prepare*	Formal Assurances
Agreement (PCA)	credits are carried forward and become recognized mitigation actions to offset impacts from a development action following species listing	non-federal applicant working with state agencies with assistance from USFWS.	be processed faster than CCAAs, which are subject to more exacting approval requirements	as mitigation or a compensatory measure to offset impacts in the event the species is eventually listed as threatened or endangered under the ESA.

*Additional information provided by the USFWS Ecological Services Program regarding the policies and regulations for listed ESA compliance strategies, including estimates of the length of time to prepare, is available at http://www.fws.gov/endangered-species.

4.3.1 Section 7

Formal consultation: A process between the Services and a federal agency or applicant that: (1) determines whether a proposed federal action is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat; (2) begins with a federal agency's written request and submittal of a complete initiation package; and (3) concludes with the issuance of a biological opinion and incidental take statement by either of the two Services.

Informal consultation: An optional process that includes all discussions and correspondence between the Services and a federal agency or designated non-federal representative, prior to formal consultation, to determine whether a proposed federal action may affect listed species or critical habitat.

If a project has a federal nexus (again, meaning that the project requires a federal permit under some law other than the ESA, or a federal license or funding), the federal agency taking action (i.e., issuing the permit or license, or granting the contracts, leases, easements, rights-of-way [ROWs], or grants-in-aid) is required to comply with Section 7 of the ESA. For linear projects (like most transportation projects), examples of a federal nexus include the U.S. Army Corps of Engineers Clean Water Act Section 404 permitting process for impacts on waters of the United States (which include wetlands), a ROW authorization from the U.S. Forest Service or Bureau of Land Management, or administration of federal funds by FHWA. Section 7 requires the federal agency (sometimes referred to as the action agency), in consultation with the Services, to ensure its action (or, more specifically, the actions of the project sponsor, such as a DOT, directly or indirectly causing modifications to the land, water, or air [50 CFR § 402.02]) will not jeopardize the continued existence of a federally listed species or a species proposed for listing under the ESA. The federal agency also needs to ensure its action will not destroy or adversely modify designated critical habitat for ESA-listed species. Furthermore, Section 7(a)(1) requires the federal action agency to carry out programs to benefit species and habitats protected under the ESA. Typically, at least a portion of this requirement is addressed via the non-federal partner's actions that are funded or permitted by the lead federal agency. Complying with the ESA through a federal nexus requires that the Services use a defined timeline for formal consultation. In practice, this results in a much speedier process than the development of a Habitat Conservation Plan (HCP) under Section 10.

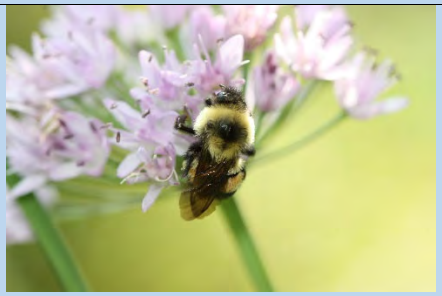
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4.3.2 Section 7 Consultation Process

The process for consultation under Section 7 is well defined in regulations and guidance. During the informal consultation process, after obtaining a species list from the Service(s) for the proposed Action Area, the federal action agency determines if its action has the potential to affect listed species or critical habitat. The Action Area is all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR § 402.02). If the action does not have the potential to affect listed species or critical habitat, the ESA compliance process is concluded. If the federal agency determines its action *may affect* a listed species or critical habitat, consultation with the Services is required. It is important to note that, unlike projects carried out under Section 10, the trigger for consultation under Section 7 is the *potential* to affect the species rather than *take* of the species being *reasonably certain to occur*. For projects with a federal nexus (when there is discretionary federal involvement or control over the action), the ESA requires action agencies to consult or confer with the Services if the project has the potential to affect the species, even when it is unknown whether take is reasonably certain to occur.

For actions that may affect listed species, the federal agency (or often the project sponsor, following formal designation of the non-federal representative by the federal agency) prepares a biological evaluation or biological assessment to determine if the listed species and/or critical habitat would be *adversely affected*. Biological assessments are required for major construction activities, which include dams, buildings, pipelines, roads, water resource developments, channel improvements, and other such projects that modify the physical environment and that constitute major federal actions (50 CFR § 402.12; 50 CFR § 402.02). If the agency determines the proposed action is *not likely to adversely affect* the listed species and/or critical habitat (that is, the effects would be discountable, insignificant, or beneficial), and the Service(s) concurs with that determination, the ESA consultation process is concluded (this is referred to as *informal consultation*) and the action agency may proceed with the action as proposed. At the completion of informal consultation, an action agency may request written concurrence from the Services that the proposed action will have no effect on listed species or critical habitat. Although it is not required, a letter of concurrence is recognized as useful for the administrative record.

Rusty Patched Bumble Bee Section 7(a)(2) Federal Project Review



The rusty patched bumble bee (*Bombus affinis*) is the first bumble bee protected under the federal ESA.

Photo Credit: Sarina Jepsen, The Xerces Society

To help ensure compliance with the requirements under Section 7(a)(2) for federal actions that may affect listed species, the Midwest Region of USFWS developed a four-step approach as part of a voluntary guidance document to help federal action agencies and applicants carry out efficient and effective Section 7(a)(2) consultation relative to the rusty patched bumble bee (*Bombus affinis*).

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Step 1 – Define the Action Area. Describe the Action Area, recognizing the Action Area is not only the immediate area involved in the action, but also all areas to be affected directly or indirectly by the action (50 CFR § 402.02).

Step 2 – Determine whether the rusty patched bumble bee is likely to be present in the Action Area. Consult the USFWS Information for Planning and Consultation website (https://ipac.ecosphere.fws.gov/) or an up-to-date map kept by USFWS with distribution data specifically for the rusty patched bumble bee (https://www.fws.gov/species/rusty-patched-bumble-bee-bombus-affinis). Determine whether the Action Area overlaps with a High Potential Zone for the rusty patched bumble bee. If the Action Area falls within a High Potential Zone and contains suitable habitat, follow the appropriate survey guidance provided by USFWS to confirm presence or absence.

Step 3 – Review the action for potential direct or indirect effects. If the rusty patched bumble bee occurs in the Action Area, the action agency will need to determine whether its action may affect the species. The action agency will need to determine if the species will be exposed to one or more stressors associated with the action, and, if exposed, how the species will respond to the relevant stressor(s). When an action may affect the rusty patched bumble bee but is not likely to adversely affect the species, the action agency may request concurrence on that determination from USFWS. Consultation would conclude with the written concurrence of USFWS (50 CFR § 402.13(a)).

Step 4 – Incorporate measures to avoid or minimize effects on the rusty patched bumble bee. If the action is likely to adversely affect the rusty patched bumble bee, the action agency is to incorporate conservation measures to remove adverse effects. The recovery plan and recovery implementation strategy, once completed for the rusty patched bumble bee, will provide primary reference for agencies to implement actions that will help it fulfill its Section 7(a)(1) mandate. Until then, USFWS recommends measures taken to address the major conservation needs of the species, as described in the status assessment for the rusty patched bumble bee (https://ecos.fws.gov/ecp/species/9383). Federal agencies are to initiate formal consultation with USFWS if the project's conservation measures do not remove all adverse effects. If USFWS anticipates the action will result in incidental take of the species and is not likely to jeopardize the species' continued existence, it will include an incidental take statement with the biological opinion. The incidental take statement will include terms and conditions that the agency must follow to ensure that any take is not a violation of the ESA's Section 9 prohibitions.

Link to Rusty Patched Bumble Bee Section 7(a)(2) Federal Project Review:

https://www.fws.gov/sites/default/files/documents/Section%207%20guidance%20for%20rusty%20patched%20bumble%20bee%20%28Bombus%20affinis%29.pdf

If the federal agency determines the proposed action or its interrelated or interdependent actions *is likely to adversely affect* listed species, the agency needs to request *formal consultation* with the Service(s). A written request from the action agency to the Service(s) marks the beginning of formal consultation. Note that the federal agency determines how

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applicants are to be involved in the consultation and may designate a non-federal representative, such as the project sponsor (e.g., DOT), to conduct informal consultation on behalf of the agency (50 CFR § 402.13). Throughout the consultation process, however, the ultimate responsibility for Section 7 compliance remains with the federal agency and the Services will not work directly with or take comments directly from the applicant without the knowledge or consent of the action agency (50 CFR § 402.14).

A formal consultation includes:

- a description of the action being considered,
- a description of the specific area and any listed species or critical habitat that may be affected by the action,
- description of the manner in which the action may affect any listed species or critical habitat, including analysis of any cumulative effects, and
- relevant reports, such as environmental impact statements (EIS), environmental assessments (EA), biological assessment, and other relevant studies.

In total, and without any allowable extensions, 135 days is the statutory guideline for completing Section 7 consultation.

- Within 90 days of receipt of all information required to complete formal consultation, the Service(s) must complete consultation with the agency and provide a draft biological opinion to the agency for review. The draft biological opinion consists of a description of the proposed action, status of the species and/or critical habitat, environmental baselines, effects of the action(s), cumulative effects, conclusion, and alternatives, as appropriate.
- The Services have 30 days from receipt of all information for the consultation process to determine if the information is complete enough to proceed.
- Within the next 45 days, the federal agency or the designated project applicant has the opportunity to provide comments to the Service(s) on the draft biological opinion. Then, the Service(s) will issue the final biological opinion.

The biological opinion will reflect the Service(s)'s determination of whether the action would *jeopardize the continued existence of a species or adversely modify critical habitat* (known as a *jeopardy finding*).

- If a jeopardy finding is made, the Service(s) must recommend reasonable and prudent alternatives that would avoid jeopardy and that the federal agency must implement prior to taking action.
- If no jeopardy finding is made, the Service(s) will issue an *incidental take statement* with the biological opinion. If incidental take is anticipated, the agency or the applicant must comply with the reasonable and prudent measures identified in the biological opinion and implement terms and conditions in the Services' incidental take statement to avoid potential liability for any incidental take.

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4.3.3 Single Project versus Programmatic

The formal and informal Section 7 consultation processes can be applied to either a single defined project or a suite of projects (i.e., a program). When applied to a program, the consultation is referred to as *programmatic*. If there are multiple projects within an area and they will all potentially affect a listed species, a programmatic consultation can achieve several objectives with positive administrative benefits for all parties. Equally, a programmatic consultation can be used to clear certain project types—such as sidewalk repair or construction, pavement milling, and resurfacing—that are recognized as minor projects implemented by transportation agencies that the Services can evaluate collectively for their likelihood to adversely affect a species. A programmatic approach streamlines the procedures and time involved in consultations for numerous similar activities with predictable effects on listed species and/or critical habitat in a particular geographic area, thus reducing the amount of time spent on individual project-by-project consultations and maximizing the flexibility to modify project designs early on in the project design phase. Although it may initially take more time to ensure early coordination among agencies and gather data for all the activity types that need to be included under the program, workloads are streamlined under a programmatic approach compared to consulting on each project separately.

Under programmatic consultations, the effects analysis for a suite of activities exposed to a set of applicable stressors is completed up front in the biological evaluation or biological assessment and programmatic consultation response document, allowing for reduced project-specific review. Resulting programs guide implementation of future actions by establishing standards, guidelines, or governing criteria to which future actions must adhere. At the project-specific consultation stage, a proposed activity is reviewed to determine if it can be implemented in accordance with the programmatic consultation. From a conservation perspective, one of the great advantages of doing programmatic consultations is that consultations generally involve development of a conservation strategy or program defined in the biological opinion with design criteria based on the needs of the species rather than attempting to build the needs of the species into individual development projects. Establishing the conservation recommendations and terms and conditions written into the biological opinions typically requires ongoing communication and coordination between transportation agencies and the Services. Given many transportation projects involve a federal agency, the ability to develop a conservation strategy for a listed species or suite of species is typically a readily available route for DOTs, with the biological opinions often being referenced in future contract documents to ensure contractor compliance on development projects.

4.3.4 Section 10

In cases where no federal nexus exists, such as when a private landowner (or state agency) is planning an activity that will incidentally take a listed animal species and the landowner or state agency neither needs a federal permit under some law other than the ESA nor receives federal funding for that activity, species take tied to the proposed activity is permitted through the Section 10 process. Section 10 was created in 1982 after Congress, recognizing the need for a process to reduce conflicts between listed species and economic development, amended the ESA to add an exemption for incidental take of listed species that would result from non-federal activities (Section 10(a)(1)(B)). Incidental take is that incidental to, and not the purpose of, carrying out an otherwise lawful activity. To obtain a

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permit for such take under this provision, an applicant must develop a conservation plan that meets specific requirements identified in Section 10(a)(2)(A) of the ESA and its implementing regulations. These habitat conservation plans have become known as HCPs. The permits obtained through this process are known as *incidental take permits* and allow the permit holder to legally proceed with an activity that would otherwise result in the unlawful take of a listed species.

4.3.5 Habitat Conservation Plans

HCPs are a means for non-federal entities to obtain a permit to incidentally take listed species by providing for actions that minimize and mitigate the impact. HCPs describe the anticipated effects of the proposed taking, how those impacts are to be minimized or mitigated, and how the HCP is to be funded. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing.



HCPs can help to create conservation plans for at-risk pollinators that will be affected by DOT activities such as construction projects.

Photo Credit: Washington DOT/Flickr CC

HCPs are required to meet the permit issuance criteria of Section 10(a)(2)(B) of the ESA, such that,

(1) taking will be incidental (that is, take of listed fish or wildlife species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a federal agency or applicant [50 CFR § 402.02]),

(2) the applicant will, to the maximum extent predictable, minimize and mitigate the impacts of the taking,

(3) the applicant will ensure that adequate funding for the plan will be provided,

(4) taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild, and

(5) other measures, as required by the Secretary, will be met. An HCP can include plants and provide take authorization to a DOT.

HCPs can be used by transportation administrators and planners to develop conservation strategies to address impacts on at-risk and listed pollinator species from transportation projects, such as new road construction, road widening, or road alignment activities, recognizing such activities may result in both permanent and temporary impacts. HCPs can vary in size, complexity, and duration. HCPs can be project specific with relatively short preparation times and permit durations (often less than 3 years), or they can be regional and programmatic (i.e., developed to cover multiple projects), typically taking more time to prepare but addressing a greater permit duration (30 years is typical) and scope. Project-specific HCPs can often qualify as low-effect HCPs (see **Valley Elderberry Longhorn Beetle Low-Effect HCP** example). Low-effect HCPs must have minor or negligible effects on the species and their habitats covered under the HCP and qualify for a categorical exemption under NEPA. NEPA applies to all "major federal actions," a term that has generally been determined to include both those actions that a federal agency directly undertakes and those actions proposed by non-federal entities that require federal funding or approval. Issuance of an incidental take permit under Section 10 of the ESA is a federal action subject

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to compliance with NEPA. As a result, USFWS or NMFS need to conduct a NEPA review and prepare an EA or EIS as part of the process of issuing an incidental take permit.

Valley Elderberry Longhorn Beetle Low-Effect HCP (Yolo County, California)



Valley elderberry longhorn beetle

Photo Credit: Robin Agarwal, Flickr CC

In Yolo County, California, the Sacramento Regional County Sanitation District was issued a Section 10(a)(1)(B) permit for the incidental take of two species federally listed as threatened, the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) and giant garter snake (*Thamnophis gigas*), from covered activities described in the sanitation district's low-effect HCP. As described in the HCP, potential taking would occur incidental to construction of a new flood-protection levee and raised all-weather access road around an existing pump station within a 136.4-acre project site. The permit covers a period of 5 years and the HCP provides measures for avoiding and minimizing adverse effects on the valley elderberry longhorn beetle and giant garter snake for activities associated with construction of the new levee and road. The HCP summarizes information about the project and identifies responsibilities of USFWS and the sanitation district for implementing actions to benefit both threatened species. Proposed mitigation measures include purchase of valley elderberry longhorn beetle credits from a USFWS-approved conservation bank, transplanting of removed elderberry shrubs to the conservation bank, and restoration of temporarily affected upland giant garter snake habitat to pre-project conditions within the same calendar year of the impacts. It was determined by USFWS that the proposed project and mitigation measures would individually and cumulatively have a minor or negligible effect on the species covered in the HCP and therefore issuance of the incidental take permit qualifies as a categorical exclusion under NEPA.

Link to proposed Low-Effect HCP information:

https://www.federalregister.gov/documents/2016/06/20/2016-14567/proposed-low-effect-habitat-conservation-plan-for-the-valley-elderberry-longhorn-beetle-and-giant

When it comes to developing HCPs, DOTs need to consider ESA compliance options relative to short- and long-term needs and goals. Different compliance options present distinct challenges, including intra-organization coordination, identification of appropriate decision makers, and management of contractors. Taking the necessary time at the beginning to thoroughly plan how the HCP will be developed and ultimately implemented is wise. A common understanding between the Services and the applicant needs to be developed with regard to the needs and goals of each, as well as their respective planning processes. Spending the time up front to develop a realistic schedule for development of the HCP and identifying key milestones goes a long way to eliminating misunderstanding and future conflicts during the planning process. Additionally, having a simple checklist of the specific information needs of the Services to complete the biological opinion, make findings, and issue permits is helpful when getting started on HCP development.

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An HCP is one of the most comprehensive tools available to transportation planners and provides partnering agencies with incidental take privileges for multiple covered species. HCPs can involve localized areas with only one or a few partners or cover large geographic areas (e.g., statewide or multistate HCP) and involve dozens of partners, including both public and private landowners, working across an extensive landscape. Under an HCP, conservation measures adopted for ROWs that lead to improved conditions for covered species and offset both the permanent and temporary impacts associated with road construction and maintenance could include the purposeful creation of habitat corridors through woodlands or shrub-dominated landscapes, increases in the use of native plants in managed areas, or maintenance of a shifting mosaic of suitable habitat through coordinated management of the greater regional landscape (see **Karner Blue Butterfly Statewide HCP** example).

Karner Blue Butterfly Statewide HCP (Wisconsin)



Activities covered under the Wisconsin HCP help to implement disturbance needed for conservation of the Karner blue butterfly.

Photo Credit: Joel Trick, USFWS

This HCP is the first statewide habitat conservation plan developed in the nation and ensures the continued existence of the Karner blue butterfly (*Lycaeides melissa samuelis*) on more than 260,000 acres of land in Wisconsin. The Wisconsin Department of Natural Resources led the effort to develop the HCP in cooperation with a diverse group of 26 partners, including major forestry stakeholders, conservation organizations, county forests, utility companies, private landowners, and the Wisconsin Departments of Agriculture and Transportation. The Karner blue butterfly requires its habitat to be disturbed periodically and, under the HCP, landowners can manage their activities by disturbing habitat in ways that benefit the species. In the absence of disturbance activities, such as fire, grazing, or mowing, shrubs and trees invade the open savanna and barrens and shade out the grass and herbaceous plants, including wild lupine (*Lupinus perennis*), which is the only plant the Karner caterpillar is recognized to feed on, and is thus critical to the butterfly's survival. Lands supporting the Karner blue butterfly include ROWs, abandoned agricultural fields, managed forest lands, military training areas and bombing ranges, and managed and unmanaged barrens, savannas, and prairie areas that support wild lupine plants. Conservation measures described in the statewide HCP include changing the timing of mowing and herbicide applications to the fall to protect the plants used by the butterflies, creating habitat corridors linking Karner blue butterfly sites, and maintaining a shifting mosaic of suitable habitat for the butterfly throughout the landscape.

Link to Karner Blue Butterfly Statewide HCP:

https://dnr.wisconsin.gov/topic/endangeredresources/karner/determine

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Agreed-upon conservation measures implemented through an HCP could allow for both incidental take tied to construction activities and cover of management activities in ROWs affecting covered species. As a voluntary compliance strategy, HCPs allow for incidental take covering permanent impacts through offsite mitigation actions, such as the purchase of credits from an established mitigation bank, habitat acquisition, dedication of "excess land" for conservation to offset permanent impacts on listed species, or restoration of degraded lands on non-federal lands (see **Fender's Blue Butterfly HCP** as an example of the use of offsite mitigation to address local impacts tied to ROWs).

Through the creation and implementation of an adaptive management program paired with an identified funding source, HCPs offer the greatest flexibility and long-term assurances to be able to meet the changing needs of covered species in the dynamic landscape associated with road design and construction.

Fender's Blue Butterfly HCP (Yamhill County, Oregon)



Fender's blue butterfly

Photo Credit: George Gentry, USFWS

Fender's blue butterfly (*Icaricia icarioides fenderi*) is federally listed as endangered and only occurs in the Willamette Valley of Oregon. The butterfly is dependent on the presence of its host plant, the federally listed as threatened Kincaid's lupine (*Lupinus oreganus).* Fender's blue butterflies lay eggs only on Kincaid's lupine and the young caterpillars remain on the lupine to feed. Both Fender's blue butterfly and Kincaid's lupine are listed under the ESA and covered under the countywide Yamhill County HCP, as both the butterfly and lupine could be affected by the county's road maintenance activities. The incidental take permit tied to the HCP allows the county to continue to perform its otherwise lawful road maintenance activities, which have the potential to affect the covered species. Specific conservation measures identified in the HCP to support the long-term viability of both species were designed to be compatible with needed county road maintenance activities; with implementation, they will reduce the potential adverse effects of covered activities on the two species and mitigate unavoidable adverse effects within the HCP area. Specific conservation measures include establishing special maintenance zones at locations within the county ROWs known to support Fender's blue butterfly and Kincaid's lupine; establishing procedures and protocols for maintenance activities occurring within special maintenance zones; implementing avoidance and minimization measures for road maintenance activities in the county ROWs to reduce potential effects on the covered species and their habitat; enhancing upland prairie habitat within no-impact zones in the county ROWs; and restoring and managing Fender's blue butterfly habitat at offsite locations to promote restoration of upland prairie habitat.

Link to Fender's Blue Butterfly HCP:
https://yamhillswcd.org/resources-information/habitat-conservation-plan/

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Required Elements of an HCP

To receive an incidental take permit, the applicant is required to submit an HCP that includes the following content:

- **an assessment of impacts** likely to result from the proposed taking of the species for which permit coverage is requested,
- measures that the permit applicant will undertake to **monitor**, **minimize**, and **mitigate** for such impacts,
- **funding** available to implement such measures,
- **procedures** to deal with unforeseen or extraordinary circumstances,
- **alternative actions** considered that would not result in take and the reasons why the applicant did not adopt such alternatives, and
- **additional measures** USFWS may require as necessary or appropriate for purposes of the plan.

Although close coordination with the Services during HCP development is always a good idea, an HCP is an applicant's document, and development of the HCP is the responsibility of the applicant and not the Services. Because issuance of the incidental take permit constitutes a federal action, it is subject to NEPA review (specifically, cumulative effects analyses that take into consideration not just the impacts associated with taking a covered species but also impacts on other aspects of the human environment). The NEPA document is the responsibility of the Services. The Services are also required to perform internal consultation (i.e., intra-agency Section 7 consultation) and prepare a biological opinion (that includes the opinion of the Services as to whether a federal action is likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of designated critical habitat) and findings document that present the basis for the incidental take permit decision.

4.3.6 Assurances under Section 10

A key component of ESA compliance under Section 10 is the assurances afforded to the Section 10 permit holders. Called *No Surprises*, these assurances provide regulatory and financial certainty associated with implementing the terms and conditions of the HCP (50 CFR § 17.22(b)(5)). The No Surprises rule has two major components: changed circumstances and unforeseen circumstances.

- *Changed circumstances* are defined as changes in circumstances affecting a species or geographic area covered by an HCP that can be reasonably anticipated and planned for during writing of the HCP (50 CFR § 17.3). If circumstances change during implementation of the HCP and additional conservation and mitigation measures are deemed necessary to respond to those changes, and such measures were provided for in the HCP, the permittee will be required to implement such measures.
- *Unforeseen circumstances* are defined as changes in circumstances affecting a species or geographic area covered by a conservation plan that result in a substantial and adverse change in the status of the covered species that could not have reasonably been anticipated by the developers of the plan and the Services at the time of the negotiation

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and development of the plan (50 CFR § 17.3). Under the No Surprises rule, if *unforeseen circumstances* occur that adversely affect covered species, the Services will not require the commitment of additional land, water, or financial compensation or impose additional restrictions on the use of land, water, or other natural resources beyond the level otherwise agreed to in the HCP without the consent of the permit holder as long as the HCP and the incidental take permit are being properly implemented.

4.3.7 Benefits and Tradeoffs of Complying through Section 7 or Section 10

In many cases, the project proponent will have limited or no federal nexus and, therefore, no choice regarding whether to comply with the ESA through Section 7 or Section 10. However, in some cases, both compliance pathways are an option. In these cases, there are benefits and tradeoffs with each approach (summarized in Table 4-2). First, compliance through the Section 7 process is almost always faster, as it is a more systematic process driven by mandated schedules and guidelines, with responsibilities to see the process through to the end ultimately falling on the Services and the federal action agency.

The Section 10 process with an HCP typically takes longer to complete than a Section 7 consultation, but it provides the applicant with more control of the outcome. The HCP is the applicant's document, so the applicant can control its content and approach. In addition, the Section 10 permit process allows for coverage of non-listed species under an HCP and provides No Surprises assurances throughout the duration of the permit. This can be advantageous for long-term planning. Species likely to become listed during the duration of the permit, if covered by the HCP, require no new restrictions if listing occurs, as long as the permittee is properly implementing the HCP and incidental take permit. No Surprises assurances are not available under Section 7. Also, the Cooperative Endangered Species Conservation Fund (Section 6 of the ESA) is a tool that provides substantial grants to support HCP planning, which are available for Section 10 but not Section 7 processes.

Table 4-2. Comparison of ESA compliance under Section 7 versus Section 10.

Point of Comparison	Section 7	Section 10
Trigger for engagement	Proposed project *may affect* a listed species (consultation is mandatory).	Under the proposed project, *take* of a listed species is reasonably certain to occur (process is voluntary, although compliance with the ESA is mandatory and the Services may initiate an enforcement action if they have reason to believe that the ESA is being violated).
Applicability	Federal action agencies, in consultation with USFWS, must ensure their actions would not jeopardize the continued existence of a federally listed species or a species proposed for listing under the ESA or destroy	Applies to non-federal entities conducting an otherwise lawful activity through which take is reasonably certain to occur. The HCP can apply to non-listed species and includes assurances.

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Point of Comparison	Section 7	Section 10
	or adversely modify critical habitat.	
Process	Informal or formal consultation with USFWS is initiated by the federal action agency and typically follows a preparation of a biological evaluation or biological assessment by the applicant for the action agency.	The HCP is prepared by the applicant and follows the applicant's timeline during the pre-application process and development of the HCP.
Timeline	Undefined for informal consultation, although typically 30–90 days, recognizing a 60-day timeline exists for concurrence following receipt of an adequate written request; defined timeline once formal consultation is initiated (up to 135 days).	Undefined. Typically, it takes 1 to 3 years depending on the scope of the plan.
Permit and Assurances	Incidental take statement does not include regulatory assurances; terms and conditions determined by USFWS, in consultation with the action agency and applicant; reinitiation of consultation is always possible.	Permit conditions negotiated between the Services and the permit applicant. No Surprises assurances provided so USFWS cannot require additional resources (including additional commitment of land, water, or financial resources or additional restrictions beyond the level otherwise agreed on in the HCP) of the applicant to address unforeseen circumstances without the consent of the permittee.
ESA Section 6 Funding	No.	Yes, grants are available through a competitive process to support the development of HCPs and acquire land associated with approved HCPs.
NEPA	Triggered by the federal action agency that is consulting with USFWS; federal action agency prepares the NEPA review document (EIS or EA). Public participation is an integral part of procedural requirements.	Triggered by the Services' consideration/issuance of an incidental take permit. The Services prepare the NEPA review document. Public participation is an integral part of procedural requirements.

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4.4 Other Voluntary ESA Compliance Strategies

In addition to HCPs, other voluntary strategies exist to address ESA compliance (see Table 4-1 for a summary). An enhancement-of-survival permit is available under Section 10 of the ESA for entities whose activities will provide a net conservation benefit to listed species or species that are candidates for listing. Typically, these permits are pursued by landowners who may be otherwise reluctant to undertake activities that support or attract listed species to their properties, or entities planning a project with concerns about risk of taking a candidate species that may be listed during project implementation due to fear of future restrictions related to the ESA. To address these concerns, two agreements are available to transportation agencies to provide the needed assurances that future restrictions or property-use limitations will not occur without their consent: (1) a Safe Harbor Agreement (SHA) for species that are already listed, or (2) a Candidate Conservation Agreement (CCA) with Assurances (CCAA) for candidate species. These agreements are also considered by the Services when making listing decisions and may help to prevent a listing or encourage a delisting or down-listing.

4.4.1 Safe Harbor Agreement

A SHA is a voluntary agreement involving private or other non-federal property owners whose actions taken under a SHA are recognized by USFWS to provide a net conservation benefit contributing to the recovery of species listed as endangered or threatened under the ESA. Under a SHA, property owners receive formal assurances from USFWS through an enhancement-of-survival permit issued under the authority of Section 10(a)(1)(A) of the ESA that land use restrictions will not be required even if voluntary actions taken under the agreement attract particular listed species onto enrolled properties or increase the numbers or distribution of those listed species already present on those properties. The enhancement-of-survival permit authorizes incidental take of species that may result from actions undertaken by the landowner under the SHA, which would include returning the property to baseline conditions at the conclusion of the agreement. As SHAs do not require permanent conservation for enrolled properties but do provide opportunities for landowners to test and develop new habitat-management techniques, the SHA is a compliance strategy to be considered for application in ROWs by transportation agencies interested in adopting new management practices aimed at maintaining, restoring, or enhancing existing habitats; reducing habitat fragmentation; or increasing habitat connectivity on behalf of listed species found on or adjacent to their properties. The USFWS Ecological Services Program recognizes many SHAs can be developed within 6 to 9 months, although more complex agreements may take longer. When estimating the timeline for approval, a number of considerations need to be made, including the number and characteristics of the species involved, management activities being considered, number of parties to the agreement, and whether the SHA and permit decision may be eligible for categorical exclusion under NEPA (42 U.S.C. 4321 et seq).

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Willamette Valley Native Prairie Habitat Programmatic Safe Harbor Agreement for the Fender's Blue Butterfly



Fender's blue butterfly

Photo Credit: George Gentry, USFWS

This programmatic SHA provides eligible landowners with a streamlined process for obtaining assurances that certain actions taken to benefit the federally listed Fender's blue butterfly will not result in additional regulatory obligations under the ESA. The primary objective of this SHA is to encourage conservation and restoration actions by landowners designed to benefit Fender's blue butterfly, the federally listed Kincaid's lupine, and other native species occurring in open prairie habitat within Willamette Valley in Benton, Lane, Linn, Marion, Polk, and Yamhill Counties in Oregon.

Activities anticipated to produce a net conservation benefit for the Fender's blue butterfly to be undertaken by participating landowners include:

- restoration activities that result in an open community structure,
- promoting healthy populations of host and nectar plants unencumbered by overtopping shrubs, trees, or tall exotic grasses, and
- management actions, such as the manual and mechanical removal of invasive exotic plants and woody vegetation, and, in certain circumstances, chemical applications and the use of prescribed fire, designed to maintain an open, prairie structure ensuring the vigor of obligate lupine host plants and other native nectar plants.

Eligible properties for enrollment include non-federal lands where the butterfly occurs or could occur through colonization, translocation, or reintroduction. Non-federal landowners interested in participating are recognized as "Cooperators" through Certificates of Inclusion under the SHA. The SHA is administered and implemented by the USFWS Oregon Fish and Wildlife Office (OFWO) and Willamette Valley National Wildlife Refuge Complex (WV Refuge Complex). The OFWO is the designated "Permittee" and the WV Refuge Complex is a signatory that works jointly with the OFWO in all aspects of the SHA. The OFWO, WV Refuge Complex, and participating landowners are all parties to the SHA. This SHA follows USFWS's Safe Harbor Agreement policy (64 Federal Register 32717) and regulations (64 Federal Register 32706), both of which implement Section 10(a)(1)(A) of the ESA.

Link to information on Willamette Valley Native Prairie Habitat Programmatic Safe Harbor Agreement for the Fender's Blue Butterfly:

https://www.fws.gov/federal-register-document/proposed-willamette-valley-native-prairie-habitat-programmatic-safe

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4.4.2 Candidate Conservation Agreement with Assurances

Another compliance strategy for transportation planners to consider when planning for activities to be completed within ROWs is a CCAA addressing species proposed for listing or candidates for listing on non-federal land. A CCAA results in an enhancement-of-survival permit, issued under Section 10(a)(1)(A) of the ESA, which provides assurance to the applicant that if agreed-upon conservation actions for the covered species are implemented, USFWS will not require additional conservation measures beyond those in the CCAA should the species be listed. A CCAA can apply to a single species or multiple species and may vary in size, scope, structure, complexity, and activities addressed. Conservation measures transportation agencies agree to undertake on their lands to remove threats and otherwise improve the status of candidate and other at-risk pollinator species under a CCAA may include actions to:

- protect and enhance existing populations and habitats,
- restore degraded habitat,
- create new habitat,
- augment existing populations,
- restore historic populations, or
- not undertake a specific, potentially affecting/damaging activity, such as deciding not to move forward with planned construction of an approved road extension.

The duration of a CCAA needs to be sufficient to enable USFWS to determine that the benefits of the conservation measures in the CCAA provide a net conservation benefit to the covered species and remove any need to list the species covered by the agreement, when combined with those benefits that would be achieved if it is assumed the conservation would also be implemented on other necessary properties. Similar to a SHA, a CCAA can be renewed for as long as the property landowner and USFWS both agree. Both existing SHAs and CCAAs are considered by the Services when making listing decisions and may help to prevent a listing or encourage a delisting or down-listing.

4.4.3 Candidate Conservation Agreement

Although they do not lead to a permit, CCAs are formal, voluntary agreements between USFWS and one or more parties created to address the conservation needs of one or more candidate species or species likely to become candidates in the near future. Although CCAs are primarily developed by federal agencies to cover federal lands, USFWS often enters into CCAs with other federal agencies but recognizes the value of partnering on agreements with states, local governments, tribes, private property owners, and other entities. Agreements can apply to a single species or multiple species and may vary in size, scope, structure, complexity, and activities addressed. USFWS recognizes early conservation efforts for declining species can be greatly expanded through collaborative approaches that foster cooperation and exchange of ideas among multiple parties.

For large-scale transportation projects wherein the effects of thoughtful roadside management practices benefiting native pollinators occurring on non-federal lands could be strengthened from similar actions taken on adjoining federal properties, such as a national forest, a CCA can be written to perform the function of an overarching

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conservation plan for a single or multiple at-risk species. The implemented conservation plan would formally serve to link a CCA for federal property together with preventative measures taken under a CCAA implemented on non-federal lands (see Monarch Butterfly Nationwide CCAA with CCA example). Working collaboratively, federal and non-federal participants could voluntarily commit to implement specific actions designed to remove or reduce threats to a covered species across a region characterized by a patchwork of land ownership so that listing may not be necessary. The degree of detail in CCAs can vary widely, and there are no specific permits or assurances associated with them. State involvement is highly desirable, as species that are not listed or proposed for listing are under the jurisdiction of the states.

Monarch Butterfly Nationwide CCAA with CCA



Monarch butterflies on swamp milkweed (*Asclepias incarnata*)

Photo Credit: Stephanie McKnight, The Xerces Society

In 2020, USFWS approved a programmatic CCAA with an integrated CCA for the monarch butterfly (*Danaus plexippus*). The agreement is a collaborative effort among USFWS and representatives of more than 45 non-federal companies and agencies in the energy and transportation sectors, including those who collectively manage several millions of acres of ROWs and associated lands across the lower 48 states for electric power generation, transmission, and distribution (including solar and wind); oil and gas transport; and transportation (including both roads and railways).

Together with approving the agreement, USFWS issued an enhancement-of-survival permit. Through a certificate of inclusion, the partners enrolled in the agreement will create, enhance, and maintain habitat for monarch butterflies, as well as continue their general operations, vegetation management, and maintenance and modernization activities within existing ROWs. If the monarch becomes federally listed and protected under the ESA, the enhancement-of-survival permit will authorize incidental take of monarch butterflies that may result from otherwise lawful activities within ROWs on enrolled lands.

By integrating a CCAA and CCA together in the agreement, partners are able to seamlessly implement conservation measures for monarchs on non-federal and federal lands. Conservation measures expected to create, maintain, and enhance monarch habitat include the reduction or removal of threats to the monarch butterfly caused by ongoing operations, maintenance, and modernization activities on ROWs. The agreement allows partners flexibility to strategically place habitat when considering both the conservation needs of the species and the constraints that exist that may limit their ability to apply conservation measures in a given area. To maintain a net conservation

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benefit, each partner must implement selected conservation measures to create and maintain a proportion of their enrolled lands as monarch habitat each year.

Link to Monarch Butterfly Nationwide CCAA with CCA:

https://www.fws.gov/media/nationwide-candidate-conservation-agreement-monarch-butterfly

4.4.4 Recovery Crediting System

A Recovery Crediting System (RCS) is a tool that allows federal agencies to use their authorities to benefit species already listed as threatened or endangered on non-federal lands. Subject to Section 7 consultation, an RCS creates a process through which federal agencies create a "bank" of recovery credits providing for the conservation of listed species while being able to compensate for future impacts of their actions. As Section 7 applies to management of federal lands as well as other federal actions that may affect listed species (for example, federal approval of private activities through issuance of federal permits, licenses, or other actions such as funding), an RCS is a tool available to state transportation agencies through interagency cooperation. Section 7(a)(2) of the ESA establishes the process whereby federal action agencies, such as the U.S. Forest Service, Bureau of Land Management, or FHWA, and their applicants (e.g., state DOTs) and USFWS work together to ensure appropriate conservation measures are in place so that proposed actions are not likely to jeopardize the continued existence of a listed species or loss of critical habitat. Because of the importance of private lands to the recovery of listed species, the RCS is designed to encourage federal partnerships with non-federal landowners. The process of creating an RCS produces a net conservation benefit for the listed target species that advances its recovery, increases the flexibility of federal agencies to accomplish their missions while meeting their requirements under the ESA, and promotes effective partnership between federal and non-federal entities.

The basic unit of measure established by an RCS is a *recovery credit.* The credit quantifies the contribution an agency's action makes toward recovery of a federally listed species. Credits are based on, and tied to, implementation of specific conservation measures or actions identified in a species' approved recovery plan. Criteria used to establish recovery credit values and priorities include long-term habitat preservation or restoration, reduction or elimination of specific threats, support for controlled propagation and reintroduction efforts, benefits to multiple species, and establishment of dispersal corridors. Available to transportation planners and administrators, an RCS sets forth a process that allows either permanent or temporary impacts of road construction or maintenance activities to be offset by the creation of credits. Importantly, conservation efforts tied to recovery credits are not site specific, allowing conservation measures to be applied over a large service area. Operating through an RCS, a transportation agency may develop and store a "bank" of conservation credits that can be used by the agency at a later time to offset negative impacts on listed species due to road construction and operation across a road network covering a large geographic region where a listed species is known or considered to be present.

In addition to addressing permanent impacts, an RCS may also offset temporary impacts through the creation of temporary recovery credits. Temporary credits are generated

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through implementation of habitat-management activities identified in the recovery plan of a listed species, but which are discrete or short term in nature. Consistent with identified best management practices for pollinators, a transportation agency could accrue credits for the restoration and temporary protection of degraded habitat along roadsides to mitigate for habitat that will be temporarily affected elsewhere. Because temporary credits offset adverse effects that are also limited in duration, conservation measures associated with the temporary credits must remain in effect for some period of time after the adverse effects of the impacts have been reversed. As transportation projects often require temporary workspaces for construction, which are later returned to pre-construction conditions, earned temporary credits can be applied to address impacts under this scenario, streamlining approval processes for future construction activities associated with a road network.

Consultation with USFWS in an RCS occurs largely in two ways: first as an overall programmatic consultation to define and establish credits and debits, and second as individual activities are accounted for at the project level. A primary source of information to establish criteria for an RCS is the species' recovery plan. If no final approved recovery plan exists, an RCS may employ an equivalent USFWS-approved document describing specific measures that will contribute toward the down-listing or delisting goals of a listed species. When considering whether employment of an RCS is a strategy worth pursuing, it is important to note that not all listed species are appropriate for a credit system. Examples of species that would not be suited for an RCS are those whose conservation needs are poorly understood, and species that occur as single-site endemics.

4.4.5 Prelisting Conservation Agreement

A Prelisting Conservation Agreement (PCA) allows for the creation and banking of credits providing for the conservation of non-listed species. Anyone (e.g., federal agency or private entity) who wants to participate in the process can undertake a voluntary prelisting conservation action, earning credits to be carried forward as long as the action occurs in a participating state within the framework of an established conservation strategy for the species.

- Transportation agencies participating in a qualifying state-administered species-conservation program can obtain conservation credits for efforts benefiting a species recognized to be in decline.
- Credits can later be redeemed to offset or mitigate actions detrimental to the same species should it subsequently be listed under the ESA.
- Earned credits in excess of an agency's immediate or projected needs may be traded or sold to other agencies.

Conservation actions implemented under a PCA are to be based largely on a conservation strategy for a species developed by the state that principally guides all conservation efforts for the at-risk unlisted species whether conservation actions are implemented by federal, state, tribal, or private organizations. A strategy can be authored by any one of these entities, but ideally it is a collaborative effort, with states playing a primary role and the public participating in the process. Voluntary prelisting conservation actions give a landowner, whether federal or non-federal, the opportunity to have actions taken to benefit at-risk species serve as mitigation or a compensatory measure for the detrimental impact

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of an action undertaken after the species is listed as threatened or endangered. A PCA provides states with an additional tool and incentive to engage landowners, government agencies, and others in carrying out voluntary conservation actions for species not listed under the ESA.

USFWS treats voluntary prelisting conservation actions as (1) an intended compensatory measure of a proposed federal agency subject to the consultation requirements of Section 7(a)(2) or 7(a)(3) of the ESA, or (2) a measure to minimize and mitigate the impact of the taking of an endangered or threatened species pursuant to Section 10(a)(1)(B) of the ESA. To be treated as a voluntary prelisting conservation action under an agreement, the action need only be beneficial to a particular species. No specific magnitude of benefit needs to be identified. Credits are to be used within a "service area" based on the biological needs of the species. A "service area" may include more than one state. A PCA is a tool available for DOTs to generate credits prior to a species being listed. Following listing, the opportunity to create additional conservation credits can be pursued through actions undertaken under an RCS or HCP.

4.4.6 Conservation Banks

Conservation banks are worth mentioning, as they serve to address the effects of multiple activities on species and provide an opportunity for transportation agencies to take advantage of "excess land" that consists of real property rights, title to which is vested in the state DOT and that is determined and certified to be not required for ROWs or other operational purposes of the department. Conservation banks are permanently protected privately or publicly owned lands managed for endangered, threatened, and other at-risk species (see **Delhi Sands Flower-Loving Fly Conservation Bank** example). Banks compensate for adverse impacts on a listed species in advance of the impact based on the establishment of a permanent benefit (i.e., conserving the species' habitat) typically accomplished through offsite land set-asides, which leads to the creation of credits for use or sale. Both HCPs and RCS can be strengthened by the creation of banks for listed species. Equally, the effectiveness of CCAAs and PCAs could be improved by land set-asides for at-risk species.

Delhi Sands Flower-Loving Fly Conservation Bank (Colton, California)



Delhi sands flower-loving fly

Photo Credit: Moose Peterson, USFWS

A 150-acre conservation bank in Colton, California, aids in the recovery of the federally listed as endangered Delhi Sands flower-loving fly (*Rhaphiomidas terminatus abdominalis*). This unique species, native to the Inland Empire of Southern California, is the first and only fly to be listed under the ESA. Scientists petitioned the species in 1990 and USFWS listed it as endangered in 1993. The Delhi Sands habitats are highly unusual and are not found anywhere else on Earth. Protection of the fly is important, in part, because it will protect many other species also living in the dunes. The dunes

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support birds like the western meadowlark (*Sturnella neglecta*) and the burrowing owl (*Athene cunicularia*), mammals like the Los Angeles pocket mouse (*Perognathus longimembris brevinasus*), insects such as a subspecies of the Mormon metalmark butterfly (*Apodemia mormo nigrescens*), and numerous reptiles and plants. Owned by Vulcan Materials Company, the conservation bank protects the largest remaining contiguous block of habitat for Delhi Sands flower-loving fly. Land in the conservation bank will be conserved and managed in perpetuity through the placement of a conservation easement. Lands enrolled in a conservation bank can be used to offset impacts on species or habitats in areas outside of the bank's boundaries. The establishment of this 150-acre conservation bank represents one of the most significant steps in securing the future of the Delhi Sands flower-loving fly since it was listed under the ESA.

Link to information about the Delhi Sands Flower-Loving Fly:

https://ecos.fws.gov/ecp/species/1540

4.4.7 In-Lieu Fee Mitigation

Often referenced when considering voluntary options for addressing mitigation needs associated with aquatic resources, the in-lieu fee mitigation framework can provide an alternative to onsite mitigation that streamlines the process of mitigation, allowing for faster, more efficient project delivery for transportation agencies while still maintaining compliance with the requirements of the ESA for protecting the habitat of listed species. In accordance with Section 7(a)(1) of the ESA, transportation agencies working with the Services can use the in-lieu fee mitigation framework to create a mitigation strategy giving them the ability to create and contribute to a fund as their mitigation for unavoidable impacts on listed species. The amount of the contribution, or fee, is tied to the type and severity of the impact the development or maintenance project would be expected to have on the species. Money deposited into the fund is used to improve upon the conservation effort for the species above and beyond what is otherwise possible if funds were being restricted to a specific project location or to a lesser mitigation type. An in-lieu fee program typically combines fees collected from one or more impact projects to finance the mitigation benefiting the listed species. Funds can also be leveraged, and partnering is encouraged to maximize the value of the in-lieu fee mitigation. It is important to recognize this option is not available as part of most onsite mitigation plans and has not been readily applied outside of being used to offset unavoidable impacts on aquatic resources. For this reason, use of this option may require creation of a Memorandum of Understanding between transportation agencies and USFWS or NMFS to better define the overarching mitigation strategy and particulars of contributing to and managing the created mitigation fund.

4.5 Which Compliance Strategy to Use?

Early on in the decision-making process, it is important to recognize that rare and endangered pollinators often have specific habitat requirements, unique life history traits, and other traits that require knowledge of the individual species when making management decisions and evaluating which compliance strategy may ultimately be best suited for the situation. Furthermore, the types of challenges, as well as opportunities, to address ESA

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compliance issues vary by region, major land cover types, type of ROW operations, and types of design, planning, and construction activities. For these reasons and others, recommended strategies and associated management practices or prescriptions usually need to be geographically and condition specific.

This guide is intended to provide options for how DOTs can support conservation of at-risk and listed pollinator species through thoughtful management and design. The greatest value in taking a proactive approach to ESA compliance comes when specific management actions and design decisions are paired with discussed compliance strategies. Adoption of practices can lead to cost savings in the form of streamlining of permitting, planning, and design workflow with regard to listed species.

Comparison of various levels of effort and certainty gained through development of each approach is of value for transportation agencies to consider when deciding which strategy is best to pursue. Permit, process, duration of time to process, and formal regulatory assurances tied to each strategy (see Table 4-1), together with staff responsibilities and financial costs, are valuable for transportation professionals to understand when making decisions.

Other considerations for transportation agencies include risks and potential barriers, with regard to internal challenges tied to staff training; financial constraints; incompatibility with other goals; staff resources; and permit or legal limitations to successful implementation. One of the best recognized sources of information on internal challenges is the transportation professionals most familiar with and with expertise in applying the identified ESA compliance strategies in their own work and region.

With regard to their familiarity and experience with the ESA compliance strategies, a number of transportation professionals responding to survey questions (see National Cooperative Highway Research Program Project 25-59 final report for full questions and summarized responses) were familiar with identified strategies (see Table 4-3). However, a smaller percentage had experience actually applying the strategies in their own work. Additionally, only one respondent considered themselves as an expert in design or planning, the two groups of transportation professionals most likely to benefit from being educated about the different compliance strategies available to transportation agencies.

Table 4-3. Familiarity and experience of transportation professionals[1] with voluntary ESA compliance strategies.

ESA Compliance Strategy	Percentage of Respondents Familiar with the Strategy	Percentage of Respondents Who Have Applied the Strategy to Their Work
Safe Harbor Agreements	60% (24 of 40)	4% (1 of 27)
Recovery Crediting System	32% (12 of 38)	21% (5 of 24)
Habitat Conservation Plans	90% (37 of 41)	42% (14 of 33)
Candidate Conservation Agreements	78% (31 of 40)	27% (8 of 30)
Candidate Conservation Agreements with Assurances	79% (34 of 43)	36% (12 of 33)

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ESA Compliance Strategy	Percentage of Respondents Familiar with the Strategy	Percentage of Respondents Who Have Applied the Strategy to Their Work
Prelisting Conservation Agreements	54% (21 of 39)	14% (4 of 28)

[1] Forty-seven percent of respondents identified their area of expertise within their agency as "Environmental," 27% as "Maintenance," 13% as "Landscape Architecture," 3% as "Construction," 1% as "Planning," and 9% as "Other." None of the received responses were from professionals who identify their area of expertise as "Design."

4.5.1 Evaluating ESA Compliance Approaches

To inform the process of identifying a preferred strategy, the questions below can be used by planners and designers when first evaluating different proactive approaches to addressing ESA compliance. Specifically, questions are designed to (1) prompt readers to think through proactive strategies that are alternatives to the more traditional Section 7 consultation when dealing with listed species that may be affected by an action such as a building a road, and (2) help inform readers about voluntary strategies to mitigate present-day and future risks to at-risk species. An expanded version of these questions can be found in Appendix A (for listed pollinator species) and Appendix B (for imperiled pollinator species).

Questions to Consider	Answers to Help Guide Decisions
For a specific geography or project, are there multiple listed species expected to be affected or a single listed species?	If there are multiple listed species, it is of value to consider investing in a compliance strategy, such as an HCP, wherein different conservation measures can be bundled together to provide regulatory coverage for take of a number of listed species under a single permit.
Are at-risk pollinator species present in the planning area?	If so, a CCAA provides assurances to transportation agencies who invest early in the application of recognized conservation actions, such as the abandonment of an otherwise once-planned road extension, within a planning area encompassing a larger road network that benefit single or multiple pollinator species considered to be at risk for future listing.
Will at-risk species possibly be harmed by future activities?	If so, by working with state and federal agencies, a transportation agency can create credits under a PCA by implementing conservation measures benefiting a state-recognized at-risk species at select locations across its service area, providing assurances the agency will have the ability to mitigate for future impacts on the species following a federally listing.
Are listed species present in or adjacent to existing ROWs?	If so, consider use of a SHA to provide formal assurances that future land use restrictions will not result from investment in management activities that increase habitat value and/or the local abundance of the listed species covered under the permits.

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Questions to Consider	Answers to Help Guide Decisions
Are some of the suggested changes to maintenance activities to benefit listed pollinators also viewed as potential cost-saving measures?	If so, creation of SHA allows for transportation agencies to invest in maintenance activities that may result in cost savings, such as shifting the timing and frequency of mowing, but also real benefits to pollinators without fear of penalty for attracting or increasing the amount or distribution of the listed species on managed lands.
Are the same listed or at-risk species likely to be affected by recurring construction or management activities?	If listed or at-risk species are likely to be continually affected by future activities, investing early in development of an HCP, if there are multiple species deserving coverage, or an RCS or PCA, to generate a bank of credits for both permanent and temporary impacts on listed or at-risk species, respectively, may be worth pursuing.
Is offsite mitigation an option?	If offsite mitigation is an option, the creation of mitigation and conservation banks on their own or as part of an RCS or HCP creates lasting credits for local impacts on listed species that can be transferred or sold to other agencies in time.
Are there established recovery plans for listed species of interest?	If so, the conservation actions identified in the recovery plan provide a framework from which to build an appropriate and recognizable conservation strategy to be implemented under an RCS.
Are the conservation needs for a listed species poorly understood?	If so, there may be value in exploring the opportunities presented by a SHA, which allows for experimentation and knowledge building while providing assurances that agencies will not be penalized regardless of whether they are successful in benefiting listed species through their actions.
Is the species endemic to a small area or does it occur at a single site?	If so, an HCP may be most appropriate for addressing the range of conditions needed to ensure long-term protection and recovery of the species, recognizing the potential for impacts on the species associated with road construction and maintenance activities.
Are there established state-sponsored conservation plans for at-risk species of interest?	If so, the conservation plans are to serve as the preferred source for identifying the conservation strategies to be implemented under a PCA to receive credits for future impacts on at-risk species following federal listing.
Are there federal lands neighboring present-day ROWs or future project areas containing recognized habitat for at-risk species of interest?	If so, consider reaching out to neighboring federal agencies to explore the possibility of linking a CCAA with a CCA to establish a comprehensive conservation plan for at-risk species, allowing for greater consistency in management actions, and thus effectiveness, across a larger regional landscape consisting of both federal and non-federal properties.

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Questions to Consider	Answers to Help Guide Decisions
Is the existing or future road network present in wildfire-prone landscapes?	If so, explore opportunities to earn credits through an HCP, RCS, or PCA by installing road-hardening measures, such as concrete pavement, in ROWs to reduce ignition rates and protect high-value pollinator habitat harboring either listed or at-risk species in the neighboring natural areas bordering the road network.
Is the existing or future road network in lands largely dominated by agricultural activities?	If so, consider the recognized value of investing in use of native plants in ROWs to promote pollinator activity and dispersal throughout the larger landscape when discussing conservation measures that may generate credits under an RCS or PCA, or are recognized as a beneficial action taken under a CCAA or HCP, providing value to natural and agricultural systems.

4.6 Programmatic Agreements and the Value of Participating in Multiple Strategies

An HCP, CCAA, CCA, RCS, or SHA can be developed by transportation agencies into a programmatic agreement allowing for an individual compliance strategy to be applied to a suite of projects or a program involving similar activities in a particular geographic area associated with roadside maintenance or construction. Additionally, as activities associated with expansion or maintenance of a larger road network are likely to involve multiple parties and agencies, a programmatic agreement allows for such parties to come together under a single compliance framework to achieve several objectives with positive administrative benefits for all parties.

As an example, a programmatic CCAA and its associated permits authorize state, local, and tribal governments and other entities to enter into an agreement and hold the associated permit. A programmatic CCAA allows for individual property owners within a specific area or region to become enrolled and conveys the permit authorization and assurances to them through a "certificate of inclusion." When addressing listed species, whether through an HCP, RCS, or SHA, a programmatic approach streamlines the procedures and time involved in consultations for numerous similar activities with predictable effects on listed species and/or critical habitat. Collaboration among multiple parties allows for creation of compliance strategies that address listed and at-risk species issues at a regional level, increasing the overall effectiveness of individual conservation measures.

Just as there is value in establishing collaborative agreements among multiple parties and agencies, there are also benefits to exploring the relationships among identified compliance strategies (see Figure 4-1). When moving forward with planning, transportation agencies need to consider the possibility of implementing multiple strategies in a phased approach to meeting long-term programmatic needs for ESA compliance. The value of phasing or engaging in multiple strategies becomes clear when agencies are looking at longer-term time horizons associated with project work and recognize the suite of activities that may need to be permitted will take place across an expansive geography.

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Additionally, depending on the geographic and temporal scope of planned activities, agencies need to consider the value of participating in multiple programs concurrently if actions undertaken for the benefit of listed and at-risk species under otherwise separate programs are mutually exclusive. In coupling strategies that address the immediate compliance needs of listed species together with implementation of proactive conservation efforts designed to aid species before they become listed, DOTs position themselves to maximize the full value of available strategies and increase opportunities to discover ways to successfully streamline regulatory processes and incorporate simpler, more cost-effective conservation measures in roadside design and management.

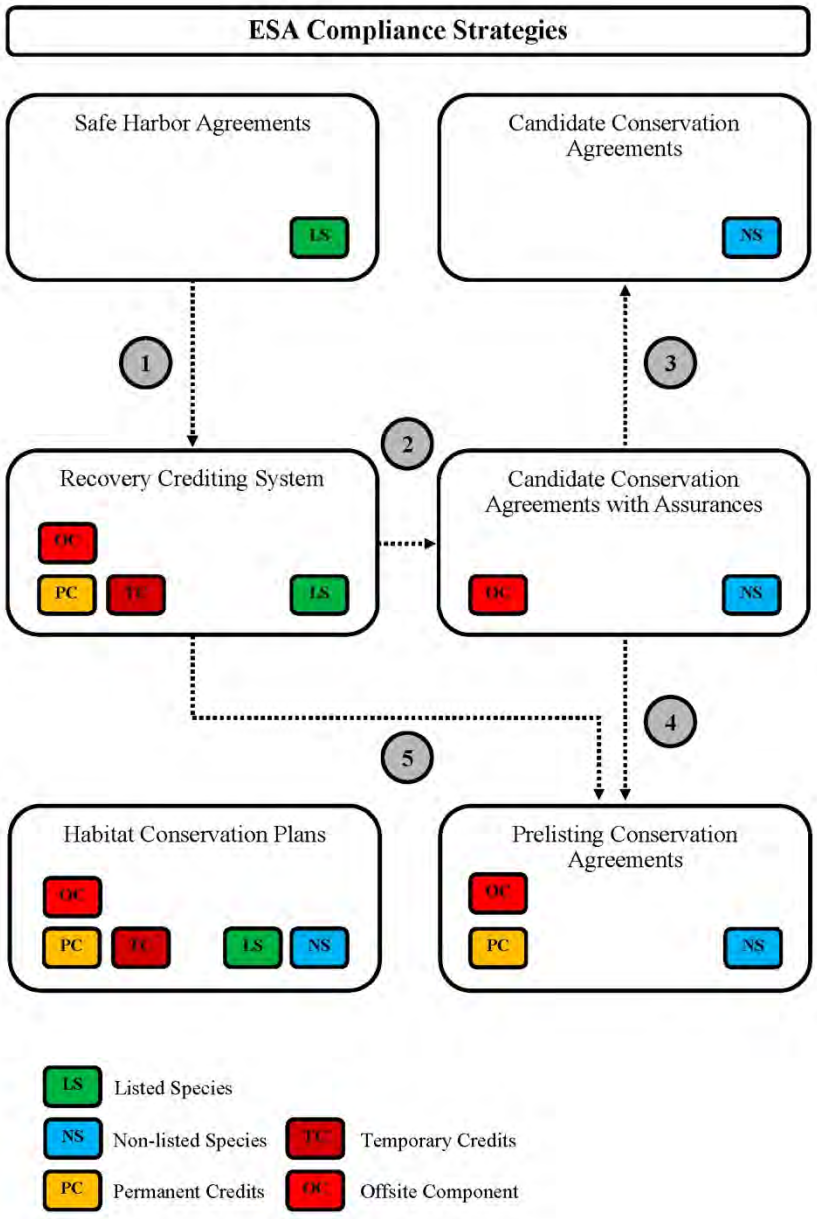


Figure 4-1. Relationships among voluntary ESA compliance strategies and opportunities for a phased approach.

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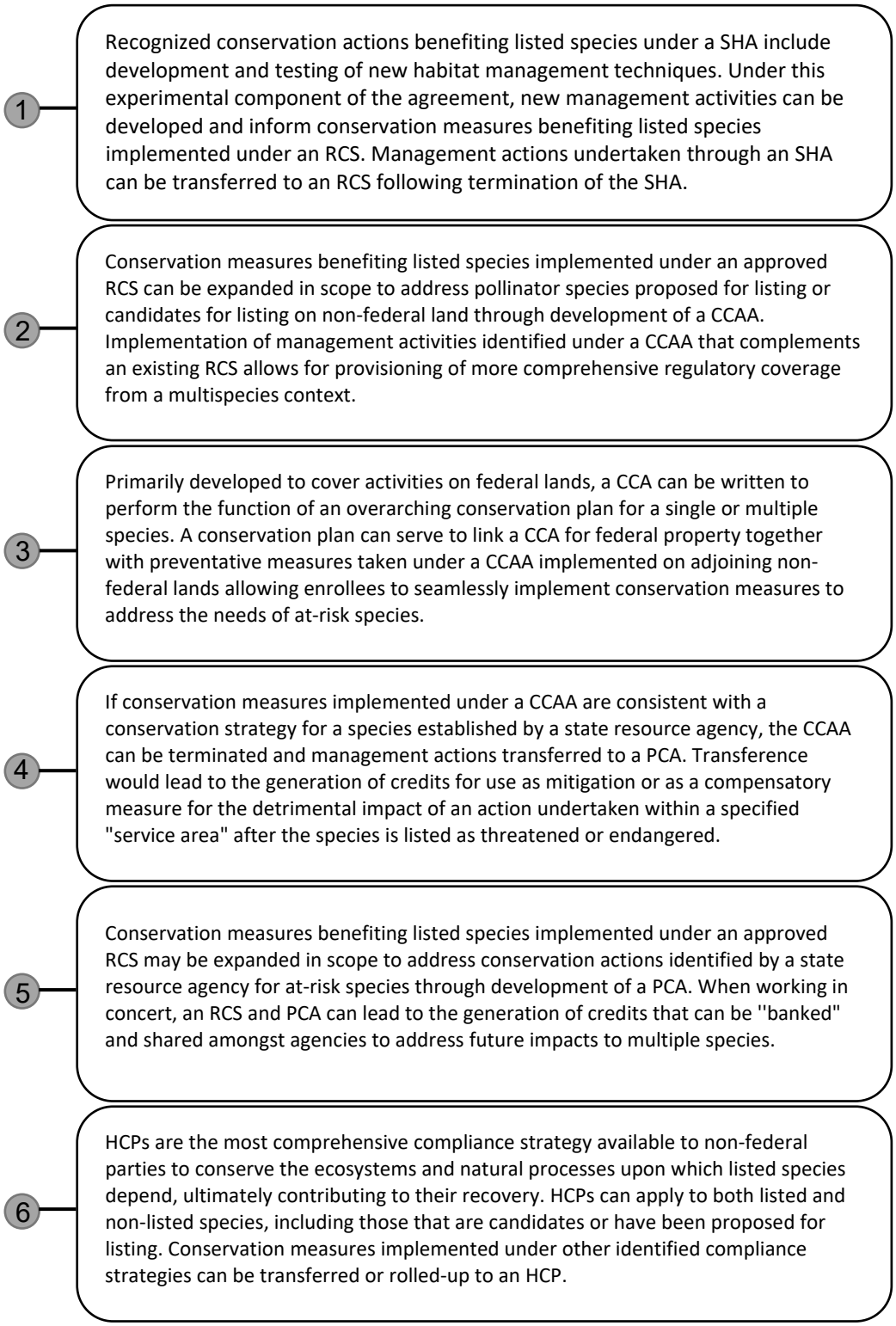


Figure 4-1 (continued)

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4.7 Summary

State DOTs can contribute to the recovery of imperiled pollinator species and potentially help to avert listings by considering pollinators in the planning process. Undertaking proactive voluntary conservation measures can help transportation agencies secure reasonable assurances regarding their future regulatory responsibilities under the ESA through a variety of mechanisms.

HCPs and associated incidental take permits have continually proven themselves to be a versatile tool for reconciling development and conservation objectives in a wide variety of contexts. Similarly, SHAs, CCAAs, CCAs, RCS, and PCAs offer transportation agencies useful strategies to be collaborative and innovative in their approach to ESA compliance. The flexibility and ingenuity tied to thoughtful, advanced planning efforts are key to developing effective compliance strategies and resolving complex and controversial issues that may arise as a transportation project or program moves from planning to implementation.

Investing in time up front to identify opportunities can allow transportation agencies to take a comprehensive approach to planning and implementing conservation measures across a larger service area or road network. With an opportunity to take a landscape-scale approach and think broadly about future impacts likely to occur across space and time, planners and designers can consider adopting compliance strategies that are programmatic in nature and take advantage of multi-agency partnerships. In particular, transportation agencies can seek out opportunities to form multi-agency partnerships across regions where similar construction and management activities have the potential to affect, but equally improve, the long-term conservation status of imperiled pollinators. For a number of infrastructure agencies, such partnerships have proven to ultimately lead to greater efficiencies in the design and build process (see Chapter 5) and long-term maintenance (see Chapter 6), saving time and resources. Furthermore, implemented measures have resulted in higher-profile conservation actions for the agencies and often greater public support and recognition.

4.8 Additional Resources

- *NCHRP Legal Research Digest 75: Legal Requirements for State Departments of Transportation Agency Participation in Conservation Plans*: https://www.nap.edu/catalog/24901/legal-requirements-for-state-departments-of-transportation-agency-participation-in-conservation-plans.
- USFWS's Pollinators Library: https://www.fws.gov/library/collections/pollinators.
- USFWS's Endangered Species Program: https://www.fws.gov/program/endangered-species.

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Chapter 5 Considering Imperiled Pollinators in Transportation Planning, Design, and Construction

5.1 Introduction

There are several opportunities to integrate pollinator conservation measures into transportation projects during the planning and project development processes. Early stages of project planning provide opportunities to avoid the most sensitive habitats, project design allows for inclusion of pollinator-friendly roadside features, and project construction provides opportunities to minimize construction impacts on pollinators and to integrate pollinator habitat into projects. From relatively small roadway improvement projects to major new transportation infrastructure projects, awareness and integration of these opportunities can provide important pollinator conservation benefits.

This chapter outlines the transportation planning and project development process and highlights opportunities to include pollinators and their habitat needs in the planning, design, and construction processes. This chapter provides examples to guide planners, designers, and construction personnel on when and how pollinator conservation and federal Endangered Species Act (ESA) compliance can be effectively integrated into transportation planning and transportation project development processes. Some of the steps presented focus more on the larger biology of pollinators and would be completed by the environmental team or through a larger regional science effort. For example, planners, designers, and construction personnel would not be responsible for developing detailed knowledge of pollinator species; they would be expected to reach out to biologists from their agency for that information at the points in the process that have been highlighted for them. To make this chapter more useful for planners, designers, and construction personnel, call-out boxes are included identifying specific steps and actions that apply to each of these phases and specialties, and identifying when to coordinate with local environmental and biology staff.

5.2 Transportation Planning and Project Development

Transportation agencies are charged with meeting the transportation needs of their community. Meeting this goal requires utilizing a multi-step approach to ensure that a community's needs are identified and addressed. This chapter was developed using the following general definitions of the Transportation Planning and Project Development portions of the process.

Transportation planning is the process of identifying transportation needs and establishing plans for infrastructure development to meet those needs. Transportation planning occurs at the local, regional, and state levels and generally includes identifying and prioritizing projects needed to maintain and improve transportation networks and achieve specific transportation goals. Transportation planning includes identifying the modes of

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transportation needed, types of projects, and locations where projects are needed to meet transportation goals.

- Local and regional transportation planning agencies develop Transportation Improvement Programs (TIPs).
- Regional Transportation Improvement Programs (RTIPs) identify projects to meet the identified transportation needs.
- Statewide Transportation Improvement Programs (STIPs) contain projects compiled and prioritized from TIPs. STIPs contain preliminary project descriptions, overall project cost estimates (including cost of environmental studies, permits, mitigation, and construction), funding sources, and identification of lead agencies for design, construction, and environmental compliance. STIP projects are congruent with Federal Transportation Acts goals.

Other transportation planning programs are associated with state highway operations, roadway maintenance, rehabilitation, and safety programs, all of which generally relate to maintenance of transportation infrastructure. The inclusion of pollinator-friendly practices in roadway maintenance is addressed in Chapter 6.

Transportation planning occurs in both long-range (20+ years) and short-range planning horizons (e.g., 4-year STIP programs). Long-range transportation planning provides programmatic-level goals, standards, and prioritization strategies for transportation system development and serves as the foundations for the development of the TIPs (Figure 5-1).

Transportation project development is the multi-phase process of initiating, designing, and delivering a specific transportation project. This process generally involves project initiation, environmental studies, project design, and construction (Figure 5-2).

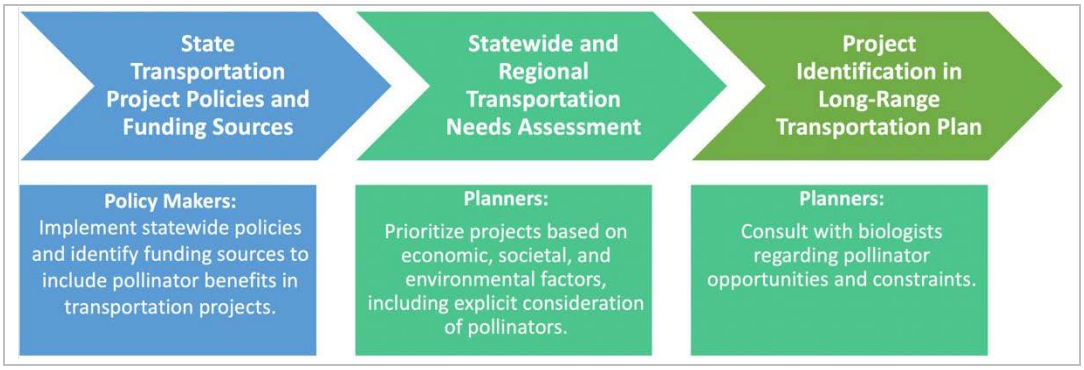


Figure 5-1. Integration of pollinators into long-range transportation planning.

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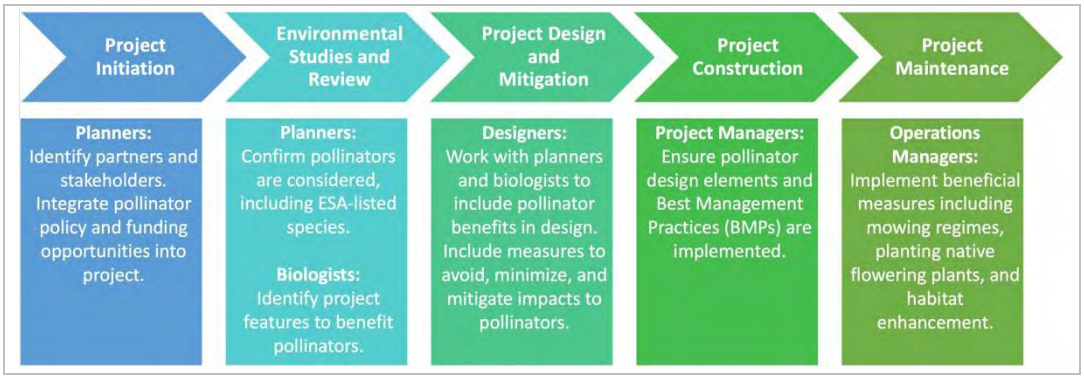


Figure 5-2. Integration of pollinators into transportation project development and implementation.

5.3 Integrating Pollinator Conservation into Transportation Planning and Project Development

There are a variety of opportunities throughout the transportation planning and project development processes to identify, develop, and implement actions that support the conservation of pollinator habitat and pollinator species. To ensure sufficient funding and integration of pollinator conservation strategies into transportation project planning and development, it is important that planners, project managers, and designers consider and incorporate environmental data and conservation needs at the appropriate phases throughout planning and project development.

Several tools have been developed to improve conservation outcomes in the transportation planning and project development processes. A well-known example is the Federal Highway Administration's (FHWA) Eco-Logical approach, which organizes currently available methods and tools that support systematic and step-wise inclusion of natural resource considerations throughout the transportation planning and project delivery processes. Such frameworks ensure timely identification of natural resources and constraints, impact avoidance, impact minimization, and compensatory mitigation needs. They also provide opportunities to establish programmatic approaches to recurring issues that are implemented at the project level. If transportation planners are using one or more of these available tools, then consideration of pollinators can readily be integrated into those steps that address natural resources, focal species, environmental regulation, and mitigation. Important actions that support successful integration of pollinator conservation into both transportation planning and project development include the following:

1. Identification of partners and stakeholders, along with an understanding of their wants and needs (see Chapter 11, *Communication Support*).
2. Collaboration and coordination with partners and stakeholders early and often.
3. Development of a detailed local and regional understanding of the ecology, conservation status, and regulatory requirements for "focal pollinators" (species that

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How can this be implemented?

Planners: Integrate pollinators through steps 1, 2, 3 (work with transportation agency biologists), and 5.

Designers: Integrate pollinators through steps 2, 3 (work with the project biologist), 4, 5, 6, 7, 8, 9, and 10.

Construction managers: Integrate pollinators through steps 4, 5, 6, and 9.

are of particular conservation concern, such as monarch butterflies or other imperiled species) potentially affected by the project. This is best done with assistance from state, federal, or other biologists that have expertise with focal species (see also Chapter 3, *Imperiled Pollinator Profiles*).

4. Understanding pollinator-friendly design elements and opportunities to include them in project design and construction (Chapter 2, *Pollinator Biology and Roadsides*, and Chapter 7, *Revegetation and Pollinators: Design and Implementation*).

5. Understanding how project implementation may affect focal species, pollinators generally, and conservation objectives. It is also important to recognize potential positive and negative impacts.

6. Identification and prioritization of avoidance and minimization measures for potential negative effects on pollinators generally and/or on specific pollinators of concern (focal pollinators).

7. Development of a pollinator mitigation strategy to offset negative effects of roadside construction and maintenance on pollinators, and a pollinator conservation strategy to enhance pollinator habitat value (Chapter 4, *Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation,* Chapter 6, and Chapter 7).

8. For federally listed species, development or use of programmatic permits and agreements when appropriate (Chapter 4).

9. Tracking environmental commitments to ensure that pollinator-friendly conservation measures are implemented and that avoidance, minimization, and mitigation measures are implemented.

10. Monitoring outcomes to document the actual benefits to pollinators, including focal pollinators, and implementing adaptive management to improve outcomes as needed (see Chapter 9, *Surveys, Monitoring Strategies, and Habitat Assessments*).

Implementation of these actions facilitates early inter- and intra-agency collaboration, stakeholder coordination, improved regional conservation outcomes, and increased efficiencies of project development cost and schedule. Early implementation benefits include:

- improved environmental planning and regulatory predictability,
- streamlined permitting and environmental review processes,
- lower risk to total project cost and schedule, and
- improved project and environmental outcomes.

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5.3.1 Federal Endangered Species Act Conservation Responsibilities

It should be noted here that, as discussed in Chapter 4, the federal ESA Section 2(c) of 16 U.S.C. 1531 states as policy, that "all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of this Act." Similarly, Section 7(a)(1) states, "[a]ll other Federal agencies shall, in consultation with and with the assistance of the Secretary, utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species and threatened species listed pursuant to section 4 of this Act." It should be noted that such policy only applies to those state departments of transportation (DOTs) with National Environmental Policy Act (NEPA) Assignment (23 USC 326 & 327). In the context of transportation planning and project development, this includes responsibilities to conserve (i.e., recover) listed species, as policy, and not only in the context of regulatory requirements.

5.3.2 How to Include Pollinators in Transportation Planning

This section provides additional guidance on the types of actions that can be implemented during each transportation planning phase to effectively incorporate pollinator conservation into transportation projects, and focuses on how transportation planners can incorporate pollinator considerations into short- and long-term transportation plans at the local, regional, and statewide scales. Incorporating consideration of pollinators early in planning will increase the likelihood of effective conservation.



Incorporating pollinator conservation goals into the planning and design process can help lead to successful projects that support pollinators along roadsides, such as this roadside planting in Arizona.

Photo Credit: Luis Colon/Arizona DOT

Long-Range Transportation Planning

Long-range transportation planning involves developing long-term (e.g., 20+ year) transportation policy and plans. Such long-range transportation plans (LRTPs) are built upon an overarching policy framework and include guiding principles, objectives, and strategies. LRTPs do not contain details about specific projects but do address the recommended mode of transportation for a region. The long-range transportation planning process typically includes outreach and engagement with partners such as state and federal agencies, tribal governments, stakeholders, and the public. Input gathered during the outreach and engagement processes may be used to develop the guiding principles and strategies implemented to achieve objectives. Environmental stewardship is a common guiding principle in many LRTPs and each plan has the opportunity to develop objectives and strategies aimed at improving environmental outcomes and conservation, including objectives specifically targeting pollinator conservation.

Pollinator conservation opportunities that exist within the long-range transportation planning phase include opportunities for stakeholder and public input on incorporating natural resource protection and conservation into the guiding principles, objectives, and strategies. Early consideration and integration of robust and inclusive environmental objectives and strategies will support pollinator conservation efforts later in the short-range transportation planning and project development processes.

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Planners: Ask the project biologist or environmental team which considerations are important for local species.

- Are there areas that are particularly beneficial or necessary?
- Will there be project features to benefit pollinators that can be identified at this point?

Regional and Local Long-Range Transportation Planning

Regional and local long-range transportation planning may occur within regional planning efforts such as Transportation Systems Plans (TSPs) and general plans. A TSP describes the transportation system and outlines projects, programs, and policies to meet its needs now and in the future based on the goals and aspirations of the community it serves. Regional transportation planning may also be conducted as part of county and city general plans (e.g., transportation elements). A general plan is a broad planning guideline to a county or city's future goals and provides policy statements to achieve those goals. A general plan transportation element will outline the transportation facilities and projects needed to support planning goals and objectives.

Pollinator conservation opportunities that exist within the regional and local long-range transportation planning phase include opportunities for stakeholder and public input on incorporating natural resource protection and conservation into the guiding principles, objectives, and strategies.

Given that, at this phase, additional details are known about potential proposed projects, more specific information may be available to foresee potential impacts and support pollinator conservation. This can include opportunities for public, stakeholder, and agency input on specific projects and environmental stewardship objectives, and identification of sensitive biological resources and constraints. Having this information available can facilitate substantiation of a project's purpose or influence the location, extent, or cost of a project, and may also improve integration of environmental stewardship and help avoid impacts, as well as reduce unforeseen project constraints and costs.

Additionally, this may be an appropriate stage to consider regional impacts of such plans and the appropriateness of proactive ESA compliance, advanced mitigation programs (e.g., California Department of Transportation [Caltrans] statewide advance mitigation program [Caltrans 2019]), or regional Habitat Conservation Plans (see Chapter 4). It should be noted, however, that such approaches may be considered and implemented at any time.

Short-Range Planning

Short-range transportation planning involves development of short-term (e.g., 4 years) TIPs that identify a list of specific transportation improvement projects. Projects contained in TIPs are prioritized based on transportation needs and congruent with LRTP objectives. Because TIPs include a list of specific projects, general information on the project purpose, type, location, extent, and cost are included. Community engagement and public outreach are required components for local, regional, tribal, and state TIPs, and all projects are presented to the public prior to being included in an RTIP or STIP.

Pollinator conservation opportunities that exist within the short-range transportation planning phase include opportunities for public, stakeholder, and agency input on specific projects and environmental stewardship objectives, which may substantiate a project's purpose or influence the location, extent, or cost of projects. For example, if a specific project is proposed and is likely to negatively impact a pollinator species or habitat, comments may be received from stakeholders, the public, and/or a regulatory/resource agency stating as such and providing input on avoiding and minimizing such impacts.

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Early consideration and integration of public, stakeholder, and agency input may improve identification of sensitive biological resources and constraints, and can improve integration of environmental stewardship, help avoid impacts on sensitive resources, and reduce unforeseen project constraints and costs.

Not all areas may be suitable for the creation of pollinator habitat. Likewise, creation of pollinator habitat in some areas may have much greater value for pollinators than habitat created in other areas. For example, roadside habitat that increases habitat connectivity or connects to important natural areas may contribute to the conservation of imperiled species. Creating regional maps that identify high-, medium-, and low-priority areas for pollinator revegetation projects may streamline choices about habitat creation in later phases and help to make decisions about where to allocate limited funds. Box 5-1 gives an overview of the different factors that can help determine whether an area should be prioritized for revegetation projects supporting pollinators (see Chapter 7 for more detail).

Box 5-1. Prioritizing sites for pollinator habitat

The following considerations can be used to guide prioritization of sites for pollinator habitat.

Planners

- *Roadside width:* Wider sites are preferred; they support greater numbers and a higher diversity of pollinator species.
- *Road density:* Sites should not be isolated within areas of high road density in which there are multiple barriers to pollinator movement (e.g., a cloverleaf median off an interstate interchange in an urban area).
- *Visibility to the public:* Sites that are more visible to the public may be important for DOT goals, including public awareness and education.
- *Traffic density:* Sites along roads with higher traffic density may be less desirable for pollinators. However, these roads often have wider rights-of-way and are more visible to the public.

Biologists

- *Presence of focal pollinator species:* Is a listed or imperiled pollinator species known to be in the vicinity or was one previously found at the site?
- *Landscape connectivity:* Does the site improve connectivity of existing habitat within the landscape? For example, is the site near or connected to a natural area (e.g., state park, national forest, nature preserve)? Or does it connect with existing high-quality roadside vegetation?
- *Landscape diversity:* Is the site in an area important to the focal pollinator species and in a landscape in which habitat is scarce, and therefore where roadside habitat would be particularly valuable to pollinators?

For further evaluation of existing habitat or prioritization, see the *Roadside Pollinator Habitat Assessment Guide* in Chapter 9.

5.3.3 How to Include Pollinators in Transportation Project Development

This section provides guidance on including opportunities for pollinator conservation and pollinator-friendly best practices into the project development process, as well as opportunities to implement avoidance, minimization, and mitigation measures.

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Incorporating pollinator considerations and identifying funding to implement project features to meet pollinator needs will increase the likelihood of effective conservation. See Table 5-1 for a summary.

Project Initiation

It is important to ensure that adequate estimation and identification of potential environmental resource impacts; avoidance, minimization, and mitigation strategies; environmental and regulatory constraints; schedule restrictions; and funding needs are included in the *Project Initiation Document* because it can be challenging to incorporate these during subsequent project development phases and not doing so may result in inadequate project funding. The project initiation phase involves development of a detailed project description that includes the project purpose and need, project limits, project alternatives, environmental constraints and permits, level of environmental document needed (e.g., NEPA Environmental Assessment or Environmental Impact Statement), project schedule, inter-agency coordination needed, and project cost, all reported in the *Project Initiation Document*. This phase culminates in an approved, programmed, and funded transportation project. *Note: When developing the Project Initiation Document, it is important to collaborate with DOT environmental staff to ensure that inclusion of measures and project elements that benefit pollinators are considered from the outset.*

Because detailed project information (e.g., detailed project description and location) is being developed in this initiation phase, conservation opportunities and considerations may be more specific. Once project details emerge, potential impacts on focal pollinators or sensitive habitats can be identified. Conservation strategies may be developed and coordinated with the project development team, and funding for anticipated avoidance, minimization, and mitigation may be identified and detailed. This is the stage where it is important to incorporate conservation strategies for pollinators such as habitat avoidance and enhancements into the project description and conceptual design. It is important to coordinate with the project biologist to identify the pollinators of concern and project features needed to address the concerns for those species.

Design team: Utilize preliminary environmental analysis reports for information regarding pollinator habitat to avoid and design features to include to benefit local species.

Coordinate with the project biologist or environmental team for more information.

During this phase, it is useful to review any maps or lists of sites that have been flagged as important for pollinator conservation (following the considerations provided in Box 5-1), to recognize where additional enhancements and mitigation measures are needed and to ensure that pollinator conservation activities take place in high-priority sites.

This is a key phase for recognizing and incorporating the needs of imperiled pollinators. By accounting for pollinators in this phase, their needs will be included in the project budget and in mitigation or avoidance strategies.

Environmental Studies and Review

The environmental review phase involves detailed environmental research and field studies. This can include surveys documenting the pollinator community, including imperiled pollinators, and important pollinator habitat that may occur in the project area. This is also the phase where potential project-related impacts on focal pollinators and/or pollinators and their habitat generally are identified, along with strategies for avoidance,

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minimization, and mitigation. This phase identifies all environmental permitting and compliance needs, and includes the opportunity for public input prior to finalizing studies and reports. Federal ESA compliance is also conducted at this time and needs to be finalized before the phase is completed (see Chapter 4 for more information on ESA compliance).

If the project will potentially impact a focal pollinator species, the environmental studies and review phase is the best time to initiate early and frequent coordination with state and federal resource agencies, and to begin consultations with species experts. During this phase detailed biological resource inventories and impact analyses for focal pollinators are also conducted (see Chapter 9). This is the phase to work with biologists to develop project-specific avoidance, minimization, and mitigation measures. Such measures could include guidance on avoiding habitat impacts, specifications for avoiding soil compaction during construction, and plant lists for revegetation. In creating plant lists for revegetation, it is important to include key plants used by any focal pollinators in the project area, such as important host plants or nectar plants. Even where there is no focal pollinator driving the revegetation project, using native plants will ensure that the roadside habitat is more beneficial to pollinators than revegetation using non-native plants (see Chapter 7).

It is important to consider the landscape context of the revegetation project. Using information collected during an inventory or vegetation assessment to develop a landscape connectivity map of the project area and adjacent lands that locates areas of high, medium, and low pollinator habitat qualities can be a base for designing a revegetation plan that improves pollinator habitat within a larger landscape connectivity context. If pollinator resources (such as floral diversity, nectar sources, host plants, and nesting sites) are limited, it can be helpful to prioritize high floral diversity and cover and other factors that influence pollinators for projects that link or act as stepping stones between existing habitats on private, municipal, state, or federal lands (see Box 5-1 and Box 5-2 for additional guidance). Corridors with high-quality habitat support more butterfly species, including specialist species, and population persistence (Habel et al. 2020). It is also important to prioritize those projects that can increase the connectivity of existing roadside habitat. If remnant roadside habitat exists, for example, it would be very beneficial if revegetation projects with high plant diversity were installed adjacent to or nearby. The comprehensive assessment of pollinator habitat found in Chapter 9 includes a category that evaluates the roadside within the context of the larger landscape and a category that evaluates possible threats to pollinators from the adjacent road and surrounding land. The scores from those categories can help to guide choices about prioritizing projects that emphasize an objective to improve habitat for imperiled pollinators.

Box 5-2. Habitat prioritization for monarchs

A habitat prioritization model was developed by the Monarch Joint Venture and research partners to help DOTs assess roadsides for monarch butterfly habitat (with funding through the Transportation Research Board's National Cooperative Highway Research Program (NCHRP) as part of NCHRP Research Report 942). The model can help managers assess potential areas of habitat along roads in their state or identify where habitat could be developed.

More information about the model can be found at:
https://monarchjointventure.org/mjvprograms/science/roadsidehabitat/habitat-prioritization-model

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Design Team: Ensure that all environmental commitments, including those to benefit pollinators, are included in the final design and bid package. This is a critical step in implementing all the planning and design work to benefit pollinators.

Design (Plans, Specification, and Estimates)

The design phase includes the development of detailed design plans and specifications as well as construction cost estimates. This includes, for example, structural, roadway, utility, and landscaping design details as well as any agreements and permits needed to construct the project.

Before completion of the design phase the project design and specifications need to be confirmed to ensure they are consistent with environmental commitments. If measures benefiting pollinators are to be included, the design plan standard specifications need to explicitly include measures that help to avoid and/or minimize negative impacts of the project on focal pollinators. Consult environmental and maintenance DOT staff to confirm that measures are appropriate and feasible. This is also the stage where detailed revegetation (e.g., ornamental landscaping, habitat restoration) plans are incorporated into the project design (see Chapter 7 for more information on design and implementation of revegetation projects). Incorporating native plants whenever possible will benefit pollinators generally. Designers should coordinate and collaborate with maintenance teams during this planning phase. Maintenance staff can inform long-term maintenance strategies of planned vegetation and can offer advice on weed control before, during, and after construction.

In addition to project design plans and specifications, construction cost estimates are included in this phase. It is important to include accurate cost estimates for construction of project components and landscaping plans to ensure adequate project funding and to reduce contract change orders during construction. During the project design phase (e.g., 60 percent design) environmental regulatory permits are applied for. Once permits are received, integration of any required compensatory mitigation is integrated into project design plans.

Construction

This phase involves the construction of a project including ground disturbance, vegetation removal, and grading, followed by associated erosion control and landscaping or habitat enhancement (revegetation).



Construction projects present an opportunity to engage in high quality (Box 5.x) revegetation that will support pollinators. that will support pollinators.

Photo Credit: Washington DOT

Construction can have a variety of negative impacts on pollinators. However, construction projects may also present opportunities to engage in revegetation projects, creating habitat to support pollinators. Construction projects can cause habitat loss and habitat fragmentation (breaking up of habitat into smaller, more isolated patches; see Box 5-3). Construction can also reduce the availability of important host plants and floral resources in an area. Additionally, soil compaction around the construction site may make the area less habitable for some species of ground nesting bees, and construction may increase the spread of invasive plants if equipment is not properly cleaned when moved between sites.

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Box 5-3. Habitat loss and pollinators

Habitat loss and habitat fragmentation are leading causes of declines in pollinators. Habitat loss occurs when some part of the habitat is transformed into another type of habitat or land use. Larger habitat patches can support more individuals and more species than smaller habitat patches. Larger populations are less vulnerable to extinction than smaller populations. Larger populations also generally have higher amounts of genetic diversity, enabling them to adapt to environmental changes.

When habitat is lost, important microhabitats may also be lost. Habitat loss can lead to reductions in the overall abundance of important host plants or floral resources that can further lead to reductions in pollinator populations.

Habitat fragmentation occurs when a larger habitat patch is broken up into smaller, more isolated patches. Building roads through intact habitat leads to habitat fragmentation. Habitat fragmentation changes the characteristics of the remaining habitat patches so that the patches contain more edge habitat than core habitat, which reduces the abundances of species that rely on core habitat. Habitat fragmentation can also increase the spread of invasive species.

It is important to remember that once habitat is destroyed, it is very difficult and expensive to restore. Therefore, it is best to avoid habitat loss and habitat fragmentation whenever possible, especially for habitat used by imperiled species. Some species are very sensitive to habitat disturbance and can only be found in high-quality, undisturbed habitat. Two such species are the Poweshiek skipperling and the Dakota skipper. These federally threatened grassland butterflies require high-quality, unplowed prairie habitat. Prairie restoration efforts have had little success in creating new habitat for these species.

When dealing with construction projects that occur inside the habitat of listed species, consult with biologists from the U.S. Fish and Wildlife Service (USFWS) to create a plan that will minimize impacts on the listed species (see Chapter 4 for more information about ESA compliance). Also, consult with state or federal biologists when working in habitat of non-listed imperiled species. Management focused on particular species must be tailored to the biology of those species. However, there are some general recommendations for reducing impacts of construction projects on pollinators, including imperiled species, as listed below. Note that implementation of these recommendations may not be feasible, cost effective, or warranted in some cases, and careful planning and consideration should be given prior to their implementation.

- Invest in high-quality revegetation efforts along the roadside (see Chapter 7 for more information). While some imperiled species may not be able to breed in these areas, the revegetated habitat may provide foraging habitat for targeted imperiled species.
- On roads with high traffic density, consider increasing the width of mown strip in the recovery area (e.g., from one to two mower swaths, or up to 20 feet) to reduce pollinator exposure to chemicals associated with roadsides, when practical (see Chapter 6 for more information).
- Think long term about maintenance in revegetated areas so that the habitat continues to be valuable to pollinators. When planning a construction project, take the biology of the imperiled species into consideration.

What is high-quality pollinator roadside habitat?

High quality revegetation projects are those that prioritize usage of native plants and high plant diversity, including an abundance of flowering plants that provide pollen and nectar or act as host plants for butterflies.

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- For short-term construction, plan construction activities so that they do not occur during sensitive times for the species.
- For long-term construction, plan construction phases or specific activities so that they do not occur during sensitive times for the species.
- Construction practices can reduce the amount of floral resources available before revegetation is implemented. Be careful to time removal of floral resources to periods when they are not needed by the imperiled species.
- Rope off sensitive areas to prevent damage during the construction process.
- Salvage existing vegetation whenever possible.
- Control noxious and invasive plants during the construction phase to facilitate revegetation afterward.

Design-Bid-Build vs. Design-Build

Design-Bid-Build and Design-Build are two methods of designing and implementing planned transportation projects. Design-Bid-Build is the more traditional method for designing and implementing a project. In this process, the design is completed to a high degree, and environmental compliance documents and permits are completed and obtained prior to putting the project out to bid and going to construction. Design-Build is intended as a more streamlined design and construction process where the project proponent solicits bids at a much lower level of project design with the intention of the contractor finishing both the design and build of the project at an accelerated pace. Design-Build is intended as a more agile method of project implementation; however, because the project goes to bid at an earlier level of design, the environmental impacts may not be fully understood at that time. Both methods of project implementation have their benefits and drawbacks.

Design Team:
Coordinate with the project biologist and environmental team to ensure that all measures are included in the bid package and contract.

Design-Bid-Build has a higher level of detail and also has permitting completed prior to bid and construction; however, that also makes any changes to design inherently more difficult. Design-Build projects may complete environmental permitting at a lower level of design, without a detailed understanding of the environmental impacts. This allows for easier adjustments to design and for changes to the project later in project implementation; however, it also removes incentives for reducing impacts on the environment. The permits will not act as a driver for reducing already permitted effects. It is important to ensure that all environmental commitments and other requirements are included in the Design-Bid-Build or Design-Build Request for Proposal (RFP) or bid package and resulting contract. This ensures that the contractor is aware of the commitments, that there is adequate funding and resources, and that implementation is contractually required.

Operations and Maintenance

The operations and maintenance phase can incorporate pollinator conservation in several ways. After vegetation is established, maintaining and protecting it is important. For more information about adjusting maintenance and vegetation management for imperiled pollinators, see Chapter 6. Additionally, this phase provides an opportunity for improved internal coordination for adaptive management and applying lessons learned to new projects, as well as developing innovative approaches to avoidance and minimization through maintenance practices.

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Table 5-1. Transportation planning and project development phases, descriptions, timelines, and pollinator conservation opportunities within each phase.

Phase	Conservation Opportunity Examples			
	Identify Environmental Constraints	**Avoidance and Minimization**	**Compensatory Mitigation**	**Voluntary Habitat Enhancement Opportunities**
		Transportation planning		
Long-range planning (30-year horizon/ every 4 years)	Identify priority/sensitive biological/environmental resources (including focal pollinator species), priority areas for conservation, and where these areas may overlap with transportation needs Identify major funding needs Identify regional studies needed to inform planning decisions	Systems, Transportation, and Natural Resource planners should collaborate on areas of pollinator habitat to avoid, especially when planning new routes or facilities Include considerations for avoidance at this stage to avoid additional design work later System, Transportation, and Natural Resource planners may collaborate early to agree on conservation priorities and to create better opportunities to integrate avoidance and minimization	Identify major mitigation needs/costs such as land acquisition, restoration, or crossing structures	Identify advance mitigation or voluntary enhancement opportunities Consider if there are pollinator needs that do not fall within planned projects that could be programmed as their own project

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	Conservation Opportunity Examples			
Phase	**Identify Environmental Constraints**	**Avoidance and Minimization**	**Compensatory Mitigation**	**Voluntary Habitat Enhancement Opportunities**
Short-range planning (2–4 year horizon/ yearly or every 2 years)	Identify priority/sensitive biological/environmental resources (including focal pollinator species), priority areas for conservation, and where these areas may overlap with transportation needs Identify studies, permits, and mitigation needs for focal pollinator species Identify funding needs (e.g., mitigation needs)	System, Transportation, and Natural Resource planners should collaborate on areas of pollinator habitat to avoid, especially when planning new routes or facilities Include considerations for avoidance at this stage to avoid additional design work later System, Transportation, and Natural Resource planners may collaborate early to agree on conservation priorities and to create better opportunities to integrate avoidance and minimization and improve conservation-informed project descriptions and alternatives (e.g., identifying an alternative project location that would meet the transportation need with less impact on target pollinator species)	Identify major mitigation needs/costs for planned projects (e.g., restoring acreage of habitat for focal pollinator species)	Identify advance mitigation or voluntary enhancement opportunities Identify habitat enhancement opportunities for planned projects (e.g., including host plants of focal pollinator species in revegetation mix)

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Phase	Conservation Opportunity Examples			
	Identify Environmental Constraints	**Avoidance and Minimization**	**Compensatory Mitigation**	**Voluntary Habitat Enhancement Opportunities**
Project development				
Project initiation Confirm project description, scope, and conceptual design Identify Project Development Team (PDT) (1–2 years per project)	Identify priority/sensitive biological/environmental resources within the project study area (including focal pollinator species) Identify funding needs Identify schedule implications (e.g., season restrictions)	Work with PDT to adjust project description, scope, schedule, conceptual design to avoid species/habitat impacts (e.g., rerouting a road to avoid critical habitat of a target pollinator species if not considered during long- or short-range planning; avoiding breeding season for target species)	Identify all project mitigation needs and costs (e.g., know when money is needed to implement project effectively)	Work with PDT to find opportunities to integrate habitat enhancement into project description/ conceptual design to avoid species/habitat impacts (e.g., note breeding season of target pollinator for consideration of long-term maintenance and key habitat needs for target species) Identify habitat enhancement opportunities (e.g., including key native plants for target pollinator species)
Environmental studies Detailed project description and preliminary design Technical studies Environmental document Federal ESA compliance (1–5+ years per project)	Coordinate early and frequently with resource agencies Consult with species experts Conduct detailed resource inventories and impact analyses	Develop project-specific avoidance and minimization measures (e.g., avoid habitat impacts, specify seed/plant lists, develop specification for avoiding soil compaction)	Identify and detail compensatory mitigation needs and options Confirm mitigation funding needs (e.g., habitat type, mitigation ratio)	Begin to detail habitat enhancement (e.g., specify locally sourced native plants)

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	Conservation Opportunity Examples			
Phase	**Identify Environmental Constraints**	**Avoidance and Minimization**	**Compensatory Mitigation**	**Voluntary Habitat Enhancement Opportunities**
Design Detailed project design, specification, and estimates prepared for advertisement, bid, and contract award Environmental commitments integrated into design Permits (2–4 years per project)	Ensure design and specifications are consistent with environmental analyses and commitments Apply for natural resource regulatory permits	Ensure avoidance and minimization are incorporated into project design plans, specifications, environmental compliance record, and cost estimates	Include detailed compensatory mitigation plan in project design and project permits	Incorporate habitat enhancement into project design (e.g., check plant lists to ensure key species are there)
Construction Construct project; install erosion control and landscaping Contract administration Environmental commitments implemented and tracked (1–10+ years per project or project construction phase)	Track implementation of construction avoidance and minimization measures	Implement construction avoidance and minimization measures (e.g., biological construction monitoring, quality control of seed/plant orders/deliveries, best management practices, weed abatement programs)	Construct compensatory mitigation (if included as part of project construction)	Construct habitat enhancement
Revegetation/Landscape establishment	Track implementation of landscaping avoidance and minimization measures Monitor success of pollinator plant establishment	Implement landscaping avoidance and minimization measures (e.g., biological construction monitoring, quality control of seed/plant orders/deliveries, best management practices)		Establish key plants to support listed or imperiled pollinator species

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	Conservation Opportunity Examples			
Phase	**Identify Environmental Constraints**	**Avoidance and Minimization**	**Compensatory Mitigation**	**Voluntary Habitat Enhancement Opportunities**
Operations and maintenance ⚑ (Ongoing)	Ensure appropriate tracking of operations and maintenance protection measure implementation (e.g., opportunities for improved communications and collaboration between maintenance and environmental staff)	Develop a maintenance plan that is effective in the short term for vegetation establishment and in the long term for maintaining plant diversity, and minimizing impacts on pollinators {e.g., consider mowing schedules/ frequency, avoid/minimize herbicide/pesticide usage, educate staff)	Ensure transportation agency–owned mitigation site is maintained and protected in perpetuity (e.g., use appropriate vegetation management techniques and consideration of target pollinator life cycle in timing and intensity of implementation)	Maintain and protect habitat enhancements (e.g., use appropriate vegetation management techniques to maintain plant diversity)

⚑ denotes phases with important opportunities to incorporate the needs of imperiled pollinators.

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5.4 Case Study: A Wildlife Overpass for the Quino Checkerspot Butterfly



Views of the Clinton Keith Overpass and vegetation, June 2021.

Photo credit: Riverside County Transportation Department (top); Shannon Crossen, ICF (bottom)

In the 1990s, the County of Riverside and the City of Murrieta, California, initiated a project to extend Clinton Keith Road from Interstate 215 to State Route 79 to address the need for an additional east–west transportation corridor due to increased traffic demand. The new six-lane arterial road was constructed in multiple phases as part of the Clinton Keith Road Extension Project. As part of project ESA compliance under the Western Riverside Multiple Species Habitat Conservation Plan (MSHCP), the project was required to maintain and facilitate connectivity and movement for wildlife for a wide variety of species including the federally endangered Quino checkerspot butterfly (*Euphydryas editha quino*). Host plants of the Quino checkerspot butterfly, as well as an individual male butterfly, were observed in the project footprint in 2000 (USFWS 2007).

The Quino checkerspot butterfly is endemic to Riverside and San Diego counties in California, and northern areas of Baja California Norte, Mexico. Quino checkerspot butterfly habitat is composed of costal scrublands occurring as landscapes of patchy shrubs or small trees with openings or swales between more dense patches of shrubs. Quino checkerspot butterflies require open areas with high solar exposure for breeding and movement and use vegetation or other substrates to mate and bask. Quino checkerspot butterfly populations often display metapopulation dynamics, and thus require conservation of both occupied and unoccupied habitat patches as well as connectivity between patches for population persistence and resilience.

The Clinton Keith Road extension passed through an area with high-value habitat and created a barrier to movement of the butterflies (and other wildlife) between habitat patches. Consequently, a series of wildlife underpasses and an overpass option considered the needs of the MSHCP and target species in the project area, the behavior of the Quino checkerspot butterfly, and the design constraints of the new six-lane roadway. The series of wildlife underpasses, in the form of bridges and culverts, and the wildlife overpass were designed to facilitate important safe movement opportunities for a range of wildlife species in the project area. The final wildlife overpass project design was determined to be the most appropriate structure to facilitate movement of the Quino checkerspot butterfly and other species. The wildlife underpasses and overpass were completed in 2018.

The overpass was vegetated with a seed mix containing the following plant species (*denotes larval host plant for Quino checkerspot; ** denotes nectar plants for the checkerspot):

- *Artemisia California* (California Sage Brush)
- *Casteilleja exserta* (Owl Clover)*
- *Colinsia concolor* (Southern Chinese Houses)
- *Cryptantha micrantha* (Redroot Cryptantha)**
- *Encelia farinosa* (Brittle Bush)
- *Eriogonum fasciculatum* (Buckwheat)
- *Eriophyllum confertiflorum* (Golden Yarrow)

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- *Eschscholzia californica* (California Poppy)
- *Gilia tricolor* (Birds Eye)
- *Lasthenia californica* (Goldfields)**
- *Layia platyglossa* (Yellow Tiny Tips)
- *Linanthus grandifloras* (Mountain Phlox)**
- *Lotus scoparious* (Deerweed)
- *Lupinus succulentus* (Arroyo Lupine)
- *Nassellia cernua* (Nodding Stipa)
- *Nassellia pulchra* (Purple Needle Grass)
- *Plantago erecta* (California Plantain)*
- *Penstemon speciablis* (Showy Penstemon)
- *Salvia apiana* (White Sage)
- *Salvia columbariae* (Chia)
- *Trichostema lanatum* (Wooly Blue Curls)

Wildlife cameras were deployed in July 2019, and Quino checkerspot butterfly surveys were conducted in 2020 and 2021 to determine use of the wildlife crossing structures. While no Quino checkerspot butterflies were detected on the overcrossing, other butterfly species were observed using the overcrossing, including Chalcedon checkerspot butterfly (*Euphydryas chalcedona*) nectaring in habitat on the overcrossing and painted lady butterflies (*Vanessa cardui*) flying across the overcrossing.

5.5 Case Study: Massachusetts GeoDOT

Massachusetts DOT has an online platform, GeoDOT, which allows staff to create and share geographic information system (GIS) data across the agency. Available data includes assets like rest areas, bridges, electric vehicle charging stations, as well as boundaries, pavement conditions maps, and more. GeoDOT also includes tools, such as the Highway Project Impact Tool that screens project areas to identify environmental justice and Title VI considerations, and the MassDOT Project Intake Tool, also known as MaPIT. MaPIT analyzes many layers of data to walk users through basic project screening of a project area, to repair or improve an existing roadway or facility, or to initiate a new project. This screening tool helps to identify projects that overlap areas of environmental sensitivity or significance and to identify environmental permitting requirements early in a project's development. In a few minutes or less, the tool analyzes layers of economic impact, connectivity, climate change resiliency, rare habitat, flood zones, and more. Projects are then scored by MassDOT to prioritize for project approval. Tools like MaPIT could add to their existing environmental layers by including a layer or layers for pollinators and pollinator habitat to help make decisions about sites of priority for revegetation and maintenance practices that support pollinators. Layers could include areas of critical habitat or the range of a particular species in need of conservation. For more information about MaPIT or GeoDOT, visit: https://massdot.maps.arcgis.com/home/index.html.

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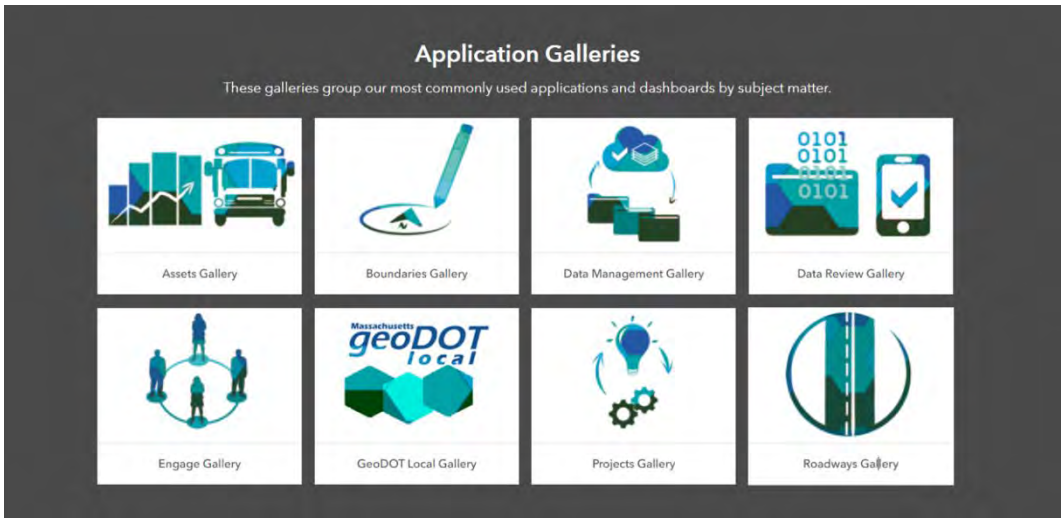


Figure 5-3. GeoDOT is Massachusetts DOT's open data portal and includes a project screening tool that could be adapted to include information about pollinators.

5.6 Case Study: Evaluating the Effects of Construction on a Roadside Pollinator

The valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) is a federally threatened insect endemic to the Central Valley of California. As this species' name suggests, it is only found in association with the elderberry shrub (*Sambucus* spp.). Elderberry shrubs are an important part of riverine and riparian habitats in California, providing food and cover for a wide variety of birds and other vertebrate species, and the valley elderberry longhorn beetle is an important pollinator for elderberry. Elderberry are also a common species on roadsides, which then host the valley elderberry longhorn beetle close to roadway maintenance and construction activities.

Caltrans was interested in learning more about the potential effects that road construction and overall proximity to the roadway might have on the valley elderberry longhorn beetle, and partnered with the University of California, Davis, Department of Environmental Science and Policy to conduct several experiments (Talley and Holyoak 2009). The studies looked at the physical and chemical effects of dust and particulates originating from roadways on the condition of elderberry shrubs and on the ability of the valley elderberry longhorn beetle to complete its life cycle. While the study found that elderberry shrubs closer to roadways and construction activities tended to have higher stress and lower nutritive quality, the valley elderberry longhorn beetle was still able to complete all stages of its life cycle despite the degraded host plant condition.

The Caltrans study also looked at the effects of roadside habitat maintenance on the valley elderberry longhorn beetle by evaluating the effects of pruning and trimming of the elderberry shrub. The study found that trimming did not impact the numbers of valley elderberry longhorn beetle, and the only negative effect of trimming that was observed was a temporary loss of the total amount of habitat for valley elderberry longhorn beetle via the reduction of branches, leaves, and flowers. Studies like this give valuable information

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regarding potential impacts from DOT operations and can inform negotiations with the USFWS regarding appropriate mitigation for unavoidable impacts.

5.7 Additional Resources

Federal Highway Administration (FHWA). No Date. *Environmental Review Toolkit. Initiatives to Accelerate Project Delivery: Eco-Logical.* Available: https://www.environment.fhwa.dot.gov/env_initiatives/eco-logical.aspx.

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Monarch Joint Venture. 2022. *Landscape Prioritization Model.* Available: https://monarchjointventure.org/mjvprograms/science/roadsidehabitat/habitat-prioritization-model.

Talley, T.S., and M. Holyoak. 2009. *The Effects of Highways and Highway Construction Activities on Valley Elderberry Longhorn Beetle Habitat.* Final Report FHWA/CA09-0925. Submitted to the California Department of Transportation. Contract Number 65A0222. Available: https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0016602-construction-impacts-valley-elderberry-longhorn-beetle.pdf.

United States Fish and Wildlife Service. No Date. *IPaC Information, Planning, and Consultation.* Available: https://www.fws.gov/ipac/.

———. 2007. Formal Section 7 Consultation for the Clinton Keith Road Extension Project, Riverside County, California (1-6-07-F-4357.3). Reference Number FWS-WRIV-4357.3. Carlsbad, California.

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Chapter 6 Roadside Maintenance and Vegetation Management for Pollinators

6.1 Introduction

Roadside vegetation management provides a safe driving environment, preserves infrastructure, and maintains a resilient plant community. Many departments of transportation (DOTs) have a statewide Integrated Vegetation Management (IVM) plan or an Integrated Roadside Vegetation Management (IRVM) plan. IVM plans typically include guidance on preventing unwanted vegetation, protecting rare plants, and preserving natural areas, along with a decision-making process for managing vegetation. IVM plans can also include guidance regarding best practices to incorporate to support pollinators through vegetation management.



Pollinators use roadside habitat beyond the recovery zone.

Photo Credit: Idaho Transportation Department

Management of roadside vegetation can significantly influence the number and types of pollinator species that live within or use roadsides. The timing and frequency of maintenance activities are important considerations when adjusting practices to support pollinators. In particular, the life histories of imperiled pollinators, which may have very specific habitat needs or short windows for breeding activity, can be incorporated into management plans. If a roadside site has a listed species or a species that is proposed for listing, please see the information in Chapter 4 for guidance on consultation with the U.S. Fish and Wildlife Service (USFWS) regarding maintenance strategies.

6.2 Consider Pollinator Life Histories When Timing Maintenance Practices

Understanding when imperiled pollinators are present and breeding in an area can help avoid management practices that are harmful to pollinators during the life stages in which they are most vulnerable. To help guide the timing of management activities, Table 6-1 presents the flight times of adults and the larval feeding times of imperiled pollinators found in this region. Management windows are ideal times for vegetation management and are used to avoid management during times when pollinators are reproducing or after plants go to seed. There is still much to learn about the phenology of many species; there may also be variations from year to year or site to site due to weather and microclimate. As such, these management windows should be viewed as approximate recommendations. If the host plant of an imperiled



Immature stages of imperiled pollinators, such as these Atala butterfly (*Eumaeus atala*) caterpillars, can be vulnerable to maintenance practices such as mowing. Timing practices before or after larvae are active can reduce mortality.

Photo Credit: Judy Gallagher

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butterfly or other needed habitat is present at a roadside site within the known range of an imperiled pollinator species, there is a chance that the pollinator is also there and that management actions could result in direct mortality. It is useful, although difficult, to survey host plants for immature stages of butterflies prior to mowing or using herbicides (or proceeding with other management actions, such as prescribed grazing). This is especially helpful if management timing falls on the cusp of the recommended window for a region or if it has been an early-spring or late-fall year. The phenology of pollinator emergence and activity may also shift as climate patterns shift (Kudo and Cooper 2019). Check with local pollinator-species experts, if available, for site-specific recommendations on timing.

If management must take place while immature pollinators are present:

- Use targeted approaches to vegetation management to avoid host plants when possible and
- Train the staff or contractors to recognize key plants and avoid mowing, spraying herbicides, or otherwise disturbing plants during the breeding season.

Questions to consider when evaluating or adjusting maintenance practices for an imperiled pollinator species.

1. *Does the imperiled pollinator species need particular host plants or nectar plants?*

   If so, compile a list of needed plant species. Consult existing roadside inventories or conduct vegetation inventories of known or suspected sites for the imperiled pollinator species.

2. *Where does the imperiled species overwinter?*

   Consider potential impacts of maintenance activities on overwintering habitat.

3. *Is a particular type of management more detrimental than other practices to the imperiled species? For example, is mowing at a certain time of the year more of a threat to the species than the application of a herbicide or another method of weed control?*

   Use the maintenance method that causes the least harm to the imperiled species.

4. *When is the adult active and breeding?*

   Consider the timing of maintenance activities, based on the windows for breeding activity.

5. *If it is a butterfly or moth (or another group that is active on vegetation, such as flower flies), when is the larval stage active on vegetation?*

   Can the timing of maintenance activities be adjusted to reduce impacts on immature stages on vegetation?

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Table 6-1. Periods of imperiled pollinator activity to avoid when conducting maintenance activities in the Northeast.

Pollinator	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Rusty patched bumble bee (*Bombus affinis*)												
Yellow bumble bee (*Bombus fervidus*)												
Yellowbanded bumble bee (*Bombus terricola*)												
Frosted elfin butterfly (*Callophrys irus*)												
Monarch butterfly (*Danaus plexippus*)												
Persius duskywing butterfly (*Erynnis persius persius*)[1]												
Leonard's skipper (*Hesperia leonardus*)[2]												

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Pollinator	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Karner blue butterfly (*Lycaeides melissa samuelis)*												



Note: Adult flight times are in blue, and larval active times (for species that have larvae active outside of a nest) are in orange. Lighter shades indicate uncertain but likely active times. Note that data are limited on the phenology of larval activity. If local experts are available, they should be consulted to make the best-informed decisions on the timing of maintenance activities.

[1] Overwinters as larvae and pupates in early spring.

[2] Adult flight time may vary with latitude. In lab studies, this species takes 3 months to develop.

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6.3 Adjusting Maintenance Practices to Benefit Imperiled Pollinators

6.3.1 Common Roadside Vegetation Management Practices

Mowing

How Mowing Affects Pollinators

Mowing is frequently used to maintain roadside vegetation, reduce occurrences of invasive weeds and woody plants, improve drivers' sight lines, allow vehicles to pull off, and reduce the risk of wildfires. Typically, vegetation in the recovery area (also known as the *clear zone*—the band of vegetation directly adjacent to the pavement or shoulder where vehicles that have left the roadway can recover) is mowed at regular intervals to keep it short for drivers who need to regain control of their vehicles. Routine mowing within the recovery area creates an environment that is not typically used by pollinators as habitat because it does not support flowering plants or places to shelter. This section focuses on impacts and potential opportunities to support pollinators in roadside vegetation beyond the mown strip in the recovery area.

Mowing can be an effective management tool for increasing or maintaining plant diversity and, likewise, pollinator habitat. In some parts of the country, early spring mowing is key to removing cool-season weedy annual grasses; fall mowing can remove litter and aid in wildflower seed dispersal. Mowing may also be used to reduce fire fuel loads in the landscape.

Mowing roadside vegetation can have detrimental effects on pollinators in general but particularly imperiled pollinators. Mowing at certain times can kill pollinator eggs or the larvae present on the vegetation directly and destroy the nests of some bumble bees (Thomas 1984; Wynhoff 1998; Humbert et al. 2010; Hatfield et al. 2016; Steidle et al. 2022) and stem-nesting bees. Mowing can also affect adult pollinators indirectly by temporarily removing host plants for butterflies and moths and the plants that provide pollen and nectar (Morris 2000; Johst et al. 2006; Noordijk et al. 2009; Kayser 2014). Vegetation structure as well as other habitat features that provide overwintering sites or temporary shelter are also altered by mowing. For these reasons, mowing can cause temporary declines in the local diversity and abundance of butterflies (Munguira and Thomas 1992; Feber et al. 1996; Halbritter et al. 2015). Significant decreases in adult butterflies occur immediately following mowing; however, when not all areas are mown in the same year, populations rebound more quickly (Weber et al. 2008). In addition, higher mowing frequencies reduce native plant growth, plant diversity (Parr and Way 1988), the ability of forbs to compete with grasses (Williams et al. 2007), and the amount of nectar and pollen present on the roadside over time. More frequent mowing can also increase roadkill involving pollinators, especially butterflies (Skorka et al. 2013). Minimizing the number of times a roadside is mowed benefits many pollinator species (Halbritter et al. 2015). Moderate mowing levels (e.g., twice per season) have been shown in multiple studies to increase plant species diversity in grassland habitats (Parr and Way 1988; Forman et al. 2003; Noordijk et al. 2009). Other studies suggest that a single mowing during the growing

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season (Valtonen et al. 2007) or in the fall (Entsminger et al. 2017) is more beneficial compared to two or more mowings in a year.

Considering the timing of mowing and frequency is particularly important if the habitat supports imperiled pollinator species. A single ill-timed mowing event can have long-lasting consequences for species that have small and isolated populations. For example, in areas of Oregon's Willamette Valley where the endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) occurs, mowing in late spring and early summer, while caterpillars are feeding on their lupine host plants, might destroy a population. Similarly, if timed before a plant sets seed, a single mowing can affect the reproduction of desirable plants.

Adjusting Mowing to Support Imperiled Pollinators

The timing and frequency of mowing can have large effects on pollinators and the vegetation they rely on. Mowing practices can be modified to reduce impacts on imperiled pollinators while also maintaining roadside safety and other management objectives. Adapting maintenance practices to support imperiled pollinators requires careful consideration of the life history of the species (see Box 6-1 for an example of how to adjust practices according to the needs of a particular pollinator species).

Conservation practices that benefit pollinators broadly:

- *Reduce the frequency of mowing beyond the mown strip to no more than twice per year.*



Reducing the frequency of mowing beyond the recovery zone allows wildflowers to flourish.

Photo Credit: Jeff Norcini

Reducing routine mowing of the entire right-of-way (fence to fence) will benefit pollinators by allowing wildflowers to bloom and thereby supply nectar and pollen as food. Mow beyond the mown strip in the recovery area only when there are well-defined objectives, such as reducing brush or maintaining lines of sight. Although most perennial wildflowers will recover from a mowing event, some may not be able to flower and reseed in the same year of a mowing event and thus will not increase their populations. Some annuals are sensitive to mowing. If mowed before they bloom, many may be unable to recover in time to bloom at a later date and may subsequently disappear from a site.

Reducing mowing beyond the mown strip to two times per growing season or less is best for pollinators and can help maintain wildflower diversity and persistence.

- *Delay mowing as late as possible during the growing season (e.g., mow after the first frost) so blooming plants are available throughout the growing season.*

  Strategic timing of mowing can also reduce effects on pollinators and promote plant diversity. It is best to delay mowing until after the first frost, if operational constraints allow it. When mowing is delayed, butterflies and other pollinators with larval stages that reside on vegetation will be able to complete their full life cycles, and flowering plants will be able to bloom and provide pollen and nectar to pollinators uninterrupted throughout the growing season. Furthermore, a mowing event in the fall can help spread wildflower seeds. Fall mowing also targets woody species that can invade pollinator

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habitats. Litter removal (e.g., haying) can complement mowing by removing the build-up of litter that can limit wildflower germination and growth.

- *Balance vegetation management with pollinator needs.*

  If mowing must take place during the growing season, consider selecting a time to mow that balances vegetation management needs (e.g., noxious weed control) with the resource needs of pollinators (e.g., flowers and host plants). For example, mow at a time that will promote the growth of wildflowers; though the temporary removal of flowers will be harmful in the short term, mowing will benefit pollinators in the long term.

  The timing of mowing can be targeted to reduce the abundance of a dominant plant species or litter and aid wildflower seed dispersal. To reduce the cover of an unwanted herbaceous species, mow when the plant is most vulnerable (i.e., during their growing season but prior to bloom or before seeds set). This action can help limit new growth of unwanted or dominant species the following year and create space for other species to grow. It is also worth considering varying the season when mowing takes place every few years to increase plant diversity. Mowing consistently at the same time every year will favor some plants over others. Plant diversity can be maintained by occasionally varying the timing of mowing, which will favor different plants and prevent certain plants from dominating the planting.

- *Clean mowing equipment after use and between sites to limit the spread of invasive weeds.*

  Weed seeds can spread after equipment is driven through infested areas. Seeds that lodge in tires and undercarriage are jarred loose at new locations. After mowing areas with a dense infestation of weeds, spray the vehicle's tires and undercarriage with an air compressor as soon as possible to remove weed seeds and prevent their unintentional spread.

Conservation practices for imperiled pollinator species include:

- *Aim to mow no more than one-third to one-half of an area beyond the mown strip in the recovery area per year (e.g., rotate mowing sections of a roadside).*

  Mowing only a portion of the roadside (e.g., one pass with a mower) in a given year leaves behind refugia (i.e., intact vegetation that can support pollinators). In addition, this heterogeneous mowing strategy can help prevent gaps in blooming and enhance the diversity of flowering species across the site.

- *Avoid mowing host plants of imperiled butterflies during butterfly breeding seasons.*

  It is important to time mowing so as to avoid vulnerable stages of the life cycle of any rare or declining species that might be present, particularly during the larval (caterpillar) stage of butterflies and moths.

  For example, in New Hampshire, to reduce harm to monarch butterflies, it is best to avoid mowing between May and October when monarchs are breeding in the region.

  See Chapter 3 for natural history information for imperiled species and Table 6-1 for adult flight times and breeding seasons of imperiled species in the region.

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- *Adjust mowing height to a minimum height of 8 to 10 inches in areas with target butterfly host plants or bumble bee colonies in grass thatch, if mowing during the growing season.*

  Mowing established vegetation at a height of 8 to 10 inches (or higher, if equipment allows; see Eco 1200 from MULAG [Steidle et al. 2022]) leaves a greater depth of vegetation for pollinators to use, which is particularly important for imperiled bumble bees that build their colonies in grass thatch aboveground or caterpillars on host plants. Adjusting the mowing height also helps vegetation to recover more quickly and reduces plant stress, particularly during dry periods or drought.

- *Explore mitigation efforts if there is a known mortality hot spot for an imperiled pollinator due to vehicle collisions.*

  Mortality hot spots can occur if landscapes funnel pollinators through high-traffic areas or the flight patterns of a particular species. Pollinators that are poor fliers or normally found flying low to the ground may be more vulnerable to vehicle collisions than pollinators that are strong fliers or normally found flying high above the ground. Mitigation efforts could include reducing traffic speeds temporarily for a mile or two near the hot spot, using fencing or netting to cause pollinators to fly higher when crossing the road, closing the outer lanes of traffic temporarily during the peak breeding season, or widening the mown strip within the recovery area to create more distance between the road and the habitat used by a pollinator (Zielin 2010; Kantola et al. 2019).

Box 6-1. Adjusting Mowing for the American Bumble Bee, an Imperiled Pollinator



The American bumble bee has one of the widest distributions of bumble bees in the United States, found in 46 of the lower 48 states.

Photo Credit: Barbara Driscoll

The American bumble bee (*Bombus pensylvanicus*) is found throughout the eastern and central parts of the United States as well as the Desert Southwest, California, and southern Oregon (but is absent from the Intermountain West). This species is in decline in the northern portions of its range and less common than it once was in the southern portions, with an average range decline of 51 percent. This species has a vulnerable status, meaning that the bee faces a risk of extinction, based on analyses from the International Union for Conservation of Nature.

Queens emerge in late spring to search for a nest site for their colonies. This period of queen nest-seeking, as well as early foraging in spring, is a vulnerable time in the life cycle of this and other bumble bee species. The species locates an insulated aboveground cavity, usually within tall grass at the soil surface. If present at a roadside site or known to occur in the area, the American bumble bee would benefit from adjustments to mowing practices to accommodate its nesting and foraging needs. For example, postponing mowing until after first frost in the fall would allow flowering plants to bloom and provide the bees with pollen and nectar throughout their flight season (i.e., late spring until early fall). Diverse sources of pollen are important for colony growth and

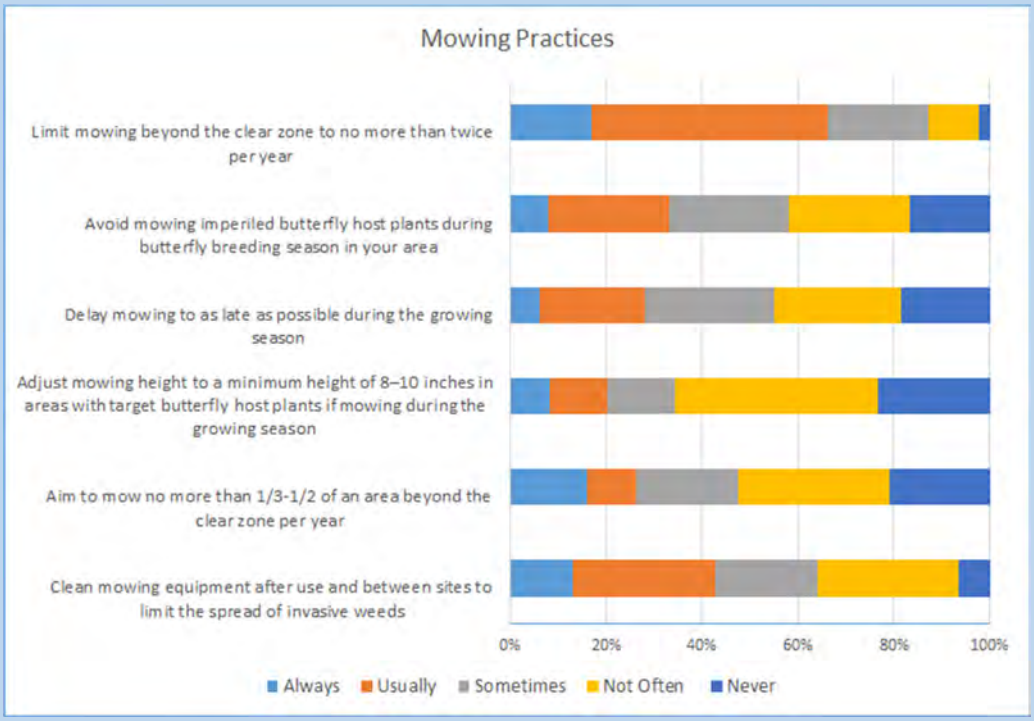
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production of the next generation of queen bumble bees. Mowing late in the season would prevent injury or destruction of the colony from use of the mower. If mowing must take place during the growing season, leaving a portion of the right-of-way unmown would leave some flowering resources and nesting habitat as refugia for bumble bees.

Bumble bees are particularly important pollinators for wild trees, shrubs, and wildflowers. They also contribute significantly to the pollination of a number of agricultural crops. Supporting the American bumble bee through roadside management would benefit adjacent lands, in addition to conservation of the species.

Box 6-2. A Snapshot of Current DOT Mowing Practices

In the national survey of DOTs, respondents were asked how often their agencies engaged in different mowing practices that benefit imperiled pollinators and pollinators broadly. Many respondents reported that their agencies always or usually engaged in practices like limiting mowing frequency beyond the mown strip in the recovery area, cleaning mowing equipment between sites, and avoiding mowing host plants of pollinators of interest during the breeding season. Other practices, such as setting the mowing height to 8 to 10 inches, were less commonly used.



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Box 6-3. How Do Other Wildlife Respond to Maintenance Practices Designed to Help Pollinators?

Two issues often raised around reduced mowing regimes are:

- whether reduced mowing increases collisions with deer and other large mammals and
- how other species in need of conservation, such as grassland birds, respond to reduced mowing.

One concern with mowing only once a growing season, or less, is that taller vegetation may provide cover for deer that could be too close to the highway. Clearing obstructive roadside vegetation is one strategy used to increase the ability of motorists to see large mammals near the road. A wider mown strip in the recovery area may help reduce collisions in some areas (Lavsund and Sandergren 1991). However, research to date does not indicate that reduced mowing of the right-of-way beyond the mown strip in the recovery area poses increased risks to drivers due to crashes with vehicles (Barnum and Alt 2013; Guyton et al. 2014). In fact, reduced mowing beyond the mown strip in the recovery area may decrease deer foraging in the right-of-way itself because mowing can increase the palatability of some plants (Mastro et al. 2008). The behavior of large herbivores can be modified by strategies other than mowing. For example, the roadside can be made less attractive for foraging by large mammals by avoiding known palatable species in plantings. Arizona DOT excludes plant species from their seed mixes that "green up" early or are otherwise known to attract deer and other large wildlife species. They have worked with partners on some projects to plant palatable species in areas leading to designated bridged wildlife crossings or habitat adjacent to roadside rights-of-way (Brown et al. 1999).

Roadside vegetation is critical habitat for birds, particularly in grassland ecosystems. Bird nesting within roadside vegetation, which increases with plant diversity, is influenced by mowing regimes (Warner 1992, 1994; Shochat et al. 2005). Mowing can kill birds that are ground nesters within roadside vegetation (e.g., waterfowl, grassland species). This encompasses all stages, from eggs to adults. Some states in grassland regions delay mowing after the breeding season (e.g., after August 1 in the Midwest) in an effort to conserve grassland birds (Kociolek et al. 2015).

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Box 6-4. Communicating Mowing Guidelines to the Staff

One challenge when implementing changes to maintenance practices such as mowing schedules is communicating those changes to the staff. The Ohio DOT solved this problem with use of window clings, which are placed in the cabs of mowers. The window clings have basic guidelines regarding the timing of mowing and the mowing height for different situations, along with a QR code that the staff can scan for more information. This creative solution helps minimize uncertainty among staff members when changing maintenance practices.



Herbicide Application

How Herbicide Applications Affect Pollinators

Herbicides are used to control woody vegetation as well as target weed species and other undesirable plant species on roadsides. The control of noxious and many invasive weeds is critical in maintaining habitat for many imperiled pollinators (Schultz and Dlugosch 1999). Invasive plants outcompete host plants as well as blooming plants that provide pollen and nectar, alter the structure of habitat, and change pollinator behavior (Severns 2008). The use of herbicides can benefit pollinators by suppressing undesirable plants and encouraging the valuable native plants that provide them with food or shelter. However, used indiscriminately, herbicides can reduce the quality of roadside habitat by removing floral resources and host plants (Kremen et al. 2002a; Tscharntke et al. 2005); they may also be toxic to some pollinators (Russell and Schultz 2010; LaBar and Schultz 2012). The overuse of herbicides can weaken stands of vegetation, making them more vulnerable to weed invasions, which indirectly affect pollinators. The drifting or subsurface movement of certain products can also cause reduced floral abundance, delay the onset of flowering, and reduce pollinator visitation (Boutin et al. 2014; Bohnenblust et al. 2016). Pollinators can be sensitive to these subtle changes in the timing and quality of floral resources. Drift-level doses of herbicides can also reduce pollen germination and seed production for flowering plants, thereby reducing reproduction and replenishment of the seed bank for pollinator-supporting species (Boutin et al. 2014; Gove et al. 2007).

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Pollinators can be exposed directly to herbicides through contact with herbicide sprays or residues on plants, or, in the case of caterpillars, through ingestion of residues on plants.

Photo Credit: Jennifer Hopwood/Xerces Society

The indirect effects of herbicide use that reduces or eliminates host plants or flowering plants that provide pollen and nectar are more likely to have greater adverse impacts on imperiled pollinators than direct toxicity. Herbicides are designed to kill plants; they are not intended to kill insects. However, pollinators can still be exposed to herbicides through direct contact, contact with herbicide residuals, or caterpillar ingestion of treated host plants. Studies indicate that some herbicides may be toxic to butterflies, causing sublethal effects such as reduced body size or wing size, which can reduce survival (Russell and Schultz 2010; Stark et al. 2012; Bohnenblust et al. 2013; Schultz et al. 2016). Alterations in development induced by herbicides can have population-level impacts (Russell and Schultz 2010), and herbicide exposure that reduces caterpillar or pupal survivorship can reduce populations over time (Stark et al. 2012).

There are unknowns about the potential toxicity of herbicides, particularly to imperiled pollinators. Few studies have measured the toxicity of herbicides for butterflies and other pollinators. How one species of butterfly or pollinator responds to an herbicide may not predict the response of another; the toxicity of herbicides to different butterfly species can vary (Brown 1987; Kutlesa and Caveney 2001; LaBar and Schultz 2012). Also, the effects of tank mixes of herbicides on pollinators are largely unknown. The effects of inert ingredients in formulated products on pollinators are also generally unknown, but there are indications that ingredients like surfactants can sometimes be more toxic to pollinators than the active ingredient alone (Mesnage and Antoniou 2018; Straw et al. 2021). What is known about how pollinators respond to contact with herbicides, including consumption, is summarized in Table 6-2. This information is based primarily on the testing of adult honey bees ahead of pesticide registration; there is very little information available on herbicide toxicity to larval bees, wild bees, or adult or larval butterflies.

The timing of herbicide applications can help avoid adverse effects on vulnerable butterfly life stages significantly (e.g., developing caterpillars that consume sprayed vegetation). Table 6-2 can help determine the best time to apply herbicides to avoid negative impacts on imperiled pollinators in the region. For example, applications made during the summer or early fall would reduce contact and oral exposure for species with adults and larvae that are active earlier in the season. Restoring habitat that has been degraded by invasive species benefits imperiled butterflies. Selective herbicides can be an important tool in controlling weeds that threaten key host plants of imperiled butterflies (Schultz and Ferguson 2019).

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Table 6-2. Herbicides used on roadsides and what is known of their potential direct toxicity to pollinators.

Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
2,4-D	Moderately toxic to honey bee adults and their brood May be repellent to foraging honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• University of California Statewide Integrated Pest Management Program 2022 • University of Hertfordshire Agriculture & Environment Research Unit (AERU) 2022 • Morton and Moffett 1972 • Elliot et al. 1979
Aminopyralid	Moderately toxic to honey bees upon contact and ingestion	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Bromacil	Practically non-toxic to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022
Bromoxynil	Practically non-toxic upon contact to honey bees or bumble bees Moderately toxic to honey bee adults upon ingestion	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• University of California Statewide Integrated Pest Management Program 2022 • AERU 2022
Carfentrazone-ethyl	Moderately toxic to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Chlorsulfuron	Practically non-toxic to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022
Clopyralid	Practically non-toxic to honey bees upon ingestion Moderately toxic to adult honey bees upon contact	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• European Food Safety Authority (EFSA) 2005 • AERU 2022

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Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
Dicamba	**Moderately toxic** to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Dichlobenil	**Moderately toxic** to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Diflufenzopyr	**Moderately toxic** to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Diquat dibromide	**Moderately toxic** to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Dithiopyr	**Moderately toxic** to adult honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Diuron	**Moderately toxic** to adult honey bees upon ingestion	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Flumioxazin	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022 • AERU 2022
Fluazifop-p-butyl	**Practically non-toxic** to adult honey bees **Moderately toxic** to larval honey bees **Toxic** to butterflies exposed as larvae, including some imperiled species	Do not apply to or allow to drift onto flowers in bloom (including weeds) Make applications outside season when caterpillars are active (see Chapter 3 for adult and larval active periods by species)	• University of California Statewide Integrated Pest Management Program 2022 • U.S. Environmental Protection Agency (EPA) 2019 • Russell and Schultz 2010
Fluroxypyr	**Moderately toxic** to adult honey bees upon ingestion	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022

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Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
Fosamine	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• AERU 2022
Glyphosate	**Moderately toxic** to honey bee adults and their brood, with impacts on gut biota, navigation, and survival	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• University of California Statewide Integrated Pest Management Program 2022 • Motta et al. 2018, 2020 • Battisti et al. 2021
Halosulfuron-methyl	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• AERU 2022
Imazapic	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• AERU 2022
Imazapyr	**Moderately toxic** to honey bees upon ingestion **Practically non-toxic** upon contact **Toxic** to butterflies exposed as larvae, including some imperiled species	Do not apply to or allow to drift onto flowers in bloom (including weeds) Make applications outside season when caterpillars are active (see Chapter 3 for adult and larval active periods by species)	• AERU 2022 • Stark et al. 2012 • Washington State Department of Agriculture 2009
Indaziflam	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• AERU 2022
Isoxaben	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022 • AERU 2022
Mecoprop-p	**Moderately toxic** to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022

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Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
Metsulfuron-Methyl	**Moderately toxic** to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Norflurazon	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022 • AERU 2022
Oryzalin	**Moderately toxic** to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Oxadiazon	**Practically non-toxic** to honey bees with acute exposure **Toxic** upon chronic exposure to honey bee adults and larvae	Avoid regular/repeated use on flowering plants within the growing season to avoid chronic exposure	• EPA 2020
Oxyfluorfen	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• AERU 2022
Pendimethalin	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022
Penoxsulam	**Moderately toxic** to honey bees and bumble bees upon ingestion **Practically non-toxic** upon contact	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Picloram	**Moderately toxic** to honey bees upon contact or ingestion **Repellent** to foraging honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022 • EFSA 2009 • Elliot et al. 1979

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Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
Pyraflufen	**Practically non-toxic** to moderately toxic to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• University of California Statewide Integrated Pest Management Program 2022 • EFSA 2015
Rimsulfuron	**Moderately toxic** to honey bees upon ingestion **Practically non-toxic** upon contact	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Sethoxydim	**Moderately toxic** to honey bees **Toxic** to butterflies exposed as larvae, including some imperiled species	Do not apply to or allow to drift onto flowers in bloom (including weeds) Make applications outside season when caterpillars are active (see Chapter 3 for adult and larval active periods by species)	• University of California Statewide Integrated Pest Management Program 2022 • AERU 2022 • Russell and Schultz 2010 • Stark et al. 2012 • Schultz et al. 2016
S-metolachlor	**Moderately toxic** to honey bees upon ingestion	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Sulfentrazone	**Moderately toxic** to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Sulfometuron-Methyl	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• University of California Statewide Integrated Pest Management Program 2022
Sulfosulfuron	**Moderately toxic** to honey bees	Do not apply to or allow to drift onto flowers in bloom (including weeds)	• AERU 2022
Tebuthiuron	**Practically non-toxic** to honey bees	No bee precaution, except when required by the label or regulations	• U.S. Department of Agriculture, U.S. Forest Service 2016

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Herbicide	Rating[a]	Precautions for Use within Roadside Pollinator Habitat[b]	Source
Triclopyr	**Practically non-toxic** to honey bees **Toxic** to butterflies exposed as larvae, including some imperiled species	Avoid regular/repeated use on flowering plants Make applications outside season when caterpillars are active (see Chapter 3 for adult and larval active periods by species)	• EPA 2017 • Stark et al. 2012

[a.] The data are incomplete because of limitations on herbicide testing on terrestrial insects. Toxicity ratings are based primarily on acute contact toxicity testing conducted on adult honey bees as part of the EPA pesticide registration process. Adult honey bees (*Apis mellifera*) are used as a surrogate for other terrestrial insects for the purposes of EPA ecological risk assessment, but toxicity ratings reported for adult honey bees may not adequately represent toxicity to larval honey bees, other species of bees, adult or larval butterflies, or other pollinators. These ratings generally do not account for oral toxicity (i.e., when an herbicide is eaten, as opposed to contact on the outside of the body), chronic toxicity, or other endpoints besides adult bee mortality, except where noted with additional references.

[b.] These are not the pollinator precautionary statements found on pesticide labels. These precautions go beyond the label. Always read the label and know and follow the applicable laws and regulations before making any pesticide application.

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Adjusting Herbicides to Support Imperiled Pollinators

Best herbicide practices for imperiled pollinators include reducing herbicide exposure as much as possible when working in their habitat. Employ a variety of vegetation management techniques, including cultural and mechanical control. When herbicides are used, avoid direct application to host plants or plants in bloom; make applications when caterpillars are not present whenever possible (see Table 6-1 for caterpillar activity windows). As with mowing, consideration of the life history of target imperiled pollinator species will help determine the conservation practices that are most relevant. By using herbicides as efficiently as possible, the maintenance staff can reduce both the amount applied and the effect on plants that benefit pollinators. Using products selectively, timing applications carefully, and following label directions can increase the effectiveness of herbicide use and decrease impacts on pollinators and other resources.

Box 6-5. Weeds and Pollinators

Some noxious and invasive problematic weeds can provide resources for pollinators (Harmon-Threatt and Kremen 2015). However, nonnative plants typically support only a subset of the overall pollinator community (Tallamy and Shropshire 2009). In addition, noxious weeds reduce overall plant diversity, which also reduces pollinator diversity (Memmott and Wasser 2002; Zuefle et al. 2008). When noxious and invasive weeds are removed and plant diversity recovers, pollinator abundance and diversity rebounds as well (Hanula and Horn 2011; Fiedler et al. 2012). Therefore, although monarch butterflies may be seen nectaring on Canada thistle (*Cirsium arvense*), the value gained from keeping those thistles is much smaller than the risks posed by retaining the noxious or invasive weeds in the landscape. If the plants that pollinators are visiting are high priorities for weed removal, use by pollinators should not preclude removal. If controlling a dense weed infestation, reseed the area after treatment with native flowering plants.

Conservation practices that benefit pollinators broadly:

- *Train the staff and contractors to recognize native plants as well as noxious and invasive weeds to reduce unintended damage to nontarget plants.*

  Conducting training in weed identification, as well as using plant identification reference materials to recognize noxious and invasive weeds, will help distinguish such species from similar nontarget species.

- *Use targeted herbicide applications on undesirable plants to avoid harming nontarget species (e.g., spot treatment applications with a backpack sprayer, targeted applications to cut stems, etc.).*

  To avoid weakening or affecting flowering and seed set among desirable species, weeds can be targeted using spot treatment applications made with a backpack sprayer, weed wiper, or similarly appropriate technology. Using highly targeted



This sprayer, connected to an ATV, allows for herbicide sprays directed to focal weeds.

Photo Credit: Steve Manning

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applications on cut stems, on stumps, or under bark can also reduce unnecessary effects on desirable plants. Use broadcast treatments or pellet dispersal only for dense infestations of weeds, the safety zone, and guardrail treatments.

- *Apply herbicides during plant life stages when weeds are most vulnerable (e.g., before blooming or before going to seed).*

  Applications can be timed to be most effective, based on the herbicide's mode of action and the application technique. For example, when using a systemic herbicide (i.e., absorbed by the plant and transported throughout the plant by the vascular system), perennial weeds can be treated in late summer and fall. During this period, perennials begin to move sugars down to their roots; the herbicide is translocated to vegetative reproductive structures where it is most effective at controlling the plant. Applications of herbicides when the weed is most vulnerable are the most successful applications. For many weeds, this is the seedling or rosette stage.

- *Use selective herbicides whenever possible to reduce damage to nontarget plants.*

  It is important to use products and application rates that are effective in controlling target weed species, with minimal effects on nontarget species. Whenever possible, the use of selective herbicides—those formulated to control specific weeds or groups of weeds—can reduce damage to nontarget plants. Nonselective herbicides—those that are broad-spectrum products and kill or damage all plants—can also be used selectively to reduce effects on nontarget plants. For example, nonselective herbicides can be used selectively by applying them on weeds when desirable native plants are dormant and using directed or targeted applications (e.g., spot spraying). In addition, understanding how quickly the herbicide being applied degrades on the site ensures that seed germination and restoration planting are not negatively affected. Herbicide labels include information about selectivity and persistence.

- *Avoid herbicide sprays when weather conditions increase drift (e.g., avoid wind speeds above 15 mph, and avoid applications during a temperature inversion).*

  It is best to avoid applications when wind speeds are greater than 15 mph and during a temperature inversion (i.e., when warmer air above traps cooler air near the ground). During inversions, herbicides and other pesticides can linger in the air and travel long distances off-site with air movement. Reducing the off-site movement of herbicides and using nonselective broadcast applications can help avoid damage to the nontarget plants that provide pollinators with food or shelter.

- *Choose and calibrate equipment with drift management in mind (e.g., calibrate equipment regularly, choose spray nozzles that reduce drift, and on boom sprayers, use the lowest effective pressure and largest droplet size possible).*

  The off-site movement of herbicides can be reduced by selecting appropriate spray equipment, periodically calibrating equipment, and adhering to instructions on the pesticide label. Nozzles that produce larger droplets are less likely to cause herbicides to drift off target. Equipment that is calibrated regularly limits over and under applications.

- *Avoid broadcast applications of systemic herbicides and persistent herbicides with long residual periods to reduce the exposure to butterfly and moth caterpillars, which can be exposed by consuming contaminated vegetation.*

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Butterfly and moth caterpillars consume host plant vegetation over days to weeks; residues in host plant vegetation could account for the bulk of exposure over the life cycle of these species. Larval butterflies and moths could be chronically exposed to systemic herbicides that are taken up by host plants or the residues of persistent herbicides, which take weeks to dissipate in the environment and have detrimental sublethal effects (Olaya-Arenas et al. 2020). See Table 6-2 for information on herbicide toxicity to pollinators.

- *Whenever possible, prevent conditions that would allow incompatible vegetation or noxious and invasive species to establish or reestablish.*

  Control woody plants that resprout or sucker to stop regrowth and encourage desirable early successional vegetation. Monitor vegetation regularly to stay on top of emerging non-compatible vegetation issues. Track weed outbreaks and herbicide usage over time to evaluate the effectiveness of herbicide treatments and inform future management decisions.

- *If necessary (e.g., if the seed bank is depleted of desirable species), replant areas that have been treated with herbicides to remove dense infestations of undesirable vegetation with desirable, competitive low-growing plant species to reduce the need to re-treat the area.*

  Revegetation with appropriate native plants can support pollinators while also helping to reduce weed pressure and need**.** Revegetation will also provide food for pollinators that may have been using noxious weeds or other undesirable plants (see Chapter 7 for more).

- *Avoid the use of pre-emergent herbicides on areas where the seed bank might contain desirable native species.*

  Native species can be beneficial to pollinators and other wildlife; therefore, choose other methods of weed suppression in areas with desirable species.

Conservation practices for imperiled pollinator species include:

- *Train the staff and contractors to recognize and avoid herbicide applications to key host plants for target imperiled butterflies and moths or key nectar plants for bumble bees.*

  Recognition of the plants that are important to imperiled pollinators by the maintenance staff is a strategy that can help reduce applications to nontarget plants.

- *Avoid use of products that have toxicity to imperiled species during breeding seasons.*

  Time the use of fluazifop-p-butyl and sethoxydim, which most likely have sublethal effects on imperiled butterflies (e.g., Taylor's checkerspot [*Euphydryas editha taylori*], Mardon skipper [*Polites mardon*], Puget blue [*Plebejus icarioides blackmorei*]), after caterpillar activity (e.g., make applications in late summer or early fall). See Table 6-1 for times when adults



Plant identification training can improve roadside management and can be a valuable professional development skill for staff to acquire.

Photo Credit: Iowa Living Roadway Trust Fund

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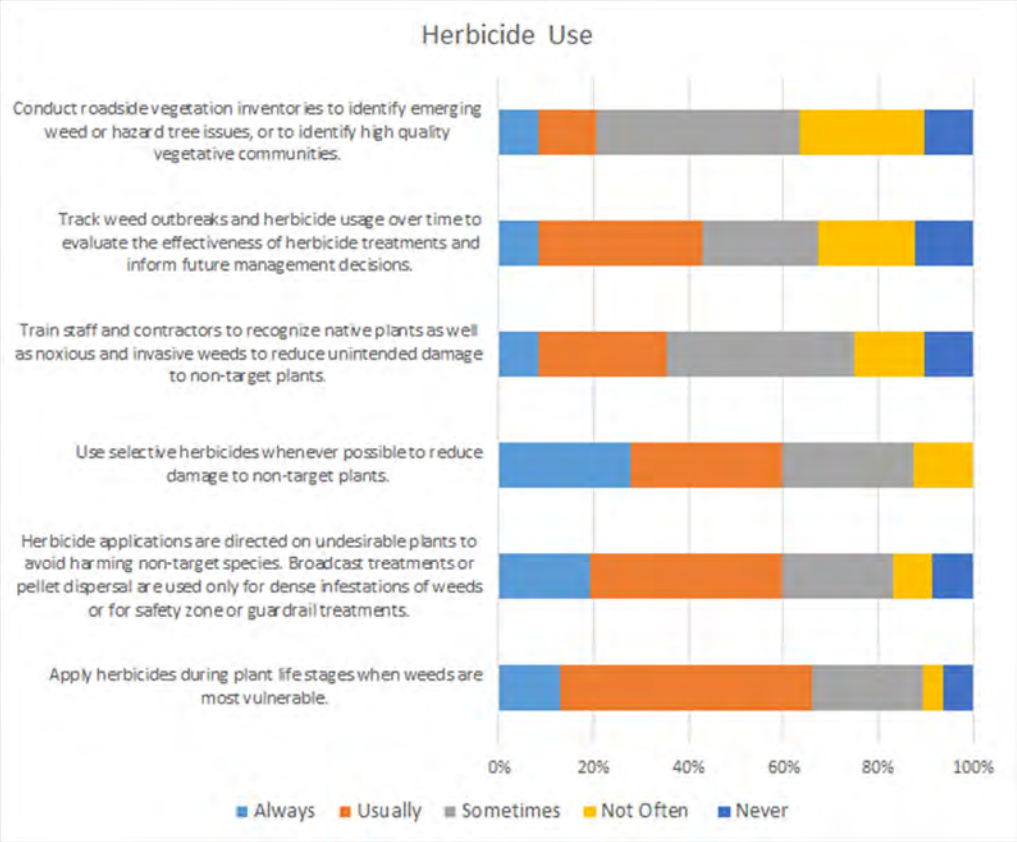
and larvae are active in this region and Table 6-2 for a list of herbicides with high toxicity to pollinators.

- *If treatment cannot be scheduled outside the window when pollinators are present, consider a mechanical control strategy when feasible if in an area where herbicide use might affect imperiled species.*

  Avoid direct applications to or near host plants of imperiled species or sources of pollen and nectar.

Box 6-6. Current Herbicide Practices Used by DOTs

Many of the practices to reduce herbicide risk to pollinators were commonly used by DOTs across the country. More than half of the respondents reported using selective herbicides, applying herbicide when weeds are most vulnerable, and using targeted applications. Practices that involved staff training or monitoring and tracking roadside vegetation were less common.



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Box 6-7. Adjusting Herbicide Practices to Support Monarch Butterflies

One of the most iconic pollinator species, the monarch butterfly (*Danaus plexippus*), is recognized and celebrated by people throughout North America. The butterfly's annual migration stretches from southern Canada to Mexico, covering most of the lower 48 states of the United States during the spring and summer. Threatened by habitat loss, climate change, pesticides, and other stressors, the species is now a candidate for listing under the Endangered Species Act.

Monarchs rely on milkweeds (*Asclepias* spp.) as host plants and require nectar sources during their spring migration, breeding season, and fall migration. A diversity of milkweed species is found on roadsides. Monarchs readily lay their eggs on roadsides and consume nectar from milkweed plants. Herbicide practices can be tweaked to reduce the impacts of herbicides on monarchs. Using targeted application methods to avoid treatments to nontarget plants is important to protect milkweeds and nectar plants. When available, use selective herbicides that are targeted to the plants in need of control. For example, when appropriate, the use of tree growth regulators is preferred for monarchs rather than broadcast use of a broadleaf herbicide, which would remove nectar and host plants. If possible, avoid broadcast applications during the monarch breeding and migration season to reduce herbicide exposure to monarchs (e.g., make applications in early spring or late fall) (see Chapter 3 for a map of management timing windows across the nation for this species).

Mechanical Weed and Brush Removal

Weed populations can be opportunistically removed mechanically during road construction. Removal can be accomplished by excavating soils within the populations at least a foot deep and transporting the weed-contaminated material off-site for disposal (e.g., at a dump or similar approved site) or burial at the depths recommended in each state. Brush may also be mechanically removed from roadsides. Mechanical trimming to remove problematic shrubs or trees, as well as selective trimming to partially remove woody vegetation (e.g., opening up the canopy along forest edges), can benefit pollinators by creating opportunities for wildflowers to grow. However, complete removal of trees and shrubs is not always beneficial because many butterflies and moths use woody native plants as hosts or for roosting during the flight period; some tunnel-nesting bees use the stems of some shrubs or old beetle borer tunnels in snags as nesting sites.

The removal of brush or trees that could be hazardous to motorists is important. This includes trees that are dangerous fixed objects as well as those that could impede sight distance, fall onto the highway, or shade the road in winter, thereby creating patches of ice. When possible, consider leaving snags or trees with cavities in areas where they are set back from the road and pose no safety risk. Snags can provide nesting habitat for some bees as well as habitat for birds and bats. Transitional areas between forest and grass can be created by using brush removal to feather or soften forest edges adjacent to the recovery area. Edge feathering involves thinning portions of the forest canopy along the edge next to grassy areas and removing undesirable or unhealthy trees. Periodic cutting to maintain healthy growth and an open canopy benefits remnant patches of savanna, forest, or other habitat dominated by woody vegetation; improves the quality of the habitat for pollinators and many birds; and is aesthetically pleasing.

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Conservation actions that support pollinators generally include:



Softening the edges of forests by cutting back trees and allowing shrubs to flourish can make an aesthetically attractive border and provide additional habitat for pollinators.

Photo Credit: Jeff Norcini

• *Feather or soften forest edges adjacent to the recovery area to create a transitional area between forests and grass (e.g., thin portions of the forest canopy along the edge next to grassy areas, removing undesirable or unhealthy trees).*

Shrubs and small trees that grow on the edges of forests provide food, nesting habitat, and overwintering habitat for pollinators. Many flowering shrubs and trees bloom at a time of year when other resources are scarce. They can be particularly important to early emerging pollinators like queen bumble bees.

• *Leave snags or trees with cavities in areas where they are set back from the road and pose no safety risk.*

Snags that are not a hazard can be home to tunnel- and cavity-nesting pollinators like yellow-faced bees (*Hylaeus* spp.).

• *Minimize soil disturbance (e.g., disking, tilling, removal of root balls) during brush removal activities to avoid spreading invasive plants and destroying overwintering sites or nests.*

Soil disturbances can bring new weed seeds to the surface, and deeper soil disturbances can destroy bee nests underground, as well as overwintering habitat for butterflies, moths, flies, and beetles.

Conservation actions that support imperiled pollinators include:

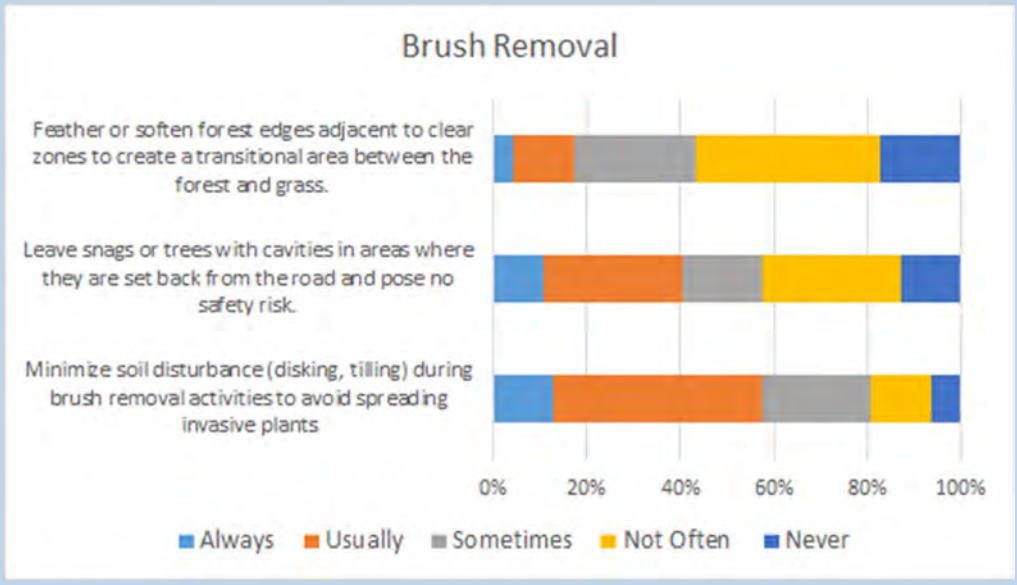
- *Time activities to avoid vulnerable times of pollinator life stages.*

  If taking action to support an imperiled butterfly or moth, avoid peak breeding periods to prevent trampling. See Table 6-1 for times when butterfly adults and larvae are active in this region. If taking action to avoid harming bumble bees, time activities during summer or early fall, outside the nest initiation phase that occurs in the spring and the overwintering phase that occurs during the dormant season when queens are most vulnerable.

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Box 6-8. Current Brush Removal Practices by DOTs

Most respondents reported using practices that minimize soil disturbance during brush removal. Leaving snags, where possible, was slightly less common; creating transitions between forested areas and roadside vegetation was not common.



Manual Weed Removal

Hand pulling is the most exhaustive and complete method of controlling specific weeds because it is highly targeted. Hand weeding is well suited for removing weeds that occur in low numbers or are scattered throughout a site. Hand weeding is often the least intrusive method of removing weedy species, thereby having the least effect on pollinators.

Tools that help with hand weeding include hoes, picks or Pulaski axes, trowels, and shovels. It is important to target weeds during their active growth stages, before weeds have flowered and set seed. For perennial and rhizomatous species, as much of the root material as possible is removed because plants can resprout from root fragments.

One strategy for hand pulling is the Bradley Method (Fuller and Barbe 1985), which prioritizes the areas to be weeded, beginning in undisturbed areas first, then working out toward more heavily infested areas. When pulling weeds by hand or with tools, it is useful to minimize soil disturbance so that new weeds will not become established. It is also important to dispose of weeds in designated areas. If weed removal results in large patches of bare soil, recolonization by unwanted species can be reduced by seeding with desirable species.

6.3.2 Less Common Roadside Vegetation Management Practices

Haying

In some states, landowners are permitted to cut and remove roadside vegetation for animal fodder. States might grant emergency hay permits under drought conditions, for example,

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or allow annual haying by adjacent landowners on certain roads throughout the growing season. Haying is not a tool that is typically used by a roadside maintenance staff, although there may be advantages to haying for vegetation management for DOTs to consider for future usage. For example, the removal of hayed vegetation can be beneficial for plant diversity by reducing the amount of plant litter (also known as thatch or duff), which can suppress new seedlings or existing growth. The removal of vegetation through haying also removes nutrients and creates low-fertility conditions that encourage a greater diversity of plants by favoring wildflowers rather than grasses or invasive species (Foster et al. 2009).

In general, haying once in the middle of the growing season can favor wildflowers and cool-season grasses that are often suppressed by dominant warm-season grasses. However, too-frequent haying in a growing season can reduce vegetation abundance and diversity over time (Jacobsen et al. 1990), thereby reducing floral resources for pollinators. If an entire site is hayed at one time, the abrupt removal of flowers and host plants from a site can have severe consequences for rare or endemic pollinator species, depending on the timing. When possible, the maintenance staff that conducts haying or communicates with landowners could consider haying only a portion of a site at one time, thereby leaving a refuge for pollinators. In addition, setting mower blades at 10 inches or higher, when equipment allows, reduces the effect on vegetation structure that provides nesting and overwintering habitat and allows vegetation to recover and bloom more quickly.

Classical Biological Control

Classical biological control is the process of introducing natural enemies of a target species to limit its growth and spread. The natural enemies are insect herbivores, nematodes, or pathogens that suppress the plant within its native range. Because classical biological control involves introducing these enemies into regions outside of their (and the weed's) native range, introductions are highly regulated by the U.S. Department of Agriculture and monitored by government scientists, university researchers, and state agencies. Although biological weed control is not currently widely implemented by state departments of transportation, some have worked with partners to release natural enemies to weeds such as purple loosestrife (*Lythrum salicaria*), leafy spurge (*Euphorbia esula*) (Johnson 2000), yellow starthistle (*Centaurea solstitialis*), and Russian thistle (*Salsola kali*) (Harper-Lore et al. 2013).

Biological control can be an effective and focused approach to weed control. However, there are ecological and economic risks associated with introducing a species outside its natural range, including unpredictable and irreversible consequences (Simberloff and Stiling 1996). The Eurasian weevil (*Rhinocyllus conicus*), for example, was introduced to control musk thistle (*Carduus nutans*) but expanded its host plants to include native thistles after introduction, including several rare thistle species (Louda et al. 1997). The loss of native thistles or other native species affects wildlife species that depend on the plants, including pollinators that visit the plants for pollen and nectar or use the plants as hosts for their caterpillars.

It is best to avoid using natural enemies that have expanded their hosts to include native plants. This could reduce food sources and alter habitat quality for imperiled pollinators. Coordinating carefully with state agencies and researchers, as well as keeping records about the locations of releases and monitoring the target weed populations and potential

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nontarget native species, is important in evaluating the potential effects of biocontrol agents.

Prescribed Grazing

Grazing is used to limit tree and shrub invasion, provide structural diversity, and encourage the growth of nectar-rich plants. However, livestock grazing is beneficial to plant diversity, and, in turn, pollinators, at only low to moderate levels during short periods, which are separated by long periods of recovery (Hopwood et al. 2016a). Grazing can negatively affect insect communities by changing plant community structure and diversity (Kruess and Tscharntke 2002). Over-grazing can remove enough flowering resources to decrease bumble bee populations (Carvell 2002; Hatfield and LeBuhn 2007) and destroy potential nest sites through trampling (Sugden 1985). Intensive grazing can also affect butterfly populations through trampling (Warren 1993) and altered plant community composition (Stoner and Joern 2004).



Goats can be used to control noxious weeds and brush on some roadsides or other transportation agency lands.

Photo Credit: Idaho Transportation Department

Development of a grazing plan that includes careful consideration of the type of grazer, its food preference, and how well it can be managed is important for managing invasive species and compatibility with pollinators and other resources. For example, goats and sheep can be controlled through herding when they are brought onto a site and when they are removed, thereby bracketing periods of time when pollinators and pollinator habitat are least affected. Goats and sheep prefer broadleaf plants and therefore are the preferred grazers for sites where broadleaf weeds are an issue. At specific densities and durations, goats and sheep can control large infestations of invasive weeds, including weeds in areas near water, thereby reducing effects on water quality. Goats and sheep can also be effective in inaccessible spots, such as steep slopes.

It is best to introduce grazers at a time when they preferentially feed on the target weed species. Grazing is most effective, for example, when target weeds are palatable; however, this period may be detrimental to pollinators. If rare or imperiled pollinators are present, timing grazing so as to avoid breeding and foraging periods is best. Avoiding grazing during the adult flight period or when imperiled butterfly or moth larvae are feeding on host plants reduces the effect on pollinators. It is also important to avoid grazing during periods when floral resources are already scarce because grazing during such times can eliminate pollinators from sites over time. Lastly, the stocking density of grazers can help to determine the duration of grazing. If stocking density is high, it is best to keep the duration relatively short so that desirable vegetation is not affected.

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Prescribed burns can be a challenge to conduct on roadsides due to traffic and safety concerns, but they can be beneficial for roadside vegetation.

Photo Credit: Iowa Living Roadway Trust Fund

Prescribed Fire

Prescribed fire is used to manage roadside vegetation and rejuvenate plant diversity in some regions of the United States that have a history of natural fires. Prescribed fire can remove old vegetation to create room for new growth, can reduce the spread of some invasive plants, and can stimulate the seed germination of some wildflowers. Prescribed fire can benefit pollinators through restoration or maintenance of suitable habitat (Huntzinger 2003), but it can have long-term effects on the populations of some species when refuges from burns are not available (Ne'eman et al. 2000). Burns during the growing season destroy eggs, caterpillars, and aboveground nests and remove vegetation at a time when pollinators need floral resources, host plants, and nesting materials. Winter burns destroy species that overwinter in leaf litter or stems. Limiting the scale of the prescribed fire, making sure that some habitat remains unburned, helps to reduce impacts on pollinators. For example, an extremely large and expansive fire may kill pollinators overwintering in aboveground biomass. Such fires during the growing season may eliminate floral resources in a given area. Smaller dispersed fires, on the other hand, conserve floral resources and support pollinators in the area by providing refuge.

Limiting the scale and frequency of each burn are important pollinator-friendly practices. It is best to use prescribed burning on sections of the roadside corridor rather than the entire corridor. By leaving unburned roadside habitat, enough pollinators remain to recolonize the burned areas. Rotational burning, such as burns conducted 3 to 5 years apart or more, allow time for pollinator populations to recover. Rotational burning can provide the benefits of prescribed fire without irreparably damaging the local pollinator community (Black et al. 2011). Varying the timing of prescribed burns can also reduce harm to pollinators by not continuously affecting certain pollinators and components of the roadside plant community. Burns affect pollinators no matter when the burn occurs. Therefore, altering the timing of burns can reduce negative effects on a particular group or suite of pollinators.

It can be logistically challenging for DOTs to implement prescribed burns on roadsides. Staff or contractors require training and equipment to conduct burns, weather conditions must be amenable to burning (e.g., no high winds), warning signs and traffic control must be put in place to keep drivers safe, and other concerns must be addressed in order to implement burning safely and effectively. When these challenges can be met, prescribed burns can be a valuable component of roadside vegetation management.

6.3.3 Managing for Plant Diversity

If a particular focal species of imperiled pollinator is not being considered during management, pollinator communities overall can be supported by managing roadside vegetation so as to maintain a diversity of plant species. There is a direct relationship between the diversity of blooming species and the diversity of pollinators; managing for plant diversity can provide a diverse community of pollinators. The following list provides guidance on the general timing of vegetation maintenance practices that best encourage

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plant diversity in this region. However, it is important to note that the timing can be in direct conflict with the activity of certain imperiled pollinator species. If the goal is to conserve a particular species (e.g., monarch butterflies), then carefully balance the timing of activities with the overall goals.

- **Mowing for diversity:** Oct–Nov
- **Grass-selective herbicides:** Spray cool-season grasses in spring or fall
- **Haying:** Not commonly used
- **Prescribed fire:** Mar–May: spring burn before green-up; Nov: before snow
- **Prescribed grazing:** Not commonly used

6.3.4 Road Salts and Heavy Metals

Routine vehicle use and road maintenance contribute to roadside vegetation contamination by depositing pollutants, including vehicle exhaust and de-icing materials. Vehicle-derived heavy metal contamination in roadside soils and vegetation is proportional to traffic levels (Leharne et al. 1992; Mitchell et al. 2020) and generally highest adjacent to a road (Quarles et al. 1974; Dale and Freedman 1982; Jablonski et al. 1995; Swaileh et al. 2004). Heavy metal deposition can have harmful effects on some pollinators (e.g., Perugini et al. 2011); however, the concentrations that occur on roadsides may not reach levels that result in harmful effects (Mitchell et al. 2020).

De-icing salts used on roads alter roadside soil chemistry by increasing sodium levels in soil and plant tissues significantly (Snell-Rood et al. 2014; Mitchell et al. 2020). Salts can damage some plants (Bogemans et al. 1989), which may indirectly affect pollinators but can directly affect butterfly and moth caterpillars that consume contaminated vegetation. Sodium is an important micronutrient for butterflies. Moderate levels can increase flight muscle and brain size in adults; however, too much can be toxic (Snell-Rood et al. 2014). Soil and leaf sodium levels are higher close to the road edge and on roads with more traffic; however, sodium levels reach lethal levels in only 1 percent of roadside plants in Minnesota (Mitchell et al. 2020).

Concentrations of heavy metals or road salts in roadside soils and plants are not well documented across the United States. More data about the impacts of salts, heavy metals, and exhaust on pollinators are needed.

Conservation recommendations for pollinators:

- *Maintain plant diversity in the roadside.*

  Different plant species have different levels of heavy metal and salt uptake. By encouraging plant diversity, there will be variable concentrations of these toxins, which may help to reduce exposure to pollinator communities.

- *Increase the width of the mown strip in the recovery area along roadways where traffic is very high and in regions where road salts are frequently used.*

  Until widespread data are available, DOTs that use road salts frequently in areas with high-traffic levels may consider increasing the width of the mown strip in the recovery area. (Plants are more likely to be toxic when traffic levels exceed 20,000 cars per day.)

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Removing vegetation close to the road, an area where salt and heavy metal contamination is highest, will help reduce pollinator exposure to contaminants by removing the most toxic plants. This measure may not be necessary in all high-traffic or salt-heavy areas, but it is a step DOTs could take to reduce exposure for imperiled pollinators that use vegetation adjacent to the road.

6.3.5 Signage

Signage can be used to help the maintenance staff identify areas that need particular management techniques or understand the timing of management that is unique to a particular site. The use of signs during maintenance may help the staff recognize sites with known populations of listed or imperiled pollinators, which may require specialized maintenance. For example, Oregon DOT has a Special Management Area (SMA) program, which was developed to formalize and organize the protection of rare and protected plants on Oregon roadsides. SMAs are established after roadside inventories of plants that are protected by state or federal legislation. More than 100 SMAs have been designated so far. SMAs also include compensatory wetland mitigation sites, cultural resources, and areas that need specialized maintenance. Signage designates each SMA site. The signs include codes for the particular maintenance activities (e.g., mowing, herbicide spraying, blading) allowed on the site. Each site has a unique management plan, which has been approved by the Oregon DOT Geo-Environmental Section, Oregon DOT district maintenance personnel, and relevant state and federal agency personnel.



Signs can provide maintenance staff with directions about any special management that might be needed for certain sites that support imperiled pollinators.

Photo Credit: Oregon DOT

For additional information of the value of signage to the public, please see Chapter 11.

6.3.6 Beyond Roadsides

If roadside maintenance practices cannot be adjusted in ways that support pollinators, there are other opportunities for pollinator habitat on land managed by DOTs that are not roadside rights-of-way. These areas include DOT "back 40" lots, stockpile lots, maintenance yards, underused DOT office land, special management areas, bicycle paths, scenic viewpoints, historic or geologic points of interest, stormwater ponds, or roadside rest areas. Such areas offer opportunities for collaboration with citizen groups because they are less exposed to traffic hazards, and DOTs may be more willing to allow volunteer groups to install or manage pollinator gardens in these areas.

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6.4 Case Studies

6.4.1 Adjusting Mowing Practices to Benefit Monarch Butterflies in Illinois

The monarch butterfly (*Danaus plexippus*) is the official state insect of Illinois. Spurred by low numbers of overwintering monarch butterflies in 2013 and 2014, the Illinois DOT began considering ways that mowing practices could be adjusted to support breeding and migrating monarchs in the state. Milkweed species, which serve as host plants for monarch caterpillars, can be abundant on Illinois roadsides, along with other wildflowers that serve as nectar sources for adult monarchs. In 2017, Illinois DOT altered mowing patterns to reduce the amount of roadside right-of-way that is mown regularly. By mowing only the 15 feet adjacent to the roadway, the goal was to leave more vegetation that could be used by monarchs. Mowing is still used when needed beyond the 15-foot zone to control the spread of invasive species and maintain sight lines for driver safety. Each year, Illinois DOT mows one-third of the roadside, leaving the other two-thirds of roadside vegetation standing. Rotating mowing within different roadside strips every 3 years leaves a refuge from the mower that allows flowers to bloom, which supports pollinators, as well as produce seed and reproduce. Illinois DOT also times mowing to periods outside the peak breeding period of monarchs in Illinois. It also allows midsummer mowing, which can rejuvenate stands of common milkweed (*Asclepias syriaca*) and make those stands more attractive to monarchs that breed in late summer.



Milkweeds, host plants to monarch butterflies, can be abundant on roadsides.

Photo Credit: Jennifer Hopwood/Xerces Society

For more information on how Illinois DOT is helping monarchs, visit:
http://www.idot.illinois.gov/home/monarch and
https://www.ilfb.org/media/5266/final_imp_mowingguidance_june2019_printversion.pdf.

6.4.2 Managing Plant Community Succession in Washington State

The Washington State Department of Transportation (WSDOT) maintains about 100,000 acres of roadside property. WSDOT has been implementing an integrated vegetation management approach for many years, with the overarching goal of reducing undesirable vegetation while encouraging desirable vegetation. Many WSDOT practices and policies for managing vegetation also promote pollinator habitat.

Whenever possible, WSDOT preserves existing native habitat, which can provide food, host plants, shelter, and nesting opportunities for pollinators. WSDOT also identifies roadsides for managed succession (WSDOT 2022). These are areas that have desirable vegetation that could flourish under a strategy that allows natural plant succession to proceed to a stable plant community. Outside the mown strip in the recovery area or sight lines where repeated mowing still occurs, roadsides managed for natural succession have multi-year treatment strategies that



Native trees, shrubs, wildflowers, and grasses all thrive on this Washington roadside.

Photo Credit: Washington DOT

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employ a variety of vegetation management tools, including reduced mowing and targeted herbicide use. Managed succession allows native vegetation to emerge and flourish, with sagebrush (*Artemisia tridentata*), greasewood (*Sarcobatus vermiculatus*), and native grasses taking hold in prairie regions and understory shrubs that are attractive to pollinators like snowberry (*Symphoricarpos albus*), Oregon grape (*Mahonia nervosa*), and spirea (*Spiraea* sp.) in other regions.

When roadside revegetation is necessary, WSDOT prioritizes the use of native plants, including a diversity of native wildflowers and flowering shrubs and trees. Landscape designers focus on native plants that can establish with minimal input and compete with weeds. Key considerations for pollinators during the planning process include sequential bloom periods for flowering plants and high plant diversity. The maintenance staff is included in the planning process to provide input on long-lived plants that require minimal management.

Mapping and planning are key elements of WSDOT's approach to roadside revegetation and maintenance. Vegetation inventories help identify areas with weed infestations as well as areas that are conducive to managed succession. All maintenance personnel have tablets, which are used to record data and view maps and aerial images.

WSDOT personnel use the best available science to inform their actions and undertake their own research to determine the right methods for their management needs. For example, experimental plots have been established to test seed mixes and planting methods. WSDOT also monitors the effectiveness of maintenance techniques on vegetation and pollinators.

More information about the actions WSDOT is taking to protect pollinators and promote pollinator health can be found at: https://www.wsdot.wa.gov/NR/rdonlyres/767B37F7-EB70-4C0A-92FB-DD04F94965C6/0/PollinatorsFactSheet.pdf.



The endangered Fender's blue butterfly and its hostplant, the threated plant Kincaid's lupine, are found on some of Oregon's roadsides.

Photo Credit: Candace Fallon

6.4.3 Maintenance Practices in Oregon Help Fender's Blue Butterfly

Fender's blue butterfly (*Icaricia icarioides fenderi*), an endangered species that was once thought to be extinct, is known to occur only in the prairies of Oregon's Willamette Valley. An estimated 99 percent of the valley's native prairies have been turned into farmland or otherwise developed. In addition to habitat loss, another major threat to the butterfly comes from invasive plants such as Himalayan blackberry and Scotch broom, which have outcompeted and displaced Kincaid's lupine (*Lupinus oreganus*), the host plant for this species, as well as other native wildflowers in upland prairies where the butterflies live. Kincaid's lupine is a threatened species. Both the plant and butterfly can be found on county-managed roadsides in the Willamette Valley.

In Yamhill County, Kincaid's lupine and Fender's blue butterfly occurred on both the foreslope of roadsides (i.e., from the edge of the roadway to the bottom of the roadside ditch) and the backslope of roadsides (i.e., the slope from the bottom of the ditch up to natural ground and the edge of the right-of-way). Routine

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maintenance activities like grading and herbicide spraying on the foreslope had negative impacts on Fender's blue butterfly and Kincaid's lupine. Under these conditions, it became appropriate to reduce the attractiveness of the foreslope to Fender's blue butterfly by managing it so that Kincaid's lupine would not persist. Working with USFWS, Yamhill County developed a habitat conservation plan for Fender's blue butterfly and Kincaid's lupine.

As part of the habitat conservation plan, Yamhill County conducted surveys of roadsides and designated and marked zones on the backslope of roadsides, which were designated Threatened and Endangered Special Maintenance Zones. Yamhill County maintenance personnel manage backslopes to minimize impacts on Kincaid's lupine and Fender's blue butterfly. Yamhill County uses maps and Global Positioning System coordinates, as well as photos of Kindcaid's lupine, for identifying and tracking of these sensitive areas. Yamhill County is also working to restore upland prairie at a mitigation site to provide habitat for these protected species.

Yamhill County's Habitat Conservation Plan is found here: https://www.fws.gov/oregonfwo/documents/hcp/YamhillHCP_Final.pdf.

6.5 Additional Resources

Federal Highway Administration Environmental Review Toolkit for Pollinators:

https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx.

Literature Review: Pollinator Habitat Enhancement and Best Management Practices in Highway Rights-of-Way:

https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinator_reports/pollinators_BMPs_in_highway_ROW.pdf.

Roadside Best Management Practices that Benefit Pollinators: Handbook for Supporting Pollinators through Roadside Maintenance and Landscape Design:

https://www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_landscapes.pdf.

Pollinators and Roadsides: Best Management Practices for Managers and Decision-Makers:

https://www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_roadsides.pdf.

Identifying the Current State of Practice for Vegetation Management Associated with Pollinator Health and Habitat: An Interview Report:

https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinator_reports/pollinator_interview_rpt.aspx.

Mowing and Management: Best Practices for Monarchs:

https://monarchjointventure.org/images/uploads/documents/MowingForMonarchs.pdf.

Monarch Butterflies, Weeds, and Herbicides Fact Sheet:

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https://monarchjointventure.org/images/uploads/documents/HerbicideFactsheet.pdf.

Evaluating the Suitability of Roadway Corridors for Use by Monarch Butterflies:

https://www.nap.edu/catalog/25693/evaluating-the-suitability-of-roadway-corridors-for-use-by-monarch-butterflies

and

http://www.trb.org/Main/Blurbs/180186.aspx.

Milkweed Recognition Guides:

https://www.xerces.org/monarchs/roadsides.

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Chapter 7 Revegetation and Pollinators: Design and Implementation

7.1 Introduction

Habitat loss is a leading factor in the decline of many pollinators (NRC 2007), and increasing pollinator habitat is an effective conservation strategy (e.g., Tonietto and Larkin 2018). Revegetation on roadsides involves replanting and reestablishing plant communities in areas where the vegetation and habitat have been disturbed or removed. In addition to providing a safe driving environment, common roadside revegetation objectives include erosion control, water quality protection, weed control, visual enhancement, carbon sequestration, and wildlife enhancement. Enhancing habitat for pollinators can be addressed while meeting these other objectives. Improving roadside habitat for imperiled pollinator species through revegetation can help to preclude the need to list new species under the U.S. Endangered Species Act (ESA) and can help to support listed and common pollinator species alike. Roadside revegetation projects that incorporate habitat needs of pollinators can result in habitat that can be used by a species for its whole life cycle (e.g., a ground-nesting bee nests in roadside soil and forages on roadside vegetation), or support a species for a portion of its life cycle (e.g., host plants support the caterpillar stage of a butterfly's life).



Native plants on roadsides like this sundial lupine (*Lupinus perennis*) showcase regional beauty while also providing pollinators with habitat.

Photo Credit: Chris Staron, Ohio DOT

Roadsides with intact native plant communities can lessen the effects of habitat fragmentation by functioning as corridors and connecting larger habitat patches (Forman et al. 2003; Huijser and Clevenger 2006; Dániel-Ferreira et al. 2022a). Additionally, if roadside revegetation projects contain plenty of floral resources, pollinators will be less likely to seek habitat elsewhere, reducing the risk of being killed by vehicles (Ries et al. 2001; Skórka et al. 2013). The removal of noxious and invasive plant species increases pollinator abundance and diversity (Hanula and Horn 2011; Fiedler et al. 2012), and roadside revegetation projects that replace invasive plants with native vegetation improve pollinator habitat.

It can be a challenge to recreate the exact habitat needs of some imperiled species; augmenting existing habitat through management or restoration is preferable whenever possible. If construction alters roadside habitat of a listed species, compliance commonly occurs using processes under Section 7 and Section 10 of the ESA. Permanent removal of habitat or delays in reestablishing habitat can result in population declines and losses of species from the site that may not be regained.

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7.2 Considering Imperiled Pollinators in Revegetation

Enhancing habitat for imperiled pollinators, or for pollinators in general, can be a specific objective for revegetation projects. Even if it is not a specific objective, elements that increase the value of the revegetation project to pollinators can be incorporated into other project objectives. To meet objectives such as water quality protection and erosion control, quick-growing native wildflowers and grasses can be used, including species that also provide resources for pollinators. Deep-rooted shrubs or trees might be used for visual enhancement, stabilization, snow retention, or carbon sequestration; selecting species that provide larval food or pollen and nectar will also enhance the project's value to pollinators. Consideration of the needs of pollinators when planning a revegetation project can have significant benefits for pollinators.

Pollinators have complex life cycles, with different needs at different stages of their lives. Table 7-1 provides an overview of habitat needs of pollinators and how revegetation projects can meet those needs. Chapter 3 of this guide includes profiles of listed and imperiled pollinators within this region, with natural history information, such as specific habitat needs.

Table 7-1. Roadside revegetation goals for enhancing habitat for different groups of pollinators.

Pollinators	Food for Larval Stage	Food for Adult	Shelter, Overwintering	General Revegetation Goals
Bumble bees	Provisions of nectar and pollen within the nest.	Nectar.	Nest in small underground cavities in abandoned rodent nests, under clumps of grass, or in hollow trees, bird nests, or walls.	• Increase density and diversity of native flowering plants. • Include species with sequential bloom periods; early season blooms are particularly important. • Plant native bunch grasses for bumble bee nesting habitat.
Ground-nesting bees	Provisions of nectar and pollen within the nest.	Nectar.	Excavate nest tunnels in bare or partially vegetated, well-drained soil.	• Increase density and diversity of native flowering plants. • Retain areas with bare or partially vegetated, well-drained soil.

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Pollinators	Food for Larval Stage	Food for Adult	Shelter, Overwintering	General Revegetation Goals
Tunnel-nesting bees	Provisions of nectar and pollen within the nest.	Nectar.	Nest in narrow tunnels in dead standing trees, or excavate nests in hollow stems or pith of twigs. Some construct domed nests of mud, plant resins, saps, or gums on the surface of rocks or trees.	• Increase density and diversity of native flowering plants. • Retain or install woody plants and herbaceous plants with hollow or pithy stems. • Leave snags of non-hazard trees outside of the recovery zone.
Beetles	Some species are herbivorous, feeding on plants; many are carnivorous and eat prey such as aphids, slugs, and insect eggs.	Pollen, nectar, floral parts; some species are also carnivorous.	Overwinter in soil or leaf litter, under rocks, logs, brush, or bark.	• Increase density and diversity of native flowering plants. • Retain overwintering sites when feasible.
Butterflies	Vegetation of host plants.	Nectar; some males obtain nutrients, minerals, and salt from rotting fruit, tree sap, animal dung and urine, carrion, clay deposits, and mud puddles.	Protected site such as a tree, bush, tall grass, or a pile of leaves, sticks, or rocks.	• Increase density and diversity of native flowering plants. • Include specific host plants. • Maintain vegetation structure.
Flower-visiting moths	Vegetation of host plants.	Nectar.	Protected site such as a tree, bush, tall grass, or a pile of leaves, sticks, or rocks.	• Increase density and diversity of native flowering plants. • Include specific host plants. • Maintain vegetation structure.

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Pollinators	Food for Larval Stage	Food for Adult	Shelter, Overwintering	General Revegetation Goals
Flies	Some species are carnivorous, consuming prey such as aphids, scales, or mites; others are decomposers in the soil.	Nectar; some species also eat pollen.	Overwinter in soil or leaf litter.	• Increase density and diversity of native flowering plants. • Retain overwintering sites when feasible.
Wasps	Provisions of insect prey such as caterpillars, aphids, grasshoppers, planthoppers, true bugs, and more.	Nectar.	Many nest in the ground; others nest in tunnel nests in wood or cavities in mud or resin.	• Increase density and diversity of native flowering plants. • Retain areas with partially vegetated well-drained soil. • Retain or install woody plants and herbaceous plants with hollow or pithy stems.

Roadsides can provide pollinators with their key habitat needs—food for larvae and adults, and shelter and overwintering habitat. In particular, native plants are important for pollinators. Roadsides with native wildflowers support a greater number of individuals and species of butterflies and bees compared with those dominated by non-native grass and flowers (Ries et al. 2001; Hopwood 2008). Native plants are more attractive as sources of pollen and nectar for pollinators than non-native plants and support more species and more individuals seeking pollen or nectar, even when both plant types are present on the same site (Williams et al. 2011; Morandin and Kremen 2013). Native plants also support more caterpillars than do non-native plants (Narango et al. 2017); native woody plants used as ornamentals in the eastern U.S. support fifteen times more native butterflies and moths than do introduced species of ornamental plants (Tallamy and Shropshire 2009). Adding non-native plants to landscapes does not increase butterfly and moth diversity or abundance (Burghardt et al. 2010), and non-native plants can reduce bird populations as a consequence of reduced insect availability (Narango et al. 2018).

7.2.1 Use of Native Plants in Revegetation

Establishing native plant communities on roadsides provides economic benefits as well as ecological advantages (Berger 2005). Native plants can support safety objectives by reducing headlight glare, serving as crash barriers, reducing wind speed across roads, and reducing snow drifts across roads (Forman et al. 2003). Additionally, wildflowers and other flowering plants on the roadside improve driver performance by breaking up driver

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monotony, contributing to clearer thinking, and reducing driver stress (Topp 1990; Cackowsky and Nasar 2003; Mok et al. 2006; Macdonald et al. 2008).

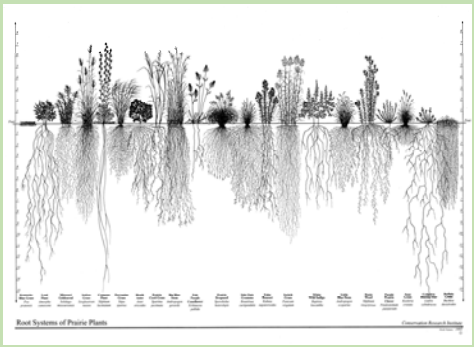
Native grasses and flowers are best adapted to local growing conditions, require minimal inputs for establishment, and are able to tolerate drought or heat, which will become more common in many regions.

- Some native species are particularly able to tolerate the poor growing conditions found on roadsides (Harper-Lore and Wilson 2000; O'Dell et al. 2007).
- Under some conditions, native plants have a competitive advantage over non-natives (Tinsley et al. 2006).
- An established diverse native plant community provides the most stable cover for reducing erosion and keeping out weeds (Quales 2003; Blumenthal et al. 2005; Falk et al. 2013).
- Improved weed and erosion control can reduce the need to spray herbicides and to mow, thereby reducing long-term maintenance costs (Berger 2005; O'Dell et al. 2007; Harper-Lore et al. 2013).
- The root systems of native plants can increase water infiltration, which reduces runoff and water pollution and helps to replenish groundwater (Cramer 1991; Bugg et al. 1997; Harrison 2014).

Native plants are species that originated in or occur naturally in a particular geographic area. Grasses, wildflowers, shrubs, and trees that existed before European settlement of North America are native plants. Native plants are best suited to local conditions, generally require less maintenance, and persist longer that non-local species. They can form plant communities that are robust, self-sustaining, and resilient.

Native plants are central to healthy, functional ecosystems. They support soil health and water quality, sequester carbon, and are habitat for wildlife. Native plants are at the heart of food webs, as they are food sources for animals such as caterpillars or grasshoppers that in turn feed birds, frogs, and other animals. Native plants also support more pollinators and more wildlife than do non-native plants (Narango et al. 2017; Williams et al. 2011).

Native plants are less likely to encroach on land bordering roadsides and rarely become weed issues (Harper-Lore and Wilson 2000). In contrast, a number of introduced species used for roadside revegetation have become weed problems elsewhere, including crown vetch (*Securigera varia*), sweet clover (*Melilotus* spp.), sericea lespedeza (*Lespedeza cuneata*), reed canary grass (*Phalaris arundinacea*), and smooth brome (*Bromus inermis*) (Harper-Lore and Wilson 2000).



Native plant root systems can be extensive and support resilience to drought, fires, and weeds.

Photo Credit: Heidi Natura, Conservation Research Institute

Finally, native revegetation plantings are aesthetically pleasing and can support tourism. The Texas Department of Transportation (DOT) has several designated wildflower routes, for example, that showcase native wildflowers; when bluebonnets (six species of *Lupinus* that are collectively considered the state flower of Texas) are in bloom, some towns along these routes hold bluebonnet festivals. Travelers form perceptions about regions based on their views of the highway landscape, and drivers prefer "natural-looking roadsides with native grasses, wildflowers, and butterflies," to turf roadsides (Guyton et al. 2014). Roadsides with native plants can showcase a region's natural beauty and provide a sense of place, natural heritage, and opportunities for education. Natural beauty may also align with driver preferences. One study conducted in Minnesota on driver perception of

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Blooming bluebonnets are colorful sight on Texas roadsides between March and May.

Photo Credit: Texas DOT

roadside landscapes found that prairie plantings were ranked as most attractive, and a mix of trees, shrubs, and prairie also ranked highly. Mown turf, along with brome grass with a mowed turf edge, were ranked the least attractive by drivers (Nassauer et al. 2006). Similarly, a majority of Iowa drivers preferred the appearance of managed roadside prairie plantings (Nemec et al. 2021). In a Georgia study of rest area plantings, the traveling public found block plantings of a single species most attractive but preferred overall a matrix of species due to the environmental benefits. Additionally, 87 percent of those surveyed preferred native plants over non-native for roadside plantings (Tania et al. 2020).

Native Plants and Safety Concerns

During roadside revegetation design, a roadside planting and maintenance plan can be used to contribute to the reduction of animal browsing within the right-of-way (ROW). If designated or safe crossing points (e.g., crossing structures) exist, native vegetation can be used to provide conditions that will attract wildlife to those points. In areas that have high wildlife–vehicle collision rates, it is important to focus on planting species that have low palatability close to the roadway (Huijser et al. 2008). Arizona DOT's approach has been to exclude plant species from its seed mixes that "green up" early or are otherwise known to attract deer and other large wildlife species. It has worked with partners on some projects to plant palatable species in areas leading to designated bridged wildlife crossings or habitat adjacent to roadside ROWs (Brown et al. 1999). In areas with known high wildlife–vehicle collision rates, prioritizing shorter plant material (3 feet tall or less; this should not include flowers or seed head stalks) will provide less cover for large mammals and will allow drivers to potentially see and respond to animals in the ROW. When palatability is known, it is included in the plant lists in this chapter (Table 7-3).

It is also important to consider the frequency and timing of cutting and mowing maintenance. Maintaining a regularly mown recovery zone can increase driver visibility and reduce deer–vehicle collisions (Mastro et al. 2008). However, cutting and mowing can attract browsing activity because large hoofed mammals (such as white-tailed deer or moose) prefer to browse on fresh growth. Consideration of nutritional value of key forage plants for large mammals as it relates to cutting is important in areas with high rates of wildlife–vehicle collisions (e.g., Rea 2003). Reduced mowing beyond the safety zone may decrease deer foraging because mowing can increase the palatability of some plants (Mastro et al. 2008).



A green sweat bee collecting pollen.

Photo Credit: Barbara Driscoll

7.3 Design Considerations for Revegetation Projects

7.3.1 Roadside Plants as Food for Pollinators

Flowering plants in roadsides are important sources of nectar and pollen for pollinators that reside within the roadside habitat (e.g.,

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Munguira and Thomas 1992), as well as those that use the roadside as a partial habitat for foraging but reproduce or overwinter elsewhere (e.g., Ouin et al. 2004). The availability of pollen and nectar influences the abundance and diversity of pollinators found on roadsides (Saarinen et al. 2005; Hopwood 2008). Different pollinators have different floral needs and preferences, so including a diversity of plant species with different flower shapes, sizes, colors, and growth habits helps support a variety of pollinators (Ghazoul 2006; Ponisio et al. 2015).

It is important to have flowers available to pollinators throughout the growing season. While pulses of bloom can provide critical resources to pollinators, sustained resources without temporal gaps create functional habitat throughout the growing season to best support robust populations and communities. Bees that emerge early in the growing season can begin to forage in March in the Northeast region, with late-season bees foraging through September. Within that period, different species will be active at different times. Solitary bees have distinct flight seasons that last 4 to 6 weeks. Bumble bees are social, with an annual colony that expands gradually and requires forage throughout the growing season. Similarly, different species of butterflies and moths may have distinct emergence periods with one generation a year, or multiple generations a year. For an example of a phenology chart that illustrates overlapping bloom periods, see Table 7-2.

Table 7-2. Bloom calendar for several wildflower species found in the Northeast region.

Plant Species	April	May	June	July	Aug	Sept	Oct
Viburnum prunifolium							
Rosa virginiana							
Monarda fistulosa							
Penstemon digitalis							
Echinacea purpurea							
Verbena hastata							
Solidago rugosa							
Symphyotrichum lateriflorum							
Eurybia divaricata							

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It can be helpful to emulate the species diversity found on reference sites in nearby natural plant communities. Diverse plantings that resemble natural communities are the most self-sustaining and longest lasting because they better resist weed invasions and pest outbreaks.

When possible, prioritize the use of plant materials that are sourced from local ecotype providers. Plant materials that originated in geographic proximity to the project site are best adapted for local growing conditions and for pollinators. The bloom times of non-locally sourced plants have the potential to be out of sync with pollinators (Norcini et al. 2001), especially specialist bees that are reliant on the pollen from a small subset of plants and time their emergence annually with the bloom time of their host plants, or butterflies seeking to lay eggs on their host plants before the plants senesce. However, there is an emerging school of thought about the potential importance of including genetic diversity in plantings to increase the likelihood of adaptations to changes in the climate. Using multiple local sources within the region may be one way to address this concern. See Chapter 8 for discussion of strategies to address climate change through seed provenance.

7.3.2 Roadside Plants as Shelter for Pollinators



Some bee species create nests in plant stems. Roadside plants can provide shelter and nesting resources for bees and other pollinators.

Photo Credit: Sara Morris

Woody vegetation such as trees and shrubs can provide shelter for pollinators during the growing season, and can also provide niches for overwintering. Some pollinators will overwinter under bark or in the soil just under shallow roots, or in piles of brush. Grasses can provide shelter for a variety of pollinators, but notably for butterflies on roadsides (Saarinen et al. 2005). The root systems and grass thatch can also serve as overwintering habitat for a variety of pollinators.

Nesting is a critical factor affecting the ability of bees to persist within a site (Winfree 2010; Menz et al. 2011; Morandin and Kremen 2013). Ground-nesting bees need access to soil surfaces between vegetation to excavate and access their nests (Michener 2007). Some species will nest in a variety of soils, while others have very specific requirements for the soil type, moisture, alkalinity, slope, and aspect (Cane 1991). Bunch grasses tend to provide better nesting habitat than sod-forming grasses. Roadsides with native bunch grasses have more nesting opportunities for ground-nesting bees and, consequently, a greater abundance of ground-nesting bees (Hopwood 2008). A number of aboveground nesting bees nest in hollow stems or excavate pithy stems (e.g., elderberry or cane fruits), while other native bees nest in tunnels in wood, such as abandoned beetle tunnels in logs, stumps, and snags (Michener 2007). Plant lists included in this chapter provide information about known plants that provide nesting resources for bees. Maintaining dead wood, snags, or wood with holes in it (e.g., fence posts) where safe and appropriate within the project site will also benefit tunnel-nesting bees. Bumble bee colonies require an insulated cavity in which to nest, such as underneath grass clumps (Svennson et al. 2000), under the thatch of bunch grasses, or under rocks (Hatfield et al. 2012).

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7.3.3 Roadsides and Connectivity

Landscape connectivity is increasingly important for the populations of many species, including pollinators (Haddad 1999; Haddad and Baum 1999). Roadsides have the potential to help pollinators move between habitat fragments by acting as corridors or stepping stones to connect to larger patches of habitat (Soderstrom and Hedblom 2007; Dániel-Ferreira et al. 2022). Pollinators may use roadsides as corridors to facilitate movement through the landscape in search of food or in pursuit of new habitat (Lövei et al. 1998; Ries et al. 2001; Valtonen and Saarinen 2005; Hopwood et al. 2010), or they may expand their ranges along roadsides (Dirig and Cryan 1991; Brunzel et al. 2004). Corridors like roadsides and other linear strips of vegetation such as utility ROWs may provide habitat resilience as changes in climate drive species range contractions or expansions.



Highway overpasses with habitat plantings and structures—such as the I-90 Snoqualmie Pass East Restoration Project that connects habitat on either side of I-90—benefit large wildlife as well as small wildlife like pollinators.

Photo Credit: Kelly Evans / Washington DOT

7.3.4 Designs and Conservation Practices

There are a number of conservation practices to consider when designing revegetation plans. The following revegetation design practices benefit pollinators broadly:

- **Prioritize native plants in designs.** Roadsides with native plants support more species of pollinators and larger populations (Ries et al. 2001; Hopwood 2008). Native flowering trees, shrubs, and wildflowers provide nectar and pollen or are host plants. Native grasses are also host plants and provide shelter.
- **Prioritize sourcing native plants locally.** Plant materials that are sourced locally or within the ecoregion are best for pollinators because the phenology (flowering period) can also differ with the provenance of the plant material (Norcini et al. 2001; Houseal and Smith 2000; Gustafson et al. 2005). Bloom times of non-locally sourced plants have the potential to be out of sync with pollinators. This may be particularly problematic for bee species that are pollen specialists (e.g., the thistle longhorn bee [*Melissodes desponsa*] is a pollen specialist on thistles) because they are reliant on the pollen from a small subset of plants and time their emergence from overwintering with the bloom time of their host plants. Locally sourced ecotypes are also adapted to local conditions.
- **Increase flowering plant diversity and abundance.** High flowering plant diversity provides sustained resources throughout the growing season to best support robust pollinator populations and communities. Higher plant diversity can also reduce pollinator exposure to heavy metals and salts, as different plant species uptake pollutants at different rates. Floral abundance is also important. Sparse resources will not sustain pollinator populations, whereas high densities of blooms are more attractive and can support higher numbers of pollinators (Herrera 1989). A diverse combination of grasses and wildflowers can also effectively resist weed colonization and provide soil stabilization. Having 45 percent cover of flowering



A roadside in Arkansas with a variety of flowering plants. Incorporating diversity into revegetation projects has many benefits, including supporting a larger number of pollinators and increased climate resilience.

Photo Credit: Ray Moranz, The Xerces Society

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plant vegetation across a growing season in seed mixes should be the goal in order to prevent grasses from outcompeting wildflowers. Flowering plant cover could be spread out throughout the growing season, with 15 percent cover of species that flower in spring, 15 percent in summer, and 15 percent in autumn.

- **Include species with overlapping and sequential bloom periods.** Providing a diversity of flowering plants throughout the growing season supports species with multiple generations as well as those that time their emergence and flight period with the bloom of certain plant species. This approach also provides a more resilient plant community that can better support a diversity of pollinators. Early-season pollen and nectar sources are important for those species that have flight seasons in the late winter or spring, as well as those with season-long flights, and will lead to greater reproduction of those species. Increasing the diversity of flowering plants in seed mixes and planting plans can help to prevent gaps in bloom.

Revegetation design practices for imperiled pollinator species include:



Many butterflies use specific plant species as host plants for their caterpillars. Including hostplants of butterflies that occur in the area will contribute to pollinator conservation.

Photo Credit: Anne Stine, The Xerces Society

- **Include key host plants for target pollinator species.** Imperiled butterflies and moths may rely on plants of a single species or genus as host plants for their caterpillars. Providing caterpillar host plants is a well-established way to sustain butterfly and moth populations (Croxton et al. 2005; Feber et al. 1996). Roadsides with host plants can support habitat generalist butterflies as well as habitat specialists and migrant species, such as the monarch butterfly (e.g., Ries et al. 2001). Many native plants commonly used in revegetation projects serve as butterfly and moth host plants (e.g., little bluestem [*Schizachyrium scoparium*]). However, it is necessary to include specific native host plant species matched to support the particular butterfly or moth species that are adapted to feeding on them. For example, planting milkweeds (*Asclepias* spp.) will contribute to the recovery of the monarch butterfly. Plant lists included in this guide include specific host plants for butterflies and moths that are imperiled (Table 7-3).

- **Consider the bloom time of flowering plants within the project area.** Include a number of different species of flowering plants during the flight time of focal pollinators. Adults of butterflies and moths of most imperiled and listed species have limited flight times; therefore, make sure that in addition to host plants, a site has plenty of flowering plants during the flight time of the adults (see Chapter 3 or 6 for flight times of adults).

- **Include key nectar and/or pollen plants for target pollinator species.** Some pollinator species have dietary restrictions and need the floral resources from certain flowering plants to survive. For example, bees that are pollen specialists can only rear their young on pollen from a certain species or groups of closely related plants. Bumble bee species have different tongue lengths that allow them to preferentially feed on certain flowers. Adult butterflies are often generalist foragers of nectar, but some species may exhibit preferences for nectar from certain plants. For example, grass skippers in the Midwest and Great Plains prefer to drink nectar from purple coneflowers (*Echinacea* spp.) and blazing stars (*Liatris* spp.) (Moranz 2010; Dana 1991). Plant lists included in this guide include known nectar plants for imperiled and listed species (Table 7-3).

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- **Consider additional specific habitat needs, such as nesting or overwintering habitat.** Some imperiled species have very specific habitat needs. For instance, a bumble bee species may prefer nesting aboveground in a particular type of insulated cavity, and a tunnel-nesting, yellow-faced bee needs a particular place to tunnel. Consult the profiles of listed and imperiled pollinators in Chapter 3 to learn more about any specific habitat needs. In general, including a diversity of types of plants in revegetation plans can help to ensure that vegetation structure that can act as shelter and overwintering habitat is present. Trees and shrubs may not be appropriate for every revegetation project; in those situations, including a diversity of grasses (both cool and warm season grasses) can increase vegetation structure.
- **Consider the connectivity of planned revegetation sites to existing habitat within the landscape.** Developing a landscape connectivity map of the project area and adjacent lands—using information collected during the vegetation assessment that locates areas of high, medium, and low pollinator habitat qualities—can be a base for designing a revegetation plan that improves pollinator habitat within the context of larger landscape connectivity. Corridors with high-quality habitat support more butterfly species, including specialist species, and population persistence (Habel et al. 2020; Dániel-Ferreira et al. 2022a). It is also important to prioritize those projects that can increase the connectivity of existing roadside habitat. If remnant roadside habitat exists, for example, it would be very beneficial if revegetation projects with high plant diversity were installed adjacent to or nearby.
- **Consider timing of revegetation projects.** While high-quality revegetation is ultimately beneficial to pollinators, it can lead to a temporary decrease in the availability of food and nesting resources for pollinators. If a revegetation project is being conducted in an area with an imperiled pollinator, ideally the project should be timed to avoid adult flight times or other sensitive times in the species' life cycle (Chapter 3).

7.3.5 Developing a Plant Species List

To improve pollinator habitat as a revegetation objective, select a mix of plant species and site improvements that encourage foraging, breeding, nesting, and overwintering of a variety of pollinator species. Revegetation efforts for pollinators should use diverse, stable communities of plants that include key plant species that support local pollinators, including imperiled and state- or federally listed pollinator species. Plant diversity in a revegetation plan is important from several angles. Diverse plant communities are better able to prevent erosion and resist weed invasions, and they are more persistent over time and more resilient as climates shift (see Chapter 8 for more information). Roadsides are variable in soil type and moisture, fertility, land-use history, solar radiation, and more. With such a range of microsites, diverse plantings help ensure that there are a number of species that could fill in the various niches; if one or more species does not do well at the site, there are others that will, creating a resilient system. Diverse plantings also best support pollinators, providing flowers that have sequential bloom periods, host plants for breeding, nest sites, grasses that provide vegetative structure for shelter and overwintering, and more.

Different plant groups provide different functional roles and benefits, and they can occupy different niches. Cool-season rhizomatous grasses green up early in the spring and can provide erosion control from late winter into early summer, while warm-season grasses

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provide erosion control as they grow through the summer months and into the fall. Legumes can fix nitrogen and improve soil health. Annual or biennial wildflowers can establish quickly and provide attractive vegetative cover, erosion control, and food for pollinators and birds while slower growing, but deeper-rooted, perennial species establish. Shrubs and trees also play important roles in revegetation projects, where appropriate, and are ecologically valuable to pollinators as well.

Guidelines for developing a species list that supports pollinators and other revegetation objectives are presented below:

- Select species adapted for the sunlight and soil conditions present at the roadside site (e.g., use moisture-tolerant species for wet ditches). Projects that contain special microclimates or soils may require a unique mix of species. If seed mixes cannot be context-specific, include species adapted to a wide range of growing conditions.
- Prioritize the use of native plants. Avoid using introduced (non-native) species in high-quality mixes, as these species may outcompete native plants during establishment, diminishing the quality of habitat over time and supporting fewer species of pollinators.
- Include key plant species that support imperiled pollinators, such as host plants for caterpillars or plants that are known to provide nectar or pollen to adults.
- Ensure that non-aggressive species are able to establish by limiting the abundance of aggressive species as needed.
- Avoid temporal gaps in bloom periods. To ensure that there are always flowers in bloom, include multiple species that bloom in the spring, species that bloom in summer, and those that bloom in the fall. Some mixes fall short on spring blooms in particular (Havens and Vitt 2016).
- Design plantings with plant communities in mind and include species that will grow well together.



This planting, made as part of a bridge replacement and interchange reconfiguration, includes layers of native trees like oaks and hawthorn; shrubs such as viburnum, chokeberry, and bayberry; and perennial grasses.

Photo Credit: Tara Mitchell, Massachusetts DOT

- Include layers of plants. For example, include an understory of shrubs, wildflowers, grasses, or sedges with tree plantings. Layers help to shade out weeds, reduce moisture loss, provide layers of habitat for wildlife, and reduce maintenance requirements.
- If installing vegetation via seeding, balance the proportion of grass seeds to wildflower seeds. If grass density is too high, grasses will outcompete wildflowers over time, reducing plant diversity. At minimum, 25 percent of the seed mix should be wildflowers, but a mix that is 50 percent wildflowers results in a considerably more diverse and stable planting (Dickson and Busby 2009). In highly visible areas, consider increasing the wildflower component to create more showy plantings, if that is an objective for the revegetation site.
- Check erosion control mulches or straw, seed laboratory reports, and legal seed labels of the planting stock. Mulches, seed, and other planting stock should be free of noxious weeds, invasive or introduced species, and other crop components.

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- 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, 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 pollinators.
- 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.
- When possible, salvage native plants, particularly those that are more difficult to establish or are longer lived, from the site prior to construction and disturbance for use in the revegetation project. Enlist the help of other agencies or volunteers to temporarily relocate the salvaged vegetation for installation at the site after construction or for installation at another appropriate site.



These saguaro cacti, which are very slow growing and long-lived plants, are relocated temporarily during a construction project.

Photo Credit: Arizona DOT

7.3.6 Plants for Imperiled Pollinators in the Northeast Region

This plant list includes wildflowers and flowering shrubs and trees that are sources for pollen and/or nectar for a diversity of pollinators, plants that serve as host plants for caterpillars of butterflies and moths, and grasses, sedges, and woody species that provide nesting or materials for nesting for bees and wasps.

- All species in this list are native to this region. Many have been commercially available (White et al. 2018). Contact local or regional native plant producers to check on their current availability or to inquire about species that may require collecting plant materials for propagation.
- Many of the species in this list are “workhorse” species that broadly support pollinators, are found in a number of ecological settings in abundance, and are relatively easy to propagate. Workhorse species also tend to survive well once they are installed.
- This list also includes plant species that are important for imperiled pollinators listed in Chapter 3. Some of these plant species do not meet the workhorse criteria, and may be more challenging to establish. They may also be less widely available commercially or more expensive because they take more time to propagate.
- This plant list is available as an Excel file on the National Academies Press website (https://nap.nationalacademies.org).

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Table 7-3. Native Plants with value to pollinators for use on roadsides in the Northeast region.

Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Acer rubrum	Red maple	Mar–Apr	Perennial	Tree	Sun, part shade	Wet			X		
Achillea millefolium	Common yarrow	May–Jul	Perennial	Forb	Sun, part shade	Moist			X	Stems	X
Agrostis spp.	Bentgrass		Perennial	Grass	Sun, part shade	Wet, moist, dry	X				
Amelanchier laevis	Allegheny serviceberry	Mar–Apr	Perennial	Tree, shrub	Sun, part shade, shade	Moist					
Aquilegia canadensis	Red columbine	Apr–May	Perennial	Forb	Sun, part shade	Moist					
Asclepias amplexicaulis	Claspiing milkweed	Jun–Aug	Perennial	Forb	Part shade	Dry	X	X	X	Stems	
Asclepias exaltata	Poke milkweed	Jun–Jul	Perennial	Forb	Part shade, shade	Moist, dry	X	X	x	Stems	
Asclepias incarnata	Swamp milkweed	Jun–Sep	Perennial	Forb	Sun, part shade	Wet	X	X	X	Stems	
Asclepias syriaca	Common milkweed	Jun–Aug	Perennial	Forb	Sun, part shade	Dry, moist	X	X	X	Stems	
Asclepias tuberosa	Butterfly milkweed	Jun–Aug	Perennial	Forb	Sun, part shade	Dry	X	X	X	Stems	

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Asclepias viridiflora	Green comet milkweed	Jun–Sep	Perennial	Forb	Sun	Dry	X	X	X	Stems	
Arabis lyrate	Lyrate rockcress	Apr–May	Biennial, perennial	Forb	Sun, part shade	Moist, Dry		X			
Baccharis halimifolia	Eastern baccharis	Jul–Sep	Perennial	Shrub	Sun, part shade	Wet, moist		X	X		
Baptisia tinctorial	Yellow wild indigo	Jun–Aug	Perennial	Forb	Sun, part shade	Dry	X		X		
Bouteloua gracilis	Blue grama		Perennial	Grass	Sun	Dry	X			x	
Castanea pumila	Chinquapin	Apr–May	Perennial	Tree, shrub	Sun, part shade	Dry					
Ceanothus americanus	New Jersey tea	Jun–Jul	Perennial	Shrub	Sun, part shade	Dry		X	X		
Cephalanthus occidentalis	Buttonbush	Jun–Aug	Perennial	Shrub	Sun, part shade	Wet		X	X		
Chamaecrista fasciculata	Partridge pea	Jul–Sep	Annual	Forb	Sun, part shade	Moist			X		
Cirsium discolor	Field thistle	Aug–Sep	Biennial, perennial	Forb	Sun	Moist		X	X		
Coreopsis lanceolata	Lanceleaf coreopsis	Apr–Jun	Perennial	Forb	Sun	Moist			X		
Dalea purpurea	Purple prairie clover	Jul–Aug	Perennial	Forb	Sun,	Dry		X	X		

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Echinacea purpurea	Purple coneflower	Jun–Aug	Perennial	Forb	Sun	Moist			X	Stem	
Erigeron strigosus	Prairie fleabane	May–Jun	Perennial	Forb	Sun	Moist, dry		X	X		
Eupatorium perfoliatum	Common boneset	Jun–Oct	Perennial	Forb	Sun, part shade	Wet			X	Stems	
Euthamia graminifolia	Flat-top goldenrod	Jul–Sep	Perennial	Forb	Sun, part shade	Wet, moist		X	X		
Eurybia divaricata	White wood aster	Aug–Oct	Perennial	Forb	Part shade, shade	Dry			X		
Eutrochium fistulosum	Joe Pye weed	Jul–Sep	Perennial	Forb	Sun	Wet		X	X	Stems	
Geranium maculatum	Wild geranium	Apr–May	Perennial	Forb	Sun, part shade	Moist, dry		X	X		
Hamamelis virginiana	American witchhazel	Sep–Nov	Perennial	Tree, shrub	Sun, part shade, shade	Moist			X		
Helenium autumnale	Common sneezeweed	Sep–Nov	Perennial	Forb	Sun, part shade	Moist			X		
Helianthus angustifolius	Swamp sunflower	Jul–Sep	Perennial	Forb	Sun	Moist				Stems	
Ilex opaca	American holly	Apr–May	Perennial	Tree, shrub	Sun, part shade, shade	Moist			X		

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Lespedeza capitata	Roundhead lespedeza	Jul–Sep	Perennial	Forb	Sun, part shade	Dry			x		
Liatris spicata	Dense blazing star	Jul–Sep	Perennial	Forb	Sun, part shade	Moist		x		Stems	
Lupinus perennis	Sundial lupine	Apr–Jun	Perennial	Forb	Sun	Dry	x	x	x		
Mimulus ringens	Allegheny monkeyflower	Jun–Sep	Perennial	Forb	Sun, part shade	Wet					
Monarda fistulosa	Wild bergamot	May–Sep	Perennial	Forb	Sun, part shade	Moist		x	x	Stems	
Monarda punctata	Spotted beebalm	Jun–Aug	Perennial	Forb	Sun	Moist		x	x		
Oligoneuron rigidum	Stiff goldenrod	Aug–Sep	Perennial	Forb	Sun, part shade	Moist			x	Materials	
Packera aurea	Golden ragwort	Mar–Apr	Perennial	Forb	Sun, part shade, shade	Moist					
Penstemon digitalis	Foxglove beard tongue	Jun–Jul	Perennial	Forb	Sun	Dry		x			
Potentilla simplex	Common cinquefoil	Apr–Jun	Perennial	Forb	Part shade, shade	Dry		x			
Prunella vulgaris	Common selfheal	Jun–Aug	Perennial	Forb	Sun, part shade	Moist					
Prunus americana	American plum	Apr–May	Perennial	Tree, shrub	Sun, part shade	Moist			X		

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Pycnanthemum tenuifolium	Narrowleaf mountain mint	Jun–Aug	Perennial	Forb	Sun	Wet, moist, dry		X	X		
Pycnanthemum virginianum	Virginia mountain mint	Jun–Aug	Perennial	Forb	Sun	Moist		X	X	Stems	
Ratibida pinnata	Gray-headed coneflower	Jun–Aug	Perennial	Forb	Sun	Moist			X	Stems	
Rhus aromatica	Fragrant sumac	Apr–Jun	Perennial	Shrub	Sun, part shade, shade	Dry			X	Stems	
Ribes americanum	American black currant	May–Jun	Perennial	Shrub	Sun, part shade	Dry			X		
Rosa virginiana	Virginia rose	May–Jun	Perennial	Shrub	Sun, part shade	Moist			X	Nests and materials	
Rubus occidentalis	Black raspberry	Apr–May	Perennial	Shrub	Sun, part shade	Moist			X	Nests and materials	
Rudbeckia hirta	Black-eyed Susan	Jun–Aug	Annual or Perennial	Forb	Sun, part shade	Moist			X		
Rudbeckia laciniata	Cutleaf coneflower	Jul–Sep	Perennial	Forb	Sun, part shade, shade	Dry, moist		X	X		
Salix discolor	Pussy willow	Feb–Apr	Perennial	Tree, shrub	Sun	Wet			X		
Sambucus nigra	Black elderberry	Apr–May	Perennial	Tree, shrub	Sun, part shade	Moist			X	Stems	

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Schizachyrium scoparium	Little bluestem	Aug–Sep	Perennial	Grass	Sun, part shade		X			X	
Senna hebecarpa	American senna	Jul–Aug	Perennial	Forb	Sun, part shade	Moist			X	Materials	
Solidago caesia	Wreath goldenrod	May–Jun	Perennial	Forb	Sun, part shade	Moist		X	X		
Solidago nemoralis	Gray goldenrod	Aug–Sep	Perennial	Forb	Sun, part shade	Dry		X	X		
Solidago rugosa	Wrinkleleaf goldenrod	Jul–Sep	Perennial	Forb	Sun, part shade	Moist		X	X	Stems	
Spiraea tomentosa	Steeplebush	Jun–Aug	Perennial	Shrub	Sun, part shade	Dry			X	Materials	
Symphyotrichum laeve	Smooth blue aster	Aug–Sep	Perennial	Forb	Sun	Moist		X	X	Stems	
Symphyotrichum lateriflorum	Calico aster	Aug–Oct	Perennial	Forb	Sun	Moist		X	X	Stems	
Symphyotrichum novae-angliae	New England aster	Aug–Oct	Perennial	Forb	Sun	Wet		X	X	Stems	
Tiarella cordifolia	Heartleaf foamflower	Apr–Jun	Perennial	Forb	Sun, part shade, shade	Moist					
Tilia americana	American basswood	May–Jun	Perennial	Tree	Sun, part shade	Moist			X		

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Scientific Name	Common Name	Bloom Period	Life Cycle	Form (Forb, Shrub, Tree, Sedge, Grass)	Sun	Soil (Dry, Moist, Wet)	Imperiled Butterfly and Moth Larval Host	Nectar/ Pollen for Imperiled Pollinators	Bumble Bee Plant	Nest Site or Nest Materials	Deer Resistant
Vaccinium spp.	Blueberries	Mar–Aug	Perennial	Shrub	Sun, part shade, shade	Wet, moist, dry		X	X		
Verbena hastata	Swamp verbena	Jul–Sep	Perennial	Forb	Sun, part shade	Wet			X		
Vernonia spp.	Ironweed	Jul–Sep	Perennial	Forb	Sun, part shade	Wet, moist, dry		X	X		
Veronicastrum virginicum	Culver's root	Jun–Aug	Perennial	Forb	Sun	Moist			X	Stems	
Viburnum prunifolium	Blackhaw	Apr–May	Perennial	Shrub	Sun, part shade, shade	Moist			X		
Viola spp.	Violets	Mar–Jul	Annul, perennial	Forb	Sun, part shade, shade	Wet, moist, dry		X	X		

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To identify additional species appropriate to this region and valuable to pollinators, use the Ecoregional Revegetation Assistant Tool, a map-based online tool to aid practitioners when selecting native plants for restoration and pollinator habitat enhancement. The map can be used to find a state or US Environmental Protection Agency Level III Ecoregion, and the tool will produce a list of plants and plant attributes suitable for that area. The database includes plant attributes such as soil type, moisture needs, palatability, salt tolerance, value to pollinators, and workhorse plant species. Data can be downloaded by county, state, or ecoregion, and plant species can be filtered by attributes. The tool is available at http://www.nativerevegetation.org/era.

When designing revegetation projects, it is important to consult with the site's maintenance department. Maintenance departments have processes and practices in place for reasons that may not be known to habitat designers, and coordination with maintenance can improve revegetation outcomes. Discussions with maintenance departments can help to build willingness to adapt maintenance practices to facilitate pollinator habitat establishment and persistence. Consider if the agency could create a staff position that focuses on ecological roadside revegetation and is shared by both the maintenance and design teams. This role could ensure that what is designed gets implemented across the state and can be maintained effectively by maintenance crews.

Box 7-1. Rest areas, welcome centers, and pollinator habitat



Signage for this Ohio DOT planting describes why pollinators are important and plants that support them.

Photo Credit: Joel Thrash, Ohio DOT

Welcome centers and rest areas are places where the traveling public can relax and take a break. DOTs also provide learning opportunities at these stopping points, where signs and brochures are frequently used to inform the public. DOTs can also use these spaces to create demonstration gardens or plantings, including pollinator habitat. These plantings help DOTs inform the public about pollinators and habitat that support them, and showcase conservation efforts.

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Plantings for pollinators at rest areas or welcome centers can also be opportunities for experimentation, places where DOTs can trial particular seed mixes or planting methods on a smaller scale before implementing them on a larger area. Wisconsin DOT, for example, is currently restoring prairie at two of its busiest rest areas, removing invasive species and interseeding additional prairie species. There are also opportunities for collaborations and partnerships in these spaces. Georgia DOT is in the process of installing pollinator habitats at some of rest areas and welcome centers, in partnership with the Georgia Association of Conservation Districts. Kansas DOT worked with partners to trial prescribed burning to manage plantings at several of their rest areas.



Invasive brush and a dead tree are removed from a prairie restoration at a Wisconsin rest area before additional wildflower seeds are added.

Photo Credit: Wisconsin DOT

7.4 Installation Considerations for Revegetation

7.4.1 Sourcing Plant Materials

Obtaining locally or regionally sourced native plant materials in sufficient quality and quantities for a project involves advance planning. Coordination with native plant providers early in the planning process is important. If a special plant species is needed for a site, the agency or plant vendors can collect wild plant material and amplify seeds, cuttings, or plants with enough lead time. Guidance for collecting and propagating wild-type plant materials can be found in *Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat* (FHWA 2017): http://www.nativerevegetation.org/learn/manual_2017/chpt5_implementation/5_3_obtain_plant_mat.aspx.

If there are not enough abundance and diversity of locally sourced species available for a project, prioritize regionally sourced native plant materials. These might include species that do not naturally occur in the local ecosystem but are present within the region. If regional plant materials cannot be found, consult restoration experts and seed producers to determine if cultivars may be appropriate to use for the site. Commercial cultivars are less preferable because some do not provide sufficient pollen or nectar to support pollinators, and some may either not establish effectively in the area or may become too aggressive at the expense of other valuable plants. However, cultivars might be appropriate in some locations for certain revegetation objectives (e.g., landscape planting in an urban setting).

When obtaining seed, it is recommended to require vendors to provide a seed testing certificate for each species in the seed mix. Commercially procured seed is certified to guarantee a number of quality standards, including proper species, germination rate, and

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any amount of weed seed or inert material. Review the certificate before purchase of the seed lot and reject seed lots that contain undesirable species as contaminants that might pose a risk to the planting.

Native Plants and Costs of Revegetation

Although the initial costs of establishing native plant material may be more significant than using widely available introduced species, particularly for projects that include a higher density and diversity of flowering plants or specialized species, native plants are often more cost effective in the long term. Once established, the native plants persist well over time and often require less mowing, herbicides, and other weed control measures, decreasing long-term maintenance efforts and cost (Berger 2005). For more information about costs and benefits of native plants, see Chapter 10.

Legislation Supporting Native Plants on Roadsides

Federal Legislation

In 2014, the White House issued a Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators." This memo directed the U.S. Department of Transportation to evaluate guidance and identify opportunities to increase pollinator habitat along roadways, and to work with state DOTs and transportation associations to promote practices that support pollinators, including increasing native plantings. In 2015, the Fixing America's Surface Transportation (FAST) Act was signed into law and included language on efforts to support pollinators. Section 1415 of the FAST Act authorizes that activities to establish and improve pollinator habitat may be eligible for federal funding if they are related to transportation projects funded under Title 23, U.S.C.

Additionally, Section 1415 of the FAST Act directs the Federal Highway Administration (FHWA), in conjunction with willing states, to encourage:

1. Integrated vegetation management practices on roadsides and other transportation rights-of-way, including reduced mowing; and

2. The development of habitat and forage for Monarch butterflies, other native pollinators, and honey bees through plantings of native forbs and grasses, including noninvasive, native milkweed species that can serve as migratory way stations for butterflies and facilitate migrations of other pollinators.

In 2021, the Infrastructure Investment and Jobs Act included language to establish two funding programs that could be used to support pollinator habitat for agencies that manage roadsides. Section 11522 established the Invasive Plant Elimination Program to provide grants to states to control invasive species, up to $50 million per year (for fiscal years 2022–2026). Priority is given to projects that utilize revegetation with native plants that support pollinators. Section 11528 established the Pollinator-Friendly Practices on Roadsides and Highway Rights-of-Way grant program to provide grants of up to $150,000 for use in the development, implementation, or improvement of a pollinator-friendly practices plan, with up to $2 million available per year ((for fiscal years 2022–2026). Examples of pollinator-friendly practices include:

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- mowing strategies that limit disturbance during periods of highest use by target species;
- an integrated vegetation management plan to address weed issues;
- the planting of native species to enhance pollinator habitat;
- removal of non-native species from species mixes; and
- obtaining expert training or assistance on pollinators-friendly practices.

Funding was not appropriated by Congress as part of the FY 2022 budget for either the Invasive Plant Elimination Program or the Pollinator-Friendly Practices grant program but will hopefully be included in future budgets.

Beyond FHWA, many other land management agencies in the United States have policies mandating the prioritization of native plants in revegetation projects, including the U.S. Forest Service and the Bureau of Land Management.

State Legislation

At the state level, there have been several approaches to encouraging native plants as the first choice in revegetation efforts. In Iowa, the state legislature passed Integrated Roadside Vegetation Management (IRVM) legislation in 1987 to promote an ecologically integrated approach to roadside management, while maintaining a safe travel environment (Code of Iowa, Section 314, available here: https://www.legis.iowa.gov/docs/ico/code/314.pdf). The legislation emphasized the establishment and protection of native vegetation as well as judicious use of herbicides, mowing, prescribed burning, and other management tools.

The bill also established the Living Roadway Trust Fund, an annual competitive grant program administered by the Iowa DOT that provides funding for school, city, county, and state projects, as well as research projects involving IRVM. Iowa's road use tax, along with several other sources, funds the Living Roadway Trust Fund. County roadside managers can submit applications to obtain resources to help them implement IRVM, including vegetation inventories, native seeds, equipment for burns or plant establishment, GPS units, signage, workshops, and more. Roadsides are seeded with mixes of species that are appropriate for a particular site, including many wildflowers that are attractive to pollinators. Seed mixes also contain species that bloom at different times throughout the growing season, which helps support pollinators all season long. Research projects have also been supported by the Living Roadway Trust Fund, including studies of restoration techniques.

Since the bill passed, more than 100,000 acres of Iowa's nearly 600,000 acres of state and county roadsides have been planted with native vegetation (Brandt et al. 2011). In the process, Iowa has fostered the development of experienced roadside managers who are equipped to collaborate with other land managers around the state and bring habitat, and wildlife such as pollinators, back to Iowa's much-altered landscape.

In 2017, New Jersey passed a bill that requires New Jersey DOT, New Jersey Turnpike Authority, and the South Jersey Transportation Authority to use only native vegetation for landscaping, land management, reforestation, or habitat restoration. The legislation also directed the Department of Environmental Protection and Department of Agriculture to identify plants native to the state in hardiness zones within the state. Proponents of the

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bill pointed to saving taxpayers expenses due to replanting, and to benefits for wildlife and clean water. The text of the bill can be found here:
https://legiscan.com/NJ/text/S227/2016.

North Carolina passed an act to prioritize the use of native plants on roadsides in 2019. Recognizing that native plants are part of North Carolina's natural heritage and are well adapted to North Carolina's landscapes, the bill directs North Carolina to give precedence to the use of native trees, shrubs, vines, grasses, and wildflowers in erosion control and landscaping projects, as well as in roadside parks, scenic overlooks, and picnic areas. The bill can be found here:
https://webservices.ncleg.gov/ViewBillDocument/2019/2522/0/DRS35248-MW-38.

7.4.2 Prioritizing Sites for Revegetation Efforts to Benefit Imperiled Pollinators

It can be helpful to prioritize sites for roadside revegetation projects that support imperiled pollinators in order to maximize conservation value and use resources effectively.

Considerations to guide decisions about prioritization of sites to improve pollinator habitat include:

- **Presence of target pollinator species.** Prioritize locations where a listed or imperiled pollinator species is known to be in the vicinity or was previously found at the site.
- **Landscape connectivity.** Prioritize sites that improve connectivity of existing habitat within the landscape.
- **Landscape diversity.** Prioritize sites that exist in an area important to the target pollinator species and is in a landscape in which habitat is scarce, and therefore roadside habitat would be particularly valuable to pollinators.
- **Roadside width.** Prioritize wider sites because they appear to support greater numbers and diversity of pollinator species. Medians are lower priorities because they are often narrow and, due to their placement between roads, may pose a higher risk from vehicle mortality to pollinators.
- **Traffic density.** Prioritize sites with lower roadway traffic density.
- **Road density.** Prioritize sites that are not isolated within areas of high road density in which there are multiple barriers to pollinator movement (e.g., cloverleaf median off an interstate interchange in an urban area).
- **Visibility to the public.** Consider prioritizing sites that are more visible to the public if public awareness and education is a goal.

Use the scorecard in Box 7-2 to determine a site's attributes and its relative suitability for prioritizing enhancement for pollinators.

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Box 7-2. Scorecard for prioritizing sites for revegetation to support imperiled pollinators

Resources to install high-quality, diverse native plant material may be limited. Limited resources can be leveraged by prioritizing some roadside sites for revegetation that involves habitat restoration for imperiled or at-risk pollinators. Use this tool to help determine a score for a site that can be helpful in site prioritization. Select all the options that apply to the site:

☒ **Presence of focal pollinator species.** A listed or imperiled pollinator species is known to be in the vicinity or was previously found at the site. (2pts)

☒ **Landscape connectivity.** The site improves connectivity of existing habitat within the landscape. For example, the site is near or connected to a natural area (e.g., state park, national forest, nature preserve) or connects with existing high-quality roadside vegetation. (2pts)

☒ **Landscape diversity.** The site exists in an area important to the focal pollinator species and is in a landscape in which habitat is scarce; therefore, roadside habitat would be particularly valuable to pollinators. (2pts)

☒ **Project scale.** The planned project is large in scale; the size of a habitat patch influences the number of individuals and species that use it. (1pt)

☒ **Roadside width.** Wider sites are preferred because they appear to support greater numbers and diversity of pollinator species. (1pt)

☒ **Traffic density.** Sites with higher traffic density (more than four lanes of traffic) on adjacent roads may be less desirable for pollinators. (1pt)

☒ **Road density.** Site is not isolated within areas of high road density in which there are multiple barriers to pollinator movement (e.g., cloverleaf median off an interstate interchange in an urban area). (1pt)

☒ **Visibility to the public.** Sites that are more visible to the public may be important for DOT goals, including public awareness and education. (1pt)

☒ **Weed pressure:** The site has low weed pressure from noxious and invasive weeds. (1pt)

☒ **Benefits to adjacent land.** The existing or future road network is in lands largely dominated by agricultural activities that could benefit from pollinators. (1pt)

Final score: _____

Scale:

Scores of 7 or more points: This site is a high priority for revegetation with pollinators in mind.

Scores of 4–6 points: This site is a medium priority for revegetation with pollinators in mind.

Scores of 3 and lower: This site is a lower priority for revegetation with pollinators in mind.

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Chapter 9 includes a tool to help evaluate sites for their conservation value to pollinators: the Pollinator Habitat Assessment Guide for Roadsides. The tool includes a rapid assessment and a comprehensive assessment of roadside pollinator habitat. The comprehensive assessment includes 1) a category to determine the priority of the roadside site within the context of the larger landscape and 2) a category that evaluates possible threats to pollinators from the adjacent road and surrounding land. The scores from those categories can help to guide choices about prioritizing projects that emphasize an objective to improve habitat for imperiled pollinators. The Roadside Pollinator Habitat Assessment Guide is available on the National Academies Press website (https://nap.nationalacademies.org).

The Monarch Joint Venture and partners (funded through the National Academy of Sciences Transportation Research Board's National Cooperative Highway Research Program) developed a habitat prioritization model for roadsides as monarch butterfly habitat for DOTs. The model can help managers assess potential areas of habitat along roads in their state or identify where habitat could be developed. More information about the model can be found here: https://monarchjointventure.org/mjvprograms/science/roadsidehabitat/habitat-prioritization-model.

7.4.3 Plant Establishment

After disturbance or construction, roadside sites may be in poor condition for plant growth. Mitigation measures may be needed, such as reconstructing soils (note: if new soils are brought to a location, they should be free of invasive seeds, to the extent possible) or making amendments through composts or fertilizers or the introduction of beneficial microorganisms that play crucial roles in soil and plant health. Topographic enhancements to improve the plant establishment can also be made. These include modifying topography to capture runoff water for use by plants or creating terraces on slopes to support seedling establishment.

Installing Plant Materials

Installing diverse native plant materials, including diverse seed mixes, requires consideration of timing of installation and matching installation method to the site characteristics. Generally, diverse seed mixes have the best establishment when planted in the fall or during the dormant season, allowing the many species that require cycles of cold moisture to germinate. Transplants generally do best when installed in winter or early spring when soil moisture is high, or sometimes in the fall for dormant plants. In this region, the optimal timing to install native plant materials is presented in Table 7-4.

Table 7-4. Timing windows for installing native plants in the Northeast region.

When to Seed	When to Install Container Plants	When to Install Bare Roots
Oct–Nov	May–June	Apr–June

Although these time windows are optimal for plant establishment, it may be especially difficult to time seeding accordingly because of time constraints from construction schedules. Seeding should take place as needed for erosion control after repairs or construction, as long as the seed is protected in place (e.g., under a layer of hydrostraw tackifier or compost blanket) until the conditions for germination occur.

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When installing seeds, select the method of seeding that is most appropriate for the site. See Table 7-5 for an overview of the advantages, disadvantages, and tips on seeding techniques, using the three main seeding methods used in roadside revegetation.

General guidance on installing native seeds to achieve optimal establishment includes:

- Place seed in direct contact with soil, and do not bury the seed more than ¼ inch deep, which will affect establishment. If broadcasting seed, tamp or press down the seed lightly into the soil using a tractor or cultipacker after planting. If hydroseeding, apply the seed, mixed with fertilizer and a small amount of fiber or straw and tackifier first, then follow up with a second pass of hydromulch mixed with tackifier to hold it in place. This ensures seeds are covered by the hydromulch.
- If the site requires rapid plant establishment, include nurse or cover crops in seed mixes to help hold the soil while native species establish. Suitable nurse crops include sterile hybrids or annuals such as oats (*Avena sativa*), winter wheat (*Triticum aestivum*), or rye (*Lolium multiflorum*).
- Coordinate with maintenance staff about conducting weed control during the establishment phase. Weed control to reduce weed competition while allowing native seedlings to grow is critical in the first and second years after planting. Weeds should also be prevented from going to seed. Use spot-sprays of herbicides as needed or mowing where appropriate. (See "Short-Term Management: Before and During Establishment" below.)
- Because roadsides planted with seed can take time to establish, it may be helpful to install a sign to indicate the site is a planting that is underway.

Table 7-5. Seeding methods for planting seed and the techniques involved.

Seeding Method	Where to Use	Site Preparation Needed	Seeding Techniques	Following Seeding
Broadcast seeders or hand broadcasting (Throwing seed)	• This method is inexpensive and easy to use. It is particularly useful for sites that cannot be reached by mechanical equipment. • Spreading seed evenly over site is difficult, and the seed bed must be smooth. • Greater quantities of seed (up to 50%	• Remove as much stubble as possible prior to planting, creating a smooth lightly packed seedbed. • Seed before a rain.	• Bulk up seed using an inert carrier, such as sand or clay-based cat litter. • Make multiple passes, scattering seed over the site.	• Pack the seed into the soil using a tractor or cultipacker.

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Seeding Method	Where to Use	Site Preparation Needed	Seeding Techniques	Following Seeding
	more) are required. • Additional step of pressing seed into soil after seeding to help germination is required.			
Drill seeding (Using a native seed drill)	• Drill seeding is convenient for planting large, level areas, but it does not work well on slopes. • Seed can be planted into areas with light stubble and seed does not need to be pressed into the soil. • Depth at which seeds are planted can be controlled. • An experienced operator is required.	• Seed can be planted into stubble.	• Plant when the soil is dry enough to prevent sticking to the parts of the drill. • Set depth controls to plant no deeper than 1/4 inch.	• Make multiple passes with the drill to pack the seed in well.
Hydroseeding (Spraying the area with a mix of water, mulch, and seed)	• Hydroseeding is useful for slopes, culverts, bridge approaches, and wet areas because it reduces soil erosion. • The project can be seeded from the shoulder. • Hydroseeding is good for visible sites; hydromulch can hold the seed	• Bare ground is needed, but the seedbed does not need to be smooth. • Seed after a rain if possible.	• Apply the seed first, mixed with fertilizer and a small amount of fiber or straw and tackifier. Then follow up with a second pass of hydromulch mixed with tackifier to hold the	• No action is required following seeding.

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Seeding Method	Where to Use	Site Preparation Needed	Seeding Techniques	Following Seeding
	in place until there is enough moisture for germination and protect it from seed predators. • Hydromulch can be expensive, and the seeding rate is harder to control; well-trained applicators are needed.		seed in place. • Seed the area furthest from the road first.	

General installation guidelines for optimizing establishment of transplants include the following:

- Determine the equipment needed for the installation of transplants. Shovels are often adequate for excavating holes for many transplants, but power augers are a particularly efficient way to create a hole for large container stock. Steep or rocky slopes may require specialized planting equipment such as expandable stingers.
- Stage the planting before digging holes. The objectives of the project will determine the planting patterns, whether transplants will be spaced out evenly, in clumps, or at random. Remember to consider the size of each species at maturity when spacing out plants. For example, most woody shrubs should be spaced on 4- to 10-foot centers to give them ample room to grow.
- In areas where soil is compacted or degraded, add compost to holes prior to planting. Use clean compost (no manure or biosolids) to reduce the introduction of unwanted weeds during planting. The use of sphagnum peat moss should be avoided because of the impact on wetlands and the associated release of greenhouse gases.
- Spread weed-free straw, bark, or wood chip mulch around the plants to reduce weed competition and to hold in moisture.
- Irrigate the transplants thoroughly immediately after planting. Depending on weather, region, and site conditions, regular follow-up irrigation may be needed in the first year or two after planting but can be discontinued after establishment. Some non-native plants may require longer periods of irrigation.
- Install netting or other plant guards where needed to protect transplants from browsing animals that can cause significant damage.

Detailed guidelines for installing plant materials are found in *Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat* (FHWA 2017). If plant installation is conducted by contractors, it can be useful to include language in

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contracts that outlines specifications for best practices. Arizona has an example of language for seeding specifications for contractors available at: https://apps.azdot.gov/files/roadway-engineering/roadside-dev/sample-class-ii-seeding-special-provisions_reference-only_adot-ido-roadway-roadside-development.pdf, and their best practices are outlined here: https://azdot.gov/node/5372.

7.4.4 Short-Term Management: Before and During Establishment

Before installing plants, reduce competition with invasive, noxious, or undesirable plants that would otherwise pose a threat to the establishment of desired vegetation. Some DOTs, for example, include noxious and invasive species control in construction specifications so that those weeds are controlled before, during, and after construction. Remove weeds through herbicide applications or by repeated mowing. Focus on removing perennial weeds, which are harder to control after planting.

Following planting, the site may require some management to keep annual weeds from seeding or to control any perennial weeds that were not eliminated before construction or planting. Additionally, in the first year of establishment, new seedlings require light and are greatly affected by weed canopies that stunt their growth. In this region, mowing to 8 inches high multiple times (2–4 times) in a growing season is often used to suppress annual weeds and help sunlight reach emerging wildflowers and grasses. Establishment mowing allows wildflower seedlings to better establish, survive, and flower in subsequent years (Williams et al. 2007; Meissen et al. 2019).



Weeds can limit native plant establishment by limiting the light that reaches the new seedlings, which grow more slowly than the weeds in the first year after planting.

Photo Credit: Dave Williams

For long-term success, weeds should be prevented from going to seed in the first 2 or 3 years. Care should be taken to properly identify weeds before removal; some young wildflower seedlings and weed seedlings may look alike. Common weed management strategies include:

- targeted herbicide applications (e.g., spot-spraying or rope-wick treatments),
- use of selective herbicides (e.g., grass-selective herbicides for grass weeds), and
- strategic mowing (e.g., using a carefully timed high mow to target weeds).

7.4.5 Long-Term Management: After Establishment

Plant communities need management over time to maintain species diversity and reduce encroachment by weeds or woody plants that may shade out plants in their understory. Practitioners generally follow these best practices in long-term management of plantings:

1. Assess the conditions on the ground.
2. Implement maintenance practices that help maintain wildflower diversity.
3. Consider flight and breeding periods of the listed and imperiled pollinators that are in the area when planning timing of maintenance activities. (See Chapter 6 for table of activity windows.)

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4. Evaluate the effects of maintenance activities in order to adapt and modify future activities based on experience.

Within the framework of these practices, a combination of maintenance strategies can be used to maintain wildflower diversity. Practitioners agree that varying management activities is critical to encouraging wildflower diversity, but there is little agreement on how to vary practices, even within a region. Some managers are strong proponents of mowing mid-season to suppress warm-season grasses and stimulate wildflowers, while others suggest limiting mowing during the growing season so that wildflowers can reseed. This discordance underscores the value of adaptive management approaches that are tailored to address the conditions of a particular revegetation project. Table 7-6 provides an overview of common issues related to managing a diverse plant community, along with options that can be used to address these issues. (Note that more than one of these management options can be relevant to any site.)

Table 7-6. Common long-term management issues for maintaining plant diversity.

Issues / Concerns	Management Options
Cool-season grasses dominate in planting	Grass-selective herbicide, mowing, or haying (or less commonly, prescribed burning or grazing) at vulnerable grass growth stage (boot stage, when the shoot is elongating and the seed head is developing inside the shoot).
Warm-season grasses dominate over wildflowers	Mid- to late-summer grass-selective herbicide or haying (or less commonly, prescribed burning or grazing) at vulnerable grass growth stage (boot stage).
Woody encroachment	Spot mow or cut brush in the spring or fall, apply an appropriate herbicide to the cut stump, and follow up with prescribed fire if woody plants resprout or sucker.
Maintaining wildflower abundance and diversity	Periodically hay or mow (at different times of growing season) or use grass-selective herbicides. (Less commonly, use prescribed fire in the dormant season or graze rotationally, targeting active growth periods of dominant grasses.)
Invasive weed management	Use mowing or herbicides (or less commonly, prescribed burning or grazing) to control invasives, timing management for when target species are most vulnerable.

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7.5 Case Studies

7.5.1 Adapting Design and Management in Washington

Washington DOT is working to restore corridors of ROWs to design roadsides so that they look seamless with the surrounding landscape, as if no construction has taken place. To learn more about restoration of grasslands, Washington DOT is using the Scatter Creek Rest Area as a testing ground. Experiments are being conducted at the rest area to help inform seed mix designs and installation practices. By experimenting with drilling seed, broadcasting seed, and broadcasting with a furrow, Washington DOT is learning more about installation techniques that lead to the most successful native plant establishment.



Camas (*Camassia quamash*) and other native plants are filling in as invasive scotch broom plants grow fewer with yearly treatments.

Photo Credit: Washington DOT

Washington DOT is also experimenting with timing of management to control invasive species that are present, such as scotch broom (*Cytisus scoparius*). Scotch broom is an introduced shrub that forms dense stands that can crowd out native plants and wildlife and is a difficult weed to control. In fact, scotch broom management can take decades because of the long-lived seeds that can germinate many years after falling from the plant. Washington DOT has also experimented with different management techniques, such as timing targeted herbicide sprays to scotch broom stems after mowing, or using prescribed burning to flush out the scotch broom seed bank.

By monitoring pollinators and counting bumble bees, beetles, and other species, Washington DOT is gathering data that informs their design and maintenance practices regularly over time.

7.5.2 Roadside Plantings in New York for Monarchs along Their Migration Route

As monarch butterflies in the Northeast fly thousands of miles south to their overwintering grounds in Mexico each fall, they often travel along the coastlines. In New York State, monarchs are frequently seen along the Ocean Parkway in autumn. As part of a coastal greenway project to develop a 10-mile shared use path along the shore between Captree State Park and Tobay Beach, New York DOT installed plants to support monarch butterflies in the median of the Ocean Parkway. In wide, open center medians, a layered planting system of native plant materials was developed. The interior section of the median was planted with a seed mix of wildflowers and grasses appropriate for the coastal region. The mix included species known to provide nectar for monarchs, including purple coneflower (*Echinacea purpurea*), smooth aster (*Symphyotrichum laeve*), and seaside goldenrod (*Solidago sempervirens*). Bayberry shrubs were planted around the perimeter of the planting. Landscape designers worked with New York DOT's maintenance staff to determine when and where mowing should be avoided. Additionally, vertical mowing



This layered planting along Ocean Parkway in New York was designed to support monarch butterflies, and it includes special mowing markers to help maintenance know when to mow.

Photo Credit: Crystal Peritz, New York DOT

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markers were placed along the edge of the plantings, with words clearly marked, "Wildflower Area – Only Mow after 2nd Week of October."

7.5.3 Revegetation focusing on Layers, Density, and Diversity



This planting, located between a main corridor and a ramp, is in its second year of growth.

Photo Credit: Tara Mitchell, Massachusetts DOT



In its fourth year of growth here, that same planting has filled out so that plants are layered effectively.

Photo Credit: Tara Mitchell, Massachusetts DOT

Aesthetics is an important component of revegetation designs, but is secondary to creating a functional planting and healthy ecosystem. Massachusetts DOT Landscape Designer Tara Mitchell recommends focusing on ecological factors in order to create long-term, self-sustaining vegetation. Tara designs her plantings for resilience. For example, by selecting a diversity of species and plant types (ever-green, deciduous, herbaceous), plantings are more resilient to plant loss – both ecologically and visually. Tara selects species that are rapid colonizers so there is early plant cover, species like evergreens that provide winter habitat and aesthetic interest, and shrubs and understory trees to create layers. Layers of plant species of different heights and different rates of growth provide an attractive visual effect and more habitat.

Tara also spaces plants relatively close together to create dense cover once established and to maintain coverage if some plants or species die. Along with layers, dense plantings provide better soil protection and helps shade out undesirable weeds. Tara has found that such plantings require less water and mulch during establishment, and that the survival rate of plants is very high, much higher than in trees or shrubs planted individually.

7.6 Resources

- *Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat:* http://www.nativerevegetation.org/learn/manual_2017/
- Ecoregional revegetation application tool: http://www.nativerevegetation.org/era/
- Revegetation resource library: http://resources.nativerevegetation.org/
- Plant lists for pollinators: https://xerces.org/publications/plant-lists

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Chapter 8 Creating Climate-Smart Pollinator Habitat along Roadsides

8.1 Introduction

More than 98 percent of climate scientists agree that climate change is occurring and that human activities, primarily the burning of fossil fuels and deforestation, are the cause. The effects are already being felt across the country in rising temperatures and increased frequency of extreme weather events. Climate change presents challenges for department of transportation (DOT) managers—extreme events, heatwaves, and sea level rise can all significantly affect transportation infrastructure. Climate change also affects pollinators and the plants that rely on them. This chapter presents an overview of the effects that climate change can have on pollinators, the components of climate-smart pollinator roadside habitat, and additional benefits of such habitat for mitigating the climate crisis.

8.2 Climate Change Projections

Climate change will have a variety of effects on climate, many of which are already occurring (see Box 8-1). Increases in average temperatures will continue nationwide, with increased frequency of extreme temperature events, including heatwaves. Weather variability will increase in most regions, with extreme weather events becoming more frequent and intense. Drought will become more common in many regions, which can play a role in increased wildfire frequency. Flooding will also become more common as a result of more frequent extreme weather events and sea level rise. Sea level rise will increase flood risk in coastal areas, while extreme weather events may increase flooding in both coastal areas (such as with increased number and intensity of hurricanes) and inland, especially near rivers and floodplains.



Unprecedented rains and flooding in summer 2022 in Yellowstone National Park led to the destruction of roads and other infrastructure. Extreme weather events like this will become more common as a result of climate change.

Photo Credit: AP via NPS

Climate change will also have many impacts on the nation's infrastructure and create additional challenges for DOT staff who manage and maintain safe roadways. In many areas, increases in temperature will reduce the amount of time that employees can safely spend working outdoors, especially during heatwaves. However, the need to update and/or repair infrastructure in response to climate change will also create opportunities for revegetation projects that support pollinators and other wildlife.

According to the Fourth National Climate Assessment (USGCRP 2018):

- Increased temperatures, combined with more frequent extreme weather events (including flooding, drought, and fire) and sea level rise, will compromise infrastructure.

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- Increased temperatures can cause rutting, cracking, and buckling of roads.
- Nationally, 60,000 miles of bridges and roads run through coastal floodplains, which are at increased risk from flooding and storms.
- Increases in inland flooding will threaten 2,500 to 4,600 bridges nationwide by 2050 and 5,000 to 6,000 bridges by 2090.

Box 8-1. Climate projections for the Northeast Region

Climate projections for this region include:

- Increases in average temperatures are expected.
  - Temperatures in this region will warm more and at a faster rate than other parts of the U.S., except Alaska. By 2035, average temperatures will be 2°C (3.6°F) warmer.
  - Heatwaves will increase in intensity and duration.
  - There will be higher temperature extremes.
  - The freeze-free period will be longer.
  - The urban heat island effect (UHIE), which is due to large amounts of concrete and asphalt in urban areas, leads to higher temperatures in cities than in the surrounding vegetation.
    - Higher temperatures and more intense heat waves associated with climate change exacerbate the UHIE.
    - The relatively low amount of vegetative cover in Northeastern cities, makes these areas especially vulnerable to heat waves and increasing temperatures.
  - There will be earlier snowmelt.
  - More precipitation will fall as rain instead of snow.
- Precipitation will increase in the Northeast.
  - The total amount of precipitation will increase, especially during winter and spring, but not summer.
  - By 2070 to 2100, the average monthly rainfall between December and April will increase by 2.5 centimeters (1 inch) each month under high-emissions scenarios.
  - Rainfall intensity, amount, and persistence will increase.
  - Flooding risk will increase.
- Sea level rise will continue.
  - Sea level will increase by 61 to 137 centimeters (2 to 4.5 feet) by 2100 under moderate emissions scenarios, and by up to 335 centimeters (11 feet) by 2100 under high-emissions scenarios.
  - Flood risk associated with storm surge will increase.

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  - Storm impacts will increase.
  - Coastal erosion will increase.
  - Hurricanes will become more frequent and intense.
- Severe winter storms will increase in frequency and intensity.

References: USGCRP 2018.

8.2.1 Where Do These Numbers Come From?

Scientists use models to project the effects of climate change in the future (usually up to 100 years). Predicting how climate change will affect future climate requires information about how greenhouse gas emissions and human population size will change over time. The Intergovernmental Panel on Climate Change (IPCC) has developed a set of scenarios that describe a range of possible future greenhouse gas emissions levels and human population sizes for use in climate models. In addition to using multiple IPCC scenarios, scientists typically use multiple climate models that differ in their sensitivity to different parameters. By using multiple models and multiple IPCC scenarios, scientists can bracket the potential effects of climate change to provide a range of likely expected conditions. A recent analysis shows that such models have been successful in predicting changes in climate over time (Hausfather et al. 2020).

8.3 How Will Climate Change Affect Pollinators?

Creating climate-resilient pollinator habitat first requires an understanding of the variety of ways that climate change can affect pollinators. Below is a list of effects of climate change on pollinators. These are not mutually exclusive, as pollinators are likely to experience multiple effects of climate change simultaneously. While some pollinator species may fare better under climate change, many species will be negatively affected.

- *Range shifts.* Species may change their distributions to track more optimal climate. In general, species are expected to shift poleward or to higher elevations, but not all species will respond the same way. Differences in future distributions of pollinators and host/nectar plants may lead to spatial mismatches. Range shifts require habitat corridors for species to move through.
- *Altered phenology.* Phenology is the timing of biological events such as flowering time in plants and adult flight time in butterflies. Shifts in phenology in response to climate change may be especially problematic if pollinators and their host plants respond differently, leading to phenological mismatches. For example, a bee that specializes on the pollen of a particular group of plants may emerge after its host plants have begun to bloom, missing out on resources they need to provide for their young.
- *Physiological responses.* Temperature is extremely important in influencing a variety of physiological processes in insects, including metabolism, growth rate, and digestion. But temperature can also affect behaviors, such as foraging rates and the amount of time each day that pollinators are active. Therefore, changes in temperature can affect many aspects of pollinator performance (e.g., survival, reproduction, size at maturity).

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- *Altered species interactions.* The outcome of species interactions, such as competition, predation, or disease can be affected by changing climate, especially temperature change.
- *Changes to the diversity, quantity, and quality of floral resources.* Plants will also respond to climate change. Changes in plant diversity or community composition will affect competitive relationships among pollinators. Specialist pollinators may be especially sensitive to such changes in plant communities. Drought, heatwaves, and increases in temperature, as well as increasing atmospheric carbon dioxide (CO_2) concentrations can all affect the quantity and quality of pollen and nectar, as well as floral attractiveness to pollinators.
- *Combined stressors.* Climate change may exacerbate the effects of other stressors, such as habitat loss, pesticide use, and pathogen exposure, magnifying effects on pollinators.

8.4 What Species Are Most Vulnerable to Climate Change?

Species most likely to be negatively affected by climate change include resource specialists (e.g., species that use only a narrow subset of plants as larval host plants or for pollen), species that are already declining, species that occur at high latitudes or high elevations, and species with limited distributions or narrow habitat requirements. Many of the species featured in Chapter 3, *Imperiled Pollinator Profiles*, fit into several of these categories and will be at increased risk as the effects of climate change continue to become apparent.



Specialist pollinators that use a narrow range of plants for food—such as the Hermes copper, which only feeds on spiny redberry—are generally expected to be more vulnerable to climate change than generalist pollinators.

Photo Credit: Michael Klein SR/USFWS

8.5 Increasing Climate Resiliency for Pollinators

Increasing climate resilience for pollinators requires a multifaceted approach. Creating and restoring habitat, increasing habitat connectivity, and reducing other stressors are all key components for increasing pollinator climate resilience. Roadside habitat has an especially important role to play in increasing habitat connectivity.

8.5.1 Habitat

Enhancing and restoring pollinator habitat is crucial for improving climate resilience of pollinator communities. Habitat with abundant pollinator-attractive floral resources that bloom from spring through fall is required to support large, stable, and diverse pollinator communities. Larger populations, in general, will better withstand bad years and extreme weather events that become more frequent with climate change. Maintaining a diverse pollinator community will also be key to ensuring that the valuable ecosystem service performed by these animals remains resilient in the future.

Habitat with a diversity of plant species helps to buffer pollinators from extreme weather events by creating important refugia—spaces where they can be protected from heat waves or other extreme weather events—for pollinators. Habitat with a diversity of plant species also provides

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important pollinator nesting sites and larval host plants that may be less abundant in developed areas.

8.5.2 Habitat Connectivity

Improving habitat connectivity is another key aspect of creating a climate-resilient environment. Habitat corridors act as pathways, connecting larger natural areas that act as reservoirs of pollinator diversity. Because roads and other rights-of-way create vast networks crisscrossing the landscape, linear habitats created or maintained alongside them are ideal for improving habitat connectivity for pollinators. This is an area where DOTs and other managers of roadsides can make especially meaningful contributions to climate resilience of wild pollinators.

Habitat corridors and stepping-stones (patches of habitat that are close enough to allow movement among them) are important because they allow bees, butterflies, and other insect pollinators to move around the landscape. This increases gene flow and helps prevent pollinator populations from becoming too small by enabling individuals to move among patches. Habitat corridors and stepping-stones also enable species to migrate, facilitating range shifts in response to climate change. While not all species will change distributions in response to climate change, increasing habitat connectivity provides the opportunity for those that will.

8.5.3 Reducing Additional Stressors

Reducing stressors (i.e., drivers of pollinator declines; see Chapter 3) to pollinators such as pesticide exposure, habitat loss, and invasive species is important because these different stressors can interact with each other and with climate change to magnify negative effects on pollinators. For example, exposure to a particular pesticide may be non-lethal in ordinary circumstances, but exposure to that same pesticide may become lethal during a heatwave or drought. Therefore, it is important to reduce other stressors as much as possible to increase climate resilience of pollinators.

8.5.4 Building Climate-Smart Roadside Pollinator Habitat

The most important steps to increasing climate resilience of pollinators are protecting and enhancing pollinator habitat, increasing habitat connectivity, and reducing other stressors. Creating pollinator habitat along roadsides and other DOT land holdings can contribute significantly to this effort. When creating roadside habitat for pollinators, following a few

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basic principles can help make that habitat more resilient to climate change. Resilient habitat will help to foster resilient pollinator communities.



Incorporating biodiversity into revegetation projects is key to increasing carbon sequestration services as well as for increasing climate resilience of the planting.

Photo Credit: Dianne Kahal-Berman

Pay Attention to Flowering Phenology

Ensure that a minimum of three species of nectar plants bloom at all times during the season of activity for bees and butterflies (generally from spring through fall; see Chapter 7, *Revegetation and Pollinators: Design and Implementation*, for a plant list, example bloom time charts, and other information on revegetation). This practice will ensure that important food resources are always available for pollinators. This practice may also help reduce effects of phenological mismatches between hosts and pollinators by ensuring that some floral resources will be available (Olliff-Yang et al. 2020). For example, early warm springs may lead to truncated bloom periods for some plant species, meaning spring-emerging pollinators will have fewer resources and less time to find food. More pollinators can be supported in habitat with abundant, diverse blooms compared to habitat with few flowering plants. However, this may be more effective for generalist pollinators than for specialists that need specific plant species. If possible, work to better understand what specialist pollinators might be found on the property in question, including imperiled pollinators (Chapter 3), and include specific flowering resources for those species if possible. Whenever possible, include more than three species per bloom period; plantings that are more diverse can support more species of pollinators and have greater resilience.

Provide Nesting Habitat for Native Bees

When many people think about bees, they think about honey bee hives or bumble bee nests; however, the vast majority of bees are solitary—nesting in narrow tunnels in the ground or in wood. About 70 percent of native bees nest in the ground and installing vegetation like bunch grasses that can provide access to small patches of earth will provide areas for these species to build nests (Chapter 2, *Pollinator Biology and Roadsides*). About 30 percent of native bees nest in wood or pithy-stemmed plants. Retaining downed logs and snags where possible will provide nesting habitat for some of these species, while planting native, pithy-stemmed plants like goldenrod or wild rose will provide nesting habitat for others (see Chapter 7 for a plant list that includes species used for nesting by cavity-nesting bees). In general, a diverse plant community is more likely to provide necessary nest sites and nesting materials for a diverse community of pollinators.

Biodiversity Is Key—Include a Variety of Native Plants

Biodiversity is the variety and variability of life on earth. This concept includes not only the number of species in a given location, but the amount of genetic variation within each species or population at that location. Adapting to climate change and conserving biodiversity go hand-in-hand. Indeed, people's ability to adapt to climate change and retain important ecosystem services such as pollination will depend on their ability to protect

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biodiversity. When creating climate-smart pollinator habitat, incorporating biodiversity in the planting is key to creating sustainable habitat that will support a variety of pollinators.

Incorporate as many native plant species as possible into habitat projects. Habitat with a diverse native plant community can support more species of pollinators than habitat with only a few plant species. Many species of insects, including pollinators, exhibit some degree of resource specialization during their lives. For example, the monarch butterfly feeds only on species of milkweed during its larval stage (Chapter 3). Incorporating a diversity of native plants into habitat projects means the habitat will be more likely to support some of the many specialist pollinators in this region. Finally, a diverse native plant community will have greater habitat heterogeneity that can provide an array of microclimates, which serve as important refugia for pollinators during heatwaves and other extreme weather events.

A biodiverse habitat (both in terms of species richness and genetic variation) has many additional benefits for climate resilience. First, generally speaking, more-diverse ecological communities are better able to provide ecosystem services such as erosion control, carbon sequestration, and pollination over time than species-poor ecological communities (Tilman et al. 2006). Second, genetically diverse populations are generally more likely to contain the traits that will enable them to adapt to climate change than populations with low genetic diversity. Third, diverse communities will be better able to withstand bad years and extreme weather events than species-poor communities. For example, a roadside habitat with a variety of plant species is more likely to include plants that can persist during both drought and flooding than a habitat with only a few plant species. Given that climate change will lead to more extreme weather events and more variability in weather, having a diverse plant community will better ensure that some plants will be able to persist and thrive, supporting the pollinators that depend on them. This may be especially important in regions where opposing conditions will both become more common. For example, in many regions both flooding and drought will become more common. It can be difficult to find plant species that can thrive in the range of expected conditions, so including a variety of plant species will help to ensure that at least some will do well in any given year or season. For similar reasons, diverse plant communities may be more resistant to pressure from invasive species or diseases, and pressure from invasive species is especially predicted to increase in this region.

Climate change is likely to also affect the quantity and quality of floral resources for pollinators. Abiotic factors associated with climate change, such as increased temperature or increased atmospheric CO_2 concentrations, may also affect the quantity and quality of nectar and pollen as well as floral attractiveness to pollinators (Rusetrholz and Erhardt 1998; Burkle and Runyon 2016; Ziska et al. 2016; Glenny et al. 2018; Russo et al. 2019). Because the effects of climate change on these plant traits are likely to be species specific, having a diverse array of flowering plants will help ensure pollinators have the resources they need.

Choosing Climate-Smart Plants

An additional challenge for creating pollinator habitat is trying to anticipate what plant materials will be resilient to future climate scenarios. As stated above, incorporating biodiversity, both in terms of genetic diversity within species and in terms of species richness within plantings is a good strategy for creating plantings that will persist over time as climate changes (Wilsey 2020). Using local ecotypes (Chapter 7) can help ensure the plants used will be adapted to local conditions. However, as local conditions change,

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incorporating as much genetic diversity as possible may be beneficial. Therefore, try to get local ecotypes from several different source populations when possible (St. Clair et al. 2020) and consider working with the local native plant industry to increase genetic diversity of important pollinator plants used in revegetation projects. Another possibility is to incorporate a small percentage of seed from lower elevation or lower latitude populations that more closely mimic future climate conditions for the area (Sgrò et al. 2011; Ramalho et al. 2017; Camarretta et al. 2020). This may be more important for long-lived shrubs and trees than for annuals.

It can be difficult to predict what plant species will be most successful in the future. Plants will also respond to climate change, and plant characteristics such as phenology and nutritional value of pollen and nectar may vary with climate change. Additional research is needed to understand what traits or characteristics make plants more resilient to extreme weather events and to increases in weather variability. Research is also needed to understand how competitive relationships between key invasive plants and native plants will be altered by climate change. However, choosing native plants that are adapted to future climate projections for this region is vital (Box 8-1). For example, many regions will experience increased drought, so choosing drought-tolerant plants is a wise choice. Table 8-1 lists some plant traits that are generally associated with adaptations to different climatic conditions. Use this list to select plant species for revegetation projects, along with the list of workhorse pollinator plants in Chapter 7, as well as any plants that support imperiled pollinators occurring in the revegetation project area (Chapter 3). As discussed above, the best approach for creating resilient, sustainable roadside habitat is to harness the benefits of biodiversity, planting a diverse assemblage of plant species.

Table 8-1. Plant traits that will generally be beneficial for adapting to different conditions associated with climate change.

Plant trait	Climate variable
Taller grasses	Increased temperatures
Shorter trees	Increased temperatures
Thicker leaves	Drought, increased temperatures
Greater belowground biomass	Drought
High water-use efficiency	Drought
Deeper roots	Drought
Higher wood density	Drought
Thicker bark	Fire

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Plant trait	Climate variable
Ability to resprout	Fire

Source: Willis 2017.

This region will become wetter and warmer (see Box 8-1), with increases in temperature and the frequency of large downpour events. Flood-tolerant plants and heat-tolerant plants may be better able to persist. In coastal areas, plants that can tolerate salt water and plants that can outcompete the invasive reed *Phragmites australis* will be beneficial, as invasive pressure from this species is expected to accelerate with climate change.

Recommended plants for inland areas include: golden alexanders (*Zizia aurea*), cutleaf coneflower (*Rudbeckia laciniata*), Joe pye (*Eutrochium* spp.), golden ragwort (*Packera aurea*), New England aster (*Symphyotrichum novae-angliae*), wild senna (*Senna hebecarpa*), blue vervain (*Verbena hastata*), oxeye sunflower (*Heliopsis helianthoides*), and switchgrass (*Panicum virgatum*).

Recommended plants for coastal areas include (asterisks indicate species that successfully compete with *P. australis*): saltmeadow cordgrass (*Spartina patens*)*, switchgrass (*Panicum virgatum*)*, crimson eyed rosemallow (*Hibiscus moscheutos*)*, seaside goldenrod (*Solidago sempervirens*), and New York aster (*Symphyotrichum novi-belgii*).

8.5.5 Additional Benefits of Climate-Smart Pollinator Habitat

Creating climate-smart pollinator habitat along roadsides has many additional benefits beyond pollinator conservation. Pollinator habitat also provides benefits such as erosion control and reduced runoff. This helps reduce the impacts of flooding, which will be critical in many areas where increased flooding is projected, and in coastal areas where sea level rise will increase the frequency of coastal flooding.

Pollinator habitat can also help to mitigate the climate crisis. Creating diverse plantings along roadsides will increase soil health, which in turn increases carbon sequestration. Studies of grassland soils show that increasing plant diversity increases the amount of carbon stored by the soils (Lange et al. 2015; Chen et al. 2018; Yang et al. 2019). A recent study estimated the value of carbon sequestration services of roadside habitat in Florida at $39 million/year, and this number could increase with the sale of carbon credits (Harrison 2014). Thus, diverse plantings created for pollinator conservation also help to mitigate climate change by increasing carbon sequestration services of those habitats (Ament et al. 2014). This is the idea behind "nature-based climate solutions," which encourages the restoration and protection of natural habitats as a means of combating the climate crisis. Recent studies suggest that nature-based climate solutions alone could provide one-third of the climate mitigation required to keep warming below 2°C (warming of 2°C causes extreme heat and droughts, as well as increased water stress and sea levels, altering the livability of millions of acres of land and escalating risks to millions of lives) (Griscom et al. 2017; Fargione et al. 2018; IPCC 2018). DOTs are in a position to make real contributions to nature-based climate solutions through the creation of roadside pollinator habitat.

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8.6 Additional Resources

- *Engineering with Nature* website: https://ewn.el.erdc.dren.mil/.
- U.S. Forest Service Transportation Resiliency Guidebook: Addressing Climate Change Impacts on U.S. Forest Service Transportation Assets: https://www.volpe.dot.gov/FS-Transportation-Resiliency-Guidebook.
- Federal Highway Administration's *Climate Change Adaptation Guide for Transportation Systems Management, Operations, and Maintenance*: https://ops.fhwa.dot.gov/publications/fhwahop15026/fhwahop15026.pdf.
- National Oceanic and Atmospheric Administration's *State Climate Summaries*: https://statesummaries.ncics.org/.
- U.S. Global Change Research Program's *Fourth National Climate Assessment, Volume II: Impacts, Risks, and Adaptation in the United States* (includes regional information as well as a chapter on transportation and infrastructure): https://nca2018.globalchange.gov/.
- The *Seedlot Selection Tool* (matches seedlots with climatic parameters using a map-based program): https://seedlotselectiontool.org/sst/.
- The Transportation Research Board's *Critical Issues in Transportation 2019*: http://www.trb.org/Main/Blurbs/178402.aspx.

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Chapter 9 Surveys, Monitoring Strategies, and Habitat Assessments

9.1 Introduction

Assessments of pollinator communities and metrics for roadside pollinator habitat can provide valuable information for departments of transportation (DOTs) looking to implement voluntary pollinator conservation goals. Surveys for listed and imperiled species in project areas can help guide revegetation choices and federal Endangered Species Act (ESA) compliance options. Monitoring over time can be used to determine if conservation goals are being met. Measuring the response of vegetation or a pollinator community will help determine whether changes implemented to improve roadside vegetation for pollinators have been effective and met the objectives. Monitoring is also a key component of adaptive management; monitoring data can be used to determine if and what corrective actions may be needed. In addition to helping to effectively manage and maintain a current project, monitoring also can inform the implementation of future projects or management activities.

The term *monitoring* is used here to specifically describe data from repeated sampling that can be used to detect changes, such as to evaluate the effectiveness of revegetation or maintenance practices over time (e.g., Elzinga and Salzer 1998). Monitoring is also sometimes used as a general term to describe other data collecting activities, such as surveys or inventories. An inventory aims to catalog all species or a subset of species within an area, whereas surveys are samples of a particular species or a representative portion of an area (e.g., Pokorny et al. 2006). In this document, the term *survey* describes sampling to determine the presence or absence of a particular imperiled pollinator species at a given site. Surveys are important for DOTs seeking to determine if a listed or imperiled species occurs on a particular right-of-way in order to take appropriate action for ESA compliance.

This chapter includes protocols that can be used to survey for and detect imperiled species of pollinators, specifically a protocol for imperiled butterflies and a protocol for bumble bees, as well as a monitoring protocol that can be used to measure general bee and butterfly community responses to changes. A rapid and comprehensive roadside habitat assessment guide is also included, along with guidance for monitoring roadside vegetation as pollinator habitat. It may take some time and familiarity with these different protocols to determine which data collection method is best for a project's objectives.

9.2 Pollinator Surveys and Monitoring

The protocols presented in this section provide instructions for monitoring the general pollinator community (bees and butterflies), as well as ways to survey and monitor bumble bees and imperiled butterflies. The monitoring protocols involve collecting data on abundance, which can be useful to detect changes over time. However, if your target species is difficult to detect or occurs in low densities, it may be preferable to survey for occupancy

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rather than measure abundance (Taron and Ries 2015). The monitoring protocols can be used to assess roadside habitat in a number of ways, such as determining the following.

1. Whether revegetation efforts have increased pollinator richness and abundance (by including nearby non-revegetated roadsides in samples as reference sites)
2. If pollinator richness and abundance change over time
3. Habitat quality
4. The effects of different roadside management strategies or seed mixes on pollinators
5. Survival rates for specific imperiled species

The survey protocols can be used to determine the presence or absence of a target species, also known as occupancy, which is a procedure used to understand if a species is present at a particular site. Whether surveying to determine if a species occurs on a right-of-way or monitoring a population or community of pollinators to assess change over time (e.g., before and after a construction project), there are several important considerations:



Oklahoma State University operates research areas on ODOT rights-of-way to study the effects of mowing and other maintenance practices on roadside vegetation and on monarch butterflies. The survey and monitoring methods outlined in this chapter can be used on roadsides to provide information on how practices are affecting pollinator communities.

Photo Credit: Vonceil Harmon

- Know the life history and habitat needs of your target species. Understanding host plant needs, known habitat, and flight windows of adults will help you have the best chances to find your target species (see Chapter 3, *Imperiled Pollinator Profiles*, to find this information for some at-risk pollinators in your region). For example, it is very helpful to be able to narrow down where the Uncompahgre fritillary might be found by knowing that it only feeds on snow willow that has a lot of water throughout the summer (to make it more palatable) and so only lives under year-round snow fields on the north side of peaks above 13,000 feet in southern Colorado.
- Surveying for adult pollinators is most practical. It may be impractical to find and/or difficult to recognize other life stages of pollinators and it may be harmful to them (e.g., searching for a bumble bee nest or butterfly eggs laid singly within a grass clump). Adult flight periods are also more well-known than activity of other stages.
- It can be challenging to identify pollinators. For example, most native bees can only be identified to species by examining pinned specimens under a microscope and obtaining confirmation from experts. Standard pollinator monitoring techniques typically employ destructive sampling, with specimens collected using nets or traps, pinned, and then identified by a taxonomist. While these collection techniques provide the most robust data, they can be labor intensive, time consuming, and expensive—and result in loss of pollinators. Using non-lethal methods when possible should be a priority (Tepedino and Portman 2021). Collecting observational data on pollinators is an economical and effective alternative to monitoring pollinators. However, training and practice are needed to recognize members of different groups of pollinators, commonly occurring local species, and imperiled species.

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- If your target species is listed under the ESA, you may need to obtain a recovery permit if working in zones where the species may occur. Check with the U.S. Fish and Wildlife Service (USFWS) for specific information on the permit required. Details on how to apply for a permit are provided online at "Obtaining a Recovery Permit under the ESA and FAQs" (https://www.fws.gov/midwest/Endangered/insects/rpbb/surveys.html). Having species experts assist with the surveys whenever possible is recommended to assist with identification.

9.2.1 Monitoring for Bee and Butterfly Diversity

Overview of Protocol

What the protocol will measure: Abundance and richness of bees and butterflies in a community

Sampling design: Transects within the project area

Sampling time of year: Three visits per growing season, at a minimum—late-spring, mid-summer, late-summer

Sampling weather and time of day: Warm, sunny, and calm days (15.6˚C [60˚F] or greater, wind speeds less than 10 miles per hour, and skies mostly clear), between 10 a.m. and 4 p.m.

Level of identification needed: Morphological groups (groups of species with similar body size, shape, and structure) of bees and butterflies; expertise in insect identification not required

Equipment needed: Stopwatch or clock, data sheets, clipboard and pencils, long measuring tape (100 meters [100 yards]), flags/stakes to mark transects, global positioning system (GPS) device, this procedure and pollinator identification guides, and plant lists and plant identification guide

Personnel needed: Two people: one person to identify pollinators; one to keep time and record data

Data Sheets: Bee and Butterfly Diversity Data Sheet (available on the National Academies Press website https://nap.nationalacademies.org/)

This protocol can be used to collect consistent observational data on bee and butterfly richness and abundance over time or to identify specific associations between pollinators and their habitat. The procedure is based on a standardized method designed by researchers and practitioners (Kremen et al. 2011; Minnerath et al. 2016). Bee and butterfly communities vary depending on the quality of the immediate and surrounding habitat. This protocol can be used to document changes in bee and butterfly communities and to assess the efficacy of any changes made to roadside vegetation through revegetation or maintenance.

Monitoring takes place along set transects, which are located within sampling units that have relatively uniform vegetation and site characteristics. If the project is large or composed of several different plant communities, then several sampling units may be

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delineated and sampled separately. The number of transects placed in a sampling unit depends on the size of the unit and topographic relief:

- **<0.8 hectare (<2 acres)** – no relief: establish one 120-meter (400-foot) transect through the middle of the area outside of the mowed strip in the recovery area, running parallel to the road
- **≤0.8 hectare (≤2 acres)** – with relief: orient multiple transects of equal length that add up to a total of 120 meters (400 feet) running perpendicular to road (for ease of walking the transect) and spaced apart evenly (e.g., 3 meters [10 feet])
- **≥0.8 hectare (≥2 acres)** – no relief: establish three 120-meter (400-foot) transects through the middle of the area outside of the mowed strip in the recovery area, running parallel to the road separated evenly
- **≥0.8 hectare (≥2 acres)** – with relief: orient multiple transects of equal length that add up to a total of 365 meters (1,200 feet) running perpendicular to road (for ease of walking the transect) and spaced apart evenly

If making comparisons between sites, it is best to keep the individual transect length and the distances between transects constant. For sites that are greater than 0.8 hectare (2 acres) in size, three 120-meter-long (400-foot-long) transects are used that are spaced evenly throughout the site. Transects are located in full sun where possible (or notations are made on data sheets when in shade) because pollinator activity declines in shade. Record GPS coordinates to allow others to monitor the area in the future.

Monitoring is conducted at least three times a growing season, ideally monthly. This is because many bee and butterfly species fly for a limited number of weeks each growing season, and the communities may differ greatly between samplings. It is important to be consistent from year to year in the frequency and approximate timing of monitoring so that comparisons between years can be made.

Weather conditions strongly influence bee and butterfly behavior. Bees avoid activity on cold, windy, or overcast days, so monitoring is optimal when sampling on days with air temperatures over 15.6˚C [60˚F], wind speeds less than 10 miles per hour, and skies mostly clear. Standardizing the time of day that sampling occurs is also important. Pollinators are most active between 10 a.m. and 4 p.m.

These procedures can be implemented by observers working on their own, but it is easier when working in pairs, with one person to act as an observer and the other to record observations and data. It is also easiest to conduct observations of bees and butterflies on separate walks of the transects to help focus identification. This monitoring approach is geared toward users who are not experts in insect identification; however, training and practice with identifying bee and butterfly groups used in this protocol will provide more accurate monitoring. The Bee and Butterfly Diversity Data Sheet is available on the National Academies Press website (https://nap.nationalacademies.org/).

When making observations of floral visitors within a transect:

- Insects should be observed carefully and only identified to a level at which the surveyor is confident.

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- Insects visiting flowers should not be disturbed before an observation can be made. The surveyor should walk slowly and avoid sudden movements. Insects will respond to shadows passing overhead, so the surveyor should walk so as not to cast a shadow where observations are to be made.

Bee Monitoring

The transect is walked at a steady pace, such as 3 meters (10 feet) per minute; expect each 120-meter (400-foot) transect to take about 40 minutes. The surveyor walks slowly, looking for flower visitors within 1 meter (3.3 feet) to each side of the transect. Surveyors do not need to spend more than a couple of observational minutes at any flower or group of flowers. The time spent walking transects should be consistent so that the data is collected with the same level of effort to allow for comparisons between samples over time.



Bees are recorded when they are observed visiting flowers along the transect.

Photo Credit: Sara Morris/The Xerces Society

For each flower visitor observed, the surveyor should record: the identification of the bee to the level the observer is comfortable, the number of times an individual of this bee was seen during the monitoring period, and the flower species on which the bee was observed. If using a two-person team, one can dictate the bees and flowers, while the other records the data. Only bees that are on the reproductive parts of the flower are identified and recorded. Bees sitting on petals, leaves, or in flight are not recorded. When a bee is visiting a flower, the bee is observed and identified using the recognition guide. See Appendix C, *Bee and Bee Group Recognition,* for the bee recognition guide. Note that honey bee abundance cannot provide a measure of the value of habitat because the number of individual honey bees visiting habitat is determined by the number of managed hives in the vicinity.

The recorder reports these observations on a data sheet, which will be available here (this will link to a data sheet available on Web Resources project webpage). It can also be helpful to note other floral visitors beyond bees, and the species of the flower on which the bees are observed. If more than one floral visitor is observed on a single flower, the number of visitors is noted first and then they are identified. After the bee data is collected, each additional flower species that is in bloom but did not have floral visitors during the survey is noted.

At the end of each transect, the recorder tallies the number of pollinators, the travel time, time of day, the length of transect, transect number, and weather conditions. If other monitoring procedures (e.g., Soil Cover, Species Cover, and Species Presence) are to be conducted, the team returns to the beginning of the transect and conducts these procedures.

Records of roadside sampling areas also include the site name, sampling area designation, date, name of the sampler, weather conditions, time of visit to the site, and any pertinent notes about the site. It is also valuable to record the plants that are blooming along the transect at the time of the survey, as well as to collect data on the floral associations of the bees at the site.

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If multiple roadside sampling areas are surveyed, the differences observed in native bee abundance reflect differences in habitat quality among sites. Native bee counts can be used to rank the quality of sites or the quality of seed mixes, or can be used over time to assess changes at a site.

Butterfly Monitoring



Butterflies can be monitored using Pollard Walks, where butterflies are counted along a transect.

Photo Credit: Angela Laws/The Xerces Society

This monitoring procedure is based on the standardized Pollard Walk (Pollard et al. 1975) and can be used to collect observational data on the abundance and richness of butterflies. The objective of this procedure is not to count all butterflies present at the entire site or within the habitat being monitored, but to count those individuals that occur in, or move through, the transect's sampling area while the surveyor is walking at a steady pace of 3 meters (10 feet) per minute. The surveyor identifies and counts butterflies on flowers or in flight if they occur within approximately 4.5 meters (15 feet) on each side of the transect or overhead of the surveyor. Butterflies that fly in from behind the surveyor are not counted to avoid counting the same individual twice. Butterflies are identified to the level most comfortable to the surveyor (refer to butterfly identification guide) and recorded as whether the butterfly was observed in flight or nectaring on a flower. If the butterfly is nectaring, it can be helpful to record the species of the plant on which the butterfly was feeding.

Considerations include the following:

- It is important to be consistent, using the same level of effort with each time transect.
- The time spent walking the transect is recorded each time.
- Records of observations should include the site name, date, name of the sampler, weather conditions, time of visit to the site, and any pertinent notes about the site.
- It is also valuable to record the plants that are blooming along the transect at the time of the survey, as well as to collect data on the floral associations of the pollinators at the site.

See Appendix D, *Butterfly and Butterfly Group Recognition,* for guidance on recognizing groups of butterflies.

Data Analysis for Community Monitoring

To draw meaningful conclusions about the effects of roadside habitat on bees and butterflies, data needs to be collected consistently over time in the same areas. To determine changes in abundance over time, the number of individuals observed during each monitoring event is tallied (transects can be combined if multiple transects are sampled). These numbers can be averaged for each year (e.g., the results from late-spring, mid-summer, and late-summer can be averaged) and plotted on a graph or table to show changes between years. The numbers of individuals can also be totaled for each monitoring event and evaluated separately. Honey bee counts may be excluded in many analyses because the placement of hives and human intervention influences their abundance.

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To calculate species richness for each sampling period or each year, the total number of bee groups and butterfly groups observed is tallied. Richness can then be plotted to record changes over time, whether comparing the average or total number of groups observed across all sample periods for each year, or comparing the total number of groups observed during a certain sampling period from year to year.

As noted before, pollinator populations vary over the course of the growing season and from year to year, so it is important to schedule monitoring accordingly. Pollinator populations also vary annually, increasing as plants become established and mature, which may take several years after seeding or planting. For this reason, monitoring is conducted for several years after the project has been completed, ideally 3–5 years. The longer the period over which sites are surveyed, the more meaningful the results.

9.2.2 Imperiled Butterfly and Moth Protocol

Overview of Procedure

What the procedure will measure: Butterfly and/or moth presence or absence; can be used over time to estimate population size

Sampling design: Transects within the project area

Sampling time of year: Survey once or more within the window of the documented flight period of your target species (see species-specific details in Chapter 3)

Sampling weather and time of day: Warm, sunny, and calm days (15.6˚C [60˚F] or greater, wind speeds less than 10 miles per hour, and skies mostly clear), between 10 a.m. and 4 p.m.

Level of identification needed: Identify species of butterflies or moths

Equipment recommended: Stopwatch or clock, data sheets, clipboard and pencils, aerial insect net, binoculars (if applicable), GPS device, field identification guides, glassine envelopes, long measuring tape (100 meters [110 yards]), flags/stakes to mark transects, and federal or state permits (if applicable)

Personnel needed: Can be conducted by a single person, but easier with two

Data Sheets: Imperiled Butterfly Data Sheet (available on the National Academies Press website [https://nap.nationalacademies.org/]).

Begin by identifying areas of potentially suitable habitat for your target species, areas with adequate larval food plants, nectar sources, and habitat to sustain a population. Many species have highly specific larval feeding preferences (e.g., limited to one or a few related plant species whose defenses they have evolved to overcome), while other species exhibit more general feeding patterns, with representatives from multiple plant families in their diet. For species-specific dietary preferences and habitat information, see the species profiles in Chapter 3. Survey areas of suitable habitat or known occupied sites for your target species during adult flight periods (also in the species profiles in Chapter 3). Be aware that flight times may vary due to weather conditions in the spring and early summer,

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and will vary with elevation when planning the survey period. If there are local species experts in the region, consult them on the optimal survey timing.

Surveys need to be conducted with at least one butterfly expert present; an expert is someone who can definitively identify the target species. Non-expert surveyors can be paired with experts, but limit the number of surveyors to three in total at small sites (<1.2 hectares [<3 acres]) to reduce trampling of vegetation.

Upon arriving at each potential site, the following survey protocol can be used to determine the presence or absence of species:

1. Approach the site and scan for any butterfly activity, as well as suitable habitat. Butterflies are predominantly encountered nectaring at flowers, in flight, basking on a warm rock or the ground, visiting host plants, or puddling (sipping water rich in mineral salts from a puddle, moist ground, or dung). Walk through the site slowly (about 100 meters [110 yards] per 5 minutes), looking back and forth on either side, approximately 6–9 meters (20–30 feet) out. Try to walk in a path such that you cover the entire site with this visual field—your route can twist and turn—or at least all of the areas of suitable habitat. If you must leave the transect path (e.g., to look at a particular butterfly), do your best to return to the specific place where you left your path when you resume walking/searching through the site.

2. When a suspected target species is encountered, the optimum method is to net the butterfly to confirm its identification. Adults are collected using a long-handled aerial sweep net with mesh light enough to see the specimen through the net. When stalking perched individuals, approach slowly from behind. When chasing, swing from behind and be prepared to pursue the insect. A good method is to stand to the side of a butterfly's flight path and swing out as it passes. After capture, quickly flip the top of the net bag over to close the mouth and prevent the butterfly from escaping. Once netted, most insects tend to fly upward, so hold the narrow end of the net bag up (with the mouth downward) and reach in from below when retrieving the butterfly. You will need permits to catch listed butterflies. Having experts assist with the surveys is recommended to aid identification and with collection, to minimize potential injuries to the butterflies.

3. Binoculars and cameras may also be used to view wing patterns of perched butterflies, in lieu of catching the butterfly. Because most butterflies can be identified by macroscopic characters, high-quality photographs will likely provide sufficient evidence of species occurrences at a site, and those of lesser quality may at least be valuable in directing further study to an area. Use a camera with a good zoom or macro lens and focus on the aspects of the body that are the most critical to species determination (i.e., dorsal [upper] and ventral [lower] patterns of the wings) (Pyle 2002). When possible, take several photographs of potential target species showing a clear view of the ventral and dorsal sides of the wings at each survey area where they are observed. This method may be preferred to catching the butterflies, especially for listed species.

4. If needed, collect and chill individual butterflies within a vial or envelope, placing the container in a cooler with ice, buffering the specimen from the ice with a towel. After 5–10 minutes of chilling, place the butterfly on a flat surface with high contrast to photograph it from several angles, making sure to get photos of the dorsal view (back

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side) forewings and hindwings, the ventral view (the underside of the wings), and the head and antennae. After photographing, move the butterfly to a sunny spot and allow it to warm up and fly away.

5. Fill out all of the site information on the datasheet, including site name, survey date and time, elevation, aspect, legal location, latitude and longitude coordinates of the site, weather conditions, and a thorough description of habitat, including vegetation types, vegetation canopy cover, suspected or documented host plant species, landscape contours (including direction and angle of slopes), and insect behavior (e.g., "puddling"). Record the number of target species observed, as well as butterfly behavior, plant species used for nectaring or egg-laying, and survey notes. Photographs of habitat are also useful.

If looking to estimate population size and monitor changes over time, abundance can be measured by using either the Pollard Walk method (see the butterfly monitoring protocol above for details on applying a Pollard Walk to roadsides), in which the recorder walks only along a precisely marked transect, or the checklist method, in which the recorder is free to wander at will in active search of productive habitats and nectar sites (Royer et al. 1998). A test of differences in effectiveness between these two methods at seven sites found that checklist searching produced significantly more butterfly detections per hour than Pollard Walks at all sites, but the overall number of species detected per hour did not differ significantly between methods (Royer et al. 1998). Checklist surveys are a more efficient means for initial surveys and generating species lists at a site, whereas the Pollard Walk is more practical and statistically manageable for long-term monitoring. Recorded information needs to include start and end times, weather, species, sex, and behavior (e.g., "female nectaring on flowers of *Lathyrus nevadensis*"). For detailed summaries of approaches to butterfly monitoring, see Taron and Ries (2015) and Haddad et al. (2008).

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9.2.3 Bumble Bee Protocol

Overview of Procedure

What the procedure will measure: Bumble bee presence or absence, species diversity

Sampling design: Transects within the project area

Sampling time of year: Survey once or more within the window of the documented flight period of your target species (see species-specific details in Chapter 3); early June to early August often is the best chance to detect most species and reduce impacts to queens (which typically fly earlier in the season)

Sampling weather and time of day: Warm, sunny, and calm days (15.6˚C [60˚F] or greater, wind speeds less than 10 miles per hour, and skies partly cloudy to clear), between 10 a.m. and 4 p.m.

Level of identification needed: Distinguish bumble bees from other flower visitors; distinguish species of bumble bees to the best of your ability

Equipment recommended: Stopwatch or clock, data sheets, clipboard and pencils, aerial insect net, clear vials or small Ziploc plastic bags, camera, cooler with ice, long measuring tape (100 meters [110 yards]), flags/stakes to mark transects, GPS device, field identification guide or Bumble Bee Watch phone app, and federal or state permits (if applicable)

Personnel needed: Can be conducted by a single person, but easier with two

Data Sheets: Bumble Bee Data Sheet (available on the National Academies Press website [https://nap.nationalacademies.org/])



Bumble bees should be sampled in the summer on sunny, warm days with low wind.

Photo Credit: Rich Hatfield/The Xerces Society

Begin by identifying areas of potentially suitable habitat for your target species—areas with adequate flowering plants and potential nesting habitat to sustain a population. See the species profiles in Chapter 3 for nesting habits of your target bumble bee species and known sources of pollen and nectar. Survey areas of suitable habitat or known occupied sites for your target species during adult flight periods (see species profiles in Chapter 3). Be aware that flight times may vary due to weather conditions in the spring and early summer when planning the survey period, and that the phenology of queens, workers, and male bumble bees change throughout the growing season.

Take in-field habitat assessments, collecting the basic habitat information included on the bumble bee data sheet (available on the National Academies Press website [https://nap.nationalacademies.org/].) and taking representative photographs of the survey area, including high- and low-quality habitat. Record the coordinates of the corners of the surveyed area using a GPS device and estimate the size of the area surveyed. Note the flowers on which any bumble bees are

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captured or photographed. If unsure of the plant species when in the field, make sure to take photos of the flower, stem, and leaves for identification later.

Survey Protocol to Detect a Species

Protocol Set-up

Conduct surveys during three evenly spaced sampling periods across the flight period of your target species. Early June to early August often is the best chance to detect most species and also reduces impacts on queens, which typically fly earlier in the season (negative impacts on queens are more likely to affect populations than impacts on workers). Identify your survey area, and spend 1 hour sampling within the highest quality habitat of that area; if sampling a large area (>0.8 hectare [>2 acres]), sample 1 hour per 0.8 hectare (2 acres) or have multiple people sampling simultaneously. Preferentially capture the bumble bees that match or are similar to the description of your target species, capturing individuals one at a time using a net.

Bumble Bee Sampling

To survey bumble bees, you will net bumble bees off of flowers or catch them in a vial, capturing all bumble bees observed, one at a time. If the target species is listed, obtain the proper permit to be able to handle the bees, or you can opt to photograph the bees as they forage rather than handling them (if photographing, take a series of photos for each individual to properly document the bee's characteristics, including the face, side, and back; see Appendix E, *Bumble Bee Recognition and Photography,* for more tips). Identify and record the species and number of individuals if an expert is present (one who can definitively identify the target species). Otherwise, chill the bees within their bag or vial in an ice-filled cooler in order to take photographs of each individual. Assign a number to each vial and write the same number on your data sheet to keep each bee connected to its flowering plant (or you can place a petal from the flower within the vial to help you later connect the flower to the bee). Continue searching for bees until you have reached the end of your transect, when you should stop the timer, note the end of your survey, and begin to photograph your chilled bees.

Placing the bees in a cooler will slow them down (bees are ectothermic), making photographs from multiple angles much easier to take. *Take care not to leave bees in the cooler longer than 1 hour or to leave bees within vials in direct sunlight for longer than a few minutes.* Bees may take a few minutes to warm up enough to fly away after being released from their vial. To photograph a chilled bee, remove it from the vial and place it on a flat surface with a solid background of high contrast (e.g., pale colored paper). Use a digital camera or a smartphone to capture different angles of the bee useful in identification. See Appendix E for more details on photographing bumble bees that have been chilled or that are foraging on flowers. Link each photograph to a particular individual for tracking. Photographs can be submitted to Bumble Bee Watch for confirmation of identifications by experts. See https://www.bumblebeewatch.org/ or download the app (e.g., https://apps.apple.com/us/app/bumble-bee-watch/id1112626392).

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Monitoring Protocol

This protocol can be used to detect trends in known populations by using the following protocol multiple times per year for multiple years. This protocol is similar to the survey protocol, except that sampling is conducted along permanent transects. Monitoring needs to have a standard level of effort across sampling sessions.

Protocol Set-up

Establish at least one transect of 120 meters (400 feet) (meandering transects are fine) that covers the highest quality habitat of the site; establish multiple transects as needed to adequately cover the site's habitat. Use a GPS unit to track transects, or flag the transects so you can easily revisit them over the course of the season (or multiple years). Plan to spend about 15 minutes surveying per 30 meters (100 feet), capturing bees within 1 meter (3.3 feet) of each side of the transect. Use more time if needed, and record the time spent per transect each visit. Sample transects three separate times across the growing season. Follow protocols described in the *Bumble Bee Sampling* section above to document bumble bees observed along established transects.

9.3 Habitat Assessment and Vegetation Monitoring

9.3.1 Roadside Pollinator Habitat Assessment

Existing roadside vegetation can be evaluated using a pollinator habitat evaluation guide. The Roadside Pollinator Habitat Assessment Tools, available on the National Academies Press website [nap.nationalacademies.org], that accompany this guide include a rapid assessment that can be used to determine the general condition of the habitat (Figure 9-1), and a more comprehensive assessment, used to identify existing components of pollinator habitat and places for improvement (Figure 9-2). This assessment process can help in determining components that should be included when considering changes to maintenance strategies or when developing revegetation plans. This assessment can also help planners evaluate sites for connectivity or may help when prioritizing sites for high-quality pollinator habitat.

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Roadside Pollinator Habitat Evaluation Guide **Rapid Assessment**

Agency: _____ County: _____ Date: _____
Assessment Area: _____ Planner: _____
Road type: _____ Site length: _____ Adjacent land: _____
ROW width (fence to shoulder) _____
ROW width minus clear zone _____ Notes _____

Select the appropriate current conidtion of the		Benchmark	Options to address poor habitat condition	Desired Future Rating
	Roadside managed as hayland: Adjacent landowners hay the roadside multiple times during growing season. Vegetation is often introduced grass species, low forb richness.	**Poor**	Coordinate with landowners to conduct haying once per growing season	
	Intensively managed roadside dominated by nonnative plants: Vegetation is frequently mowed beyond the clear zone (3x/year), and/or treated with herbicide regularly, with low numbers of flowering plants. Grasses often introduced.	**----**	Consider adjusting maintenance practices to increase flowering plant diversity and reduce impacts of mowing or herbicides on pollinators	
	Noxious or Invasive species dominate: Federal, State or county noxious and invasive species present at a high density.	**----**	Conduct weed management to control noxious and invasive species; revegetate assessment area if weed removal left large patches unvegetated	
	Intensively managed roadside dominated by native plants: Vegetation is frequently mowed beyond the clear zone (3x/year), and/or treated with herbicide regularly, with low numbers of flowering plants. Grasses mostly native.	*Complete* the **Comprehensive Assessment** to assess benchmark pollinator habitat condition.		
	Natural or semi-natural plant community: Grassland, shrubland, forest.	*Complete* the **Comprehensive Assessment** to assess benchmark pollinator habitat condition.		

[1] Take photos to document the benchmark conditions.

Notes:

Assessment Area (AA) Defined as the area selected by the roadside manager as a possible candidate for enhacement of pollinator habitat. AA can be a portion of a larger tract. This evaluation guide is designed to evaluate the resource concerns with respect to pollinators in the assessment area and in adjacent land.

Figure 9-1. Pollinator Habitat Assessment Guide for Roadsides: Rapid Assessment.

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Roadside Pollinator Habitat Evaluation Guide
Comprehensive Assessment

Agency: _____ County: _____ Date: _____

Assessment Area: _____ Planner: _____

Road type: _____ Site length: _____ Adjacent land: _____

ROW width (fence to shoulder) _____ Notes _____

ROW width minus clear zone _____

Assessment Area (AA) Defined as the area selected by the roadside manager as a possible candidate for enhancement of pollinator habitat. AA can be a portion of a larger tract, but should not include the clear zone. This evaluation guide is designed to evaluate the resource concerns with respect to pollinators in the assessment area and in adjacent land.

Management objectives for this assessment area:

Pollinator conservation objectives for this assessment area (e.g. target species for conservation):

1. Pollen and Nectar Sources

Pollinator Plant (sources of Nectar and Pollen) Cover in the Assessment Area

Estimate percentage vegetative cover in the AA that is wildflowers, flowering shrubs or trees used by pollinators. Do not count noxious or invasive species.

	Score	Present	Planned
Pollinator forage cover in AA > 50% cover	1		
Pollinator forage cover in AA 30-50%	0.7		
Pollinator forage cover in AA 20-30%	0.5	0.3	
Forbs and legumes in AA ≤ 25% cover	0.3		
Cover in AA < 10%	0		

Pollinator Foraging Habitat: Forage Plant Composition - Early Season (March - May)

Estimate the number of **spring-blooming** native forbs, legumes, trees and shrubs that provide florar resources to pollinators within the AA.

	Score	Present	Planned
7+ species	1		
4-6 species	0.8		
2-4 species	0.5	0.5	
1-2 species	0.2		
0 species	0		

Pollinator Foraging Habitat: Forage Plant Composition - Mid Season (June - mid-August)

Estimate the number of **summer-blooming** native forbs, legumes, trees and shrubs that provide florar resources to pollinators within the AA.

	Score	Present	Planned
7+ species	1		
4-6 species	0.8		
2-4 species	0.5	0.5	
1-2 species	0.2		
0 species	0		

Pollinator Foraging Habitat: Forage Plant Composition - Late Season (Mid-August - October)

Estimate the number of **autumn-blooming** native forbs, legumes, trees and shrubs that provide florar resources to pollinators within the AA.

	Score	Present	Planned
7+ species	1		
4-6 species	0.8		
2-4 species	0.5	0.8	
1-2 species	0.2		
0 species	0		

Figure 9-2. Pollinator Habitat Assessment Guide for Roadsides: Comprehensive Assessment (1 of 2).

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Roadside Pollinator Habitat Evaluation Guide
Comprehensive Assessment (continued)

2. Breeding, Nesting, and Overwintering Habitat

Butterfly and moth host plants in the Assessment Area

Estimate abundance of host plants for target butterfly and moth species

	Score	Present	Planned
Abundant	1	0.5	
Sparse	0.5		
Absent	0		

Nesting habitat for native bees that nest in wood, pithy stems, or other plant material.

Estimate presence of these sources of nesting habitat in the Assessment Area. Select all that apply.

	Score	Present	Planned
Native shrubs with pithy or hollow stems (e.g. wild rose, ninebark)	0.3	0.6	
Native wildflowers with pithy or hollow stems (e.g. ironweed, wild bergamont)	0.3		
Unmown bunch grasses present throughout the growing season to support bumble bee nests	0.3		
Diversity of native grasses to provide vegetation structure for shelter and overwintering	0.3		

3. Landscape Connectivity

Assessment Area and the surrounding landscape

Estimate the landscape context for the Assessment Area. Select all that apply.

	Score	Present	Planned
Assessment Area increases landscape connectivity by linking existing habitat on nearby land	0.5	1	
Assessment Area increases landscape connectivity by linking roadside habitat	0.5		
Assessment area does not increase landscape connectivity because it is isolated with the landscape matrix but does increase habitat in the landscape	0.2		

4. Threats from adjacent road

Risks associated with road

Select all that apply.

	Score	Present	Planned
Assessment Area is not isolated within areas of high road density in which there are multiple barriers to pollinator movement.	0.5	1	
If the Assessment Area is adjacent to a road with high traffic volume, the AA has reduced mowing and high plant diversity (increased mowing and low plant diversity are associated with pollinator traffic mortality).	0.5		
Width of the clear/safety zone is at least 5 feet.	0.2		
The width of the safety zone is increased along roads with high salt use and high volumes of traffic (reduces exposure of pollinators to salts and heavy metals)	0.3		

5. Threats from adjacent land

Reduce risks to pollinators from the land adjacent to rights-of-way

Select all that apply.

	Score	Present	Planned
Adjacent landowner does not utilize insecticdes, herbicides, or fungicides in their land management activities.	1	0.5	1
Adjacent landowner manages pesticide drift to reduce exposure to the roadside habitat.	0.75		
Adjacent landower is aware that the roadside could harbor an imperiled pollinator species and that their use of pesticides could impact pollinator habitat or pollinator populations.	0.5		

6. Vegetation Management

Reduce risks to pollinators from maintenance activities

Select all that apply.

	Score	Present	Planned
Timing of mowing (beyond clear zone) is timed to reduce impact to pollinator life cycles (e.g. not mown during caterpillar stage of target butterfly species)	1	0.5	
Mowing and herbicide use is timed to support plant diversity.	0.75		
Herbicide use beyond safety zone is targeted to noxious and nonnative plants.	0.75		
Brush removal is used to increase plant diversity or to maintain woody plants that support pollinators.	0.5		
No. Factors Rated		10	1
Habitat Suitability Index (SUM/No. factors rated) =		**0.62**	**1.00**

Notes:

Figure 9-2. Pollinator Habitat Assessment Guide for Roadsides: Comprehensive Assessment (2 of 2).

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These habitat assessment guides are included as a separate document and can be found on the National Academies Press website (https://nap.nationalacademies.org/).

These habitat assessment guides are designed for evaluating roadside conditions. Prior to conducting an in-field assessment, it may be helpful to consult or print aerial photos to help with site and landscape questions. Ideally, this assessment should be conducted twice—once during the habitat evaluation process (before undertaking construction, to inform the planning and design phase) and once after maintenance changes have been made or after revegetation has taken place.

Instructions for Habitat Assessment Guide Use:

1. Each category in the comprehensive assessment should be given the appropriate value from the "Score" column.
2. An overall habitat suitability index score will be automatically generated based upon the scores from each category.
3. The scores for each category can be used to identify resource concerns. For example, if the score for spring blooming flowering plants is low, take actions to increase spring blooming species in revegetation plans. Factors that improve pollinator habitat can be considered in design plans.
4. The site needs to be reevaluated after revegetation to measure increased benefits to pollinators. Ideally, each site should strive to achieve a score of at least 0.65.

If working at a particular site with positive identification of an imperiled species, consider using a more detailed habitat assessment for a particular species if it is available. Currently, detailed habitat assessments are limited, but examples include:

- Rusty Patched Bumble Bee Habitat Assessment Form and Guide: https://www.fws.gov/midwest/endangered/insects/rpbb/pdf/HabitatAssessmentFormGuideByXercesForRPBB.pdf
- Monarch Breeding Habitat Assessment: https://www.fws.gov/southwest/es/Documents/R2ES/Pollinators/9-Monarch_Habitat_Assessment_Tool_Monarch_Joint_Venture_2014.pdf
- Roadside Habitat for Monarchs Evaluator Tool: https://monarchjointventure.org/mjvprograms/science/roadsidehabitat/habitat-evaluator-tool
- Rights-of-Way as Habitat Working Group Pollinator Scorecard, the Monitoring Tool for the Monarch Candidate Conservation Agreement with Assurances: http://rightofway.erc.uic.edu/pollinator-habitat-scorecard/

These assessments can help planners prioritize conservation actions and quantify habitat or management improvements for a particular species.

9.3.2 Pollinator Plant Monitoring

Monitoring plant species found on a project site is a method of assessing existing or potential pollinator habitat, or assessing survival and evaluating plant establishment in revegetation projects. Data can be collected using plant monitoring procedures such as those found in Chapter 6 of the Federal Highway Administration's *Roadside Revegetation:*

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An Integrated Approach to Establishing Native Plants and Pollinator Habitat (2017). *Measuring & Monitoring Plant Populations* by Elzinga and Salzer (1998) also provide guidance on measuring and monitoring plants. Plant species recorded during surveys can be categorized as sources of pollen or nectar, host plants, whether they provide nesting structure, or other characteristics important for pollinator habitat. A species list can also be used to determine if there is overlapping bloom time throughout the growing season so that flowering species are available sequentially for pollinators.

Photo point monitoring is a method of recording landscape changes in vegetation over time and showing the success or failure of a revegetation project. Photo monitoring can be established for long-term monitoring where a permanent point has not been established and subsequent photographs are taken, or where permanent locations have not been located from historic photographs; or photo monitoring can be reconstructed from historic photographs (see, for example, Sections 6.5.1 and 6.5.2 in FHWA 2017).

Landscape images from photo point monitoring, in conjunction with data collected from other monitoring methods, can be a powerful way to describe the results of a revegetation project. The U.S. Forest Service's *Photo Point Monitoring Handbook* (Hall 2002) provides a thorough coverage of this subject.

9.4 Resources for Identification of Pollinators

Borror, D. J., R. E. White, and R. T. Peterson. 1970. *A Field Guide to Insects: America North of Mexico (Vol. 19).* Houghton Mifflin Harcourt.

Brock, J. P. and K. Kaufman. 2006. *Kaufman Field Guide to Butterflies of North America.* Houghton Mifflin Harcourt.

Eaton, E. R., and K. Kaufman. 2007. *Kaufman Field Guide to Insects of North America.* 392 pp. New York, NY: HarperCollins Publishers.

Williams, P. H., R. W. Thorp, L. L. Richardson, and S. R. Colla. 2014. *Bumble Bees of North America.* 208 pp. Princeton, NJ: Princeton University Press.

Wilson, J. S., and O. Messinger Carril. 2016. *The Bees in Your Backyard: A Guide to North America's Bees.* 288 pp. Princeton, NJ: Princeton University Press.

9.5 Resources for Monitoring Plant Populations

Elzinga, C. L., and D. W. Salzer. 1998. *Measuring & Monitoring Plant Populations.* U.S. Department of the Interior, Bureau of Land Management. Available: https://digitalcommons.unl.edu/usblmpub/41/.

Federal Highway Administration (FHWA) 2017. *Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat.* Available: http://www.nativerevegetation.org/learn/manual_2017/.

Hall, F. C. 2002. *Photo Point Monitoring Handbook.* Gen. Tech. Rep. PNW-GTR-526. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. Available: https://www.fs.usda.gov/pnw/pubs/pnw_gtr526.pdf.

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Hamilton, Randy. Photo Point Monitoring. A Weed Manager's Guide to Remote Sensing and GIS -Mapping & Monitoring. Available: https://deq.nd.gov/publications/WQ/3_WM/NPS/SWCBinder/Riparian/Photopoint_monitoringUSFS.pdf.

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Chapter 10 Cost-Benefit Considerations for Pollinator Management on Roadsides

10.1 Introduction



There are environmental, societal, and economic benefits to managing roadsides for pollinators.

Photo Credit: Luis Colon/Arizona DOT

The relative costs and benefits of maintaining existing or establishing new pollinator habitat along roadsides are important considerations when incorporating Endangered Species Act (ESA) compliance, species conservation, and habitat management into transportation planning, design, construction, and maintenance. As has been demonstrated throughout this guide, there are many opportunities to benefit pollinators and contribute to the recovery of listed and imperiled species through changes in roadside management. Many of these changes may have a relatively minor effect on costs, and those that are more costly can often lead to long-term cost savings, while having important substantial benefits for imperiled pollinators and the pollinator community in general. Furthermore, the benefits can extend well beyond the pollinator community. For example, roadsides managed for pollinators by planting beneficial plants and reducing mowing can broadly benefit wildlife and ecosystem health, and are also an opportunity to showcase natural beauty and promote tourism, reduce maintenance (a cost savings to departments of transportation [DOTs]), and support a wide range of important ecosystem services such as carbon sequestration and erosion control. Roadsides are an integral part of the highway system and are valued by the general public as important natural and scenic resources. Therefore, it is important to consider all types of potential benefits when considering investing in pollinator-friendly roadsides.

10.2 Cost-Benefit Analysis for Sustainability

A cost-benefit analysis is an approach to decision-making weighing the various costs of a particular action with the value of the benefits expected as an outcome of the action. Cost-benefit analyses have been used in project decision-making for many decades (Elkington 2018) and have traditionally only focused on the quantitative economic costs and benefits. More recently cost-benefit analyses have been approached from the perspective of long-term sustainability and include other non-economic factors such as societal and environmental costs and benefits. When cost and benefit considerations include environmental, societal, and economic factors they are often referred to as the triple bottom line (Figure 10-1).

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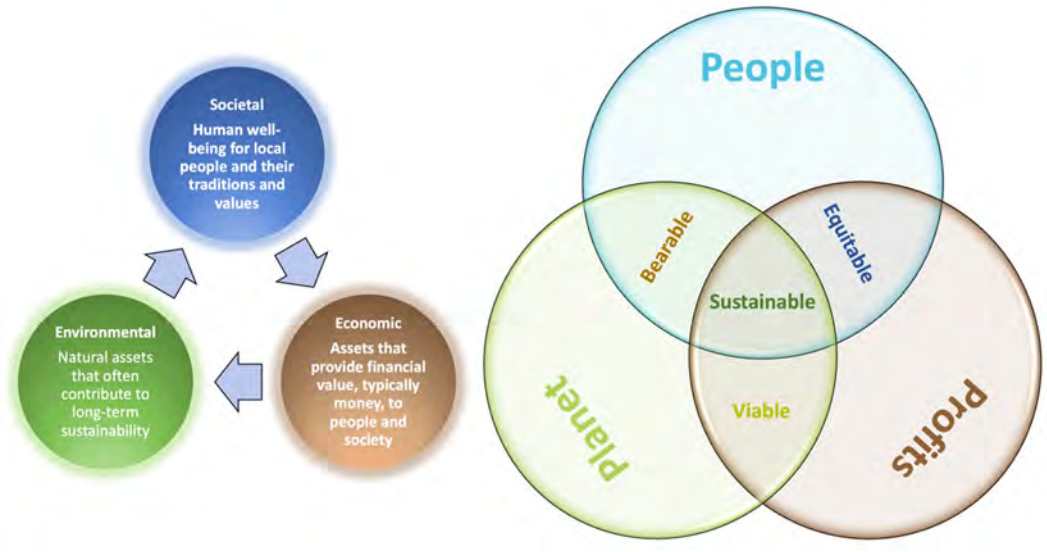


Figure 10-1. Objectives of a triple bottom line.

The triple bottom line approach is a cornerstone of the Federal Highway Administration (FHWA) Sustainable Highways Initiative (sustainablehighways.dot.gov), which supports the U.S. Department of Transportation Strategic Plan for FY2022–2026 (USDOT 2022). The triple bottom line considers long-term sustainability and therefore long-term costs and benefits, including the full range of factors important to human quality of life. Considering the importance of pollinators to human sustenance, the triple bottom line approach is particularly relevant to cost-benefit consideration of pollinator-friendly measures.

While cost-benefit analyses can be useful in the decision-making process, they can be difficult to complete. In a 2016 report to Congress, the FHWA noted that only about 10 percent of state DOTs regularly use any form of formal cost-benefit analyses (FHWA 2016), and mostly only for relatively large projects. Some of the greatest hurdles to conducting a cost-benefit analysis include the inconsistency and difficulty of obtaining quantitative cost information, lack of institutional support, and difficulty quantifying societal and environmental costs and benefits (FHWA 2016). These difficulties still hold true today.

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Case Study: Arizona DOT Sustainable Transportation Program: INVEST Case Studies

Arizona DOT recognizes the importance of sustainability in the long-term success of the state's transportation network, and has embraced the triple bottom line approach systematically through its administrative, planning, design, construction, operations, and maintenance activities.

To achieve its ambitious sustainability goals, Arizona DOT has applied the sustainability tools of the FHWA INVEST program to a wide variety of case studies. Application of the performance measures and metrics to the three INVEST modules of system planning, project development, and operations and maintenance has helped Arizona DOT undertake cost-benefit analyses, life cycle cost analyses, and return on investment evaluations across the environmental, societal, and economic factors essential for sustainable operations and project implementation. The environmental, social, and economic benefits of this approach are carried forward into Arizona DOT projects through its Sustainable Project Development checklist, which guides project design and construction to consider project elements to optimize all three areas of sustainability, including habitat protection, and wildlife connectivity. While pollinators are not mentioned explicitly, they are an important element of the environmental and societal factors considered by the checklist.

Source: Arizona DOT 2020.

Given the challenges DOTs have faced in obtaining information for quantitative cost-benefit analyses, this guide proposes the application of a simple, qualitative cost-benefit tool using the triple bottom line approach that considers the environmental, societal, and economic costs, as well as benefits of, pollinator-friendly habitat. This approach can be used when making decisions about pollinator habitat during the planning, design, construction, and maintenance phases of a project. Costs are evaluated from the point of view of a state DOT. Benefits are evaluated in terms of environmental benefits (e.g., to habitat diversity and endangered species recovery), societal benefits (e.g., to crop pollination services), and operational benefits to a state DOT (e.g., operational flexibility through ESA compliance, or reduction of future risk of regulation by contributing to species recovery and avoidance of future listing).

10.2.1 Land Use Context and Variability of Costs and Benefits

Not only are quantitative costs and benefits of roadside management for pollinators difficult to obtain (as mentioned above), they vary regionally and may depend on the surrounding land use, ecological context, and pollinator species of interest. It might cost more to adjust mowing schedules to accommodate a particular species of butterfly that breeds during a time when mowing is most cost efficient for a DOT, for example, or the costs of plant materials used in revegetation to support one imperiled species might be higher than the cost of plant materials to support another imperiled species. Although the upfront costs associated with the conservation of a particular species might be higher, the benefits of taking those conservation actions might also be greater. Investments made to proactively conserve a rare species, for example, can prevent state or federal listings and may reduce costs DOTs might otherwise incur in the future.

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The costs and benefits could also be considered in the context of the adjacent urban, agricultural, or natural land uses. For example, improving pollinator habitat on roadsides surrounded by natural habitat may seem unnecessary (providing little additional relative conservation value) if the target pollinator species has all its needs met in the adjacent habitat. On the other hand, revegetation projects in such areas may bring value by helping to reduce the spread of invasive plants to sensitive areas as well as increasing habitat connectivity. Or consider, for example, that improving pollinator habitat on roadsides adjacent to agricultural lands can provide additional pollination services, but that the particular economic benefit might be lower for roadsides adjacent to urban landscapes. However, habitat improvement actions on urban roadsides may provide the only suitable habitat for miles and can create vital connectivity between distant areas of natural habitat, bringing broader benefit and greater overall value.

The relative costs and benefits of pollinator-friendly actions can also vary by region. Modification of mowing regimes in the Southeast can have substantial benefits but may not be relevant in the driest areas of the Southwest where mowing is rarely needed. A cost-benefit analysis in one region may not directly apply to another.

Given the high variability of costs and benefits across species and regions and within differing land use contexts, it is difficult to provide definitive cost-benefit rules and relationships. Instead, this guide provides simple cost and benefit tools and concepts that can be applied and adapted by each DOT for the evaluation of pollinator-friendly actions being considered in project planning, design, construction, and maintenance.

10.3 Types of Costs and Benefits

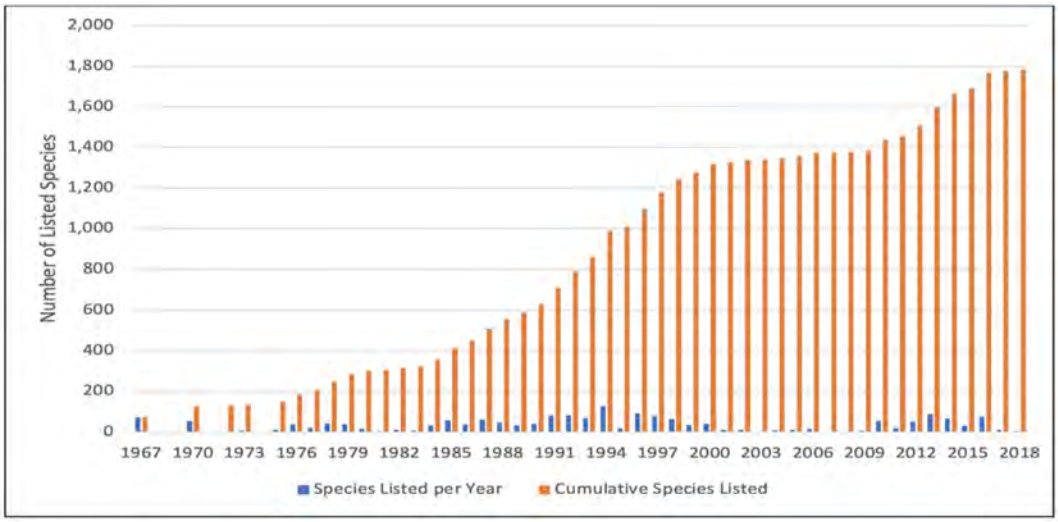
10.3.1 Regulatory Costs and Benefits

The primary federal regulation addressing pollinators is the ESA (see Chapter 4, Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation). Many states have similar endangered species protection acts that can also regulate pollinator species. The growing awareness of the importance of pollinators and the evidence of dramatic declines in the health and diversity of pollinator species have also led to additional state and federal regulations protecting pollinators (e.g., Maryland Pollinator Protection Act of 2016, Save Oregon's Pollinators Act of 2014, Connecticut Pollinator Health Act of 2017). Many of these regulations focus on restricting the use of certain pesticides, some encourage or require inclusion of pollinator habitat on public lands and rights-of-way (ROWs), many require improved public and agency education of the importance of pollinators, and some provide funding incentives when pollinator-friendly measures are included in projects. The reality is that pollinators and their habitat will be more tightly regulated in the coming years, which brings potential increased costs and potential benefits.

As of June 2022, there are 48 invertebrate pollinator species listed as endangered or threatened under the ESA (USFWS 2022). It is worth noting that insects are disproportionately underrepresented under the ESA; although they make up 72 percent of animal diversity, only 10.3 percent of listed species are insects (Black 2012). Figure 10-2 shows the trend in the number of all species listings over time. The number of pollinator species listed under the ESA has increased in recent years and this trend for pollinators,

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and species overall, is unlikely to slow down because of ongoing factors such as loss of habitat, impacts from pesticides, and the effects of climate change.



Source: USFWS 2018.
Note: Includes Threatened and Endangered listings under the 1973 ESA and its precursors.

Figure 10-2. Listings of all species under the ESA by year.

As noted in Chapter 4, 75 percent of transportation planners and managers surveyed recognize the possibility that if an imperiled pollinator species in their project area became listed, it could cause barriers, such as altered project timelines, increased workloads, and higher costs to their agencies.

Implementing actions to benefit unlisted pollinators and prevent them from being listed under the ESA will provide substantial long-term regulatory cost savings. Upfront planning by DOTs can result in substantial future time and cost savings as workflow is improved and the number of project redesigns and modifications to operations are reduced across their larger road network. A total of 81 percent of the surveyed transportation professionals confirmed that the risk of an imperiled pollinator species becoming listed would motivate their DOT to proactively protect pollinators in order to reduce the risk of listing. These same transportation professionals also recognized that early adoption of regulatory compliance strategies was good for public relations and consistent with identified sustainability goals for their transportation agencies.

Once a species is listed, the only options are to avoid impacting the species or seeking an incidental take permit under Section 7 or 10 of the ESA, either of which can cause project delays and increase costs. However, strategic planning to comply with the ESA and other laws and regulations can reduce DOT regulatory



Voluntary conservation measures to support imperiled pollinators like the American bumble bee (*Bombus pensylvanicus*) may help to recover the species and avert a listing under the ESA, potentially saving transportation agencies time and money.

Photo Credit: Ray Moranz/Xerces Society

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costs. Developing long-term Habitat Conservation Plans (Section 10 of the ESA) for non-federal actions or "programmatic" Section 7 permits for federal actions can provide long-term cost and time savings through increased regulatory certainty and project streamlining for large and small road projects as well as maintenance activities.

Case Study: Programmatic Section 7 ESA Permits for Colorado DOT

Colorado DOT developed a conservation strategy as a part of a 20-year programmatic Section 7 permitting agreement to cover 38 species, including 4 pollinators (butterflies), in the Central Shortgrass Prairie ecoregion of Colorado. The programmatic agreement and conservation strategy has three goals:

1. Proactive conservation of the declining and listed species in this ecoregion;
2. Providing mitigation for potential impacts of Colorado DOT projects within the existing transportation corridor; and
3. Improved efficiencies and cost savings for the environmental compliance of Colorado DOT project.

The conservation strategy includes a range of actions to offset impacts on the covered species from Colorado DOT transportation improvement and routine maintenance, including recommended practices and land protection projects.

Source: Grunau et al. 2003.

Case Study: Economy of Scale: Major Improvements in Transportation Project Delivery Cost and Schedule with Long-Term Multi-Species Habitat Conservation Plan (MSHCP)

In Riverside County, California, the Western Riverside MSHCP has provided substantial economic benefits to regional transportation projects. Approved in 2004, the MSHCP covers 146 species, including 2 endangered pollinators: the Delhi sands flower-loving fly (*Rhaphiomidas terminatus abdominalis*) and the Quino checkerspot butterfly (*Euphydryas editha quino*). As of March 2019, the implementing entity of the plan, the Western Riverside County Regional Conservation Authority (RCA), has compiled the following economic benefits of their plan to transportation projects, based in part on a comprehensive cost-benefit study prepared in 2008 by the Rand Corporation (Dixon et al. 2008) and 15 years of plan implementation:

- The Western Riverside County MSHCP has accelerated $4 billion in transportation and infrastructure projects by 1 to 5 years or more. This includes a new rail line, two new freeways, five major freeway-widening projects, a dozen freeway and highway interchange projects, a major dam rehabilitation, a new Metrolink line, major water projects, and major regional power transmission lines.
- The Western Riverside County RCA estimates $312 million savings in transportation costs due to early delivery (Based on the National Highway Construction Cost Index Average of 3.9 percent per year and an average time savings).

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- Every transportation project proposed in the plan area has been built; none have been stopped or stalled due to ESA or California ESA issues. With the MSHCP in place, ESA compliance no longer impedes the path of project environmental compliance.
- Projects with an ESA Section 7 consultation received their biological opinions from U.S. Fish and Wildlife Service in an average of 2 months, versus over 2 years without the MSHCP.

10.3.2 Management and Maintenance Costs and Benefits

Mowing the many acres of roadside ROWs every year represents a substantial expenditure, and mowing a limited portion of the ROWs means potential cost savings as well as aesthetic and ecological benefits, without compromising safety. Data is limited, but includes these examples:



Mowing a highway once a year rather than seven times allows wildflowers like tall false foxglove (*Agalinis aspera*) to flourish in Florida.

Photo Credit: Eleanor Dietrich

- Delaware DOT spent over $3.4 million mowing roadsides in 2008. In 2009, budget restrictions forced Delaware DOT to reduce mowing by 25 percent. If Delaware DOT took 500 acres +of roadsides out of routine mowing, the state could save $1.3 million per year (Lucey and Barton 2010).
- Florida DOT spent $13 million on roadside mowing in 2011–2012. The University of Florida, Institute of Food and Agricultural Sciences report, *Economic Impact of Ecosystem Services Provided by Ecologically Sustainable Roadside Right of Way Vegetation Management Practices*, found that Florida DOT could reduce its costs by 30 percent by implementing sustainable management practices such as reduced mowing (Harrison 2014).
- In Florida, Norcini (2014) found that limiting mowing to once a growing season, in the fall, along a stretch of Interstate 10 in Madison County reduced mowing costs by $1,000 per mile. (Typically, that highway is mowed up to seven times a growing season.) A 10- to 15-foot-wide mown strip in the recovery area adjacent to the pavement continued to be mowed seven times each growing season. Over time, more and more desirable plant species were found in the section of the ROW with the reduced mowing regime. As blooming wildflowers increased, the section of the road became more aesthetically appealing, particularly in the spring.
- Indiana DOT found a cost savings of over 40 percent can be achieved with one application of herbicide instead of one cycle of mowing, and that there are cost savings associated with planting native vegetation (e.g., prairie plant community wildflowers had a greater initial cost, but that cost was offset in the analysis by lower long-term management costs) (Lucey and Barton 2010).
- Mississippi DOT mows approximately 139,253 acres of roadsides four times per year at a cost per acre of greater than $250, or a total annual cost of around $35 million. Reducing mowing of roadsides by one mowing could save approximately $8.7 million; eliminating two mows per growing season could save over $17 million (Guyton et al. 2014).

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Reduced Mowing, a Triple Bottom Line for DOTs

Environmental Benefits

- Reduced mowing can allow flowering plants to flower, providing pollinators with pollen and nectar and small wildlife with seeds and fruits. The transition from frequently mowed grass to more diverse grasslands or early successional habitat can increase wildlife habitat quality and reduce habitat fragmentation (AASHTO 2011). More birds use roadside habitat when vegetation is taller and more dense (McCleery et al. 2015) and when mowing does not interrupt grassland breeding season (Warner 1992).
- Reduced mowing can mean reduced greenhouse gas emissions from mowing equipment and reduced amounts of carbon stored in plant tissues returned to the atmosphere after mowing. Emissions from mowing can result in up to 35 kilograms (kg) of carbon dioxide (CO_2) emissions per shoulder and kilometer (Sonntag et al. 2011). If reduced mowing is implemented in just half of the roadsides associated with the National Highway System, CO_2 emissions could be cut by approximately 2 million kg every year (FHWA 2011).

Societal Benefits

- Non-turf roadside vegetation provides aesthetic variety, breaks up monotony (Billings 1990), and can have a positive effect on human performance and improve driver safety (Topp 1990; Cackowsky and Nasar 2003; Mok et al. 2006; Macdonald et al. 2008).
- Public perception surveys have found strong support for more wildflowers on roadsides and reduced mowing, with respondents also indicating they would tolerate a less manicured roadside if it made the roads safer (Guyton et al. 2014).

Economic Benefits

- Reducing routine mowing of the entire ROW can reduce costs. Other strategies to reduce costs include making only one pass with the mower next to the operational zone rather than mowing the entire ROW multiple times during the growing season.
- Though in general reducing routine mowing is a straightforward method of reducing costs for many ROWs, altering the timing of mowing to encourage breeding of imperiled species (e.g., avoiding mowing during peak Karner blue butterfly [*Lycaeides melissa samuelis*] breeding) or blooming of wildflowers may be less straightforward because there may be other operational constraints to consider (e.g., such as mowing at a time of the year when maintenance staff are trying to prepare for winter). However, if these constraints translate to additional ongoing costs, those costs are likely to be offset by the value of proactive conservation to avert ESA listings.
- Mowing can sometimes spread noxious and invasive weeds; switching from routine mowing to more targeted weed control can bring about cost savings.

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10.3.3 Revegetation Costs and Benefits: Use of Native Plants

Native plants can be used to meet goals for safe and efficient transportation, while supporting ecosystem health. Although the initial costs of establishing native plant material are higher—particularly where a higher density and diversity of flowering plants are required—than the costs of low diversity mixes that are heavy on introduced grasses, native plants are often more cost-effective in the long term. Once established, the plantings persist over time and require less mowing, herbicides, and other weed control measures, decreasing long-term maintenance efforts and cost (Berger 2005). In contrast, controlling the growth and spread of invasive plants along roadsides through repeated mowing and rigorous herbicide use is very expensive (Westbrooks 1998).

Another advantage of using a diverse assemblage of native plants in revegetation projects is that it may be more resilient to climate change. For many regions, climate projections include an increase in extreme weather events. Many regions will experience both more frequent drought and more frequent flooding. Having a diverse plant community along roadsides means that the community is more likely to contain plants that will persist under different conditions and will continue to provide benefits like erosion control.

Though data is limited, what does exist indicates that establishing native vegetation on roadsides can reduce maintenance costs. Consider these examples:

- Texas DOT estimated an annual mowing cost savings of $20–$30 million through wildflower establishment (Guyton et al. 2014).
- In 1987, Massachusetts Department of Public Works managed roadsides at a cost of about $1.1 million, or $330 per acre; if every acre was instead managed as wildflowers, nearly $280 per acre per year could be saved (Ahern et al. 1992).
- In California's Yolo County, Robins et al. (2001) estimated roadside native vegetation installation costs, which included earthwork, tillage, herbicide, and seeding, at $522 to $1,433 per acre of roadside. They estimated maintenance costs for each of the first 3 years of establishment at $52 to $153 per acre, with similar maintenance costs occurring subsequently every 2 to 3 years. Standard roadside management, for comparison, costs $140 to $490 per acre per year.

Reducing Costs and Finding Funding to Support the Use of Native Plant Materials

Obstacles encountered by transportation agencies seeking native plant materials can include the cost and, depending on region, the availability of locally or even regionally sourced native plant materials. Some solutions that transportation agencies have used to fund plant material purchases or increase the supply of native plant material include the following:

- Committing to purchasing and planting seed or plant material that originates in the state or region. Coordinate with local or regional native plant vendors about plant material needs for projects 3–5 years in the future, so the vendors can plan ahead to have the plant material available. Such a sustained commitment fosters a stable market that will lead to greater production and reduced costs.
- Partnering with private nurseries or state agencies in a cooperative effort to build up a local plant material industry.

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- Taking advantage of federal funding. Planting native vegetation is an eligible use of federal-aid highway funds. The cost of native plant materials purchased for revegetation projects can be reimbursed by the FHWA.
- Finding alternative sources of funding to support the planting of roadside wildflowers. For example, a state might offer a specialty wildflower license plate, the sales of which support the purchase and installation of wildflowers on roadsides, or the state transportation agency could partner with a state or local organization that obtains funding from the FHWA's Surface Transportation Block Grant Program to implement vegetation restoration.

Native Plants in New Roadside Plantings, a Triple Bottom Line Win!

In addition to their value to pollinators, there are many advantages of using native plants to providing triple bottom line benefits:

Environmental Benefits

- Native grasses and flowers are best adapted to local growing conditions, require minimal inputs for establishment, and are better able to tolerate extreme weather events such as drought.
- 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.

Societal Benefits

- Native plants can be aesthetically pleasing during the growing season.
- Native plants can act as snow fences in the winter, trapping and preventing snow from blowing across roads.
- The root systems of native plants can increase water infiltration, which reduces runoff and water pollution and keeps waters cleaner.

Economic Benefits

- Although native plants may cost more upfront, they can provide cost savings over time.
- A diverse native plant community can reduce soil erosion and resist weed invasions, which can reduce maintenance costs.

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Case Study: Prairie Plants More Cost-Effective over Time on Indiana Roadsides

A collaborative highway research project involving researchers from Purdue University, the Indiana DOT, and the FHWA evaluated plants for use on Indiana's roadsides. Specifically, the project looked at establishment of three types of roadside plantings: turfgrass, garden wildflower mixes, and native wildflower mixes. The project team also calculated costs of establishment and maintenance of each approach (Dana et al. 1996).

Turf plantings were a mix of introduced grasses installed as sod, while the garden wildflower seed mix included 11 species of short-lived annuals or biennials, primarily introduced species such as cosmos, California poppy, and rocket larkspur. The native prairie seed mix was 8 species—3 native grass species (20 percent of the mix) and 5 wildflower species (80 percent of the mix).

Garden wildflowers were the least costly to establish, but maintenance was more costly over time, including reseeding repeatedly over time due to the short lifespan of the plants. Another downside of the garden wildflowers mix is that it was not appropriate for erosion control. The prairie plant mixes were more costly up front, but researchers found that the more permanent turfgrass and prairie plantings were cost competitive when long-term management costs were incorporated.

This study, conducted in the mid-1990s, reflects the higher costs of native seed at the time. Native seed mixes are more affordable and available today, so the mix tested in this study would cost much less if purchased today. For example, a significantly more diverse native seed mix of 22 species could be purchased from a local Indiana native plant nursery in 2021 for about $400 per acre. That is considerably less than the $2,179.44 cost per acre for the mix included by Dana et al. in 1996. An updated analysis of the costs associated with revegetation of roadsides and roadside vegetation management would be highly beneficial.

10.4 Incorporating Costs and Benefits into the Planning and Design Phases

During the planning and design process, it is important to consider actions to benefit pollinators early and often (such as revegetation or location considerations) so that they can be included in the project and costs can be incorporated into the project budget. Weighing the short-term vs. long-term costs and benefits of pollinator conservation actions and using the triple bottom line approach outlined below may aid in this process.



Native plants develop extensive root systems over time that are important for erosion control, water infiltration, weed resistance, carbon sequestration, and more.

Photo Credit: Kirk Henderson

10.4.1 Short-Term vs. Long-Term Costs and Benefits

Humans are notoriously bad at making long-term decisions (Ornstein and Ehrlich 1989). People have evolved to make decisions based on perceived risk (cost) and expected reward (benefit), and their brains are much better equipped to judge and react to near-term risks and rewards. However, to make better decisions people need to consider the full implications of the

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decision over time. This is especially true when considering decisions regarding sustainability and the triple bottom line (Waite 2013).

When planning transportation projects, it is relatively easy to add up the short-term costs of planning, design, and construction, and relatively easy to understand conceptually long-term economic and societal gains of transportation system improvements. But when considering project elements to benefit pollinators (or any environmental resource) it is easy to be dissuaded by short-term costs if the long-term environmental and additional associated societal benefits are not carefully described and considered, or if the potential long-term cost savings are not considered.

Most pollinator-friendly project elements include actions to change the species composition and distribution of the plant community. Plants take time to grow and become established, and the pollinator community will take time to discover and then disperse into the newly improved habitat conditions. Revegetation and habitat management projects typically require a larger initial investment of time and money until they become established and self-sustaining due to more intensive watering, weeding, and management needs, which are not required once the plants are established, leading to reduced long-term costs.

Once the desired pollinator habitat is established a range of benefits that diverse habitat confers will start to emerge, such as ameliorating climate change through increased carbon sequestration, reduced soil erosion, increased water infiltration, and, in agricultural settings, crop pest control and crop pollination. These environmental and societal benefits increase over time; therefore, it is important to establish the proper time frame for analysis in a triple bottom line cost-benefit analysis.

Table 10-1. Examples of the benefits of DOT pollinator conservation that could be considered when using the triple bottom line framework to evaluate the costs and benefits of conservation actions.

Environmental Benefits	Societal Benefits	Economic Benefits
• Supports local pollinator communities • Supports imperiled pollinators • Supports other wildlife • Diverse plantings are more likely to be resilient to climate change • Controls erosion • Reduces runoff; reduces flood risk • Suppresses weeds • Reduces mowing frequency, which reduces greenhouse gas emissions	• Protects pollinators and imperiled species • Roadside habitat preserves natural heritage • Pollinator habitat is aesthetically pleasing and showcases regional beauty • Pollinator habitat increases interest for drivers and can improve driver safety Increases carbon sequestration in roadsides through diverse plantings	• Potential for increased pollination services to surrounding landscape • Potential for increased pest predation services to surrounding landscape • Weed suppression, which can reduce long-term maintenance costs • Reduced mowing frequency, which reduces mowing costs • Reduced risk of new species being listed under the ESA, which reduces costs and project delays • Increased tourism due to scenic roads • Improved plant infrastructure, which can protect roads

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10.4.2 Triple Bottom Line Cost-Benefit Analysis Tool

The purpose of this tool is to assist state DOTs in evaluating design features and maintenance actions that can be implemented to benefit pollinators. This tool will assist with organizing cost and benefit information, establishing the environmental and temporal contexts for evaluation, and providing the rationale and justification for selection of the preferred choice, considering the short- and long-term environmental, societal, and economic costs and benefits.

As discussed previously, it is challenging to quantify the range of costs and benefits across all elements of the triple bottom line. Therefore, costs and benefits are evaluated qualitatively as a relative change compared to the status quo (e.g., costs are higher, the same, or lower to implement an action compared to current costs).

Qualitative cost differences need to be evaluated relative to the overall project costs. For example, including native seed in a new interchange construction project may seem expensive because native seed costs more than nonnative seed. However, relative to the overall cost of the interchange construction, proportionally this is a very small additional cost. Therefore, this would be considered a low relative cost overall. In contrast, switching to native seed for interseeding (also known as overseeding) an existing ROW during ongoing operations and maintenance is proportionally a larger additional cost that would be considered a medium or higher relative cost as ROW maintenance is a much smaller total cost than new construction. The temporal context is important to consider as well. In the previous example the more expensive native seed may be a proportionally larger short-term cost, but if the long-term maintenance for native species is lower, then the investment in native seed leads to long-term savings.

Finally, under the sustainability-centered framing of the triple bottom line model, in many cases the total long-term benefits to society and the environment can justify higher economic costs of actions that benefit pollinators compared to the status quo (which does not support a robust pollinator community). Use of this tool will help state DOTs develop pollinator-friendly practices and will them present the rationale for selected actions to decision-makers. This tool is available as a Word document on the National Academies Press website, https://nap.nationalacademies.org/.

Steps to Conduct a Triple Bottom Line Cost-Benefit Analysis for Pollinators on Roadsides

There are three basic steps to using this tool to evaluate pollinator-friendly measures for roadsides: *define, evaluate,* and *decide*. The process to implement each of these steps is described below. Prompts have been provided to help the user conduct a more complete analysis.

1. **Define:** Describe the project area where the action is to be implemented.

    a. Describe the landscape context for the project area, including adjacent land uses and distances between natural habitats where roadsides traverse urbanized or agricultural landscapes.

    b. Describe in detail the pollinator-friendly action or project element being considered.

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c. Describe the intended outcome of the action using the pollinator cost-benefit cubes (refer to the *Pollinator Cost-Benefit Cubes* section below) to determine the potential benefits to the pollinator community in general, and to imperiled pollinators in the project area.

d. Define and then describe the appropriate time frames for analysis (short-term project implementation and long-term operations to realize fulfillment of project results).

2. **Evaluate:** Consider the costs and benefits from an environmental, societal, and economic perspective.

   a. Environmental Evaluation: List all the potential environmental benefits (including pollinator benefits) that might result from the action and rate the likely strength of the benefit as high, medium, or low. Use the prompt questions to contribute to the evaluation.

   b. Societal Evaluation: List all the potential societal benefits that might result from the action and rate the likely strength of the benefit as high, medium, or low. Use the prompt questions to contribute to the evaluation.

   c. Economic Evaluation: Adjust the relative cost in the pollinator cost-benefit cube as needed for the region and landscape context. Consider how total costs change over time, from short-term initial investment costs to potential long-term cost savings. Rate the likely strength of the economic costs and benefits as high, medium, or low. Use the prompt questions to contribute to the evaluation.

3. Decide: Place the evaluation results in three columns (Environmental, Societal, and Economic) in descending order of rating (high, moderate, low). With the importance of long-term sustainability in mind, review the triple bottom line costs and benefits side by side and decide if the complete suite of benefits justify the potential costs. Describe the rationale for the decision.

Prompts for DOT Staff to Apply Cost-Benefit Matrix to Their Pollinator Management Decisions

Environmental Evaluation Prompts

- Could the action provide medium to high benefits to native pollinators?
- Could the action provide benefits to listed pollinators (state or federally regulated species)?
- Is the action adjacent to or near agricultural lands where it could support beneficial crop pollination services?
- Does the action have ecological benefits that extend beyond those to pollinators (e.g., does it increase habitat for birds or improve water infiltration)?

Societal Evaluation Prompts

- Does this action increase the aesthetics of the area where work is being done?

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- Is the project located on a stretch of road in which the landscape is monotonous, and increasing plant diversity could improve driver safety?
- Does the action have landscape benefits that extend beyond benefits to pollinators (e.g., does it increase carbon sequestration)?
- Is the general public engaged and interested in pollinator conservation, and will it respond supportively to actions the DOT may take?
- Is the project good for public relations for the agency?

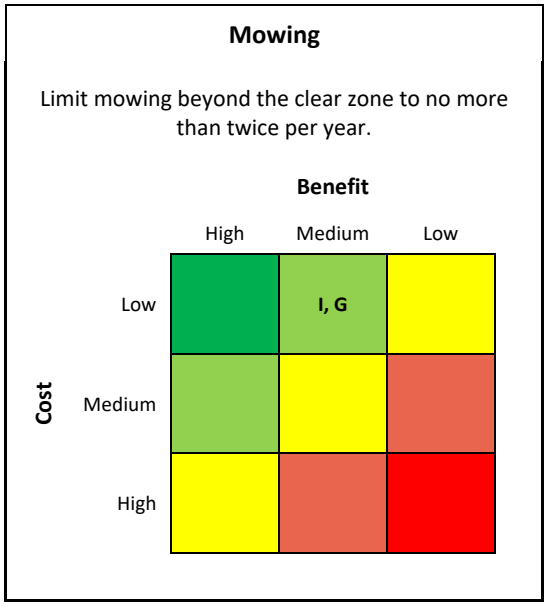
Economic Evaluation Prompts

- Does the action cost more or less in the short term than current practices?
- Does the action cost more or less in the long term than current practices?
- Are costs higher in the short term but the benefits are more long lasting?
- Would the cost to implement this action prevent implementation of other essential operations?
- Does the action help contribute to an agreement that provides compliance and regulatory assurances (e.g., a Candidate Conservation Agreement with Assurances)?

Example: Application of Triple Bottom Line Cost-Benefit Tool

This sample application of the cost-benefit tool uses the proposed pollinator-friendly management action "Limit mowing beyond the mown strip in the recovery area to once or less per year." Cost-benefit cubes for other conservation actions are included in the *Pollinator Cost-Benefit Cubes* section below.

Sample Pollinator Cost-Benefit Cube



I= Benefits to imperiled species; G= Benefits to general pollinator community

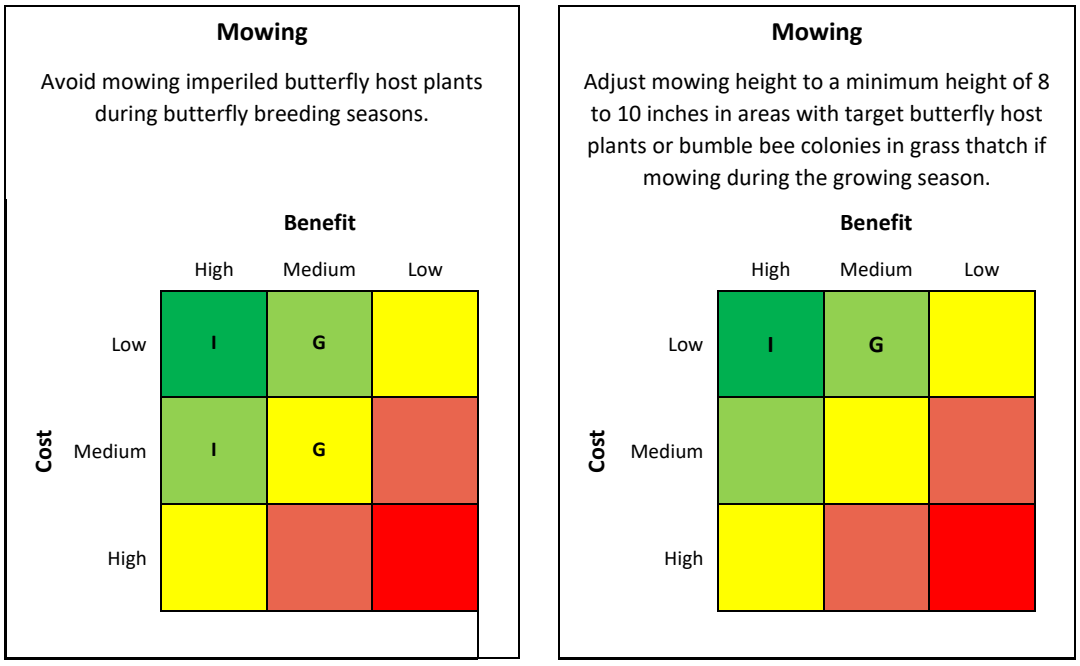
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Pollinator Cost-Benefit Cubes

Use these cubes to identify conservation actions for pollinators to consider in roadside projects and management. Integrate the selected cubes into the triple bottom line cost-benefit analysis as described in the *Steps to Conduct a Triple Bottom Line Cost-Benefit Analysis for Pollinators on Roadsides* section above. The actions are grouped into five different categories: mowing, herbicides, mechanical weed and brush removal, revegetation, and training/education. Table 10-2 lists the benefits to imperiled pollinators and the general pollinator community that are associated with conservation actions that might be implemented on roadsides.

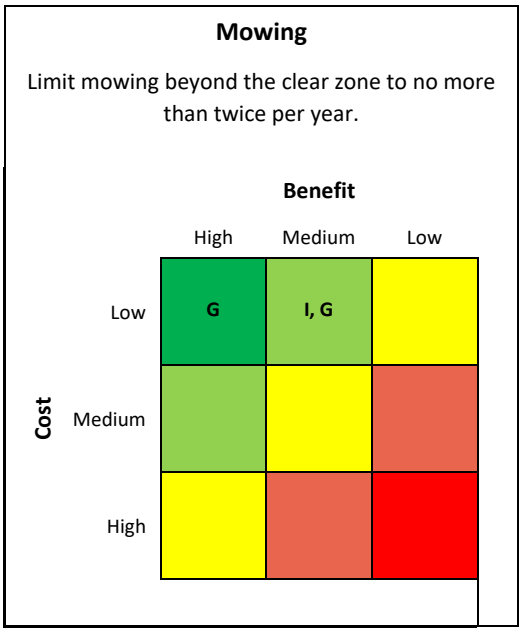
The benefits of each action are indicated across the top of the cube as High, Medium, or Low for the general pollinator community (indicated with a G) and imperiled pollinator species (indicated with an I). Similarly, relative cost to implement the action is indicated along the side as Low, Medium, or High. Costs are based on general assumptions for standard implementation of these actions. However, costs may vary by region, and the costs may be adjusted up or down to indicate expected relative costs for the action being considered in the specific project area.

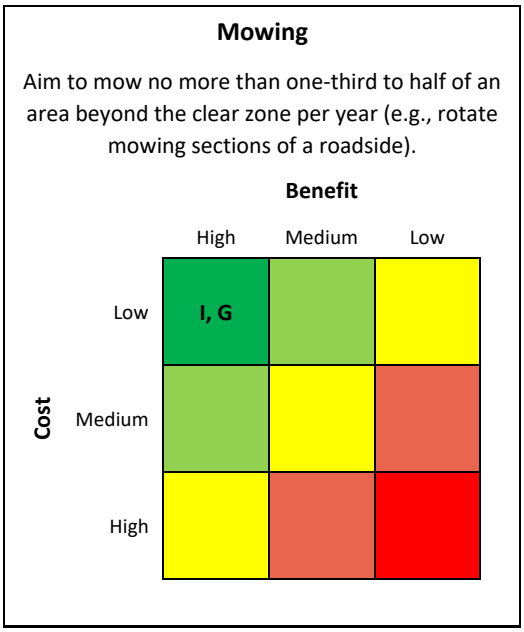
Mowing



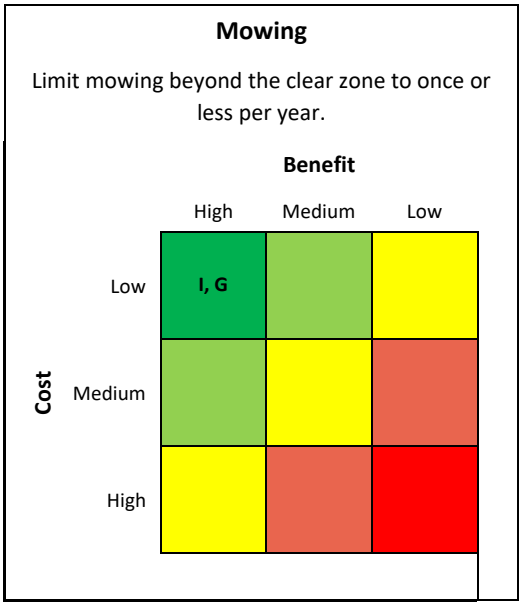
I= Benefits to imperiled species; G= Benefits to general pollinator community

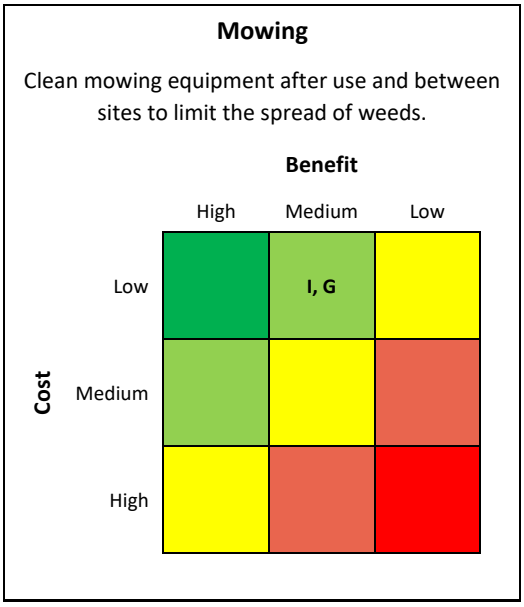
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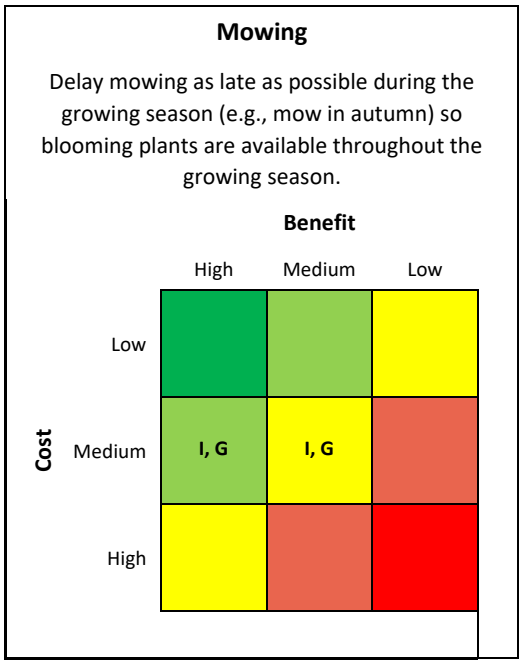
I= Benefits to imperiled species; G= Benefits to general pollinator community





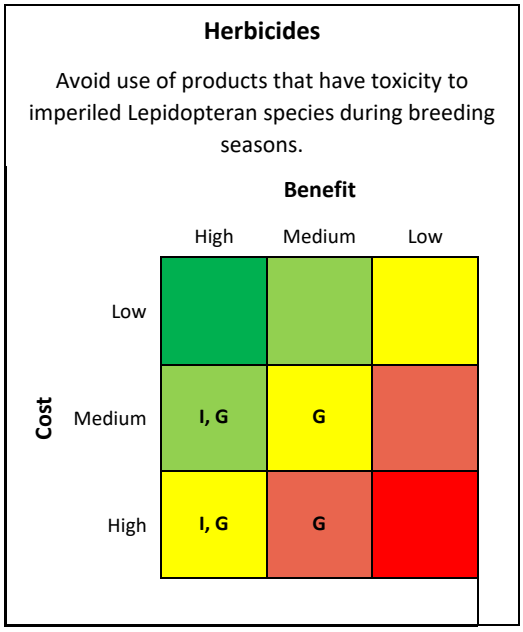
I= Benefits to imperiled species; G= Benefits to general pollinator community

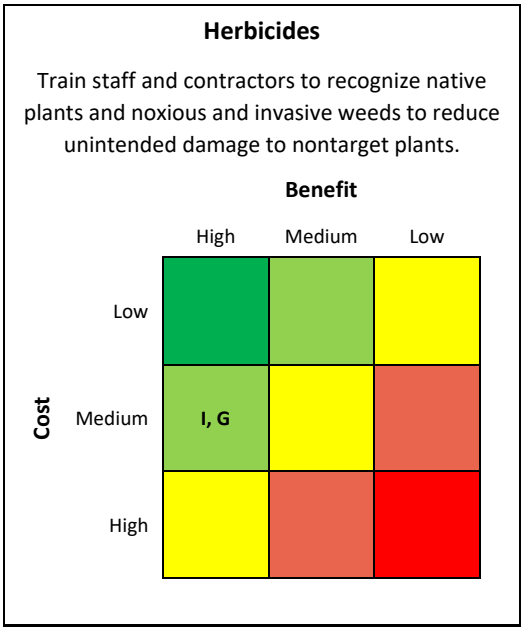
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I= Benefits to imperiled species; G= Benefits to general pollinator community

Herbicides



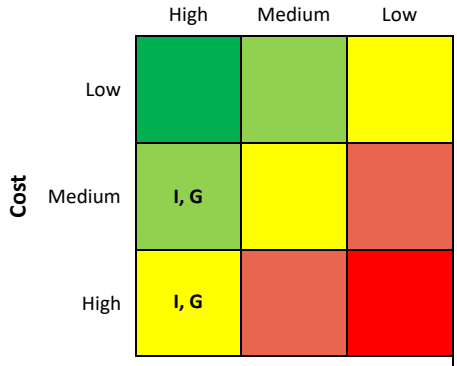


I= Benefits to imperiled species; G= Benefits to general pollinator community

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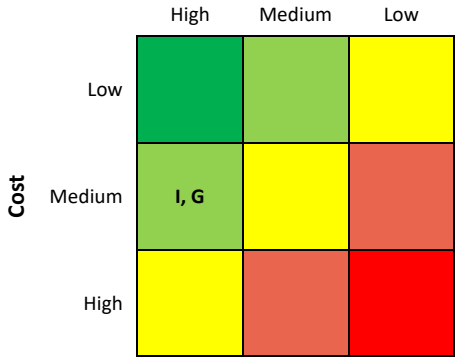
Herbicides

Direct herbicide applications to undesirable plants to avoid harming nontarget species (e.g., spot-treatment applications with a backpack sprayer, targeted applications to cut stems).



Herbicides

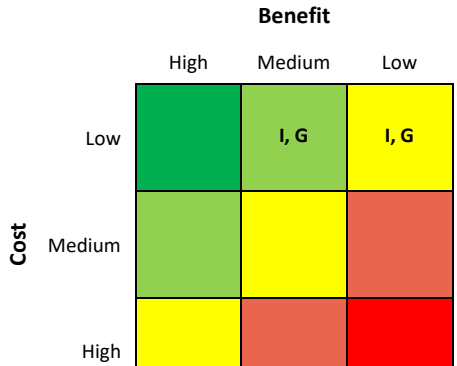
Avoid herbicide sprays when weather conditions increase drift (e.g., avoid wind speeds >15 mph; avoid applications during a temperature inversion).



I= Benefits to imperiled species; G= Benefits to general pollinator community

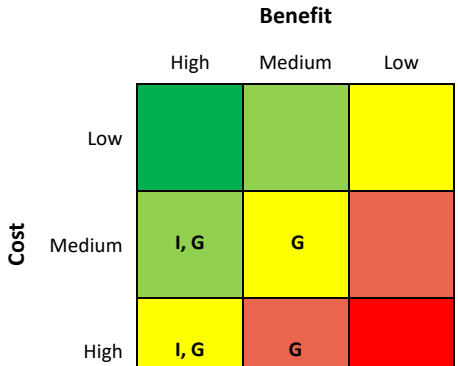
Herbicides

Choose and operate equipment with drift management in mind (e.g., calibrate equipment regularly; choose spray nozzles to reduce drift; on boom sprayers; use the lowest effective pressure and largest droplet size possible).



Herbicides

Avoid broadcast applications of systemic herbicides and herbicides with long residuals to reduce exposure to butterfly and moth caterpillars that can be exposed to residuals by consuming contaminated vegetation.

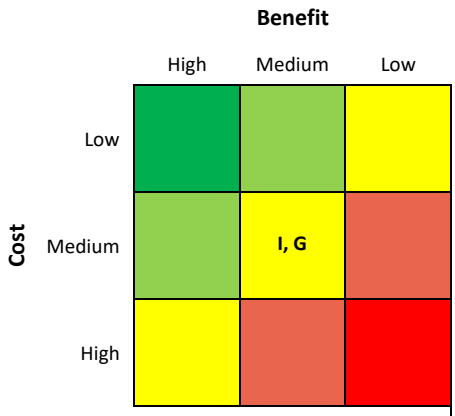


I= Benefits to imperiled species; G= Benefits to general pollinator community

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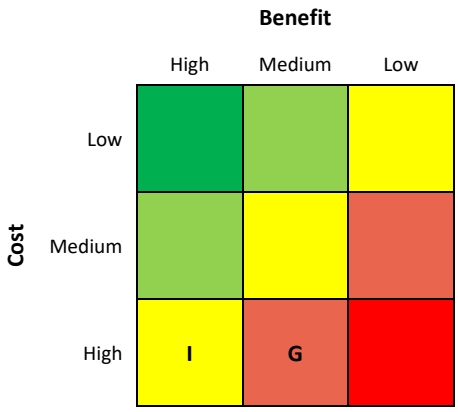
Herbicides

If necessary (e.g., if the seed bank was depleted of desirable species), replant areas that have been treated with herbicides to remove dense infestations of undesirable vegetation with desirable, competitive, low-growing plant species to reduce the need to re-treat the area.



Herbicides

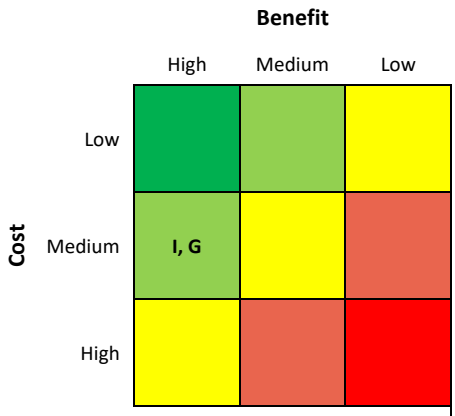
When feasible, hand pull or use another mechanical control strategy if in an area where herbicide use might result in impacts on imperiled species.



I= Benefits to imperiled species; G= Benefits to general pollinator community

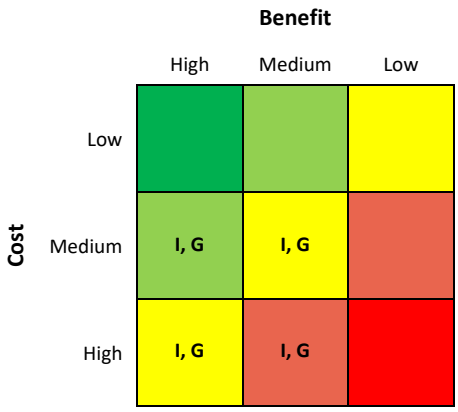
Herbicides

Use selective herbicides whenever possible to reduce damage to nontarget plants.



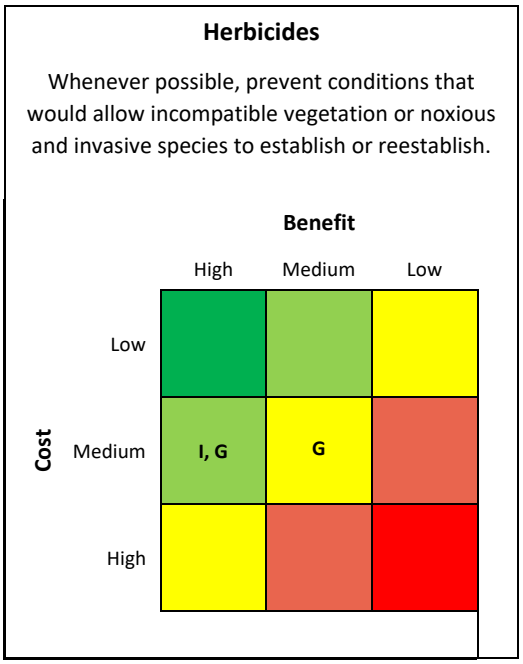
Herbicides

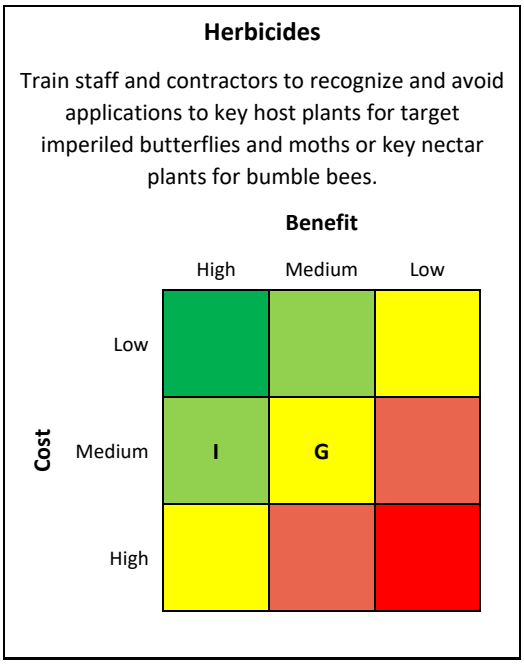
Apply herbicides during plant life stages when weeds are most vulnerable (e.g., before blooming or before going to seed).



I= Benefits to imperiled species; G= Benefits to general pollinator community

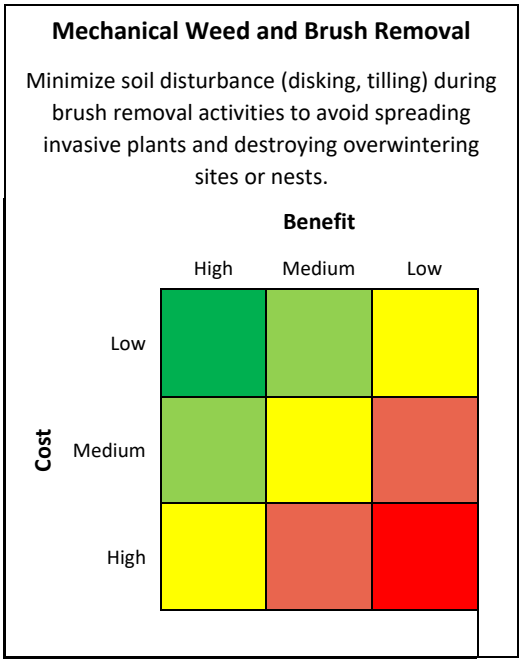
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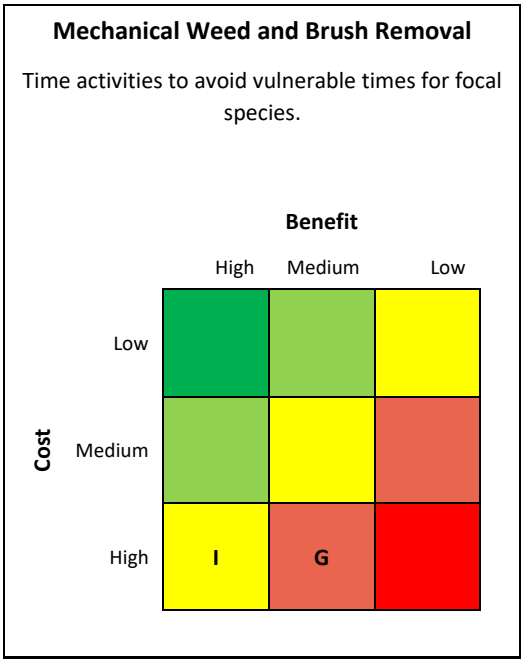




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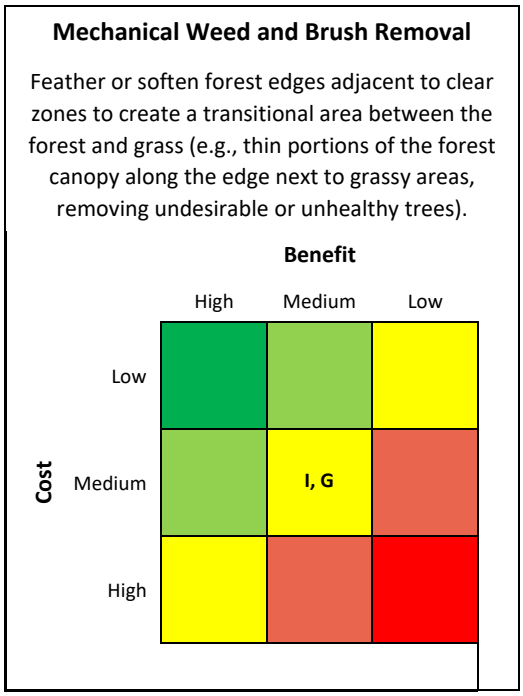
Mechanical Weed and Brush Removal

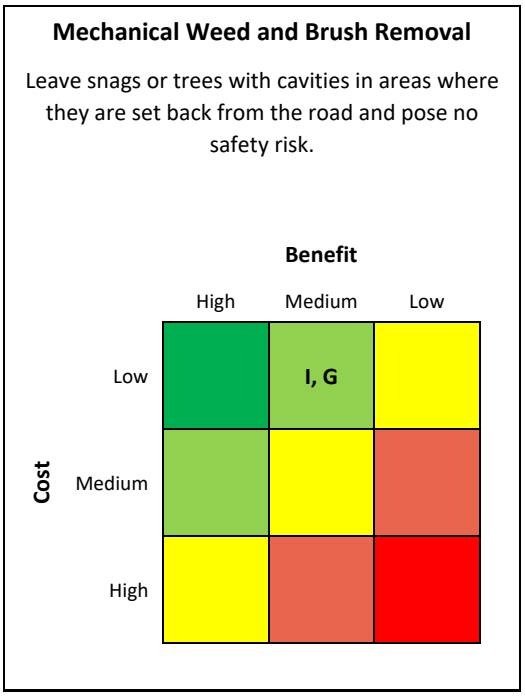




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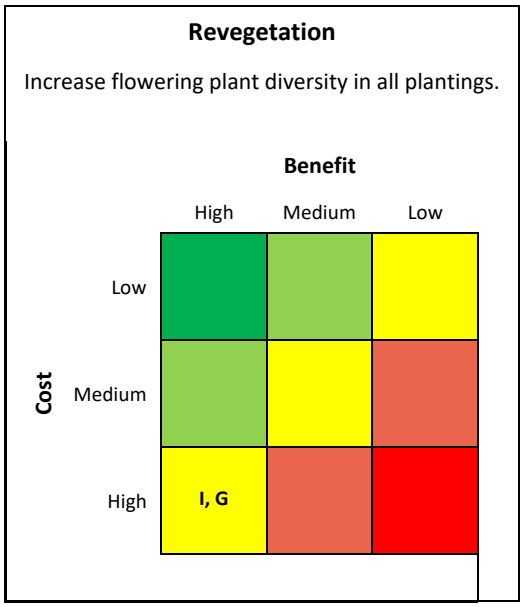
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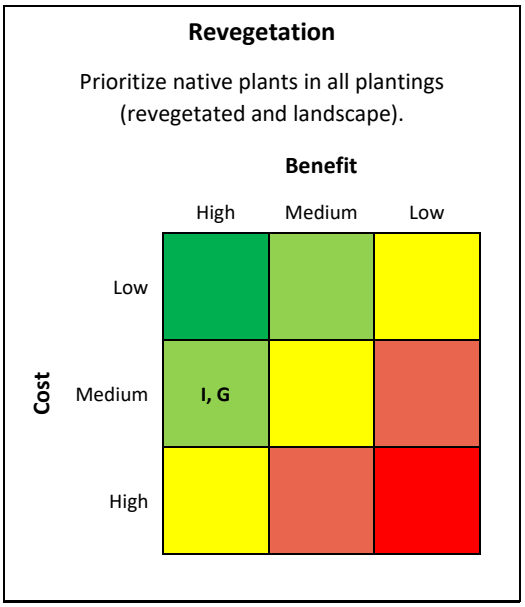




I= Benefits to imperiled species; G= Benefits to general pollinator community

Revegetation



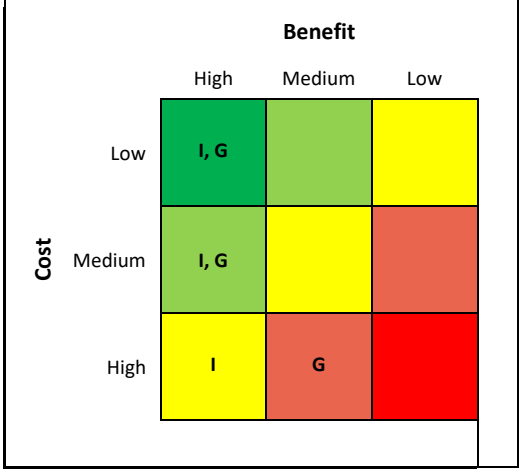


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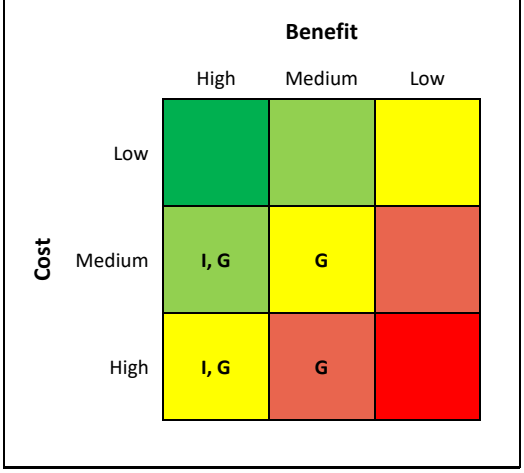
Revegetation

Increase host plants in revegetation plantings.



Revegetation

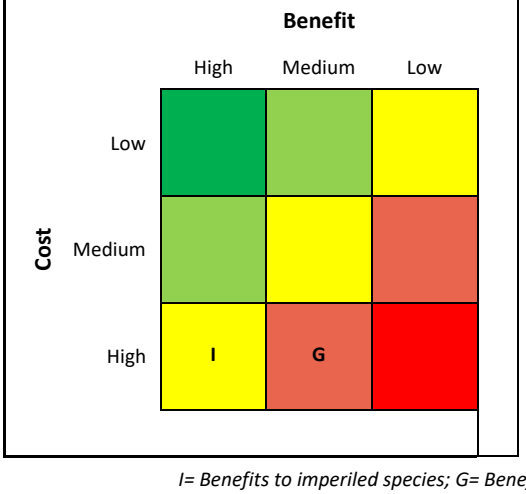
Interseed host plants into existing roadside vegetation.



I= Benefits to imperiled species; G= Benefits to general pollinator community

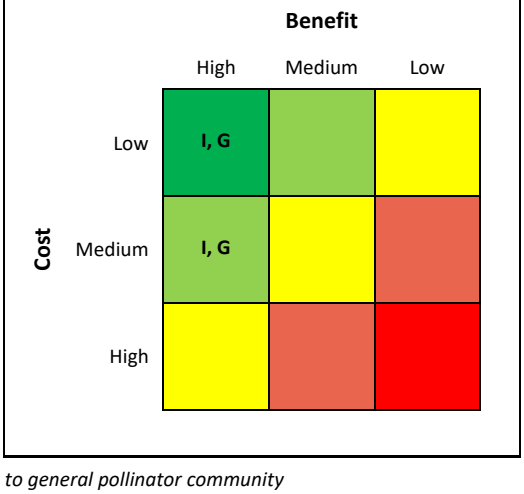
Revegetation

When possible, salvage native plants at construction site for replanting.



Revegetation

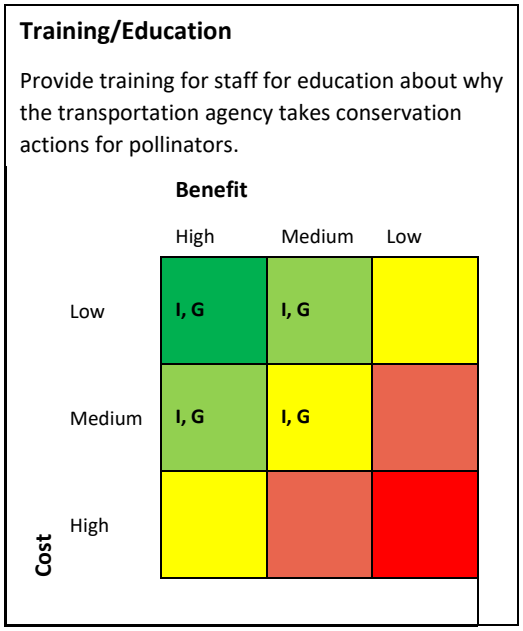
Control weeds to reduce weed competition and allow native seedlings to grow in the first and second years after planting. Prevent weeds from going to seed.



I= Benefits to imperiled species; G= Benefits to general pollinator community

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Training/Education



I= Benefits to imperiled species; G= Benefits to general pollinator community

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Table 10-2. Value of benefits to pollinators of potential conservation actions to be implemented by DOTs.

Conservation actions	Benefits to general pollinator community	Benefits to imperiled species
Mowing		
Avoid mowing imperiled butterfly host plants during butterfly breeding seasons	Medium	High
Adjust mowing height to a minimum height of 8–10 inches in areas with target butterfly host plants or bumble bee colonies in grass thatch if mowing during the growing season	Medium	High
Limit mowing beyond the mown strip in the recovery area to once or less per year	High	High
Aim to mow no more than 1/3–1/2 of an area beyond the mown strip in the recovery area per year (e.g., rotate mowing sections of a roadside)	High	High
Limit mowing beyond the mown strip in the recovery area to no more than twice per year	Medium/High	Medium
Delay mowing as late as possible during the growing season (e.g., mow in autumn), so blooming plants are available throughout the growing season	Medium/High	Medium/High
Clean mowing equipment after use and between sites to limit the spread of invasive weeds	Medium	Medium
Herbicide Use		
Train staff and contractors to recognize and avoid applications to key host plants for target imperiled butterflies and moths or key nectar plants for bumble bees	Medium	High
Avoid use of products that have toxicity to imperiled butterfly and moth species during breeding seasons	Medium/High	High
Hand pull or use another mechanical control strategy if in an area where herbicide use might impact imperiled species, when feasible	Medium	High
Train staff and contractors to recognize native plants as well as noxious and invasive weeds to reduce unintended damage to nontarget plants	High	High
Use selective herbicides whenever possible to reduce damage to nontarget plants	High	High

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Conservation actions	Benefits to general pollinator community	Benefits to imperiled species
Direct herbicide applications to undesirable plants to avoid harming nontarget species (e.g., spot treatment applications with a backpack sprayer, targeted applications to cut stems, etc.)	High	High
Apply herbicides during plant life stages when weeds are most vulnerable (e.g., before blooming or before going to seed)	Low/Medium	Low/Medium
Avoid herbicide sprays when weather conditions increase drift (e.g., avoid wind speeds >15 miles per hour, avoid applications during a temperature inversion)	High	High
Choose and operate equipment with drift management in mind (e.g., choose spray nozzles to reduce drift; on boom sprayers, use the lowest effective pressure and largest droplet size possible)	Low/Medium	Low/Medium
Avoid broadcast applications of systemic herbicides and herbicides with long residuals, thus reducing exposure to butterfly and moth caterpillars that can be exposed to residuals by consuming contaminated vegetation	Medium/High	High
Whenever possible, prevent conditions that would allow incompatible vegetation or noxious and invasive species to establish or reestablish	Medium/High	High
If necessary (e.g., if the seed bank was depleted of desirable species), replant areas that have been treated with herbicides to remove dense infestations of undesirable vegetation with desirable, competitive, low-growing plant species to reduce the need to re-treat the area	Medium	Medium
Mechanical Weed and Brush Removal		
Time activities to avoid vulnerable times of focal species	Medium	High
Feather or soften forest edges adjacent to the mown strip in the recovery area to create a transitional area between the forest and grass (e.g., thin portions of the forest canopy along the edge next to grassy areas, removing undesirable or unhealthy trees)	Medium	Medium
Leave snags or trees with cavities in areas where they are set back from the road and pose no safety risk	Medium	Medium
Minimize soil disturbance (disking, tilling) during brush removal activities to avoid spreading invasive plants and destroying overwintering sites or nests	Medium	Medium

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Conservation actions	Benefits to general pollinator community	Benefits to imperiled species
Revegetation		
Prioritize native plants in all plantings (revegetation and urban landscaping)	High	High
Increase flowering plant diversity in all plantings	High	High
Increase host plants in revegetation plantings	High	High
Control weeds to reduce competition while allowing native seedlings to grow—this is critical in the first and second years after planting—and weeds should also be prevented from going to seed	High	High
Interseed host plants into existing roadside vegetation	Medium/High	High
Weed control prior to planting	High	High
When possible, salvage native plants at the construction site for replanting	Medium	High
Training/Education		
Provide training for staff for education about why conservation actions are taken by the transportation agency for pollinators	Medium/High	Medium/High

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Worksheet for Triple Bottom Line Cost-Benefit Tool

Define	**Describe the project area**
	Describe the landscape context
	Describe the intended outcome
	Define and describe the timeframe for analysis

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Evaluate

	Strength of Factor		
Environmental	**High**	**Medium**	**Low**
Societal	**High**	**Medium**	**Low**
Economic	**High**	**Medium**	**Low**

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Decide	Rationale for Decision:			
		List in order of strength of factors		
		Environmental	Societal	Economic
	High			
	Medium			
	Low			

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Chapter 11 Communication Support

11.1 Introduction

Outreach and communication are important parts of the process when taking action for pollinator conservation. Many of the actions necessary to protect pollinators may involve increased up-front costs, such as using locally or regionally sourced native plants in revegetation projects, or require cultural changes in planning or maintenance activities, such as reduced mowing frequency. Outreach and communication with the public and within your agency are important for building support for such actions. It is important for people to understand why pollinators are important, why pollinator conservation efforts are needed, and how Departments of Transportation (DOTs) can contribute meaningfully to pollinator conservation. This outreach can help improve buy-in from the public as well as the DOT staff members who will carry out this important work. Sharing the story with the community and its leaders about the work your agency is doing to manage roadsides while also supporting pollinators will elevate awareness and build support for your agency and for pollinator conservation.

Outreach to the public can:

- build public support,
- share accomplishments and progress over time,
- educate decision-makers and partners about the impact and reach of your work,
- demonstrate responsible use of resources and funding to the public,
- share practices with other DOTs, and
- attract new organizations and partners for collaboration and outreach.

Internal communication can:

- build internal support for actions that benefit pollinators,
- improve understanding of why particular actions are important for pollinator conservation,
- share accomplishments and progress over time, and
- attract new organizations and partners for collaboration and outreach.

This chapter was created to serve as a communications tool kit. It provides materials to help you communicate your pollinator-related projects, actions, and commitments to department or agency staff members as well as the general public. For guidance and inspiration, examples of what DOTs have already created are also included.

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11.1.1 What is in this Toolkit?

This toolkit contains a variety of resources for communicating with the public and with DOT staff members. These tools include:

- examples of signs, posters, brochures, and websites from many DOTs that can serve as inspiration for your own communications efforts;
- sample social media posts and a calendar of relevant pollinator-related events that you can use in social media outreach with the public;
- *Frequently Asked Questions* about pollinators and roadside habitat, which may be especially helpful for public outreach efforts;
- *Talking Points* about pollinators and roadside habitat, which may be especially helpful for outreach within your DOT; and
- a list of *Top DOT Actions for Pollinators* that can be used to highlight important conservation actions to DOT staff members and decision-makers.

In addition, there are links to a variety of resources to aid in your communications efforts. These include:

- photo libraries of pollinators,
- graphics,
- relevant video sites,
- an editable PowerPoint presentation for use in educating DOT staff members about pollinators and roadside habitat,
- a video for the public about the importance of pollinators and roadside habitat that can be used in public outreach, and
- a video for DOT staff members about the importance of pollinators and roadside habitat that can be used for internal training or communications.

The other chapters in this guide also contain background information that can be useful when responding to media requests for more details or answering questions within your agency or from the general public. For example, detailed information on pollinators and how pollinators use roadsides can be found in Chapter 2.

11.2 Communicating with a General Audience

Communicating with the public is important for building public support for DOTs and their conservation efforts. There are a variety of ways to tell the public about the important work your agency is doing, including signs, publications, and social media outreach. This section provides examples of outreach activities from DOTs around the country, along with additional resources that you can use in your own outreach efforts.

11.2.1 Signage

Signs can be used to indicate to DOT staff members the roadsides with special maintenance instructions or designated areas of concern (Figure 11-1). Signs can also be used to

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showcase to the public an established planting along a roadside or at a highly visible area such as a rest area (Figure 11-2). Signs can also indicate habitat in progress, demonstrating a transportation agency's intentions for a new planting that is not yet fully established. Signs for the public can include project partners and background information regarding a project (Figure 11-3).



Figure 11-1. Oregon DOT uses signs to indicate special management areas so the maintenance staff will know the specific vegetation management needed for that particular site.



Figure 11-2. A simple but effective roadside sign in Kansas indicates a stretch of roadside with native wildflowers.

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Figure 11-3. This educational sign is next to a display garden created by the Missouri DOT at the Missouri State Fairgrounds.

11.2.2 Websites

Some DOTs have created web pages on their websites that specifically address pollinators and pollinator-related issues. These websites can be very useful in educating the public about why pollinators are important and what DOT initiatives are in place to support pollinators. Many of these websites have general information about pollinators and pollinator biology as well as specific information about DOT work that supports pollinators. Such websites are an ideal place to include maps of pollinator habitat work, videos, brochures, or factsheets and other information. Three great examples are:

- Florida DOT: https://www.flawildflowers.org/fdot-wildflower-program-pollinators/
- Virginia DOT: https://www.virginiadot.org/programs/pollinator_habitat_program.asp
- Washington DOT: https://wsdot.wa.gov/construction-planning/protecting-environment/maintaining-vegetation-along-our-highways/protecting-pollinators

11.2.3 License Plates

Several states have specialty license plates that highlight pollinators or native wildflowers (Figure 11-4). The sales of these license plates often go toward supporting additional wildflower plantings or related research and education efforts. Depending on the state, transportation agencies may not be directly involved in license plate designs but can work with outside groups that will promote certain designs.

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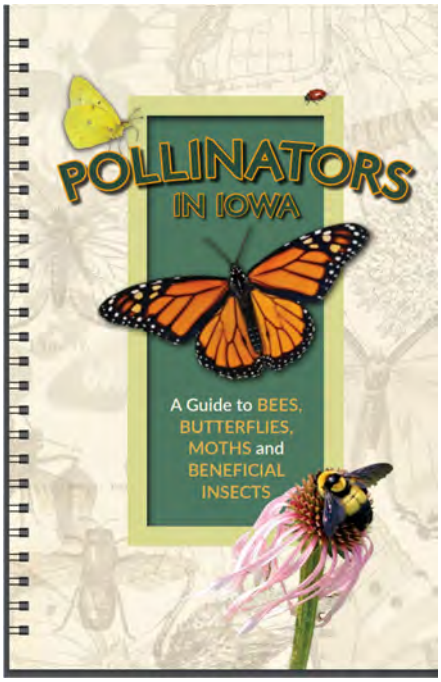


Figure 11-4. Many states offer specialty license plates that highlight pollinators or native wildflowers.

11.2.4 Printed Publications

Many DOTs have created publications to celebrate the local diversity of pollinators and native plants. These publications might provide information on the natural history of pollinators or showcase species of interest (Figure 11-5). Other publications might focus on highlighting and recognizing key native plants that can be found on roadsides in the region (Figure 11-6). Examples include posters, booklets, and factsheets (Figure 11-7). Many of these publications were created in collaboration with government agencies, nonprofit organizations, and others.

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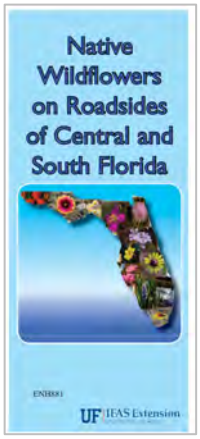




Note: Guides are available on the following websites:

- https://iowadot.gov/lrtf
- https://viz.wspis.com/flipbooks/tdot_pollinator_guide/

Figure 11-5. These guides, created by the Iowa and Tennessee DOTs, highlight pollinators as well as the work that the DOTs are doing to support them.







Note: Brochures are available on the following websites:

- https://edis.ifas.ufl.edu/publication/EP138
- https://dot.nebraska.gov/media/3933/wildflower2009.pdf
- https://ftp.dot.state.tx.us/pub/txdot-info/trv/wildflowers/wildflowers_brochure.pdf

Figure 11-6. Brochures created by the Florida, Nebraska, and Texas DOTs bring attention to native plants found on their respective roadsides and are often available at rest areas and other tourist stopovers.

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Note: Posters are a great tool for sharing information with wide audiences, particularly with schools and land management agencies. Posters are available on the following website: https://iowadot.gov/lrtf

Figure 11-7. These posters were created for the Iowa DOT as part of the Iowa Living Roadway Trust Fund and are available free on request to anyone in the state.

11.2.5 Events

Local or statewide events can be opportunities for outreach to the public on the pollinator-related work of your agency. Creating a booth or display that can be used at events such as a county or state fair that includes pictures of roadside habitat and pollinators will educate the public about these important animals and how your DOT is working to support them. Illinois DOT once set up a state fair display with monarch butterflies in a net cage to grab attention of fair attendees and start conversations about the connections between roadsides and monarchs. Public meetings can be another opportunity to engage with the public directly. When Ohio DOT's Region 6 was considering installing several pollinator plantings in collaboration with partners, they set up a series of public meetings to discuss the plantings. These meetings were instrumental in helping the public understand why Ohio DOT was experimenting with native plants and what to expect as the plantings established (i.e., the plantings would not look colorful during the establishment phase but would begin to bloom a few years after planting).



Oklahoma DOT provided information about roadside pollinator habitat to the public at one of their Tourist Information Centers

Photo Credit: R. Perkins

11.2.6 Demonstration Sites

Demonstration plantings with native plants that are showy and colorful are ideal for smaller spaces such as rest areas or gardens that receive lots of foot traffic from people within the state as well as tourists from elsewhere. Signage or brochures can educate the public as to why a DOT is showcasing these plants. In 2012, Missouri DOT installed a pollinator garden on the Missouri State Fairgrounds. The 60- by 25-foot garden included 17 species of wildflowers that attract pollinators. The garden also had two 4-foot-wide signs that offered information (and photos) regarding some of the known species of bees in Missouri and explanations as to why pollinators are important.

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11.2.7 Social Media

Social media is an effective way to communicate with the public quickly about the work your DOT is doing to support pollinators. Social media can help draw attention to articles, meetings, new publications, interviews, podcasts, or demonstration sites or just generate interest in a DOT.

There are a growing number of social media platforms, but Facebook, Instagram, and Twitter remain the three with the largest reach and the ones that are most commonly used by agencies. These platforms have very different limits on how long posts can be (see Table 11-1) as well as some other differences regarding what can be posted. For Facebook and Twitter, photos or videos are optional in posts; live links can be included (they will display as a highlighted panel). Instagram does not allow live links and does require a photo or video. If you are using multiple platforms, it is worth using the same post on as many platforms as you can for efficiency, despite the different character limits. Facebook and Instagram both allow longer, more descriptive posts compared with Twitter; therefore, it is typical to use the same text for Facebook and Instagram and shorter text for Twitter.

Table 11-1. Quick guide to different social media platforms.

Platform	Ideal for:	Length of Post (character limit)	Hashtag Limit
Facebook	Promoting events, summarizing recent work, live video streams	63,206	2
Instagram	Photos	2,200	30
Twitter	Sharing links, news, marketing	280	2

The following calendar (Table 11-2) lists some events that your communications department may wish to take advantage of when using social media to share the importance of pollinators and the role DOTs play in supporting them.

Table 11-2. Calendar of events relevant for pollinator outreach through social media.

Month	Opportunities for Highlighting Pollinators and Their Habitat
January	Overwintering monarch butterfly counts in the west (Thanksgiving Count, New Year's Count data released)
February	Monarchs start to leave overwintering sites
March	Bumble bee queens are emerging
April	Earth Day/Week and National Native Plant Month; bumble bee queens emerging

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Month	Opportunities for Highlighting Pollinators and Their Habitat
May	Spring wildflowers and their importance for bees; National Wildflower Week, Endangered Species Day (May 19), World Bee Day (May 20)
June	Pollinator Week (third week in June)
July	Moth Week (third week in July)
August	Wildflowers in bloom on roadsides
September	Fall monarch migration
October	Fall monarch migration
November	Overwintering habitat for pollinators
December	Overwintering habitat for pollinators

Sample Social Media Posts

Social media posts that focus on pollinator-related outreach can cover a variety of topics, such as the importance of pollinators; provide photos or information about particular species of pollinators found on roadsides; or discuss the value of native plants and roadside habitat projects.

- "On average, one in three bites of food is dependent on pollinators."
- "Planting native plants along roadsides has many benefits, including providing pollinator habitat, flood prevention, and carbon sequestration."
- "Monarch butterflies use milkweeds along roadsides during the breeding season."
- "Spring is here! Keep an eye out for the first bumble bees of the season."
- "Monarch butterflies in the west are in trouble – our DOT is taking action by avoiding mowing during the breeding season."
- "Migrating monarch butterflies east of the Rocky Mountains may travel as far as 3,000 miles during their lifetime, one of the longest butterfly migrations in the world!"
- "Roadsides can be home for a number of rare plants and animals, including butterflies like the Karner blue butterfly."

11.2.8 Frequently Asked Questions

There are a number of frequently asked questions (FAQs) that the general public may ask of a DOT regarding pollinator conservation and roadsides. The FAQs and suggested answers that follow have been compiled into a Word document that is available for download so that the text can be used as needed in your outreach efforts (available on the National Academies Press website https://nap.nationalacademies.org/.

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Why Are Pollinators Important?

Pollinators are important to human health and well-being. More than 85 percent of flowering plants require an animal, usually an insect, for pollination. One out of every three bites of food is pollinated by an insect, including bees, butterflies, moths, wasps, flies, and beetles. Unfortunately, populations of many insect pollinators are declining. This includes species that were formerly widespread, such as the monarch butterfly. Insect pollinator populations are declining due to a range of factors, including habitat loss, pesticide exposure, and climate change.

How Can My DOT Help Pollinators?

DOTs can help pollinators by creating pollinator habitat along roadsides that includes a diversity of native plants. DOTs can also help pollinators by protecting plant species that are important to pollinators where they occur along roadsides. These include preferred nectar and/or pollen plants as well as butterfly and moth host plants (i.e., the plants that caterpillars eat) of local pollinators.

Do Roadsides Make Good Habitat for Pollinators?

Yes! Roadsides can provide good habitat for pollinators when the habitat contains a variety of native plants that provide food, nesting sites, and places to overwinter. Food for pollinators can mean host plants for butterfly or moth caterpillars as well as flowers, which provide nectar and pollen.

Why Is It Important to Create Pollinator Habitat Along Roadsides?

One of the primary drivers of biodiversity decline for many species, including pollinators, is habitat loss. With more than 10 million acres in the United States, roadsides present a valuable opportunity to increase the amount of habitat available to pollinators. Increasing the amount of habitat available will increase the number of pollinators that can be supported on the landscape, thereby decreasing the risk of extinction. Roadside habitat is also ideally suited to increasing habitat connectivity, making it easier for animals to move among high-quality habitat patches such as nature preserves or other natural areas. Increased habitat connectivity also helps to reduce extinction risks.

Will Pollinator Habitat Affect Driver Safety?

No. Driver safety is a top priority for DOTs. Pollinator habitat can be maintained or planted along roadsides beyond the mown strip in the recovery area so that safety is not compromised.

Won't Pollinators Be Killed by Traffic?

Although some pollinators are killed by traffic, research suggests that creating pollinator habitat along roadsides does not increase the number of pollinators killed. In fact, some research shows that pollinator mortality from traffic is actually lower in places where roadside vegetation has more plant species. Quality habitat on roadsides may reduce the number of pollinators killed by vehicles by providing necessary habitat, thereby reducing the need for pollinators to move elsewhere. In many parts of the country, roadsides are the

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primary sources of habitat; therefore, ensuring that roadsides have native plants that provide the resources pollinators need is highly beneficial. Roadsides can also be very important for increasing habitat connectivity.

Are There Other Advantages to Creating Roadside Habitat for Pollinators?

Creating climate-smart pollinator habitat along roadsides has many additional benefits beyond conservation. Pollinator habitat helps control erosion and reduces runoff, which reduces flooding and improves water quality. Planting a diverse assemblage of native plants can also increase soil health and improve carbon sequestration. In addition, habitat for pollinators can provide habitat for other beneficial insects, such as insect predators that contribute to the control of crop pests.

How Can I Help?

You can help by contacting your representatives at all levels of government and letting them know that you support DOT efforts to increase pollinator habitat along roadsides. In your own communities, you can help pollinators by planting native plants and reducing your use of pesticides, especially insecticides, around your home.

11.3 Communication Within Your DOT

Internal communication efforts can be valuable for building awareness about the importance of pollinators and the strategies that can be used to create and maintain roadside habitat for them. Awareness of the potential of roadsides as habitat for pollinators should be increased within the administration as well as at other levels (Lampinen and Anttila 2021). It can also be helpful to highlight safety, possible cost savings, public engagement, and other benefits of pollinator habitat, such as erosion control and carbon sequestration, as these may increase adoption by decision-makers (Nemec et al. 2021). Internal outreach efforts can also be useful for building enthusiasm and support for such actions among DOT staff members. This is valuable when seeking to make and implement changes successfully. Additional resources are provided here that may be useful in outreach within your DOT: the *FAQs*, *Talking Points* and *Top DOT Actions for Pollinators* are available for download as Word documents so that the text can be used as needed for internal communications (available on the National Academies Press website, https://nap.nationalacademies.org/).

11.3.1 Staff Training

DOTs have identified staff training as a very important component to integrating changes made to maintenance and design plans regarding pollinators. Training helps build internal support and an understanding of new approaches within the agency, from the managerial staff to the crews working on the ground. Topics for training might include:

- basic biological and habitat needs for pollinators,
- roles that roadsides and rights-of-way can play in pollinator conservation,
- current best practices to minimize impacts of vegetation management on pollinators,
- landscape designs with pollinators in mind,

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- recognition of important native plants,
- updated noxious and invasive weed management techniques, and
- monitoring techniques for roadside vegetation and/or pollinators.



Figure 11-8. Agenda for pollinator training for Colorado DOT staff.

If your agency does not have in-house expertise to conduct the training, partner with a local organization or agency that can help share their knowledge. In Iowa, for example, the Tallgrass Prairie Center at the University of Northern Iowa provides native plant identification training to roadside managers as well as staff members from agencies within the state, such as the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service. See Box 11-1 for an example agenda of training for DOT staff members geared toward providing background and information on practices that support pollinators.

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Box 11-1. Roadside Landscape Design and Pollinator Conservation Course

Welcome, Introductions, Overview of the Day

Module 1. The Importance of Pollinator conservation

- Pollination biology
- Pollination economics
- Pollinators in decline

Module 2. Bee and Butterfly Biology

- Pollinator recognition
- Pollinator ecology
- Identifying pollinator habitat

Module 3. Pollinator-Friendly Roadside Management

- The value of habitat
- Importance of roadsides to pollinators
- Conducting roadside vegetation inventories
- Adapting mowing practices
- Use of herbicides to reduce risks to pollinators
- Discussion about the potential for adjusting practices regionally

Module 4. Roadside Design and Planning Considerations

- Plant selection
- Sourcing plant material
- Prioritizing new locations
- Brainstorming – opportunities and constraints
- Coordinating with maintenance

Module 5. Enhancing Establishment of Roadside Vegetation

- Site preparation
- Planting techniques for woody and herbaceous plants

Module 6. Communicating with the Public about Pollinators

- Signage, messaging, social media
- Future research needs

Module 7. Additional Resources and wrap up

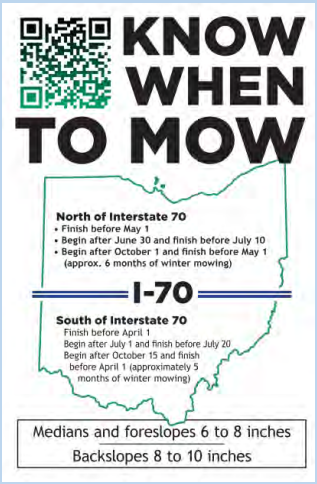
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11.3.2 Partnerships

State or federal agencies, as well as local, regional, or national organizations, can be excellent partners for outreach to the general public as well as internal communications (see Box 11-2). A land management agency or organization, for example, could offer new cutting-edge weed management techniques to the maintenance staff or organize a regional workshop to help share collective knowledge. Similarly, native plant conservation or natural heritage organizations could provide feedback to the design staff on native plants that are unfamiliar to them. Other agencies or organizations could also be partners in communications with the public when there are common goals. The Audubon Society and Pheasants Forever/Quail Forever are good partners for sharing the advantages of reduced mowing strategies involving songbirds and game birds. Possible collaborations could include events like field days or garden visits, sharing costs on plant materials or signage for habitat installations, or just spreading the word about DOT practices that support pollinators and biodiversity.

Box 11-2. Communicating Timing of Mowing Within an Agency

The Ohio Department of Transportation came up with a creative solution to help maintenance staff know when to mow in different parts of the state. They created window clings to be placed in the cabs of mowers that give basic guidelines on mowing height and timing, as well as a QR code that staff can scan to get more information. This type of creative communications solutions can help keep staff informed about best practices for maintaining pollinator habitat.



Partnerships with other agencies or organizations can help fill knowledge gaps within your agency. A transportation department that has little experience with establishing native plants could partner with the USDA Natural Resources Conservation Service, a habitat organization such as Pheasants Forever/Quail Forever, or another group that installs native vegetation and provides guidance on habitat management. Organizations with a specialized focus on pollinators could provide background information for a DOT or provide tailored guidance or staff training. Table 11-3 has examples of organizations or groups that could be partners in pollinator conservation efforts.

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Table 11-3. Potential partners in communicating with the public regarding revegetation projects or training and educational collaborations on vegetation management techniques.

Potential Partner Organization/Agency	Description
State and Federal Agencies	
State departments of natural resources	Protect air, water, and soil; their roles sometimes also encompass fishing and hunting as well as environmental conservation and natural heritage
State fish and game departments	Involved in stewardship of parks, fish, game, and state outdoor recreational resources; some also track species of concern
U.S. Fish and Wildlife Service	Federal agency that protects endangered species and manages fisheries, refuges, and migratory birds
USDA Natural Resources Conservation Service	Federal agency that provides technical support to producers and landowners as well as financial support for voluntary conservation actions on working lands
USDA Forest Service	Federal agency that manages national forests and grasslands
Bureau of Land Management	Federal agency that manages public lands for recreation, grazing, or energy extraction; also manages national monuments and wilderness areas
National Park Service	Federal agency that manages national parks, some national monuments, and other land that has historic or conservation value
State departments of agriculture	State departments of agriculture may be the primary agencies for managing insects in some states
Military bases	Military bases often have conservation and management mandates that overlap with those of DOTs
Working Groups	
Rights-of-Way as Habitat Working Group	A collaborative group of partners from the energy and transportation sectors: http://rightofway.erc.uic.edu/
Western Association of Fish and Wildlife Agencies	Regional working group in the western states that has taken a leadership role in monarch conservation

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Potential Partner Organization/Agency	Description
Midwest Association of Fish and Wildlife Agencies	Regional working group in the Midwest that has taken a leadership role in monarch conservation
Non-Government Organizations with Expertise Pertaining to Outreach about Natural Heritage	
State master naturalists	Groups that provide naturalist training for volunteers who are eager to make a difference
State natural heritage foundations or commissions	Organizations devoted to protecting land and wildlife
State biological surveys	Some states have divisions that are devoted to monitoring biological diversity; these can provide detailed information about the locations of habitat or particularly important diverse lands
Non-Government Organizations with Expertise Pertaining to Native Plants	
Native plant societies	State or local groups that focus on native plants, restoration, and ecosystem health: https://nanps.org/native-plant-societies/
Wild Ones	National nonprofit organization with local chapters that focus on native plants and landscaping: https://wildones.org/
Natural Areas Association	National nonprofit organization that provides support to a community of natural area managers: https://naturalareas.org/
Non-Government Organizations with Expertise Pertaining to Native Plant Establishment	
The Nature Conservancy	Nonprofit that focuses on protecting and restoring land and water, often through partnerships: https://www.nature.org/en-us/
Pheasants Forever/Quail Forever	Nonprofit organizations that focus on creating and maintaining habitat for game birds: https://www.pheasantsforever.org/ https://quailforever.org/
Xerces Society for Invertebrate Conservation	Nonprofit that works to support invertebrates and the important roles they play; has significant expertise in habitat establishment and restoration to support pollinators: https://xerces.org/

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Potential Partner Organization/Agency	Description
Grassland Restoration Network	An association of projects with staff members who work on restoration in a variety of grassland ecosystems. They share knowledge and information about grassland restoration.
Non-Government Organizations with Expertise on Pollinators	
Xerces Society for Invertebrate Conservation	Nonprofit that works to support invertebrates and the important roles they play; has the largest pollinator conservation team in the world and many relevant resources: https://xerces.org/
Pollinator Partnership	Nonprofit known for spearheading Pollinator Week: https://www.pollinator.org/
Monarch Joint Venture	A partnership of federal and state agencies, nongovernmental organizations, businesses, and academic programs that work to protect monarchs: https://monarchjointventure.org/
Non-Government Organizations with Expertise Pertaining to Small Wildlife Species that Use Roadside Habitat	
National and state Audubon Society chapters	Nonprofit organization that works to protect birds: https://www.audubon.org/
Local Wildlife Society chapters	Nonprofit organization that provides support for wildlife professionals; local chapters have a regional focus: https://wildlife.org/

In addition to national or statewide agencies or organizations, local groups that have a wide reach may be potential collaborators. Examples include the People and Pollinators Action Network, based in Boulder, Colorado; the Pollinator Conservation Alliance, based in Buffalo, New York; and the Pollinator Friendly Alliance, based in Stillwater, Minnesota.

Fostering Pride for Your Work within Your Agency

Creating a sense of pride in the work your agency is doing to protect pollinators is a great way to build support for continuing such work. At the 2022 Pollinator Habitat Conservation along Roadways Peer Exchange Meeting, many DOT staff members indicated that having leadership on board was crucial to implementing conservation practices for pollinators. Fostering a sense of agency pride in pollinator work is one way to get leadership support for pollinator conservation. Scott Lucas, assistant administrator with the Ohio DOT Office of Maintenance Operations, noted the importance of identifying the priorities of senior leadership in order to help engage them.

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Some steps that Scott Lucas suggests for success include:

- Know what senior leadership is interested in and find out what motivates them. Some possibilities include eco-credits, financial gain, recognition, and aesthetics.
- What motivates the staff? Find something that many staff members care about and connect it to pollinators. It might be a shared love of nature, recreational activities like hunting or fishing, or interest in our food supply. Find out what motivates people in your department and show how creating pollinator habitat connects to this shared interest.
- Have a clear goal for your group.
- Do not exclude people (e.g., do not make it political).
- Give a shout-out to partners and recognize them whenever possible.
- Apply for awards related to exemplary ecosystem management or roadside stewardship.
- Do outreach events with staff members and the public to showcase the work you have done.

11.3.3 Talking Points

This collection of talking points, also available for download as a Word document, may be useful in communications with the public or with DOT staff members. These talking points can help explain to decision-makers in your department the importance of pollinators and the types of actions DOTs can take to protect pollinators.

Pollinators Are Important to Human Health and Well-being

More than 85 percent of flowering plants require an animal, usually an insect, to move pollen between flowers for reproduction. Because they provide this important service, pollinators are vital to our natural areas as well as human health and well-being. Insect pollinators are important for many crops. It has been estimated that about one in three bites of food that humans eat every day can be traced back to pollinators.

As habitat within rural landscapes decreased, agricultural crops became more dependent on pollination from managed honey bees. The bees, which are native to Europe, can be brought in during bloom and moved between crops throughout the growing season. Studies show that wild native bees contribute substantially to crop pollination as well. Furthermore, pollination improves when native bees are present compared to periods when only honey bees are present (Greenleaf and Kremen 2006; Garibaldi et al. 2011; Brittain et al. 2013).

Many Species of Pollinators Are Declining and in Need of Conservation Actions

Many species of insects are declining around the world, including a number of pollinators. Pollinators in the United States are no exception. For example, long-term studies in both Ohio and California have documented declines in butterfly abundance and richness (Forister et al. 2011; Wepprich et al. 2019). A recent study of butterflies in the western

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United States looked at long-term data as well as community science data and found a long-term decline in butterfly abundance amounting to 1.6 percent per year over the last 40 years (Forister et al. 2021). This decline includes previously abundant and widespread species like monarch butterfly. Native bees are also showing declines, with 27 percent of mason bees and 50 percent of leafcutter bees at risk of extinction. Similarly, 28 percent of bumble bee species in the United States and Canada are imperiled, with several on the brink of extinction.

Roadsides Can Provide Valuable Habitat for Pollinators

State DOTs manage substantial amounts of land and associated natural resources across North America, including more than 10 million acres in the United States (Forman et al. 2003). This acreage holds the potential to create a network of habitats that will be able to support pollinators across urban and rural landscapes. Pollinator diversity can be high in roadsides, areas where communities include a significant portion of the species found in the region (Ries et al. 2001; Hopwood 2008; Noordijk et al. 2009). Furthermore, roadsides can be home to rare species as well as common species (Munguira and Thomas 1992; Ries et al. 2001). Roadsides provide pollinators with food as well as breeding or nesting opportunities and can increase habitat connectivity.

Creating and Managing Roadside Habitat for Pollinators Will Not Compromise Safety

Sight lines can be maintained on roadsides with native plants through careful plant selection. Landscape designers can use the palatability of plants to large mammals to inform plant selections. In addition, reduced mowing (of the entire roadside) does not appear to influence the number of deer/vehicle collisions (Mastro et al. 2008; Barnum and Alt 2013; Guyton et al. 2014). Deer may prefer roadsides that are mowed more frequently because mowing can increase the palatability of some plants; deer often prefer new growth to older vegetation. Regular mowing of the strip of vegetation adjacent to the pavement (i.e., recovery area, also known as the clear zone), while letting the rest of the roadside grow to a reasonable height, can help maintain driver visibility and prevent deer/vehicle collisions.

Creating and Managing Pollinator Habitat Along Roadsides Has Many Benefits for DOTs

Creating climate-smart pollinator habitat along roadsides has many benefits beyond pollinator conservation. Pollinator habitat provides benefits such as erosion control and reductions in runoff. This reduces flooding, which is critical in areas where increased flooding is projected.

Pollinator habitat can also help mitigate the climate crisis. Creating diverse plantings along roadsides increases soil health, which, in turn, increases carbon sequestration. Studies of grassland soils show that increasing plant diversity increases the amount of carbon stored by the soils (Lange et al. 2015; Chen et al. 2018; Yang et al. 2019). Thus, diverse plantings created for pollinator conservation also help mitigate climate change by increasing carbon sequestration within those habitats.

Natural climate solutions encourage the restoration and protection of natural habitats as a means of combating the climate crisis. Harrison (2014) measured the value of carbon

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sequestration within roadside habitat in Florida at $39 million per year; that number could increase with the sale of carbon credits. Other more recent studies suggest that natural climate solutions alone could provide one-third of the climate mitigation required to keep warming below 2°C (3.6°F) (Griscom et al. 2017; Fargione et al. 2018). DOTs are in a position to make real contributions to natural climate solutions through the creation of roadside pollinator habitat.

Some Actions that Promote Pollinator Habitat May Save Money Compared to Current Practices

Some practices, such as reduced mowing, can provide cost savings. Other practices that may have higher up-front costs, such as using native plants in revegetation projects, may have lower long-term costs through the savings provided by increased weed suppression and increased resilience to climate change.

Native Plants Are Better for Pollinators

Native plants are central to healthy, functional ecosystems. They support soil health, improve water quality, sequester carbon, and are habitat for wildlife. Native plants support more pollinators and more wildlife than do nonnative plants (Narango et al. 2017; Williams et al. 2011). In addition to supporting more caterpillars, native plants are more attractive as sources of pollen and nectar for pollinators than nonnative plants and support more species and more individuals (Williams et al. 2011; Morandin and Kremen 2013).

Native grasses and flowers are best adapted to local growing conditions, require minimal inputs for establishment, and are able to tolerate drought or heat, which will become more common in many regions. In addition, some native species are able to tolerate the poor growing conditions found on roadsides (Harper-Lore and Wilson 2000; O'Dell et al. 2007).

Although the initial costs associated with establishing native plant material are relatively high, particularly in plans that include a higher density and diversity of flowering plants or specialized species, native plants are often more cost effective in the long term. Once established, the plantings persist over time and require less mowing as well as fewer herbicides and other weed control measures, thereby reducing long-term maintenance efforts and cost (Berger 2005). In contrast, controlling the growth and spread of invasive plants along roadsides through repeated mowing and rigorous herbicide use is very expensive (Westbrooks 1998).

Noxious and Invasive Plants in Roadsides Negatively Affect Pollinators

Noxious and invasive plants on roadsides can greatly reduce the diversity and abundance of host plants and flowering plants by outcompeting them for water, light, space, and nutrients, thereby limiting the reproductive potential of pollinators. Flowering weeds do confer some benefits to pollinators (e.g., Canada thistle provides nectar and pollen), but these benefits do not outweigh the ecological costs of keeping those plants in the landscape.

Vegetation Management Is Important for Pollinators

Disturbance to vegetation (e.g., mowing, haying), as well as the use of herbicides, can result in direct or indirect harm to pollinators. However, in many ecosystems, periodic

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disturbance is important for maintaining plant diversity. For example, periodic disturbances in grasslands can prevent encroachment by woody plants. The frequency of such activities, as well as the scale at which they are implemented, influences their impacts on pollinators. Overall, negative pollinator response to vegetation management is usually temporary (aside from a poorly timed event that affects a population of an imperiled species that has no other populations nearby).

Herbicides Can Be Used in Ways that Reduce Harm to Pollinators

Widespread use of herbicides can have negative effects on pollinators by reducing important food plants. Roadside managers and other vegetation managers can reduce the impacts of herbicide use on pollinators by:

- using herbicides within an integrated approach that incorporates a range of methods to prevent or manage weeds and non-compatible vegetation,
- targeting nonselective broadcast applications that can damage host or nectar plants,
- using herbicides as efficiently and effectively as possible,
- reducing off-site movement of herbicides, and
- limiting direct exposure of pollinators to herbicides when possible.

Collisions with Vehicles Are Not a Major Source of Mortality for Most Pollinators

Hundreds of thousands of pollinators are killed by vehicles on roads (McKenna et al. 2001; Munoz et al. 2015), but research suggests that the numbers appear to be a small proportion of the overall populations using roadsides. Mortality rates of butterflies on roads, for example, range from 0.6 to a maximum of 10 percent of the population within the roadside, depending on the species, rates that are lower than numbers killed by natural enemies like predators or parasitoids (Munguira and Thomas 1992; Zielin et al. 2010). However, road mortality can be higher for some species of pollinators than others (Ries et al. 2001). For example, butterflies appear to be one of the more common groups of insects killed by cars (Rao and Girish 2007). Some butterflies that are strong fliers have the ability to dodge vehicles, while other species that are less able fliers are more susceptible (Munguira and Thomas 1992; Zielin et al. 2010). Migratory species like monarch butterflies may have higher rates of mortality due to vehicle collisions; during the fall migration, the eastern population of monarchs encounter hotspots of mortality while crossing a few highways (Kantola et al. 2019). The available science indicates that the benefits of supporting pollinators on roadsides outweighs any costs (Philips et al. 2020).

Roadsides with High-quality Habitat Do Not Increase the Number of Pollinators Killed by Vehicles

Although pollinators and other wildlife are going to be killed by vehicles as long as roads exist, there are ways to reduce pollinator road mortality. Reducing roadside mowing can reduce butterfly mortality (Skorka et al. 2013), as can enhancing the diversity and abundance of wildflowers on roadsides (Munguira and Thomas 1992; Ries et al. 2001; Skorka et al. 2013). Current research suggests that roadsides with high-quality habitat

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actually reduce pollinator mortality rather than lure pollinators to their death by vehicle. This is because the pollinators stay on the roadsides rather than going off in search of flowers for nectar or pollen.

Pollinator Conservation Has Public Relations Benefits

Pollinator conservation is very popular with the public. Many people intuitively understand the importance of pollinators and are motivated to help protect these important animals. In addition to concern for pollinators generally, many people feel deep connections to individual pollinator species, such as the monarch butterfly. Talking about DOT work to protect pollinators and native plants can increase public support for DOTs and inspire the public to engage in pollinator conservation as well.

Additional roadside and pollinator FAQ documents can be found at:

- https://monarchjointventure.org/mjvprograms/science/roadsidehabitat/frequently-asked-questions-monarchs-and-roadsides
- https://xerces.org/publications/fact-sheets/roadsides-as-habitat-for-pollinators-frequently-asked-questions

11.3.4 Top DOT Actions for Pollinators

The list below can be useful for communicating within your department or agency and highlighting some of the most important actions that DOTs can take to contribute to pollinator conservation.

- Reduce mowing frequency beyond the mown strip in the recovery area so flowering plants have a chance to bloom and support pollinators.
- Use native plants in revegetation projects because native plants support more pollinators than nonnative plants.
- Protect butterfly host plants, especially the host plants of imperiled butterfly species.
- Target herbicide use so that nontarget plants, including those that are host plants or that provide nectar and pollen to pollinators, are not affected.
- Time maintenance activities to avoid key breeding periods for imperiled species.
- Control noxious and invasive weeds.
- Increase diversity of native plants in revegetation areas, which will make the habitat more resilient and able to support a diversity of pollinators.
- Prioritize revegetation projects along roadsides where they will be most beneficial for pollinators, such as areas near natural areas or near populations of imperiled pollinators.
- Inform the public about the work you are doing to protect pollinators.
- Increase the mowing height to 8 to 10 inches to leave vegetation for pollinators to use.
- Use adaptive management for managing roadside vegetation; learn from what is working and what needs tweaking.

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- Experiment with vegetation management techniques; learn from local land managers and peers in surrounding states.
- Provide training for staff members so they stay up to speed on new management techniques and plant identification and understand how these measures fit into the goals of the DOT and why they are important.
- Communicate early with native plant vendors so that they can accommodate your needs, such as growing out any plant material needed for your projects.
- Control weeds during construction, before planting, and during revegetation establishment.
- Design staff need to coordinate with maintenance staff about future maintenance needed for pollinator habitat revegetation projects.

11.4 Communication Resources

This section contains links to resources that may be useful to your communications efforts.

11.4.1 Photo Library

The Xerces Society has made photos of roadside habitat as well as photos of pollinators, including butterflies, bees, and monarchs, available for DOTs to use in outreach efforts. The photo library is available on the National Academies Press website (https://nap.nationalacademies.org/).

11.4.2 Graphics

Graphics can be a powerful tool for communicating with the public. Graphics can make complicated ideas or processes easier to understand by using visual representations. Consider asking your communications department to create some graphics about the importance of pollinators and native plants found along roadsides in your state for use in outreach materials and social media posts. Below are some additional graphics that may be useful in communicating with the public.

- **Xerces Graphics**. Xerces has created several relevant graphics, including graphics on the importance of pollinators, the many benefits of roadside habitat, and the linkage between plant diversity and the diversity of pollinators and other wildlife. These graphics can be used in DOT communications efforts and can be accessed here: https://xerces.org/pollinator-conservation/roadsides/benefits-roadside-pollinator-habitat and here: https://xerces.org/pollinator-conservation/roadsides/pollinators-keystone-species.
- **Monarch Life Cycle.** This graphic shows the life cycle of the monarch butterfly and could be used in educational materials about these iconic animals. This graphic was created by the Xerces Society and the Monarch Joint Venture 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. This graphic is available on the National Academies Press website: https://nap.nationalacademies.org/.

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11.4.3 Videos

The Pollinator Habitat Conservation along Roadways video for use in outreach with the public is available on the National Academies Press website (https://nap.nationalacademies.org/). The Pollinator Habitat Conservation along Roadways video for use internally within your transportation agency is available on the National Academies Press website (https://nap.nationalacademies.org/). Videos from other organizations that may be shared to raise awareness of pollinators and the importance of restoring pollinator habitat include:

- the Xerces Society YouTube channel:

  https://www.youtube.com/channel/UCAiPLPJuySOgn6CbjkOxqLQ;
- U.S. Fish and Wildlife Service YouTube channel (has several videos on pollinators): https://www.youtube.com/c/usfws/search?query=pollinator; and
- a webinar series on monarch butterfly biology and conservation, organized by the U.S. Fish and Wildlife Service and the Monarch Joint Venture: https://nctc.fws.gov/topic/online-training/webinars/monarch-conservation.html.

Videos about transportation agencies and their work with pollinator habitat include:

- Center for Transportation Studies, University of Minnesota:

  https://www.youtube.com/watch?v=DdDD0hYUkPo;
- Nebraska Department of Transportation:

  https://www.youtube.com/watch?v=TMHB3pOafjs; and
- Oklahoma Gardening: https://www.youtube.com/watch?v=OZz9keOMW3A.

11.4.4 Editable Presentation

A PowerPoint file with regional guidance is available on the National Academies Press website (https://nap.nationalacademies.org/) and can be adapted to give a presentation within your organization.

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11.5 Case Studies

11.5.1 Volunteers Help Grow the Colorado Pollinator Highway

Recognizing the role that roadsides play in supporting pollinators, the Colorado State Legislature unanimously passed legislation in 2017 that established Interstate 76 as the Colorado Pollinator Highway. The Colorado DOT then launched a pilot project along Interstate 76 near Julesburg, Colorado, with goals to establish native pollinator plants along rights-of-way, improve weed management practices, and increase public awareness of pollinator habitat and connectivity. The Julesburg area was selected for the pilot project because of its proximity to the Nebraska/Colorado state line. The Colorado Welcome Center was an ideal place for the public to learn more about pollinator conservation efforts. Because of the focus on pollinators, Colorado DOT partnered with a number of organizations, including the People and Pollinators Action Network, Butterfly Pavilion, Loveland Initiative for Monarch Butterflies, Colorado Native Plant Society, Denver Botanical Garden, Pheasants Forever, Xerces Society, National Resources Conservation Service, and several native plant seed companies based in Colorado. Partners offered technical assistance, recruited volunteers, or donated seed or equipment. In the fall of 2018, nearly 50 volunteers planted more than 4 acres of roadside pollinator habitat safely. The project has since sparked interest in collecting native seed on roadsides, monitoring habitat and pollinators, identifying appropriate spot treatments, and conducting vegetation inventories in the future.



Colorado DOT worked with a large group of volunteers to help create pollinator habitat along Interstate 76.

Photo Credit: Jason Roth/CDOT

11.5.2 Communities Collect Milkweeds in Ohio

The Ohio DOT is one of many state agencies and organizations that compose the Ohio Pollinator Habitat Initiative (OPHI). Through OPHI, Ohio DOT has engaged with communities to connect roadsides with pollinator conservation. One effort involved recruiting volunteers throughout the state to collect milkweed seed pods. Volunteers dropped off pods at their local soil and water conservation office, which were then taken to participating Ohio Department of Rehabilitation and Correction facilities. Inmates would remove the milkweed floss from the seeds within the pods. Seeds were then packaged for future distribution at outreach events or planted and grown out in plugs that were planted by Ohio DOT at various sites.

11.5.3 Highway Sponsorships in Minnesota

Minnesota DOT acquired land in the early 1970s as a possible site for a new highway rest area. However, the rest area was never built. Some of the land was instead used for staging during construction on the nearby State Route 95. Included in the parcel of land owned by Minnesota DOT was a 4-acre prairie on a steep bluff known as Blueberry Hill. For several decades, Minnesota DOT granted volunteers from The Prairie Enthusiasts, a nonprofit organization, access to the land to conduct land management actions. Volunteers

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collectively spent thousands of hours controlling invasive plants and managing the site for biodiversity. Blueberry Hill is also home to the endangered rusty-patched bumble bee. In 2021, Minnesota DOT proposed that the group become part of the agency's Highway Sponsorship Program, authorized by state law in 2017. The program allows "businesses, civic groups, and individuals to support the enhancement and maintenance of interstates as well as U.S. and Minnesota highway roadsides." Minnesota DOT has developed a number of highway sponsorship programs with partners throughout the state. The Prairie Enthusiasts continue to be stewards of Blueberry Hill and the species it harbors.

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Chapter 12 Conclusion

A diverse community of pollinators is important for sustaining wild plant communities and the wildlife that depends on those plants. This diversity is also critical for crop pollination and production of the many foods that provide crucial nutrients for human wellbeing. As more and more species of pollinators are in decline in the United States and worldwide, strategies to manage existing habitat and create additional habitat are needed to ameliorate those declines. Roadsides, which extend across landscapes, are an opportunity for pollinator habitat, providing pollinators with food, shelter, and connectivity to other patches of habitat. Departments of Transportation (DOTs) can make a difference for imperiled pollinators by managing existing roadside vegetation and designing new revegetation plantings with their habitat needs in mind, and they can do so in compliance with the Endangered Species Act so there are regulatory assurances if a species becomes listed.



Roadsides provide a safe driving environment and so much more.

Photo Credit: Luis Colon/Arizona DOT

Highlighting the work that DOTs do for pollinators can generate public support for the agency. Pollinators are becoming more and more visible to the public, and the public views them favorably. People are willing to donate time to conduct bumble bee surveys, for example, or conduct outreach to kids. Additionally, U.S. households valued monarchs at up to $6 billion, levels similar to many endangered vertebrate species, according to survey findings. Actions to support pollinators are popular with the general public.

Beyond their value to pollinators, roadsides managed for diverse plant communities provide a wide range of ecological services in urban, agricultural, and natural landscapes, including supporting biodiversity, storing carbon, and filtering air and water. They aid driver safety by reducing monotony and keeping drivers more alert. They also support cultural services such as health and aesthetic benefits by providing access to nature and showcasing unique regional beauty. Roadsides are also an opportunity to mitigate the negative ecological effects of roads.

How DOTs manage their roadsides influences the surrounding lands, but their reach can also extend further, to local and regional businesses and the adoption of sustainable maintenance and revegetation practices. The scale at which DOTs work means that they heavily influence associated industries and can help drive the markets and therefore the availability and affordability of things like native plant materials and wildlife-friendly erosion blankets. Therefore, roadsides can be assets to DOTs, to states, to pollinators, and to ecosystems as DOTs maintain them as ecologically valuable components of the landscape.

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Acronyms and Abbreviations

Term	Definition
Btk	*Bacillus thuringiensis* var. *kurstaki*
CCA	Candidate Conservation Agreement
CCAA	Candidate Conservation Agreement with Assurances
CFR	Code of Federal Regulations
CO_2	carbon dioxide
DOT	department of transportation
EA	environmental assessment
EIS	environmental impact statement
ESA	Endangered Species Act
FAQs	frequently asked questions
FAST	Fixing America's Surface Transportation
FHWA	Federal Highway Administration
HCP	Habitat Conservation Plan
IPCC	Intergovernmental Panel on Climate Change
IRVM	Integrated Roadside Vegetation Management
IUCN	International Union for Conservation of Nature
IVM	Integrated Vegetation Management
MSHCP	Multi-Species Habitat Conservation Plan
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NYSDOT	New York State Department of Transportation
OFWO	Oregon Fish and Wildlife Office
OPHI	Ohio Pollinator Habitat Initiative
PCA	Prelisting Conservation Agreement
RCA	Riverside County Regional Conservation Authority
RCS	Recovery Crediting System
ROW	right-of-way
SHA	Safe Harbor Agreement
SMA	Special Management Area
the Services	U.S. Fish and Wildlife Service and National Marine Fisheries Service
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
WSDOT	Washington State Department of Transportation
WV Refuge Complex	Willamette Valley National Wildlife Refuge Complex

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Glossary

This glossary defines terms used throughout this guide.

Term	Definitions
Action Area	Under Endangered Species Act Section 7 consultation, all areas to be affected directly or indirectly by a federal action and not merely the immediate area involved in the action. See also *consultation*.
adaptive management	Using the results of new information gathered through a monitoring program to adjust management strategies and practices to help provide for the conservation of species and their habitats.
alkaline soil	A type of soil with high amounts of calcium, sodium, and magnesium, with a pH level above 7.
apiary	A place where honey bees are kept for commercial, hobby, or educational purposes; a collection of honey beehives.
areas of high conservation value	Areas determined to have both high biological value and high landscape intactness; prioritized for conservation actions.
biodiversity	The full array of living things considered at all levels, from genetic variants of a single species to arrays of species and arrays of genera, families, and higher taxonomic levels; includes natural communities and ecosystems.
bivoltine	Having two generations (broods) per year.
boreal	Relating to or characteristic of the climate zone in the Northern Hemisphere with a subarctic climate.
brood	The young that hatch from a group of eggs laid at the same time by one mother.
Candidate Conservation Agreement	Formal, voluntary agreements between the U.S. Fish and Wildlife Service and one or more parties created to address the conservation needs of one or more candidate species or species likely to become candidates in the near future; can be entered into with states, local governments, tribes, private property owners, and other entities.
Candidate Conservation Agreement with Assurances	Addresses species proposed for listing or candidates for listing on non-federal land; results in an enhancement-of-survival permit, which provides assurance to the applicant that if agreed-upon conservation actions for the covered species are implemented, the U.S. Fish and Wildlife Service will not require additional conservation measures beyond those in the agreement should the species be listed. See also *enhancement-of-survival permit*.
candidate species	A species that has been found warranted for listing as threatened or endangered under the Endangered Species Act, but whose listing is precluded by higher priority species.
canopy	The aboveground portion of a plant cropping or crop, formed by the collection of individual plant crowns; also refers to the upper layer or habitat zone formed by maturing tree crowns.
carbon sequestration	A natural or artificial process by which carbon dioxide is removed from the atmosphere, thereby stabilizing it in solid and dissolved forms to prevent it from causing warming of the atmosphere.
chrysalis	The pupal stage of butterflies, covered by a hard exoskeleton, inside of which they complete metamorphosis; typically found hanging from a surface.

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Term	Definitions
climate change	Long-term shifts in temperatures and weather patterns, caused by human activities such as burning of fossil fuels and deforestation.
climate change vulnerability	Refers to the degree to which an ecological system, natural community, habitat, or individual species is likely to be adversely affected as a result of changes in climate and is often dependent on factors such as exposure, sensitivity, and adaptive capacity.
climate resiliency	The ability of species to adapt to and withstand changes in climate; biodiversity assists species in persisting over time as climate changes.
cocoon	The pupal stage of moths (and some other holometabolous insects) within which they complete metamorphosis; typically found hanging from a surface or buried underground or in leaf litter.
colony	Large community of individual bees living together as one social unit; typically includes workers, males, and a queen.
coloration	The colors, patterns, and general appearance used to identify species.
community	See *natural community*.
compensatory mitigation	Actions taken to fulfill, in whole or in part, mitigation requirements under state or federal law or a court mandate.
congener	A member of the same taxonomic genus as another plant or animal.
conservation	The use of habitat and other natural resources in ways such that they may remain viable for future generations. This includes permanent protection of such resources.
conservation action/measure	An action that, when implemented, would protect or restore and manage natural elements, including imperiled species and their habitats, natural communities, ecological processes, and wildlife corridors.
conservation bank	Permanently protected privately or publicly owned lands managed for endangered, threatened, and other at-risk species. May include habitat restoration or creation in addition to protecting occupied habitats. See *mitigation bank.*
conservation easement	A voluntary legal agreement between a landowner and a land trust or government agency that permanently limits the uses of the land in order to protect its conservation values.
conservation status	The current status of the species as either listed in, a candidate for listing in, or petitioned for listing under the Endangered Species Act or as imperiled without formal legal protection.
conservation strategy	Conservation actions or habitat enhancement actions that, if implemented, will sustain and restore species and their habitats, natural communities, biodiversity, habitat connectivity, ecosystem functions, water resources, and other natural resources.
consultation	A process between the U.S. Fish and Wildlife Service or National Marine Fisheries Service and a federal agency or applicant that: (1) determines whether a proposed federal action is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat; (2) begins with a federal agency's written request and submittal of a complete initiation package; and (3) concludes with the issuance of a biological opinion and incidental take statement by either of the two agencies.
corridor	Strips or patches of habitat that connect larger patches of habitat.

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Term	Definitions
creation (of natural community or species' habitat)	The creation of a specified resource condition where none existed before. See *establishment.*
critical habitat	Habitat designated as critical[1] refers to specific areas occupied by a federally listed species at the time it is listed, and that are essential to the conservation of the species and that may require special management considerations or protection. Critical habitat also includes specific areas outside occupied habitat into which the species could spread and that are considered essential for recovery of the species.
crop pest	Includes seed eaters, herbivores, frugivores, and pathogens (e.g., insects, fungi, bacteria, and viruses) that can result in reduced agricultural productivity or total crop loss.
diapause	A physiological state of delay in development with reduced metabolic rate, in response to regular and recurring unfavorable environmental conditions; the time of the year and the stage of life when diapause occurs in insects vary among species.
dimorphism	A trait that has two or more forms within a species (e.g., sizes or coloration).
dispersal	In insects, the process of moving from the place their eggs were laid to another location or population where they will settle and reproduce; can occur in reaction to environmental conditions (weather and habitat quality) and social factors (variations in population density and sex ratio). *Migration* is a type of dispersal.
disturbance regime	The historic patterns (frequency and extent) of natural processes such as fire, insects, wind, and mass movement that affect the ecosystems and landscapes in a particular area.
diurnal	Active during the daytime.
diversity	See *biodiversity*.
dormant, dormancy	Having normal physical functions suspended or slowed down for a period of time.
ecological resources	Species, habitats, biological resources, and natural resources identified in a conservation strategy. See *natural resources*.
ecoregion	As used in this document, ecoregion means a U.S. Department of Agriculture (USDA) Section.[2] USDA describes four geographic levels of detail in a hierarchy of regional ecosystems including domains, divisions, provinces, and sections. Sections are subdivisions of provinces based on major terrain features, such as a desert, plateau, valley, mountain range, or a combination thereof.[3]

[1] 16 United States Code 1532(5)(a).

[2] Goudey, C. B., and D. W. Smith, Eds. 1994. Ecoregions California07_3. McClellan, CA. Remote Sensing Lab. Updated with ECOMAP 2007: Cleland, D.T.; Freeouf, J. A.; Keys, J. E., Jr.; Nowacki, G. J.; Carpenter, C; McNab, W. H. 2007. Ecological Subregions: Sections and Subsections of the Conterminous United States [1:3,500,000] [CD-ROM]. Sloan, A. M., cartog. Gen. Tech. Report WO-76. Washington, DC: U.S. Department of Agriculture, Forest Service. Miles and Goudey 1997. *Ecological Subregions of California*. Technical Report R5-EM-TP-005, USDA Forest Service, Pacific Southwest Region, San Francisco, CA.

[3] Goudey, C. B., and D. W. Smith, Eds. 1994. Ecoregions California07_3. McClellan, CA. Remote Sensing Lab. Updated with ECOMAP 2007: Cleland, D.T.; Freeouf, J. A.; Keys, J. E., Jr.; Nowacki, G. J.; Carpenter, C; McNab, W. H. 2007. Ecological Subregions: Sections and Subsections of the Conterminous United States [1:3,500,000] [CD-ROM]. Sloan,

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Term	Definitions
ecosystem	A natural unit defined by both its living and nonliving components; a balanced system of the exchange of nutrients and energy. See *habitat*.
ecosystem function	The ecosystem processes involving interactions among physical, chemical, and biological components, such as dynamic river meander, floodplain dynamism, tidal flux, bank erosion, and other processes necessary to sustain the ecosystem and the species that depend on it.
ecosystem services	The beneficial outcomes to humans from ecosystem functions such as supplying of oxygen; sequestering of carbon; moderating climate change effects; supporting the food chain; harvesting of animals or plants; providing clean water; recharging groundwater; abating storm, fire, and flood damage; pollinating and fertilizing for agriculture; and providing scenic views.
ecotone, ecotonal	A region of transition between two biological communities or habitats.
encroach, encroachment	The natural phenomenon characterized by the increase in density of certain types of plants, bushes, or shrubs at the expense of the herbaceous layer.
endangered	A species that has become so rare it is in danger of becoming extinct throughout all or a significant portion of its range.
Endangered Species Act (ESA)	Federal law enacted in 1973 to prohibit the import, export, or taking of fish, wildlife, and plants listed as threatened or endangered species; provide for adding species to and removing them from the list of threatened and endangered species and for preparing and implementing plans for their recovery; provide for interagency cooperation to avoid take of listed species and for issuing permits for otherwise prohibited activities; provide for cooperation with state governments, including authorization of financial assistance; and implement the provisions of the Convention on International Trade in Endangered Species of Wild Flora and Fauna.
endemic	A species, subspecies, or variety found only in a specified geographic region.
enhancement	A manipulation of an ecological resource or natural resource that improves a specific ecosystem function. An enhancement does not result in a gain in protected or conserved land, but it does result in an improvement in ecological or ecosystem function.
enhancement-of-survival permit	Available under Section 10 of the ESA for entities whose activities will provide a net conservation benefit to listed or candidate species.
erosion (of soil)	The natural process of denudation of the upper layer of soil (topsoil) caused by water, ice, snow, air, plants, and animals; the process is accelerated by conversion of natural vegetation to cropland or pasture.
establishment	The manipulation of the physical, chemical, or biological characteristics present on a site to develop an aquatic or terrestrial habitat resource for species. Establishment will result in a gain in resource area and/or function. See *creation*.
extinction	The dying out or extermination of a kind of organism or a group of kinds, usually a species.

A. M., Cartog. Gen. Tech. Report WO-76. Washington, DC: U.S. Department of Agriculture, Forest Service. Miles and Goudey 1997. *Ecological Subregions of California*. Technical Report R5-EM-TP-005, USDA Forest Service, Pacific Southwest Region, San Francisco, CA.

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Term	Definitions
extirpation	The situation in which a species or population no longer exists within a certain geographic area, while at least one other population of the species still persists in other areas; also known as local extinction.
eyespot	A rounded, eye-like marking on the wing of a butterfly or moth.
federal nexus	When a project requires a federal authorization apart from ESA compliance, license, or funding.
fire regime	The pattern, frequency, and intensity of the wildfires that prevail in an area over long periods of time; an integral part of fire ecology and renewal for certain types of ecosystems.
fire return interval	The average period between fires, both natural and prescribed, under the historical fire regime.
flight time	The month or months of the year in which adult pollinators are observed in flight.
focal species	In this guide, sensitive pollinators that are of particular conservation concern, such as monarch butterflies or other imperiled species.
food web	The overall food relationships (food chains) among organisms in a particular environment, detailing the interconnectivity in complex feeding relationships for that ecosystem. All the food chains in a single ecosystem represent the multiple possible paths that energy and nutrients may take as they move through the ecosystem.
foraging territory	The distance or area over which an individual of a species is known to travel to find food resources, as reported in agency reports or peer-reviewed literature for that species.
forb	An herbaceous flowering plant other than a grass, sedge, or rush.
forewing	The anterior (front, closer to the head) wing of an insect, attached to the middle segment of the thorax.
fringe	Long, narrow scales at the outside edges of butterfly wings.
genetic variability	The tendency of individual genetic characteristics in a population to vary from one another; greater genetic variability and diversity give species a better chance of survival, as variability can be lost when populations get smaller and more isolated, decreasing a species' ability to adapt.
graminoid	An herbaceous plant with a grass-like structure, such as grasses, rushes, and sedges; contrast with *forbs*, which have no grass-like features.
habitat	An ecological or environmental area that is, or may be, inhabited by a species of animal, plant, or other type of organism. Habitat is also the physical and biological environment that surrounds, influences, and is used by a species' population and is required to support its occupancy.
habitat assessment	A process whereby habitat conditions are rated as optimal, suboptimal, marginal, or poor based upon descriptions and a rating scale.
habitat connectivity	The capacity of habitat to facilitate the movement of species and ecological functions. See also *landscape connectivity*.

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Term	Definitions
habitat conservation plan (HCP)	A planning document that is required as part of an application for an incidental take permit under the ESA. HCPs provide for partnerships with non-federal parties to conserve the ecosystems upon which listed species depend, ultimately contributing to their recovery. HCPs describe the anticipated effects of the proposed taking, how those impacts will be minimized or mitigated, and how the HCP is to be funded.
habitat degradation	When habitat conditions decline due to invasive species, pollution, development, or overutilization of natural resources.
habitat enhancement	Actions that, when implemented, are intended to improve the quality of wildlife habitat or to address risks or stressors to wildlife. Habitat enhancement would have long-term durability but would not involve acquiring land or permanently protecting habitat.
habitat fragmentation	When larger habitats are broken up into smaller patches, which may be too small to sustain populations of some species or species are unable to move between patches.
habitat loss	When habitat is eliminated or transformed into another type of habitat.
habitat needs/requirements	In this guide, conditions that must be present in order for pollinator species to inhabit and thrive in their surroundings, including climate, vegetation, associated species, and natural processes.
habitat quality	The capacity of a habitat to support a species. The precise meaning of habitat quality varies by species and depends on the specific needs of a species in the context of a particular area. High-quality habitat for species may have only foraging and resting elements or it may include foraging, resting, and nesting elements. For other species, it may encompass all elements needed for the species to complete its lifecycle. Low-quality habitat has only the minimal elements to support occurrence of the species. High-quality habitat tends to support larger numbers of species than low-quality habitat.
harass	As defined by the ESA, actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns, which include, but are not limited to, breeding, feeding, or sheltering.
harm	As defined by the ESA, includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns, such as breeding, feeding, or sheltering.
herbaceous	Vascular plants with little or no persistent woody stems above ground; includes grasses and forbs.
herbicide	A substance that is toxic to plants, used to destroy unwanted vegetation.
hindwing	The posterior (back) wing of an insect, attached to the last segment of the thorax.
holometabolous	Describing insects with four life stages: egg, larva, pupa, and image (or adult).
home range	The area in which an individual of a species lives and moves to meet its needs such as feeding, foraging, breeding, and sheltering.

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Term	Definitions
host plant	Plants upon which butterflies and moths lay their eggs, and upon which their caterpillars (larvae) will feed after hatching.
hydrologic regime	The timing, volume, and duration of water flow events, which may be influenced by the climate, soils, geology, groundwater, watershed land cover, connectivity, and valley and stream morphology.
imperiled species	A species that is in decline and may be in danger of extinction. In this guide, this term identifies species that are not legally protected under the ESA.
incidental take permit	A permit issued under Section 10 of the ESA to private, non-federal entities undertaking otherwise lawful projects that might result in the take of a listed species. See also *take*.
indicator species	A species whose presence, absence, or abundance reflects a particular habitat, community, or set of environmental conditions.[4]
infiltration (of water)	The movement of water into the ground from the surface.
in-lieu fee mitigation	A framework to create a mitigation strategy, giving entities the ability to create and contribute to a fund as mitigation for unavoidable impacts on listed species; money deposited into the fund is used to improve upon the conservation effort for the species beyond what is otherwise possible if funds were being restricted to a specific project location or to a lesser mitigation type.
instar	The stage of the insect between molts, shedding the exoskeleton.
introduced species	An organism not native to the place or area but accidentally or deliberately transported to the new location by human activity.
invasive species, nonnative species	A nonnative species that can spread into the ecosystems and displace native species, hybridize with native species, alter biological communities, and alter ecosystem processes and that has the potential to cause environmental or economic harm. According to the California Invasive Plant Council, *nonnative plants* are species introduced to California after European contact and as a direct or indirect result of human activity.[5]
invertebrate	Lacking a backbone.
land conversion	The conversion of natural and agricultural land to other land uses through the process of development.
land cover type	The dominant feature of the land surface defined by vegetation, water, or human uses.
land preservation	Generally, the preservation of natural resources by acquiring land.
landscape connectivity	The extent to which the landscape facilitates or impedes movement among habitat patches. See also *habitat connectivity.*
larva	The active immature form of a holometabolous insect in the stage between egg and pupa.
life cycle	For all insect pollinators, includes four distinct life stages: egg, larva, pupa, and adult, which may occur in different habitats.

[4] Lincoln, R., G. Boxshall, and P. Clark. 1998. *A Dictionary of Ecology, Evolution and Systematics.* Second Edition. Cambridge University Press, Cambridge, UK.

[5] California Invasive Plant Council. 2022. "Definition of Invasive Plants." Available: https://www.cal-ipc.org/plants/impact/.

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Term	Definitions
listed species	Species currently listed as threatened or endangered under the ESA; the species has been determined to be in danger of extinction in the near or foreseeable future by the U.S. Fish and Wildlife Service.
managed bees	Bees that are bred and managed by people for commercial purposes. For example, honey bees kept for honey production or rental for commercial crop pollination; can harm other wild pollinators through increased competition for nectar and pollen resources and spread of disease.
mesic	Containing a moderate or well-balanced supply of moisture.
microclimate	The atmospheric conditions of a very small or restricted area that differ from those in the surrounding areas.
migration	The mass movement of individuals among areas, generally directional and synchronized; see also *dispersal*.
mitigate, mitigation	To lessen the effects of an action, particularly adverse effects, on a species or habitat.
mitigation bank	Land managed for its natural resource values, with an emphasis on targeted resources. Typically requires the restoration or creation of aquatic resources. See *conservation bank*.
monitoring	Data collected from repeated sampling to detect changes over time, such as in response to revegetation or maintenance practices.
monitoring protocols	The methodology used to collect data. This guide contains protocols for monitoring imperiled pollinators, imperiled species of pollinators, and bumble bees.
monoculture	The cultivation of a single crop in a given area.
morphology	The form and structure of living organisms.
National Environmental Policy Act (NEPA)	The national environmental law that promotes the enhancement of the environment by requiring federal agencies to assess the environmental effects of their proposed actions prior to making decisions and to incorporate environmental considerations in their planning and decision-making through a systematic interdisciplinary approach by preparing detailed statements assessing the environmental impact of major federal actions significantly affecting the environment.
native species	A species whose presence in a given region or ecosystem is the result of only natural evolution and distribution.
natural community	A group of organisms living together and linked together by their effects on one another and their responses to the environment they share.[6] A general term often used synonymously with habitat or vegetation type.
natural resources	Biological and ecological resources including species and their habitats, including waters of the state, waters of the United States, wetlands, and natural communities.

[6] Sawyer, J. O., T. Keeler-Wolf, and J. E. Evens. 2009. *A Manual of California Vegetation*. Second Edition. California Native Plant Society, Sacramento, CA.

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Term	Definitions
NatureServe	A non-profit organization comprising a network of conservation scientists that collects, aggregates, and standardizes data about the status and distribution of species and ecosystems of conservation concern in North America and assigns its own conservation rankings to such species.
NEPA Assignment	The process by which some states (Alaska, Arizona, California, Florida, Nebraska, Ohio, Texas, and Utah as of April 2022) assume federal responsibility for transportation projects for the Federal Highway Administration. States with NEPA Assignment may use the Section 7 ESA compliance process even when no other federal nexus exists.
nest	Places constructed and provisioned by bees and wasps in which their offspring develop; can be on the ground, in soil, underground, in tunnels, or in insulated cavities.
nocturnal	Active during the nighttime.
nonnative species	Any species introduced after European contact and as a direct or indirect result of human activity to a new place or new habitat where it did not previously occur.[7] See *invasive species*.
noxious plant	A plant that can directly or indirectly injure or cause damage to crops, livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment. The U.S. Department of Agriculture Animal and Plant Health Inspection Service maintains a list of federally recognized noxious weeds, and each state also has its own list.
objective, conservation objective	A concise, measurable statement of what is to be achieved and that supports a conservation goal. The objective should be based on the best available scientific information to conserve the species or other conservation elements for which the conservation goal and objective is developed.
obligate	Restricted to a particular condition of life, such as dependent on a particular habitat or forage.
overwinter	The process by which some organisms pass through or wait out the winter season, when conditions make normal activity or survival difficult or near impossible.
oviposit, oviposition	To lay an egg or eggs.
parasite	An organism that lives in or on a host but does not kill the host.
parasitoid	An organism that lives on or inside a host and always kills the host.
pathogen	A bacterium, virus, or other microorganism that can cause disease.
perennial	Lasting or existing for a long time (in plants, more than 2 years); enduring or continually recurring.
pesticide	A substance used for destroying insects, plants, or other organisms.
petitioned species	A species for which a petition to list the species as threatened or endangered under the ESA has been received and is being evaluated
phasing/phased approach	Implementation of multiple conservation strategies in a systematic approach to meet long-term needs for ESA compliance and/or to cover an expansive geographic area.

[7] California Invasive Plant Council. 2022. "Definition of Invasive Plants." Available: https://www.cal-ipc.org/plants/impact/.

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Term	Definitions
phenology	The timing of cyclic and seasonal natural phenomenon, such as when plants bloom and when insects emerge from pupal stages.
pollinator	An animal that helps carry pollen, either intentionally or accidentally, from the male part of the flower (stamen) to the female part of the same or another flower (stigma) to facilitate fertilization and production of fruit, seeds, and young plants. Most flowers are pollinated by insects and animals—such as bees, wasps, moths, butterflies, birds, flies, and small mammals, including bats. *Specialist pollinators* are more selective and visit flowers of one or very few plant species.
population	The number of individuals of a particular taxon inhabiting a defined geographic area.
population decline	The reduction in abundance of individuals of a species, often as a result of human activity and climate change.
population density	The concentration of individuals within a species in a specific geographic locale.
Prelisting Conservation Agreement	Allows for the creation and banking of credits providing for the conservation of non-listed species. Anyone (e.g., federal agency or private entity) who wants to participate in the process can undertake a voluntary prelisting conservation action, earning credits to be carried forward as long as the action occurs in a participating state within the framework of an established conservation strategy for the species.
prescribed burning	The controlled application of fire by a team of fire experts under specified weather conditions to restore health to ecosystems that depend on fire.
programmatic	As opposed to a single defined project, indicating a suite of activities or a program encompassing multiple areas or projects.
programmatic agreement	An agreement allowing for an individual compliance strategy to be applied to a suite of projects or a program involving similar activities in a particular geographic area.
protected area	Public or private lands managed for open space use.
pupa, pupate, pupation	In holometabolous insects, an insect in its immature form between larva and adult; usually inactive; see also *chrysalis* and *cocoon*.
queen	In truly social insect species (e.g., honey bees, bumble bees, paper wasps, ants), an adult female bee with fully developed reproductive organs who is usually the mother of all of the bees in a particular hive or colony and is responsible for laying the eggs. There is normally only one adult, mated queen in a hive or colony.
range	See *home range.*
rangeland	Open country, usually grasslands, shrublands, woodlands, wetlands, or deserts, grazed by domestic livestock or wild animals.
reclamation	The act or process of recovering, and/or the state of being recovered. Many reclamation techniques can be used on the path to recovering or restoring pre-disturbance profiles.

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Term	Definitions
recovery	The process by which the decline of an endangered or threatened species is halted or reversed or threats to its survival are neutralized, so that its long-term survival in nature can be ensured.[8] Recovery entails actions to achieve the conservation and survival of a species, including actions to prevent any further decline of a population's viability and genetic integrity. Recovery also includes actions to restore or establish environmental conditions that enable a species to persist (i.e., the long-term occurrence of a species through the full range of environmental variation).
recovery area	The band of low-growing or routinely mowed vegetation directly adjacent to the pavement or shoulder of a road where vehicles that have left the roadway can recover; also known as the clear or safety zone. The recovery area is free of obstruction and the width is determined by the type of road and traffic volume, as well as the slope of the embankment.
Recovery Crediting System	A tool that allows federal agencies to use their authorities to benefit species already listed as threatened or endangered on non-federal lands; subject to consultation under Section 7 of the ESA. Creates a process through which federal agencies create a "bank" of recovery credits providing for the conservation of listed species while being able to compensate for future impacts of their actions
refugia	Locations or areas providing a safe resting place for animals to hide from predators.
restore, restoration	Manipulation of a piece of land with the goal of repairing natural or historical ecosystem functions to degraded habitat or natural resources. This results in an improvement in ecological or ecosystem functions, but it does not result in a gain in area.
revegetation	The process of replanting and rebuilding the soil of disturbed lands such as roadsides. This may be a natural process produced by plant colonization and succession, human-made rewilding projects, or accelerated processes designed to repair damage to a landscape due to construction or operational disturbance, wildfire, mining, flood, or other cause.
riparian	Relating to wetlands adjacent to rivers and streams.
roadside	Areas along the sides of roads and highways extending across both urban and rural landscapes; often the only natural vegetation that remains in highly altered landscapes. Roadsides provide pollinators with a place to find food, reproduce, and take shelter or overwinter, and they can increase habitat connectivity.
roadside contamination	Deposit of pollutants through routine vehicle use and maintenance, including vehicle exhaust, de-icing materials, and heavy metals from tire rubber, brake dust, and gasoline and diesel combustion products.
roadside management/ maintenance	The planning, design, construction, and maintenance of the non-paved highway right-of-way.
roadside restoration	See *restoration, revegetation.*

[8] U.S. Fish and Wildlife Service and National Marine Fisheries Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California*. Portland, OR: Region 1.

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Term	Definitions
runoff (of water)	The draining away of water from the surface of an area of land; can be problematic when it occurs as a result of excess rainwater, stormwater, meltwater, or other water no longer infiltrating (soak) the soil, especially due to increased impervious surfaces created through extensive development.
senesce, senescence	To deteriorate with age because of the loss of a cell's power to divide and grow.
sensitive species	Any special-status species identified by a state or federal agency.
sexual dimorphism	The condition where the sexes of the same species exhibit different forms (e.g., sizes or color patterns).
solitary	Solitary bees do not live in a communal nest or hive. Females build nests and provision their eggs on their own.
Species of Greatest Conservation Need (SGCN)	SGCNs are selected, for each state, to indicate the status of biological diversity in the state, specifying at-risk species that have the greatest need for conservation.
Species of Special Concern (SSC)	Species of Special Concern[9] is an administrative designation and carries no formal legal status. The intent of designating SSCs is to: (1) focus attention on animals considered potentially at conservation risk by state, local, and federal governmental entities, regulators, land managers, planners, consulting biologists, and others; (2) stimulate research on poorly known species; and (3) achieve conservation and recovery of these animals before they meet criteria for listing as threatened or endangered.
State Wildlife Action Plan (SWAP)	A comprehensive plan for conserving fish and wildlife across the state.[10]
status	See *conservation status.*
stewardship	Land planning and ecological resources management with the goal of protecting and enhancing ecosystems and biodiversity.
strategy	A plan of action or policy designed to achieve a major or overall aim.
succession	The process by which one habitat type is overtaken by another through changing dominance of pioneer species, altering the ecosystem dynamics. Early successional habitat contains vigorously growing grasses, forbs, shrubs, and trees that provide excellent food and cover for wildlife but need disturbance to be maintained.
survey	Sampling conducted to determine the presence or absence of a particular imperiled pollinator species at a given site.
take	According to the ESA, any action to "harass, harm pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." *Incidental take* is take of listed species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a federal agency or applicant.
thorax	The section of an insect body that follows the head and is before the abdomen; this section bears six legs and wings.

[9] https://www.wildlife.ca.gov/Conservation/SSC.

[10] California Department of Fish and Wildlife. 2017. *SWAP Final 2015 Document.* Available: https://www.wildlife.ca.gov/SWAP/Final.

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Term	Definitions
threat	An anthropogenic (human-induced) or natural driver that could result in changing the ecological conditions of the species or its habitat in a negative way.
threatened	Plants and animals that are likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges.
transportation planning	The process of identifying transportation needs and establishing plans for infrastructure development to meet those needs; occurs at the local, regional, and state levels and generally includes identifying and prioritizing projects needed to maintain and improve transportation networks and achieve specific transportation goals. Can involve either short- (e.g., 4 years) or long-range (e.g., 20+ years) time frames.
U.S. Fish and Wildlife Service (USFWS)	The federal agency responsible for conserving, protecting, and enhancing fish, wildlife, and plants and their habitats; administers the ESA with NMFS.
univoltine	Having one generation per year.
vegetation management	The targeted control and elimination of unwanted vegetation and replacement with desirable vegetation.
ventral	Of, on, or relating to the underside of an animal or plant (abdominal).
worker	In truly social bees (e.g., bumble bees), non-reproducing females that collect food for other bees in the colony.
working land	An area where people live and work in a way that allows ecosystems or ecosystem functions to be sustained (e.g., farms, ranches). Human activities are done in a way that minimizes disturbance on native plants and animals while still retaining the working nature of the landscape.

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Appendix A Decision Support for Compliance with the Endangered Species Act: Listed Pollinators

If there is a listed pollinator species in the area that will impact a project or general work, the questions below can help in developing proactive strategies as alternatives to the more traditional Section 7 consultation when dealing with listed species. Select as many questions as apply.

Under the proposed project, is "take" (impact) of a listed species reasonably certain to occur, and is the project proponent a non-federal entity?

If so, consider complying with the federal Endangered Species Act (ESA) through Section 10, a voluntary process, and developing a Habitat Conservation Plan (HCP) in order to maintain more control of the outcome while investing a reasonable amount of time and resources upfront and overseeing the process through to the end.

> *Go Further:* The HCP is the applicant's document, so the applicant can control its content and approach. In addition, the Section 10 permit process allows for coverage of non-listed species under an HCP and provides *No Surprises* assurances throughout the duration of the permit. This can be advantageous for long-term planning. Species likely to become listed over the permit duration, if covered by the HCP, require no new restrictions if the species becomes listed as long as the permittee is properly implementing the HCP and Incidental Take Permit.

Is the potential presence of listed species in or adjacent to existing rights-of-way preventing investment in roadside vegetation management strategies that could otherwise improve roadside habitat for pollinators?

If so, consider use of a Safe Harbor Agreement (SHA) to provide formal assurances that future land use restrictions would not result from investment in management activities that increase habitat value and/or the local abundance of the listed species covered under the permits.

> *Go Further:* Recognized conservation actions benefiting listed species under a SHA include development and testing of new habitat management techniques. Under this experimental component of the agreement, new management activities can be developed and inform conservation measures benefiting listed species implemented under a Recovery Crediting System (RCS). Management actions undertaken through a SHA can be transferred to an RCS following termination of the SHA.

For a specific geography or project, are there multiple listed species expected to be impacted, or a single listed species?

If there are multiple listed species, consider investing in a compliance strategy, such as an HCP, wherein different conservation measures can be bundled together to provide regulatory coverage for take of a number of listed species under a single permit.

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Go Further: HCPs are the most comprehensive compliance strategy available to non-federal parties to conserve the ecosystems and natural processes upon which listed species depend, ultimately contributing to their recovery. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Conservation measures implemented under other identified compliance strategies can be transferred or rolled-up to an HCP.

Are there established recovery plans for the listed species of interest?

If so, the conservation actions identified in the recovery plan provide a framework from which to build an appropriate and recognizable conservation strategy to be implemented under an RCS.

Go Further: Conservation measures benefiting listed species implemented under an approved RCS can be expanded in scope to address pollinator species proposed for listing or candidates for listing on non-federal land through development of a Candidate Conservation Agreement with Assurances (CCAA). Implementation of management activities identified under a CCAA that complements an existing RCS allows for provisioning of more comprehensive regulatory coverage from a multispecies context.

Are some of the suggested changes to maintenance activities to benefit listed pollinators also viewed as potential cost-saving measures?

If so, creation of a SHA allows for transportation agencies to invest in maintenance activities that may result in cost savings, such as shifting the timing and frequency of mowing, but also real benefits to pollinators without fear of retribution for attracting or increasing the amount or distribution of the listed species on managed lands.

Go Further: Recognized conservation actions benefiting listed species under a SHA include development and testing of new habitat management techniques. Under this experimental component of the agreement, new management activities can be developed and inform conservation measures benefiting listed species implemented under an RCS. Management actions undertaken through a SHA can be transferred to an RCS following termination of the SHA.

Are the same listed or at-risk species likely to be impacted by reoccurring construction or management activities?

If listed or at-risk species are likely to be continually impacted by future activities, investing early in development of an HCP, if there are multiple species deserving coverage, may be worth pursuing, or consider an RCS, to generate a bank of credits for both permanent and temporary impacts on listed species.

Go Further: Conservation measures benefiting listed species implemented under an approved RCS may be expanded in scope to address conservation actions identified by a state resource agency for at-risk species through development of a Prelisting Conservation Agreement (PCA). When working in concert, an RCS and PCA can lead to the generation of credits that can be "banked" and shared among agencies to address future impacts on multiple species.

Are the conservation needs for a listed species poorly understood?

If so, there may be value in exploring the opportunities presented by a SHA, which allows for experimentation and knowledge building while providing assurances that whether

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agencies are successful or not in benefiting listed species through their actions, they will not be penalized.

> *Go Further:* Recognized conservation actions benefiting listed species under a SHA include development and testing of new habitat management techniques. Under this experimental component of the agreement, new management activities can be developed and inform conservation measures benefiting listed species implemented under an RCS. Management actions undertaken through a SHA can be transferred to an RCS following termination of the SHA.

Is the species endemic to a small area or does it occur at a single site?

If so, an HCP may be most appropriate for addressing the range of conditions that need to be addressed to assure long-term protection and recovery of the species, recognizing that the potential for impacts on the species associated with road construction and maintenance activities is very localized and likely not to be repeated in other geographies, thus limiting the geographic extent of the value of conservation actions.

> *Go Further:* HCPs are the most comprehensive compliance strategy available to non-federal parties to conserve the ecosystems and natural processes upon which listed species depend, ultimately contributing to their recovery. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Conservation measures implemented under other identified compliance strategies can be transferred or rolled-up to an HCP.

Is offsite mitigation an option?

If so, the creation of mitigation and conservation banks on their own, or as part of an RCS or HCP, creates lasting credits for local impacts on listed species that can be transferred or sold to other agencies in time.

> *Go Further:* Conservation measures benefiting listed species implemented under an approved RCS may be expanded in scope to address conservation actions identified by a state resource agency for at-risk species through development of a PCA. When working in concert, an RCS and PCA can lead to the generation of credits that can be "banked" and shared among agencies to address future impacts on multiple species.

Is the existing or future road network present in wildfire-prone landscapes?

If so, explore opportunities to earn credits through an HCP or RCS by installing road-hardening measures, such as concrete pavement, in rights-of-ways (ROWs) to reduce ignition rates and protect high value pollinator habitat harboring listed species in the neighboring natural areas bordering the road network.

> *Go Further:* HCPs are the most comprehensive compliance strategy available to non-federal parties to conserve the ecosystems and natural processes upon which listed species depend, ultimately contributing to their recovery. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Conservation measures implemented under other identified compliance strategies can be transferred or rolled-up to an HCP.

More about ESA compliance is included in Chapter 4, Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation, of this guide.

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Appendix B Decision Support for Voluntary Actions and Regulatory Assurances: Imperiled Pollinators and the Endangered Species Act

If there is an imperiled pollinator species in the area that may become listed, the questions below can help in developing voluntary strategies to mitigate present-day and future risks to at-risk species and regulatory assurances. Select as many questions as apply.

Are at-risk pollinator species present in the planning area?

If so, a Candidate Conservation Agreement with Assurances (CCAA) provides assurances to transportation agencies who invest early in the application of recognized conservation actions, such as the abandonment of an otherwise once planned road extension, within a planning area encompassing a larger road network that benefit single or multiple pollinator species considered to be at-risk for future listing.

> *Go Further:* If conservation measures implemented under a CCAA are consistent with a conservation strategy for a species established by a state resource agency, the CCAA can be terminated and management actions transferred to a Prelisting Conservation Agreement (PCA). Transference would lead to the generation of credits for use as mitigation or as a compensatory measure for the detrimental impact of an action undertaken within a specified "service area" after the species is listed as threatened or endangered.

Are the same at-risk species likely to be impacted by reoccurring construction or management activities?

If at-risk species are likely to be continually impacted by future activities, investing early in development of a PCA, to generate a bank of credits for both permanent and temporary impacts on at-risk species, may be worth pursuing.

Will at-risk species possibly be harmed by future activities?

If so, by working with state and federal agencies, a transportation agency can create credits under a PCA by implementing conservation measures benefiting a state-recognized at-risk species at select locations across their service area, providing assurances the agency will have the ability to mitigate for future impacts on the species following a federal listing.

> *Go Further:* Credits generated under a PCA can be used as mitigation or as a compensatory measure for the detrimental impact of an action undertaken within a specified "service area" after the species is listed as threatened or endangered.

Are there established state-sponsored conservation plans for at-risk species of interest?

If so, the conservation plans are to serve as the preferred source for identifying the conservation strategies to be implemented under a PCA to receive credits for future impacts on at-risk species following federal listing.

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Are there federal lands neighboring present-day rights-of-way or future project areas containing recognized habitat for at-risk species of interest?

If so, consider reaching out to neighboring federal agencies to explore the possibility of linking a CCAA with a Candidate Conservation Agreement (CCA) to establish a comprehensive conservation plan for at-risk species allowing for greater consistency in management actions, and thus effectiveness, across a larger regional landscape consisting of both federal and non-federal properties.

> *Go Further:* Primarily developed to cover activities on federal lands, a CCA can be written to perform the function of an overarching conservation plan for a single, or multiple, species. A conservation plan can serve to link a CCA for federal property together with preventative measures taken under a CCAA implemented on adjoining non-federal lands, allowing enrollees to seamlessly implement conservation measures to address the needs of at-risk species.

Is the existing or future road network present in wildfire-prone landscapes?

If so, explore opportunities to earn credits through a Habitat Conservation Plan (HCP) or PCA by installing road-hardening measures, such as concrete pavement, in rights-of-way to reduce ignition rates and protect high value pollinator habitat harboring at-risk species in the neighboring natural areas bordering the road network.

> *Go Further:* HCPs are the most comprehensive compliance strategy available to non-federal parties to conserve the ecosystems and natural processes upon which listed species depend, ultimately contributing to their recovery. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Conservation measures implemented under other identified compliance strategies can be transferred or rolled-up to an HCP.

More information about voluntary Endangered Species Act actions is included in Chapter 4, Native Pollinators and the Federal Endangered Species Act: Compliance Strategies for State Departments of Transportation, of this guide.

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Appendix C Bee and Bee Group Recognition

C.1 Recognizing Bees

Distinguishing floral visitors such as butterflies, beetles, and moths from bees is fairly straightforward, but separating bees from wasps or flies can be more difficult (Figure C-1 and Table C-1).



Figure C-1. Common floral visitors: butterfly (top left), bee (top center), wasp (top right), beetle (bottom left), moth (bottom center), fly (bottom right).

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Table C-1. Key characteristics of bees, and the flies and wasps that can be mistaken for them.

Floral Visitor	Wings	Body Shape, Size	Hairs on Body	Body Color	Body Patterns	Pollen-Carrying Structures	Antennae
Bees	4 wings (2 pairs)	Robust body, constricted waist	Hairy bodies, often with a fuzzy appearance	Black, brown, orange, red, or metallic green blue, or copper	Some species have stripes of hairs on abdomen	Female bees carry pollen on their bodies in corbicula (concave pollen basket) or scopa (specialized longer hairs on hind legs or long hairs underside of abdomen)	Slender, long antennae, typically with a distinct elbow
Wasps	4 wings (2 pairs)	Slender body, constricted waist	Not hairy	Black, brown, red, orange, yellow, or metallic blue or green	Stripes on exoskeleton (not stripes of hairs)	None	Slender, long antennae
Flies	2 wings (1 pair)	Robust body, no constricted waist	Usually without many hairs	Black, brown, yellow, metallic blue or green	Stripes on exoskeleton (not stripes of hairs)	None	Short, thick antennae

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C.2 Recognizing Bee Groups

Bees are difficult to identify to species or family without having pinned specimens. But bee richness at a site can be measured by identifying bees to groups based on their morphology (also known as morphogroups), which use characteristics that can be seen in the field to categorize bees. See Appendix E, *Bumble Bee Recognition and Photography,* for characteristics of bumble bees.

Note that honey bees are not native to North America. When sampling for bees, distinguishing between honey bees and native bees is the most important observation one can make.

C.2.1 Honey Bees

Key Characteristics (Figure C-2):

- Size and shape: Medium to large with torpedo-shaped bodies
- Color and hair: Amber-brown to nearly black; moderately fuzzy thorax and head, with less hairy legs and abdomen
- Stripes: Abdomen tri-toned with black, pale, and orange-brown stripes
- Corbicula: Concave flattened plates, fringed by a few long hairs, on hind legs to carry moist pollen

Notes: Makes buzzing sound when flying and often flies methodically from flower the flower.



Figure C-2. Honey bees.

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C.2.2 Chap Leg Bees

Key Characteristics (Figure C-3):

- Size and shape: Medium to large, robust
- Color and hair: Dark with white, yellow, or brown hairs; often hairy—especially on thorax—with short, dense, velvety hair
- Stripes: Often with bands of pale hair on abdomen
- Scopa: Carries dry pollen on noticeably longer, dense hairs on lower hind legs, but pollen is often on the whole body

Notes: Antennae are typically longer than most other bees, especially on males. The legs of males are not as hairy as those of females because males do not transport pollen. Some fly fast (usually in smooth motions that almost look like they are tracing a figure 8) and can visit flowers rapidly.



Figure C-3. Chap leg bees.

C.2.3 Medium Dark Bees

Key Characteristics (Figure C-4):

- Size and shape: Small to large; relatively narrow to moderately robust
- Color and hair: Dull, dark-bodied; thorax and face are moderately hairy
- Stripes: May have bands of pale hair on abdomen
- Scopa: Carries pollen on upper hind legs and back of thorax (armpits)
- Other notable feature: Face may have two hairy depressions between the eyes (*Andrena*) or be heart-shaped (*Colletes*)

Notes: Among the first to emerge in early spring. Nest in the ground, often in large aggregations.



Figure C-4. Medium dark bees.

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C.2.4 Green Sweat Bees

Key Characteristics (Figure C-5):

- Size and shape: Medium sized, narrow bodied
- Color and hair: Bright metallic green; abdomen can be green like the thorax, or dark with stripes; body covered in pale hairs that are less noticeable
- Stripes: Some have yellow-and-black striped abdomens
- Scopa: Carries dry pollen on hairs on hind legs, less noticeable than other bees unless covered in dry pollen

Notes: Relatively fast flying and numerous. Antennae are short on females and longer on males.

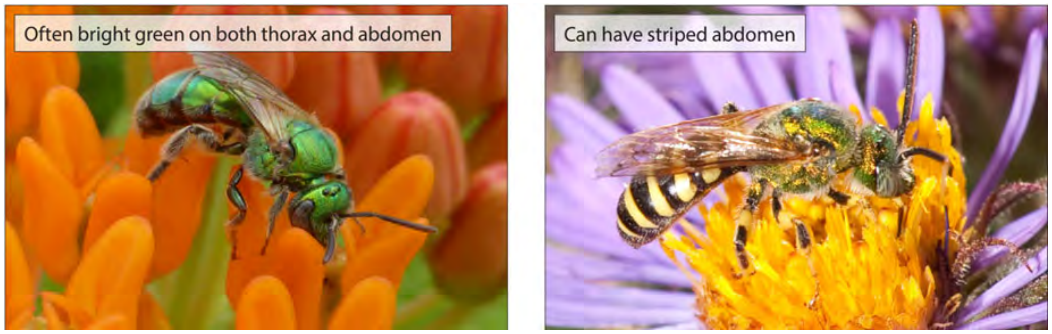


Figure C-5. Green sweat bees.

C.2.5 Striped Sweat Bees

Key Characteristics (Figure C-6):

- Size and shape: Small to medium, narrow bodied
- Color and hair: Usually dark with bands of pale hairs on abdomen
- Stripes: Stripes on abdomen may appear faint and vary in color from creamy to dark gray
- Scopa: Brush of hair on upper part of hind legs, sometimes loaded with pollen

Notes: May crawl around the base of flowers or inside flowers. Fast moving; sometimes with jagged movements.



Figure C-6. Striped sweat bees.

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C.2.6 Tiny Dark Bees

Key Characteristics (Figure C-7):

- Size and shape: Tiny and narrow bodied
- Color and hair: Can be dull black/brown, pale golden, metallic black/brown or blue/green; sometimes with white or yellow markings on face; body sparsely covered in pale hairs that are less noticeable, but some with dense patches of hair on abdomen
- Stripes: Faint stripes on abdomen, if any
- Scopa: Small carpenter bees (*Ceratina*) and sweat bees (*Halictus*) have brushes of pollen collecting hairs on hind leg; yellow-faced bees (*Hylaeus*) carry pollen in a crop, and lack external scopa

Notes: Often crawl deep into flowers. Can move fast—some with jagged movements.

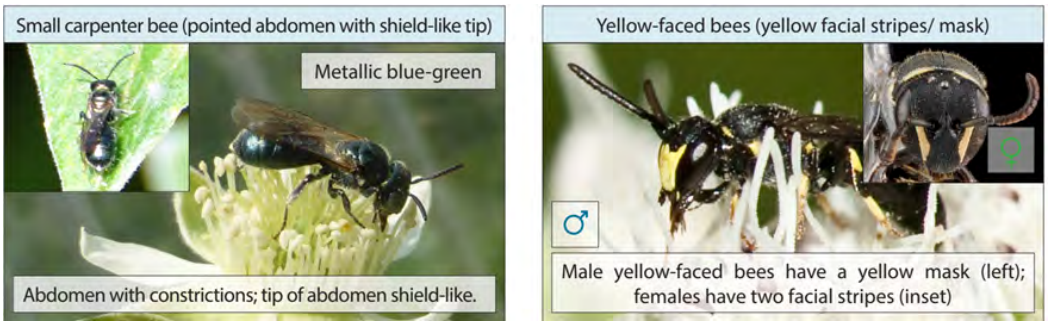


Figure C-7. Tiny dark bees.

C.2.7 Hairy Belly Bees

Key Characteristics (Figure C-8):

- Size and shape: Small to medium and typically very robust; often with a broad head and strong jaws used to cut leaves for nesting materials
- Color and hair: Black with thorax and head covered in silver, white, or yellow hairs OR black with yellow markings on exoskeleton
- Stripes: Abdomen has light hairs that create stripes, or markings are on exoskeleton
- Scopa: Females carry dry pollen on thick hairs on underside of abdomen

Notes: When visiting flowers, these bees often elevate abdomen, revealing pollen underneath.

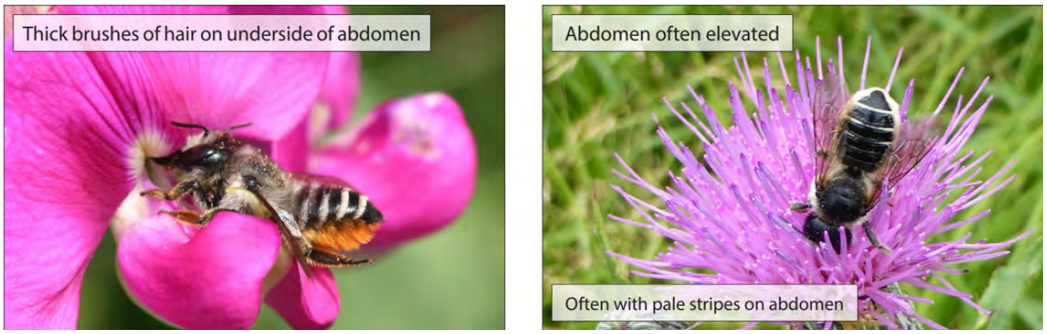


Figure C-8. Hairy belly bees.

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C.2.8 Metallic Hairy Belly Bees

Key Characteristics (Figure C-9):

- Size and shape: Small to medium, stout, robust bodies
- Color and hair: Metallic green, blue, or bluish black; brushes of hair beneath abdomen—no prominent hair bands
- Stripes: None
- Scopa: Females carry dry pollen loads on underside of abdomen

Notes: Among the first bees seen during the pollinating season. Most are observed in early spring and summer. As their name suggests, some species of Mason Bees gather mud and pebbles to construct their nests. These bees are also often called Orchard Bees, due to their frequent pollination of fruit tree blossoms.

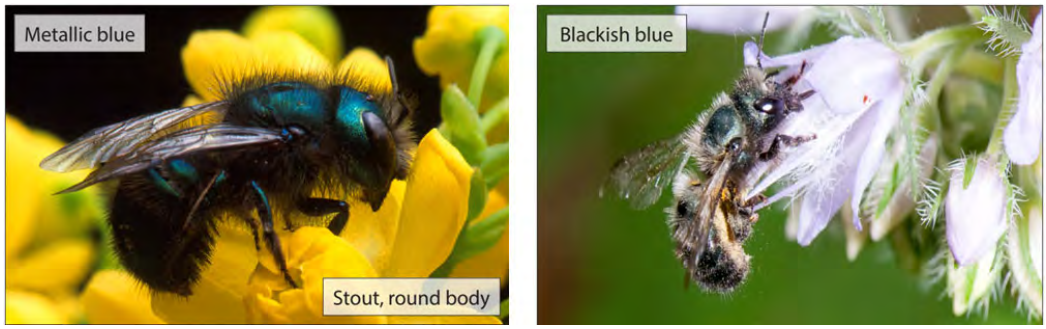


Figure C-9. Metallic hairy belly bees.

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Appendix D Butterfly and Butterfly Group Recognition

D.1 Recognizing Butterflies

Butterflies can be distinguished from moths by the way they hold their wings at rest and by their antennae. Butterflies hold their wings open or vertically closed over their bodies, while moths tend to hold their wings flat. Butterfly antennae are club-shaped at the tips, while moth antennae either taper to a point or have a feathery appearance.

D.2 Recognizing Butterfly Groups

With practice, butterflies can be identified to family by observing characteristics such as size, color, wing patterns, and flight patterns. The following sections describe common characteristics of common butterfly families.

D.2.1 Skippers

Key Characteristics (Figure D-1):

- Short wings
- Must flap rapidly to gain flight
- Bodies are compact and broad
- Antennae are often short, with hooked bulb at the end
- Fairly small, usually brown or orange
- Fly in speedy, skipping, stop-and-go manner
- Often hold their wings separated partially making two V's



Figure D-1. Skippers are smaller butterflies with brown and orange coloring.

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D.2.2 Swallowtails

Key Characteristics (Figure D-2):

- Large butterflies
- Swift, sailing flight pattern
- Unhooked antenna
- Less wing loading, allowing them to soar
- Can possess hind wing extensions (tails)



Figure D-2. Swallowtails are large butterflies that are usually black, yellow, and/or white.

D.2.3 Whites and Sulphurs

Key Characteristics (Figure D-3):

- Predominantly yellow or white in most species
- Bright orange wingtips and striking black marginal patterns are common



Figure D-3. Whites and sulphurs are often white or yellow.

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D.2.4 Gossamer-Winged

Key Characteristics (Figure D-4):

- Many of the smallest and brightest butterflies
- Brightly colored (can shimmer in sunshine) in blues, greens, or coppers
- May be dotted with bold spots or checkers
- Glittering, silky wings



Figure D-4. Gossamer-winged butterflies are often smaller and have striking colors on the upper sides of their wings.

D.2.5 Brush-Footed

Key Characteristics (Figure D-5):

- Various shades of orange, red, brown, and black are common among brush-footed butterflies
- The front pair of legs is reduced to tiny, brush like appendages held tightly beneath the thorax, so they appear to have only four legs



Figure D-5. Brush-footed butterflies are commonly colored orange, red, and black, with only four clearly visible legs.

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Appendix E Bumble Bee Recognition and Photography

E.1 Recognizing Bumble Bees

Family: Apidae, Genus: *Bombus*

E.1.1 Identification

- Size and shape: Medium to very large, robust (workers and males are smaller than queens)
- Color and hair: Mostly black with yellow, orange, or brown markings; entire body is fuzzy
- Stripes: Hair can form yellow, black, orange, or brown stripes or markings
- Pollen-carrying structures: Females have flattened plate on upper hind leg surrounded by long, stiff hairs (known as a corbicula) for carrying moist clumps of pollen.

E.1.2 Notes

Bumble bees make a low buzzing sound when flying. Several flies are excellent bumble bee mimics, but they have short stubby antennae, large eyes that meet in the middle of their face, and skinny hind legs.

E.1.3 Look-Alikes

In addition to flies that mimic bumble bees, there are numerous native bee species that appear similar to bumble bees. Large carpenter bees look very similar to bumble bees, but they are shinier (less hairy), especially on the abdomen.



Figure E-1. Key characteristics of bumble bees.

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E.2 Photographing Bumble Bees

If photographing bumble bees while they are foraging, the following can be helpful:

- Wait at a group of flowers instead of following a bumble bee around
- Do not be afraid to get close to the bees when they are on flowers (they pose no risk of stinging while foraging unless one grabs their bodies)
- Use a camera with a macro setting; digital SLRs and point-and-shoots have the most flexibility with macro settings, but cameras in smartphones can be used if no other option is available
- Take photos from several different angles, aiming for shots that show the bee's back (dorsal view), one side, and face

If photographing chilled bees, the following can be helpful:

- Choose a clean, solid background surface on which to photograph a chilled bee (e.g., white printer paper); it can be hard to see details of bees within vials, so it is best to take the bee out of the vial for photos; if the bee has been chilled for 5–10-plus minutes, it will not be able to fly off for several minutes until it warms up significantly
- Take photos of different angles of the bee: top, back, side, face, and hind leg
- Take photos in full sun; make sure to focus on the bee
- Release the bee in a warm, shady spot

More details and examples can be found at:

- https://www.bumblebeewatch.org/photo-tips/

https://www.nebraskabumblebeeatlas.org/photo-tips.html

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