CHAPTER 7

POLLINATOR HABITAT DESIGN

INTRODUCTION

Beautiful blooming Tennessee landscapes are powered by pollinators as they visit flower after flower seeking nectar and pollen for food. Pollen is transferred during the visits, and the cross-pollination that happens when a pollinator visits flowers of the same species helps to increase plant seed and fruit production, and overall health of the plant species.

Figure 7.1: Tiger Swallowtail Visiting Butterflyweed
Photo Credit: Eric Kobal

Over the past few decades, the number of pollinators has drastically declined throughout the world. The amount of beneficial native flowering plants and pollinator habitat has also declined. This is an international concern that threatens the world food supply and millions of jobs in many nations. In the United States, concerns about pollinator and pollinator habitat decline has led to a call for action at Federal, State and local levels of government. Initiatives such as the Presidential Memorandum – Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators on June 20, 2014; Federal Pollinator Health Task Force and Action Plan; Mayors for Monarchs; and the Million Pollinator Garden Challenge have been developed to encourage Federal, State and local agencies, communities, volunteer groups and homeowners to restore and develop new pollinator habitats to support and increase the number of pollinators. Federal, State and local agencies are adding pollinator habitats to park sites and other land holdings and utility agencies and State Departments of Transportation (DOT) are transforming their reduced mowing maintenance areas into pollinator habitats.

Figure 7.2: TDOT Pollinator Habitat Program Logo

The Tennessee Department of Transportation (TDOT) Highway Beautification Office (HBO) created its Pollinator Habitat Program to develop pollinator habitats throughout the State at various locations including Welcome Centers, rest stops, and in roadside revegetation projects. The program modified roadside mowing schedules to be compatible with pollinators, and reduced mowing to only swaths along the edge of roadways. Pollinator information, signage, and brochures were created to present the benefits of pollinators to the public. The HBO has also been working with the Tennessee Department of Environment and Conservation (TDEC) to create pollinator habitats within State Parks. More Pollinator Program information is available at: https://www.tn.gov/tdot/environmental-home/environmental-highway-beautification-office/beautification-pollinator-habitat-program.html

This chapter further highlights pollinators, the benefits they provide, the issues that they face and how we can best support them through our landscape design and maintenance practices. The applications discussed are generally intended for roadside revegetation through seeding and turning existing roadsides into pollinator habitats. However, the considerations and processes have application for plug planting and are scalable and applicable for all homeowners and landowners who would like to support pollinators and develop a pollinator habitat on their land.

BENEFITS OF POLLINATORS

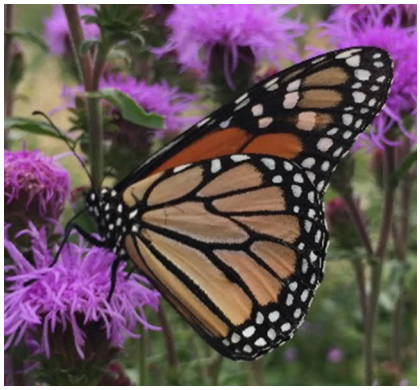


Figure 7.3: Monarch Butterfly
Photo Credit: Eric Kobal

Figure 7.4: Honeybee
Photo Credit: Eric Kobal

Figure 7.5: Bumble Bee
Photo Credit: Eric Kobal

Pollination is a natural and free ecosystem service carried out by specialized insects and animals. Simply put, pollination is an act that enables plant reproduction. This critical life sustaining service occurs as a byproduct of bees, birds, butterflies, bats, and other fauna visiting flowering plants to obtain nectar and pollen. These resources are then used by the pollinators for nourishment. Unfortunately, this symbiotic relationship between plants and pollinators has been historically overlooked or discounted.

In recent years however, researchers have been better able to quantify and qualify the plant/pollinator relationship. With these findings, we have begun to better understand and appreciate the previously unnoticed services and value that pollinators provide to humans. Take for instance the world's agricultural industry.

Although our food crops are managed through human cultivation, some 35%, or more than one-third, depend upon the aid of pollinators to set seed and reproduce.[1] Seeds are often carried inside fruits or vegetables, which we humans consume daily. Without pollinators, apples, peaches, strawberries, tomatoes, and other everyday produce would become costly, scarce, or vanish entirely. In the United States, if the otherwise free service of pollination carried out by native insects were to be monetarily quantified it would total more than $3 billion annually.[2]

In addition to fruits and vegetables, other agricultural crops dependent upon pollinators include those that produce oils, such as sunflower and canola. Another report released by the United States Department of Agriculture (USDA) found that the value of bee pollination to managed crops alone was roughly $217 billion globally.[3] For Tennessee crops, pollinators contribute more than $19 million

[1] https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/plantsanimals/pollinate/
[2] https://academic.oup.com/bioscience/article/56/4/311/229003
[3] https://www.fsa.usda.gov/FSA/webapp?area=home&subject=ecpa&topic=nra-pl

annually in services.[4] Clearly, pollinators are directly and integrally linked to our food system. Pollinators are responsible for keeping everyday items we humans depend on abundant and affordable.

Figure 7.6: Tennessee Pollinated Produce Photo Credit: TN Department of Agriculture

Aside from feeding the world, pollinators are responsible for other critical ecosystem services that directly benefit society. Pollinators create more diverse and resilient plants through the ongoing exchange of genetic material. In turn, stronger plants and plant communities enable landscapes to be more productive.

A landscape that emerges through the help of pollinators can aid with carbon sequestration, soil stabilization, water infiltration, as well as air and water purification. Native North American plants, in particular prairie species, possess extensive and deep root systems. These roots are what stabilize soil and prevent erosion during rain events.

Similarly, these roots allow water to infiltrate deep into the soil, replenishing aquifers and alleviating the risk of floods. Most people know plants are responsible for purifying our air, but many are also able to remove pollutants and particulates from water. Without these plants and their services, society would face a financial and engineering nightmare.

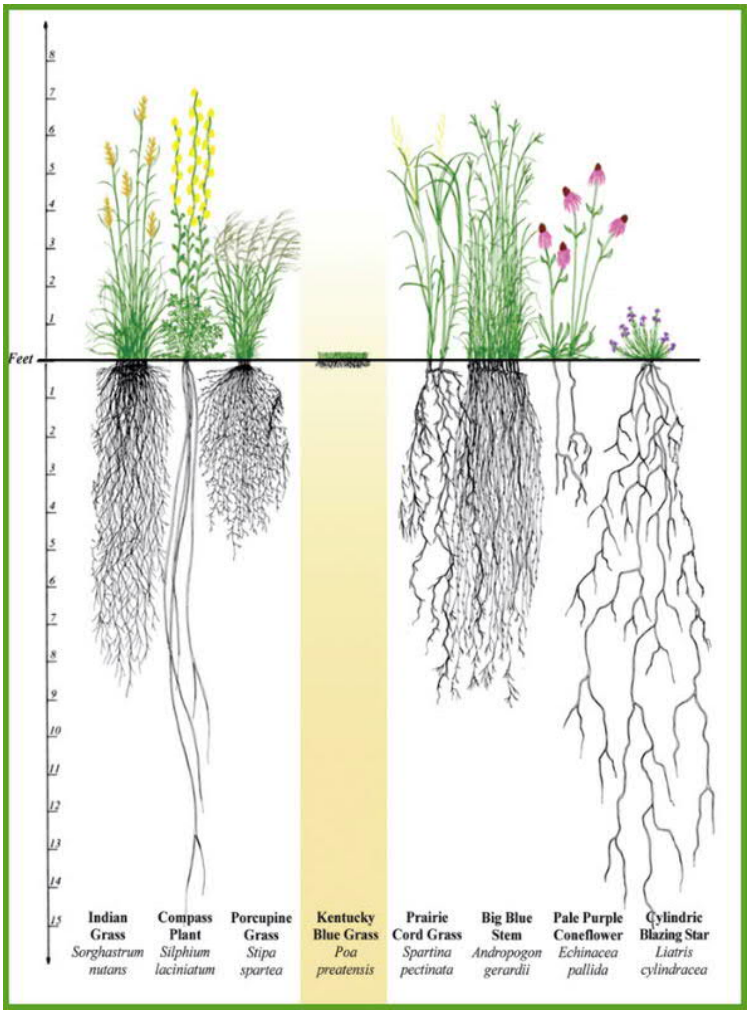


Figure 7.7: Root Systems of Native Grasses. Illustration Credit: Conservation Research Institute

[4] https://www.tn.gov/tdot/environmental-home/environmental-highway-beautification-office/beautification-pollinator-habitat-program.html

CURRENT CONCERNS

In the past decade, declines in monarch butterfly and European honeybee populations have made international news. These charismatic and well-known insects have garnered the support of individuals, corporations, and governments alike. Less publicized, but even more alarming, is the fact that pollinators as a whole are vanishing at alarming rates. For every well-known species like the monarch butterfly, there are hundreds of other inconspicuous pollinator species that are in decline. The loss of any one of these species can have devastating and wide-ranging consequences. We must value all pollinators, not just those we find attractive or familiar.

Figure 7.8: Endangered Rusty Patched Bumble Bee
Photo Credit: Kim Mitchell; USFWS

Why does a single bee visit hundreds of flowers on any given day? The answer is not because it wants to pollinate plants. Instead the bee, and all pollinator species, have a much simpler goal in mind – finding food. Nectar and pollen are what all pollinators search for when they probe or climb into a flower. These are essentially treats the plant has produced to entice the pollinator to stop and visit.

Almost all native wildflowers produce a mix of pollen and nectar, which is why they make the perfect addition to any pollinator habitat. Today though, many common and widely sold hybridized-species of flowers are cultivated by humans. Although beautiful to us, they develop minimal pollen or nectar and provide limited benefits for the pollinator.

Beyond providing nectar and pollen, many native plants are also hosts for various pollinators. A host is a unique genus or species of plant that a specific pollinator species depends upon to reproduce. Many moth and butterfly pollinators will only lay their eggs on a few specific species of plant. Once these eggs hatch, the larvae consume the plant's foliage. In order to grow and evolve, these larvae are restricted to their host species. A good example of the host/pollinator relationship is milkweed and the monarch butterfly. The monarch butterfly will only lay its eggs on certain species of milkweed (Asclepias spp.). The monarch caterpillars then grow as they feed on the milkweeds' leaves. The dramatic decline in monarch populations in recent decades have largely been attributed to a loss in its host plants population. One study estimated that between 1999 and 2010, milkweed populations in the American Midwest declined by 58%, while monarch reproduction declined by a staggering 81%.[5]

Figure 7.9: Monarch Caterpillar on Host Common Milkweed Leaf
Photo Credit: Eric Kobal

[5] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1752-4598.2012.00196.x

For many of our native, North American pollinators, their declines appear to be a result of habitat loss. More specifically, researchers have identified habitat fragmentation as a chief culprit.[6] In the United States, such fragmentation occurs when large, native plant communities are broken up into smaller, isolated pieces for new land uses (i.e. residential, commercial, or agricultural). Often, these new landscapes are so large and devoid of useful flowering plants that many pollinators cannot traverse them to reach other remnant habitat fragments.

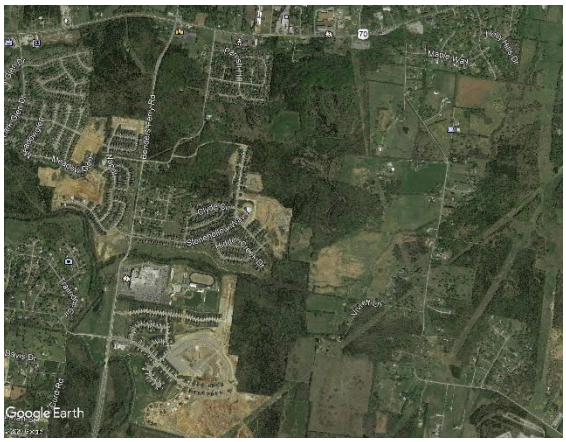


Figure 7.10: Fragmented Natural Areas Image Credit: Google Earth

Imagine miles of asphalt, fescue lawn, or corn fields which are essentially deserts for a pollinator. These remaining habitat fragments may be thought of as islands, with only isolated populations. Over time, the diversity of plant material within these islands may decline as a result of the inability of pollinators to exchange genetic material between unique individuals. As a population becomes less diverse it too becomes less resilient and more susceptible to disease.

Over the course of many years and as the result of various disturbances, it is possible that a majority of the native plant species within the island disappears. Often what takes their place are non-native, invasive plant species with little pollinator value. What's more, the invasive species grow and seed prolifically. In a short time, they will likely kill off whatever beneficial pollinator habitat remained. With this loss of habitat our pollinators are impacted in a variety of ways.

First, there is the obvious loss of nectar and pollen resources. For pollinators making long migratory journeys, particularly those migrating in Spring and Fall like the monarch butterfly, the absence of abundant food sources is life ending. Second, the lack of native host plants limits the number of offspring each species can produce. Third, limited habitat in the form of dead vegetation lessens the odds of pollinators, like native bees, successfully overwintering. In addition to these impacts, there is the broader aspect of disturbance (or lack of disturbance) and how it relates to the overall health of our pollinators. Although disturbances are often thought to be negative, in Ecology disturbances can be highly beneficial. For instance, consider fire in the context of a grassland and prairie. Grasslands, particularly those in North America, are among the most diverse landscapes in the world. The reason for this vast diversity is the repeated occurrences of fire.

Figure 7.11: Prescribed Burn for Portion of Pollinator Habitat. Photo Credit: Eric Kobal

[6] https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/pollinator-decline

Over thousands of years, fire has allowed our prairies to evolve into seas of countless grasses, sedges, and forbs, while simultaneously preventing the establishment of large woody trees and shrubs. Then, beginning in the 19th century, fire was cut out of the equation thanks to Anglo-American landscape norms. In an ecosystem where disturbance is the engine for growth and diversification, its absence spelled disaster. The absence of fire from our prairies has greatly lessened the capacity by which these landscapes can provide resources for pollinators.

Figure 7.12: Pollinator Habitat is Rejuvenated after a Burn
Photo Credit: Eric Kobal

CAUSES OF POLLINATOR DECLINE

Disturbances can both negatively or positively impact pollinators. With fire, the impact is widely positive in that it generates greater diversity and habitat health. However, there are many modern human inflicted disturbances that negatively affect pollinators. It is often not our intention to harm a butterfly or hummingbird. However, our actions in the landscape typically can and do have unintended consequences.

The use of non-selective herbicides and insecticides, particularly in modern agriculture, are both good examples of an unintended consequence. Traditionally, these herbicides and insecticides have been widely applied to agricultural lands indiscriminately. Without concern given to the proximity of surrounding native landscapes, these airborne toxic chemicals drift well beyond their intended targets.

Figure 7.13: Pesticide Spray Drift
Photo Credit: Philippe Huguen; AFP/Getty

Although they were used to kill off weeds and insect pests within corn, soy, and cotton fields, these chemicals just as easily killed milkweed and monarchs.

Like fire, mowing can be a generative disturbance. However, it is critical that mowing occur at times in keeping with the rhythms and cycles of plant and pollinator life (see information on TDOT Integrated Mowing, pg. 30). Mowing in early Spring or late Fall for example can be extremely harmful to pollinators. During these two times of year, there are a limited number of forb species in flower and resources are extremely limited. Mowing down these precious flowers could cut short the lives of many pollinators. Additionally, mowing between Fall and Spring can kill overwintering pollinators like native bees, which nest in the dead stems of many plants.

Finally, one of the greatest risks to pollinators and pollinator habitats are non-native, invasive plants. According to the U.S. Forest Service, “Invasive species have contributed to the decline of 42% of U.S. endangered and threatened species, and for 18% of U.S. endangered or threatened species, invasives

are the main cause of their decline."[7] A non-native, invasive plant is exactly that – a species that evolved elsewhere in the world and is extremely aggressive in its new growth habitat.

What makes these species so detrimental to our pollinators is their ability to overtake and crowd out or shade out native flowering forbs. Many non-native invasive species green up or leaf out early, establish a dense canopy of leaves that shade the ground, and then maintain their leaves late in the year, allowing native plants little access to sunlight or rain water. Given the chance, Kudzu, Privet, Bush Honeysuckle and Knotweed, species native to Asia, will easily destroy pollinator habitats in North America. Their prolific root systems, ability to readily seed or regenerate from cuttings, and allelopathic compounds make these and other invasive species nearly unbeatable.

Figure 7.14: Invasive Kudzu Vine (Pueraria montana)
Photo Credit: Missouri Department of Conservation

Although some invasives do provide nectar and pollen resources, such flowering occurs for only a limited period of time. What's more, these invasives overtake large areas, forming monocultures. This means that nectar and pollen only exist while the invasive species is in bloom, the rest of the year an area may be entirely without pollinator resources. In addition to lost nectar and pollen, non-native invasive monocultures prevent the growth of various host species, thereby stymieing future pollinator populations even further.

CORRECTIONS IN LANDSCAPE MANAGEMENT

To save our pollinators and their habitat, certain corrections in landscape management need to be made. These corrections do not have to be monumental changes, nor necessarily costly. Rather, they can be logical, conservative, and beneficial to humans. What is paramount is a stronger cultural understanding of the pollinator/plant relationship. Through appreciation of this symbiotic relationship, we may begin to identify the most critical areas in land management that need change. Examples of corrections in landscape management to benefit pollinators, include:

- Minimizing the use of herbicides and pesticides, or only using herbicides and pesticides when no other option exists
- Spot spraying pesticides as opposed to broad, nondiscriminatory spraying
- Spraying at night when MOST, but not all, pollinators are inactive
- Reincorporating fire with controlled burns
- Minimizing the use of non-native plant and turf grass species
- Reducing mowing maintenance needs and area
- Mowing smart and high
- Eradicating non-native invasive species that compete with native pollinators

[7] https://www.fs.fed.us/wildflowers/invasives/index.shtml

Non-native invasive grasses, plants and insects that have been brought into the United States are the top threats to beneficial native plants that pollinators rely on for food and habitat. The agriculture industry and landscape maintenance professionals have traditionally turned to a variety of selective and non-selective herbicides and pesticides to quickly remove threats to protect crops and desirable vegetation. While highly effective, widespread use of chemicals is also one of the primary causes of the decline of pollinators and pollinator habitat. The injury and death of native plants and pollinators is often unintended collateral damage of the absorbed or ingested chemicals.

Growing awareness of the impacts of aerial and broad blanket pesticide spraying of agriculture and road rights-of-way on human and animal health and on pollinators and native plants has resulted in application and use changes. The vegetation management industry is employing greater use of targeted spraying of invasive patches, use of selective herbicides and pesticides designed for specific target species, and the use of more natural invasive control measures and strategic mowing techniques to support pollinators and pollinator habitat.

Natural invasive control measures include repeated tilling, prescribed burning, selective cutting and mowing of invasive plant patches through mechanical means or by goats and then revegetating invasive removal areas with desirable native grasses and forbs using no-till drill seeding. Tilling cuts and exposes roots to kill invasive plants and encourages weed seeds in the existing seed bed to germinate. Repeat tilling every two months over the course of one year beginning in April depletes the existing seed bed and reduces future competition for native plant seeding that can take place over winter.

Prescribed burns should only be conducted by trained professionals on land with the correct site conditions, with full coordination with local fire department officials, during the right weather conditions, and in Tennessee counties that allow burns. The Tennessee Department of Agriculture Division of Forestry (TDF) offers prescribed burn services. The current Tennessee county burn ban list is available at BurnSafeTN.org. County burning bans are applied and removed depending on the current weather conditions, so the burn ban list is continually updated and available for reference.

Figure 7.15: Field Analysis for Treatment Plan
Photo Credit: TN Wildlife Resources Agency

Site conditions, invasive species types and project schedule will often determine the appropriate invasive species elimination program. The site and area surrounding the site should be evaluated by an environmental, landscape architecture, horticulture professional, or qualified specialist that is able to evaluate overall site value and conditions. The evaluator should determine value based on existing native plant and wildlife diversity presence, habitat quality, physical site conditions and type and extent of invasive species pressure and then recommend the appropriate invasive removal program for the site. The site should be fully walked, and sensitive water and environmental resource areas and animal and pollinator nesting sites should be marked and protected from chemical or other potentially destructive means of invasive removals.

For sensitive resource areas and existing high value habitat sites with minimal invasive species pressure, invasive plant cutting and removal, spot mowing and localized controlled spray wand and wicking herbicide and pesticide applications by trained and licensed pesticide application professionals may be the most effective and have the least impact on pollinators and their habitat. Spot invasive plant removals using teams of goats has also been used by DOTs with some success. Temporary pens (up to one-acre in size) are set up around the invasive plants and the goats eat until the offending plants are gone. Using this method, the invasive plants are removed with minimal brush or debris clean up and the area can then be seeded or planted with desirable native plants.

Figure 7.16: Invasive Species Removal by Goat Team
Photo Credit: Gabriela Szymanowska; UT Knox News

Pollinators are in dire need of high-quality habitat without competition from non-native invasive plant species. For sites with widespread invasives, drastic invasive removal measures can be used to allow a late Fall or late Spring seeding or Spring planting of a pollinator habitat. Drastic measures consist of a short mowing, baling and removal of grass material followed by non-selective glyphosate applications and tilling events spread throughout a full year, or a combination of a prescribed burn and spot glyphosate applications for a year. Site preparation for a year allows multiple seed exposures, germinations and kills. The high heat of a prescribed burn destroys most non-native invasive and annual broadleaf weed seeds in the soil and allows native seeds to germinate without competition. Monitoring and follow-up spot herbicide applications removes any invasive species that survive the burn.

Prescribed burns (where allowed and safe) are often recommended for every third year. During the non-burn years, localized controlled spray wand and wicking herbicide applications may be needed to remove volunteer woody species and any returning invasive grass or plant species, if desired. It is important to note that pollinators are heavily stressed if they are displaced by a mowing or burn and need to find another habitat. Once a habitat is established, it is a best practice to burn or mow one-third or less of a habitat each year to allow for lower stress pollinator relocations.

Pollinators achieve the most benefit from a diverse habitat that is free of invasive plants and is not disturbed. DOTs have generally adopted a policy of reduced mowing areas within the right-of-way that they maintain. Typically, the maintenance consists of an early winter or late winter mowing prior to spring annually for urban sites or every two to three years to eliminate woody species as desired. This reduces maintenance costs, enhances erosion control and storm drainage capacity and quality and creates limited wildlife habitat. Invasive plant pressure still must be monitored and managed for these areas to remain diverse and beneficial. To reduce invasive species pressures when creating a new reduced mowing maintenance area, it is recommended that the use of non-native invasive perennial ryegrass and fescues for quick vegetative cover be eliminated in favor of seeding a cover crop of oats or annual ryegrass with native grasses and forbs to create pollinator habitat.

In some portions of the TDOT rights-of-way, invasive tree and plant species pressure from adjacent surrounding properties may increase the need for spot mowing of invasive species, annual mowing, or mowing every two to three years to remove undesirable invasive woody plant species. Native grasses and forbs should be mowed high (at a 12-inch height) to better preserve the lower portion of plants where some pollinators may nest and to preserve more of the native plants for a quicker recovery and blooming, see information on TDOT Integrated Mowing, page 30.

POLLINATOR HABITAT FUNDAMENTALS

Site Appropriate and Functional Habitat

Pollinator habitat can take on a variety of forms and be composed of countless combinations of species. There are however, several fundamentals that should be followed when developing such habitat. Whether planting trees, shrubs, forbs or a combination, the habitat created should be designed to fit the specific site conditions and constraints and support a wide variety of pollinators, for the habitat to evolve into a functional plant community. A plant community may be thought of as a collection of vegetation of multiple species and morphologies that cohabitate within a physical area. These species do not compete with one another, but rather complement each other. Examples of compatible plants include shade tolerant grasses and sedges that cover and stabilize exposed soil beneath taller forbs or different forb species that bloom in succession, providing uninterrupted flowering resources for pollinators throughout the year.

Figure 7.17: Complementary Layered Forb Mix Photo Credit: Todd Teuscher

Often, a good source of complementary species may be found in native or wild habitats, where plants have been evolving together for millennia. This leads to another key component of high value pollinator habitat - native plants. Using native plants is always advantageous given the fact that these species have also evolved with the native pollinators.

Native Plants

There are three degrees of native-ness that are used in designing a plant community. Two have a high level of acceptance by the design and botany science community and one is viewed entirely not acceptable. Pre-packaged pollinator or wildflower mixes obtained from national retail chains, from local garden centers and most online seed sources contain annual species, non-native invasive species and non-regional native seed obtained from States far away from Tennessee and are not acceptable to professional designers and botany science practitioners. Using such seed likely means introducing non-native species into the local ecosystem, which could weaken or change the native species as cross-pollination occurs and the resulting plant seeds are spread.

The two acceptable plant source alternatives consist of native plants commercially grown and seeds harvested within the county of the project site and native plants commercially grown and seeds harvested within a few hundred miles of the site. The choice for the designer may be based on the project geographical location in the United States. Some States simply do not have many commercial growers of native grasses and forbs, or only the top 40 favorite native plants are grown. Local ecotype plant species or ecoregional natives are the consensus of acceptably sourced plants. Finding local seed sources can be a difficult and time-consuming process.

Ecoregional Plant Selection

Ecological regions or ecoregions are geographical areas that have similar ecosystems including vegetation types, topography, elevation range, geology, soil types, land use and general environmental resources of the same type, quantity and qualities. The U.S. Environmental Protection Agency (EPA) has mapped the specific ecological regions throughout North America.

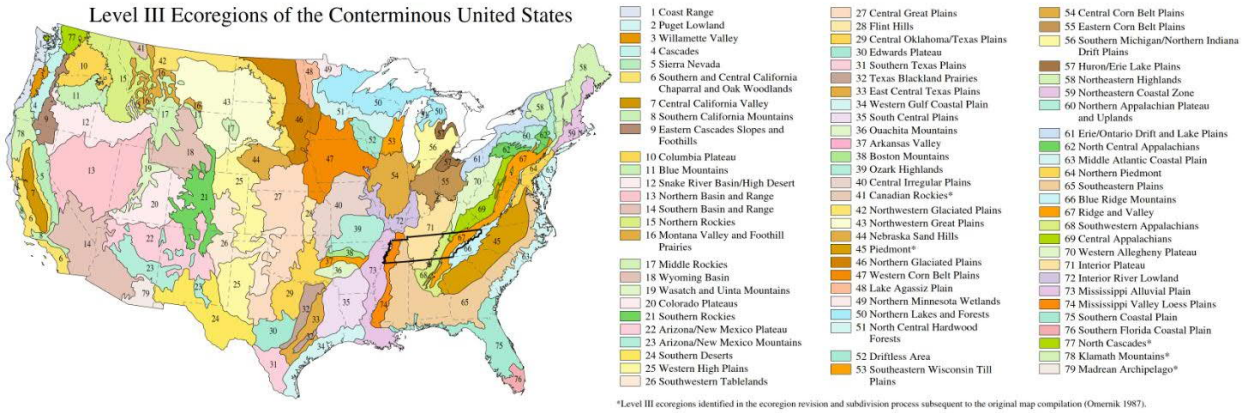


Figure 7.18: U.S. EPA Level III Ecoregions. Image Credit: J.M. Omernik; US EPA

These ecoregions are bound by ecological system, not by country borders or state lines. The scale and degree of ecosystem similarity refinement is referred to as EPA Levels.

EPA Level I identify 15 basic ecological regions across North America. Twelve are within the continental U.S. Level I ecoregions identify global scale land areas such as mountain regions, desert, plains and forests. These ecoregions consist of: Arctic Cordillera, Tundra, Taiga, Hudson Plains, Northern Forests, Northwestern Forested Mountains, Marine West Coast Forests, Eastern Temperate Forests, Great Plains, North American Deserts, Mediterranean California, Southern Semi-Arid Highlands, Temperate Sierras, Tropical Dry Forests, and Tropical Wet Forests.

EPA Level II further divides the Level I regions into 25 more detailed ecological regions within the U.S. EPA Level II identifies continental scale ecosystems such as northern and southern, wet and dry mountain areas, upper plains and lower plains, northern and southern forests and everglades.

EPA Level III further divides the 25 Level II regions into 105 ecoregions that stretch across states and identify the national scale regions such as upper and lower, northern and southern, eastern and western lowlands, river valleys, lake areas, plains, plateaus, deserts, highlands and mountain areas of the south, southeast, mid-west, northeast, southwest and the like.

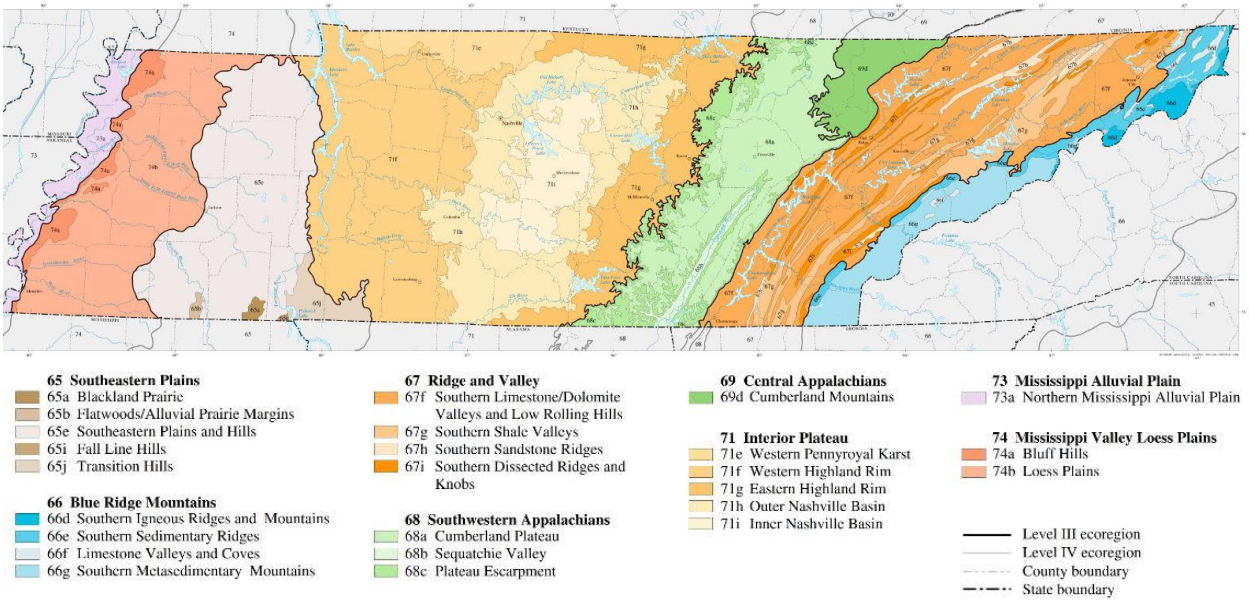


Figure 7.19: Tennessee EPA Level III Ecoregions. Image Credit: J.M. Omernik; US EPA

EPA Level IV identifies 967 ecoregions within EPA Level III regions that generally stretch across counties that have similar topography, landform and ecosystems. The regions of each level are more similar and specific in terms of the total elevation range, landform and ecosystem within the ecoregion boundary.

The EPA, U.S. Department of Agriculture (USDA), U.S. National Resource Conservation Service (NRCS), U.S. Forest Service (USFS), and national botanical community continue to collaborate to gather historical and current plant data to identify plants that are specific to the counties within each ecoregion where the plants have been found to grow naturally. For more information about plants specific to Tennessee Ecoregions, please visit https://tnpollinators.org/database-map/.

Local Seed Source

Figure 7.20: Fall Seed Harvesting of Local Ecotype
Photo Credit: Steve Tarlton; Writes of Nature.com

The goal of designing with native plants and the importance of EPA ecoregional plant information is to select seed or plant species grown from seeds that originated from the county where the site or project is located to support native pollinators that rely on those specific plants. Unfortunately, while some states have multiple local native seed and plant growers, other states are more limited with most local native plants not in seed or plant production and not commercially available. Tennessee is a state without major local native seed and plant growers. Therefore, designers may not be able to prepare an appropriate seed mix list of plants for a diverse pollinator habitat that are native from their site, project county, or adjacent counties. Seeds may need to be purchased from plant sources that are located within a few hundred miles, preferably less than 300 miles, from the project site for example, in Kentucky, Indiana or Missouri.

Diverse Plant Types

Figure 7.21: Tree and Shrub Cover Habitat for Pollinators
Photo Credit: Gary Wade; UGA Extension

Pollinator habitat is more than just native grasses and flowering forb groundcover. Many pollinators find rest, cover, food and nesting opportunities in trees and shrubs. Clusters of trees and shrubs provide habitat for many pollinators including birds, bats and moths. There are many trees and shrubs like linden, magnolia, tulip tree and viburnum that also offer beneficial flowering as a food source. Where space exists, it is recommended to supplement areas of blooming native forbs and grasses with clusters of native trees and flowering shrubs.

Wetlands and low areas with soils that stay moist for long durations provide additional opportunities to create pollinator habitat. Similar to the dry or mesic prairie, there are native grasses and forbs that prefer moist or inundated soils as well as native rushes and sedges to cover wet ground. Although the rush and sedge plants may not provide nectar or pollen, many serve as hosts for the larvae of countless pollinators, including skippers, butterflies, and beetles.

Water Resources

Water is a critical component to pollinator habitat function. A water source may consist of a wetland, drainage ditch, creek, pond or lake. A dependable water source within 100 yards of a pollinator habitat is ideal to help pollinators conserve energy for more food gathering. Incorporating shallow depressions in the landscape where water can collect and slowly percolate after rain events provides drinking and reproductive resources for many pollinators.[8] A water source can also be used for making mud which benefits solitary bees, such as mason and leafcutter bees.

Soil Access

High grade habitat should also include areas of exposed soil and fine clay soil. Although it may sound counterintuitive, bare earth in proximity to native plants is important to a select group of pollinators - ground nesting bees. Unlike European honeybees which nest in colonies above ground, many native North American bees, such as bumblebees are solitary, digging chambers in the earth where they raise their young and store resources. These bees prefer sandy, well-drained soils that receive southern exposure that keep them dry. Fine clay is used by solitary mason bees that dig

Figure 7.22: Digger/Miner Bee Soil Nesting Site
Photo Credit: Todd Teuscher

[8] https://ento.psu.edu/pollinators/public-outreach/cert/cert-steps-step2

and create chambers in hollow stems to compartmentalize their brood. The clay should be fine soil without sandy grains.

Continuous Bloom

One final fundamental, which has already been alluded to, is a continuous period of bloom. An area could be home to dozens of forbs, but if all the plants flower between June and July, the habitat is regarded as Spring and Fall deficient. The early Spring and late Fall are critical times for a pollinator. While many forbs are in bloom during the Summer, forbs that bloom in the Spring and Fall months are naturally less abundant. As pollinators emerge from hibernation in the Spring or make their final push to reproduce, migrate, or hibernate in the Fall, many pollinators are dangerously exhausted. Providing nectar and pollen resources during these particular months helps to ensure our pollinators survive these periods of extreme.

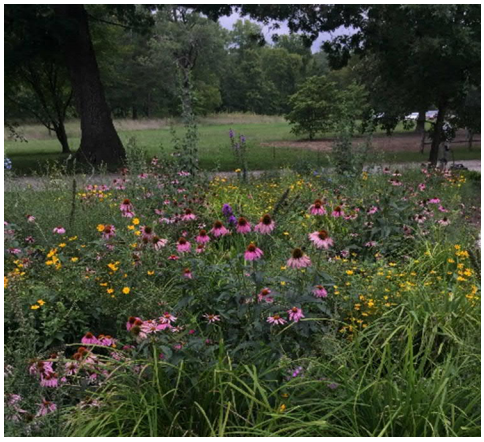


Figure 7.23: Multiple Forb Species in Bloom
Photo Credit: Eric Kobal

Multiple Blooming Species

A best practice for supporting pollinators throughout the year is to provide a diverse mix of plants that include a minimum of three native blooming plant species in each month, March through November. This is a practice that may conflict with the goal of providing only local, or county-specific native plant species. In certain counties and in certain ecoregions, native early Spring and late Fall flowering plants may not exist or may not be in commercial production. In this instance, the designer must decide whether to stay true to local native plants and provide a limited pass-through pollinator habitat or expand to EPA Level III regional plants that may be native in adjacent counties or to counties within the project site ecoregion, and still within a few hundred miles of the site. Plant sources within the ecoregion and within 300 miles of the site or project is a designer consensus acceptable target distance. Designers and landowners are encouraged to only purchase native seeds and plants if their origin is known and can be confirmed by the supplier.

DESIGNING FOR POLLINATORS

Tennessee pollinators are a diverse mix of birds, bees, butterflies, beetles, flies, bats and moths among others, and they have a diverse mix of food and habitat needs to assure their survival. Habitat size, diversity, and convenience are keys to their habitat needs. Expanding development of our cities and suburbs has fragmented wooded and open grassland areas where pollinators can find food and habitat. Natural habitat areas are smaller and spread farther apart. The distance between habitat and food sources makes finding food for many pollinators a dangerous proposition. The distance, coupled with weather conditions, finding water sources, vehicle conflicts, predators, and finding their way back to their nest adds stress that can affect pollinator health. Roadside revegetation that creates pollinator habitat begins to restore food and habitat links between undisturbed native natural areas that are so important for the survival of pollinators and native plant species.

Vegetation

Building a pollinator habitat begins with diverse vegetation that may include trees, shrubs, forbs, grasses, sedges, rushes and vines. The primary focus is the groundcover layer that provides pollinator sustenance. Nectar and pollen are primary food sources for pollinators, so a groundcover for pollinators should be a heavy mix of native flowering forbs with grasses. The grasses provide structural support for the forbs to keep flowered stems vertical, a resting place for pollinators, cover for nesting, and fuel for prescribed burns if appropriate.

Figure 7.24: Pollinator Habitat along Roadside.
Photo Credit: MNDOT

The consensus forb to grass ratio for pollinator habitat is 3:1 or 4:1 by weight of pure live seed (PLS). Pure live seed is the percentage of viable seed that will germinate, minus stem and hull fragments, debris and weed seeds. The native plant palette or palettes should respond to the various conditions found on the site and be constructed with the goal of providing a minimum of three flowering forb species in near equal abundance for each month, March through November.

As previously discussed, the plant palette should be built with plant species that grow natively as close to the project site as possible. Local plants are better adapted to the physical site and local climatic conditions, and selecting from local seed sources preserves and strengthens the ecosystem. Unfortunately, in Tennessee the number of flowering forb species that grow native within a county are limited, native seed growers have limited species inventory, and there is a lack of native seed growers.

If the plants cannot be harvested from the project site or the same county, the next best course of action is to select plants from the same ecoregion of the project, but within 300 miles of the site. A designer should look for available native plant species that grow wild within adjacent counties, or within the EPA Level III or Level IV ecoregions. Given the lack of native seed growers in Tennessee, to build a plant palette for a pollinator habitat that has three or more flowering forbs in each month, March through November, many plant species will need to be obtained from native seed growers located within 300 miles from the site.

Figure 7.25: Butterflies Feeding along Gravel Path
Photo Credit: Todd Teuscher

Trees and shrubs are valuable components of a pollinator habitat. As most flower at some point, they are additional food sources. But they also serve to provide crucial pollinator cover during storms, offer protection from predators, and provide opportunities for nesting and shaded resting. Where space allows, include clusters or hedgerows of native trees and flowering shrubs, with preference for long-flowering species and those that flower early or late in the year.

Select native tree and shrub species that are found growing naturally near the site and supplement with other species that are native to the county.

Dead Trees and Brush

Dead trees in all their forms, from standing (snags), fallen, and stumps, to piles of sticks and branches, make wonderful habitat for pollinators. Standing and fallen trees, even their stumps, typically offer bug holes, gaps behind bark and soft wood that can be used for cover, protection and nesting. If present on the site, outside the required highway safety clear zone and not a danger to property if it should fall or impacted by spreadable disease, it is recommended that standing dead trees be allowed to remain on site as part of the overall habitat. Similarly, large dead trees that have fallen are also recommended to remain. Loose branches and sticks can become valuable habitat when stacked tightly in two to three-foot tall bundles. Logs and branch bundles can be placed in quiet, back of habitat locations where they can remain undisturbed and will not conflict with mowing maintenance. Drilling holes in the tree stumps, snags and fallen trees can create additional nesting locations for pollinators.

Soil

Ground nesting pollinators will often dig underground nest sites near clump forming plants, logs, rock or in larger bare soil areas if present. As a seeded pollinator habitat matures and fills in, there may be an absence of exposed soil that is desirable to ground nesting pollinators and they may only be able to locate soil area for their nest far away from the food source. This can create a long commute that adds stress and predator dangers to the pollinator's day. Reserving or creating bare areas of topsoil, clay soil, sandy soil and/or gravelly soil within or near the pollinator food source area can provide pollinators more close housing options and allow them to be healthier and more productive. The soil areas on level ground sized at 4' x 4' to 8' x 8' and located in quiet areas at the center or back of planting areas are adequate. Ground level or raised bed areas with a stone or log edges will help slow native plant encroachment and keep soil contained. A diverse soil landscape with mounds, flat areas and depressions will create desirable conditions for a wider range of pollinators.

Rock

Rock in the form of existing or created rock outcrops, boulder clusters, rock piles, stone beds and gravel beds provides structure and protection for pollinators who dig nests under or between the rocks. Concrete pavement demolition waste can similarly be used to create outcrops and piles for pollinator nesting. Pollinators often seek cover and refuge among rock outcrops and rock or concrete debris piles. Rocks are also used for resting, sunning and warmth and as a source for essential salts and minerals. Stone beds or gravel beds in a depression can pool water for drinking and can provide a dry place to perch while drinking or eating the salts and minerals from stones at the water's edge.

Figure 7.26: Butterflies Mud-Puddling for Essential Nutrients
Photo Credit: Missouri Department of Conservation

Water

Close continuous water sources for drinking, bathing and mud creation are essential for a functional pollinator habitat. Sources can take multiple forms, from continuous sources like

lakes, ponds, and streams to ephemeral sources like ditches, swales or depressions. Stone or gravel-lined depressions or depressions created in open soil areas can provide quick local water, nutrient, and mud resources after rain events.

PLANNING

Successful pollinator habitats are developed with thoughtful planning which involves selecting the right seed for the conditions, removing invasive plant species, locating and scheduling appropriate equipment, scheduling the ground preparation and planting activities, and identifying and scheduling monitoring and maintenance tasks to take place after planting. Study and knowledge of the site informs the rest of the decisions for the development of the habitat. It is best to begin with a review of available background documentation on the site followed by an extensive field analysis.

Figure 7.27: Site Analysis Preparation
Photo Credit: Brittany Morris

Site Inventory & Analysis

A site inventory and analysis should be conducted by a landscape architect, environmental planner or certified horticulturist, collectively referred to as designer, who is experienced with site evaluations, site design, native plant communities, soil types and considerations, designing with native plants, and installation and care of native prairies. Preparation for the site analysis begins with acquisition and review of all available construction site and grading plans, site survey, record plat, U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) county soil survey, and U.S. Geological Survey (USGS) topographic maps for the site. Historical land use and ownership should be investigated as applicable, as this could add perspective on how the existing soils have been disturbed and treated with pesticides in the past and what might be lingering in the soil that could affect future plant germination and pollinator health.

Locate and inventory nearby remnant pollinator habitat communities for obtaining historical knowledge, species selection and possible seed collection sources. A remnant habitat is an ecological community containing native flora and fauna that has not been significantly disturbed by destructive activities such as agriculture, logging, pollution, development, fire suppression, or non-native species invasion.

The designer should prepare a measurable site analysis plan that inventories all existing property lines, clear zones, site structures, utilities, and physical conditions (including topography, ditches, steep slopes, depressions, rock outcrops, drainage patterns, wet areas, dry gravel areas, compacted soils), as well as identifies full sun, part shade, and heavy shade exposed areas.

The site inventory should identify existing native vegetation, invasive plant species and their measured extents, existing wildlife, pollinators, and nesting sites. The inventory should identify invasive plant species that surround the site, such as cottonwood trees, bush honeysuckle, and Japanese stiltgrass that will likely continue to infiltrate a new pollinator habitat unless removed and replaced with permission from the adjacent landowner (if applicable). Site observations and discoveries begin to inform the site soil preparation tasks for a native seeding, layout of the site design, and the tolerances required of the plant material.

On-site soils should be tested to identify general structure and components, nutrient content and deficiencies, soil pH, and organic content. Some native plants have specific tolerances or preferences that can affect their germination and survival. Soil test results will help guide the selection of native plants for the project or removal from consideration. Each soil test location should be dimensioned and coded on the site analysis for future reference. The number of soil tests to conduct is up to the designer's judgement and experience. Native plants typically have a wide soil tolerance range and are adapted to the soil and climate conditions within the ecoregion. It is advisable to test unique site areas, high and low areas, gravel or soil areas where plant growth is minimal, wet areas, and typical representative site areas to create a complete picture of the soil conditions on which to base plant species selection. Two tests per acre on a typical open site with limited distinguishing features, or three tests per acre on a standard highway right-of-way fore-slope, ditch, and backslope section will likely tell the story.

If grading of an existing high-quality site is preformed, plan for harvesting seed bank and topsoil. Also consider quality control of topsoil brought to the site.

Site Design

The site design should respond to the specific qualities, elements, and areas documented on the site analysis. The size and shape of a pollinator habitat planting project is determined by budget, schedule, and existing site features that create natural edges or limits of the planting. Physical features and recorded or prescribed measurable limits of a planting area include property boundaries, road rights-of-way, maintenance access paths, road safety clear zones, driveway and roadway view triangles, DOT mowing limits for the area, water features, drainage ditches, existing wooded areas, diverse native vegetation and wetland areas to remain, signage view sheds, and drainage and utility structures.

Surrounding development and land use may influence the size and type of vegetation to be installed within a right-of-way. Tallgrass prairie species that reach four to seven feet in height may be appropriate for rural highway roadsides, and low-profile grass and forb species that reach one to four feet in height may be more appropriate in dense urban areas. Supplemental clusters of native large canopy shade, understory trees, and flowering shrubs should be added as appropriate to a pollinator habitat. Existing vegetation, site soils, water resources, site topography and sun exposure will guide the native plant species selection for the project. Wet ditch and low areas that may collect and hold stormwater for extended periods of time should be planted with species that are tolerant of wet and moist soils and can withstand periods of inundation.

Plant Selection

The selection of plant species for a project should address the specific conditions of the site. Sites with varied conditions such as low wet areas in full sun or heavy shade or full sun areas on steep slopes will need to have multiple seed mixes and tree and shrub selections to be planted in those areas to avoid wasting seed and plants that will not survive the conditions where they are placed. The goal of a pollinator habitat is to provide a diverse planting palette that will provide three or more flowering forbs in each month, March through November. Some areas will not have three or more native species that flower in March, April or November, but the designer is encouraged to work toward that goal. Early or late flowering tree and shrub species may be specified to help fill that gap, if flowering forbs are not available.

Native plant species that grow naturally in the area, in the county, or in the ecoregion are adapted to the soil and climatic conditions of the site and are most likely to germinate and survive on the site. Commercially grown native plant species are limited and the designer is encouraged to identify local seed sources and growers as close to the site as possible, with the knowledge that a portion of the seed mix may need to be obtained from multiple growers and some may be located within 300 miles from the project site. Large projects will require large amounts of seed that will likely only be available from large growers in Kentucky, Indiana and Missouri. There are other seed suppliers in Tennessee and surrounding states that obtain their seed from the larger growers as well. It is recommended that the designer have the seed supplier provide the source of each plant species to avoid planting imported seed from other regions of the country.

Figure 7.4: Prairie Dropseed Grass
Photo Credit: Todd Teuscher

Figure 7.3: Obedient Plant Forb
Photo Credit: Eric Kobal

Seed mix for a pollinator habitat should be forb heavy, seventy-five to eighty percent flowering forbs with the rest as grasses, sedges and rushes as applicable. A seed mix is developed through extensive research on plants that are native to the area or ecoregion, tolerant for site conditions and native seed species that are commercially available from growers. The designer will need to be aware of the traits of specific native plants when considering them for a seed mix. For example, Indian grass and switchgrass are aggressive spreading native plants. Certain other forb species in the sunflower, goldenrod and rudbeckia families seed and spread freely and can dominate a seeded project.

There are various resources available to the designer for plant information and development of a plant palette that contains species native to a project's county and ecoregion.

Ecoregional Revegetation Application (ERA) by the U.S. Department of Transportation, Federal Highway Administration. This online ecoregional mapping and plant database tool allows the designer to view all plant species native to the ecoregion of the project site. The spreadsheet lists all consensus attributes, tolerances, and benefits to pollinators for each plant and allows certain attributes to be selected and filtered in or out to focus the list to the conditions of the site. The resulting spreadsheet can be downloaded for further review. The ERA tool combines a number of plant and pollinator databases from organizations such USDA Plants, Xerces Society, Pollinator.org, and wildflower.org, with EPA Level III ecoregional mapping. http://www.nativerevegetation.org/era/

USDA Plants Database by U.S. Department of Agriculture, Natural Resources Conservation Service. This is an online native plant database with plant attribute descriptions, plant facts, and mapping of reported native occurrence by county for each plant. It is suggested to find a list of appropriate plants using the ERA tool and then to check the county occurrence of each plant through the USDA Plants map zoom tool. This is currently the best tool for locating plants native to a project county. https://plants.sc.egov.usda.gov/java/

Landscaping with Native Plants Lists by Tennessee Invasive Plant Council. This online PDF lists native plants observed in East, Middle and West Tennessee. The plant lists were developed with oversight by the Tennessee Native Plant Society, Department of Botany of the University of Tennessee, Tennessee Department of Environment and Conservation (TDEC), Tennessee Exotic Pest Plant Council (TN-EPPC) and Great Smoky Mountains National Park. https://www.tnipc.org/

Native Seed Vendors Map by Native Seed Network. An online interactive map showing the location of native seed and plant growers and seed distributors of regional and non-regional native seed. The designer is encouraged to confirm the origin of all seed used on their project and to acquire seed harvested from sources as close to the project site as possible.
https://nativeseednetwork.org/find-seed/

Plant Finder by Missouri Botanical Garden. An online database of over 7,500 native and non-native plants with plant attributes, photographs, designer comments, and use recommendations. The database is searchable and a designer can filter plant attributes for a focused viewable plant list by USDA Hardiness Zone.
https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx

Native Plant Database by the Lady Bird Johnson Wildflower Center. An online plant database of native plants with plant attributes, photographs, and designer comments. The database is searchable and a designer can filter plant attributes for a focused viewable plant list by state.
https://www.wildflower.org/plants/search.php?search_field=&newsearch=true

Research Plants in Tennessee Counties by Pollen Library.com. An online list of native and non-native plants found in Tennessee counties that are notable allergen sources. Plant lists may be filtered for degree of allergens or as all plant species in a county and then by season. Native forbs are listed in the Weeds section, followed by the Grasses list. This site is useful for identifying plants flowering in each season within each Tennessee county to cross-reference with the ERA tool plant list and to confirm as native to a county using the USDA Plants mapping tool.
http://www.pollenlibrary.com/State/Tennessee/

Tennessee Smart Yards Native Plants for Tennessee by University of Tennessee Institute of Agriculture. An online database of Tennessee native plants with select attributes and photographs and general description of where each plant grows within the state.
https://ag.tennessee.edu/tnyards/Pages/The-Benefits-of-Native-Plants.aspx or
https://tynnativeplants.wordpress.com/

iNaturalist. An online searchable research and photographic log of flora and fauna species reported in each city or county throughout the U.S. and around the world. Photos and location of flora and fauna can be submitted by anyone, observers can then suggest an identification and natural origin in a voting process. Once a voting threshold is reached, the identified photo and location is added as data for that plant or creature. There are additional informational links provided for site visitors to read more about the plant or creature. Designers can view the plant photos from a city or county

near their project site to find local native plant options to consider for their project.
https://www.inaturalist.org/observations?place_id=307&view=species

Seeding Rates

Application of seeding rates for a plant mix considers the variables of site slopes and soil conditions, plant aggressiveness, number of plant seeds per ounce, cost of seed per ounce, and the cumulative number of seeds that will be applied per square foot of planting area. Sites with steep slopes, poor or varied soils, existing vegetation, or sites that have had thick vegetation or invasive plants removed will need a higher seeding rate to compensate for seed that will not immediately germinate due to potential seed displacement, vegetation competition, poor soil or rocky conditions. One recommendation from those who plant prairies is to consider doubling the seed amount for difficult sites.

Seeding rates for plant species will need to vary, as some plants germinate and reseed themselves easily and aggressively while others require near perfect conditions for germination. This key information is available to designers through the plant research sources listed in the previous section. The aggressive species should be seeded at a lower rate to let other species establish and compete for soil area and light. Native plant seed sizes vary widely and should affect seeding rates. Purple coneflower seeds are large (approximately 7,300 seeds per ounce), while Blackeyed Susan (approximately 92,000 seeds per ounce) is quick to germinate, so the seeding rate should be much lower. Seed costs also vary widely and the price per pound for rare species can be significant. It is recommended that the designer include a price per ounce for each plant species on their draft seed mix spreadsheet to consider while making seeding rate adjustments. Expect a final seed mix price range for a March through November flowering pollinator habitat to be $1,800 to $2,400 per acre.

A standard seed mix for a native pollinator habitat should typically result in an application of approximately 60-90 pounds of Purse Live Seed (PLS) per acre. On slopes and difficult sites, the target rate is recommended to be doubled to 162 Total PLS per acre. In each case, 75 to 80 percent (by weight) of the seed mix should be dedicated to forb seed.

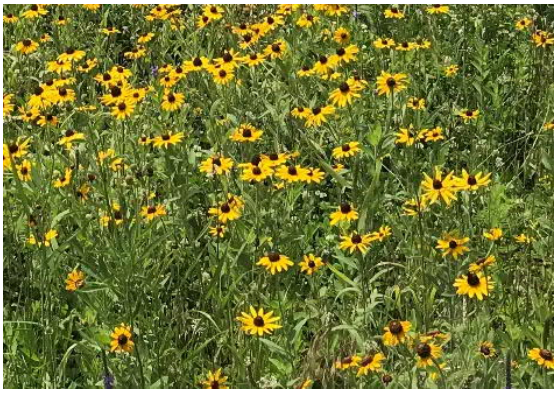


Figure 7.5: Rudbeckia Thriving in the Garden Photo Credit: Todd Teuscher

Seed mix calculator spreadsheet templates can be obtained through the organization links provided below or by typing “pollinator program seed mix calculator” or “native seed mix design calculator” into your Internet browser. The DOT spreadsheets listed below already have some plant species incorporated, but additional species will need to be added with their consensus seed per ounce quantity. Native seed growers and distributors typically include the number of seeds per ounce in their plant descriptions.

Seed Mix Calculator for Virginia Department of Game and Inland Fisheries (DGIF) by USDA-NRCS (the link below will download an excel spreadsheet).
https://www.dgif.virginia.gov/wp-content/uploads/Wildlife-Seed-Mix-Calculator-V3.2-May-2016.xlsx

Native Seed Mix Design Worksheet by Minnesota Department of Transportation.
http://www.dot.state.mn.us/environment/erosion/vegetation.html

Equipment

Roadside revegetation and maintenance crews will need a wide variety of equipment for the process of preparing the site, planting the seed, mowing at various heights, spraying pesticides and haying. Roadside locations for pollinator habitat and reduced or no-mow areas may be difficult to access with large mowing and haying machinery. The sites may also be narrow backslope areas with steep slopes and many obstructions, so the equipment will need to be selected for the site conditions. This section leans toward providing smaller nimbler pieces of equipment for greater flexibility and care in managing one- to 15-acre segments that will be often occur at and between interchanges. Many of the recommended equipment pieces are small pull-behind attachments for a tractor. If road crews are not familiar with the equipment it is best to consult with local no-till farmers in the area to learn about the various equipment options and to get their recommendations prior to any purchase or equipment rental. A summary of the recommended equipment is provided below.

General Transport

- Full one-ton pickup trucks – one or more for pulling equipment trailers and a supplemental water tank.
- All-terrain vehicles – one or more for checking the perimeter of large sites and pulling a supplemental water tank or pesticide tank to remote areas of the site.
- Tractor – a compact or utility tractor for pulling all equipment, and moving fallen trees and boulders to desirable locations. Size the tractor on Power Take Off (PTO) horsepower needed for pulling attachments. Consult attachment and tractor manufacturer PTO horsepower recommendations.
- Tractor – Utility tractor with front bucket loader and auger attachments, for moving fallen trees and boulders to desirable locations, digging tree planting holes and depressions, and skinning ground to expose soil at specific locations.
- Trailers – two or more to transport the tractor, hay bales, and other equipment.

Clearing

- Chainsaw – for sapling and tree removal, and cutting out large roots.
- Handsaw – for cutting dead and low branches that may conflict with mowing and seeding operations, and for sapling and tree removal and cutting out small roots.
- Hand pruners – for pruning small dead and low branches that may conflict with mowing and seeding operations.
- Rotary Cutter – for cutting heavy vegetation prior to raking and baling operations. Pull-behind mowing attachment for a tractor with a variable one- to 14-inch cutting height and able to cut brush up to 3-1/2 inches in diameter.
- Belt Rake – for lifting wet or dry cut grass material into windrows prior to baling. This is a pull-behind rake attachment for a tractor designed not to disturb soil during the raking process.

- Mini round roto-baler with gathering wheels – for baling cut grass windrows for removal and composting off-site. Pull-behind baling attachment for a tractor. A few bales could be stacked on site for pollinator nesting.

Soil Preparation

- Tractor rotary tiller – for deep-tilling the soil multiple times to kill invasive plants.
- Disc harrow – for tilling and leveling the top four inches of soil.
- Cultipacker – for leveling and compacting tilled soil areas to ready them for planting. For fluffing up the top of soil and creating shallow depressions to prepare soil for seeding.
- Sod cutter – for harvesting high quality topsoil and plants.

Seeding

- Hydroseeding (see TDOT specifications)
- No-Till Seed Drill – for sowing seeds into soil at a depth of 1/8-inch up to 1/4-inch.

Figure 7.6: No-Till Seed Drill in Action Photo Credit: Doolev Tractor

Figure 7.7: No-Till Seed Drill Photo Credit: Truax Company,

Maintenance

- Rotary Cutter – for cutting heavy vegetation prior to raking and baling operations. Pull-behind mowing attachment for a tractor with a variable one- to 14-inch cutting height and able to cut brush up to 3-1/2 inches in diameter.
- Belt Rake – for lifting wet or dry cut grass material into windrows prior to baling. This is a pull-behind rake attachment for a tractor designed not to disturb soil during the raking process.
- Mini round roto-baler with gathering wheels – for baling cut grass windrows for removal and composting off-site. Pull-behind baling attachment for a tractor. A few bales could be stacked on site for pollinator nesting.
- Large watering tank with hose, watering wand and sprayer – placed on trailer or pickup truck bed for remote supplemental watering of tree and shrub plantings and accessible perimeter seeded areas under drought stress.
- Gas-powered string trimmers – for spot mowing of invasive plant species.
- 50-gallon herbicide spray rig with a 15-foot boom – for bulk herbicide applications to kill invasive species.
- Herbicide brush – for applying herbicide to individual plant leaves.
- Herbicide wick – for applying herbicide to individual plant leaves.
- Herbicide weed-wand applicator – for applying herbicide to individual plant leaves.

- Herbicide backpack with tank and sprayer – for spraying invasive species within the seeded area.
- Herbicide spray cone applicator – for focused herbicide spray application to individual plants or small groups of plants.
- Weed wrench – for honeysuckle shrub and Bradford pear tree removal.

Planting Schedule

Native plant seeding is typically conducted in the Winter or in the Spring. This scheduling takes place after the flower season when pollinators are hibernating or settled into their nests, and generally are safely out of the way. Preparation of the area to be seeded occurs a couple weeks earlier in the form of a prescribed burn or focused glyphosate application, and a low mowing and baling to remove most of the existing vegetation, exposing the soil to be seeded. Typically, the selection of a winter or spring seeding time depends on the planning and site preparation schedule.

Winter seeding is optimum for native grasses and forbs as it allows the natural freeze-thaw action to break the protective coating on seeds. The seeds work into the soil and wake up slowly into their new surroundings in the spring. In Tennessee, winter seeding should take place after November 1 and before January 15 to maximize beneficial freeze-thaw events for the seed.

Spring seeding should be conducted between May 1 and June 15. The spring timing allows the ground to warm up and partially dry out so ground preparations and seeding can take place without rutting. The timing also allows for cool-season annual weed seeds to germinate so they can be hit with one more round of glyphosate and/or, so the area can be burned in February or March prior to pollinator activity and all competing vegetation can be removed prior to seeding.

PREPARATION

The initial planning for the project identifies the components of a pollinator habitat and the steps and equipment needed to implement the project. The site analysis identifies all the site conditions that site clearing, mowing, seeding equipment, and the pollinator habitat seed mix will need to address. The site design responds to the analysis findings and the seed mix is developed. The next step is to prepare the site, equipment and acquire the seed mix for the implementation. Preparation for a successful pollinator habitat seeding or planting is dependent upon the following key factors:

1. Elimination of competing undesirable invasive non-native plant species, including spreading native and non-native broadleaved annual weeds and volunteer woody trees, shrubs, and vines from the immediate area to be planted.
2. Elimination of the same undesirable groundcover plant material mentioned above, growing within 50 feet of the immediate area to be planted.
3. Killing vegetation with non-selective herbicide applications and scalp-mowing lawn with low mowing blades and/or string trimmers to expose soil area, for mown lawn sites where pollinator habitat does not exist.
4. Exposing more soil area and removing obstructions for mechanical seeders for heavily vegetated sites, by marking and protecting existing pollinator nesting sites and removing existing vegetation by mowing and baling and/or by a prescribed burn.

5. Creating a comprehensive seed mix or plant mix from local native ecotype species that responds to the site conditions, primarily sun and shade exposure, wet, dry, slope, etc.
6. Including flowering forb seed mix species that will provide three or more flowering species from March through November, with emphasis on early Spring and late Fall to support pollinators into and out of winter.
7. Ensuring a smooth soil seed bed on recently tilled and exposed soil sites, cultipacking, rolling or dragging may be required to level the soil.
8. Ensuring solid seed-to-soil contact through use of a no-till seed drill to insert seed into soil at shallow depths or broadcasting seeds onto exposed soil in late Fall or early Winter, to let the natural freeze/thaw cycles work seeds into the soil (seed loss from mice and birds is lessened with seed drilling).

Site Preparation

The elimination of invasive and unwanted plant species ahead of a native grass and forb seeding is the first step toward planting success. Typically, the process takes a year of repeated tilling every two to three weeks through Summer and once again in Fall to get the seed bed smoothed and ready for Winter seeding, or herbicide spray applications and tilling in Spring, Summer and Fall plus a tilling in Fall to prepare the existing seed bed for Winter seeding. A controlled prescribed burn can be used alone or to clear undesirable vegetation prior to tilling or to clear dead vegetation after the herbicide spraying process. Some non-natives like fescue grass can tolerate a little burning and may need follow up and/or localized herbicide applications throughout the year.

The site preparation can consist of a prescribed burn if allowable or a close mowing, baling and removal of existing vegetation followed by multiple non-selective glyphosate herbicide spray applications Prescribed burns, should be scheduled and conducted by the Tennessee Department of Agriculture Division of Forestry (TDF), or an experienced prairie prescribed burn company with preparation and stand-by assistance from TDF or trained staff, plus local fire department personnel, check with your county to confirm prescribed burns are an option. Additionally, please consult the Chattanooga/Hamilton County Air Pollution Bureau and BurnSafeTN.org website and obtain all relevant approvals/permits prior to any prescribed burn in that county.

Slopes can be difficult to establish with seed due to seed displacement and erosion caused by rain. A slope that rises about twelve inches over a distance of three feet (3:1) or steeper that is seeded with native species should also be planted with an annual nurse crop and covered with a biodegradable erosion control blanket. The nurse crop will green up quickly to hold the soil and erosion control blanket in place and will work with the erosion control blanket to absorb and slow rainwater and dissipate rain drop energy to reduce the amount of seed displacement and erosion. Mowing will keep the annual nurse crop from reseeding, spreading and competing with the native plants in year two and will biodegrade with the erosion control blanket as the native plants grow and take over the area.

Seed Acquisition

After the selection of invasive vegetation removal methods, the focus moves to preparing the seeding mix and getting it to the site. Seed acquisition for a pollinator habitat will always require purchasing from multiple growers to get the species and seed quantities that are required. Seed growers harvest and process seed in the fall of each year in preparation of winter and spring seeding. Seed viability after being stored for more than one year is variable, so it is best to acquire freshly harvested seed. It is

recommended to prepare the desired seed mix and to place the orders with growers as soon as possible, as some species are not prolific seeders and quantities sell out quickly. Contacting and visiting grower operations and discussing target species and potential annual quantities needed for an ongoing program can create a strong relationship that allows the grower to plan for the future, lock-in prices around a reliable client, and potentially add native plant species to provide a greater share of the seed mix. The TDOT Pollinator Habitat Program also serves as an opportunity to approach small local growers about expanding their species offerings to help supply early and late flowering native species and support the pollinator habitat seeding effort.

Seed Delivery, Transport, and Storage

In order to reduce the time that seed will need to be stored, schedule the delivery of the seed within a day or two prior to the actual seeding date. Store the seed in a cool, dry location per grower recommendations for no longer than one year. Protect the seed in similar cool, dry conditions as it is transported to the project site. Do not expose the seed to wind, rain, snow, high humidity, abrupt temperature or moisture changes prior to seeding, as this could trigger germination or cause moisture and mold to form on the seeds. Wet or molded seed may clog the seed drill, causing an uneven seed distribution that could reduce germination rates and success of the project.

Equipment Preparation

Check and clean all equipment before it is brought to the site and before it is moved to the next site. To clean equipment, use one of or any combination of: hose nozzle, pressure washer, air compressor, or leaf blower. Clean, run, and calibrate the no-till seed drill per manufacturer recommendations to set seed no deeper than 1/4-inch into soil. Scrub and clean all machinery that is used for cutting and mowing to remove all weed seed residue. Scrub and clean all tires, rims, cutting blades, debris chains and the entire cutting deck, top to bottom. Weed seeds are small like dust and very prolific germinators so equipment cleaning must involve detergent, scrubbing with brushes, and pressure washing to avoid dragging annual weeds to the next project site.

IMPLEMENTATION

Schedule and Weather Considerations

Site preparation activities in late fall will have reduced existing vegetation, removed it or burned it off completely, to expose the soil and accept seed drilling. Schedule winter seeding activities when the site soil is dry enough to resist rutting from the tractor and the seed drill. Cold or frozen soil is fine for native seeding. Winter seeding between November 15 and January 15 is generally safe from a warmup and is recommended for a native grass and forb installation to maximize seed exposure to natural freeze-thaw events. Avoid seeding during rain and wet snow events that could lead to soil rutting and clogging of the seed drill.

Seeding Equipment

Seeding should be accomplished with a no-till seed drill. If the equipment is not already owned, it is possible that the equipment can be borrowed from an agency, local land owner, no-till farmer, or rented. Contact the Tennessee Wildlife Resources Agency (TWRA) for availability of their equipment or other possible sources. Calibrate the equipment per manufacturer recommendations to install seed at a 1/4-inch maximum depth and at one-half of the required seeding rate to allow the full rate to be applied with two perpendicular passes over the seeding area.

Figure 7.33: Interseeding with No-Till Seed Drill
Photo Credit: Brittany Morris

Pollinator Habitat Seeding

Install native seed using a no-till seed drill. Install 8-10 pounds of pure live seed (PLS) per acre on flat and gentle sloping sites. Install 160 pounds of PLS per acre over areas with slopes of 3:1 or steeper, or on excessively compacted, rocky or weedy sites. For pollinator habitat, the seed mix should be 20 to 25 percent grasses and 75 to 80 percent flowering forbs (by weight). Install half of the mix over the area to be seeded and then provide the second half while seeding perpendicular to the initial direction.

When using a no-till seed drill, install half of the seed parallel across the planting area, and install the other half of seed mix perpendicular across the planting area to ensure an even distribution. Set the no-till drill to install seeds at a 1/4-inch depth maximum.

Hydroseeding is an option for steep slopes and hard to reach areas but is not ideal in that the light native seeds can be suspended in the hydro slurry and may not reach soil until the slurry begins to biodegrade later in the Spring.

Planting a Nurse Crop

A nurse crop should be seeded with or prior to native seed on slopes of 3:1 or steeper. For Spring planting, seed oats (Avena sativa) with a no-till seed drill at 60 to 90 pounds per acre and depending on slope, use the higher rate for steeper slopes. In preparation for a winter seeding, seed annual rye (Lolium multiflorum) with a no-till seed drill at 30 pounds per acre depending on slope. Seed annual rye one week after site preparation in November.

Erosion Control

Site soil and seeds can be better maintained in place on slopes using an erosion control blanket. The blanket disperses raindrop energy, allows sunlight to reach the soil, and maintains soil temperature and moisture for the new seeding. It is recommended that an erosion control blanket made of 100% biodegradable plant-based mat, with top and bottom netting, and anchored with 100% biodegradable plant-based stakes be placed over all seeded slopes of 3:1 and greater.

Plant Plugging

Locating and obtaining all seed species for a pollinator habitat or finding the required quantity of seed for some plants may be difficult. In these cases, it is recommended to expand the search to native plant growers to see if the plant is available in plug form. Native plant plugs are generally two inches square

by five inches deep and are easily planted with a steel Dibble Bar. If plugs are used, it is recommended to install them after site preparation and seeding and erosion control activities, match the dollar amount of the seeded species with plant plugs, disperse the plants to site locations that match their soil type, soil moisture and sun exposure preferences and space the plants at 18 inches on center. The plugs should be planted through the erosion control blanket if present. If planted in bare soil areas, the immediate eight-inch by eight-inch area around each plant should be mulched with two inches of compost or shredded hardwood bark mulch and the area thoroughly watered. Flag or stake the perimeter of each group of plants with "no mowing" stakes. Continue to bring water to the plants each week through November of the first year.

Watering

Watering should only be considered for maintenance of special display seeded areas where drought is an issue and when plant plugs are installed. Consider a temporary irrigation system, if needed. Water the soil around plug plantings once each week for the first growing season through November. Water plants only in the morning. In the case of a drought condition, a late afternoon watering can be added.

Water any created habitat stone-lined or soil depressions when possible. Many pollinators get nutrients from wet soils and use mud to build nests. Similarly, wet gravels and stones can bring out salts and minerals that are beneficial to pollinators.

MONITORING AND MAINTENANCE

Pollinator habitat monitoring and maintenance tasks should be outlined at the planning stage of the project and should begin soon after planting. Initial concerns are soil erosion, invasive broadleaf weeds, locust invasion, and drought. Planning for monitoring and maintenance should consist of identifying methods and providers of pest management, regular watering if needed, deciding how prolonged drought will be handled, and deciding if erosion repairs during the season will be mulched and re-seeded or filled with plant plugs. Monitoring involves monthly walks at the habitat perimeter, views in and across the site using binoculars or a drone with video camera, and careful walks into the habitat to photograph and review plant growth, invasive pressures, and soil conditions.

Appearance

Initially the appearance of a pollinator habitat will be poor. Any nurse crop grasses will look good, and some invasive species will germinate and require mowing. Native plant coverage will appear sparse and plants may grow to be two to six inches tall by the end of the year. Invasive species seeds will be dropped in by birds or blown in by wind and the seeds will immediately sprout, but they will not dominate because of your site preparation. The second year will be better, with more clumps of diverse plants and blooms that you will mow down to a 12-inch height in May to encourage other species to germinate. The pollinator habitat will look great during the third year and continue to improve.

Expectations

Manage expectations for the pollinator habitat for the first two years. Native plants spend their first two years growing large root masses that will eventually grow from two to 20 feet deep. There are a few typical native flowering forbs that will begin to flower yellow in year one and then it will be time to mow and you will cut off most of the blooms. The planted area will slowly fill in in year two but will need another mowing to reduce grass and invasive competition, with many blooms being temporarily cut off. Year three is when blooming species appear in most months and heavy pollinator activity will be seen.

Figure 7.34: Ardmore Planting at One Year
Photo Credit: Michael McClanahan

Figure 7.35: TDOT Pollinators at Work Sign

Documentation of Pollinators

Review, photograph, and document the diversity of the pollinators that visit each month. Document the flowers that the pollinators are visiting. Compare the findings each year with the variety of flowers to determine if supplemental seeding of certain grass or forb species should be accomplished.

Documentation of Plants

Review, photograph and document the diversity of the plant mix each year. Compare the findings with the original seeding list. Track the number of different blooming species and their distribution by month. Also, note the extent of coverage and evaluate if supplemental seeding of a certain group or species is warranted to increase early Spring or late Fall blooming species.

Maintenance by Herbicide

Continue to monitor and identify invasive plant and pest species that try to move into the pollinator habitat. Hire a Tennessee licensed pesticide professional who specializes in native prairie maintenance to treat invasive species that appear to be thriving and spreading.

Maintenance by Fire

Prescribed burning is the most effective way to eliminate non-native invasive plant species while rejuvenating the native grass and forb species. Burn every three to five years after plant flowering has ended in November, to ensure best wildflower health and to remove non-desirable woody plant species. Only burn one-third of a habitat area at a time to reduce stress on pollinator species that will be required to temporarily relocate from the burn section.

Maintenance by Mowing

During the first year after seeding, mow sites seeded with annual oats or annual ryegrass at a six-inch height to prevent those plants and any annual weeds from going to seed as the native plants come up. Spot mow invasive species to a 12-inch height to prevent seeding, or spot treat with herbicide. Pollinator habitat can be rejuvenated as needed through early spring mowing. Only one-third of a pollinator habitat should be mowed in one season and mowing height should be set at a 12-inch minimum height to protect hibernating pollinators at the base of plants and to give the plants a better start at growth the following year. Mowing should take place when pollinator activity is over and hibernating pollinators are protected in the ground or at the base of grass clumps. In Tennessee, it is best to mow after December 1 and before March 15. A mowing maintenance schedule is provided for reference below.

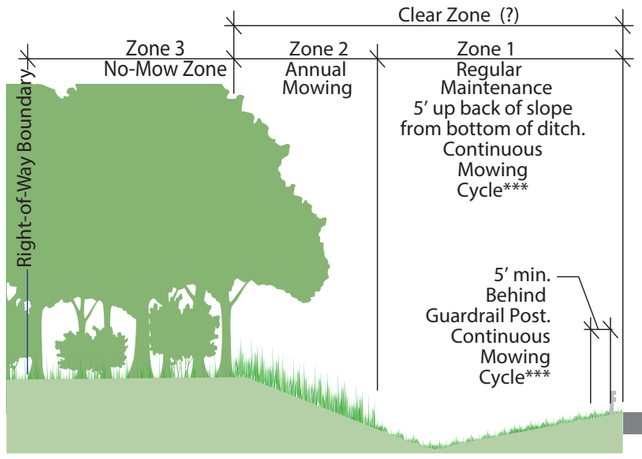
Table 7.1 - Mowing Maintenance Schedule

Year	Spring (Feb.-Mar.)	Summer (Apr.-Jun.)	Summer (Jul.-Aug.)	Fall (Sept.-Nov.)
Year 1	Mow all vegetation to a height of 6" Mow every two weeks	Mow all vegetation to a height of 6-8" Mow every two-three weeks	Mow all vegetation to a height of 8" Mow every two-three weeks	Mow all vegetation to a height of 8" Mow every three weeks until frost
Year 2	Mow all vegetation to a height of 8-12" Mow once in late February or early March	Mow all vegetation to a height of 12" Mow once in early May	Spot mow only problematic areas to a height of 12" Mow only once	Spot mow only problematic areas to a height of 12" Mow only once
Year 3	Low mow all vegetation to a height of 12" Mow only once	Spot mow only problematic areas to a height of 12" Mow only once	Do not mow Wait until winter of Year 3 or spring of Year 4	Do not mow Wait until winter of Year 3 or spring of Year 4

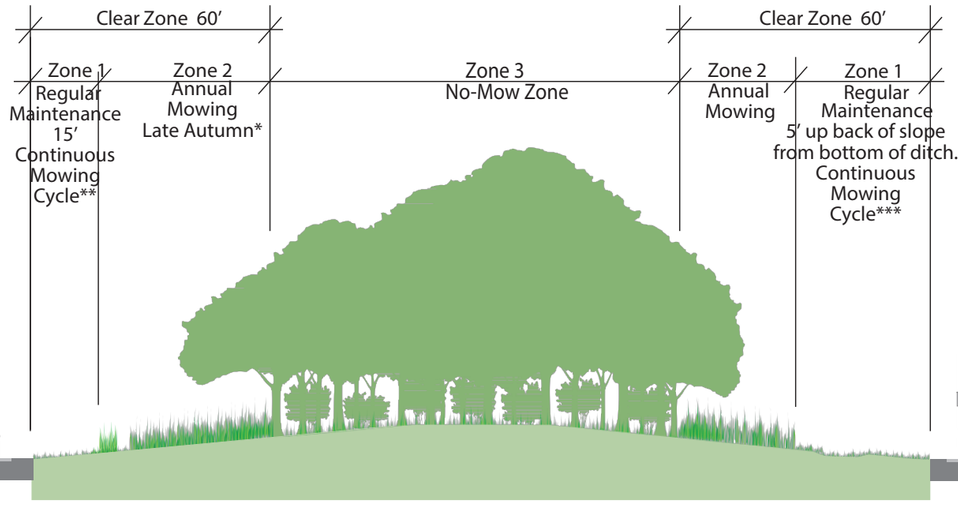
*Notes:

1) Mowing schedules are approximate and will vary depending upon the presence and growth rate of problematic weed species. If weeds are scarce, limited mowing is necessary.
2) During Year 1, weed species should always be mown before reaching 12" in height. Doing so will prevent the shading out of desirable forbs and grasses.
3) In the early spring of Year 3, a low mow of 6" is desirable to mimic the effects of a prescribed burn. If burns are permitted in your area, do so in lieu of a low mow. Low mow only 1/3 of the habitat area. Low mow the next 1/3 of the area the following early spring of year 4 and final 1/3 area in year 5. Repeat every 3 years as desired.

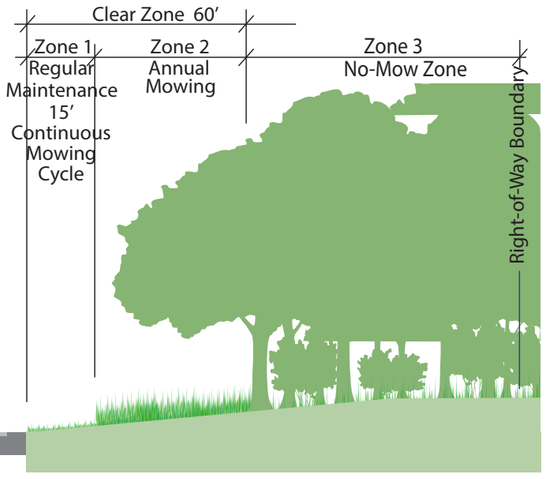
TDOT Mowing Section Diagram



Reduced Mowing in the Right-of-Way with Drainage Ditch



MEDIAN



Reduced Mowing in the Right-of-Way

* FHA, Literature Review: Pollinator Habitat Enhancement and Best Managment Practices in Highway Right-of-Way, by Xerces Society , May 2015, page 5.2

** TDOT IVMP Guidelines, Swath Mowing, 2016, pages 9-10 and
TDOT Landscape Guidelines, 2010, Chapter 5, Reduced Mowing, pages 5.19-5.21

***TDOT SP806 Special Provison Regarding Rights-of-Way Mowing 2015

Figure 7.36: TDOT Mowing Section Diagram

ADDITIONAL POLLINATOR INFORMATION RESOURCES

There are a number of organizations including Federal agencies who are dedicated to sharing information that can help others support pollinators and create habitat for pollinators. They generously provide the most current information and best practices to guide us through the process at the links below.

- tnpollinators.org
- Pollinator.org
- Xerces.org
- https://www.fs.fed.us/wildflowers/pollinators/
- Beeinformed.org
- Nativerevegetation.org
- https://www.environment.fhwa.dot.gov/env_topics/ecosystems/pollinators.aspx
- https://www.environment.fhwa.dot.gov/env_topics/ecosystems/Pollinators_Roadsides/BMPs_pollinators_landscapes.aspx
- iNaturalist.org

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https://www.prairienursery.com/prairie-nursery/neil-diboll/

Tables

Figures