A Roadmap for New England DOTs to Transition to Sustainable Roadside Practices for Strengthening Pollinator Habitats and Health

Task1: Current knowledge and practices

Notes on the content of this document:

Subtask 1: *The current understanding of the seed zones in New England is summarized based on the recent publications. It is expected that regional discussion will be initiated by the Northeastern Seed Network during the next year to achieve the consensus on some unclear issues. This information will be included in the Manual later.*

Subtask 2: *It appears that the knowledgebase about the existing populations of native roadside herbaceous plants in each New England seed zone is available through references and expertise; therefore, limited time was dedicated to Subtask 2.*

Subtask 3: *"Compilation of lists of species" appeared to be* ***the most important task during this stage of our project****. Therefore, considerable effort was spent on its definition and justification.*

Subtask 5 and **Subtask 6** ***are under development.***

Subtask 1. *Define New England seed zones.*

Ecological restoration involves the process of bringing back native biological diversity and ecological function to degraded landscapes. The DOTs objective to transition to using native plant communities to revegetate roadsides is considered a form of ecological restoration. The use of locally adapted, genetically appropriate seed – or genotypic seed – is an important consideration when planning any restoration project. Nonlocal genotypic plant material may decrease the success of restoration programs if the material is maladapted, thus potentially negatively impacting through gene flow adjacent native populations adapted to local climatic conditions. Using genetically appropriate native plant material will limit negative impacts on ecosystem health and remnant native plant populations. Using genetically inappropriate seed material carries several risks. Seed originating from distant sources could result in the mismatch of bud break, bud set, flower production, or cold hardiness (Pike et al. 2020).

Two concepts are integral to ensure a match between genetically appropriate seed and planting sites: seed collection zones, which determine the origin of the seed, and the seed-use guideline, also known as the seed transfer rule, which delineates where seed from a particular location should be planted (Pike et al. 2020). Ideally, **empirical seed zones** for each species would be developed. Empirical seed zones take into consideration species specific plant traits such as morphology, phenology, and reproduction combined with climatic variables. Determining these species-specific empirical seed zones usually requires the planting of common garden experiments in several distant locales to determine the ability of that specific species to adapt to the common garden's local climatic conditions (GBFireScience 2016). Such mapping of specific species has mostly happened for species important to the western United States because research resources have flowed from the Bureau of Land Management (BLM).

Since the BLM rarely expends resources on New England states, it's unrealistic to create empirical seed zones for New England native species. Instead, the more practical approach involves the creation of **provisional seed zones**, which take into consideration two climatic factors: minimum winter temperatures and aridity (GBFireScience 2016). Provisional seed zones were developed and designed specifically as a seed transfer guideline and are intended for use with species for which no specific knowledge of or data is available on local adaptation and population differentiation. The basis for creating provisional seed zones rests on the fact that ecological distance is frequently a better predictor of local adaptation than geographic distance and, thus, likely a better indicator of potential success in restoration (Bower et al. 2014). As a result, provisional seed zones usually are designated by combining areas of climatic similarity with ecological similarities as delineated by Level III Ecoregions. In addition, common garden research has shown that relatively common and widespread species perform more uniformly across these provisional seed zones. (Miller et al. 2011). However, rare species may not conform as uniformly to provisional seed zones, depending upon the reasons for the species' rarity. For example, it may be appropriate to use ecoregions as seed zones for species that were once widespread but are now rare as a result of recent habitat loss and fragmentation. On the other hand, rare species that historically have disconnected population centers may be more appropriate for smaller empirical seed zones. For our work, we deal with rare plants by excluding them from projects.

The ecoregion approach for roadside species selection is recommended by the Federal Highway Administration (FHWA 2023). The Native Plant Trust (formerly the New England Wildflower Society) also recommends the ecoregion approach (Richardson and Jaffe 2018). Ecoregions represent areas with relatively uniform environmental conditions and similar ecosystems, and many ranges of plants match the ecoregion's boundaries.

The boundaries of the Level III Ecoregions will be considered for dividing New England into four seed zones (Figure 1):

- Ecoregion 58: *Northern Highlands* (Vermont, New Hampshire and the northwestern inland part of Maine, northwestern Connecticut, and western Massachusetts).

- Ecoregion 59: *Northeastern Coastal Zone* (Rhode Island, southeastern New Hampshire, most of Connecticut and Massachusetts).
- Ecoregion 82: *Acadian Plains and Hills* (most of Maine).
- Ecoregion 84: *Atlantic Coastal Pine Barrens* (Cape Cod/Long Island).

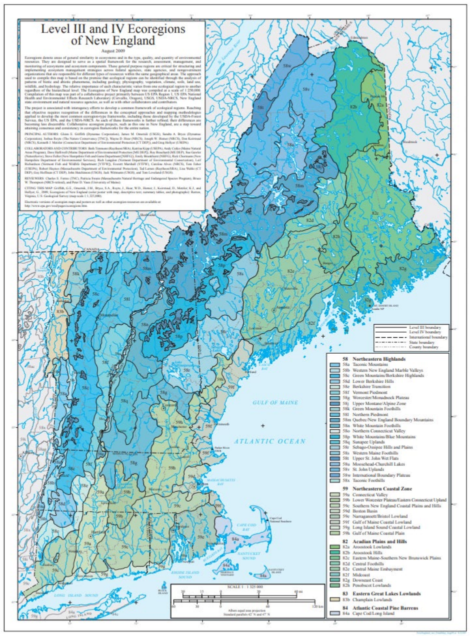


Figure 1. Level III and IV Ecoregions of New England

However, while working on NETC 09-2 Manual, our team discussed seed zones with two conservationists from the New England Wildflower Society, Bill Brumback and Arthur Haines. Both believed that the difference in *photoperiodism* – the ability of plants and animals to measure environmental day length (photoperiod), typically by monitoring night length – that accompanies changes in latitude had to be considered when designating seed zones since the length of daylight will affect *anthesis* (when a plant blooms) and seed ripening. This will optimize persistence of new native plant community establishments and preserve regional species *anthesis* timing that help maintain the co-evolved synchronization between pollinators and their foraging for the floral rewards of nectar and pollen.

The soundness of Brumback and Haines' approach was reinforced by recommendations of a group assembled by the USDA Forest Service called the Eastern Seed Zone Forum (ESZF) (Figure 2) (Pike et al. 2020). This group developed a map of 245 seed-collection zones for 37 Eastern states by combining plant the USDA Plant Hardiness Zones (PHZ) (USDA Agricultural Research Service 2012*)* and Bailey's ecoregions (Cleland et al. 2007) (Figure 3 and 4). As part of their deliberations, the ESZF thought it important to consider a measure of precipitation, which they believed were adequately addressed by the province scale in the ecoregion hierarchy in Bailey's system. In addition, the group decided to align the zones with county boundaries because seed collectors are accustomed to designating seed sources by county and most counties in the eastern United States are relatively small and well defined.

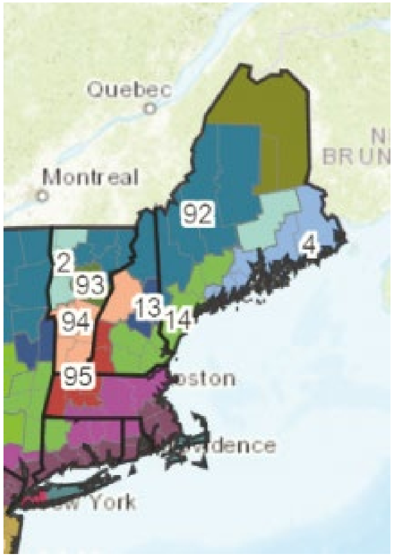


Figure 2. Latest version of the Eastern Seed Zone Forum map, version 2.1, available at www.easternseedzones.com.

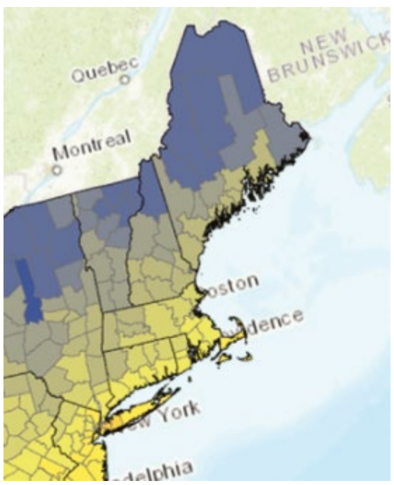


Figure 3. Plant hardiness zones (USDA Agricultural Research Service 2012) snapped to county lines.

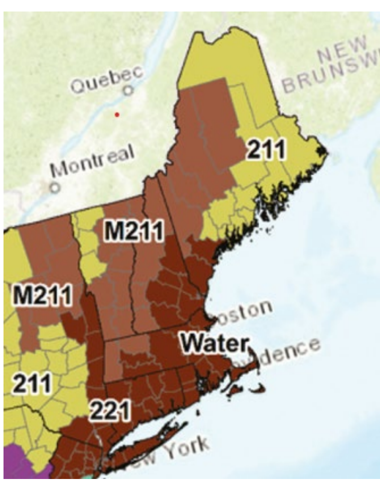


Figure 4. Bailey's ecoprovinces (Cleland et al. 2007) snapped to county lines.

Our team has been working on developing a consensus seed transfer zone map with the newly formed Northeast Seed Network (NSN), a group of stakeholders who work with native plants and headed by the Native Plant Trust. Those members working on the Seed Zone committee will each submit their recommended map with the intent of comparing and synthesizing each submitted map. Upon reviewing the recommendations of the ESZF, we determined that their final seed zone map, which contained 12 seed transfer zones for the New England region, was unrealistic to use in practice considering the current state of ecotypic seed production in the region. Producers are already struggling to develop preliminary sets of ecotypic seed. Limiting seed transference to within these 12 seed zones would be unworkable. The consensus during discussion of seed zones by members of the NSN was that three to four seed zones for New England would be most practical, at least during the inception of regional ecotypic seed production. Therefore, the map our team decided to submit to the NSN would conform to Bailey's ecoprovinces, which consists of three seed transfer zones.

Subtask 2. *Identify existing populations of native roadside herbaceous plants in each New England seed zone, as applicable to creating a native seed mix.*

Plant species naturally self-organize into communities.

In order to specify appropriate and adapted species to be used in each zone, we will select a few reference sites and inventory existing populations of native plants along roadsides to examine floristic compositions and plant associations (or **working groups**) that are suitable for various conditions. These reference sites will allow us to make observations about species combinations suitable for the roadsides with dry, mesic, or wet soils. This information will provide the basis for creating native seed mixes for each zone and site condition and promote the ecologically appropriate plant combinations.

Identify reference sites and their floristic compositions to develop ecologically appropriate plant combinations.

Reference sites, or native plant communities, with similar aspects, soils, and moisture conditions are frequently used in restoration projects to identify plant associations or working groups that are suitable for each project. The selection of reference sites allows us to make observations about the kinds of species combinations suitable for the roadsides.

Railroad and power-line rights-of-way corridors and old fields with poor, dry soils and full sun exposure are similar to the harsh environments along roadsides and provide suitable reference sites. State Natural Heritage Programs, local chapters of The Nature Conservancy, botanical societies and local land trusts have information how to locate such sites.

Note: The seed mixes identified in Subtask 3 were assembled based on the existing knowledgebase of ecological plant associations and verified by experts in the field.

Subtask 3. *Compile a list of species that are adaptable to roadside conditions and construction schedules/practices, including species that are beneficial to pollinators. Consider different roadside environments (sloped, dry, mesic, inundation).*

The following four mixes were developed for various roadsides conditions in New England. In addition, two lists of native shrubs were compiled – one for areas distant from the road along woodland edges and back slopes and another for coastal regions.

Each seed mix "recipe" includes a suite of native grasses and forbs to create a well-structured native plant community. Grasses are included to provide stable cover for reducing erosion and minimizing weeds, promote successful forb establishment, and create nesting sites for pollinators. Cover crops were included to decrease erosion and block weeds during the establishment period for the longer-lived perennials.

This species selection followed the recommendations presented in the NETC 09-2 Manual. The following criteria were prioritized:

1. Include only species native to the region and exclude the introduction of plant species from outside their known historical ranges.
2. Exclude species of conservation concern ("rare," "threatened," and "endangered" designations) for large scale plantings.
3. Select an appropriate *ideotype* for roadside plantings.
4. Prioritize "workhorse species" with the most potential for success in roadside plantings:
5. *Focus on species with high wildlife value* for various species including pollinators groups pf pollinators.
6. Include some aesthetically pleasing species.
7. *Ensure economic feasibility to produce* by selecting species easy to propagate from seed (herbaceous) or by vegetative propagation (some shrubs) available at reasonable cost.

Below we present the detailed clarifications of the criteria (p. 6-12) that clarify **what makes a plant an appropriate choice for the roadside** followed by lists of species suitable for each site condition (mesic, dry, wet, and costal) (p. 14-18**).**

Criterion 1. *Include only species native to the region and exclude the introduction of plant species from outside their known historical ranges.*

How to determine the nativity of plant species within the New England ecoregions? Defining what makes a plant species native to a specific region is the vital first step toward species selection. While in-depth discussions about what makes a species native to a region go back a long way, the most common definition of a native species describes it as a plant that was present before European settlement occurred (Richardson & Jaffe 2018), or prior to significant human impacts.

The definition of a "region" is changing as the concept of nativity is evolving from a very broad approach (such as native to a continent) to a very specific approach (such as native to a particular state or county). Historically, the Native Plant Trust focused on plants native to North America, then on plants native to New England, with the latest recommendations to use the ecoregion approach as many ranges of plants match the ecoregion's boundaries (Richardson & Jaffe 2018).

The ecoregions represent areas with similar ecosystems. The ecoregion approach for species selection was recommended by the Federal Highway Administration (FHWA 2023). Finding reliable references to identify regionally appropriate native species is another important step toward native species selection. There is some disagreement among nation-wide databases, such as the Native Plants of North America (Lady Bird Johnson Wild Flower Center), the Biota of North America Program (BONAP), USDA Plant Database or Federal Highway Administration (FHWA 2019), and various regional sources. The issue then becomes: if someone wants to use the national references as a starting point for finding native species in an ecoregion, the accuracy of the listings should be cross-referenced using regional botanical sources.

Regional botanical organizations have done extensive research to understand which plants are native to particular areas within regions, and the regional databases and local floras contain the most current sources of information as they are based on accurate botanical records of species presence. The best resource for the six New England states include the "Go Botany" website maintained by the Native Plant Trust. In addition to "Go Botany," other New England regional and state-wide treatments (Cullina et al. 2011; Haines 2011, Angelo & Boufford 2014; Dreyer et al. 2014; Gilman 2015) provide accurate information about a species' presence in each state of the region.

It is better not to rely on existing recommendations of native plants for the region as it is always better to develop lists based on the above-mentioned dependable sources. Inaccurate information regarding a species' natural distribution often stems from an incorrect generalization that a species is native to a large region and even to the entire continent. Some lists of recommended species for New England contain North American native species, which are not native to New England, although they may be naturalized, which means spreading non-invasively in the wild after being introduced from elsewhere. For example, *Baptisia australis* (blue wild indigo), *Echinacea purpurea* (Eastern purple coneflower) and *Liatris spicata* (sessile-headed blazing star) which are often marketed as generically native (meaning they are American natives). They are included in some planting guides for New England but are not considered native to this region based on the data used by *Go Botany*. These species are mistakenly indicated as native for parts of New England by the *USDA PLANTS Database* (USDA 2023).

Criterion 2. *Exclude species of conservation concern ("rare," "threatened," and "endangered" designations) for large scale plantings.*

Following the recommendations of botanists from the Native Plant Trust, we have excluded species of conservation concern, including "rare," "threatened," "endangered," "uncommon," and "special concern" designations, from the seed planting mixes because of potential problems for native plant conservation. It is best to leave rare species alone in their known wild populations to prevent any confusion with the conservation status and origin of the plants.

Go Botany uses the following categories levels to identify the for state-level conservation status:

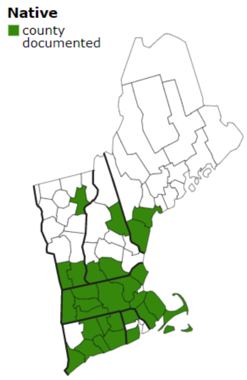
H (not seen for several years)
E (endangered)
T (threatened)
S1 (extremely rare)
S2 (rare)
S3 (uncommon)

S4 (fairly spread)
S5 (wide spread)

Only species with the conservation status S4 (fairly spread) and S5 (wide spread) according to *Go Botany* were included into the mixes.

The conservation status of each species to be included into the roadside planting should be verified by consulting botanists, the "Go Botany" website, and the most recent state conservation lists generated by the Natural Heritage programs or its equivalents. They include the NatureServe Explorer site (https://explorer.natureserve.org/Search), Connecticut Endangered, Threatened and Special Concern Species List (2015), Maine Natural Areas Program Rare, Threatened, and Endangered Plant Taxa (2015), List of Endangered, Threatened, and Special Concern Plant Species in Massachusetts (2019), Rare Plant List for New Hampshire (2018), Rhode Island Rare Plants (2016), and Endangered and Threatened Plants of Vermont (2015).

For example, *Asclepias tuberosa* (butterfly milkweed), an important species for Monarch butterfly conservation, is limited in mixes from all but Connecticut, Massachusetts, and New Hampshire because it appears to be in decline in half of New England states, according to *Go Botany* and *Nature Serve Explorer* (Figure 5 and 6).



Conservation status

Exact status definitions can vary from state to state. For details, please check with your state.

Maine	extirpated (S-rank: SX), potentially extirpated (code: PE)
Rhode Island	rare (S-rank: S2), concern (code: C)
Vermont	historical (S-rank: SH), threatened (code: T)
ssp. tuberosa	
Massachusetts	fairly widespread (S-rank: S4)
New Hampshire	extremely rare (S-rank: S1), endangered (code: E)

Figure 5. The New England distributions map and the conservation status of *Asclepias tuberosa* (butterfly milkweed) according to *Go Botany*.

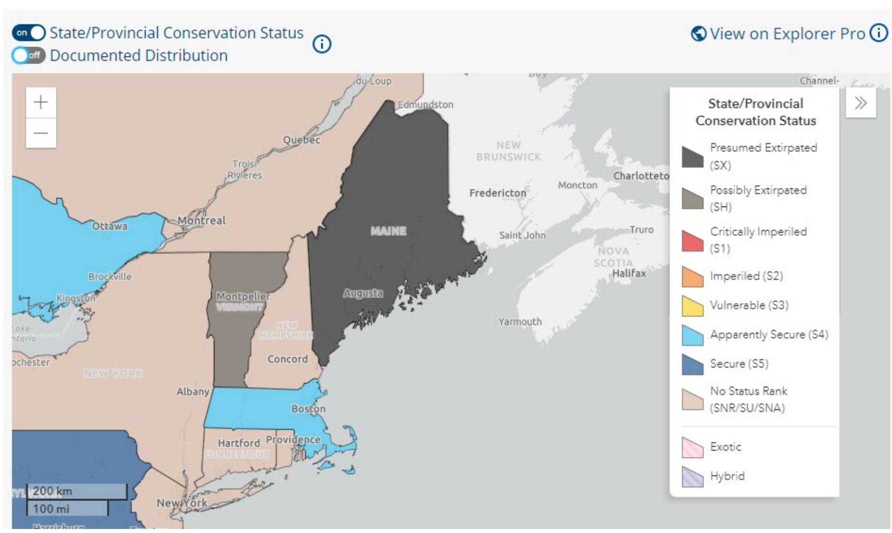


Figure 6. The conservation status of *Asclepias tuberosa* (butterfly milkweed) according to *Nature Serve Explorer*. This species is considered to be “presumably extirpated in Maine, “possibly extirpated” in Vermont, “no status rank” in New Hampshire and Connecticut, and only “apparently secure” in Massachusetts.

Criterion 3. ***Select an appropriate ideotype for roadside plantings.***

The characterization of the required ideotype, or idealized plant, with a clear set of essential attributes and characteristics relevant to roadside plantings is the first step in plant selection. The following conditions should be met as important considerations for roadside plantings when selecting plant species.

a. <u>Satisfy the DOT requirements of driver, vehicle, and pedestrian safety.</u>

Selected plants should satisfy the main safety-related goals of roadside vegetation (Eck & McGee 2008): maintaining visibility of signs and road users – vehicles, bicycles, pedestrians; improved visibility of wildlife and livestock near roads; eliminating trees growing close to roadways to prevent severe crashes when vehicles need to leave the paved portion of roads; minimizing wildlife related accidents by excluding plant species commonly browsed by wildlife; and improving winter maintenance involving snow drift and ice formation. For maintaining visibility, only plants of short or moderate stature were selected to allow for sight lines and suitable for full sun or partial shade. Grasses should be included to provide stable cover for reducing erosion, minimizing weeds, and promoting successful forb establishment. Cover crops will be included to provide immediate resources for pollinators, decrease erosion, and block weeds during the establishment period for the longer-lived perennials.

b. <u>Provide ecosystem services.</u>

Roadside rights-of-way provide regulating and cultural ecosystem services, which include establishment of vegetation cover for erosion control, flood protection, minimization of snow drift, air and water purification, carbon sequestration, and control of noxious weeds. Native grasses have deep, fibrous root systems, which provide effective long-term erosion control and soil stabilization. Their root systems extend deep into the soil, enabling them to obtain access to essential soil moisture and tolerate drought. Native grasses also address the threat of climate change as they require less frequent mowing, resulting in reduced tractor emissions. Also, labor released from mowing can be directed toward invasive species control.

Criterion 4. ***Prioritize "workhorse species" with the most potential for success in roadside plantings.***

Plant species included in the recommended mixes provide reliable performance defined as "workhorse species" by the Federal Highway Administration (FHWA 2023). The "workhorse species" should be able to establish quickly using minimal agricultural inputs of water and fertilizer in order to stabilize soil in a timely manner and prevent erosion. Plant species suitability for growth along the roadsides with different climatic conditions, various sun exposures, and soil conditions (drainage and nutrients) were also considered. Other important factors include adaptability to low fertility soils, resistance to insect damage and disease, the ability to sustain themselves without intensive human intervention, long lifespan, and the ability to achieve long term stability and persistence without being aggressive.

Criterion 5. ***Focus on species with high wildlife value.***

The following factors will be considered when selecting species and preparing seed mixes that support various wildlife species including pollinators:

- Sunny bare patches of soil around the base of bunch grasses, such as little bluestem (*Schizachyrium scoparium*) and purple lovegrass (*Eragrostis spectabilis*), provide places for some bumblebee species and other pollinators and insects to nest and lay eggs. Also, some grasses and sedges are larval host plants for butterflies.
- Larval host plants for specific pollinators, such as milkweed for Monarch and other endangered butterflies, should be included.
- Nectar-producing and pollen-rich plants should be prioritized. Pollinator habitats should have a diversity of plants that flower at different times throughout the season, and plants with overlapping bloom times to provide continuous floral resources. For each mix, sequential flowering charts were created for early and late spring, early and late summer, and early and late fall to ensure uninterrupted nectar and pollen sources. The goal is to include at least three species blooming simultaneously during each season, with a variety of flower colors and shapes.
- Cover crops will be included to provide immediate resources for pollinators during the establishment period for the longer-lived perennials.
- In addition, native shrubs may be recommended for areas distant from the road and along woodland edges and back slopes, to encourage populations of wood tunnel–nesting bees and provide additional floral resources especially important in early spring.

Varieties of pollinators include bees, butterflies, moths, birds, beetles, and flies. Most recommended seed mixes include limited number of plant species that would provide resources for a wide range of common species, which are mostly generalist, meaning they have broad diets consuming pollen and nectar from a wider range of flowers and visiting many unrelated plant taxa. However, the populations of many generalist species are stable, and it is important to attract and sustain many threatened pollinator species which may have specialized needs. In fact, recent studies of the northeastern United States bee community found a disproportionate loss of specialist bee species. Thus, it is important to not only provide resources for generalists but also to include plants important for the survival of **specialists and endangered pollinator species**. Specialist species have individualized needs for survival. They include various wild bees, including bumble bees, as well as Monarch and other butterflies.

Criterion 6. ***Include some aesthetically pleasing species.***

Important cultural services of native plant communities include aesthetic appeal that add to the sense of ecoregional identity of roadsides and visual enhancement of transportation corridors. Roadside native plantings should appear pleasing with diverse colors and textures that not only decrease incidents of road rage but also increase driver awareness and reduce driver fatigue (Fitzpatrick et al. 2014). Desirable traits include multiple seasonal interest, showy flowers, attractive foliage, bright fall coloration, winter silhouettes, and reliable performance throughout the growing season. Every mix will include aesthetically pleasing plants to improve public perception of the plantings, which will look different from the mowed swaths of turfgrass drivers and passengers are used to seeing along roadsides.

Criterion 7. *Ensure economic feasibility to produce.*

Production of native species is not achieved equally. Some biological characteristics of plants make their production difficult. For example, the Northeast Seed Network decided to exclude recalcitrant species and focus only on species of seed that can be stored. In addition, each species has unique qualities that impacts the cost of their production, including different stratification regimens as well as different planting, harvesting, and cleaning techniques. As a result, the prices of species vary widely. Because roadside revegetation projects are government funded, projects have limited resources. Therefore, it is imperative to select species that are economically feasible within budget constraints.

In summary, to meet these seven criteria, a native plant ideotype should include multiple traits and characteristics, defined as being optimal for roadside plantings. Traits include being a perennial herbaceous plant of short or moderate stature that conforms to the specific size of up to 24" to meet DOT safety concerns; easy to establish under various roadside conditions; suitable for full sun or partial shade; able to survive and grow on highly unfavorable substrates, including dry soils; and has a long-life span and attractive appearance. A plant should have a deep and extensive root system for erosion control and rapid recovery after frequent disturbances if vehicles pull off onto the side of the road. It should have a strong vertical habit, which is important for mowing once a year or even once every other year with persistent aboveground structures in wintertime to minimize snowdrift. An appropriate plant should have low value for animal browse, but high wildlife value for arthropods while providing superior nutrition, breeding and shelter habitats for various pollinators. The general criteria also include being inexpensive and easy to propagate and establish in the field.

Seed mixes

We have created four lists for mesic, wet, dry, and coastal conditions. To create a well-structured native plant community, the building guilds of each mix include warm-season and cool-season grasses, sedges, flowering forbs, and shrubs. Various factors were considered when preparing seed mixes, with special attention to species that support pollinators. Each mix includes many plant species as biodiversity has been shown to be fundamental to a functional plant-pollinator network. The diversity of plants would form various plant-pollination networks and promote numerous plant-pollinator interactions. This will result in resilient and healthy ecosystems where loss of one plant or insect species can be readily compensated.

Each list contains two sets of species for each site condition. The species listed in black print include the workhorse species aimed to provide resources for generalist pollinators and the species listed in blue print include additional species for specialists and pollinators at-risk. If available, it is recommended to use both groups for two reasons: they provide resources for a greater number of insect species and form more biodiverse and thus more resilient plant communities.

These lists are recommended for all six New England states. However, a few species are of conservation concerns for some states, which were noted in the Tables.

The *shotgun approach*, or a broad mix of plant species suitable for many sites across the region, was chosen here. Each mix includes small amounts of numerous “bullets” or 30-40 species “fired” over a wide range of conditions. It is possible that not all species proliferate at each site, and the final communities will reflect the specific topographic and climatic conditions of each habitat. However, it is expected that a diverse and resilient plant community will be established at every site.

This approach considers the diverse conditions and various ecological niches of the New England region while eliminating the decision-making process by the DOT managers to adjust the seed mix to each site based on the local conditions. Importantly, these diverse mixes will not have higher cost compared to the homogeneous assortments (we will run a comparison).

Note: Of the ecotypic seed currently produced for the New England region, the mesic list has the most species currently available.

Plant Mixes for Mesic Sites

These species were selected to thrive in mesic soils, which refers to an area that contains "average" soil. A significant portion of roadsides tend to have mesic soils. Mesic sites usually contain sandy loam, loamy sand, or sand soils that drain well or moderately well. Water is usually available throughout most of the growing season, though plants may suffer under drought conditions Thus, the community contains species adapted to a broad range of moisture classes but is dominated by species of upland affinity.

Exclusions refer to those states in which the species is of rare or conservation concern.

Species whose fonts are blue cater to specialists and pollinators at-risks but are not necessarily workhorse species.

The mix is composed of approximately 47% grass-like species and 53% forbs by seed count. However, the below mix percentages are relative to a mix consisting of approximately 69% Oats (*Avena sativa),* the cover crop, which is part of the mix but not included in bloom time chart.

Apply this mix at 43 lbs. PLS/acre with the inclusion of the Oats cover crop.

If planting between August 1 to December 31, substitute Grain Rye (*Secale cereale)* for Oats.

Botanical Name	Common Name	% of mix	Exclusions	March	April	May	June	July	August	September	October
Elymus virginicus	Virginia wildrye	9.3									
Anemone virginiana	tall windflower	0.2									
Viola sororia	woolly blue violet	0.2									
Fragaria virginiana	wild strawberry	0.2									
Zizia aurea	Golden Alexanders	0.7									
Penstemon digitalis	Foxglove beardtongue	0.5	RI								
Asclepias exaltata	poke milkweed	0.2	RI, VT								
Sorghastrum nutans	Indian grass	1.4	ME, RI								
Eupatorium perfoliatum	boneset thoroughwort	0.2									
Rudbeckia hirta	Black-eye Susan	1.4									
Solidago flexicaulis	zig-zag goldenrod	0.1									
Asclepias tuberosa	butterfly milkweed	0.2	ME, RI, VT								
Eutrochium dubium	coastal plain Joe-Pye weed	0.2	ME								
Schizachyrium scoparium	Little bluestem	8.9									
Solidago juncea	early goldenrod	0.1									
Asclepias incarnata	Swamp milkweed	0.3									
Asclepias syriaca	Common milkweed	0.2									
Solidago flexicaulis	zig-zag goldenrod	0.1	RI								
Achillea millefolium	Common yarrow	0.1									
Chamerion angustifolium	firweed	0.4									
Cirsium discolor	field thistle	0.1	VT								
Cirsium pumilum	field thistle	0.1									
Monarda fistulosa	Wild bergamot	0.2									
Vernonia noveboracensis	New York Ironweed	0.2									
Desmodium canadense	showy tick-trefoil	0.2									
Symphyotrichum novae-angliae	New England Aster	0.2									
Eutrochium purpureum	purple Joe-Pye weed	0.2	ME								
Panicum virgatum	switch panicgrass	1.6	VT								
Pycnanthemum muticum	Broad-leaved mountain mint	0.1	ME, VT								
Pycnanthemum tenuifolium	Narrowleaf mountain mint	0.1									
Lespedeza capitata	round-headed bush-clover	0.5	VT								
Solidago nemoralis	Gray goldenrod	0.1									
Symphyotrichum cordifolium	heart-leaved American-aster	0.2									
Eragrostis spectabilis	purple lovegrass	0.8									
Solidago puberula	downy goldenrod	0.1									
Sorghastrum nutans	Indian grass	1.4									
Symphyotrichum lateriflorum	calico American-aster	0.2									
Symphyotrichum novi-belgii	New York American-aster	0.2									
Solidago caesia	Blue-stem goldenrod	0.1									

Plant Mixes for Dry Sites

Dry roadsides native plant communities tend to be patchy and short in comparison to more moist sites. These communities occur on sand or loamy sands on excessively well-drained to somewhat excessively well-drained, sandy glacial outwash, dominated by shallow soils composed of medium to coarse sands and even gravel. Existing native plant communities tend to be dominated by warm-season grasses, whose roots can penetrate deeply to better access water.

Exclusions refer to those states in which the species is of rare or conservation concern.

Species whose fonts are blue cater to specialists and pollinators at-risks but are not necessarily workhorse species.

The mix is composed of approximately 45% grass-like species and 55% forbs by seed count. However, the below mix percentages are relative to a mix consisting of approximately 66% by seed count of Oats (*Avena sativa),* the cover crop, which is part of the mix but not included in bloom time chart.

Apply this mix at 43 lbs. PLS/acre with the inclusion of the Oats cover crop.

If planting between August 1 and December 31, substitute Grain Rye (*Secale cereale)* for Oats.

Botanical Name	**Common Name**	**% of mix**	**Exclusions**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**
Elymus virginicus	Virginia wildrye	9.3										
Aquilegia canadensis	Columbine	0.2										
Achillea millefolium	Common yarrow	0.1										
Zizia aurea	Golden Alexanders	0.7										
Penstemon digitalis	Foxglove beardtongue	0.5	VT									
Danthonia spicata	poverty oatgrass	2.1										
Sorghastrum nutans	Indian grass	1.4										
Baptisia tinctoria	yellow wild indigo	0.1	ME, VT									
Asclepias syriaca	Common milkweed	0.1										
Dichanthelium clandestinum	deer-tongue rosette-panicgrass	2.2										
Rudbeckia hirta	Black-eye Susan	1.4										
Schizachyrium scoparium	Little bluestem	9.2										
Solidago flexicaulis	zig-zag goldenrod	0.1										
Monarda fistulosa	Wild bergamot	0.2										
Desmodium canadense	showy tick-trefoil	0.2										
Symphyotrichum novae-angliae	New England Aster	0.2										
Panicum virgatum	switch panicgrass	1.4										
Pycnanthemum muticum	Broad-leaved mountain mint	0.1	ME, VT									
Pycnanthemum tenuifolium	Narrowleaf mountain mint	0.2										
Eupatorium perfoliatum	boneset thoroughwort	0.2										
Lespedeza capitata	round-headed bush-clover	0.5	VT									
Solidago nemoralis	Gray goldenrod	0.1										
Solidago puberula	downy goldenrod	0.1										
Symphyotrichum cordifolium	heart-leaved American-aster	0.2										
Euthamia graminifolia	flat-top goldentop	0.1										
Eragrostis spectabilis	purple lovegrass	0.5										
Euthamia graminifolia	flat-top goldentop	0.1										
Symphyotrichum lateriflorum	calico American-aster	0.2										
Solidago caesia	Blue-stem goldenrod	0.1										
Sorghastrum nutans	Indian grass	1.4	ME, RI									
Symphyotrichum novi-belgii	New York American-aster	0.2										

Plant Mixes for Wet Sites

The plants selected for wet soils tend to be classified as Facultative Plants, which can thrive in both wetlands and non-wetlands, thus tolerating a wide range of soil moisture conditions. These plants predominately occur with hydric soils, often in geomorphic settings where water saturates the soils or floods the soil surface at least seasonally. The occurrence of these plants in different habitats represents responses to a variety of environmental variables other than just hydrology, such as soil pH, elevation, light, and other factors.

Exclusions refer to those states in which the species is of rare or conservation concern.

Species whose fonts are blue cater to specialists and pollinators at-risks but are not necessarily workhorse species.

The mix is composed of approximately 75% grass-like species and 25% forbs by seed count. However, the below mix percentages are relative to a mix consisting of approximately 66% Oats (*Avena sativa),* the cover crop, which is part of the mix but not included in bloom time chart.

Apply this mix at 45 lbs. PLS/acre with the inclusion of the Oats cover crop.

If planting between August 1 to December 31, substitute Japanese Millet (*Echinochloa esculenta)* for Oats.

Botanical Name	Common Name	*% of mix*	Exclusions	March	April	May	June	July	August	September	October	November
Elymus virginicus	Virginia wildrye	*8.1*										
Packera aurea	golden groundsel	*0.1*										
Apocynum cannabinum	hemp dogbane	*0.2*										
Iris versicolor	Blue Flag Iris	*0.1*										
Juncus tenuis	path rush	*0.2*										
Zizia aurea	Golden Alexanders	*0.4*										
Geranium maculatum	spotted crane's-bill	*0.2*										
Carex lurida	sallow sedge	*1.7*										
Solidago juncea	early goldenrod	*0.2*										
Asclepias incarnata	swamp milkweed	*0.9*										
Carex vulpinoidea	common fox sedge	*6.1*										
Lilium canadense	Canada lily	*0.3*	RI									
Oenothera biennis	common evening-primrose	*0.1*										
Mimulus ringens	Monkeyflower	*0.1*										
Lysimachia terrestris	swamp yellow-loosestrife	*0.1*										
Verbena hastata	blue vervain	*1.4*										
Vernonia noveboracensis	New York Ironweed	*0.4*										
Carex scoparia	pointed broom sedge	*1.8*										
Desmodium canadense	showy tick-trefoil	*0.2*										
Chelone glabra	Pink turtlehead	*0.5*										
Eutrochium dubium	coastal plain Joe-Pye weed	*0.2*										
Eutrochium maculatum	spotted Joe-Pye weed	*0.1*										
Juncus effusus	common soft rush	*0.7*										
Panicum virgatum	switch panicgrass	*6.7*	VT									
Hypericum majus	greater Canada St. John's-wort	*0.2*										
Scutellaria galericulata	hooded skullcap	*0.2*										
Eupatorium perfoliatum	boneset thoroughwort	*0.4*										
Cirsium muticum	swamp thistle	*0.2*										
Impatiens capensis	jewelweed	*0.1*										
Lobelia cardinalis	cardinal-flower	*0.2*										
Symphyotrichum novae-angliae	New England Aster	*0.6*										
Solidago rugosa	wrinkle-leaved goldenrod	*0.1*										
Solidago sempervirens	seaside goldenrod	*0.2*										
Gentiana clausa	meadow bottle gentian	*0.2*										
Solidago patula	rough-leaved goldenrod	*0.1*	ME, RI, VT									
Symphyotrichum novi-belgii	New York American-aster	*0.2*										

Plant Mixes for Coastal Sites

New England coastal regions have a wide range of habitats and growing conditions, including tidal marshes and coastal forests. Their soils vary from fine silts to sandy or rocky soils, whose soil moisture conditions range from wet to moist to very dry. Vegetation depends on a complex set of characteristics. Species selection for roadsides in coastal regions requires that plants can tolerate both dry periods as well as occasional flooding. Most importantly, plants should have a high salt tolerance and tolerance of sunny conditions.

Exclusions refer to those states in which the species is of rare or conservation concern.

Species whose fonts are blue cater to specialists and pollinators at-risks but are not necessarily workhorse species.

The mix is composed of approximately 90% grass-like species and 10% forbs by seed count. However, the below mix percentages are relative to a mix consisting of approximately 66% by seed count of Grain Rye (*Secale cereale),* the cover crop, which is part of the mix but not included in bloom time chart.

Apply this mix at 45 lbs. PLS/acre with the inclusion of the Grain Rye cover crop.

If planting between August 1 to December 31, substitute Japanese Millet (*Echinochloa esculenta)* for Grain Rye.

Botanical Name	Common Name	% of mix	Exclusions	March	April	May	June	July	August	September	October
Elymus virginicus	common eastern wild-rye	8.2									
Sorghastrum nutans	Indian grass	1.2	ME, RI								
Juncus tenuis	path rush	0.2									
Carex crinita	fringed sedge	0.7									
Carex stricta	tussock sedge	1.7									
Zizia aurea	common golden Alexanders	0.2									
Eutrochium dubium	coastal plain Joe-Pye weed	0.2									
Eutrochium fistulosum	hollow Joe-Pye weed	0.2	ME, NH								
Scutellaria lateriflora	mad dog skullcap	0.1									
Carex lurida	sallow sedge	3.2									
Carex vulpinoidea	common fox sedge	6.2									
Asclepias incarnata	swamp milkweed	0.8									
Impatiens capensis	jewelweed	0.1									
Mimulus ringens	Monkeyflower	0.1									
Scutellaria galericulata	hooded skullcap	0.1									
Vernonia noveboracensis	New York Ironweed	0.4									
Carex scoparia	pointed broom sedge	3.1									
Desmodium canadense	showy tick-trefoil	0.3									
Symphyotrichum novae-angliae	New England American-aster	0.2									
Panicum virgatum	switch panicgrass	5.8	VT								
Juncus effusus	common soft rush	0.6									
Chelone glabra	white turtlehead	0.2									
Eutrochium maculatum	spotted Joe-Pye weed	0.2									
Eupatorium perfoliatum	boneset thoroughwort	0.2									
Cirsium muticum	swamp thistle	0.1	VT								
Helenium autumnale	fall sneezeweed	0.2	ME, VT								
Scirpus cyperinus	common woolsedge, woolgrass	0.1									
Euthamia graminifolia	flat-top goldentop	0.1	ME								
Solidago rugosa	common wrinkle-leaved goldenrod	0.3									
Solidago sempervirens	seaside goldenrod	0.2									

Woody Plants

This list of native woody plants is recommended for areas distant from the road, usually along woodland edges and back slopes, to encourage populations of wood tunnel–nesting bees and provide additional floral resources especially important in spring and early summer.

Botanical Name	Common Name	Exclusions	January	Feburary	March	April	May	June	July	August	September	October	November	December
Juniperus communis	common juniper													
Salix bebbiana	long-beaked willow													
Salix lucida	shining willow													
Salix humilis	prairie willow													
Alnus incana	speckled alder													
Amelanchier canadensis	eastern shadbush	VT												
Arctostaphylos uva-ursi	red bearberry													
Aronia melanocarpa	Black Chokeberry													
Chamaepericlymenum canadense	bunchberry	RI												
Corylus cornuta	beaked hazelnut	VT												
Gaylussacia baccata	black huckleberry													
Ilex verticillata	common winterberry													
Lindera benzoin	northern spicebush	ME												
Morella caroliniensis	small bayberry													
Myrica gale	sweetgale													
Rubus allegheniensis	common blackberry													
Salix discolor	pussy willow													
Swida amomum	silky dogwood													
Swida sericea	red-osier dogwood													
Vaccinium angustifolium	common lowbush blueberry													
Viburnum dentatum	smooth arrowwood													
Amelanchier laevis	smooth shadbush													
Comptonia peregrina	sweet-fern													
Rosa palustris	swamp rose													
Sambucus nigra	black elderberry													
Clethra alnifolia	coastal sweet-pepperbush	ME												
Diervilla lonicera	bush-honeysuckle													
Kalmia angustifolia	sheep American-laurel													
Rhus hirta	staghorn sumac													
Rosa carolina	Carolina rose													
Rosa virginiana	Virginia rose													
Rubus odoratus	flowering raspberry													
Cephalanthus occidentalis	common buttonbush													
Rosa blanda	smooth rose													
Spiraea alba	white meadowsweet													
Spiraea tomentosa	rosy meadowsweet													
Corylus americana	American hazelnut													

Woody Plants for Coastal Regions

Botanical Name	Common Name	Exclusions	January	Feburary	March	April	May	June	July	August	September	October	November	December
Salix bebbiana	long-beaked willow													
Salix discolor	pussy willow													
Rosa palustris	swamp rose													
Lyonia ligustrina	maleberry	VT												
Prunus maritima	beach plum	ME												
Cephalanthus occidentalis	common buttonbush													
Iva frutescens	maritime marsh-elder	ME, NH												
Gaylussacia bigeloviana	dwarf huckleberry	ME, RI												
Spiraea alba	white meadowsweet													
Spiraea tomentosa	steeplebush													
Chamaecyparis thyoides	Atlantic white cedar	ME, NH												

Investigating local seed production opportunities

Recommendation for local seed production.

The *conservative* approach – to avoid species introductions from outside of their known historical ranges and exclude species of conservation concern from the planting mixes – realized as the result of our consultations with botanists from the Native Plant Trust (formerly New England Wildflower Society) and outlined in the Manual published in 2016 (Kuzovkina and others 2016) was proposed as an important approach for any large-scale restoration plantings in the region. It was emphasized that focus on ecotypic seed, or seed origin, should be prioritized for revegetative efforts to ensure that restored roadsides contribute to the integrity of local populations, and only local ecotypes of native plants should be used for restoration projects to protect the genetic resources of local plant communities. It has been recommended that, when making decisions about the distance for seed transfer to a project site, one should maintain plant seed collection within the relatively uniform environmental conditions of a project ecoregion.

The Challenges and Implications

Since the publication of our manual in 2016, other stakeholders who work with native seeds and plant material also have concluded that a *conservative* approach would be ecologically beneficial to the New England region and in 2022 commenced a work group that has developed into the Northeast Seed Network (NSN), which is now being headed by the Native Plant Trust. The objective of the NSN is to encourage the growth and integration of the supply chain for production of ecotypic native seed and plant material for New England. Unfortunately, as the NSN works to meet the demand for ecotypic seed in our region, the challenges of balancing the DOTs goals for vegetated roadsides with the recommended *conservative* approach to roadside restoration have become apparent.

First, we learned that we still do not have any or enough reliable seed supply for local genotypes, and this is a major bottleneck for implementation of the recommended practices of species selection. Local seed supply is extremely limited in New England, and only a few sources offer, at best, an incomplete selection of small quantities of local seed. However, the increasing number of roadside restoration projects requires large volumes of seed for a diverse range of native species.

Currently, most DOTs in New England purchase their bulk non-local seed predominantly from large producers in the Midwest, such as Ernst Seeds in northwestern Pennsylvania, bringing "*ex situ*" propagules to the restoration sites.

Expansionist approach. The realization that the lack of local seed supply may limit revegetation efforts along roadsides by following our firm recommendations for species selection and strict restoration guidelines in the region prompted further discussions with specialists.

If the main goal is to build healthy and ecologically enhanced roadsides and, if following the firm guidelines of the *conservative* approach may halt the forward movement of projects due to the absence of local seed, then, according to some specialists, plant selection may be approached differently. Some botanists propose a broader view regarding the definition and uses of native species. Conversations with botanists (D. Jaffe and M. Richardson, pers. comm. July 19, 2019) suggested an expansionist approach for species selection, which involves a broader definition of a region when selecting native species. They note that this approach is justified by the current geographic migration of native species as influenced by changing climate, acid rain, and human disturbance, which alter plant ranges resulting in changed distribution boundaries. Therefore, according to this point of view, it is not so critical to mirror the current distribution of native species and exclusive use of local seed, but reasonable and acceptable to use species and seeds from adjacent regions.

Our examination of influential gardening books also revealed that native plant selection is not clearly defined, echoing the *expansionist* approach. Tallamy (2011) and Darke and Tallamy (2014) focused on the importance of plants' functional ecological roles and relationships with the physical environment and other organisms rather than on the geographic origins of native plants.

The dilemma. Summarizing the above, the lack of local native seed in the New England region often halts the restoration efforts by following the strict guidelines of the *conservative* approach. Recent policies require restoring roadsides with native plant communities for multiple ecosystem services suggesting an acceptance of the *expansionist* approach to roadside restoration as the only viable option currently. This would provide the desired ecological outcomes by enhanced ecosystem services. Nonetheless, while being practical, following the *expansionist* approach to species selection remains controversial among conservationists because of unknown environmental consequences and potential risks for local biodiversity conservation. Deciding which strategy to choose is an important matter, resulting in discussions, which should be continued.

We conducted a survey of stakeholders in 2022 concerning their opinions regarding the ecological soundness of using non-local ecotypes versus local ecotypes. We used a Likert scale question that asked the following question:

"How ecologically sound would you rate each of the following approaches for roadside revegetation using native plant material currently available for New England DOTs?"

The Likert scale ranged from 1 to 5 with 1 representing *Not ecologically sound* to 5 representing *Ecologically sound.* Two of the choices were the following:

1. Using New England ecotypic native seed and plant material
2. Using non-regional native seed and plant material

Choice 1 had an average score of 4.875 while choice 2 had an average score of 3.625. These results indicated to us that, while New England ecotypic seed and plant material was clearly considered ecologically more sound than non-regional native seed and material, the average for non-regional material was still within a range considered ecologically sound.

However, another question we asked revealed that these stakeholders still prioritized other practices by DOTs other than the use of non-regional plant material. We asked the following question:

"Please rank from first to last how you believe DOTs should prioritize the use of these approaches for revegetating roadsides."

The choices and the final average rankings resulted in the following prioritization of these practices:

1. Using New England ecotypic native seed and plant material.
2. Implementing mowing strategies that encourage the spread of existing native plant communities along roadsides.
3. Harvesting seed from existing New England roadside native plant communities, which may not meet the strict protocols for determining ecotypic native plants as set out by the Seeds of Success program.
4. Contracting an existing native seed company located outside the New England region, such as Ernst Seed in western Pennsylvania, to grow New England ecotypic seed using protocols to limit possible genetic mixing among species ecotypes.
5. Using non-regional native seed and plant material.

As the results show, although the previous question results indicate stakeholders consider non-local native plant material use to be relatively ecologically sound, they still rank it lower relative to all other practices in terms of ecological benefit. As one stakeholder articulated: "Rome is burning. Don't let he perfect be the enemy of the good. While the ecotypic supply chain develops in New England, progress should be made to transition roadsides to native plantings."

Finding the middle ground is important for achievement of both outcomes – restoration of ecosystem services and conservation of biodiversity while transitioning to native plant communities along roadsides in the region. Before making these choices, we need to redirect efforts to find a new solution.

Subtask 4. *Investigate and develop a list of currently available supply resources for regional native seed.*

Our preliminary investigation during preparation of this proposal identified over 50 entities that offer native plant materials. However, few of these entities appear to offer *ecotypic* native plant material. We surveyed these entities with a series of questions regarding seed availability and type. Therefore, we have selected only a few sources that we believe have the most localized seed production. We have prioritized these sources by the ecotypic status of their seed and their comparable distances from the New England region. We will indicate the relative amounts of seed they currently have available.

Eco59 (https://www.eco59.com/)

This seed company consists of a collective of small farmers growing only seed ecotypic to Ecoregion 59, which spans from Connecticut through Massachusetts and New Hampshire and ends in the southern portion of Maine. While their seed is the most genetically appropriate for this region, the farmers only started growing seed in 2019 and sell relatively small quantities. However, since seed mixes often require just a few ounces of forb seeds, Eco59 represents a viable though more costly choice for several desirable species.

Wild Seed Project (https://wildseedproject.net/)

This seed company harvests and grows their seed within the state of Maine, which includes seeds originating from the three Ecoregions of Maine: 58, 59, and 82. While the Wild Seed Project has the greatest number of ecotypic species currently available, they currently mostly sell small packets of seed. We suggest reaching out to the company to determine if they sell any particularly desirable species in larger quantities.

Vermont Wetland Plants (https://www.vermontwetlandplants.com/)

This seed company sells native seed mixes with ecotypes from Vermont, New York, and Pennsylvania. However, some of their seed mixes do contain species, such as *Coreopsis lanceolata,* that are not native to New England. We suggest reaching out to the company to determine if they can specify the origin of each species and if they are willing to customize mixes to include only *Go Botany* specified native species and those species originating as closely to the New England region.

Ernst Seed (https://www.ernstseed.com/)

Ernst Seed has been a staple source for native seed for our region for years. They offer the greatest number of species at some of the most affordable prices. Unfortunately, most of their ecotypes originate outside the New England region. However, it is possible to find a significant number that are harvested from the New England region. Nevertheless, while they try to grow these ecotypes far enough away from species ecotypes originating from outside New England, the risk exists that the genetic material will cross pollinate. Probably one of the greatest assets Ernst has been their lead botanist, Mark Fiely, who is friendly and extremely helpful when trying to compose specialized seed mixes.

Pinelands Nursery & Supply (https://www.pinelandsnursery.com/)

This New Jersey-based seed company grows ecotypes from New Jersey, New York, and Pennsylvania. They have far fewer species available than Ernst but they can compete in terms of proximity of their species to the New England region. However, they have been actively involved in the work of the Northeast Seed Network and has indicated they would like to start catering to the ecotypic needs of New England.

Prairie Moon Nursery (https://www.prairiemoon.com/)

This Minnesota-based seed company grows quality seed at prices competitive to Ernst. However, their distance from our region makes their seed less ecologically sound for use in New England. They should be used as a supplier of last resort if the need arises for a particular species not available from the other recommended seed sources.

Ecotypic Plant Material

Planters' Choice Nursery (https://planterschoice.com/)

This wholesale nursery recently has moved aggressively into the ecotypic plant sector. They sell both plugs and potted plants. So far, they have grown all their plugs organically and intend to continue doing so.

Hilltop Hanover Farm (https://hilltophanoverfarm.org/)

This Westchester, New York-based farm grows native plugs sourced from ecotypic seed originating from the New England and New York region.

Subtask 5. *Summarize existing seeding, establishment, and management practices to promote pollinator habitats on New England roadsides.*

Establishment of Roadside Native Plant Communities

Our team has decided to use the process of establishing demonstration plots in Connecticut, Massachusetts, and Vermont along Route 91 as an opportunity to replicate the subcontracting protocols currently in place for revegetating roadsides in the context of construction contracting. Rather than have our team conduct the revegetation process in a piecemeal manner, delegating and hiring workers to conduct the various establishment stages, we have decided to hire one contractor in an attempt to reproduce the process by which the DOT itself would put out bids for revegetation. We will try to create a model that we hope DOTs can follow that has a realistic likelihood of being replicated in practice.

Since we want to keep the funding within a realistic and reasonable range, we realized this would require us to compare the amount currently being spent on revegetation projects following construction. Therefore, we requested that landscape designers from each of the three states provide us with at least two previous examples of revegetation projects that involved native seed following construction so we can compare the costs with those from the contractor we would hire. We also asked that the two projects might be somewhat dissimilar so we can get a range of what the costs might be under different circumstances.

Once we decided to select sites along Route 91 to benefit the migration of Monarch butterflies, we requested that DOT managers from CT, MA, and VT to select sites of approximately one acre that they deemed suitable for our projects. The sites selected by CT and MA managers already have existing vegetation while the VT site would be for a site following new construction and thus would have bare soil. These differing site conditions would allow us to experiment with different techniques for establishment. For the two sites with existing vegetation, we decided we would plant both in the fall since we have not had enough lead time to observe the existing vegetative cover. As a result, we are uncertain as to which grasses, weeds, and invasive occupy each site. By waiting to plant in the fall, we will allow ourselves enough lead time to ensure we have controlled existing vegetation, which can compromise the establishment of the native plant communities. The VT site also would be planted in the fall following completion of construction. Many of the landscape contractors with whom we consulted have asserted that practioners have concluded that fall plantings benefit forb establishment by allowing for winter stratification and increased seed-to-soil contact resulting from winter frost heaving of the soil.

Since research as well as our previous work have shown that specialized no-till seed drills deliver some of the most effective establishment of native seed, we contacted several contractors who own or use such drills to get estimates. After comparing estimates, we currently have been working with David Roach, the owner of All Habitat Services LLC, an ecological management firm. We explained to him that we were looking for a contractor who could lead all three site projects and could work within a set budget. Mr. Roach agreed to such terms with the understanding that the VT site located toward the most northern portion of the state may require him to subcontract some of that site's work. Mr. Roach suggested it would be best that he use his seed drill for the CT and MA sites since they have existing vegetation since the drill can penetrate the vegetative cover. However, for the VT site, he suggested broadcast seeding after applying a thin layer of ProGanics™ Biotic Soil Media™, a topsoil alternative that accelerates the development of depleted soils/substrates with low organic matter, low nutrient levels and limited biological activity.

Since we are currently in the preliminary stages of planning, we expect possible changes to our approach as we confront the complexities and reality of budget constraints and unexpected complications.

Mowing Strategies

Since the publication of NETC 09-2 Manual*,* our team has noticed that roadsides in Connecticut and other New England states look noticeably different as native plant communities have emerged because of significant reduction of mowing by state DOTs over the last few years. The goal is to further refine management practices to achieve more extensive habitats and provide cost savings.

Reduced mowing should be considered an essential approach to the establishment of native plant communities along the roadsides, especially during times when building capacity for ecotypic seed production is in progress.

The New England roadsides already contain seed banks for native plant species. Their growth and functionality in the ecosystem can be enhanced by appropriate mowing schedules in the region. Furthermore, personnel who are doing less roadside mowing can be trained to identify and control invasive species, which compete with native plants on roadsides.

Figure 7. Native plant communities of common milkweed (*Asclepias syriaca*) (top photo) and foxglove beardtongue (*Penstemon digitalis*) (bottom photo) are emerging along Rt. 6 between Willimantic and Columbia as the result of reduced mowing by CT DOT in the last few years. This road is one of a few designated by CT DOT as Conservation Roads across the state.

Various mowing practices have significant ecological consequences, including the suppression or enhancement of native plant populations. The detailed guidelines regarding mowing schedules and manners will help:

1. To achieve even higher quality habitats.
2. Roadside personnel understand how management techniques and timing impact ecological dynamics.
3. Provide cost savings.

Many considerations should be considered to achieve the best habitats, such as:

- **Seasonal cycles of pollinators**. Phenological patterns of both plants and insects in New England should be considered to ensure that mowing does not interfere with peak times of vegetative growth, flowering, and seed ripening of key plant species nor with egg-laying, larval development, or pupation of pollinator species. It is best to mow when most plants are past bloom. The current practice of mowing during early-to-mid fall prevents many native plants from setting seed. Mowing later in the season (after mid-October) or during the following spring will ensure that all seeds have matured and dispersed. Later mowing will also ensure that migrating Monarch butterflies will have access to nectar throughout the month of September, when they are moving through the New England states toward their winter habitat in Mexico.
- **Protection of shrubs**. It is desirable to identify areas where mowing operations can be reduced to once every few years to promote native flowering shrubs along woodland edges.
- **Mower height.** Adjustment of the vegetation height by raising the height of the mower blade in areas that need to be mowed regularly can result in increased native plant survival and promote flowering in some species. Native plants are more sensitive to basal cutting than many invasive species.
- **Staggered mowing schedules.** Mowing the landscape in thirds can prevent wholesale cutting of large swaths of flowering plants and thus prevent the creation of pollinator deserts.
- **Invasive control.** Invasive plants may need to be controlled using selective herbicides, mechanical trimming and removal, as well as biological treatments.

Reduced mowing regimens work well on the roadsides where seed and propagules of indigenous species are well represented but invasive species are absent from the seed bank. Seed bank characteristics can direct the suitability of restoration techniques. Therefore, it is critical to develop accurate methods to predict the occurrence and composition of native species along the roadside corridors. The Best Management Practices Manual will discuss how to identify the sites where native species are present in roadside systems but suppressed because of frequent mowing. We will develop a methodology for ranking the sites for future installations and for identifying stretches of roadsides with high potential for success as pollinator habitats.

Our Best Management Practices Manual will provide instruction and advice for towns and DOTs on how to:

- Conduct a systematic survey and prepare a checklist of existing plants.
- Create a series of pilot management tests to evaluate the regeneration potential of each roadside habitat to provide consistent seed bank responses.
- Identify the optimal size suitable for the habitats.
- Identify roadsides with adjacent farms—for example, cranberry bogs in Massachusetts and blueberry farms in Maine—that can benefit from increased feeding and nesting opportunities provided by the roadside pollinator habitats.
- Identify roadsides along the migratory route of the Monarch butterfly (western part of NE) and create migratory way stations with native milkweed species. Ideally, way stations are positioned along a continuous migratory corridor.
- Create and install effective signage alerting maintenance crews that areas are designated pollinator habitats to discourage mowing and the spraying of herbicides.

Ideally, this manual will help regional planners to create a 5-year Pollinator Habitat development plan for each of the New England states.

Reduced mowing approach. Because so many existing roadsides already contain great numbers of native plants, another approach to promote native plant communities of early successional meadows and low shrublands along the roadsides is to implement reduced mowing regimens.

Mowing regimens that are appropriately coordinated with the seasonal cycles of native plants have been developed to promote pollinator health through provisions of flowering resources and establishments of nesting cover for wildlife and were outlined in a few DOTs manuals (Texas DOT 2018).

Moreover, the most important aspect is that the rights of way already contain seed banks for the state's native flora, which can play an important role in native plant revegetation. Native species are often present in roadside systems, but suppressed because of frequent mowing. Their seeds survive in the seed bank. There is evidence that disturbed sites, such as mowed transmission line corridors and roadsides in the Northeast, provide early successional habitats and important refugia for a taxonomically rich array of native plants, including rare species (Brown and Sawyer, 2012; Wagner and others 2014). Mowing operations reduced to once every few years can be implemented to avoid weakening existing stands of native species.

The timing and manner in which the remaining portion of the roadside is mowed have significant ecological impacts. Mowing later in the season (around mid-October) or during the following spring will ensure that all seeds have matured and dispersed. It is critical not to mow a specific area for at least one growing season to allow all native seeds to disperse and promote strong regeneration of the site. The establishment of reduced-mow or natural areas at appropriate locations provides establishment and preservation of native plant communities. On rural roadways with wide rights-of-way, mowing more than once a year can be limited to a mowing strip or swath (15 feet from the edge of the road) instead of full width mowing of the entire space between the road and the right-of-way fence.

An important role of roadside planting is to create corridors and connect fragmented native populations. In this context, it is especially important to prevent the loss of fitness of native populations surrounding roadsides through the addition of non-local genes from plants used in the corridors. When our roadsides are restored, they could serve as stocks of bulk seed for future sowing of the nearby construction sites.

Regeneration of native plant communities (NPCs) through reduced mowing takes advantage of already present native plants represented by local ecotypes. This practice can be called "*in situ*" restoration when no propagule is introduced to the site from other sources. This approach is effective on the roadsides where seed and propagules of indigenous species are well represented, and invasive species are absent from the seed bank. The methodology to evaluate local soil seed bank contents and to estimate the regeneration potential of each roadside ecosystem should be developed to provide consistent seed bank responses. It is most important that restoration efforts be regenerated by native vegetation represented by local ecotypes while preserving the integrity of local populations of native plants.

Understanding the impact of reduced mowing on the local soil seed bank is important from a conservation perspective as seed bank characteristics can direct the suitability of restoration techniques. Reduced mowing could be a key approach to the establishment of NPCs along the roadsides in New England while production of local seed is not fully developed. It is critical to develop methods to predict the occurrence and composition of native species along the roadside corridors. Future studies on the understanding of the impact of reduced mowing on the recovery of existing native plants and the role of the soil seed bank would be extremely important to promote conservation practices in the region.

As development of local seed production is arduous in New England, we assert that restoration of roadsides through reduced mowing should be the future approach to promote NPCs while preserving the integrity of local populations of native plants. In addition, complicated management practices required to establish NPCs and the constant lack of funding favor this approach. Reduced mowing practices would help to overcome the usually high cost associated with native plant establishment and extensive labor required during the establishment phase. It would also stimulate local genotypes of the native species while promoting conservation solutions based on sound biodiversity science. Furthermore, personnel who are doing less roadside mowing can be trained to identify and control invasive species, which can also utilize roadsides as dispersal corridors and are a growing threat to NPCs.

Subtask 6 (new, not listed in the Proposal). *Develop Monarch conservation strategies.*

Natural history of the Monarch Butterfly. The Monarch Butterfly's (*Danaus plexippus*) unique migration story from Mexico to Canada has inspired significant conservation effort across the country. They fly 2000 miles roundtrip each spring, stopping four times to breed and lay their eggs. Monarchs have a migration route that requires four generations to complete. In early spring, the individuals that overwinter in the central Mexican highlands (called Generation 4) die, but their eggs will hatch, develop into caterpillars, pupate, and become Generation 1 one month later. This generation migrates to northern Mexico and across the Gulf to the southern U.S. In early June, they produce a new generation in the middle of the U.S. One month later, Generation 2 moves further north, reaching New England in early July where they lay their eggs on the undersides of leaves of milkweed (genus *Asclepias*; family Apocynaceae, subfamily Asclepiadoideae), but especially the common milkweed (*Asclepias syriaca*). Common Milkweed flowers in July and August when Generation 3 moves around in the northern U.S. and Canada and produces Generation 4. Each generation takes about four weeks to develop from egg through to the larval (caterpillar), then pupal (chrysalis), to finally the butterfly stage. Generations 3 and 4 can be seen in midsummer in New England. Then Generation 4 migrates from the northern states and Canada to Central Mexico.

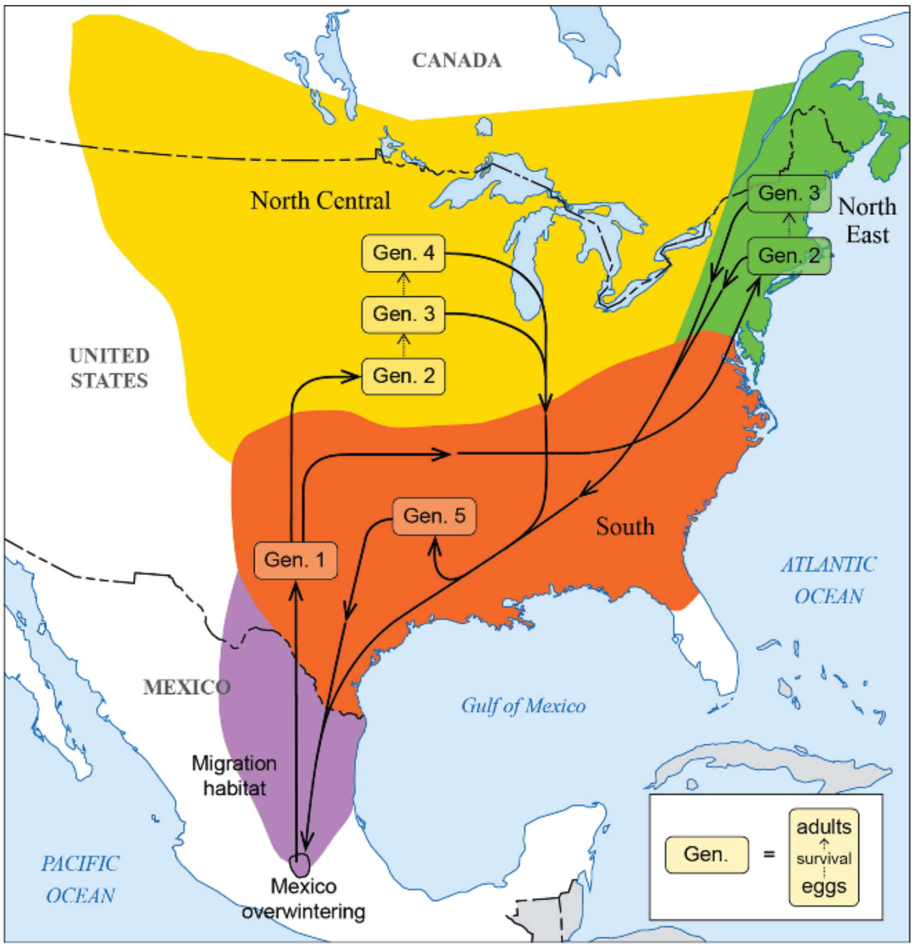


Figure 8. Map of monarch butterfly annual migration in Eastern North America (Oberhauser, et al., 2017).

Problem: Monarch butterflies have declined by 94.6% in the last 20 years, according to the US Wildlife Federation. The reasons for this decline include the loss of their habitats due to agriculturalization, urbanization and logging of their overwintering grounds. The most significant factor contributing to the decline is the shrinking number of milkweeds. This is the only plant that monarch caterpillars eat, and without it the butterflies cannot complete their life cycle and sustain their migration and species preservation.

> **Interesting fact**: Seven states, including Vermont, have adopted the monarch butterfly as an official symbol. Other states include Alabama, Idaho, Illinois, Minnesota, Texas, and West Virginia. Vermont designated the monarch as the official state butterfly in 1987.

Monarch legal status: According to the U.S. Fish and Wildlife Service, the monarch butterfly is a candidate to be listed in the *Lists of Endangered and Threatened Wildlife and Plants*. Its listing priority number, which indicates the magnitude of threats, is moderate. It is not federally protected under the Endangered Species Act (ESA) at this time, though the U.S. Fish and Wildlife Service recommends federal agencies reduce adverse effects and promote Monarch conservation across its range.

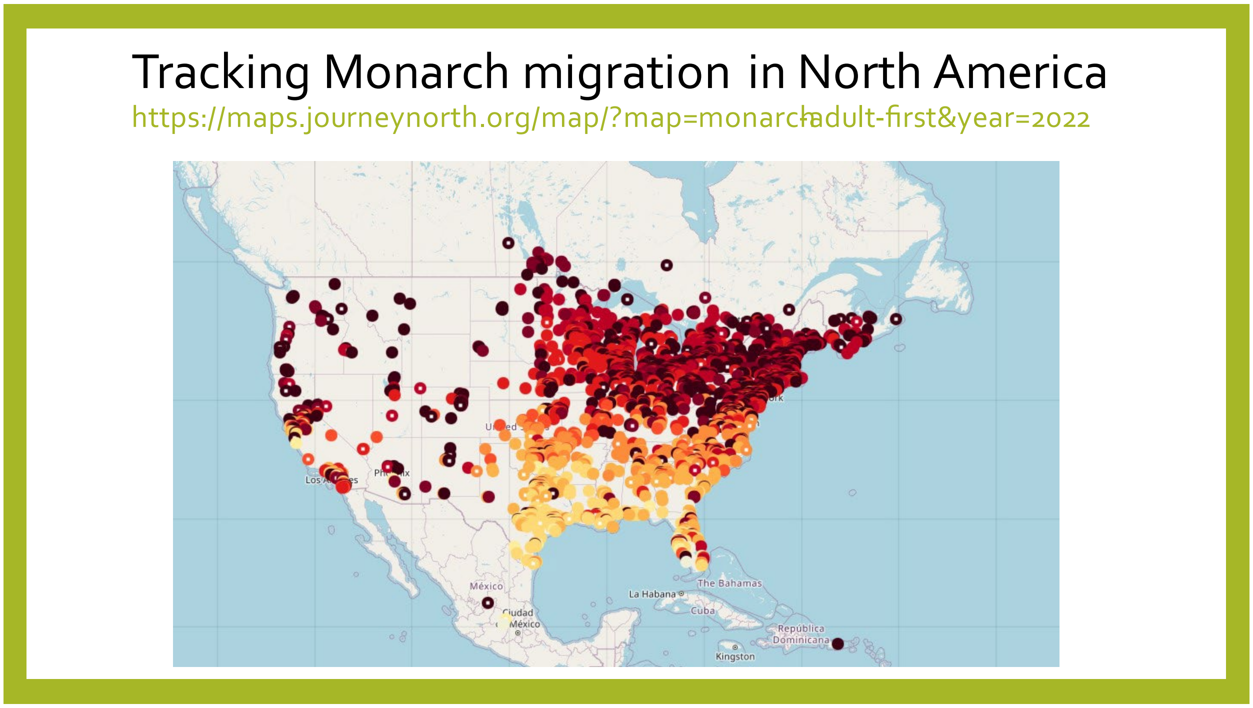
In July 2022, Monarchs have been listed as an endangered species by the International Union for Conservation of Nature (https://www.iucn.org/press-release/202207/migratory-monarch-butterfly-now-endangered-iucn-red-list).

Even though this designation does not have regulatory weight, it indicates that the species is of conservation concern, and Monarch butterflies are currently candidates for federal protection under the ESA. Its status is reviewed each year. Currently there are no requirements for federal agencies with respect to Monarch species and the proposed efforts are voluntary. Today many state departments of transportation are voluntarily committing time and funding to carry out monarch butterfly-friendly management practices.

The monarch butterfly Candidate Conservation Agreement with Assurance (CCAA) with integrated Candidate Conservation Agreement (CCA) for energy and transportation lands additionally provides participants regulatory assurances that, if the monarch is protected under the ESA, additional conservation measures will not be required.

Partners who enroll in the agreement through a certificate of inclusion will provide conservation actions, enhance and maintain habitat for monarch butterflies, as well as continue their general operations – management activities that will occur throughout the life of the agreement and associated permit. An enhancement of survival permit authorizes *incidental take* of monarch butterflies that may result from those activities within rights-of-way on enrolled lands if the monarch butterfly becomes protected under the federal ESA Monarchs | U.S. Fish & Wildlife Service (fws.gov). *Take* as defined under the ESA means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." *Incidental take* is an unintentional, but not unexpected, taking.

Today most efforts to conserve the Monarch focus on habitat restoration in the agricultural landscapes of the U.S. Midwest. Some believe that the Monarch migration path does not span the New England states. The *Journey North* maps provide illustration of the importance of the Northeast Roads to conservation efforts. They show that most areas in New England, except central and northern Maine and northern New Hampshire, provide habitat opportunities and should be included in monarch conservation strategies to increase the amount of milkweed stems and monarch habitat across the country.



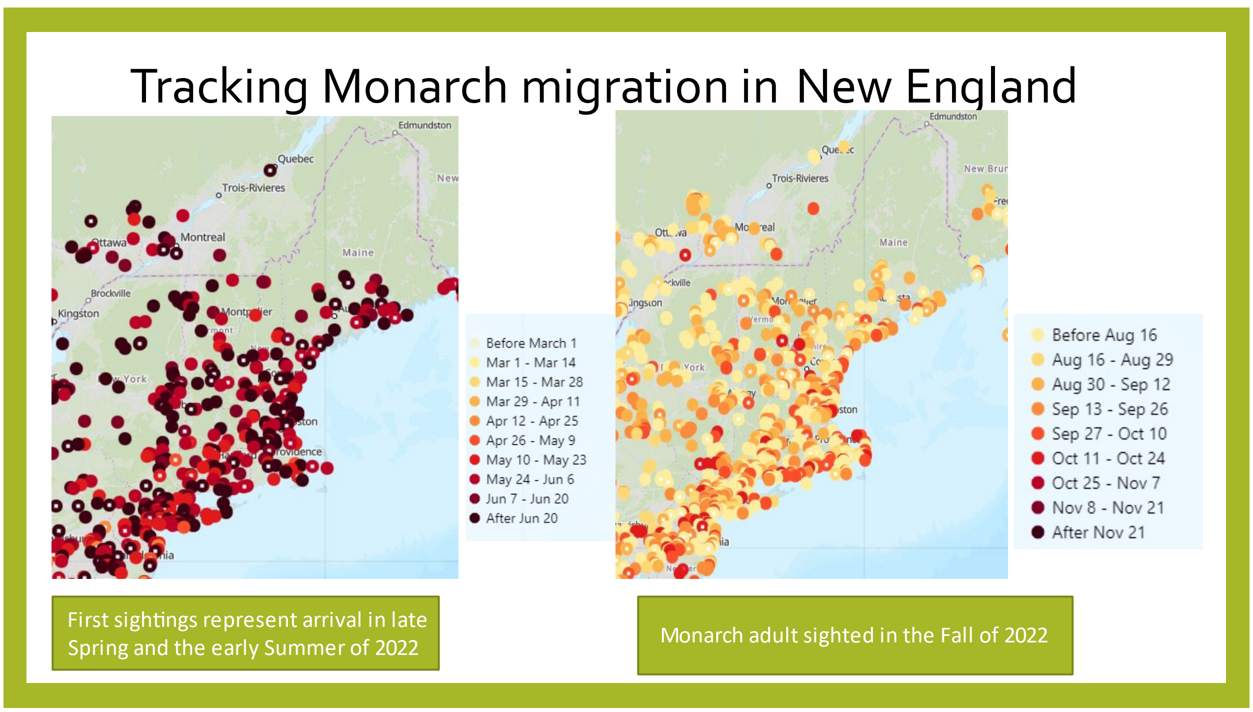


Figure 9. Demographic models of a colonization map of Monarch butterflies in North America and New England (https://maps.journeynorth.org/map/?map=monarch-adult-first&year=2022).

To be continued…

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