PART ONE

CONSERVING PLANT DIVERSITY

purple milkweed
(*Asclepias purpurascens* L.)

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Background

PLANT DIVERSITY AND RESILIENCE

In this report, we focus on the diversity and resilience of habitats rather than on plant diversity as the number of species. Plant communities translate the land's geophysical variation into living habitats that support many types of species. Conserving multiple intact examples of every habitat is a strategy for sustaining the natural benefits plants provide and for maintaining the full diversity of species that depend on them. In this section, we review the importance of habitat diversity, while in later sections we describe the habitats and rare species of the region. To account for the overarching effect of climate change on the distribution of plant species, we present an approach for identifying occurrences of each habitat that have the greatest resilience to climate change. Using The Nature Conservancy's map of site resilience and fine-scale maps of land securement, we assess the status of each habitat with respect to protection and resilience, and we set goals for conserving a resilient network of representative habitats.

Gray's flatsedge (Cyperus grayi)
Michael Piantedosi © Native Plant Trust

For many conservation activities, plants are considered background, yet they furnish and cleanse the air we breathe and provide the basis for our medicines and food.

For many conservation activities, plants are considered background, yet they furnish and cleanse the air we breathe and provide the basis for our medicines and food (Grifo and Rosenthal 1997). They are the basis for all life on planet Earth, and their role in forming and maintaining the ecosystems of the world has been valued at $125 trillion per year in tangible ecological services that benefit humans (Costanza et al. 2014). Plants also remove carbon dioxide from the atmosphere and store it as wood, leaves, roots, and soil. Plants process 123 billion metric tons of carbon each year across the globe (Beer et al. 2010), thus stemming the buildup of greenhouse gases. Half the weight of a tree consists of stored carbon, and since 80% of New England is forested, forests can help reduce the impact of climate change (Catanzaro and D'Amato 2019).

Species Diversity

Plant diversity is often measured as "richness," the number of species within a given area or the average number of species within a habitat. Diversity may also be represented as taxonomic diversity (the genetic relationships between different groups of species) and be quantified by the relative abundances of the species present. Further, plant diversity may be described in terms of functional diversity—those traits of the species present in an ecosystem that influence how an ecosystem operates or functions. The structure of a plant community (trees, shrubs, herbaceous plants) is part of the functional diversity of the community.

Ecologists have long held that a more diverse community tends to be more stable, and there is some evidence to support this. A classic study in the 1990s demonstrated that grassland plots with the most species, that is, those with greater diversity, were most resistant to the effects of drought and were most likely to have a growth rebound after the drought ended (Tilman 1999). A more recent study shows that vegetation, such as a patch of prairie or forest stand, is more productive in the long run when more plant species are present (Reich et al. 2012). Moreover, when biodiversity in the landscape is reduced, as in a cornfield, pine plantation, or suburban lawn, we fail to capitalize on the natural services that biodiversity provides (Reich et al. 2012). Some studies show that high local and regional diversity enhances multiple ecosystem services over time in a changing world (Duffy 2008). Of course, many habitats (e.g., alpine areas, peat bogs) have been stable for millennia despite having relatively few species in the assemblage, suggesting that species counts are most meaningful within the context of a given region and the communities and habitats that characterize it.

Habitat Diversity

"What better expresses the land than the plants that originally grew on it?" (Leopold 1949). Habitat diversity refers to the extent and distribution of vegetated habitats within a region. Plants have evolved to exploit almost every terrestrial situation on Earth, and in each they must negotiate the challenges and limitations of the local conditions. Thus, habitat diversity conveys information about representation of the physical landscape and sets the context for a more nuanced understanding of richness and productivity. For example, tropical forests, with their ample warmth, moisture, and nutrients, represent almost the ideal condition for plants; as a result, they are rich in diversity. In contrast, a New England salt marsh is low in plant diversity because few species have the complex adaptations needed to tolerate cyclic exposure to air, freshwater, and saltwater, but those that do can utilize the rich sources of available nutrients. As a result, salt marshes are extraordinarily productive. These two habitats have evolved to fit different sets of physical conditions, and one cannot substitute for the other. Both habitats are necessary for sustaining the Earth's diversity; thus, the principle of representation—conserving examples of every habitat—is fundamental to maintaining the diversity of life.

The New England landscape is a study in variation. Set over a complicated layering of bedrock and stamped with thousands of wetlands and waterbodies during glaciation, the region's rocky terrain can stretch from coastal marsh to alpine tundra in a single state. As plants transform the abiotic variation into living biotic habitats, their forms and composition become the recognizable habitats that characterize the region. Gnarled wind-buffeted firs among compact cushions of tiny-flowered herbs immediately convey the underlying alpine conditions, where plants are designed to minimize exposure, conserve water, and trap heat. Wet depressions filled with huge-leaved herbs like skunk cabbage and false hellebore convey early spring near the coast and anticipate the deep shady oak-pine canopy to come. As the climate changes, we expect the compositional details of each habitat to adjust in response, but the underlying geophysical settings and terrain-driven processes to remain stable.

Habitats, as described by their characteristic plants and physical setting, are used in conservation as a coarse filter, or shorthand, for the full biotic communities they represent. Alpine habitats, for example, harbor more than 200 plant species, but the habitat's full diversity includes the 3,000 invertebrate species supported by those plants, as well as the 30+ birds, mammals, and herptiles that depend on them both as a food base (Jones et al. 2018). Interspecies relationships may be loose or highly intertwined, such as the blooming cycle of alpine flowers, which is tuned to the seasonal availability of pollinators. Relationships can get very specific; for example, the larva of the endangered White Mountain arctic butterfly (*Oeneis melissa semidea*) feeds on only two alpine sedges, including the rare Bigelow's sedge (*Carex bigelowii*). Evidence suggests that protecting enough habitat also conserves the associated species and relationships.

> *"What better expresses the land than the plants that originally grew on it?"* ALDO LEOPOLD 1949

Habitat diversity goes beyond a count of associated organisms. It also includes the functional differences among a diversity of traits and the fulfillment of niche roles in an ecosystem. A diversity of functional traits is often correlated with a diversity of species in everything from phenological variation to biomass accumulation to root establishment. A study in a freshwater stream habitat found that variation in the role of plant functional diversity between seasons highlighted the importance of fluctuations in the relative abundances of leaf biomass on insect detritivore diversity and for ecosystem processes at various trophic levels (Frainer et al. 2014). Functional diversity can convey resilience by increasing the options available for recovery, as was found in a study on shortened intervals of climate-related wildfire, which showed that plants reliant on both soil seed banks and vegetative spread for growth were more resilient than those dependent on one strategy alone (Enright 2014). The associations between plant species richness and arthropod species richness has also been tied to the functional and structural diversity of plants in both grasslands and forests (Schuldt et al. 2019). In this study, there was a direct relationship between forest herbivores and plant species richness, a pattern that held for overall arthropod species richness because of the large proportion of herbivores.

To correctly use habitat diversity as a target for conservation, it is necessary to understand the different scales at which habitats occur and the intricate ways in which they nest. Matrix-forming forests reflect a region's dominant climate and soils, while wetland habitats respond to smaller scale hydrologic settings. Patch-forming habitats reflect very specific edaphic or disturbance factors (Poiani et al. 2000). Matrix forests define the character and fauna of the region, so in order to retain the full suite of services derived from them, they must be conserved at much larger scales than wetland or patch habitats (Anderson, 2008). One approach used by The Nature Conservancy (TNC) to identify areas for matrix forest conservation was to identify large 5,000- to 25,000-acre blocks of relatively unfragmented forest and then prioritize them for conservation action based on the number of embedded wetland and patch habitats (Anderson et al. 2006). Colloquially, this was referred to as prioritizing the chocolate chip cookie with the most chips. Similarly, the IPAs identified in this study are characterized by their dominant habitat but can be evaluated by the number of other habitats and the number of rare species contained within.

In summary, habitats make informative conservation targets because they reflect the region's geophysical variation, support thousands of associated species, convey resilience through functional diversity, and can form the basis of a representative conservation network appropriately configured and scaled to sustain diversity and services. We acknowledge, however, that habitats are messy entities. On the ground, distinctions between similar types can be subtle, and their boundaries are subject to interpretation. For this report, we use NatureServe's ecological system classification and TNC's terrestrial habitat map (Ferree and Anderson 2018). Although these are widely used tools, there is no agreed-upon scale of classification for habitats comparable to that for genus-species. Further, like all living systems, habitats are not static entities, and their composition is dynamic in both time and space. This makes it even more critical that we identify and conserve the most resilient examples of each habitat to ensure that the sites protected will continue to support diversity and ecological function into the future.

Climate Resilience

Climate change is expected to alter species distributions, modify ecological processes, and exacerbate environmental degradation (Pachauri and Reisinger 2007). Assessments of past and projected future climates indicate that New England is already experiencing increased temperatures and altered precipitation patterns (Dupigny-Giroux 2018). In response, trees are shifting their ranges, creating potentially new species combinations (Fei et al. 2017). Although, conservationists have long prioritized land acquisitions based on habitats (Groves 2003), now they need a way to ensure

cinnamon fern (Osmundastrum cinnamomeum)

Liza Green © Native Plant Trust

that sites targeted for a specific habitat will continue to conserve biological diversity into the future, despite climate-driven changes in community composition. To address this issue, The Nature Conservancy has devised an approach for identifying climate-resilient areas based on enduring geophysical characteristics of the land (Anderson et al. 2014).

A climate resilient site is one that maintains species diversity and ecological function even as it changes in response to a changing climate (Anderson et al. 2014). Identifying resilient sites requires that we look beyond the composition and structure of the vegetation and assess the characteristics of the land itself. Plants experience climate at a very fine scale (inches to yards), such that a site with ample topographic and hydrologic variation is experienced by plants as a mix of microclimates. If well connected, areas of high topoclimate variation have the potential to buffer climate-change impacts by enabling local dispersal to more favorable microclimates and may also provide stepping-stones to facilitate longer distance range shifts (Suggitt et al. 2018). This "microclimatic buffering" (Willis and Bhagwat 2009) enables species to persist, even where the average background climate appears unsuitable.

Microclimate buffering was first reported in California's serpentine grasslands, where microtopographic thermal climates showed a 34 °F difference between maximum values on different slopes (Dobkin et al. 1987). Another study found areas of high local landscape diversity were important for long-term population persistence of butterfly species and their host plants under variable climatic conditions (Weiss et al. 1988). Many more studies of landscape-based climate variation have now shown how local climatic variation strongly influences species persistence, leading some scientists to suggest that microclimates not only slow the rate of transition, but also may act as long-term refugia (Morelli et al. 2018; Reside et al. 2013; Ashcroft 2010; DeFrenne et al. 2013; Dobrowski 2011). In the largest and most definitive study, Suggitt et al. (2018) examined five million distribution records for 316 plant species over 30+ years across England and found that microclimatic heterogeneity strongly buffered them against regional extirpations linked to recent climate change, reducing extirpation risk by 22%.

This is all good news for New England, where topography, aspect, moisture, and elevation modify local conditions and create microclimatic patterns that are relatively predictable at the site scale. TNC staff in Vermont measured the soil temperature at six points along Rattlesnake Ridge (a site mapped as having high resilience) and found differences up to 10 °F depending on aspect, elevation, and slope. Combined with moisture and bedrock differences, the small area supported seven distinct natural community types (Goodwin, personal communication, 2019). Even at finer scales there can be considerable climatic variation. A study of ten bogs in the Adirondacks (Langdon et al. 2018) found that while coarse-scale climate models predicted they would have a relatively long growing season averaging 128 days, temperature loggers at each bog found them to be much cooler and more variable, with an average growing season of only 73 days and a range from 22 to 128 days.

Moisture and hydrologic microrefugia are likely to prove essential for species persistence, especially plants (McLaughlin et al. 2017). At the site level, moisture is correlated with topography and aspect and can explain 40-72% of soil moisture variation (Yeakley et al. 1998). Mesic microenvironments are generated by a wide array of hydrologic processes and may be only loosely coupled to the regional climate. Thus, the presence of wetlands, riparian habitats, and groundwater-fed springs and seeps can be used to indicate relative differences in site resilience for areas with flatter topography. The extent and variety of wetlands can be a good indicator of microclimatic variation derived from subtle differences in topography and soils that are challenging to model.

saltmarsh hay (Spartina patens)
Michael Piantedosi © Native Plant Trust

TNC's spatially explicit model of **site resilience** is based on observations that intact sites with little fragmentation and a large variety of microclimates and wetlands enable species to persist longer under a changing climate (Anderson et al. 2014). In the model, every patch of land within an ecoregion is compared, and areas with more microclimates and less fragmentation are scored as having greater resilience than flatter and more fragmented areas of the same geophysical setting. The two measured factors used by TNC to map site resilience are: 1) landscape diversity, defined as microclimatic variation derived from topography and hydrology, and 2) local connectedness, derived from local fragmentation patterns. These factors underlie the map of climate resilience that forms the base data layer used in this report.

Landscape diversity refers to landscape-based climate variation defined as the variety of temperature and moisture environments created by an area's topography, wetlands, and elevation range. Landscape diversity is quantified by summarizing the variety of landforms, the elevation range, and the density of wetlands in a 0.4 sq km (100 acre) search area around every 30 m patch of land in the region.

Local connectedness is the degree to which a given landscape is conducive to the movement of organisms and the natural flow of ecological processes such as local dispersal (Meiklejohn et al. 2010). TNC's model of local connectedness uses 30 m data on land cover, roads, railroads, pipelines, energy infrastructure, and industrial forestry; and each element is assigned a "resistance weight" based on its theoretical resistance to population movements. The analysis measures the connectivity of a focal cell to its surrounding neighborhood when the cell is viewed as a source of movement radiating out in all directions to simulate dispersal through a medium of mixed resistance (Compton et al. 2007).

The **site resilience score** is an equally weighted combination of landscape diversity and local connectedness applied and scored for every cell in the region relative to the cell's geophysical setting and ecoregion (e.g., low-elevation sand in the North Atlantic Coast is compared to other low-elevation sand in the North Atlantic Coast, etc.). Full methods can be found in the published literature (Anderson et al. 2014; Anderson et al. 2012; Anderson et al. 2018). TNC uses the information to incorporate microclimate variation, local connectedness, and site resilience into conservation planning (see http://maps.tnc.org/resilientland/).

GLOBAL STRATEGY FOR PLANT CONSERVATION AND GLOBAL DEAL FOR NATURE


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The genesis of this report was an interest in assessing how well a century or more of conservation action is protecting plant diversity in New England, as measured against the Global Strategy for Plant Conservation, which is part of the United Nations' Convention on Biological Diversity (CBD). We extended the analysis to encompass goals of the Global Deal for Nature (Dinerstein et al. 2019), which calls for protecting 30% of the world's ecosystems by 2030. The 30 by 30 goals are being incorporated into the 2021 update to the CBD and were recently adopted by the current administration as part of its "Conserve and Restore America the Beautiful" initiative (Executive Order 14008).

Global Strategy for Plant Conservation

The Global Strategy for Plant Conservation (GSPC) was first adopted by the Conference of the Parties to the Convention on Biological Diversity (CBD) in 2002. The GSPC considers plants in the terrestrial, inland water, and marine environments. Further, it applies to the three primary levels of biological diversity as recognized by the Convention, hence plant genetic diversity, plant species and communities, and their associated habitats and ecosystems. The GSPC originally included sixteen targets to be achieved by 2010. The targets were revised for a 2020 timeline and are being updated again in 2021 with a 2030 deadline.

The GSPC emphasizes that the outcome-oriented global targets are a flexible framework within which national and/or regional targets may be developed, according to national priorities and capacities, and taking into account differences in plant diversity between countries (Convention on Biological Diversity 2012).

For this study, we primarily focus on three targets for assessing the conservation of plant diversity in New England:

- Target 4: At least 15% of each vegetation type secured through effective management or restoration
- Target 5: At least 75% of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity
- Target 7: At least 75% of known threatened plant species conserved *in situ*.

The GSPC has a goal (Target 8) specifically related to ensuring that 75% of threatened plant species are in *ex situ* collections (seed banks and living collections at botanic gardens), which we address later in this report. In addition, prior work by Native Plant Trust achieved the first two targets: Go Botany satisfies Target 1, which is "an online flora of all known plants"; and "*Flora Conservanda:* New England" (Brumback and Gerke 2013) fulfills Target 2, "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action."

Liza Green © Native Plant Trust

Global Deal for Nature

The Global Deal for Nature (Dinerstein et al. 2019) is a landmark paper authored by nineteen prominent scientists that advances a science-driven plan to save the diversity and abundance of life on Earth. The GDN targets 30% of Earth to be formally protected by 2030, plus an additional 20% designated as climate stabilization areas to ensure the temperature change stays below 1.5°C. The authors argue that pairing the GDN and the Paris Climate Agreement would avoid catastrophic climate change, conserve species, and secure essential ecosystem services. The 30 by 30 target is derived from five fundamental goals of conservation science: (1) represent all native ecosystem types or "representation"; (2) maintain viable populations of all native species in natural patterns of abundance and distribution; (3) maintain ecological function and ecosystem services; (4) maximize carbon sequestration by natural ecosystems; and (5) address environmental change to maintain evolutionary processes and adapt to the impacts of climate change (Noss and Cooperrider 1994). Based on these axioms, and the area needed to fulfill them, the GDN argues for 30% of each of the Earth's ecoregions to be protected by 2030.

In this report, we give more detail in the form of a 2030 New England Target (NET), demonstrating how protection should be defined and distributed within ecoregions by translating the goal from 30% of the ecoregion to 30% of each habitat within ecoregions.

SECURED LANDS AND GAP STATUS

Land and water permanently maintained in a natural state remains the most effective, long lasting, and essential tool for conserving species and habitats (Dudley 2008). Through land securement, conservationists aim to maintain the quality of land and water by regulating its use in specific places. In New England, conservation lands are far from uniform entities; instead, they have a wide range of management intents, are governed by a variety of public and private stakeholders, and represent an array of restrictions, designations, tenures, easements, interest holders, and ownership types.

The evolution of land and water protection to encompass a broader palette of securement is one of the important advances in conservation, because it offers a realistic chance to create conservation infrastructure at a larger scale and with a more diverse set of players. Protected reserves are still critical, but other strategies can inform responses to the increasingly complex nature of the environmental crisis.

Secured Lands: The Nature Conservancy's secured lands dataset (Prince et al. 2018) shows public and private lands that are permanently secured against conversion to development through fee ownership, easements, or permanent conservation restrictions. Each land parcel is tagged with acreage, ownership type, and GAP status.

GAP Status: GAP status was developed by the U.S. Fish and Wildlife Service (Crist et al. 1998) as a way of classifying all public and private conservation lands relative to the intent of the landowner or easement holder. It is widely used in the U.S. by public agencies, and it is included as part of the Protected Area Database maintained by the U.S. Geological Service.

GAP 1 and 2 lands are considered **protected**, and we adopt that language in this report.

- **GAP Status 1: Secured for Nature and Natural Processes**
  An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management. *Examples: nature reserves, Forever Wild easements, wilderness areas.*

- **GAP Status 2: Secured for Nature with Management**
  An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance. *Examples: national wildlife refuges, national parks.*

GAP 3 lands are considered multiple use. They are secured against conversion to development but open to many uses, including extraction and recreation.

- **GAP Status 3: Secured for Multiple Uses**
  An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging) or localized intense type (e.g., mining), or motorized recreation. It also confers protection on federally listed endangered and threatened species throughout the area. *Examples: state forests, forest management easements, conservation restrictions on working forest.*

Unsecured lands are not permanently secured against conversion; this includes most private land.

Using GAP Status to Assess Progress: In this report, we consider land in GAP status 1-3 to be "secured against conversion" but only land in GAP status 1 and 2 to be "protected." We consider GSPC target 4 ("secured through effective management and/or restoration") and GSPC target 5 ("secured with effective management in place for conserving plants and their genetic diversity") to be equivalent to GAP 1-2 protection, as multiple-use lands do not have a mandate for sustaining the habitats or natural features. In New England, there is an important conservation role for multiple-use lands (GAP 3) that enables us to maintain forest cover at large regional scales. Thus, for the primary (not IPA) NE target we explicitly aim for a mix of protected land (GAP 1-2) nested within a larger matrix of multiple-use land secured against conversion (GAP 3).

The secured land dataset (Prince et al. 2018) used for this study is compiled biannually by TNC from over sixty sources. For the most part, it is a combination of public land information maintained by each state and private conservation land information compiled by TNC's state field offices from land trusts and individuals. Staff in each state office compile the dataset for their state, assign the GAP status to each tract, and fill out the other standard fields. The completed state datasets are then compiled by the regional science office and quality checked for consistency and discrepancies.

For this study, we overlaid the secured land dataset on the habitat and climate resilience maps to identify the proportion of each that fall within each GAP status. Only parcels where the ownership duration is permanent are included in the mapped dataset. Although many volunteer, temporary, or non-permanent agreements may contribute to conservation, it is beyond our capacity to track and maintain information on non-permanent ownerships or activities at a regional scale.

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NEW ENGLAND FLORA AND RARE TAXA

As one of the earliest colonized areas of the United States, the New England region has a long history of botanical interest and published science. Native Plant Trust's comprehensive flora of the native and naturalized higher vascular plants, *Flora Novae Angliae* (Haines 2011), is the primary reference for the region's plants. This manual has been converted into an interactive, online flora, Go Botany (Native Plant Trust 2012), that can be continuously updated to reflect taxonomic and nomenclatural changes to the flora, as well as actual changes in plant taxa of the region. This online flora for the region meets the criteria for Target 1 of the GSPC, "an online flora of all known plants" (Convention on Biological Diversity 2012).

The six states that make up New England cover more than 186,443 km^2, roughly the size of Washington State, with a comparable number of plant taxa (Farnsworth 2015). More than 3,500 species occur in the region, but almost a third of these are introduced (not native) (Haines 2011; Mehrhof 2000). Maine is the largest state in New England, covering almost half the region. Massachusetts has the most native taxa and also the most introduced taxa. TABLE 1 shows the breakout by state. An excellent summation of the history and development of the region's flora can be found in Native Plant Trust's "State of the Plants" (Farnsworth 2015).

TABLE 1. Number of Taxa per New England State

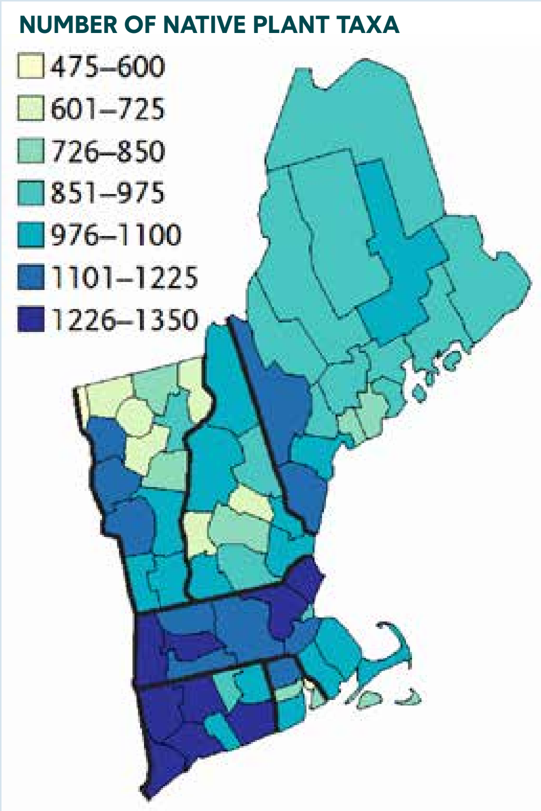
"Taxa" includes all species, varieties, and subspecies. Data also include taxa that are considered either native or naturalized but are no longer present in New England (historic). Source: Native Plant Trust's Go Botany database.

STATE	NATIVE	NON-NATIVE	SUM*	TOTAL INDIVIDUAL TAXA**
MA	1816	1487	3303	3275
CT	1731	1100	2831	2816
ME	1603	867	2470	2453
VT	1622	799	2451	2407
NH	1592	683	2275	2267
RI	1352	654	2006	1997

* Sum of native and non-native taxa. Taxa may be native in one county of a state, but may also be considered non-native in another county, and therefore counted under both categories.

** Total individual taxa counted only once per state, whether native or non-native.

FIGURE 1. Native Plant Taxa in New England by County
Source: Go Botany.



Habitat and Plant Diversity

The varied physical features of New England's landscape—low coastal plains, rocky coasts, river floodplains, alluvial valleys, glacial lakes, forested mountains, and alpine peaks—in part account for the diversity of the region's flora. This following summary of the region's flora is based on Haines (2011) and Seymour (1969).

The region is home to part of the Appalachian Mountain chain, which is especially prominent in the northern states of ME, NH, and VT. Alpine habitats are also present in these states, and the highest peak in the region is Mt. Washington in NH at 1917 meters. The underlying bedrock of the region is primarily acidic (granite schist), but rock that is basic in nature (limestone, marble) is found mainly along the western border in CT, MA, and VT. Glaciers covered all but a tiny fraction of the region (part of the island of Martha's Vineyard), and before European settlement the region was primarily forests with a wide variety of coniferous and deciduous trees. New England is known for the extensive spruce fir-forests of NH and ME as well as several types of hardwood forest, the most renowned being the sugar maple hardwood forest, famous for its maple syrup and fall color.

All states in New England except VT border the Atlantic Ocean, and the seacoast has salt marshes and salt water species typical of eastern North America. Southeast MA and RI harbor numerous coastal plain species, many of which are typical of the mid-Atlantic states. The coastal plain pond shores of MA and RI, connected to and maintained by groundwater, are a globally rare habitat with a unique flora.

The Connecticut River, the largest in New England, flows the entire length of the region, from a small lake in NH near the Canadian border to Long Island Sound in CT. Several other large rivers in the region hold recognizable plant assemblage due to their underlying bedrock and climate. These include the St. John and Aroostook rivers in ME (ice-scoured Laurentian shorelines), the Housatonic River in western MA and CT (limestone and marble bedrock), and the lower Connecticut River, Merrimack River (MA), and Kennebec River (ME), which all contain fresh tidal and brackish tidal habitat.

There are several notable hotspots of rare plant diversity in New England; these are sites in which clusters of specialized plants co-occur on unusual substrates or in uncommon ecological community types. These hotspots include the marble valleys of western New England (CT, MA, VT), Connecticut River Valley (CT, MA, NH, VT), Cape Cod and the Islands (MA), southern RI, St. John River Valley (ME), and the Presidential Range (NH) (Farnsworth 2015).

© Wikimedia / Connecticut River

Plant Rarity

From 1993 to 1996, Native Plant Trust (at that time New England Wild Flower Society) and its partners compiled data on the status of rare plants in the six New England states to formulate "*Flora Conservanda:* New England," a list of higher tracheophyte plant taxa to be prioritized for regional conservation" (Brumback and Mehrhoff et al. 1996). To account for nomenclatural and taxonomic changes since 1996 and to suggest updated priorities for protection at both the species and population level, *Flora Conservanda* was updated in 2012 by Native Plant Trust and its New England Flora Committee, which consists of representatives of each of the six New England state's Natural Heritage programs, or their equivalents, and other botanists familiar with the regional flora. Determination for listing was based on the global rank (per NatureServe 2013) of the species and the number of Element Occurrences (EOs *sensu* NatureServe 2013) known in New England. By applying strict definitions for the inclusion of a taxon within one of the five divisions, the group identified 593 taxa of high regional concern out of a total of approximately 2300 species indigenous to New England (Brumback and Gerke 2013).

Flora Conservanda focuses on taxa that are globally and regionally rare (Divisions 1 and 2). It also identifies taxa that may be declining throughout a significant portion of the region or that have occurrences of conservation importance owing to their biological, ecological, or (potential) genetic significance (Division 3). It further identifies taxa that are considered historic in the region (Division 4) as well as those that may be rare throughout New England, but for which taxonomic or distributional information is insufficient to determine status (Division IND). *Flora Conservanda* meets Target 2 of the GSPC, which calls for "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" (Convention on Biological Diversity 2012).

Flora Conservanda indicates that 22% of the region's native plants are now considered rare or have populations in need of conservation (TABLE 2). Among them are 62 globally rare taxa and 10 endemic taxa, three of which are now considered extinct. An additional 96 taxa have been extirpated from their New England range and, in many cases, are imperiled in the remainder of their range (Farnsworth 2015). Since publication of *Flora Conservanda*, another globally rare species, American chaffseed (*Schwalbea americana*), has been rediscovered in Massachusetts, after last being seen in the 1960s.

TABLE 2. Comparison of *Flora Conservanda* (1996 and 2012)

DIVISION	1996	2021
1 – Globally Rare	57	62
2 & 2(a) – Regionally Rare	272	326
3 – Locally Rare	76	57
4 – Historic in New England	56	95
IND – Status Indeterminate	114	53
TOTAL	**575**	**593**

See Appendix 1 "Divisions of the List" for definitions of these divisions and Appendix 2 for definitions of global status.

American chaffseed
(Schwalbea americana)

Uli Lorimer © Native Plant Trust

THREATS TO PLANT DIVERSITY IN NEW ENGLAND

As outlined in the "State of New England's Native Plants" (Farnsworth 2015), plant diversity in New England faces a variety of anthropogenic stressors. These include air pollution and trampling in the alpine zone; thousands of acres of forest cleared each year; more than 10,250 dams altering hydrology along rivers; fire suppression leading to succession of grassland habitats to forests; and a combination of ditching, draining, and overfishing, resulting in severe die-back of vegetation and erosion of substrate in estuarine marshes. Further, anthropogenic threats include those indirectly influenced by human activity, such as an overabundance of deer from having eliminated their predators. These threats have been exacerbated by the introduction of invasive plants, insects, and pathogens, which readily colonize habitats with significantly disturbed ecological processes. Each of these threats is altered or compounded by the effects of a changing climate, further pushing ecological systems out of balance.

Habitat Loss and Fragmentation

Loss of habitat is the most significant driver of declines in plant diversity. Habitat loss in a landscape can fragment and isolate patches of suitable habitat for plant species, thereby reducing the potential for many organisms to move within a contiguous area.

Fragmentation of habitat as a result of road construction, residential and commercial development, altered hydrology (damming, locks, channeling), and associated infrastructure modifications has isolated blocks of forests, rivers, and wetlands, leading to isolated plant communities, disconnection of animal migration routes, and the breaking of intricate relationships based on connectivity that are critical to the survival of both.

With increased habitat fragmentation comes a compounding of associated threats to plant diversity through increased edge-effects. These include increased invasive species instances in native plant habitats, increased predation of interior forest birds and amphibians by edge-dwelling wildlife (and feral housecats), and alteration of microclimates by increased sunlight, wind, and soil erosion (Woolsey 2010).

Implications of fragmented habitats for plant life include a reduction of dispersal rates by seed or spore and reduced pollinator-visitation frequency, leading to declines in seed set. With habitat loss comes changes in abundance of species, affecting the network of interspecific interactions in a community. Syntheses published on plant-pollinator networks have found that many mutualistic networks, like plant-pollinator interactions, exhibit a relatively high degree of connectivity, especially when compared with networks of antagonistic interactions, such as food webs at various trophic levels. Literature suggests these general attributes of mutualistic networks are not only correlated with declines in habitat, but also that when maintained, impart significant stability and enable more species to persist in a community (Okuyama and Holland 2008; Bastolla et al. 2009; Thebault and Fontaine 2010).

In addition, residential, commercial, and industrial development has resulted in 1.1 million acres (21% of total land area) in Massachusetts alone being developed (Woolsey 2010), with adjacent habitats and plant communities degraded or disturbed by invasive species encroachment; light, air, and water pollution; excessive noise; and the compounded effects of each on shifting lands from carbon sinks to carbon sources.

downy rattlesnake-plaintain
(Goodyera pubescens)
Dan Jaffe © Native Plant Trust

Invasive Species

Among the many threats to global biodiversity, the movement of species across historically distinct biogeographic borders remains one of the most intractable (Facon et al. 2006; Barney and Whitlow 2008; Moles et al. 2008). Introduction of invasive organisms, largely a result of human actions, has caused plant, animal, and pathogenic pests to transform many habitats in New England. While threats of invasive species on native habitats are well documented, they vary in level of severity depending on the habitat and the invasive species in question, and they tend to dominate in areas where disturbance events are consistent. Invasive species should generally be regarded as both a direct threat and a symptom of other, broader threats (e.g., climate change, development, fire suppression, etc.) to native plant communities.

In New England, the Invasive Plant Atlas of New England (IPANE) improved our understanding of the effects and distribution of invasive plant species in the region. At the time of IPANE's inception in 2001, 30-35% of the plant species known to New England were thought to be non-native and of those 3-5% were considered aggressive invaders. Since then, the number of non-native and invasive species in New England appears to have increased slightly, as the "State of the Plants" report notes that "31% of the 3,514 documented plants are not native, and 10% of those are invasive" (Farnsworth 2015).

Introduction of invasive organisms, largely a result of human actions, has caused plant, animal, and pathogenic pests to transform many habitats in New England.

Since its inception in 2005, EDDMaps (Early Detection & Distribution Mapping System) has become a primary repository for invasive species presence data, and the database contains nearly four million points documenting invasive species across North America. As described on its website, EDDMaps "aggregates data from other databases and organizations as well as volunteer observations to create a national network of invasive species and pest distribution data that is shared with educators, land managers, conservation biologists, and beyond." In addition to resources like IPANE and EDDMaps, local and regional CISMAs (Cooperative Invasive Species Management Areas) are active nationwide as a means of bringing together representatives from federal, state, tribal, and non-government organizations, as well as individuals, into organized groups working on invasive species management in a defined geographic area. Networks that cross political boundaries, such as IPANE, are critical for establishing early-detection systems and sharing consistent data with everyone from conservation land managers to the general public.

Plant communities already stressed by the effects of habitat loss and fragmentation are more susceptible to invasion from pests and pathogens. An example is the impact on plant diversity as a result of invasive earthworms. Research has shown that exotic earthworms in northern hardwood forests cause remarkable changes in soil structure, nutrient cycling, and plant communities. The most arresting of these findings is earthworm invasions turning these ecosystems from important global carbon sinks into carbon sources (Alban and Berry 1994; Bohlen et al. 2004a) through increased heterotrophic respiration (Li et al. 2002). In addition, earthworms shift the soil system from fungal dominated to bacteria dominated, resulting in a loss of important mycorrhizal-plant root relationships (Wardle 2002). Loss of mycorrhizae can lead to negative effects on plant root function (Lawrence et al. 2003), plant growth (Gundale 2002), and plant community assemblages (Holdsworth et al. 2007), ultimately affecting plant community diversity and every trophic level reliant on such diversity. In addition, an increase in earthworm diversity may cause a decrease in plant species diversity due to different earthworm species occupying multiple soil niches, such as those which live in the organic soil horizons and below in the organic-mineral horizons (Hopfensperger et al. 2011).

Altered Hydrology (anthropogenic)

Throughout New England altered hydrology, most often a result of damming and channeling rivers, drastically affects both terrestrial and aquatic plant communities. The manmade modifications shift the seasonality, level, flow rate, and regularity of river flow. The result is decreased water and ice scour, altered patterns of sediment deposition, and reduced migration of plant propagules such as seeds and rhizomes along river shores, all of which affect the composition and viability of plant communities.

Further, as modifications to lands adjacent to coastal areas and wetlands increases (impervious surfaces, storm-wall construction, development, etc.) plant diversity in these hydric systems will likely decline. A 2014 study showed the influence of elevation and salinity on vegetation structure in tidal wetlands (when compared to estuarine hydrology and other variables) and found that global climate change may lead to changes in species distributions, altered floristic composition, and reduced plant species richness in estuarine wetlands. This conclusion largely shows the likelihood of near-term changes to plant diversity as coastal plant communities face several compounding threats, including sea-level rise, increased flood intensity, and exposure of freshwater wetland plant communities to salt water (Noto 2017, Janousek and Folger 2014).

Fire Suppression

Fire suppression has removed an important disturbance event from the landscape and significantly altered New England's plant communities. Reduction of fire, primarily as a result of dense human habitation and the immediate threat of fire to infrastructure, has caused declines in fire-adapted plant communities, such as early-successional sandplains. In habitats such as sandplain grasslands and heathlands, a history of lightning-caused wildfires resulted in plant communities adapted to fire events. Without fire, much of New England's grassland habitats will over time become new-growth forests. In addition, with shortened fire intervals, species dependent on seedling recruitment (such as annuals) are more vulnerable to local extinction than are species that spread vegetatively (Enright 2014). In a changing climate, a projected reduction in post-fire rainfall in certain areas is likely to impact seedling recruitment, further altering plant diversity.

Trampling

In plant communities less adapted to regular disturbance, such as in alpine, subalpine, and bog habitats, trampling by humans can have significant negative impact. Studies have shown varied impacts of trampling in alpine and subalpine plant communities (Chardon et al. 2018; Gremmen et al. 2003), as well as the degradation of bog systems as a result of deer trampling (Pettorelli 2006) – which will likely continue to increase as forest-edge habitat increases and with the absence of predatory megafauna (both anthropogenic impacts) keeping deer populations in control.

In incline- and elevation-driven habitats, some studies have shown that light to moderate disturbances can maintain high species diversity, while others emphasize that heavier disturbance reduces plant species richness and plant diversity. Highly disturbed and trampled alpine and subalpine systems could therefore be at greater risk for upward encroachment of lower-elevation species in a changing climate (Chardon et al. 2018).


Uli Lorimer © Native Plant Trust

CONSERVATION ACTIONS TO COUNTER THREATS TO PLANT DIVERSITY

Protect as Much Intact, Diverse, Complex Habitat as Possible

The focus of this report is land securement—whether through purchase or conservation easements—as the primary tool for sustaining plant diversity and the range of plant communities on the New England landscape. We argue that the goal is securing a proportional representation of habitats across the landscape and ensuring the sites conserved are resilient to climate change, as defined above.

There are other important conservation actions that have a prominent role in countering or mitigating threats to plant diversity.

Monitor Plant Populations for Health and Threats

Monitoring of individual taxa and entire habitats to record baseline data is crucial for effective management of species, communities, and ecological systems. This baseline of what is "normal" for a species or a habitat is often a result of both biological and historical data gathered through consistent intervals of monitoring floristic health and changes to the system.

In New England, we are fortunate to have state-level Natural Heritage programs (or their equivalent), land trusts monitoring conservation lands they own or manage, and regional community-science monitoring programs, such as Native Plant Trust's New England Plant Conservation Program (NEPCoP) and Plant Conservation Volunteer (PCV) program. NEPCoP's primary goal is to address the questions of plant rarity at the population level, taking a regional perspective on endangerment, availability of resources, and likely benefits of species and habitat management (Parks 1993). For nearly thirty years, monitoring efforts through NEPCoP and the PCV program have gathered data on imperiled plant populations throughout New England to inform applied conservation actions. Data collected through regular monitoring of imperiled plant populations are fundamental to understanding trends occurring in an ecological system over time. For example, monitoring data can reveal the disproportionate decline of insect-pollinated plant species (Farnsworth and Ogurcak 2006; Farnsworth 2015), or the regional loss of dominant forests trees in the Northeast as a result of climate change (Clark 2014). Measuring and monitoring the results of management actions such as habitat restoration or species augmentation are critical to understanding the potential for species or ecosystems to adapt to the changes brought by climate change.

Collect and Bank Seeds to Preserve the Genetic Diversity of Species and Habitats

Seed banking of wild species, one facet of *ex situ* conservation, is critical to integrated conservation measures seeking to protect plants in their native habitats (*in situ*), as seed banks provide a safety net against extinction in the wild and a source of local genotype seed for restoration projects (Havens et al. 1999). Unfortunately, there is a well-documented scarcity of seed for restoration; insufficient research in such areas as seed transfer zones, seed physiology, and longevity; and inefficient supply chains without clear documentation of seed origin and quality (Bischoff et al. 2010).

Effective seed banking collects from a range of geographically isolated species and populations and ensures intraspecific genetic diversity within each collection, often achieved through randomized sampling of a population. This approach has implications not only for individual taxa, but also for successful restoration of habitats. Several studies have shown genotypic diversity among plants may play a larger role in community and ecosystem processes than previously realized (Cook-Patton 2011; Kotowska 2009). In addition, a sufficient genotypic diversity of plants sown in habitat restorations may be "biological insurance" against fluctuations in ecosystem processes, thus increasing the reliability of restoration measures (Bischoff 2010).

In New England, Native Plant Trust banks the seeds of imperiled taxa at highest risk of extirpation from the wild, has engaged in a multi-year effort to collect and bank seeds of coastal habitats for restoration of public lands, many damaged by Hurricane Sandy in 2012, and participates in the collection of tissue of common orchids for long-term banking. Further, programs such as Seeds of Success, a partnership between the federal Bureau of Land Management and botanic gardens, zoos, and municipalities, aim to collect and bank seeds from common native taxa whose presence on the landscape are invaluable to maintaining habitat-scale function in ecosystems.

Manage Habitats for Plant Diversity Where Necessary and Feasible

Ecological management of habitat is a complex and often challenging approach to maintaining plant diversity at the ecosystem scale. Its goal is sustaining or restoring composition, structure, and function (of individual taxa or entire habitats) and enhancing resistance and resilience under climate change. Highest priority for action is preserving exemplary, biodiverse habitats and areas important to their function and resiliency.

In New England, stewardship of terrestrial and aquatic ecosystems often requires controlling invasive species, using adaptive management techniques for species lost through succession (often a result of fire suppression, altered hydrology, or development of wild lands), and implementing species- or habitat-specific management practices. For example, prescribed burning is commonly used for managing successional growth of trees or some invasive species, which may compete with fire-adapted herbaceous plants in habitats traditionally kept open through wildfires. Similarly, tree-canopy thinning enables light to reach the forest floor for spring ephemerals or certain orchids requiring increased light levels to germinate and flourish. The common thread of these different approaches is a balanced interval and intensity of disturbance events (relative to each particular habitat and plant community) to support the greatest diversity of plant species. Habitat management may entail augmenting populations (see below) with plugs or small plants grown from locally-adapted, genotypic seed. Measuring success through consistent monitoring and data collection is critical to ensuring that information about techniques for preserving plant diversity can be shared with colleagues engaged in conservation and land management.

Jesup's milk-vetch
(*Astragalus robbinsii* var. *jesupii*)
Lisa Mattei © Native Plant Trust

Augment and Introduce Plants

As plant communities are progressively degraded, invaded, or highly fragmented, ecological restoration becomes essential for maintaining imperiled taxa and overall plant diversity. Either augmentation (introducing plants or seeds to an extant site) or introduction (introducing plants or seeds at a new location within a species' known, historic range) of species is most effective when areas of appropriate habitat already exist. At both the species and habitat scales, augmentation or introduction with seed is typically undertaken only when other strategies to counter impacts to plant diversity have been deemed ineffective. Best practices include: establishing baseline data on species' populations, plant communities, and entire habitats (including historic and projected data when possible); comprehensive research into reproductive ecologies and seed germination; consistent and long-term monitoring of augmentation and introduction sites; and strategic partnerships with scientists and organizations with specialties in species conservation and ecological restoration (Havens, Guerrant, and Maunder 1999; Havens, Kramer, and Guerrant 2014).

Conduct Assisted Migrations

With compelling evidence that climate change will be a significant driver of extinction (McCarthy et al. 2001; McLaughlin et al. 2002; Root 2003; Thomas et al. 2004), ecologists and land managers must consider the implications of using assisted migration (sometimes referred to as "managed relocation") to protect plant diversity. Assisted migration is one way of facilitating range shifts for plant species that may not be able to adapt in place and are restricted—by limits to propagule dispersal or significant barriers to migration routes—in their ability to move outside their historic range in response to climate or other environmental changes.

Over the past two decades, a healthy and often contentious debate has surfaced in the scientific community over the costs and benefits of assisted migration as a climate-adaptation strategy for plants and wildlife (Hulme 2005; Hunter 2007; McClanahan et al. 2008; Sax et al. 2009). This discussion has led to the development of multiple frameworks for weighing and evaluating ecological, legal, and ethical factors (Hoegh-Guldberg et al. 2008; Joly and Fuller 2009; Richardson et al. 2009; Sandler 2010).

Among the contentious issues is the lack of research into fundamental biological questions that could form the scientific basis for sound policies: Which species should be moved? What is the demographic threshold to initiate a need for assisted migration? How can populations be introduced while minimizing adverse ecological effects?

goldenseal (Hydrastis canadensis)

Dan Jaffe © Native Plant Trust

Those against assisted migration assert that it is folly to assume ecologists are capable of determining when assisted migration will be effective and whether translocated species will do more harm than good (Ricciardi and Simberloff 2009; Seddon et al. 2009). They cite the unpredictable (and often negative) impacts of invasive species and a lack of comprehensive understanding into the function of ecological systems, particularly in a changing climate. Disconnected and fragmented lands further complicate the migration of species and habitats, and those areas with high connectivity may be otherwise degraded or their biodiversity configurations may be different from what a particular species has adapted to within a given historic range. Often the arguments made against assisted migration as a conservation strategy refer directly or indirectly to the precautionary principle; and thus, due to many unknown variables in the process of moving and introducing plants, assisted migration should be avoided. Opponents argue that the potential for invasive spread of a plant species that has been relocated to avoid extinction is too great a risk to overall ecological function, and that the data are not available to determine the invasive potential of many species (Simberloff 2009).

Those in favor of assisted migration also point to precautions, but focus on the unknown ecological impacts of allowing plants to become locally or regionally extirpated or driven to permanent extinction by rapidly changing climates (Sax et al. 2009). Further, those arguing for assisted migration rebuff the claims about the lack of knowledge on the invasion potential of native species beyond their historic ranges (as many examples of this are available, particularly for more common species) and disagree that assisted migration is or would be enacted haphazardly, without ecological context. Most proponents of assisted migration argue for a systematic and gradual approach to moving species beyond their historic ranges, and frequently the methods described for moving plants mimic the typical dispersal range of their propagules. This nuanced approach often focuses on predicted climate envelopes that could support the species.

With this report, we hope to further the discussion about assisted migration by delineating areas of high climate resilience where, if the sites are protected, plant species facing high extinction threats may find refuge, both within and beyond their historic ranges.

Conservation of Habitats and Important Plant Areas

INTRODUCTION

Terminology

This report uses several terms that describe ecological units across a variety of scales. When describing a broad, ecologically-distinct area, we have chosen to use the terms (from broadest to finest scale): ecoregion, macrogroup, ecological system. When describing plant groups at a finer scale, we have chosen to use the terms (from broadest to finest scale): habitat, plant community, vegetation type, plant association. These terms, which denote particular groupings of plants, are used interchangeably, but are consistent throughout this report in reference to scale.

Each of these terms is defined as follows (NatureServe 2016; TNC 2020):

- **Ecoregion**: Part of a larger ecozone, ecoregions are large units of land and water that contain a geographically distinct combination of natural communities and species, share similar characteristics (such as climate and soils), and interact in ways that are critical for the long-term viability of the communities and species.
- **Macrogroup**: The fifth level in the U.S. National Vegetation Classification (NVC) natural vegetation hierarchy, in which each vegetation unit is defined by a group of plant communities with a common set of growth forms and many diagnostic plant taxa, including many characteristic taxa of the dominant growth forms, preferentially sharing a broadly similar geographic region and regional climate, and disturbance regime (cf. Pignatti et al. 1995, and Braun-Blanquet concept of "Class").
- **Ecological system** (synonymous with "habitat"): A terrestrial ecological system is defined as a mosaic of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients, in a pattern that repeats itself across landscapes. Systems occur at various scales, from "matrix" forested systems of thousands of hectares to small patch systems, such as cliffs, basin wetlands, or barrens on a particular bedrock type, of a hectare or two.
- **Habitat** (synonymous with "ecological system"): A general term referring to the locality, site, and particular type of local environment occupied by an organism or community (adapted from Lincoln et al. 1998).
- **Plant community**: A group of plant species living together and linked together by their effects on one another and their responses to the environment they share (modified from Whittaker 1975). Typically the plant species that co-occur in a plant community show a definite association or affinity with each other (Kent and Coker 1992).
- **Vegetation type**: A named category of plant community or vegetation defined on the basis of shared floristic and/or physiognomic characteristics that distinguish it from other kinds of plant communities or vegetation (Tart et al. 2005a).
- **Plant association**: A vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy (Jennings et al. 2006).

Ecological system, habitat, ecosystem, natural community, and natural association refer to a variety of scales but are generally applied to ecological facilitation, which encompasses climate, hydrology, geological structure, soil, flora, and fauna.

Plant community, vegetation type, and plant associations refer to the floristic makeup of an area, primarily focused on the plants and plant interactions.

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Overview and Methods

In this section we evaluate the conservation status of New England's habitats relative to global and regional targets, identify trends in securement and conversion, and make recommendations on where to focus conservation efforts. Additionally, we for the first time identify 234 Important Plant Areas, the conservation of which would move us a long way toward meeting both habitat and species goals.

We assess the conservation status of each habitat relative to well-developed international goals in the Global Strategy for Plant Conservation (GSPC; Convention on Biological Diversity 2012) and regional goals developed for New England based on the Global Deal for Nature (Dinerstein et al. 2019; see "Background" for details).

GSPC Target 4: At least 15% of each vegetation type secured through effective management and/or restoration (GAP 1-2 protection).

NE Target: At least 5-15% of each habitat protected (GAP 1-2) and at least 30% secured against conversion (GAP 1-3). At least 75% of the securement on climate-resilient land.

The Global Deal for Nature advocates for conserving representatives of all native habitats and viable populations of all native species by protecting 30% of the landscape by 2030. The New England target builds on this by adding criteria to ensure that sites are more resilient to climate change and by adding more detail to the types of securement.

Why Focus on Climate Resilience?

A key tenet of this document is that to succeed in sustaining plant diversity over the next century, we must focus protection on sites with the highest climate resilience. Site resilience is defined as the ability of a site to sustain diversity and ecological functions into the future, even as species move and vegetation types change in response to a changing climate (Anderson et al. 2014). To identify resilient sites, we use an approach known colloquially as "Conserving Nature's Stage" (Beier et al. 2015). This approach is based on the strong evidence and ample observations that although climate sets broad distribution limits and regulates the region's overall species pool, the places where species and communities are actually found, where they are persisting, and where they will be in the future are determined primarily by the properties of the land: soil, geology, topography, elevation (Anderson and Ferree 2010).

Our "Conserving Nature's Stage" approach asserts that rather than trying to protect biodiversity one species at a time, we should protect the ultimate drivers of biodiversity. The world has always experienced some measure of climate change, and species ranges are not fixed. Accordingly, we should seek to maintain the landscape features that ultimately control species richness. Plant distributions are coupled with moisture, light availability, and soil chemistry and texture, which in turn reflect geology and topography. This relationship is so tight that in New England, we can predict the total number of plant species present in every state (adj. $R2 = 0.94$) just by knowing the amount and types of geology present, the latitude, and the elevation range (Anderson and Ferree 2010). Studying how the current distribution of plant species and vegetation communities is coupled with the distribution of geophysical variables enables us to develop a conservation plan that protects diversity under both current and future climates.

The vegetation map used in this assessment (FIGURE 2, Ferree and Anderson 2013) provides a snapshot of how vegetation is currently distributed, and it illustrates how the current vegetation is correlated to landforms, geology, soils, and moisture patterns. The "random forest" models that underlie the distribution of each vegetation type integrate both climatic and geophysical variables. As the climate changes, the land's geophysical properties endure and can be used to predict where habitats might be in the future or where the land is buffered from change due to topography. This is the principle behind the TNC climate resilience map used in this assessment (FIGURE 2, Anderson et al. 2014), which was created directly from the geophysical variables with the understanding that while the climate might change, the topography, soils and elevation gradients will not—at least not for the next several centuries. Using the two maps together enables us to create a conservation plan that starts with what is there now but incorporates a different future, while maintaining a high degree of certainty with respect to what places will be important under many scenarios.

The geophysical variables used in the climate resilience map (FIGURE 3, Anderson et al. 2014) were derived based on their importance to plant species and natural community distributions. That makes them useful as a basis for representation, because it gives us the tools to measure the distribution of secured lands across all the landscape properties needed to support the full spectrum of plant diversity.

FIGURE 2. The Northeast Terrestrial Habitat Map

This dataset (Ferree and Anderson 2015) maps the distribution of 140 types of forests, wetlands, unique communities, and tidal systems across the Northeast. To explore the map and view the legend, go to http://nature.ly/NEhabitat

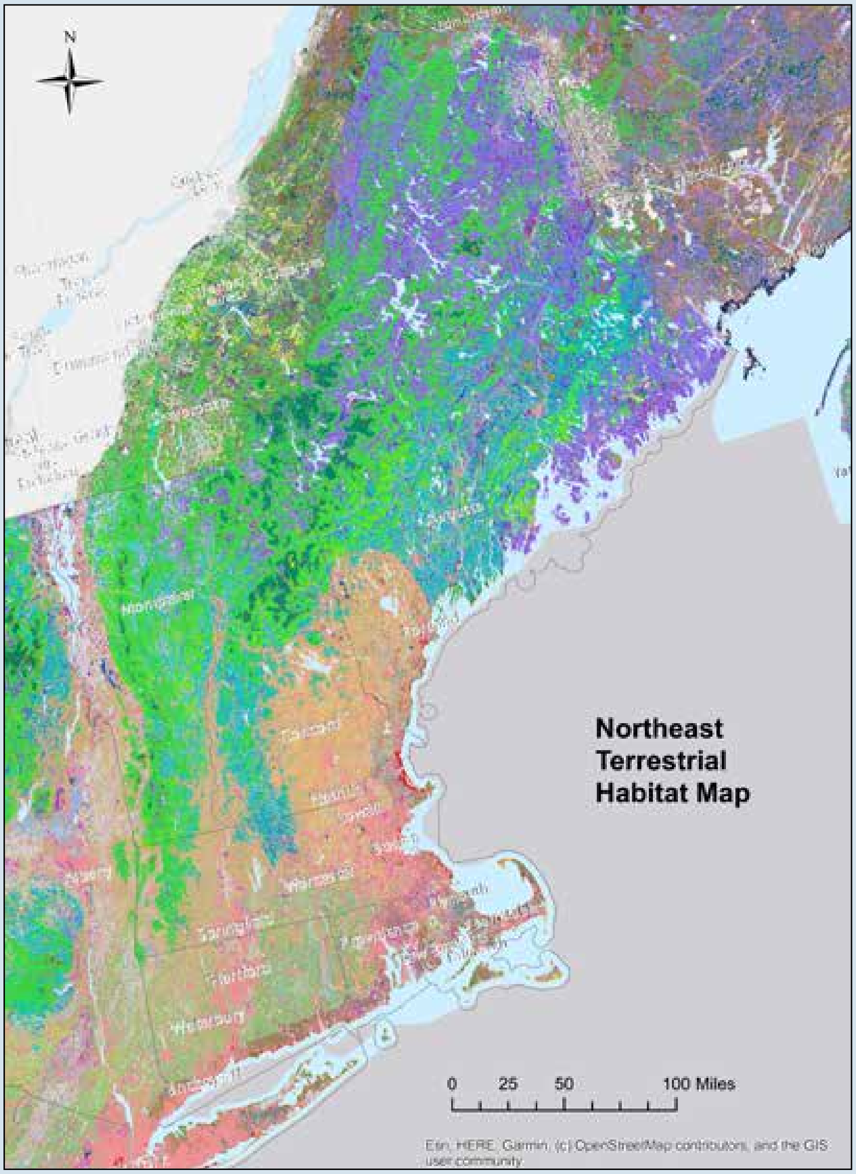
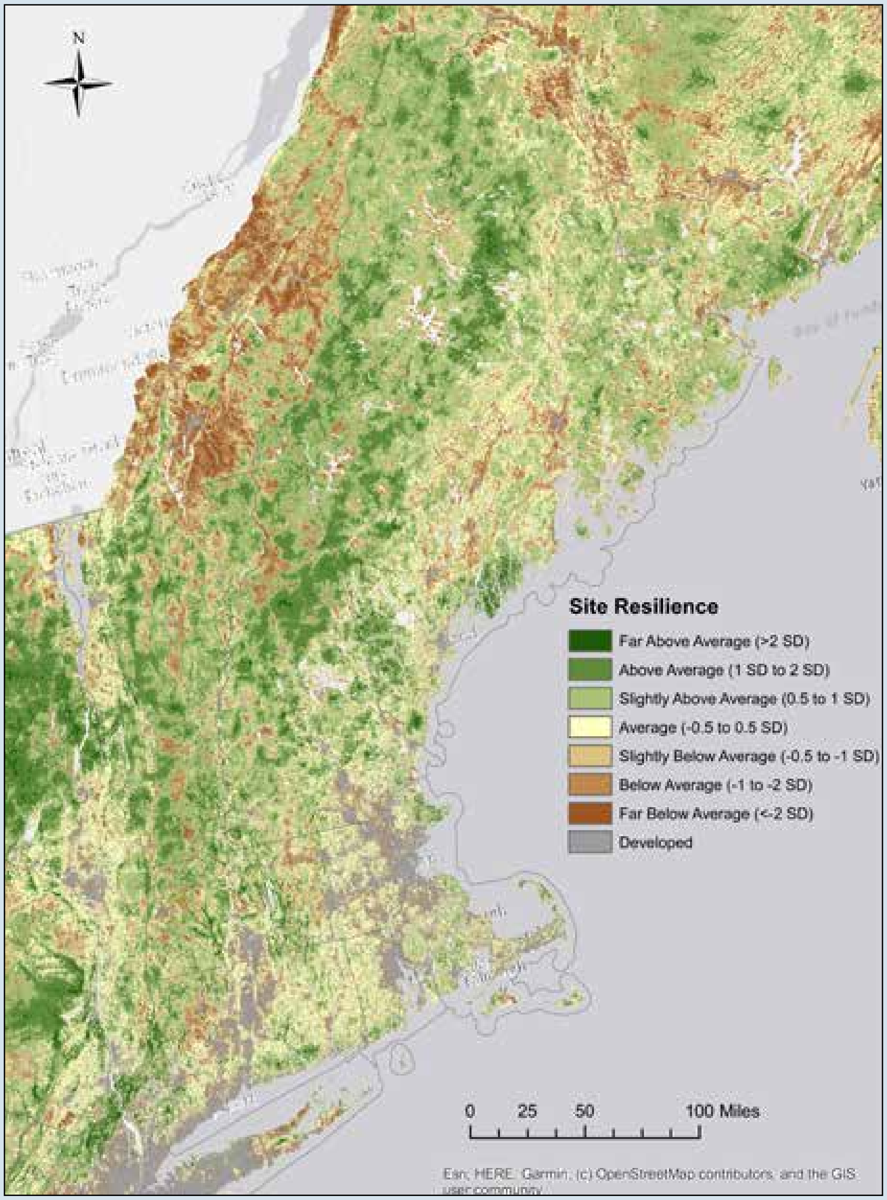


FIGURE 3. The Northeast Terrestrial Resilience Map

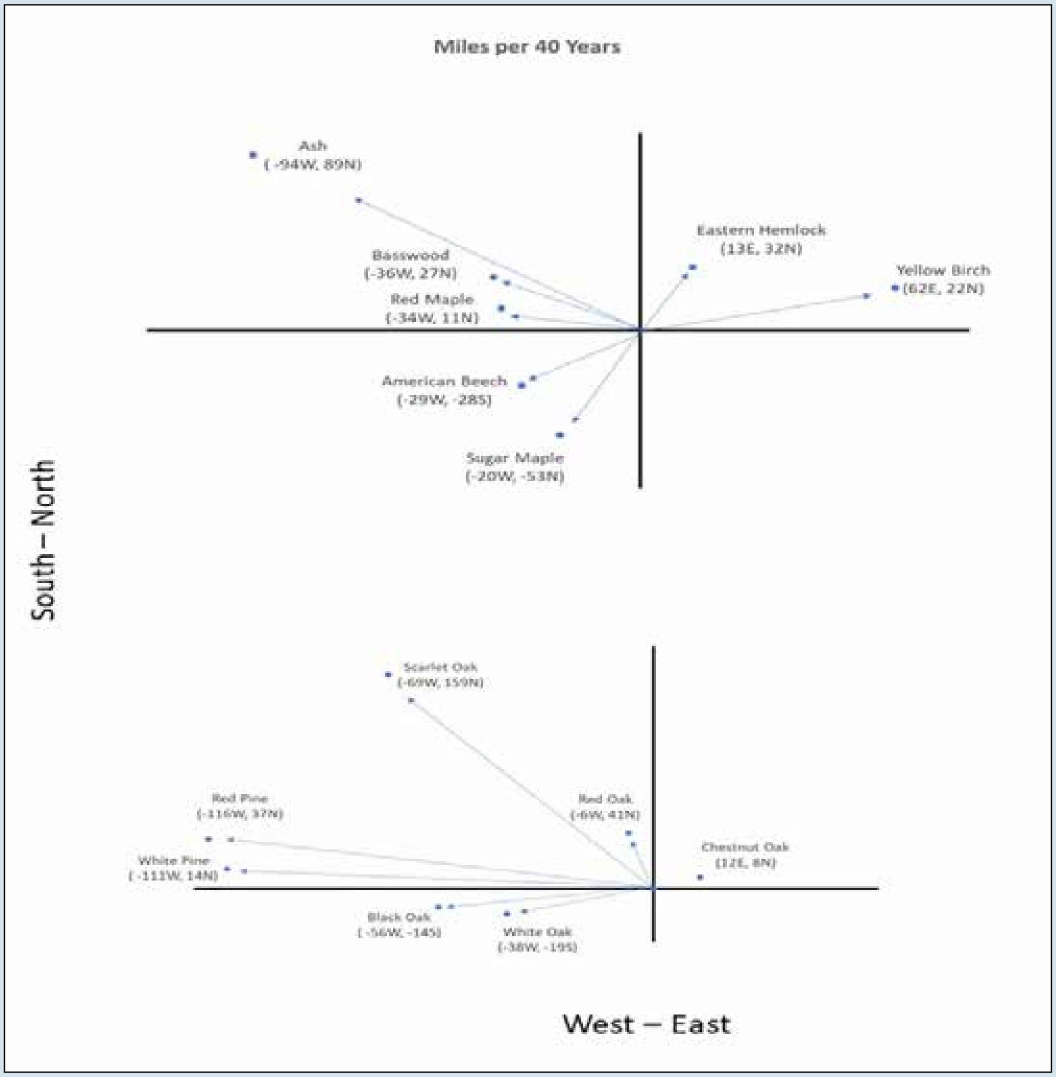
This map shows the areas with the most microclimates and the highest connectedness (i.e., highest resilience) relative to all the distinct geophysical settings within each ecoregion (Anderson et al. 2017). This map and underlying data can be explored using this web tool: http://maps.tnc.org/resilientland/



The habitats mapped in the Terrestrial Habitat Map have existed in New England for as far back as written records go, but they are always changing. American chestnut used to be a dominant component of Eastern forests but now persists as a shrubby understory species (Paillet 2002). Red maple has increased dramatically in response to current land use and forest management practices (Fei and Steiner 2007). Pollen records show dramatic range expansions and complete range shifts of oaks and pine during the retreat of the glaciers (Hunter et al. 1988). U.S. Forest Inventory and Analysis records for the last 40 years show substantial range shifts in 86 tree species (Fei et al. 2017). Moreover, tree species are not moving in concert, but are showing individual responses to changes in moisture and temperature (FIGURE 4). At some point New England's vegetation types will be very different from the familiar compositions we know today. This reinforces the need to focus on resilient places where plant species are likely to be most successful because of the properties of the land.

FIGURE 4. Tree Range Shifts over the Last 40 Years

These charts show the direction and distances that the distribution centers of Eastern trees have shifted over the last 40 years, based on U.S. Forest Inventory and Analysis data (Fei et al. 2017). The upper chart for Northern Hardwoods shows maple and beech moving west and south, likely following increases in moisture, while hemlock and yellow birch have moved north, likely following increases in temperature. The lower chart for Oak-Pine forests shows a similar pattern.



CONSERVATION OF HABITATS: PROGRESS TOWARD GLOBAL AND REGIONAL GOALS

The global and regional goals we use to evaluate the conservation status of New England's habitats were fully described above. Below we compare each group of habitats to the GSPC targets and to a customized NE target that considers the scale of the habitat, the resilience of the land, and the relative amounts of securement and protection.

To create realistic ten-year NE targets, we divided the habitats into three groups:

- Matrix Forest: the ten dominant forest types that cover 86% of the natural landscape
- Wetland Habitats: the swamps, bogs, floodplains, and marshes that cover 12% of the natural landscape
- Patch-forming Habitats: the summits, cliffs, dune, and barrens that are embedded in the matrix of forests and wetlands. Although patch habitats make up only 2% of the natural landscape, they are hotspots of plant diversity.

Grouping the vegetation types this way enabled us to develop and assess New England-specific targets that reflect the natural distribution and resilience of these communities.

Matrix Forest

GSPC Target 4: At least 15% of each forest type secured through effective management and/or restoration (i.e., GAP 1-2 protection).

NE Target: At least 5% of each forest type protected (GAP 1-2) and at least 30% of each secured against conversion (GAP 1-3). Resilient land makes up 75% of total securement.

New England's dominant vegetation is forest. The 28 million acres of forest create a connected matrix of natural cover composed of ten distinct habitats, each covering a half million to eight million acres. An additional four forest types are now so small and scattered that, with respect to goals, we treated them as patch-forming habitats (see section below).

Collectively, forests provide the region's primary ecosystem services, especially carbon sequestration. Climate regulation, water storage and filtering, pollution mitigation, and oxygen production. Economically, they support a century-long timber industry that harvests 8.2 million cords annually for building materials, fuel, fiber, and lumber (NEFF 2017) and support modest markets for maple syrup, holiday decorations, edibles, and medicinal plants as well. New England forest forms the natural backdrop for hunting, fishing, hiking, and camping, and the surrounding matrix in which high-diversity wetlands or patch-forming habitats are embedded. Intact forests have a marked vertical structure of canopy, understory, and herbaceous layer, and sustain moderate levels of plant diversity skewed toward shade-tolerant species.

Most of New England's forest is privately owned and managed for wood supply; and the majority of secured forest is multiple use and actively managed for recreation and timber harvest. To ensure that carbon continues to be removed from the atmosphere and naturally filtered clean water is available for New England citizens, advocates like Harvard's David Foster have argued for keeping 70% of New England forested (Foster et al. 2017). That means retaining 100% of the existing forest. Foster's Wildlands and Woodlands initiative (W&W) aims for 10% of natural lands protected as wildlands (i.e., protected as GAP 1-2) and 70% actively and sustainably managed for wood, food, and other values. The New England Forestry Foundation has endorsed the W&W vision and argues that not all of the 70% needs to be under securement because a healthy forest-based economy and strategic tax incentives could ensure that much of the land stays forested (private land enrollment in current use tax programs is 58%; Perschel et al. 2014).

Michael Piantedosi © Native Plant Trust

Currently, 21% of New England's forests are secured against conversion and 3% are protected. Securement is very unevenly distributed across forest types, with southern forests having less securement. Increasing securement to meet the NE target (30% and 5%) focused on resilient examples of every forest type would move us toward both the W&W 10% protection goal and the GSPC 15% protected target. The climate-resilience criteria in the NE target is critical if we are to ensure tangible, lasting results in the face of climate change.

Results: Only one forest habitat currently meets both the GSPC and NE targets: *Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest* (TABLE 3). This high-elevation forest forms the backdrop of New England's hiking and "peak-bagging" culture and is largely out of the range of practical timber management. *Laurentian-Acadian Northern Hardwood Forest*, the maple-beech-birch mix that gives New England its fall color and the dominant forest across the northern part of the region, also meets the NE target but not the GSPC target. This habitat is 30% secured against conversion, with 7% secured for nature; 96% of that is on resilient land. Because this forest covers 8.3 million acres, this is a relative success story, although we still need another 249,000 protected acres to reach the W&W 10% and another 415,000 protected acres beyond that to meet the GSPC target of 15%. Intelligently applied sustainable management practices on the secured multiple-use land might be able to sustain many of the functions of the forest type.

A few other habitats are close to meeting the NE target. Maine's *Acadian Sub-boreal Spruce Flats* are just 21,000 acres short, and both the *Acadian Lowland Spruce-Fir-Hardwood Forest* and *Laurentian-Acadian Red Oak-Northern Hardwood Forest* partially meet the target, with more than 5% protected and more than 85% on resilient lands, but less than 30% secured against conversion. In all, reaching the full NE target will require an additional to 2 million acres of forest conservation on resilient lands as well as effective management on the 5.3 million acres already in GAP 3 (TABLE 4). Reaching the GSPC goal of 15% protection across all matrix forest habitats will require investing in 3 million acres, through a combination of acquisition and increasing GAP levels on already secured land.

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TABLE 3. Goal Assessment for Matrix Forests

Columns 2-5 show the % protected, resilient (R), and secured. Columns 6-7 indicates if it meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 estimates the acreage of resilient land to be secured/protected to meet the NE target of 30%.

MATRIX FORESTS	% PROTECTED (GAP 1-2)	% R	% SECURED FROM CONVERSION (GAP 1-3)	% R	GSPC	NET	RESILIENT ACRES FOR 30%
Montane Spruce-Fir-Hardwood Forest	38%	99%	62%	98%	Y	Y	
Northern Hardwood Forest	7%	96%	30%	89%		Y	
Lowland Spruce-Fir-Hardwood Forest	6%	85%	26%	72%		P	196,801
Sub-boreal Spruce Flat	5%	83%	29%	74%		P	20,806
Coastal Plain Hardwood Forest	5%	46%	19%	44%		P	67,475
Red Oak-Northern Hardwood Forest	5%	92%	18%	92%		P	131,907
Interior Dry-Mesic Oak Forest	4%	46%	18%	42%			166,952
Hemlock-Northern Hardwood Forest	3%	70%	18%	67%			463,408
Coastal & Interior Pine-Oak Forest	2%	40%	17%	38%			194,748
Pine-Hemlock-Hardwood Forest	2%	74%	14%	67%			735,828
TOTAL							**1,977,926**

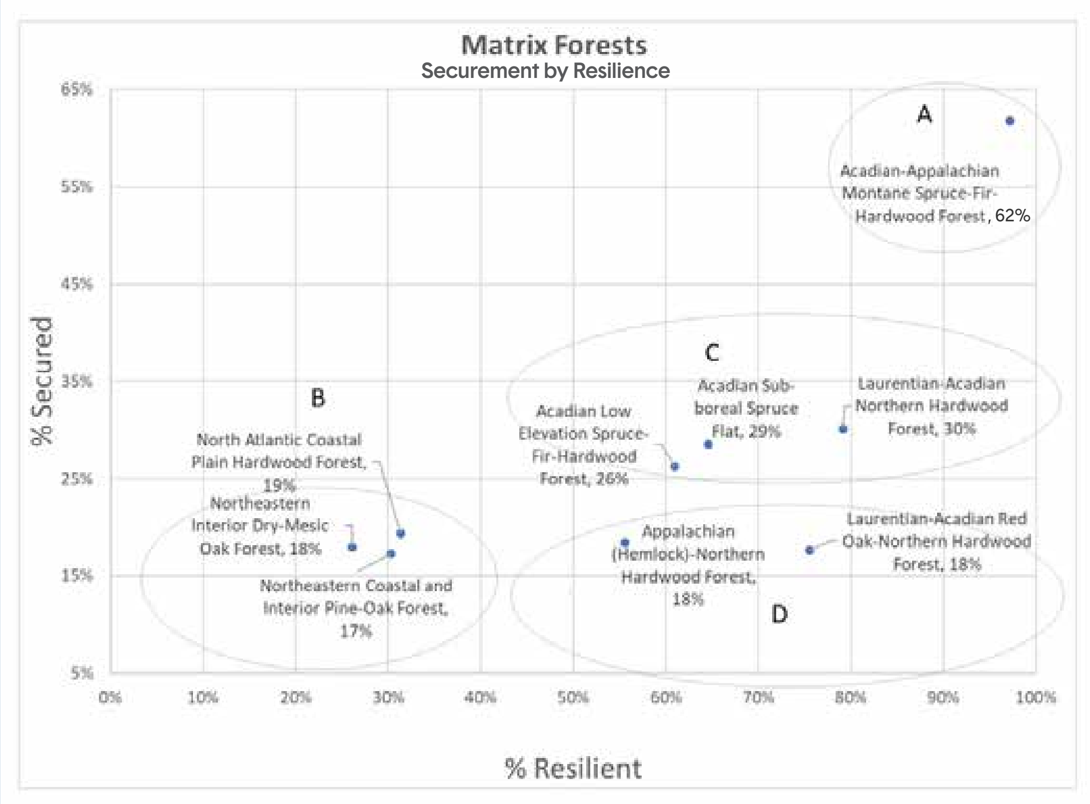
TABLE 4. Improved Management

Current and potential acres of multiple-use land (GAP 3) by forest type. These lands will need rigorous creation and enforcement of best management practices if they are to provide the expected benefits to people, plants, and wildlife.

MATRIX FORESTS	% GAP	ACRES GAP 3	% INCREASE IN RESILIENT LAND FOR 30%	RESILIENT ACRES FOR 30%
Montane Spruce-Fir-Hardwood Forest	23%	204,967	0%	0
Northern Hardwood Forest	23%	1,914,169	0%	0
Red Oak-Northern Hardwood Forest	23%	326,824	16%	131,907
Sub-boreal Spruce Flat	20%	1,063,434	2%	20,806
Lowland Spruce-Fir-Hardwood Forest	15%	620,338	6%	196,801
Hemlock-Northern Hardwood Forest	13%	137,930	21%	463,408
Pine-Hemlock-Hardwood Forest	14%	90,825	34%	735,828
Coastal Plain Hardwood Forest	14%	188,525	34%	67,475
Coastal & Interior Pine-Oak Forest	15%	227,828	42%	194,748
Interior Dry-Mesic Oak Forest	11%	508,535	46%	166,952
TOTAL		**5,283,374**		**1,977,926**

FIGURE 5. Matrix Forest Securement by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score across all acres of each forest type. A = high securement, high resilience, B = low securement, low resilience, C = average securement, average resilience, and D = low securement, average resilience. Total securement (GAP 1-3) is listed after the forest name.



Some forest types are urgently in need of targeted conservation. The mid-elevation *Laurentian-Acadian Pine-Hemlock-Hardwood Forest* has relatively high resilience but the lowest protection (2%) and securement (14%) of any forest type. Our coastal and southern interior forests also have challenges with resilience. *North Atlantic Coastal Plain Hardwood Forest, Northeastern Interior Dry-Mesic Oak Forest,* and *Northeastern Coastal & Interior Pine-Oak Forest* have low securement, low resilience, and fall far short of the GSPC and NE targets (FIGURE 5, GROUP B). The lower resilience is due to these forests occurring on gentle lowland topography and being more fragmented by roads, powerlines, and development, reflecting the populated portion of New England where they are found. *North Atlantic Coastal Plain Hardwood Forest* does meet the NE target of 5% protected, but less than half of that is on resilient land. *Northeastern Interior Dry-Mesic Oak Forest* and *Northeastern Coastal & Interior Pine-Oak Forest* are both in high need of conservation, with less than 20% secured against conversion, less than 5% protected, and less than half of land already secured being resilient. The collective acreage needed to reach the NE 30% target for both forest types is relatively small (361,700 acres), and there is an ample amount of these forests on resilient land.

A large portion of our forests (5.3 million acres) are lands managed for multiple uses (TABLE 4). This could be an effective and cost-efficient strategy for conservation, but if the strategy is to succeed, these lands will need science-based and rigorously applied management aimed at producing the natural benefits and sustaining the diversity that we depend on. A discussion of the best forest management practices to sustain biological diversity and increase carbon is beyond the scope of this report, but suffice it to say improving forest management to maintain biodiversity, store carbon, and yield a sustainable harvest is an area of active research.

Wetland Habitats

GSPC Target 4: At least 15% of each wetland type secured through effective management and/or restoration (i.e., GAP 1-2 protection).

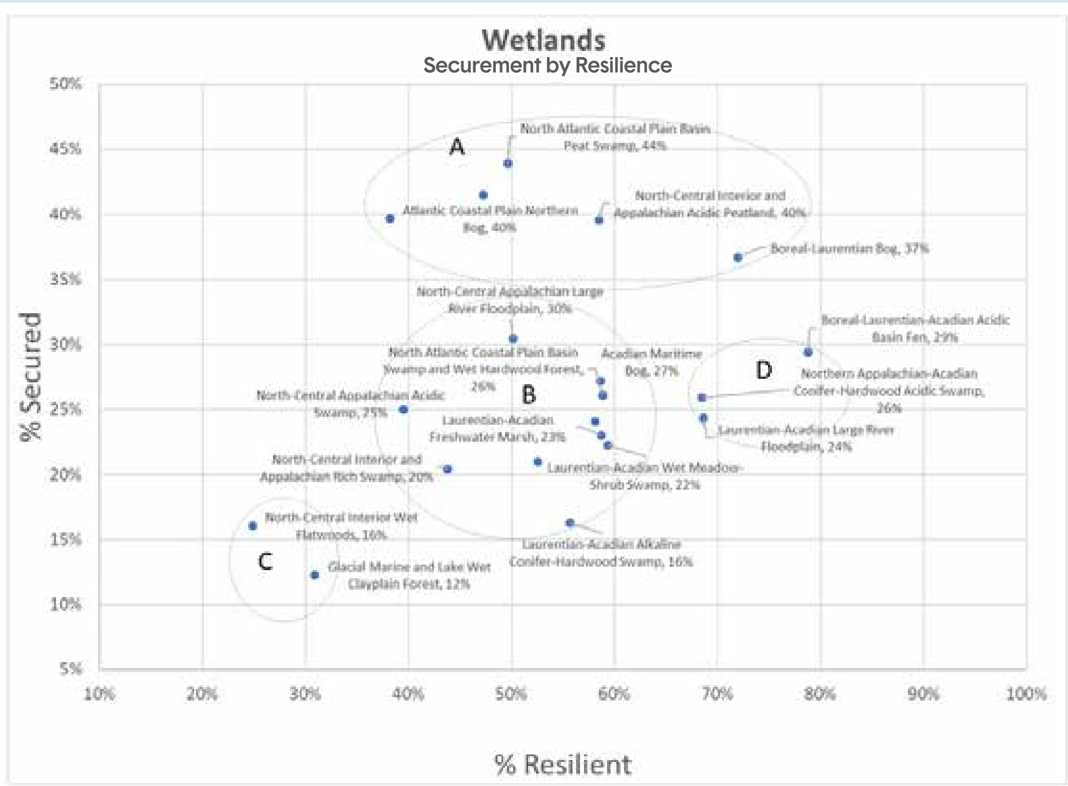
NE Target: At least 10% of each wetland habitat protected (GAP 1-2) and at least 30% of each secured against conversion (GAP 1-3). Resilient land makes up 50% of securement.

Wetlands are essential to sustaining New England's plant diversity. The four million acres of swamps, bogs, marshes, fens, and floodplains that punctuate the landscape contain four to five times the density of rare plant species of upland forests (based on an overlay of Natural Heritage program rare species locations on the vegetation map). Although wetlands make up only 12% of the natural lands, roughly 48% of the total vascular flora are legally considered to be obligate or facultative to wetlands (Lichvar et al. 2016).

The resilience approach targets larger unfragmented wetland complexes that are likely to persist over time. Small individual wetlands occurring in fragmented landscapes tend to score low for resilience, reflecting their vulnerability to the effects of climate change. As some kinds of wetlands occur predominantly in the latter context (FIGURE 6, GROUP B), resilience scores are intertwined with wetland type. For example, less than half of New England's freshwater marshes occur as large unfragmented complexes; most are scattered and small. Wet basins, moist depressions, ponds, and lakes help sustain the resilience of larger areas because they are cooler and moister than their surroundings, and this function will likely become more important as temperatures rise (McLaughlin et al. 2017; Simsek and Odul 2018). To account for the differences between wetlands and matrix forests in the NE target, we kept the criterion for base securement at 30%, increased the percentage of protection to 10% (GAP 1-2), and lowered the resilience criteria to 50% on the existing secured lands. The aim is to focus new acquisition on wetlands with the highest resilience, while acknowledging that vulnerable wetlands currently secured will remain important in the future due to their topographic setting, even if the structure and composition are compromised.

FIGURE 6. Wetland Securement by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score across all acres of each wetland type. A = high securement, moderate resilience, B = moderate securement, moderate resilience, C = low securement, low resilience, and D = moderate securement, high resilience. Total securement (GAP 1-3) is listed after the wetland name.



Results: New England's wetlands are 24% secured, but none of the region's five most common wetland types meet either GSPC or NE targets, although most do occur on resilient land, and most have more than 20% securement (TABLE 5). Six wetland habitats meet the GSPC target of 15% protection, but they are all unique small-acreage swamps or peat bogs (TABLE 5). Most of these also meet the NE target. *Acadian Maritime Bog* and *North Atlantic Coastal Plain Basin Swamp & Wet Hardwood Forest* are short in overall securement, and *Coastal Plain Basin Peat Swamp* falls short in resilience. Urgently in need of protection are *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp*, *North-Central Interior Wet Flatwoods*, and the *Glacial Marine & Lake Wet Clayplain Forest*, which have little protection or securement (FIGURE 6). Perhaps the protection of common wetlands is lower than expected because regulations are in place to prevent the destruction of wetlands; however, without targeted conservation action, it is unlikely the full diversity of wetlands will persist. Reaching the NE target will require securing an additional 253,902 acres of resilient wetland, while meeting the GSPC target would require 405,083 acres of newly protected wetlands.

Tidal wetlands are a special case. Despite relatively high levels of securement, we are still losing these wetlands due to inundation by sea-level rise. This phenomenon has been studied in detail by The Nature Conservancy (Anderson and Barnett 2017), which recommends conserving the "migration space" adjacent to each wetland to facilitate its migration landward and thus support its persistence. Not all existing wetlands have access to migration space, and much of the available migration space is not necessarily even in natural cover; but currently 33% of the migration space is secured against conversion, including 17% that is already protected. Most of that is associated with resilient sites.

TABLE 5. Goal Assessment for Wetlands

Columns 2-5 show the percent secured and percent of that which is on resilient land (%R). Columns 6-7 indicate if the wetland type meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 gives the acreage of resilient land to be secured to meet the NET 30%. Superscript next to the name indicates the rank in total acreage of five most common types. Although tidal salt marsh protection is included in the table, the protection of existing salt marsh is not a useful indicator due to inundation by sea-level rise.

WETLAND HABITATS	% PROTECTED (GAP1-2)	% R	% SECURED FROM CONVERSION (GAP 1-3)	% R	GSPC	NET TARGET	RESILIENT ACRES FOR 30%
Acadian Maritime Bog	25%	61%	27%	63%	Y	P	149
Boreal-Laurentian Bog	23%	71%	37%	74%	Y	Y	
Coastal Plain Basin Swamp/Hardwoods	22%	63%	26%	62%	Y	P	24
Coastal Plain Basin Peat Swamp	17%	49%	44%	48%	Y	P	
Tidal Salt Marsh	17%	56%	42%	52%	NA	NA	12,863
Tidal Marsh Migration Space	17%	94%	33%	91%	NA	NA	
Coastal Plain Northern Bog	16%	75%	40%	56%	Y	Y	
Interior/Appalachian Acidic Peatland	15%	33%	40%	52%	Y	Y	
Acadian Acidic Basin Fen	10%	80%	29%	85%		P	1,819
Appalachian Large River Floodplain	9%	43%	30%	56%		P	
Acadian Large River Floodplain	7%	73%	24%	81%			17,434
Freshwater Marsh[5]	7%	74%	23%	70%			25,734
N. Conifer-Hardwood Acidic Swamp[1]	6%	84%	26%	80%			31,289
Wet Meadow-Shrub Swamp[4]	5%	74%	22%	71%			38,109
Appalachian Acidic Swamp[2]	5%	51%	25%	46%			30,464
Interior/Appalachian Rich Swamp	5%	54%	20%	50%			24,048
Alkaline Conifer-Hardwood Swamp[3]	4%	71%	16%	75%			78,818
Wet Clayplain Forest	3%	71%	12%	37%			2,489
Interior Wet Flatwoods	3%	38%	16%	26%			3,525
TOTAL							**253,902**

Patch-forming Habitats

GSPC Target 4: At least 15% of each habitat type secured through effective management and/or restoration (i.e., GAP 1-2 protection).

NE Target: At least 15% of each patch-forming habitat protected (GAP 1-2) and at least 30% of each secured against conversion (GAP 1-3). Resilient land makes up 75% of securement.

Patch-forming habitats are terrestrial plant communities that occur in small patches on the landscape, nested within, and often contrasting with, the background matrix of forest and wetlands. Although patch habitats make up only 2% of New England's natural land, and none of them has more than 150,000 acres of total extent, they are hotspots of plant diversity. The summits, cliffs, barrens, dunes, grassy openings, and talus slopes have a density of rare species ten times higher than wetlands and forty times higher than upland forests, based on an overlay of species tracked by the state Natural Heritage programs. The overlay illustrates how important some of these communities are to rare plant species: alpine (66 species), acidic cliffs (38 species), calcareous cliffs (23), beach and dune (36), coastal grassland (8). The acreage of these communities may be dispersed as thousands of small patches (e.g., acidic cliffs) or clumped as in alpine tundra.

Patch-forming habitats are small in extent and concentrated in their biodiversity, and thus are more vulnerable to localized threats. Currently only 21% are secured against conversion. To recognize their high biodiversity value and small extent, we increased the NE protection target to 15%, which matches the GSPC target, while keeping the securement target at 30% and the climate resilience target high: 75% occurring on resilient land.

We included four forest types in this section (instead of the matrix forest section, where they appear in Part Two) because their current distributions are so restricted to small patches that the higher NE target for patch-forming habitat is more appropriate. These are: *North Atlantic Coastal Plain Pitch Pine Barrens*, *Northeastern Interior Pine Barrens*, *North Atlantic Coastal Plain Maritime Forest,* and *Glacial Marine & Lake Mesic Clayplain Forest*.

Results: Seven patch habitats meet the GSPC target, but only four of those also meet the NE target for area and resilience (TABLE 6). In general, the rocky landform-based habitats (e.g., cliff, summit) tend to have a high resilience score, reflecting the microclimates associated with their settings. Most of these habitats meet both targets. The coastal plain sand and silt communities occur mostly on climate-vulnerable land, with only 19-50% of the secured examples occurring on resilient sites. Two of these communities–*North Atlantic Coastal Plain Pitch Pine Barrens* and *North Atlantic*

Coastal Plain Heathland & Grassland—are also fire dependent. These habitats may be able to tolerate warming temperatures better than some, but their fragmented and developed settings could make burning difficult. The third, *North Atlantic Coastal Plain Beach & Dune*, is already experiencing a change in sea level. Unlike tidal salt marshes, which are literally migrating inland in response to sea-level rise, it is unclear what the future holds for the creation of new beaches to replace those drowned by inundation. Slightly elevated dune systems are more likely to persist through the next century, albeit as increasingly isolated islands.

The percent of the habitat that meets resilience goals differs dramatically between the bedrock-based communities, which are mostly above the 75% mark (FIGURE 7 A & D) and the sand/silt-based communities, which score much lower (FIGURE 7 B & C). Because patch habitats are small, only an additional 7,556 acres are needed to reach the GSPC 15% protected target and 17,726 to reach the NET 30% securement based on acres alone. But it would require an additional 88,620 acres of targeted resilient land to bring the sand/silt-based systems (pine barrens, dune, heathland) up to the target for climate resilience. Sustaining these habitats could be a challenge.

Two forest habitats are so restricted that they may be better thought of as patch-forming habitats need urgent conservation attention: *North Atlantic Coastal Plain Maritime Forest* and Vermont's *Glacial Marine & Lake Mesic Clayplain Forest*. The latter has very little protection or securement.

Two patch-forming habitats that just reach into New England are not included in the full assessment in Part Two but are shown in the tables and charts here for completeness. They are *Central Appalachian Dry Oak-Pine Forest* and *Central Appalachian Pine-Oak Rocky Woodland*.

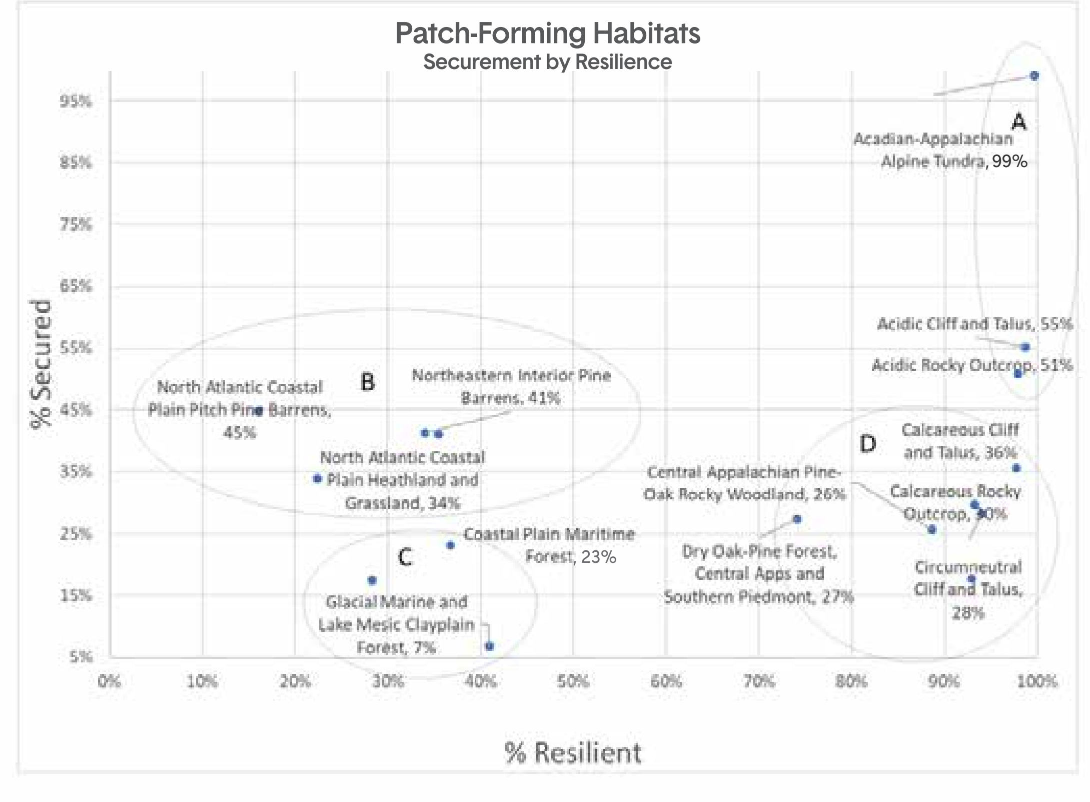
TABLE 6. Goal Assessment for Patch-Forming Habitats

Columns 2–5 show the percent secured and percent of that which is on resilient land. Columns 6–7 indicate if the habitat type meets (Y) or partially meets (P) the GSPC and NE targets. Column 8 gives the acreage of resilient land to be secured to meet the NET 30% and, in italics, *the additional resilient acres required to meet the 75% resilience criterion.*

PATCH-FORMING TERRESTRIAL HABITATS	% PROTECTED (GAP1-2)	% R	% SECURED FROM CONVERSION (GAP 1-3)	% R	GSPC	NET TARGET	RESILIENT ACRES FOR 30% SECURED / 75% RESILIENT
Acadian-Appalachian Alpine Tundra	85%	100%	99%	100%	Y	Y	
Acidic Cliff & Talus	36%	99%	55%	99%	Y	Y	
Acidic Rocky Outcrop	30%	100%	51%	99%	Y	Y	
Coastal Plain Pitch Pine Barrens	16%	31%	45%	19%	Y	P	*58,431*
Northeastern Interior Pine Barrens	9%	49%	41%	33%			*8,403*
Coastal Plain Beach & Dune	27%	54%	41%	50%	Y	P	*9,140*
Calcareous Cliff & Talus	15%	99%	36%	99%	Y	Y	
Coastal Plain Heathland & Grassland	21%	23%	34%	25%	Y	P	*12,646*
Calcareous Rocky Outcrop	11%	100%	30%	99%			118
Circumneutral Cliff & Talus	9%	97%	28%	95%			242
Central Apps Dry Oak-Pine Forest	7%	87%	27%	80%			3,146
Central Apps Pine-Oak Rocky Woodland	7%	88%	26%	90%			1,366
Coastal Plain Maritime Forest	12%	51%	23%	47%			5,400
Mesic Clayplain Forest	3%	77%	7%	57%			7,454
TOTAL							**17,726 / *88,620***

FIGURE 7. Patch-Forming Habitats by Resilience

This chart shows the average securement (GAP 1-3) and the average resilience score across all acres of each patch habitat. A = high securement, high resilience, B = moderate securement, low resilience, C =low securement, low resilience, and D = moderate securement, high resilience. Total securement (GAP 1-3) is listed after the community name.



Risk of Conversion

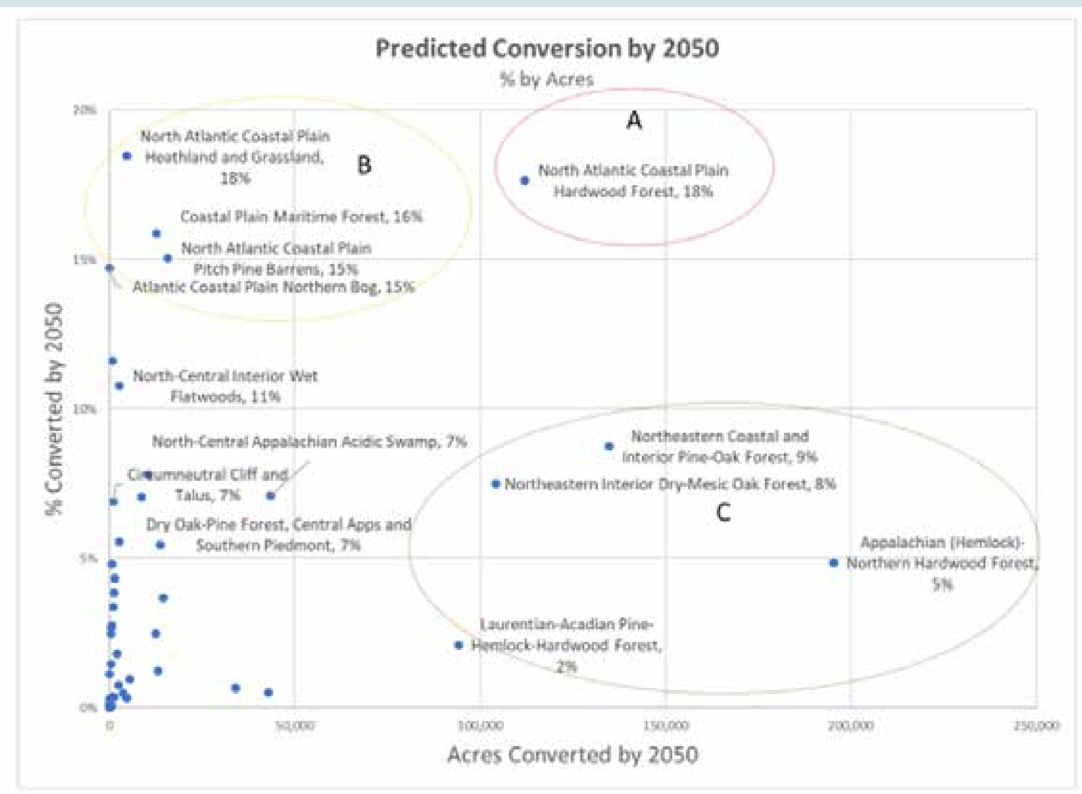
Throughout this report we note that securing land against conversion to development is often a first step toward protecting the land for nature and natural processes. In many parts of New England, the threat of habitat loss through direct conversion to development remains high and is estimated to total almost a million acres by 2050.

To understand how this is distributed across habitats, we used a Land Transformation Model developed by the Human-Environment Modeling and Analysis Laboratory at Purdue University (Tayyebi et al. 2012) to estimate the amount of each habitat predicted to be lost to development over the next 30 years. In this model, the quantity of urban growth at county and city scales is simulated using population, urban density, and nearest-neighbor-dependent attributes; areas near current development are the most likely to convert to development.

The results indicate large difference in the amount and percentage of likely development for each habitat. Several coastal plain patch-forming habitats are likely to lose a significant portion of their extent (15% to 18%), although because they are small, the total acres lost would be less than 75,000 (FIGURE 8, GROUP B). At the other end of the spectrum, three of southern New England's matrix forest types are predicted to lose more than 100,000 acres each (FIGURE 8, GROUP C), but because they are so dominant on the landscape, it is less than 10% of their respective extents. The most threatened habitat is *North Atlantic Coastal Plain Hardwood Forest*, which is predicted to lose more than 100,000 acres, equal to 18% of its current extent.

FIGURE 8. Threat of Conversion

The proportion of each habitat predicted to be developed is plotted against the total acreage predicted to be lost. A= high percent loss, high acreage loss. B = high percent loss, low acreage loss, C = low percentage loss, high acreage loss.



CONSERVATION OF IMPORTANT PLANT AREAS

Important Plant Areas for Diversity and Resilience

The GSPC calls for the identification and protection of Important Plant Areas (IPA) around the world, and several countries have completed IPA strategies as part of their national plans under the Convention on Biological Diversity. We therefore made identifying IPAs in New England a high priority, as securing these areas would be one of the most substantial approaches to land conservation for plant diversity.

In this section, we assess the resilience and habitat characteristics of the land on which rare species occur. The goal is to ensure that we conserve the areas of highest site resilience that also support a diversity of rare species, and, if possible, a diversity of habitats. Areas of high site resilience have the most topographic microclimates and the highest degree of connectedness relative to their geology, soil, and elevation zone, making them natural strongholds where species are likely to persist longer in the face of climate change.

Definition and Location of IPAs

The GSPC sets three basic criteria for an Important Plant Area:

Criteria A: threatened species

Criteria B: exceptional botanical richness

Criteria C: threatened habitats

A site can be identified as an IPA if it qualifies under **one or more** of these criteria (www.plantlife.com/criteria).

For this study, we defined an IPA as a contiguous patch of resilient land with a high diversity of rare plant species relative to its size. Rare plants were limited to globally and regionally rare species listed as division 1, 2 or 2a in *Flora Conservanda* (Brumback and Gerke 2013). Resilient land was defined as land with an above-average site resilience score based on the TNC resilience map (Anderson et al. 2014). We adopted the global GSPC goal and created a regional NE target as follows:

GSPC Target 5: At least 75% of the most important areas for plant diversity (IPA) of each ecological region protected, with effective management in place for conserving plants and their genetic diversity (i.e., GAP 1-2 protection).

NE Target: At least 30% of each resilient area with the highest rare plant diversity (IPA) protected and at least 75% of each IPA secured against conversion (GAP 1-3) across habitats and states.

To identify and map IPAs, we first created a dataset of contiguous resilient land in GIS by grouping adjacent cells of resilient land into larger aggregates and converting them to polygons, which we called "resilience patches." Next, we overlaid known locations of rare plants on the resilience patches and tabulated the size of the patch and the number of species and taxa per patch. To account for the size difference in the patches, we used a regression model to predict the average number of rare taxa based on the patch size (R^2= 0.11, $P < 0.0000$) and then calculated the standardized residuals (the difference between the observed value and the predicted value) to identify sites that had more rare taxa than expected from their size. Note, the dataset and overlay are from 2014 and were used with permission; however, they do not reflect recent years of inventory (details in Anderson et al. 2014).

golden-club (Orontium aquaticum)
Liza Green © Native Plant Trust

The results identified 234 IPAs (FIGURE 9) spread across all six states. Collectively the IPAs cover 2.6 million acres and contain multiple populations of 212 Flora Conservanda species. Each site supports an average of three rare taxa, but diversity ranges from 2 to 26 taxa depending on the size of the site. Large IPAs over 100,000 acres average 11 taxa (range 5-26), small 100-acre sites average 6 taxa (range 5-6), and tiny 10-acre patches average 2 taxa (range 2-5). All sites scored high for climate resilience, but small sites will need to be assessed for their landscape context and likely nested within larger protected sites if they are to retain their species.

FIGURE 9. Important Plant Areas (IPAs)

These 234 sites are climate-resilient areas with multiple populations of *Flora Conservanda* Division 1 and 2 species. Very high diversity = 9 taxa, range 5-26; high diversity = 3 taxa, range 2-5.

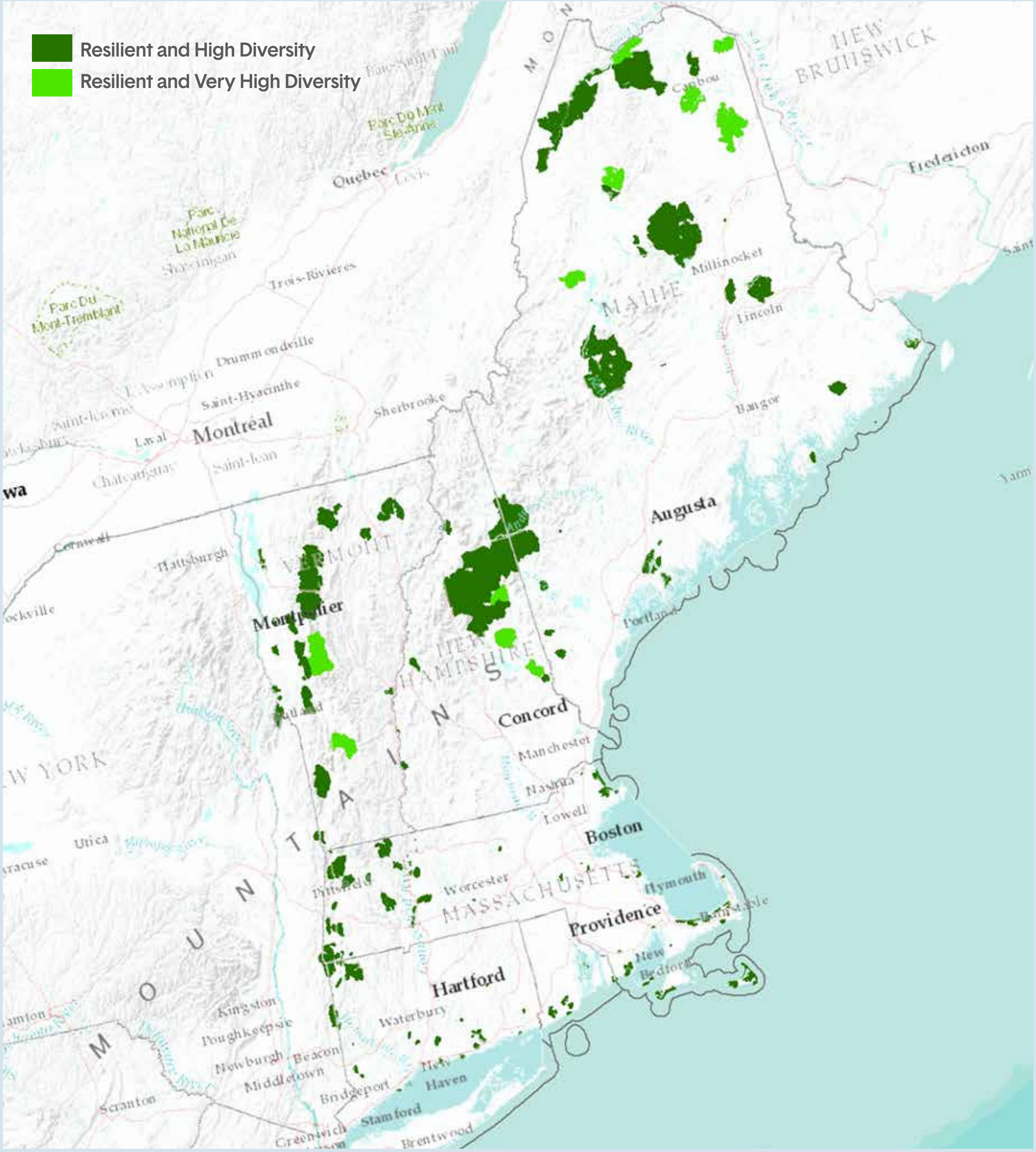
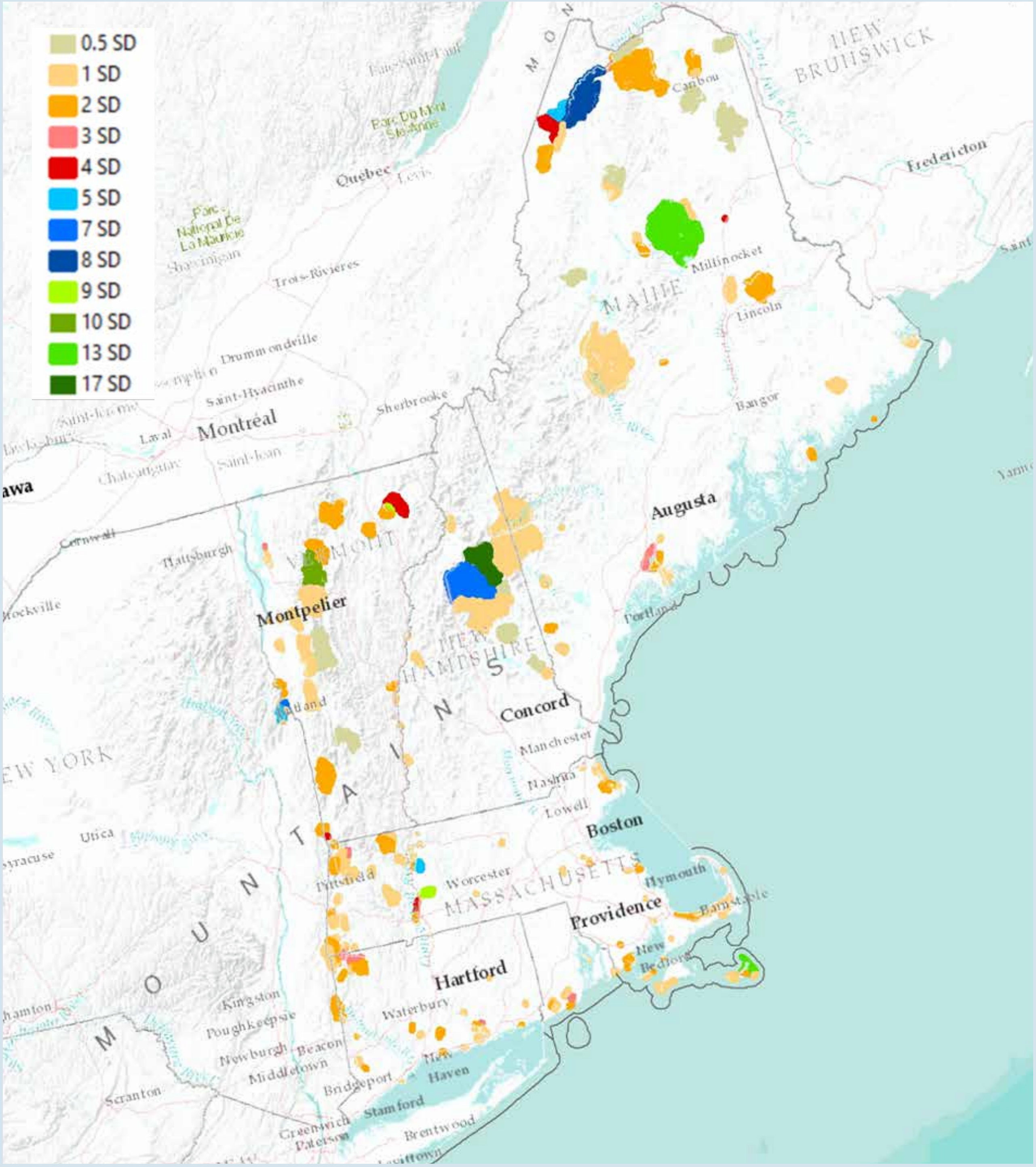


FIGURE 10. IPAs by Diversity Status

The average resilient site in New England has less than one rare species, but the IPAs have many more. The colors indicate the number of standard deviations above the mean each IPA has. The highest-scoring site (15 SD above the mean) is a 106,000-acre mountain site in NH with 26 rare plant taxa and 506 total rare species occurrences.



Conservation Status and Progress Toward IPA Goals

To assess conservation goals, we labeled the IPAs with their primary state of occurrence, dominant habitat type, and degree of protection. Although all IPAs contain multiple habitats, tagging them with the dominant habitat enabled us to assess their ecological distribution across the region.

Conservation Status of Sites: GSPC Target 5 defines its IPA goal in terms of the number of sites protected. Here we define a protected IPA as one with 75% or more of its area in GAP status 1 or 2. Of the 234 IPAs, only 10 (4%) meet this criterion, and these are distributed relatively evenly across matrix, patch, and wetland habitats (TABLE 7). An additional 32 sites (14%) have 75% of their area secured (GAP 1-3) in a combination of protected and multiple-use land. These 32 sites are mostly forest dominated and occur on state lands or private lands with a conservation easement that permits management. A strategy for these places might be to raise the GAP status inside the IPA boundary by designating the area as a place of recognized biodiversity value or botanical concern. Of the remaining 192 IPAs, 155 have some level of securement, including 122 with GAP 1-2 in some portion of the site (although the securement does not add up to 75% of the area). These warrant further investigation, with a goal of either expanding the area protected or fee acquisition where possible and appropriate. The remaining 37 IPAs have no securement whatsoever and would benefit from on-the-ground investigation to establish both priority for and feasibility of conserving these sites.

Conservation Status by Area: The individual IPAs differ dramatically in size, so it is helpful to assess protection by total area rather than by counting the sites protected. This reveals a clearer picture of conservation progress. Of the 2.6 million acres included in the IPAs, 29% are protected (GAP 1-2) and another 23% are on multiple-use land (GAP 3); thus 52% of the IPA area is in some level of securement (TABLE 7).

Collectively, the set of IPAs dominated by the following habitats are all more than 30% protected, although only two are more than 75% secured (TABLE 7): *Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest, North Atlantic Coastal Plain Maritime Forest, North Atlantic Coastal Plain Pitch Pine Barrens, Laurentian-Acadian Northern Hardwood Forest, Boreal-Laurentian Bog, North-Central Appalachian Acidic Swamp,* and *Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp*. These results reflect the fact that the IPAs differ in size and that protection may be concentrated in a few sites.

Individually, 19 IPAs meet both the protection (30%) and securement (75%) of the NE target. These are mostly forest-dominated IPAs.

Boreal Upland Forest: *Acadian Low-Elevation Spruce-Fir-Hardwood Forest (3), Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest (2)*

Northern Hardwood & Conifer Forest: *Appalachian (Hemlock)-Northern Hardwood Forest (3) Laurentian-Acadian Northern Hardwood Forest (7)*

Central Oak-Pine Forest: *North Atlantic Coastal Plain Maritime Forest (1), North Atlantic Coastal Plain Pitch Pine Barrens (1), Northeastern Interior Dry-Mesic Oak Forest (1)*

Grassland & Shrubland: *North Atlantic Coastal Plain Heathland & Grassland (1)*

Conversely, the set of IPAs dominated by the following habitats collectively have less than 10% protection: *Laurentian-Acadian Pine-Hemlock-Hardwood Forest, Northeastern Coastal & Interior Pine-Oak Forest, North-Central Interior Wet Flatwoods, Laurentian-Acadian Wet Meadow-Shrub Swamp, and North-Central Appalachian Large River Floodplain.*

See Appendix 3 for a complete list of IPAs by habitat and state, with acreage, GSPC protection status, and percent of area protected and secured.

TABLE 7. Protection and Securement Status of the IPAs

#P = the number of IPAs with more than 75% protection

#S = the number with more than 75% securement

#U includes 155 sites with some level of protection or securement but below 75% in total

IMPORTANT PLANT AREAS BY DOMINANT HABITAT	BY COUNT			BY AREA		
	#P	#S	#U	Protected (GAP 1-2)	Multiple Use (GAP 3)	Total Secured
MATRIX FOREST HABITATS	**9**	**26**	**145**	**29%**	**23%**	**52%**
Boreal Upland Forest	**3**	**5**	**13**	**35%**	**25%**	**60%**
Acadian Low-Elevation Spruce-Fir-Hardwood Forest	3	3	13	10%	22%	32%
Acadian-Appalachian Montane Spruce-Fir-Hardwood Forest		2		68%	29%	97%
Central Oak-Pine Forest	**3**	**4**	**26**	**16%**	**12%**	**28%**
North Atlantic Coastal Plain Hardwood Forest		1	11	15%	12%	27%
North Atlantic Coastal Plain Maritime Forest	1		1	44%	0%	44%
North Atlantic Coastal Plain Pitch Pine Barrens	1	2	4	55%	34%	89%
Northeastern Interior Dry-Mesic Oak Forest	1	1	10	13%	12%	25%
Northern Hardwood & Conifer Forest	**3**	**17**	**106**	**27%**	**22%**	**49%**
Appalachian (Hemlock)-Northern Hardwood Forest	2	5	59	12%	19%	31%
Laurentian-Acadian Northern Hardwood Forest	1	11	35	30%	22%	52%
Laurentian-Acadian Pine-Hemlock-Hardwood Forest			11	5%	13%	18%
Northeastern Coastal & Interior Pine-Oak Forest		1	1	5%	27%	32%
PATCH-FORMING HABITATS	**1**	**1**	**11**	**14%**	**16%**	**30%**
Grassland & Shrubland	**1**	**1**	**11**	**14%**	**16%**	**30%**
Agriculture			7	15%	5%	20%
Atlantic Coastal Plain Beach & Dune			3	16%	8%	24%
North Atlantic Coastal Plain Heathland & Grassland	1	1	1	11%	37%	48%
WETLAND HABITATS		**5**	**34**	**29%**	**24%**	**53%**
Central Hardwood Swamp			**1**	**0%**	**0%**	**0%**
North-Central Interior Wet Flatwoods			1	0%	0%	0%
Freshwater Marsh & Shrub Swamp		**1**	**7**	**25%**	**21%**	**46%**
Laurentian-Acadian Freshwater Marsh			6	27%	16%	43%
Laurentian-Acadian Wet Meadow-Shrub Swamp		1	1	7%	60%	67%
Large River Floodplain		**1**	**2**	**0%**	**47%**	**47%**
North-Central Appalachian Large River Floodplain		1	2	0%	47%	47%
Northern Peatland			**1**	**37%**	**1%**	**38%**
Boreal-Laurentian Bog			1	37%	1%	38%
Northern Swamp		**2**	**9**	**34%**	**24%**	**58%**
North-Central Appalachian Acidic Swamp		1	6	32%	27%	59%
North-Central Interior & Appalachian Rich Swamp		1	2	28%	18%	46%
Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp			1	48%	9%	57%
Tidal Marsh		**1**	**14**	**24%**	**35%**	**59%**
North Atlantic Coastal Plain Tidal Salt Marsh		1	14	24%	35%	59%
Open Water / Lakeshore			**2**	**0%**	**0%**	**0%**
TOTAL	**10**	**32**	**192**	**29%**	**23%**	**52%**

Representation of Habitats in the IPAs

The IPAs make a perfect starting point for conserving resilient sites that contain rare species and represent a range of habitats. An efficient strategy would be to prioritize IPAs whose dominant habitat is generally not well conserved, as discussed in a previous section. Toward that end, we assessed the representation of habitats within the 234 IPAs to see how much of each habitat would be protected if conservation efforts focused on the IPAs. This assessment goes much deeper into the IPA composition than did the dominant-habitat analysis above, as many habitats (for example, *Cliff & Talus*) never dominate an IPA but occur across many sites.

For matrix forest (FIGURE 11), most of the IPA acreage occurs in the more northern forest types, but it also occurs in types urgently in need of conservation, such as *North Atlantic Coastal Plain Hardwood Forest, Northeastern Coastal & Interior Pine-Oak Forest,* and *North Atlantic Coastal Plain Maritime Hardwood Forest.*

For wetlands, all the common habitats (FIGURE 12) have ample IPA acreage, including *Laurentian-Acadian Wet Meadow-Shrub Swamp, Laurentian-Acadian Freshwater Marsh,* and *Laurentian-Acadian Large River Floodplain*. The wetland habitats most urgently in need of protection all occur in IPAs also needing protection, especially *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* and to a lesser extent *North-Central Interior Wet Flatwoods* and *Glacial Marine & Lake Wet Clayplain Forest.*

Patch habitats are well represented in the IPAs (FIGURE 13). Among the habitats with IPAs needing protection are *North Atlantic Coastal Plain Heathland & Grassland, Calcareous Rocky Outcrop,* and *Circumneutral Cliff & Talus.*

Elizabeth Farnsworth © Native Plant Trust

FIGURE 11. IPA Representation of Matrix Forest Habitats
Collectively the 234 IPAs encompass 2.6 million acres, most of which is forest.

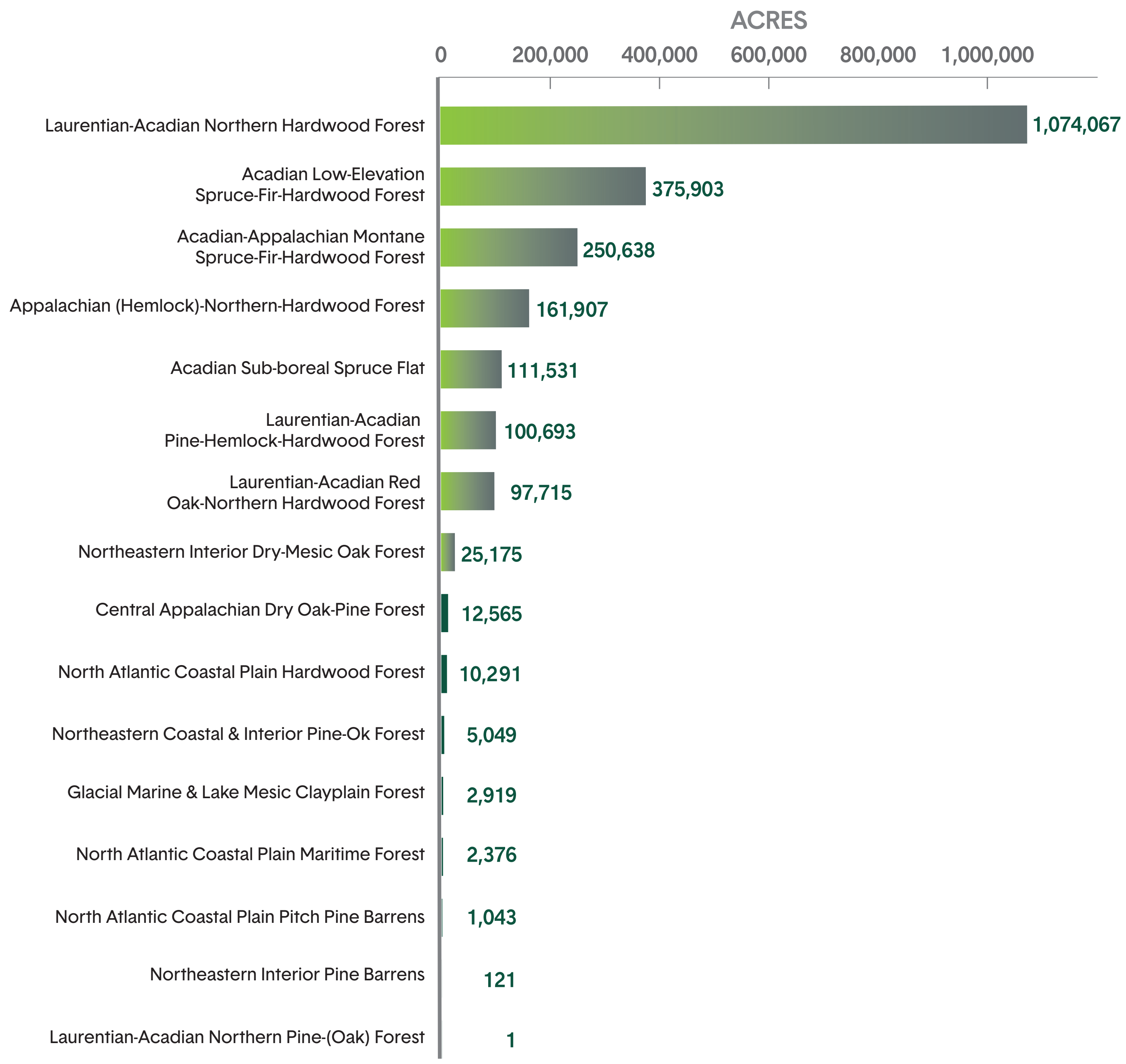


FIGURE 12. IPA Representation of Wetland Habitats

Collectively the 234 IPAs encompass 184,000 acres of wetland habitat.

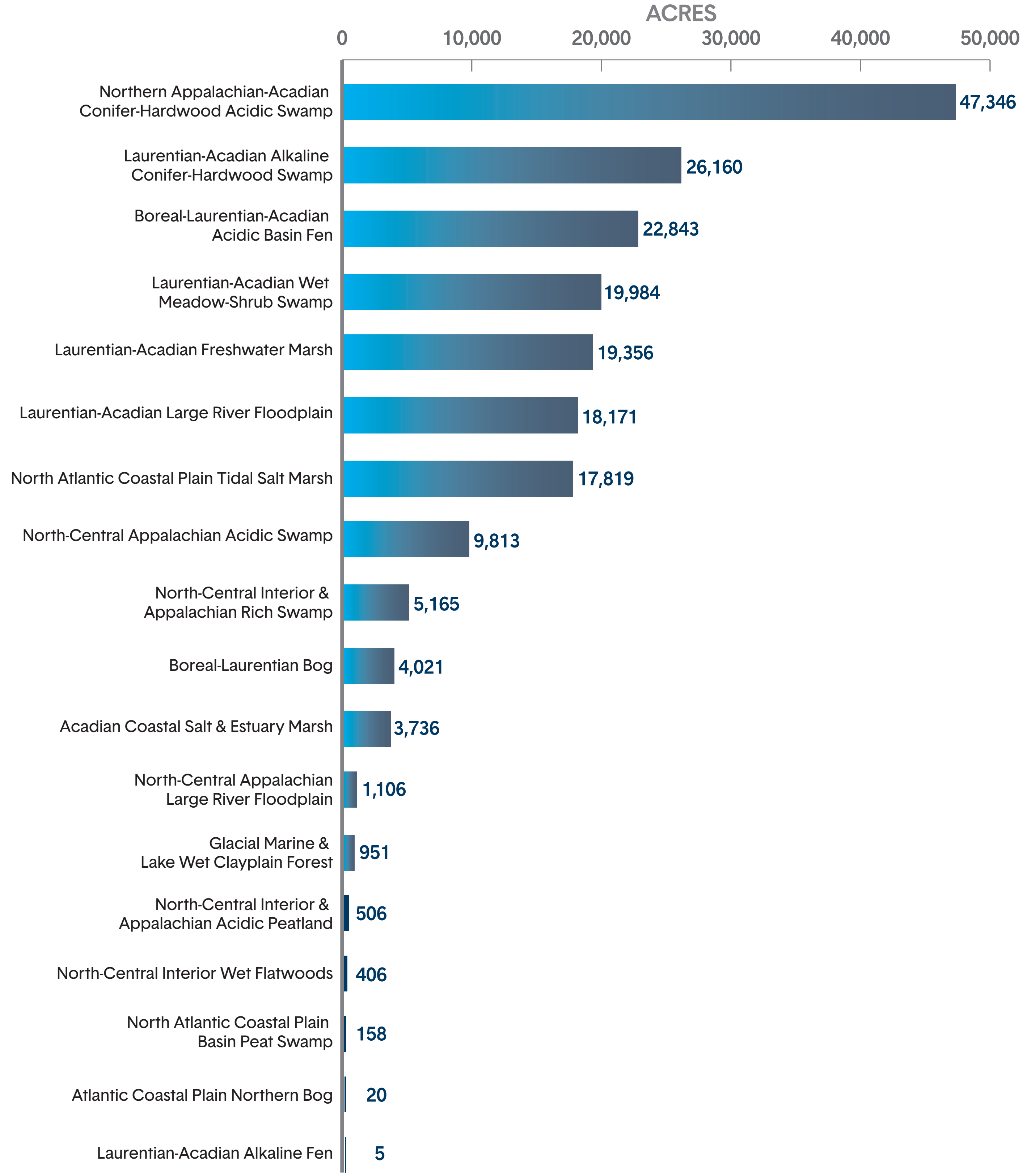
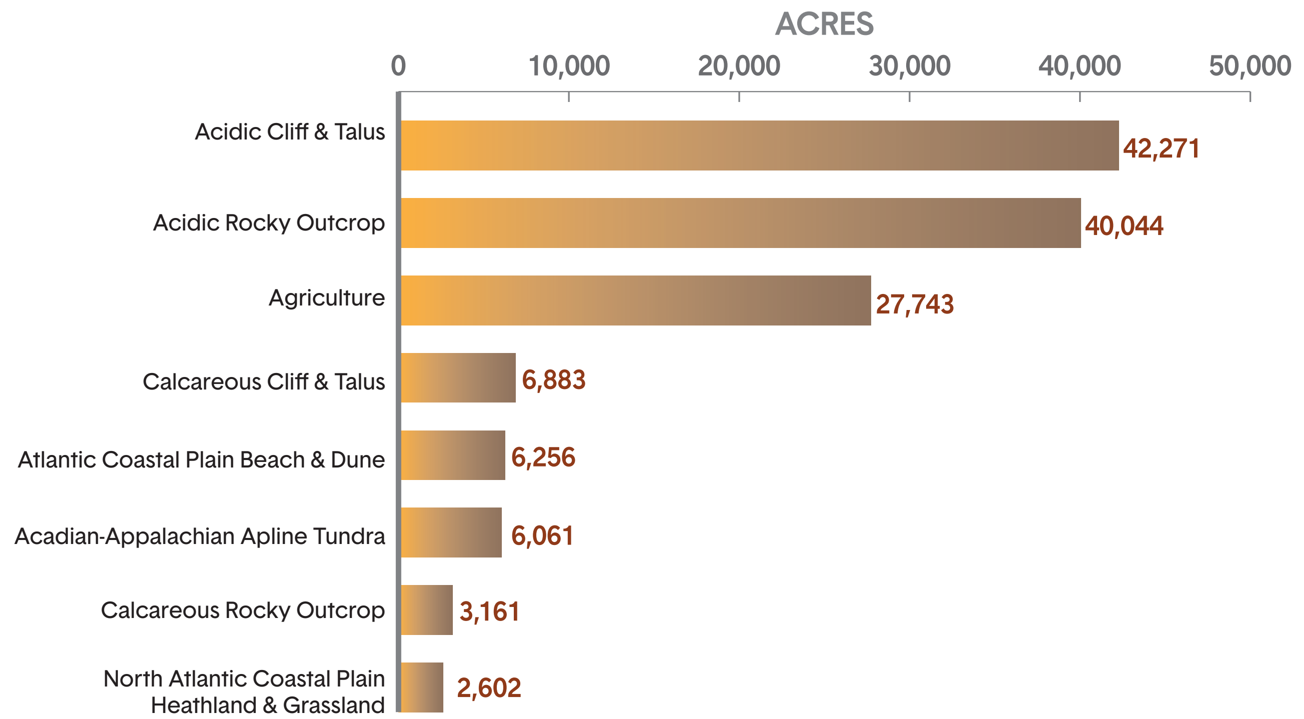


FIGURE 13. IPA Representation of Patch-forming Habitats

Collectively the 234 IPAs encompass 138,000 acres of patch-forming terrestrial habitat.



Top Sites: Another approach to prioritizing IPAs is simply by their diversity value. Of the 27 sites that scored far above average for diversity, only 1 is more than 75% protected (GSPC target), 9 are more than 30% protected (NE target), and 9 are less than 5% protected (TABLE 8). The sites with the highest diversity are generally the best protected, with the exception of a large site on the St. John River in Maine and a small site on Mount Pisgah in Vermont.

Rare Plant Sites Outside IPAs: In New England, rare plant sites are often found on resilient land. More than 60% of all occurrences of *Flora Conservanda* Division 1 and Division 2 taxa are in the IPAs (resilient areas with high diversity of rare plants), while 39% are on resilient areas not in an IPA (resilient area with low diversity of rare plants – usually just one occurrence). Only 1% are on vulnerable areas (not resilient areas, FIGURE 14). This bodes well for conservation of rare species populations in New England, but increases the importance of protecting the IPAs. Since only 4% of the 234 IPAs are fully protected, many rare plant occurrences are not secure. Element occurrences of rare species not located on resilient land or in IPAs are immediate candidates for *ex situ* conservation, particularly seed banking (FIGURE 14).

TABLE 8. Top Sites

A list of sites scoring far above average for resilience AND diversity. GAP 1-2 is the percent of the site secured for nature and natural processes (i.e., protected).

SITE ID	STATE	ACRES	SITE NAME	# FLORA CONSERVANDA TAXA	GAP 1-2
74690	ME	231,550	Mt Katahdin	22	86.3
177296	NH	142,457	Mt Lincoln/Lafayette	12	72.9
166592	NH	106,908	Mt Eisenhower/Jackson/Crawford/	26	62.1
39751	ME	101,523	St John River-Basford Rips-Blue Brook	12	1.7
170730	VT	62,857	Mount Mansfield	14	22.8
52265	ME	25,411	White Pond Acidic Fen, Northwest Lobe	6	3.3
49094	ME	28,493	St John River-Blue Brook	8	2.3
167837	ME	10,134	Abagadasset Point	5	0.5
150311	VT	21,853	Bald Mountain-Westmore	7	0.0
245357	VT/NY	6,792	Bald Mountain-West Haven	8	50.1
309129	MA	6,734	Mt Greylock/Ragged Mt/Saddleball Mt	5	31.2
383349	CT	8,548	Canaan Mountain	5	20.1
382379	MA	4,675	Nantucket Harbor/Squam Head	17	52.9
332418	MA	3,445	Holyoke Range/Skinner State Park	12	48.3
331473	MA	4,068	Mt Norwottock/Devils Garden	11	40.6
407472	RI	1,364	Hot House Pond, Strange Pond	5	30.8
168001	VT	1,315	Eagle Mountain	5	16.7
243370	VT	3,506	Massachusetts Ledge	9	12.7
422809	CT	1,163	Eightmile River	5	7.2
381217	CT/MA	1,488	Toms Hill	5	4.8
315708	MA	4,292	No Name	7	3.3
153805	VT	3,664	Mount Pisgah	13	0.0
391955	MA	404	Nantucket/Shawkemo/Folgers Marsh	5	30.4
300520	VT	339	Pownal Hills-Quarry Hill	6	28.0
77427	ME	194	Crystal Bog	6	15.7
38769	ME	286	St John River, Wesley Brook	5	0.0

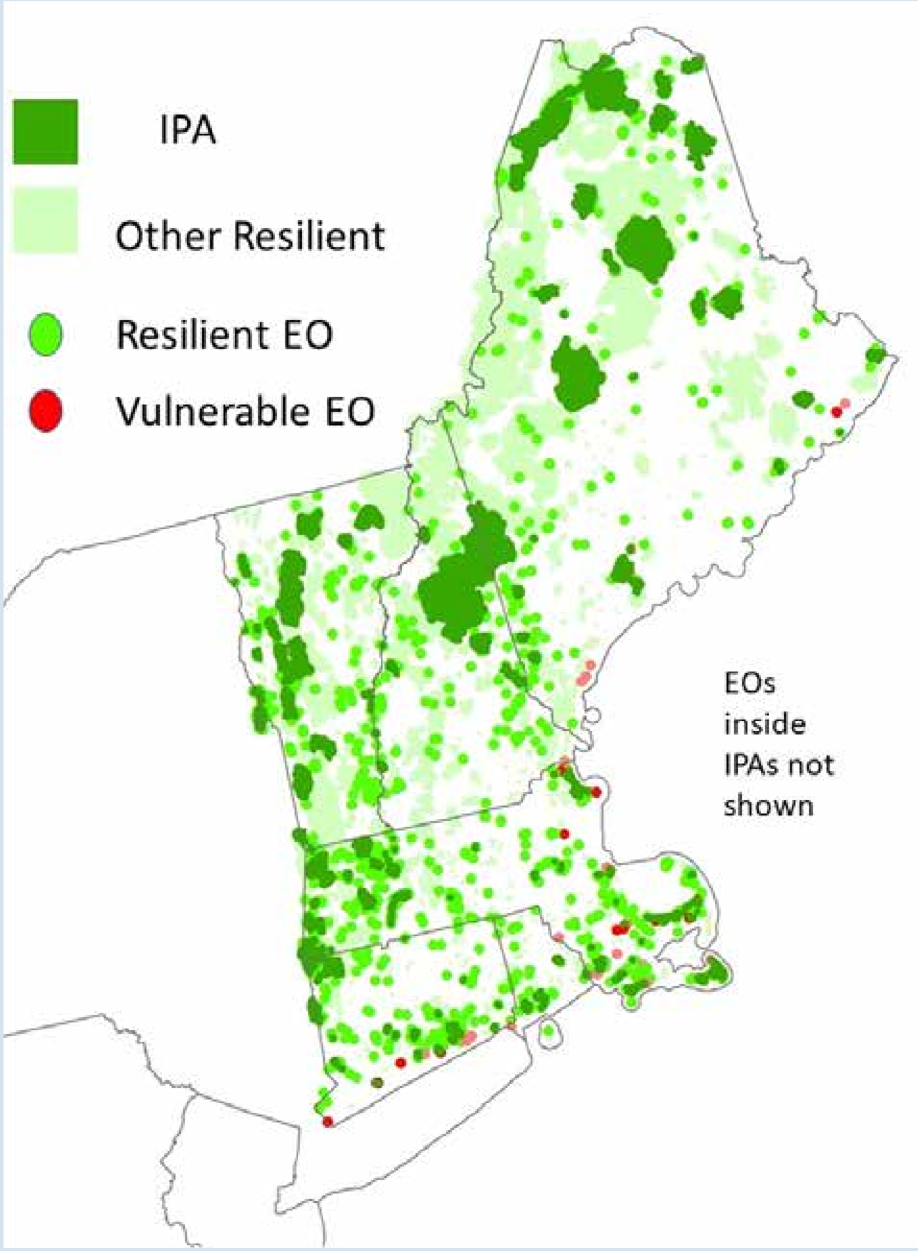


FIGURE 14. Element Occurrences of Rare Plant Sites in IPAs and on Other Resilient Land

Most occurrences of rare species are on resilient land, with only 24 on vulnerable land (red). Occurrences that are on resilient land but not in an IPA are shown in light green. The majority of occurrences are within the IPAs and hidden under the dark green areas on this map.

Plants are rooted organisms and thus sustaining plant diversity requires a long-term commitment to conserving places where they can thrive. The IPAs are a set of places where conservation is both critical and likely to succeed. Each site encompasses a diversity of habitats, contains a high density of rare plants, and has the highest possible site resilience relative to the geology and ecoregion in which they occur. Further, IPAs occur in every state across a range of sizes, habitats, and landscapes, making their conservation accessible to many scales of action. The sites and boundaries can be explored in detail on the accompanying web tool, and we encourage agencies and land trusts to ground check sites to assess their current condition.

Conservation of Threatened Species

Threatened Plants Conserved *in situ*

In 1996 and again in 2013, Native Plant Trust's *Flora Conservanda* (Brumback 1996; Brumback and Gerke 2013) designated the globally and regionally rare taxa in need of conservation. *In situ* protection is the primary method of conserving these species, and therefore knowing whether instances of rare taxa are located on protected land is important. Using 2015 data for numbers of plant occurrences (called an Element Occurrence or EO*) provided primarily by Natural Heritage programs in each New England state (or their equivalent), we were able to describe GAP securement levels for 245 of the 388 taxa in Divisions 1 and 2 (globally and regionally rare taxa) on the 2013 *Flora Conservanda* list. The list of 245 taxa with GAP status appears in Appendix 4.

The results indicate that 226 (92%) of the 245 well-mapped threatened plant species have some occurrences on secured land in New England, which is above the threshold set by the GSPC:

> **GSPC Target 7**: At least 75% of known threatened plant species conserved *in situ*. "Conserved *in situ*" is understood to mean that biologically viable populations of these species occur in at least one protected area or the species is effectively managed outside the protected area network, through other *in situ* management measures.

However, fewer than half the taxa (42%) have 50% or more of their total occurrences on secured land, and of these only 16% occur on GAP 1-2 land. Nineteen taxa (8%) have no occurrences on secured land. Thus, a large percentage of threatened species are in GAP 3 securement. Although secured against conversion, plants on these lands are not protected from other threats, such as those associated with logging or recreation (Farnsworth 2015 identifies up to five threats for many of these species). The securement status of the remaining 143 of the 388 Division 1 and 2 taxa was not available. Threatened plants in GAP 1-2 are covered in more detail in the Important Plant Areas section above.

The data show significant effort by public and private land conservation agencies and organizations in New England to protect rare plant habitat. Several caveats should be mentioned:

- The GSPC target does not specify a number or percentage of occurrences that should be in protected areas, only that "biologically viable populations occur in at least one protected area." Most biologists would not consider a species sufficiently secure if only one of its occurrences is on protected (GAP 1-2) land. In New England, the presence of endangered or threatened species has been one of the main drivers of land protection, and thus it is not surprising that a large percentage of threatened plants exist on secured land.

- The total number of EOs for each taxon in the GAP analysis is usually more than the number of EOs listed for each taxon in *Flora Conservanda* (Brumback and Gerke 2013). This is probably the result of all EOs of each taxon, including some historic locations for the taxa, being included in the GAP percentages. *Flora Conservanda* lists only EOs that are currently extant, defined as existing at a location within 20 to 25 years from present. Thus, the percentages of current occurrences on secured land may not be current.

*The term Element Occurrence was devised by The Nature Conservancy and is used in conservation as an alternative to "population." Populations of organisms often are difficult to delineate without intensive research, and use of the term "population" often implies that its limits are known. Somewhat broader in scope, an occurrence is defined as follows: the "area of land and/or water where a species is, or was, present and has practical conservation value"; it is the spatial representation of a species at a specific location (NatureServe 2012).

White Mountain avens (Geum peckii)
Liza Green © Native Plant Trust

- Based on the resilient-site analysis for the various ecological systems of New England (Part Two of this document), it seems likely that some current locations for a species may not be viable as climate change progresses. If this is the case, introduction to resilient sites within the historic range of a species or assisted migration to resilient sites outside its historic range may be necessary.

Threatened Plants Conserved in *ex situ* Collections

Ex situ conservation is an indispensable component of integrated plant conservation, especially for imperiled species facing multiple threats on the landscape as the climate changes rapidly. Botanic gardens worldwide have long maintained rare plants in their living collections as a way to ensure their survival, and one recent study estimates that 41% of known threatened plant species are in such collections, primarily holding species from temperate regions (Mounce et al. 2017).

In recent decades, seed banking has become the predominant tool for maintaining rare plant diversity (and increasingly for common species essential for habitat restoration). Seed banking has several distinct advantages over living collections, including the ability to store large quantities of plant material for long periods of time at relatively low cost. Seed banking enables the preservation of genetic diversity within a population as it was collected on the landscape, at a specific moment in time. Maintaining genetic diversity in *ex situ* living collections is logistically complicated, as plantings are more vulnerable to genetic drift, artificial selection, and active problems with pests and pathogens (Guerrant et al. 2004).

The value of seed bank collections with representative genetic diversity cannot be overstated as species and habitats shift ranges as the climate changes. Seed collections give conservationists the option to augment, introduce, or assist in the migration of imperiled plant species to prevent local extirpation or extinction.

Native Plant Trust established its seed bank in 1985 and has spent decades refining protocols to maximize potential viability of seeds and to ensure representative genetic diversity in each seed collection. Recently, Native Plant Trust has focused on achieving goals set by the GSPC; for seed banking, it is Target 8:

GSPC Target 8: At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs.

The GSPC sets a target for species conservation but lacks a target for the percentage of element occurrences collected of any individual species. To ensure genetic diversity, which safeguards adaptive abilities inherent in each occurrence of the species, research suggests collecting from at least two-thirds of the occurrences. The focus of such collection is on occurrences that are large in number of individual plants and representative of the geographic and ecological distribution of the species in New England.

Native Plant Trust has made significant strides in banking the rare flora of our region. In New England, there are 388 globally and regionally rare species (defined as Div. 1, 2, and 2[a] in *Flora Conservanda*) with approximately 3,300 element occurrences. The seed bank currently has ~800 collections, representating 244 occurrences of 167 globally or regionally rare species, plus ~500 collections of 20 locally rare and historic taxa (Div. 3, 3(a), 4). These represent 73 rare plant families and just under a tenth of the known occurrences of the most imperiled plants in New England.

seaside threeawn (Aristida tuberculosa)
Michael Piantedosi © Native Plant Trust

Among our highest priorities is to collect viable representatives of all globally and regionally rare species and to have sufficient quantities of each for research, augmentation, or other conservation initiatives. We are also focusing on acquiring seed from regional endemics, where New England is host to the majority of occurrences of a rare species. As we learn more about the presence of globally rare or endemic species on areas designated as "low resiliency" to climate change, or those with range strongholds in precarious positions on unsecured lands, we will focus collection targets more heavily on occurrences in those vulnerable locations.

Despite decades of effort to bank seeds of the region's imperiled species, work remains to bank those taxa which either do not produce true seeds (typically producing spores or vegetative propagules) or otherwise produce recalcitrant and unorthodox seeds. Among rare New England taxa, "unorthodox" plant groups—such as ferns and fern allies, many orchids (Orchidaceae), adder's tongues (Ophioglossaceae), and willows (Salicaceae)—will need continued research and expanded infrastructure for effective *ex situ* storage.

Shared knowledge has become a crucial research utility in applied *ex situ* conservation and often informs protocols and best practices for effective long-term storage of seed (and increasingly spore and gemmae). As of 2018 the number of botanical institutions that collect and bank seed of wild species has grown to 370 in 74 countries (Sharrock et al. 2018). Many, like Native Plant Trust, have partnered with the Millennium Seed Bank at the Royal Botanic Gardens, Kew, or with umbrella organizations, such Botanic Gardens Conservation International and the Center for Plant Conservation, which is a network of conservation partners that collectively work to save the imperiled plants of the United States and Canada.

NATIVE PLANT TRUST SEED BANK STATISTICS

- Total collections (cleaned, frozen): 1,639
- Total unique taxa: 419
  - Div.1, 2, 2[a] (globally and regionally rare) taxa: 167
  - Div. 3(a), 3(b), (taxa declining in a large portion of the region 3(a) or common taxa with strongly disjunct occurrences 3(b)): 20
- Total rare plant families: 73
- Of the 388 Div. 1, 2, and 2a (globally and regionally rare) taxa: 167 collected and banked, 43%
- Of the ~309 Div. 1, 2, and 2a (globally and regionally rare) taxa that are considered orthodox seed producers (excludes most ferns and orchids): 167 collected and banked, 54%
- Of the ~3,300 occurrences of the 388 taxa, 244 occurrences collected and banked, 7%
- Of the ~3,000 occurrences of ~309 taxa, 244 occurrences collected and banked, 8%

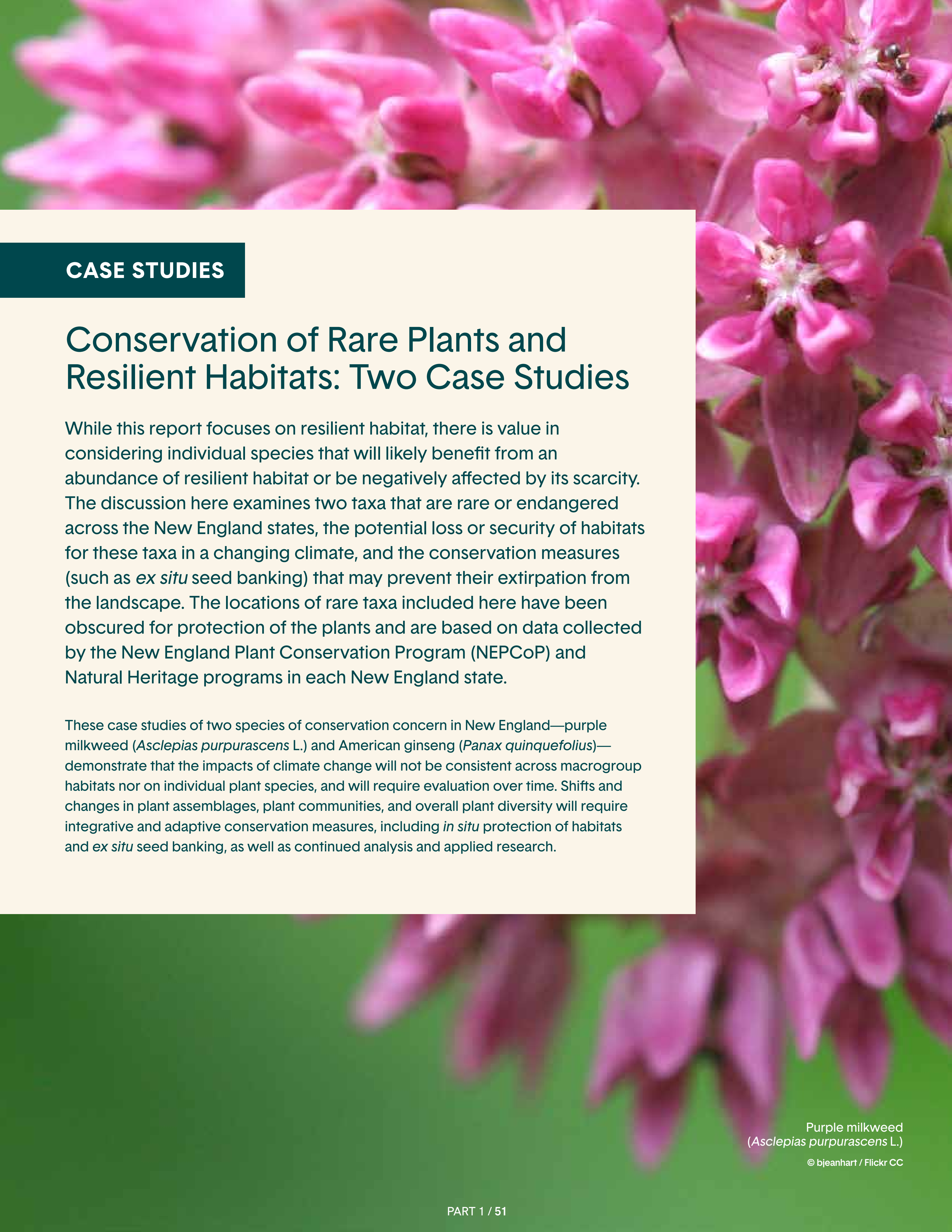
beaked spikesedge (Eleocharis rostellata)
Michael Piantedosi © Native Plant Trust

CASE STUDIES

Conservation of Rare Plants and Resilient Habitats: Two Case Studies

While this report focuses on resilient habitat, there is value in considering individual species that will likely benefit from an abundance of resilient habitat or be negatively affected by its scarcity. The discussion here examines two taxa that are rare or endangered across the New England states, the potential loss or security of habitats for these taxa in a changing climate, and the conservation measures (such as *ex situ* seed banking) that may prevent their extirpation from the landscape. The locations of rare taxa included here have been obscured for protection of the plants and are based on data collected by the New England Plant Conservation Program (NEPCoP) and Natural Heritage programs in each New England state.

These case studies of two species of conservation concern in New England—purple milkweed (*Asclepias purpurascens* L.) and American ginseng (*Panax quinquefolius*)—demonstrate that the impacts of climate change will not be consistent across macrogroup habitats nor on individual plant species, and will require evaluation over time. Shifts and changes in plant assemblages, plant communities, and overall plant diversity will require integrative and adaptive conservation measures, including *in situ* protection of habitats and *ex situ* seed banking, as well as continued analysis and applied research.



Purple milkweed
(*Asclepias purpurascens* L.)

Asclepias purpurascens – Purple milkweed

Purple milkweed (*Asclepias purpurascens* L., Asclepiadaceae) is a rare but widely distributed species currently recorded from twenty-five Eastern and Midwestern states and Ontario, with historic records from another four states. All extant New England populations are restricted to Connecticut and Massachusetts; the species is considered historic in Rhode Island and New Hampshire. Only 11 occurrences have been seen since 1980, of 82 collected before that time (Table 11 includes all occurrences documented in the last 25 years). Of these, only 6 have been observed recently and 1 remains to be confirmed as purple milkweed. Both confirmed populations are small (with fewer than 30 plants) and appear precarious.

Exhibiting a broad ecological amplitude, purple milkweed typically inhabits semi-open margins of woodlands (often with oak-pine associations), roadsides, utility corridors, and old fields on soil substrates ranging from dry to quite moist. Many of its populations in North America occur on calcium-rich parent material, indicating a loose affinity for richer soils with high cation exchange capacity. Although succession to forest, road maintenance, and development has negatively impacted these habitats, there is still ample area available to support the taxon range-wide. However, existing populations rarely produce fruit; therefore, population growth and range expansion proceed very slowly. Reasons for the decline of purple milkweed may include major intrinsic limits to reproduction (including self-incompatibility), competition with other plant species, and other environmental factors that have yet to be identified (Farnsworth and Gregorio 2001).

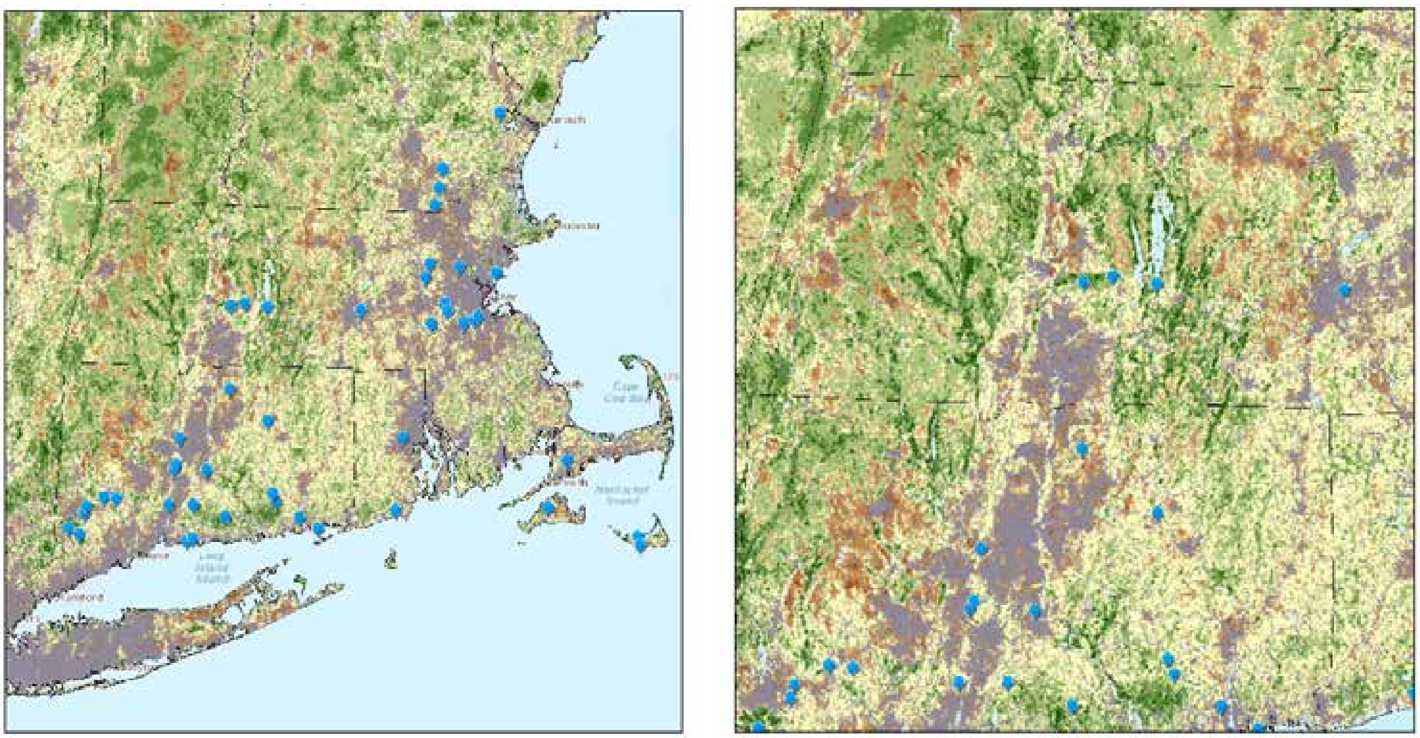
Purple milkweed
(*Asclepias purpurascens* L.)

TABLE 9. Conservation Status of *Asclepias purpurascens* L. (purple milkweed), *Flora Conservanda* Div. 2, G4G5

STATE	CONSERVATION STATUS
CT	rare to uncommon (S-rank: S2S3), special concern (code: SC)
MA	extremely rare (S-rank: S1), endangered (code: E)
NH	historical (S-rank: SH), endangered (code: E)
RI	historical (S-rank: SH), state endangered (code: SE)

FIGURE 15. Resilience

These maps depict areas of resiliency (highest in dark green to green; lowest in gray-brown and brown) overlaid with generalized population areas of purple milkweed (*Asclepias purpurascens* L.) in the New England states. Most extant populations of purple milkweed are located in low-resiliency areas.



15A. ME, VT, MA, RI, CT

15B. VT, MA, CT, small section of RI

TABLE 10. Resilience Status of Land on which *Asclepias purpurascens* L. Occurs

***ASCLEPIAS PURPURASCENS* L. (PURPLE MILKWEED)**	**CONTEXT**		**SITE RESILIENCE**		
HABITAT OR MACROGROUP	**OCCURENCES**	**% HABITAT**	**RESILIENT**	**AVERAGE**	**VULNERABLE**
Central Oak-Pine Forest	14	31%	28%	21%	50%
Urban/Suburban Built	13	29%	8%	8%	85%
Northern Hardwood & Conifer Forest	12	27%	16%	42%	41%
Agricultural Grassland	2	4%	0%	50%	50%
Water	2	4%	0%	0%	0%
Northern Swamp	1	2%	0%	0%	100%
Ruderal Shrubland & Grassland	1	2%	0%	100%	0%
Total	**45**	**100%**	**16%**	**24%**	**55%**

As described in the conservation plan authored by Farnsworth and Gregorio (2001), the primary conservation objectives for purple milkweed in New England are to locate, protect, maintain, or establish at least twenty separate occurrences in Massachusetts and Connecticut. They recommend that the majority of these populations occur on protected land, and we would add that, in addition to protected land, purple milkweed element occurrences located on land areas of high-resilience to climate change should be given greater priority for protection and management. Consistent, quantitative monitoring of all known element occurrences of purple milkweed is taking place through Native Plant Trust's New England Plant Conservation Program, and with targeted monitoring by state Natural Heritage programs. Among the most critical research needs for purple milkweed are improved understanding of the reproductive biology of this species and the protocols for augmenting or establishing new populations from seed.

Based on the distribution of most purple milkweed across *Central-Oak Pine* (31%), *Urban/Suburban Built* (29%), and *Northern Hardwood & Conifer* (27%) macrogroups (total 87%), and with individual element occurrences largely located outside resilient habitat areas (66%), it is likely that purple milkweed will face significant losses as climate change alters temperature and precipitation. This is particularly concerning for locations of this species on islands (Nantucket, Martha's Vineyard), where remnants of isolated genetic diversity in this species are likely to be negatively impacted. With many of the populations of purple milkweed considered historic in New Hampshire and historic or lacking recent observational data in eastern and northeastern Massachusetts, many of the exemplary occurrences are located in areas of central Massachusetts and southern Connecticut where habitats are likely to degrade with climate change. The 16% of purple milkweed occurrences located in resilient areas are largely concentrated in south-central Connecticut and near the Quabbin Reservoir in Worcester County, Massachusetts. Occurrences of purple milkweed outside these resilient areas, particularly those located in *Urban/Suburban Built* environments where development pressures remain high, should be the immediate focus of monitoring and seed banking efforts, if sizeable and reproductive populations are observed. Large occurrences in resilient habitat areas should also be monitored and seed banked, but also considered as introduction or augmentation sites for ensuring the survival of this species in the New England portion of its range. Areas of high resilience within the *Central Oak-Pine* macrogroup habitats, largely in south-central and north-coastal Massachusetts, coastal New Hampshire, and southwestern Maine, may also be areas of value for assisted migration of this species from seed bank resources.

As outlined in Farnsworth and Gregorio (2001) and several other sources (USDA 2003; NHESP 2015), this species is self-incompatible and has high potential for inbreeding depression; as a result, it rarely produces fruits (NHESP 2015). Given its small population numbers, further hindrance to production of follicles and seeds will likely slow the increase in individuals in both resilient and non-resilient areas and will likely cause losses and significant declines in the genetic diversity of this species. Although cross-fertilization may be tried as a means of conservation, seed banking from large occurrences of purple milkweed is an immediate priority.

Panax quinquefolius – American ginseng

American ginseng (*Panax quinuefolius* L., Apiaceae) is distributed over the eastern half of North America and is present in all New England states, though rare and protected in most.

Based on the New England distribution of American ginseng across *Northern Hardwood & Conifer Forest* (78%), *Cliff & Talus* (10%), *Central Oak-Pine Forest* (6%), and *Outcrop, Summit & Alpine* (5%) macrogroups, and with individual plant populations primarily located within resilient areas (84% in far above average, above average, and slightly above average), it is likely that many of the American ginseng occurrences will not be significantly impacted by changing temperature and precipitation. Further, threats from development in these primary macrogroup areas is quite low, with only 4% of the key habitat areas for this species facing any development. Highest areas for resilience include parts of the White Mountain National Forest of New Hampshire and Maine, northwestern Vermont, and smaller areas near the Quabbin Reservoir in central Massachusetts.

Given the likelihood of American ginseng's primary habitat areas persisting under climate change, other more numerous and severe threats should be a major focus of conservation plans for the species. Impacts from fragmentation of unsecured habitat areas within these macrogroups (see detailed maps of each macrogroup for GAP 1–3 status) could cause dislocation of important genetic variation among what are often small populations. This potential habitat-scale threat is compounded by immediate anthropogenic threats, such as over-harvesting in the wild for medicinal components, proliferation of invasive species (such as exotic earthworms and pathogens affecting dominant tree species), and impacts to insect and avian wildlife populations that contribute to fruit development and dispersal. Perhaps the most important conservation action in the case of American ginseng is protection *in situ*, where parcels of unprotected land (lacking GAP 1–3 status) should be managed to retain connectivity and above-average resiliency. Other strategies include augmentation and restoration to ensure the persistence of minimum viable populations throughout American ginseng's New England range (USFS Eastern Reg. 2003). A minimum viable population is defined as a population size likely to give a population a 95% probability of surviving over a 100-year period (Nantel 1996). Maintaining or increasing the size of the existing populations of American ginseng will also ensure that local seed sources are available for future reintroductions of the species.

American ginseng
(*Panax quinquefolius* L.)
Dan Jaffe © Native Plant Trust

TABLE 11. Conservation status of *Panax quinquefolius* L. (American ginseng), *Flora Conservanda* Div. 1, G3

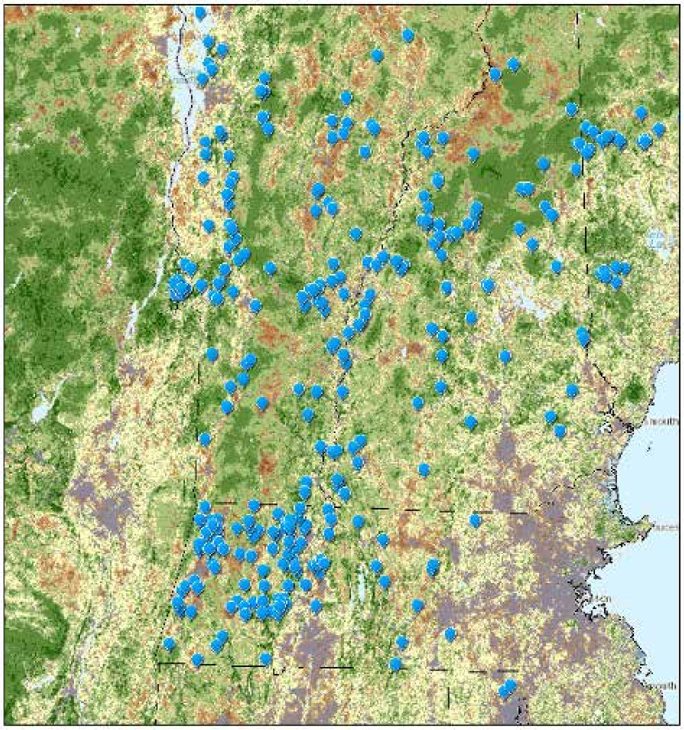
STATE	CONSERVATION STATUS
CT	rare (S-rank: S2), special concern (code: SC)
MA	uncommon (S-rank: S3), special concern (code: SC)
ME	uncommon (S-rank: S3), endangered (code: E)
NH	rare (S-rank: S2), threatened (code: T)
RI	extremely rare (S-rank: S1), state endangered (code: SE)
VT	uncommon (S-rank: S3)

TABLE 12. Resilience Status of Land on which *Panax quinquefolius* L. Occurs

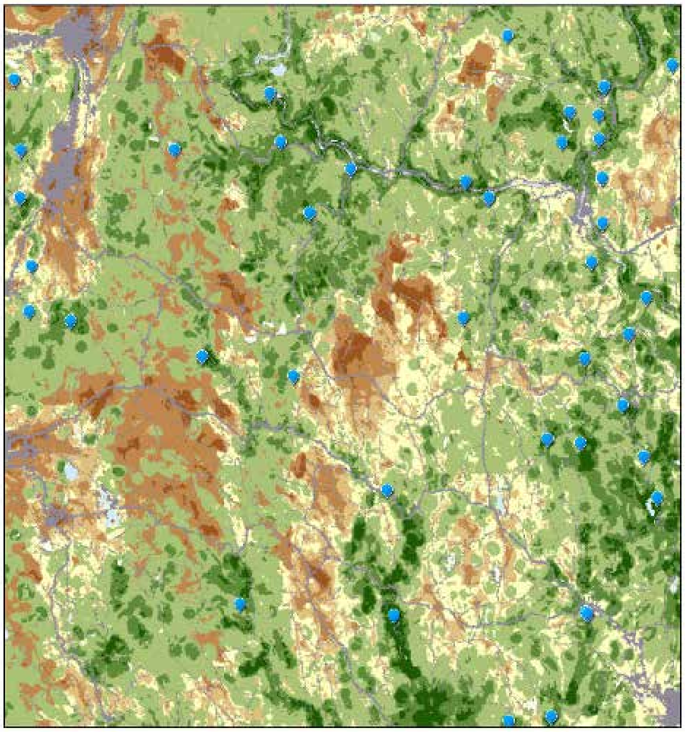
***PANAX QUINQUEFOLIUS* L. (AMERICAN GINSENG)**	**CONTEXT**		**SITE RESILIENCE**		
HABITAT OR MACROGROUP	OCCURENCES	% HABITAT	RESILIENT	AVERAGE	VULNERABLE
Northern Hardwood & Conifer Forest	251	78%	85%	8%	7%
Cliff & Talus	32	10%	94%	0%	6%
Central Oak-Pine Forest	18	6%	83%	11%	6%
Outcrop, Summit & Alpine	6	2%	100%	0%	0%
Water	4	1%	0%	0%	0%
Agricultural Grassland	3	1%	33%	0%	66%
Northern Swamp	3	1%	66%	33%	0%
Urban/Suburban Built	2	1%	50%	0%	50%
Central Hardwood Swamp	1	0%	100%	0%	0%
Freshwater Marsh & Shrub Swamp	1	0%	0%	100%	0%
Total	**321**	**100%**	**84%**	**7%**	**8%**

FIGURE 16. Resilience

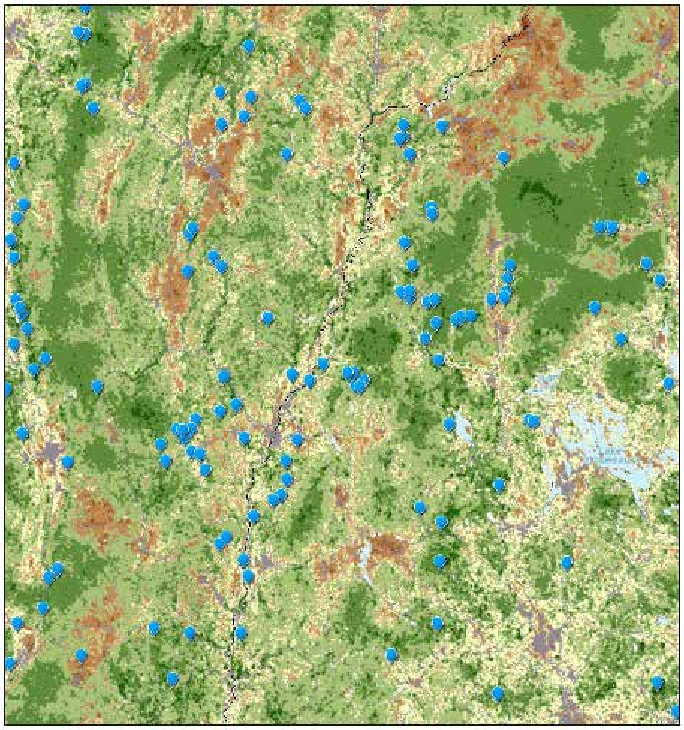
These maps depict areas of resiliency (highest in dark green to green; lowest in gray-brown and brown) overlaid with generalized population areas of American ginseng (*Panax quinquefolius)* in the New England states. Most extant populations of American ginseng are located within above-average to high-resiliency areas.



16A. ME, VT, NH, MA, northern CT, northern RI



16B. Berkshire County, MA



16C. VT, NH, northern MA

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Results and Recommendations

INTRODUCTION

In this study, we analyzed whether a century or more of land conservation in New England has protected enough land in the right places to save the region's plant diversity. While government agencies, land trusts, and private landowners have together made significant progress toward conserving natural environments, there are large biases in the distribution of conserved lands that need to be corrected if we are to sustain the full spectrum of plant and habitat diversity.

Of the 36 million acres of natural lands in New England, approximately 8.3 million acres (22%) are secured against conversion, with 2.1 million protected for nature and natural processes (GAP 1-2) and 6.2 million secured and managed for multiple uses (GAP 3). To achieve the goal of 30% of the region's lands conserved by 2030—a goal incorporated into both international and national initiatives—will require securing another 2.3 million acres against conversion and protecting at least 419,000 acres of that for nature.

Identifying which specific acres to preserve, especially in the context of a changing climate and thus a changing flora, is a goal of this report. As explained earlier, we used habitat diversity and scale, rather than species richness, as a metric for plant diversity. We then analyzed securement levels for 43 habitats and 234 newly identified Important Plant Areas (IPAs) in their distribution across the region and set conservation targets based on scientifically defined benchmarks. In addition, we assessed the climate resilience of the land that is currently conserved and factored site resilience into the recommendations for future conservation.

The data in this report coupled with the interactive mapping tool provide a robust framework for conservation action that effectively directs limited funding to habitats, areas, and specific sites that will help sustain plant diversity—and indeed biodiversity—in New England as the climate changes.

MAJOR FINDINGS

Our analysis is framed by two sets of benchmarks: the Global Strategy for Plant Conservation (GSPC) in the United Nations' Convention on Biological Diversity and the Global Deal for Nature (Dinerstein et al. 2019). The New England targets (NET) derived from the latter are tailored to the scale and diversity of habitats in New England and explicitly include climate resilience. To recap, the primary land conservation goals by 2030 are:

Global Strategy for Plant Conservation Targets

- **Target 4**: At least 15% of each vegetation type secured through effective management or restoration (GAP 1-2 protection)
- **Target 5**: At least 75% of the most important areas for plant diversity (IPAs) of each ecological region protected with effective management in place for conserving plants and their genetic diversity. We defined IPAs in New England as habitats with exceptionally high rare plant diversity (>1 rare species per 10,000 acres), with the Target 5 goal attained through at least 75% of the areas with high resilience conserved with GAP 1-2.
- **Target 7**: At least 75% of known threatened plant species conserved *in situ* (in their natural place in the wild).

New England Targets

- At least 5-15% of each habitat protected and at least 30% secured against conversion, with at least 50-75% securement on climate-resilient land, depending upon habitat type. The target sets the protected level (conserved to protect nature and natural processes) needed based on habitat scale: dominant matrix forests 5%, wetlands 10%, patch-forming habitats 15%. Similarly, the resilience criteria are adjusted downward to 50% for wetlands to include some vulnerable but already protected examples of these critical habitats.
- At least 30% of each climate resilient area with the highest rare plant diversity (IPA) protected, and at least 75% of each IPA secured against conversion across habitats and states.

Reaching the NE target of 30% secured by 2030 will require conserving an additional 2.3 million acres focused on specific habitats and climate-resilient sites.

Results

Matrix forests cover 86% of the natural landscape and provide essential benefits to people and wildlife, but of New England's ten dominant forest types only one meets the GSPC target and only two meet the NE target.

- Reaching the NET 30% will require adding 2 million acres of new conservation land targeted toward climate-resilient areas.
- Increasing GAP 1-2 protection to 15% across resilient land for the other nine matrix forest types to meet the GSPC target would require an investment in three million acres of land, including increasing the GAP level on land that is already secured.
- Existing conservation is concentrated in the northern and high-elevation forest types. Urgently in need of securement and protection are the oak-pine and coastal hardwood forests of southern New England that have limited climate resilience and are predicted to lose up to 18% of their current distribution to development by 2050.
- Saving plant diversity will also require improved and science-based management of the 5.3 million acres already secured against conversion but open to multiple uses.

Wetlands are less conserved than we expected. Of the eighteen types of bogs, swamps, floodplains, and marshes that are critical to sustaining almost half our plants, birds, and other wildlife, only six meet the GSPC and three the NE targets.

- Wetlands cover 12% of the region, but the types that meet the targets are largely small unique bogs and peatlands covering less than 1% of land area. None of the five most common wetland types meet either the GSPC or NE targets, although all of them have more than 20% securement and most meet the goals for climate resilience.
- Reaching the NE target will require conservation of an additional 253,902 acres of resilient wetland, including 151,901 acres protected explicitly for nature.
- Meeting the NE target also steps nearly 40% of the way toward the GSPC goal of protecting 405,083 more acres for nature.

Patch-forming terrestrial habitats are hotspots of plant diversity and of particular importance as habitats of rare and endangered plant species. Covering only 2% of the landscape, these summits, cliffs, barrens, and dunes sustain densities of rare species ten times higher than wetlands and forty times higher than upland forests, according to an overlay of Natural Heritage program rare species locations. Results indicate that seven of the fourteen habitats meet the GSPC goal, but when resilience is factored in, only four of these also meet the NE target. These are all bedrock-based habitats like cliffs and summits.

- Large conservation challenges are apparent in the low-elevation sand- and silt-based patch habitats such as pine barrens and coastal grasslands. These habitats are under high threat of conversion (15%-18% of current extent by 2050), and much of the current protection is on flat and fragmented land that is vulnerable to climate change.
- An additional 7,556 acres are needed to reach the GSPC 15% protected target.
- Meeting the NE target requires only 17,726 acres to reach 30% securement based on acres alone, but it would require an additional 88,620 acres of targeted resilient land to bring the silt- and sand-based systems up to the standard for climate resilience.

Important Plant Areas (IPAs) are patches of resilient land that contain a high density of rare plant species. We identified 234 IPAs for New England that cover 2.6 million acres, contain multiple occurrences of 212 globally and regionally rare taxa, and have resilient examples of 92% of the habitats. Each IPA's rare plant diversity ranges from 2 to 26 taxa depending on the site's size and location.

- For the GSPC target, 10 IPAs (4%) are more than 75% protected, and 32 (14%) have more than 75% securement by a combination of protected and multiple-use land.
- Of the remaining 192 IPAs, 155 have some level of securement, including 122 with GAP 1-2 in some portion of the site (although securement does not add up to 75% of the area). The remaining 37 IPAs have no securement.
- By acreage, the IPAs are 29% protected, with another 23% secured against conversion on multiple-use land.


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We also examined two additional GSPC targets that are critical to saving plant diversity.

- **Target 7**: "At least 75% of known threatened plant species conserved *in situ*." Of the 245 rare taxa for which we have securement status, 226 (92%) have at least one occurrence on secured land (GAP 1-3), leaving 19 taxa with no permanent protection. For most taxa, more than 50% of their known locations are on secured land. However, only 16% of the occurrences of these threatened species are on GAP 1-2 land, and the securement status of the remainder of the 388 globally and regionally rare taxa was not available.

- **Target 8**: "At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programs." In New England, Native Plant Trust manages the primary seed bank of rare and endangered species. Currently the seed bank holds collections of 43% of globally and regionally rare taxa. However, the collections are from only 7% of the populations.

RECOMMENDATIONS

We recommend an approach to land conservation that focuses on more proportional representation of the region's habitats across their ranges, rather than on securing more acres of habitat types that are abundantly conserved already. Our findings show the conservation of New England's habitat and plant diversity is an achievable goal, yet one which requires significant increases in resilient habitat areas effectively secured against conversion (30%), with a smaller proportion protected for nature (5-15% depending on the habitat type). To achieve these percentages, 2.3 million acres of additional resilient land targeted toward specific habitats must be secured against conversion, with at least 419,000 acres of that protected for nature. Conserving the unsecured IPAs (1.3 million acres) is an important focus, as it would save rare plant species and would go a long way toward sustaining the region's floristic and habitat diversity. In addition, we must ensure the effective management of 5.3 million acres of existing GAP 3 forest land, which is open to multiple uses.

By increasing the amount of area targeted for habitat conservation and incorporating effectively managed multiple-use land (GAP 3) as part of the solution, meeting the New England target will also maintain critical carbon resources and source water areas needed for people. Of course, there is no substitute for permanent GAP 1-2 protection, which is an essential measure for the health and longevity of trees and plants, many of which have multi-century life spans and develop complex co-evolutions and intertwined ecological networks. The New England target addresses this by targeting at least 5% GAP 1-2 protection in every forest type, and higher amounts for wetlands and patch habitats. We hope this target will help spur conservation of the more southern and low-elevation forests, which are vastly under-protected compared with their northern and high-elevation counterparts. Additionally, by increasing the area goal for securement and focusing on resilient land, we keep the options open for more protection, which can be achieved through redesignation of existing secured land (GAP 3) into a higher protection status (GAP 1-2).

The report's interactive maps and state-specific data will enable policy makers, federal and state agencies, and land trusts in each state to effectively target the most significant areas for protecting New England's plant diversity and the biodiversity it supports. For example:

- Habitats that are rare within New England, such as coastal plain habitats primarily in Massachusetts and Rhode Island, warrant greater protection efforts, with a higher proportion protected within the states where they occur.
- States with relatively large areas of a common habitat lacking conservation protection should also increase the amount of that habitat secured in their state. For example, 90% of the regional habitat area of *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is found in Maine, yet 84% of this habitat is unsecured in the state.
- Habitats facing significant losses to development by 2050, such as the *North Atlantic Coastal Plain Hardwood Forest* of southern New England, are also high priority.

A recommended starting point is **conserving the IPAs in each state**, which saves rare species across multiple habitats. The two primary strategies are focusing on IPAs that are unsecured and increasing the amount of protection within IPAs that are partially secured, either by conserving more acres or raising the level of securement to GAP 1 or GAP 2, depending upon the density of rare species. The table in Appendix 3 lists all 234 IPAs by dominant habitat and primary state (some cross boundaries), with acreage, number of rare species, and protection status. Using that table with the mapping tool, conservationists can also see the range of habitats within each IPA.

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The securement and resilience data in the report's tables and on the mapping tool provide a regional, state, and ultimately parcel view of both conservation achievements and the path to either GSPC or New England targets by 2030. While most of the 43 habitats need additional securement, we highlight several, and their IPAs, that need urgent conservation action. See the state summaries for more detail.

Matrix Forests

- Mid-elevation *Laurentian-Acadian Pine-Hemlock-Hardwood Forest* in Maine and Vermont has relatively high resilience but the lowest protection (2%) and securement (14%) of any forest type.
    - In Maine, there are eight unsecured IPAs within this habitat, totaling 22,980 acres.
    - New Hampshire has a single unsecured IPA of 5,537 acres.
    - Vermont has two unsecured IPAs totaling 3,515 acres.
- *North Atlantic Coastal Plain Hardwood Forest* (in all states but Vermont) meets the NE target of 5% protected, but less than half of that is on resilient land; it is also only 19% secured and highly threatened by development. All states should focus on this habitat, but Connecticut, Maine, and Rhode Island have the least securement.
    - In this habitat, there are twelve IPAs needing protection: six in Connecticut (6,402 acres), three in Massachusetts (2,085 acres), and three in Rhode Island (3,175 acres).
- *Northeastern Interior Dry-Mesic-Forest* and *Northeastern Coastal & Interior Pine-Oak Forest* have low securement, low resilience, fall short of the GSPC and NE targets, and are moderately threatened by development. The former needs securement in Connecticut, Massachusetts, and Rhode Island, and the latter is especially unsecured in southern Maine. The small IPAs will likely need to be embedded in a larger matrix of protected lands to remain viable.
    - In *Northeastern Interior Dry-Mesic Forest*, Connecticut has ten IPAs on a total of 7,754 acres, nine of which are unsecured. Massachusetts has two IPAs on 2,441 acres needing protection.
    - In *Northeastern Coastal & Interior Pine-Oak Forest*, Maine (9 acres), Massachusetts (468 acres), and New Hampshire (2,612 acres) each have a single IPA needing protection.

Wetland Habitats

- *Laurentian-Acadian Alkaline Conifer-Hardwood Swamp* is well-secured in the southern part of its range, but it is predominantly in Maine, where it is largely unsecured. The habitat also needs conservation in Vermont, where only 14% of total acres and 21% of resilient acres are secured.
- *North-Central Interior Wet Flatwoods* is a rare habitat with only 25,306 acres across five states (all but Rhode Island), very little of which is protected, and most of the 16% total securement is not on resilient land. The habitat is also threatened by development. A single unsecured IPA in Massachusetts of only 67 acres should be a high priority for investigation.
- The 14,032 acres of *Glacial Marine & Wet Clayplain Forest* occur only in Vermont and are a high priority for conservation. Only 3% of total acreage is protected and 12% secured; only 14% of resilient acres are secured.
- *Laurentian-Acadian Large River Floodplain* is home to an exceptionally high density of regionally or globally rare plant species, with more than 30 rare taxa, many of which occur primarily in this habitat type. While 29% of the resilient acreage of this habitat (212,136 acres) is secured regionally, only 7% is protected (GAP 1-2). This habitat is predominantly found in Maine, where 71% of the 186,857 resilient acres are unsecured.


Michael Piantedosi © Native Plant Trust

Patch-forming Habitats

- Four forest habitats are so restricted that they are included in the patch-forming habitat analysis, and two are high priority for conservation. The *North Atlantic Coastal Plain Maritime Forest* is only 15% secured in Maine, and only 18% of resilient acres are secured. Vermont's *Glacial Marine & Lake Mesic Clayplain Forest*, encompassing 32,066 acres, is only 7% secured.
  - Of the two IPAs in the maritime forest, a 500-acre site in Massachusetts needs protection.
- The coastal plain sand- and silt-based habitats are especially vulnerable to climate change. While the number of acres needed to reach targets is relatively small, it may be difficult to sustain these habitats over time. A clear focus should be saving the 36 rare plant species in the beach and dune habitats and the 8 in the coastal grassland.
  - Three *North Atlantic Coastal Plain Heathland & Grassland* IPAs in Massachusetts, encompassing 2,657 acres, are priorities; only one is protected.

While this report focuses primarily on land conservation, we also examine and recommend additional conservation strategies, such as assisted migration, restoration and augmentation of sites and populations, and seed banking to preserve genetic diversity. What is certain in a changing climate is that we need multi-layered, science-based approaches to saving plant diversity and the life it sustains. We know that a rapidly changing climate will stress the ability of individual species and entire habitats to adapt, and thus recognize that some will migrate, some will die, and some will form new assemblages. With this report and its mapping tool, we aim to ensure that New England's native plants—the green foundation for functioning ecosystems—are at the forefront of conservation policy and action as climate plans develop.