Increasing Forest Resiliency
for an Uncertain Future

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Introduction

Forests are the natural vegetative cover for most of New England. In many parts of our region, the forests have been cleared twice, yet today they continue to dominate the landscape. Our forests have also faced threats, such as the introduced chestnut blight, which removed this once dominant tree species from the landscape. Despite this and other losses, we continue to enjoy the many essential benefits forests provide to our daily lives, such as clean water, carbon sequestration, wildlife habitat, scenic landscapes, recreational opportunities, and forest products. In other words, our forests are resilient.

We are now facing an uncertain future, in which our forests will encounter many challenges, including land conversion; invasive plants, insects, and diseases; heavy deer browse; and climate change. Though our forests are resilient, they also have characteristics that make them vulnerable to these stressors to varying degrees. While there is uncertainty as to how our forests will react to these stressors, we can be confident that our forests **will** change.

There are a number of excellent resources that address these challenges individually. The goal of this publication is to provide you, the critical forest decision makers in New England—landowners, foresters, conservation organizations, and municipal officials—with a framework for addressing these challenges in an integrated way that is specific to your forest and takes into consideration your individual goals, available time, and resources. Based on current understanding of how forests work, this publication suggests a number of actions that have a high likelihood of helping you reduce your forest's vulnerability and increase its resiliency so that it can continue to provide the benefits you enjoy—and we depend on—in the face of these challenges. Importantly, these actions will allow you the ability to adjust to new conditions and integrate new knowledge as you go forward. An extensive list of resources that will help you move ahead with these actions is provided at the end of this publication.

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Forest Stressors

Pressures on a forest that can reduce its resiliency and impair its ability to function properly

Understanding the main stressors that our forests face will help inform the actions we take to address them. A brief description of each follows.

Forest Conversion

Conversion of forests to other land uses eliminates all the benefits that forests provide. Simply put, no forests equals no forest benefits. Forest conversion isolates forests from one another through fragmentation—the breaking apart of large areas of forest. Isolated forests are likely to be more vulnerable to stressors because plants and animals may have greater difficulty moving between forest fragments. Developed land near forests can be a source for invasive plants and insects, which increase forest vulnerability. Furthermore, land conversion and fragmentation reduce the amount and quality of interior forest habitat and increase impervious surfaces—like pavement—placing additional stress on nearby forests and forested wetlands due to increased water runoff.

Invasive Plants

Invasive plants can out-compete native vegetation through rapid growth and prolific seed production. Increased amounts of invasive plants can reduce plant diversity by dominating forests. When invasive plants dominate a forest, they can inhibit the regeneration of native trees and plants. This reduced regeneration further reduces the forest's ability to regenerate in a timely and sufficient manner following a disturbance event. In addition, invasive plants have been shown to provide less valuable wildlife habitat and food sources.

Invasive Insects and Diseases

The world has gotten smaller, and while global trade offers some advantages, it has also led to the movement of a number of invasive insects and diseases. Many of these insects and diseases have been found in New England, including the hemlock woolly adelgid, the Asian long-horned beetle, and beech bark disease. These organisms have no natural predators or controls and are significantly affecting our forests by changing species composition as trees susceptible to these agents are selectively killed.

Over-Browsing

Deer populations have increased dramatically due to a lack of natural predators, increased habitat from forest fragmentation, and a general decline in hunting across the region. Deer browse can be so intense in some areas that the sustained browsing of seedlings can prevent certain tree species or areas of forest from regenerating. This over-browsing can make a forest vulnerable to disturbances, since there are no young trees to take over as the older trees die.

Conversion of forests to other land uses eliminates all the benefits that forests provide. Simply put, no forests equals no forest benefits.

Climate Change

New England's climate has changed, with warmer days, shorter winters, and more intense rain and storm events, and changes are expected to continue. The growing season has already increased by more than one week in some parts of New England. Longer growing seasons help increase forest productivity but may make trees more susceptible to late spring frosts. Increased amounts of carbon dioxide in the atmosphere (a driver of climate change) also improves tree growth by playing a fertilizing role, since carbon dioxide is a raw material used in photosynthesis and plant growth. As temperatures increase, conditions may become drier than we currently experience in the periods between extreme rain events, resulting in drought-like conditions. These changes are predicted to shift the habitat conditions for many plant species (and the animals that depend on them) north and to higher elevations. These conditions are also predicted to favor species that are more competitive in warmer, drier climates.

Stressor Interactions

Of course, these stressors do not act in isolation. Rather, they interact with one another, increasing their negative impact and making it difficult to address them individually. Examples of these interacting stressors are as follows:

- A combination of an earlier growing season, more frequent gaps in the forest canopy from wind and ice storms, and carbon dioxide fertilization will likely favor invasive plants over our native trees and forest vegetation.
- Preferential browse of native plants by larger deer populations may favor invasive species and inhibit the ability of a forest to regenerate after wind and ice storms.
- Warming temperatures favor some invasive plants, insects, and diseases, whose populations have historically been kept in check by the cold climate.
- Periods of drought weaken trees and can make them more susceptible to insects and diseases.

Because these stressors interact with one another, it is important to address them as part of a larger whole.

Carbon and Forests

Forests are important for removing carbon dioxide from the atmosphere and for serving as carbon sinks—places where carbon can be stored. Carbon dioxide (CO_2) is a greenhouse gas. A tree uses CO_2 from the atmosphere during photosynthesis. The energy produced during photosynthesis is used to help the tree grow. When the tree grows, CO_2 is stored in its roots, stem, branches, and leaves. In fact, almost half of a tree's mass is carbon. After a tree dies, carbon continues to be stored in the deadwood until it decomposes. Carbon is also stored in forest soils. In the eastern United States, it is estimated that 50 percent of carbon in a forest is stored in the forest soil, 36 percent is stored in living plants and trees, 8 percent is stored in deadwood (standing dead trees and logs), and 6 percent is stored in the leaf litter on the forest floor. **Maintaining our forests and increasing their resiliency will help them continue their critical function of carbon sequestration.**

Forest Resiliency

The capacity of a forest to respond to a disturbance by resisting damage or stress and recovering quickly

Although your forest faces an increasing number of stressors, the good news is that it may have a number of characteristics that make it resilient, including the following:

Formal Plans for the Future of the Property

Most of the land in New England is family forest, owned by families and individuals. The average age of family forest owners is over sixty. The coming years will see the largest intergenerational transfer of land and assets our country has ever seen. The decisions family forest owners make (or don't make) about who will own their land when they are gone and how it will be used (e.g., converted to another land use, parcelized into smaller properties, or protected from development) are likely the biggest and most permanent drivers of forest change we face.

A resilient forest is one that will continue to be forest into the future. To ensure a critical level of forest cover, it is imperative that family forest owners make formal plans for the future of their land.

Minimal Forest Stress

As previously described, our forests are facing a number of stressors that threaten the benefits they provide. Each landscape has a unique combination of stressors and levels of exposure to them. Minimizing the level of invasive plants, insects, and diseases; lowering deer populations; ensuring that soil is abundant in organic matter and not compacted or eroding; and ensuring that water resources have forested buffers minimize the amount of stressors a forest faces and increase its resiliency.

High Forest Complexity

The complexity of a forest is generally based on the following characteristics: tree species diversity, tree adaptedness, tree size and age, tree arrangement, and amount of deadwood present. Promoting forests that have a diversity of tree species, ample tree regeneration of future-adapted species, vigorous trees of various sizes and ages, a variety of tree arrangements, and an appropriate amount of deadwood gives forests a complex structure and helps them withstand and recover from stressors. A description of each of these characteristics follows.

DIVERSITY OF TREE SPECIES

A forest is made up of different tree and plant species, which influence its ability to cope with stress and change. The two primary determinants of the trees and plants in your forest are soil conditions (water and nutrients) and the past land use and disturbance history of the property. Generally speaking, forests with higher levels of tree and plant diversity have higher resiliency. For example, some tree species are expected to

A resilient forest is one that will continue to be forest into the future.

face more challenges in the future as a result of increased pressures from pests and diseases as well as warmer climate conditions, and forests primarily made up of these species may be at greater risk. In contrast, forests that have a greater diversity of species tend to be more resilient to many types of stressors simply because not all species are susceptible to the same challenges. Taking actions to increase forest diversity or encourage species that are likely to do better in the future through forest stewardship can increase the resiliency of your forest.

AMPLE TREE REGENERATION OF FUTURE-ADAPTED SPECIES

In addition to a diversity of species, it is very important to consider maintaining and promoting species that are predicted to be well adapted—that is, more competitive—given expected future conditions. Thus, it is critical to consider how well a species is likely to do in a particular place, both now and in the future. Soil conditions (water and nutrients) play an important role in determining not only the tree species that can survive on a site but also those species that can thrive. Some trees compete very well on wet, nutrient-rich sites, while others compete best on dry, nutrient-poor sites. Some trees have a narrow range of soil conditions in which they will compete, and others will compete in a wide range of conditions. Changes in temperature, evaporation, and precipitation are predicted to change soil conditions in New England. By varying the timing of harvests and creating different-sized openings, trees that are better suited to the likely future climate and forest health issues can be regenerated, which will improve the likelihood of a vigorous future forest, thereby increasing its resiliency.

Planting and sowing tree seed is not a common practice in New England; however, depending on one's goals and resources, there may be opportunities to use enrichment planting and seeding of native tree species to promote a forest with a species composition well suited to expected future conditions.

[TABLE 1] Predicted Change in Suitable Habitat

The following table provides tree species and predictions of how competitive they will be in the future. The values following each species name indicate whether species-suitable habitats will increase (+), decrease (−), or stay the same (●) under projected climate change.

Northern New England (Ecological subsections M211A, B, C, and D, and M211E and J)		
Tree Species	Low Emissions (PCM B1)	High Emissions (GFDL A1FI)
Balsam Fir	−	−
Black Spruce	−	−
Northern White Cedar	−	−
Paper Birch	−	−
Red Spruce	−	−
Tamarack	−	−
White Spruce	−	−
American Beech	●	−
Quaking Aspen	●	−
Sugar Maple	●	−
Yellow Birch	●	−
Bear/Scrub Oak	●	●
Bigtooth Aspen	●	●
Eastern White Pine	●	●
Red Maple	●	●
American Basswood	●	+
Bitternut Hickory	●	+
Black Cherry	●	+
Pitch Pine	+	●
Black Birch	+	+
Black Oak	+	+
Chestnut Oak	+	+
Northern Red Oak	+	+
Shagbark Hickory	+	+
White Oak	+	+
Threatened by Current Forest Health Issues (Do not target)		
Black Ash	−	−
Eastern Hemlock	●	●
White Ash	●	●

Southern New England (Ecological subsection M221A)		
Tree Species	Low Emissions (PCM B1)	High Emissions (GFDL A1FI)
Balsam Fir	−	−
Black Spruce	−	−
Eastern White Pine	−	−
Northern White Cedar	−	−
Paper Birch	−	−
Quaking Aspen	−	−
Red Spruce	−	−
White Spruce	−	−
Tamarack	−	●
American Beech	●	−
Northern Red Oak	●	−
Red Maple	●	−
Yellow Birch	●	−
Bear/Scrub Oak	●	●
Black Cherry	●	●
Sugar Maple	●	●
Bigtooth Aspen	+	●
Pitch Pine	+	●
American Basswood	●	+
Bitternut Hickory	+	+
Black Oak	+	+
Chestnut Oak	+	+
Shagbark Hickory	+	+
White Oak	+	+
Threatened by Current Forest Health Issues (Do not target)		
Black Ash	−	−
Eastern Hemlock	●	●
White Ash	●	●

Projected change in suitable habitat in the year 2100 based on Tree Atlas projections for a given ecological subsection. Prasad, A. M., L. R. Iverson, S. Matthews, M. Peters. 2007–ongoing. A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States [database]. www.nrs.fs.fed.us/atlas/tree, Northern Research Station, USDA Forest Service, Delaware, Ohio.

Table 1 provides tree species and predictions of how well they will be able to grow in a particular region in the future. The values following each species name indicate whether species' suitable habitats will increase (+), decrease (−), or stay the same (●) under projected climate change. Stewardship efforts should target species that are not expected to decline under either emissions scenario or that are not threatened by current forest health issues.

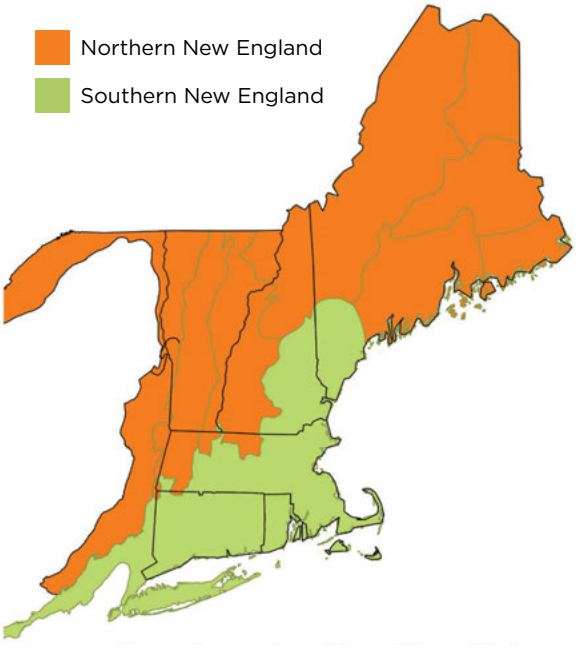
VIGOROUS TREES OF VARIOUS SIZES AND AGES

Some stressors have a disproportionate influence on trees of particular sizes and ages. For example, windstorms have a bigger influence on large trees with dominant crowns. Certain insects target or are more lethal to trees of a particular size, such as white pine weevil and spruce budworm. Forests with a diversity of tree sizes and ages are more resilient to a given stressor, and there is a lower probability that any given stressor will affect a large proportion of the stand.

Trees in overcrowded forests compete with one another for limited sunlight, water, and nutrients. This severe competition can increase the stress of a tree and reduce its vigor, increasing its vulnerability to stressors. Reducing the number of trees in a forest can free up limited space and resources, increasing the overall vigor of the forest.

VARIETY OF TREE ARRANGEMENTS

Complex forests also have variety in how trees are arranged spatially. This includes open areas associated with recent canopy gaps created by disturbance or forest stewardship, denser areas with multiple canopy layers, and other spots where there may be widely spaced older trees. A resilient forest has a range of these spatial conditions to create unique microsites, as well as resource conditions that provide multiple ways to recover from and resist stressors (e.g., gaps for regeneration, deeply shaded areas for habitat, and widely spaced trees that can withstand drought).



The above map illustrates the demarcation of northern and southern New England used in Table 1 based on ecological subsections. Northern New England includes ecological subsections M211A, B, C, and D, and M211E and J. Southern New England includes ecological subsection M221A.

APPROPRIATE AMOUNT OF DEADWOOD

Given our land-use history, our forests are still relatively young. One component that is lacking or greatly reduced in many of our forests is deadwood—dead standing trees (called snags) and large logs on the ground. Though this deadwood can make the forest look messy, it is a critical part of a healthy forest. Snags provide habitat for insects, birds, and small mammals. When snags or live trees fall to the ground, the logs provide habitat for another suite of species, including insects and amphibians. They also serve as "nurse logs" for certain tree species, such as yellow birch, which regenerate well on these moist, organic substrates. Finally, logs can store carbon for decades. Having an appropriate amount of snags and logs in the forest helps maintain these critical ecosystem functions, increasing resiliency.

Stewardship efforts should target species that are not expected to decline under either emissions scenario or that are not threatened by current forest health issues.

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HEALTHY SOIL AND WATER

Healthy soil and water are the foundation of a forest. Soil with ample organic matter that is neither compacted nor eroding provides critical nutrients and water to forest plants and produces clean water. A lack of organic matter in the soil can reduce the amount of available nutrients, the soil's water-holding capacity, and the soil's structure. Compacted soil will increase the amount of stress a tree is under, making it more vulnerable to additional stressors. Soil erosion can reduce the fertility of the soil, reducing tree growth and vigor while degrading water resources.

Forested buffers along water resources help maintain water quality by filtering runoff; maintaining cool water temperatures; and adding leaves, branches, and logs to the water to be used by a variety of fish and other aquatic species.

PROTECTION FOR THREATENED, ENDANGERED, AND AT-RISK SPECIES

Species differ in their response to pests and weather disturbances. In general, the higher the species diversity, the higher the resiliency of a forest. Species are also connected to one another. Each species often has a unique suite of organisms that depend on its presence in the forest. Maintaining our full range of native species across the landscape improves the chances of species and forest adaptation by providing the opportunity to maintain genetic diversity and the connections between species. This can be done by protecting threatened, endangered, and at-risk species and by looking for opportunities to maintain trees and plants predicted to be less competitive in the future by finding areas of the landscape where they may still be competitive and encouraging their perpetuation (e.g., red spruce in higher-elevation areas in Massachusetts).

Increasing Forest Resiliency

The aforementioned characteristics make your forest resilient to stressors. If your forest has these characteristics, then maintaining them is important. A lack of these characteristics increases your forest's vulnerability. The landscape surrounding your forest also has a significant impact on its resiliency. Forests and the landscapes they lie within are highly variable, giving them varying degrees of both resiliency and vulnerability (see diagram 1, page 12).

Forest Vulnerability

A forest's susceptibility to undesired change from stressors

It is possible to increase the resiliency of your forest to current and future stressors by increasing the characteristics that will make it more resilient. Importantly, incorporating these characteristics into your forest still leaves ample room for a broad range of additional landowner goals. In other words, **you can improve your forest's resiliency *and* reach your unique landowner goals.**

There are a number of specific actions that you can take to help make forests more resilient while also providing the benefits that you value (see diagram 2, page 24). These actions can be grouped under four goals that, when reached, increase the level of resiliency of your forest:

Goals of Forest Resiliency

- **Goal 1: Keep forest forested and connected**
  Ensure connected, conserved forest cover, preferably on a range of environmentally diverse sites.
- **Goal 2: Reduce stressors**
  Limit the amount of stress that forests face in order to increase forest vigor.
- **Goal 3: Reduce vulnerability**
  Make the forest more resilient by establishing forests with complex structure and by reducing forest disturbances.
- **Goal 4: Provide refuge**
  Maintain the maximum level of plant and animal diversity over time.

The ways in which these actions will be implemented to obtain these goals will vary based on the unique qualities of a particular forest, such as the type of forest, its location, its land-use history, and its landscape context. Some forests have a greater exposure or susceptibility to stressors, which may increase their vulnerability and make it more important to take actions to reduce stressors and increase the forest's resilience. These steps are described in detail in the Framework for Increasing Forest Resiliency, beginning on page 14.

You can improve your forest's resiliency *and* reach your unique landowner goals.

[DIAGRAM 1]
Gradient of Forest Resiliency

High Resiliency
Low Vulnerability

PROPERTY LEVEL CHARACTERISTICS

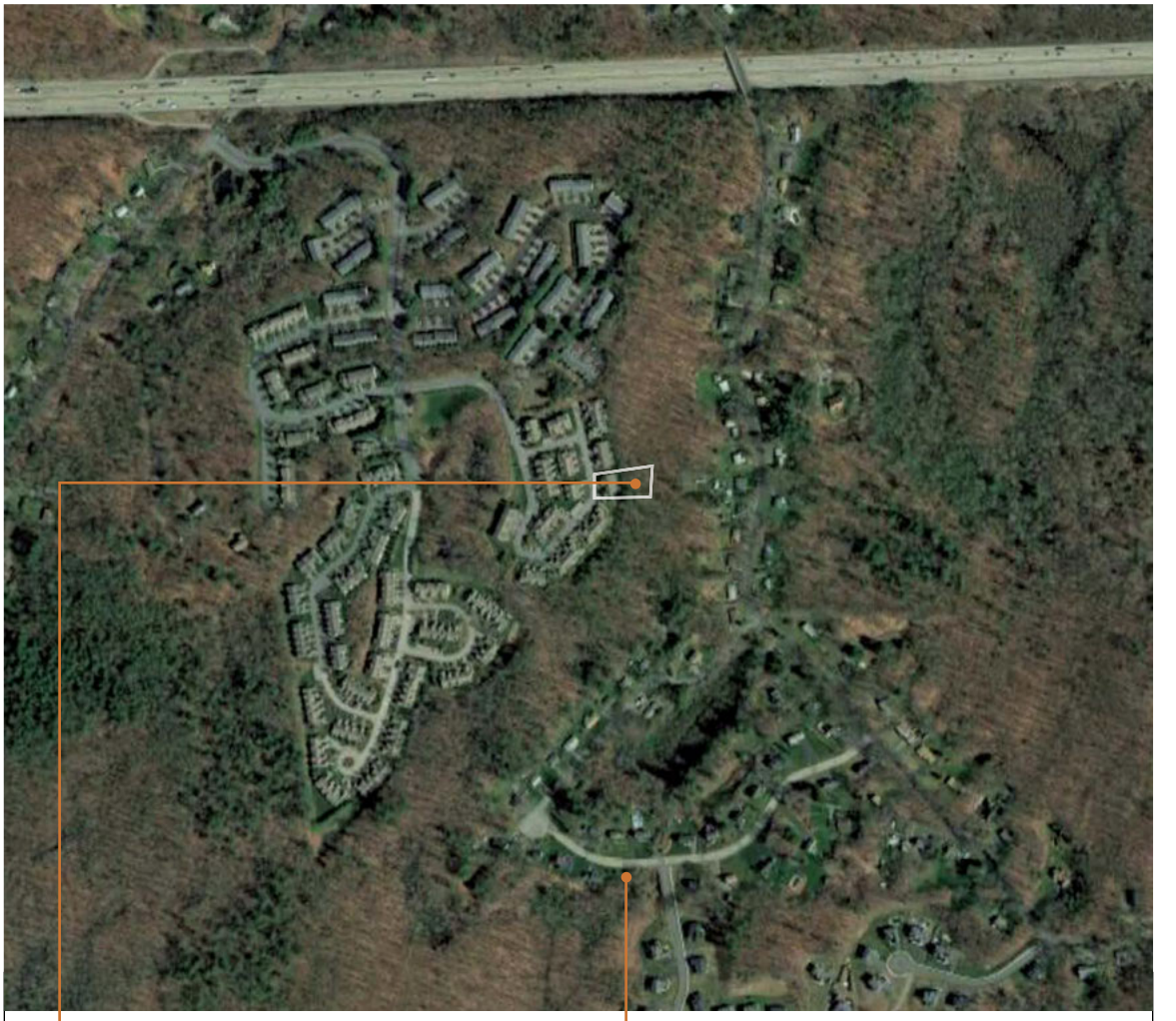
- Formal plans for continued forest use
- Complex forest structure
- Diverse forest composition
- High proporation of well-adapted species
- Healthy soil

SURROUNDING LANDSCAPE

- Low conversion rates
- Large continuous areas of connected forests
- Diverse soil and growing conditions
- Low deer populations
- Low invasive plant, insect, and disease pressure

There is a gradient of forest resiliency from low to high. Where a property falls on this gradient depends on both its property level characteristics and the surrounding landscape.

Low Resiliency
High Vulnerability



PROPERTY LEVEL CHARACTERISTICS

- Future ownership and use is uncertain
- Simple forest structure
- Forest dominated by a few species
- Low proportion of well-adapted species
- Compacted and/or eroding soil with low organic matter

SURROUNDING LANDSCAPE

- High conversion rates
- Fragmented forests
- Uniform soil and growing conditions
- High deer populations
- High invasive plant, insect, and disease pressure

Step 1

Assess Forest Resiliency

The first step is to assess the resiliency of the forest (or forested landscape) you are interested in and evaluate the vulnerabilities of that forest to current and future stressors. Once you have identified the characteristics of resiliency and vulnerability that your forest possesses, you can determine the specific actions necessary to make the forest more resilient (see Step 2, page 16).

Following is a checklist to help you determine the characteristics of resiliency and vulnerability of your forest of interest. The checklist will also help you determine important characteristics of your forest that you need to learn more about. Check the appropriate box for each statement:

Goal 1: Keep Forest Forested and Connected

Yes (Resiliency)	No (Vulnerability)	Don't Know (Need More Info)	
☐	☐	☐	1.1: Conservation-based estate planning has been implemented to ensure the continuation of this land as forest into the future.
☐	☐	☐	1.2: The property is part of a resilient forest or serves as a connection between large areas of forest (>250 acres in southern New England, >500 acres in northern New England).

Goal 2: Reduce Stressors

Yes (Resiliency)	No (Vulnerability)	Don't Know (Need More Info)	
☐	☐	☐	2.1: Invasive plants are NOT found on or near the property.
☐	☐	☐	2.2: Invasive insects and tree diseases are NOT found on or near the property.
☐	☐	☐	2.3: There are NO signs of significant deer impacts or an increasing deer population.
☐	☐	☐	2.4: The soils are NOT compacted or exhibiting evidence of significant erosion.

Goal 3: Reduce Vulnerability

Yes (Resiliency)	No (Vulnerability)	Don't Know (Need More Info)	
☐	☐	☐	3.1: The forest has a diverse amount of species of various sizes, ages, and spatial arrangements.
☐	☐	☐	3.2: The forest is largely dominated by species predicted to be well adapted to future conditions.
☐	☐	☐	3.3: The forest contains a low abundance of preferred host species for invasive insects or diseases threatening the area (e.g., white ash: host of the emerald ash borer; eastern hemlock: host of the hemlock woolly adelgid; and red and sugar maple: host of the Asian long-horned beetle).
☐	☐	☐	3.4: There are NO areas of the forest with dense, crowded tree stems.
☐	☐	☐	3.5: There are 5 or more large snags (>16" diameter) per acre.
☐	☐	☐	3.6: There are 5 or more large logs (>16" diameter) per acre.
☐	☐	☐	3.7: Water resources have forested buffers.

Goal 4: Provide Refuge

Yes (Resiliency)	No (Vulnerability)	Don't Know (Need More Info)	
☐	☐	☐	4.1: The property is habitat for threatened, endangered, or at-risk species.
☐	☐	☐	4.2: The property can harbor species that we may lose from the landscape.

Taking the Next Step

With a clear understanding of your forest's inherent resilience and vulnerability, as well as the stressors that it faces, it is now possible to determine the suite of specific actions in Step 2 (see page 16) that can be taken to reduce vulnerability, increase resiliency, and address stressors.

Step 2

Increase Forest Resiliency

To increase forest resiliency, use your answers from Step 1 as a guide. If you checked "Yes (Resiliency)," it is important to continue monitoring your forest over time to make sure these conditions are maintained in light of current and future stressors affecting our region. If you answered "No (Vulnerability)" to any factor in the list, refer to the corresponding action number in the section that follows. Finally, if you checked "Don't Know (Need More Info)," contact a person or resource in the Resources section at the end of this publication to learn more.

Following are icons that designate which actions are more suited for the different roles you may play in conserving and stewarding forestland. Depending on the role you play in caring for a forest, some of the actions may be more appropriate than others. If you are a landowner or forester, the actions include standard recommendations for any forest management, as well as some that require taking a new perspective on the forest. There are also actions most appropriate for municipal officials, such as conservation commissions, open space committees, and planning boards. Communities and conservation groups that own land can implement landowner actions. Land trusts and municipal officials can also play a critical role by helping landowners with conservation-based estate planning.


Foresters


Conservation Groups


Landowners


Municipal Officials

Importantly, the actions you adopt must also fit the overall goals for the land, as well as your available time, energy, and resources. **Don't feel overwhelmed. Even choosing to do a single action can help ensure more resilient forests. Resources and contact information for these actions can be found in the Resources section beginning on page 27.**

Goal 1: Keep Forest Forested and Connected

1.1 Action: Engage in conservation-based estate planning to ensure the continuation of the land as forest.

Contact a local land trust or estate planning attorney with land conservation experience to investigate your conservation-based estate planning options to keep some or all of your land in its natural state, including

- specifying your wishes for the land in a will or trust;
- changing the ownership of your land (e.g., trust) to make sure it is passed on according to your wishes;
- donating or selling a conservation easement/restriction on your land to eliminate development on some or all of it;
- donating or selling your land to a conservation organization.

Enroll your land in your state's current use tax program to help you keep the land undeveloped and reduce property taxes.

1.2 Action: Conserve resilient forests and the connections between them.

Determine whether your property is part of a resilient forest or serves as a connection between large areas of forest by working with a forester, a land trust, an open space committee, or a conservation commission to determine the landscape position and role your property plays. You can also refer to an online resource to determine your property's landscape position and role. See the Resources section of this publication for resources to help.

Conserving large, intact, and resilient forests, as well as the connections between them, helps plant and animal species move to suitable habitats that best fit their needs, even under climate extremes. These areas are also most likely to recover from extreme events, including droughts, ice storms, windstorms, insect outbreaks, and flooding. Though your land may not be thousands of acres in size, when combined with other properties it is part of an expansive landscape. When considering actions that may affect the connectivity of forested areas, it is important to see your land as part of the bigger landscape.

Work with your neighbors and local land trusts to encourage conservation of these large areas of land and the connections between them. Examples include inviting your neighbors to a walk of your land, hosting a neighborhood meeting to talk about the things you like about your neighborhood forests and ways to conserve them, reviewing maps and other information to better understand your land and the surrounding landscape, and connecting your neighbors with resources and local contacts so that they know their options for conserving their land.

Encourage conservation-based zoning that minimizes parcelization and forest fragmentation. Examples include low-impact development, cluster development, natural resource conservation zoning, and forest conservation zoning.

Encourage open space protection that builds on core areas of already conserved land in highly developed landscapes. In areas that are less developed, strive to build on core areas of protected and resilient land, and build connections between those areas.

Encourage municipal officials to get beyond planning and focus on reaching out to private landowners to help them understand their conservation options.

Importantly, the actions you adopt must also fit the overall goals for the land, as well as your available time, energy, and resources. Don't feel overwhelmed. Even choosing to do a single action can help ensure more resilient forests.

Goal 2: Reduce Stressors

2.1 Action: Prevent the introduction of invasive plants, remove small populations of existing ones, and learn to manage extensive areas of infestation.

Learn how to identify the most harmful invasive plants in your area, and look for them when you are out on your land. It is far cheaper, easier, and more effective to control a few individual plants than to try to treat a larger invasion.

Work with neighbors to control invasive plants, since controlling them on your land will do little if they are not controlled across the stone wall. Help your neighbors identify invasive plants, and share how you are working to control them.

Before implementing forest management, inventory for invasive plants, and plan for their control and management before you harvest trees. Allowing sunlight into a harvested forest will trigger invasive plant growth and encourage its spread.

Work to prevent the introduction of invasive species into your woods by cleaning clothing and boots that may carry seeds or fragments of invasive plants. When conducting a timber harvest, require the timber harvester to power-wash machines before entering your woods.

2.2 Action: Prevent the introduction of invasive insects and diseases, and limit the impact of existing ones.

Learn about damaging invasive insect species and diseases in the region, and monitor your woods and community. Report any sign of these pests and diseases to the appropriate agency. See the Resources section for contact information.

Implement strategies to slow the spread of invasive insects or reduce their impact (e.g., increase representation of nonhost species in the forest).

Some pests are spread unknowingly when firewood is moved. When camping, always buy your firewood from local sources rather than bringing it with you.

2.3 Action: Manage deer to ensure ample regeneration.

Leave treetops whole that have fallen to the ground or have been felled as part of a timber harvest in order to provide enough light for seedlings to grow while also sheltering them from browse.

Allow deer hunting to control deer populations and ensure forest regeneration.

Erect temporary fences in the woods around pockets of ecologically and economically important tree seedlings until they grow tall enough to avoid excessive browsing.

Apply deer repellants or physical barriers, such as plastic tubing or bud caps, to individual seedlings of desired tree species to minimize the effects of browse.

2.4 Action: Maintain or restore soil and water health.

Forestry best management practices

Work with a consulting forester to develop a contract with loggers that includes language about minimizing soil disturbance and using forestry best management practices. The contract should require a performance bond before the start of the timber harvest to ensure that the work is done according to the contract. A consulting forester can supervise the timber harvest to make sure that the requirements of the contract are being met. If the site isn't stabilized according to the contract, the performance bond provides the opportunity to pay someone else to properly stabilize the site.

Plan skid roads and trails to minimize their number and impact.

Work only during stable ground conditions, such as dry or frozen.

Stabilize the site after the job by installing water bars and seeding exposed soil with a cover crop.

Leave as many tops and limbs as possible to contribute to soil fertility and help stabilize slopes from erosion.

Recreation

Reduce the effects of ATVs by directing their use to appropriate locations, such as very sandy or rocky sites, and blocking entry points to other, more sensitive areas.

If your property sees moderate to heavy recreational use, ensure that users respect provided trails, install water-bar features, and discourage recreation in sensitive areas.

Goal 3: Reduce Vulnerability

3.1 Action: Promote diverse species of various sizes, ages and spatial arrangements.

Establish or maintain at least two age classes of trees by regenerating portions of your forest. Create gaps in the canopy to let sunlight reach the forest floor. The canopy gap size will depend on which species you are trying to regenerate. For example, sun-loving early-successional species need large gaps (>1/2 acre), whereas shade-tolerant late-successional species need gaps created by felling a single mature canopy tree.

Convert plantations to mixed woods with native tree species that are well adapted to the site.

3.2 Action: Promote the establishment of well-adapted species.

Beech-Birch-Maple Forest

On warmer, drier sites, such as south-facing slopes, promote drought-tolerant species such as red oak. On cooler, moister sites, such as northern slopes, continue promoting traditional northern hardwood species, such as sugar maple and yellow birch.

Oak-Hickory Forest

The species composition of transition hardwood forest types is typically a combination of species from central hardwoods and northern hardwood forests. Promote species from these forest types that prefer warmer sites, such as red and white oak, white pine, and black birch.

Oak-Pine Forest

Central hardwood species such as oak and hickory are well adapted to warmer, drier sites and therefore promote the central hardwood species that will best meet landowner or land manager goals.

Spruce-Fir Forest

Spruce fir is a very vulnerable forest type in southern New England. If you are working in this region and have spruce-fir forest on northern, cooler slopes, work to reduce stressors such as invasive plants and insects, and consider turning the area into a small reserve without any active forest management (see Goal 4 for a more detailed explanation), with the goal of maintaining this forest type. If you have spruce-fir forest on southern, warmer sites, promote species comparatively better adapted to the changing climate, such as northern hardwood species.

In northern New England, this forest type exists across a diversity of landscape settings and is comparatively less vulnerable to future changes in climate than southern populations. Nonetheless, other stressors, namely spruce budworm, pose greater immediate threats to these forests, and the use of management strategies that promote mixed-wood conditions can minimize their impacts.

Pitch Pine–Scrub Oak Forest

Pitch pine and scrub oak are well adapted to drought and heat. Maintain both of these current species, which are predicted to do well.

This type of forest is fire dependent, meaning it needs periodic fires to regenerate itself. Without periodic fires, these forests turn into closed-canopy, mixed white pine–hardwood forests. Where politically feasible, a prescribed burn will help maintain this important and unique forest type and may be the most efficient way to remove forest fuels before they accumulate to dangerous levels. Note, however, that extreme care must be taken, including proper permitting and preparation. Contact your local fire department about fire regulations.

If prescribed burns are not feasible, enhancement plantings of pitch pine in combination with treatments to reduce the abundance of competing oak species may help maintain this forest type.

3.3 Action: Reduce the proportion of trees that host invasive insects and diseases.

Reduce the number of trees that serve as host species for invasive insects and diseases in a manner that considers the overall health and function of your forest. Removal of host species from the canopy without accounting for long-term impacts on forest regeneration and understory plant communities could cause unwanted changes to your forest. As such, their removal should be part of regeneration harvests or thinning treatments designed to encourage the establishment and growth of nonhost tree species that meet your long-term objectives. Work to prevent the introduction of invasive species into your woods by cleaning clothing and boots that may carry seeds or fragments of invasive plants. When conducting a timber harvest, require the timber harvester to power-wash machines before entering your woods.

3.4 Action: Reduce stem crowding to increase forest vigor.

Thinning your woods will decrease tree competition for sun, water, and growing space and increase the vigor of the trees that remain. Thin areas of the forest that are crowded, leaving trees of good vigor and desirable species that help you meet your overall goals for the land. The intensity of thinning can also be varied across your forest to create a range of spatial conditions and environments.

3.5 and 3.6 Actions: Increase the amount of large snags and logs.

Take a passive approach and allow the forest to accumulate deadwood over time, as trees die from storm impacts and insects. Note, however, that it will likely take decades for these natural processes to accumulate a critical amount of deadwood (see next bullet).

Reduce the amount of time it takes to develop snags and downed wood by taking an active approach: create standing deadwood by girdling low-quality trees, and create downed deadwood by felling and leaving low-quality trees to serve as large logs on the ground.

Protect deadwood during a timber harvest. Contracts should specify that snags should be left standing and downed deadwood should not be removed from the woods.

3.7 Action: Restore and protect riparian areas.

Allow areas next to rivers, streams, and other water resources to regrow into forests in order to provide soil stability and shade to keep streams cool. In addition, forests add twigs, branches, leaves, and logs into the stream to provide food and in-stream structure for fish and other aquatic species.

If having a timber harvest, follow the best management practices (BMPs) for streamside areas. See the Resources section for BMP resources in your state.

Goal 4: Provide Refuge

4.1 Action: Protect threatened, endangered, and at-risk species.

Determine if your land contains any threatened, endangered, and at-risk species, and identify measures that you can take to ensure their survival.

Prioritize these areas for land protection, open space planning, and conservation zoning efforts.

Sometimes the best way to conserve something is through taking a passive approach to forest stewardship. Small reserves are small areas of unmanaged forest surrounding important ecological resources. These reserves can be as small as 10–15 trees or as large as dozens of acres. Place reserves around rare plants, endangered species habitats, areas of high diversity, and high-value habitat features (e.g., vernal pools). Mark reserves in the field with paint, and note the locations on a map to ensure they are maintained through time.

4.2 Action: Harbor species that are at risk of being lost from the landscape.

Areas of diverse topography (e.g., mountains, hills, and valleys) create microclimates that are different from the general climate of the area. These microclimates provide the opportunity for plant and animal species to find suitable habitats to meet their needs. These microclimates are most effective at providing a refuge for species when they are part of large intact forests that are connected to other large areas of forest, allowing plants and animals to move through the landscape and access these microclimates. For example, red spruce is predicted to be less competitive in Massachusetts because it prefers cooler growing conditions, but northern slopes may provide a microclimate that is cooler than the surrounding area, providing an opportunity for red spruce to persist in the Massachusetts landscape.

Conserve resilient areas of diverse topography, geology, and local connectivity to provide options to plant and animal species. Refer to mapping tools identifying resilient lands, and work with neighbors, local officials, and land trusts to maximize the conservation of resilient lands.

Identify tree species and other natural communities at risk of being lost from the landscape that are currently growing in areas well suited to sustaining those species, and take action to conserve those species. This may mean designating an area as a reserve in the hopes that it will persist, or promoting its survival through active forest management.

Conserve resilient areas of diverse topography, geology, and local connectivity to provide options to plant and animal species.

Step 3

Monitor and Evaluate

Your forest is a dynamic ecosystem that is constantly changing. In addition, the stressors facing your forest will continue to advance and evolve.

Monitoring your forest helps early detection of stressors, giving time for remedial actions. Monitoring can also determine whether or not past conservation practices achieved the desired goals. Don't assume your actions were successful! Further actions may be needed.

If new stressors or vulnerabilities arise or past actions have not led to your desired outcomes, revisit Steps 1 and 2 to determine your options to address stressors and increase forest resilience.

Evaluating and monitoring your forest can be done either informally or formally.

Have your forest evaluated by a forester. This can be done informally with a walk-through of your forest or formally through an inventory of natural resources, done by collecting data and information at a number of inventory plots spread throughout the forest. Periodic inventories will help you monitor and track changes over time—both positive and negative.

Monitor and evaluate your forest through periodic hikes, which are also excellent opportunities to engage your friends, neighbors, and community members by inviting them along.

Characteristics of **Resilient Forests**

Formal plans for the future of the property

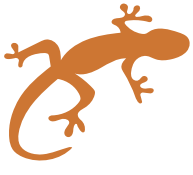
Minimal forest stress from invasive plants, insects, and diseases, and deer

High Forest Complexity

- ✔ **Diversity** of tree species
- ✔ Ample tree **regeneration** of future-adapted species
- ✔ Vigorous trees of **various sizes and ages**
- ✔ **Variety** of tree arrangements
- ✔ Appropriate amount of **deadwood**

Healthy soil and water

Protected threatened, endangered, and at-risk species



Step 1

Assess Forest Resiliency

(Check all that apply)

GOAL 1 Keep Forest Forested and Connected

- ☐ 1.1: Formal plans have NOT been made to keep the forest as forest
- ☐ 1.2: The property is either part of a resilient forest or connected to large areas of forest

GOAL 2 Reduce Stressors

- ☐ 2.1: Invasive plants are found on or near the property
- ☐ 2.2: Invasive insects or tree diseases are found on or near the property
- ☐ 2.3: There are significant effects from deer on the vegetation
- ☐ 2.4: There is significant soil compaction or erosion

GOAL 3 Reduce Vulnerability

- ☐ 3.1: The forest does NOT have many different types of tree species of various sizes, ages, and spatial arrangements
- ☐ 3.2: The forest does NOT have young trees predicted to be well adapted to future conditions
- ☐ 3.3: The forest has a high abundance of preferred host species for invasive insects or diseases
- ☐ 3.4: The forest has areas with dense, crowded tree stems
- ☐ 3.5: There are NOT 5 or more large snags (>16" diameter) per acre
- ☐ 3.6: There are NOT 5 or more large logs (>16" diameter) per acre
- ☐ 3.7: Water resources do NOT have forested buffers

GOAL 4 Provide Refuge

- ☐ 4.1: The property includes threatened, endangered, or at-risk species
- ☐ 4.2: The property can harbor species that we may lose from the landscape

Step 2

Increase Forest Resiliency

(Implement the corresponding action for each statement chosen)

GOAL 1 Keep Forest Forested and Connected

ACTIONS

- 1.1: Engage in conservation-based estate planning
- 1.2: Conserve resilient forests and the connections between them

GOAL 2 Reduce Stressors

ACTIONS

- 2.1: Identify and remove invasive plants, and prevent their introduction
- 2.2: Monitor for invasive insects and diseases, and implement measures to control or slow their spread
- 2.3: Manage deer to ensure ample regeneration
- 2.4: Maintain or restore soil and water health by avoiding soil compaction, stabilizing accelerated erosion, and establishing forested buffers around water resources

GOAL 3 Reduce Vulnerability

ACTIONS

- 3.1: Maintain and/or promote diverse species, sizes, ages, and spatial arrangements
- 3.2: Promote the establishment of tree species predicted to be well adapted to future moisture and temperature conditions
- 3.3: Increase the representation of nonhost tree species
- 3.4: Reduce stem crowding by thinning to concentrate limited resources on remaining trees in order to increase forest vigor
- 3.5: Increase the amount of large snags
- 3.6: Increase the amount of large logs
- 3.7: Establish forested buffers around all water resources

GOAL 4 Provide Refuge

ACTIONS

- 4.1: Protect threatened, endangered, and at-risk species
- 4.2: Identify areas of your land that may support species predicted to not do well, and establish small reserves around these and other areas of high ecological value

Step 3

Monitor and Evaluate

Evaluate past conservation actions to ensure that the goals have been reached

Monitor your woods for stressors and vulnerabilities

Revisit Steps 1 and 2 if past actions haven't achieved goals or new stressors or vulnerabilities arise

Step 1 **Assess** Forest Resiliency

Step 2 **Increase** Forest Resiliency

Conclusion

Change in forests is natural and healthy, yet it is likely that we are at a time when the number of stressors facing our forests is greater than it has ever been. In addition, the pace with which the stressors are arising is increasing. These pressures threaten the personal benefits that forests provide to their owners as well as the many benefits they provide to the public.

All forests have particular characteristics that make them resilient and others that make them vulnerable to stressors. We can increase the resiliency of our forests by evaluating these characteristics and implementing actions to address the vulnerabilities. Taking even one single action can have a major impact on your land and the landscape around you. There are many excellent resources and people working locally that can help.

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Resources

Steps 1 and 2: Assess and Increase Forest Resiliency

Goal 1: Keep Forest Forested and Connected

- Conservation-based estate planning:
  - *Your Land, Your Legacy: Deciding the Future of Your Land to Meet the Needs of You and Your Family*, UMass Extension: masswoods.net/sites/masswoods.net/files/pdf-doc-ppt/YLYL-2-web_0.pdf
  - *Creating a Legacy: A Guide to Planning Your Land's Future*, Small Woodland Owners Association of Maine: www.swoam.org/Store.aspx#!/Creating-a-Legacy-A-Guide-to-Planning-Your-Lands-Future/p/43784141/category=2796143
  - Ties to the Land, Oregon State University: http://tiestotheland.org/

- Find a land trust:
  - Connecticut: www.ctconservation.org/findalandtrust
  - Maine: www.mltn.org/search.php
  - Massachusetts: masswoods.net/professionals
  - New Hampshire: http://nhltc.org/find-land-trust
  - Rhode Island: www.rilandtrusts.org/landTrusts.htm
  - Vermont: www.vlt.org/

- State current use tax programs:
  - Connecticut: www.ct.gov/deep/cwp/view.asp?a=2697&q=322788&depNav_GID=1631
  - Maine: www.maine.gov/revenue/propertytax/propertytaxbenefits/current_use.htm
  - Massachusetts: masswoods.net/landowner-programs/chapter-61-current-use-tax-programs
  - New Hampshire: http://extension.unh.edu/current-use-taxes
  - Rhode Island: www.dem.ri.gov/programs/bnatres/forest/pdf/citgui03.pdf
  - Vermont: http://fpr.vermont.gov/forest/your_woods/use_value_appraisal

Goal 2: Reduce Stressors

Invasive Plants

- Invasive Plant Atlas of New England: www.eddmaps.org/ipane/
- USDA Forest Service, Northeastern Area: Forest Health Protection—Invasive Plants: http://na.fs.fed.us/fhp/invasive_plants/index.shtm
- Picking Our Battles: Planning Successful Invasive Plant Management Projects: www.wildlife.state.nh.us/invasives/
- Vermont Invasives: www.vtinvasives.org/

Forest Pests and Diseases

- USDA Forest Service, Pest Alerts: http://na.fs.fed.us/pubs/palerts.shtm
- USDA Forest Service, Forest Health Protection: Forest Pest Conditions Interactive Map: http://foresthealth.fs.usda.gov/portal/Flex/FPC
- Massachusetts Invasive Pests Outreach Project: massnrc.org/pests/factsheets.htm
- Don't Move Firewood: www.dontmovefirewood.org/

Deer

- USDA Forest Service, White-Tailed Deer in Northeastern Forests: Understanding and Assessing Impacts: www.na.fs.fed.us/pubs/2014/NA-IN-02-14_WhitetailedDeerNEForestsWEB.pdf

Forestry Best Management Practices

- Connecticut: www.ct.gov/deep
- Maine: www.maine.gov/dacf/mfs/publications/handbooks_guides/bmp_manual.html
- Massachusetts: https://masswoods.net
- New Hampshire: www.goodforestry.org
- Rhode Island: www.timbersource.com/prices/RIBMP.pdf
- Vermont: fpr.vermont.gov/forest/your_woods/voluntary_harvesting_guidelines

Riparian Forest Buffers:

- USDA Forest Service, Riparian Forest Buffers: www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm

Goal 3: Reduce Vulnerability

Promoting Complex Forests

- Find a forester:
    - Connecticut: www.ct.gov/deep/cwp/view.asp?a=2697&q=329934&deepNav_GID=1631#Service
    - Maine: www.maine.gov/dacf/mfs/policy_management/district_foresters.html
    - Massachusetts: masswoods.net/professionals
    - New Hampshire: http://extension.unh.edu/Contact-Forestry-and-Wildlife-Staff
    - Rhode Island: www.dem.ri.gov/programs/bnatres/forest/pdf/forester.pdf
    - Vermont: http://fpr.vermont.gov/forest/your_woods/county_forest/who_where

Climate Change and Forest Resiliency

- New England Climate Change Response Framework: http://forestadaptation.org/new-england
- Climate Change Tree Atlas: www.fs.fed.us/nrs/atlas/
- Northern Institute of Applied Climate Science: www.nrs.fs.fed.us/niacs/
- USDA Northeast Climate Hub: www.climatehubs.oce.usda.gov/northeast
- Creating and Maintaining Resilient Forests in Vermont: http://fpr.vermont.gov/node/1250

Goal 4: Provide Refuge

- State endangered species programs:
  - Connecticut: www.ct.gov/deep/cwp/view.asp?a=2702&q=323486
  - Maine: www.maine.gov/ifw/wildlife/endangered/index.html
  - Massachusetts: www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/
  - New Hampshire: www.wildlife.state.nh.us/nongame/endangered-list.html
  - Rhode Island: http://rinhs.org/
  - Vermont: www.vtfishandwildlife.com/learn_more/critter_cirriculum/endangered_and_threatened_species
- Massachusetts Wildlife, Climate Action Tool: https://climateactiontool.org/
- Understand the resilience of your land and the role it plays in your landscape:
  - The Nature Conservancy, Analysis of Resilient Sites for Conservation: maps.tnc.org/resilientland
  - North Atlantic Landscape Conservation Cooperative: https://nalcc.databasin.org/
  - Mapping and Prioritizing Parcels for Resilience Project (Massachusetts): www.massaudubon.org/our-conservation-work/advocacy/shaping-the-future-sustainable-planning/current-projects/mappr-project

Step 3: Monitor and Evaluate

- Wildlands and Woodlands, Stewardship Science: www.wildlandsandwoodlands.org/science-initiatives/stewardship-science
- USDA Forest Service, Naturewatchers—Citizen Science: www.fs.fed.us/outdoors/naturewatch/topics/citizen-science.php
- USA National Phenology Network: www.usanpn.org/

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The University of Vermont

NECSC Northeast Climate Science Center

NIACS Northern Institute of Applied Climate Science