REGIONAL FOREST HEALTH MONITORING PROGRAM

2023 Report

Forest Ecosystem Monitoring Cooperative

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Regional Forest Health Monitoring Program: 2023 Report

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Executive Summary

Forest health monitoring is a critical tool for understanding how forests change and respond to stressors such as climate change, invasive species, pests and pathogens, and land use. As these stressors become more prevalent in the Northeast, robust, annual forest health monitoring can provide important insights on how these disturbances are affecting forests in the region.

Many forest monitoring programs revisit sites in 5-10 year intervals, which does not allow for the observation of small-scale temporal changes in response to specific events or outbreaks. A significant defoliation event, or a forest's subsequent response to it, may be missed in the longer cycles of typical forest health monitoring programs.

Annual forest health monitoring programs, like FEMC's regional program, can help capture subtle changes and long-term trends in forest composition and condition—patterns that other, longer interval programs may struggle to detect (Bechtold et al., 2007). Additionally, the health of mature, overstory trees in the forest can be tracked by measuring annual diameter and height, evaluating canopy condition, determining the overall vigor, and identifying specific damages and diseases. Changes in forest composition can also be assessed by tracking regeneration, growth, and mortality patterns year to year. Monitoring the prevalence of invasive pests, pathogens, and animal browse is also important, as this can provide further understanding of the impacts of common stressors on forest health and condition. Understanding how our forests are changing and how those changes affect forest health provides critical information for mitigation and adaptation strategies; this information can also help ensure the sustained provisioning of key ecosystem services in the face of a changing climate.

By the 2022 field season, the Forest Ecosystem Monitoring Cooperative (FEMC) had worked with state partners in Connecticut, New Hampshire, New York, Maine, Massachusetts, and Rhode Island to expand the Forest Health Monitoring (FHM) network beyond the existing VT network to include permanent plots in each of the seven northeastern states. In most cases, these FHM plots were co-located with each state's existing Continuous Forest Inventory (CFI) or Forest Inventory and Analysis (FIA) plot network and were designed to complement the state's network with annual measurements (vs. the more typical 5- to 10-year rotation for re-measurements) on a subset of existing FIA or CFI plots. Replicating these protocols from CFI and FIA plots allows easy comparison with data from other long-term monitoring programs, thus expanding the impact of FEMC data.

In 2023, FEMC visited all 196 plots from CT (15), MA (25), ME (35), NH (25), NY (40), RI (7), and VT (49) to measure and monitor forest health metrics. Results from the 2023 monitoring season indicate that the most abundant species across the 196-plot network were red maple (*Acer rubrum*; 17% calculated from stems per acre), sugar maple (*Acer saccharum*; 13%), and balsam fir (*Abies balsamea*; 9%). From the 6,759 trees (≥5 inch DBH*) measured, average live overstory tree density in 2023 was 176 stems per acre (SPA) and 127 ft^2/ac basal area. Regeneration assessments show sapling densities of 3,169 live SPA with balsam fir and American beech (*Fagus grandifolia*) representing the most abundant species. Red maple was the most abundant seedling tallied in 2023 (36% composition, 5,493 SPA), followed by balsam fir (14%, 2,184 SPA), and sugar maple (13%, 2,009 SPA).

*DBH = Diameter at breast height

While there is a wide range of stressors and vulnerabilities impacting northeastern forests, data from the 2023 season suggest that the region's forests are overall diverse, vigorous, and healthy. However, there were notable exceptions that should continue to be monitored. From the 2023 crown health assessments, we identified black oak (*Quercus velutina*), American beech, and white oak (*Quercus alba*) as species of concern. Average vigor ratings for these species were 1.8, 1.9 and 1.5 respectively, where 1 is healthy and 4 is severe decline (Table 1). Average defoliation ratings for the same species were 0.9, 0.6, and 0.9, respectively, where 0 is no to trace defoliation, 1 is less than 30 percent crown defoliated, and 2 is 30-60% defoliation (Table 2). The average percent of fine twig dieback for these species was 17, 17, and 11% of the tree crown. With the recent spongy moth outbreaks across the Northeast, we recorded 11% of oaks with >30% defoliation. Seedling regeneration was also sparse for swamp white oak (*Quercus bicolor*; 0 SPA), slippery elm (*Ulmus rubra;* 0 SPA), and shagbark hickory (Carya ovata; 0 SPA). This highlights the importance of continuing annual assessments to better understand trends, patterns, and drivers of change for each state's forested ecosystems, especially focusing on tree species that are vulnerable to a changing climate, disturbances, and/or diseases.

Background

Northeastern forests currently face multiple threats, including various invasive species, vector-borne diseases, abiotic damages, and other forest health concerns. Common insects of concern for northeastern forests include the Asian longhorned beetle (*Anoplophora glabripennis*), eastern spruce budworm (*Choristoneura fumiferana*), emerald ash borer (EAB; *Agrilus planipennis*), hemlock woolly adelgid (HWA; *Adelges tsugae*), elongate hemlock scale (*Fiorinia externa*), southern pine beetle (*Dendroctonus frontalis*), and spongy moth (*Lymantria dispar dispar*; USFS, 2022). Combined with invasive insects, various diseases have been primary concerns for northeastern forest health, including beech leaf disease, oak wilt, and white pine needle damage (USFS, 2022).

Of the insects listed, EAB, HWA, and spongy moth remain insects of high concern. In 2022, EAB was rated the "top tree killing agent recorded in the Eastern Region," with new annual detections in Vermont (USFS, 2021 and 2022). However, various management practices are being implemented to reduce the spread of EAB in the Northeast. Such management practices include biocontrol management, which is underway through the release of parasitoid wasps (*Oobius agrili*, *Tetrastichus panipennisi*), who prey on EAB in the Eastern Region (USFS, 2022). New Hampshire is taking an Integrated Pest Management (IPM) approach, wherein researchers and resource managers are locating and collecting seeds from remaining healthy, mature white ash trees with the aim of cultivating ash trees with resistance or an increased tolerance to EAB (USFS, 2022).

HWA has continued to persist in the southern part of FEMC region, particularly in the Finger Lakes and Catskills of New York and the southern New England states. With the trend of milder winters due to climate change, overwintering HWA mortality rates may not reach the estimated threshold of ninety percent to maintain or decrease HWA populations (USFS, 2022).

Spongy moth also remains a concern in the Northeast. Specific hotspots in western Massachusetts and western Connecticut indicate high levels of spongy moth egg mass counts (CT) and significant defoliation (MA; USFS, 2022). However, recent surveys suggest a possible decrease in populations of spongy moth; elevated levels of NPV (nucleopolyhedrosis virus), *Entomophaga maimaiga*, and insect predation are likely causes for reduced spongy moth populations. In New Hampshire and Vermont, larval mortality has increased due to both the fungi (both VT and NH) and the virus (NH).

Tree diseases are common and detrimental to northeastern forest health, and several operate in concert with invasive insects. A prime example of invasive insects and fungal pathogens working together to create a devastating disease for northeastern forests is beech bark disease (BBD), which is the combined result of the scale insect (*Cryptococcus fagisuga*) and the fungal invasion of *Neonectria*. In North America, a typical forest stand will range from an 80-90% infection rate for American beech infected with BBD, with approximately 50% of American beech either dead or dying from BBD (Stephanson and Coe, 2017). Currently, researchers and natural resource managers are exploring resistant genetics in American beech against BBD as well as mapping habitat ranges and the expansion of BBD in future years (Stephanson and Coe, 2017). Considering that American beech is one of the most prolific seed dispersers through biennial masting and provides an important food resource for wildlife (Lamere, McNulty, & Hurst, 2011), the negative impact of BBD on American beech, combined with climate change, can have a detrimental, cascading effect on other aspects of northeastern ecosystems.

Another prevalent disease is Beech Leaf Disease (BLD), which has been spreading throughout the Northeast since 2012, likely due to *Litylenchus crenatae* spp. *maccannii*, a foliar nematode. As of 2022, 27 new counties in FEMC region have encountered new cases of BLD, including every county in Connecticut, Massachusetts, and Rhode Island, and new cases in New Hampshire (USFS, 2022). Despite the rapid BLD expansion, there are ongoing efforts to manage BLD through a pesticide trial of PolyPhosphite 30, which will continue to be studied in experimental plots (USFS, 2022).

Another third common disease in northeastern forests is white pine needle damage (WPND), which is present in all FEMC regional states to an extent, and most common in Vermont and Massachusetts. WPND is known to have multiple causal agents, including brown spot needle blight (*Lecanosticta acicula*, most common causal agent), Dooks needle blight (*Lophophacidium dooksii*), needle cast (caused by *Bifusella linearis*), and *Septorioides strobi* (USFS, 2022). Warmer winters and wetter springs are believed to be contributing factors to fungal growth and dispersal for WPND; however, despite dryer springs over the past few years, the prevalence of WPND has remained relatively constant. In 2022, Vermont experienced substantial yellowing and needle-drop in white pines while Massachusetts observed crown discoloration, thinning canopies (USFS, 2022); as a result, we expect that FEMC states will continue to experience WPND symptoms in the near future.

Finally, oak wilt (*Bretziella fagacearum*) is of some concern within FEMC region but is only prevalent in a few counties in New York with no recent counties observing new cases (USFS, 2022).

Invasive plant species are also a concern for northeastern forest health. Since invasive plants act as aggressive colonizers, they can outcompete indigenous plants while degrading habitat for wildlife, reducing plant diversity, degrading water quality, and increasing soil erosion. Examples of common invasive plant species in FEMC region include glossy buckthorn (*Frangula alnus*), common buckthorn (*Rhamnus cathartica*), Japanese barberry (*Berberis thunbergii*), multifloral rose (*Rosa multiflora*), kudzu (Pueraria montana var. *lobata*), and Japanese honeysuckle (*Lonicera japonica*; USFS, 2022). Management of invasive species continues to progress. For example, Vermont has established the Forest Health Invasive Plant Program (IPP), which advocates for research, outreach, and management projects through funding, and has been motivating community engagement on invasive plant management and education since 2014 (USFS, 2022).

With the combination of both invasive insects and disease, abiotic damages can cause enhanced and significant mortality for northeastern forest ecosystems. Most often, trees that are damaged from abiotic stressors—including frost damage, drought, saltwater intrusion (a more important issue in coastal areas than in FEMC plots), fire, wind, and flooding—are more susceptible to infection of invasive insects and diseases. For example, Maine experienced severe drought resulting in higher incidences of stress-related cankers on trees, early senescence, fall needle drop on pines, declines in oak health, and overall tree mortality (USFS, 2022). Other states, such as Rhode Island, experienced brief torrents that broke a 3-year drought but were interspersed with dry spells that kept the state's annual precipitation levels below average (USFS, 2022). With the rising concerns of the effect of climate change on forest ecosystems, abiotic damages are likely to remain consistent causal agents of tree mortality for northeastern forest ecosystems.

In 1990, a national Forest Health Monitoring program was established by the U.S. Forest Service to monitor forest health and detect emerging threats (Bechtold et al., 2007). The program had three main objectives: 1) to identify deteriorating conditions in forest ecosystems; 2) to monitor forest ecosystem resources, specifically where conditions are deteriorating; and 3) to comprehend the intricate complexities behind forest health problems (Bechtold et al., 2007). Plots consisting of four fixed area subplots, each measuring 7.32 m (24 ft) in radius, were initially set up across six northeastern states. Eventually, the program was expanded to 45 states (Bechtold et al., 2007). Since 1999, Forest Health Monitoring (FHM) field plots have been integrated into the ground plot network maintained by the US Forest Service's Forest Inventory and Analysis (FIA) program. Continuous Forest Inventory (CFI) networks have also been established across the region by various state and public agencies. The FIA program assesses demography and forest utilization trends (Gillespie, 2000). CFI programs record similar metrics to assess timber stocks and yields. For both FIA and CFI programs, periodic inventories are designed to assess a subset of plots each year to capture changes over time across a large network of plots (Gillespie, 1998). FIA programs run on 5–7-year re-measurement cycles (USFS, 2013), while CFI rotations vary by agency but typically follow a 10-year return cycle (Nevins et al., 2019).

Annual plot assessments can better capture year-to-year changes that can fluctuate due to weather, disturbance, or pest and pathogen outbreaks. While periodic inventories, like the FIA and CFI programs described previously, allow for a larger number of total plots across the landscape, this is accomplished at the expense of the information revealed by annual inventories.

In response to this need for more detailed annual measurements to provide a more nuanced and informative understanding of forest health, the FEMC established 49 FHM plots spanning Vermont's forest types and biophysical regions between 1991 and 2018. For each plot, FHM technicians annually assess tree demography, canopy condition, seedling abundance, sapling survivorship, invasive species, browse presence, and damage agents. These metrics were selected to provide information on early symptoms of tree stress and changes in forest structure and composition. The information obtained from FEMC FHM program provides timely assessments of current forest conditions and emerging trends while complementing other forest assessment programs that have longer re-measurement cycles, such as the FIA and CFI programs.

After successfully establishing and conducting annual assessments on FHM plots in Vermont for almost three decades, FEMC expanded its FHM program into surrounding states to yield a more complete picture of forest health across the New England and New York region. In 2019, FEMC collaborated with MA DCR to establish FHM plots on MA state and private lands to add to its annual FHM network. Following a similar approach in 2020 and 2021, FEMC expanded efforts to establish permanent plots in CT (15 plots), ME (35 plots), NH (25 plots), and NY (40 plots), and RI (7 plots). To improve comparability and utility of each program, the FHM plots were co-located at established, long-term plot locations, representing the major forest types and geographies on public and private lands in each state. Co-locating FHM plots with the FIA and CFI networks provides FEMC FHM program with access to historic long-term data that may give insight into previous land use, forest health, and large-scale changes that have occurred over time. The state and federal programs will have access to annual measurements on a subset of plots to better understand year-to-year changes and detect emerging forest health issues. This report provides details on FEMC FHM program and plot selection, and highlights findings from the 2023 FEMC FHM field season.

FEMC is also actively pursuing efforts to integrate current and past land histories and cultures of Indigenous peoples into its work. FEMC recognizes that its region consists of unceded lands of approximately 50 Indigenous nations. FEMC also recognizes the historical and ongoing violence inflicted by Western colonial powers on these lands and peoples, including attempts to erase their traditions, culture, and knowledge. FEMC is committed to including consideration of both this history and ongoing colonization and land dispossession in its work; incorporating and amplifying Indigenous voices in projects and organizational governance; including different ways of knowing in its science; and explicitly recognizing the history of Indigenous peoples in its many fora, from meetings to publications. FEMC acknowledges that this is merely a first step in an ongoing process of justice.

Methodology

Plot selection

All plots were in place prior to the 2023 season (Figure 1).

In expanding the FHM Network from a Vermont-only network to a region-wide network in 2021 and 2022, FEMC opted to for a similar sampling concentration of plots in each state as was established in VT. FEMC partnered with various organizations and agencies within each of the seven regional states to gather existing long-term monitoring plot information. Nesting FHM plots on top of or adjacent to these existing networks when available allows for temporal comparisons of metrics monitored at the site.

In addition to plots co-sited with existing FIA and CFI plot networks where possible, new plots were established where current networks did not exist or where certain forest types were underrepresented by existing plot locations.

State partners reviewed plot locations, and changes were made based on plot access, incorrect forest type designation, management considerations, and other factors. The final location review was confirmed or amended by the crew as they visited each plot for the first time during the field season. Individual plots may be moved in future years based upon feedback from the field crew and review of the data.

Previous reports provide additional detail regarding plot selection and establishment (Wilmot et al., 2019; Sirch et al., 2020; Porter et al., 2022).

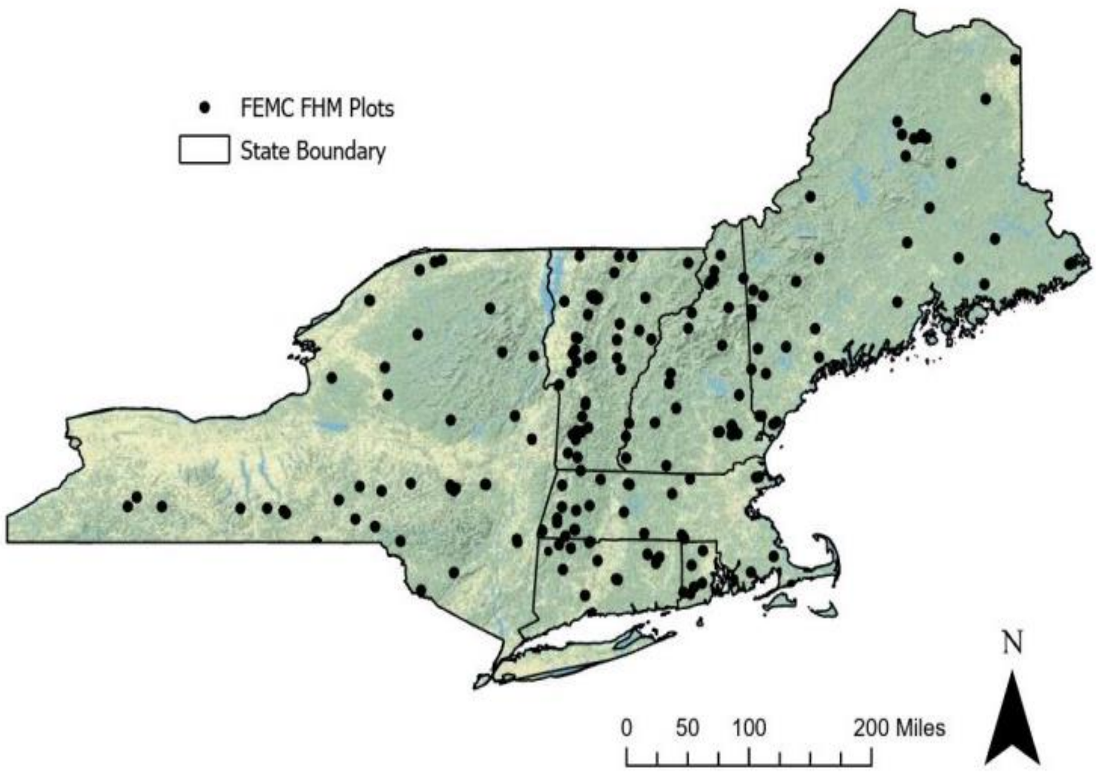

Figure 1. One hundred and ninety-six (196) plot locations were included in the total FHM analysis. As of 2023, our regional states include Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont.

Plot layout

Clustered (FIA) Style

New Hampshire, Rhode Island, and Vermont FHM plots follow the layout shown in Figure 2, mirroring the FIA plot layout. The clustered plot style consists of 4 subplots, each with a 24-ft radius and area of 1809.6 ft^2, and one nested regeneration microplot each with a radius of 6.8 feet and an area of 145.3 ft^2 (Figure 2). The four regeneration microplots are 12 feet from the subplot center at the 90° (referenced to true north). Three subplots radiate from a central subplot 120° apart, 120 feet from the center of subplot 1. To maintain continuity with historical inventories on these plots, FEMC utilized this same plot design for the plots in New Hampshire, Rhode Island, and Vermont. As it is critical that regeneration subplot locations remain consistent for annual assessments, FEMC technicians marked the regeneration subplot centers of the plots with fiberglass or wooden dowel stakes.

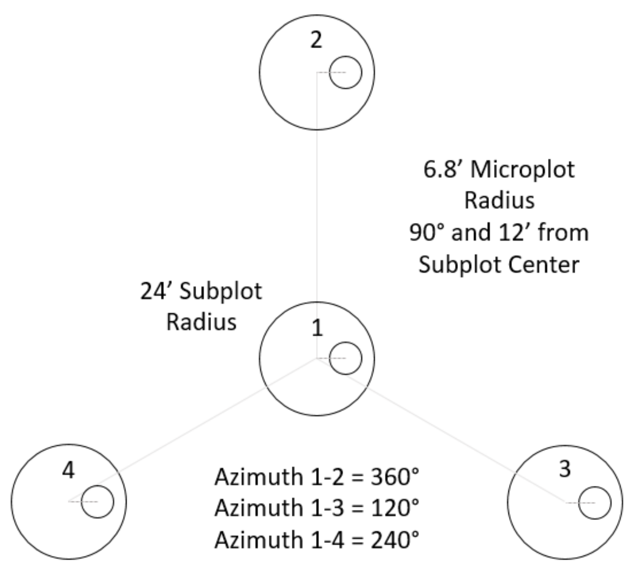

Figure 2. Layout of Clustered-Style FIA and FEMC FHM plots showing the 4 clustered subplots and four regeneration micro-plots within each.

Larger Nested (CFI) Plot Style

Connecticut, Massachusetts, Maine, and New York FHM plots are laid out based on the larger nested style. The large plot style consists of one large overstory plot, with a radius of 52.7 feet and area of 8,725.11 ft^2, and four nested regeneration microplots each with a radius of 6 feet and an area of 113.1 ft^2 (Figure 3). The four regeneration microplots are 26 feet from the overstory plot center at the cardinal directions (referenced to true north). To maintain continuity with historical inventories on these plots, FEMC utilized this same plot design for the plots in Connecticut, Massachusetts, Maine, and New York. State CFI plots typically have the overstory plot center permanently marked, but not the locations of the regeneration subplots. Similar to the clustered style, FEMC technicians marked the regeneration subplot centers of the plots with fiberglass or wooden dowel stakes.

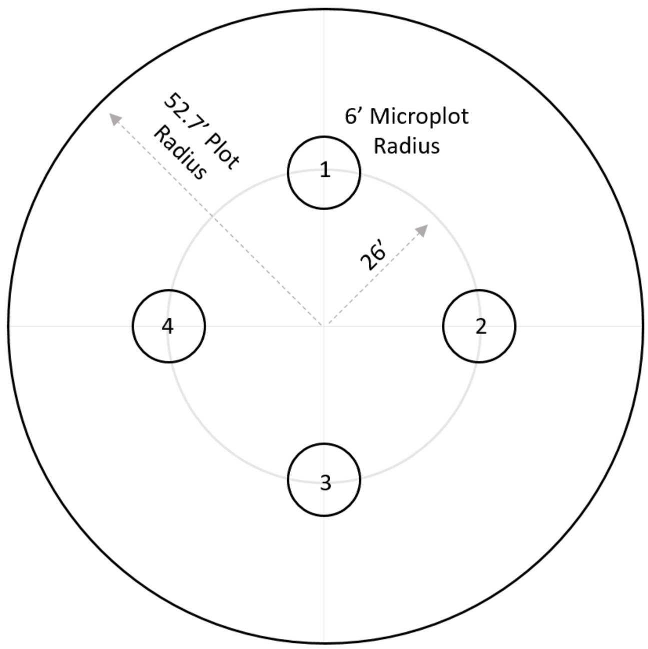

Figure 3. Layout of Nested-Style CFI and FEMC FHM plots showing the overstory plot (large circle) and four nested regeneration micro-plots (small circles at cardinal directions; MA DCR 2014).

Field metrics

In 2023 FEMC inventoried all 196 plots across Connecticut, Massachusetts, Maine, New Hampshire, New York, Rhode Island, and Vermont. All metrics have been outlined in the FEMC FHM protocol (Wilmot et al., 2019). These metrics include assessments of tree biometry and health in the overstory plot, regeneration assessments that include seedling tallies by species and size class, and sapling biometry and health (e.g., species, diameter, status) assessments in the four subplots (Wilmot et al., 2019). Other metrics, like animal browse, invasive plants, and forest composition (prism plots), were collected at the overstory plot level. Detailed methods for each metric are provided below.

Field crew and calibration

During the 2023 FHM field season, three crews consisting of 3-4 technicians conducted monitoring in Massachusetts, New Hampshire, New York, and Vermont. Crews from the Connecticut Agricultural Experiment Station completed plots in Connecticut and Rhode Island; the Maine Department of Agriculture, Conservation and Forestry conducted monitoring in Maine. These crews were properly trained by Vermont Forests, Parks, and Recreation (FPR) personnel on forest health metrics before the FHM field season. FPR forest health specialists also led calibration of crew members conducting crown health assessments to ensure standardization of ratings from year-to-year. Additionally, all technicians were informed of FEMC's standard operating procedure, including inclusivity and outdoor safety while in the field. All technicians were trained in the use of forestry equipment, such as DBH tapes, hypsometers, compasses, GPS units, remote tablets for data entry, prisms, and other tools.

Tree biometry and health

Within the overstory subplots, FEMC FHM technicians assessed all trees ≥5 in. diameter at breast height (DBH, measured at 4.5 feet). On most plots, each sampled tree within the overstory subplots were either marked with paint or a bark scoring to signify the tree is within the subplot radius and should be sampled. Some plots were left with unmarked trees where limited disturbance was preferred by landowners. Distance and azimuth from the plot center were recorded for each individual tree for future inventories. Any new trees (in-growth) were assessed, assigned a number, and mapped. Species, DBH, height, special damages, vigor, and crown health assessments were recorded for all trees.

Diameter and height

Diameters of all trees were measured at traditional breast height (4.5 ft from the ground), following the guidelines in the FEMC FHM protocol (Wilmot et al., 2019). Heights were assessed to the top of the tree, regardless of whether the tallest leader was alive or dead. If applicable, the amount of dead top was recorded. The length of the live crown was also measured. Trees marked with a paint line at DBH are measured using a "modified" DBH approach in future years. Trees marked with this method were painted at DBH and will be measured along that line in future years to account for tree growth and to track changes over time. Trees without painted lines will be measured using the traditional DBH method, measuring 4.5 ft up from the ground.

Special Damages

For each tree in the overstory plot, any recent bole or crown damage was recorded, if obvious. Note that this damage assessment was not comprehensive, and some damage may not have been recorded if it was not obvious to a technician from the ground. Damage categories assessed included: animals, borers, insects, cankers, conks, diseases, human causes, and weather. Up to three different damage types could be recorded for each tree. For special damage codes and descriptions, see Table A2 in the Appendix.

Vigor

Tree vigor is a categorical assessment on a 1 to 9 scale that summarizes the overall health or status of the tree (Table 1) and comprises the total impact of a combination of stress-induced characteristics, including branch mortality, dieback, and missing crown area. Dead, cut, and fallen trees were recorded as vigors 5, 6, 7, and 8. Vigor was assessed on all trees in the overstory plot. A vigor code of 9 represented previously recorded trees that could no longer be located.

Table 1. Tree vigor codes and definitions from the FEMC FHM protocol (Wilmot et al. 2019).

Code	Definition
1	Healthy; tree appears to be in reasonably good health; no major branch mortality; crown is reasonably normal; less than 10 percent branch mortality or twig dieback.
2	Light decline; branch mortality, twig dieback present in 10 to 25 percent of the crown; broken branches or crown area missing based on presence of old snags is less than 26 percent.
3	Moderate decline; branch mortality, twig dieback in 26 to 50 percent of the crown; broken branches, or crown area missing based on presence of old snags is 50 percent or less.
4	Severe decline; branch mortality, twig dieback present in more than 50 percent of the crown, but foliage is still present to indicate the tree is alive; broken branches, or crown area missing based on presence of old snags is more than 50 percent.
5	Dead and standing, natural caused; tree is dead and still standing; phloem under bark has brown streaks; few epicormic shoots may be present on the bole; record the dead tree's height and DBH.
6	Dead and down, human caused; tree cut, or removed. Only record vigor/status
7	Dead and standing, human caused; tree is standing dead and there are signs of human cause (i.e., girdled or damaged by equipment). Record DBH and height
8	Dead and down, natural caused: tree is dead and on the ground or a snag less than 4.5' (DBH). Only record vigor/status.
9	Missing: Tree cannot be located, only record vigor/status.

Crown health assessments

Ocular crown health assessments were conducted on all trees inventoried in the fixed radius overstory plot. Assessments were conducted by two trained technicians using binoculars to distinguish seeds from leaves and detect the presence of insect defoliation. When the technicians conducting crown health assessments disagree on the rating, they discussed the estimates and moved around the tree to view it from different angles until an agreement could be reached. Crown health metrics include dieback, foliar transparency, discoloration and defoliation.

Percent fine twig dieback

The amount of fine twig dieback in a tree's crown reflects that tree's response to recent stress events. Dieback was visually estimated as a percentage of the total live crown volume occupied by fine twig dieback in 5% classes, rounded up to the nearest 5% (Wilmot et al., 2019; Table 3). For example, if a tree has 0-5% dieback it was assigned a rating of 5. As some species experience natural dieback of lower and interior limbs that is not stress related, the fine twig dieback assessment in the FEMC FHM protocol only considers dieback *of upper and outer* branches where dieback is likely a result of stress and not due to self-pruning or shading (Figure 3).

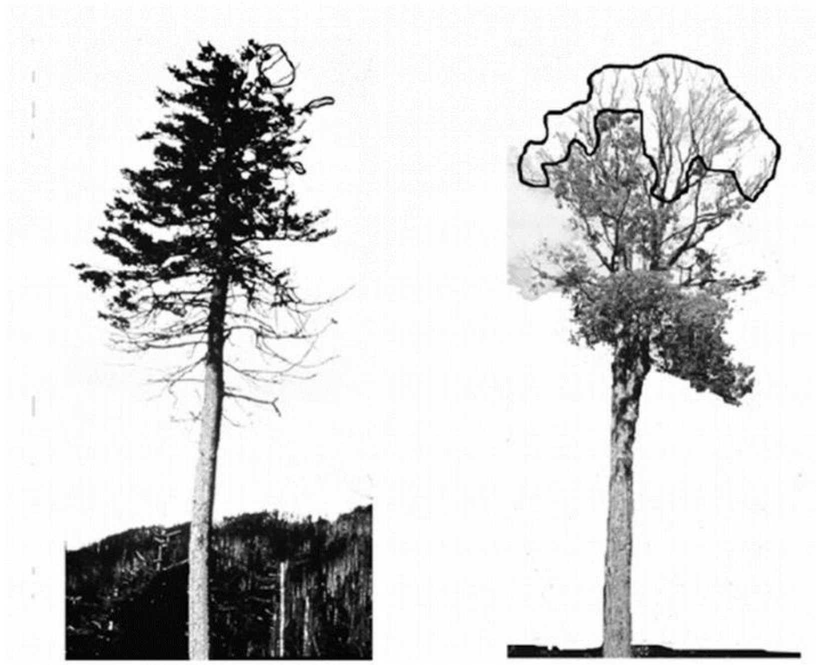

Figure 4. Crown dieback rating outline examples (Randolph, 2010). Dieback of left tree: 5%. Dieback of right tree: 30%. Note that self-pruning of lower branches is not included in the assessment.

Percent foliar transparency

Foliar transparency is the amount of light visible through the live, normally foliated portion of the crown, excluding areas that are occupied by branches. FEMC FHM technicians estimate each tree's crown transparency, rounding up to 5% intervals, such that a rating of 10% indicates that only 6-10% of the total possible skylight is visible through the foliage (Wilmot et al., 2019). Transparency considers live foliage only; branches and areas of dieback are not included, while areas exhibiting defoliation are.

Percent defoliation

Defoliation is an estimate of leaf area missing as a result of leaf-eating insects (e.g.,spongy moth caterpillars, pear thrips) or due to weather-related leaf damage (e.g., frost, hail). This metric includes leaves with missing sections or, in severe cases, leaves with only veins intact (Wilmot et al., 2019). Areas of the crown experiencing fine twig dieback where entire leaves are missing were not included. Defoliation was estimated in four broad categories based on the total live crown with reduced leaf area (Table 2).

Table 2. Foliar discoloration and defoliation classes and definitions from the FEMC FHM protocol (Wilmot et al., 2019).

Class	Definition
0	None to trace defoliation or discoloration
1	Less than 30 percent of crown defoliated or discolored.
2	31 to 60 percent defoliation or discoloration.
3	More than 60 percent defoliation or discoloration.

Percent foliar discoloration

Foliar discoloration was estimated in the same four percentage classes as defoliation (Table 3). Only foliated portions of the crown were assessed. Foliage was considered discolored when the overall appearance of a leaf was more yellow, red, or brown than green (Wilmot et al., 2019). Binoculars were strongly recommended during this assessment as masting can be mistaken for discoloration. It is important to note that normal discoloration occurs as deciduous trees prepare for fall leaf senescence; this was noted if monitoring was conducted during this time.

Regeneration assessments

Regeneration assessments were completed on all four microplots within each overstory plot or subplot. At each regeneration microplot, saplings (≥1” and <5” DBH) were assessed for DBH, status (live or dead), and species. Each sapling was given a unique ID and the location (azimuth and distance from microplot center) was also recorded. Sapling status was recorded as follows: 1 indicates that the sapling is alive, 2 indicates that the sapling is dead (DBH is measurable), 7 indicates that the sapling grew into a tree, 8 indicates that the sapling is dead and down, and 9 indicates that the sapling was not surveyed or was missing. Additionally, all live seedlings with at least one true leaf and < 1” DBH were tallied by species and height class based on the heights as shown in Table 3.

Table 3. Definitions of seedling classes used in regeneration assessment.

Seedling Type	Class 1	Class 2
Conifer	< 6 in (15 cm) tall	≥ 6 in (15 cm) tall
Hardwood	<12 in (30 cm) tall	≥ 12 in (30 cm) tall

Other assessments

Invasive plants

Non-native invasive plants were recorded on each overstory plot or subplot using a 5-class abundance system for each species on the invasive plant list (Table 4). For a list of invasive plant species that one would expect to find in these plots, see Table A3 in the Appendix.

Table 4. Invasive plant abundance codes and definitions from FEMC FHM Program protocol (Wilmot et al., 2019). Invasive species abundance is determined by searching the entirety of the overstory plot for invasive species and estimating prevalence.

Code	Description	Density
1	Infrequent occurrence	1 to a few present
2	Sparsely throughout	1-2 plants together, in a few locations
3	Localized patches	Several plants together, occurring in a few locations
4	Frequent in stands	Dense areas of plants occurring in a few locations
5	Densely throughout	High populations making up understory and/or regeneration

Animal browse

Evidence of browse on the vegetation in the overstory plot was assessed as either: (1) present or (0) absent. A code designating the amount of animal browse pressure exerted on the regeneration of the accessible forest area within the overstory plot or subplot was recorded on a scale of 1-5** (Table 5).

Table 5. Browse codes and definitions from FEMC FHM Program protocol (Wilmot et al., 2019).

Code	Definition
2	Low – No browse evidence observed, vigorous seedlings present.
3	Medium – Evidence of browse observed but not common. Seedlings common.
4	High – Browse evidence common. Seedling presence rare.
5	Very high – Browse evidence omnipresent. Forest floor bare, or severe browse line present.

** A browse code of 1 refers to a site that is within a well-maintained, deer-free exclosure. No FEMC FHM plots are within such conditions, so our scale begins at 2.

Forest composition

A 10-basal-area-factor wedge prism was used to assess the forest composition of the larger forest stand. The prism was held over the overstory plot/subplot center, and the number of trees of each species within the prism's variable radius plot were tallied. Trees determined to be 'in' were tallied by species and status (live or dead); those that were 'borderline' were counted every other time.

Data entry, quality control, and analysis

Data were collected on paper field forms and/or electronically into a custom online browser-based web-form via tablets. 2023 was the first season with tablets used for data entry; this provided ease of digital archiving of data and allowed real-time quality control of data. All paper field forms were scanned and digitally archived; PDF screenshots were digitally archived for plots entered via tablets. Original physical copies of paper datasheets were also retained. The online web form was built using the open source ODK standard and hosted on an open source ODK server implementation. A custom REST component was also developed allowing data to automatically be submitted to FEMC servers and databases and immediately available for review.

Quality assurance

10% of the plots assigned to each regional field crew were chosen for quality assurance (QA) field visits to check for tool, technique, and human errors. A supervisor visited each plot selected for QA checks within two weeks of the original data collection date and recollected data for all metrics for a randomly selected subplot. A QA subplot was said to have failed the data-entry QA protocol if more than 10% of its metrics were outside of the specified tolerance and measurement quality objective (MQO) standards (available upon request). If a plot failed a QA visit, that plot was re-sampled and further QA checks were performed on the respective crew's plots.

Quality control

Several protocols were followed to ensure accuracy of data entry via the online data entry tool. Quality checks were built into the form to identify errors, typos, large changes to metrics from previous years' data, and duplicate entries. The following are a few examples of features implemented for quality control:

- A technician enters a new tree found on the plot as ingrowth (a sapling has become a tree) but enters a DBH of 12.5 cm. The form highlights the DBH with an error warning stating that the minimum DBH of a tree must be 12.7 cm or greater to be considered a tree.
- A technician enters a DBH of a tree that is smaller than last year's tree. A warning message appears and asks the user to double check the measurement.

The online and paper forms also show previous years' data so the technicians collecting and entering data can compare their data in real time to check for typos and errors.

Following the automated quality checks and after all data were submitted to the database, we identified any outlier data that needed to be reviewed. These outliers were identified by querying the data for any measurements outside of a typical range for that metric. These standards were based on the database QA procedures from the VT FEMC FHM program.

The following queries were run on the data:

- Tree heights that exceeded 35 m in total
- DBH measurements greater than 75 cm
- Dieback and transparency ratings that exceeded 55%
- Live or standing dead trees (vigor <5) with missing height measurements
- Tree diameters that were missing in cases where tree vigor was <5
- Trees with missing vigor measurements
- Trees and saplings where IDs were missing
- Plot, seedling, sapling, tree, and prism counts compared to previous years data
- Checking for major changes in dieback, transparency, or other crown health metrics from previous year
- Additional queries to check that spatial measurements were within the plot boundaries, including tree and sapling distance from plot center and azimuths that exceeded the range of 0-360 degrees

Where outliers or errors were found, appropriate correcting action was taken. Once outlier measurements were identified, technicians compared the raw digital data to corresponding field sheet entries to ensure that data entry errors did not occur.

Data analysis

Data from the 2023 field season were analyzed across all 196 regional FEMC FHM plots. Overstory composition was computed in several different metrics for each species, including: total stems (*N*), average stems per acre (SPA), basal area (ft^2/acre; BA), percent composition, and importance value (IV). Total stems and average trees per acre provide raw metrics of the composition, while basal area and percent composition provide more information on the prevalence of each species relative to the total stocking. Only standing trees (vigor ratings 1-5) were included in most analyses for overstory trees. However, in some analyses, it was appropriate to include only live trees (vigor ratings 1-4). The importance value is a representation of how dominant a species is in a given forest, and is calculated as follows for a given species:

$$\left(\left(\frac{SPAspecies1}{SPAallspecies}\right) + \left(\frac{TotalBAspecies1}{TotalBAallspecies}\right)\right) \div 2 \times 100\%$$

*SPA = Stems Per Acre; BA = Basal Area

Results & Discussion

In 2023 FEMC FHM crews measured 6,413 live trees and 7,828 live saplings, and tallied 35,784 seedlings across the 196 FEMC FHM plots. Below, we provide summaries of these data.

Overstory composition

We found that species composition by basal area across the 196 plots was relatively similar to the regional composition, according to FIA data (USFS 2020; Figure 5). Some outliers such as sugar maple (VT) and red oak (CT) are likely due to over representation in certain states.

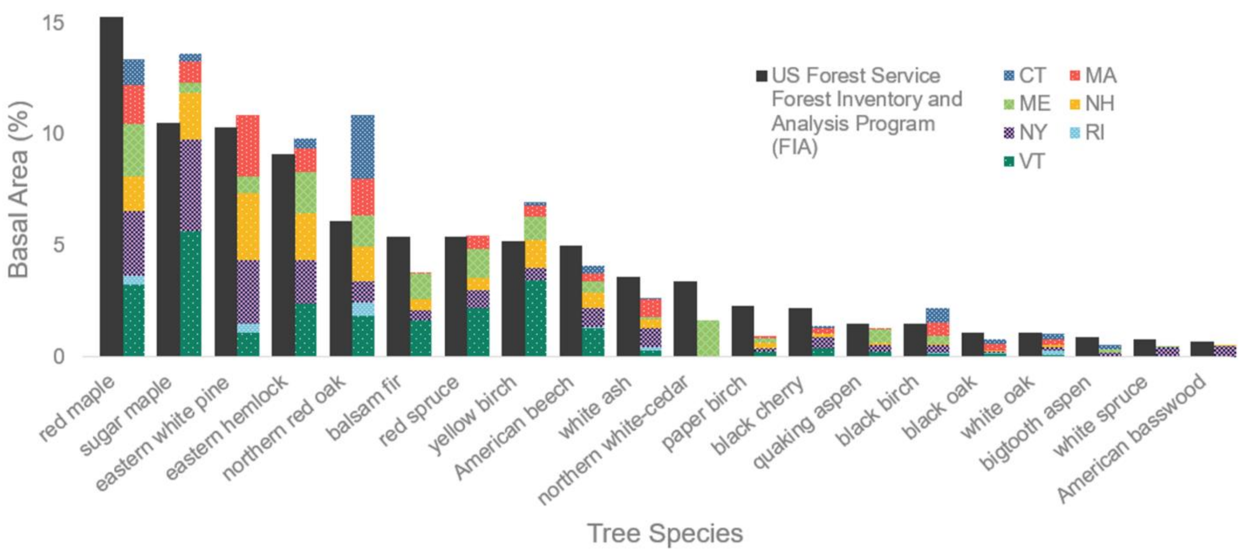

Figure 5. A comparative analysis between FEMC FHM and the USFS FIA species compositions. Percent live species composition by basal area for CT, MA, ME, NH, NY, RI, and VT from both the FHM 2023 season and the FIA 2020 season were included (only trees with ≥5 inch DBH were included; USFS 2020).

Across the 196 FEMC FHM plots, there were a total of 6,413 live and 266 standing dead trees. For live trees, this equated to an average of 176 live stems per acre (SPA) and basal area (BA) of 127 ft^2/ac. Standing dead trees averaged 7 SPA and a BA of 4 ft^2/ac. The total BA (live and standing dead) was 130 ft^2/ac, which may be too high to encourage regeneration, especially for shade-intolerant species. Only 4% of standing trees sampled were dead snags.

Across the survey area, hardwoods comprised 65% of the total overstory composition by live stem count. Red maple had the greatest live SPA (30), followed by sugar maple (24 SPA) and balsam fir (17 SPA; Table 6). Red maple also had the highest live Importance Value with an IV of 15.3% and BA of 17 ft^2/ac across all plots. Sugar maple had the second highest live IV (13.6%) with a BA of 18 ft^2/ac, followed by eastern hemlock (*Tsuga canadensis*; 9.4%, BA 13 ft^2/ac) and eastern white pine (*Pinus strobus*; 8.7%, BA 14 ft^2/ac).

Table 6. Overstory composition of trees from FEMC FHM plot network in 2023 showing total live stems (*N* live), total standing dead trees (*N* snags), live tree stems per acre (SPA), live tree basal area per acre (BA, ft^2/ac), percent composition by stems per acre (SPA; %), and live tree importance value (IV).

Species	N Live	N Snags	SPA	BA	SPA %	IV
red maple	1,096	27	30	17	17	15
sugar maple	840	20	24	18	13	14
eastern hemlock	558	12	15	13	9	9
eastern white pine	409	26	11	14	6	9
northern red oak	351	14	10	14	5	8
yellow birch	442	8	13	9	7	7
balsam fir	589	47	17	5	9	7
red spruce	407	16	11	7	6	6
American beech	446	31	12	5	7	6
black birch	194	<1	5	3	3	3
white ash	150	12	4	3	2	3
red pine	90	2	2	3	1	2
northern white-cedar	125	5	3	2	2	2
paper birch	110	9	3	1	2	1
black cherry	80	7	2	2	1	1
quaking aspen	64	11	2	2	<1	1
white oak	60	1	2	1	<1	1
black oak	42	3	1	1	<1	<1
pitch pine	39	1	1	<1	<1	<1
bigtooth aspen	33	2	<1	<1	<1	<1
white spruce	31	<1	<1	<1	<1	<1
American basswood	23	<1	<1	<1	<1	<1
eastern hophornbeam	39	2	1	<1	<1	<1
shagbark hickory	23	<1	<1	<1	<1	<1
green ash	25	2	<1	<1	<1	<1
Other hardwood	121	6	3	1	<1	2
Other softwood	26	2	<1	<1	<1	<1
Total	6,413	266	176	127	100	100

The distribution of size classes across the FEMC FHM plot network in 2023 reflects the typical age of forests in the region, resulting from the widespread abandonment of agriculture in the mid-twentieth century (Hall et al., 2002). Forests are dominated by mid-successional species that would have become established around that time period, with the majority of trees in the 5–10 inch diameter size class. Some larger trees persist that measure greater than 30 inches DBH, particularly of eastern white pine, northern red oak (*Quercus rubra*), red maple, eastern hemlock , sugar maple, and yellow birch *(Betula alleghaniensis*). As northeastern forest stands continue to age, we can expect to see the number of large stems increase, particularly for late successional species like eastern hemlock and sugar maple (Figure 6).

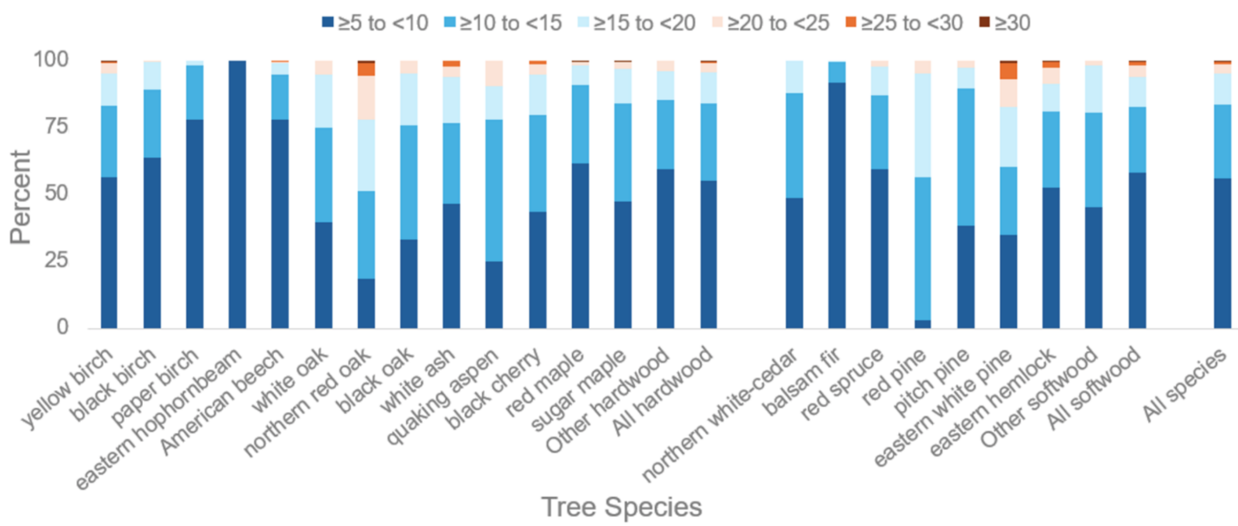

Figure 6. Size classes of live trees by diameter at breast height (DBH; inches) across FEMC FHM plot network in 2023. Live trees with a DBH of ≤5 inches were included, as well as live trees with relatively high importance values.

Tree health

Across the 196 FEMC FHM plots assessed in 2023, live tree vigor (mean ± SD) was 1.4 ± 0.7, or between 'healthy' and 'light decline.' Of live trees measured, we found that 5,999 trees (93.5%) had vigor ratings corresponding to 'healthy' and 'light decline' (vigor 1 and 2, respectively) and 414 trees (6.5%) were in 'moderate' to 'severe decline' (vigor 3 and 4, respectively).

For tree species with more than 10 individuals measured, crown health assessments show black oak with lower vigor rating (average vigor of 1.8, where 1 is healthy and 4 is severe decline), average crown dieback of 17%, and average defoliation of 0.9 (where 1 is less than 30 percent crown defoliated and 2 is 30-60% defoliation). Two other species of concern were American beech with vigor 1.9, dieback 17%, and defoliation of 0.6; and white oak with vigor 1.5, dieback 11%, and defoliation of 0.9.

The overstory trees with the highest average rates of moderate or severe decline were American beech (9.4%), gray birch (*Betula populifolia*; 8.7%), Norway spruce (*Picea abies*; 5.9%), white ash (*Fraxinus americana*; 5.3%), and northern white-cedar (*Thuja occidentalis*; 4.8%) (Figure 7). Across all species, <3% of total live stems surveyed were determined to be in severe decline. Overall, this points to a healthy, vigorous population of trees in the sampled plots.

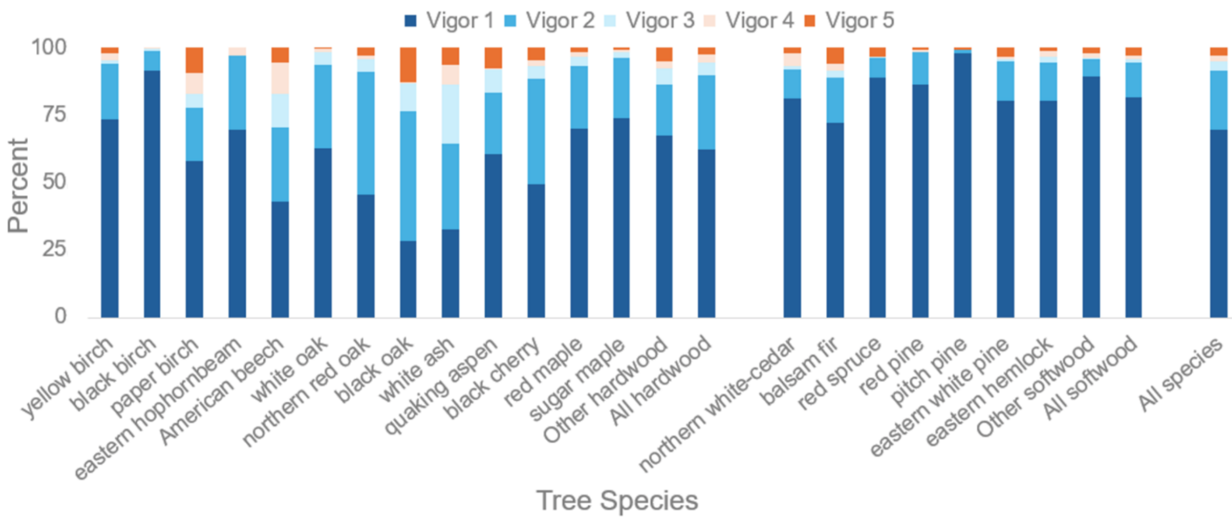

Figure 7. Average basal area (%) of each vigor (1 is healthiest, 2-4 is increasing decline, 5 is dead and standing) for each overstory tree species. Tree species with relatively high importance (abundance) values were included and only standing trees were included.

Across all live trees, the average fine twig dieback was 10.4%. American beech had the highest mean dieback at 16.9%, while black oak and white ash had 16.7% and 15.7% mean dieback, respectively (Table 7). Average dieback for tree species ranged from 0-25%, with particular species such as American beech and white ash displaying higher dieback percentages, specifically in Rhode Island, Massachusetts, and Connecticut (Figure 8). Despite higher dieback averages in these two species, most dieback averages for tree species ranged from 0 to 10% across all states in the monitoring region. These values do not suggest widespread crown health issues, but certain species or genera (e.g., American beech, oaks, and ash species) should continue to be monitored for widespread changes in dieback over time.

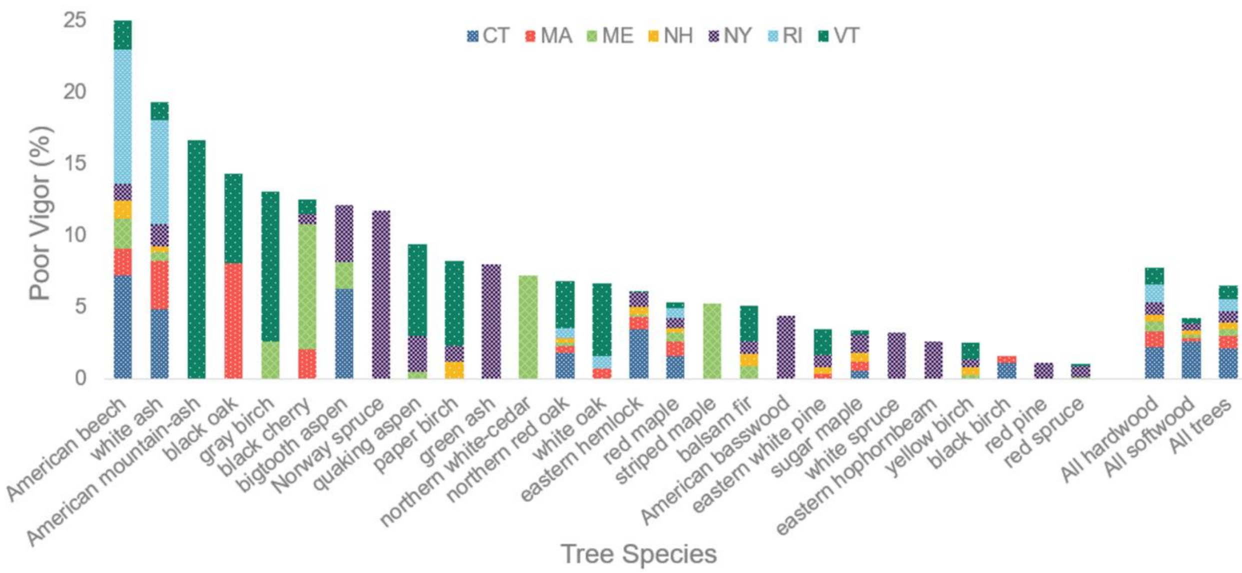

Figure 8. Percentage of trees with a 'poor vigor rating' sampled in 2023 across the seven states in FEMC Forest Health Monitoring plot network where at least 10 individuals of each species were measured. Percent poor vigor is the proportion of live trees per species that were classified to be 'in decline' (vigor ratings of 3 or 4).

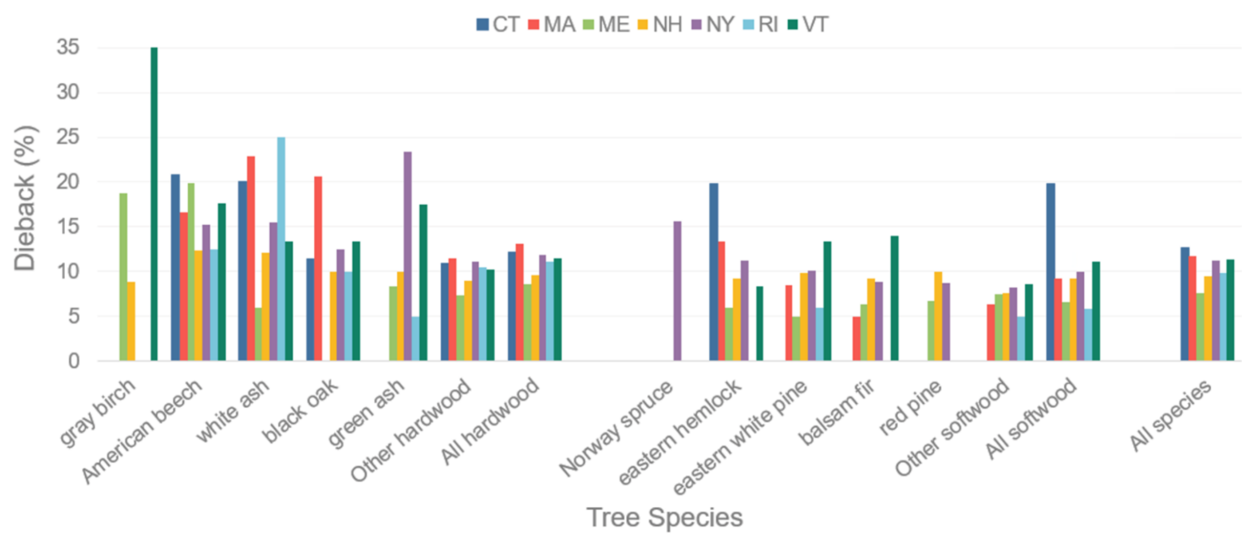

Figure 9. Species with the greatest average crown dieback (%) across seven (7) regional states. Crown dieback is identified as the percent of fine twig dieback and is rated from 0-100% (0% indicating no find twig dieback, 100% indicating complete fine twig dieback). Tree species were included if at least 10 individuals were measured.

Table 7. Crown health metrics from live trees in 2023 across the FEMC FHM plot network where at least 10 individuals of each species were measured. Percent poor vigor is the proportion of trees per species that were classified to be 'in decline' (vigor ratings of 3 or 4). Dieback and transparency were recorded in categories of 5% intervals. Discoloration and defoliation are estimates associated with the class assignment (Table 3). For example, a species with a mean discoloration rating of 0.5 will be between class 0 (none to trace discoloration) and class 1 (<30% discoloration). Percent class is based on the mean discoloration and defoliation. Species are ranked by % poor vigor.

	Poor Vigor	Dieback %		Transparency %		Discoloration (0-3)			Defoliation (0-3)		
Species	%	*mean*	*median*	*mean*	*median*	*mean*	*median*	*% class*	*mean*	*median*	*% class*
American beech	25	17	10	26	20	0.4	0	0	0.6	0	0
white ash	19	16	10	30	30	0.1	0	0	0.4	0	0
Am. mountain-ash	17	11	10	24	25	0.3	0	0	0.3	0	0
black oak	14	17	15	26	25	0.1	0	0	0.9	1	0
gray birch	13	13	10	29	25	0.2	0	0	0.7	1	0
black cherry	12	15	15	26	25	0.1	0	0	0.5	0	0
bigtooth aspen	12	10	5	25	25	0.2	0	0	0.4	0	0
quaking aspen	9	10	8	26	25	0.5	1	0	0.6	1	0
paper birch	8	10	10	25	25	0.2	0	0	0.5	0	0
green ash	8	13	10	31	30	0	0	0	0.3	0	0
northern red oak	7	11	10	25	25	0.2	0	0	0.7	1	0
white oak	7	11	10	25	25	0.3	0	0	0.9	1	0
red maple	5	10	10	21	20	0.2	0	0	0.4	0	0
striped maple	5	9	5	22	20	0.5	0	0	0.5	0	0
American basswood	4	8	5	17	15	0.1	0	0	0.4	0	0
sugar maple	3	10	10	18	15	0.1	0	0	0.4	0	0
eastern hophornbeam	3	9	10	20	20	0.2	0	0	0.3	0	0
yellow birch	2	8	5	21	20	0.1	0	0	0.5	0.5	0
black birch	2	8	5	20	20	0.1	0	0	0.3	0	0
All hardwood	**8**	**11**	**10**	**22**	**20**	**0.2**	**0.2**	**0**	**0.5**	**0**	**0**
Norway spruce	12	16	10	22	20	0	0	0	0	0	0
northern white-cedar	7	11	5	34	35	0.6	1	0	0.3	0	0
eastern hemlock	6	10	10	19	15	0	0	0	0.2	0	0
balsam fir	5	10	5	21	20	0.4	0	0	0.1	0	0
eastern white pine	3	9	5	22	20	0.1	0	0	0.1	0	0
white spruce	3	8	5	21	20	0.1	0	0	0	0	0
red pine	1	9	10	25	25	0.1	0	0	0.1	0	0
red spruce	1	7	5	18	15	0.1	0	0	0.1	0	0
All softwood	**2**	**9**	**5**	**21**	**20**	**0.2**	**0.2**	**0**	**0.1**	**0**	**0**
All live trees	**6**	**10**	**10**	**22**	**20**	**0.2**	**0**	**0**	**0.3**	**0**	**0**

Across all live trees, average foliar transparency ranged from 17% to 34% (Table 7). Transparency was rated the same way across all species. American beech, black cherry (*Prunus serotina*), and black oak had average transparencies greater than 25%.

Foliar discoloration was observed most often in northern white-cedar, with a mean discoloration estimate of 0.6 (Table 7). All species fell into the "zero-to-trace" discoloration class, but northern white-cedar's score (0.6) was somewhat higher than the average score for other species (0.1).

Defoliation rates were highest among black oak with mean defoliation rates of 0.9 (Table 7). Nearly every species saw some level of defoliation, with minimal defoliation recorded on softwood species. The average defoliation rate for all species was 0.39, indicating trace-to-medium defoliation on average for all species. In several plots we observed spongy moth caterpillars and egg masses on the trunks of trees. With recent spongy moth outbreaks across the Northeast, we recorded 11% of oak species with >30% defoliation.

Agents of change: tree damage, browse, and invasive plants

In 2023, damage related to beech bark disease (BBD) was the most common damage agent recorded across plots. In total, 35% of the plots (68) were impacted by BBD and approximately 74% of live American beech trees showed symptoms of the disease (Table 8). Another prevalent damage was crack and seam, which occurs when a tree splits due to weather or other stressors. This damage was present on 53% of plots (103) and impacted 4% of live trees (Table 8). Asian longhorned beetle, emerald ash borer, hemlock woolly adelgid, and sapsucker damage were observed on <2% of trees. Of the other damage types recorded, conks and other indicators of decay were the most common damage agents, followed by other weather damage and defoliation that was greater than 20%. Evidence of browse was recorded on 88% of plots (172), which may negatively impact regeneration success. For invasive species, we found 4% of plots (7) containing honeysuckle (*Lonicera spp.*), 2% of plots (3) with buckthorn (*Rhamnus cathartica* or *Frangula alnus*) present, 2% of plots (3) containing multiflora rose (*Rosa* multiflora), and 2% of plots (3) containing barberry (*Berberis spp.*).

Table 8. Special damages recorded on live trees across the 196 FEMC FHM plots in 2023. Damages are shown as the percent affected per species and damage type. Note that not all damages were recorded if damages were not obvious or visible from the ground. For example, eastern hemlock trees that were surveyed may have appeared discolored and/or showed symptoms of hemlock woolly adelgid (HWA), but often we cannot confirm the presence of HWA.

Species	Total # live trees	Asian long-horned beetle (%)	Beech bark disease (%)	Crack and seam (%)	Emerald ash borer (%)	Hemlock woolly adelgid (%)	Sapsucker (%)	Other damages (%)	Damage recorded (%)
American beech	446		74	3				20	85
striped maple	19			15				47	57
white ash	150			8	40			4	48
quaking aspen	64			3				43	46
American elm	3			33					33
green ash	25				28			8	32
*ash spp.	7								28
black ash	7				28				28
Am. mountain-ash	18			16				11	27
blackgum	9							22	22
N. white-cedar	125							20	20
bigtooth aspen	33			3				15	18
Am. basswood	23			4			4	8	17
pitch pine	39			5			10		15
black cherry	80			2			1	11	15
sugar maple	840			6			<1	7	14
northern red oak	351			1			<1	7	13
yellow birch	442			5				7	13
white oak	60			3				10	13
balsam fir	589			2			1	10	13
shagbark hickory	23			8					13
paper birch	110			2				10	12
red maple	1,096			4			<1	8	12
e. white pine	409			1				11	12
black oak	42			4				9	11
black birch	194			5				4	11
chestnut oak	9								11
eastern hemlock	558			1		4		5	10
gray birch	23							4	8
red spruce	407			3				4	7
bitternut hickory	13							7	7
E. hophornbeam	39							7	7
Norway spruce	17							5	5
All live trees	6,413	0	5	4	1	<1	<1	9	18

*trees were identified to genus when species was unknown

Tree regeneration

Saplings

Seventeen (17) out of 196 plots did not contain any saplings in any of their four microplots. There were 7,828 living saplings across the remaining 179 plots, with 482 stems per acre (SPA). The sapling layer displayed the lowest species diversity of the three strata (trees, saplings, seedlings). Across all plots, 34 different species were recorded in the sapling plots, compared to 49 tree species and 48 seedling species. The number of sapling species recorded per plot ranged from 0 to 8. Regeneration assessments show sapling densities of 482 live SPA with balsam fir and American beech representing the most abundant species. The most abundant species in the sapling layer were balsam fir (34% of the total sapling composition, 1,202 SPA), American beech (14%, 14 SPA), and red spruce (12%, 12 SPA) (Table 9). American beech stems were likely suckers based on their small size (Figure 6) and due to the prevalence of BBD on mature trees (see Agents of Change section).

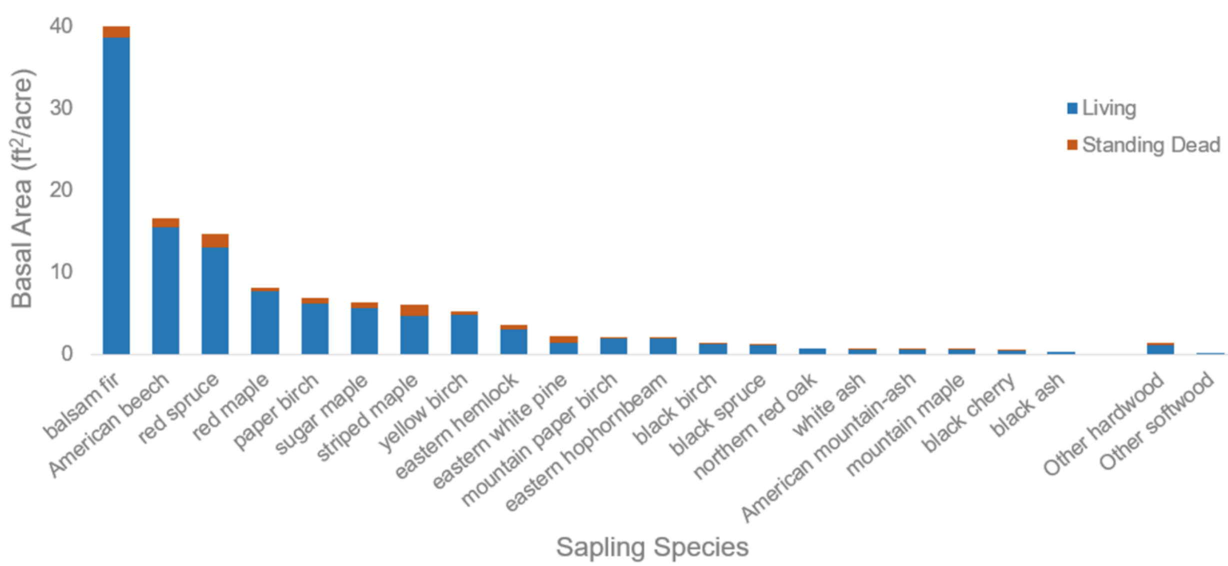

Figure 10. Basal area (ft²) per hectare for most common sapling species with respective statuses (e.g., statuses 1, 2, 7, 8, and 9).

Table 9. Composition of live saplings from FEMC FHM regeneration microplots in 2023 including total stems, saplings per acre (SPA), basal area per acre (BA, ft^2/ac), and percent composition (%) of sapling layer. Information for the aggregate for all species sapling data is shown in the last row.

Species	Live saplings	SPA	BA	%
balsam fir	3,056	1,202	38	34
American beech	1,324	536	15	14
red spruce	955	389	13	12
red maple	361	159	8	7
paper birch	214	84	6	6
sugar maple	275	111	6	5
yellow birch	301	121	5	4
striped maple	398	160	5	4
eastern hemlock	170	71	3	3
eastern hophornbeam	128	56	2	2
mountain paper birch	53	20	2	2
eastern white pine	65	31	1	1
black birch	81	36	1	1
black spruce	73	36	1	<1
northern red oak	28	14	<1	<1
white ash	48	21	<1	<1
American mountain-ash	51	20	<1	<1
mountain maple	66	25	<1	<1
black cherry	23	10	<1	<1
black ash	9	3	<1	<1
Other hardwood	134	57	2	1
Other softwood	15	6	<1	<1
All species	7,828	3169	112	100

Seedlings

In total, 35,784 seedlings (<1-inch DBH) were tallied across FEMC FHM regeneration microplots in 2023. Of all seedlings counted, 84% (30,065) were classified as class 1 (hardwood seedlings <12 inches tall and softwood seedlings <6 inches tall) while 16% (5,719) were classified as class 2 (more established, with hardwood ≥12” and softwood ≥6 inches tall). Seedling counts per plot ranged from 2 seedlings to 1,256 seedlings per plot. There was an average density of 15,365 stems per acre (SPA) across the entire 196-plot network in 2023.

Seedling diversity was high within microplots with seedlings identified for 40 species, and 8 genera where species identification was not clear. Species diversity per plot ranged from one to 12 unique species, and there did not appear to be a relationship between the number of species in the overstory trees and the number of species in the understory (paired t-test using R; $t(195) = 0.30443$, $p = 0.76112$).

Red maple was the most abundant seedling tallied in 2023 (36%, 5,493 SPA). This is a substantial increase of 3,913 SPA over 2022. Balsam fir (14%, 2,184 SPA) and sugar maple (13%, 2,009, SPA; Table 10) were the next most abundant seedling species. Seedling regeneration was sparse for swamp white oak (*Quercus bicolor*; 0.4 SPA), slippery elm (*Ulmus rubra*; 0.5 SPA), and white spruce (*Picea glauca*; 1 SPA) with only 1, 1, and 2 seedlings identified for each of these species in 2023. This highlights the importance of continuing annual assessments to better understand trends, patterns and drivers of change for the states' forested ecosystems. Average seedling densities remained relatively consistent between years 2022 and 2023, except certain species such as American beech, sugar maple, and balsam fir (Figure 9). Seedling densities are subject to yearly shifts due to changing weather conditions (e.g., available precipitation), herbivory, and seed availability (e.g., masting events). Future region-wide monitoring data from the FEMC FHM program will aid in distinguishing long-term trends from inter-annual variation.

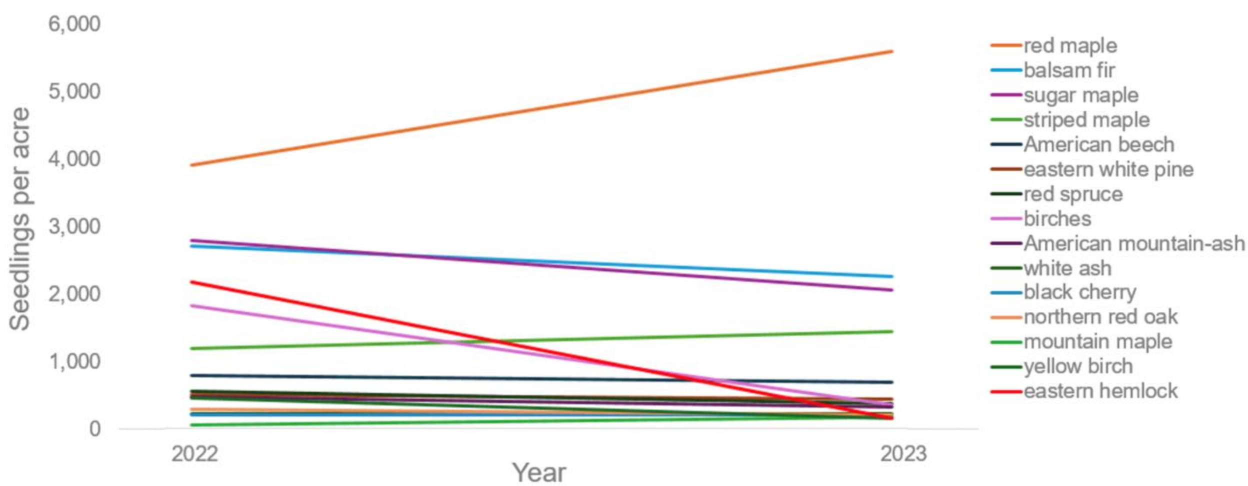

Figure 11. A temporal analysis of the mean seedling density (counts per acre) for each species between 2022 and 2023. Plots consistently visited (190 plots) since 2022 were used in the analysis. Masting could also be the cause of large seedling discrepancies.

Table 10. Seedling composition across FEMC FHM plots in 2023 showing total seedling (<1 inch DBH) count as well as class 1 (hardwood <12 inches tall, softwood <6 inches tall) and the more established class 2 (hardwood ≥12 inches tall, softwood ≥6 inches tall). Average density of stems per acre (SPA) and percent composition (%) of the seedling layer is also included. To accommodate for space, species observed at very low rates are not listed.

Species	Seedling count	Class 1	Class 2	SPA	%
red maple	12,720	12,261	459	5,493	36
balsam fir	5,211	3,905	1,306	2,184	14
sugar maple	4,943	4,697	246	2,009	13
striped maple	3,352	2,824	528	1,461	10
American beech	1,575	661	914	671	4
eastern white pine	982	697	285	433	3
red spruce	812	509	303	366	2
birches*	811	725	86	349	2
American mountain-ash	796	755	41	316	2
white ash	514	296	218	241	2
black cherry	476	364	112	218	1
northern red oak	466	386	80	210	1
mountain maple	424	374	50	174	1
yellow birch	349	272	77	157	1
eastern hemlock	356	215	141	155	1
serviceberry	298	177	121	135	0.9
eastern hophornbeam	308	146	162	134	0.9
pitch pine	234	234	0	115	0.8
northern white-cedar	162	59	103	79	0.5
black spruce	147	31	116	72	0.5
black birch	143	49	94	67	0.4
white oak	117	86	31	54	0.4
American elm	99	89	10	47	0.3
red pine	79	16	63	37	0.2
quaking aspen	64	20	44	27	0.2
Other hardwood	331	207	124	151	1
Other softwood	15	10	5	7	<0.1
All species	35,784	30,065	5,719	15,365	100

*seedlings were identified to genus when species was unknown

Conclusions

Although northeastern forests face a broad range of stressors and exhibit significant vulnerabilities, preliminary indicators suggest that they are in a relatively diverse, robust, and healthy state. Species diversity is apparent across all three strata, encompassing overstory trees, saplings, and seedlings, although it is slightly lower in the sapling layer. On average, the overstory trees were vigorous with healthy crowns. Despite a widespread outbreak of spongy moth infestation in southern New England, the defoliation levels of our most affected species, black oak, remain below 30% throughout the region. While regeneration is observed in all monitored areas, seventeen plots lack saplings, which warrants continued monitoring and investigation.

While the baseline data from 2021, 2022, and 2023 are significant, we hope to expand our analysis in 2024 to include more comprehensive comparisons between states and over time. Annual forest health monitoring offers valuable insights into subtle changes in forest conditions resulting from prolonged weather events like drought, as well as stress factors such as pests and pathogens. It also helps identify subtle alterations in composition and overall health due to long-term changes in climate. Assessing crown health can serve as an early warning system for hidden or widespread stressors, while the understory condition can indicate what the future forest may look like.

As the FEMC FHM program continues and more annual measurements are collected, we will be able to assess emerging trends in forest health across the entire Northeast region and subregionally. Specifically, we will analyze changes in seedling and sapling survival rates from year to year, as well as variations in crown health between different states, which may indicate persistent decline issues. These insights are crucial for forest managers aiming to ensure the future vitality, productivity, and resiliency of these ecosystems.

Future Improvements

Following each field season, we reflect on the successes and failures of that season and the resulting analytical outputs. In the future we hope to explore analyses focusing on vulnerable species (e.g., ash, oak, etc.) and how disease is currently impacting northeastern trees. Incorporating spatial analyses into our reports also could deepen understandings of these trends in vulnerable trees across FHM plots and states. As this program grows and data accumulates over future years, more opportunity to explore temporal and spatial trends in forest health will arise.

Another improvement that the FHM program plans to incorporate is the addition of more damages and diseases to our online web form for data collection, along with additional tree species to cover a wider array of what technicians are seeing in the field. This will enhance data collection efficiency and provide consistency with field observations.

Data

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Appendix

Table A1: List of special damages to trees in FEMC Forest Health Monitoring program (Wilmot et al., 2019).

Bole Damage Code	Bole Damage Agent
Animal Damage	
441	Animal browse
444	Beaver damage
445	Porcupine damage
446	Sapsucker damage
447	Other animal damage
Borers and Insects	
707	Asian long-horned beetle
101	Balsam woolly adelgid
104	Beech bark scale only
111	Defoliation >20%
103	Hemlock woolly adelgid
710	Sirex wood wasp
108	Sugar maple borer
110	Other bark beetles
711	Emerald ash borer
109	Other borers
Cankers Conks and Diseases	
106	Beech bark disease symptoms
201	Butternut canker
206	European larch canker
203	Eutypella canker
204	Hypoxylon canker
202	Nectria canker
207	Other canker
208	Conks and other indicators of decay
209	Dwarf mistletoe
210	White pine blister rust
Human-related	
702	Logging damage > 20% of circumference
Weather-related	
708	Cracks and seams
501	Wind-thrown/uprooted
505	Other weather damage

Table A2: List on invasive plants and their codes for the Forest Health Monitoring program (Wilmot et al., 2019).

Code	Common name	Scientific name
1	Barberry: Japanese or common	*Berberis thunbergii, B. vulgaris*
2	Buckthorn: common or glossy	*Rhamnus cathartica, Frangula alnus*
3	Bittersweet: oriental	*Celastrus orbiculatus*
4	Honeysuckle: bell, Japanese, amur, Morrow or tartarian	*Lonicera* X *bella, L. japonica, L. maackii, L. morrowii, L. tatarica*
5	Multiflora rose	*Rosa multiflora*
6	Norway maple	*Acer platanoides*
7	Autumn or Russian olive	*Elaeagnus umbellate, E. angustifolia*
8	Japanese knotweed	*Fallopia japonica (Polygonum cuspidatum)*
9	Garlic mustard	*Alliaria petiolata (A. officinalis)*
10	Privet	*Ligustrum vulgare*
11	Tree of heaven	*Ailanthus altissima*
12	Wild chervil (cow parsnip)	*Anthriscus sylvestris*
13	Burning bush or winged euonymus	*Euonymus alatus*
14	Goutweed	*Aegopodium podagraria*
15	Amur maple	*Acer ginnala*
99	Other	

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