

---

# MASSACHUSETTS FOREST HEALTH MONITORING PROGRAM

---

## 2019 Report



Last updated: July 10, 2020

# Massachusetts Forest Health Monitoring Program: 2019 Report

Published July 20, 2020

Version 1.0

Forest Ecosystem Monitoring Cooperative

South Burlington, VT, USA

[femc@uvm.edu](mailto:femc@uvm.edu)

(802) 656-2975

**Matthias Sirch, Matthias Nevins, Alexandra Kosiba, John Truong, Julia Pupko, James Duncan and Jennifer Pontius**

DOI: <https://doi.org/10.18125/b6nka0>

**Cover image:** Sirch, MS. 2019.

## Preferred Citation

Sirch M, Nevins M, Kosiba A, Truong J, Sirch M, and Duncan J. 2020. Massachusetts Forest Health Monitoring Program: 2019 Report. Forest Ecosystem Monitoring Cooperative: South Burlington, VT.

<https://doi.org/10.18125/b6nka0>

## Acknowledgements

The Forest Ecosystem Monitoring Cooperative (FEMC) is grateful for the guidance and support provided by Massachusetts Department of Conservation and Recreation Forester Bill Van Doren and Forest Health Program Director Nicole Keleher, as well as the numerous state employees that assisted FEMC FHM crews at campsites and with accessing gated roads.

We are appreciative of the long-term funding from the U.S. Department of Agriculture, Forest Service State & Private Forestry, Vermont Agency of Natural Resources, and the University of Vermont.



# Table of Contents

---

Table of Contents.....	3
Executive Summary.....	4
Background.....	5
Methodology.....	7
Plot layout.....	9
Field metrics .....	9
Tree biometry and health .....	10
Regeneration assessments .....	13
Other assessments .....	13
Data entry, quality control, and analysis.....	14
Quality control.....	15
Data analysis.....	15
Results & Discussion .....	16
Overstory composition.....	16
Tree health.....	19
Agents of change: tree damage, browse, and invasive plants.....	22
Tree regeneration.....	23
Saplings.....	23
Seedlings .....	25
Conclusions .....	27
Data .....	27
References .....	27
Appendix.....	29

# Executive Summary

---

Annual forest health monitoring can help capture subtle changes and long-term trends in forest composition and condition. 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. Changes in forest composition can be assessed by tracking regeneration, growth and mortality patterns. Monitoring the prevalence of invasive pests, pathogens, and animal browse provides further understanding of the impacts of common stressors on forest health and condition. Healthier forests have greater carbon sequestration, provide higher quality wildlife habitat, and are more resilient to ongoing stressors. An understanding of forest health and how our forests are changing provides critical information for mitigation and adaptation strategies. This information will also ensure the sustained provisioning of key ecosystem services in the face of a changing climate.

In 2019, the Forest Ecosystem Monitoring Cooperative (FEMC) collaborated with the Massachusetts (MA) Department of Conservation and Recreation (DCR) to establish 20 permanent Forest Health Monitoring (FHM) plots on DCR properties across the state. These FHM plots were co-located with the state's Continuous Forest Inventory (CFI) network, previously established by DCR to assess forest growth and yield. The FEMC FHM program was designed to complement the state's CFI network with higher temporal resolution (annual vs 10-year rotation for re-measurements) on a subset of CFI plots. This report highlights the findings from the first year of FHM efforts in MA.

Results from the 2019 monitoring season indicate that white pine (16% composition), eastern hemlock (14%), and red maple (11%) were the most abundant species on average within the monitoring plots. On average, overstory tree densities in 2019 were approximately 190 stems per acre (>5" DBH) and 120.5 ft<sup>2</sup>/acre of tree basal area. Regeneration assessments show sapling densities of 318 stems per acre (SPA) with American beech and eastern hemlock representing the most abundant species across the 20-plot network. Seedling densities were calculated to be 17,318 stems per acre, on average, with red maple and sweet (black) birch representing the most abundant seedling species. Crown health assessments show oak species with lower vigor rating and higher rates of crown dieback (9-14%), transparency (18-24%), and defoliation (up to 30%) when compared to other overstory tree species in 2019.

While there are a wide range of stressors impacting MA forests and significant vulnerabilities do exist, data from the 2019 season suggest that the state's forests are overall diverse, vigorous, and healthy. However, there are a few notable exceptions that should continue to be monitored. These include continued defoliation by gypsy moth caterpillars and sparse regeneration for some species. Red maple was the most abundant seedling tallied in 2019 (42.12% composition, 7,294 SPA), followed by sweet birch (22.30%, 3,861 SPA), and striped maple (6.2%, 1,074 SPA) (Table 11). This highlights the importance of continuing annual assessments to better understand trends, patterns and drivers of change for the state's forested ecosystems.

# Background

---

In 1990, a national Forest Health Monitoring program was established to monitor forest health and detect emerging threats (Bechtold et al., 2007). Plots consisting of four, fixed area subplots, measuring 7.32 m (24 feet) 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 which is 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 a variety of 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 runs on 5-7 year re-measurement cycles (USFS 2013) while CFI rotations vary by agency but usually follow a 10 year re-measurement 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. Examples of these changes include seedling abundance, sapling survivorship, ungulate browse, tree crown health, and damages. While periodic inventories 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 in Vermont between 1991 and 2018 that span Vermont's forest types and biophysical regions. 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 designed to provide information on early symptoms of tree stress and changes in forest structure and composition. The information obtained from the 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, the FEMC has been preparing for an expansion of 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, the FEMC collaborated with MA DCR to establish 20 FHM plots on MA state lands to add to its annual FHM network. To improve comparability and utility of each program, the FHM plots were co-located at established, long-term MA CFI plot locations, representing the major forest types and geographies on public lands in Massachusetts.

The MA CFI program was started in 1957 with 93 plots established across state lands (MA DCR 2014) and has expanded to 1,800 CFI plots in the current network. The focus of the program is regeneration, growth, and mortality of trees to track changes in growth and yield across the state (MA DCR 2014). The MA CFI dataset can provide a level of ecological insight to changes in forest ecosystem health over time, which can be expanded on when coupled with the annual FHM

measurements. Co-locating FHM plots with the MA CFI network provides the 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 MA CFI program 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 the FEMC FHM program, plot selection, and highlights findings from the 2019 FEMC FHM field season.

# Methodology

---

## Plot selection

We used the following criteria for FEMC FHM plot selection from the existing MA CFI plot network:

- 1) Plot must be a natural forest (plantations are not considered natural forests);
- 2) Plot must be in reserve status and not designated for timber management;
- 3) Plots must be representative of the overall forest composition for the state and spatially balanced across the state's forestland.

MA DCR provided plot locations for the CFI network (n=1,800 plots; MA DCR 2019). We selected only those plots deemed *Active* (n=1,733) and joined resulting plots with the associated fields from the MA CFI database using *Type*, *Sub\_type*, *Last Inventory year*, and *Landscape Designation*. Using look-up tables extracted from the MA CFI methodology (MA DCR 2014), we excluded the major types "swamp hardwood", "swamp softwoods", and "non-commercial" based on the included description of these types (resulting n=1,594). We filtered plots to those with a *Sub\_type* 'forest' by first creating a *Sub\_type\_group* field where 'none' indicates 'non-forest' (see Table A1 for sub-types not considered forests). We also excluded plots with no sub-type designation (resulting n= 1,561). We selected only plots in 'Reserve' status under *Landscape Designation* (code = 1); this excluded parkland and woodland plots (resulting n = 610).

Table 1. The most prevalent tree species in MA according to Forest Inventory and Analysis data (USFS 2019) shown as percent (%) of the total tree composition on forestland, along with the proportional number of plots selected for the final FEMC FHM plot network. *N* plots were assigned to a species group if they contained  $\geq 25\%$  of the target species.

Species	%	N plots
red maple	21.2	4
eastern white pine	16.8	3
eastern hemlock	12.4	2
northern red oak	8.9	2
sweet birch	5.5	1
sugar maple	4.5	1
black oak	3.6	1
white ash	3.1	1
scarlet oak	3.1	1
white oak	2.9	1
yellow birch	2.9	1
American beech	2.7	1
pitch pine	2.2	1

We used Forest Inventory and Analysis' EVALIDator (Version 1.8.0.01, USFS 2019) to determine the species composition of the state of MA forestland by querying for the number of trees  $\geq 5$  in diameter at breast height (DBH) by species. We summarized the species composition per MA CFI plot using species information for live trees (status = 1 or 2) extracted from the MA CFI database (MA DCR 2019). For each plot, we summed the number of trees per species to determine which species were the most dominant within the plot and distributed our network accordingly to avoid clusters of plots with similar species. For a plot to be considered dominated by a species, that species had to comprise more than 25% of the trees by count in that plot. Based on the proportion of MA forest composition by species (Table 1), we selected a proportional number of plots per species from the resulting plot list generated with the aforementioned filtering steps (n = 610). We also overlaid plots on Level IV ecoregions (EPA) to ensure that the plots represent all forested ecoregions across the state and implemented a 10 mile buffer between plots to ensure they were spatially distributed across the state. For example, for plots dominated by northern red oak, we attempted to ensure that selected locations were spatially distributed in red oak forests in different locations rather than clustered in a single region. The resulting plot network is show on the map in Figure 1.

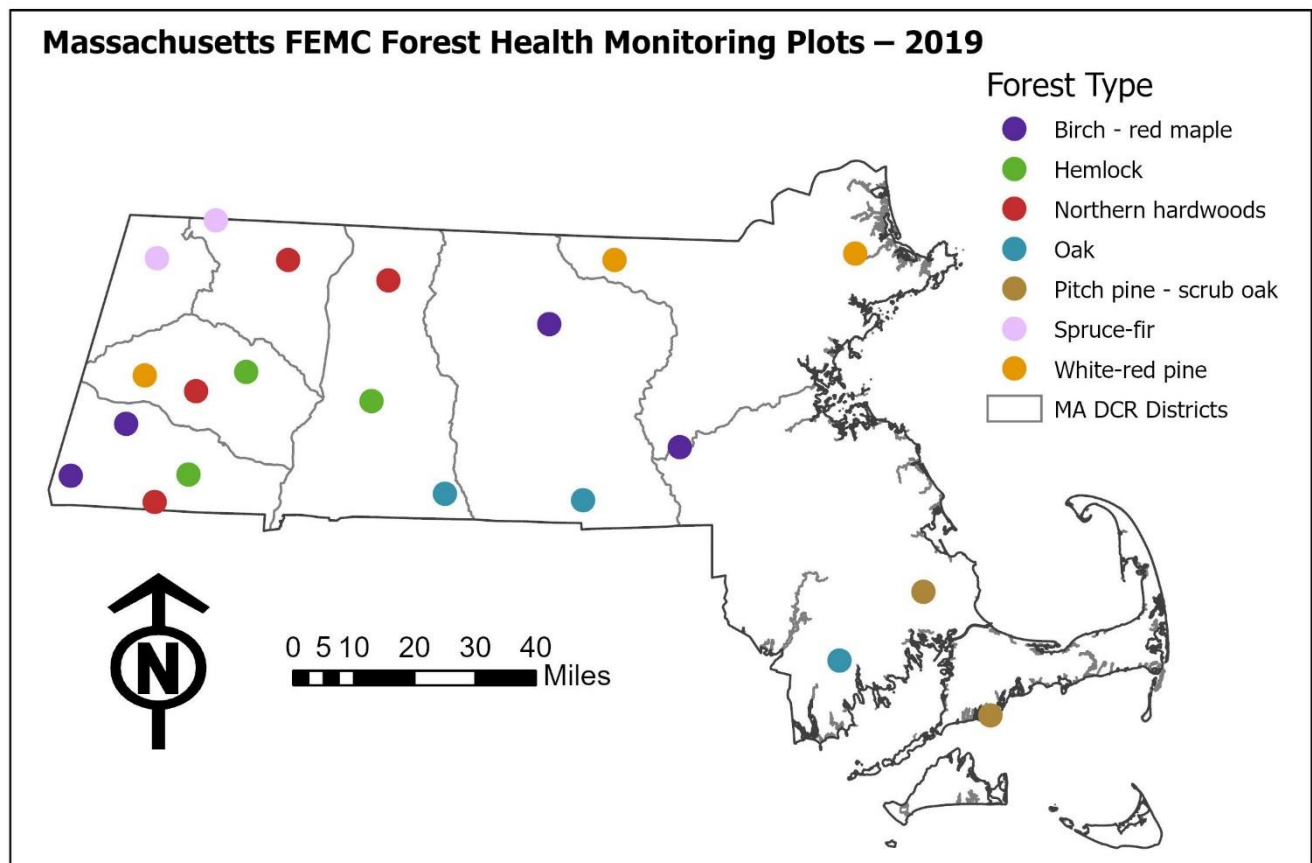


Figure 1. Twenty plot locations for the 2019 FEMC FHM program in MA that were co-located with MA CFI plots. Plots are color coded based on the forest type indicated in the MA CFI database (MA DCR 2019).



## Plot layout

The MA CFI plot layout consists of one large overstory plot, with a radius of 52.7 feet and area of 8,725.11 ft<sup>2</sup>, and four nested regeneration subplots each with a radius of 6.0 feet and an area of 113.1 ft<sup>2</sup> (Figure 2). The four regeneration subplots are 26.0 feet from the overstory plot center at the cardinal directions (referenced to true north). To maintain continuity with historical inventories on these plots, the FEMC utilized this same plot design for the 20 plots. MA DCR personnel permanently marked the overstory plot center, but not the locations of the regeneration subplots. As it is critical that regeneration subplot locations remain consistent for annual assessments, the FEMC technicians marked the regeneration subplot centers with fiberglass stakes.

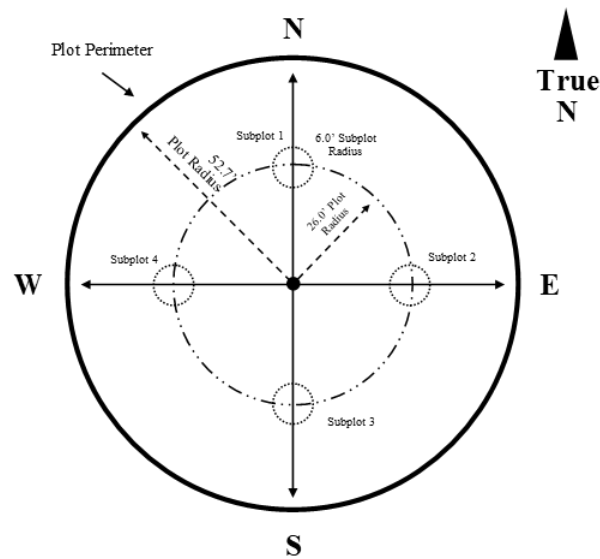


Figure 2. Layout of MA CFI and FEMC FHM plots showing the overstory plot (large circle) and four regeneration sub-plots (small circles at cardinal directions; MA DCR 2014).

## Field metrics

For the 2019 field season, FEMC inventoried the 20 selected plots for all metrics outlined in the Vermont 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 (species, diameter, status) assessments in the four sub-plots. Other metrics, like animal browse, invasive plants, and forest composition (prism plots) were collected at the overstory plot level. Additionally, canopy hemispherical photos were collected at each sub-plot and overstory plot center, when possible, to quantify canopy gaps and leaf area index. Details of each metric are provided below.

## Tree biometry and health

Within the overstory plot, FEMC FHM technicians assessed all trees  $\geq 5$  in diameter at breast height (DBH, measured at 4.5 ft). MA DCR personnel previously marked each sampled tree within the overstory plot with paint to signify the tree number. Distance and azimuth from the plot center were recorded for each individual tree for future inventories (MA DCR 2014). 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 breast height (4.5 ft) 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.

### *Special Damages*

For each tree in the overstory plot, any recent bole or crown damages were recorded, if obvious. It should be noted that these damages are not comprehensive and some damages may not be recorded if they are not obvious to a technician from the ground. Damage categories include: animals, borers, insects, cankers, conks, diseases, human causes, and weather. Up to three damages for each tree may be recorded. For special damage codes and descriptions, see Table A2 in the Appendix.

### *Vigor*

Tree vigor is a categorical assessment on a 1 to 8 scale that summarizes the overall health or status of the tree (Table 2) 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 are recorded as vigor 5, 6, and 8, respectively. Vigor was assessed on all trees in the overstory plot. Note that we also utilized a vigor code of 9 for all missing trees in the MA CFI data that could not be identified as standing or dead and down.

Table 2. 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, natural; tree is dead, either standing or down; phloem under bark has brown streaks; few epicormic shoots may be present on the bole; no further entries needed.
6	Dead, human caused; tree removed; tree has been sawed or girdled by humans.
8	Dead and down; If a tree is found to be dead and down two years in a row, it is removed from the tree list.

### *Crown health assessments*

Ocular crown health assessments are conducted on all trees inventoried in the overstory plot. Prior to the field season, training and calibration of crew members conducting crown health assessments are led by Vermont Forest Parks and Recreation (FPR) forest health specialists to ensure standardization of ratings from year-to-year. Assessments are conducted by two technicians using binoculars to distinguish seeds from leaves and detect presence of insect defoliation. When the technicians conducting crown health assessments disagree on the rating, they discuss the estimates and move around the tree to view it from different angles until an agreement can 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 a response to recent stress events. Dieback is visually estimated as a percentage of the total live crown volume that is 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 1-5% dieback is it 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).

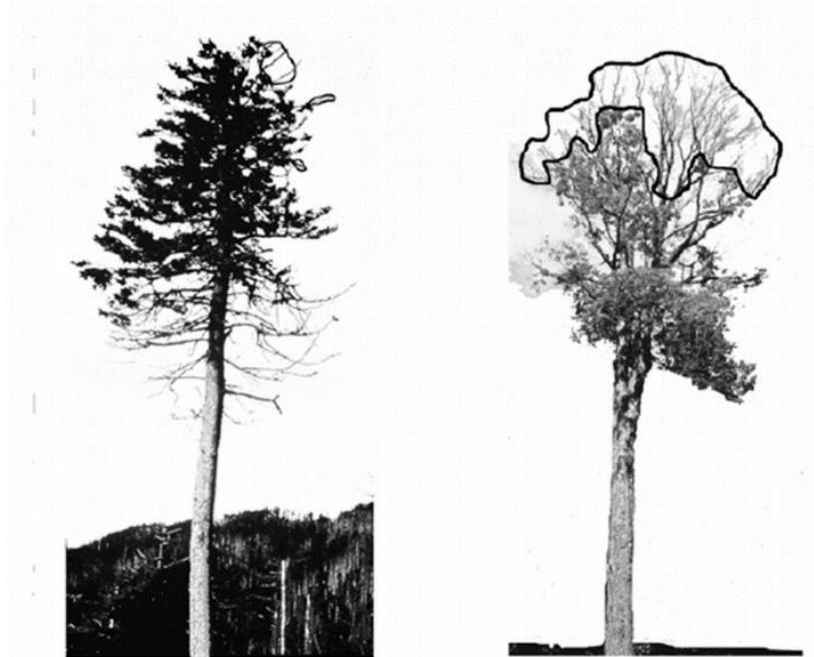


Figure 3. Crown dieback rating outline examples (Randolph, 2010). Dieback of left tree: 5%. Dieback of right tree: 30%. Note that self-pruning of lower branches is not included in the assessment.

### 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 (such as gypsy moth caterpillars or pear thrips) or due to weather related leaf damage (such as frost or 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 are not included. Defoliation is estimated in four broad categories based on the total live crown with reduced leaf area (Table 3).

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

### Regeneration assessments

Regeneration assessments were completed on all four sub-plots within each overstory plot. At each regeneration subplot, saplings ( $\geq 1$  and  $< 5$  in 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 subplot center) was also recorded. Additionally, all live seedlings with at least one true leaf and  $< 1$  in DBH were tallied by species and height class based on the heights as shown in Table 4.

Table 4. Definitions of seedling classes used in regeneration assessment.

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

### Other assessments

#### *Invasive plants*

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

Table 5. Invasive plant abundance codes and definitions from the 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.

<b>Code</b>	<b>Description</b>	<b>Density</b>
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.

### *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 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.

### *Canopy cover*

Hemispherical photos were taken at the overstory plot center and at each of the subplot centers, when possible. The presence of dense understory, or a tree close to the plot center, renders the photo unusable. Photos were not taken under these conditions. Hemispherical photos will be converted to a leaf area index and canopy gap fraction to quantify subtle changes in canopy cover over time.

## Data entry, quality control, and analysis

Data were collected on paper field forms and entered into a custom Access database following field collection. All paper field forms were scanned and archived, and original copies were retained. A project archive was created for the FEMC FHM program in MA at:

<https://www.uvm.edu/femc/data/archive/project/massfhm>

## Quality control

Several protocols were followed to ensure accuracy of data entry. After each data section of a plot was entered (e.g., sapling data) it was compared to the field data sheet for any potential entry mistakes. Spot checks were conducted on random entries within each section. On average, one data entry point out of every five was compared during the spot check.

Following the manual quality checks, 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 off of the database QA procedures from the VT FEMC FHM program.

The following queries were run on the data:

- Tree heights that exceeded 30.48m in total: identified 11 trees requiring review, one of which was determined to be a data entry error and was corrected
- Dieback and transparency ratings that exceeded 55%: identified five trees requiring review, all of which were found to be correct
- Live or standing dead trees (vigor <5) with missing height measurements: identified eight trees requiring review, two trees were found to have missing height measurements and notes were made to collect the measurements in 2020
- Tree diameters that were missing in cases where tree vigor was <5: identified two trees which required review, one of which erroneously did not have diameter measured in the field
- Trees with missing vigor measurements: one tree was found to have missing vigor ratings
- Trees and saplings where IDs were missing: revealed two entries determined to be data entry errors and were corrected
- Additional queries were run to check that spatial measurements were within the plot boundaries. These include tree and sapling distance from plot center and azimuths that exceeded the range of 0-360 degrees. No errors were found for these metrics.

Once outlier measurements were identified, technicians reviewed the corresponding raw digital data, compared to field sheet entries, to ensure that data entry errors did not occur. In total there were 33 errors that required review and correction out of 1148 trees measured. 30 out of the 33 errors were data entry errors and were corrected. Three out of the 33 errors were errors in the field and were noted to be corrected the following field season.

## Data analysis

Data from the 2019 field season were analyzed across all 20 MA FEMC FHM plots. Overstory composition was computed in several different metrics for each species, including: total stems ( $N$ ), average trees per acre (TPA), basal area ( $\text{ft}^2/\text{acre}$ ; 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 given species:

$$\left( \left( \frac{TPA \text{ species } 1}{TPA \text{ all species}} \right) + \left( \frac{Total \text{ BA species } 1}{Total \text{ BA all species}} \right) \right) \div 2 \times 100\%$$

## Results & Discussion

---

In 2019, FEMC FHM crews measured 761 live trees, 127 standing dead trees, 66 saplings, and tallied 3,597 seedlings across the 20 MA FEMC FHM plots. We estimated that 100 hours were spent on planning, 500 hours on field data collection, 50 hours on data entry and QA/QC, and 70 hours on data analysis and report preparation, totaling 690 hours or 34 hours per plot. Below, we provide summaries of data collected from the 2019 field season.

### Overstory composition

We found that species composition across the 20 plots was similar to the state-wide composition, according to FIA data (USFS 2019, Table 6). One notable exception was that the percentage of red maple was lower in the FEMC FHM plots (12.6%) compared to the statewide average (21.2%), which may be explained by the plot selection process. FEMC FHM plots were located in intact forests on state lands while FIA data encompasses all types of forestland, including highly disturbed areas where red maple may be more prevalent. In 2020, five additional plots may be added to the MA FEMC FHM network and could target those species where the composition was lower in the FEMC FHM network compared to state-wide analyses, including; red maple, white pine, red oak, white ash, and scarlet oak.



Table 6. Percent species composition of MA forestland according to FIA inventories (USFS 2019), as measured on FEMC FHM plots.

<b>Species</b>	<b>FIA % Composition</b>	<b>FEMC FHM % Composition</b>
red maple	21.2	12.6
eastern white pine	16.8	13.4
eastern hemlock	12.4	14.6
northern red oak	8.9	6.2
sweet birch	5.5	6.7
sugar maple	4.5	6.4
black oak	3.6	3.8
white ash	3.1	2.5
scarlet oak	3.1	1.8
white oak	2.9	3.7
yellow birch	2.9	5.8
American beech	2.7	6.0
pitch pine	2.2	3.4

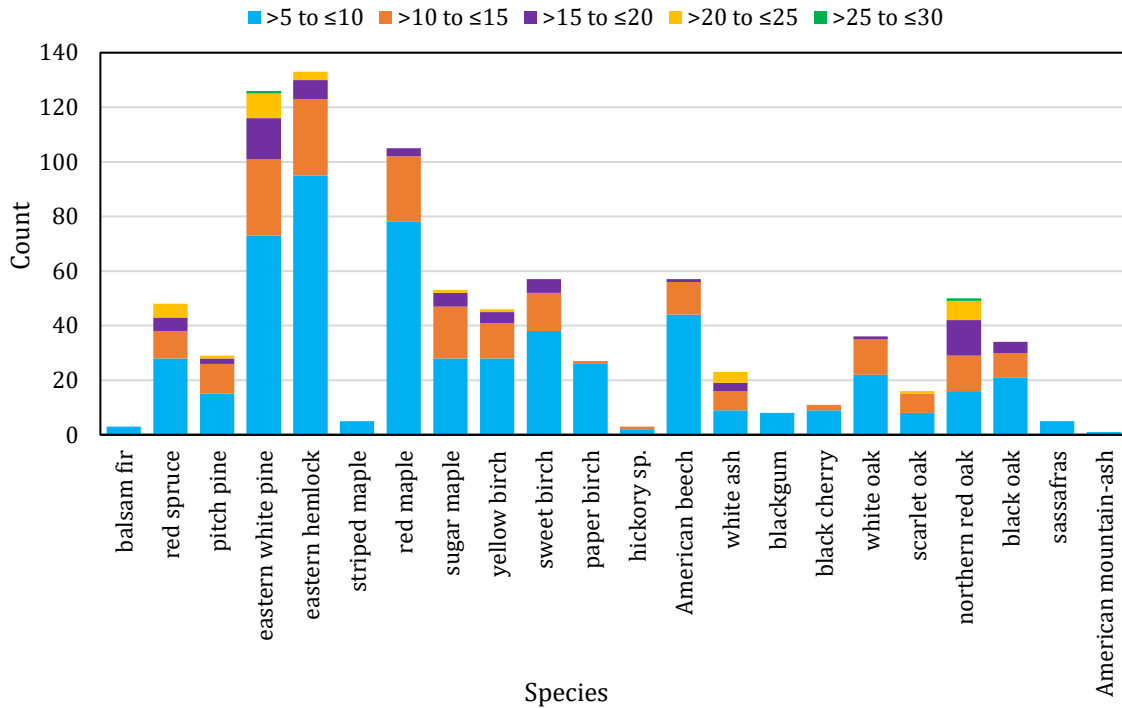
Across the 20 MA FEMC FHM plots, there were a total of 761 live and 127 standing dead trees. For live trees, this equated to an average of 190 live trees per acre (TPA) and basal area (BA) of 120.5 ft<sup>2</sup>/ac. Standing dead stems averaged 31 TPA and a BA of 14.0 ft<sup>2</sup>/ac. The total BA (live and standing dead) was 134.8 ft<sup>2</sup>/ac, which may be too high to encourage regeneration, especially for shade-intolerant species. However, the high number of standing dead snags (14% of the trees sampled) suggests that these forests have ample opportunities for wildlife habitat.

Eastern hemlock had the greatest TPA (28) of these species, followed by eastern white pine (26) and red maple (24) (Table 7). Eastern white pine had the highest BA (22 ft<sup>2</sup>/ac) and Importance Value (IV) across all plots (16%). Eastern hemlock had the second highest BA and IV (15 ft<sup>2</sup>/ac, 13.8%) (Table 7). Despite the dominance of these conifers (eastern hemlock and white pine), hardwoods comprised of 61.5% of the total overstory composition with maple, oak, and birch species occurring most frequently. Red maple was the third most dominant species (IV 11%), followed by northern red oak (IV 9%) (Table 7).

Table 7. Overstory composition of trees from the MA FEMC FHM plot network in 2019 showing total live stems (*N* live), total standing dead trees (*N* snags), live trees per acre (TPA), live tree basal area per acre (BA, ft<sup>2</sup>/ac), live tree percent composition (%), and live tree importance value (IV). Species are ranked by the importance value (IV).

<b>Species</b>	<b><i>N</i> Live</b>	<b><i>N</i> Snags</b>	<b>TPA</b>	<b>BA</b>	<b>%</b>	<b>IV</b>
eastern white pine	102	24	25	22	14	16
eastern hemlock	111	21	28	15	15	14
red maple	96	9	24	10	13	11
northern red oak	47	3	12	15	6	9
red spruce	36	11	9	7	5	5
sugar maple	49	4	12	8	6	7
sweet birch	53	4	13	7	7	6
American beech	46	12	11	4	6	5
yellow birch	44	3	11	7	6	6
black oak	29	7	7	4	4	4
white oak	28	9	7	4	4	3
pitch pine	26	4	6	5	3	4
white ash	19	2	5	4	3	3
black cherry	10	3	2	2	1	1
paper birch	27	0	7	2	4	3
scarlet oak	14	2	3	3	2	2
blackgum	2	0	0	0	<1	<1
American mountain-ash	1	0	0	0	<1	<1
balsam fir	1	0	0	0	<1	<1
hickory sp.	3	0	1	0	<1	<1
sassafras	5	0	1	0	<1	<1
striped maple	4	1	1	0	<1	<1
unknown	2	3	<1	<1	<1	<1
<b>Total</b>	<b>755</b>	<b>122</b>	<b>188</b>	<b>120</b>	<b>100</b>	<b>100</b>

Figure 4. Overstory composition of the MA FEMC FHM plot network in 2019. Total count of trees per species measured by DBH size class (inches): >5 to ≤10, >10 to ≤15, >15 to ≤20, >20 to ≤25, and >25 to ≤30.



The distribution of size classes across the MA FEMC FHM plot network in 2019 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). The majority of trees are in the 5-10 in size class, dominated by mid-successional species that would have become established around that time period. Some larger trees persist, particularly northern red oak, white pine and red spruce. As these stands continue to age, we can expect to see these numbers of large stems increase, particularly for late successional species such as eastern hemlock, American beech, and sugar maple (Figure 4).

## Tree health

Across the 20 MA FEMC FHM plots assessed in 2019, live tree vigor (mean ±SD) was  $1.4 \pm 0.6$ , or halfway between 'healthy' and 'light decline'. Of live trees, we found that 713 trees (93.5%) had vigor ratings corresponding to 'healthy' and 'light decline' (vigor 1 and 2, respectively) and 48 trees (6.5%) were in 'moderate' to 'severe decline' (vigor 3 and 4, respectively). The overstory trees with the highest average rates of moderate or severe decline were striped maple (50%), scarlet oak (21%), black cherry (20%), sassafras (20%), and black oak (14%) (Table 7). This is not surprising considering that these are predominantly shade intolerant species that will decrease in abundance as these forests continue to age. Across all species, ≤10% of total stems surveyed were determined

to be in severe decline. Overall, this points to a healthy, vigorous population of trees in the sampled plots.

Across all live trees, the average fine twig dieback was 10%. Striped maple had the highest mean dieback at 24%, while black cherry and black oak had 16% and 15% mean dieback, respectively (Table 8). These values do not suggest widespread crown health issues, but certain species or genera (e.g., oaks) should continue to be monitored for widespread changes in dieback overtime.

Table 8. Crown health metrics from live trees in 2019 across the MA FEMC FHM plot network. 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 are averages of ratings grouped in bins of 5% intervals. Discoloration and defoliation are averages of estimates associated with the class assignment for that species (Table 3). For example, a species with a mean of class 1 rating for discoloration (e.g., 1-30%), has an average rating of  $\leq 30\%$  and  $>1\%$ . Species with an average of a class 0.4 (between trace (t) and class 1) rating for discoloration has a rating between trace and  $\leq 1\%$ . Percent class is based on the mean discoloration and defoliation. Species are ranked by % poor vigor.

Species	Poor Vigor (%)	Dieback (%)		Transparency (%)		Discoloration			Defoliation		
		mean	median	mean	median	mean	median	% Class	mean	median	% Class
striped maple	50	24	15	24	25	1.5	1.5	31% - 60%	1.5	1	31% - 60%
scarlet oak	21	14	13	24	25	0.2	0	t-1%	1.3	1	31% - 60%
black cherry	20	16	8	25	23	0.4	0	t-1%	0.8	1	t-1%
sassafras	20	11	5	13	15	0.2	0	t-1%	0.2	0	t-1%
black oak	14	15	15	21	20	0.3	0	t-1%	1	1	1% - 30%
American beech	13	11	10	19	20	0.2	0	t-1%	1.2	1	31% - 60%
northern red oak	11	11	10	18	20	0.2	0	t-1%	1	1	1% - 30%
red maple	6	9	10	18	15	0.4	0	t-1%	1	1	1% - 30%
sweet birch	6	10	5	18	20	0.1	0	t-1%	0.9	1	t-1%
white ash	5	9	10	21	20	0.1	0	t-1%	0.8	1	t-1%
yellow birch	5	9	10	18	15	0.1	0	t-1%	0.9	1	t-1%
white oak	4	9	10	20	20	0.1	0	t-1%	1	1	1% - 30%
American mountain-ash	0	10	10	30	30	0	0	t-1%	2	2	31% - 60%
blackgum	0	8	8	18	18	0.5	0.5	t-1%	0.5	0.5	t-1%
hickory spp.	0	7	5	20	20	0.3	0	t-1%	0.7	1	t-1%
paper birch	0	9	5	21	20	0.6	1	t-1%	0.8	1	t-1%
sugar maple	0	7	5	17	15	0.1	0	t-1%	1	1	1% - 30%
eastern hemlock	7	9	5	15	15	0.8	1	t-1%	0	0	t-1%
red spruce	6	9	5	15	15	0.5	0	t-1%	0	0	t-1%
eastern white pine	2	7	5	19	20	0.1	0	t-1%	0	0	t-1%
balsam fir	0	5	5	15	15	0	0	t-1%	0	0	t-1%
pitch pine	0	8	5	18	20	0.4	0	t-1%	0	0	t-1%

Across all trees, foliar transparency ranged from 13% to 30% (Table 8). Transparency is rated the same way across all species, however each species has a different range of commonly observed transparency ratings due to the general structure of each species crown. Striped maple, scarlet oak, black cherry, white ash, and sassafras had mean transparency  $\geq 20\%$ .

Foliar discoloration impacted striped maple the most with a median discoloration estimate of 1.5 (Table 8), which indicates striped maple exhibited approximately 31-60% discoloration on average. All other species had trace - 1% foliar discoloration. Since monitoring occurred in early September, it is possible that some of the deciduous species' leaves were beginning to change color, particularly for black gum, which is known to begin the senescence process early. It is possible that the eastern hemlock discoloration noted was related to hemlock woolly adelgid infestations, but we were unable to confirm this.

Defoliation rates were the highest (mean class value of 2 percent class 31-60% crown defoliation on average) among striped maple, scarlet oak, American beech, and American mountain-ash trees and occurred in 1-30% (mean class value equal to 1) of the crown area of black oak, northern red oak, red maple, white oak, and sugar maple, on average (Table 8). Nearly every species saw some level of defoliation. In several plots, we observed gypsy moth caterpillars and egg masses on the boles of trees.

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

In 2019, damage related to beech bark disease (BBD) was the most common damage agent recorded across plots. In total, 45% of the plots (9) were impacted by BBD and approximately 80% of American beech trees showed symptoms of the disease (Table 9). Another prevalent damage was crack and seam, which occurs when a tree splits due to weather. This damage was present on 45% of plots and impacted between 1-9% of trees (Table 9). We found that 65% of plots (13) had evidence of browse impacts, which may negatively impact regeneration success. Surprisingly, we found only one plot with invasive species present, though the infestation of European buckthorn was dense on this plot.

Table 9. Special damages recorded on live trees across the 20 MA FEMC FHM plots in 2019. Damages are shown as the percent affected per species and damage type. Note that not all damages have been recorded if the damages were not obvious or visible from the ground. For example, many eastern hemlock trees that were surveyed appeared discolored and showed symptoms of hemlock woolly adelgid (HWA), but we did not have the means to confirm the presence of HWA.

Species	% Crack and seam	%Bark beetles	%Other canker	%Sapsucker	%BBD
red spruce	6				
pitch pine		4			
eastern white pine	1				
eastern hemlock	4				
red maple	3				
sugar maple	2		2	2	
yellow birch	9				
sweet birch	4				
American beech	9				80
white ash	5				
northern red oak				2	
black oak	3				

## Tree regeneration

### Saplings

Four out of 20 plots did not contain any saplings. It is possible that saplings exist near or in the overstory plots but not within the regeneration subplots. There were 66 living saplings across the remaining 16 plots, with 318 stems per acre (SPA). These numbers are on the low side for this forest type. For comparison, the 49 VT FEMC FHM plots have a SPA of 624, however these include high elevation spruce fir plots that tend to have a dense regeneration layer.

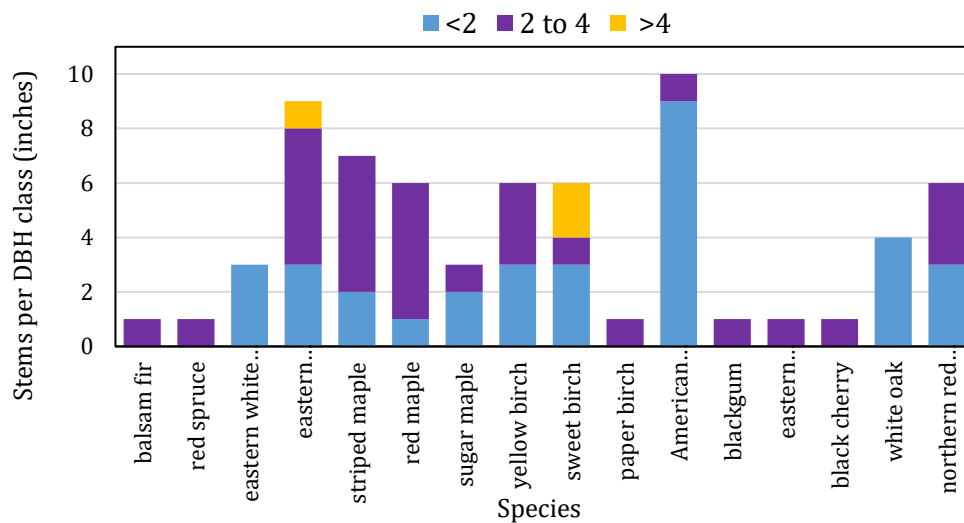
The sapling layer displayed the lowest species diversity of the three strata (trees, saplings, seedlings). Across the plots, there were 16 different species captured in the sapling plots, compared to 23 tree species represented and 28 seedlings. The number of sapling species recorded per plot ranged from 0 to 7. We found that American beech (15.2% of the total sapling composition, 48 SPA), eastern hemlock (13.6%, 45 SPA), and striped maple (10.6%, 34 SPA) where the most abundant species in the sapling layer (Table 10). American beech stems were likely suckers based on their small size (Figure 5) and due to the prevalence of BBD on mature trees (see Agents of Change section).

Table 10. Sapling composition from the MA FEMC FHM plot network in 2019 showing total stems (N), saplings per acre (SPA), percent composition (%) of sapling layer, and basal area per acre (BA, ft<sup>2</sup>/ac). Information for the aggregate for all species sapling data is shown in the last row. Species are sorted by percent composition of sapling layer. Species are ranked by percent composition of sapling layer.

<b>Species</b>	<b>N</b>	<b>SPA</b>	<b>%</b>	<b>BA</b>
American beech	10	48	15.2	0.67
eastern hemlock	9	43	13.6	2.15
striped maple	7	34	10.6	1.35
red maple	6	29	9.1	1.34
yellow birch	6	29	9.1	0.86
sweet birch	6	29	9.1	1.61
northern red oak	6	29	9.1	0.57
white oak	4	19	6.1	0.20
eastern white pine	3	14	4.5	0.15
sugar maple	3	14	4.5	0.44
balsam fir	1	5	1.5	0.16
red spruce	1	5	1.5	0.16
paper birch	1	5	1.5	0.34
blackgum	1	5	1.5	0.29
eastern hophornbeam	1	5	1.5	0.16
black cherry	1	5	1.5	0.28
<b>All species</b>	<b>66</b>	<b>318</b>	<b>100</b>	<b>10.73</b>



Figure 5. Total number of saplings measured by size class: <2, ≥2 and <4, and ≥4 across all subplots in the 20 MA FEMC FHM overstory plots.



## Seedlings

In total, 4,382 seedlings in class one and two (3,597 class 1 and 785 class 2) were tallied across the 20 MA FEMC FHM plots in 2019. Seedling counts per plot network ranged from a low of three, to a high of 719 and identified 28 unique species. There was an average density of 17,318 stems per acre (SPA) across the entire 20-plot network in 2019. For comparison, VT FEMC FHM plots had an average density of 13,911 SPA in 2019. The VT plots cover a wider range of plots, including dense spruce-fir stands with minimal advance seedling regeneration.

The seedling layer was the most diverse of the three measured strata, with 28 species. Species diversity per plot ranged from two to 13 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 (the plots with the highest and lowest number of species in the seedling stratum each had eight species of overstory trees).

Red maple was the most abundant seedling tallied in 2019 (7,294 SPA, 42.12% composition), followed by sweet birch (22.30%, 3,861 SPA), and striped maple (6.2%, 1,074 SPA) (Table 11). Seedling densities are subject to yearly shifts due to changing weather conditions (e.g., available precipitation), herbivory, and seed availability (e.g., masting events). Therefore, it will become increasingly valuable to assess shifts in composition and density over multiple years while tracking regeneration success.

Table 11. Seedling composition across MA FEMC FHM plots in 2019 showing total seedlings (class 1, class 2, and combined counts (N) per size class), average density of stems per acre (SPA), and percent composition (%) of the seedling layer, sorted by percent composition. Information for the aggregate for all species seedling data is shown in the last row.

<b>Species</b>	<b>N class 1</b>	<b>N class 2</b>	<b>N</b>	<b>SPA</b>	<b>%</b>
red maple	1,515	354	1,869	7,294	42.12%
sweet birch	802	21	823	3,861	22.30%
striped maple	223	47	270	1,074	6.20%
American beech	189	93	282	910	5.25%
eastern white pine	159	52	211	765	4.42%
yellow birch	102	30	132	491	2.84%
American mountain-ash	91	0	91	438	2.53%
birch spp.	79	0	79	380	2.20%
paper birch	73	1	74	351	2.03%
eastern hemlock	59	55	114	284	1.64%
northern red oak	52	11	63	250	1.45%
bear oak, scrub oak	47	26	73	226	1.31%
mountain maple	47	36	83	226	1.31%
white oak	34	16	50	164	0.95%
sassafras	28	3	31	135	0.78%
balsam fir	22	18	40	106	0.61%
black oak	19	0	19	91	0.53%
sugar maple	16	1	17	77	0.44%
red spruce	11	11	22	53	0.31%
black cherry	8	0	8	39	0.22%
Unknown	6	3	9	29	0.17%
American chestnut	4	4	8	19	0.11%
blackgum	2	1	3	10	0.06%
chokecherry	2	2	4	10	0.06%
pignut hickory	2	0	2	10	0.06%
scarlet oak	2	0	2	10	0.06%
apple spp.	1	0	1	5	0.03%
bur oak	1	0	1	5	0.03%
oak spp.	1	0	1	5	0.03%
All species	3,597	785	4,382	17,318	100%

## Conclusions

---

Annual monitoring of forests can provide valuable insights into subtle changes in the forest condition due to protracted weather (e.g. drought), and stress conditions (e.g. low-level pests and pathogens), as well as subtle changes in composition and health due to longer-term changes in climate. Assessments of crown health can provide early warning signs of subtle or pervasive stressors, while the understory condition can indicate what the future forest may look like. As the FEMC FHM program continues in MA, and more annual measurements are collected, we can begin to assess emerging trends in forest health, particularly changes in seedling and sapling survivorship from year-to-year and changes in crown health that may signal chronic decline issues. These insights may prove important as managers look to ensure that MA forests remain healthy, productive, and resilient in the future.

While there is a wide range of stressors affecting MA forests, and significant vulnerabilities do exist, early indicators suggest these forests are diverse, vigorous, and healthy. Species diversity was evident across all three strata (overstory trees, saplings, and seedlings), although it was lowest in the sapling layer. On average, the overstory trees were vigorous with healthy crowns. Despite widespread gypsy moth outbreak in southern New England, defoliation of oaks was <30%. Based on U.S. Forest Service Insect and Disease Surveys, two out of the 20 plots (Plot 1607: Mount Holyoke Range State Park and Plot 3662: Myles Standish State Forest) were within the boundaries of forests stands defoliated by gypsy moth in the previous year. Our data suggests that scarlet oak was affected more severely than the other oak species. While regeneration was evident in all plots, four plots did not contain saplings, which warrants ongoing monitoring and investigation.

## Data

---

Data and metadata were archived on the FEMC data archive located at <https://www.uvm.edu/femc/data/archive/project/massfhm>.

## References

---

- Bechtold, W., Tkacz, B., and Riitters, K. 2007. *The historical background, framework, and the application of forest health monitoring in the United States*. In: Proceedings of the international symposium on forest health monitoring; 2007 January 30-31; Seoul; Republic of Korea.
- Gillespie, A. 1998. *Pros and Cons of Continuous Forest Inventory: Customer Perspectives*. Integrated Tools for Natural Resources Inventories in the 21st Century Conference.
- Gillespie, A. 2000. *Changes in the Forest Service's FIA program*. USDA Forest Service.
- Hall, B., Motzkin, G., Foster, D., Syfert, M. and J. Burk. 2002. Three hundred years of forest and land-use change in Massachusetts, USA. *Journal of Biogeography* 29: 1319–1335.
- Massachusetts Division of State Parks and Recreation (MA DCR). 2014. *Manual for Continuous Forest Inventory Field Procedures*.

Massachusetts Division of State Parks and Recreation (MA DCR). 2019. *Massachusetts CFI database*. Available by request.

Millers, I., Lachance, D., Burkman, W. G., and Allen, D. C. 1991. *North American sugar maple decline project: organization and field methods*. USDA Forest Service.

Nevins, M., Duncan, J., and Kosiba, A. M. 2019. *Comparing Continuous Forest Inventory Program Methodologies Across the Northeast*. Forest Ecosystem Monitoring Cooperative.

Randolph, K. 2010. *Phase 3 Field Guide - Crowns: Measurements and Sampling*. Version 5.0. USDA Forest Service. Available at: [http://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/2011/field\\_guide\\_p3\\_5-0\\_sec23\\_10\\_2010.pdf](http://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/2011/field_guide_p3_5-0_sec23_10_2010.pdf).

USDA Forest Service (USFS). 2013. *Forest Inventory and Analysis National Core Field Guide*. Vol. 1 Version 6.0.2.

USDA Forest Service (USFS). 2019. *EVALIDator Version 1.8.0.01*. Available at: <https://apps.fs.usda.gov/Evalidator/evaluator.jsp>

Wilmot, S., Duncan, J.A., Pontius, J., Gudex-Cross, D., Sandbach, C., and J. Truong. 2019. *Vermont Forest Health Monitoring Protocol*. Forest Ecosystem Monitoring Cooperative. Available at: <https://www.doi.org/10.18125/d2c081>.

## Appendix

Table A1: List of plot description 'sub types' (MA DCR 2014) that were considered non-forest and removed from consideration for Forest Health Monitoring Plots.

Sub type	Name	Description
<b>AO</b>	Abandoned Orchards	Usually apple orchards abandoned around former farms, used only where more than 10 trees are observed.
<b>BF</b>	Seasonally Flooded basins and flats	Occur principally on stream floodplains. The most common plants are grasses and herbaceous species. The soil is waterlogged and covered with water during spring freshets, but well drained during the growing season.
<b>BG</b>	Bogs	Typically acidic, peaty soil is waterlogged and supports a distinctive plant community which usually includes; heath, shrubs, cranberries, pitcher plants and sedges. Scattered tree cover may be present.
<b>BL</b>	Black Locust	Black locust is pure or predominant. Often the result of artificial reforestation. Many associated species.
<b>BP</b>	Beaver Pond	These ponds resemble one or more of the above types but they owe their origin to beaver.
<b>BR</b>	Upland Brush	Mixture of shrubs with no single species predominating - may include dogwood, serviceberry, sheep laurel, etc. among others.
<b>DF</b>	Duff	Soil covered with leaf or needle litter layer with little or no other reproduction. Common under pure softwood stands and mature hardwoods.
<b>FN</b>	Bracken fern	Any species of fern.
<b>GR</b>	Grasses and forbs	Ground cover of any species of grasses or forbs common to open areas and tree covered areas.
<b>HE</b>	Heath	Bearberry ( <i>Arctostophylus uva-ursi</i> ), low-bush blueberry, etc., often associated with sandplains.
<b>LA</b>	Mountain laurel and other laurel like plant	<i>Kalmia latifolia</i> - mountain laurel or other laurels (azaleas) or rhododendrons. Dense cover on more acidic soils.
<b>MA</b>	Sweetfern	<i>Comptonia peregrina</i> or <i>Myrica gale</i> . A common shrub of uplands, abandoned fields and dry sites.
<b>MD</b>	Deep Marsh	Water depth ranges from six inches to three feet. Fairly large open water areas are bordered by, or interspersed with, emergent vegetation like that found in shallow marsh. Floating and submergent plants such as water lilies, duckweed, watershield, and pondweeds are also present.
<b>MS</b>	Shallow Marsh	This type is wetter than meadow. The soil is completely waterlogged and often covered with up to six inches of water during the growing season. There is usually some open water and the predominant vegetation is emergent, including such plants as cattails, bullrushes, burreed, pickerel-weed and arrowhead with some grasses and sedges present.

<b>MT</b>	Salt Marsh	Since these areas are under tidal influence, they are flooded twice daily. Vegetation is primarily saltmarsh cordgrass.
<b>MW</b>	Meadow	Standing water is present only for short periods in the spring. Soil is waterlogged during the growing season. Vegetation is predominantly grasses, rushes and sedges.
<b>NV</b>	No vegetation	Rock or gravel banks or open administrative land – roads, etc.
<b>OP</b>	Open	Reserved for either bare land, just prepared for tree planting, or as the understory type for essentially ground cover overstory types.
<b>RU</b>	<i>Rubus</i> species	Raspberries or blackberries ("brambles") usually on cutover areas or in small openings in the forest.
<b>SN</b>	Norway Spruce	Norway spruce is either pure or predominant and is the result of artificial reforestation.
<b>SP</b>	Scots Pine	An introduced species, always in plantations.
<b>SS</b>	Shrub Swamp	The soil is waterlogged during the growing season and is often covered with as much as six inches of water. Common woody species are alder, buttonbush, dogwood and willow. Sedges are usually found on tussocks.
<b>VA</b>	<i>Vaccinium</i> species	Blueberries, huckleberry or cranberry. Low shrub cover.
<b>VI</b>	Viburnum	A genus that occurs across a wide range of soil and moisture conditions.
<b>WA</b>	Open Water	Lakes, rivers and large streams. Water depth is greater than three feet during the growing season. The boundary of coastal water is located by drawing a line at the river mouth to connect the edges of the coastline, or man-made features like roads, railroads or bridges crossing rivers or inlets are used to establish it.

Table A2: List of special damages to trees in the FEMC Forest Health Monitoring program (Wilmot et al. 2019).

<b>Bole Damage</b>	<b>Bole Damage Agent</b>
<i>Animal Damage</i>	
441	Animal browse
444	Beaver damage
445	Porcupine damage
446	Sapsucker damage
447	Other animal damage
<i>Borers and Insects</i>	
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

<b>Bole Damage</b>	<b>Bole Damage Agent</b>
<i>Cankers Conks and Diseases</i>	
106	Beech bark disease symptoms
201	Butternut canker
206	European larch canker
203	Eutypella canker
204	Hypoxyton canker
202	Nectria canker
207	Other canker
208	Conks and other indicators of decay
209	Dwarf mistletoe
210	White pine blister rust
<i>Human-related</i>	
702	Logging damage > 20% of
<i>Weather-related</i>	
708	Cracks and seams
501	Wind-thrown/uprooted
505	Other weather damage

Table A3: List on invasive plants and their codes for the Forest Health Monitoring program (Wilmot et al. 2019).

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





# FEMC

Forest Ecosystem Monitoring Cooperative



The University of Vermont

*The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at 202-720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call 800-795-3272 (voice) or 202-720-6382 (TDD). USDA is an equal opportunity provider and employer.*

*Providing the information needed to understand, manage, and protect the region's forested ecosystems in a changing global environment*

This work is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/).

