DRAFT Maine 2018 - Forest Health Indicators

Urbanization and Fragmentation, Regen, Tree Crown Health and Damage, Invasive Plants, and Pests and Diseases

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Urbanization and Fragmentation

Freshly paved highway traveling along the Schoodic Bay in northern Maine, by Jorge Moro, Shutterstock.

The wildland-urban interface (WUI) is the zone where human development meets or intermingles with undeveloped wildland vegetation, and it is the fastest-growing land use type in the conterminous United States (Radeloff et al. 2018, Mockrin et al. 2019). Although originally created to identify the area where wildfires pose the greatest risk to people, the WUI is associated with a variety of consequential human-environment conflicts. These include impacts such as the loss and fragmentation of native species, the introduction and spread of non-native species (e.g. Gavier-Pizarro et al. 2010, Riitters et al. 2018), the loss of habitat area or critical connectivity (e.g. Bregman et al. 2014, Rogers et al. 2016), increased mortality of wildlife (e.g. Loss and Marra 2013, Klem 2009), reductions in regional complexity of plant and animal communities (e.g. Ferguson et al. 2017, Mack et al. 2000), increases in non-native insect and disease invasions (e.g. Guo et al. 2018), and impacts on water quality and quantity from impervious surfaces and increased pollution (e.g. Gonzalez-Abraham et al. 2007; Bar-Massada et al. 2014). The 2018 report from the New England Climate Change Response Framework on New England and New York forest ecosystem vulnerability (Janowiak et al. 2018) identified fragmentation and land-use change as one of the top six current major stressors and threats to forest ecosystems, and two of the other threats – invasion by non-native species, and forest diseases and insect pests –are themselves heavily influenced by forest fragmentation and urbanization.

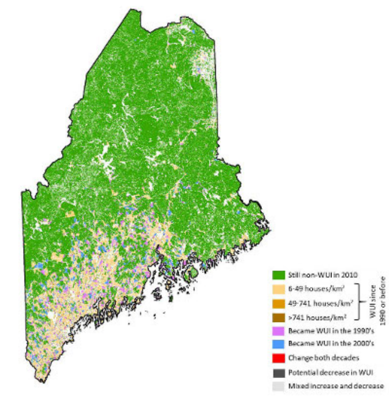


Figure 24 - Map of NLCD forest by census block-level change in WUI status (1990-2010), Maine.

With the recent completion of a temporally consistent census block-level dataset capable of accurately comparing block-level change in housing densities from 1990-2010 (Radeloff et al. 2017, Mockrin et al. 2019), we analyzed changes in housing density and forest land at a finer spatial resolution and with more accuracy than was previously possible. We have used this data here to identify FIA forest land and changes in WUI status via the following categories: forest land in census blocks that have had housing densities above established Wildland Urban Intermix (WUI) thresholds for 30+ years (from 1990 or before), forest that became WUI in the 1990's, forest that became WUI in the 2000's, forest that experienced change in WUI density both decades, and forest land that still remained in non-WUI census blocks in 2010. We examined a number of metrics such as how much forest land is already experiencing or is at risk of change because of its proximity to WUI levels of housing development, and what that rate of change has been in the last 20 years of available data (1990-2010).

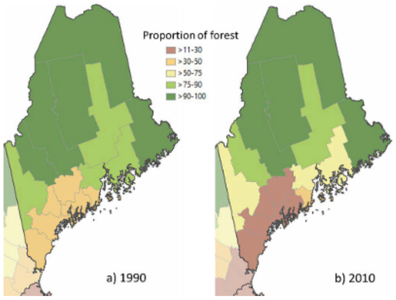


Figure 25 - Proportion of forest that's non-WUI in a) 1990 and b) 2010.

What we found

Both the acres and proportion of forest that is non-WUI is continuing to shrink, from 15.2 to 14.2 million acres in Maine (86 to 81 percent of the total forest land) between 1990 and 2010. By 2020, 2.4 million acres of Maine forest land will have been in WUI conditions for at least 30 years with an additional 0.97 million acres of forest land crossing the WUI threshold between 1990 and 2010. Some areas experienced more forest urbanization in the 1990's, some in the 2000's, and some both decades, with half the counties experiencing additional urbanization at rates averaging greater than 5 percentage points per decade.

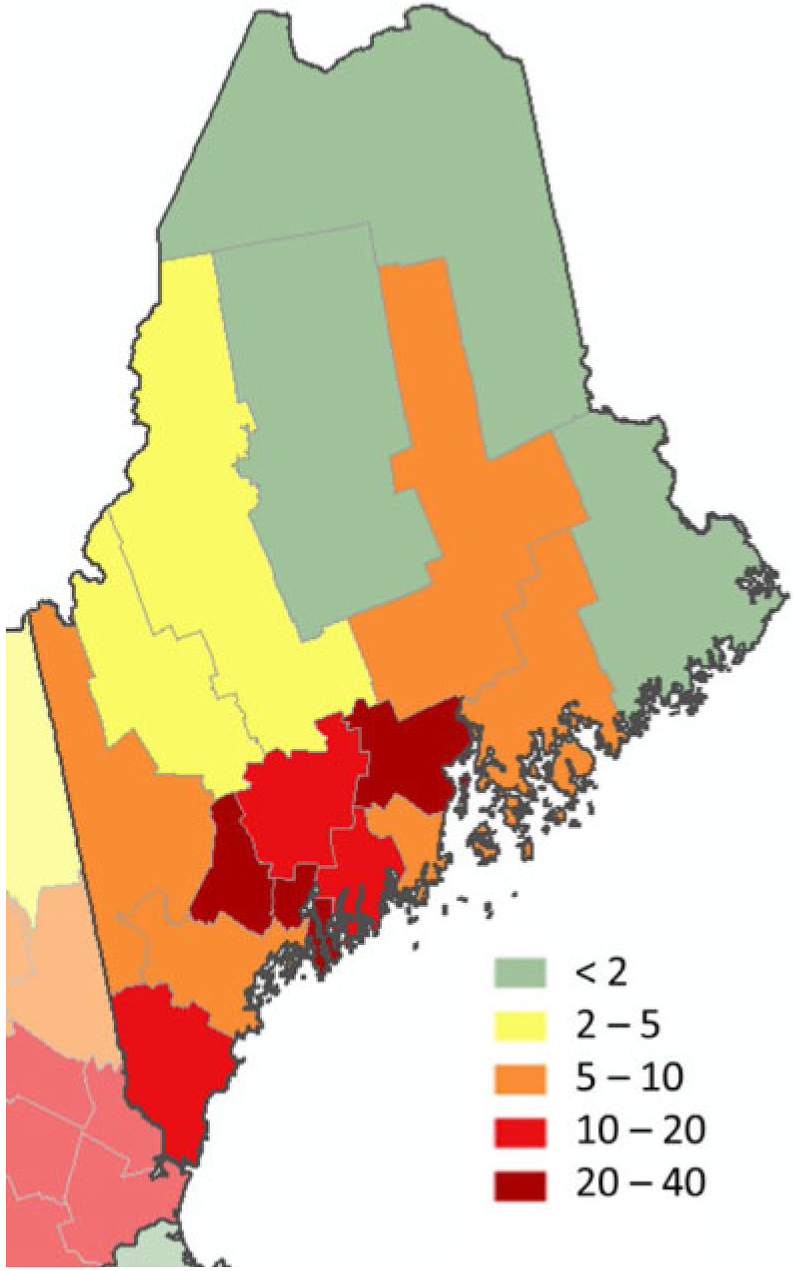


Figure 26 - Proportion of forest land in each county that changed from non-WUI to WUI intermix during the 20 years between 1990 and 2010.

Forest type	Total acres	All classes	WUI change group				
			WUI from 1990 or earlier	new WUI 1990-2010	still non-WUI as of 2010	1990 WUI decrease to non-WUI	proportion of area in WUI in 2010
Total	17,636,080	100	14	5	81	0	19
Eastern white pine/northern red oak	349,752	2	53	13	34	0	66
Northern red oak	235,737	1	51	9	39	0	61
Eastern white pine/eastern hemlock	157,721	1	44	10	46	0	54
Eastern white pine	580,444	3	38	15	46	1	53
Red maple / lowland	253,074	1	37	12	51	0	49
Eastern hemlock	306,464	2	22	12	64	2	34
Gray birch	223,144	1	24	9	67	0	33
White spruce	179,284	1	23	8	67	3	31
Red maple / upland	758,385	4	21	9	70	0	30
Aspen	836,756	5	17	11	72	0	28
Hard maple / basswood	197,061	1	18	8	74	0	26
Remaining types (< 176,000 acres, < 1% of forest	758,434	4	19	6	75	0	25
Sugar maple / beech / yellow birch	6,273,230	36	11	5	83	0	16
Paper birch	894,969	5	8	5	87	1	13
Northern white-cedar	988,103	6	7	4	90	0	10
Red spruce	929,664	5	8	2	90	0	10
Balsam fir	2,102,784	12	6	2	92	0	8
Red spruce / balsam fir	1,054,107	6	3	1	96	0	4
Black spruce	556,967	3	1	0	99	0	1

Table 1 - Wildland-urban interface change class breakdown by forest type, Maine.

Forest types were affected to differing degrees in 2010, from 1 percent of their forest area (Black spruce type) to 66 percent of their forest area (Eastern white pine/northern red oak type). Three additional forest types had >=50 percent of their area in WUI as of 2010 (Northern red oak, Eastern white pine/eastern hemlock, and Eastern white pine types). The Eastern white pine and EWP/NRO types had the greatest proportion of their area converted to WUI intermix between 1990-2010, at 15 and 13 percent, respectively, and 6 forest types had >=10 percent of their forest area converted to WUI intermix during that time. Some forest types are being disproportionately affected by WUI development. For example, 9 percent of the total forest area in WUI in Maine in 1990, and 9% of the new WUI between 1990 and 2010 was in the Eastern white pine type, which itself only represents 3 percent of the total forest area in Maine. Conversely, the Balsam fir type was affected by WUI to a much lower degree (4 percent) than its proportion of the total forest area in Maine (12 percent).

Forest type	Total acres	All classes	WUI change group: WUI from 1990 or earlier	new WUI 1990-2010	still non-WUI as of 2010	1990 WUI decrease to non-WUI
Total	17,636,080	100	2,399,185	965,769	14,211,348	54,422
Sugar maple/beech/yellow birch	6,273,230	36	29	34	37	50
Balsam fir	2,102,784	12	6	4	14	5
Red spruce / balsam fir	1,054,107	6	1	1	7	5
Northern white-cedar	988,103	6	3	4	6	0
Red spruce	929,664	5	3	2	6	0
Paper birch	894,969	5	3	4	5	10
Aspen	836,756	5	6	9	4	0
Red maple / upland	758,385	4	7	7	4	0
Eastern white pine	580,444	3	9	9	2	11
Black spruce	556,967	3	0	0	4	0
Eastern white pine/northern red oak/white ash	349,752	2	8	5	1	0
Eastern hemlock	306,464	2	3	4	1	11
Red maple / lowland	253,074	1	4	3	1	0
Northern red oak	235,737	1	5	2	1	0
Gray birch	223,144	1	2	2	1	0
Hard maple / basswood	197,061	1	2	2	1	0
White spruce	179,284	1	2	1	1	8
Eastern white pine/eastern hemlock	157,721	1	3	2	1	0
Remaining types (<176,000 acres, <1% of forest area ir	758,434	4	6	4	4	0

Table 2 - Forest type breakdown of wildland-urban interface change class, Maine.

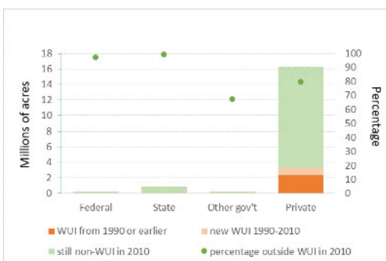


Figure 26 - Proportion of forest land in each county that changed from non-WUI to WUI intermix during the 20 years between 1990 and 2010.

Ownerships with the greatest proportion of their forest land area remaining as non-WUI forest were state (100 percent) and Federal (97 percent) ownerships, followed by the private ownership group (80 percent). The county and local government ownership group had the lowest proportion of its forest land remaining in non-WUI conditions in 2010 (68 percent). The large amount of forest land in private ownership in Maine meant that it had 12 times the number of acres remaining in non-WUI conditions in 2010 as all other ownerships combined. All the forest land experiencing a change in WUI status between 1990 and 2010 was in private ownership.

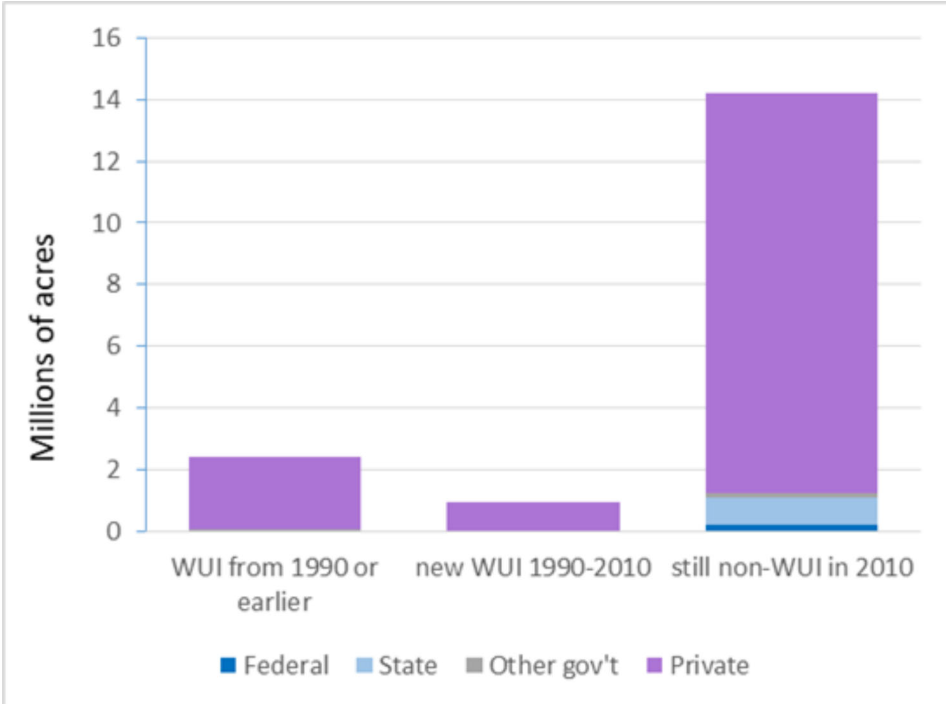


Figure 28 - Forest land by WUI change group by ownership group.

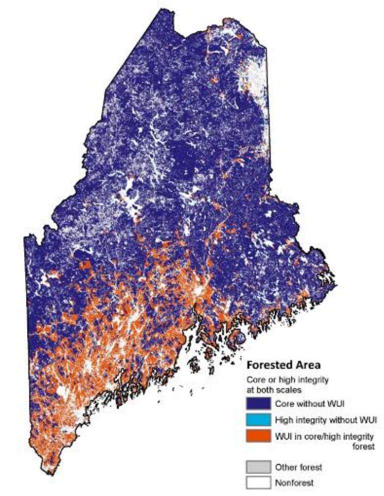


Figure 29 - Locations where wildland-urban interface occurred within forest land calculated to have core or high spatial integrity at both scales, Maine.

In Maine, 78 percent of the forest land had a spatial integrity index value of “core” and/or “high integrity” at both the 30m and 250m scales, as defined by its patch size, local forest density, and connectedness (see also Widmann et al. 2015). However of that core/high forest land, 18 percent occurred in WUI conditions in 2010, the most recent census data available. Between 1990 and 2010 conversions of core and high spatial integrity forest to WUI conditions took place at an average rate of 3 percentage points per decade.

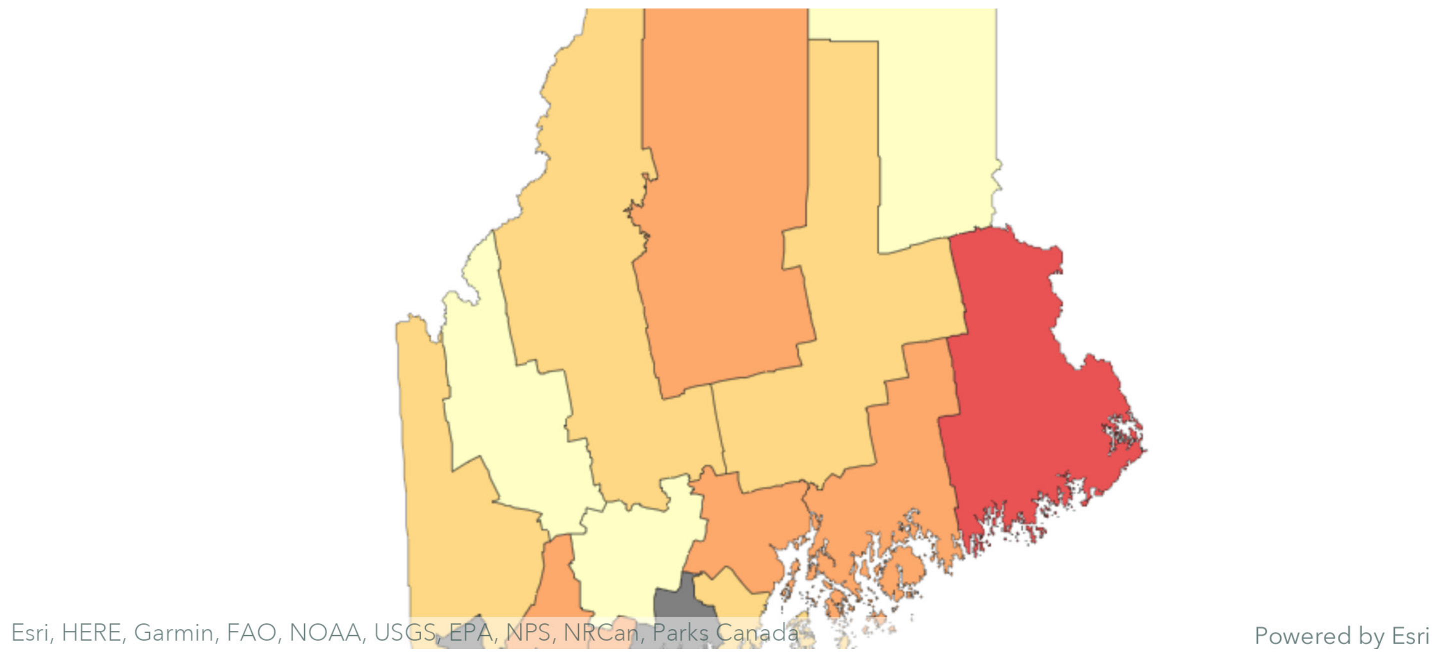
Looking only at core forest, 63 percent of the forest land in Maine had a spatial integrity index value of “core” at both scales, however 14 percent of that core forest occurred in WUI conditions in 2010. From 1990 to 2010 this core forest was still being converted to WUI conditions at an average rate of 2.5 percentage points per decade.

What this means

Urbanization is affecting an increasing amount of forest area in Maine, including unfragmented forest land in otherwise core or high spatial integrity situations. A total of 2.4 million acres (14 percent of Maine’s forest land) was in WUI conditions by 1990. Conversion to WUI conditions between 1990 and 2010 occurred at the highest rates in the counties around Portland and nearest Boston, and in all but one coastal county forest land was being converted to WUI conditions at rates greater than 4.5 percentage points per decade. In

Regeneration

The species composition, abundance, and structure of tree regeneration is an important indicator of the future sustainability and trajectories of numerous forest ecosystem attributes such as live tree stocking and/or resilience to disturbance events. Various facets of FIA's inventory can quantitatively address tree regeneration including the abundance of advanced tree regeneration on all plots and the abundance of all seedlings measured on a subset of plots (McWilliams et al. 2015).



Interactive Figure 27 - Interactive map of percent of forest land with stand age <20 years.

What we found

Over the past 15 years the percent of Maine's forest classified as young (< 20 years in age) has decreased from over 14 percent to below 4 percent. At the same time, the abundance of advanced tree seedlings (less than 1 inch d.b.h and at least 6 inches in length for softwoods and 12 inches in length for hardwoods) and saplings have been fairly stable. From 2012 to 2018, over 62 percent of Maine's forest land was assessed as having very low to low ungulate browse impact on seedlings. In contrast, less than 2 percent of Maine's forest land was identified as suffering from high to very high impact of seedling browse.

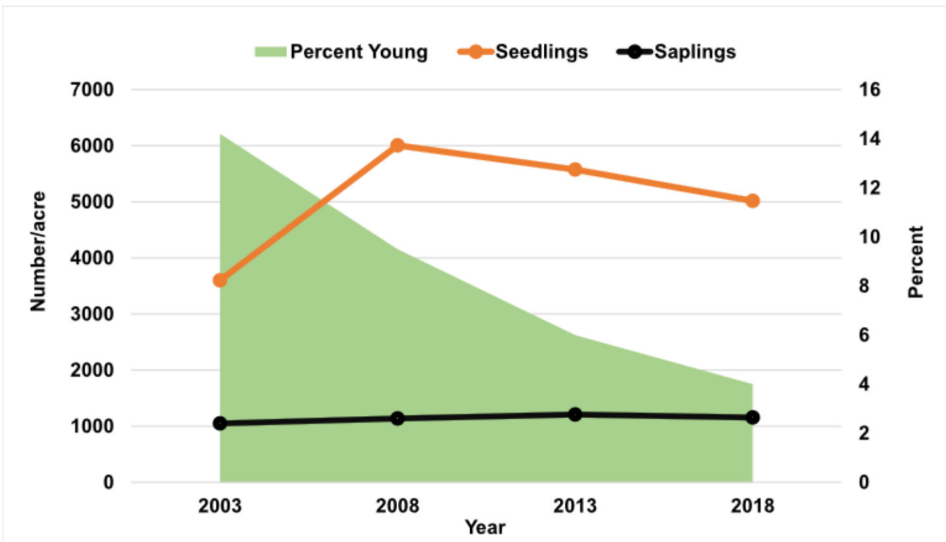


Figure 30 - The percent of young forest (< 20 years in age) and abundance of advanced tree regeneration (>5.9 inches and >11.9 inches in height for softwoods and hardwoods, respectively) and saplings (1 to 4.9 inches dbh) for forest land in Maine, 2003-2018.

Additional regeneration assessments on a subset of plots classify seedlings by height and estimated the total number of all established seedlings at over 193 billion with an average of over 10,500 seedlings per acre. Balsam fir, red maple, and sugar maple were the most abundant tree seedlings across all height classes. Balsam fir, red maple, and American beech were the most abundant species in the largest seedling height class (5.0+ feet in height). In terms of the difference between the abundance of the smallest versus largest seedling size classes, red maple had the greatest disparity with an average of over 1,500 small seedlings per acre (2.0-11.9 inches in height) across all of Maine's forest land but less than 100 per acre for the largest height class (> 5.0 feet). In contrast, American beech had over 75 small seedlings compared to 125 per forest land acre that were five feet or taller.

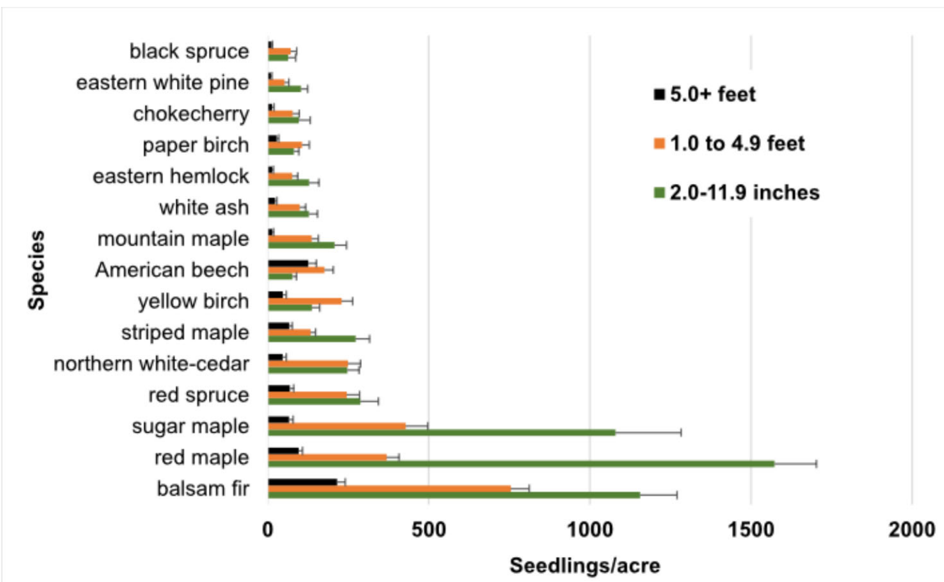


Figure 31 - The abundance of the top fifteen tree seedling species across three height classes, Maine's forest land, 2012-2018. Error bars represent a 68 percent confidence interval around the estimated mean.

What this means

Similar to many states in the eastern US, there is a lack of younger aged forests across Maine despite a relatively abundant understory of seedlings. Unlike many forests in the eastern US, Maine does not suffer from widespread browsing of tree seedlings which can impede effective tree regeneration. The abundance of seedling species across height classes can indicate a variety of forest stand dynamics such as stand senescence or changing successional directions. Balsam fir, sugar maple, and red spruce appear to have abundant populations of the smallest seedlings with recruitment into the larger height classes while American beech, which suffers from beech bark disease, has greater abundance of the largest-sized seedlings than smaller ones. Although not as commercially important nor critical for ensuring future sustainability, red maple had the largest number of the smallest seedlings among all tree species. Overall, the lack of young forest and scarcity of tree regeneration will remain a problem for select forest types dependent on relatively open conditions for regeneration such as eastern white pine. In contrast, reasonable levels of regeneration may enable continued active management of the commercially important species of red spruce and balsam fir. The prevalence of red maple in the understory coupled with health concerns of other major species such as American beech (beech bark disease) and red spruce (spruce budworm) should be monitored.

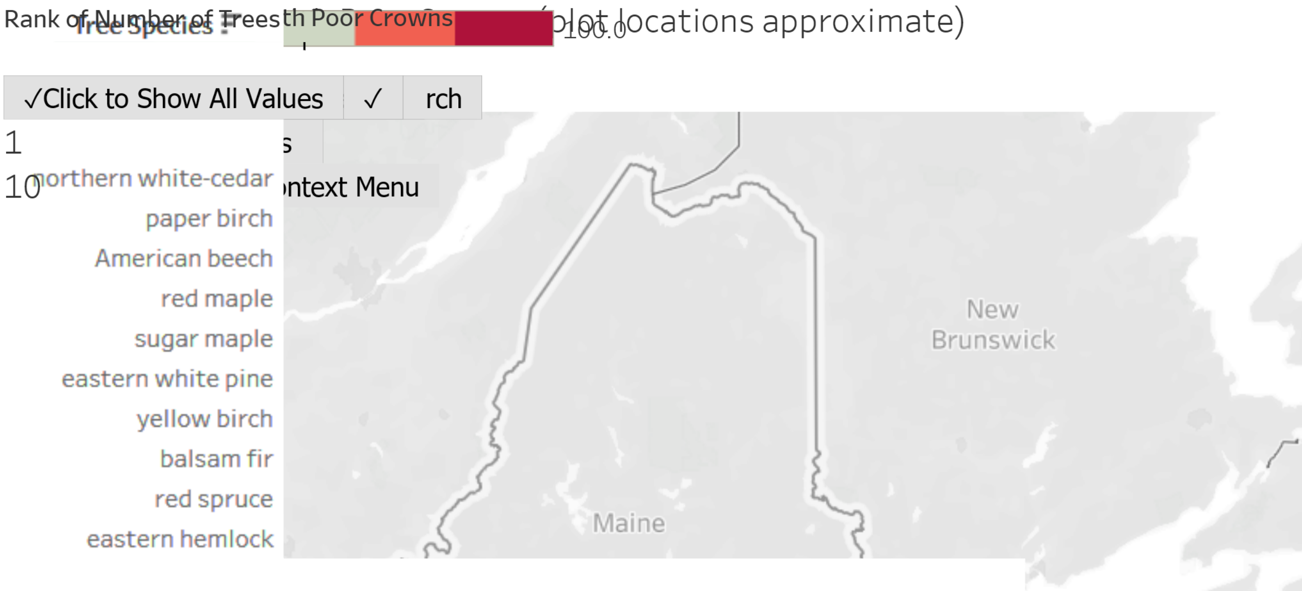
Tree Crown Health and Damage

The overall health and crown condition of trees can be impacted by various types of stressors. Biotic stressors can include native or introduced insects, diseases, invasive plant species, and animals. Abiotic stressors such as storm damage, drought, flooding, cold temperatures, nutrient deficiencies, the physical properties of soils that affect moisture and aeration, and toxic pollutants. Invasions by exotic diseases and insects are one of the most important threats to the productivity and stability of forest ecosystems around the world (Liebhold et al. 1995, Pimentel et al. 2000, Vitousek et al. 1996).

What we found

Over the last century, Maine's forests have suffered the effects of well-known exotic, invasive agents such as beech bark disease, balsam woolly adelgid (*Adelges piceae Ratzeburg*), and chestnut blight (*Cryphonectria parasitica*) as well as the native pest, spruce budworm (*Choristoneura fumiferana Clemens*). More recently, invasions by the hemlock woolly adelgid (*Adelges tsugae*) and emerald ash borer (*Agrilus planipennis*) are threatening the health of eastern hemlock and ash species, respectively. Additionally, although Asian longhorned beetle (*Anoplophora glabripennis*) and European wood wasp (*Sirex noctilio*) have not yet been discovered in Maine, they are emerging threats that have been confirmed in nearby states.

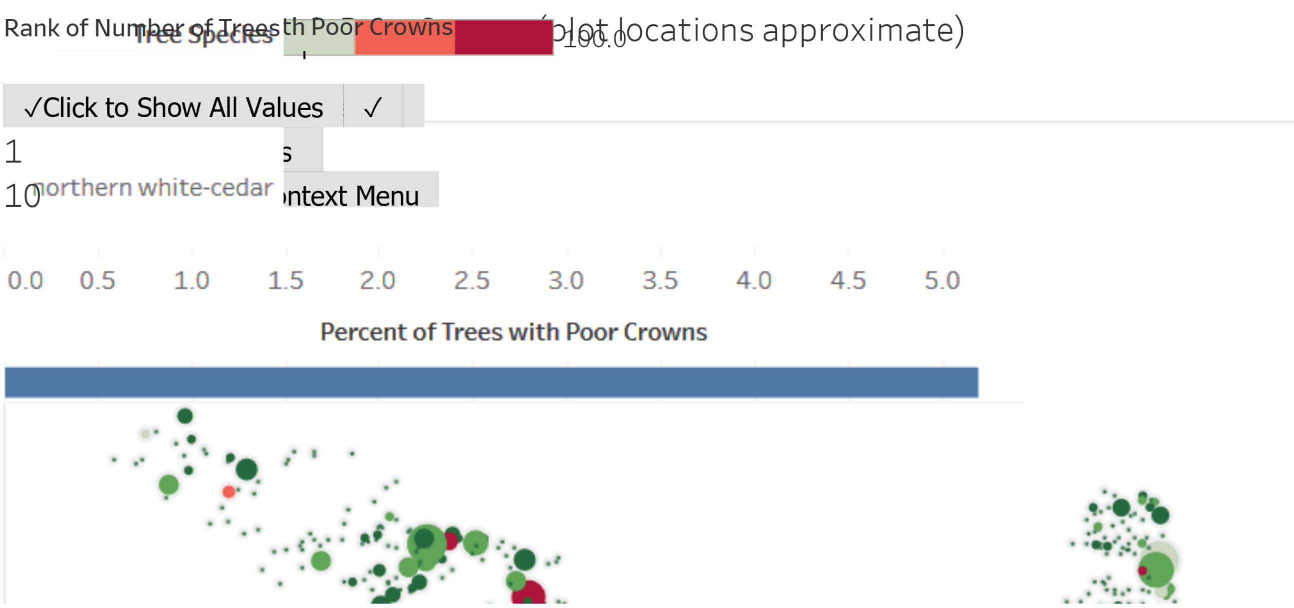
percent or greater.



Interactive Figure 28 - Interactive Tableau dashboard of percent of trees with poor crowns (plot locations approximate).

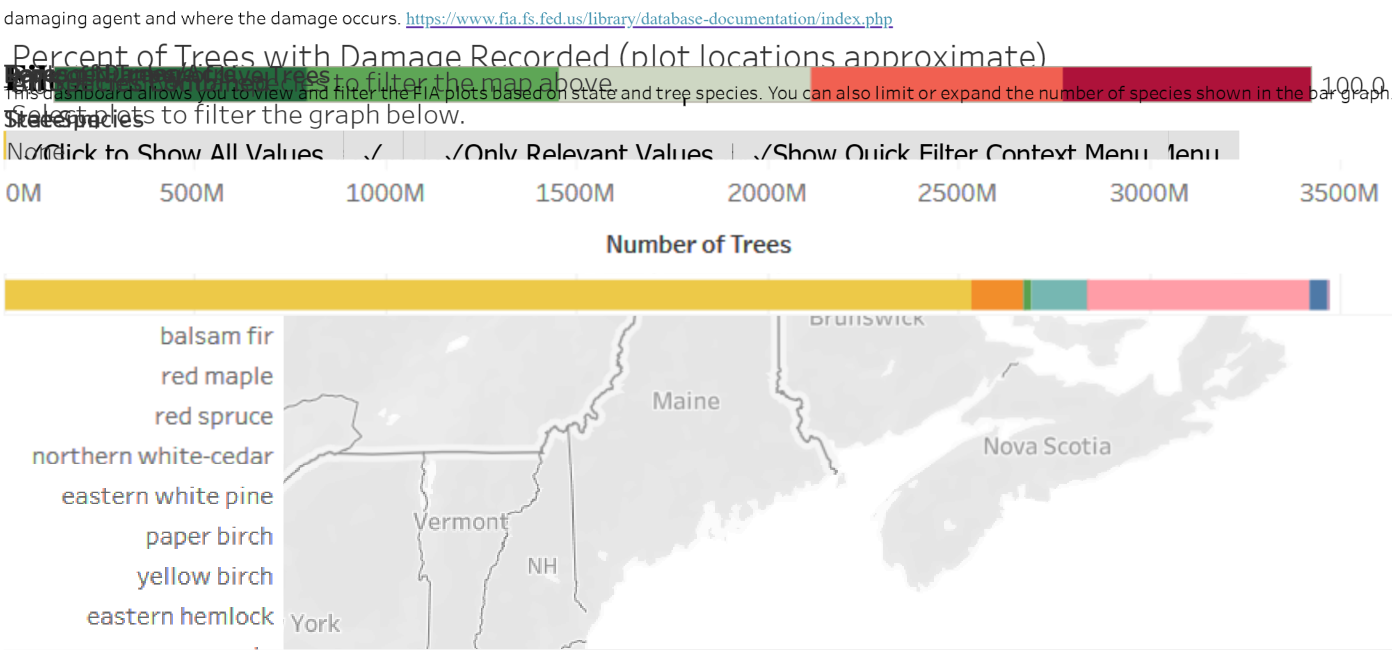
The incidence of poor crown condition is low across Maine with no discernible spatial pattern for all species combined

percent or greater.



> *Interactive Figure 29 - Interactive Tableau dashboard of percent of trees with poor crowns (plot locations approximate).*

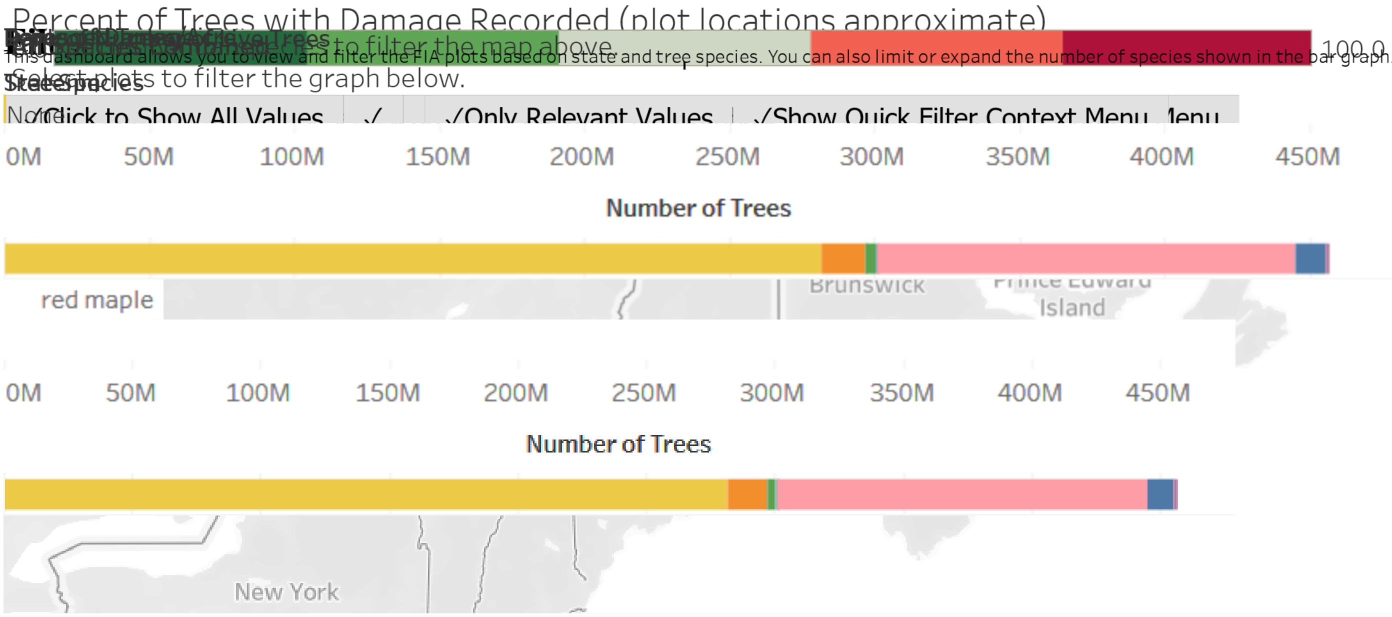
The only top 10 species with more than 5 percent of live trees having poor crowns is northern white-cedar (6 percent). The occurrence of unhealthy northern white-cedar appears to be highest in the east-central portion of the State, and proportion of trees with poor crowns is similar across the species' range.



> *Interactive Figure 30 - Interactive Tableau dashboard of percent of trees with damage recorded (plot locations approximate).*

Damage was recorded on approximately 24 percent of the trees in Maine, and the most frequent type of damage overall was decay (17 percent). Decay ranged from zero percent on many species to approximately 33 percent on American beech and red maple trees.

damaging agent and where the damage occurs. https://www.fia.fs.fed.us/library/database-documentation/index.php



Interactive Figure 31 - Interactive Tableau dashboard of percent of trees with damage recorded (plot locations approximate).

American beech also had canker damage recorded on 58 percent of trees. Damage on American beech was evenly distributed across Maine, whereas damage on red maple appears to be more prevalent in the northern half of the State. All other damage types occurred on less than five percent of trees.

What this means

Despite activity by several damaging forest pests the trees of most of the important species in the forests of Maine generally have healthy crowns. Crown health of ash species should be monitored closely in the coming years given the recent introduction of emerald ash borer (see subsequent section?). Although damage was recorded on approximately one-quarter of trees, the occurrence of damage is lower than nearby states. The most commonly observed type of damage, decay, was driven by high rates in American beech red maple. The high rates of decay and cankers in American beech are mostly due to the impacts of beech bark disease.

Invasive Plants

Tree Species
Black locust (*Robinia pseudoacacia*)
Chinaberry (*Melia azedarach*)
Norway maple (*Acer platanoides*)
Princesstree (*Paulownia tomentosa*)
Punktree (*Melaleuca quinquenervia*)
Russian olive (*Elaeagnus angustifolia*)
Saltcedar (*Tamarix ramosissima*)
Siberian elm (*Ulmus pumila*)
Silktree (*Albizia julibrissin*)
Tallow tree (*Triadica sebifera*)
Tree of heaven (*Ailanthus altissima*)
Woody Species
Autumn olive (*Elaeagnus umbellata*)
Common barberry (*Berberis vulgaris*)
Common buckthorn (*Rhamnus cathartica*)
European cranberrybush (*Viburnum opulus*)
European privet (*Ligustrum vulgare*)
Glossy buckthorn (*Frangula alnus*)
Japanese barberry (*Berberis thunbergii*)
Japanese meadowsweet (*Spiraea japonica*)
Multiflora rose (*Rosa multiflora*)
Nonnative bush honeysuckle (*Lonicera* spp.)
Vine Species
English ivy (*Hedera helix*)
Japanese honeysuckle (*Lonicera japonica*)
Oriental bittersweet (*Celastrus orbiculatus*)
Herbaceous Species
Black swallow-wort (*Cynanchum louiseae*)
Bohemian knotweed (*Polygonum xbohemicum*)
Bull thistle (*Cirsium vulgare*)
Canada thistle (*Cirsium arvense*)
Creeping jenny (*Lysimachia nummularia*)
Dames rocket (*Hesperis matronalis*)
European swallow-wort (*Cynanchum rossicum*)
Garlic mustard (*Alliaria petiolata*)
Giant knotweed (*Polygonum sachalinense*)
Japanese knotweed (*Polygonum cuspidatum*)
Leafy spurge (*Euphorbia esula*)
Purple loosestrife (*Lythrum salicaria*)
Spotted knapweed (*Centaurea stoebe* ssp. *micranthos*)
Grass Species
Common reed (*Phragmites australis*)
Japanese stiltgrass, Nepalese browntop (*Microstegium vimineum*)
Reed canarygrass (*Phalaris arundinacea*)

Table 3 - Table of invasive species on P2 invasive plots.

Invasive plant species (IPS) are both native and nonnative species that can negatively affect ecosystems. Several factors contribute to the success of invasive plants such as rapid growth, prolific seed production, survival in harsh environments, and vegetative propagation. Humans, ungulates, fragmentation, and disturbance promote the spread of IPS. Once established, they can quickly take over an area, displacing native species, and affecting habitat suitability. IPS often form dense monocultures that alter light, nutrient, and water availability. In forests, infestations may increase runoff and limit food, cover, and nesting sites. For example, infestation by nonnative bush honeysuckles (Lonicera spp.) can form a shrub layer so dense that it completely shades out understory plants. If nonnative bush honeysuckles gain hold in the stand initiation stage, they can eliminate tree regeneration and the future forest. This impacts many species dependent on mature forests. Cavity dwellers dependent on snags are displaced. By reducing the number of trees, IPS can impact the carbon cycle. Additionally, they affect aesthetic beauty which influences tourism and local economies. While there are some useful benefits of these plants, the negative impacts are worrisome. Invasives cost billions of dollars annually through eradication, monitoring, and timber loss.

	2018		2013	
Species	Observances	Percentage of plots	Observances2	Percentage of plots3
Nonnative bush honeysuckle (*Lonicera* spp.)	17	4.4	12	2.2
Canada thistle (*Cirsium arvense*)	11	2.8	5	0.9
Multiflora rose (*Rosa multiflora*)	10	2.6	4	0.7
Bull thistle (*Cirsium vulgare*)	7	1.8	10	1.9
Reed canarygrass (*Phalaris arundinacea*)	5	1.3	27	5.0
Glossy buckthorn (*Frangula alnus*)	4	1.0	4	0.7
Oriental bittersweet (*Celastrus orbiculatus*)	4	1.0	3	0.6
Norway maple (*Acer platanoides*)	3	0.8	2	0.4
Common buckthorn (*Rhamnus cathartica*)	2	0.5	3	0.6
Autumn olive (*Elaeagnus umbellata*)	1	0.3	1	0.2
Japanese barberry (*Berberis thunbergii*)	1	0.3	6	1.1
Japanese knotweed (*Polygonum cuspidatum*)	1	0.3	-	-

Table 4 - Most commonly found IPS.

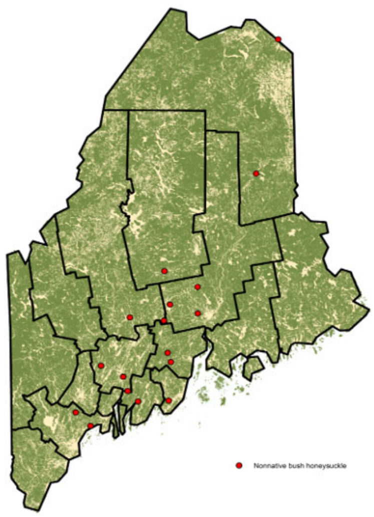
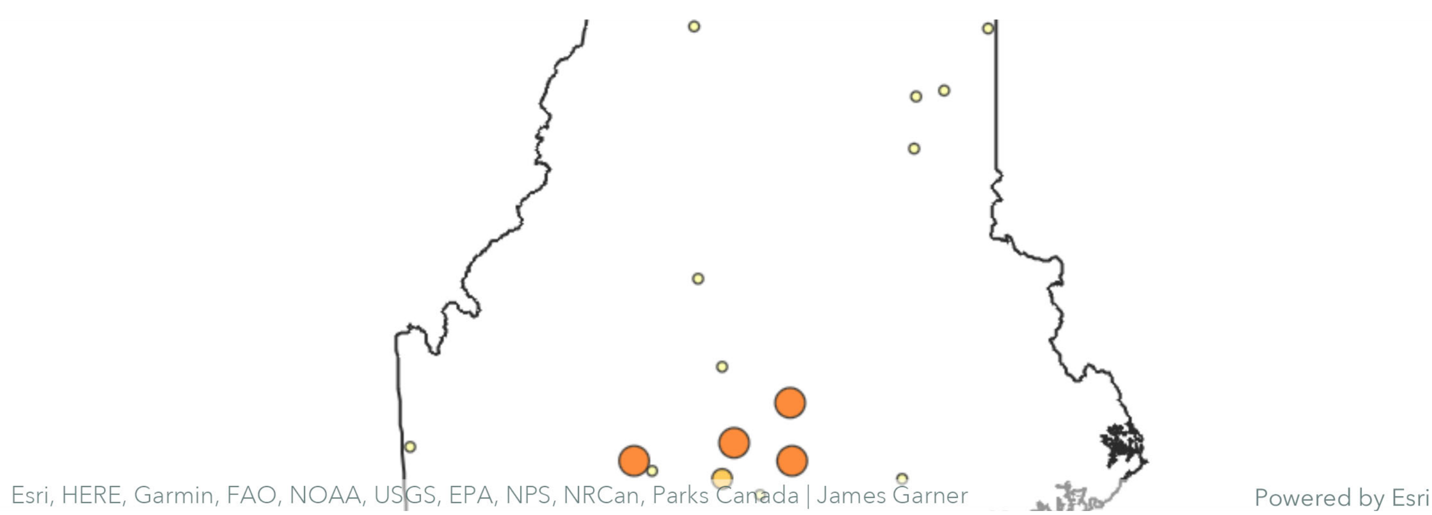


Figure 32 - Approximate plot locations with nonnative bush honeysuckle.

FIA assesses the presence and cover of 40 IPS (39 species and one undifferentiated species) on P2 invasive plots. In 2018 there were 386 plots monitored for IPS in Maine. Of the 12 invasive plants recorded, nonnative bush honeysuckle was the most commonly found. This shrub was recorded on 17 plots (4.4 percent) and was most frequently observed in the south-central part of the state. Nonnative bush honeysuckle is problematic in many NRS states, consistently ranking among the top invasive species recorded. The number of IPS per plot varied from zero to four.



Interactive Figure 32 - Interactive map of approximate plot locations of number of IPS per plot.

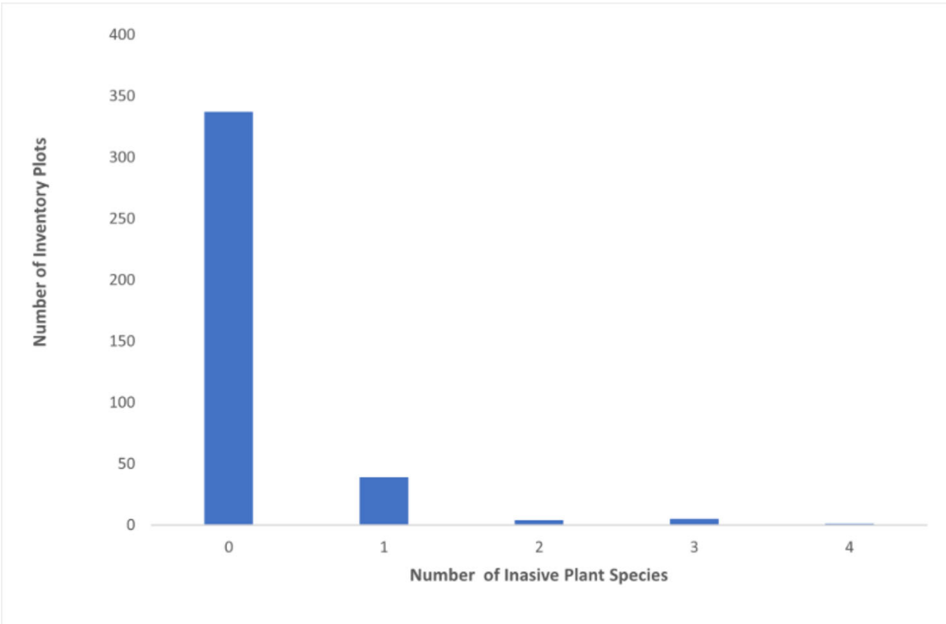


Figure 33 - Number of IPS by number of inventory plots.

In general, plots in the southern part of the state have more invasive plant species per plot. Between 2013 and 2018 the number of invasive plant species observed on plots in Maine changed slightly. There were 11 IPS on plots in 2013 and 12 in 2018. Japanese knotweed was observed this inventory but was not present in 2013. The percentage of plots in the state with invasive plants increased from 2013, with 12.7 percent of plots having one or more IPS versus 10.4 percent in 2013.

Bull thistle, by Sjana Schanning USFS, Shutterstock.

What this means

The presence of IPS within Maine's forestland is a concern. When looking at these trends it is important to note that the sample size was smaller this inventory due to a region wide change in sampling intensity. In 2013, 536 plots were monitored. Additionally, since the inventory only covers forested areas, areas with less forest land have fewer plots. This is important to note with respect to species distribution. Comparing Maine to neighboring New Hampshire, Maine had a lower percentage of plots with invasive plants. Nearly 15 percent of plots in New Hampshire had one or more of the monitored IPS present in 2018.

Invasive plants can cause vast ecosystem and economic consequences. Invasive presence is influenced by time since introduction, forest fragmentation, and propagule pressure. Careful forest management and outreach are crucial to mitigate spread. It is important that people are aware of these noxious invaders. The presence of IPS is concerning and future monitoring is necessary. With future measurements, changes in the percentage of plots with IPS in the state, species presence and distribution, newly observed invasives, and an increase in the number of IPS per plot are all key metrics. Further analysis of the invasive plant data may also help to reveal noteworthy site and regional trends.

Forest Insect and Disease

Insects and disease pathogens help shape the structure and composition of forest ecosystems. Monitoring their status provides a measure of forest health and is crucial in assessing the current state and changing trends in Maine's forests. Mortality caused by insect and disease activity can be hard to differentiate from other causes and natural senescence. The ratio of mortality-to-gross growth has been used as a national indicator of mortality; ratios above 0.6 are considered high and may be indicative of an acute forest health issue, if forests are not senescing (Ambrose 2019). Further, a high mortality-to-gross growth ratio, in combination with high average annual mortality as a percentage of live volume suggests an increased likelihood of a serious threat to forest health.

Over the 2018 inventory cycle, Maine's forests have been impacted by a variety of insects and diseases, including spruce budworm (*Choristoneura fumiferana* Clemens); *Diplodia* tip blight; *Sirococcus* shoot blight; hemlock woolly adelgid (*Adelges tsugae*), winter moth (*Operophtera brumata*); white pine needle diseases complex; and emerald ash borer (*Agrilus planipennis*). Some of the major species of concern are discussed below.

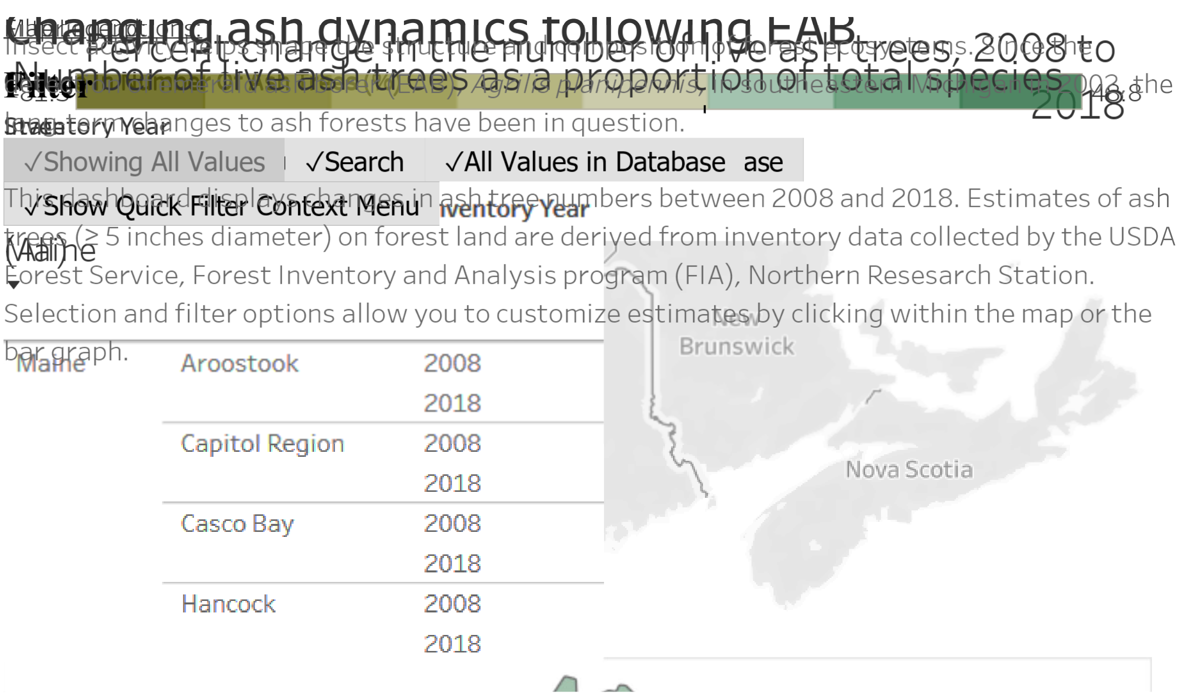
Agrilus planipennis - Emerald ash borer, by Herman Wong HM, Shutterstock.

Emerald Ash Borer

Emerald ash borer (EAB), a wood-boring beetle native to Asia, was first detected in Maine in 2018, where it was found in northern Aroostook County along the Canadian border and then in York County along the New Hampshire border. As EAB is difficult to detect at low-levels, natural spread was enhanced by human-mediated transportation of infested materials; subsequently, spread of EAB has outpaced detection, with population establishment averaging 4 to 6 years prior to identification (McCullough 2020). All North American ash (*Fraxinus spp.*) are hosts of EAB; however, host preference appears to vary by species, with consistently high observations of green and black ash mortality and variable white ash mortality (McCullough 2020; Herms and McCullough 2014). Although EAB shows some preference for stressed trees, all trees 1 inch diameter or greater are susceptible regardless of vigor.

Video 1 - Emerald ash borer destructive forest pests could be in Maine, from NEWS CENTER Maine, YouTube.

Ash trees represent 2 percent of total species abundance on forest land. There are an estimated 467.1 million ash trees (greater than or equal to 1-inch diameter), a 7 percent increase since 2013; this is largely due in an increase in saplings. White ash is most prevalent (58 percent), followed by black ash (41 percent), and green ash (1 percent). Ash is found throughout the State, however, the greatest proportion of ash trees (greater than or equal to 5-inches diameter) is in southwestern Maine.



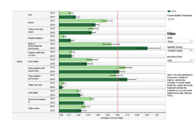
Interactive Figure 33 - Interactive Tableau dashboard of changing ash dynamics following EAB, Maine, 2008 to 2018.

Combined, ash species have a low mortality-to-gross growth ratio, which increased from 0.12 to 0.17 between 2013 and 2018. By species, the mortality-to-gross growth ratio is highest for black ash, decreasing from 0.64 in 2013 to 0.55 in 2018; this is due to mortality of trees greater than 11 inches diameter. Average annual mortality as a percentage of total volume is 0.54 percent for white ash and 1.8 percent for black ash.

Interactive Figure 34 - Mortality to Grow...

Interactive Tableau dashboard of the ratio of average annual mortality volume to gross growth...

https://public.tableau.com/views/MortalitytoGrowthRatio-Maine/Dashboard4?:showVizHome=no



Maine's ash trees are valued for their ecological importance, and their cultural and economic significance, making them an important component of Maine's forest resource. As black ash represents a large portion of the ash resource, changes in abundance and mortality could have a considerable impact on the composition and function of wetland communities. Black ash is both culturally significant and used in traditional basket weaving, therefore, its long term viability is linked to maintaining cultural traditions. The low mortality-to-gross growth ratio indicates that current statewide mortality of ash does not yet exceed growth. Considering the relative regency of EAB detections in Maine, the higher mortality-to-gross growth ratio of black ash may indicate senescence of large diameter trees. Ash mortality is expected to increase as EAB persists and populations spread; this may be particularly true for black ash given EAB host preference (McCullough 2020; Herms and McCullough 2014). Continued monitoring will help to identify the long-term impacts of EAB.

Spruce budworm moths flocking to a bush, by Joris Wiersinga, Shutterstock.

Spruce Budworm

One of the most damaging native insects in North American forests, eastern spruce budworm (SBW) is a primary defoliator of balsam fir, white spruce, red spruce, and black spruce (Robert et al. 2018; Wagner et al. 2015; Bouchard and Auger 2014). Outbreaks of SBW are periodic, with occurrences averaging between 30 – 60 years (Wagner et al. 2015). The last budworm outbreak occurred during the 1970s-80s, therefore, the next infestation is likely to be eminent. Average trap catches across the State began to increase in 2011 and have remained elevated (Maine Forest Service 2019). Over the course of an outbreak, repeated defoliation events cause reduced growth and can lead to tree mortality within 5 years (Wagner et al. 2015).

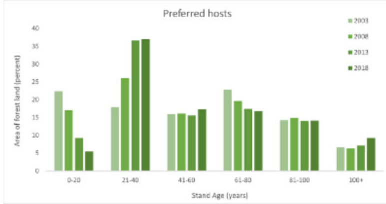


Figure 34 - Dynamics of the SBW preferred host resource by area of forest land for SBW host forest-types (in percent) by stand age, Maine, 2003-2018.

Representing 6.0 million acres, the spruce/fir forest type group is the second largest forest type group in Maine. Eight-four percent of the spruce/fir forest type group is made up of five forest types that contain a majority of SBW preferred hosts. Of the SBW types, balsam fir is the largest (2.3 million acres), followed by red spruce/balsam fir (1.1 million acres), red spruce (896.3 thousand acres), black spruce (581 thousand acres), and white spruce (167 thousand acres). Since 2003, the area of SBW forest types with a stand age of less than 20 years has decreased and the majority of SBW area is now aged 21 to 40 years. The percentage of SBW area greater than 60 years has remained around 40 percent for the last 15 years, however, stand age in the 41-60 year category has increased by 14 percent since 2003.

Video 2 - Spruce budworm spread from southern Quebec to Maine, from The University of Maine, YouTube.

Nearly half of all trees in Maine's forests, or 11.7 billion trees, are preferred hosts of SBW. Balsam fir makes up nearly three-quarters (72 percent) of preferred hosts, followed red spruce (21 percent), black spruce (5 percent) and white spruce (2 percent). The number of SBW host trees in stands with insect damage was relatively low between 2003 and 2008; however, this estimate increased from 85.9 million trees in 2013 to 636.6 million trees in 2018. SBW hosts account for 7.3 billion cubic feet of growing-stock volume, a 15 percent increase from 2003. Sawtimber volume for SBW hosts increased by 11 percent since 2003, currently totaling an estimated 15.3 billion board feet. The mortality-to-gross growth ratio for SBW hosts, equivalent to the spruce and balsam fir species group, is 0.25. Similarly, the mortality-to-volume ratio is also low at 1.4 percent.

Maine's last SBW outbreak caused millions of acres of tree mortality, which in turn had a devastating impact on the State's economy. The severity, duration, and extent of historical SBW outbreaks have been associated with older forests that contain high host density (Robert et al. 2018). Forests with a majority of overstory host species aged over 60 years old have been identified as posing increased risk to SBW (Wagner et al. 2015). While 42 percent of Maine's SBW host dominated forests are less than 60 years old, the overall age of these forests is increasing. The cyclical nature of SBW suggests that the next outbreak is likely on the horizon. Sustained monitoring will help identify the implications of stand characteristics and forest management techniques on future SBW outbreaks.

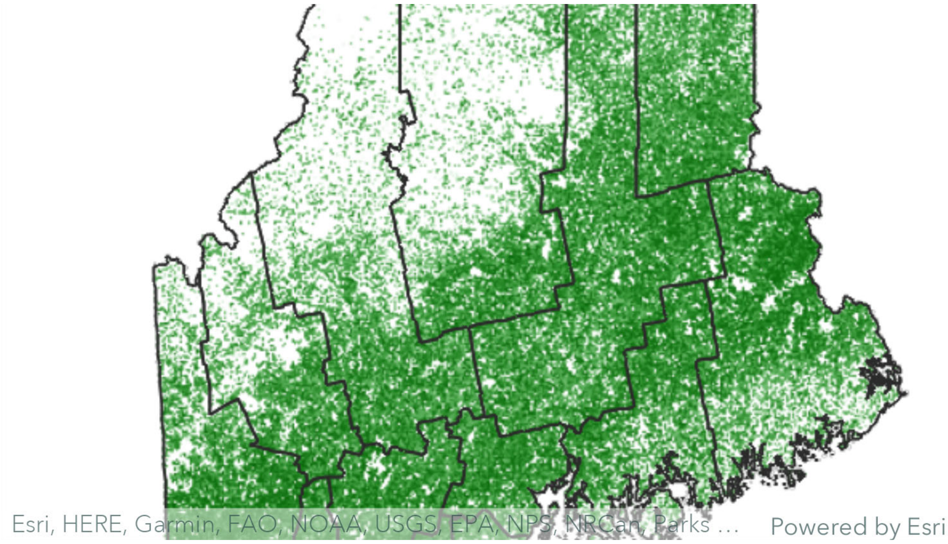
Hemlock woolly adelgid infestation, by Jay Ondreicka, Shutterstock.

Hemlock Woolly Adelgid

First reported in Virginia in 1951, hemlock woolly adelgid (HWA) was accidentally transported to Maine in 1999. Subsequent spread has yielded HWA detections along the Maine's Atlantic coast. Eastern hemlock mortality generally occurs within 4 to 15 years of infestation by HWA (Havill et al. 2014). Though colder winter temperatures have historically helped limit spread and control HWA populations, recent evidence suggests that changes in climatic conditions may contribute to increases in HWA cold tolerance and the availability of suitable habitat (Havill et al. 2014; Limbu et al. 2018). The rate of tree mortality increases if infested trees also experience drought, attack by secondary insects and diseases, or other stresses.

Video 3 - Maine scientists release predatory beetles to fight invasive insect, by Aislinn Sarnacki, Bangor Daily News.

There are an estimated 670.3 million hemlock trees (greater than 1 inch in diameter) on Maine's forest land; this represents a 20 percent increase since 2003 that is largely due to a rise in the number of saplings and trees greater than 15 inches diameter. While hemlock is distributed across much of the State, the highest proportion of hemlock basal area is in southwestern and south central Maine. Average annual mortality of hemlock is an estimated 8.1 million cubic feet. While this is an 89 percent increase since 2008, all of the additional hemlock mortality occurred in trees greater than 15 inches diameter or mortality was attributed to weather damage. One percent of hemlock mortality was ascribed to insect disturbance and was limited to Hancock, Waldo, and Penobscot counties; Hancock and Waldo counties have confirmed detections of HWA. Statewide, the rate of hemlock mortality to total volume is 0.4 percent. The mortality-to-gross growth ratio is similarly low, though it increased from 0.06 to 0.12 between 2013 and 2018.



Interactive Figure 35 - Interactive map of hemlock density on forest land, Maine, 2009.

Eastern hemlock has played a significant role in the historical development of eastern forests in North America (Ellison et al. 2018). Identified as a foundation species, the widespread distribution and abundance of hemlock underpins the surrounding forest ecosystem, and its associated plants, animals, and processes (Ellison 2014; Ellison et al. 2018). Loss of hemlock will have implications for plant diversity; ecosystem dynamics; wildlife habitat; soil stability along streams; invertebrate habitat; water temperature and quality; and timber products availability. Though HWA has been present in Maine for approximately 20 years, current hemlock mortality appears to be localized and relatively stable.

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