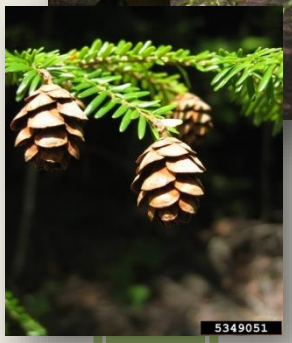
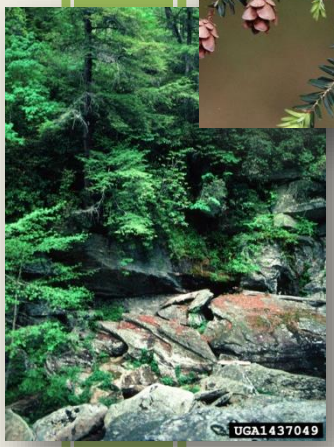
Eastern hemlock

Tsuga canadensis





Hemlock is a very slow-growing, shade tolerant species which was much more prevalent before the Cutover at the turn of the century. However, hemlock volume is recovering with an increase of 60% since 1983. Volume is predicted to increase about 30% in the next 40 years.

In the last two decades, growth rates have increased and mortality has remained unchanged, though much lower than other species. Hemlock accounts for about 2.1% of all volume but only 1.4% of mortality and 0.8% of removals in Wisconsin.

Hemlock is not an important timber species, accounting for less than 1% of all roundwood. The low volume of hemlock and relative low wood density may make this species less valuable for biomass production.

- *How has the hemlock resource changed?*
  Growing stock volume and diameter class distribution
- *Where is hemlock found in Wisconsin?*
  Growing stock volume by region with map
- *What kind of sites does hemlock grow on?*
  Habitat type and site index distribution
- *How fast is hemlock growing?*
  Average annual net growth: trends and ratio of growth to volume
- *How healthy is hemlock in Wisconsin?*
  Average annual mortality: trends and ratio of mortality to volume
- *How much hemlock do we harvest?*
  Roundwood production by product and ratio of growth to removals
- *How much hemlock biomass do we have?*
  Tons of aboveground biomass by region of the state
- *Does hemlock have any disease or pest issues?*
  Hemlock woolly adelgid: Signs and possible impact
- *Can we predict the future of hemlock?*
  Modelling future volumes

Division of Forestry
WI Dept of Natural Resources 2016

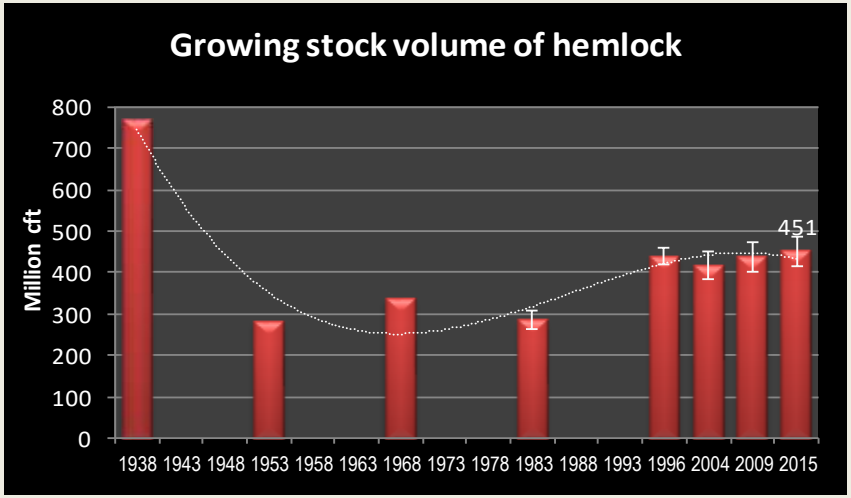
"How has the hemlock resource changed?"

Growing stock volume and diameter class distribution by year

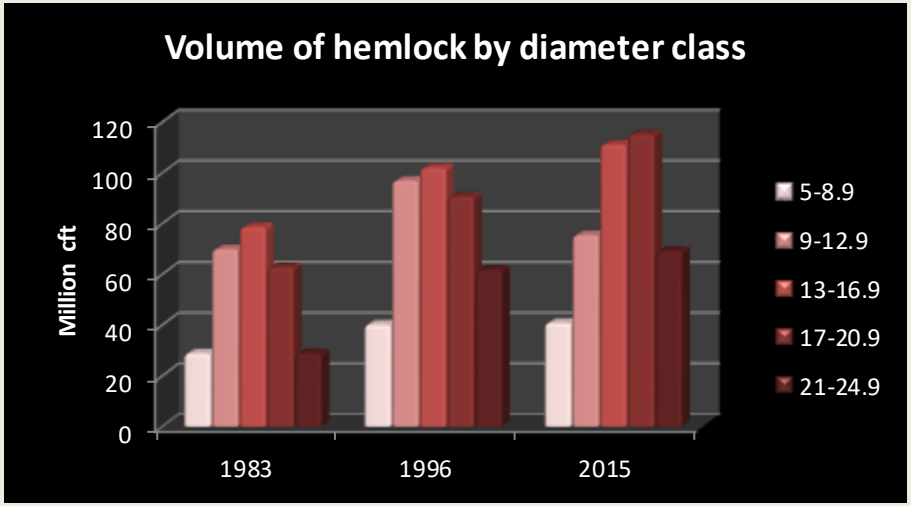
The growing stock volume of hemlock in Wisconsin was about 451 million cubic feet or 2.1% of total volume (chart on right). This is an increase of 59% since 1983. Volume has remained statistically unchanged since 1996.

The hemlock resource has matured since 1996 with more volume in the largest size classes (chart below left). For instance, the volume in small trees (5-12.9 inches) has increased 18% since 1983 and the volume in large trees (13+ inches) has increased 81%. Half of hemlock volume is in trees 17+ inches in diameter.

The number of saplings, poles and sawtimber trees has increased (chart below right).



Growing stock volume (million cubic feet) by inventory year.
Source: USDA Forest Inventory and Analysis data



Growing stock volume (million cubic feet) by inventory year.
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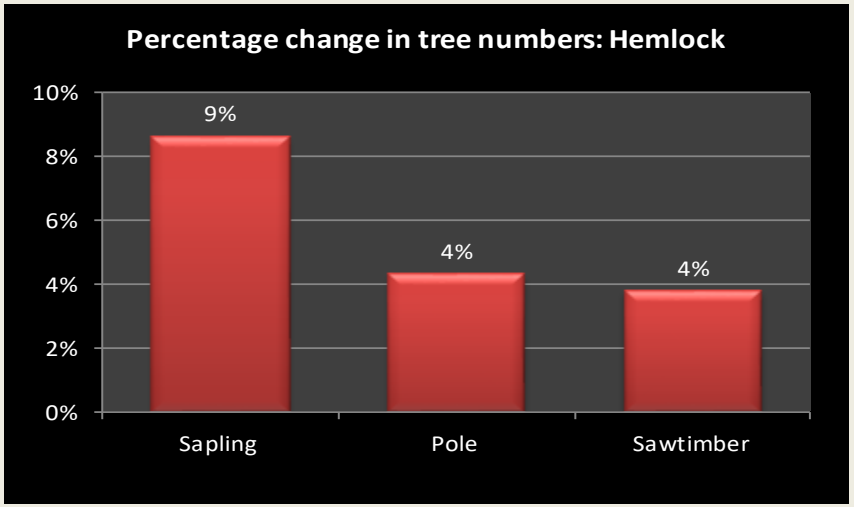
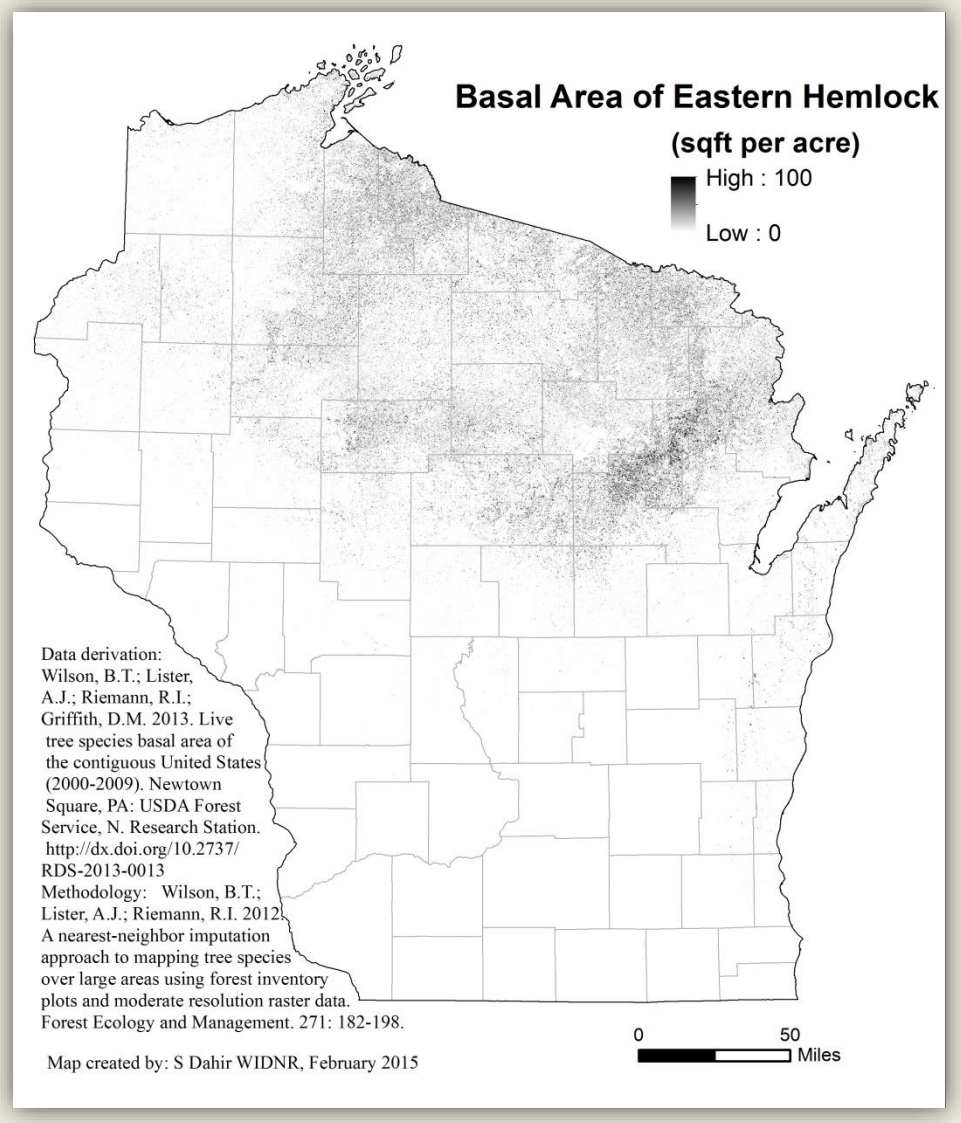


Percentage change in the number of live trees by size class between 1996 and 2015.
Source: USDA Forest Inventory and Analysis data

"Where is hemlock found in Wisconsin?"

Growing stock volume by region with map



About 88% of hemlock volume is located in northern Wisconsin, mainly in the northeast region (Table 1).

Half of hemlock volume is found on the maple / beech / birch forest type and about 40% on the white / red / jack pine type.

Table 1. Growing stock volume (million cft) by species and region of the state.

Species	Central	North east	North west	South east	South west	Total
Eastern hemlock	33	280	116	22	-	**451**
Percent of total	**7%**	**62%**	**26%**	**5%**	**0%**	**100%**

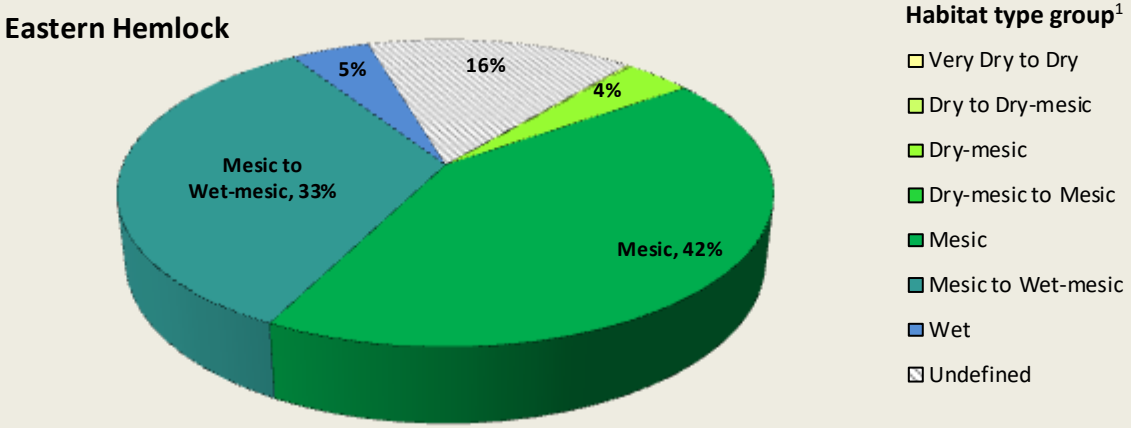
Source: USDA Forest Service, Forest Inventory and Analysis

For a table of **Volume by County** go to:
http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/VolumeCountySpecies.pdf

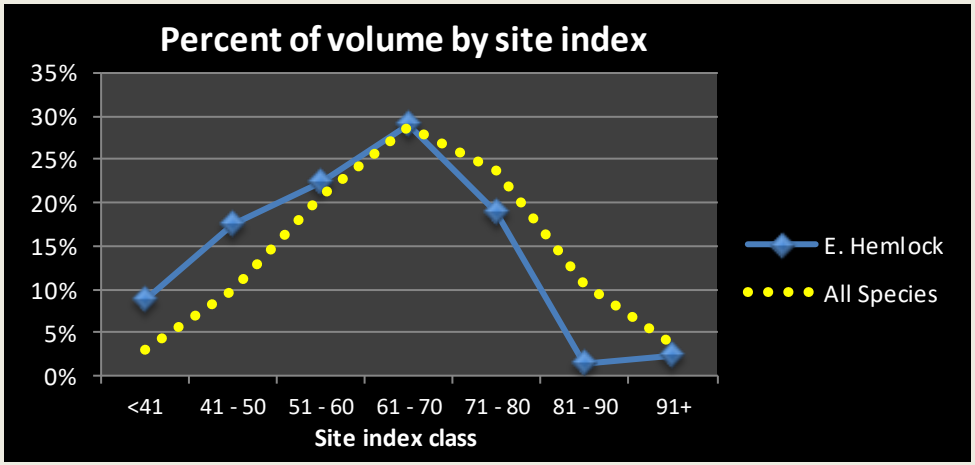
"What kind of sites does hemlock grow on?"

Habitat type[1] and site index distribution

The majority (75%) of hemlock growing stock volume is found on mesic and mesic to wet-mesic habitat types (chart below). Only 4% occurs on drier sites.



Percent distribution of growing stock volume by habitat type group (USDA Forest Inventory & Analysis data).



Percent distribution of growing stock volume by site index class (USDA Forest Inventory & Analysis data).

The majority of hemlock growing stock volume is found in stands with fairly low site indices (chart on left). About half of volume is located on sites with site index below 60. Hemlock thrives on wet-mesic to wet sites which typically have a lower site index.

The average site index for hemlock by volume is 60, much lower than the average for all species, 66.

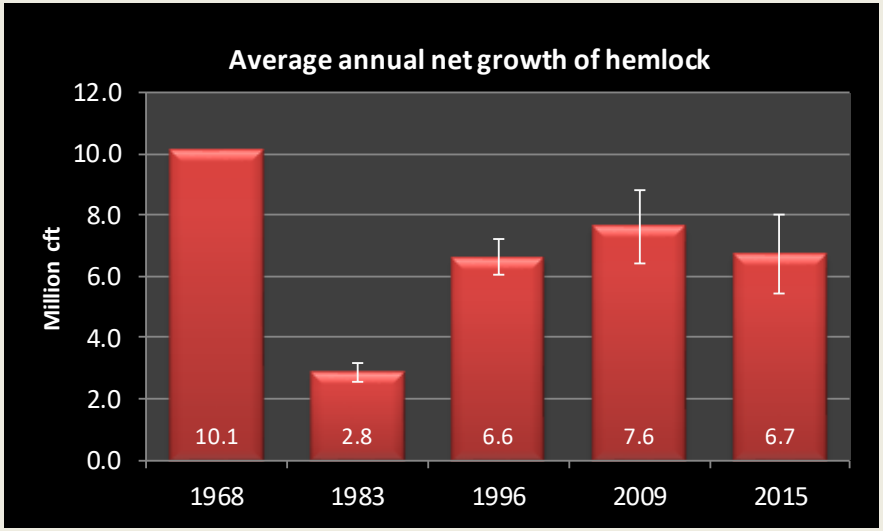
[1] For more information on habitat types see Schmidt, Thomas L. 1997. Wisconsin forest statistics, 1996. Resource Bulletin NC-183. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central

"How fast is hemlock growing?"

Average annual net growth: trends and ratio of growth to volume

Average annual net growth of hemlock is 6.7 million cubic feet per year for the period 2010 to 2015 (chart on right). This represents about 1.2% of total volume growth in the state. Growth rates have more than doubled since 1983 but remained unchanged since 1996.

Although northern Wisconsin has the highest percentage of volume growth in hemlock, 80%, the ratio of growth to volume is highest in the central part of the state (Table 2).



Average annual net growth (million cubic feet).
Source: USDA Forest Inventory & Analysis data

Table 2. Average annual net growth (million cft/year) of growing stock and the ratio of growth to volume by region of the state.

Region	Net growth	Percent of Total	Ratio of growth to volume
Northeast	4.8	71%	**1.7%**
Northwest	0.6	9%	**0.5%**
Central	0.9	13%	**2.6%**
Southwest	0.0	0%	**.**
Southeast	0.5	7%	**2.1%**
Statewide	**6.7**	**100%**	**1.5%**

Source: USDA Forest Inventory & Analysis data

The average statewide ratio for hemlock, 1.5%, is much lower than the statewide average of 2.7% for all species. Hemlock is a very shade tolerant, slow-growing species.

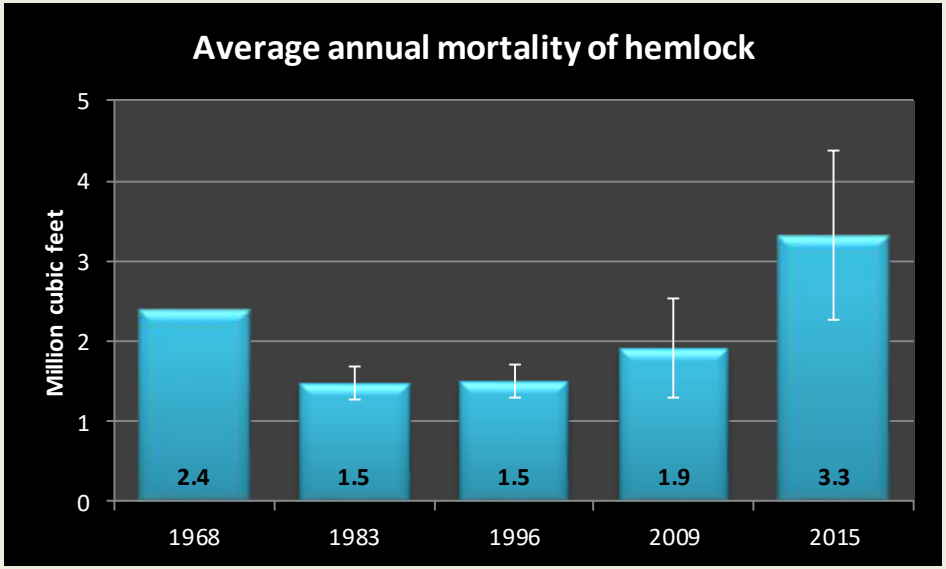
For a table of **Average annual growth, mortality and removals by region** go to:
http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf

"How healthy is hemlock in Wisconsin?"

Average annual mortality: trends and ratio of mortality to growth

Average annual mortality of hemlock, about 3.3 million cubic feet per year, is significantly higher than in 1996 (chart on right). Note the high sampling error for these numbers.

The ratio of mortality to volume is 0.7% for hemlock, much lower than the statewide average of 1.1% (Table 3). Hemlock accounts for 2.1% of statewide volume but only 1.4% of mortality.



Average annual mortality (million cubic feet) by inventory year.
Source: USDA Forest Inventory & Analysis data

Table 3. Mortality, volume and the ratio of mortality to volume.

Species	Average annual mortality (cft)	Growing stock volume (cft)	Mortality / volume
Eastern Hemlock	**3,314,912**	**450,825,106**	**0.7%**

Source: USDA Forest Inventory & Analysis data

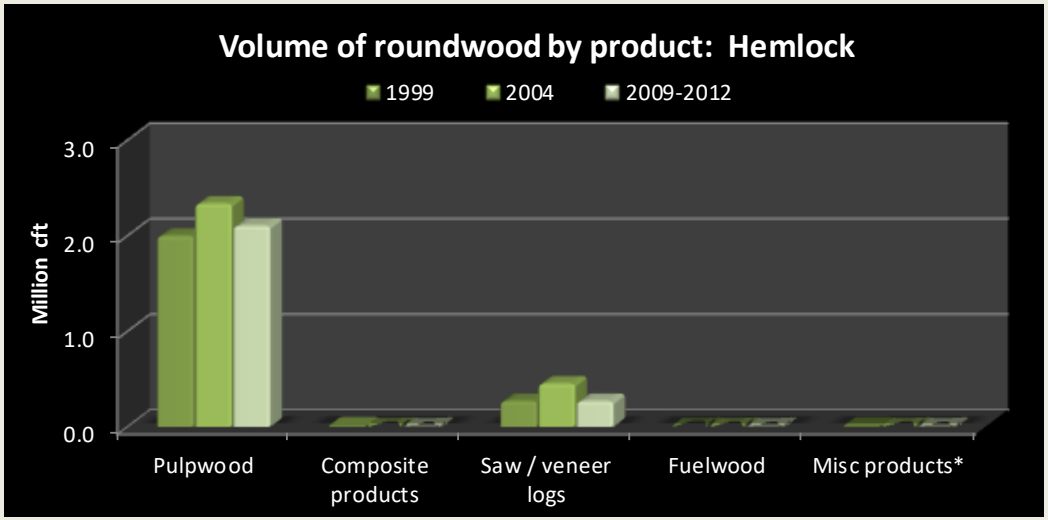
For a table of **Average annual growth, mortality and removals by region** go to:
http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf

"How much hemlock do we harvest?"

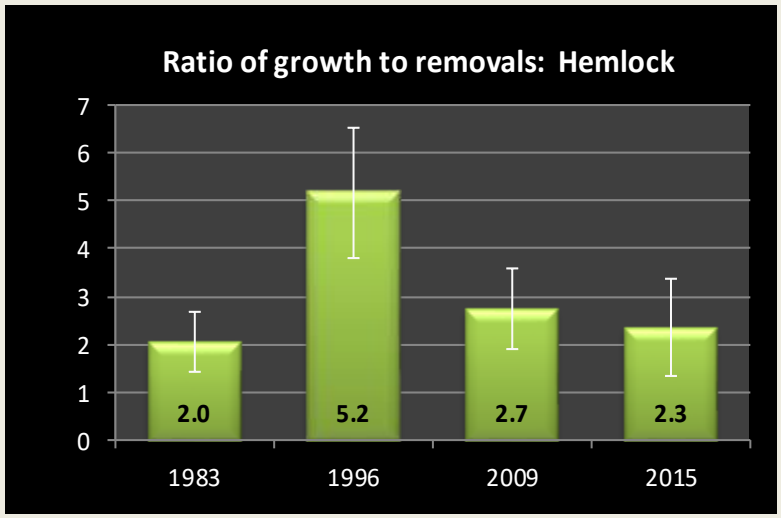
Roundwood production by product and ratio of removals to growth

In 2009-2012, hemlock produced 2.4 million cubic feet or about 0.6% of Wisconsin's total roundwood production (chart on right). Of this, 91% was used for pulpwood and 9% for sawlogs and veneer.

Between 2004 and 2012, hemlock pulpwood production had decreased by 8%. Between 2004 and 2012 production of sawlogs and veneer decreased by 41%.



Volume of roundwood. Most recent figures for pulpwood and composite products are from 2012 while other product volumes are from 2009. * Miscellaneous products include poles, posts and pilings.
Source: Ronald Piva, USDA Forest Service, Northern Research Station, St. Paul MN



Source: USDA Forest Inventory & Analysis data

Removals of hemlock totaled 2.6 million cubic feet per year from 2010 to 2015. This is equal to 0.8% of total removals in the state.

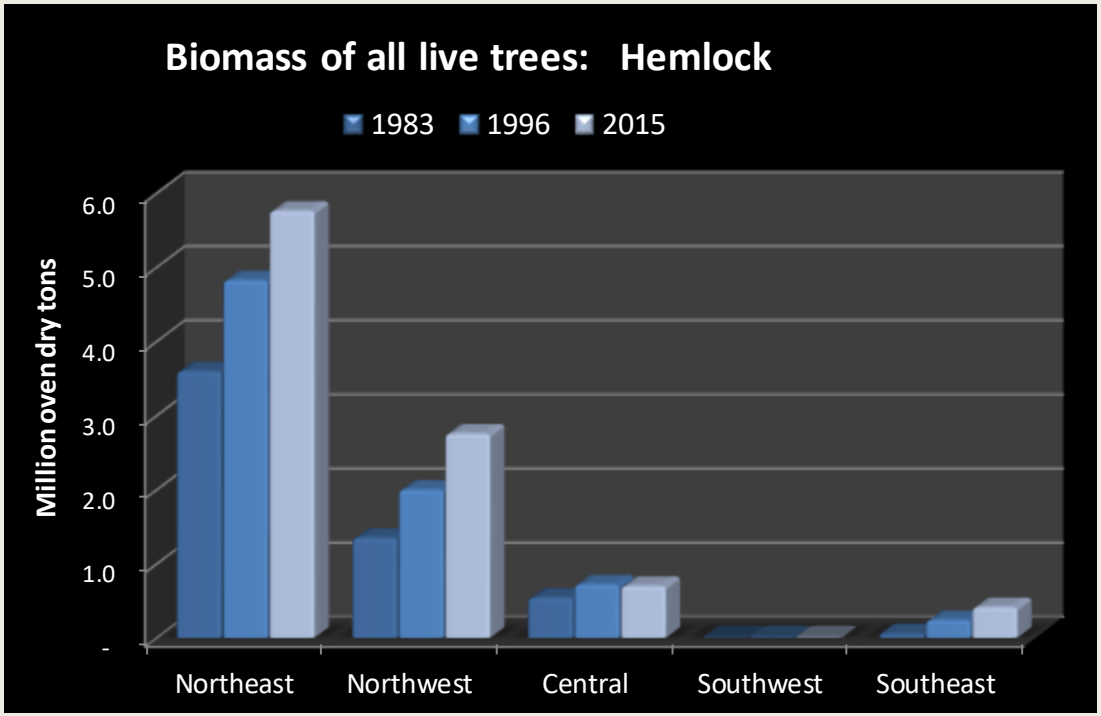
The ratio of average annual growth to removals has decreased significantly since 1996 and now stands at 2.3, higher than the average of 1.9 for all species in the state (chart 7). The decrease since 1996 is due to a doubling in removals with growth remaining constant.

For a table of **Average annual growth, mortality and removals by region** go to:
http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/GrowthMortalityRemovals.pdf

"How much hemlock biomass do we have?"

Tons of aboveground biomass by region of the state

There were 9.6 million tons of aboveground biomass in live hemlock trees, an increase of 74% since 1983. This is equivalent to approximately 4.8 million tons of carbon and represents 1.5% of all biomass statewide. As with volume, most hemlock is located in northeast Wisconsin (chart below).



Biomass (million oven-dry tons) by year and region.
Source: USDA Forest Inventory & Analysis data

Hemlock has a fairly low wood density but higher than other softwood species, with a ratio of biomass to volume of 29 oven-dry lbs. per cubic foot (ODT/cft). The average for all softwoods is about 21 ODP/cubic feet and for all species is 33 ODP/cubic feet.

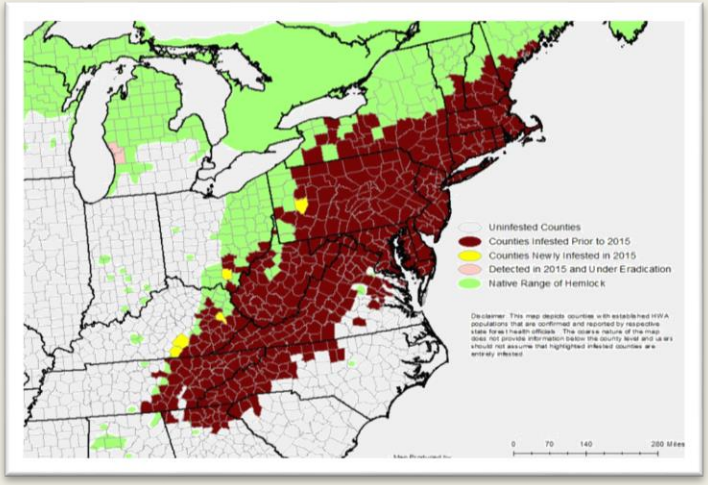
A very high proportion, 82%, of all hemlock biomass is located in the main stem with only 14% in branches.

For a table of **Biomass by County** go to:
http://dnr.wi.gov/topic/ForestBusinesses/documents/tables/BiomassByCounty.pdf

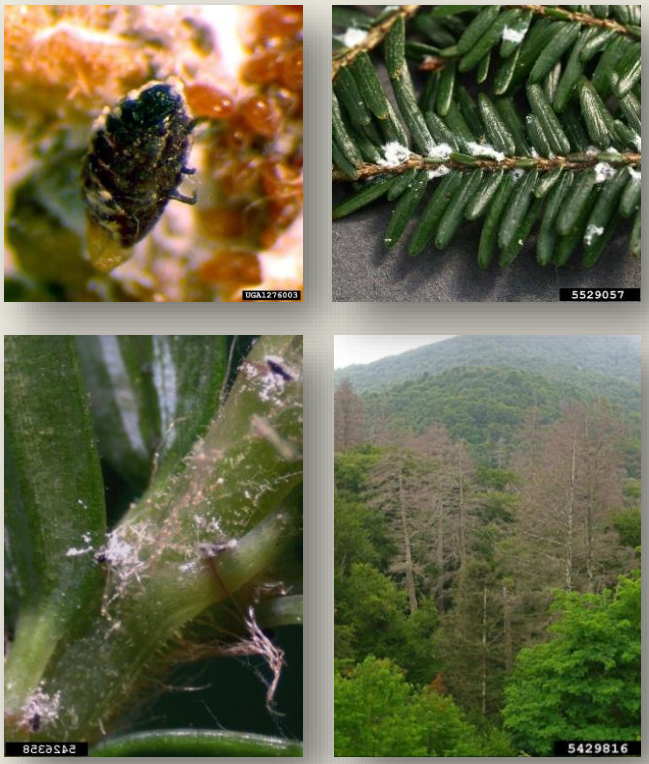
"Does hemlock have any disease or insect pests?"

Hemlock woolly adelgid: signs and impact

Hemlock woolly adelgid had not been found in Wisconsin as of December 2016. So far, hemlock woolly adelgid has only invaded part of the range of eastern hemlock extending from northern Georgia to southern Maine and from northern California to southeast Alaska. In Asia, the insect is found in very cold climates so it is likely to live in most or all of the range of the eastern hemlock species (Map on right). Eastern hemlock has little resistance to hemlock woolly adelgid damage.



Range of hemlock woolly adelgid. Brown and yellow represent infested counties, as of 2015 and green shows the native range of eastern hemlock. https://www.na.fs.fed.us/fhp/hwa/maps/2015_HWA_Infestation_Map_20160502.pdf



Top left: adult adelgid, Top right: egg sacs on underside of hemlock needles. Lower left: Mycosis caused by *Beauveria bassiana*
Bottom right: hemlock mortality due to adelgid damage.

The white, cottony egg sacs of the hemlock woolly adelgid can be seen on the underside of hemlock branches at the base of needles in late winter and early spring (Figure on left). Hemlocks that are infested will develop needles that yellow and eventually fall off, leaving dead, bare branches and thin crowns. Infested trees decline and die over several years. Heavy infestations can kill the tree within four to 10 years and trees are also weakened and made vulnerable to attack by other insects and diseases.

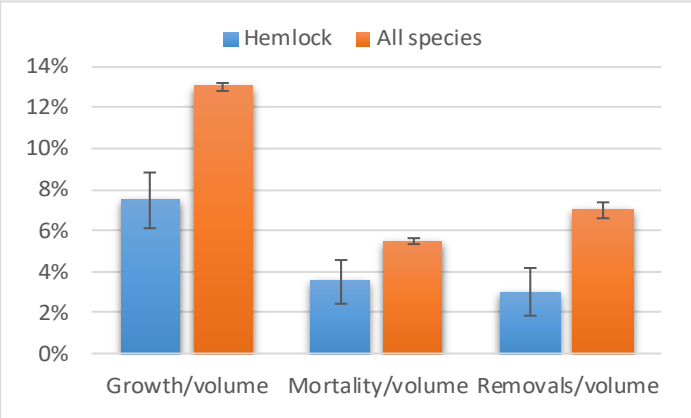
One approach to managing hemlock woolly adelgid has been to introduce natural enemies from the insect's native range in Asia. One predatory beetle (*Sasajiscymnus tsugae*) has been mass reared and released in the eastern U.S. Its adults and larvae prey on hemlock woolly adelgid and help to reduce its numbers.

"Can we predict the future of hemlock?"

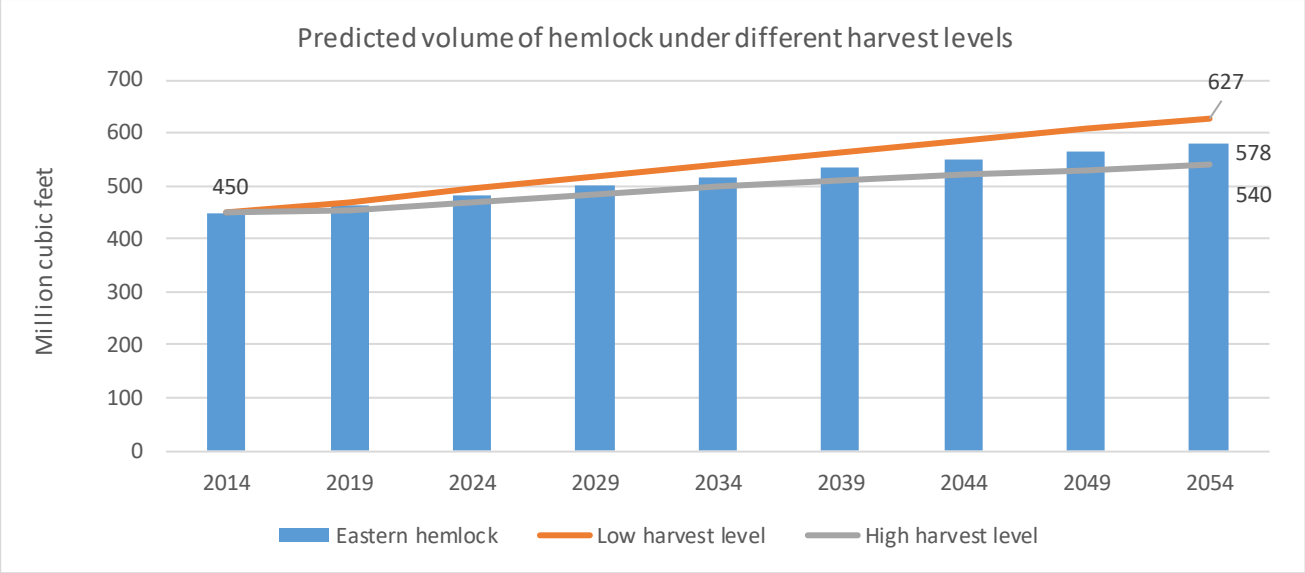
Predicted volumes based on current rates of mortality and harvest

The 5-year ratios of mortality to volume, removals to volume and growth to volume are significantly lower for eastern hemlock compared to all species in the state (chart on right).

The Forest Vegetation Simulator (FVS[1]) was used to predict future volumes of hemlock through 2054. Three scenarios are forecast. One with current rates of mortality and removals (i.e. average annual mortality and removals for 2009 to 2014). Another with current mortality rates and the lower 67% confidence interval for current removals and another with the upper 67% confidence interval for removals.



Five year ratios of mortality, removals and growth to volume.
Source: USDA Forest Inventory & Analysis data



Volume increases by 2054 in all three scenarios, 29% for current removal levels, 39% for low removals and 20% for high removals.

The Forest Vegetation Simulator is a forest growth and yield simulation model created by the USDA Forest Service, see http://www.fs.fed.us/fmsc/fvs/.